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

Public Design Report

We Energies
ADA Environmental Solutions, Cummins & Barnard, and the Electric Power Research Institute

DOE Cooperative Agreement No. DE-FC26-04NT41766

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DISCLAIMER

ABSTRACT

This document provides a summary of the design efforts involved in the project *"TOXECON™ Retrofit for Mercury and Multi-Pollutant Control on Three 90-MW Coal-Fired Boilers."* This U.S. Department of Energy (DOE) Clean Coal Power Initiative (CCPI) project was based on a cooperative agreement between We Energies and the DOE Office of Fossil Energy's National Energy Technology Laboratory (NETL) to design, install, evaluate, and demonstrate the EPRI-patented TOXECON™ air pollution control process. Project partners included Cummins & Barnard (C&B), ADA Environmental Solutions (ADA-ES), and the Electric Power Research Institute (EPRI). The primary goal of this project was to reduce mercury emissions from three 90-MW units that burn Powder River Basin coal at We Energies' Presque Isle Power Plant in Marquette, Michigan. Additional goals were to reduce nitrogen oxide, sulfur dioxide, and particulate matter emissions; allow reuse and sale of fly ash; advance commercialization of the technology; demonstrate a reliable mercury continuous emission monitor (CEM) suitable for use at power plants' and demonstrate recovery of mercury from the sorbent.

In addition to the primary air pollution control system, balance-of-plant design considerations were addressed. These included booster fans, a compressed air system, an ash handling system, ductwork, electrical, and instrumentation and controls. Design considerations of a mercury continuous emissions monitor are included in this report.

The costs of equipment and installation for the TOXECON™ and balance-of-plant systems were $34.6 million, including the engineering effort.

This project demonstrated a significant reduction in the rate of emissions from Presque Isle Units 7, 8, and 9, and substantial progress toward establishing the design criteria for one of the most promising mercury control retrofit technologies currently available. The Levelized Cost for 90% mercury removal at this site was calculated at $77,031 per pound of mercury removed with a capital cost of $63,189 per pound of mercury removed. Mercury removal at the Presque Isle Power Plant averaged approximately 97 pounds per year.

POINTS OF CONTACT

Steve Derenne
Principal Engineer
We Energies
333 West Everett Street
Milwaukee, WI 53201
414-221-4443
steven.derenne@we-energies.com

Robin Stewart
Manager, Contract R&D
ADA-ES, Inc.
8100 SouthPark Way, Unit B
Littleton, CO 80120
303-734-1727
robins@adaes.com

Michael H. McMillian
U.S. Department of Energy
National Energy Technology Laboratory
3610 Collins Ferry Road
Morgantown, WV 26507
304-285-4669
mmcmil@netl.doe.gov

Ramsay Chang
Electric Power Research Institute
3420 Hillview Avenue
Palo Alto, CA 94304-1338
650-855-2535
rchang@epri.com

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LIST OF ABBREVIATIONS

A/C	Air-to-cloth ratio
acfm	Actual cubic feet per minute
ACI	Activated carbon injection
A/E	Architect/Engineer
BOP	Balance-of-plant
CCPI	Clean Coal Power Initiative
CEM	Continuous emissions monitor
COHPAC®	Compact Hybrid Particulate Collector
DCS	Distributed control system
DOE	Department of Energy
EPRI	Electric Power Research Institute
ESP	Electrostatic precipitator
gr/acf	Grains per actual cubic foot
HESP	Hot-side electrostatic precipitator
Hg	Mercury
HP	Horsepower
HVAC	Heating ventilation air conditioning
ID	Induced draft
I/O	Input/output
lb/hr	Pounds per hour
LOI	Loss on ignition
MCC	Motor control center
MMacf	Million actual cubic feet
MW	Megawatts
NEP	National Energy Policy
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
NO_x	Oxides of nitrogen
NFPA	National Fire Protection Association
O_2	Oxygen
O&M	Operation and Maintenance

OEM	Original equipment manufacturer
PAC	Powdered activated carbon
PIPP	Presque Isle Power Plant
PM	Particulate matter
ppm	Parts per million
PPS	Polyphenylene sulfide
ppt	Parts per trillion
PRB	Powder River Basin
psig	Pounds per square inch gauge
RATA	Relative Accuracy Test Audit
RIO	Remote I/O
rpm	Revolutions per minute
scfm	Standard cubic feet per minute
SO_2	Sulfur dioxide
T/R	Transformer Rectifier
VAC	Volts alternating current
VIV	Variable inlet vane
WAPC	Wheelabrator Air Pollution Control
” w.c.	Inches of water column

GLOSSARY OF TERMS

The following information provides the reader with an introduction to common terminology related to fabric filters and the TOXECON™ technology.

Pressure Drop/Drag – Pressure drop and drag are both used to monitor the permeability of the filter and filter cake. Pressure drop is a direct measurement of the pressure difference across the fabric filters. Drag is a calculated number that normalizes pressure drop to flow by dividing pressure drop by the air-to-cloth (A/C) ratio. These values are a function of inlet grain loading, filtering characteristics of the particulate matter, flue gas flow rate, and time between cleaning. The particulate matter, or dust, adhering to the outside of the bags is usually referred to as "cake," which acts as a filtering medium and presents a resistance to flow. A greater inlet loading or longer bag cleaning cycle time will result in deposition of a thicker cake collected on the bag surface. A thicker cake on the surface results in a higher pressure drop. Excessive pressure drop is undesirable because of the energy required to overcome it. Fans need to be sized to compensate for this expected pressure drop and higher pressure drops require larger fans and subsequently more horsepower. Once a system is designed and in operation, excessive pressure drop is a problem if the pressure drop exceeds the fan capacity. In this case, a generating unit becomes load limited due to insufficient fan capacity to run at full load. In addition, the cleaning system needs to run more often, which consumes additional compressed air motor energy, and the bag life is shortened due to additional cleaning cycles. Bags flex when they are cleaned because they are made of a fabric material, and this flexing eventually causes a failure of the material (McKenna, 1989).

Cleaning Frequency – Pressure drop and drag are controlled in a baghouse by the cleaning frequency. Higher inlet loading causes increased pressure drop and subsequent increased cleaning frequency. Cleaning cycles are initiated by a set pressure drop value for the system. When the system pressure drop increases to this point a cleaning cycle is initiated (see "Cleaning Modes" below). Cleaning frequency increases with the increased particulate loading from sorbent injection.

Opacity/Emissions – Cleaning frequency and particulate matter characteristics can affect collection efficiency across the baghouse. Most emissions occur immediately following cleaning, so increasing the cleaning frequency can increase outlet emissions. The emissions could also increase if the particulate does not form a high-efficiency filter, but tends to work through the fabrics.

Air-to-Cloth (A/C) Ratio – The ratio between flue gas flow (acfm) and total fabric surface area (ft^2), expressed in ft/min. A lower A/C ratio indicates a larger, more conservative design. Typically, pulse-jet fabric filters are designed with A/C ratios between 3 and 4 ft/min. COHPAC® and TOXECON™ applications target a higher, more economical design between 5 and 8 ft/min.

Cleaning Modes – Pulse-jet fabric filters are generally cleaned with either "online" or "offline" cleaning. In either case, cleaning is usually initiated when a predetermined pressure drop or drag setpoint is reached. In the case of offline cleaning, when the setpoint is reached, inlet and/or outlet dampers close, isolating a single compartment. This compartment is then systematically pulsed, row-by-row, until it has been entirely cleaned. The isolating dampers are then opened and flue gas reenters the compartment. In the case of online cleaning, when the setpoint is reached single rows are cleaned around the various compartments without any isolation. Because flue gas continues to flow through the bags being cleaned during online cleaning, the degree of cleaning is reduced. The benefits of online cleaning are that there is not a pressure spike (from isolating a compartment) and there is not a sudden very clean area in the fabric filter. When a compartment is cleaned offline, it creates a "hole" in the fabric filter, which can temporarily reduce particulate control and potentially mercury control.

EXECUTIVE SUMMARY

This document provides a summary of the design efforts involved in the project *"TOXECON™ Retrofit for Mercury and Multi-Pollutant Control on Three 90-MW Coal-Fired Boilers"* that was completed on September 30, 2009. This U.S. Department of Energy (DOE) Clean Coal Power Initiative (CCPI) project was based on a cooperative agreement between We Energies and the DOE Office of Fossil Energy's National Energy Technology Laboratory (NETL) to design, install, evaluate, and demonstrate the EPRI-patented TOXECON™ air pollution control process. Project partners included Cummins & Barnard (C&B), ADA Environmental Solutions (ADA-ES), and the Electric Power Research Institute (EPRI).

The primary goal of this project was to reduce mercury emissions from three 90-MW units that burn Powder River Basin coal at the We Energies' Presque Isle Power Plant in Marquette, Michigan. Additional goals were to reduce nitrogen oxide, sulfur dioxide, and particulate matter emissions; allow reuse and sale of fly ash; advance commercialization of the technology; demonstrate a reliable mercury continuous emission monitor (CEM) suitable for use at power plants; and demonstrate recovery of mercury from the sorbent.

The project was chosen for award in 2003 with Budget Period 1 taking place in 2004 and early 2005. Budget Period 2 of the project began in 2005 and came to a close in September 2009. Budget Period 1 included activities of project definition, design and engineering, prototype testing, major equipment procurement, and foundation installation. Budget Period 2 activities included CEMS demonstration, TOXECON™ erection, TOXECON™ operation, and carbon ash management demonstration.

Technology Overview

We Energies and the project team designed, installed, evaluated, and operated an integrated emissions control system for mercury and particulate matter that treated the flue gases of three 90-MW subbituminous coal-fired units. This was the first commercial full-scale TOXECON™ demonstration using activated carbon injection (ACI) for mercury removal. TOXECON™ is an EPRI-patented process (U.S. Patent 5,505,766) for removing pollutants from combustion flue gas by injecting sorbent between an existing particulate collector and a fabric filter (baghouse) installed downstream for control of toxic species. At Presque Isle, the existing collectors were hot-side electrostatic precipitators (HESP). The TOXECON™ configuration, shown in Figure 1, allowed for separate treatment or disposal of the ash collected in the hot-side ESP (99% or greater) and the ash/sorbent collected in the TOXECON™ baghouse, unlike other configurations that have ACI upstream of the particulate control device.

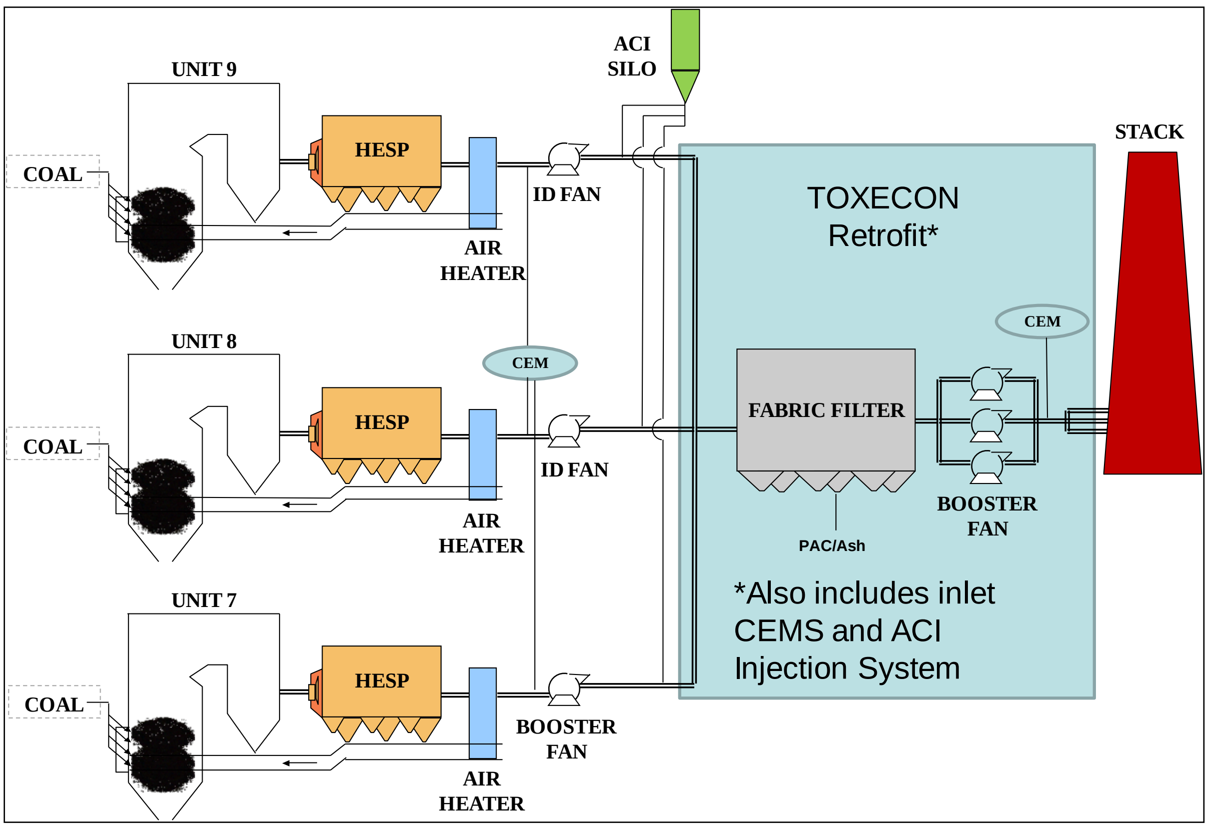

Figure 1. Process Flow Diagram.

The TOXECON™ system at Presque Isle consisted of a modification of the flue gas ductwork from each of the three units into a single duct that led to the new baghouse. A single duct exited the baghouse and then split into three individual branches with three new booster fans. The ducts exiting the booster fans were then recombined into a single duct back to the existing stack where the combined duct was again separated into three branches that supplied the three existing individual unit stack flues. The combined design condition for the three-unit flue gas system flow was 1,200,000 acfm @ 350 °F with approximately 14" w.c. of pressure drop from the ID fan discharges to the stack.

Also included in the TOXECON™ system was the PAC storage silo and injection system; and a new ash storage silo and ash unloading system.

Design and Engineering Considerations

A full evaluation of the commercial potential of TOXECON™ required long-term data on an installation that was specifically designed for both particulate control and sorbent injection. The installation also needed to have the flexibility to handle potential variability in particulate loading due to mercury control parametric and optimization testing, as well as increased loading from injecting sodium sorbents for the sulfur dioxide reduction tests. The design specifications for the pulse-jet style baghouse are listed in Table 1.

Table 1. Baghouse Design Specifications.

Item	Specification
Total Compartments	10
Bags per Compartment	648
Total Bags in Baghouse	6480
Air-to-Cloth Ratio (gross)	5.2
Design Gas Volume	1,200,000 acfm
Cleaning Method	On-line

The bag fabric chosen was 18 oz/yd^2, 2.7 denier PPS (polyphenylene sulfide fiber) felt. The bags were 26 feet long and 5 inches in diameter. Several test bags made from newer materials were also installed and tested throughout the demonstration project.

Norit Americas DARCO® Hg and Hg-LH were the two primary sorbents tested during the project. The activated carbon injection system installed was designed by ADA-ES and equipment was provided by Norit Americas. The design injection rate was 216 lb/hr (3 lb/MMacf total) and there were three injection trains (one per duct). The maximum capacity of the injection system was 600 lb/hr. The silo storage capacity was 4,490 cu ft, and depending upon the PAC density, could hold 80–100 tons of sorbent. Several other experimental and/or imported carbons from Norit and ADA-ES were also tested full-scale using temporary injection equipment.

In addition to the primary air pollution control system, balance-of-plant design considerations were addressed. These include booster fans, compressed air system, ash handling system, ductwork, electrical, and instrumentation and controls. A task in the project was devoted to advancing a monitoring system that would reliably measure mercury in flue gas from coal-fired power plants. Design considerations for the mercury continuous emissions monitors, including reporting and monitoring needs were also included.

Modifications to the Installation

After the construction was complete and throughout the demonstration portion of the project, several modifications to the equipment and structures were required.

Baghouse Modifications

Several modifications were incorporated to gain more optimal temperature control in the baghouse and booster fan building including larger ventilation fans and louvered windows at the top of the baghouse, additional walls in the upper and lower baghouse areas to block flow of hot air from the fan building, additional louvered windows at the booster fan inlet gate level and modified temperature controls to achieve better heat control, and additional walls and larger heaters in the lower baghouse area.

Additional modifications were added to improve structural integrity and maintenance access: the baghouse covers were rebuilt with checker plate and angle iron, and additional stiffeners were added across the width of the covers to improve strength; a redesigned lifting spreader for the covers was provided to keep from bending the covers when trying to open under negative pressure; platforms were added to access the booster fan outlet; and ice breaks were added to the top of the baghouse vent louvers.

Ash Handling System Modifications

Excessive dusting was occurring during the use of the wet unloading system, especially when starting the pin mixer. Several modifications were incorporated into the original pin mixer. Finally, a larger pin mixer had to be installed because the modifications still did now allow for a dust-free unloading process. This helped to eliminate the dusting and equipment issues seen during the demonstration. The main differences between the original mixer and the new mixer were additional fogging and spray nozzles, and the motor was increased from 7.5 HP to 10 HP, thereby increasing the mixer speed at 60 Hz motor frequency from 76 rpm to 100 rpm.

Additional modifications were made to improve flow of the PAC/ash mixture into the pin mixer. A new rotary valve was added to replace the original butterfly valve and, although fluidization at the silo discharge was normally not required, the original fluidization valves were replaced by three large air cannons.

There were other modifications to improve operability of the ash unloading system. A rubber skirt was added to the wet unloading spout to improve dust control, the sequencing of the exhauster and system relief valves was optimized to allow dust to be purged from vacuum relief piping before purging, an extension to the unloading shelter to the east of the silo was installed. This reduced the wind tunneling effect and protected the area from the elements.

Ductwork Modifications

Two inches of insulation was added to all expansion joints on the baghouse ductwork (approximately 28 places) to minimize corrosion due to flue gas condensation on cold spots in and around the joints.

Access Platform Additions

Four access platforms were added to the baghouse discharge ducts. Three platforms (one for each unit) were located underneath the ductwork at the 90° elbows just upstream of the diverter damper. The fourth additional platform was added on top of the Unit 8 ductwork to provide access to the baghouse.

Equipment and Installation Costs

The costs of equipment and installation for the TOXECON™ and balance-of-plant systems were $34.6 million, including the engineering effort. The cost of the additions and modifications after construction were $413,500.

1.0 PROJECT OVERVIEW

1.1 Purpose of the Public Design Report

This Public Design Report provides non-proprietary information on the performance and economics of the TOXECON™ air pollution control system installed at We Energies' Presque Isle Power Plant (PIPP) located in Marquette, Michigan, under U.S. Department of Energy Cooperative Agreement No. DE-FC26-04NT41766. This report describes the design and equipment associated with the TOXECON™ multi-pollutant system. This is the second of two final documents describing the installation at PIPP. The first document is the Project Performance and Economics Report (We Energies, 2009). A Preliminary Design Report was issued after the completion of the construction phase (We Energies, 2006), and this document is an expanded update of that report.

1.2 Brief Description of the Project

The project described in this report was conducted under the Department of Energy's (DOE) Clean Coal Power Initiative (CCPI). The CCPI is an industry/government cost-shared partnership to implement clean coal technologies.

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. The CCPI builds upon the advancements made by previous and continuing clean coal research and ensures the ongoing development of advanced systems for commercial power production.

1.2.1 Project Schedule

The project was selected for award in early 2003 with Budget Period 1 taking place in 2004 and early 2005. Budget Period 2 of the project began in 2005 and came to a close in September 2009. Budget Period 1 included activities of project definition, design and engineering, prototype testing, major equipment procurement, and foundation installation. Budget Period 2 activities included CEMS demonstration, TOXECON™ erection, TOXECON™ operation, and carbon ash management demonstration.

1.2.2 Project Organization

The project team included We Energies, ADA Environmental Solutions (ADA-ES), Cummins & Barnard (C&B), and the Electric Power Research Institute (EPRI). We Energies provided and operated the demonstration site, as well as provided project management, environmental permitting, and reporting. ADA-ES was the project management interface with DOE's National Energy Technology Laboratory (NETL), and was responsible for the design of the mercury control system, design of the mercury monitoring system, demonstration testing of the overall process, and reporting. Wheelabrator was responsible for the design and construction of the baghouse, support of baghouse installation, and provided startup support under a subcontract to We Energies. C&B provided architectural and engineering services, construction management, design and specification of equipment, equipment installation, and startup training for plant operators. EPRI provided technical advice to We Energies. Figure 1-1 is a simplified organizational chart for the project.

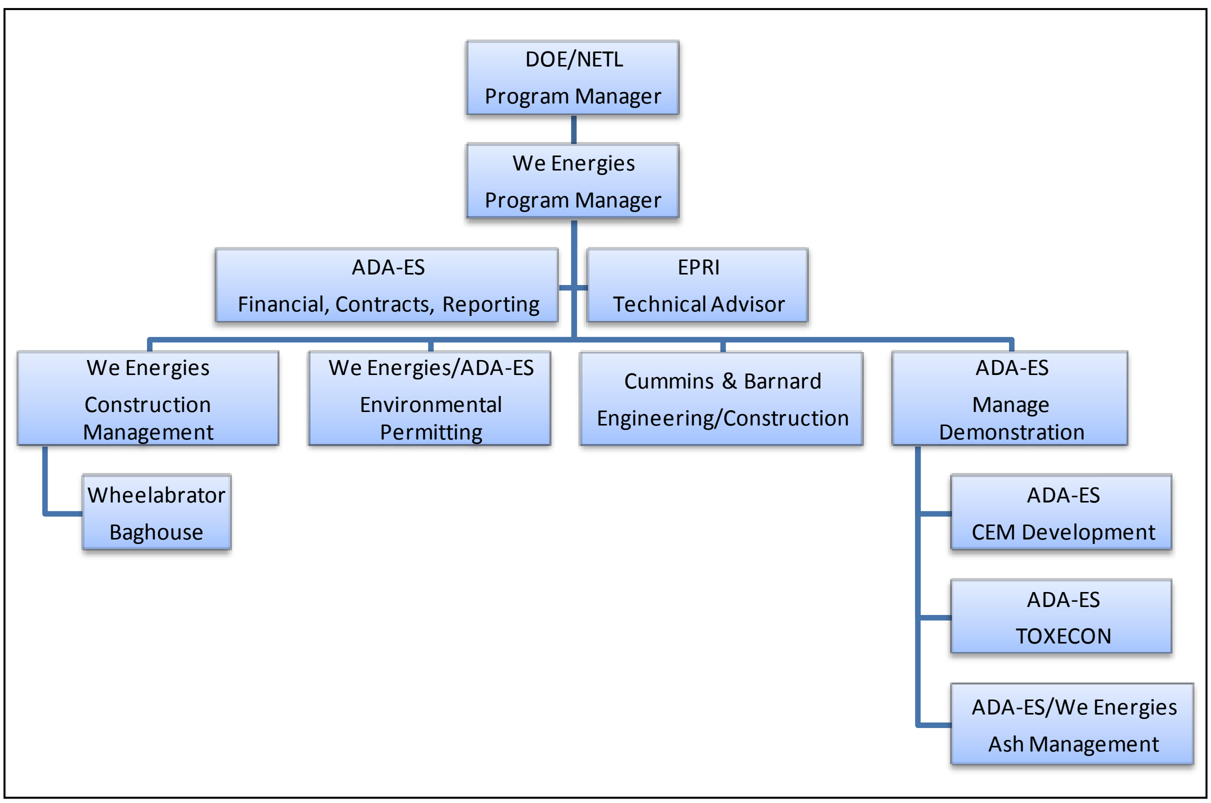

Figure 1-1. Organizational Chart.

1.2.3 Project Description

We Energies and the project team designed, installed, evaluated, and operated an integrated emissions control system for mercury and particulate matter that treated the flue gases of three 90-MW subbituminous coal-fired units. This was the first commercial full-scale TOXECON™ demonstration using activated carbon injection (ACI) for mercury removal. TOXECON™ is an EPRI-patented process (U.S. Patent 5,505,766) for removing pollutants from combustion flue gas by injecting sorbent between an existing particulate collector and a fabric filter (baghouse) installed downstream for control of toxic species. At Presque Isle, the existing collectors were hot-side electrostatic precipitators (HESPs). The TOXECON™ configuration, shown in Figure 1-2, allows for separate treatment or disposal of the ash collected in the HESP (99% or greater) and the ash/sorbent collected in the TOXECON™ baghouse.

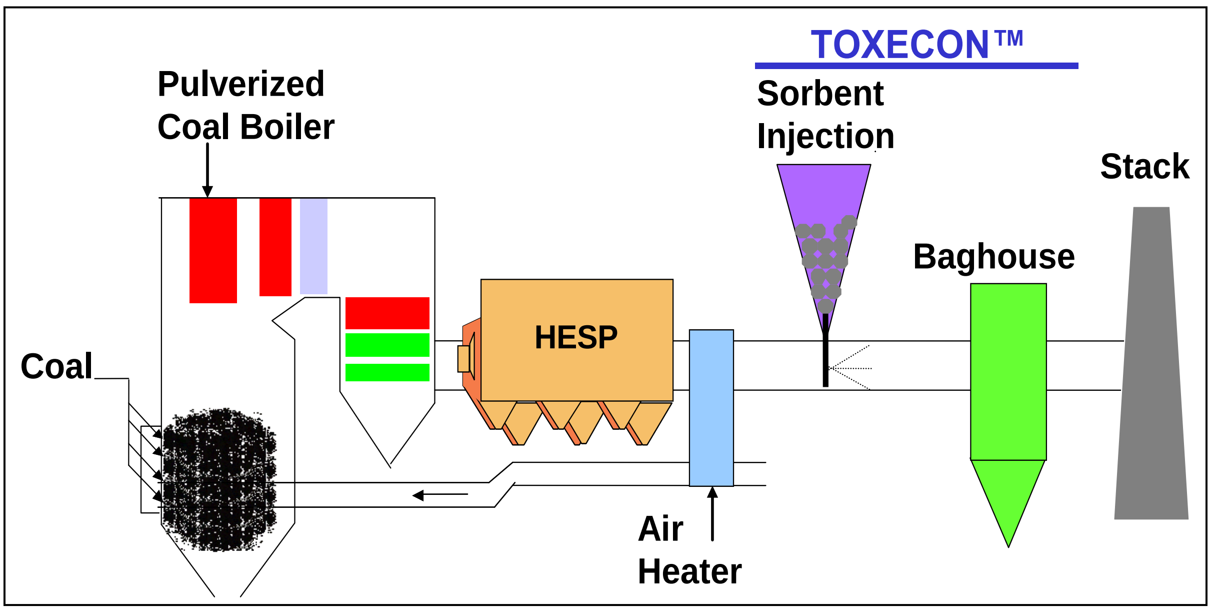

Figure 1-2. TOXECON™ Configuration.

The project advanced the ancillary processes that are significant to mercury control, such as mercury measurement technology and waste minimization. As a secondary priority, the project also investigated SO_2 and NO_x control after mercury control issues had been addressed.

1.2.4 Project Location

The project took place at We Energies' Presque Isle Power Plant (PIPP) located in Marquette, Michigan. PIPP had nine boilers and this project applied to Units 7, 8, and 9. Each of the 90-MW units had a HESP as the primary particulate matter (PM) control device. The exhausts from the three HESPs were ducted into individual flues of a common stack. The project involved controlling the emissions from the three units using a single baghouse. Integrating the three units into one project and structure provided significant cost savings over treating the units separately, and optimized the use of space.

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

The PIPP Units 7, 8, and 9 were placed in service in 1978, 1978, and 1979 respectively by Upper Peninsula Power Company to meet the needs of Cleveland-Cliffs Iron Co. Wisconsin Electric purchased the plant in 1988. Refer to Appendix C for plant schematics.

The boilers were Riley Turbo units rated for a maximum continuous capacity of 615,000 lb/hr steam flow at 1625 psig superheater outlet pressure and 1005 ºF. Reheater steam flow was 555,000 lb/hr at 390 psig and 1005 ºF. Each unit was fired by two 10' X 13' Riley ball tube mills and directional flame burners.

The precipitators were designed and built by Joy-Western and were designed as HESPs with an operating range of 565–745 ºF. The units were two chambers wide and were a weighted wire unit consisting of six mechanical fields per chamber and twelve electrical frames, six per chamber powered by six full-wave transformer/rectifiers (T/R). The units were designed to collect fly ash from a pulverized coal boiler with a gross rating of 93 MW and a design gas volumetric flow rate of 530,000 acfm. The design collection efficiency was 99.20%.

Typical flow rates and gas components in the flue gas exiting the HESPs of Units 7–9 are shown in Table 1-1.

Table 1-1. Flue Gas Composition Downstream of HESPs in Flues 7, 8, and 9 at PIPP.

Characteristic	Flue 7	Flue 8	Flue 9
Gas Volumetric Flow Rate, acfm	377,719	375,014	335,439
Average Gas Temperature, ºF	364.6	344.8	366.6
Flue Gas Moisture, % by volume	12.1	13.3	12.7
Average % CO_2 by volume, dry basis	12.8	13.0	13.0
Average % O_2 by volume, dry basis	6.2	6.0	6.0
Filterable PM, lb/hr	15.13	9.99	20.35
NO_x, lb/hr	407.8	410.5	406.8
SO_2, lb/hr	461.9	464.7	474.7
Mercury, ppm dry (Average Units 7–9)	0.062	0.062	0.062

The combustion process was controlled by an Emerson distributed control system with a SmartProcess® Combustion Optimization software package to optimize NO_x and loss on ignition (LOI).

PIPP burned Powder River Basin (PRB) subbituminous coal in Units 7–9. Analysis of the coal sampled at PIPP during the project showed a mercury concentration of 0.062 µg/g on a dry basis. PRB coal was supplied by several mines in Wyoming and Montana (dependent on the price of the fuel) and shipped by rail to Superior, Wisconsin, where it was then loaded onto a lake boat for delivery to PIPP.

1.3 Objectives of the Project

The primary goal of this project was to reduce mercury emissions from three 90-MW units at the We Energies Presque Isle Power Plant. Additional objectives were to reduce nitrogen oxide (NO_x), sulfur dioxide (SO_2), and particulate matter (PM) emissions; allow for reuse and sale of fly ash; develop and demonstrate a reliable mercury continuous emissions monitoring system (CEMS) suitable for use in the power plant environment; and demonstrate methods for sorbent regeneration and/or by-product reuse. This demonstration provided for the use of a novel multi-pollutant control system to reduce emissions of mercury and other air pollutants while minimizing waste from a coal-fired power generation system.

The specific objectives of this project were to demonstrate the operation of the TOXECON™ multi-pollutant control system and achieve:

- 90% mercury removal from flue gas through activated carbon injection.
- An evaluation of the potential for 70% SO_2 control and trim control of NO_x from flue gas through sodium-based or other novel sorbent injection.
- Reduced PM emission through collection by the TOXECON™ baghouse,
- Recovery of 90% of the mercury captured in the sorbent.
- 100% availability for utilization of fly ash collected in the existing electrostatic precipitator.
- Demonstration of a reliable, accurate mercury CEMS suitable for use in the power plant environment.
- A successful system integration and optimization of TOXECON™ operation for mercury and multi-pollutant control.

1.4 Significance of the Project

The CCPI demonstration of the TOXECON™ process was important to the industry because it provided long-term operational experience directly applicable to power plants that burn western subbituminous coal. With its proven ability to reduce mercury emissions, the process offers a significant benefit to operators of subbituminous-fueled units in that mercury in flue gas produced by these units exists primarily in the elemental vapor form that is insoluble in water and, as such, will pass through most types of other air pollution control devices. As a result of this project, the TOXECON™ process is in the position to become a leading mercury control choice for western coals, especially for units that use a hot-side electrostatic precipitator.

A primary benefit of this project was the long-term demonstration of 90% mercury removal from the stack emissions. The project also demonstrated emission control of particulate matter and sulfur dioxide. In addition, the process is able to maintain the beneficial use of HESP fly ash as a concrete additive.

A very important additional benefit has been identifying and solving the technical hurdles as they were discovered. One of the most notable issues was the overheating and autoignition of the high carbon ash in the baghouse hoppers. The subsequent investigation into the mechanism and development of operational guidelines has proven to be useful to other utilities using the TOXECON™ configuration. Optimization testing also provided important data on reducing sorbent costs and maximizing the life of the bags in the baghouse.

The project was able to significantly reduce the rate of carbon injection needed for achieving an average 90% mercury removal rate. The results of numerous test runs pointed out the importance of various factors that impacted mercury removal efficiency. These factors included the temperature of the flue gas, the amount of time PAC remained on the bags, the amount of PAC on the bags, and the amount of carbon in the fly ash. The result led to a revised control scheme for cleaning the baghouse that reduced operating costs while not impacting emissions or maintenance costs.

1.5 DOE's Role in the Project

The TOXECON™ project is part of the DOE's Clean Coal Power Initiative, which is an industry/government cost-shared partnership. Under the CCPI, the DOE provides up to 50% of the funding for the projects. The total cost share for this project was just under $48 million with the DOE contributing about $24 million and We Energies contributing about $24 million.

In 2003, a management plan was prepared to provide a suitable strategy for tracking project progress at the task level using an Earned Value Management system. The management plan included final work breakdown structure, final statement of project objectives, schedule baseline, cost baseline, technology baseline, and management controls. As part of the management plan, the DOE had oversight of the project while We Energies communicated project results to DOE to keep DOE fully informed of all aspects of the project. We Energies provided quarterly Technical Progress Reports summarizing technical progress, quarterly Cost Status Reports summarizing financial status, and quarterly Schedule Status Reports summarizing schedule status.

The extended project team including the DOE, EPRI, We Energies, and ADA-ES personnel participated in weekly phone meetings to coordinate project activities and to discuss relevant project management and technical issues. In this way, all participants including the DOE were able to provide value-added input to the success of the project.

2.0 TECHNOLOGY DESCRIPTION

2.1 Brief Description of the Technology Being Used

Injecting a sorbent such as PAC into the flue gas represents one of the simplest and most thoroughly studied approaches to controlling mercury emissions from coal-fired boilers (Government Accountability Office, 2005). The gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface. The sorbent with attached mercury is then collected by the existing particulate control device, either an electrostatic precipitator (ESP) or in the case of a TOXECON™ technology, a fabric filter. Over the past several years, the results from numerous full-scale evaluations of ACI for mercury removal indicate that activated carbon is a viable technology for mercury control on many coal-fired power plants (Durham, 2003; Bustard, et al., 2001).

For some plants, one of the disadvantages of injecting activated carbon is its impact on the salability of ash for making concrete. Tests have shown that the activated carbon interferes with chemicals used in making concrete (Bustard, 2003). This has also been confirmed under the project described in this report. One straightforward, cost-effective approach to achieving high mercury removal without contaminating the fly ash is the use of the EPRI TOXECON™ process. With the TOXECON™ configuration, the ash collected upstream of the carbon injection remains acceptable for sale. The downstream fabric filter provides an effective mechanism for the activated carbon to have intimate contact with vapor-phase mercury, resulting in high levels of mercury control at relatively low sorbent injection rates.

The advantages of the TOXECON™ configuration are:

- Sorbents are mixed with a small fraction of the ash (the less than 1% that exits the primary PM device), which reduces the impact on ash reuse and waste disposal.
- Full-scale field tests have confirmed that fabric filters require significantly less sorbent than ESPs to achieve similar mercury removal efficiencies (Bustard, 2004). This was also confirmed on the CCPI project.

- Outage time can be significantly reduced with TOXECON™ systems in comparison to the major ESP rebuilds/upgrades that might be required to handle the increased loading and greater collection difficulty of the injected carbon. Since the TOXECON™ unit is added downstream of the ESP, experience shows that it can be built, installed, and checked while the ESP is still in full operation, thus keeping outage time to a minimum.

- Baghouse types include shaker-cleaned, reverse-air-cleaned, pulse-jet-cleaned, and sonic-cleaned. A pulse-jet-cleaned baghouse was chosen for this application. Pulse jet baghouses use fabric filtration media shaped like tubes called bags, which are usually 4–6 inches in diameter and 10 to 26 feet long, to remove the particulate matter from the flue gas stream. The bags are mounted (hung) from a tube sheet and the gas stream flows from the outside of the bag through the bag, depositing particulate matter on the outside of the bag. A wire cage inside the bag supports the bag during filtration and cleaning. The particulate matter is removed from the bags by a cleaning system that employs compressed air (systems are designed to use compressed air from 30–120 psig) to back flush the bags (McKenna, 1989).

2.1.1 Proprietary Information

There is no proprietary information listed in this report.

2.2 Overall Block Flow Diagram

Figure 2-1 shows a simplified process flow diagram showing the TOXECON™ retrofit equipment. The inlet CEM probes and lines were integrated into the three ducts upstream of the ID fans. The ACI lances were installed in each duct downstream of the ID fans and just before the ducts' exit from the building envelope. Mercury data was taken upstream of PAC injection and downstream of the baghouse, and, occasionally, at the stack.

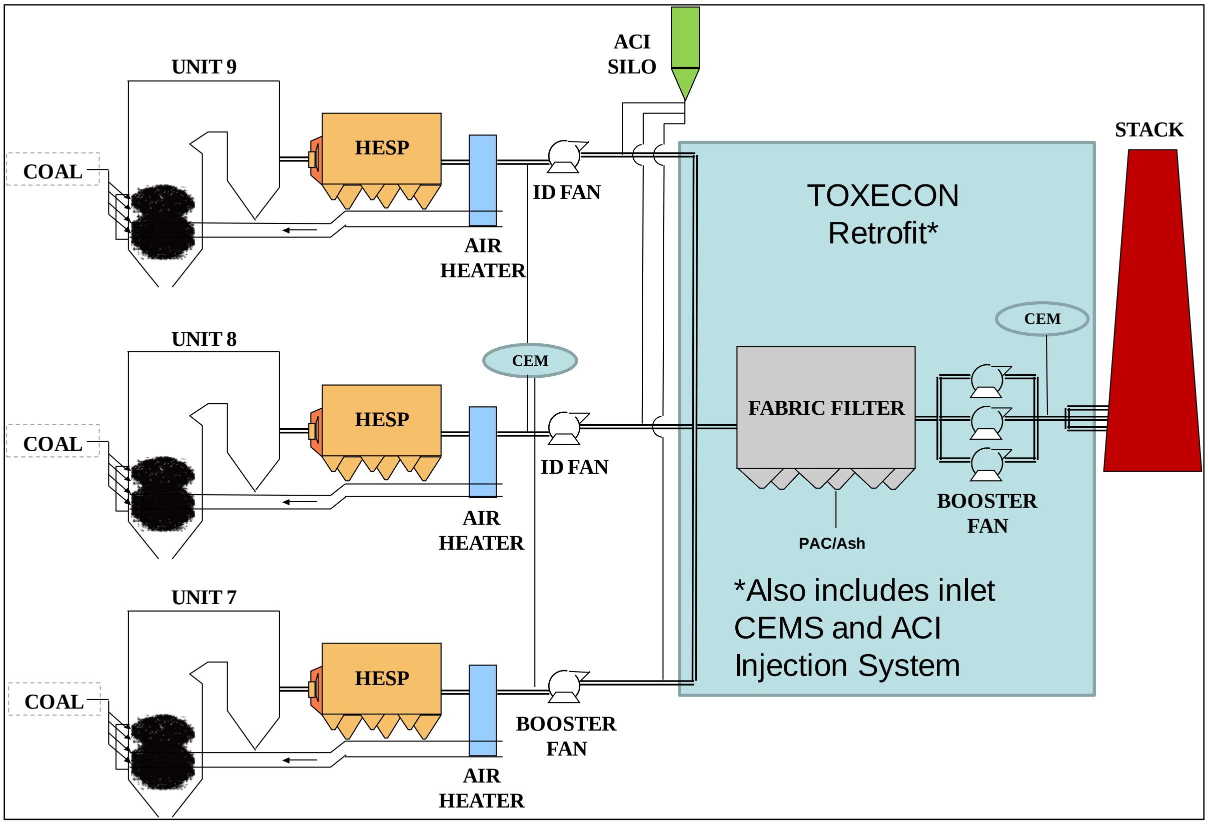

Figure 2-1. Process Flow Diagram.

Table 2-1 shows some of the process stream data for the TOXECON™ baghouse. Many stream components remained unchanged, such as gas flow rate and all major flue gas components. Mercury concentration in the flue gas was reduced by an average of 90%. Particulates were significantly reduced through the baghouse also. The flue gas temperature was reduced slightly as it passed through the baghouse. More detailed information can be found in Section 4.1 of this report.

Table 2-1. Stream Data.

Stream Parameter	Baghouse Inlet	Baghouse Outlet	TOXECON™ Ash
Volumetric Flow Rate	1,200,000 acfm	1,200,000 acfm	----
Mercury Concentration	5.5–7.0 ug/m^3	< 1 ug/m^3	40–80 ppm
Temperature	320–375 ºF	5 ºF below inlet	----
Particulates	0.0116 gr/acf	0.0016 gr/acf	Approx. 200 lb/hr PAC/ash mixture
Loss on Ignition (LOI)	< 1%	----	40–50%

3.0 PROCESS DESIGN CRITERIA

3.1 Design Recommendations for Presque Isle TOXECON™

A full evaluation of the commercial potential of TOXECON™ required long-term data on an installation that was specifically designed for both particulate control and sorbent injection. The installation also needed to have the flexibility to handle potential variability in particulate loading, as was planned for the SO_2 reduction testing with sodium sorbents, and between the short-term parametric and long-term testing periods.

Operational experience from the only two existing COHPAC® fabric filters in the U.S. at the time this project was in the design phase (Gaston Units 2 and 3 and TXU's Big Brown Units 1 and 2) and test results from bench-, pilot-, and full-scale tests provided a good basis for design recommendations (Miller, et al., 1999; Bustard, et al., 2001). These recommendations included:

- **Air-To-Cloth Ratio** – The Gaston tests showed that TOXECON™ units designed at lower A/C ratios than COHPAC® were capable of high, 90%, mercury removal (short term). The recommendation for this TOXECON™ fabric filter, based on the low A/C ratio tests at Gaston, was for a maximum design gross A/C ratio of 6.0 ft/min.

- **Fabric** – The most accepted fabric for pulse-jet fabric filters installed on coal-fired power plants is made from a polyphenylene sulfide fiber, commonly referred to worldwide as PPS. PPS felted material is currently available under the trade names TORCON™ and PROCON™. The original equipment manufacturer (OEM) fabric for the four existing COHPAC® fabric filters was an 18 oz/yd^2, 2.7 denier PPS felt. Denier is a unit used to measure the fineness of fabric, equal to the mass in grams of 9,000 meters of thread. For example, 9,000 meters of 15 denier nylon, used in nylon stockings, weighs 15 g/0.5 oz, and in this case the thickness of thread would be 0.00425 mm/0.0017 in.

- In recent years, advancements have been made with higher permeability fabrics that operate at lower pressure drop. A high permeability fabric made with a 7.0 denier fiber has replaced the OEM fabric at both Gaston and Big Brown. The 2.7 denier fabric was recommended for PIPP because:

- TOXECON™ was designed at a lower A/C ratio than COHPAC® and did not require higher fabric permeability.
- Field observations indicate that there may be higher particle penetration through 7.0 denier bags. Although this had not been quantified, it was desirable in this demonstration to use a more conservative design.

- **Sorbent** – Norit Americas DARCO® Hg (formerly DARCO® FGD) activated carbon had been the benchmark sorbent used in test programs starting as early as 1991. This sorbent had a proven record on many different coals, excellent quality control, and adequate capacity to supply 20–30 units. DARCO® Hg is made from Texas lignite coal, has a mass mean diameter of nominally 17 microns and a bulk density of about 30 lbs/ft^3. Appendix A contains detailed information on DARCO® FGD carbon. DARCO® FGD carbon was used at the Gaston plant with excellent mercury removal efficiencies (Bustard, et al. 2004). The initial PAC injection concentration was 3.0 lb/MMacf and was based on the Gaston and EPRI tests described above (Bustard et al., 2001; Sjostrom, et al., 2002).

- **Cleaning** – In order to obtain the highest utilization of the activated carbon, it was originally desirable to keep the carbon on the bag as long as possible before cleaning. With that in mind, online cleaning was recommended. During the demonstration, mercury removal data indicated that more frequent cleaning improved mercury control by preventing reemission of the mercury from the carbon particles.

3.2 Baghouse Design Specifications

The design specifications for the baghouse are listed in Table 3-1.

Table 3-1. Baghouse Design Specifications.

Item	Specification
Total Compartments	10
Bags per Compartment	648
Total Bags in Baghouse	6480
Air-to-Cloth Ratio (gross)	5.2
Design Gas Volume	1,200,000 acfm
Cleaning Method	On-line

3.3 Coal Analysis

Presque Isle Units 7–9 bur PRB subbituminous coal. A typical coal analysis is shown in Table 3-2.

Table 3-2. PIPP PRB Coal Analysis.

Parameter	Results (as received)
Proximate	
Water	26.52%
Volatiles	30.46%
Fixed Carbon	38.45%
Ash	4.57%
Ultimate	
Carbon	52.49%
Hydrogen	3.65%
Oxygen	12.3%
Nitrogen	0.75%
Sulfur	0.28%
Chlorine	0.01%
Water	25.85%
Ash	4.64%
High Heating Value	9052 Btu/lb

4.0 DETAILED PROCESS DESIGN

4.1 General Arrangement

The TOXECON™ system at Presque Isle consisted of a modification of the flue gas ductwork from each of the three units into a single duct that led to the new baghouse. The single duct exited the baghouse and was then split into three individual branches with three new booster fans. The ducts exiting the booster fans were then recombined into a single duct back to the existing stack where the combined duct was again separated into three branches that supplied the three existing individual unit stack flues. The combined three-unit flue gas system flow was 1,200,000 acfm @ 350 °F with approximately 14” w.c. of pressure drop from the ID fan discharges to the stack.

Also included in the TOXECON™ system were the PAC storage silo and injection system and a new ash storage silo.

Refer to Appendix C general arrangement drawings 4937-CGA-M1000, 4937-CGA-M1001, 4937-CGA-M1002, 4937-CGA-M1003, and 4937-CGA-M1004 for a layout of the project. Drawing 4937-CBA-M0112 is a piping and instrumentation diagram of the flue gas system.

4.2 Equipment List

Table 4-1 lists all significant items of process equipment.

Table 4-1. Major Equipment List.

Item No.	Item Name	Number		Vendor
		In Use	Spare	
1	Baghouse	1	0	Wheelabrator
2	Electrical Equipment	n/a	n/a	Various
3	Controls (Including Enclosure)	n/a	n/a	Emerson
4	Air Compressor/Dryer	1	1	Sullair
5	ID Booster Fans	3	0	Flakt-Woods
6	Ash System	1	0	United Conveyor
7	PAC System	1	0	Norit
8	Dampers	n/a	n/a	Wahlco
9	Expansion Joints	n/a	n/a	PAPCO
10	Ductwork and Structural Steel	n/a	n/a	Merrill, Cives
11	Mercury Continuous Emissions Monitors	2	0	Thermo Fisher

Design conditions were:

1) Unit capacity of 270 MW.
2) Air/cloth = 5.2 ft/min.
3) Flue gas flow rate of 1,200,000 acfm.

4.3 Baghouse Design

The mercury concentration in the ducts exiting the HESPs at Presque Isle was measured in 2005 using both the Thermo Electron (now Thermo Fisher) CEM and the Sorbent Trap Method (STM) and was found to be around 6 μg/dNm^3 (Sjostrom, 2005). This was the mercury concentration typically entering the baghouse along with the 1% of the total ash.

4.3.1 Inlet Particulate Loading

The original particulate loading was based on the collection rate of fly ash (200 lb/hr max) and the injection rate of PAC (450 lb/hr max), which included not only the initial PAC collection, but any recycled material that might be collected in later tests. The total maximum baghouse loading for fly ash/PAC was 650 lb/hr (0.325 tons per hour). Particulate tests were performed at the stack at Presque Isle in June 2005. Table 4-2 shows the particulate loading for Presque Isle and a comparison to the conditions during testing at Gaston.

Table 4-2. Typical Particulate Loading at Presque Isle.

Location	Particulate Loading (gr/acf)	Carbon Injection (gr/acf)
PIPP Flue 7	0.0047	-
PIPP Flue 8	0.0031	-
PIPP Flue 9	0.0071	-
PIPP Estimated Inlet (Total 7–9)	0.0050	0.021
Gaston – Low Load	0.0062	0.0063–0.014
Gaston – High Load, Mid-Range Values	0.07–0.14	0.0025

4.3.2 Type of Baghouse

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

4.3.3 Air-to-Cloth Ratios

Low flow tests performed at Gaston showed that a baghouse configuration utilizing an A/C ratio of less than 6 ft/min was recommended for new TOXECON™ units (Bustard, et al., 2004). These tests also showed that a mercury removal over 90% was achievable under these conditions. These tests also showed that the outlet mercury concentrations varied from 3.2-

0.61 μg/Nm^3 with an injection concentration of 0.9–3.3 lbs/MMacf, respectively. For PIPP to have a 90% removal at an inlet concentration of 6 μg/Nm^3 or an outlet concentration of 0.6 μg/Nm^3, it was anticipated that the design injection rate of 216 lb/hr (3.0 lb/MMacf) was required. Gaston was used as a guide here since no other test data was available. The differences in coal composition and gas temperatures between the two sites were substantial. Knowing this, the installed excess injection capacity allowed for adequate removal considering that the system could inject up to 600 lb/hr (8.3 lb/MMacf). The excess capacity also allowed testing of additional sorbents such as recycled PAC injection material.

Based on industry historical experience, test results from Gaston, bag supplier experience, the project stated goals, and compartment configuration; an A/C ratio of 5.2 ft/min was selected. The net (one compartment out of service) and net-net (two compartments out of service) A/C ratios were 6.1 and 6.8 ft/min, respectively.

The volumetric flow of 1,200,000 acfm of flue gas was calculated using heat balance software and compared to test data that were 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.

4.3.4 Flue Gas Cooling

A technical concern of this project was the expected range of flue gas temperatures. The air preheater on each of the three units deviated significantly from its design such that the gas outlet temperature operating range was measured at about 350 °F to 380 °F. This range was above the optimal condition for untreated sorbent performance and would likely preclude acceptable mercury control with the standard sorbent. Additionally, the high gas exit temperature could have a negative impact on unit heat rate and would be a risk to the filter bags. As such, efforts were undertaken to reduce the gas outlet temperature using sootblowers on the air preheaters in each of the three units. This should have improved the efficiency of the air preheaters and increased the cooling of the exit gas from the HESPs. Sootblowing tests performed during the demonstration showed a significant reduction in flue gas temperature, allowing 90% mercury removal at relatively low PAC injection rates (1.2 lb/MMacf for brominated PAC).

The alternative was to use a spray system to cool the flue gas before treating it with sorbent. After completion of the parametric testing and sootblowing tests, the project team determined that a spray cooling system was not needed.

4.3.5 Bag Material and Length

4.3.5.1 Base Bag Design

The fabric filter bag material chosen was a polyphenylene sulfide (PPS) material based on the flue gas temperature, flue gas analysis, and PAC properties (Appendix A). The base design for the TOXECON™ fabric filter was to use PPS fabric bags with the following specifications:

- Felted, 2.7 denier PPS fabric
- Weight of nominally 18 ounces/yd^2
- Singed on both sides
- Scrim material made from 3 ounces/yd^2 of PPS
- Mullen burst minimum of 500 psi
- Maximum temperature for continuous use is 375 ºF
- Permeability at 0.5” w.c. of 25–40 cfm/ft^2

Three of the four baghouse proposals offered a 26-foot bag, while the fourth offered a 20-foot bag. The final selection was a 26-foot bag with a nominal 5-inch diameter.

4.3.5.2 Alternate Test Bag Materials

The TOXECON™ program also included testing of bags and/or materials provided by other manufacturers. A description of the different types of test fabrics installed in Compartment 8 can be found in Table 4-3. All test bags were installed in bundle A, or the bundle closest to the inlet and outlet plenums. In the case of the Ahlstrom fabric, four approximately 4” x 11” 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 were preferred for the tests, using swatches reduced the risk of premature failures with experimental bags. For comparison, four OEM swatches were also installed. Additional test bags and swatches were installed and tested throughout the demonstration project. Refer to the Project Performance and Economics Report (We Energies, 2009) for more detail.

Table 4-3. Test Bag Materials.

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	9
1342	P84	Higher temperature, higher collection efficiency	11
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	10
Toray	Proprietary material		2
Environmental Products and Systems, Inc.	PPS fabric	Alternate source of PPS bags	1
Ahlstrom GFTS #4406	Armorguard felt, proprietary blend		Swatches only

4.3.6 Cleaning Method

Baghouses typically clean the filter bags in one of two methods: offline and online cleaning. Offline 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. Offline cleaning is an efficient method for cleaning the bag thoroughly; however, a disadvantage to this method is an increase in velocities and the resulting pressure drop in the other compartments in service when isolating a compartment for cleaning. Online 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. Although the online cleaning method would cause some re-entrainment of the dust on the bags, an advantage of the online cleaning method is that it can be accomplished in a shorter duration because compartment isolation is not required.

Both cleaning methods clean the filter bags by 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 and into the collection hopper at the bottom of the compartment.

Online and offline cleaning capabilities were considered and online cleaning was chosen with the objectives of maintaining a consistent pressure drop across the baghouse and dust cake on the bags. With offline cleaning, all of the bags in a compartment are cleaned at once, dislodging the fly ash/activated carbon 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. During the demonstration program, online cleaning proved to be efficient and was chosen for long-term operation.

The baghouse was configured to clean three rows of filter bags in a compartment, then advancing to another compartment. Staggering the cleaning cycle through multiple compartments evenly distributed the flow through the baghouse and prevented short circuit issues.

During testing it was determined that moisture in the exposed baghouse pulse-air piping may have been freezing and restricting air flow during bag cleaning. The plant built a sheet metal cover to help insulate this piping from the cold weather (ref: JPG_002, Appendix D).

4.3.7 Compartments

The selection of ten compartments in the baghouse design was based upon the total footprint area available at Presque Isle, and the desire to isolate compartments in order to simulate higher A/C ratios. Each compartment had 18 rows and 18 columns, and contained 648 bags. In this configuration, isolating one or two compartments allowed testing at A/C ratios of 6.1 and 6.8 ft/min.

4.3.8 Tube Sheet Pressure Drop

The specified design pressure drop across the TOXECON™ baghouse tube sheet was expected to be between 4” w.c. and 6” w.c., which is typical for baghouses installed on coal-fired boilers. At this site, the particulate cake consisted of PAC/ash, and adsorption on the cake was the primary mercury removal mechanism.

The PIPP baghouse was sized based on WAPC historic design parameters and the design guideline of the We Energies specifications. The plenums were sized based on traditional flow velocities and were within the guidelines set by the We Energies specifications. Inlet and outlet dampers were sized as large as physically possible for the plenums and compartments selected. The compartments were provided with vanes and perforated plates to achieve the flow and dust distribution required in the specifications and not specifically to reduce pressure loss. Inlet and outlet plenums were modeled with various vane arrangements to reduce pressure loss without any significant improvements. The model study mechanical pressures losses exceeded the expectations of WAPC. WAPC stated the model study results were not representative of past WAPC baghouse designs.

ADA-ES's calculation using a residual filter drag coefficient generally accepted in the industry is listed below. The formula for predicting pressure loss in a fabric filter is:

$\Delta P = \Delta P_R + K_2 V^2 Ct/7000$ Predictive equation for fabric filter pressure loss, where:

K_2	Specific resistance coefficient of freshly deposited dust (" w.c.)/(ft/min)/(lb/sq ft)
K_2	70 (" w.c.)/(ft/min)/(lb/sq ft)
ΔP_R	Anticipated residual drag was 0.7" w.c./(ft/min) at design air-to-cloth ratio
ΔP_R	5.48 ft/min
V	Face velocity or A/C (ft/min)
C	Dust loading (grains/acf)
t	Filtration time (min)

The residual filter drag coefficient of 0.7 for this calculation was conservative for this application. The calculated pressure loss based on the above factors was 8.0" w.c. with a cleaning time of about 100 minutes. The allotted pressure drop for the PIPP collector was 8.0" w.c. A minimum accepted cleaning cycle time was every 40 minutes.

4.3.9 Model Study Objectives and Results

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

- Determine baghouse gas flow and dust distribution
- Confirm design velocities and flow distribution in compartments
- Evaluate temperature mixing at the baghouse inlet
- Determine pressure drop of system
- Confirm minimal dust deposits in the ductwork
- Configure PAC injection location flow distribution
- Determine velocity distribution and gas flow angle at proposed CEM duct location
- Confirm balanced flow in the three stacks

Flow modeling was used primarily to study gas flow distribution in the inlet and outlet ducts and in the baghouse primarily in the hopper region. These model studies can visually show gas distribution patterns. Model testing of filter bag and tube sheet loss was not accurate and was just used to simulate resistance in the system for the purpose of flow and dust distribution. The purpose of the baghouse model study was primarily for flow and dust distribution.

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

Design velocities within each TOXECON™ baghouse compartment were chosen based upon ash-only baghouse designs with similar pressure drop and outlet emissions. Low vertical gas velocity at the bottom of the filter bags was desired since this enabled online bag cleaning. Providing low vertical gas velocity was accomplished by including gas distribution baffles in the compartment inlet hopper area that direct a portion of the gas flow away from the bottom of the compartment toward the top of the filter bags. This distribution also had an additional benefit of providing a flow pattern that caused the particulate flow to impact the bags rather than dropping out when it entered the bag compartment. Deposition of particles on the bags was beneficial in this application because it provided gas-solid contact that enabled mercury capture, as compared with conventional baghouse applications where particle dropout is desirable. The distribution baffles were included in the baghouse model study that confirmed their performance.

With regard to particle re-entrainment, the individual particles collected on filter bags agglomerate in conventional baghouse applications where fly ash is filtered. This system was designed assuming carbon particles would agglomerate with fly ash particles making them large and heavy enough to fall to the hopper, not subject to excessive re-entrainment. WAPC experience was that a portion of the filter ash cake would fall into the hopper after bags were pulsed and a portion of the ash would return to the filter bags. The pulse would cause all of the ash cake to break and when a portion of the ash would re-deposit on the filter bag the structure of the ash cake would be altered in a manner that further reduces resistance to gas flow.

4.3.9.1 Baghouse Modifications Required After Construction

Several modifications were incorporated to gain more optimal temperature control in the baghouse and booster fan building including:

- Added larger ventilation fans and louvered windows at the top of the baghouse
- Added walls to the upper and lower baghouse areas that block flow of hot air from the fan building
- Added louvered windows at the booster fan inlet gate level and modified temperature controls to achieve better heat control
- Added walls and larger heaters to the lower baghouse area

Additional modifications were added to improve structural integrity and maintenance access:

- The baghouse covers were rebuilt with checker plate and angle iron. Additional stiffeners were added across the width of the covers to improve strength.
- A redesigned lifting spreader for the covers was provided to keep from bending the covers when trying to open under negative pressure.
- Platforms were added to access the booster fan outlet (ref: JPG_006, Appendix D).
- Ice breaks were added to the top of the baghouse vent louvers.

4.4 Powdered Activated Carbon System Design

Norit Americas and ADA-ES provided the PAC injection system for Presque Isle. Norit Americas supplied the PAC and hardware, while ADA-ES supplied the engineering design for the system, and the distribution and duct injection system. The system consisted of two general components: the PAC storage and feeding system and the duct injection system.

The PAC storage and feeding system consisted 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 eductor, and a transport air blower. This system was complete with the necessary control provisions to operate and monitor the system equipment.

The duct injection system consisted of the transport piping from the feeding system and the necessary injection lances.

The PAC system was designed for an injection concentration of 3 lbs/MMacf. This projected injection rate was based on data obtained from full- and bench-scale testing. Appendix B contains a simplified drawing for the PAC system installed at Presque Isle.

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

- Design flue gas flow rate: 1,200,000 acfm at 350 ºF.
- PAC design injection concentration: 3.0 lb/MMacf
- PAC design injection rate (total): 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: 4,490 cu ft
- Silo storage capacity at 35 lb/cu ft: 157,000 lbs or 78 tons
- Storage capacity of bulk storage silo at design injection rate: 30 days
- Method for determining PAC distribution to the baghouse compartments: physical flow modeling, 1:12 scale

As a part of the effort to optimize the design of the injection system and the performance of the PAC system for mercury removal, NELS performed physical modeling of PAC injection at two locations in the ductwork leading to the baghouse using the existing 1:12 scale model.

This modeling looked at the distribution of the injected PAC in the baghouse inlet duct and inlet plenum and at the discharge of each of the compartments. The testing used two methods for making this determination: visible plume testing in the ducts, and carbon monoxide concentration distribution.

The first injection location consisted of a multi-lanced injection grid in the duct just prior to the inlet connection to the baghouse. Because of a widely varying flue gas flow distribution at this point, the modeling indicated a very uneven PAC distribution to the baghouse compartments using this design.

The second injection location consisted of a single injection lance in the round duct at the ID fan outlet for each generating unit. The modeling indicated that injecting at these locations gave a significantly better PAC distribution to the baghouse compartments.

Based on these tests, the PAC injection system used a single lance in the discharge duct of each ID fan. With three feeder trains, each generating unit had a dedicated injection train, transport line, and injection nozzle. The injection rate was controlled based on several variables, including boiler load/flue gas flow and mercury removal. Two CEMs were used, one measuring mercury concentration prior to ACI and the other in the common booster fan discharge duct.

The overall system design included the capability to inject a recycled PAC/ash mix collected from the baghouse hoppers. Since this mix would include partially spent PAC along with ash, the volume of injected material would increase substantially. Thus, the system capacity would accommodate the injection of the PAC/ash mix with the design PAC injection rate of sorbent (3.0 lb/MMacf) and the ash escaping the HESP. At the time of the original design, the benefit of recycling the PAC/ash mixture was unknown. During the demonstration program, it was determined that the PAC quickly reached equilibrium with the mercury in the flue gas and therefore was unable to sequester more mercury. Sorbent re-injection was not tested because of this observation.

4.5 Balance-of-Plant Considerations

4.5.1 Booster Fans

4.5.1.1 Two versus Three Fans

With the additional pressure drop associated with the installation of the TOXECON™ baghouse and associated ductwork, new ID booster fans were required. A study was prepared outlining the pros and cons of two versus three booster fans. The final decision to select three 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 National Fire Protection Association boiler purge flow requirements.

4.5.1.2 Margin (Test Block Performance)

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 25 ºF margin on temperature. The conditions of the fan with margin were referred to as "Test Block" conditions. The expected operating conditions were referred to as "Net" conditions. Test Block conditions were specified to account for system losses in the actual fan installation as compared to the ideal test setup installation with which the fans have been shop-tested to determine their capacity.

4.5.1.3 Purge Flow

The booster fans needed to have sufficient turndown capability in order to purge the boiler during a unit startup. The initial purge flow requirements were calculated and it was determined that the fan manufacturer needed to install sealing strips on the fan control damper to limit leakage. This would achieve the turndown on the fan performance necessary to meet the purge flow requirements.

4.5.1.4 Inlet Damper versus Variable Inlet Vanes

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

4.5.1.5 Fan Description

Manufacturer:	Fläkt Woods
Quantity:	3
Test Block Rating:	460,000 acfm @ 375 ºF with 18.5” w.c.
Net Rating:	400,000 acfm @ 350 ºF 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:	RENK-ERZLQ 18–180mm - 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
Vibration Transmitters:	Alaron Model VT-100
Lube Oil Console Manf.:	Howard Martin
Lube Oil Console Capacity:	3.5 gal/min

This minimum design of 400,000 acfm @14” w.c. was consistent with the flow modeling. The flow model report stated “the pressure drop measured in the model study ductwork and baghouse from the ID fan discharges to the stack was 10.72” w.c**., excluding the filter bags, ash cake on the bags, and buoyancy effects of the hot flue gas in the stack.**” The result of summing the expected pressure drop across the bags and cake (4–8” w.c.) and the buoyancy effect of the hot flue gas (negative 1.5–2" w.c.) was 12–16" w.c. This result indicated that the design was close to the modeling results.

Each fan was sized for one unit's flue gas flow. The booster fans controlled the draft on the discharge side of the ID fans by modulating VIV control dampers at the fan inlet. The booster fans were sized to offset the additional pressure drop of the baghouse and ductwork. The booster fan control scheme was 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 dampers. Each booster fan had an isolating guillotine gate on the inlet and outlet to allow online maintenance.

4.5.2 Compressed Air System

4.5.2.1 Compressed Air Users

The compressed air system provided instrument quality compressed air to the following systems and equipment:

- PAC System (10 SCFM)
- Ash Handling System (52 SCFM)
- Fabric Filter Baghouse (350 SCFM)
- Mercury CEMs Shelter (20 SCFM)

4.5.2.2 Capacity and Design

The compressed air system consisted of the compressed air skid and the associated distribution piping network. Refer to Drawing 4937-CIA-M0113, Appendix C for a P&ID of the compressed air skid. The compressed air skid was supplied by Sullair and included:

- Pressure: 80–120 psig (normal operation at 100 psig)
- Dew point: -40 ºF at 100 psig
- Particulate: Less than 1 micron

- Oil Content: 0.008 ppm
- Maximum Flow: 475 SCFM

4.5.2.3 Equipment Description

The compressed air system consisted of the compressed air skid and the associated distribution piping network. The piping distribution network consisted of ASTM A53 carbon steel piping. The compressed air skid included:

- Two single stage, heavy duty, flood lubricated rotary screw type compressor units
- Coalescing pre-filters
- Two fully automatic, regenerative desiccant dryers composed of a fully automatic pressure swing, twin tower using an activated alumina desiccant bed
- Particle after-filters
- Storage tank
- Flow controller

4.5.3 Ash Handling System

4.5.3.1 System Type

The ash handling system selected was a dilute-phase pneumatic conveying system. This type of system has been used in conveying both fly ash and PAC. The supplier of the system was United Conveyor Corporation (UCC).

4.5.3.2 Capacity and Margin

The particulate generation rate was based on the collection rate of fly ash (200 lb/hr max) and the maximum injection rate of sorbent (450 lb/hr max). The total maximum baghouse loading for fly ash/PAC was 650 lb/hr (0.325 tons/hr).

The conveying rate of the ash handling system was based on four times the total particulate loading rate of 0.325 tons/hr. This converts to 1.3 tons/hr.

4.5.3.3 Ash System Hardware

Refer to drawings M-54025-020 and M-54025-021, Appendix C for piping and instrumentation drawings of the ash handling system.

The ash system at Presque Isle was a vacuum dilute-phase transport system. The hardware consisted of the ten hoppers in the baghouse, transport lines from the bottom of each hopper leading to a filter/separator located on the penthouse of the ash storage silo, the ash storage silo itself, and finally trucks to transport the ash for disposal. A mechanical exhauster downstream of the filter/separator created the vacuum in the lines.

Each of the ten hoppers had a valve at the bottom to separate the ash from the lines. The ash was removed from the hoppers sequentially, starting at the furthest hopper on one side of the baghouse. When one side was emptied, the sequence was repeated on the other side. A purge cycle then cleared the main line of any residual ash. As each hopper emptied, the ash/air mixture was conveyed to the filter/separator. When the level probe in the filter/separator was activated, the transport of ash from the hoppers was discontinued. Then the exhauster relief and the system relief valves opened to relieve conveyor line vacuum and enabled the mechanical exhauster to pull in atmospheric air. After a predetermined time delay, the bottom gate opened so the ash discharged by gravity into the storage silo. After another predetermined time delay, the bottom gate closed. The exhauster relief and the system relief valves then closed, allowing the system to reestablish a vacuum. With sufficient vacuum available, ash transporting resumed to the filter/separator.

Fly ash/PAC was removed from the conical bottom storage silo by two different means. The fly ash/PAC was conditioned with water and unloaded through a pin paddle mixer, or it could be unloaded dry through a telescopic spout.

4.5.3.4 Unloading System Selection

Disposal of the fly ash/PAC mixture was by open bed trucks to a landfill. 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. A dry unloading system was also installed on the ash silo to allow the ash/PAC mixture to be recovered dry for use in testing re-injection (recycling) of the mixture into the flue gas stream, or for testing methods of recovering the mercury from the used PAC.

4.5.3.5 Modifications to the Ash Handling System since Start Up

Excessive dusting was occurring during the use of the wet unloading system, especially when starting the pin mixer. Several possible causes of the dusting were identified:

- Inadequate water mixing in the pin mixer
- Vacuum relief piping was venting to atmosphere
- Inconsistent flow of material from the silo through the valves at the bottom of hopper
- Bags in filter/separator improperly installed
- Ash becoming airborne at mixer discharge into truck
- Wind tunneling effects creating turbulence in uncovered truck beds

Several modifications were incorporated in to the pin mixer:

- The mixer cover was raised to allow the water spray to enter above the rotor (ref: JPG_001, Appendix D).
- A high-pressure water spray was added and sequenced into the control logic for mixer start-up.
- Baffles were added in the space above the pin mixer shaft to help control dust flow.
- A smaller sprocket was added to the mixer drive to increase the mixer speed.
- A VFD was added to allow adjustment of mixer speed.

Finally, a larger pin mixer was installed (ref: Dwg 5-5200-PIPP, Appendix D). This helped to eliminate the dusting and equipment issues seen during the demonstration. The main differences between the original mixer and the new mixer were as follows:

- Additional fogging nozzles.
- The motor was increased from 7.5 Hp to 10 Hp. Mixer speed at 60Hz motor frequency was increased from 76 rpm to 100 rpm.
- The tensioner design was changed.

Additional modifications were made to improve flow of the PAC/ash mixture:

- A new rotary valve was added to replace the original butterfly valve (ref: JPG_007, Appendix D).
- Although fluidization at the silo discharge was normally not required, the original fluidization valves were replaced by three (3) large air cannons (ref: JPG_008, Appendix D).

Other modifications to improve operability of the ash unloading system:

- A rubber skirt was added to the wet unloading spout to improve dust control (ref: JPG_0012, Appendix D).
- The sequencing of the exhauster and system relief valves was optimized to allow dust to be purged from vacuum relief piping before purging. The 7-9 baghouse fly ash system setpoints were modified to provide a better differential pressure between the empty line and empty hopper vacuums. Increasing vacuum on hoppers helped to ensure they emptied.
- The plant extended the unloading shelter to the east of the present shelter below the silo. This reduced the wind tunneling effect and protected the area from the elements.

Two recommendations for any similar program were made:

- Use a larger pin mixer
- Design the silo hopper leg to have a smoother transition into the discharge valves. The current design had a somewhat square transition which may have impeded smooth flow of PAC/Ash.

New setpoints:

- Full load vacuum (hopper valve closes): 6.8" Hg
- Vibrator vacuum (vibrator is activated in this range): 4.7"–2.5" Hg
- Plugged hopper vacuum (if vacuum stays in this range for a fixed amount of time): 4.7"–2.5" Hg
- Empty line (index – no hopper valves open, pulling air through the intake end check): 2.8" Hg
- No load (hopper gate opens - value set between empty line and empty hopper): 2.5" Hg
- Empty hopper (pulling on an empty hopper - hopper step sequence after time duration): 2.1" Hg
- The vacuum relief piping was rerouted from atmospheric release to release back into silo.
- The vacuum relief piping was insulated (ref: JPG_005, Appendix D).
- An external control station was provided to give the operator a better view of unloading and minimize exposure to dusting (ref: JPG_003, Appendix D).
- A silo inspection hatch, access platform, and inspection port were added at the bottom of the straight section to assist inspection of silo internals (ref: JPG_004, Appendix D).

4.5.4 Ductwork

4.5.4.1 Layout, Area Constraints, Existing Ductwork Tie In

The layout of the ductwork system to tie the existing units to the new baghouse was governed by the configuration of the existing power plant and its surrounding structures and equipment. Refer to general arrangement drawings 4937-CGA-M1000, 4937-CGA-M1001, and 4937-CGA-M1002, Appendix C for a layout of the plant. A location north of the existing Unit 9 boiler building was the site for the new baghouse. The location of the new baghouse was constrained to the north by the existing plant access road and property line, to the south by the existing Unit 9 boiler building, to the west by an emergency coal discharge chute and administration building, and to the east by the plant access road.

The ductwork layout to tie Units 7–9 to the new baghouse was constrained by the back wall of the existing boiler building and the exhaust stack for Units 7–9. With the proximity of the new ductwork run to the existing plant, the existing boiler room structure was used to tie into the new ductwork support structure. Because of the space constraints between the plant west wall and the existing stack, the use of round ductwork was precluded and rectangular cross-section ductwork was utilized. The ID fans for the existing units were located inside the existing boiler building near the back wall of the plant. The discharge ducts of the ID fans penetrated the back wall of the building and were routed to the exhaust stack location, which was centrally located on the centerline of Unit 8. The distance between the back wall of the boiler building and the exhaust stack provided just enough room to tie a supply duct and return duct into the existing flue gas stream. The supply duct and return duct were routed parallel with each other along the back wall of the boiler building and the tie-in location for each unit was "stepped" into the ductwork flow stream by increasing the vertical height of the common duct as each unit ties in.

4.5.4.2 Velocity Design

The new ductwork was sized to provide a similar cross sectional area to the existing round duct, thereby matching the existing velocity. The combined unit ductwork size was larger to provide a lower pressure drop. Table 4-4 reflects the sizing of the ductwork and the design velocities.

Table 4-4. Ductwork Sizing Summary.

Duct Section	Size (ft x ft)	Flow Area (sq ft)	Flow (acfm)	Velocity (ft/s)
One unit's flow – existing duct	9.5 dia	70.88	400,000	94.1
One unit's flow – new duct	8.5 x 8.5	72.25	400,000	92.3
Two units' flow – new duct	8.5 x 20	170	800,000	78.4
Three units' flow – new duct	8.5 x 30	255	1,200,000	78.4

A two-stage static mixer was included in the inlet duct to the baghouse to provide a more uniform temperature profile from the three units and promote even carbon distribution across the duct cross section. The static mixer consisted of opposed inclined plates and was supplied by KOMAX Systems.

4.5.4.3 Structural Design

The structural design aspects of the ductwork system and its supporting structure utilized industry standard practices for ductwork and structural steel design. The provisions of the American Institute of Steel Construction's (AISC) *Specification for Structural Steel Buildings – Allowable Stress Design and Plastic Design (ASD)* presented in the *AISC Manual of Steel Construction – Allowable Stress Design (AISC-ASD)* were used with allowances made for elevated temperatures in the ductwork system. The load criteria governing the design of the structural systems included dead loads; live loads; environmental loads such as wind, seismic, and snow loads; and operating loads such as normal and transient pressures, unbalanced pressures, operating and excursion temperatures, and ash loading. The various load combinations were analyzed to determine the most critical case for each component of the system. Once the most critical load case was determined for a particular component, the structural aspects of that component were designed to withstand the loads being applied. This philosophy was carried through the entire structural system to determine member sizes, spacing, and ductwork support locations.

4.5.4.4 Diverter Damper Provisions

The ductwork from each unit between the ID fan and the stack was modified to install two diverter dampers in series forming a four-port arrangement. The first port was connected to each unit's ID fan discharge ductwork, the second port was connected to ductwork that combined the flue gas flows from all three units into a common header directed to the fabric filter baghouse, the third port connected to the common return ductwork from the baghouse, and the fourth port connected to each unit's stack. When flue gas was directed to the baghouse, the diverter dampers were aligned to block the direct flow of flue gas to the stack. If required, the diverter dampers could 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 units were 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.

An engineering and economic evaluation prior to damper procurement compared the costs associated with installation of three diverter dampers in lieu of nine guillotine type dampers. Based on considerations including the purchase cost of the dampers, the required ductwork costs, and flue gas pressure drop through the dampers and associated ductwork, the total evaluated life cycle costs of utilizing the diverter dampers for this application provided an overall savings in cost when compared to the guillotine damper option.

4.5.4.5 Diverter Damper Upgrades since Start Up

Baghouse discharge duct pressures varied from slightly positive at Unit 9 to negative at Units 7 and 8. The positive pressure at the Unit 9 diverter damper allowed exhaust gas to leak back through the seal air system and corrode seal air fan blades. A new tighter sealing, 10" Ultraflo Cast Iron actuated valve was installed and seal air logic was modified to ensure that seal air valves were shut during fan cycling to minimize possibility of leakage.

4.5.4.6 Ductwork Modifications since Start Up

Two inches of insulation was added to the exterior of all expansion joints on the baghouse ductwork (approximately 28 places) to minimize corrosion due to flue gas condensation on cold spots in and around the joints.

4.5.4.7 Access Platform Additions since Start Up

Four (4) access platforms were added to the baghouse discharge ducts. Three (3) platforms (one for each unit) were located underneath the ductwork at the 90° elbows just upstream of the diverter damper. These platforms allow access to hatch covers that provide maintenance access to the dampers. The fourth additional platform was added on top of the Unit 8 ductwork to provide access to the baghouse. Pictures of these platforms are included in Appendix D (ref: JPG_009 & JPG_010, Appendix D).

4.5.5 Electrical

4.5.5.1 Electrical Constraints and Upgrades

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 transformer to the reserve system to maintain boiler draft and safely shut down unit loads.

Units 7, 8, and 9 switchgear (2,400 VAC) were studied to determine if the existing gear could adequately power the running load, and were capable of starting the motors. The plant reserve system was also checked to see if it could provide enough power to satisfy the requirements of startup and multiple unit trips. The study verified the suitability of the switchgear to handle the new running loads, but pointed out deficiencies in the reserve system 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. Refer to drawings 4937-CMP-E1000 and 4937-CMP-E1001, Appendix C for an overview of the one-line diagram.

4.5.5.2 Electrical System Configuration and Hardware

The electrical systems supporting the baghouse were related to the function and size of the baghouse equipment. To achieve the desired exhaust gas flow from boiler to stack, ID booster fans were added to the baghouse outlet to compensate for the pressure drop across the baghouse and ductwork to maintain suitable flow to the stack. These booster fan motors were each rated 1,700 hp, with one booster fan associated with each unit. These motors were controlled by dedicated medium voltage starters, which are fed from the unit 2,400-volt switchgear attached individually from each respective unit. The motor starters receive commands from the baghouse distributed control system (DCS) for start/stop, and supply information to the DCS to allow operators in the control room to monitor booster fan 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 allowed the individual motors to start at reduced voltage and current draw.

Remaining baghouse systems comprised the balance-of-plant electrical system. These loads were powered from motor control centers (MCCs) operating at 480 volts. This system provided 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 were fed from MCCs, which received power from existing plant equipment to ensure the most reliable source and functionality possible.

4.5.6 Instrumentation and Controls

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

An overview of the DCS expansion for the PIPP TOXECON™ project is shown on the Control System Overview drawings 4937-CCX-K6000 and 4937-CCX-K6001, Appendix C. This expansion provided all functions required for controlling the plant equipment and monitoring of other plant systems installed as part of the TOXECON™ project.

The DCS expansion included three new cabinet groups that were interconnected as shown on the Control System Overview drawings. Each cabinet group consisted of the required redundant controllers, I/O modules, redundant power supplies, communication modules, and other components as required to implement the required control strategies.

One of the cabinet groups (Unit 8, Drop 4) provided control and monitoring for the baghouse. Unit 8, Drop 4 consisted of the following cabinets:

- 79CX-CPU-0004 (Processor I/O Cabinet)
- 79CX-EXP-0004A (Expansion I/O Cabinet)

A second cabinet group consisting of unitized remote I/O cabinets (Unit 7, Drop 1; Unit 8, Drop 1; Unit 9, Drop 1) was dedicated to providing controls interfaces with the existing plant control system for booster fan draft control, control of their respective unit booster fans, control of their respective unit baghouse supply and return diverter dampers, and control of their respective baghouse supply and return diverter damper seal air blowers and valves. The remote I/O (RIO) group consisted of the following cabinets:

- 7CX-RIO-0001 (Unit 7 RIO)
- 8CX-RIO-0001 (Unit 8 RIO)
- 9CX-RIO-0001 (Unit 9 RIO)

The third cabinet group (Unit 8, Drop 5) was dedicated to control of the remaining TOXECON™ balance-of-plant (BOP) equipment including booster fan draft control, fly ash system, PAC injection system, compressed air system, and baghouse outlet mercury CEMs. Unit 8, Drop 5 consisted of the following cabinets:

- 79CX-CPU-0005 (Processor I/O Cabinet)
- 79CX-EXP-0005A (Expansion I/O Cabinet)
- 79CX-EXP-0005B (Expansion I/O Cabinet)
- 79CX-EXP-0005C (Expansion I/O Cabinet)

4.6 Mercury Measurements

When this CCPI program was selected in 2003, stack compliance-grade continuous emissions monitor (CEM) mercury monitors were not available. Several research-grade mercury monitors were proven to be accurate and reliable; however, they required operation by a highly skilled engineer and continuous maintenance.

Throughout the demonstration project, ADA-ES worked with Thermo Electron (now Thermo Fisher) Corporation to develop a mercury CEM for use on this program to measure mercury concentrations at the inlet and outlet of the TOXECON™ fabric filter. ADA-ES's role was to validate different components by operating them in parallel with ADA-ES's semi-continuous mercury monitor. The Thermo instrument had four key components: sample extraction probe, sample converter, mercury analyzer, and calibration module. Figure 4-1 shows a schematic of these components.

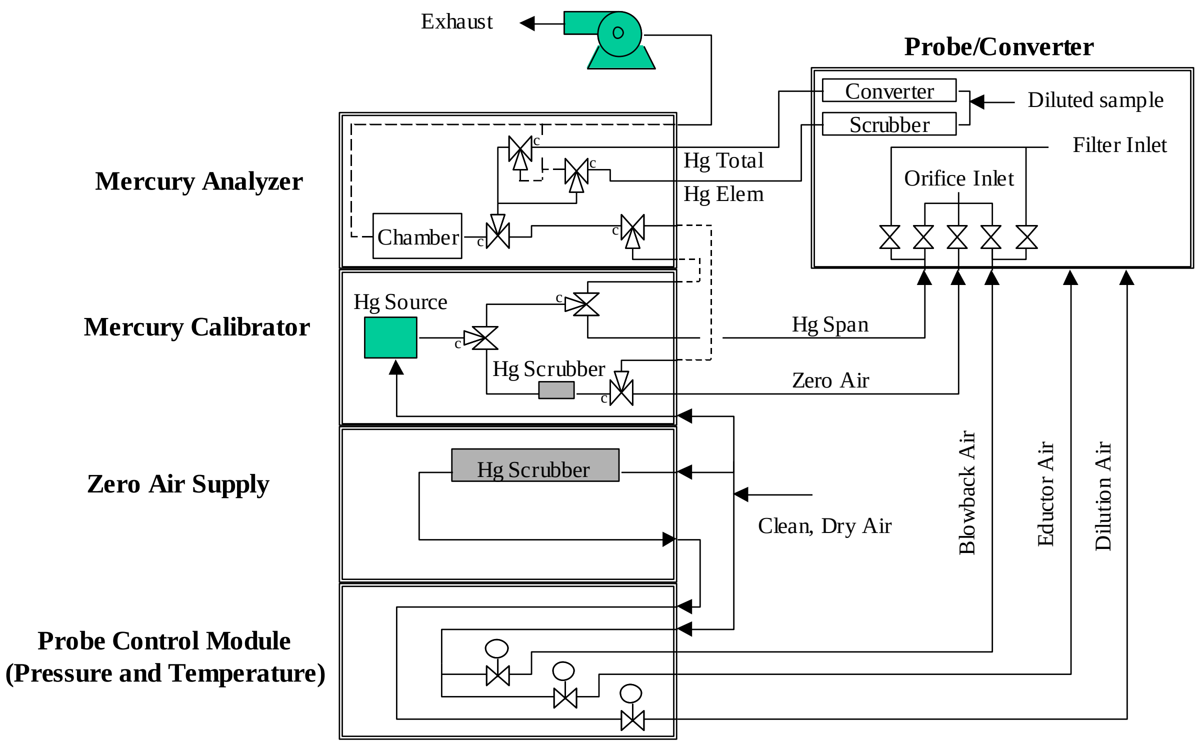

Figure 4-1. Schematic of Thermo Prototype Mercury CEM.

The extraction probe used an inertial filter to obtain a particulate-free vapor-phase sample without passing the gas through a fly ash filter cake. This minimized the sample gas interactions with the fly ash, which could cause sampling artifacts. An eductor, driven with compressed, dry, mercury-free motive air, drew the ash-free sample from the inertial filter. The line between the inertial filter and the vacuum port on the eductor contained a critical-flow orifice. To maintain a constant sample flow rate to the analyzer, the eductor diluted the sample with the motive air resulting in a dilution ratio between 25:1 and 100:1, depending on the size of the critical-flow orifice. The dilution ratio was determined based on flue gas conditions and operator preference. All of the extraction probe internal surfaces exposed to sample gas had a glass coating to prevent unwanted chemical reactions with the mercury.

Calibration gas from the calibration module was introduced into the sample stream either upstream or downstream of the inertial filter.

The converter module converted the oxidized mercury in the diluted sample to elemental mercury for a total vapor-phase mercury measurement, or it scrubbed oxidized mercury from the diluted sample to deliver only elemental mercury to the analyzer when a speciated measurement is desired. The proprietary design combined high temperature (> 750 ºF) and a chemical reaction to achieve the conversions.

The analyzer measured mercury directly using Cold Vapor Atomic Fluorescence technology. Because the sample was diluted, it had low moisture, was relatively non-reactive, and therefore had minimal interference from other gases. The analyzer detection limit was 1 ng/m^3 (~ 0.1 ppt) and no cross interference from SO_2 has been observed.

5.0 PROCESS CAPITAL COST

The capital cost associated with construction of the TOXECON™ was $34,644,237. This is the actual installed cost expressed in 2005 dollars. A listing of the costs by major equipment item is shown in Table 5-1.

Table 5-1. Summary of Equipment, Balance-of-Plant, and Engineering Costs.

TOXECON™ and Balance-of-Plant Equipment and Installation Costs Presque Isle Power Plant Units 7, 8, and 9	
Item Description	**Cost**
Baghouse	
Baghouse Supply and Erection	$9,728,779
Equipment	
Electrical Equipment	$624,102
Controls (Including Enclosure)	$295,295
Air Compressor/Dryer	$121,589
ID Booster Fans	$1,199,802
Ash System	$623,789
PAC System	$360,786
Dampers	$655,744
Expansion Joints	$101,519
Ductwork and Structural Steel	$3,114,209
Erection	
Construction Supervision and Indirects	$1,659,883
Foundations	$1,603,112
Electrical Installation	$1,455,979
Mechanical and Structural Installation	$7,796,968
Other	
Engineering Costs (A/E and Utility)	$3,949,052
Mercury Continuous Emissions Monitors (2)	$1,353,629
TOTAL *(excludes testing program costs)*	**$34,644,237**

Baghouse: Includes baghouse casing structure and support steel, hoppers, bags and cages, maintenance elevator, exterior siding and roof structure, inlet and outlet plenums, access stairways and platforms.

Electrical Equipment: Includes medium voltage motor starters, motor control centers, and transformers.

Controls: Includes a digital control system and a prefabricated enclosure for the digital control system equipment.

Air Compressor/Dryer: Includes skid mounted air compressor with an air receiver tank and dryer.

ID Booster Fans: Includes booster fans, motors, lube oil skid, and fan control instruments.

Ash System: Includes ash storage silo, ash piping and ash hopper valves, vacuum exhausters, and ash system controls.

PAC System: Includes powdered activated carbon storage silo, blower, piping, injection ports, and control instruments.

Dampers: Includes damper assemblies and drives.

Expansion Joints: Includes ductwork expansion joint material and hardware.

Ductwork and Structural Steel: Includes, ductwork to and from the baghouse, internal turning vanes, static mixer, ductwork support steel, booster fan building support steel, access platforms, and stairways.

The bulk of the construction consisted of site fabrication of process elements. One notable exception was the PAC system which was pre-fabricated. Construction commenced in November, 2004 and ended in December 2005. This resulted in significant work being done during winter weather conditions which can be severe at this location. Construction costs in a milder climate would be expected to be somewhat less.

This installation was a retrofit application which represents higher costs than would be required for a new plant application. However, it is felt that new plant applications of the TOXECON™ technology as demonstrated at this site are unlikely. This is because hot-side ESP installations on units burning PRB coal are no longer being considered. The application of retrofits using TOXECON™ technology is expected to continue.

5.1 Additional Cost of Modifications since Start Up

Table 5-2 is a summary of changes made to the TOXECON™ installation which were not covered in the original proposed costs shown in Table 5-1. These additional costs are broken down into four categories: Baghouse; Pin Mixer; Silo/Unloading; and Diverter Dampers and Ductwork. In general, these changes were considered necessary to meet the performance specifications set forth in the original contract and to ensure trouble-free operation in the future. The cost for the additional modifications was $413,500.

Table 5-2. Additional Equipment Costs since Startup.

Item: Baghouse	**Material**	**Labor**
Install larger ventilation fans: upper baghouse	$15,000	$5,000
Install larger louvered windows: upper BH	$3,000	$5,000
Install louvered windows booster fan inlet	$4,000	$5,000
New heaters: lower baghouse	Warranty	$10,000
Insulating wall: lower baghouse	$2,500	$2,500
Insulating wall: upper baghouse	$2,500	$2,500
Rebuild baghouse covers: checkerplate and angle iron	$3,000	$5,000
Build new lifting spreader	$1,000	$2,000
Platform additions at booster fan outlet	$30,000	$25,000
Ice breaks upper baghouse vent louvers	$500	$1,000
Sheet metal cover for purge air piping	$500	$500
Item: Pin Mixer		
Add high pressure washer	$2,500	$500
Add baffles	$200	$400
Modify cover (raise)	$1,500	$500
Add higher speed drive sprocket	$500	$1,000
Item: Silo/Unloading		
Add rotary valve	$8,000	$1,000
Add (3) air cannons	$3,000	$1,500
Add rubber skirt to wet unloading spout	$1,500	$500
Add rubber truck skirt to enclosure	$1,500	$500
Add external control station	$8,000	$2,000
Insulate/modify vacuum relief piping	$500	$500
Add silo hatch	$1,500	$1,000
Add inspection nozzle for above	$200	$200
Add platform for silo hatch	$2,500	$2,000
Extend ash unloading building		$100,000
Item: Diverter/Dampers/Ductwork		
Replace 10" seal air valve	4,500	$500
Insulate expansion joints (~ 28 plcs)	10,000	$65,000
Add (3) platforms under duct for Diverter access	15,000	$15,000
Add (1) platform on top of unit 8	20,000	$15,000
Total Cost	**142,900**	**270, 600**

6.0 ESTIMATED OPERATING COSTS

The operating costs for TOXECON™ were determined based on actual project expenditures associated with long term, ongoing operation. This does not include costs associated with testing, technology demonstration, or other costs not directly related to standard utility practice. These costs are in 2008 dollars and are summarized in Table 6-1. The operation is assumed to target an average 90% mercury removal level on a long-term basis.

Table 6-1. Summary of Operating and Maintenance Costs.

TOXECON™ Summary of Operating & Maintenance Costs				
Annual Fixed O&M Cost				
			Cost, $/yr	
Operating Labor			27,851	
Maintenance Labor			18,574	
Maintenance Material			255,719	
Administration/Support Labor			43,586	
Sub-Total Annual Fixed O&M Cost			**345,730**	
Variable Operating Cost				
Commodity	**Unit**	**$/Unit**	**Qty/hr**	**Cost $/hr**
Powdered Activated Carbon	lb	1.009	72.8	73
Electric Power	kW	0.02	3000	60
Waste Disposal Charges	ton	81.5	0.07	11
Sub-Total Annual Variable Cost				**145**

The startup of the TOXECON™ facility began on December 17, 2005, and was completed on February 12, 2006. The costs associated with this activity are shown in Table 6-2 and were $360,000 (based on year of occurrence dollars).

Table 6-2. Summary of Startup Costs.

TOXECON™ Summary of Startup Costs	
Description	**Cost**
Internal Labor	$50,563
Misc. Expenses	$62,332
Contractor Support	$148,145
Electrical Power	$83,520
PAC	$33,004
Waste Disposal	$15,405
TOTAL	**$359,965**

7.0 COMMERCIAL APPLICATIONS

This demonstration project was the first dedicated, full-scale use of the TOXECON™ process and identified issues relating to the technology itself and balance-of-plant issues. Valuable experience was gained by testing a full-scale TOXECON™ unit over the course of several years, allowing fine-tuning of the process. Testing for simultaneous removal of SO_2 and NO_x, and mercury using trona injection showed that there is a significant negative impact on mercury removal when injecting trona at the levels required for SO_2 removal. Testing of new bag fabrics will also aid others in choosing fabrics for their installation. Marketplace acceptance will be higher by demonstrating long-term use of the TOXECON™ process and providing economic information so that other potential users can determine if TOXECON™ is cost-effective for their situation.

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Appendix A. PAC Data Sheet

ISO 9002
BSI REGISTERED
FM 36335

NORIT Americas Inc.

Most Choices + Precise Fit = Best Performance.

DATASHEET

Product No. FGD
Revised 9-97

DARCO® FGD

POWDERED ACTIVATED CARBON

DARCO FGD is a lignite coal-based activated carbon manufactured specifically for the removal of heavy metals and other contaminants typically found in incinerator flue gas emission streams. It has been proven in numerous full scale operating facilities to be highly effective for the removal of gaseous mercury, dioxins (PCDD) and furans (PCDF). Its open pore structure and fine particle size permit rapid adsorption, which is critical for high performance in flue gas streams where contact times are short.

DARCO FGD is a free flowing powdered carbon with minimal caking tendencies which makes it ideal for automatic dosing systems with dry or wet injection. It is manufactured with a very high ignition temperature to permit safe operation at the elevated temperatures inherent in incinerator flue gas streams.

Product Specifications	
Molasses decolorizing efficiency, %	80 min.
Moisture, % as packed	8 max.
Mesh size:	
Less than 325 mesh (45 µm), %	95 min.

Typical Properties*	
Iodine number, mg/g	600
Bulk density, tamped, g/ml	0.53
$lbs./ft^3$	33

General Characteristics *	
Surface area, m^2/g	600
Heat capacity	0.22
Total sulfur, %	1.8
Ignition temperature, ºC	450

* For general information only, not to be used as purchase specifications.

Packaging

Standard package is 40 lb. bags, 50 bags per pallet for a net pallet weight of 2000 lbs. Alternate packages include bulk trailer, and woven polypropylene bulk bags, 900 lbs. net, with a glued plastic liner.

Safety

CAUTION: Wet activated carbon depletes oxygen from air and, therefore, dangerously low levels of oxygen may be encountered. Whenever workers enter a vessel containing activated carbon, the vessel's oxygen content should be determined and work procedures for potentially low oxygen areas should be followed. Appropriate protective equipment should be worn. Avoid inhalation of excessive carbon dust. No problems are known to be associated in handling this material. However, dust may contain greater than 1.0% silica (quartz). Longterm inhalation of high dust concentrations can lead to respiratory impairment. Use forced ventilation or a dust mask when necessary for protection against airborne dust exposure (see Code of Federal Regulations - Title 29, Subpart Z, par. 1910.1000, Table Z-3).

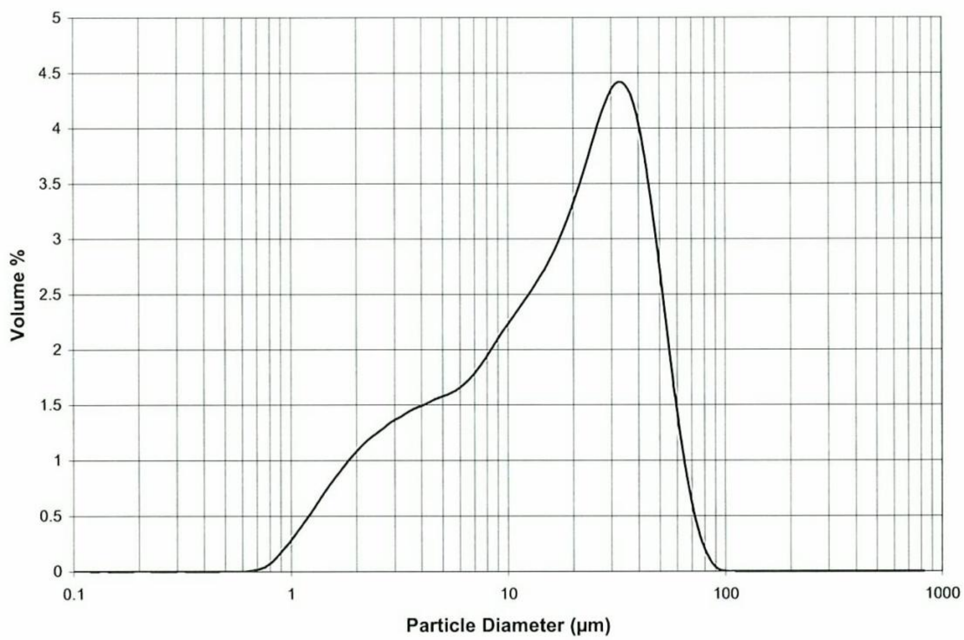
5775 Peachtree Dunwoody Road NE • Building C • Suite 250 • Atlanta, GA 30342
Telephone (404) 256-6150 • 1-800-641-9245 • FAX (404) 256-6199 www.norit.com

NORIT

DARCO FGD

Typical Laser Particle Size Distribution

File name:	fgd.$01		
Sample ID:	FGD	Group ID:	1999
Comments:	SAM#8051 / NO SONIC	Operator:	GWD



Calculations from 0.1 μm to 900 μm	
Volume:	100 %
Mean:	22.27 μm
Median:	18.6 μm
Mode:	35.52 μm
Specific Surf. Area:	7624 cm^2/mL
95% Conf. Limits:	0 - 56.54 μm
S.D.:	17.48 μm
Variance:	305.7 μm^2

Particle Dia. μm	Volume % ≤
5	18.76
10	32.45
44	87.17
74	99.31
149	100
220	100

	≤5%	≤10%	≤50%	≤95%	≤97%
Particle Size, μm:	1.964	2.887	18.6	55.49	60.85

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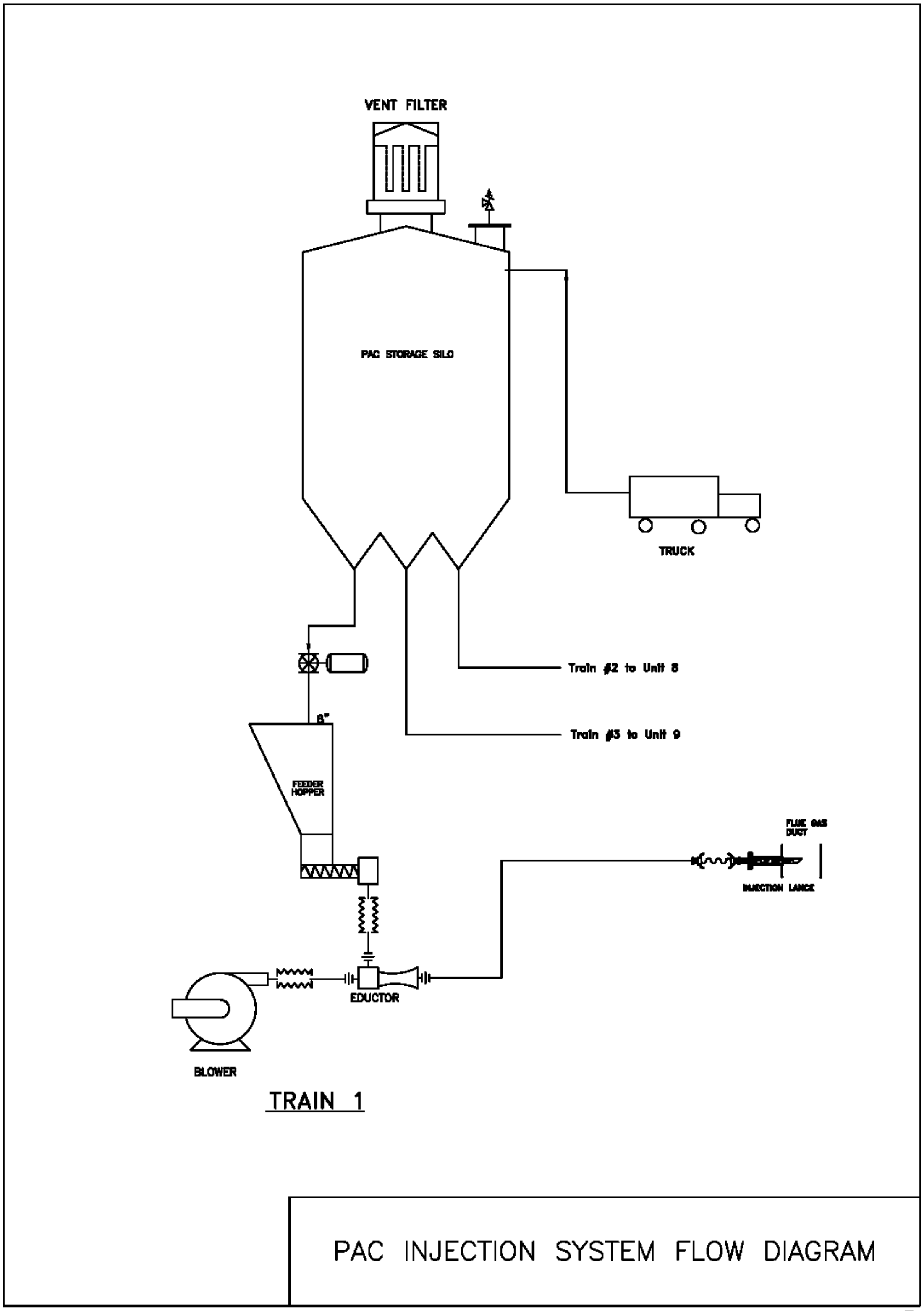
Rev. 1, APR 2001

Appendix B. PAC Injection System Flow Diagram

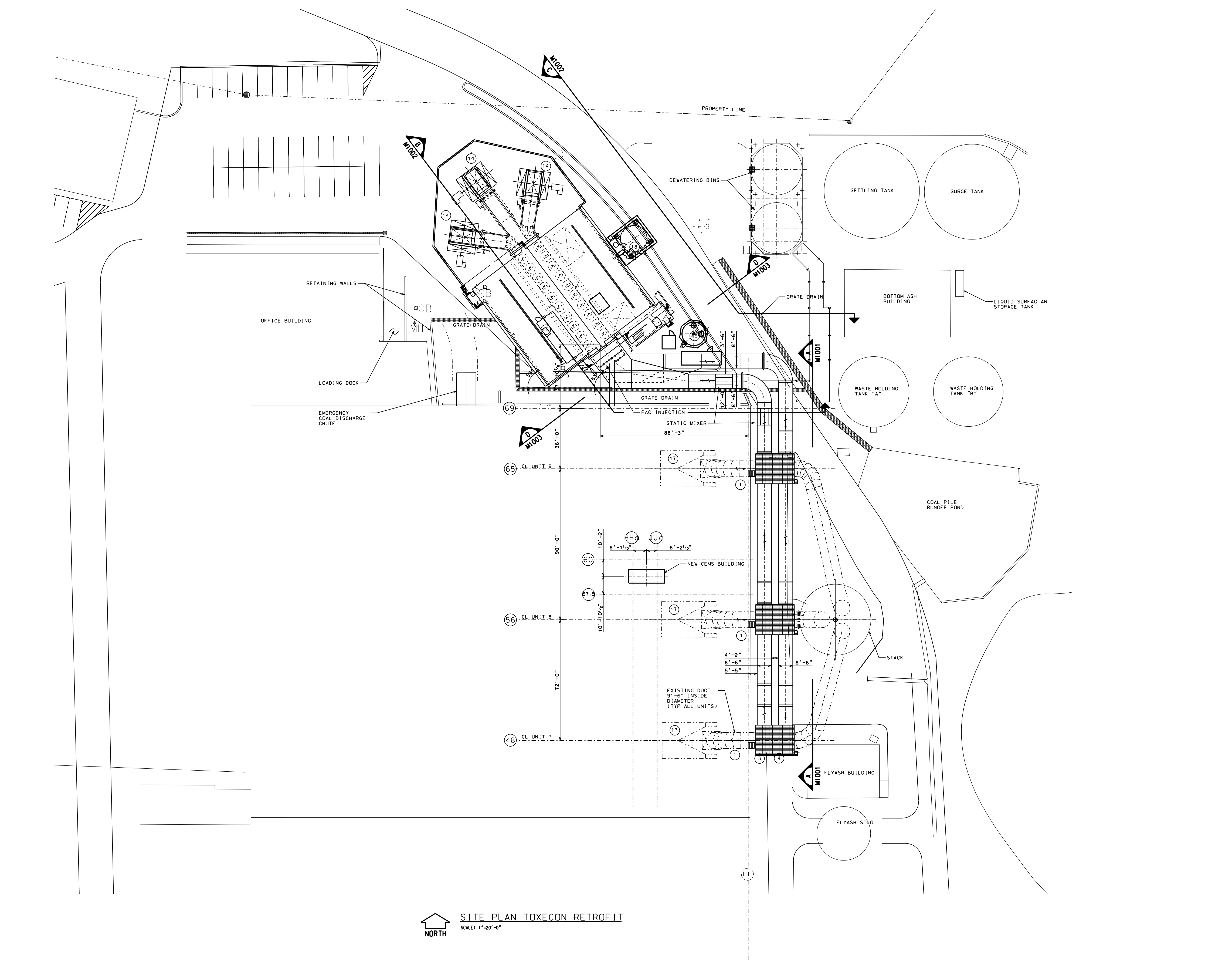


F

Appendix C. Drawings

This Appendix contains the following drawings related to the project:

Drawing	Title
4937-CGA-M1000	Site Plan
4937-CGA-M1001	Flue Gas Ductwork West Elevation
4937-CGA-M1002	Baghouse and Fan Enclosure Elevation
4937-CGA-M1003	Fan Enclosure Plan and Sections
4937-CGA-M1004	Flue Gas Ductwork Sections and Details
4937-CBA-M0112	P&ID Flue Gas System
4937-CIA-M0113	P&ID Compressed Air Skid
M-54025-020	P&ID Fly Ash System
M-54025-021	P&ID Fly Ash System
4937-CMP-E1000	One-Line Diagram
4937-CMP-E1001	One-Line Diagram 7–9
4937-CCX-K6000	Control System Overview
4937-CCX-K6001	Control System Overview



SITE PLAN TOXECON RETROFIT

SCALE: 1"=20'-0"

LEGEND

1. NOx, CO, CEMS, TEMPORARY SO2, Hg SAMPLING TEMPORARY PAC INJECTION
2. PRESSURE TRANSMITTER (NOT SHOWN)
3. BAGHOUSE SUPPLY DIVERTER DAMPER
4. BAGHOUSE RETURN DIVERTER DAMPER
5. FLUE GAS DUCTWORK
6. STATIC MIXER
7. PRESSURE SENSOR (NOT SHOWN)
8. Hg MONITOR (NOT SHOWN)
9. 6" EPA TEST PORTS (NOT SHOWN)
10. PARTICULATE MONITOR (NOT SHOWN)
11. NOx /SO2 MONITOR (NOT SHOWN)
12. FAN INLET DAMPER (NOT SHOWN)
13. FAN DISCHARGE DAMPER (NOT SHOWN)
14. BOOSTER FAN
15. DCS ENCLOSURE
16. EXPANSION JOINT (NOT SHOWN)
17. EXISTING ID FAN
18. ASH SILO
19. PAC SILO

NOT TO BE USED FOR CONSTRUCTION

REV NO.	DATE	REVISION DESCRIPTION	DRAWN
D	12-15-04	BIDS	KFH
C	10-22-04	REVISED	KFH
B	8-13-04	REVISED	PVJ
A	7-02-04	ISSUED FOR REVIEW	KFH

REFERENCE DRAWINGS

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ANN ARBOR, MI 48108
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REVISION D

SHEET 4937-CGA-M1000

MICROFILM NO. 354534

DRAWN KFH DATE 7-2-04
PROJECT NO. 493704
ACTIVITY NO. 5033
SCALE 1"=10'-0"

we energies

CGS NO. 115895

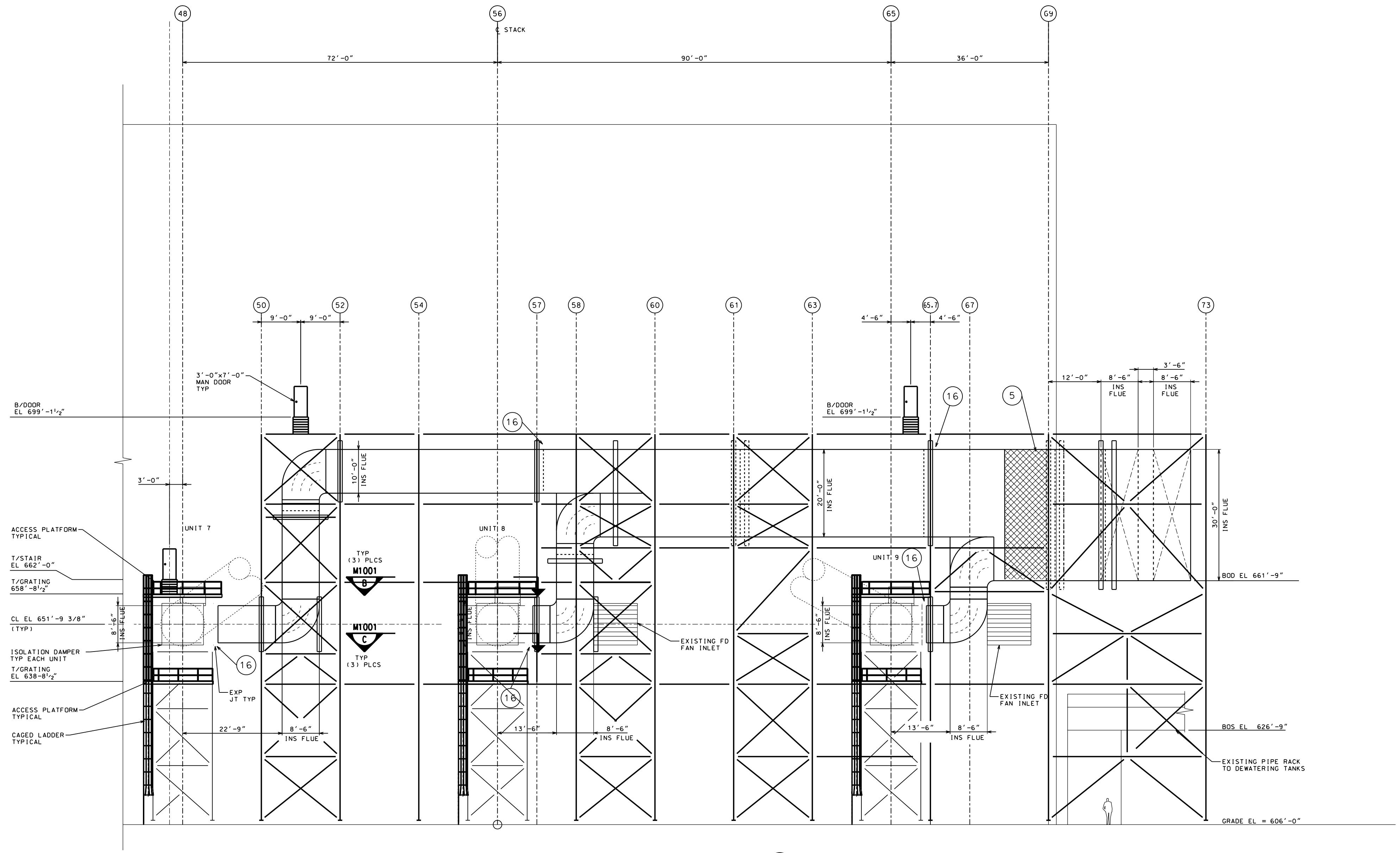
PRESQUE ISLE POWER PLANT
GENERAL ARRANGEMENT
TOXECON PROJECT
SITE PLAN

EPI 07 MEIL403007

$DATE$

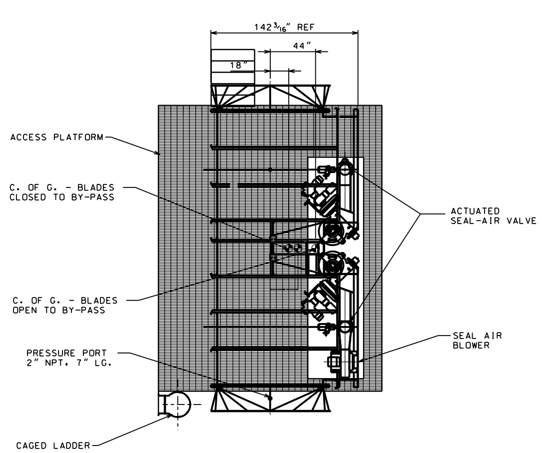
LEGEND

1. NOx, CO, CEMS, TEMPORARY SO2, Hg SAMPLING TEMPORARY PAC INJECTION
2. PRESSURE TRANSMITTER (NOT SHOWN)
3. BAGHOUSE SUPPLY DIVERTER DAMPER
4. BAGHOUSE RETURN DIVERTER DAMPER
5. FLUE GAS DUCTWORK
6. STATIC MIXER
7. PRESSURE SENSOR (NOT SHOWN)
8. Hg MONITOR (NOT SHOWN)
9. 6" EPA TEST PORTS (NOT SHOWN)
10. PARTICULATE MONITOR (NOT SHOWN)
11. NOx /SO2 MONITOR (NOT SHOWN)
12. FAN INLET DAMPER (NOT SHOWN)
13. FAN DISCHARGE DAMPER (NOT SHOWN)
14. BOOSTER FAN
15. DCS ENCLOSURE
16. EXPANSION JOINT (NOT SHOWN)
17. EXISTING ID FAN
18. ASH SILO
19. PAC SILO

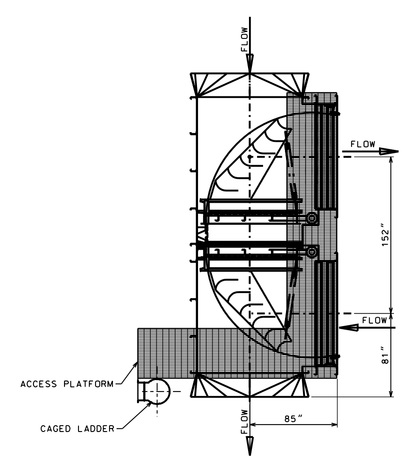


WEST ELEVATION VIEW (A / M1000)

SCALE: 1"=10'-0"



SECTION (B / M1001)



SECTION (C / M1001)

NOT TO BE USED FOR CONSTRUCTION

REV NO.	DATE	REVISION DESCRIPTION	ACT	DRAWN	CHK'D	APPRV'D
D	12-15-04	BIDS		KFH		
C	10-22-04	REVISED		KFH		
B	8-13-04	REVISED		PVJ		
A	7-2-04	ISSUED FOR REVIEW		PVJ		

REFERENCE DRAWINGS

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REVISION: D

SHEET: 4937-CGA-M1001

LEVEL USAGE: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63

CGS REF FILES

MICROFILM NO. 354353

DRAWN	DATE	PROJECT NO.
PVJ	7-2-04	493704
CHECKED	DATE	ACTIVITY NO. 5033
APPROVED	DATE	SCALE 1"=10'-0"

we energies

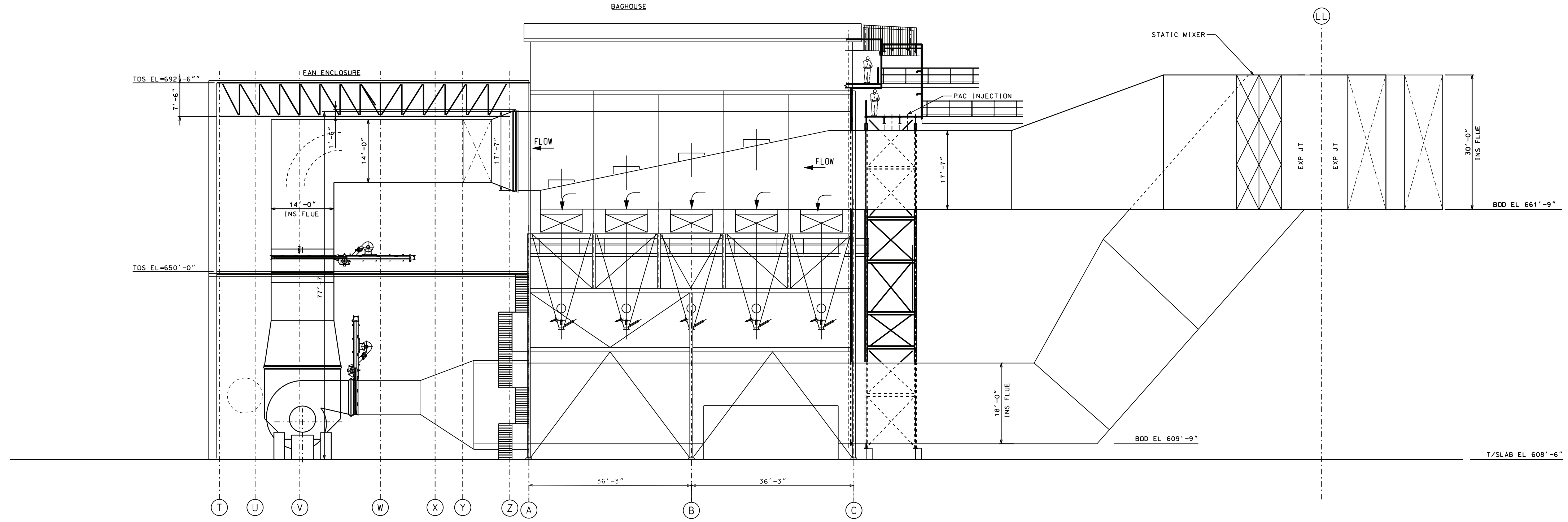
CGS NO. 115896

PRESQUE ISLE POWER PLANT
GENERAL ARRANGEMENT
FLUE GAS DUCTWORK
WEST ELEVATION

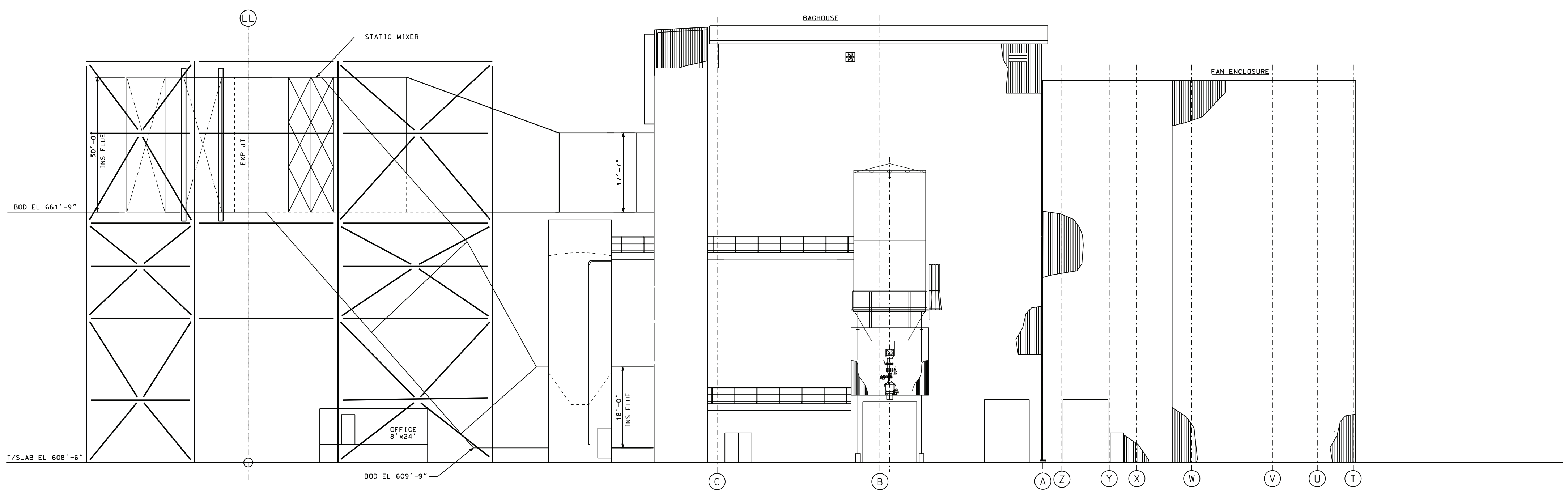
E PI 07 MEIL403008

WAS:

$DATE$



SECTION TITLE B / M1000
SCALE: 1"=10'-0"



SECTION TITLE C / M1000
SCALE: 1"=10'-0"

NOT TO BE USED FOR CONSTRUCTION

REV NO.	DATE	REVISION DESCRIPTION	ACT	DRAWN	CHK'D	APPRV'D
D	12-15-04	BIDS		KFH		
C	10-22-04	REVISED		KFH		
B	8-13-04	REVISED		KFH		
A	07-02-04	ISSUED FOR REVIEW		KFH		

REFERENCE DRAWINGS

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REVISION: D
SHEET: 4937-CGA-M1002

MICROFILM NO. 354536
DRAWN: KFH DATE: 7-2-04
PROJECT NO. 493704
ACTIVITY NO. 5033
SCALE 1"=10'-0"
CGS NO. 115897

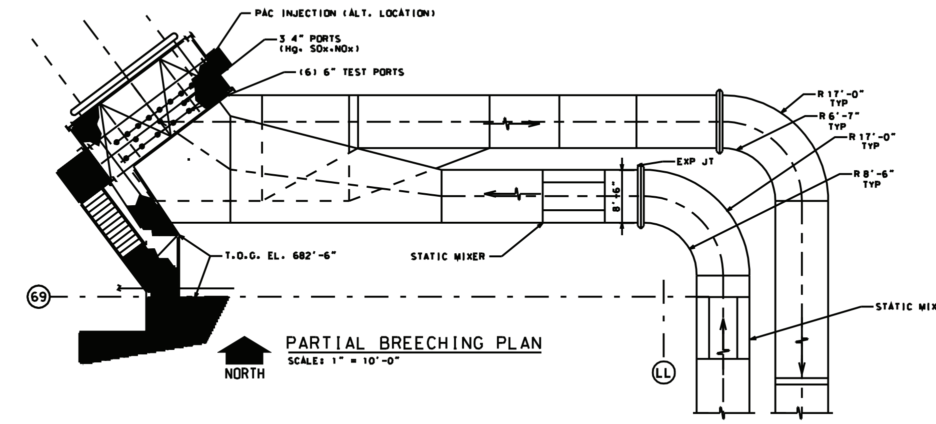
we energies

PRESQUE ISLE POWER PLANT
GENERAL ARRANGEMENT
BAGHOUSE & FAN ENCLOSURE
ELEVATION VIEW

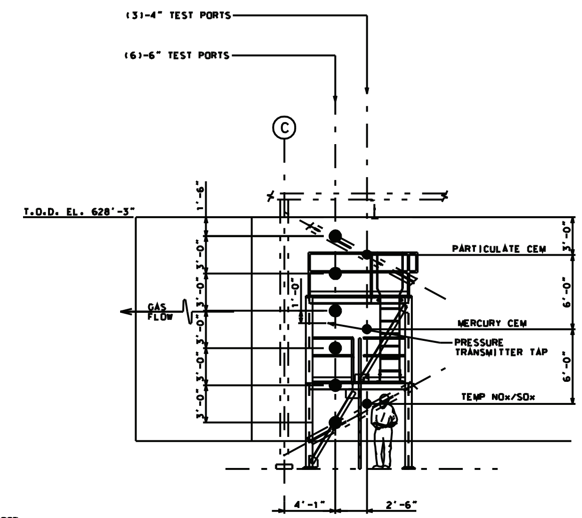
E PI 07 MEIL 403009

WAS:

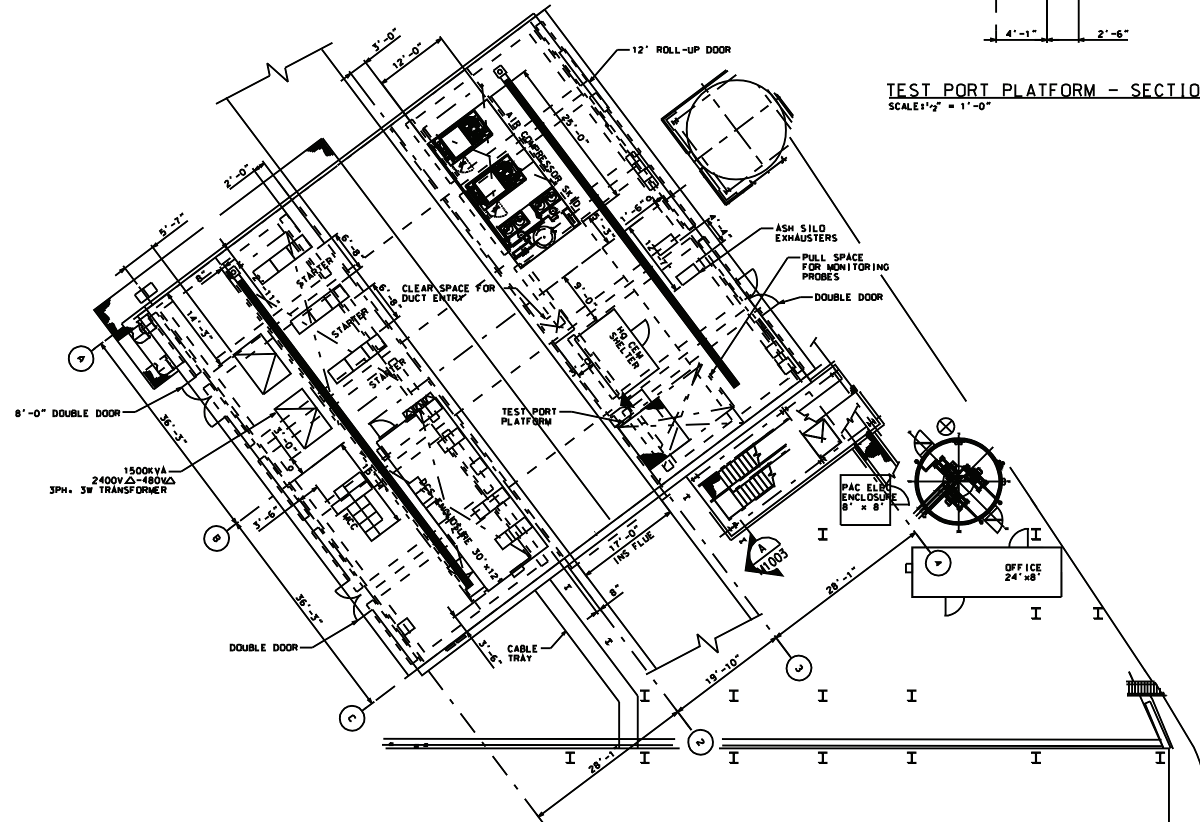
$DATE$



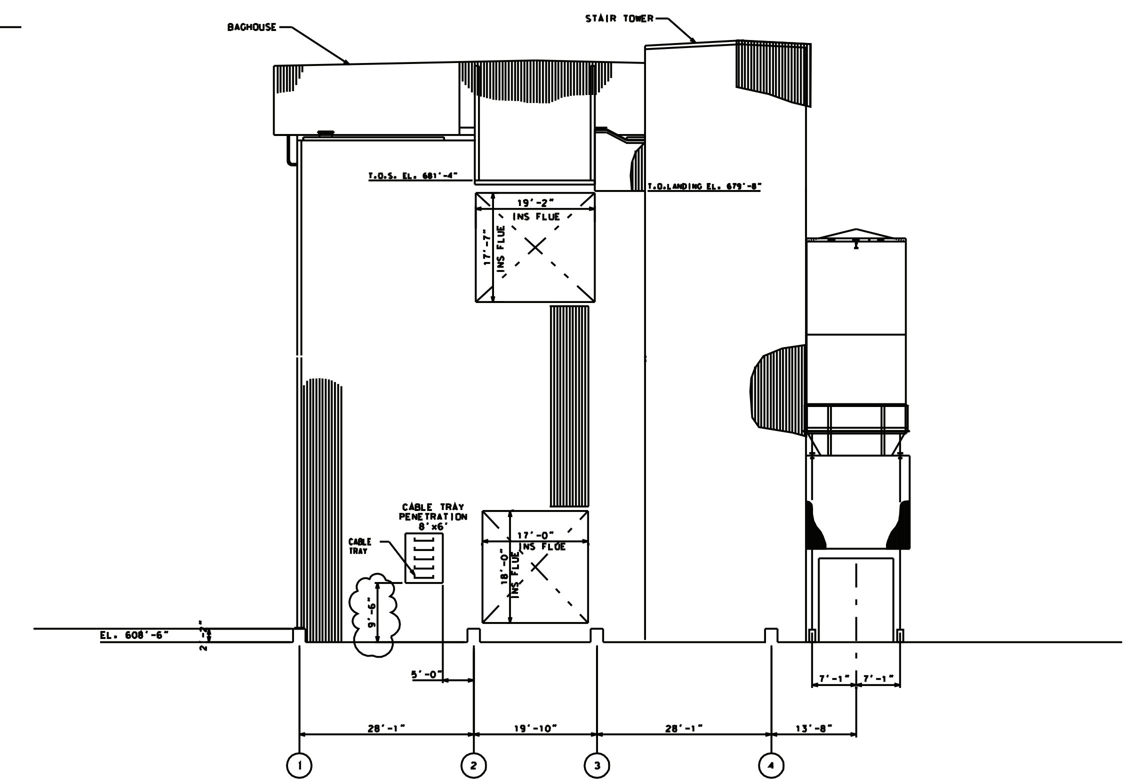
PARTIAL BREECHING PLAN
SCALE: 1" = 10'-0"



TEST PORT PLATFORM - SECTION A
SCALE: 1/2" = 1'-0" M1003



BAGHOUSE PLAN @ TOC EL. 608'-6"
SCALE: 1" = 10'-0"



BAGHOUSE SECTION D
SCALE: 1" = 10'-0" M1000

NOTE: SEE THIS DRAWING FOR SECTIONS

REFERENCE DRAWINGS
PI 07MEIL403007 - GA TOXECON PROJECT - SITE PLAN
PI 07MEIL403008 - GA FLUE GAS DUCTWORK - WEST ELEVEATION
PI 07MEIL403009 - GA BAGHOUSE & FAN ENCLOSURE ELEVATION VIEW
PI 07MEIL403011 - GA FAN ENCLOSURE PLAN & SECTIONS

REV NO.	DATE	REVISION DESCRIPTION	BY	DRAWN	CHK'D	APPRV'D
0	03-18-05	ISSUED FOR CONSTRUCTION		KFH	JC	JC

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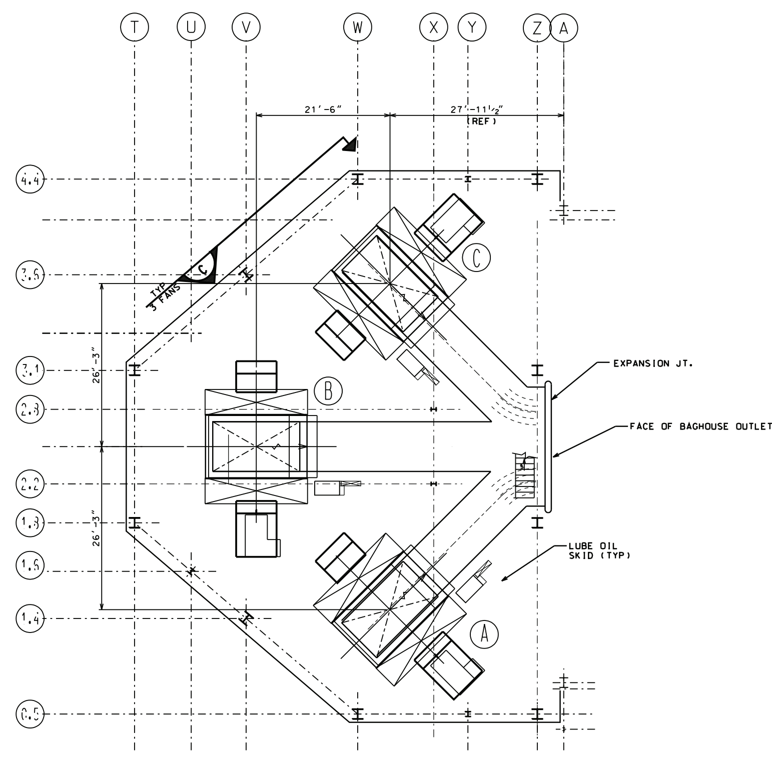
REVISION	0
SHEET	4937-CGA-M1003
MICROFILM NO.	354537
CGS NO.	115898
DRAWN	PVJ
DATE	7-2-04
PROJECT NO.	493704
CHECKED	
ACTIVITY NO.	5033
APPROVED	
SCALE	1"=10'-0"

we energies

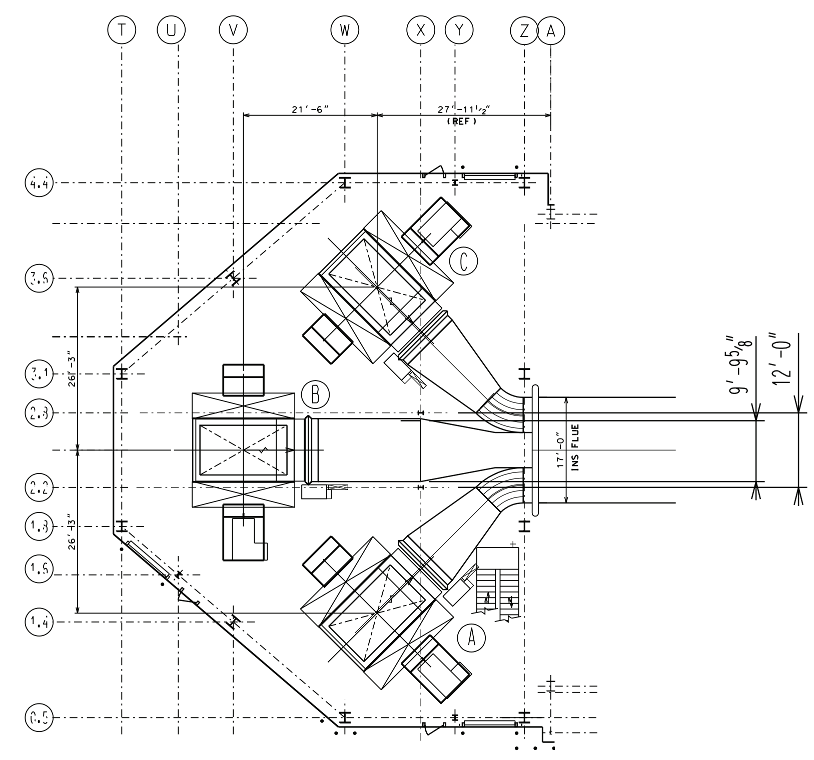
PRESQUE ISLE POWER PLANT
GA-FLUE GAS DUCTWORK
SECTIONS AND DETAILS

EPI 07 MEIL40301000

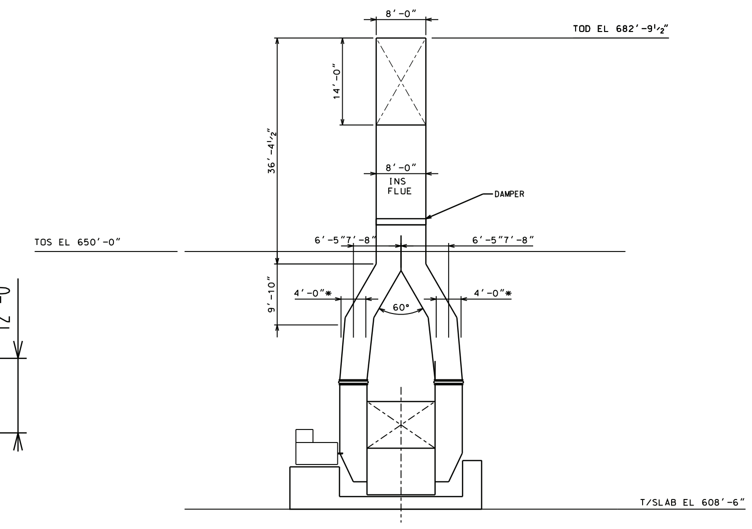
$DATE$



BOOSTER FAN INLET SECTION A M1004
SCALE: 1"=10'-0"

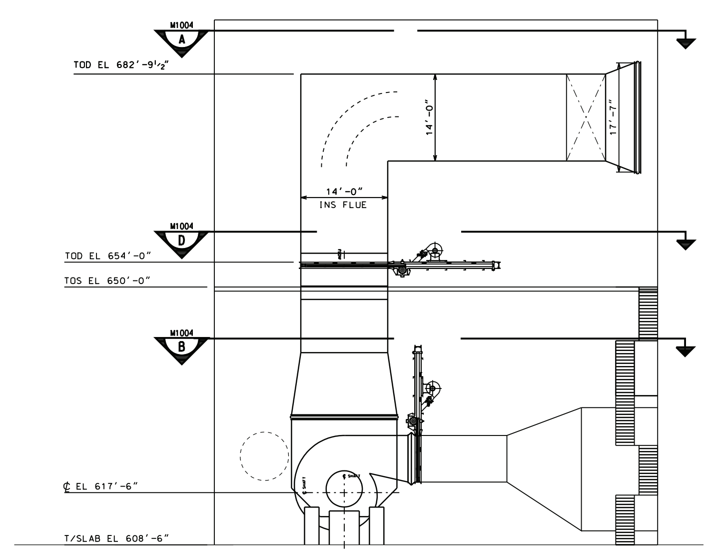


BOOSTER FAN OUTLET SECTION B M1004
SCALE: 1"=10'-0"

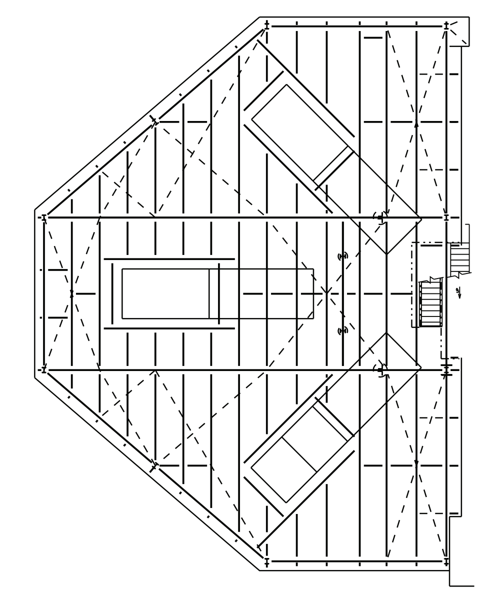


SECTION C M1004
SCALE: 1"=10'-0"

NOTE: DIMENSIONS WITH (*) TO BE VERIFIED AFTER FANS ARE PURCHASED.



TYPICAL BOOSTER FAN ELEVATION
SCALE: 1"=10'-0"



SECTION D M1004
SCALE: ⅛"=1'-0"

NOT TO BE USED FOR CONSTRUCTION

REFERENCE DRAWINGS

REV NO.	DATE	REVISION DESCRIPTION	ACT	DRAWN	CHK'D	APPRV'D
D	12-15-04	BIDS		KFH		
C	10-22-04	REVISED		KFH		
B	8-13-04	REVISED		KFH		
A	07-02-04	ISSUED FOR REVIEW		KFH		

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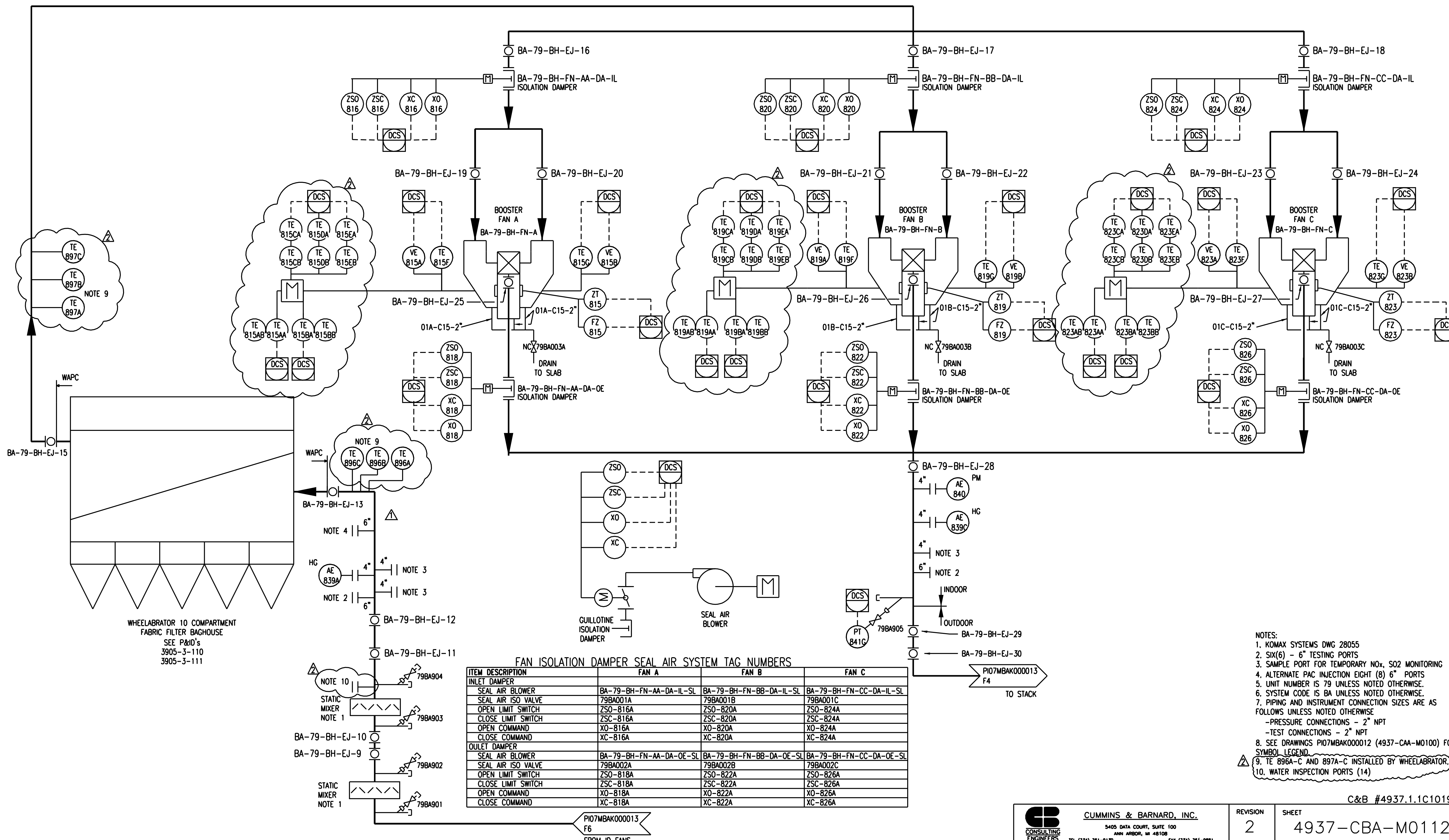
REVISION D
SHEET 4937-CGA-M1004

MICROFILM NO. 354538
DRAWN KFH DATE 7-2-04
PROJECT NO. 493704
CHECKED DATE
ACTIVITY NO. 5033
APPROVED DATE
SCALE AS NOTED
CGS NO. 115899

PRESQUE ISLE POWER PLANT
GENERAL ARRANGEMENT
FAN ENCLOSURE
PLAN & SECTIONS

E PI 07 MEIL 403011



FAN ISOLATION DAMPER SEAL AIR SYSTEM TAG NUMBERS

ITEM DESCRIPTION	FAN A	FAN B	FAN C
INLET DAMPER			
SEAL AIR BLOWER	BA-79-BH-FN-AA-DA-IL-SL	BA-79-BH-FN-BB-DA-IL-SL	BA-79-BH-FN-CC-DA-IL-SL
SEAL AIR ISO VALVE	79BA001A	79BA001B	79BA001C
OPEN LIMIT SWITCH	ZSO-816A	ZSO-820A	ZSO-824A
CLOSE LIMIT SWITCH	ZSC-816A	ZSC-820A	ZSC-824A
OPEN COMMAND	XO-816A	XO-820A	XO-824A
CLOSE COMMAND	XC-816A	XC-820A	XC-824A
OULET DAMPER			
SEAL AIR BLOWER	BA-79-BH-FN-AA-DA-OE-SL	BA-79-BH-FN-BB-DA-OE-SL	BA-79-BH-FN-CC-DA-OE-SL
SEAL AIR ISO VALVE	79BA002A	79BA002B	79BA002C
OPEN LIMIT SWITCH	ZSO-818A	ZSO-822A	ZSO-826A
CLOSE LIMIT SWITCH	ZSC-818A	ZSC-822A	ZSC-826A
OPEN COMMAND	XO-818A	XO-822A	XO-826A
CLOSE COMMAND	XC-818A	XC-822A	XC-826A

NOTES:
1. KOMAX SYSTEMS DWG 28055
2. SIX(6) - 6" TESTING PORTS
3. SAMPLE PORT FOR TEMPORARY NOx, SO2 MONITORING
4. ALTERNATE PAC INJECTION EIGHT (8) 6" PORTS
5. UNIT NUMBER IS 79 UNLESS NOTED OTHERWISE.
6. SYSTEM CODE IS BA UNLESS NOTED OTHERWISE.
7. PIPING AND INSTRUMENT CONNECTION SIZES ARE AS FOLLOWS UNLESS NOTED OTHERWISE
   - PRESSURE CONNECTIONS - 2" NPT
   - TEST CONNECTIONS - 2" NPT
8. SEE DRAWINGS PI07MBAK000012 (4937-CAA-M0100) FOR SYMBOL LEGEND.
9. TE 896A-C AND 897A-C INSTALLED BY WHEELABRATOR.
10. WATER INSPECTION PORTS (14)

WAS:

C&B #4937.1.1C10198

REFERENCE DRAWINGS

REV NO.	DATE	ORDER NO.	REVISION DESCRIPTION	JOB	DRAWN	CHKD	APVD
2	02/11/05		ADDED INSTRUMENTATION				
1	01/10/05		REVISED PAC INJECTION LOCATION, TAG NUMBERS		JLC	JAC	JAC
0	10/11/04		FOR CONSTRUCTION		JLC	JAC	JAC

CUMMINS & BARNARD, INC.
CONSULTING ENGINEERS SINCE 1932
5405 DATA COURT, SUITE 100
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REVISION 2

SHEET 4937-CBA-M0112

REF FILES

MICROFILM NO. 354533

we energies

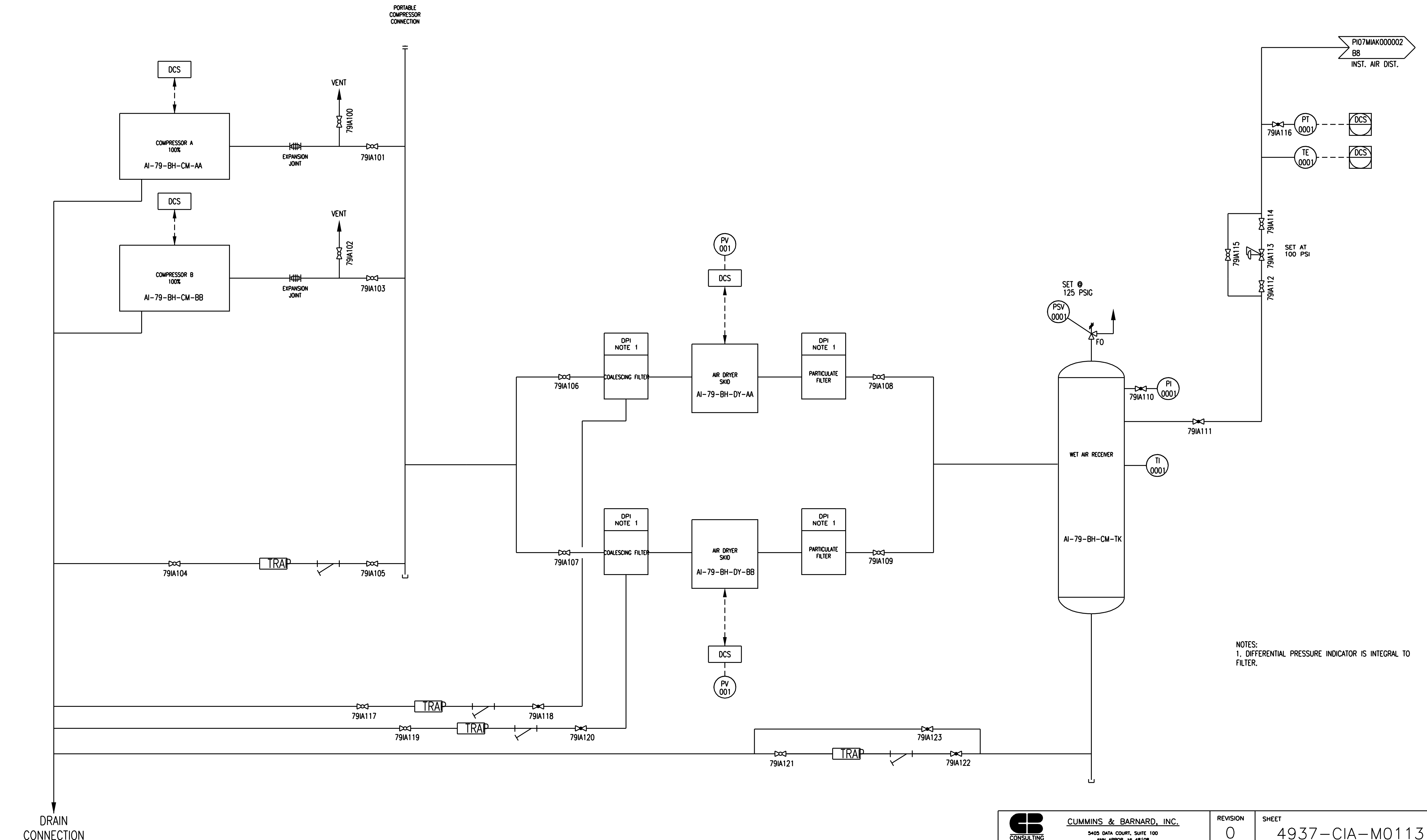
DRAWN DATE ORDER NO. 493704
CHECKED DATE JOB NO.
APPROVED DATE SCALE AS NOTED

CGS NO. 115894

PRESQUE ISLE POWER PLANT
PIPING & INSTRUMENT DIAGRAM
FLUE GAS SYSTEM

D PI 07 MBAK 000 014 2

$DATE$



NOTES:
1. DIFFERENTIAL PRESSURE INDICATOR IS INTEGRAL TO FILTER.

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REVISION 0

SHEET 4937-CIA-M0113

REFERENCE DRAWINGS
PI07MBAK000012 "P&ID LEGEND"

REV NO.	DATE	ORDER NO.	REVISION DESCRIPTION	JOB	DRAWN	CHKD	APVD
0	03/04/05		FOR CONSTRUCTION				

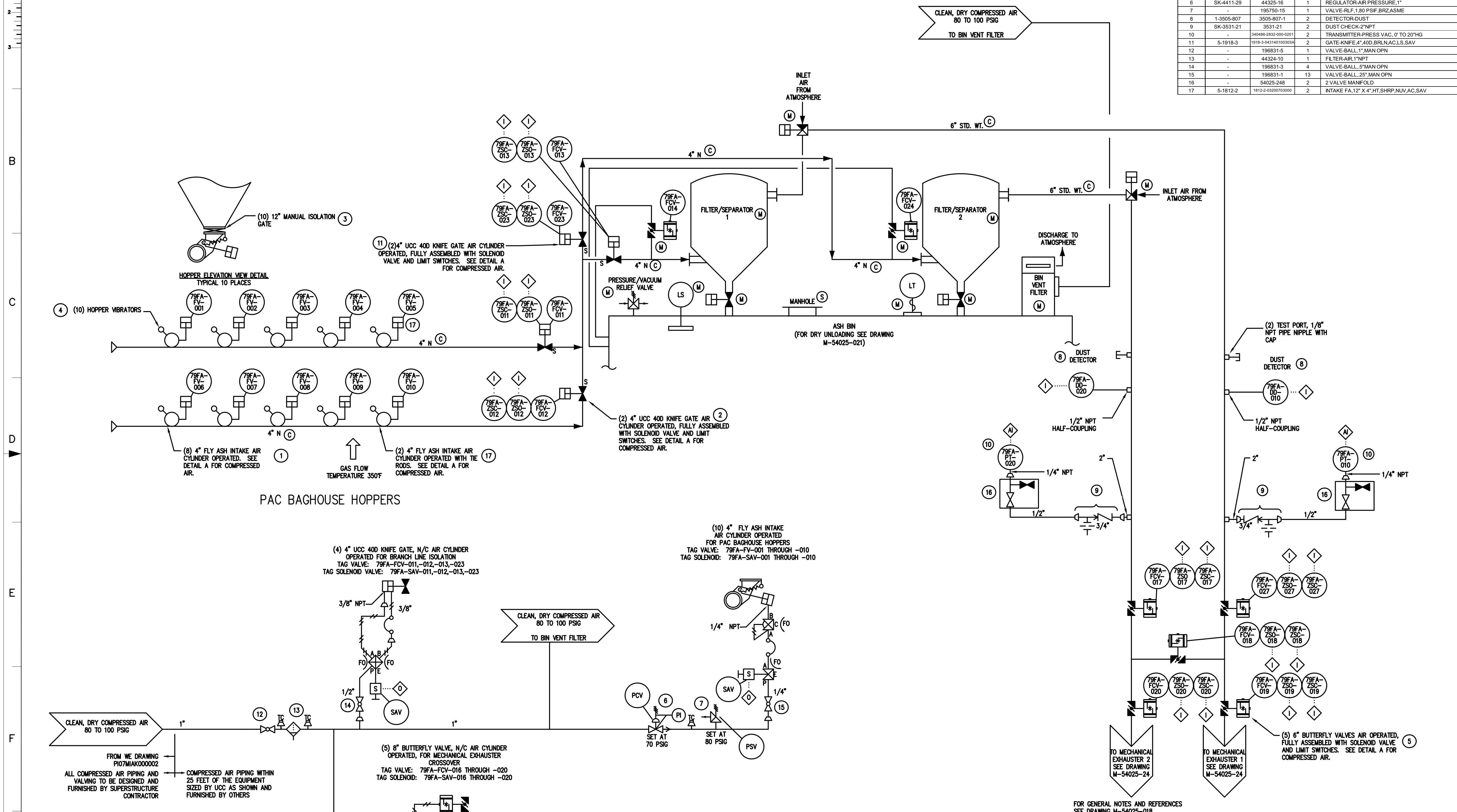
REF FILES
MICROFILM NO.
DRAWN ... DATE ..... ORDER NO. 493704
CHECKED ... DATE ..... JOB NO.
APPROVED ... DATE ..... SCALE AS NOTED

We Energies
CGS NO.

PRESQUE ISLE POWER PLANT
PIPING & INSTRUMENT DIAGRAM
COMPRESSED AIR SKID SYSTEM

D PI 07 MSAK 000 003 0

$DATE$



ITEM* A-B-N M - 020 -	DRAWING NUMBER	PART NUMBER	QTY	DESCRIPTION
1	5-1812-2	1812-2-03010703000	8	INTAKE FA,12" X 4",HT,SHRP,NUV,AC,SAV
2	5-1918-3	1918-3-043110100303A	2	GATE-KNIFE,4",40D,BRLN,AC,LS,SAV
3	-	197056-5-1	10	VALVE-KNFG,12",HANDWHEEL OPERATED
4	-	45308-9	10	VIBRATOR-115V,1PH,60HZ
5	-	197052-2-1-1	5	VALVE-6",BUTTERFLY,AC OPER,SAV,LS
6	SK-4411-29	44325-16	1	REGULATOR-AIR PRESSURE,1"
7	-	195750-15	1	VALVE-RLF,1,80 PSIF,BRZ,ASME
8	1-3505-807	3505-807-1	2	DETECTOR-DUST
9	SK-3531-21	3531-21	2	DUST CHECK-2"NPT
10	-	340486-2832-000-0201	2	TRANSMITTER-PRESS VAC, 0' TO 20"HG
11	5-1918-3	1918-3-043140100303A	2	GATE-KNIFE,4",40D,BRLN,AC,LS,SAV
12	-	196831-5	1	VALVE-BALL,1",MAN OPN
13	-	44324-10	1	FILTER-AIR,1"NPT
14	-	196831-3	4	VALVE-BALL,.5"MAN OPN
15	-	196831-1	13	VALVE-BALL,.25",MAN OPN
16	-	54025-248	2	2 VALVE MANIFOLD
17	5-1812-2	1812-2-03200703000	2	INTAKE FA,12" X 4",HT,SHRP,NUV,AC,SAV

FOR GENERAL NOTES AND REFERENCES SEE DRAWING M-54025-018

THIS DRAWING SHALL NOT BE CONSIDERED A CERTIFIED DOCUMENT UNLESS WRITTEN APPROVAL SIGNATURES OR INITIALS ARE PRESENT.

THE INSTALLATION AND OPERATION OF UNITED CONVEYOR CORPORATION EQUIPMENT, IN ACCORDANCE WITH APPROVED PLANS AND OPERATING INSTRUCTIONS, SHALL BE THE SOLE RESPONSIBILITY OF THE PURCHASER, UNLESS OTHERWISE SPECIFIED BY CONTRACT.

MODIFICATION TO UNITED CONVEYOR CORPORATION EQUIPMENT AND STRUCTURES TO AVOID FIELD OBSTRUCTIONS, OR CORRECTIONS DUE TO MINOR DRAWING DISCREPANCIES WITH FIELD CONDITIONS AND/OR FABRICATION MISFITS ARE CONSIDERED NORMAL ERECTION AND INSTALLATION OPERATIONS AND ARE NOT CHARGEABLE TO UNITED CONVEYOR CORPORATION. WE WILL NOT ACCEPT BACKCHARGES FOR ANY WORK PERFORMED IN THE FIELD UNLESS APPROVED BY OUR SERVICE GROUP (U.C. SERVICE CORPORATION) AT WAUKEGAN.

REVISION	DESCRIPTION	DATE	DSGN	CHKD	APPD (ENGR)	APPD (PROJ)
D	REVISED COMPRESSED AIR NOTE, VALVE P/N & VENT TO SILO	11/01/07	GCL		GCL	GCL
C	REVISED P/NS ITEM 12, AND REV'D PER C & B COMMENTS	02/25/05	GCL	MEM	GCL	GCL
B	ADDED CUSTOMER'S TAGS	01/05/05	GCL	MEM	GCL	GCL
A	INITIAL SUBMITTAL	11/22/04	GCL	MEM	GCL	GCL

DRAWING TITLE

P & I DIAGRAM
FLY ASH NUVEYOR VACUUM SYSTEM
PAC BAGHOUSE HOPPER AREA
UNIT 7-9

PLANT NAME

WE ENERGIES
PRESQUE ISLE POWER PLANT
MARQUETTE, MICHIGAN

UNITED CONVEYOR CORPORATION
2100 NORMAN DRIVE WEST
WAUKEGAN, ILLINOIS 60085

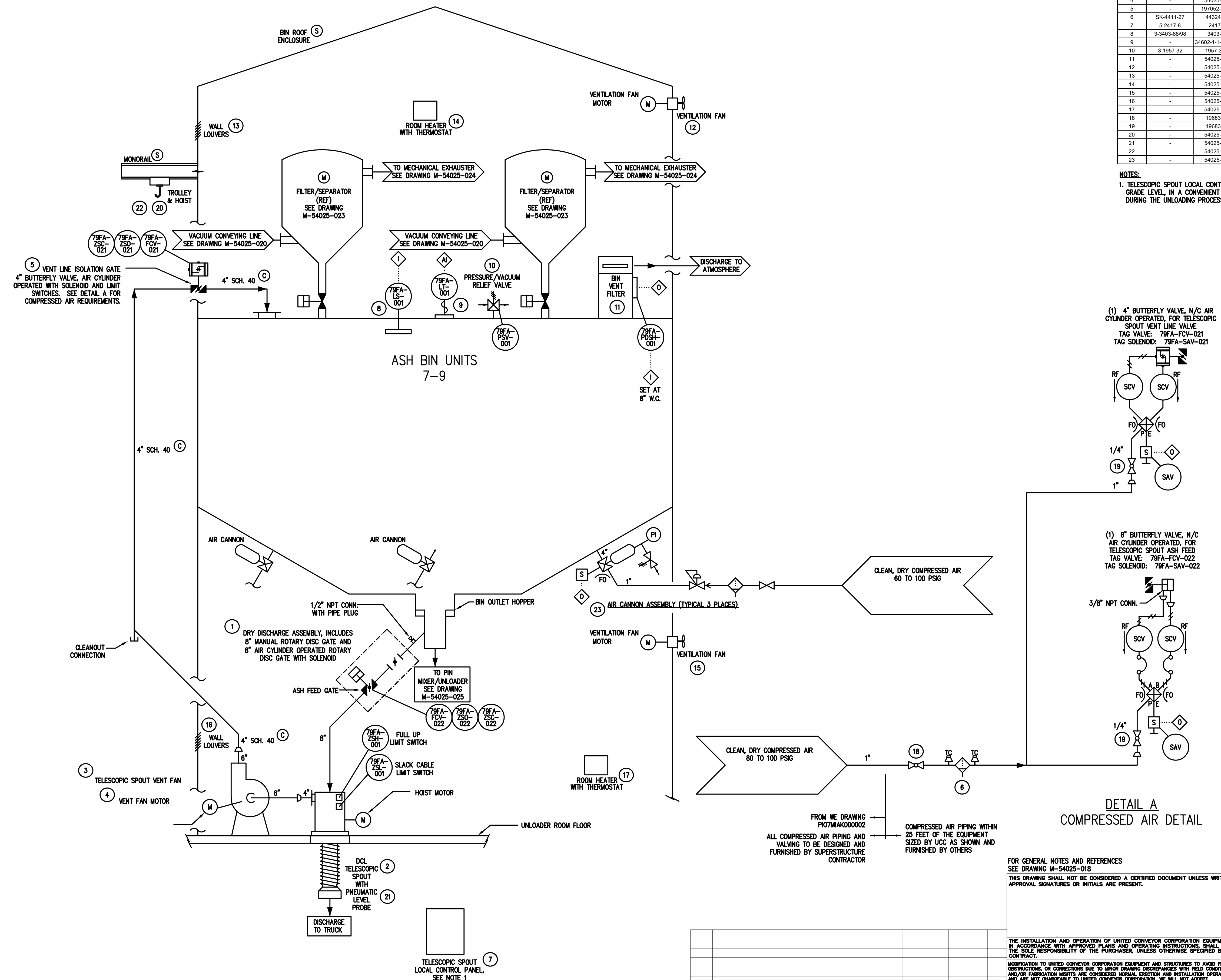
SCALE	CONTRACT NUMBER	SUBSYSTEM	DRAWING SIZE	DRAWING NUMBER	REVISION
NONE	54025-24	R	5	M-54025-020	D

FORM 9820-09 10/99

ITEM* A-B-N M - 021 -	DRAWING NUMBER	PART NUMBER	QTY	DESCRIPTION
1	2-2326-31	2326-31-2-311	1	DISCHARGE-8" DRY UNLD
2	-	54025-235	1	SPOUT,TELESCOPIC
3	-	54025-234	1	FAN-VENT,6CI
4	-	54025-236	1	MOTOR- HP, RPM, 480V, 60 Hz, 3 Ph, TEFC
5	-	197052-1-1-2	1	VALVE-4",BTFLY,AC OP,SAV,LS
6	SK-4411-27	44324-10	1	FILTER-AIR,1" NPT
7	5-2417-8	2417-8	1	PANEL-CONTROL,TELE SPT & FAN
8	3-3403-88/98	3403-92	1	INDICATOR-LVL,120V,60 HZ,A=4'
9	-	34602-1-1-1-019-1	1	LEVEL-DETR-USONIC,19',200F MAX, 120VAC
10	3-1957-32	1957-32-4	1	VALVE-VAC/PRESS,RLF VENT
11	-	54025-238	1	BIN VENT FILTER
12	-	54025-240	2	BIN ROOF ENCLOSURE VENTILATION FAN
13	-	54025-241	2	BIN ROOF ENCLOSURE LOUVER
14	-	54025-242	2	BIN ROOF ENCLOSURE HEATER
15	-	54025-244	2	UNLOADING ROOM VENTILATION FAN
16	-	54025-245	2	UNLOADING ROOM LOUVERS
17	-	54025-246	2	UNLOADING ROOM HEATER
18	-	196831-5	1	VALVE-BALL,1",MAN OPN
19	-	196831-1	2	VALVE-BALL,.25",MAN OPN
20	-	54025-243	1	3 TON HOIST AND TROLLEY
21	-	54025-257	1	SPOUT,TELESCOPIC - LEVEL SENSOR,
22	-	54025-258	1	HOIST, ELECTRIC-1 TON, W/ ELEC TROLLEY
23	-	54025-259	3	CANNON, AIR

NOTES:

1. TELESCOPIC SPOUT LOCAL CONTROL PANEL TO BE LOCATED NEAR GRADE LEVEL, IN A CONVENIENT LOCATION FOR OPERATOR ACCESS DURING THE UNLOADING PROCESS.



DETAIL A
COMPRESSED AIR DETAIL

FOR GENERAL NOTES AND REFERENCES SEE DRAWING M-54025-018

REVISION	DESCRIPTION	DATE	DSGN	CHKD	APPD (ENGR)	APPD (PROJ)
D	REVISED COMP. AIR NOTE, ADDED LVL PROBE & AIR CANNON	08/08/06	GCL		GCL	GCL
C	REVISED PER C & B COMMENTS	02/25/05	GCL	MEM	GCL	GCL
B	REVISED DWG PER CUSTOMER COMMENTS & ADDED TAGS	01/05/05	GCL	MEM	GCL	GCL
A	INITIAL SUBMITTAL	11/22/04	GCL	MEM	GCL	GCL

THIS DRAWING SHALL NOT BE CONSIDERED A CERTIFIED DOCUMENT UNLESS WRITTEN APPROVAL SIGNATURES OR INITIALS ARE PRESENT.

THE INSTALLATION AND OPERATION OF UNITED CONVEYOR CORPORATION EQUIPMENT, IN ACCORDANCE WITH APPROVED PLANS AND OPERATING INSTRUCTIONS, SHALL BE THE SOLE RESPONSIBILITY OF THE PURCHASER, UNLESS OTHERWISE SPECIFIED BY CONTRACT.

MODIFICATION TO UNITED CONVEYOR CORPORATION EQUIPMENT AND STRUCTURES TO AVOID FIELD OBSTRUCTIONS, OR CORRECTIONS DUE TO MINOR DRAWING DISCREPANCIES WITH FIELD CONDITIONS AND/OR FABRICATION MISFITS ARE CONSIDERED NORMAL ERECTION AND INSTALLATION OPERATIONS AND ARE NOT CHARGEABLE TO UNITED CONVEYOR CORPORATION. WE WILL NOT ACCEPT BACKCHARGES FOR ANY WORK PERFORMED IN THE FIELD UNLESS APPROVED BY OUR SERVICE GROUP (U.C. SERVICE CORPORATION) AT WAUKEGAN.

SCALE	CONTRACT NUMBER	SUBSYSTEM	DRAWING SIZE
NONE	54025-24	V	5

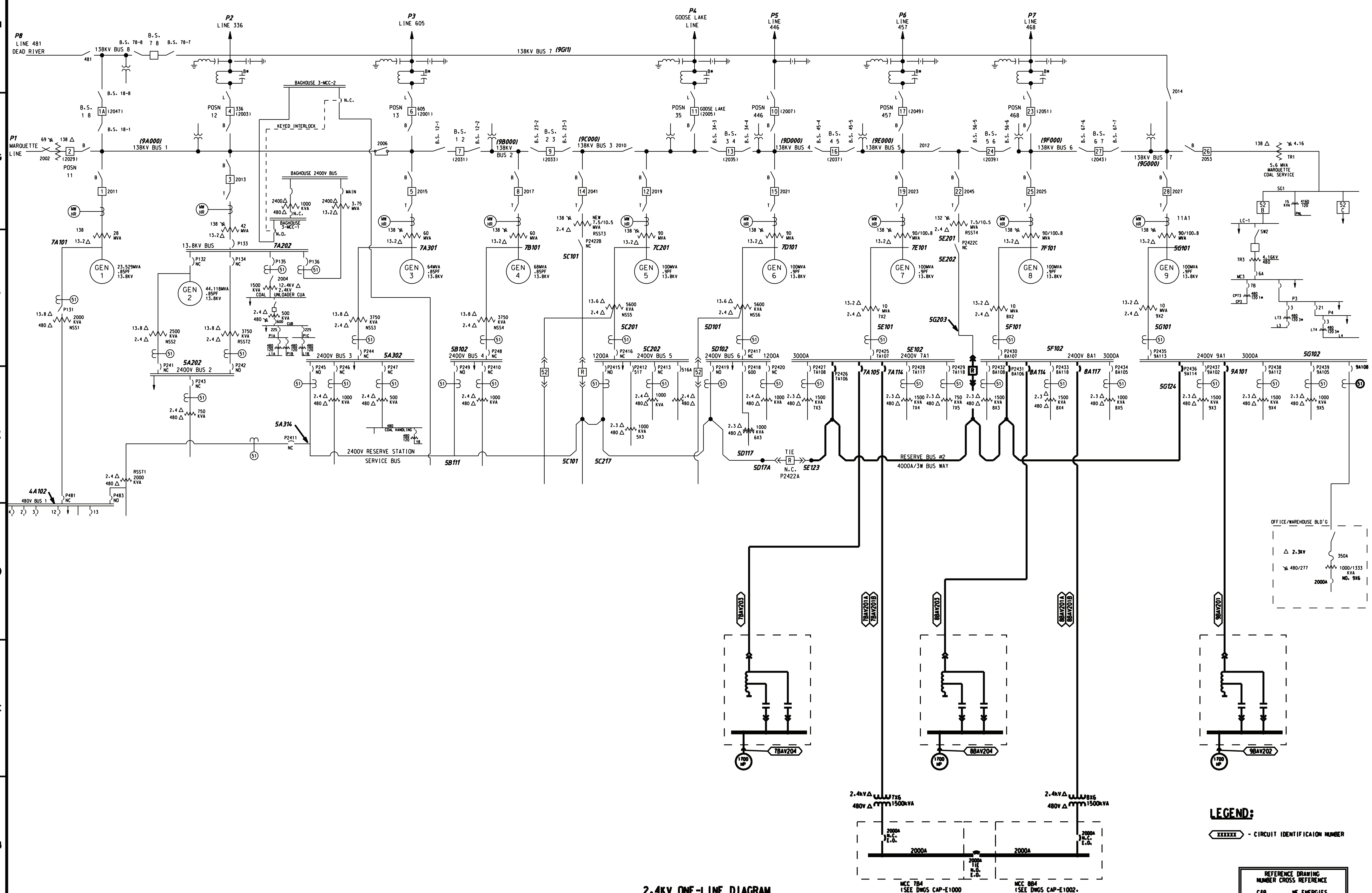
DRAWING TITLE
P & I DIAGRAM
BIN AREA AND DRY UNLOADING
UNITS 7-9

PLANT NAME
WE ENERGIES
PRESQUE ISLE POWER PLANT
MARQUETTE, MICHIGAN

UNITED CONVEYOR CORPORATION
2100 NORMAN DRIVE WEST
WAUKEGAN, ILLINOIS 60085

DRAWING NUMBER: M-54025-021
REVISION: D

FORM 9820-09 10/99



2.4KV ONE-LINE DIAGRAM

NOTE:

1. ID BOOSTER FAN STARTERS ARE AUTO-TRANSFORMER STARTS.

LEGEND:

XXXXXX - CIRCUIT IDENTIFICAION NUMBER

REFERENCE DRAWING NUMBER CROSS REFERENCE

C&B	WE ENERGIES
CAP-E1000	PI 07 EAPL166002
CAP-E1001	PI 07 EAPK166006
CAP-E1002	PI 08 EAPL166001
CAP-E1003	PI 08 EAPK166005
CAP-E1004	PI 08 EAPK166006

REFERENCE DRAWINGS

0 4-21-05 ISSUED FOR CONSTRUCTION

CUMMINS & BARNARD, INC.
5405 DATA COURT, SUITE 100
ANN ARBOR, MI 48108
TEL (734) 761-9130 FAX (734) 761-9881

REVISION: 0

SHEET: 4937-CMP-E1000

MICROFILM NO. 364283

CGS NO. 120604

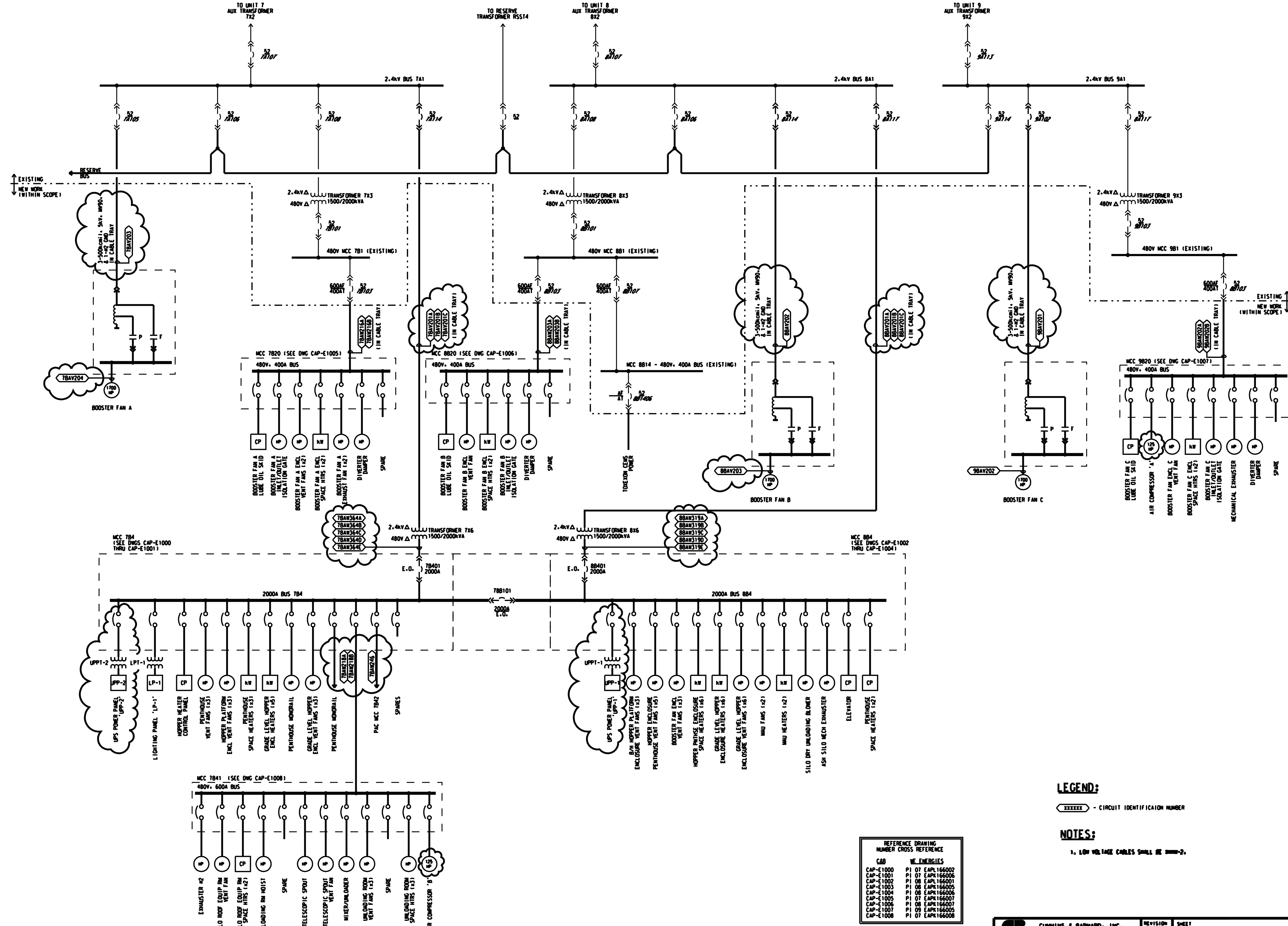
PROJECT NO. 493704

DRAWN: MEB DATE 11-15-04
CHECKED: CMP DATE 4-15-05
APPROVED: JAC DATE 4-15-05
SCALE: NONE

we energies

PLANT MEDIUM VOLTAGE ONE-LINE DIAGRAM

E PI 07 EMPK00000900



LEGEND:

XXXXXX - CIRCUIT IDENTIFICAION NUMBER

NOTES:

1. LOW VOLTAGE CABLES SHALL BE XHHW-2.

REFERENCE DRAWING NUMBER CROSS REFERENCE

C&B	WE ENERGIES
CAP-E1000	PI 07 EAPL166002
CAP-E1001	PI 07 EAPK166006
CAP-E1002	PI 08 EAPL166001
CAP-E1003	PI 08 EAPK166005
CAP-E1004	PI 08 EAPK166006
CAP-E1005	PI 07 EAPK166007
CAP-E1006	PI 08 EAPK166007
CAP-E1007	PI 09 EAPK166005
CAP-E1008	PI 07 EAPK166008

REFERENCE DRAWINGS

REV	DATE	REVISION DESCRIPTION	BY	CHK'D	APPR'D
1	6-6-05	REVISED PER VENDOR DRAWINGS	REB	CRP	JAC
0	4-21-05	ISSUED FOR CONSTRUCTION	REB	CRP	JAC

CUMMINS & BARNARD, INC.
5405 DATA COURT, SUITE 100
ANN ARBOR, MI 48108
TEL (734) 761-9130 FAX (734) 761-9881

REVISION: 1
SHEET: 4937-CMP-E1001
MICROFILM NO. 364284
we energies
CGS NO. 120605
DRAWN: REB DATE 11-15-04
CHECKED: CRP DATE 4-15-05
APPROVED: JAC DATE 4-15-05
PROJECT NO. 493704
SCALE: NONE

ONE-LINE DIAGRAM UNITS 7, 8, & 9

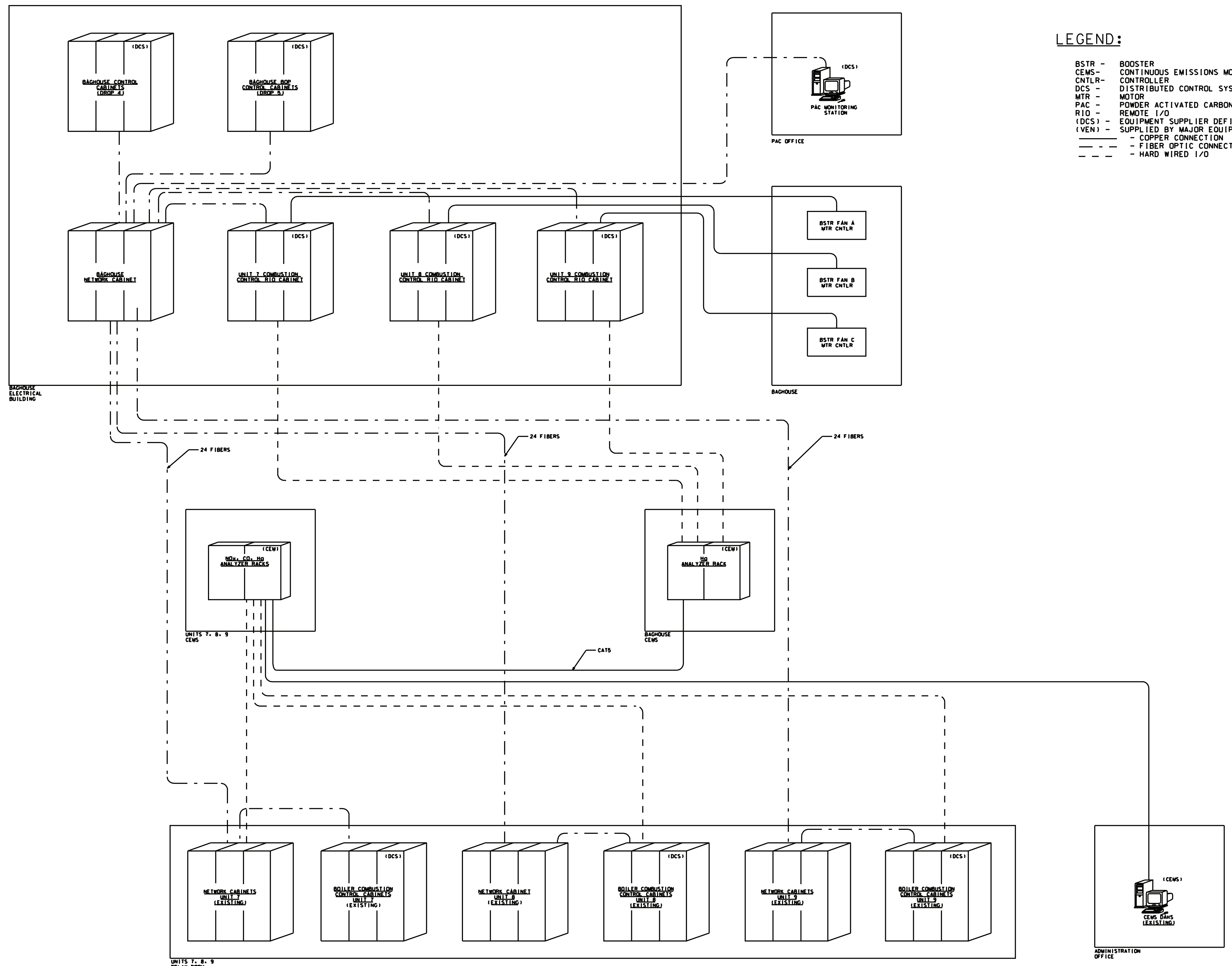
E PI 07 EMPK00001001

NOTES:

1. ALL EQUIPMENT AND CIRCUITS ARE NEW UNLESS NOTED OTHERWISE.
2. DCS ARCHITECTURE INCLUDES DUAL REDUNDANT DATA HIGHWAY CONNECTIONS.

LEGEND:

- BSTR - BOOSTER
- CEMS- CONTINUOUS EMISSIONS MONITORING SYSTEM
- CNTLR- CONTROLLER
- DCS - DISTRIBUTED CONTROL SYSTEM
- MTR - MOTOR
- PAC - POWDER ACTIVATED CARBON
- RIO - REMOTE I/O
- (DCS) - EQUIPMENT SUPPLIER DEFINITION
- (VEN) - SUPPLIED BY MAJOR EQUIPMENT VENDOR
- ——— - COPPER CONNECTION
- —·—·— - FIBER OPTIC CONNECTION
- — — — - HARD WIRED I/O



WAS:

REFERENCE DRAWINGS

REV	DATE	REVISION DESCRIPTION	DRAWN	CHK'D	APPRV'D
0	4-08-05	ISSUED FOR CONSTRUCTION	DAV	CAR	JAC

LEVEL USAGE: 1 2 3 4 5 6 7 8 9 / 10 11 12 13 14 15 16 17 18 / 19 20 21 22 23 24 25 26 27 / 28 29 31 32 33 34 35 36 / 37 38 39 40 41 42 43 44 45 / 46 47 48 49 50 51 52 53 54 / 55 56 57 58 59 60 61 62 63

CGS REF FILES

CUMMINS & BARNARD, INC.
CONSULTING ENGINEERS SINCE 1957
5405 DATA COURT, SUITE 100
ANN ARBOR, MI 48108
TEL (734) 761-9130 FAX (734) 761-9881

REVISION: 0

SHEET: 4937-CCX-K6000

MICROFILM NO. 356046

we energies

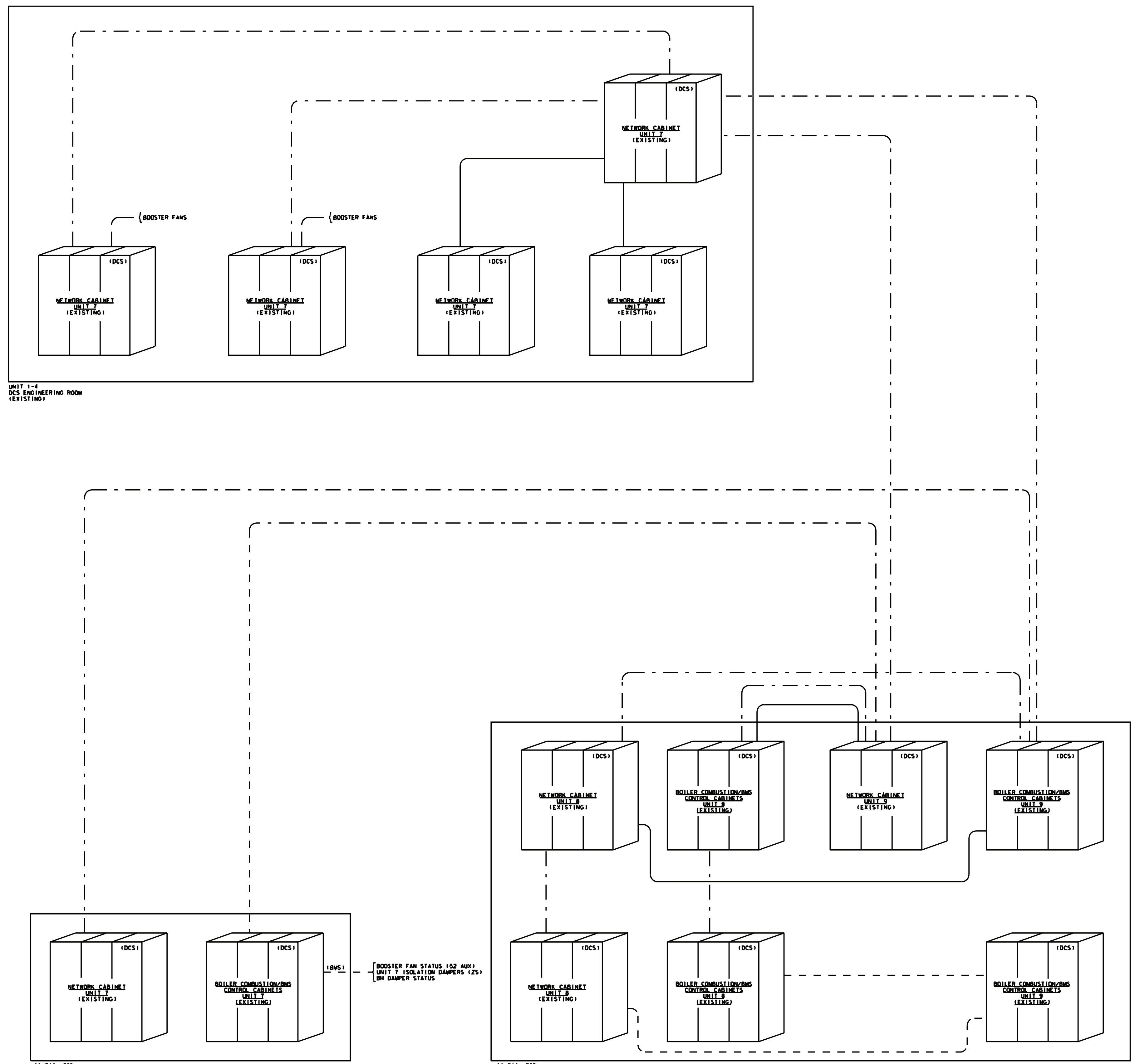
CONTROL SYSTEM OVERVIEW

DRAWN	DATE	PROJECT NO.
KFH	6-16-04	
CHECKED	DATE	ACTIVITY NO.
CAR	4-08-05	
APPROVED	DATE	SCALE
JAC	4-08-05	NTS

CGS NO. 116992

E P I 07 E C X K 1 4 1 0 0 1 0 0

$DATE$



NOTES:

1. ALL EQUIPMENT AND CIRCUITS ARE NEW UNLESS NOTED OTHERWISE.
2. EACH DCS CONTROL & RIO CABINET WILL BE SUPPLIED WITH TWO (2) 120 VAC UPS POWER SUPPLIES.
3. DCS ARCHITECTURE INCLUDES DUAL REDUNDANT DATA HIGHWAY CONNECTIONS.
4. EACH UNIT RIO CABINET ON DROP 1 WILL BE RELOCATED TO ITS RESPECTIVE UNITS DROP 4 DCS CONTROL CABINET AFTER COMPLETION OF THE BAGHOUSE.

LEGEND:

BH - BAGHOUSE
DCS - DISTRIBUTED CONTROL SYSTEM
RIO - REMOTE I/O
(DCS) - EQUIPMENT SUPPLIER DEFINITION
(UCC) - SUPPLIED BY MAJOR EQUIPMENT VENDOR
——— - COPPER CONNECTION
— - — - FIBER OPTIC CONNECTION
——— - NETWORK CONNECTION
— — — - HARD WIRED I/O

NOT TO BE USED FOR CONSTRUCTION

REFERENCE DRAWINGS

REV NO.	DATE	REVISION DESCRIPTION	DRAWN	CHK'D	APPR'D
A	6/16/04	OWNER REVIEW	KFH	CAR	

CUMMINS & BARNARD, INC.
CONSULTING ENGINEERS SINCE 1932
5405 DATA COURT, SUITE 100
ANN ARBOR, MI 48108
TEL (734) 761-9130 FAX (734) 761-9881

REVISION: A
SHEET: 4937-CCX-K6001

LEVEL USAGE
1 2 3 4 5 6 7 8 9
10 11 12 13 14 15 16 17 18
19 20 21 22 23 24 25 26 27
28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45
46 47 48 49 50 51 52 53 54
55 56 57 58 59 60 61 62 63

CGS REF FILES
MICROFILM NO.
DRAWN KFH DATE 6/16/04
CHECKED DATE
APPROVED DATE
PROJECT NO.
ACTIVITY NO.
SCALE NTS

we energies
CGS NO.

CONTROL SYSTEM OVERVIEW

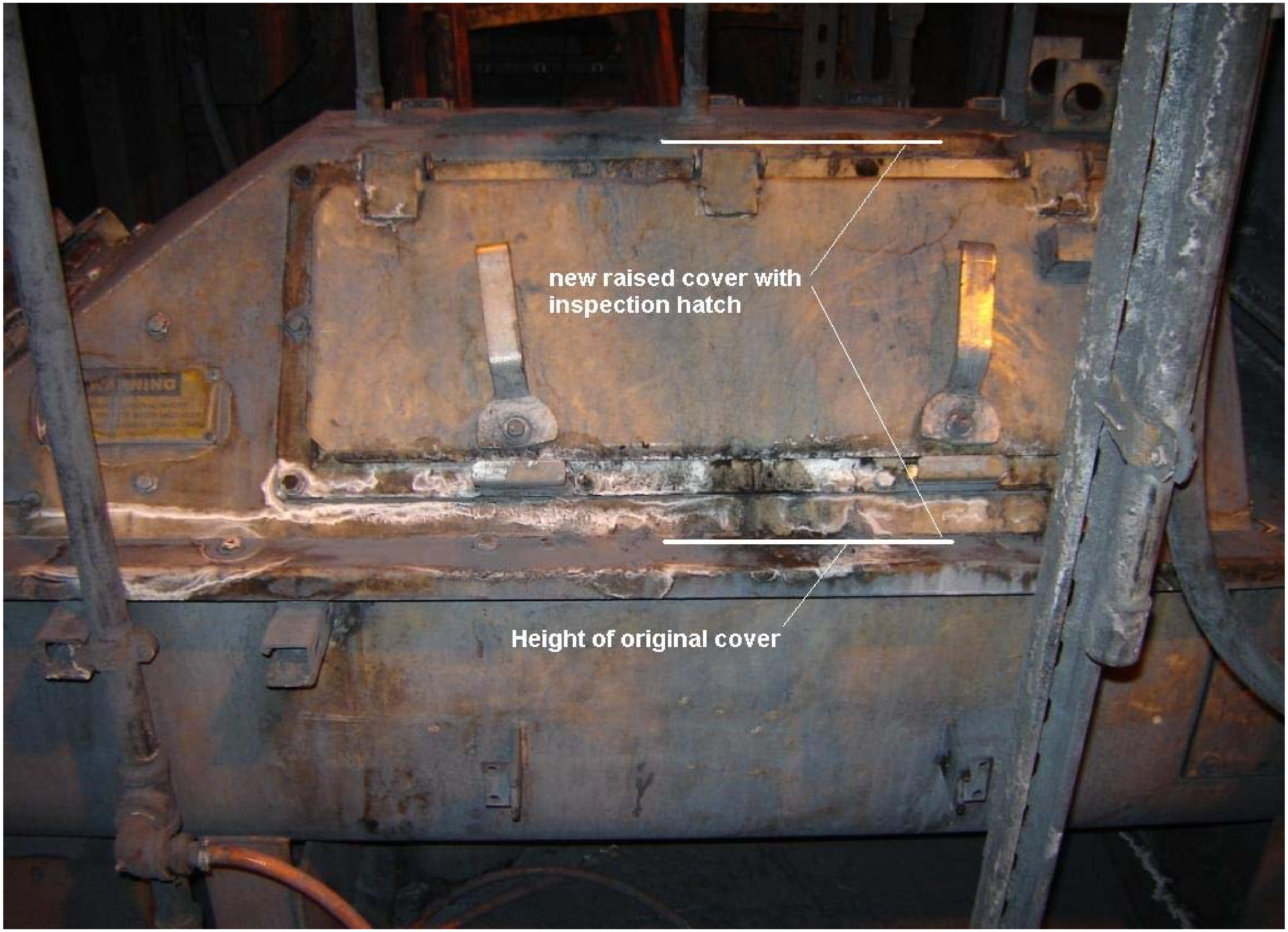
E P I 07 E C X K 1 4 1

WAS:
$DATE$

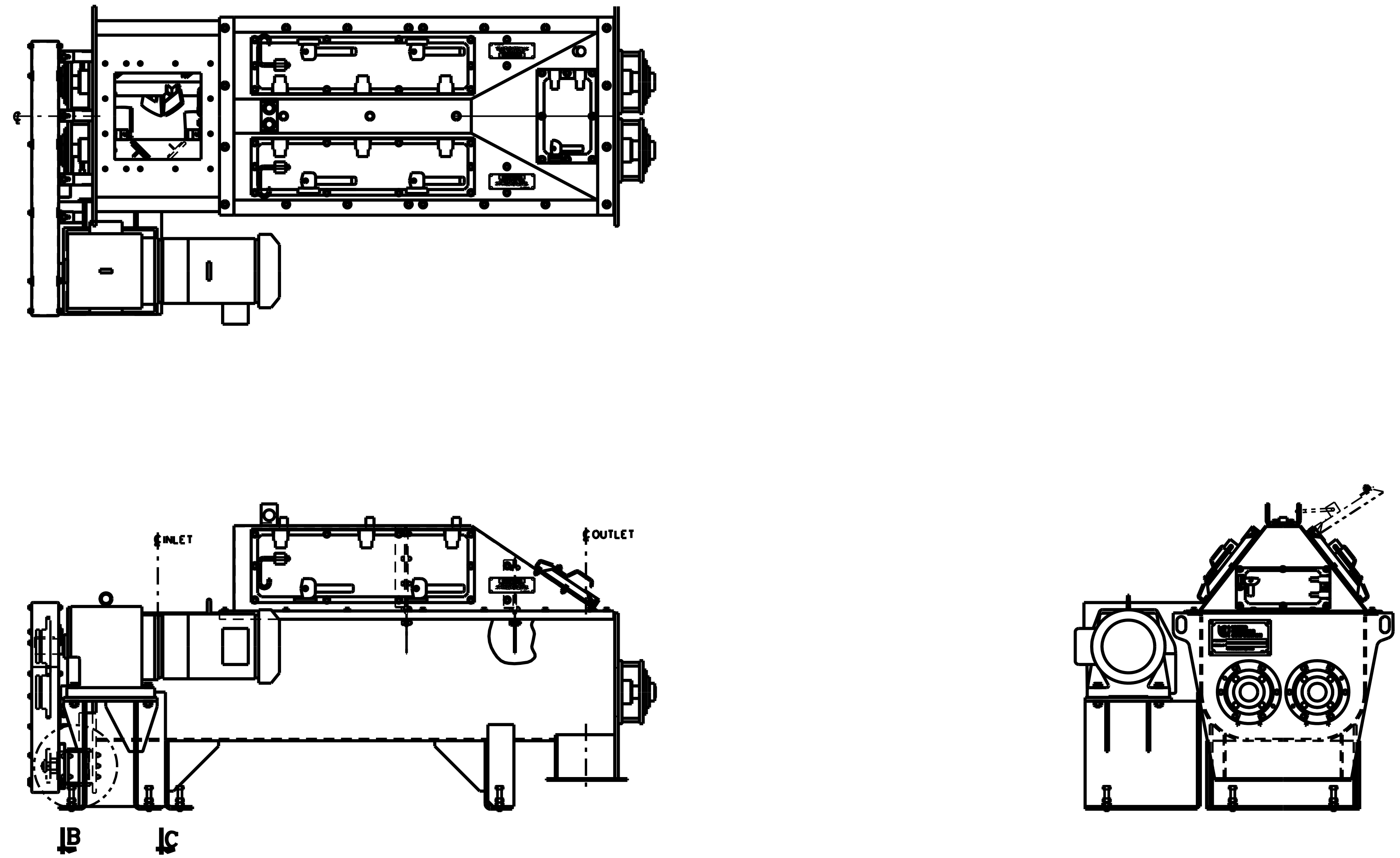
Appendix D. Modifications Since Startup

This Appendix contains the following photos and drawing related to the project:

Photo	**Title**
JPG_001	Raised Cover Pin Mixer
Dwg 5-5200-PIPP	New Pin Mixer
JPG_002	Baghouse Pulse Pipe Cover
JPG_003	External Control Panel Ash Silo
JPG_004	Silo Access Hatch and Inspection Port
JPG_005	New Insulation Vacuum Unloading Pipes
JPG_006	New Platform – Booster Fan Outlet (TYP 3)
JPG _007	New Rotary Valve for Ash Unloading
JPG_008	Air Canon (TYP3)
JPG_009	Platform on Top of Duct Unit 8
JPG_010	Platform for Diverter Access Doors
JPG_011	Ash Unloading Truck Enclosure
JPG_012	Rubber Skirt, Wet Unloading System



JPG_001: Raised Cover Pin Mixer



L	
K	
J	
H	
G	
F	
E	
D	
C	
B	
A	INITAL RELEASE 9/10/09 DCT
REVISIONS	

THIRD ANGLE PROJECTION

ECN

Est. Wt. kg. 1,570 lbs.

TOLERANCES
UNLESS OTHERWISE SPECIFIED:
ALL TAPPED HOLES AND BOLT HOLE LOCATIONS TO BE ±1/32"
FRACTIONAL DIMENSIONS: ±1/16"
METRIC DIMENSIONS: ± 1.6 mm
ALL ANGLES: ± 1°

General fabrication specification 98001 is a part of this drawing.

MIXER - PIN/PADDLE
MODEL 10/100

UNITED CONVEYOR CORPORATION
2100 NORMAN DRIVE WEST
WAUKEGAN, ILLINOIS 60085

DRAWN	KEC	1/5/09	SCALE 1/2" = 1'-0"
CHECKED	DCT	1/14/09	DRAWING NUMBER 5-5200-PIPP
APPROVED	RJL	1/14/09	REV A
APPROVED		/ /	
APPROVED		/ /	

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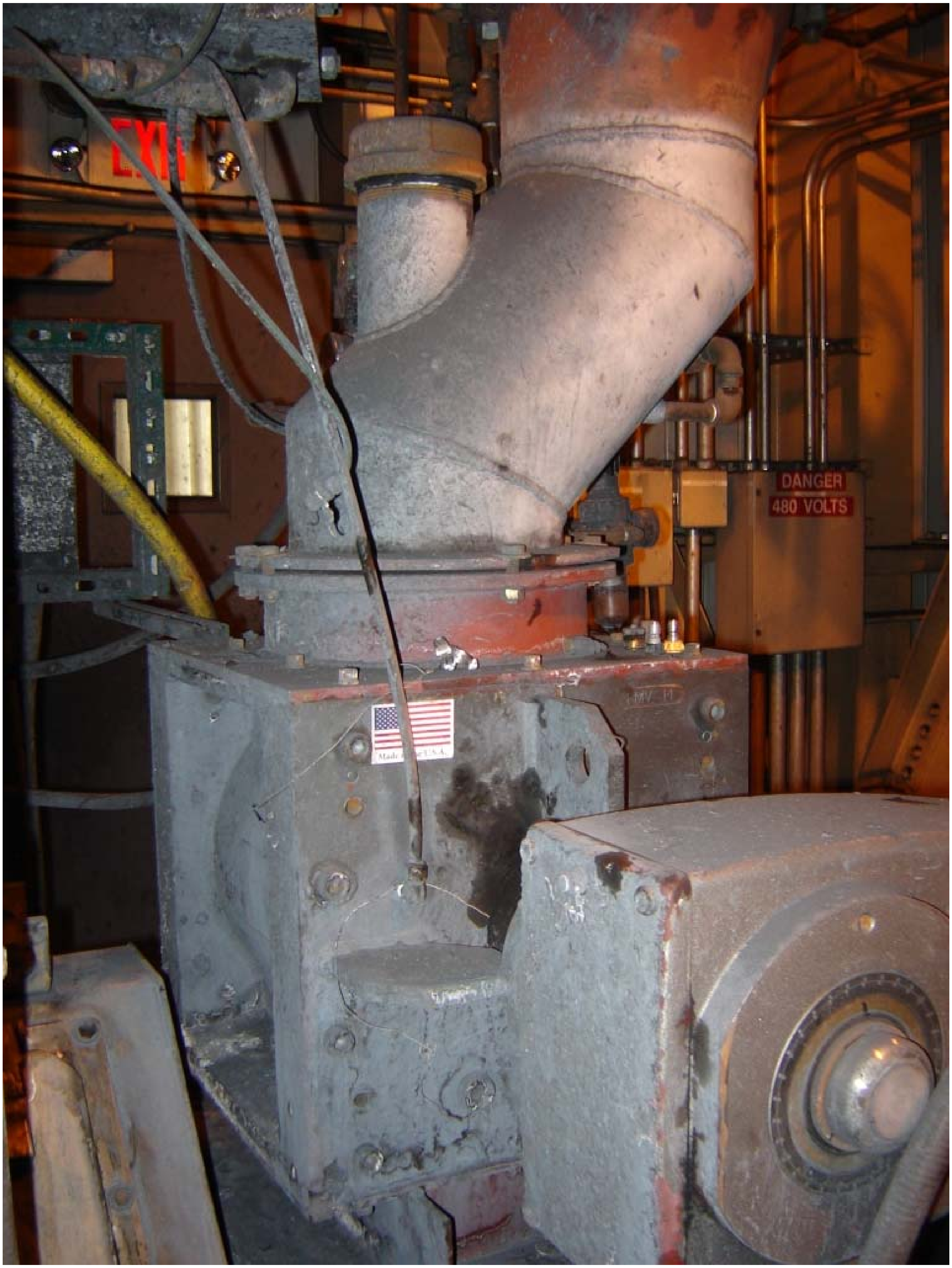
JPG_002: Baghouse Pulse Pipe Cover

JPG_003: External Control Panel Ash Silo

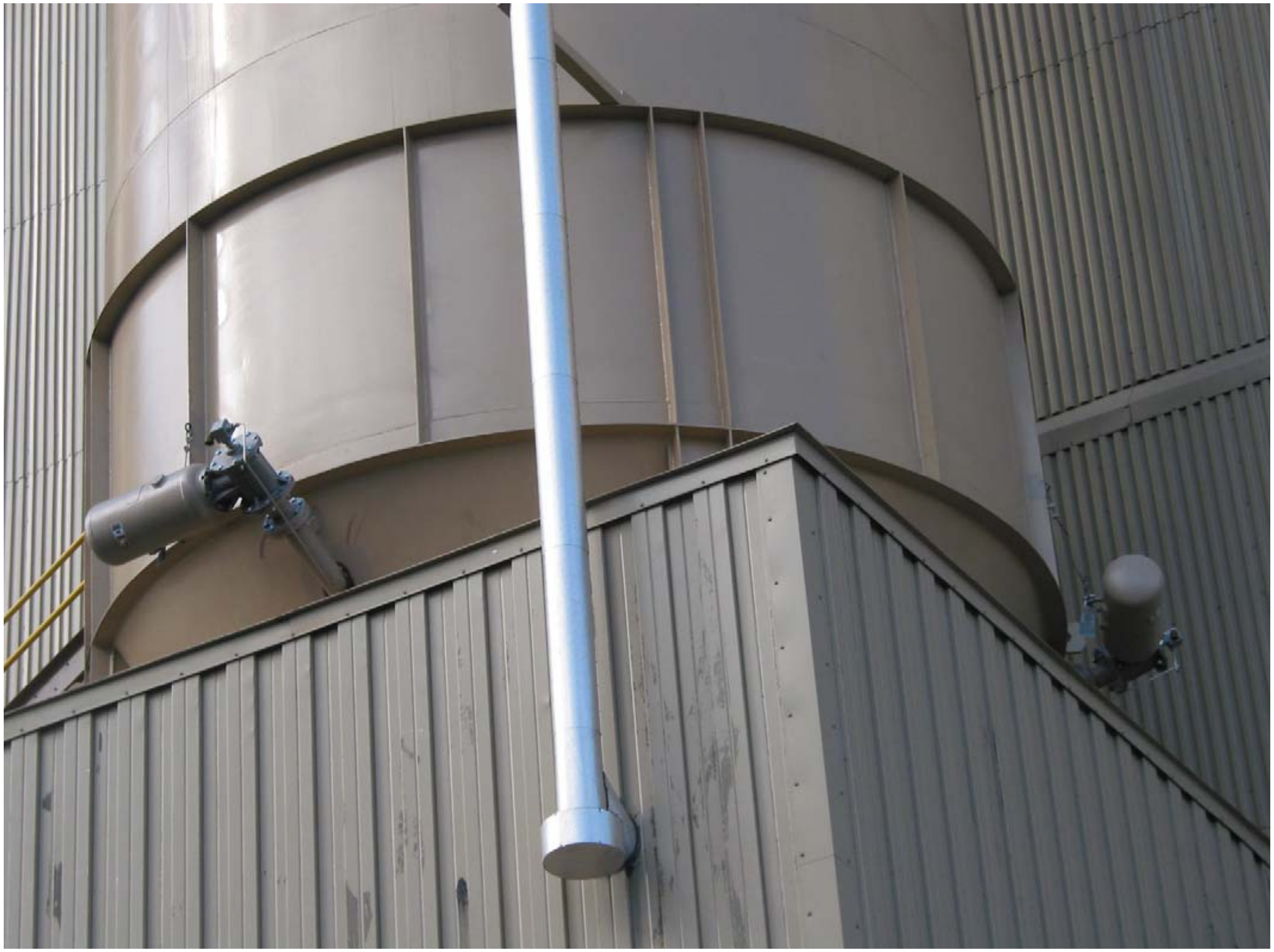
JPG_004: Silo Access Hatch and Inspection Port

JPG_005: New Insulation Vacuum Unloading Pipes

JPG_006: New Platform – Booster Fan Outlet (TYP 3)



JPG _007: New Rotary Valve for Ash Unloading



JPG_008: Air Canon (TYP3)

JPG_009: Platform on Top of Duct Unit 8

JPG_010: Platform for Diverter Access Doors

JPG_011: Ash Unloading Truck Enclosure

JPG_012: Rubber Skirt, Wet Unloading System