

**Field Test Program for Long-Term Operation
of a COHPAC[®] System for Removing Mercury
from Coal-Fired Flue Gas**

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ABSTRACT

This document provides a summary of the full-scale demonstration efforts involved in the project “*Field Test Program for Long-Term Operation of a COHPAC[®] System for Removing Mercury from Coal-Fired Flue Gas.*” The project took place at Alabama Power’s Plant Gaston Unit 3 and involved the injection of sorbent between an existing particulate collector (hot-side electrostatic precipitators) and a COHPAC[®] fabric filter (baghouse) downstream. Although the COHPAC[®] baghouse was designed originally for polishing the flue gas, when activated carbon injection was added, the test was actually evaluating the EPRI TOXECON[™] configuration.

The results from the baseline tests with no carbon injection showed that the cleaning frequency in the COHPAC[®] unit was much higher than expected, and was above the target maximum cleaning frequency of 1.5 pulses/bag/hour (p/b/h), which was used during the Phase I test in 2001. There were times when the baghouse was cleaning continuously at 4.4 p/b/h. In the 2001 tests, there was virtually no mercury removal at baseline conditions. In this second round of tests, mercury removal varied between 0 and 90%, and was dependent on inlet mass loading. There was a much higher amount of ash exiting the electrostatic precipitators (ESP), creating an inlet loading greater than the design conditions for the COHPAC[®] baghouse. Tests were performed to try to determine the cause of the high ash loading.

The LOI of the ash in the 2001 baseline tests was 11%, while the second baseline tests showed an LOI of 17.4%. The LOI is an indication of the carbon content in the ash, which can affect the native mercury uptake, and can also adversely affect the performance of ESPs, allowing more ash particles to escape the unit.

To overcome this, an injection scheme was implemented that balanced the need to decrease carbon injection during times when inlet loading to the baghouse was high and increase carbon injection when inlet loading and mercury removal were low. The resulting mercury removal varied between 50 and 98%, with an overall average of 85.6%, showing that the process was successful at removing high percentages of vapor-phase mercury even with a widely varying mass loading.

In an effort to improve baghouse performance, high-permeability bags were tested. The new bags made a significant difference in the cleaning frequency of the baghouse. Before changing the bags, the baghouse was often in a continuous clean of 4.4 p/b/h, but with the new bags the cleaning frequency was very low, at less than 1 p/b/h.

Alternative sorbent tests were also performed using these high-permeability bags. The results of these tests showed that most standard, high-quality activated carbon performed similarly at this site; low-cost sorbent and ash-based sorbents were not very effective at removing mercury; and chemically enhanced sorbents did not appear to offer any benefits over standard activated carbons at this site.

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INTRODUCTION

With the nation's coal-burning utilities facing tighter controls on mercury pollutants, the U.S. Department of Energy is funding projects that could offer power plant operators better ways to reduce these emissions at much lower costs. Injecting a sorbent such as powdered activated carbon 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 and attached mercury is then collected by the existing particulate control device along with fly ash in the flue gas stream.

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). One straightforward, cost-effective approach to achieving high mercury removal without contaminating the fly ash is the use of the EPRI Compact Hybrid Particulate Collector (COHPAC[®]) and TOXECON[™] processes. COHPAC[®] is an EPRI patented concept that places a high air-to-cloth ratio baghouse downstream of an existing ESP to improve overall particulate collection efficiency. The process becomes TOXECON[™] when a sorbent such as activated carbon is injected upstream of the baghouse and downstream of an electrostatic precipitator (ESP) (Figure 1). TOXECON[™] is also an EPRI patented process (U.S. Patent 5,505,766) for removing pollutants from combustion flue gas by injecting sorbent in between an existing particulate collector and a baghouse installed downstream of the existing collector for control of toxic species. With this configuration, the ash collected upstream of the carbon injection remains acceptable for sale. The downstream baghouse 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.

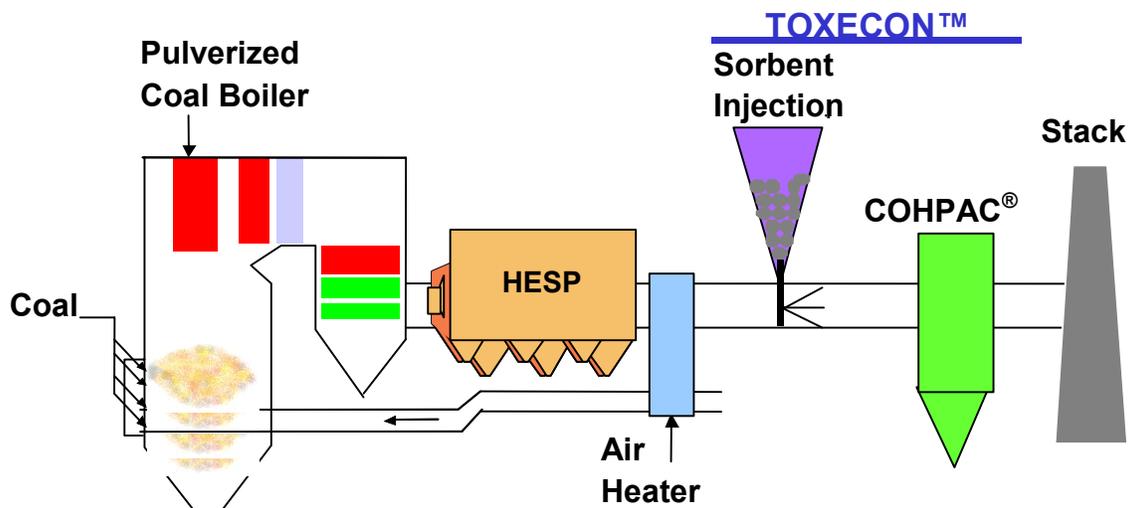


Figure 1. TOXECON[™] Configuration Combining Sorbent Injection and a COHPAC[®] Baghouse.

Assuming that a capital investment in a new ESP or baghouse is being considered, the advantages of the COHPAC[®] and TOXECON[™] configurations are:

- Sorbents are mixed with a small fraction of the ash (nominally 1%), 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).
- Capital costs for COHPAC[®] can be less than either a larger ESP or full-sized baghouse or larger ESP, depending on the need for new ID fans and balance-of-plant considerations.
- COHPAC[®] requires much less physical space than either a larger ESP or full-size baghouse system.
- Outage time can be significantly reduced with TOXECON[™] systems in comparison to 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 and installed while the ESP is still in full operation, thus keeping outage time to a minimum.

Cooperative Agreement No. DE-FC26-02NT41591 was awarded to ADA-ES, Inc., to demonstrate Activated Carbon Injection (ACI) technology to control mercury on a coal-fired boiler equipped with a COHPAC[®] baghouse. Under the contract, ADA-ES worked in partnership with the Department of Energy's National Energy Technology Laboratory (DOE/NETL), Alabama Power, and EPRI.

This program was made possible by significant cost-share support from the following companies:

- Duke Power
- EPRI
- Southern Company and Alabama Power Company
- Hamon Research-Cottrell, Inc.
- Allegheny Power
- Ontario Power Generation
- TVA
- Arch Coal, Inc.
- ADA-ES, Inc.

A group of highly qualified individuals and companies was assembled to implement this program. Project team members include:

- ADA-ES, Inc.
- Southern Research Institute
- Grubb Filtration Testing Services, Inc.
- Reaction Engineering International

EXECUTIVE SUMMARY

During 2001, ADA-ES, Inc., conducted a full-scale demonstration of sorbent-based mercury control technology at the Alabama Power Company's E.C. Gaston Station (Wilsonville, Alabama). This unit burns a low-sulfur bituminous coal and uses a hot-side ESP (HESP) in combination with a COHPAC[®] baghouse to collect fly ash. The majority of the fly ash is collected in the ESP with the residual being collected in the COHPAC[®] baghouse. Activated carbon was injected between the ESP and COHPAC[®] units to collect the mercury.

Short-term mercury removal in these 2001 tests was between 78 and 95% using the COHPAC[®] unit. The tests also showed that activated carbon was effective in removing both elemental and oxidized forms of mercury. However, a great deal of additional testing was required to further characterize the capabilities and limitations of this technology relative to use with baghouse systems such as COHPAC[®]. For example, testing also showed that cleaning frequency of the baghouse increased proportionally with carbon injection concentration. It was important to determine performance over an extended period of time to fully assess the impact on all operational parameters.

The project described in this report focused on the long-term demonstration of sorbent injection technology at a coal-fired power generating plant that is equipped with a COHPAC[®] system. Testing was conducted at Alabama Power Company's Plant Gaston Unit 3 (nominally 135 MW) in 2003 and 2004. The overall objective was to evaluate the long-term effects of sorbent injection on mercury capture and COHPAC[®] performance. The work was conducted on one-half of the gas stream (designated B-side).

In the initial baseline tests, COHPAC[®] cleaning frequency and native mercury removal (removal of vapor-phase mercury by the carbon in fly ash) were very different from what was seen during the 2001 tests. Cleaning frequency was much higher than expected, and was above the target maximum cleaning frequency of 1.5 pulses/bag/hour (p/b/h), which was used during the two-week test in 2001. Also, in the earlier tests there was virtually no mercury removal at baseline conditions. In this second round of tests, mercury removal varied between 0 and 90%, and was dependent on inlet mass loading.

Substantially higher particulate mass loading exiting the HESP and entering the baghouse caused the difference in performance. HESP performance was evaluated and suggested that the HESP was operating within design conditions for the type of ash being collected and without any flue gas conditioning. So, although the HESP was performing within design specifications, there was a much higher amount of ash exiting the unit than previously, creating an inlet loading greater than the design conditions for the COHPAC[®] baghouse.

In order to understand the high inlet loading to the COHPAC[®] unit, loss on ignition (LOI) tests were performed on the ash. The LOI of the ash in the first baseline tests was 11%, while the second baseline tests showed an LOI of 17.4%. This increase in LOI could have been a factor in both the high inlet loading to the COHPAC[®] unit and the intermittent high native mercury removal. Hamon Research-Cottrell was brought in to inspect the HESP in an effort to determine why there was a high particulate loading entering the COHPAC[®] unit. Power levels were found to be extremely low in all fields of the HESP, which may have

been caused by the high carbon/low resistivity ash. Low power levels could also directly reduce capture efficiency. Also, two chambers fields were out of service, which could also negatively impact particulate capture efficiency. Several other factors may have contributed to the creation of low resistivity ash such as coal type and/or boiler operations, but no definitive source was identified.

Because of the highly variable baseline conditions and the already high cleaning frequency of the baghouse, the ability to inject activated carbon was severely limited. There were times when the baghouse was in a continuous clean during baseline conditions with no carbon injection. To overcome this, an injection scheme was implemented that balanced the need to decrease carbon injection during times when inlet loading to the baghouse was high and increase carbon injection when inlet loading and mercury removal were low. A signal from a particulate monitor measuring COHPAC[®] inlet mass loading was used to control activated carbon injection (ACI) concentration.

Between July 19 and November 24, 2004, activated carbon injection for mercury control was operated continuously using the inlet mass loading control logic. During this testing, inlet mass loading varied from 0.03 gr/acf to 0.19 gr/acf and carbon injection concentration was adjusted to these changes. Average mercury removal was 85.6%, with a minimum daily average of 63.5% and a maximum daily average of 98.1%. The maximum carbon injection concentration was 0.66 lb/MMacf, and at times carbon injection was turned off. The average injection concentration was 0.55 lb/MMacf, which was much lower than what was needed in the 2001 test to obtain similar removal efficiencies. It is believed that the higher removal efficiencies obtained at lower carbon injection concentrations than predicted in the earlier tests occurred because there was significant carbon on the bags from the higher baseline mass loading entering the baghouse. The COHPAC[®] hopper ash had a relatively high carbon content with LOI between 15 and 30%.

One thing that was clear from these tests was that the existing air-to-cloth (A/C) ratio was too high to inject sufficient carbon to achieve 90% mercury control. A new TOXECON[™] baghouse would have to be designed at a lower A/C ratio. One way to evaluate performance at a lower A/C ratio was to operate Unit 3 at low load/lower flow for an extended period. Alabama Power was able to schedule an extended period of low load operation for Gaston Unit 3 in November 2004.

The results from this test more closely matched the results from the 2001 tests. At an injection concentration of 0.9 lb/MMacf, mercury removal was between 80 and 90%. When injection concentration was increased above 2 lb/MMacf, mercury removal was well above 90%, and there were no episodes when the removal dropped below this level. Cleaning frequency was acceptable at all injection rates during these short duration tests (baghouse pressure drops normally increase over long operational periods requiring increased cleaning frequency).

In an effort to improve baghouse performance, a set of high-permeability (high-perm) bags was purchased and installed in the B-side baghouse. The new bags made a significant difference on the baseline cleaning frequency of the B-side baghouse. Before changing the bags, the Unit 3B baghouse was often in a continuous clean of 4.4 p/b/h, similar to the

cleaning frequency trend for the Unit 3A baghouse. Even with a much higher inlet mass loading, B-side baghouse cleaning frequency was very low, at less than 1 p/b/h. Mercury removal with activated carbon and the high-perm bags was comparable to the results obtained with the standard bags. However, the high-perm bags resulted in a much lower baseline cleaning frequency, which reduced the impact on baghouse performance.

Alternative sorbent tests were also performed using these high-perm bags. The results of these tests showed that most standard, high-quality activated carbon performed similarly at this site; low-cost sorbent and ash-based sorbents were not very effective at removing mercury; and chemically enhanced sorbents did not appear to offer any benefits over standard activated carbons at this site.

BACKGROUND

In 2001, a short-term test of ACI upstream of COHPAC[®] was conducted on one-half of Alabama Power Company's E.C. Gaston Station Unit 3 (Bustard et al., 2001). Figure 2 presents the results from the parametric tests, which evaluated mercury removal at different ACI concentrations. The tests showed that 90% mercury removal could be achieved at relatively low injection concentrations (< 3 lb/MMacf); however, they also showed that baghouse cleaning frequency increased proportionally with injection rate (Figure 3).

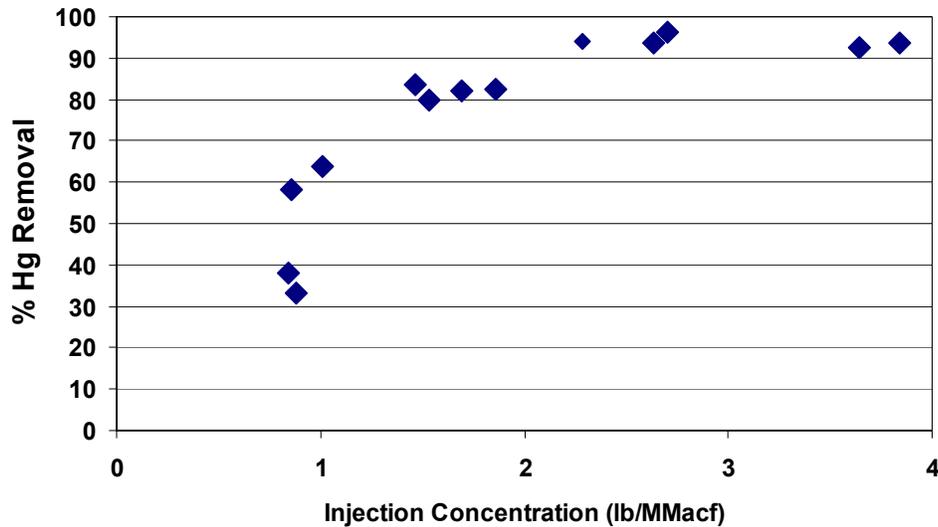


Figure 2. Mercury Removal with Activated Carbon Injected Upstream of COHPAC[®] at Alabama Power's Plant Gaston, Spring 2001.

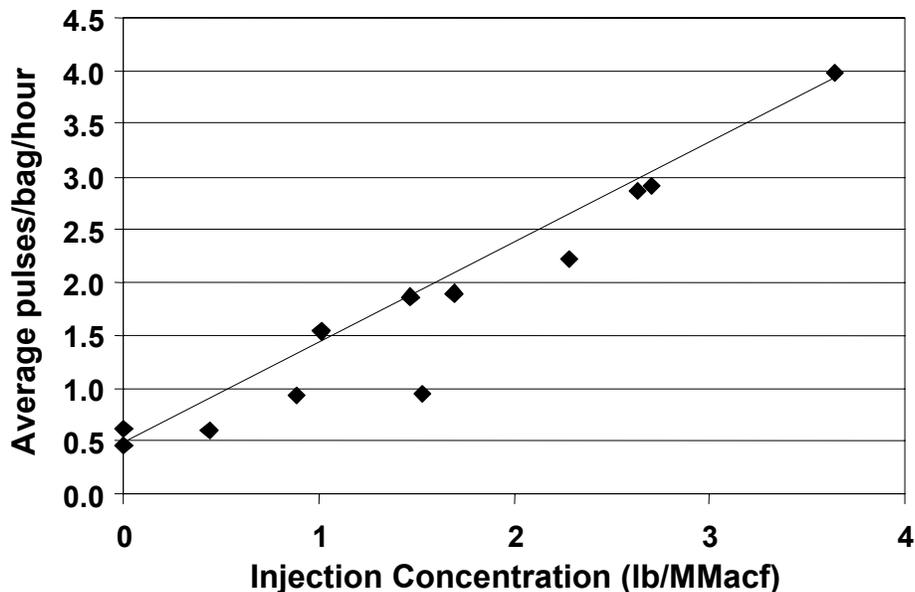


Figure 3. COHPAC[®] Cleaning Frequency in Pulses/Bag/Hour as a Function of ACI Concentration. Measurements made during Parametric Tests, March 2001.

Based on these results, a two-week injection test was conducted at an injection concentration of 1.5 lb/MMacf, which was the highest injection rate possible without significantly impacting cleaning frequency. Figure 4 shows inlet and outlet mercury concentrations, boiler load, and carbon injection concentration for a portion of the two-week test. Also shown in this graph are the results from Ontario Hydro mercury measurements, which confirmed the accuracy of the mercury analyzer measurements.

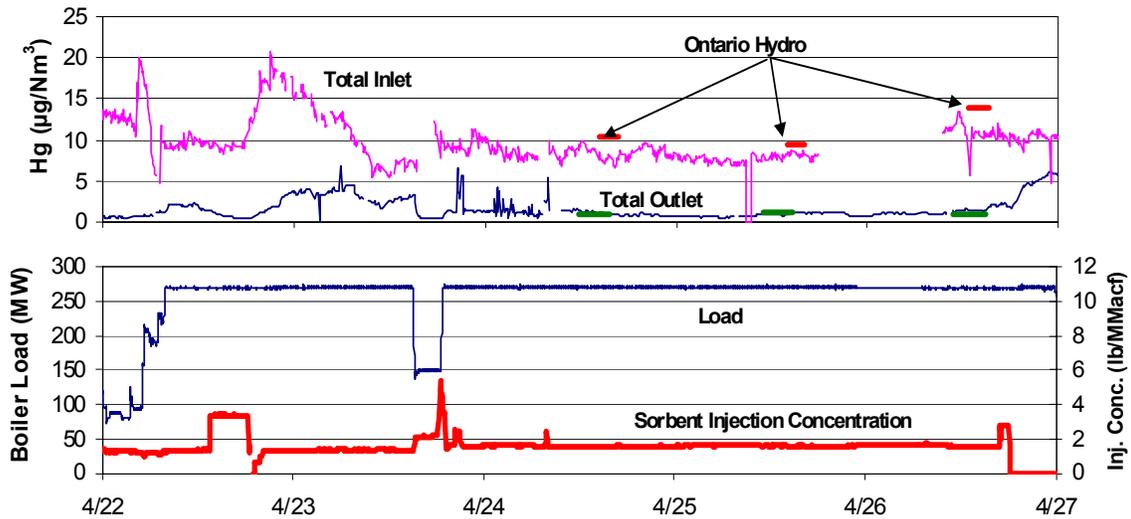


Figure 4. Inlet and Outlet COHPAC[®] Mercury Concentrations, Boiler Load, and ACI; Plant Gaston, 2001.

The results from this 2001 field test program at Gaston provided a good indication of the capabilities (high mercury removal) and limitations (high cleaning frequency) of the TOXECON[™] technology for controlling mercury. However, the tests were performed for a limited amount of time (< 200 hours of continuous operation) and did not allow for a thorough operational analysis of the use of this technology for mercury control. The tests also suggested that designing the baghouse for a lower air-to-cloth (A/C) ratio might allow carbon injection at a rate consistent with high removals without excessive pressure drop.

PROGRAM OVERVIEW

In the fall of 2002, ADA-ES was selected by the Department of Energy's National Energy Technology Laboratory (DOE/NETL) to continue to mature the TOXECON™ technology by conducting a long-term test program of ACI on a coal-fired boiler equipped with a COHPAC® baghouse. Testing was conducted at Alabama Power Company's E.C. Gaston Station. Under the contract, ADA-ES worked in partnership with DOE/NETL, Southern Company, and EPRI. Technical and cost-share financial support were provided by EPRI, Southern Company, Alabama Power, Hamon Research-Cottrell, Ontario Power Generation, TVA, Duke Power, Arch Coal, and ADA-ES.

The overall objectives of this yearlong mercury control program were to provide data to assess the operational impacts to COHPAC® and the ability to effectively control mercury over varying operational and seasonal conditions. This program had four specific technical tasks:

1. Design and install an activated carbon injection system capable of continuous operation for up to one year.
2. Install a mercury analyzer capable of long-term, continuous operation. This analyzer is referred to as a Semi-Continuous Emissions Monitor (S-CEM).
3. Evaluate long-term performance of carbon injection upstream of COHPAC® for mercury control. This task had two separate test periods:
 - a. The first test (approximately six months) was conducted using the existing set of bags.
 - b. The second test (approximately six months) was conducted on a set of new high-perm bags.
4. Perform short-term tests of alternative sorbents and sorbent suppliers.

A key parameter evaluated in this test program was the fabric used to make the filter bags. The OEM fabric for the four COHPAC® baghouses in the U.S. (Gaston Units 2 and 3 and TXU's Big Brown Units 1 and 2) was a 2.7-denier polyphenylene sulfide (PPS) felt with the trade name of Ryton®. Denier is a measure of the linear density of a fiber and provides an indication of the cross section or thickness of the fibers.

Since 1998, EPRI has invested significant resources to develop a high-perm fabric that has inherently higher permeability and therefore lower operating pressure drop. The most successful high-perm fabric has been one made with a 6- or 7-denier instead of 2.7-denier PPS fiber. After a year of testing in one compartment at Big Brown, residual drag of the high-perm fabric was half that of the 2.7-denier fabric (Bustard, et al., 1997). Additional testing was conducted over the next several years confirmed that this fabric reduced pressure drop at Big Brown. Because of this, the plant switched to ordering high-perm fabric for all bag replacements in 2002.

This fabric was of interest at Gaston because the major impact on COHPAC[®] from the earlier short-term sorbent injection testing was an increase in cleaning frequency, or equivalent pressure drop. This high-perm fabric may provide a way to reduce the impact of increased mass loading on pressure drop and allow for either higher injection rates or less performance degradation over time.

The majority of the testing occurred under Task 3, where 6-month tests were conducted on two different fabrics. For each of the bag types, three test periods were planned:

1. Baseline: Testing in this period was dedicated to understanding baghouse operation and mercury removal with no carbon injection.
2. Optimization: The tests in 2001 showed that carbon injection directly impacted baghouse cleaning frequency (Bustard et al., 2001). This period was included to find a carbon injection scheme that achieved the highest mercury removal within the operational limits of the system.
3. Long-Term: Testing operated continuously at optimized injection conditions.

EXPERIMENTAL

Description of the Test Site

Alabama Power Company, a subsidiary of Southern Company, owns and operates the E.C. Gaston Electric Generating Plant located in Wilsonville, Alabama. The plant has four 270-MW balanced draft and one forced draft coal-fired boilers. All units fire a variety of low sulfur, washed, eastern bituminous coals. A summary of important descriptive parameters for Gaston Unit 3 is presented in Table 1.

Table 1. Site Description Summary, Gaston Unit 3.

Parameter Identification	Description
Process	
Boiler Manufacturer	B&W wall-fired
Burner Type	B&W CXL
Low-NO _x Burners	Yes
Steam Coils	No
Over Fire Air	No
NO _x Control (Post Combustion)	None
Temperature (APH Outlet)	290 °F
Coal	
Type	Eastern Bituminous
Heating Value (Btu/lb)	13,744
Moisture (%)	6.9
Sulfur (%)	0.9
Ash (%)	13.1
Hg (µg/g)	0.06
Cl (%)	0.03
Control Device	
Type	Hot-Side ESP with COHPAC [®]
ESP Manufacturer	Hamon Research-Cottrell
Design	Weighted Wire
Specific Collection Area (ft ² /1,000 acfm)	274
Flue Gas Conditioning	None
Baghouse Manufacturer	Hamon Research-Cottrell
Design	Pulse-Jet, Low Pressure – High Volume
A/C Ratio (acfm/ft ²)	8.5:1 (gross)

Hot-side ESPs are the primary particulate control equipment on all units. Units 1 and 2, and Units 3 and 4 share common stacks. The hot-side ESP is a Research-Cottrell weighted wire design. The specific collection area (SCA) is 274 ft²/1000 acfm. Depending on the operating condition of the hot-side ESP, nominally 97 to 99+% of the fly ash is collected in the ESP.

In 1996, Alabama Power contracted with Hamon Research-Cottrell to install COHPAC[®] downstream of the hot-side ESP on Unit 3 to collect the fly ash that exited the ESP. This COHPAC[®] system was designed to maintain Units 3 and 4 stack opacity levels below 5% on a 6-minute average. The COHPAC[®] system is a hybrid pulse-jet type baghouse, designed to treat flue gas volumes of 1,070,000 acfm at 290 °F (gross A/C ratio of 8.5 ft/min with online cleaning). Hopper ash from both the ESP and baghouse was sent to a wet ash pond for disposal using a hydroveyor system.

The COHPAC[®] baghouse consists of four isolatable compartments—two compartments per air preheater identified as either A- or B-side. Each compartment consists of two bag bundles, each having 544 23-foot-long, polyphenylene sulfide (PPS) felt filter bags, 18 oz/yd² nominal weight. This results in a total of 1,088 bags per compartment, or 2,176 bags per side. The evaluation was conducted on one-half of the gas stream, nominally 135 MW. The side chosen for testing was B-side. A-side was monitored as the control unit.

Task Descriptions

The following section describes the activities associated with each of the four major technical tasks.

Task 1 – Design, Procure, and Install a Sorbent Injection System

The sorbent injection silo/feeder system, shown in Figure 5, was designed and supplied by NORIT Americas Inc. (NORIT). This system consisted of:

- 2500 ft³ storage silo with twin discharge
- Bin vent bag filter
- Level switches and radar type level transmitter
- Two rotary valves
- Two feeder hoppers
- Two volumetric feeders
- Two pneumatic blower and eductor trains
- Load cells
- Pressure switches
- NEMA 4/4x design
- PLC system control panel
- Safety and trip interlocks
- Electrical requirement: 480V/3φ/60Hz: 80 Amps
- Compressed air requirement: 8 scfm @ 30 psig of instrument-quality air (intermittent use)

The bulk-storage silo had twin blower/feeder trains each rated at 750 lb/hr. Activated carbon was delivered in bulk pneumatic trucks and loaded into the silo, which was equipped with a bin vent bag filter. From the two discharge legs of the silo, the sorbent was metered by variable speed screw feeders into eductors that provided the motive force to carry the sorbent to the injection point. Regenerative blowers provided the conveying air. A PLC system was used to control system operation and adjust injection rates. Hard piping carried the sorbent from the feeders to distribution manifolds located on the ESP inlet duct, feeding the injection probes. Each manifold supplied up to six injectors.

A new distribution manifold (splitter) and injection lances were designed and fabricated. The splitter was a proprietary annulus design, which has proven to be very effective on the even distribution of the fine and abrasive activated carbon. The splitter distributed carbon to six injection lances (three in each duct). The lances were made from 1-inch carbon steel pipe, were 6 feet in length, and had a 45°-beveled edge at the nozzle end to direct the carbon cocurrent with flow.

The plant provided a load signal to the skid control panel so that carbon could be injected proportional to load. An analysis of boiler load versus flue gas flow was performed and an algorithm relating load to flow was developed. Using this approach, the system was programmed to maintain the target injection concentration (lb/MMacf) as load varied.

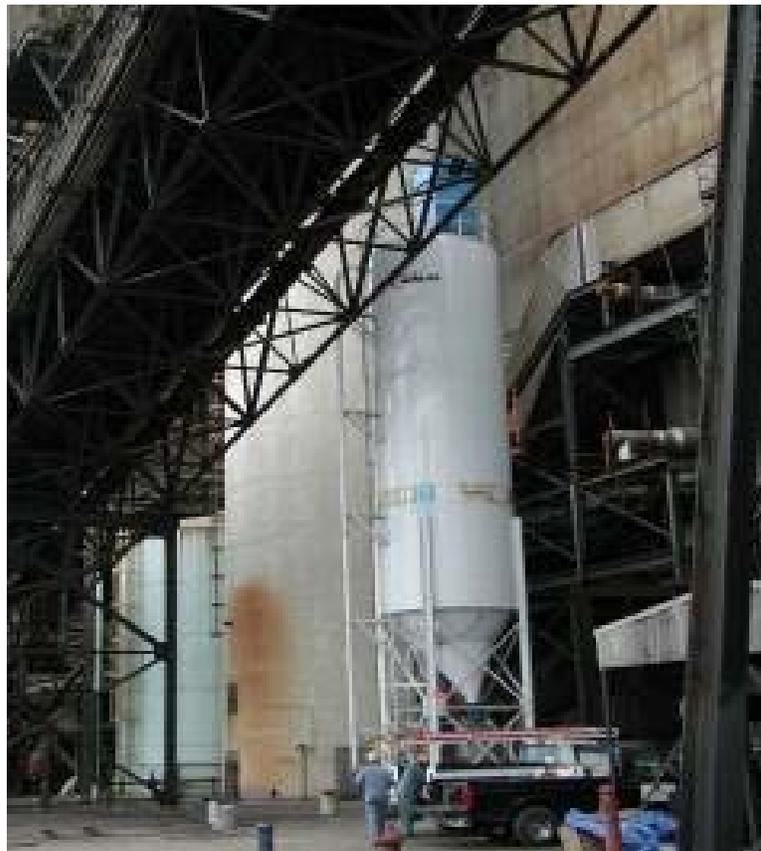


Figure 5. Carbon Injection Storage Silo and Feeder Trains Installed at Gaston, 2003.

A commercially available activated carbon supplied by NORIT, DARCO[®] FGD, was used throughout testing. (Note: this carbon was renamed to DARCO[®] Hg in 2005.) This carbon was chosen because it was the benchmark carbon in previous tests. Previous tests have shown little performance difference between high-capacity activated carbons from different suppliers. Therefore, testing with DARCO[®] FGD would provide continuity with the Phase I program as well as documenting performance with a commercially available carbon.

Figure 6 is a layout of Gaston Unit 3 and the locations of the various test components— analyzer extraction points and activated carbon injection lances.

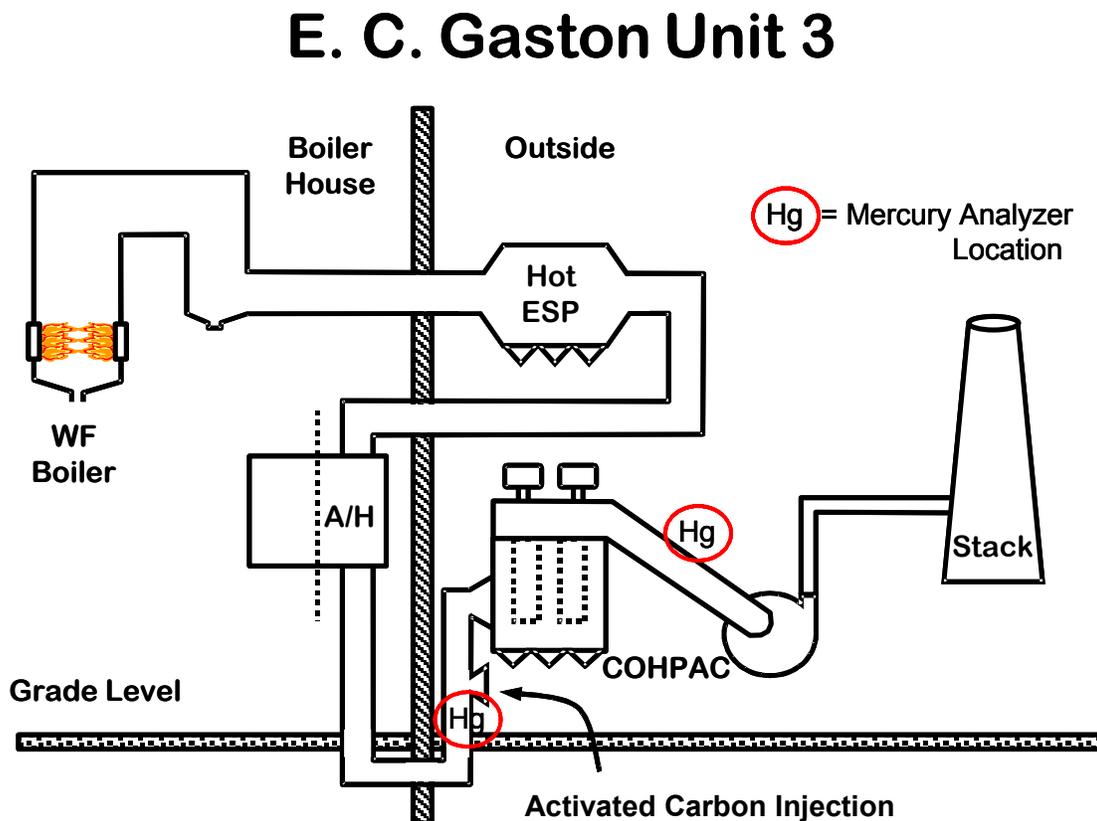


Figure 6. Layout of Gaston Unit 3 Showing Activated Carbon and Mercury Measurement Locations.

Task 2 – Procure, Install, and Operate Mercury Analyzer

Mercury measurements were key to the success of this program. As learned from previous tests, once carbon injection begins, analyzer operation and maintenance, along with timely data review, require the most significant effort from on-site personnel. The team goal was to reduce operating and maintenance requirements of the analyzers while maintaining or improving the quality of data obtained in previous tests.

Because of the success in the NETL multi-site test program with measurements using the Apogee/EPRI-designed analyzers and the investment already made in sampling components, gas conditioning components, spare parts, and the technical learning curve, it

was decided to begin this program using a cold vapor atomic absorption spectrometer (CVAAS) extractive semi-continuous analyzer. A sketch of the system is shown in Figure 7.

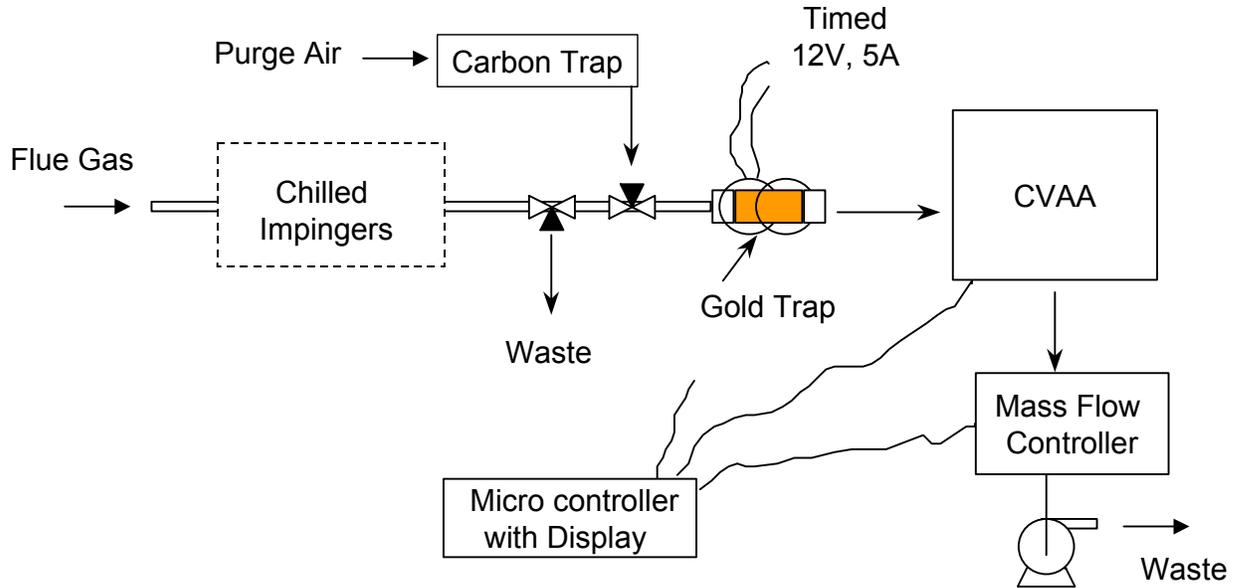


Figure 7. Sketch of Mercury Measurement System.

There were six primary components of the mercury analyzer system. A brief description follows:

Sample Extraction: Mercury was present in flue gas as both a particulate and in vapor phase. The analyzer measured only vapor-phase mercury. Particulate had to be removed before the gas sample entered the measurement chamber. This program used an extraction probe provided by Apogee Scientific, Inc. Particulate was separated from the flue gas using an inertial separation filter.

Conversion/Speciation: Vapor-phase mercury existed in the flue gas as either elemental (Hg^0) or oxidized (Hg^{2+}). Because mercury detectors measure only elemental mercury, the flue gas sample had to pass through a conversion unit so that all vapor-phase species of the mercury were converted to elemental mercury. A wet-chemistry-based conversion system was used. The sample gas passed through a set of impingers before entering a chiller to drop out moisture. Figure 8 is a photo of a set of impingers on one of the extraction probes at Gaston.

Sample Transport: The sample was transported more than 100 feet from the extraction probe to the mercury detector in the CEM shed located at the hopper level. The issues with transport were pressure drop and the need for heated PTFE lines.

Measurement (Detector): The measurement method was Cold Vapor Atomic Adsorption technology. This had been proven to be a very effective method as long as a conditioned,

moisture-free sample was delivered to the analyzer. Figure 9 is a picture of the detector installed in the shed at Gaston. The sample transport lines can also be seen in the photograph.

Calibration: To insure reliability and accuracy of all the components, the instrument was calibrated at a minimum of once a day. The analyzer was calibrated by injecting a known amount of elemental mercury upstream of the impingers.

Data Management: Data were downloaded daily from the detector data logger. Data were then entered into spreadsheets and analyzed, averaged, and plotted. These same spreadsheets were used to troubleshoot and check detector operation.

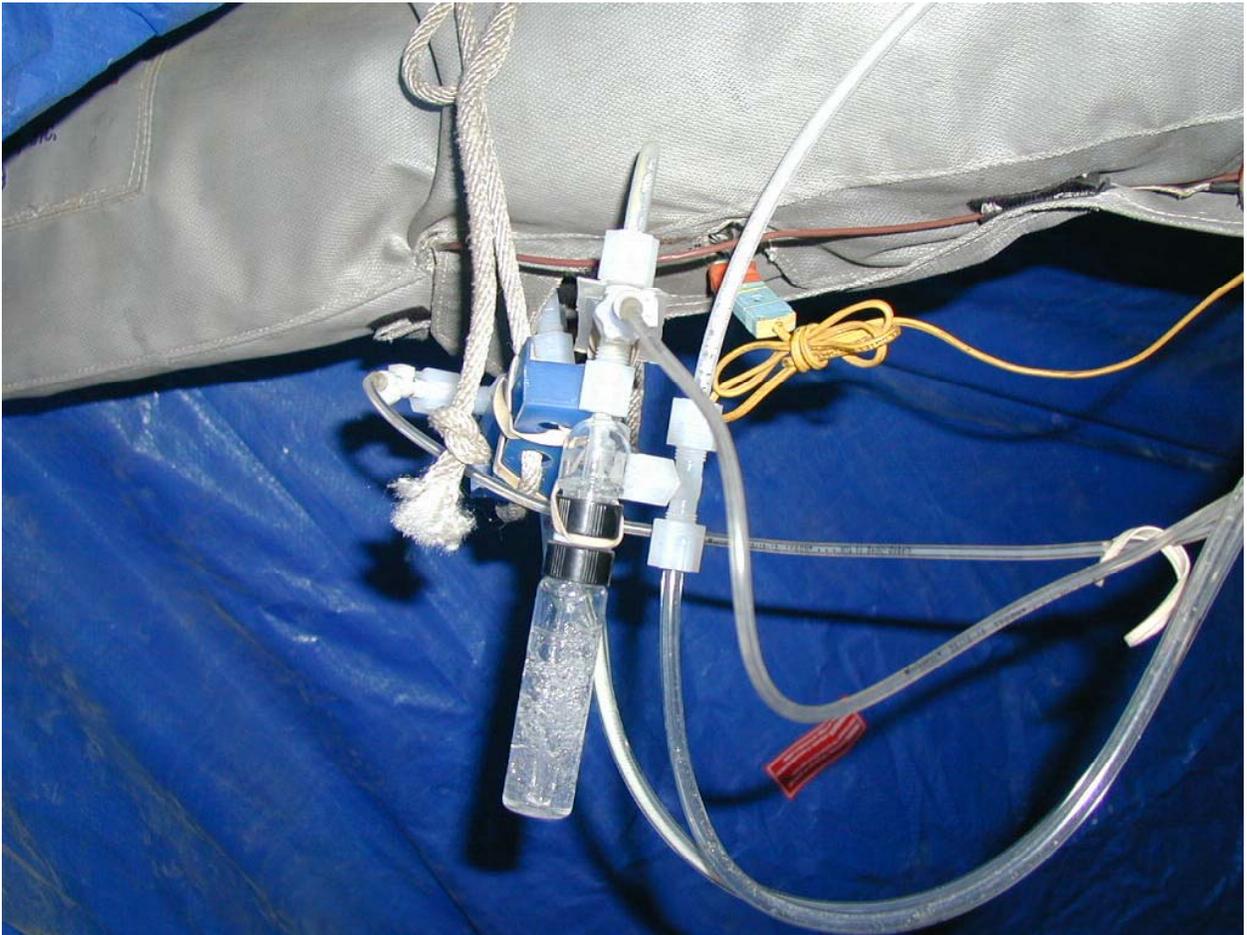


Figure 8. Impingers Used to Convert Oxidized Species of Mercury to Elemental Mercury at Gaston.



Figure 9. Mercury Analyzer Installed at Gaston.

Task 3 – Long-Term Operation and Monitoring

Task 3 was subdivided into two primary phases that differentiated between tests with two different bag materials. Each phase had three subtasks with testing activities designed to meet specific goals of the subtask. A description of each subtask and the associated activities is presented in this section.

Task 3.1 – Tests with Existing 2.7-Denier Bags

Subtask 3.1.1 – Baseline Measurements

Before injecting carbon, baseline system operation, performance, and mercury level measurements were made. PPS bags had been in service on the front bundle of bags for about 28 months and for about 16 months on the back bundle. The goal of this subtask was to measure key variables that would define baseline conditions, operation, and performance. These variables included:

- Baseline mercury removal measured with S-CEMs
- Manual mercury measurements by the draft Ontario Hydro method
- COHPAC[®] performance parameters such as pressure drop, cleaning frequency, inlet particulate loading, and outlet opacity
- Bag integrity, strength, and residual drag
- Ash and coal samples

In addition, these parameters from the A- and B-sides were compared during carbon injection tests.

Baseline Mercury Removal

Mercury measurements were made at the inlet and outlet of the B-side COHPAC[®] baghouse. These were the same locations used during the short-term test. One analyzer was used to measure both locations. Highest priority was to gather long-term mercury measurements at the outlet. The analyzer could only measure one sample at a time, but was designed to automatically switch between two sample lines. For example, when measuring total vapor-phase mercury, the analyzer was programmed to switch between inlet and outlet at set time intervals. When speciated measurements were made, the analyzer switched between elemental and total measurements at one location—either inlet or outlet.

Mercury Measurements (Ontario Hydro)

Total mercury was measured at the inlet and outlet of the COHPAC[®] baghouse by the draft Ontario Hydro method. The primary difference with this measurement and the analyzer was that the Ontario Hydro method measured total mercury (particulate, oxidized, and elemental) and the analyzer only measured vapor phase.

COHPAC[®] Performance

Performance of COHPAC[®] was critical to the success of sorbent injection for mercury control. The primary performance indicators were:

- **Pressure Drop/Drag:** Pressure drop and drag were both used to monitor the permeability of the filter and dust cake. Pressure drop is a direct measurement of pressure loss across the fabric filters. Drag is a calculated number that normalizes pressure drop to flow by dividing pressure drop by the A/C ratio. These values are a function of inlet grain loading, filtering characteristics of the particulate matter, bag fabric characteristics, and flow and time between cleaning.
- **Cleaning Frequency:** Pressure drop/drag is controlled in a baghouse by the cleaning frequency. It was expected that cleaning frequency would increase with the increased particulate loading from sorbent injection. Cleaning frequency was monitored before, during, and after sorbent injection.
- **Opacity/Emissions:** Cleaning frequency and particulate matter characteristics can affect collection efficiency across the baghouse. Most emissions occur immediately following a cleaning cycle, 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.

COHPAC[®] performance data were logged by an on-site monitoring system designed, monitored, and maintained by Southern Research Institute. A snapshot of data was collected every minute. These data files were key in providing plant operating data, such as boiler load and temperature, and COHPAC[®] performance data on A- and B-sides, such as flow, pressure drop, cleaning frequency, drag, inlet grain loading, and outlet opacity.

Inlet grain loading varied with the collection performance of the upstream, hot-side ESP. The ESP had its best performance immediately following a period when it was offline for maintenance or to be washed. Performance degraded with time of operation. COHPAC[®] performance over the previous year was reviewed to help determine what kind of cyclic, baseline performance could be expected.

Bag Strength and Residual Drag

The filter bags in COHPAC[®] were made from Ryton[®] felt. Typically, the PPS bags at Gaston had experienced very little loss in fabric strength, as measured by Mullen Burst tests, in the four years of operation. However, they did experience failures in the front bag bundles because flow patterns caused some of the bags to come into contact with each other, causing abrasion failures at the point of contact. To track whether or not carbon injection affected fabric strength, bags were removed and strength tests performed. Grubb Filtration Testing Services (GFTS) conducted Mullen Burst tests.

When bags are cleaned, there is a residual amount of fly ash that is not removed. The pressure drop or drag resulting from this permanent dust cake is referred to as residual drag. Residual drag is important because it can represent a significant portion of the total drag. Tracking residual drag over time is a good procedure to use to identify potential pressure drop problems and the performance of different bag types over time. Residual drag measurements were performed with the compartment offline using an in-situ drag measurement device designed for EPRI. Southern Research Institute performed these measurements periodically at Gaston and assisted with these tests during this test program.

Before taking the compartment offline, Visolite[™], a fluorescent powder, was injected in the inlet duct to coat the bags. The purpose of this test was to document the location of any failed bags in the compartments and insure good bag integrity for the beginning of the carbon injection tests. Bag failures were identified using a black light to detect penetration of the fluorescent powder through the bags. Bag strength and residual drag tests, and Visolite[™] inspections were made on both A- and B-side compartments.

Ash and Coal Samples

Ash generated from the E.C. Gaston Plant was impounded using a wet ash handling system. After drying in the ash pond, the ash was landfilled. Ash samples were collected from the B-side COHPAC[®] hoppers. The sampling procedure was to take samples from several hoppers and combine them for a composite sample from a specific time period. The samples were analyzed for mercury content and loss on ignition (LOI). A limited number of samples were collected from the hot-side ESP. These samples were also analyzed for mercury and LOI.

Coal samples were taken daily as coal was loaded into the bunkers. Coal was often loaded at night, so plant personnel collected these samples. Ultimate and proximate analysis of the coal was performed on selected samples, as well as measurements for mercury and chloride.

Two different leaching tests were also performed on a limited number of samples. The procedure used most often was the Toxicity Characteristic Leaching Procedure (TCLP, SW846-1311). The method was designed to simulate leaching in an unlined, sanitary landfill, based on a co-disposal scenario of 95% municipal waste and 5% industrial waste. The method is an agitated extraction test using leaching fluid that is a function of the alkalinity of the phase of the waste. Typically, an acetic acid solution having a pH of 2.88 is used.

The synthetic groundwater leaching procedure (SGLP) was developed at the University of North Dakota Energy and Environmental Research Center (EERC) and was designed to simulate the leaching of coal utilization byproducts (CUBs) under important environmental conditions. It was initially used to characterize highly alkaline CUBs, primarily fly ash produced from the combustion of low rank coals. The procedure was modeled after the TCLP, but allowing for disposal conditions other than those of a sanitary landfill. Deionized water is used as the leaching solution instead of the acidic solutions used in the TCLP. The SGLP was designed primarily for use with materials such as low-rank coal ash that undergo hydration reactions upon contact with water. Test conditions are end-over-end agitation, a 20:1 liquid-to-solid ratio, and a 13-hour equilibration time.

Subtask 3.1.2 – Optimization Tests

A period of time was set aside to optimize the carbon injection rate and mercury sampling protocol. The goal was to determine operating conditions that could be maintained continuously for several months. It was anticipated that this period would last approximately one month. Monitoring and project activities during this period included:

- Mercury measurements using S-CEM
- Monitor COHPAC[®] performance parameters, such as pressure drop, cleaning frequency, inlet particulate loading, and outlet opacity, as a function of activated carbon injection concentration
- Collect ash and coal samples

Mercury Measurements

Vapor-phase mercury was measured at the inlet and outlet of the COHPAC[®] baghouse using the S-CEM. A sampling schedule was designed so that most of the measurements would be total mercury at the inlet and outlet. Periodically, speciated mercury was measured at the inlet and outlet.

Effect on COHPAC[®] Performance from Activated Carbon Injection

The results from this task would provide the target operating conditions for the remainder of the testing with this fabric. Ideally, three different injection concentrations would be evaluated for a full week. The first injection concentration was anticipated to be 1.5 lb/MMacf, which was test condition for the long-term test in Phase I. Testing at this condition would allow for a direct performance comparison with the earlier tests. This was important because the bags were a year older, which usually implies an increase in residual drag and a higher baseline cleaning frequency.

Ash and Coal Samples

Ash samples were collected from the B-side COHPAC[®] hoppers only. A request was made to have coal samples collected three times per week. These samples were stored for analysis.

Subtask 3.1.3 – Long-Term Tests

The goal of the final subtask in this test phase was to inject activated carbon continuously for optimally six months, but at least four months (to evaluate long-term mercury removal trends and the impact on COHPAC[®] performance). Ideally, one injection concentration would be used for all boiler loads. The injection system had the capability for load following. Monitoring and project activities during this period included:

- Mercury measurements using S-CEM
- Manual mercury measurements by the draft Ontario Hydro method
- Monitor COHPAC[®] performance parameters such as pressure drop, cleaning frequency, inlet particulate loading, and outlet opacity
- Collect and analyze ash and coal samples
- Evaluate bag integrity, strength, and residual drag

Mercury Measurements (S-CEM)

Vapor-phase mercury was measured at the inlet and outlet of the COHPAC[®] baghouse using the S-CEM. A sampling schedule was designed so that most of the measurements would be total mercury at the inlet and outlet. Periodically, speciated mercury was measured at the inlet.

Mercury Measurements (Ontario Hydro)

S-CEM measurements were verified by a set of draft Ontario Hydro method measurements. These tests were scheduled sometime in the first two months of the long-term test.

COHPAC[®] Performance

The primary COHPAC[®] performance parameters discussed earlier were monitored and used to determine if changes in injection concentration were needed.

Ash and Coal Samples

Ash samples were collected from both the B-side COHPAC[®] hoppers and from the control side (A-side) hoppers. Composite samples were collected once per week, except when the Ontario Hydro tests were being conducted, or if results indicated that something unusual was occurring. During the Ontario Hydro tests, ash samples were collected daily. Periodically, ash samples were also collected from the hot-side ESP hoppers. Sampling procedures similar to those used in the baseline test were followed. Ash samples were analyzed for mercury and LOI content.

A request was made to have coal samples collected once per week, again except during the Ontario Hydro tests and during periods when something unusual was occurring. Ultimate and proximate analysis of the coal was performed, as well as measurements for mercury and chlorine.

Bag Strength and Residual Drag

Near the end of the long-term tests, compartments were isolated to pull a small number of bags for strength tests and to measure residual drag. Bag strength and residual drag tests were made on both A- and B-side compartments.

Task 3.2 – Tests with 7-Denier, High-Perm Bags

The second phase of this task was to evaluate activated carbon injection for mercury control in a COHPAC[®] baghouse with bags made from high-perm fabric (7-denier PPS fiber). The ultimate goal of testing this fabric was to demonstrate whether the high-perm bags could operate at a lower cleaning frequency with similar carbon injection rates, mercury removal efficiencies, and plant operating conditions when compared to the test with the 2.7-denier bags. It was also important to determine if outlet emissions were acceptable with the new fabric. A set of tasks similar to those outlined for Task 3.1 was followed and are listed below.

- Baseline Measurements
- Optimization Tests
- Long-Term Test on Original Bags

Task 4 – Testing of Alternative Sorbents

This test provided an opportunity to evaluate other mercury control sorbents that may have advantages in cost and/or performance. Several sorbent suppliers contacted either ADA-ES or Southern Company to have their sorbents included in the program.

Sorbents of interest included activated carbons with smaller and larger size distributions, activated carbons with lower capacity for adsorbing mercury, other coal-based sorbents, and other non-coal-based sorbents.

RESULTS AND DISCUSSION

Leaching Test Results from Phase I Program

Dr. Connie Senior of Reaction Engineering International (REI) compiled results from leaching tests performed on samples collected during the short-term ACI tests at Gaston. No significant leaching was observed, either from standard tests, like TCLP, SGLP, or from column leaching tests. A copy of a memo titled “Mercury leaching from Gaston long-term ash samples” is included in this report as Appendix A.

Task 3.1 – Tests with Existing 2.7-Denier Bags (April–November 2003)

Unit 3 came online in mid-March 2003 after a several-week outage. During this outage, the compartments were inspected and the hot-side ESPs were washed. The ESPs were washed at least yearly to remove sodium-depleted ash layers that could cause performance degradation.

Baseline Test Period 1 (March 24–April 21, 2003)

The baseline tests officially started on March 24, 2003, when continuous mercury measurements with the analyzer began. The baseline period was planned to gather operating performance of the COHPAC[®] baghouse and measure mercury at the inlet and outlet of COHPAC[®] under normal operating conditions, just before starting carbon injection. In addition, ash and coal samples were collected during this period.

During the outage on Unit 3 in March, Southern Research Institute and Grubb Filtration Testing Services were on-site to do a visual inspection of the bags and to measure in-situ drag of the bags. In-situ drag measurements provided an indication of the pressure drop caused by the bag and the residual dust cake (fly ash that remains on the bag following normal cleaning conditions).

Bag Inspection

Before taking the baghouse offline, a fluorescent powder (Visolite™) was injected into the four compartments on Unit 3 baghouse (two compartments each on A- and B-sides). The compartments were then opened and the top of the tube sheet inspected with a black light. Areas where the fluorescent powder could be seen on the tube sheet or inside the bags were identified and a closer inspection made. This is a technique used in the industry to identify leaking bags and the fluorescent powder can be bought commercially from bag suppliers.

Each bag bundle can hold up to 544 bags. There are two bundles in each compartment. On B-side, the front bag bundles (3B10 and 3B20) of each compartment had been in service for twenty-eight months. The back bundles (3B11 and 3B21) had been in service for fifteen months.

Southern Research Institute documented findings from this inspection, “Very few problems were observed. There are four bag bundles in the B-side baghouse, 3B10, 3B11, 3B20, and 3B21. There were no bag related problems in 3B10 or 3B11. There were three failed bags in 3B20 and two bags had slipped off the cages in 3B21. The bags were replaced with 2.7-denier PPS bags.”

In addition to the two bags replaced because the bags had slipped of the cages, a third new bag (for a total of three) was installed in 3B21. Three new bags were also installed in bag bundle 3B20. Bags were removed at the end of the test and used to compare bag strength and residual drag with that of the older bags.

Drag Measurements

Residual drag measurements were performed with the compartment offline using an in-situ drag measurement device designed for EPRI. The average measured drag of the four bundles was between 0.31 and 0.39 inches H₂O/ft/ min. These values were comparable to historical data. Experience shows that in-situ drag values are acceptable when less than 0.50 inches H₂O/ft/ min. Values higher than this often result in high cleaning frequencies.

COHPAC[®] Performance

At Gaston, the primary variable used to track COHPAC[®] performance was cleaning frequency. The cleaning logic was set to begin a clean at a specified pressure drop/drag set point.

There was a noticeable change in cleaning frequency before and after the spring outage. Before the outage, the average cleaning frequency varied between 1 and 2 pulses/bag/hour (p/b/h). After the outage, the average cleaning frequency was often above 2, with periods of continuous cleaning (4.4 p/b/h). This presented a problem because adding carbon to the baghouse would increase cleaning frequency further. It was believed at the time that burning certain coals caused the high cleaning frequency.

Figure 10 shows Unit 3 boiler load and Unit 3B cleaning frequency in p/b/h before and after the outage. This graph shows that cleaning frequency was higher after the outage, with periods of continuous cleaning (4.4 p/b/h). This was especially surprising since the ESPs were just washed and they should have been in the best operating condition.

Inlet loading to COHPAC[®] was measured with a BHA particulate monitor. Particulate loading on the 3B-side during baseline varied from a low near 0.025 gr/dscf to nearly 0.2 gr/dscf. This can be seen in Figure 11, which is a printout from the COHPAC[®] computer during a portion of the baseline test. The lower line in the top graph shows inlet loading. In the same figure, the lower line in the middle graph is cleaning frequency. As would be expected, inlet loading had a direct impact on cleaning frequency.

Gaston Unit 3 Baghouse (B Casing) Performance Data

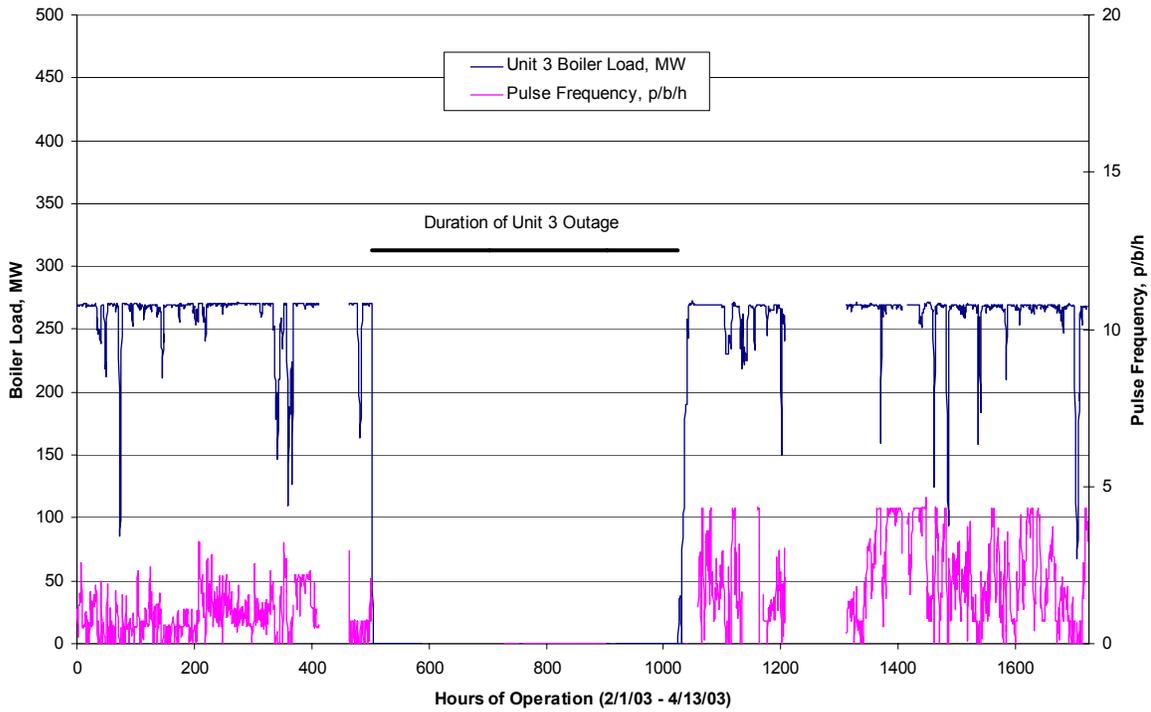


Figure 10. Unit 3B Baghouse Cleaning Frequency and Boiler Load before and after March 2003 Outage.

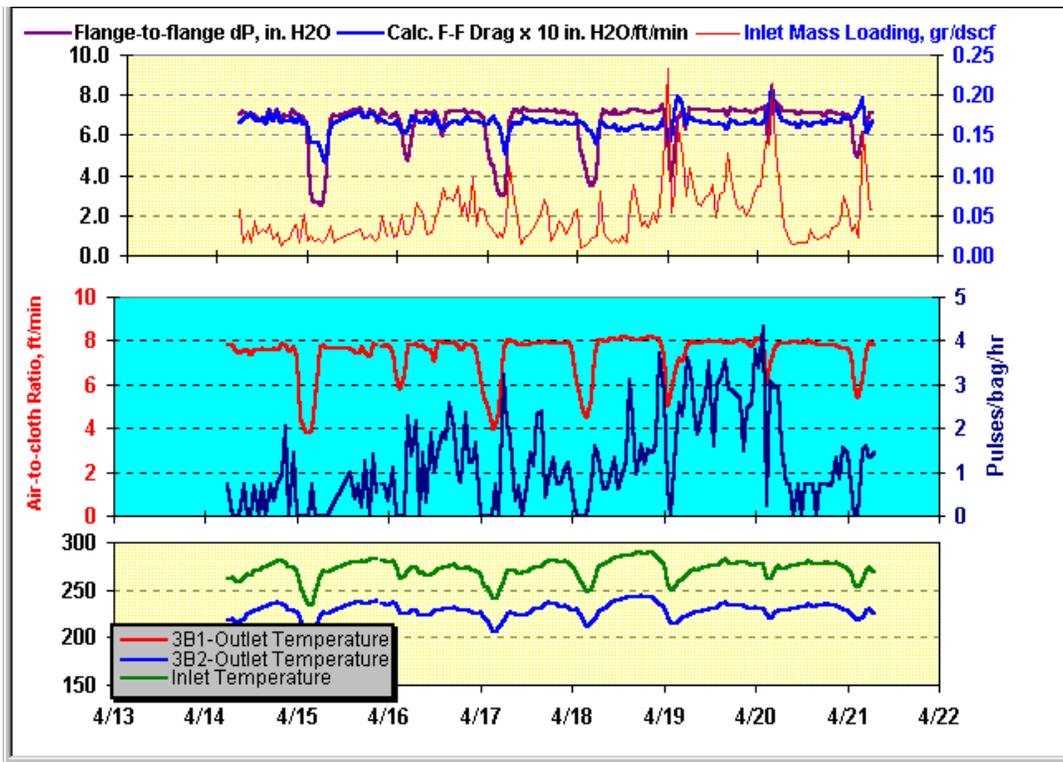


Figure 11. Printout of Unit 3B COHPAC® Operating Trends, April 13–21, 2003.

Mercury Measurements

Weston Solutions, Inc., conducted Ontario Hydro measurements for total mercury on April 1–3, 2003. Manual measurements for hydrochloric acid and multi-metals (Method 29 at outlet only) were also made at this time. Continuous total vapor-phase mercury was measured at the inlet and outlet of Unit 3B COHPAC[®] with the on-site S-CEM on working days, Monday through Friday.

S-CEM Measurements

The mercury analyzer was in operation during this period, measuring total vapor-phase mercury. The analyzer was set to alternately measure at the inlet and outlet with approximately 10 samples at each location. The analyzer was operated during the week and shut down over the weekend. Data from the baseline period are shown in Figure 12 with mercury concentrations corrected to 3% oxygen. The top graph presents inlet and outlet mercury concentrations, the second graph presents calculated mercury removal efficiency, the third graph is cleaning frequency, and the fourth is inlet grain loading. Figure 12 shows:

- Over the nearly five-week baseline period, inlet mercury varied between nominally 7 and 18 $\mu\text{g}/\text{Nm}^3$ (5.1–13.1 lb/TBtu). This was similar to variations seen during the Phase I tests.
- Outlet mercury varied between nominally 1 and 18 $\mu\text{g}/\text{Nm}^3$ (0.7–13.1 lb/TBtu), with mercury removal efficiencies varying between 0 and 90%. This was certainly not what was seen in Phase I, where baseline S-CEM measurements showed very little, if any, mercury removal.
- Often, higher mercury removal efficiencies could be correlated to periods of high cleaning frequencies and high particulate loading.

Ontario Hydro Mercury and Hydrochloric Acid Measurements

Results from the Ontario Hydro measurements including speciated mercury concentrations for each of the three runs at the inlet and outlet, corresponding removal efficiencies, and averages from the three runs are presented in Table 2. In summary:

- Inlet mercury varied between 15.6 and 19.5 $\mu\text{g}/\text{Nm}^3$ (11.3–14.2 lb/ TBtu).
- Outlet mercury varied between 11.8 and 15.1 $\mu\text{g}/\text{Nm}^3$ (8.6–11 lb/ TBtu).
- For the individual runs, mercury removal efficiency varied from nominally 5 to 39%.
- On average, there was 26.3% mercury removal across the COHPAC[®] baghouse. In the Phase I tests, average baseline mercury removal was 0%.
- At the inlet, 64.4% of the mercury measured was oxidized, 27.5% was elemental, and 8.2% was particulate.
- At the outlet, nearly all of the mercury, 92.0%, was in the oxidized form.
- Average HCl in the flue gas from three runs was 5.5 ppm.
- Note: mercury concentrations were corrected to 3% oxygen.

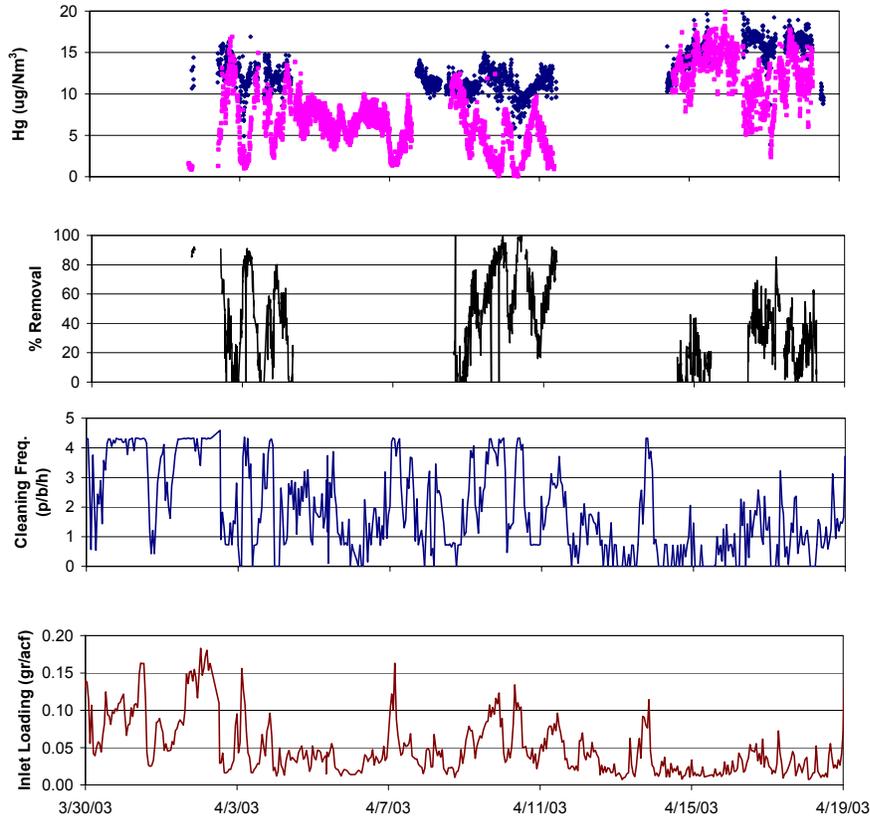


Figure 12. Mercury Concentrations, Inlet Mass Loading, and Cleaning Frequency for Unit 3B COHPAC[®] during Baseline Operation 1, Spring 2003.

Table 2. Results from Baseline Testing Series without Sorbent Injection, April 2003.

Location	Particle Bound	Oxidized Hg ²⁺	Elemental Hg ⁰	Total, Hg
Run 1				
Inlet	2.6	10.4	4.2	17.2
Outlet	0.05	10.7	1.0	11.8
RE (%)				31.4
Run 2				
Inlet	1.2	13.4	5.1	19.5
Outlet	0.02	11.1	0.8	12.0
RE (%)				39.0
Run 3				
Inlet	0.57	10.2	5.2	15.6
Outlet	0.09	13.9	1.1	15.1
RE (%)				5.3
Average Values				
Inlet	1.4	11.3	4.8	17.6
Outlet	0.05	11.9	0.99	13.0
RE (%)	96.3	-5.4	79.6	26.3
% of Total Inlet	8.2	64.4	27.5	
% of Total Outlet	0.4	92.0	7.6	

Ash and Coal Measurements

During Baseline Period 1 testing, coal samples were collected daily during the week and ash samples were collected periodically from both the A- and B-side COHPAC[®] hoppers and from the hot-side ESP hoppers. A complete list of samples collected during this period can be found in Appendix B.

Optimization Test Period 1 (April 22–May 27, 2003)

The optimization period was planned to determine the optimum carbon injection concentration that would meet mercury removal targets (90%); result in cleaning frequency less than continuous, but up to 3 p/b/h; and have sufficient margin so that this injection concentration could be maintained over a four- to six-month period. The original plan, including target injection rates and removal efficiencies, had to be modified because of higher baseline cleaning frequencies and mercury removal. A revised plan was developed and is presented in Table 3. Testing during this period included COHPAC[®] performance monitoring, mercury S-CEM measurements, and ash/coal sampling.

Table 3. Revised Test Plan for Optimization Period 1.

Test Period	Duration	Injection Concentration (lb/MMacf)	Injection Rate (lb/h)
Week 1	2 days	0.7	20
Week 1	2 days	0.35	10
Week 2	Begin continuous injection	TBD	TBD
Week 3 – End	Continuous injection	TBD	TBD

On Tuesday, April 22, 2003, carbon injection was started at an injection concentration of 0.70 lb/MMacf (20 lb/h). On Wednesday, April 23, the concentration was lowered to 0.35 lb/MMacf (10 lb/h) because of high cleaning frequency. Cleaning frequency did not improve when the injection rate was lowered; however, shortly after this change in feed rate, boiler load decreased to a very low level and cleaning frequency recovered. Per the test plan, carbon injection was stopped after a few days to evaluate the data and decide on the condition for the following week. The following week, carbon injection was started at a concentration of 0.35 lb/MMacf (10 lb/h) and the system operated at this rate until Tuesday, May 27.

Mercury Measurements

The mercury analyzer was in operation during this period measuring total vapor-phase mercury at the inlet and outlet. The analyzer was operated during the week and shut down over the weekend.

Figure 13 presents data from the first week of the optimization test period. These graphs show inlet and outlet mercury concentrations, removal efficiency, carbon injection concentration, Unit 3B cleaning frequency, Unit 3 boiler load, and inlet loading to the 3B baghouse. Carbon was injected for three days at two different rates; this can be seen as the solid line in the second graph from the top.

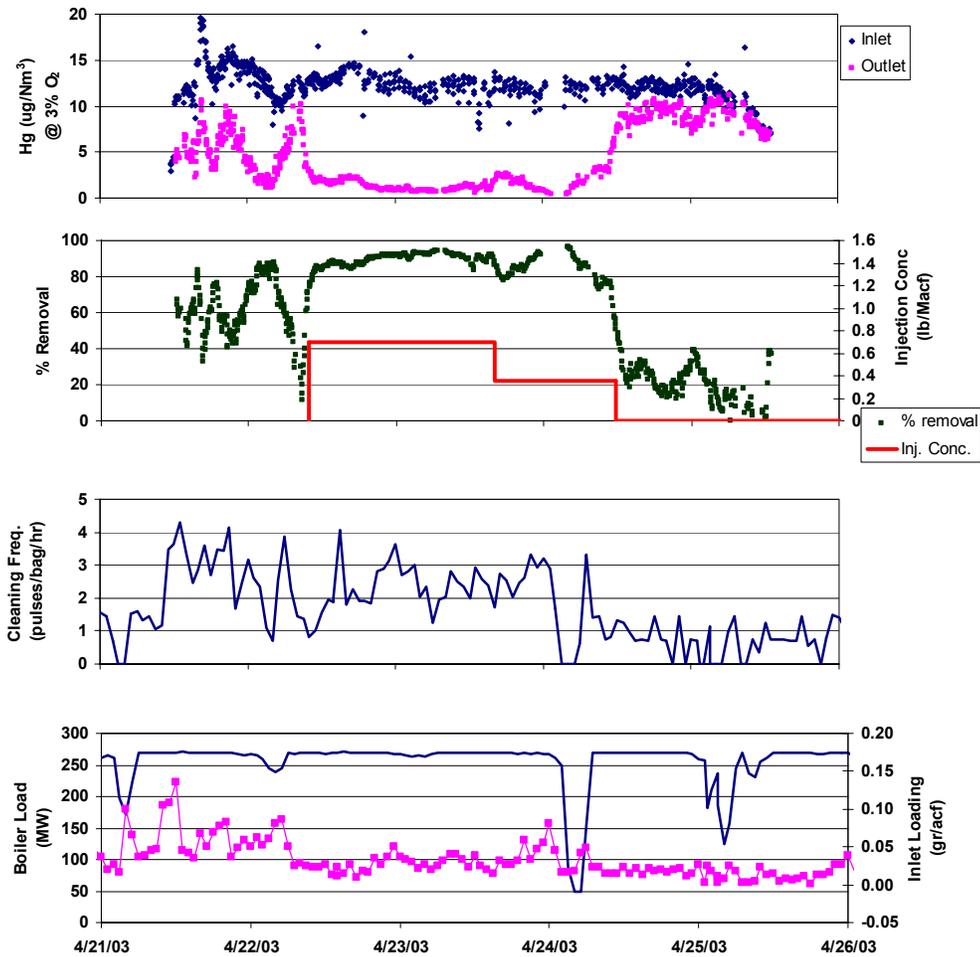


Figure 13. Unit 3B Performance and Operating Trends during the Week of April 21, 2003 (with Carbon Injection).

Outlet mercury levels can be seen to vary significantly before starting carbon injection on April 22. Once injection began, outlet mercury levels were less than $2.5 \mu\text{g}/\text{Nm}^3$ (1.8lb/TBtu). Removal efficiency was greater than 80% during this period, regardless of the injection rate. A decrease in removal efficiency can be seen when the rate was decreased on April 23, but it quickly returned to a higher level.

Figure 14 presents optimization test data from April 22 through May 23, 2003. Based on results from the first week, carbon injection was started at a low concentration of 0.35 lb/MMacf (10 lb/h) on April 29. Injection was maintained at this rate until May 27.

During this period, removal efficiency varied between 55 and 95%. At this low rate and with varying baseline mercury removal, it is not surprising to see such a large variation in removal efficiency. Carbon injection did change the lower boundary of removal efficiency to at least 55%, instead of varying between 0 and 90%.

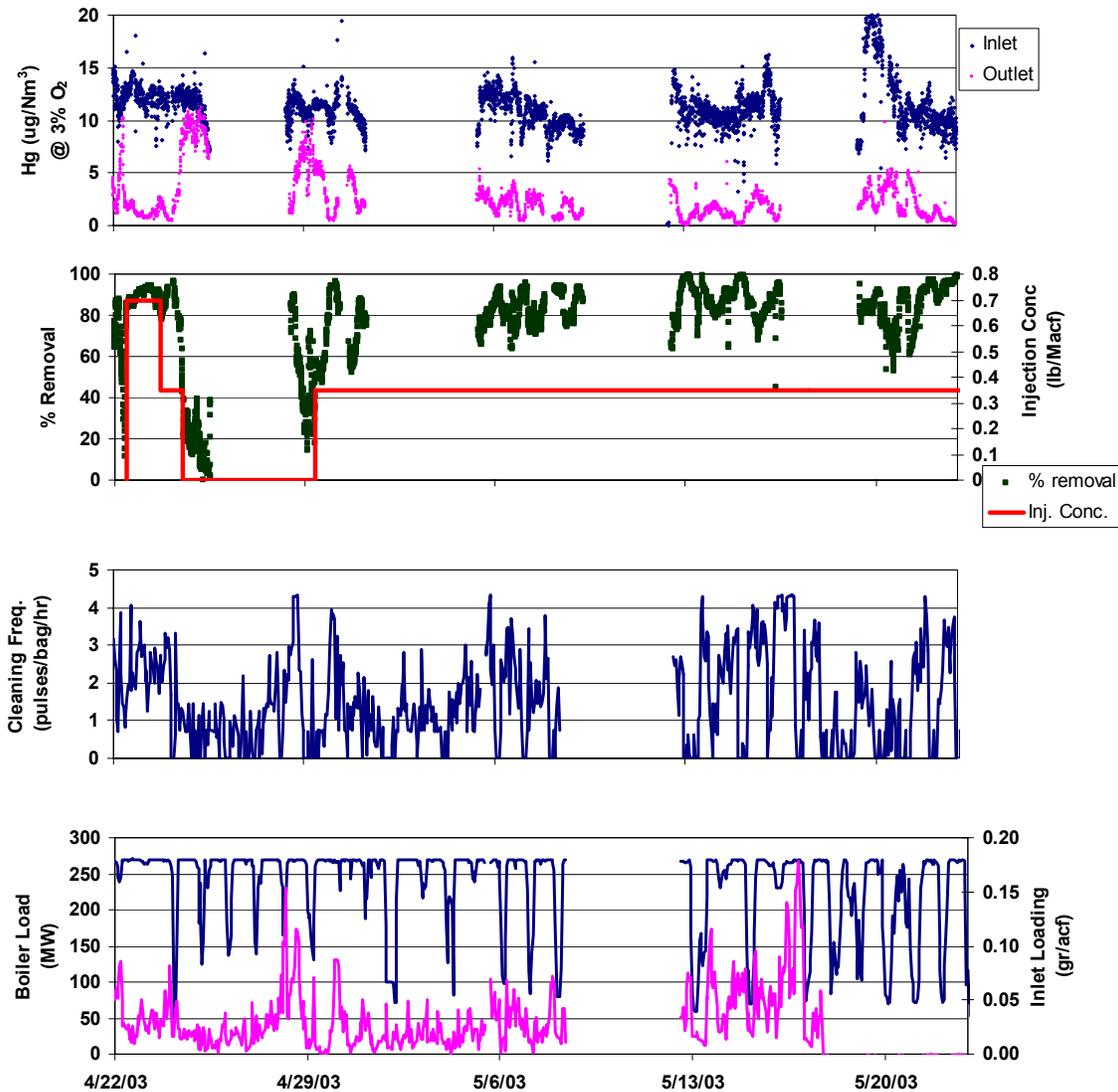


Figure 14. Unit 3B Performance and Operating Trends during Optimization Period 1, April 22–May 23, 2003.

COHPAC[®] Performance

Cleaning frequencies on both sides continued to be higher than historical averages. Both Alabama Power personnel and individuals from this test team investigated the cause of this higher cleaning frequency. It was believed that the higher loading to COHPAC[®] occurred with certain coals. One day in particular backs this theory. On Monday, April 21, 2003, the baghouse was in continuous clean and mercury removal was high. The control room operator on duty pointed out that the mills were working harder than usual. At this same time we checked the electrical conditions of the hot-side ESP. All fields were in service and the ESP was operating within expected values. However, the loading to COHPAC[®] was near 0.2 gr/dscf. Ash samples were taken and they were very dark (Figure 15). In this condition, there was a higher percentage of unburned carbon exiting the boiler. It appears

that this carbon was passing through the ESP at a higher rate than normal fly ash. Near the end of the day, the coal supply changed and COHPAC[®] cleaning frequency returned to a more normal level.

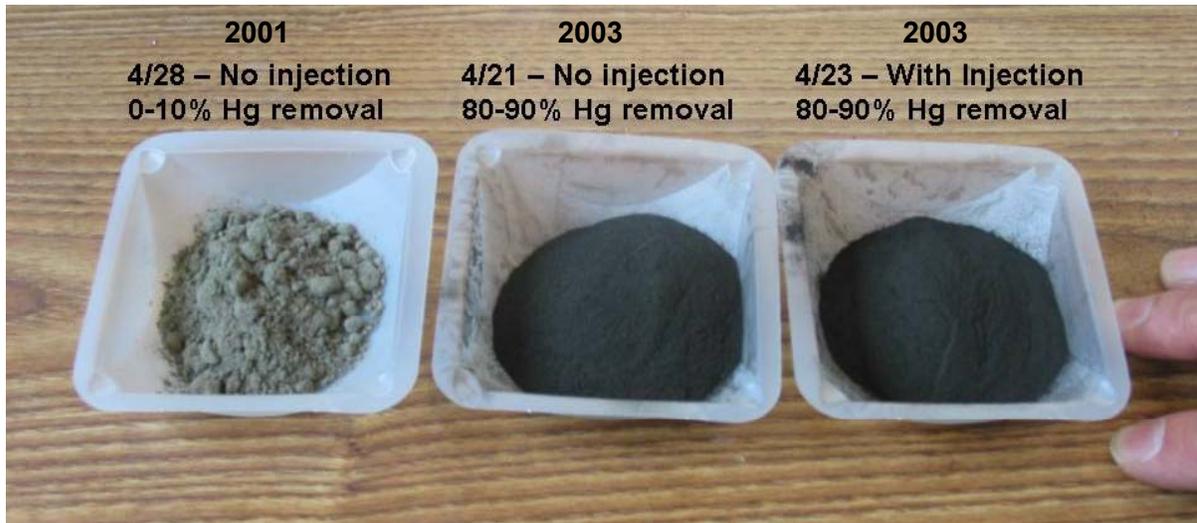


Figure 15. COHPAC[®] Hopper Ash Comparison.

Analyzing data from Week 1 parametric tests shows that when injection concentration was lowered from 20 to 10 lb/h (0.7 to 0.35 lb/MMacf), cleaning frequency did not change. Inlet loading during this period was very high, up to 0.2 gr/dscf. Cleaning frequency did improve with lower load and remained lower when load was raised. After the load drop, inlet loading as measured by the BHA particulate monitor was also much lower, < 0.05 as compared to near 0.2 gr/dscf.

Cleaning frequency for Weeks 2 and 3, when carbon was injected continuously at 0.35 lb/MMacf (10 lb/h), was higher than expected. At this injection rate, Phase I tests would have predicted an increase in cleaning frequency of about 0.5 p/b/h. During this period the inlet loading again was variable, with readings up to 0.2 gr/dscf. An injection rate of 10 lb/h and an inlet temperature of 250 °F contributed about 0.003 gr/scf in carbon.

Ash and Coal Measurements

During Optimization Period 1, coal samples were collected daily during the week and ash samples were collected periodically from both the A- and B-side COHPAC[®] hoppers and from the hot-side ESP hoppers. A complete list of samples collected during this period can be found in Appendix B.

Baseline 1 and Optimization 1 Coal and Ash Results

Coal and ash samples were taken routinely. Samples from the initial baseline period (when Ontario Hydro tests were performed) and from the first optimization period were chosen for analysis. Connie Senior of Reaction Engineering International oversaw selection of test samples, coordinated testing with Microbeam Technologies, Inc., and analyzed the results. Connie also coordinated requests for ash samples from non-team members. Both Southern Company and DOE had requirements for approval and tracking of the samples.

A copy of the Coal and Ash Sample Report for April and May 2003 can be found in Appendix C. Coal tests included ultimate and proximate analyses and measurements of mercury and chlorine. Coal mercury levels varied between 0.058 and 0.11 $\mu\text{g/g}$ (dry basis) or an equivalent of 6 and 13 $\mu\text{g/dnm}^3$ (at 3% O_2) in the flue gas. In the nearly seven weeks of baseline tests, S-CEM measurements showed mercury levels varied between 7 and 18 $\mu\text{g/dnm}^3$.

Ash samples were analyzed for LOI and mercury content. Table 4 summarizes the results from ash samples taken in April and May 2003. April samples were taken during baseline conditions and May samples during the optimization tests with carbon injection. Three things stand out:

1. Average LOI of B-side COHPAC[®] ash was 19.2% at baseline conditions compared to 16.9% with carbon injection. This shows that at the low injection rates, there was no measurable difference in LOI due to carbon injection.
2. Average mercury content of the B-side ash was 5.9 $\mu\text{g/g}$ at baseline and 7.6 with carbon injection. These data indicate that mercury was being removed under baseline conditions and that more mercury was being removed during carbon injection. This corresponded well with flue gas measurement results showing baseline mercury removal and increased average mercury removal during carbon injection.
3. The mercury content of the A-side ash was much lower than the B-side during baseline operation. No flue gas mercury measurements were made on the A-side during the ash collection period, but the lower mercury content in the A-side ash indicated that the mercury removal on the A-side was probably much lower than the B-side. The LOI was also lower on the A-side versus the B-side for the April sample shown.

Table 4. Mercury and LOI of Ash Samples from April and May 2003.

ADA-ES #	MTI #	Sampled	Description	Hg, µg/g	LOI, wt%
GAS00203	03-190	04/02/2003	B-Side BH	5.38	17.8
GAS00204	03-191	04/02/2003	Hot-Side ESP	0.334	13.6
GAS00205	03-192	04/02/2003	A-Side BH	0.241	10.8
GAS00208	03-195	04/03/2003	B-Side BH	6.4	21.4
GAS00265	03-199	05/14/2003	A-Side BH	0.894	16.5
GAS00266	03-200	05/14/2003	B-Side BH	7.61	16.9
GAS00267	03-201	05/14/2003	Hot-Side ESP	0.53	13.7

Baseline Test Period 2 (May 28–June 25, 2003)

On May 22, 2003, there was a team meeting and results were presented from several weeks of operation at an injection rate of 10 lb/h (0.35 lb/MMacf). The injection rate was limited by high baseline COHPAC[®] cleaning frequency. Mercury removal varied between 60 and 90%. The immediate action items from the meeting were:

- Continue investigating the cause of the higher than historic cleaning frequency.
- Determine whether moving to A-side will provide better test conditions.
 - Stop carbon injection on B-side to gather performance comparison between A- and B-sides.
 - Measure mercury on A-side.

Unit 3 and ESP Performance

Mark Berry from Southern Company was on-site the week of June 2, 2003, evaluating ESP performance, and the week of June 16 trying to implement a revised ESP control logic in the back fields. This unit did not have a dedicated data-logging computer for the electrical data, so it was difficult to monitor the effect on performance from changes in control logic. A new control system with real-time and historical ESP performance trending was installed.

COHPAC[®] Performance

Carbon injection was stopped on May 27, 2003. Pressure drop, cleaning frequency, and inlet loading were the primary variables for comparison. To help with this evaluation, the BHA particulate monitor was reinstalled on A-side, and maintenance was performed on both A- and B-side instruments. Figure 16 presents cleaning frequency (p/b/h) and inlet loading during full-load boiler operation (boiler load > 270 MW) for A- and B-sides from June 1 through June 11. These data show that A- and B-sides were performing similarly in both cleaning frequency and inlet loading. When the unit was at full load, cleaning frequency varied from less than 1 p/b/h to continuous cleaning (4.4 p/b/h). Average values during this period for these primary variables are presented in Table 5. These data show very little difference between the two sides. B-side cleaning was slightly higher at 1.8 versus 1.6 p/b/h. It is important to note that even though the average frequency was less than 2 p/b/h, both units had periods of continuous cleaning without activated carbon injection. It is also worth noting that the maximum allowable cleaning frequency during the Phase I tests was 1.5 p/b/h and both sides were at or above this rate at baseline conditions during Phase II.

Unit 3 Cleaning During Full Load Boiler

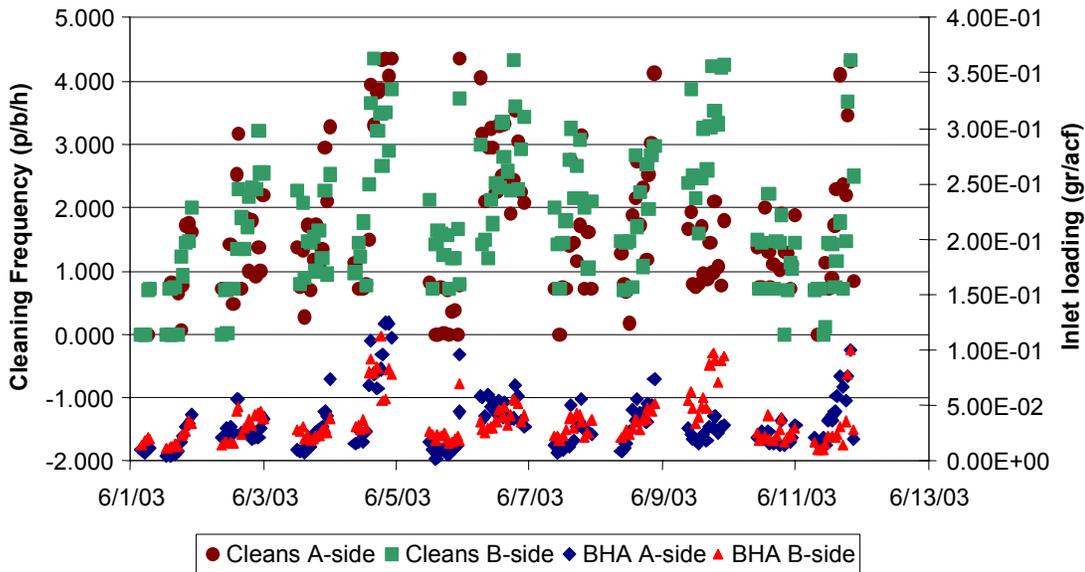


Figure 16. Comparison of A- and B-Side Full-Load Cleaning Frequency and Inlet Loading with No Carbon Injection, June 2003.

Table 5. Average Values for COHPAC[®] Unit 3B, May 31–June 12, 2003.

Side	Cleaning Frequency (pulses/bag/hour)	Inlet loading (gr/acf)	A/C Ratio (ft/min)	Pressure Drop (inches H ₂ O)
A	1.6	0.033	8.2	7.3
B	1.8	0.036	8.1	7.2

Graphs comparing cleaning frequency to inlet particulate loading (no injection) over a two-week period for both A- and B-sides at full-load conditions were developed. As would be expected, there was a direct, linear correlation between the two. In the Phase I tests, a curve of cleaning frequency and activated carbon injection concentration was developed. It was noted at the time that the activated carbon caused a higher pressure for the same amount of ash. The trend lines from all of these data are plotted in Figure 17. If the maximum carbon injection concentration was set at 1.0 lb/MMacf, the addition in grain loading was 0.0035 gr/acf and the predicted increase in cleaning frequency is 1 p/b/h. This can be seen in Figure 17 as the vertical line extending up from 0.0035 gr/acf. The final line in this figure is the predicted relationship between cleaning frequency and inlet loading when carbon was injected at 1 lb/MMacf.

Following the same logic and using the data from Table 5, the average cleaning frequency during the comparison period on B-side was 1.8 p/b/h. Adding carbon at 1 lb/MMacf would increase this to at least 2.8 p/b/h.

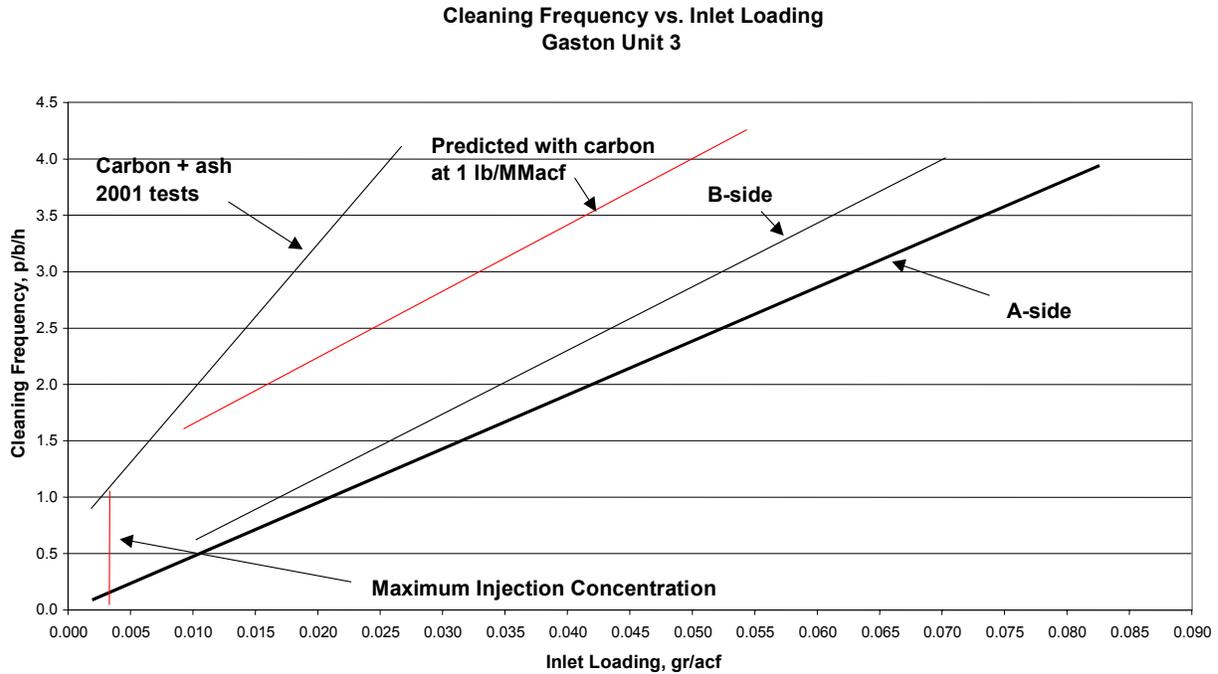


Figure 17. Comparison of A- and B-Side Full-load Cleaning Frequency and Inlet Loading with No Carbon Injection, June 2003.

Mercury S-CEM Measurements

A second mercury detector was installed at Gaston to gather simultaneous mercury measurements on A- and B-sides and to begin measuring speciated vapor-phase mercury. Figure 18 presents total vapor-phase mercury concentrations at the inlet and outlet of B-side COHPAC[®] and the outlet of A-side COHPAC[®] during the week of June 2, 2003. These data show:

- The A-outlet was often equal to the B-inlet.
- There were times when A-side was also showing mercury removal, similar to what was seen on B-side.
- Although cleaning frequency is not shown in this figure, mercury removal was higher on A-side during periods of higher cleaning frequency.

Speciated mercury was measured on A-outlet. Preliminary data showed that most (> 90%) of the mercury was in the oxidized form.

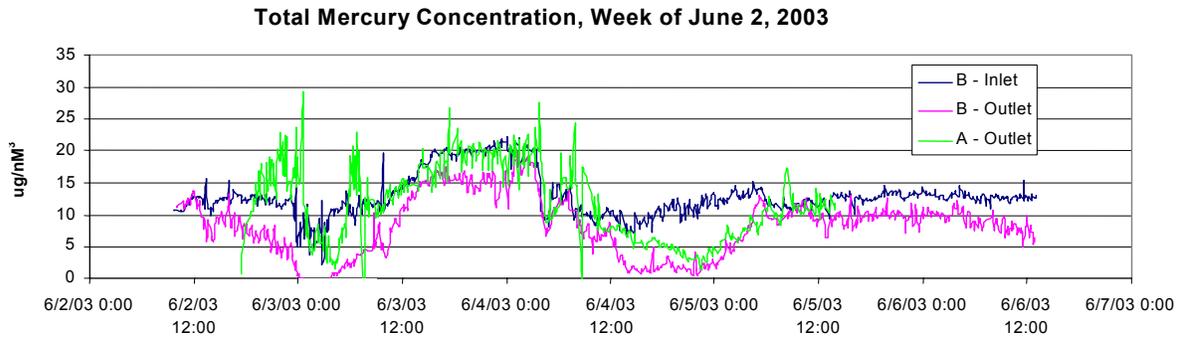


Figure 18. Mercury Measurements with No Carbon Injection the Week of June 2, 2003. Measurement Locations were Inlet and Outlet of 3B and Outlet of 3A.

Figure 19 presents data from Baseline Period 2, May 28–June 25, 2003.

- Similar to Baseline Period 1, outlet mercury varied significantly, between nominally 1 and 16 $\mu\text{g}/\text{Nm}^3$ (0.7–11.6 lb/TBtu).
- Removal efficiency during this period varied between 0 and 90%.
- Periods with higher grain loading and higher cleaning frequency correlated with periods of higher baseline mercury removal.

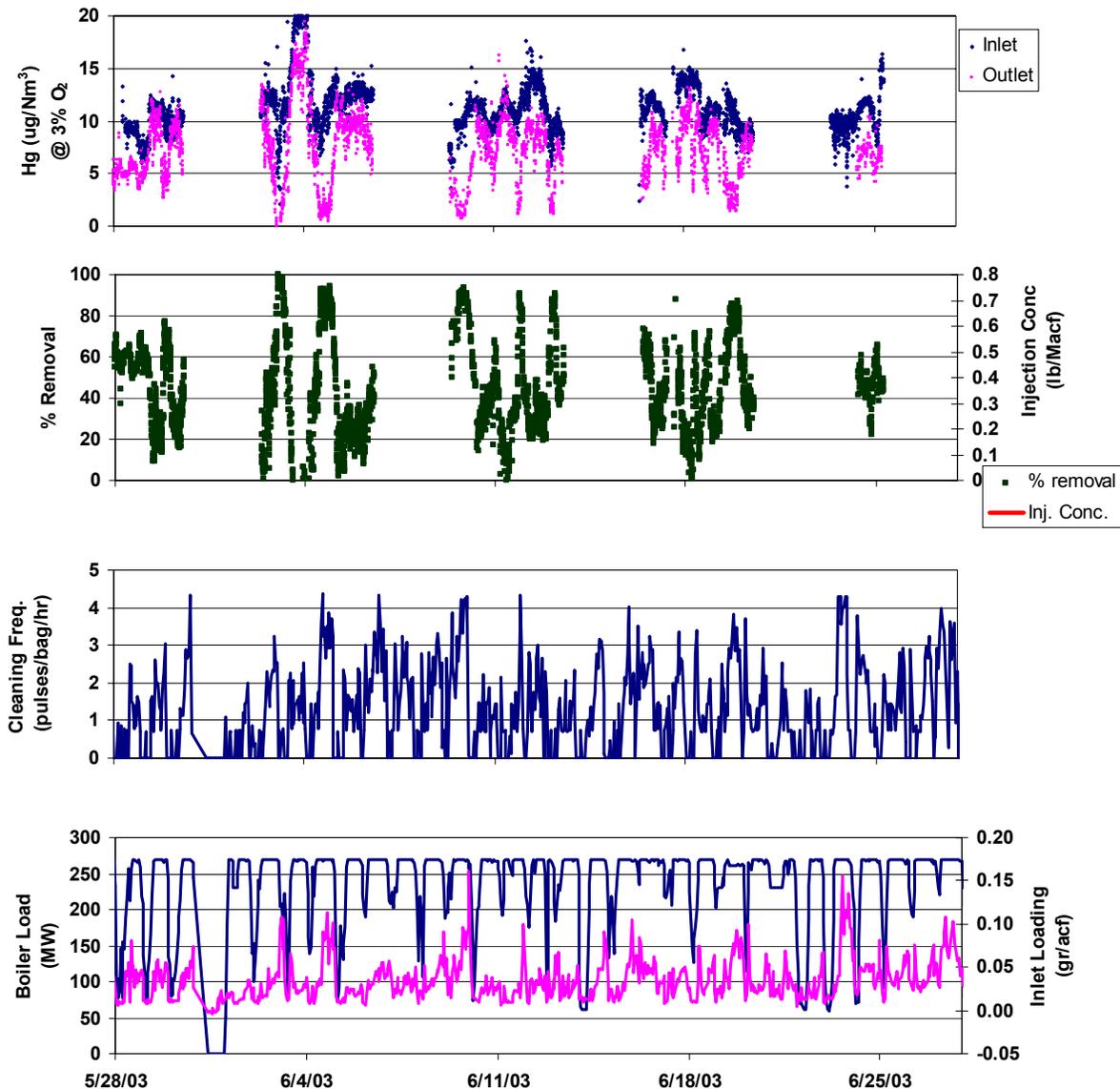


Figure 19. Unit 3B Performance and Operating Trends during Baseline Period 2.

Ash and Coal Measurements

During Baseline Period 2 testing, coal samples were collected daily during the week and ash samples were collected periodically from both the A- and B-side COHPAC[®] hoppers and from the hot-side ESP hoppers. A complete list of samples collected during this period can be found in Appendix B.

Optimization Period 2 (June 26–July 18, 2003)

Following the second baseline test, carbon injection was again started on June 26, 2003, at an injection concentration of 0.35 lb/MMacf (10 lb/h). The system was set in load-following mode, where carbon injection rate varied between nominally 5 and 10 lb/h depending on boiler load conditions. On July 1 and 2, a new carbon injection control program was installed into the system PLC. In this second optimization period, the performance goals were to:

- Inject activated carbon at a rate capable of maintaining mercury removal at or above 80%.
- Implement the capability to automatically either lower or stop carbon injection when inlet mass loading concentrations were causing the baghouse to be at or near continuous cleaning.
- Continue investigating the cause of the higher than historical COHPAC[®] inlet mass loading and cleaning frequency.

Ash and Coal Samples

To help troubleshoot and understand COHPAC[®] performance, a Hot Foil LOI analyzer was leased from FERCo. This analyzer measured the LOI of the ash by heating a sample until the remaining combustible material was burned off. This material was mostly unburned carbon. These measurements were made on-site on ash samples collected from the hot-side ESP, A-side COHPAC[®], and B-side COHPAC[®] hoppers. The analyzer was located in the site trailer. A summary of the results is presented in Table 6.

- LOI of A- and B-side hopper ash was similar when carbon was injected at a maximum of 0.35 lb/MMacf (10 lb/h). The average values were 17.4 and 17.6%. This was higher than LOI measured in the Phase I tests, where baseline hopper ash had an LOI of 11%.
- LOI was lower in the ESP ash than the COHPAC[®] ash, with an LOI of less than 13%. It was not unusual to see the percentage of carbon increase as you go through, or in this case, out of, the ESP. Carbon particles have very low resistivity and are easily re-entrained to the next field. Higher LOI and/or the characteristics of the LOI may have been contributing to the poorer ESP collection performance. However, complicating this issue was the fact that sometimes LOI particles were large and could fall out in the front hoppers.
- In Phase I, the ESP hopper ash was nominally 7% and the COHPAC[®] ash was 11%.
- When the maximum injection concentration was raised to nominally 0.52 lb/MMacf (14–16 lb/h), the LOI of the B-side ash was consistently higher than that of the A-side ash. During the same period, LOI of the A-side ash decreased slightly. The one measurement of the ESP ash showed no significant change during this period.
- Based on a carbon injection concentration of 0.52 lb/MMacf and a flow rate of 500,000 acfm, the additional inlet loading from activated carbon was nominally 0.0036 gr/acf. With an average baseline inlet mass loading of 0.054 gr/acf, one would predict an increase in carbon of about 7%.

Table 6. LOI Measurements on Unit 3 COHPAC[®] and ESP Hopper Ash.

Date	A-Side (%)	B-Side (%) ^a	ESP (%)	Maximum Carbon Injection Rate (lb/h)
07/01/03	16.2	15.2	11.3	10
07/02/03	15.5	18.3		10
07/03/03	20.2	18.5		10
07/07/03	20.0	17.6	13.8	10
07/08/03	15.3	18.4		10 and 14
Average	17.4	17.6	12.6	
07/09/03	17.2	21.0		14
07/10/03	15.3	22.9		14
07/11/03	15.6	20.3		14
07/14/03	15.1	18.8	13.1	14
Average	15.8	20.8	13.1	
07/15/03	13.8	18.7		16
07/16/03	15.0	22.8		16
07/17/03	14.8	21.7		16
07/18/03	15.5	12.7		16
Average	14.8	19.0		

a. B-side had carbon injection

Carbon Injection System

Because of the highly variable baseline conditions and the already poor performance of the baghouse, the ability to inject activated carbon was severely limited. To overcome this, an injection scheme was implemented that balanced the need to decrease carbon injection during times when inlet loading to the baghouse was high and increase carbon injection when inlet loading and mercury removal were low. The performance goals and settings of this modified injection scheme were:

- Use the output signal from the BHA particulate monitor installed at the inlet to the baghouse as a feed forward signal for controlling carbon injection.
- Inject activated carbon at a rate capable of maintaining mercury removal at or above 80%.
- Implement the capability to automatically either lower or stop carbon injection when inlet mass loading was causing the baghouse to be at or near continuous cleaning.
- The initial set points are listed in Table 7.
- The system was operated in this mode beginning July 1, 2003.

Table 7. Initial Activated Carbon Injection Operating Parameters.

Inlet Loading (gr/scf)	Carbon Injection Rate (lb/h)
< 0.1	10
< 0.2	10
> 0.2	0

The injection system was shut down from July 3 through 7, 2003, to troubleshoot problems with the load sensors on the activated carbon skid.

Mercury S-CEM Measurements

Vapor-phase total mercury was measured at the inlet and outlet of 3B COHPAC[®] throughout this period. One instrument was used to measure from both locations, alternating between the two. Figure 20 presents inlet and outlet mercury concentrations (corrected to 3% oxygen), removal efficiency, carbon injection rate, and B-side ash LOI.

With carbon injection in the load- and inlet loading-following modes, outlet mercury concentrations were maintained below nominally 4 µg/Nm³ (2.9 lb/TBtu). Except for two brief periods when mercury removal decreased to 76%, mercury removal varied between 80 and 98%. Typical removal efficiency during this period was about 89%, with a maximum injection concentration of 0.52 lb/MMacf (16 lb/h).

Figure 20 also includes data from the end of the previous baseline period. The solid vertical line on June 26, 2003, represents the start of carbon injection. This is included to show the large variation in outlet mercury and removal efficiency without carbon injection and the relatively consistent removal efficiency once carbon injection was started.

High, consistent mercury removal was obtained at relatively low carbon injection concentrations. Table 8 presents a comparison of long-term performance results from the Phase I tests and the Phase II Optimization tests. This table shows that there were significant differences in all of the primary parameters: carbon injection concentration, average mercury removal, variation in mercury removal, baseline ash LOI, baseline mercury removal, and baseline inlet mass loading.

In the Phase II Optimization tests:

- Average mercury removal was 89% compared to 78%.
- Mercury removal varied between 76 and 98%. In previous tests, there was a much larger variation, between 36 and 90%.
- Baseline ash LOI was higher, 17% versus 11%.
- Baseline mercury removal was higher, 26% versus 0%.
- Inlet mass loading to COHPAC[®] was higher, 0.054 gr/acf versus < 0.01 gr/acf.

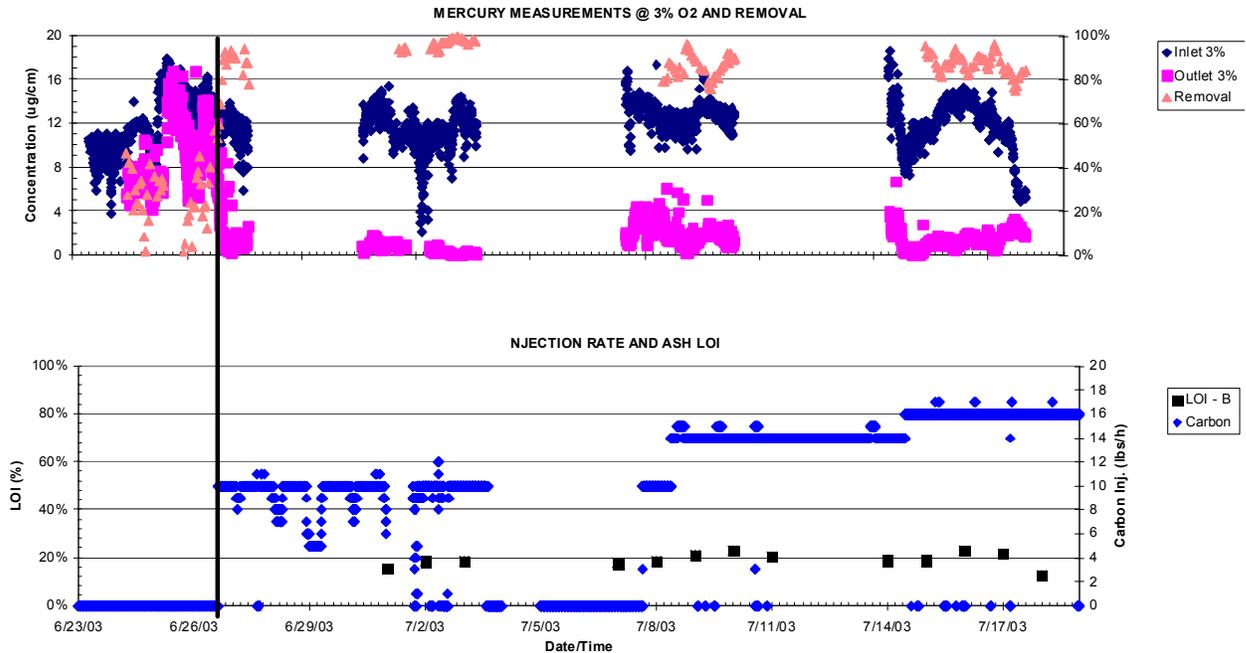


Figure 20. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Carbon Injection Rate, and B-Side Ash LOI during Optimization Period 2.

Table 8. Comparison of Phase I (2001) Long-Term and Phase II (2003) Optimization Tests.

	2001	2003
Carbon Injection Concentration	1.5 lb/MMacf	0.52 lb/MMacf
Average Mercury Removal	78%	89%
Variation	36–90%	76–98%
Average Baseline LOI	11%	17%
Average Baseline Mercury Removal (%) ^a	0	26
Average Baseline Inlet Mass Loading ^b	< 0.01 gr/acf	0.054 gr/acf

a. Average from the Ontario Hydro tests.

b. Baseline inlet loading during long-term tests.

Note: In Phase I, inlet loading was lower during long-term tests than during baseline tests.

COHPAC[®] Performance

The COHPAC[®] baghouses continued to clean at much higher rates than levels seen in either historical averages or the Phase I tests. Figure 21 presents performance data for both A- and B-side baghouses during Optimization Period 2. These data include inlet loading, boiler load, and pulse frequency.

- Figure 21 shows that both baghouses had relatively high cleaning frequencies. For this period, the average cleaning frequencies were:
 - 1.9 for A-side
 - 2.3 for B-side
 - A difference of 17%
- Carbon injection had increased the difference between the two baghouses by nominally 6%. In Phase I, the average cleaning frequency increased by nominally a factor of 3 (< 0.5 p/b/h versus 1.5 p/b/h). The average cleaning frequencies in Baseline Period 2 were:
 - 1.6 for A-side
 - 1.8 for B-side
 - A difference of 11%
- At this carbon injection concentration (~0.52 lb/MMacf) there was very little negative impact on COHPAC[®] cleaning frequency.

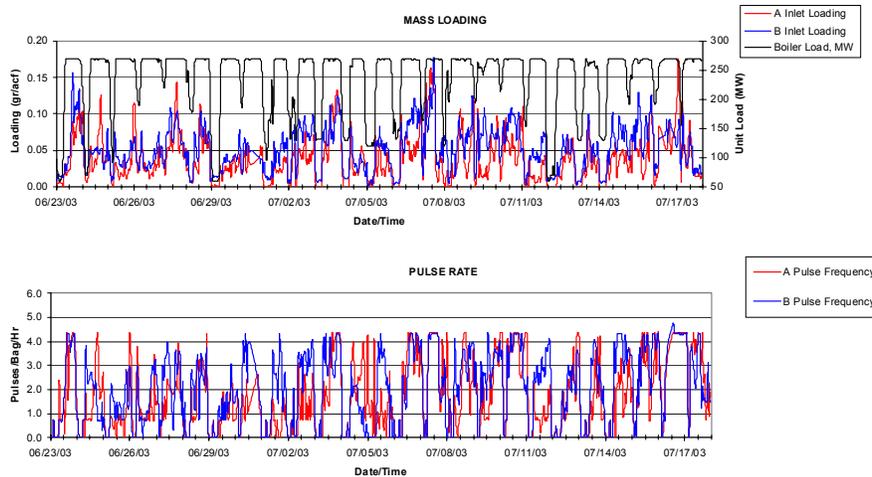


Figure 21. COHPAC[®] Performance Data for Both A- and B-Side Baghouses during Optimization Period 2.

Ash and Coal Samples

During Optimization Period 2, coal samples were collected daily during the week and ash samples were collected periodically from both the A- and B-side COHPAC[®] hoppers and from the hot-side ESP hoppers.

Long-Term Original Bags (July 19–November 25, 2003)

Between June 26 and July 18, 2003, the carbon injection control system was optimized to minimize impact on baghouse cleaning frequency while injecting sufficient carbon to maintain a target mercury removal efficiency of 80%. The long-term test on the original bags officially started on July 19.

Activated Carbon Injection and Mercury Removal Performance

New control logic was programmed into the injection skid PLC to vary carbon injection rate with respect to inlet mass loading. When baseline inlet loading and baghouse cleaning frequency were high, this new control scheme took advantage of the natural mercury removal and reduced impact on cleaning frequency by lowering or shutting off carbon injection. This program had the ability for three different carbon injection rates based on three ranges of inlet loading. The set points used during this long-term test with the original bags are listed in Table 9. The maximum injection rate was set at either 16 or 20 lb/h, depending on baghouse conditions and mercury removal. There were times when mercury removal decreased below our target of 80%, which pointed toward the native ash being less reactive and/or efficient in removing mercury at the specific conditions. At these conditions, the upper feed rate was increased to 20 lb/h.

Table 9. Activated Carbon Injection Operating Parameters.

Inlet Loading (gr/scf)	Inlet Loading (gr/acf)	Injection Concentration (lb/MMacf)	Injection Rate (lb/h)
< 0.1	< 0.07	0.52 or 0.66	16 or 20
0.1–0.2	0.07–0.14	0.35	10
> 0.2	> 0.14	0	0

Vapor-phase total mercury was measured at the inlet and outlet of the 3B COHPAC[®]. One S-CEM instrument was used to measure from both locations, alternating between the two. Up until July 21, 2003, the mercury analyzer was operating only during weekdays (Monday through Friday). Beginning on July 21, the analyzer was left running, unattended, over the weekends. Although the analyzer was in service, there were several instances where power fluctuations or plugged chemical feed lines interfered with data collection.

Inlet and outlet total vapor-phase mercury, calculated mercury removal, carbon injection concentration, and an indication whether the bypass damper was open are presented graphically in Figures 22–28 for July 19 through November 25, 2003. Weekly averages were calculated for inlet and outlet mercury concentrations and for mercury removal efficiency and are presented in Table 10. The standard deviation of the average mercury removal efficiency can also be seen in this table. Figure 29 plots daily and weekly averages of inlet and outlet mercury concentrations and mercury removal. These data and graphs are discussed in more detail in the following sections.

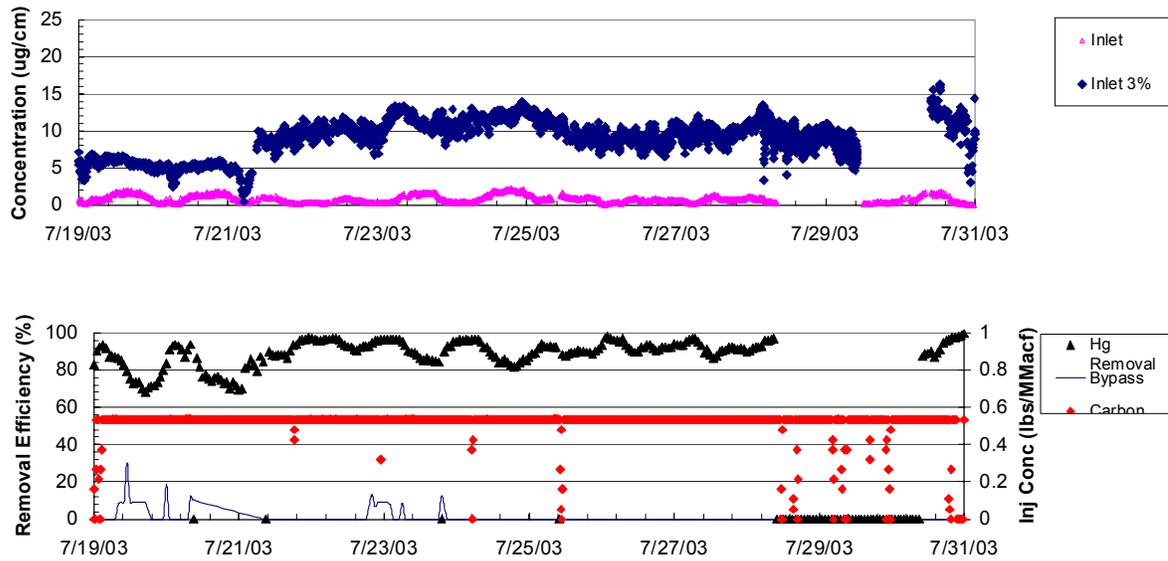


Figure 22. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, and Position of Bypass Damper on Unit 3B COHPAC[®], July 19–31, 2003.

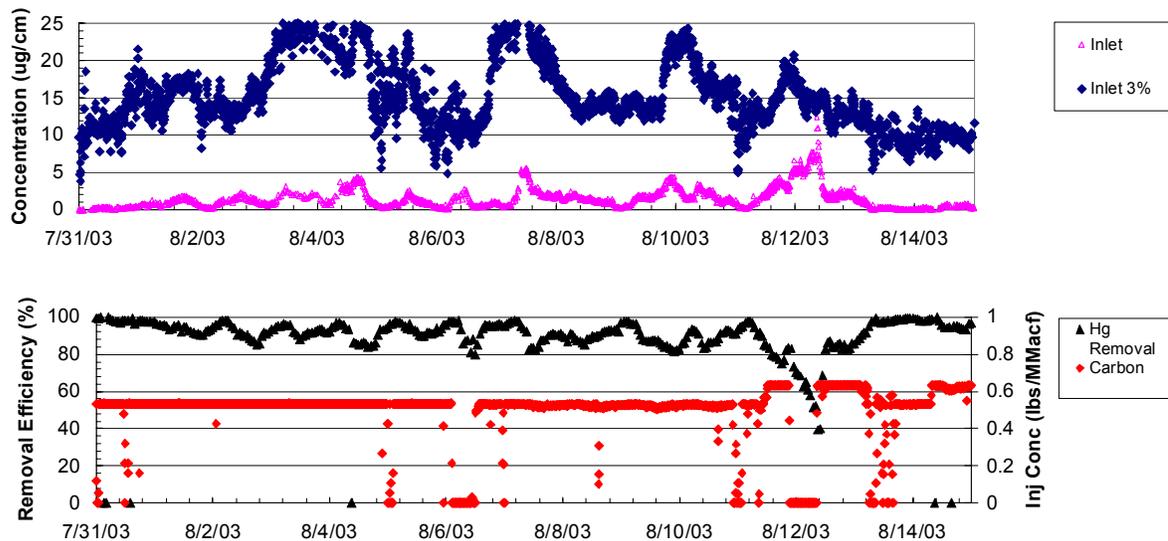


Figure 23. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, and Position of Bypass Damper on Unit 3B COHPAC[®], July 31–August 15, 2003.

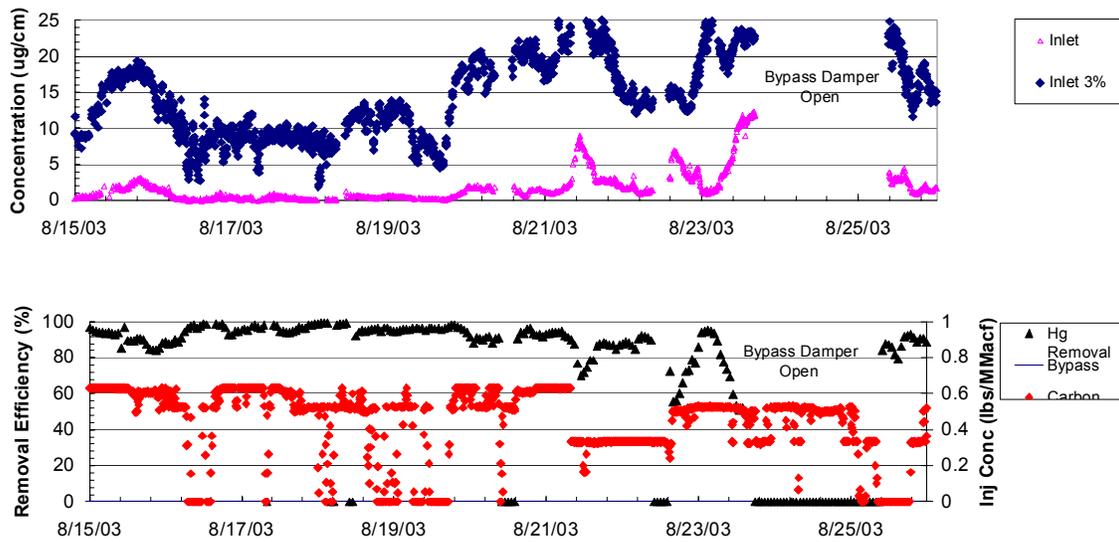


Figure 24. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, and Position of Bypass Damper on Unit 3B COHPAC[®], August 15–27, 2003.

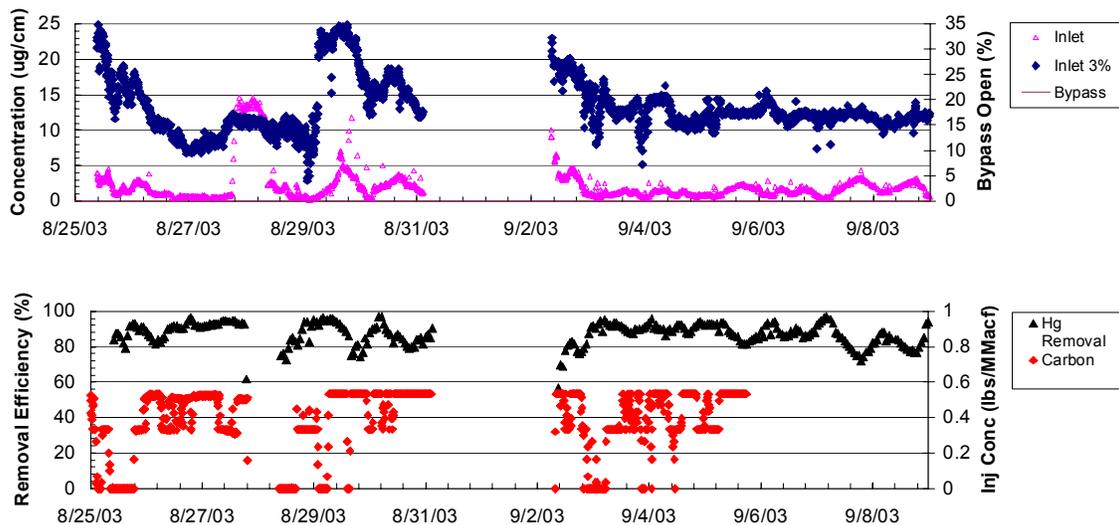


Figure 25. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, and Position of Bypass Damper on Unit 3B COHPAC[®], August 25–September 9, 2003.

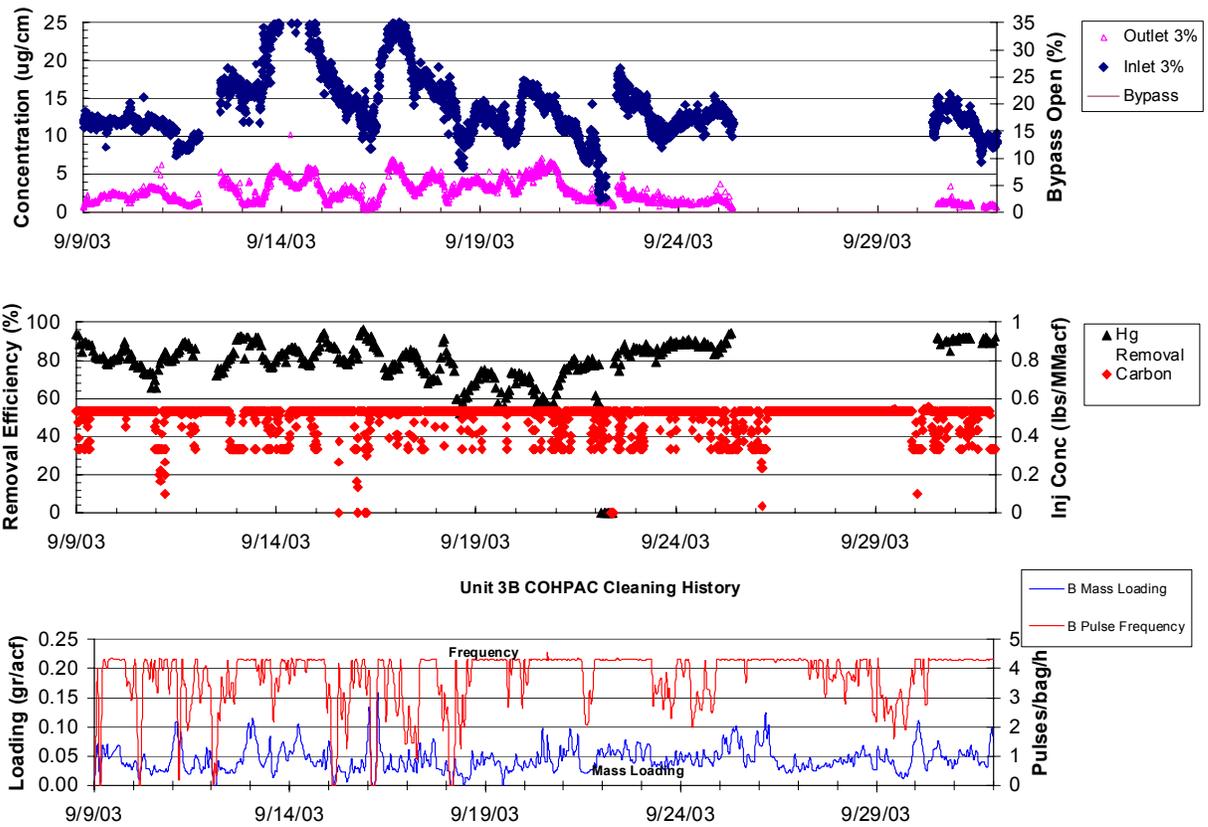


Figure 26. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, Position of Bypass Damper and COHPAC[®] Performance on Unit 3B COHPAC[®], September 9–October 1, 2003.

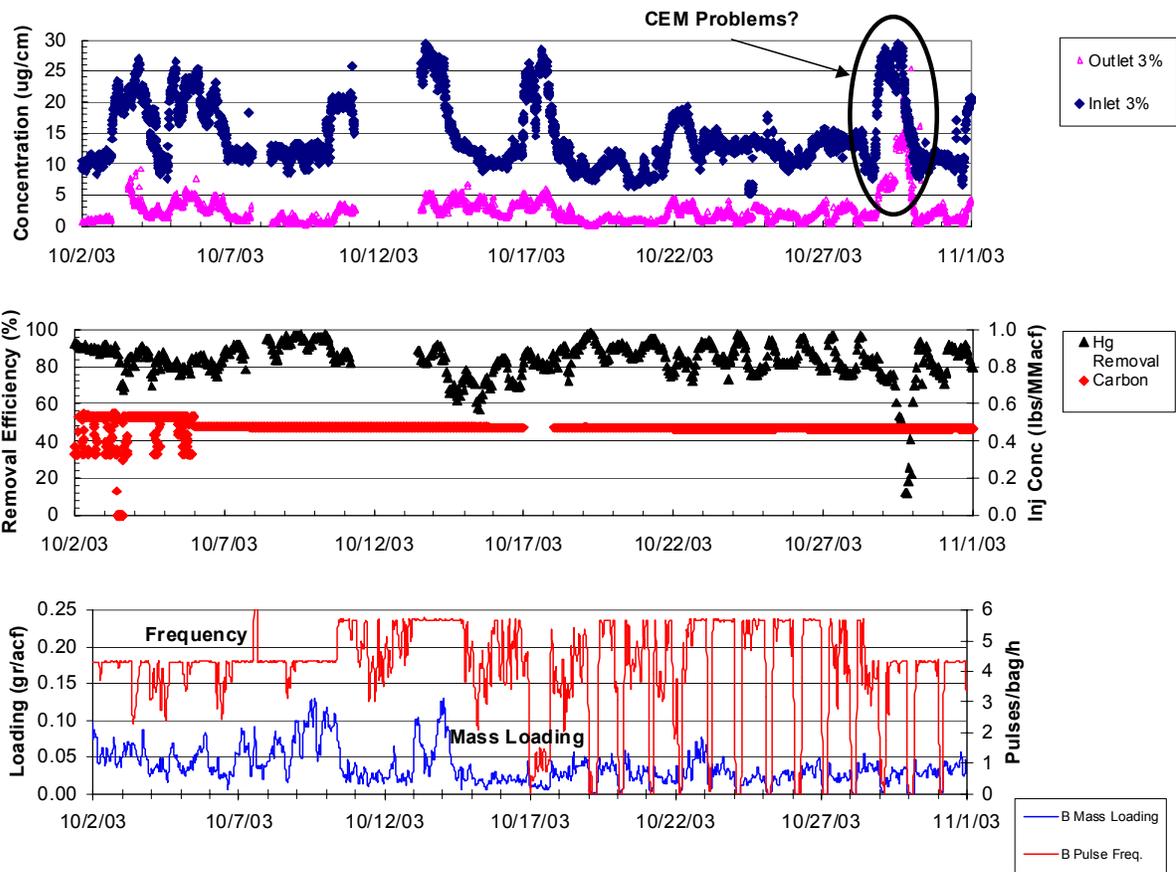


Figure 27. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, COHPAC[®] Cleaning Frequency, and Inlet Mass Loading on Unit 3B COHPAC[®], October 2–November 1, 2003.

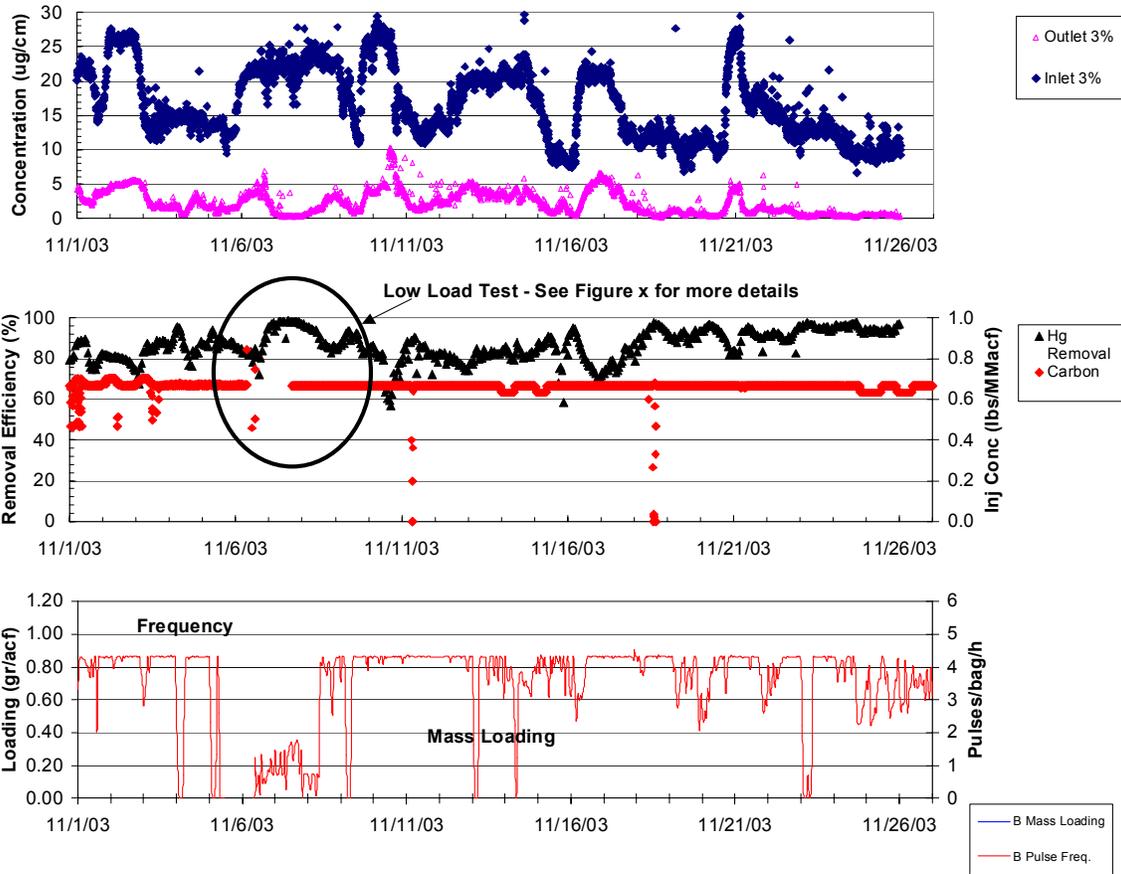


Figure 28. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, COHPAC[®] Cleaning Frequency, and Inlet Mass Loading on Unit 3B COHPAC[®], November 1–26, 2003.

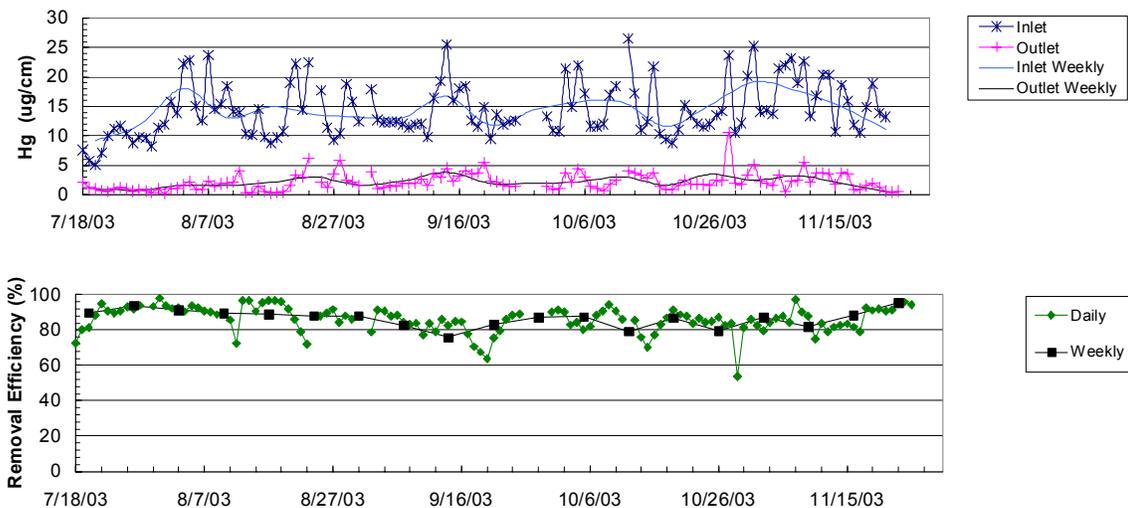


Figure 29. Daily and Weekly Averages of Inlet and Outlet Mercury Concentrations and Mercury Removal, July 19–November 26, 2003.

Table 10. Average Weekly Inlet and Outlet Mercury Concentrations, and Mercury Removal.

Week Starting	Inlet Mercury ($\mu\text{g}/\text{Nm}^3$)	Outlet Mercury ($\mu\text{g}/\text{Nm}^3$)	Mercury Removal (%)	Standard Deviation Hg Removal
07/20/03	9.2	0.8	91	6.5
07/27/03	11.8	0.8	93	3.6
08/03/03	18.1	1.6	91	4.5
08/10/03	13.0	1.6	87	10.7
08/17/03	14.9	2.0	86	12.0
08/24/03	13.9	2.9	79	6.3
08/31/03	13.2	1.7	87	5.7
09/07/03	13.1	2.3	82	6.3
09/14/03	16.7	3.8	77	10.6
09/21/03	11.8	1.9	83	7.3
09/28/03	11.3	1.1	90	1.6
10/05/03	15.8	2.16	86	6.3
10/12/03	15.8	3.1	80	8.7
10/19/03	11.6	1.6	86	6.2
10/26/03	15.2	3.5	77	14.6
11/02/03	19.2	2.4	87	6.6
11/09/03	17.6	3.2	82	6.5
11/16/03	14.9	1.9	87	7.1
Overall Average	14.3	2.1	85.6%	

Carbon Injection System

The carbon injection system was knocked offline by severe lightning in the area two different times during this period. After investigating the problem, we learned that other users had also experienced failure of electronic boards in the control system from voltage surges during lightning storms. The boards were replaced.

The system was offline on August 27 and 28, and from August 31 through September 2, 2003. An increase in outlet mercury concentration can be seen on August 27. The August 31 strike also took out the mercury analyzer.

COHPAC[®] Bypass Damper Operation

Because of high baghouse cleaning frequency and pressure drop, the bypass dampers to the baghouse were partially or fully opened to relieve pressure drop. This occurred both in July and August 2003. The COHPAC[®] computer tracked bypass damper position, but this value was not always accurate. A good example of what happened when the bypass damper was

partially opened can be seen in Figure 22. An indication of the bypass damper position is plotted on the lower graph. On July 19–21, the bypass damper opened twice. Carbon injection continued because the inlet loading was not above the set point to turn it off. Mercury removal decreased because unfiltered flue gas was mixing with filtered flue gas in the outlet. Mercury removal decreased to about 70%.

Mercury Concentrations and Removal Efficiencies

Weekly average mercury concentrations can be seen in Table 10, and these values are also plotted in Figure 29. The goal for these tests was to maintain mercury removal above 80%. During the week of September 14, 2003, the average mercury removal fell below 80% to 75.8%, even with carbon injection. Two things could have contributed to this. First, the baghouse was in continuous cleaning, which did not allow much of the activated carbon to build up on the bags. However, there were other periods when the baghouse was cleaning continuously and removal efficiency remained high. The second factor could be variations in the affinity for mercury from the native fly ash. Previous testing has shown that a much lower activated carbon injection concentration was required to obtain similar high removal efficiencies. The presence of the high carbon ash may be enhancing the performance of the activated carbon–fly ash combination. A change in coal or combustion conditions during one of the weeks may have resulted in a fly ash with a reduced impact on mercury removal and a higher requirement for activated carbon. Without changing injection concentration, the removal efficiencies increased to above 80% after a few days. This period can be clearly seen in Figure 26, which also shows cleaning frequency.

Table 10 also shows the standard deviation associated with the average removal efficiency numbers. The standard deviation was as high as 14.6%, which implies that to maintain mercury removal above 80%, more carbon would have to be added to target greater than 90% removal on average.

The average inlet mercury concentration for the entire long-term test was $14.3 \mu\text{g}/\text{Nm}^3$ (10.4 lb/TBtu), with daily average concentrations varying between nominally 5.1 and $25.6 \mu\text{g}/\text{Nm}^3$ (3.7–18.6 lb/TBtu). This was about the order of magnitude in variation seen in the Phase I test.

The average outlet mercury concentration for the same period was $2.1 \mu\text{g}/\text{Nm}^3$ (1.5 lb/TBtu), with daily average concentrations varying between 0.24 and $6.2 \mu\text{g}/\text{Nm}^3$ (0.17–4.5 lb/TBtu). Average mercury removal during the period was 85.6%, with a minimum daily average of 63.5% and a maximum daily average of 98.1%. The maximum carbon injection concentration was 0.66 lb/MMacf, and at times carbon injection was turned off. The average injection concentration over this period was 0.55 lb/MMacf.

For the long-term test, an estimate of cumulative pounds of mercury entering and exiting the Unit 3B baghouse was calculated using the average inlet and outlet concentrations and flue gas flow measured continuously in the inlet duct with Kurtz flow instruments. The estimates are:

- Inlet = 48 lbs
- Outlet = 7 lbs

About 12,000 pounds of carbon were injected during this long-term test. The Phase I tests predicted that more than double this amount would be necessary to achieve about 80% mercury removal.

Mercury S-CEM O&M Improvements

The most time-consuming effort associated with operation of the analyzer was keeping the wet-chemistry-based conversion/speciation conditioning system functioning. Three changes that were made to the impingers that decreased maintenance time were 1) modifying the impinger design to reduce the number of fittings (which reduces the potential for leaks), 2) moving the feed and waste ports for more efficient mixing, and 3) mounting the impingers on a board for easier handling. A clean set of impingers and feed lines operated for up to four days before they had to be changed and cleaned.

On a different program, an evaluation of extraction probes was conducted. This test showed that the extraction probe used at Gaston, which was stainless steel, oxidized mercury as the gas passed through the inertial filter. The tests revealed that the measurement artifact could increase measured oxidized mercury by up to 17%. Because of this measurement artifact, and that the priority was to measure total mercury at the inlet and outlet of COHPAC[®], very few speciated measurements were made.

COHPAC[®] and ESP Performance

The high cleaning frequency of the COHPAC[®] baghouses continued to be a concern. Figures 30 and 31 present performance data for A- and B-side baghouses for this period. The top graph shows inlet mass loading and pulse cleaning frequency for B-side, the middle graph presents the same data for A-side, and the bottom graph shows boiler load and carbon injection concentration into B-side.

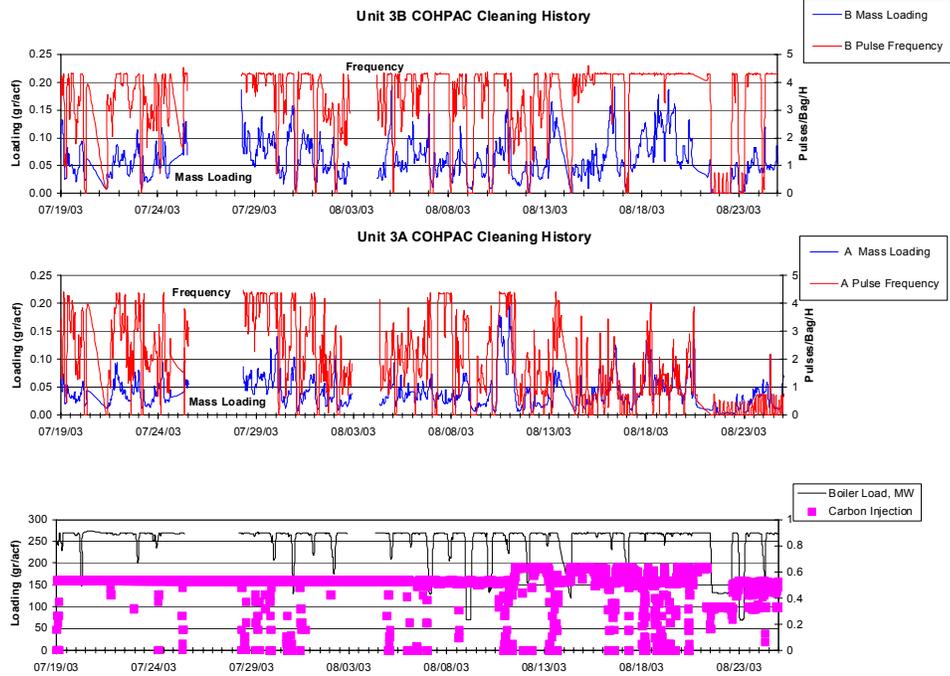


Figure 30. Units 3B and 3A COHPAC[®] Performance, Boiler Load, and Carbon Injection Concentration, July 19–August 24, 2003.

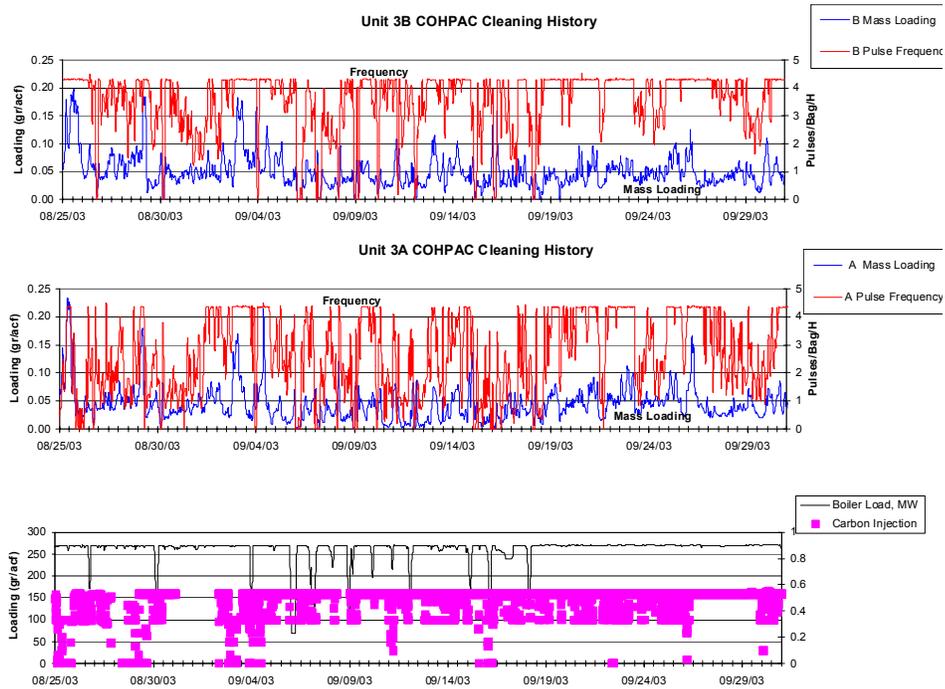


Figure 31. Units 3B and 3A COHPAC[®] Performance, Boiler Load, and Carbon Injection Concentration, August 25–October 1, 2003.

Comparing A- and B-sides in Figure 30, the inlet loading and cleaning frequency was lower on A-side, especially from August 3 through August 24. Figure 31 shows an increase in cleaning frequency on A-side in September, with extended periods of continuous cleaning.

At low load operation in August, the cleaning frequency on both baghouses decreased dramatically. Unit 3 appeared to be base loaded at high load for an extended period at the end of September. During this time, both sides had extended periods of continuous cleaning.

The average cleaning frequencies for this time period and the previous for each side were:

- A-side = 2.3 p/b/h versus 1.9 p/b/h
- B-side = 3.5 p/b/h versus 2.3 p/b/h

Cleaning frequency on A-side had increased by about 17%, while B-side had increased by 35%. B-side was very close to being in a continuous clean most of the time. At the existing injection rate, it was expected that the carbon would cause a 1 p/b/h increase in cleaning frequency. This would account for the higher cleaning frequency on B- versus A-side.

Many groups, including Southern Company, were still investigating ESP performance and its impact on the higher inlet loading to COHPAC[®]. One hurdle in troubleshooting the ESP performance was that there was not access to historical ESP power data. In July, an upgrade to the controls was implemented. ADA-ES assisted Southern Company by putting together spreadsheets to import and analyze the data.

Hamon Research-Cottrell provided two experts to go to the site and observe ESP and baghouse operation. The trip report from the ESP inspection is included in Appendix D. In summary:

- Power levels were extremely low on all fields.
- Resistivity was very low because of high LOI.
- It was suspected that there were insulator-tracking type problems from high carbon ash on the insulators.

Ash and Coal Samples

Coal samples were collected daily and ash samples were collected periodically from both the A- and B-side COHPAC[®] hoppers, and from the hot-side ESP hoppers. LOI of ash samples was measured periodically.

Ontario Hydro Test Results

In October 2003, a set of manual measurements was conducted on the Unit 3B COHPAC[®] baghouse. These tests included simultaneous inlet and outlet measurements of speciated mercury following the Ontario Hydro method, multiple metals sampling at the outlet, and hydrogen chloride sampling at the inlet. During the tests, boiler load was held steady at 270 MW and activated carbon was injected at 0.66 lb/MMacf (20 lb/h). Average inlet flue gas temperature was 243 °F and the outlet was 240 °F.

Table 11 presents a summary of the mercury measurement results from the Ontario Hydro tests. The average inlet concentration was 10.2 $\mu\text{g}/\text{Nm}^3$ (7.4 lb/TBtu) and the average outlet concentration was 2.0 $\mu\text{g}/\text{Nm}^3$ (1.5 lb/TBtu), for an average mercury removal of 80.4%. Table 11 also shows the range of mercury concentrations measured by the S-CEM for the two-day test period. S-CEM mercury concentrations are presented in this manner because, at the time of the Ontario Hydro tests, there were some operational problems with the instrument. Figure 32 shows that there are no data for a period on October 7 and 8. The questionable results during this time were caused by the gold trap slipping out of position and not being fully exposed to the sample gas.

Table 11. Results from Ontario Hydro Tests across the Unit 3B COHPAC[®] with Activated Carbon Injection and Original Bags, October 8–9, 2003.

	Particulate ($\mu\text{g}/\text{Nm}^3$) ^a	Oxidized ($\mu\text{g}/\text{Nm}^3$) ^b	Elemental ($\mu\text{g}/\text{Nm}^3$)	Total ($\mu\text{g}/\text{Nm}^3$)	S-CEM Comparison
COHPAC [®] Inlet	4.5	2.5	3.1	10.2	8.7–13.4
COHPAC [®] Outlet	0.6	1.3	0.3	2.0	0.6–2.2
Removal Efficiency	86.7%	48.0%	91.0%	80.4%	83–95%

- a. Normal conditions = 32 °F
- b. All mercury measurements corrected to 3% O₂

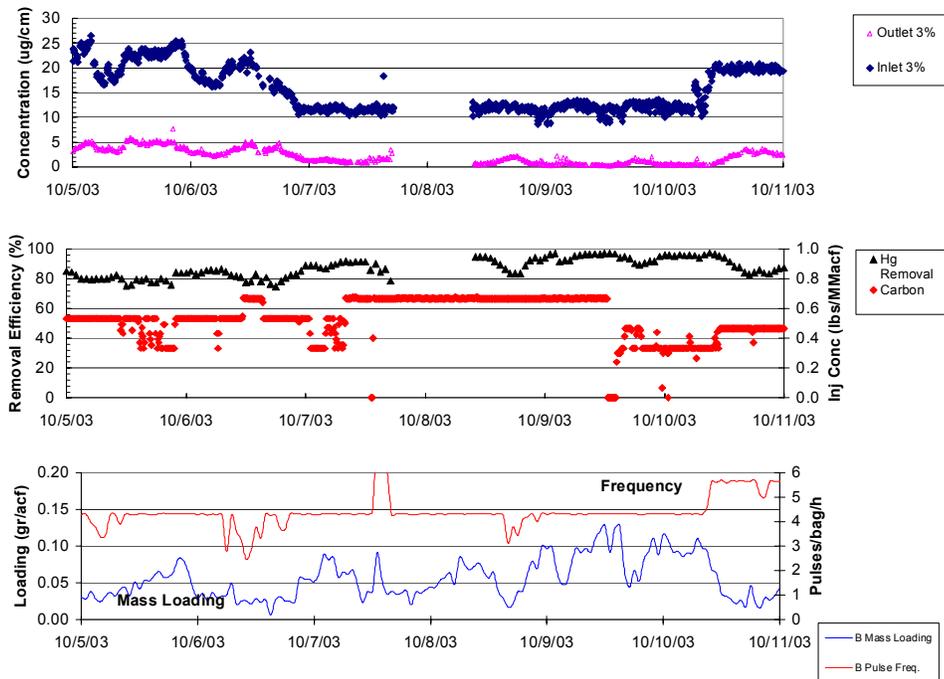


Figure 32. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, COHPAC[®] Cleaning Frequency, and Inlet Mass Loading on Unit 3 COHPAC[®] the Week of Ontario Hydro Tests, October 5–11, 2003.

The Ontario Hydro inlet speciation results show nearly 44% in the particulate phase. However, the S-CEM and Ontario Hydro had similar total vapor-phase mercury concentrations. This discrepancy indicates that the particulate speciation measurement of the Ontario Hydro method was incorrect. These results again point out the sampling artifact associated with the Ontario Hydro method when measurements were made in high-particulate loading locations. The upstream filter removed the particulate, but also provided a site to both scrub and oxidize mercury, which affected the speciation measurement.

At the outlet, the Ontario Hydro measurements were at the upper end of concentrations measured by the S-CEM, 2.0 $\mu\text{g}/\text{Nm}^3$ (1.5 lb/TBtu) versus 0.3–2.2 $\mu\text{g}/\text{Nm}^3$ (0.2–1.6 lb/TBtu). To try to explain this, a thorough Quality Assurance of the data and an investigation of the operation of the S-CEM were conducted. The findings included:

- Overboard calibrations were conducted daily to assure that mercury was not being scrubbed or that unexpected chemical reactions between the flue gas, wet chemicals, and vapor-phase mercury were not occurring. The calibration performed before the Ontario Hydro tests showed good recovery of the mercury spike.
- Onboard calibrations of the mercury analyzer were performed routinely. Again, the calibrations during this period were acceptable.
- The analyzer was set up with a battery of diagnostics, which included measurements of light intensity, temperatures, pressures, oxygen levels, solenoid operation, desorb characteristics, and several other parameters. The diagnostics showed normal operation for all data presented in Figure 32.
- A review of operator logs did not have any noted inconsistencies or unusual operation.
- The Quality Assurance documentation from Ontario Hydro test results was reviewed. Laboratory spike recovery and the sample blank looked good. All field tests were considered valid.

Based on this analysis, there was no obvious reason to discount either measurement. The Ontario Hydro results match well with the long-term mercury control performance, as shown in Table 12, and confirmed that a nominal injection concentration of 0.66 lb/MMacf resulted in about 80 to 85% mercury control.

Table 12. Average Weekly Inlet and Outlet Mercury Concentrations and Mercury Removal Efficiency, October 2003.

Week Starting	Inlet Mercury ($\mu\text{g}/\text{Nm}^3$)	Outlet Mercury ($\mu\text{g}/\text{Nm}^3$)	Mercury Removal (%)
10/05/03	15.8	2.2	86
10/12/03	15.8	3.1	80
10/19/03	11.6	1.6	86
10/26/03	15.2	3.5	77
Overall Average	14.6	2.6	82.2%

Residual Drag Measurements on Original Bags

A set of in-situ drag measurements was made by Southern Research Institute on the original bags when the baghouse was taken out of service to replace bags. The drag of the four bag bundles varied between 0.44 and 0.81 inches H₂O/ft/min, with an overall average of 0.62 inches H₂O/ft/min. In March 2003, before the carbon injection tests, the average drag was 0.36 inches H₂O/ft/min. This was a significant increase in residual drag over a relatively short period and the highest drag measured on the Unit 3 COHPAC[®] bags. However, inlet loading to the baghouse increased at the same time the carbon injection tests started, resulting in an increase in cleaning frequency of the A-side bags also. In February, drag measurements made in the 3A baghouses showed an average drag of 0.53 inches H₂O/ft/min. This indicated that the overall higher inlet mass loading from the hot-side ESPs was the primary cause of significantly higher residual drag, not the activated carbon injection.

Figure 33 illustrates the dramatic change in baghouse performance after the March 2003 outage by showing the pulse frequency for A- and B-side baghouses since new bags were installed in October 2000. This graph also shows operating drag, which was maintained by the higher cleaning frequency.

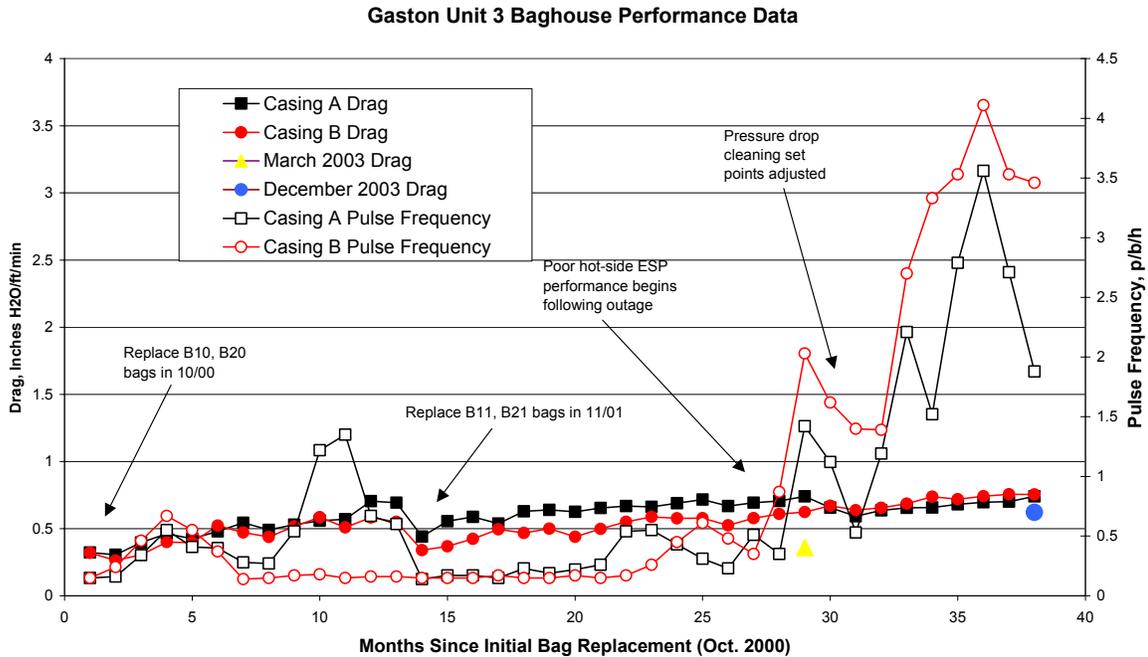


Figure 33. Gaston Unit 3 COHPAC[®] Baghouse Performance, October 2000–November 2003.

Baseline Test Ash and Coal Analyses

To better understand the differences between the 2001 and 2003 carbon injection, additional analyses of ash from 2001 and 2003 were undertaken. These analyses included:

- Particle size distribution by Malvern analysis (light scattering)
- N₂ BET surface area
- Petrography (analysis of coal macerals)
- Ultimate analysis
- Microscopy

Jim Hower at the University of Kentucky, Center for Applied Energy Research carried out petrographic and ultimate analyses. Microbeam Technologies, Inc., carried out microscopy, particle size distribution, and N₂ BET surface area tests.

A report summarizing the results of these tests is presented in Appendix E. The conclusions were:

- Particle size distribution, surface area, carbon content, and carbon maceral type were all distinct between the hot-side ESP samples and the baghouse ash samples. The A-side ash had a lower surface area than the hot-side ESP ash, which may be due to differences in the distribution of carbon macerals in the ash. Addition of activated carbon to the baghouse increased the surface area, as one would expect.
- The A-side ash had LOI values comparable to the hot-side ESP ash. However, the carbon content of the A-side ash was lower than the carbon content of the hot-side ESP ash. The measured amounts of LOI agreed well with the measured amounts of carbon for the hot-side ESP ash and the B-side ash sample (containing activated carbon). The measured amount of carbon in the A-side ash was considerably lower than the LOI. Based on the ultimate analysis of the ash, the A-side ash had a significant amount of moisture, sulfur, and oxygen, unlike the hot-side ESP ash samples and the B-side sample. Based on two sets of samples, therefore, it appears that the LOI content of the A-side ash is misleading in terms of the amount of carbon in the ash.
- The hot-side ESP ash in 2003 did not differ greatly from the hot-side ESP ash from 2001 in terms of the carbon maceral content or particle size distribution. The surface area of the 2003 hot-side ESP ash was higher than in 2001. Thus, it is hard to determine if the boiler produced the same kind of ash in 2003 as in 2001. Since the number of samples measured was small (and different coals are burned in the boiler on a continually changing basis), it may be difficult to conclude with certainty that the combustion conditions are the same.
- The A-side samples for 2003 were significantly different from the 2001 samples in that the former contained more large particles. The variability in the 2003 A-side ESP ash suggests that the hot-side ESP was not operating in a consistently efficient manner, and that more large particles were getting through the hot-side ESP in 2003 as compared to 2001.

Low Load Tests

Throughout these tests, the higher than expected mass loading into COHPAC[®] limited the quantity of carbon that could be injected. Although the test plan and injection logic was altered to accommodate for these real-life conditions, the question of how this information could be used in the design of new TOXECON[™] systems was left virtually unanswered.

One thing that was clear from these tests was that the current A/C ratio was too high to inject sufficient carbon to achieve 90% mercury control. A new TOXECON[™] baghouse would have to be designed at a lower A/C ratio. One way to overcome the operating limitations at this site was to operate at low load/lower flow for an extended period. While at these conditions, carbon injection could be increased and performance data could be tracked. The primary objectives of these short tests were to 1) determine the injection concentration necessary to achieve 90% removal and 2) determine the impact of carbon injection on cleaning frequency at this lower A/C ratio. An educated estimate of the ideal A/C ratio was about 6.0 ft/min.

Southern Company was able to schedule an extended period of low load operation for Gaston Unit 3. Full load at Gaston is nominally 270 MW. At this load, the flow rate into the 3B baghouse is nominally 520,000 acfm. In November 2003, Unit 3 was operated at 195 MW for a 72-hour block of time. The nominal flow at this condition was 375,000 acfm. Table 13 summarizes the differences in key variables at these two load conditions.

Table 13. Flow and A/C Ratio during Low Load Test.

Unit 3 Boiler Load (MW)	270	195
~ Unit 3B Flow (acfm)	520,000	375,000
~ Unit 3B A/C ratio (ft/min)	~ 8.0	~ 6.0

Three injection rates were evaluated during the 72-hour low load test. The first test was conducted at the highest injection rate possible under normal operating conditions, 20 lb/h. At this rate and the lower flow, the injection concentration was 0.9 lb/MMacf instead of 0.6 lb/MMacf. The injection concentrations were then increased up to a maximum of nominally 3 lb/MMacf.

The results from this test, including inlet and outlet mercury concentrations, mercury removal, and cleaning frequency are presented in Table 14. These data more closely matched the results shown in Figure 2 from the 2001 tests. At an injection concentration of 0.9 lb/MMacf, mercury removal was between 80 and 90%. When injection concentration was increased above 2 lb/MMacf, mercury removal was well above 90% and there were no episodes when the removal dropped below this level. Cleaning frequency was acceptable at all injection rates.

Table 14. Results Summary from Low Load Tests, November 2003.

Injection Rate (lb/h)	Injection Concentration (lb/MMacf)	Inlet Hg Concentration ($\mu\text{g}/\text{Nm}^3$)	Outlet Hg Concentration ($\mu\text{g}/\text{Nm}^3$)	RE (%)	Cleaning Frequency (pulses/bag/hour)
20	0.9	20.6	3.2	84	0.6
45 ^a	2.0	22.2	1.0	95	0.8
70	3.3	21.4	0.61	97	1.4

a. Last 18 hours of 45 lb/h test

Analysis of Used Filter Bags

Grubb Filtration Testing Services (GFTS) was contracted to perform bag inspections, bag testing, procurement of the new high-perm bags, and Quality Assurance testing of the new bags. A full report with results from testing on used bags is in Appendix F. A brief summary of that report is presented here.

Testing on this program began in March 2003. Testing was conducted with filter bags that were already in place (Long-Term Test on Original Bag). Information about these bags can be found in Table 15. The Gaston 3B baghouse has two compartments and each compartment has two bag modules. There are 544 filter bags in each module, for a total of 2,176 bags. The front modules are referred to as 3B10 and 3B20. The back modules are called 3B11 and 3B21.

Table 15. History of Original Filter Bags at Start of Long-Term Test, March 2003.

Modules	Front (3B10 and 3B20)	Rear (3B11 and 3B21)
Bag Supplier	Midwesco	BHA
Date Installed	11/4/00	11/30/01
Length of Service^a	18,809 hr	9,678 hr

a. Exposure hours (hours bags exposed to flue gas including time when bypass damper was partially opened) from Southern Research Institute summary through March 31, 2003, assuming continuous operation after outage.

Two used bags, one each from a front and rear module, were removed on March 11, 2003, and sent to GFTS for analysis to determine their baseline conditions. The results from these tests are documented in GFTS Report No. 3789, which is included as Appendix F. At that time, six new 2.7-denier bags were installed, three in Module B20 and three in Module B21. Once the long-term sorbent injection testing was completed, additional bags were removed and analyzed by GFTS. These results are documented in GFTS Report No. 3919, included as Appendix G.

Except for having somewhat lower permeability values, the original replacement bags (B20 and B21) that were exposed to carbon injection during most of their final 6,266 hours of service had properties that were similar to those of the Gaston 3 OEM bags tested in 1998–2000 after comparable lengths of service without carbon injection.

In particular, the activated carbon has had no significant effect on either the fabric strength or pH values.

Task 3.2 – Tests with 7-Denier, High-Perm Bags (December 2003–June 2004)

A set (2300 bags) of high-perm bags was purchased and installed in the B-side baghouse during December 4–8, 2003. The differences in design were denier (an indication of fiber diameter; 2.7- versus 7.0-denier) and permeability (nominally 30 versus 130 cfm/ft² @ 0.5 inches H₂O). The bag change-out was performed with the unit online. Crews worked around the clock to remove the old bags and cages, and install the new bags with the same cages. Before start-up, the bags were precoated with a silicon material called Nutralite, which was supplied by BHA Group, Inc. For the first week after the bags were installed, the baghouse was operated at partial flow by opening the bypass dampers on the B-side. This precaution is taken as part of standard start-up procedures. On December 15, the Unit 3B baghouse began filtering full flow. The primary goals for this test were to:

1. Demonstrate improved pressure drop performance of the high-perm bags
2. Increase carbon injection concentration to achieve a higher mercury removal than was possible with the original bags

Baseline Test Period 1 (December 15, 2003–January 5, 2004)

Baseline tests were performed from December 15, 2003, through January 5, 2004. Figure 34 presents inlet and outlet mercury concentrations, mass loading, and cleaning frequency for the Unit 3B baghouse from December 15 to December 31. The S-CEM was not in service over Christmas week. Stack opacity is also shown in Figure 34. This stack was used to exhaust flue gas from both Units 3 and 4. Unit 4 was offline from the beginning of December until December 20, which provided a limited opportunity to track the opacity from Unit 3.

Interestingly, the stack opacity appeared to follow the trends of both the inlet mass loading and the cleaning frequency. Comparing the opacity and cleaning frequency, a pattern can be seen on December 16–18 that when the baghouse cleaned, there was a small spike in opacity. At times (December 20), it also appeared that stack opacity followed inlet mass loading. Because of the design of these high-perm (7-denier) bags, it was possible that they were not as efficient as the standard (2.7-denier) bags. It was also believed that over time the difference in emissions from these two bag designs would decrease. However, in February 2004 a bag inspection was made when Unit 3 was offline and several bags were found to be improperly installed, causing the bags to fall into the hopper. This is the probable cause of the higher than expected stack opacity. It should be noted in Figure 34

that there appeared to be an offset in the opacity numbers. It looked like an opacity of 2 should have been the 0 (zero) level.

The new bags made a significant difference on the cleaning frequency of the B-side baghouse. This is illustrated in Figure 35, which shows inlet mass loading and cleaning frequency for both A- and B-side baghouses. Before changing the bags, the Unit 3B baghouse was often in a continuous clean of 4.4 p/b/h, similar to the cleaning frequency trend for the Unit 3A baghouse in Figure 35. Even with a much higher inlet mass loading, B-side baghouse cleaning frequency was very low, at less than 1 p/b/h.

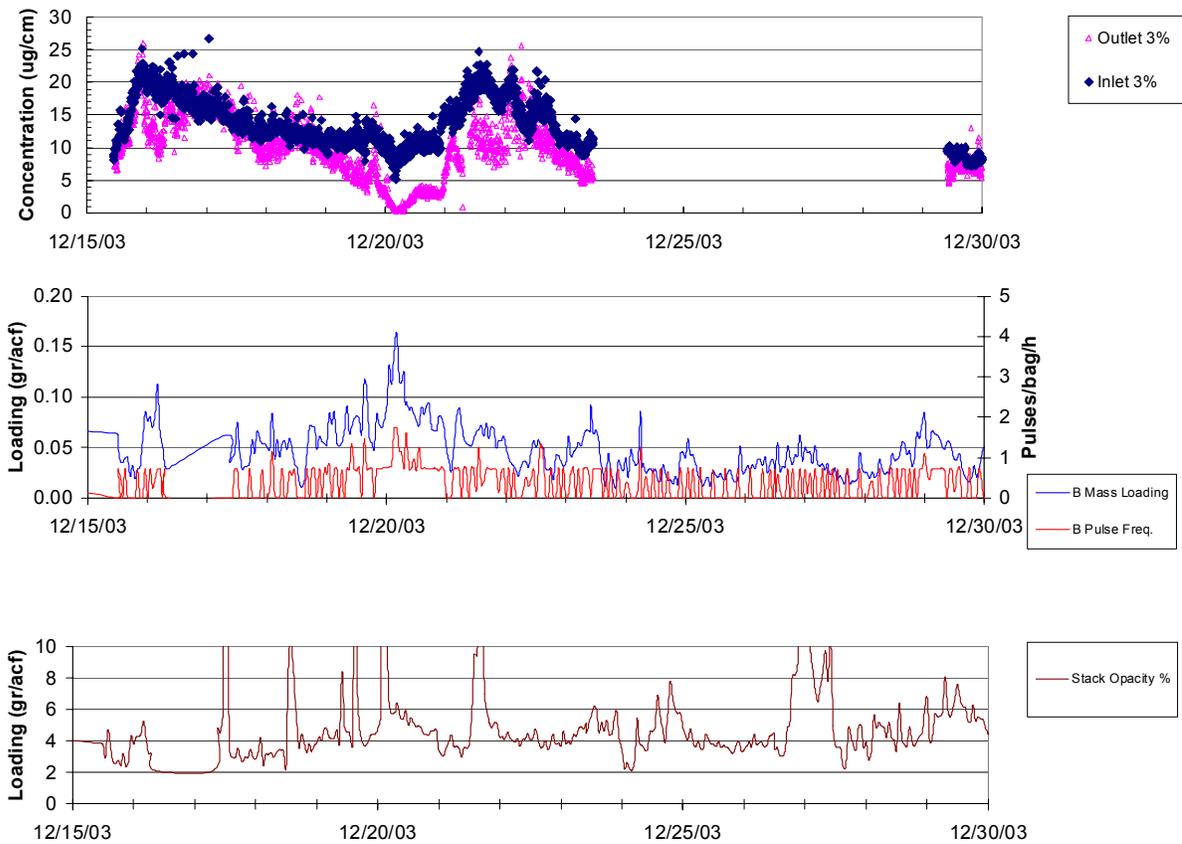


Figure 34. Inlet and Outlet Mercury Concentrations, COHPAC[®] Cleaning Frequency and Inlet Mass Loading on Unit 3B COHPAC[®], and Units 3 and 4 Stack Opacity, December 15–30, 2003.

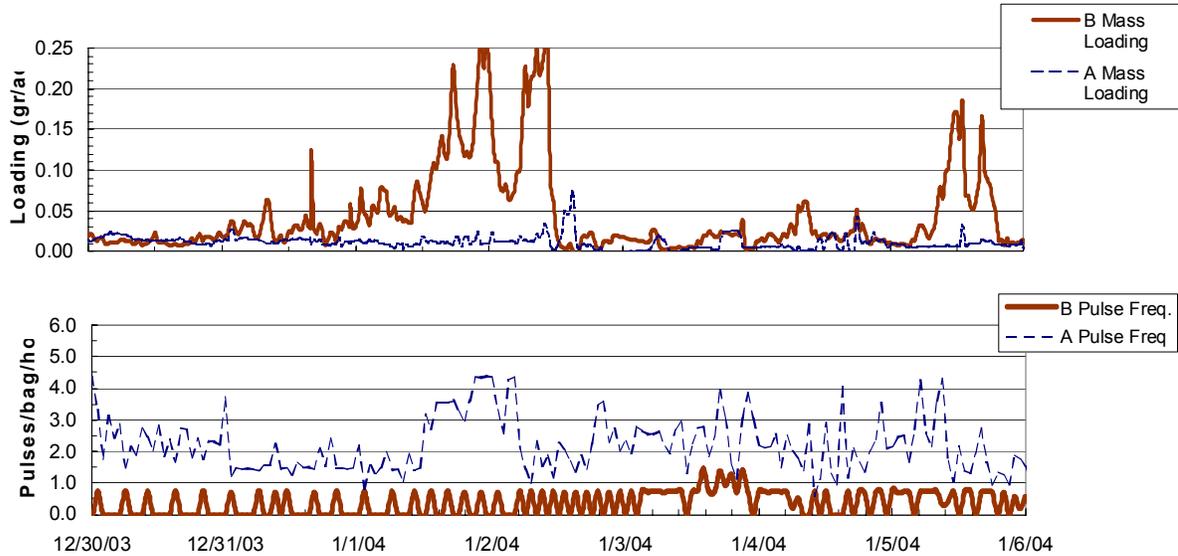


Figure 35. Comparison of 2.7- and 7-Denier Bag Performance on Units 3A and 3B COHPAC®.

Carbon Injection Test Period 1 (January 6–February 11, 2004)

Optimization tests were performed from January 6 through February 11, 2004. With lower baseline cleaning frequency after installation of the high-perm bags, it was possible to inject carbon at higher rates. However, inlet mass loading was still higher than design conditions and it was still important that average cleaning frequency be maintained at a reasonable rate. A target maximum cleaning frequency of 1.5 p/b/h was again chosen. Results from the baseline and optimization periods are shown in Figure 36.

Carbon injection rate was incrementally increased from 20 to 45 lb/h. Because the baghouse cleaning frequency was acceptable, it was possible to inject at a constant rate and not reduce injection when inlet mass loading increased. Average mercury removal for five different injection conditions is shown in Table 16. The average mercury removal was higher in each of the shorter tests than the 85.6% removal that was measured for the four-month carbon injection tests with the original bags. These tests show that there is no difference in the effectiveness of carbon injection for mercury control using either the original bags or the high-perm bags.

Average baghouse cleaning frequency and inlet mass loading are also presented in Table 16. Even with periods of high inlet loading, cleaning frequency was below the target of 1.5 p/b/h. Because it is expected that cleaning frequency will increase over time, especially as the new bags season, the long-term tests were conducted at an injection rate of 45 lb/h.

For a two-week period with an injection rate of 45 lb/h (1.3 lb/MMacf), mercury removal was 92%, with a maximum hourly value of 98% and a minimum hourly value of 80%. Unit 3 went offline for an extended outage after February 11.

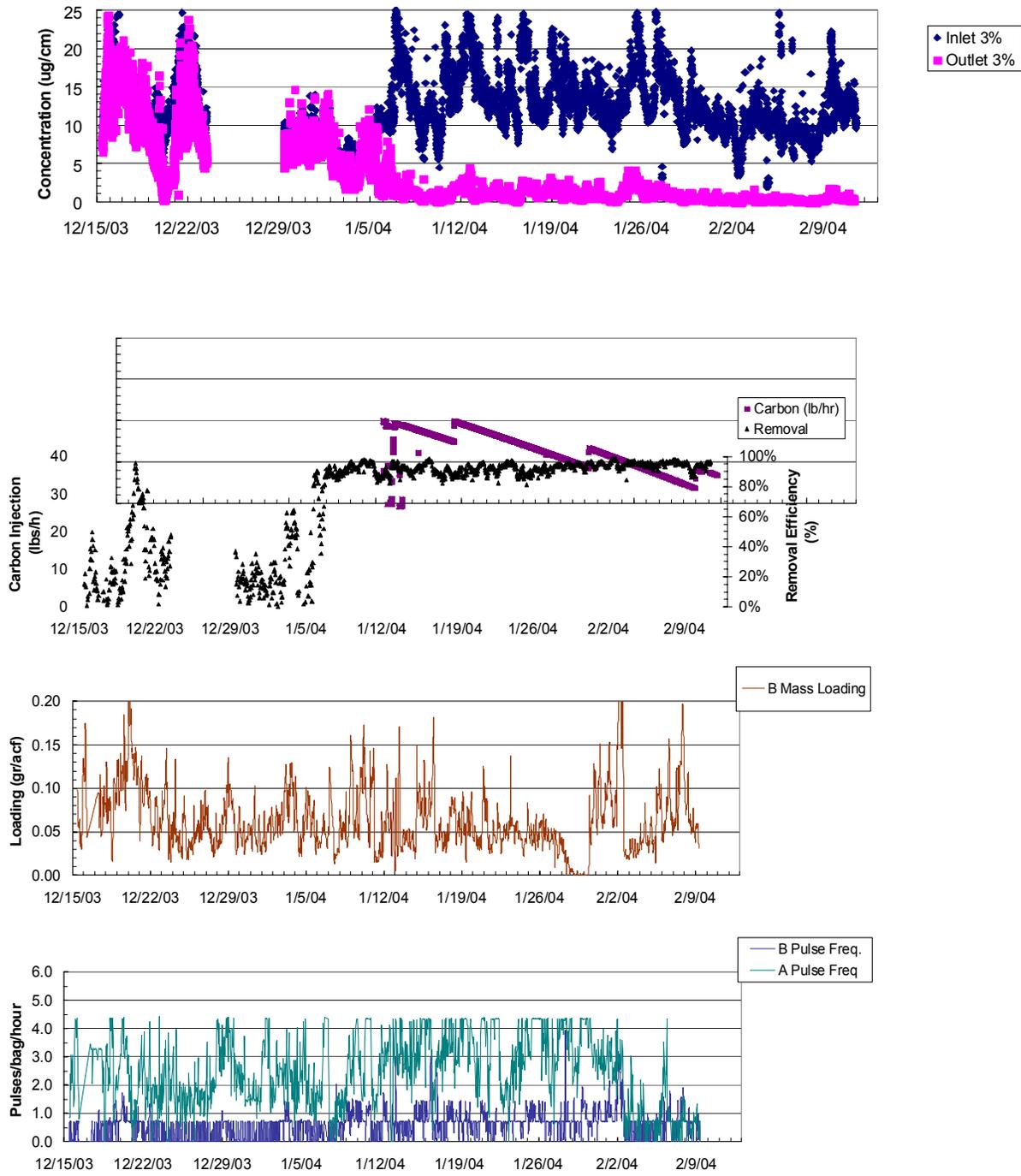


Figure 36. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, COHPAC® Cleaning Frequency and Inlet Mass Loading on Unit 3 COHPAC®, December 15, 2003–February 11, 2004.

Table 16. Average Mercury Removal, Inlet Mass Loading, and Cleaning Frequency with High-Perm Bags.

Injection Rate (lb/h)	Injection Concentration (lb/MMacf)	RE (%)	Inlet Mass Loading (gr/acf)	Cleaning Frequency (pulses/bag/hour)
20	0.6	87	0.1	0.6
25	0.8	91	0.05	0.7
30	1.0	94	0.06	0.7
35	1.1	93	0.02	0.6
45 ^a	1.3 ^a	92 ^a	0.05 ^a	1.0 ^a

a. Long-term test: these data are from only the first two weeks at this condition.

Bag Inspection and Residual Drag Measurements on High-Perm Bags

During the February outage, Southern Research Institute conducted a bag inspection and drag measurements. Before taking the baghouse offline, a fluorescent powder (Visolite™) was injected into the four compartments on Unit 3 baghouse (two compartments each on A- and B-sides). The compartments were then opened and the top of the tube sheet inspected with a black light. Seven failed bags were found in the B-side baghouse and eight bags' locations were found where there was either no bag or the bag had slipped down the cage. All of the missing or failed bags appeared to be caused by poor installation. New, high-Perm bags were used to replace the failed and missing bags.

The average drag of the high-Perm bags after less than three months of operation was 0.11 inches H₂O/ft/min. This low value is typical for a new bag.

Baseline Test Period 2 (April 20–May 4, 2004)

Unit 3 was put back into service the weekend of April 17, 2004. ADA-ES began monitoring inlet and outlet mercury concentrations on April 20. There were two additional, short outages after April 17. After an outage in which a hot-side ESP undergoes maintenance and washing, performance is generally much better than it was before the outage. Hot-side ESPs suffer from sodium depletion and washing the plates and wires removes high resistivity ash from these surfaces and allows power levels to increase to near-design conditions. In expectation of much-improved ESP performance after the outage and lower inlet particulate loading, a period of baseline operation was planned to document COHPAC® performance under these new conditions.

Unit 3B COHPAC® performance was monitored in baseline conditions, no carbon injection, from April 20 until May 4. Figure 37 presents data from this period. The graphs show inlet and outlet mercury concentrations, boiler load, mercury removal efficiency, ash LOI measurements, mass loading into both Unit 3B and 3A baghouses, and pulse frequency for Unit 3B.

As can be seen in Figure 37, inlet mass loading into Unit 3B baghouse varied from 0.012 to greater than 0.25 gr/acf. Unit 3A mass loading was much lower and did not have the high excursions that 3B experienced.

Although not shown, there was also a flow imbalance between the sides. At full-load, B-side was operating at about 580,000 acfm (A/C ratio of ~ 9.0 ft/min) while A-side was operating at about 507,000 acfm (A/C ratio of ~ 7.9 ft/min). This significant difference in flow may be part of the reason that the hot-side ESP performance was so poor on B-side immediately after the outage.

The relatively low cleaning frequency on the 3B baghouse, even with high loading and high A/C ratio, could be attributed to the recently installed high-perm bags that had low residual and dynamic pressure drop. If these conditions had occurred with the original bags, the baghouse would have been in a continuous clean.

High inlet mass loading again resulted in variable baseline mercury removal. During baseline testing, removal efficiency varied between 0 and 83%. Periods with mercury removal greater than 60% correlated with high inlet mass loading. LOI values varied between 20 and 30%, with an average LOI of 25%.

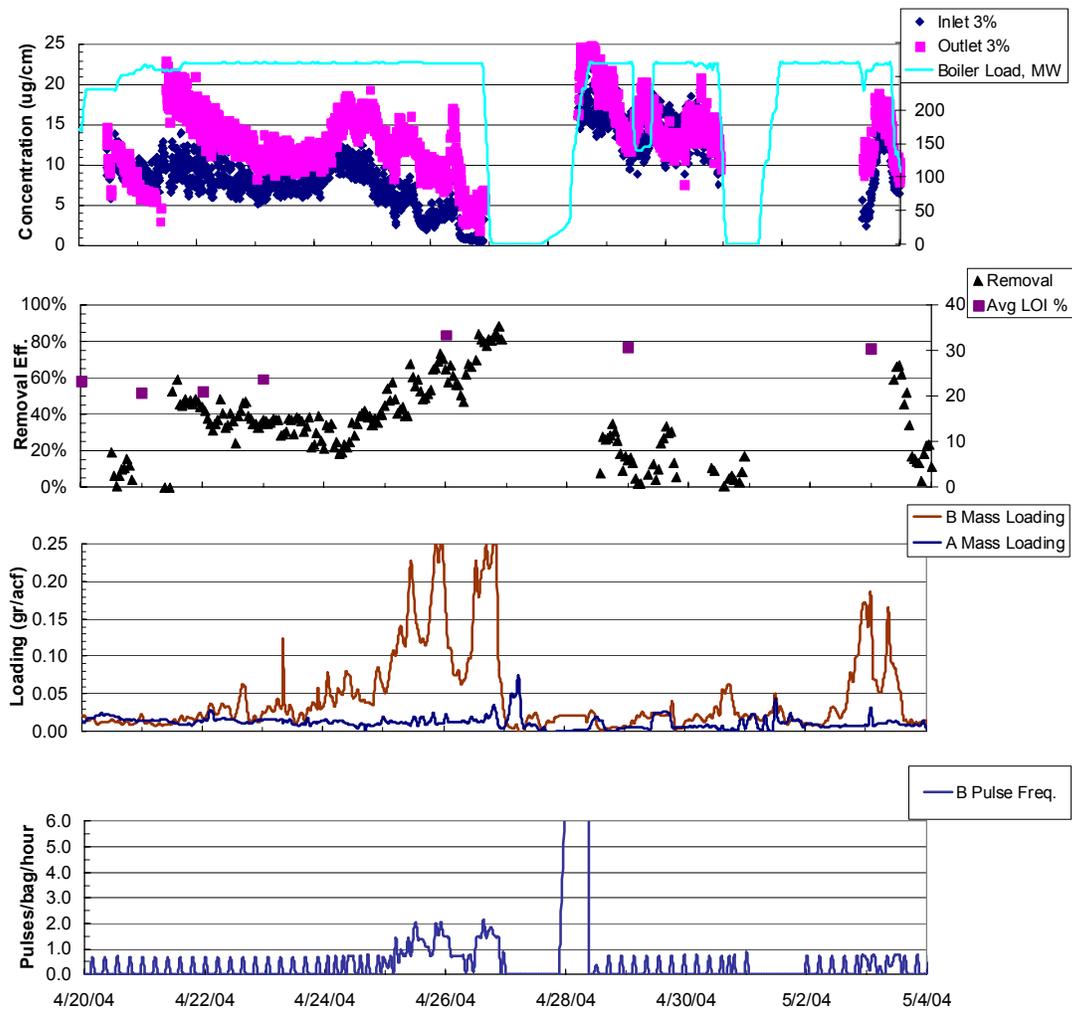


Figure 37. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, COHPAC[®] Cleaning Frequency and Inlet Mass Loading on Unit 3 COHPAC[®], April 20–May 4, 2004.

To illustrate the impact of inlet loading on native mercury removal, a comparison of the carbon content of the inlet mass loading and removal efficiency was made. Figure 38 shows an approximation of inlet carbon concentration and mercury removal over the same time period. Carbon loading was calculated by:

1. Estimating inlet total particulate loading from the output of the BHA particulate monitor
2. Estimating percent carbon from on-site LOI measurements of COHPAC[®] hopper ash
3. Using flow rate measured upstream of the baghouse and recorded on the COHPAC[®] computer

Keeping in mind that carbon concentration is an estimate, several interesting observations can be made from Figure 38:

- At native carbon concentrations above nominally 2 lb/MMacf, mercury removal varies directly with carbon concentration.
- At native carbon concentrations less than 2 lb/MMacf, mercury removal does not appear to vary with injection concentration. Comparing this performance to activated carbon performance, where 90% removal was obtained at injection concentrations > 1 lb/MMacf, illustrates the difference in effectiveness between an activated and an LOI carbon for mercury control.

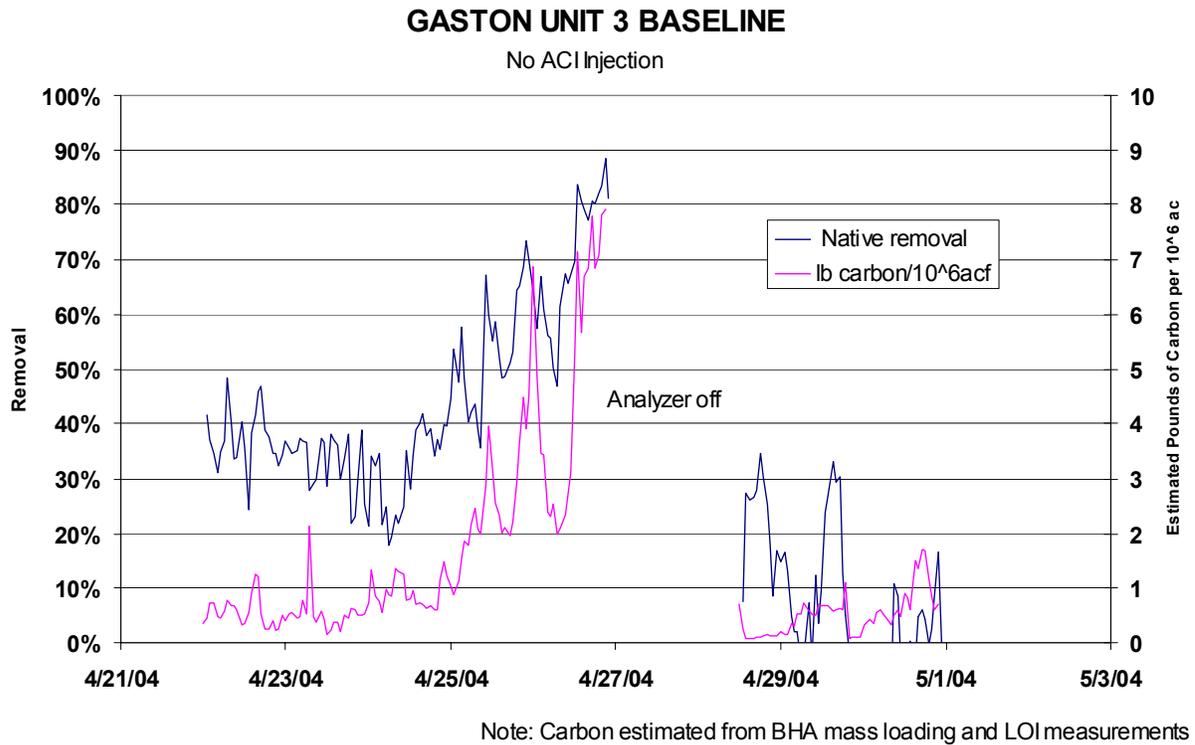


Figure 38. Comparison of Inlet Carbon Loading and Removal Efficiency Trends during Baseline Operation. Inlet Carbon Loading Estimated Using the BHA Particulate Monitor.

Carbon Injection Test Period 2 (May 4–June 4, 2004)

Carbon injection was started again on May 4, 2004. From May 4 through May 21, the injection system control logic was again set to vary injection rate based on inlet loading. Table 17 presents the set point for injection rates at different inlet mass loading conditions. On May 21, the system was set to inject continuously at 45 lb/h (1.3 lb/MMacf) to evaluate a constant injection approach.

Table 17. Activated Carbon Injection Operating Parameters.

Inlet Loading (gr/scf)	Inlet Loading (gr/acf)	Injection Concentration (lb/MMacf)	Carbon Injection Rate (lb/h)
< 0.1	< 0.07	1.0 or 1.2	30 or 35
0.1–0.2	0.07–0.14	0.6	20
> 0.2	> 0.14	0	0

Performance and operating data with carbon injection can be seen in Figure 39. The graphs show inlet and outlet mercury concentrations, carbon injection rate, mercury removal efficiency, mass loading into both Unit 3B and 3A baghouses, and pulse frequency for Unit 3B.

As can be seen in the figure, inlet mass loading was highly variable during this period, with one episode of sustained, high inlet loading. When inlet loading was high, carbon injection rate varied between 0 and 30 lb/h. Bag cleaning frequency increased to as high as 2.5 p/b/h and was often near 2.0 p/b/h.

Average mercury removal from May 4 through May 21 at 12:00 p.m., when injection rate was varying with inlet loading, was 82%. Average mercury removal when the injection rate was held steady at 45 lb/h (1.3 lb/MMacf) was 92%, with a maximum hourly value of 98% and a minimum hourly value of 80%.

Average mercury removal when the injection rate was held steady at 54 lb/h (1.6 lb/MMacf) was 91%, with a maximum hourly value of 98% and a minimum hourly value of 79%.

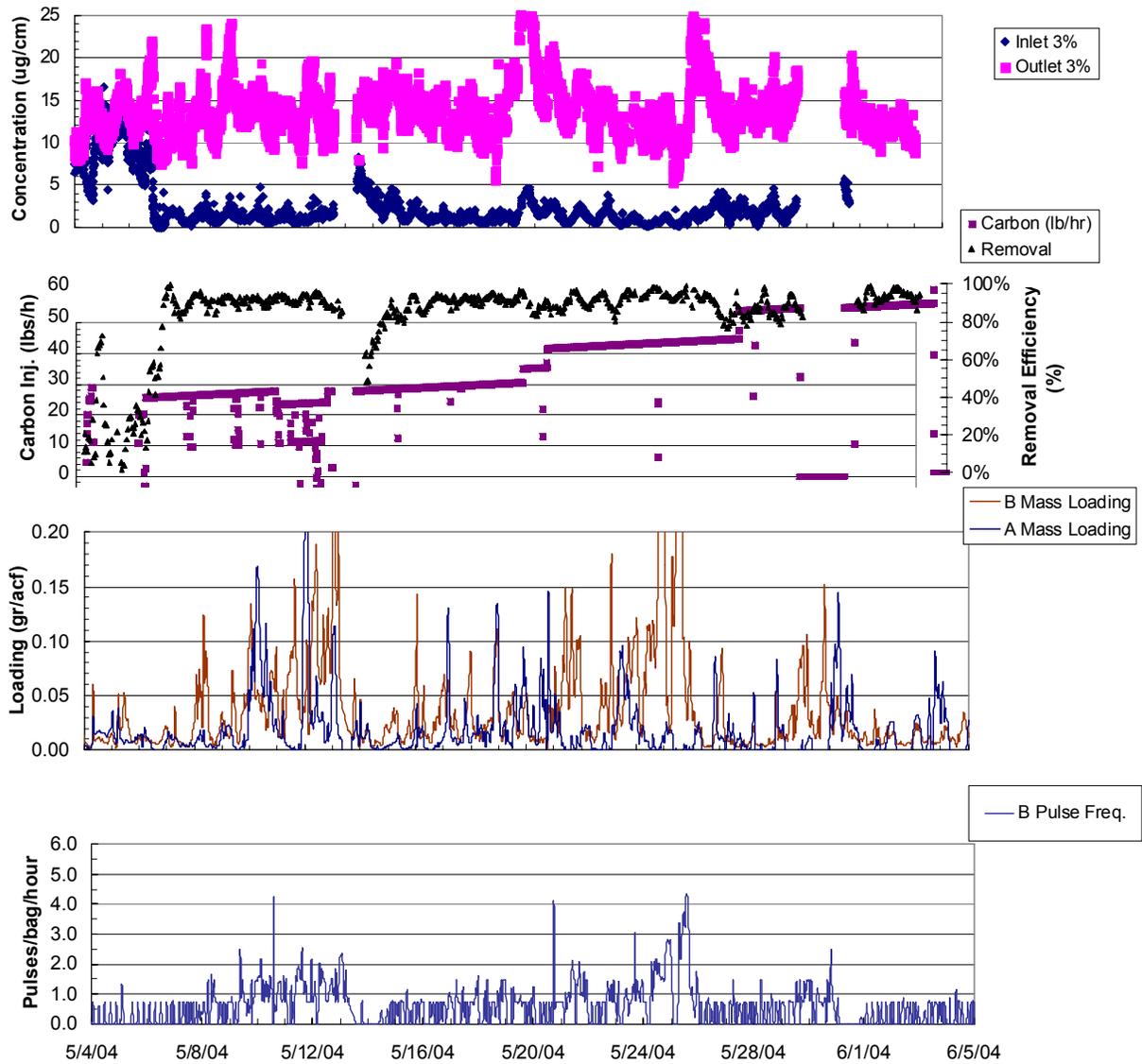


Figure 39. Inlet and Outlet Mercury Concentrations, Removal Efficiency, Activated Carbon Injection Concentration, COHPAC[®] Cleaning Frequency and Inlet and Outlet Mass Loading on Unit 3 COHPAC[®], May 4–June 4, 2004.

Table 16 showed previous results of average mercury removal at different injection rates. Table 18 presents these data again, plus the average mercury removal at 45 and 55 lb/h, which were evaluated during this period. Before the spring outage, mercury removal was held at greater than 90% at an injection rate of 35 lb/h (1.1 lb/MMacf). After the spring outage, it was difficult to maintain the same removal at the same injection rate, so the injection rate was increased to 45 lb/h. As Table 18 shows, this did not increase the injection concentration by much because flow into the 3B baghouse was significantly higher after the outage. The injection rate was then raised to 55 lb/hour (1.6 lb/MMacf). There was no measurable difference in average mercury removal between the two conditions.

Table 18. Average Mercury Removal with Carbon Injection and High-Perm Bags before and after Spring Outage.

Injection Rate (lb/h)	Injection Concentration (lb/MMacf)	Removal Efficiency Data Collected before Spring Outage (%)	Removal Efficiency Data Collected after Spring Outage (%)
20 ^a	0.6 ^a	87	
25 ^a	0.8 ^a	91	
30 ^a	1.0 ^a	94	
35 ^a	1.1 ^a	93	
45 ^b	1.3 ^b		92
55 ^b	1.6 ^b		91

- a. Data obtained before spring outage. Flow value used to calculate injection concentration was 500,000 acfm.
- b. Data obtained after spring outage. Flow value used to calculate injection concentration was 575,000 acfm.

Table 19 compares performance between the original and high-Perm bags with similar activated carbon injection rates. At 20 lb/h (0.6 lb/MMacf), mercury removal was virtually the same (86% versus 87%). The primary difference in performance was seen in the cleaning frequency required to maintain a target pressure drop < 7.0 inches H₂O. With the original bags, which had been in service for more than three years, the cleaning frequency was 3.8 p/b/h. Under similar inlet mass loading conditions, the cleaning frequency with the high-Perm bags was 0.7 p/b/h.

Table 19. Performance Comparison with 2.7- and 7.0-Denier Bags.

	2.7-Denier	7.0-Denier
Injection Rate (lb/h)	20	20
Injection Concentration ^a (lb/MMacf)	0.6	0.6
Mercury Removal (%)	86	87
Cleaning Frequency (pulses/bag/hour)	3.8	0.7
Duration (days)	20	6

- a. Injection concentration calculated at full load condition.

Ontario Hydro Mercury Testing (May 26–27, 2004)

Weston Solutions, Inc., conducted the third and final set of Ontario Hydro tests on May 26 and 27, 2004. These tests included simultaneous inlet and outlet measurements of speciated mercury following the Ontario Hydro method, multiple metals sampling at the outlet, and hydrogen chloride sampling at the inlet.

During the tests, the injection rate was set at 45 lb/h (1.3 lb/MMacf). Results from these tests can be seen in Table 20. Average inlet mercury concentration was 15.6 µg/Nm³ (11.3 lb/TBtu). There was minimal particulate phase, 43% oxidized, and 56% elemental mercury at the inlet. The average outlet mercury was 2.3 µg/Nm³ (1.7 lb/TBtu), with 43% in the particulate phase, 48% oxidized, and about 8% elemental. The average removal was 85%. For comparison, the results from testing in October on the original bags are shown in Table 21. The most notable difference between the two tests is in the particulate-phase mercury numbers. In the earlier tests, a significant percentage of the inlet mercury was reported as particulate (44%), compared to < 1% in these tests. This is especially peculiar because we know that the inlet mass loading was at least as high as it was during the first test and that when there is particulate on the filter during an Ontario Hydro test, the particulate usually scrubs the mercury causing a significant percentage of the mercury to be reported as particulate. After reviewing run sheets, samples, and laboratory analysis, there appears to be no reason to suspect these data.

Table 20. Results from Ontario Hydro Tests across the Unit 3B COHPAC[®] with Activated Carbon Injection at 1.3 lb/MMacf and High-Perm Bags, May 26–27, 2004.

	Particulate (µg/Nm ³) ^a	Oxidized (µg/Nm ³) ^b	Elemental (µg/Nm ³)	Total (µg/Nm ³)	S-CEM ^c Comparison
COHPAC [®] Inlet	0.07	6.7	8.8	15.6	9.9–18.0
COHPAC [®] Outlet	1.0	1.1	0.18	2.3 ^d	0.6–2.0
Removal Efficiency	-1,328%	83%	98%	85%	~92%

- a. Normal conditions = 32 °F
- b. All mercury measurements corrected to 3% O₂
- c. S-CEM only measures vapor-phase mercury
- d. 2.3 µg/Nm³ = 1.7 lb/TBtu

Table 21. Results from Ontario Hydro Tests across the Unit 3B COHPAC[®] with Activated Carbon Injection at 0.6 lb/MMacf and Original Bags, October 8–9, 2003.

	Particulate ($\mu\text{g}/\text{Nm}^3$) ^a	Oxidized ($\mu\text{g}/\text{Nm}^3$) ^b	Elemental ($\mu\text{g}/\text{Nm}^3$)	Total ($\mu\text{g}/\text{Nm}^3$)	S-CEM ^c Comparison
COHPAC [®] Inlet	4.5	2.5	3.1	10.2	8.7–13.4
COHPAC [®] Outlet	0.6	1.3	0.3	2.0 ^d	0.6–2.2
Removal Efficiency	86.7%	48.0%	91.0%	80.4%	83–95%

- a. Normal conditions = 32 °F
- b. All mercury measurements corrected to 3% O₂
- c. S-CEM only measures vapor-phase mercury
- d. $2.0 \mu\text{g}/\text{Nm}^3 = 1.5 \text{ lb}/\text{TBtu}$

The S-CEM data correlated well with the Ontario Hydro results. S-CEM measurements and Ontario Hydro measurements are shown together in Figure 40. The S-CEM only measures vapor-phase mercury. The Ontario Hydro data points in Figure 40 are only the vapor phase portion of mercury (particulate-phase mercury was subtracted from the total mercury concentration). Both methods showed a large increase in inlet mercury on May 27. Both methods also show about 92% removal of vapor-phase mercury.

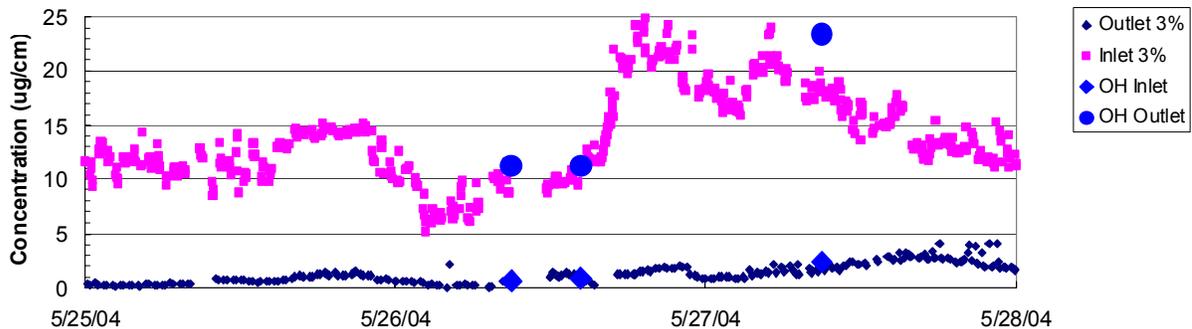


Figure 40. Inlet and Outlet, Vapor-Phase Mercury Concentrations Measured with a S-CEM and the Ontario Hydro Method, May 26–27, 2004.

Particulate Matter Emission Tests (September 9, 2004)

One important test that was inadvertently omitted while the Ontario Hydro tests were being performed in May 2004 was a measurement of outlet emissions with the high-perm bags. Weston Solutions, Inc., conducted these tests on September 9, 2004. A set of three emission tests, following EPA Method 17, were made in the outlet duct of the Unit 3B COHPAC[®] baghouse. The results from these tests and inlet tests conducted in May 2004 can be seen in Table 22.

The inlet measurements show the wide variability in inlet loading, ranging from 0.003 to 0.241 gr/dscf. The outlet mass loading, mean of 0.024 gr/dscf, was higher than expected.

This outlet emission concentration is within the range that would be expected at the inlet to the baghouse. Typical emissions from previous tests at Gaston with 2.7-denier bags were < 0.003 gr/dscf. Emissions from a COHPAC® baghouse installed at TXU’s Big Brown Station with both 2.7- and 7.0-denier bags were also much lower than the 0.024 gr/dscf measured in these tests.

It is suspected that bag failures are the cause of the higher than expected outlet emissions. In the spring outage, several bags that were improperly installed in December were found and replaced. Additional problems could have occurred between March and September. Unfortunately, it is very difficult to gain permission to isolate compartments when the unit is online.

Table 22. Results from Method 17 Particulate Emission Tests with High-Perm Bags at the Unit 3B COHPAC® Inlet in May 2004 and the Unit 3B COHPAC® Outlet in September 2004.

Location/Test Dates	Run 1	Run 2	Run 3	Mean
Inlet/May 2004	0.241	0.064	0.003	0.103
Outlet/September 2004	0.035	0.022	0.015	0.024

Task 4 – Testing of Alternative Sorbents

Evaluating carbons from different manufacturers was the final testing task of the program. This testing was included to broaden the options of suppliers and sorbents evaluated in this program. An invitation letter was sent to nine different sorbent suppliers asking them if they would like to participate in the Gaston program. Seven suppliers responded positively and two declined. Two companies provided more than one option. A summary of the company, product name, price of the sorbent for these tests, projected prices for commercial use, and a brief product description can be found in Table 23. The product description in some cases includes sorbent characteristics such as particle size, molasses number, iodine number, and density.

Southern Company also had two sorbents that were available from within their system that they wanted to test. One sorbent was ash from the Southern Company’s Power System Development Facility (PSDF). The PSDF has an advanced coal-based gasifier pilot plant. The second sorbent was a proprietary mixture of products from the Southern Company system.

Many new sorbents were being developed and tested in on-going DOE and EPRI projects. One sorbent, NORIT’s E3, showed very promising results. This sorbent was chemically treated and high removal efficiencies were achieved at much lower injection concentrations, when compared to standard, untreated activated carbons. This sorbent was included in the list of alternatives at the last minute.

Because the baseline conditions were so variable, which makes it difficult to interpret short-term tests, and because there was only a four-week period set aside for these tests, it was decided to evaluate three sorbents in weeklong tests and five sorbents in one-day tests. The weeklong tests were necessary to understand how these alternative sorbent products perform with varying conditions. It was hoped that the weeklong tests would provide the information necessary to set up the daylong tests in a way to obtain meaningful results.

Sorbents were selected by Southern Company, EPRI, and ADA-ES. The sorbents chosen for the weeklong tests were NORIT's E3, PSDF ash, and the Southern Company mix (SCS mix).

Sorbent chosen for the daylong tests were:

- CARBOCHEM's MGF-20, a low-cost (\$0.15/lb) carbon
- Superior Adsorbents' Merqsorb
- General Technologies' PC-800
- Donau Carbon's DX 400C
- RWE's HOK™ Super

The test schedule is shown in Table 24. For these tests, a portable feeder was installed next to the silo and attached to the existing transport hoses. This size feeder was used so that supersack quantities of materials could be used, instead of having to load the large silo with the alternative products. A Porta-PAC™ feeder was leased from NORIT.

Table 23. DOE/NETL Long-Term Mercury Control Program Sorbent Selection Alabama Power's E.C. Gaston Steam Plant Unit 3.

Company	Product Name	Project Price	Projected Price	Product Description
RWE	Activated Lignite HOK™ Super	1 supersack free	~ \$0.35/lb	Besides its internal pore structure suitable for adsorption, this sorbent, as a result of the milling rate applied, has an extremely large outer surface area so that correspondingly high adsorption efficiencies can be attained
CARBOCHEM	MGF-20	\$0.15/lb bulk or supersacks	\$0.15/lb bulk or supersacks	None provided
	MC-40	\$0.25/lb bulk or supersacks	\$0.25/lb bulk or supersacks	None provided
	IMC-10	\$0.49/lb bulk or supersacks	\$0.49/lb bulk or supersacks	None provided
	IMS-10	\$0.51/lb bulk or supersacks	\$0.51/lb bulk or supersacks	None provided
Donau Carbon	DESOREX® DX 400C	\$0.25/lb + freight (cost share)	~ \$0.34/lb	Iodine #mg/g > 400. Product supersedes DESOREX® HOK™ 300S. Bulk density ~ 33 lb/cu ft, particle size is 95% < 325 mesh, adsorption capacity is in excess of 7 wt. %
Superior Adsorbents, Inc.	Merqsorb	5,000–10,000 lb free (in supersacks); ADA-ES to pay freight	~ \$0.40/lb	Same product as used at Brayton Point, Pleasant Prairie, Gaston, etc. High kinetic rate of adsorption, easy flow, steam/thermal activation
General Technologies	PC-800 (FJ045)	\$0.50/lb supersack	\$0.34/lb supersack, \$0.37/lb truck	PAC made from bituminous coal. Iodine 800 mg/g
NORIT Americas	DARCO® FGD-XTR	\$0.27/lb supersack (cost share)	~ \$0.34/lb	Experimental, can be produced at lower costs and may perform as well for mercury removal in certain equipment configurations. Molasses decolorizing efficiency = 20–40, mesh size < 325, Iodine #350–450, density 40–50 lb/cu ft
	DARCO® FGL	\$0.27/lb	List price	Should be tested at this location because it may provide some cost advantages if it performs as well as DARCO® FGD. Iodine #500 mg/g, sulfur % 0.6, density 0.63 g/mL
Barnebey Sutcliffe (Calgon)	FLUEPAC™	\$0.45/lb (ADA-ES provides supersack)	\$0.38/lb supersack, \$0.32/lb bulk	Iodine #600
Amended Silicates	DECLINED			
Sorbtech	DECLINED			

Table 24. Alternative Sorbent Test Schedule.

							Test Description	
Jun-04	S	M	T	W	T	F	S	
	30	31	1	2	3	4	5	Final week of long-term tests
	6	7	8	9	10	11	12	Evaluate NORIT E3
	13	14	15	16	17	18	19	Evaluate PSDF Ash
	20	21	22	23	24	25	26	Evaluate SCS Proprietary Mix
	27	28	29	30	1	2	3	Single day tests of alternative sorbents

Single Day Test Schedule

- 28 **CARBOCHEM MGF-20**
- 29 **Superior Adsorbents Merqsorb**
- 30 **General Technologies PC-800**
- 1 **Donau DX 400C**
- 2 **RWE HOK™ Super**

Removal efficiency measured at each of the conditions tested is shown in Table 25. In most cases, the removal efficiency is shown with a “<” symbol before the value. This convention is used to indicate that this value was the highest removal efficiency measured during the test. Because these tests were short and conditions were not stable, this value is not necessarily the steady state value that would be achieved if longer testing was possible.

Figure 41 graphically presents the data in Table 25. This graph also shows results from parametric tests conducted in the Phase I program in 2001.

The results indicate that NORIT’s E3, RWE’s HOK™ Super, General Technologies’ PC-800 and Southern Company’s proprietary mix all had similar performance and were identical to performance of standard activated carbons tested in the more comprehensive parametric test series in 2001. SAI’s Merqsorb had a slightly lower mercury removal than the best performers, but taking into account the variable baseline mercury removal that occurred during this test, this sorbent performance should be considered similar to the others.

The other three sorbents were not as effective for mercury removal. The Donau product had good mercury removal, 50%, at an injection concentration of 1.6 lb/MMacf, but it did not reach the 70% range that some of the others did.

The CARBOCHEM low-cost sorbent, MGF-20, performed poorly, achieving only 20% mercury removal at greater than 3.0 lb/MMacf. CARBOCHEM responded to our request for sorbents with four different options, one of which was MGF-20. This performance was surprising because ADA-ES has tested other CARBOCHEM sorbents that showed very good performance, similar to other standard activated carbons.

Table 25. Alternative Sorbent Parametric Test Results.

Carbon ID	Injection Rate (lb/h)	Injection Concentration (lb/MMacf)	Removal Efficiency (%)
NORIT E3 (A)	20	0.6	< 60
NORIT E3 (A)	28	0.8	< 70
NORIT E3 (A)	35	1.0	< 75
NORIT E3 (A)	20	1.8	90
NORIT E3 (A)	28	1.8	93
NORIT E3 (A)	35	1.8	93
PSDF Ash (B)	60	1.7	< 36
PSDF Ash (B)	120	3.4	< 48
RWE HOK™ Super(C)	55	1.5	< 78
RWE HOK™ Super (C)	55	3.1	95
SCS Proprietary Mix (D)	63	1.9	< 79
CARBOCHEM MGF-20 (E)	55	1.6	< 20
CARBOCHEM MGF-20 (E)	110	3.1	< 20
SAI Merqsorb (F)	56	1.6	< 67
General Technologies PC-800 (G)	56	1.6	< 80
Donau DX 400C (H)	55	1.6	< 50

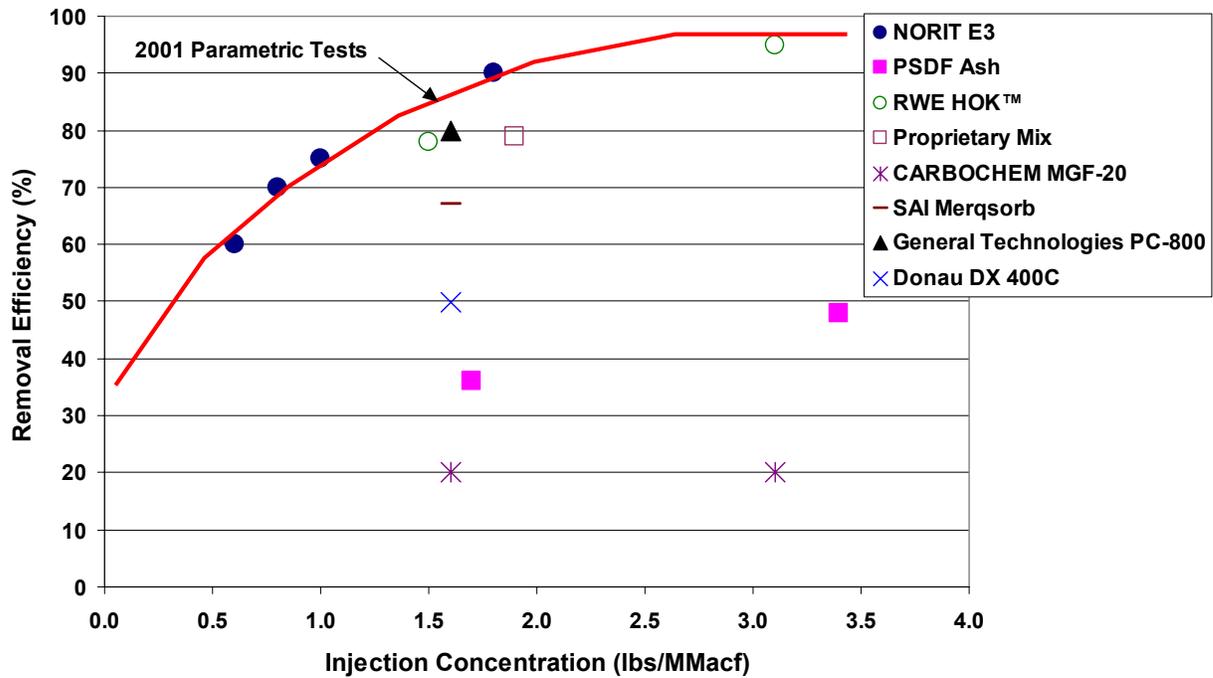


Figure 41. Results from Parametric Testing of Alternative Sorbents at Gaston Unit 3B COHPAC[®], June 2004.

Southern Company's PSDF ash showed that it is capable of adsorbing mercury, but that it might take high injection concentrations to reach removal efficiencies greater than 70%.

The overall conclusions from these tests are:

- Most standard, high-quality activated carbon performed similarly at this site.
- The low-cost sorbent and ash-based sorbents were not very effective at removing mercury.
- Chemically enhanced sorbents do not appear to offer any benefits over standard activated carbons.

ECONOMICS

After completion of testing and analysis of the data, the requirements and costs for full-scale, permanent commercial implementation of the necessary equipment for mercury control using sorbent injection technology have been determined. The cost of process equipment that is sized and designed based on long-term test results for approximately 80–90% mercury control and on the plant-specific requirements (sorbent storage capacity, plant arrangement, retrofit issues, winterization, controls interface, etc.) has been estimated. The system design was based on the criteria listed in Table 26.

Table 26. System Design Criteria for Mercury Control at Gaston Unit 3.

Parameter	
Number of silos	1
Number of injection trains	2
Design feed capacity/train (lb/hr)	100
Operating feed capacity/train (lb/hr)	40
Sorbent storage capacity (lbs)	50,000
Conveying distance (ft)	250
Sorbent	Powdered activated carbon
Aerated density (lb/ft ³)	18
Settled density (lb/ft ³)	34
Particle MMD (microns)	18

System Description

The permanent commercial ACI system will consist of a bulk storage silo and a dilute phase pneumatic conveying system. Figure 42 is a process diagram of the ACI system. NORIT provided a detailed quote for this equipment; the quote is included in Appendix H.

PAC sorbent will be received in 40,000-lb batches delivered by self-unloading pneumatic bulk tanker trucks. The silo is equipped with a pulse jet type bin vent filter to contain dusting during the loading process. The silo is a shop-built, dry-welded tank with twin mass flow discharge cones equipped with air fluidizing pads and nozzles to promote powder flow. Point level probes and weigh cells monitor sorbent level and inventory. Silo sizing was based on the capacity to hold 1.25 truckloads of PAC. This will allow one week of operation after the refill level has been reached.

The PAC is fed from the discharge cones by rotary valves into feeder hoppers. From the hoppers, the PAC is metered into the conveying lines by volumetric feeders. Conveying air supplied by regenerative blowers passes through a venturi eductor, which provides suction to

draw the PAC into the conveying piping and carry it to distribution manifolds where it splits equally to multiple injection lances. The blowers and feeder trains are contained beneath the silo within the skirted enclosure.

A programmable logic controller (PLC) is used to control all aspects of system operation. The PLC and other control components will be mounted in a NEMA 4 control panel. The control panel, MCCs, and disconnects will be housed in a prefabricated power and control building located adjacent to the silo.

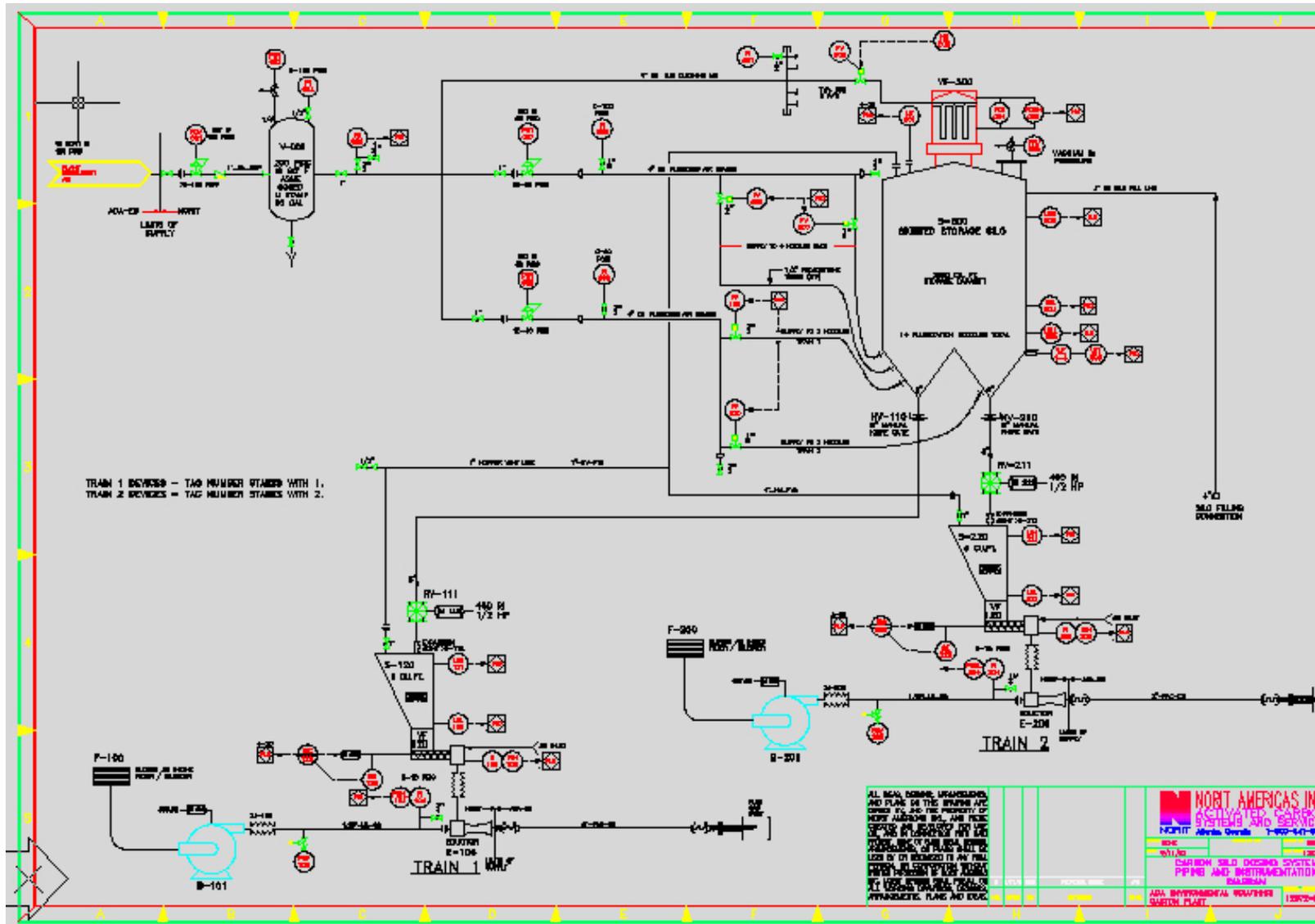


Figure 42. Diagram of Activated Carbon Injection System for Gaston Unit 3.

Balance-of-Plant Requirements

Some modifications and upgrades to the existing plant equipment will be required to accommodate the ACI system. These include upgrades to the electrical supply at Gaston to provide new service to the ACI system. Instrument air, intercom phones, and area lighting will also be required.

Cost and Economic Methodology

Costs for the sorbent storage and injection equipment were provided by NORIT based on the design data in Table 26. NORIT has built and installed dozens of these systems at waste-to-energy and incineration plants. ADA-ES provided costs for the distribution manifold, piping, and injection lances. NORIT also provided an installation man-hour estimate and crane-hour estimate that were used to develop the installation costs for the NORIT equipment, along with an estimate for foundations including pilings.

EPRI Technical Assessment Guide (TAG[®]) methodology was used to determine the indirect costs. A project contingency of 15% was used. Since the technology is relatively simple and well proven on similar scale, the process contingency was set at 5%. ACI equipment can be installed in a few months; therefore, no adjustment was made for interest during construction, a significant cost factor for large construction projects lasting several years.

Operating costs include sorbent costs, electric power, operating labor, maintenance (labor and materials), and spare parts. An average operating labor requirement of four hours per day was estimated to cover the incremental labor to operate and monitor the ACI system. The annual maintenance costs were based on 5% of the uninstalled equipment cost.

Levelized costs were developed based on a twenty-year book life and are presented in constant dollars. More detailed cost information in all categories, including labor rate assumptions, etc., is included in Appendix I.

Capital Costs

The uninstalled ACI storage and feed equipment costs are estimated at \$345,000 \pm 10%. The estimated cost for a sorbent injection system and storage silo installed on 270-MW Unit 3 is \$816,060 and includes all process equipment, foundations, support steel, plant modifications utility interfaces, engineering, taxes, overhead, and contingencies. Table 27 briefly summarizes the capital and operating and maintenance (O&M) costs.

Table 27. Capital and O&M Cost Estimate Summary for ACI System on Gaston Unit 3.

Capital Costs Summary	
Equipment	\$345,000
Site integration (materials and labor)	\$120,000
Installation (ACI silo and process equipment)	\$ 90,000
Taxes/Freight	\$ 27,900
Indirects/Contingencies	\$233,160
Total Capital Required	\$816,060
O&M Costs Summary	
Sorbent @ \$.50/lb	\$245,280
COHPAC [®] bag replacement increase: 2-year rather than 4-year basis	\$108,800
Other miscellaneous costs	\$100,615
Waste disposal	None Assumed
Annual O&M for 2003	\$454,695

Operating and Levelized Costs

The most significant operational cost of ACI is the PAC sorbent. Sorbent costs were estimated for nominally 80% mercury control based on the long-term PAC injection concentration of 1.5 lb/MMacf. For Gaston Unit 3, this would require an injection rate of nominally 80 lb/h. Assuming a unit capacity factor of 70% and a delivered cost of \$0.50/lb for PAC, the annual sorbent cost for injecting PAC into the existing COHPAC[®] baghouse would be about \$250,000. Other annual operating costs including electric power, operating labor, and maintenance were estimated to be approximately \$100,000.

No additional costs were included for waste disposal. This is based on the continued acceptance of the spent PAC sorbent in Gaston's ash pond disposal operation. Waste solids from the COHPAC[®] baghouse (fly ash escaping the ESP plus injected PAC) are estimated at between 500 and 1200 tons per year, depending on the collection efficiency of the ESP.

Baghouse Impacts

The test program showed that ACI significantly changes the required baghouse cleaning frequency. This will have a negative impact on bag life. Under normal operation, the bags at Gaston are projected to have a four-year bag life. The increased wear and tear from the more frequent bag cleaning could reduce the life expectancy to two years, doubling the bag replacement budget. A second option is to install higher-perm bags, which should reduce pressure drop and decrease cleaning frequency. Numerous risks are associated with the high-perm bags, including increased particulate emissions and reduced fabric strength.

For the cost estimate herein, an installed cost of \$100/bag was used, and a two-year rather than four-year life was assumed. With the balance of the above factors taken into account, and with assumptions for labor rates, power cost, and escalation factors as shown in Appendix I, levelized costs were calculated. The first-year costs including fixed capital are \$474,000. Annual twenty-year levelized costs on a current-dollar basis are \$674,000, which includes the increased cost of bag replacement.

Based on these test program results and assuming that the operation mode of ACI into COHPAC[®] is sustainable, between 65 and 90% mercury control can be attained at Gaston Unit 3 for a capital investment of \$816,000 and annual current-dollar levelized costs of \$674,000 (1.5 lb/MMacf sorbent concentration is assumed).

CONCLUSIONS

The conclusions from this program are:

- TOXECON™ testing at Gaston demonstrated an ability to achieve 85% mercury control even with various design limitations.
- TOXECON™ units designed at lower A/C ratios than COHPAC® units are capable of high, 90% mercury removal. For TOXECON™ baghouses, it is recommended that the maximum design gross A/C ratio be 6.0 ft/min.
- Activated carbon injection systems are simple, reliable, and commercially available. The control programs can be easily adapted to varying operating requirements.
- Continuous mercury measurements are challenging but possible. Advancements to the analyzers were made, and with routine maintenance, the analyzers operated twenty-four hours a day, seven days a week for nearly twenty months.
- Activated carbon effectively reduced mercury emissions for extended periods over a wide range of operating variables with a COHPAC® baghouse.
 - At an average injection concentration of 0.55 lb/MMacf over a four-month period, average mercury removal was 86%.
 - For these tests, injection concentration was limited by high, baseline COHPAC® cleaning frequency.
 - High inlet loading and high unburned carbon levels into the COHPAC® baghouse contributed to variable baseline mercury removal. It is also believed that these conditions allowed for higher mercury removal at a relatively low carbon injection concentration.
 - Inlet mercury concentrations varied by a factor of five, from 6 to 30 $\mu\text{g}/\text{Nm}^3$ (4.2–21 lb/TBtu).
 - The outlet mercury concentrations varied from 0.6–2.5 lb/TBtu. Even with 90% removal, there were times when outlet mercury concentrations were nearly 4.0 $\mu\text{g}/\text{Nm}^3$.
- Replacing the original 2.7-denier bags with 7-denier, high-perm bags resulted in lower cleaning frequencies at all conditions.
- Short tests at higher injection rates with the high-perm bags showed that it was possible to achieve greater than 90% average mercury removal. However, mercury removal still varied between 80 and 98% during these periods and higher injection rates would be required to maintain consistent 90% removal.
- Capital cost for the equipment to control mercury at the 270-MW Gaston Unit 3 is estimated at \$816,000 installed. The capital cost of this system is scalable upwards but not significantly scalable downwards because this system represents a relatively low sorbent consumption and storage. The basic components of the system do not decrease in number as the sorbent demand decreases.
- The first year O&M costs are estimated at \$474,000, not including bag replacement since this will not be necessary for at least two years after installation.
- Annual twenty-year levelized costs on a current-dollar basis are \$674,000, which includes the increased cost of bag replacement. This also assumes a sorbent injection concentration of 1.5 lb/MMacf.

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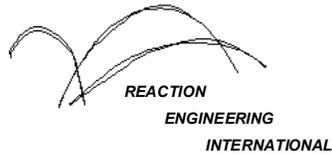
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LIST OF ACRONYMS AND ABBREVIATIONS

A/C	Air-to-Cloth Ratio
ACI	Activated Carbon Injection
APH	Air Pre-Heater
BH	Baghouse
CEM	Continuous Emissions Monitor
COHPAC [®]	<u>C</u> ompact <u>H</u> ybrid <u>P</u> articulate <u>C</u> ollector
CUB	Coal Utilization Byproducts
CVAAS	Cold Vapor Atomic Absorption Spectrometer
DOE/NETL	Department of Energy's National Energy Technology Laboratory
EERC	University of North Dakota Energy and Environmental Research Center
ESP	Electrostatic Precipitator
GFTS	Grubb Filtration Testing Services
HESP	Hot-Side Electrostatic Precipitator
LOI	Loss on Ignition
MCC	Motor Control Centers
MW	Megawatts
O&M	Operating and Maintenance
OEM	Original Equipment Manufacturers
PAC	Powdered Activated Carbon
PLC	Programmable Logic Controller
PPS	Polyphenylene Sulfide
PTFE	Poly Tetra Fluoro Ethylene
SCA	Specific Collection Area
S-CEM	Semi-Continuous Emissions Monitor
SGLP	Synthetic Groundwater Leaching Procedure
TAG	Technical Assessment Guide
TBtu	Trillion British Thermal Units
TCLP	Toxicity Characteristic Leaching Procedure
TOXECON [™]	EPRI Proprietary Air Toxics Control Technology

APPENDIX A

Mercury Leaching from Phase I Ash Samples



Date: November 6, 2002

From: Connie Senior

To: Jean Bustard, ADA-ES

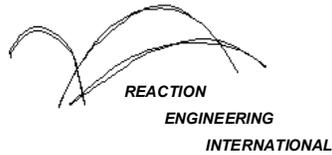
Re: Mercury leaching from Gaston long-term ash samples

Leaching Protocol (EERC)

Many standard leaching procedures exist. The procedure used most often is the toxicity characteristic leaching procedure (TCLP). The method was designed to simulate leaching in an unlined, sanitary landfill, based on a co-disposal scenario of 95% municipal waste and 5% industrial waste. The method is an agitated extraction test using leaching fluid that is a function of the alkalinity of the phase of the waste. Typically an acetic acid solution having a pH of 2.88 is used.

The synthetic ground water leaching procedure (SGLP) was developed at the University of North Dakota Energy and Environmental Research Center (EERC) and was designed to simulate the leaching of CUBs under important environmental conditions. It was initially used to characterize highly alkaline CUBs, primarily fly ash produced from the combustion of low rank coals. The procedure was modeled after the TCLP, but allowing for disposal conditions other than those of a sanitary landfill. Deionized water is used as the leaching solution instead of the acidic solutions used in the TCLP. The SGLP was designed primarily for use with materials such as low-rank coal ash that undergo hydration reactions upon contact with water. Test conditions are end-over-end agitation, a 20:1 liquid to solid ratio and a thirteen-hour equilibration time.

Samples from Gaston were leached at EERC using the standard TCLP procedure and also the synthetic groundwater leaching procedure (SGLP). The Gaston samples were also subjected to sulfuric acid leaching (SAL) at a pH of 2, following procedures similar to TCLP and SGLP. This is an extreme condition that might simulate acid mine drainage. Table 1 gives the leaching results from EERC. With one exception, all of the results (in terms of Hg in leachate) were below the detection limit of 0.01 mg/L.

**Table 1. Leaching results (EERC)**

Sample ID	Sample Type	Location	LOI wt%	Hg μg/g	Hg in TCLP	Leachate SGLP	(mg/L) SAL
GAS00148	COHPAC Ash	B-Side	28.2%	30.6	0.01	<0.01	<0.01
GAS00148	COHPAC Ash	B-Side	28.2%	30.6		<0.01	
GAS00154	COHPAC Ash	B-Side	20.7%	21.7	<0.01	<0.01	<0.01

Column Leaching (NETL)

In addition to the standard leaching procedures carried out at EERC, column leaching experiments were performed by NETL's in-house research group (Ann Kim and George Kazonich). For this test, sample GAS00131 (long-term tests, B-side ash) was leached in different solutions: water, acetic acid, sodium carbonate, "acid rain" stimulant, and sulfuric acid. Leaching was carried out for 120-140 days. These results should be considered preliminary; analysis of a duplicate Gaston sample is currently in progress.

As the following graphs illustrate, very little mercury was leached from the Gaston sample. With the exception of the "acid rain" leachate (pH ~ 8), the mercury in the leachate was below 60 ng/L (or 6×10^{-5} mg/L). The "acid rain" leachate had a maximum mercury concentration of 0.02 mg/L, which is comparable to the TCLP and SGLP results from EERC.

In summary, mercury leaching from the Gaston long-term ash samples collected from the B-side of the COHPAC was measured in solutions ranging from pH 2 to pH 11 for periods of up to 140 days. No significant leaching was observed, either from standard tests, like TCLP, or from column leaching.

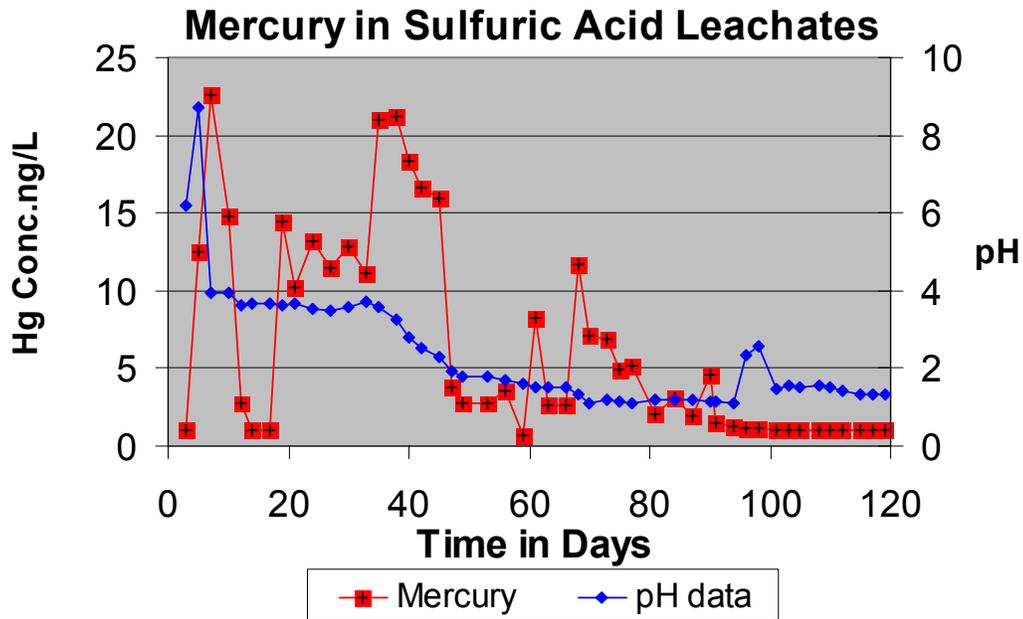
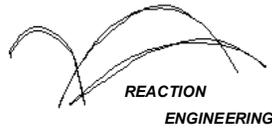


Figure 1. Concentration of mercury in leachate from column leaching procedure in sulfuric acid solution (Source: NETL).

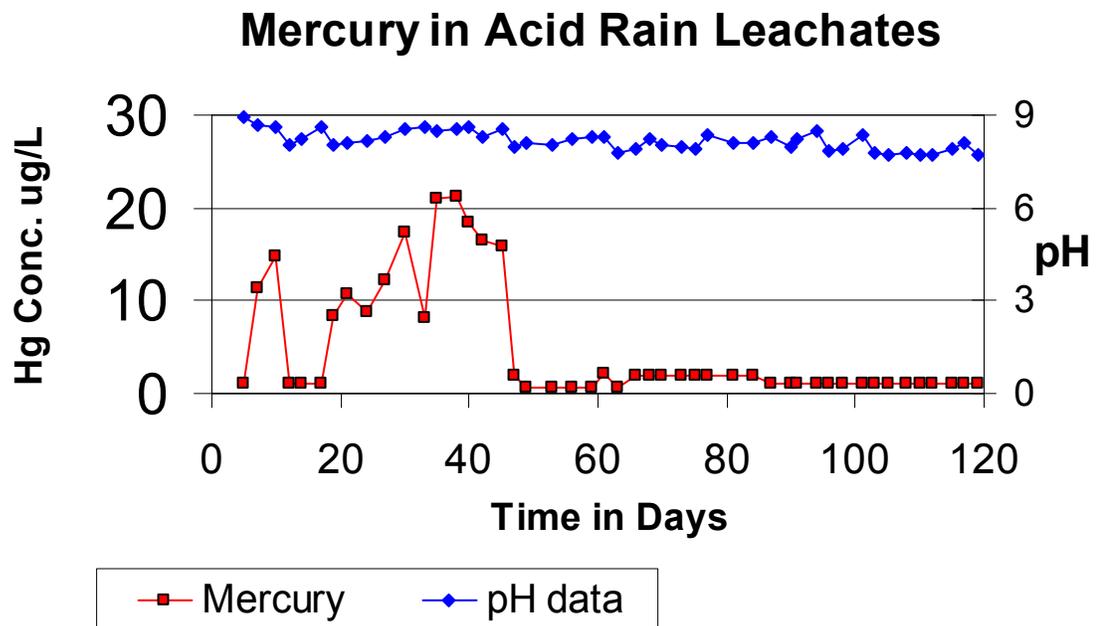


Figure 2. Concentration of mercury in leachate from column leaching procedure in acid rain solution (Source: NETL).

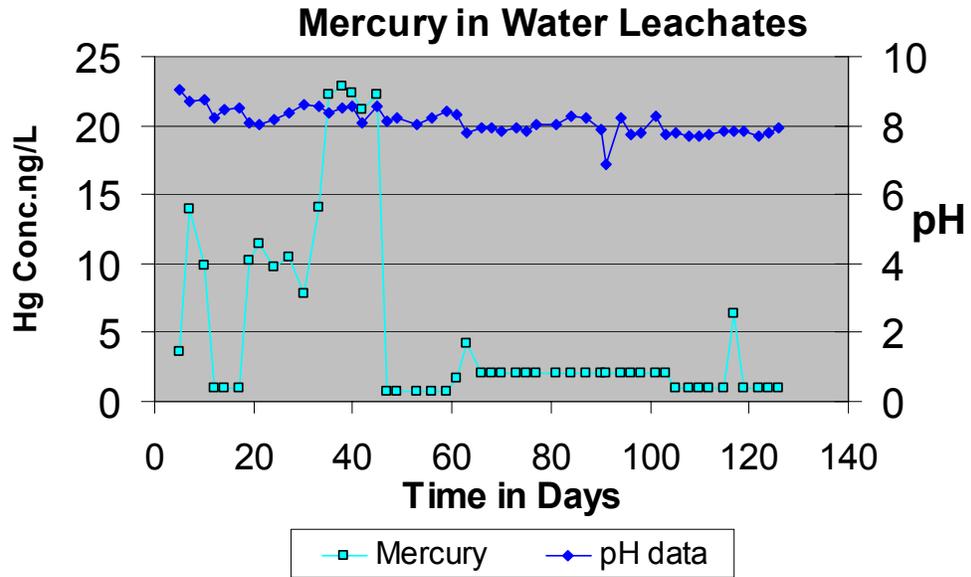
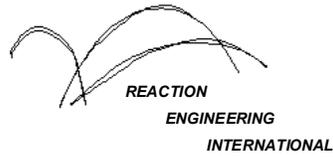


Figure 3. Concentration of mercury in leachate from column leaching procedure in water solution (Source: NETL).

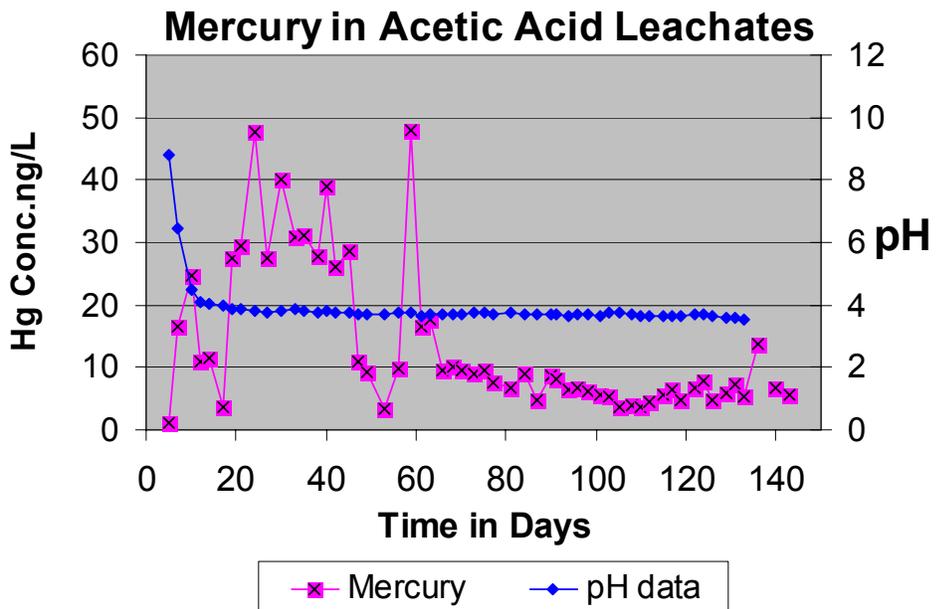


Figure 4. Concentration of mercury in leachate from column leaching procedure in acetic acid solution (Source: NETL).

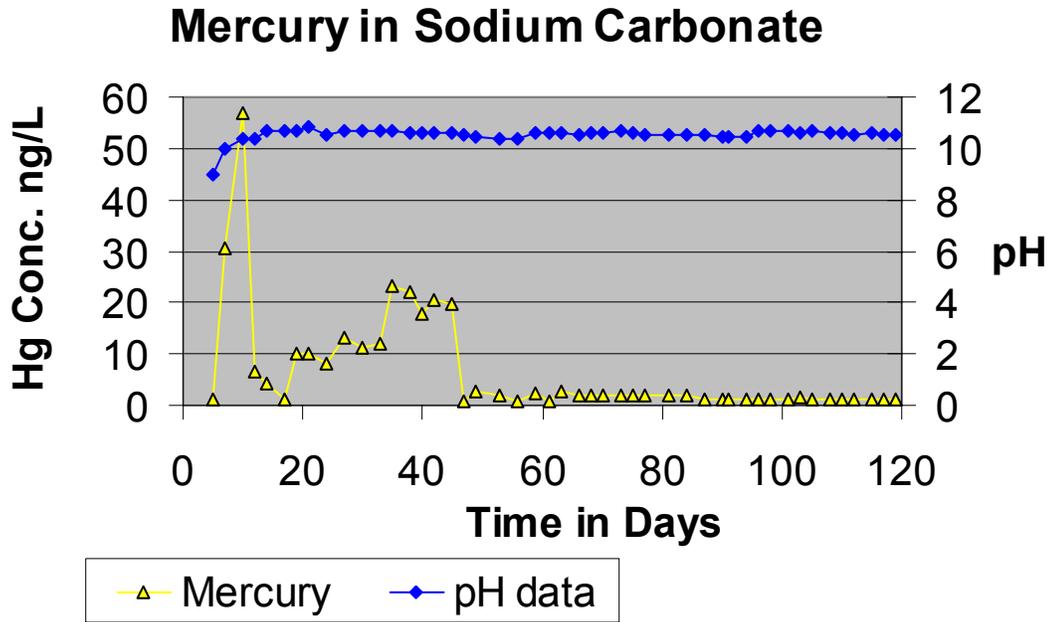
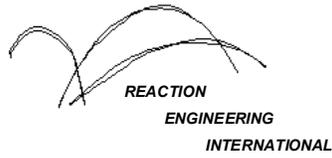


Figure 5. Concentration of mercury in leachate from column leaching procedure sodium carbonate solution (Source: NETL).

APPENDIX B

Database of Collected Samples - Phase II

Samples collected during Baseline Period 1 (March 24 – April 21, 2003)

Sample ID	Unit Number	Plant Name	Date/Time	Project Number	Sampled By	Sample Location	Sample Type	Comments
GAS00174	Unit 3	Gaston	3/23/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00175	Unit 3	Gaston	3/24/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00176	Unit 3	Gaston	3/25/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00177	Unit 3	Gaston	3/27/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00178	Unit 3	Gaston	3/28/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00179	Unit 3	Gaston	3/29/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00180	Unit 3	Gaston	3/30/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00181	Unit 3	Gaston	3/31/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00182	Unit 3	Gaston	4/1/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00183	Unit 3	Gaston	4/2/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00184	Unit 3	Gaston	3/24/03 10:00 AM	7101	CVL	Baghouse B side	Ash	5 gallon bucket
GAS00185	Unit 3	Gaston	3/24/03 10:00 AM	7101	CVL	Baghouse A side	Ash	1 lt. Bottle
GAS00186	Unit 3	Gaston	3/25/03 2:00 PM	7101	CVL	Baghouse B side	Ash	5 gallon bucket
GAS00187	Unit 3	Gaston	3/26/03 10:00 AM	7101	Sdavis	Baghouse B side	Ash	5 gallon bucket West outlet
GAS00188	Unit 3	Gaston	3/27/03 1:00 PM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle West outlet
GAS00189	Unit 3	Gaston	3/27/03 1:00 PM	7101	Sdavis	Baghouse B side	Ash	West center
GAS00190	Unit 3	Gaston	3/27/03 1:00 PM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle West inlet
GAS00191	Unit 3	Gaston	3/27/03 1:00 PM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle East outlet
GAS00192	Unit 3	Gaston	3/27/03 1:00 PM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle East center
GAS00193	Unit 3	Gaston	3/27/03 1:00 PM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle East inlet
GAS00194	Unit 3	Gaston	3/28/03 1:00 PM	7101	Sdavis	Baghouse B side	Ash	5 gallon bucket West outlet
GAS00195	Unit 3	Gaston	3/28/03 1:00 PM	7101	CVL	hot side ESP	Ash	1 lt. Bottle
GAS00196	Unit 3	Gaston	3/31/03 11:00 AM	7101	Sdavis	Baghouse B side	Ash	5 gallon bucket West outlet
GAS00197	Unit 3	Gaston	4/1/03 9:30 AM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle West outlet
GAS00198	Unit 3	Gaston	4/1/03 9:30 AM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle West center
GAS00199	Unit 3	Gaston	4/1/03 9:30 AM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle West inlet
GAS00200	Unit 3	Gaston	4/1/03 9:30 AM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle East outlet
GAS00201	Unit 3	Gaston	4/1/03 9:30 AM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle East center

Sample ID	Unit Number	Plant Name	Date/Time	Project Number	Sampled By	Sample Location	Sample Type	Comments
GAS00202	Unit 3	Gaston	4/1/03 9:30 AM	7101	Sdavis	Baghouse B side	Ash	1 lt. Bottle East inlet
GAS00203	Unit 3	Gaston	4/2/03 8:00 AM	7101	Sdavis	Baghouse B side	Ash	5 gallon bucket Weat outlet
GAS00204	Unit 3	Gaston	4/2/03 9:00 AM	7101	Sdavis	hot side ESP	Ash	1 lt. Bottle
GAS00205	Unit 3	Gaston	4/2/03 3:30 PM	7101	Sdavis	Baghouse A side	Ash	1 lt. Bottle East outlet
GAS00206	Unit 3	Gaston	4/3/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00207	Unit 3	Gaston	4/4/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00208	Unit 3	Gaston	4/3/03 1:40 PM	7101	Sdavis	Baghouse B side	Ash	5 gallon bucket East outlet
GAS00209	Unit 3	Gaston	4/4/03 11:30 AM	7101	Sdavis	Baghouse B side	Ash	5 gallon bucket East inlet
GAS00210	Unit 3	Gaston	4/7/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00211	Unit 3	Gaston	4/8/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00212	Unit 3	Gaston	4/9/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00213	Unit 3	Gaston	4/10/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00214	Unit 3	Gaston	4/11/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00215	Unit 3	Gaston	4/14/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00216	Unit 3	Gaston	4/15/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00217	Unit 3	Gaston	4/7/03 11:00 AM	7101	PB	Baghouse B side	Ash	1 lt. Bottle East center
GAS00218	Unit 3	Gaston	4/9/03 2:30 PM	7101	PB	Baghouse B side	Ash	5 gallon bucket 50% East inlet 50% East center
GAS00219	Unit 3	Gaston	4/10/03 2:00 PM	7101	PB	Hot side ESP	Ash	1 lt. Bottle East center
GAS00220	Unit 3	Gaston	4/15/03 3:30 PM	7101	PB	Baghouse B side	Ash	1 lt. Bottle West outlet
GAS00221	Unit 3	Gaston	4/15/03 2:30 PM	7101	PB	Hotside ESP	Ash	1 lt. Bottle Inlet row center
GAS00222	Unit 3	Gaston	4/16/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00223	Unit 3	Gaston	4/17/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00224	Unit 3	Gaston	4/17/03 12:00 PM	7101	CVL	Hotside ESP	Ash	1 lt. Bottle Inlet row center
GAS00225	Unit 3	Gaston	4/17/03 12:30 PM	7101	CVL	Baghouse B side	Ash	1 lt. Sample Outlet West hopper
GAS00226	Unit 3	Gaston	4/18/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab

Samples collected during Optimization Period 1 (April 21 – May 27, 2003)

Sample ID	Unit Number	Plant Name	Date/Time	Project Number	Sampled By	Sample Location	Sample Type	Comments
GAS00227	Unit 3	Gaston	4/21/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00228	Unit 3	Gaston	4/21/03 2:30 PM	7101	CVL	Hotside ESP	Ash	1 lt. Bottle Inlet row center
GAS00229	Unit 3	Gaston	4/21/03 2:45 PM	7101	PB	Baghouse B side	Ash	1 lt. Sample Outlet East hopper
GAS00230	Unit 3	Gaston	4/22/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00231	Unit 3	Gaston	4/23/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00232	Unit 3	Gaston	4/24/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00233	Unit 3	Gaston	4/25/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00234	Unit 3	Gaston	4/23/03 11:15 AM	7101	PB	Baghouse A side	Ash	1 lt. Sample Center West hopper
GAS00235	Unit 3	Gaston	4/23/03 11:00 AM	7101	PB	Baghouse B side	Ash	1 lt. Sample Outlet East hopper
GAS00236	Unit 3	Gaston	4/23/03 11:00 AM	7101	PB	Baghouse B side	Ash	1 lt. Sample Outlet East hopper
GAS00237	Unit 3	Gaston	4/23/03 9:30 AM	7101	CVL	Hotside ESP	Ash	1 lt. Sample Inlet center hopper
GAS00238	Unit 3	Gaston	4/23/03 11:00 AM	7101	PB	Baghouse B side	Ash	5 Gal. bucket Sample Outlet West hopper
GAS00239	Unit 3	Gaston	4/24/03 10:45 AM	7101	PB	Baghouse B side	Ash	5 Gal. Sample 50% ea Center E & Outlet E
GAS00240	Unit 3	Gaston	4/28/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00241	Unit 3	Gaston	4/29/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00242	Unit 3	Gaston	4/30/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00243	Unit 3	Gaston	5/1/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00244	Unit 3	Gaston	5/2/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00245	Unit 3	Gaston	5/3/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00246	Unit 3	Gaston	5/4/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00247	Unit 3	Gaston	5/5/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00248	Unit 3	Gaston	4/28/03 1:00 PM	7101	CVL	Baghouse B side	Ash	1 lt. Sample Center East hopper
GAS00249	Unit 3	Gaston	5/1/03 9:10 AM	7101	PB	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00250	Unit 3	Gaston	5/1/03 9:10 AM	7101	PB	Baghouse A side	Ash	1 lt. Sample Inlet East hopper
GAS00251	Unit 3	Gaston	5/1/03 9:30 AM	7101	CVL	Hotside ESP	Ash	1 lt. Sample Inlet center hopper
GAS00252	Unit 3	Gaston	5/6/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00253	Unit 3	Gaston	5/7/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab

Sample ID	Unit Number	Plant Name	Date/Time	Project Number	Sampled By	Sample Location	Sample Type	Comments
GAS00254	Unit 3	Gaston	5/8/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00255	Unit 3	Gaston	5/9/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00256	Unit 3	Gaston	5/8/03 3:00 PM	7101	PB	Baghouse A side	Ash	1 lt. Sample Inlet West hopper
GAS00257	Unit 3	Gaston	5/8/03 3:00 PM	7101	PB	Baghouse B side	Ash	1 lt. Sample Outlet East hopper
GAS00258	Unit 3	Gaston	5/8/03 3:15 PM	7101	PB	Hotside ESP	Ash	1 lt. Third Row East
GAS00259	Unit 3	Gaston	5/12/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00260	Unit 3	Gaston	5/13/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00261	Unit 3	Gaston	5/14/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00262	Unit 3	Gaston	5/15/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00263	Unit 3	Gaston	5/16/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00264	Unit 3	Gaston	5/19/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00265	Unit 3	Gaston	5/14/03 12:45 PM	7101	PB	Baghouse A side	Ash	1 lt. Sample Center West hopper
GAS00266	Unit 3	Gaston	5/14/03 12:40 PM	7101	PB	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00267	Unit 3	Gaston	5/14/03 1:30 PM	7101	PB	Hotside ESP	Ash	1 lt. Inlet Center
GAS00268	Unit 3	Gaston	5/20/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00269	Unit 3	Gaston	5/21/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00270	Unit 3	Gaston	5/22/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00271	Unit 3	Gaston	5/23/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00272	Unit 3	Gaston	5/21/03 2:00 PM	7101	PB	Baghouse A side	Ash	1 lt. Sample Inlet West hopper
GAS00273	Unit 3	Gaston	5/21/03 2:00 PM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00274	Unit 3	Gaston	5/21/03 2:20 PM	7101	PB	Hotside ESP	Ash	1 lt. Inlet Center

Samples collected during Baseline Period 2 (May 28 – June 25, 2003)

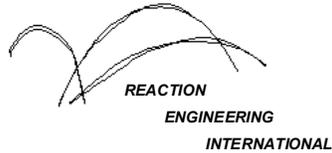
Sample ID	Unit Number	Plant Name	Date/Time	Project Number	Sampled By	Sample Location	Sample Type	Comments
GAS00275	Unit 3	Gaston	5/28/03 10:10 AM	7101	TT	Baghouse A side	Ash	1 lt. Sample Inlet West hopper
GAS00276	Unit 3	Gaston	5/28/03 10:10 AM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00277	Unit 3	Gaston	5/28/03 11:00 AM	7101	TT	Hotside ESP	Ash	1 lt. Inlet Center
GAS00278	Unit 3	Gaston	5/28/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00279	Unit 3	Gaston	5/30/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00280	Unit 3	Gaston	6/2/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00281	Unit 3	Gaston	6/4/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00282	Unit 3	Gaston	6/5/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00283	Unit 3	Gaston	6/6/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00284	Unit 3	Gaston	6/4/03 3:00 PM	7101	PB	Baghouse A side	Ash	1 lt. Sample Inlet West hopper
GAS00285	Unit 3	Gaston	6/4/03 3:00 PM	7101	PB	Baghouse B side	Ash	1 lt. Sample Middle West hopper
GAS00286	Unit 3	Gaston	6/4/03 3:15 PM	7101	PB	Hotside ESP	Ash	1 lt. Inlet Center
GAS00287	Unit 3	Gaston	6/5/03 2:30 PM	7101	TT	Baghouse A side	Ash	1 lt. Sample Inlet West hopper
GAS00288	Unit 3	Gaston	6/9/03 1:30 PM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00289	Unit 3	Gaston	6/5/03 2:30 PM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00290	Unit 3	Gaston	6/5/03 3:00 PM	7101	TT	Hotside ESP	Ash	1 lt. Inlet Center
GAS00291	Unit 3	Gaston	6/6/03 1:00 PM	7101	TT	Baghouse A side	Ash	1 lt. Sample Center West hopper
GAS00292	Unit 3	Gaston	6/6/03 1:00 PM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00293	Unit 3	Gaston	6/6/03 2:00 PM	7101	TT	Hotside ESP	Ash	1 lt. Inlet Center
GAS00294	Unit 3	Gaston	6/9/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00295	Unit 3	Gaston	6/10/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00296	Unit 3	Gaston	6/11/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00297	Unit 3	Gaston	6/12/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00298	Unit 3	Gaston	6/11/03 11:45 AM	7101	TT	Baghouse A side	Ash	1 lt. Sample Inlet West hopper
GAS00299	Unit 3	Gaston	6/11/03 11:40 AM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00300	Unit 3	Gaston	6/11/03 2:00 PM	7101	TT	Hotside ESP	Ash	1 L Inlet Center
GAS00301	Unit 2	Gaston	6/9/03 1:05 PM	7101	TT	Baghouse A side	Ash	1 lt. Sample Center East hopper

Sample ID	Unit Number	Plant Name	Date/Time	Project Number	Sampled By	Sample Location	Sample Type	Comments
GAS00302	Unit 3	Gaston	6/12/03 11:50 AM	7101	TT	Baghouse A side	Ash	1 lt. Sample Center West hopper
GAS00303	Unit 3	Gaston	6/12/03 11:45 AM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00304	Unit 3	Gaston	6/13/03 9:50 AM	7101	TT	Baghouse A side	Ash	1 lt. Sample Center West hopper
GAS00305	Unit 3	Gaston	6/13/03 11:50 AM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00306	Unit 3	Gaston	6/13/03 10:33 AM	7101	TT	Hotside ESP	Ash	1 lt. Inlet Center
GAS00307	Unit 3	Gaston	6/13/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00308	Unit 3	Gaston	6/3/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00309	Unit 3	Gaston	6/16/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00310	Unit 3	Gaston	6/17/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00311	Unit 3	Gaston	6/18/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00312	Unit 3	Gaston	6/19/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00313	Unit 3	Gaston	6/19/03 1:30 PM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00314	Unit 3	Gaston	6/19/03 1:45 PM	7101	TT	Baghouse A side	Ash	1 lt. Sample Center West hopper
GAS00315	Unit 3	Gaston	6/18/03 3:05 PM	7101	TT	Baghouse A side	Ash	1 lt. Sample Center West hopper
GAS00316	Unit 3	Gaston	6/18/03 3:30 PM	7101	TT	Hotside ESP	Ash	1 lt. Inlet Center
GAS00317	Unit 3	Gaston	6/17/03 10:20 PM	7101	TT	Baghouse A side	Ash	1 lt. Sample Center West hopper
GAS00318	Unit 3	Gaston	6/17/03 10:18 PM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00319	Unit 3	Gaston	6/18/03 3:00 PM	7101	TT	Baghouse B side	Ash	1 lt. Sample Center West hopper
GAS00320	Unit 3	Gaston	6/19/03 2:15 PM	7101	TT	Hotside ESP	Ash	1 lt. Inlet Center
GAS00321	Unit 3	Gaston	6/17/03 11:00 PM	7101	TT	Hotside ESP	Ash	1 lt. Inlet Center
GAS00322	Unit 3	Gaston	6/20/03 3:35 PM	7101	TT	Baghouse A side	Ash	1 lt. Center west
GAS00323	Unit 3	Gaston	6/20/03 3:30 PM	7101	TT	Baghouse B side	Ash	1 lt. Center west
GAS00324	Unit 3	Gaston	6/20/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00325	Unit 3	Gaston	6/23/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00326	Unit 3	Gaston	6/24/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00327	Unit 3	Gaston	6/25/03 12:00 AM	7101	Plant	Coal belt / Coal lab	Coal	Sample riffled and prepared by plant coal lab
GAS00328	Unit 3	Gaston	6/23/03 4:20 PM	7101	TT	Baghouse A side	Ash	1 lt. Center west
GAS00329	Unit 3	Gaston	6/25/03 2:30 PM	7101	TT	Baghouse B side	Ash	1 lt. Center west

Sample ID	Unit Number	Plant Name	Date/Time	Project Number	Sampled By	Sample Location	Sample Type	Comments
GAS00330	Unit 3	Gaston	6/23/03 4:30 PM	7101	TT	Hotside ESP	Ash	1 lt. Center Inlet
GAS00331	Unit 3	Gaston	6/24/03 3:05 PM	7101	TT	Baghouse B side	Ash	1 lt. Center west
GAS00332	Unit 3	Gaston	6/25/03 2:35 PM	7101	TT	Baghouse A side	Ash	1 lt. Center west
GAS00333	Unit 3	Gaston	6/24/03 3:00 PM	7101	TT	Baghouse A side	Ash	1 lt. Center west
GAS00334	Unit 3	Gaston	6/23/03 4:15 PM	7101	TT	Baghouse B side	Ash	1 lt. Center west
GAS00335	Unit 3	Gaston	6/25/03 2:45 PM	7101	TT	Hotside ESP	Ash	1 lt. Center Inlet

APPENDIX C

Coal and Ash Sample Report, 2003



Date: September 19, 2003

From: Connie Senior

To: Jean Bustard, ADA ES

Re: Coal and Ash samples from Gaston for April, May 2003

Coal and ash samples were taken in April and May 2003 as part of the long-term sorbent injection test program. The coal and ash samples were compared with similar samples obtained during the Phase I testing at Gaston in 2001. Ash samples taken on April 2 and 3 were baseline (no sorbent injection). The ash sample taken on May 14 was during injection of 0.35 lb/MMacf into the B-side of the baghouse.

Table 1 gives the coal analyses from 2003. The coal mercury levels fluctuated from 0.058 to 0.11 $\mu\text{g/g}$ (dry basis) or 6 to 13 $\mu\text{g/dnm}^3$ (at 3% O_2). This variation is not any larger than the variation observed in the coal samples obtained during the test in 2001, as can be seen by comparing Figures 1 and 2. However, neither sample size is very large.

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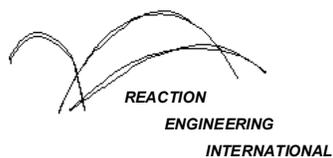


Table 1. Coal Analyses.

ADA-ES#:	GAS00181	GAS00182	GAS00183	GAS00206	GAS00207	GAS00259	GAS00260	GAS00261
MTI #:	03-187	03-188	03-189	03-193	03-194	03-196	03-197	03-198
Sampled:	3/31/03	4/1/03	4/2/03	4/3/03	4/4/03	5/12/03	5/13/03	5/14/03
Description:	coal belt							
<i>Ultimate, wt%, As Received:</i>								
Carbon	67.19	68.68	69.15	67.96	68.98	69.61	69.54	65.08
Hydrogen	4.18	4.36	4.59	3.39	4.32	4.30	4.21	4.36
Oxygen (by diff.)	12.14	11.72	11.08	12.74	11.61	10.66	11.43	14.93
Nitrogen	1.38	1.42	1.46	1.43	1.44	1.41	1.43	1.37
Total sulfur	1.52	1.41	1.67	1.66	1.45	1.25	1.16	1.22
Ash	13.59	12.41	12.05	12.82	12.20	12.77	12.23	13.04
Total moisture	6.15	7.07	6.42	6.85	7.04	7.80	8.05	9.43
<i>Heating value, BTU/lb, As Received</i>								
	12,119	12,044	12,184	12,002	12,092	12,046	12,112	11,875
Hg, µg/g, dry	0.102	0.0584	0.085	0.113	0.0721	0.0674	0.071	0.0774
Cl, µg/g, dry	170	240	210	190	210	160	150	180
Hg, lb/TBTU	7.90	4.51	6.53	8.77	5.54	5.16	5.39	5.90
Hg, µg/dnm ³ (3%O ₂)	11.39	6.27	9.00	12.91	7.73	7.08	7.52	8.66

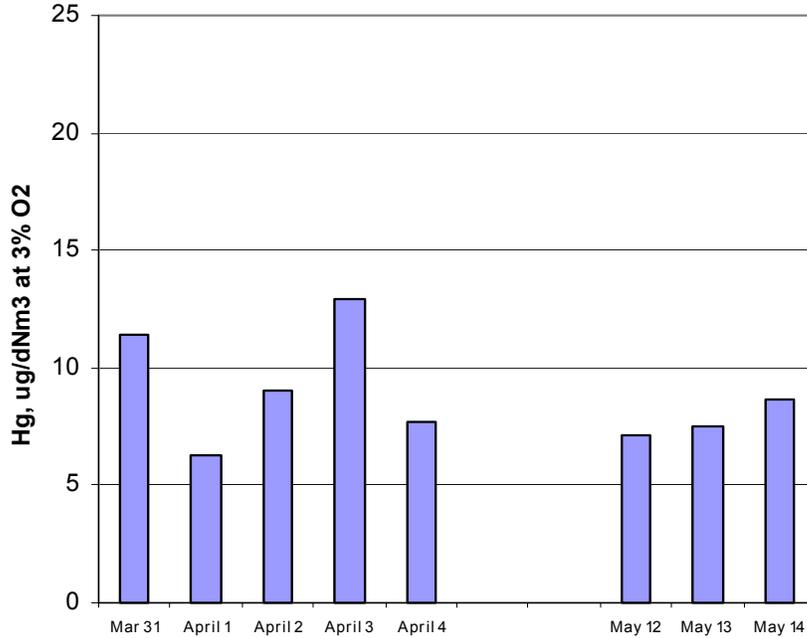
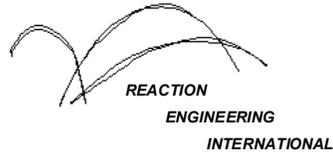


Figure 2. Coal mercury, in terms of $\mu\text{g}/\text{dnm}^3$ at 3% O₂ for 2003 samples.

Table 2 gives the mercury and LOI contents of ash samples collected in April and May 2003. Figure 3 compares the LOI of these samples to the samples taken in 2001. The LOI values of the ash from the hot-side ESP and from the A-side of the baghouse are similar in 2001 and 2003. The LOI values of the B-side ash are higher in 2001, reflecting a higher rate of PAC injection than the May 2003 B-side sample. The relationship between LOI and mercury content of the ash (Figure 4) seems similar. The mercury content of the hot-side ESP ash is generally lower in 2003 as compared to 2001.

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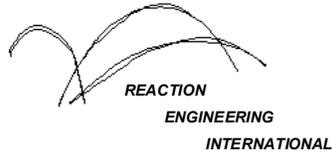


Table 2. Mercury and LOI of ash samples from April and May, 2003.

ADA-ES #	MTI #	Sampled	Description	Hg, $\mu\text{g/g}$	LOI, wt%
GAS00203	03-190	4/2/2003	B-side BH	5.38	17.8
GAS00204	03-191	4/2/2003	HESP	0.334	13.6
GAS00205	03-192	4/2/2003	A-side BH	0.241	10.8
GAS00208	03-195	4/3/2003	B-side BH	6.4	21.4
GAS00265	03-199	5/14/2003	A-side BH	0.894	16.5
GAS00266	03-200	5/14/2003	B-side BH	7.61	16.9
GAS00267	03-201	5/14/2003	HESP	0.53	13.7

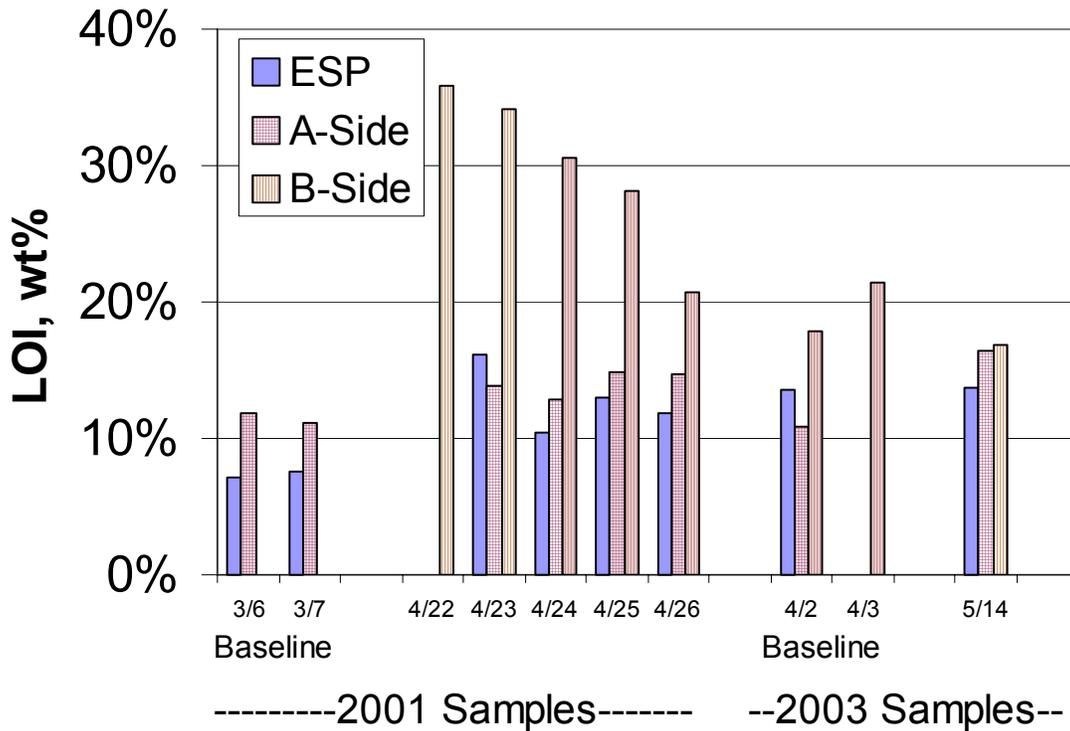


Figure 3. Comparison of LOI of Gaston Ash between 2001 and 2003.

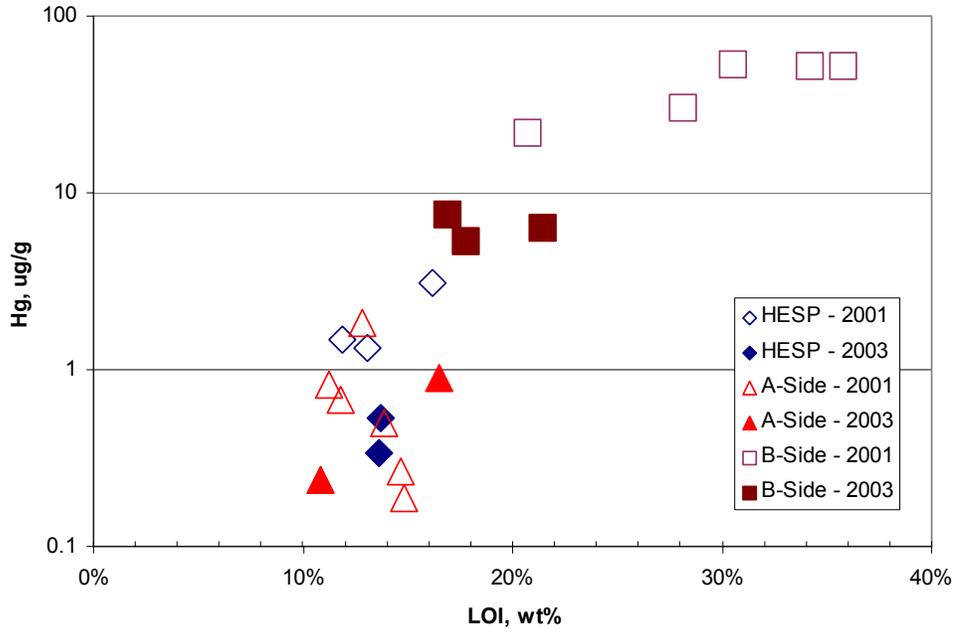
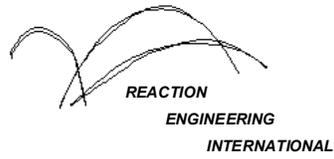
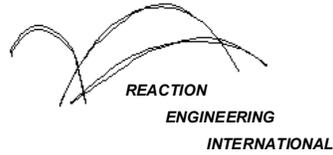


Figure 4. Mercury content of ash as a function of LOI.



To see if there is any correlation between LOI in the ESP ash and A-side ash, I looked at the hot foil LOI measurements made July-September 2003. Figure 5 shows no correlation between LOI in the ESP and in the A-side of the baghouse.

In Figure 6, all the hot foil data are plotted and compared with the LOI values for April and May 2003. During July and August, the LOI of the ESP ash varied from 7% up to 15%. A-side ash had an average LOI of about 15%, but there were excursions to more than 20%. As Figure 5 demonstrated, these excursions were not necessarily related to high LOI in the ESP. However, there may be some issues with timing of the samples and the emptying of hoppers. Without more information, I can't speculate any further.

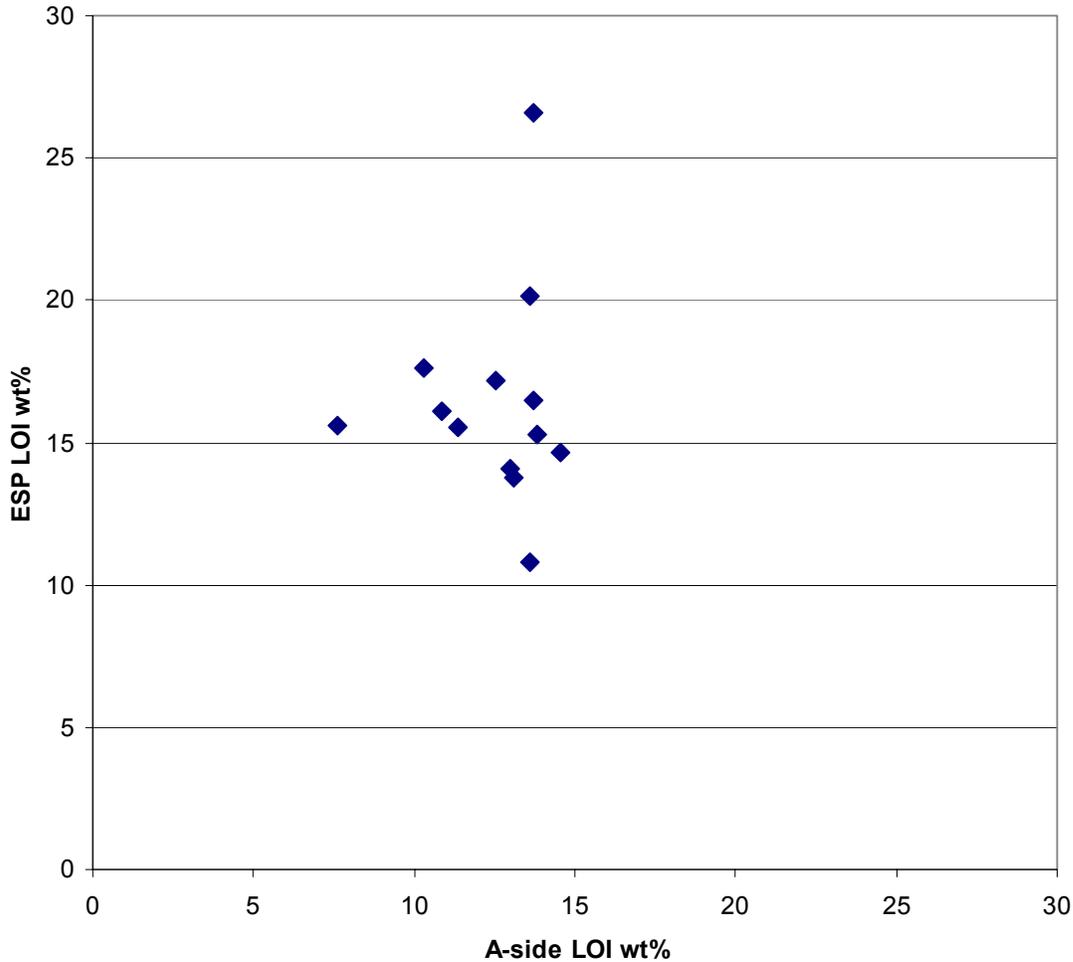


Figure 5. LOI in A-side ash as a function of LOI in ESP ash, July-August, 2003; LOI measured with hot foil technique.

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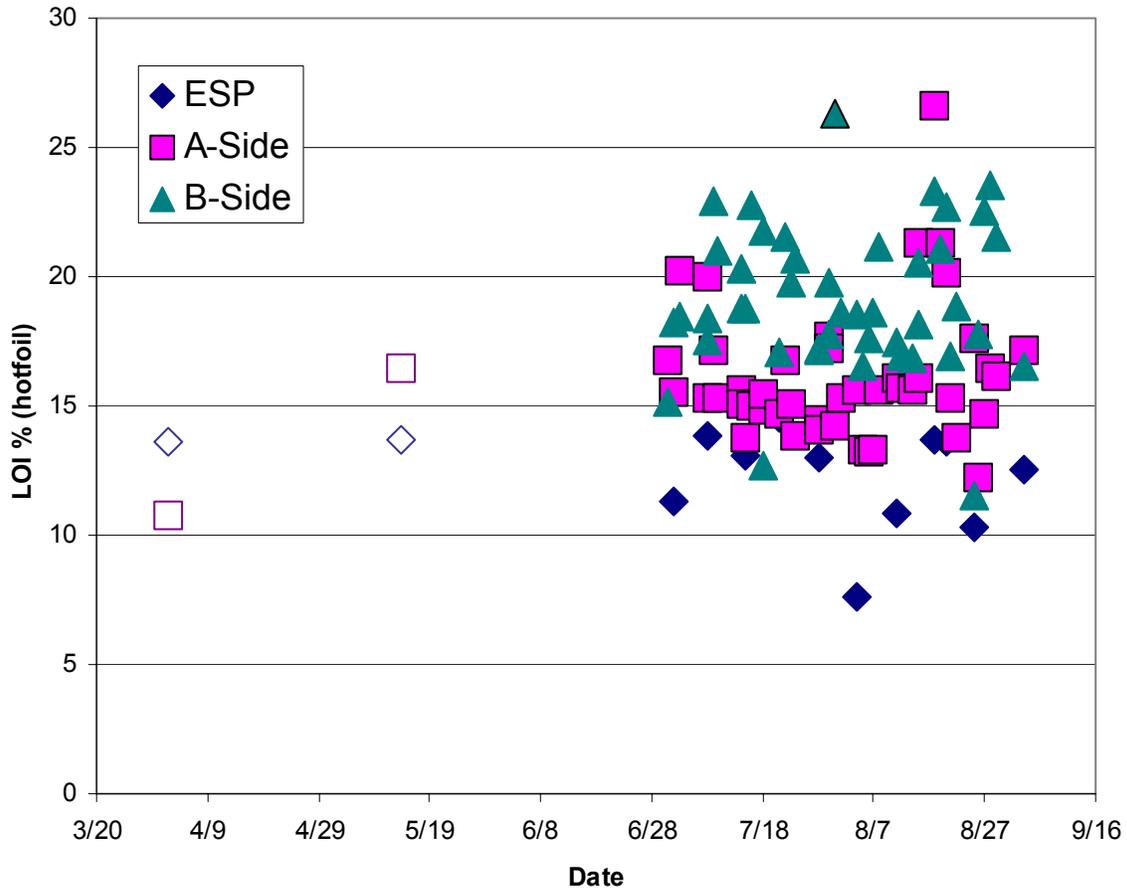
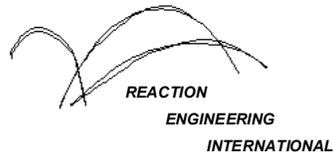


Figure 6. LOI measured by hot foil technique, July-August 2003.

APPENDIX D

Hamon Research-Cottrell ESP Report

Hamon Research-Cottrell Trip Report
ESP Inspection October 1, 2003

To: Byron Corina
From: Robert Mastropietro
Date: October 6, 2003
Subject: Southern Companies - Gaston #3 - External Process Study

Field Notes;

1. A review of the ESP sizing showed a design treatment time of 6.2 seconds. This was a typical ESP sizing for the 1973 time period. This ESP should be able to achieve about 0.1 LB/MMBTU if not in a deteriorated condition.
2. Power levels were extremely low on all fields of the ESP. On October 1, 2003, power densities ranged from 0.08 to 0.51 Watts/FT² on all fields. This is extremely low. We would consider power densities in the range of 1.0 to 3.0 Watts/FT² to be representative of good operation. Thus no part of the ESP was operating in good condition. In addition, two chamber fields were out-of-service (not in-series), out of 16 total chamber fields.
3. Predicted emission from taking two chamber fields out of service (not in-series) would be an increase of about 50% in particulate emissions. Thus if we were making 0.1 LB/MMBTU before, we would increase to about 0.15 LB/MMBTU with two chamber fields out. As a side note, if the two fields were in-series, the prediction would be a doubling of the particulate emissions to 0.2 LB/MMBTU.
4. In previous internal discussions on COHPAC, we have always discussed that the upstream ESP must clean down to the 0.4 LB/MMBTU range (I do not know the specifics of this COHPAC design). In general if this is true, and the ESP were operating good, then the increase to 0.15 LB/MMBTU would not be sufficient to cause the continuous cleaning problems observed on the baghouse. This would imply that the present problem with the baghouse cleaning is not just coming from the 2/16th of the ESP out-of-service. The very poor electrical operation of the ESP is also contributing to the higher loadings coming to the baghouse.
5. Resistivity tests were conducted on two fly ash samples from the #3 hoppers. The results are shown in Appendix A. This showed the fly ash to be extremely low in resistivity. This result typically comes from high carbon in the fly ash, coming from the low NO_x burner firing. This result clarified several things after my visit. First, all suspicions of the problem being associated with high resistivity coal can be discarded. Instead, other areas of the ESP now become suspect. The primary area of concern now would be the insulators. This high carbon ash, if it coats the insulators, can cause a conductive path to ground. V-I curves conducted at the site showed very low voltages and almost vertical increases in current. This is typical of insulator tracking type problems.
6. High voltage rapper density was installed with two rappers per high voltage frame. This results in 7,128 linear feet of wire per rapper. This is an extremely poor rapping density. This should be improved by adding a center rapper to each bus-section.

RECOMMENDATIONS

1. At the next outage, perform an internal inspection with special attention being paid to the support and stabilizer insulators. We would be looking for tracking. If the problem is in the support insulators, the heating ventilation system should be upgraded. If the problem is in the lower stabilizer insulators (high probability of the problem being in this area), the lower stabilizers should be upgraded to HRC Rigidflex Stabilizer design with 30" insulator.
2. Low resistivity ash is very re-entrainable. It may be that the rappers are rapping too hard at present, because operators were expecting high resistivity ash. The rapping program of the ESP should be tuned for low resistivity, but an opacity meter between the ESP and baghouse is needed to accomplish this task. I do not know if Southern Companies has a temporary opacity probe for this purpose or not? Alternately, we could try to tune rappers based upon baghouse cleaning cycle, but this is a difficult technical approach.
3. Center rappers should be added to each bus section, and rapper anvils cut to isolate rapping energy.
4. T-Rs are slightly over-sized on the inlet field. Future replacements should decrease the inlet T-R sizes down to 1000ma, from the present 1500ma sizing.

SOUTHERN COMPANIES – GASTON #3

RESULTS

Resistivity tests were conducted on two fly ash samples obtained from the electrostatic precipitator ash handling system. The dust samples were dark grey in color, which is typically due to high fly ash carbon levels. The fly ash appeared to be free flowing and very fine in texture. Laboratory tests were conducted with resistivity chamber gas moisture at 7 % moisture by volume, which is typical of the actual flue gas moisture from oil firing. This moisture value is not sufficient to give appreciable surface conditioning of the dust by condensed water on the dust surface, except at very low gas temperatures.

The results of laboratory testing are shown on the attached plot of resistivity, OHM-CM, vs. temperature, degrees C. The dust resistivity ranged from $1E5$ OHM-CM at low and high temperature, to $2E6$ OHM-CM at the resistivity peak. The resistivity peak was at about 300F, which is typical. In general, this fly ash was extremely low in resistivity. Electrical operation (i.e. power density levels) of an electrostatic precipitator would typically be positively impacted by this low resistivity fly ash (i.e. we should have high power levels). A relatively small ESP treatment time would be recommended for this easy ash. However, low gas velocities would be recommended to prevent re-entrainment of fly ash.

DEFINITION

Laboratory resistivity (OHM-CM) of a dust is the ratio of the applied electric potential across the dust layer to the induced current density. The value of the resistivity for a dust sample depends upon a number of variables, including dust chemistry, dust porosity, dust temperature, composition of gaseous environment (i.e. gas moisture), magnitude of applied electric field strength, and test procedure.

In working with electrostatic precipitators (ESP), resistivities are encountered in the range from about $1E4$ to $1E14$ OHM-CM. The optimum value for resistivity is generally considered to be in the range of $1E8$ to $1E11$ OHM-CM. In this range the dust is conductive enough that charge does not build-up in the collected dust layer and insulate the collecting plates. Additionally the dust does not hold too much charge and is adequately cleaned from the collecting plates by normal rapping. If resistivity is in the range $1E12$ to $1E14$ OHM-CM, it is considered to be high resistivity dust. This dust is tightly held to the collecting plates, because the dust particles do not easily conduct their charge to ground. This insulates the collecting plates and high ESP sparking levels result (also poor ESP collection efficiencies). Conversely if the dust is low resistivity, $1E4$ to $1E7$ OHM-CM, the dust easily conducts its charge to the grounded collecting plates. Then there is not residual charge on the dust particles to hold them on the plates. Thus these particles are easily dislodged and re-entrain back into the gas stream. ESP gas velocities are generally designed in the 2.5-3.5 FT/S range, if high carbon particles are to be collected.

PROCEDURE

The tests procedure was in general accordance with IEEE-548, Standard Criteria for the Laboratory Measurement of Fly Ash Resistivity. The apparatus used for the testing is a custom built arrangement utilizing a high temperature oven, a controlled temperature water bath for gas humidity adjustment, a DC power source, and a electrometer for current flow measurement. Resistivity values are calculated from

$$\rho = (V/I) \cdot (A/L)$$

where

ρ = resistivity, OHM-CM

V = applied voltage, Volts

I = measured current, Amperes

L = Ash thickness, cm

A = current measuring electrode face
area, cm²

The resistivity testing was conducted in ascending temperature order.

Robert A. Mastropietro
Mgr. ESP Technology
Hamon Research-Cottrell
October 6, 2003

APPENDIX E

Additional Coal and Ash Analyses

In order to better understand the differences between the 2001 PAC injection campaign and the 2003 PAC injection campaign at Gaston, additional analyses of ash from 2001 and 2003 were undertaken. These analyses include:

- Particle size distribution by Malvern analysis (light scattering)
- N₂ BET surface area
- Petrography (analysis of coal macerals)
- Ultimate analysis
- Microscopy

Table 1 shows which samples were analyzed. Petrographic and ultimate analyses were carried out by Jim Hower at the University of Kentucky, Center for Applied Energy Research. Microscopy was carried out by Microbeam Technologies.

Table 1. Analyses performed on Gaston ash samples.

Sample ID	MTI ID	Date/Time	Sample Location	Hg content	LOI	Malvern	BET SA, m ² /g	Ultimate Analysis	Petrography
GAS00137	01-212	4/23/2001	HESP	X	X	X			
GAS00140	01-113	4/24/2001	HESP	X	X	X			
GAS00141	01-114	4/24/2001	A-side BH	X	X	X			
GAS00146	01-117	4/25/2001	HESP	X	X	X	X		
GAS00147	01-118	4/25/2001	A-side BH	X	X	X	X		
GAS00152	01-121	4/26/2001	HESP	X	X	X	X	X	X
GAS00153	01-122	4/26/2001	A-side BH	X	X	X	X	X	X
GAS00203	03-190	4/2/2003	B-side BH	X	X	X	X	X	X
GAS00204	03-191	4/2/2003	HESP	X	X	X	X	X	X
GAS00205	03-192	4/2/2003	A-side BH	X	X	X	X	X	X
GAS00265	03-199	5/14/2003	A-side BH	X	X	X	X		
GAS00266	03-200	5/14/2003	B-side BH	X	X	X	X		
GAS00267	03-201	5/14/2003	HESP	X	X	X	X		

Particle size distribution measurements are shown in Figures 1 and 2 as cumulative volume distributions. The A-side ash particle size distributions are distinct from the hot-side ESP samples. The hot-side ESP samples have larger particles than the A-side samples and there is no significant difference between the hot-side samples from 2001 and 2003. The A-side samples for 2003 are significantly different from the 2001 samples in that the former contain more large particles. The size distribution of the 2001 A-side ash is finer than the 2003 ash. Generally, the 2001 ash has few particles greater than 25-50 microns, even though these particles are found in the HESP ash. The collection efficiency of the hot-side ESP is such that the larger particles did not reach the baghouse in 2001. However, one sample of 2003 ash from 5/14/03 contained very large ash particles, comparable to the largest particles in the HESP ash. The variability in the 2003 A-side ESP ash suggests that the hot-side ESP was not operating in a consistently efficient

manner, and that more large particles were getting through the hot-side ESP in 2003 as compared to 2001.

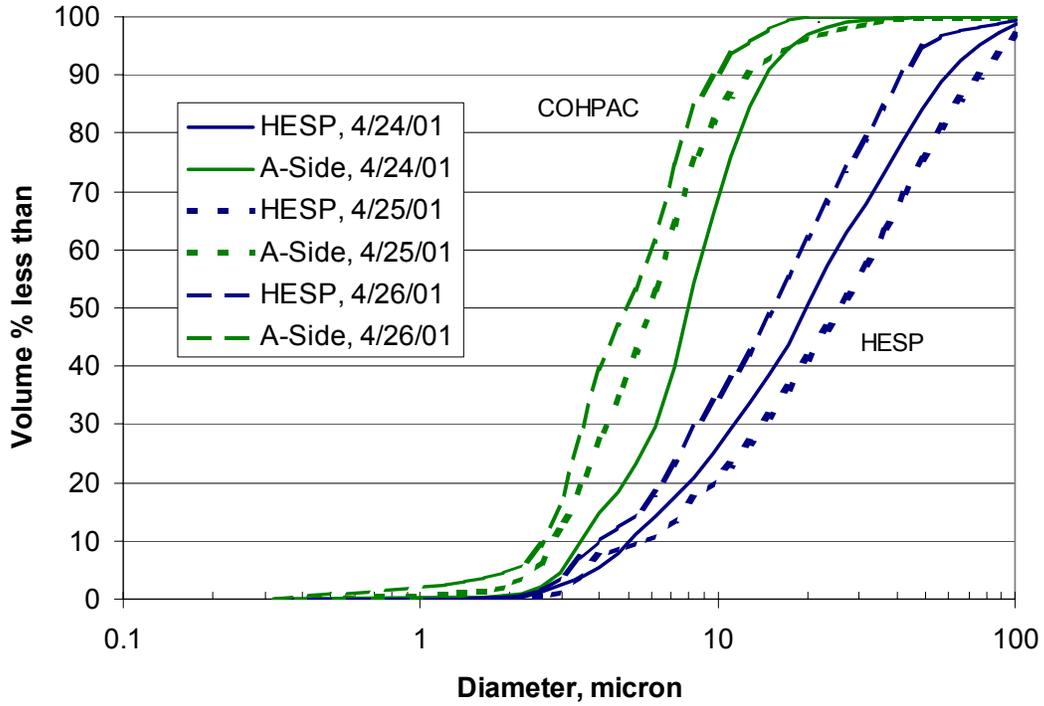


Figure 1. Cumulative Particle Size Distribution, 2001 Ash Samples.

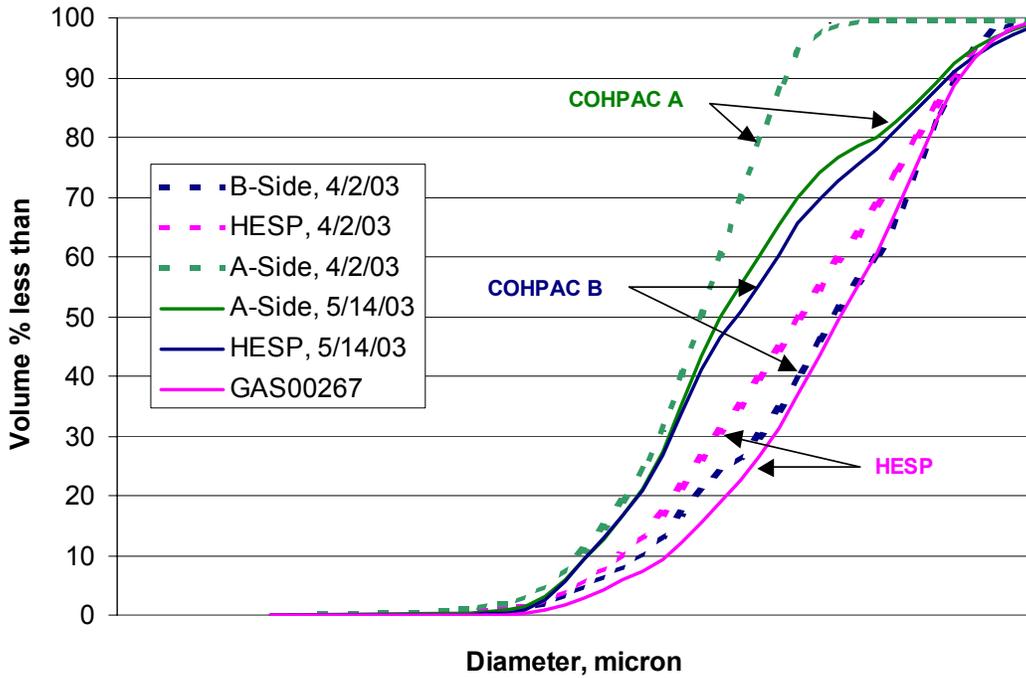


Figure 2. Cumulative Particle Size Distributions, 2003 Ash Samples.

Tables 2 and 3 give the results of carbon maceral analysis and ultimate analysis of ash samples carried out at the University of Kentucky. Ultimate analysis was carried out because the LOI values previously measured for the A-side ash samples seemed to be high, considering the color of the ash and its maceral content.

Table 2. Petrographic analysis of ash samples, volume % of phase.

Sample ID	MTI-ID	Sample	glass	mullite	spinel	quartz	isotropic coke	anisotropic coke	inertinite	oxidized material
GAS00152	01-121	HESP	78.0	0.0	2.0	0.0	10.0	7.8	2.6	
GAS00153	01-122	A-side BH	93.2	0.0	0.4	0.2	1.8	3.8	0.6	
GAS00203	03-190	B-side BH	60.8	0.0	2.4	0.4	16.8	16.8	2.8	
GAS00204	03-191	HESP	73.0	0.6	3.2	0.0	11.4	8.8	2.8	
GAS00205	03-192	A-side BH	90.2	0.0	1.4	0.0	1.4	5.6	1.2	0.2

Table 3. Ultimate analysis of ash samples, wt %.

Sample ID	MTI-ID	Sample	%Ash	%Moisture	%C	%H	%N	%S	%O
GAS00152	01-121	HESP	87.3	0.19	12.26	0.11	0.14	0.2	< 0.01
GAS00153	01-122	A-side BH	83.81	1.24	7.8	0.37	0.14	2.1	5.78
GAS00203	03-190	B-side BH	81.72	0.3	17.	0.12	0.21	0.54	0.41
GAS00204	03-191	HESP	85.73	0.14	14.11	0.04	0.16	0.36	< 0.01
GAS00205	03-192	A-side BH	83.56	2.57	5.13	0.63	0.1	2.33	8.25

The results of the petrographic analyses are shown in Figure 3.

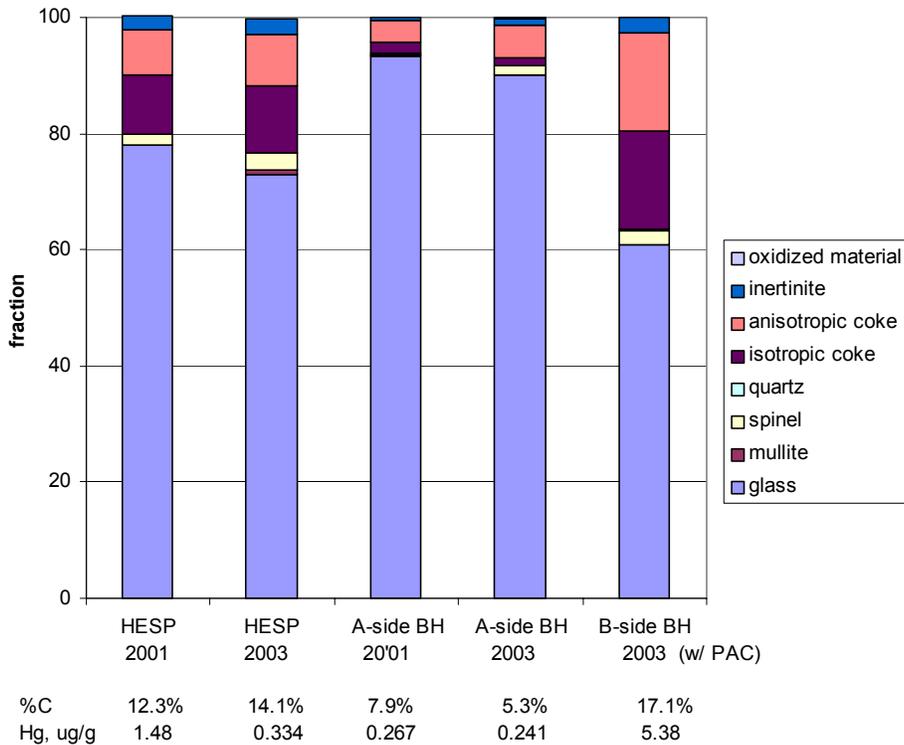


Figure 3. Petrographic Analysis, Volume Percent of Phase.

The A-side ash has LOI values comparable to the hot-side ESP ash. However, the carbon content of the A-side ash is lower than the carbon content of the hot-side ESP ash. The measured amounts of LOI agree well with the measured amounts of carbon for the hot-side ESP ash and the B-side ash sample (containing activated carbon). The measured amount of carbon in the A-side ash is considerably lower than the LOI. From the ultimate analysis of the ash, we can see that the A-side ash has a significant amount of moisture, sulfur and oxygen, unlike the hot-side ash samples and the B-side sample. Based on two sets of samples, therefore, it appears that the LOI content of the A-side ash is misleading, in terms of the amount of carbon in the ash.

SEM micrographs of polished cross-sections of ash illustrate qualitatively the petrographic analysis. Figure 4 shows a hot-side ESP ash sample from 2001. Spherical ash particles can be seen as well as darker and more irregular unburned carbon particles, which are on the order of 100 microns. The 2003 hot-side ESP ash (Figure 5) contains the same types of particles.

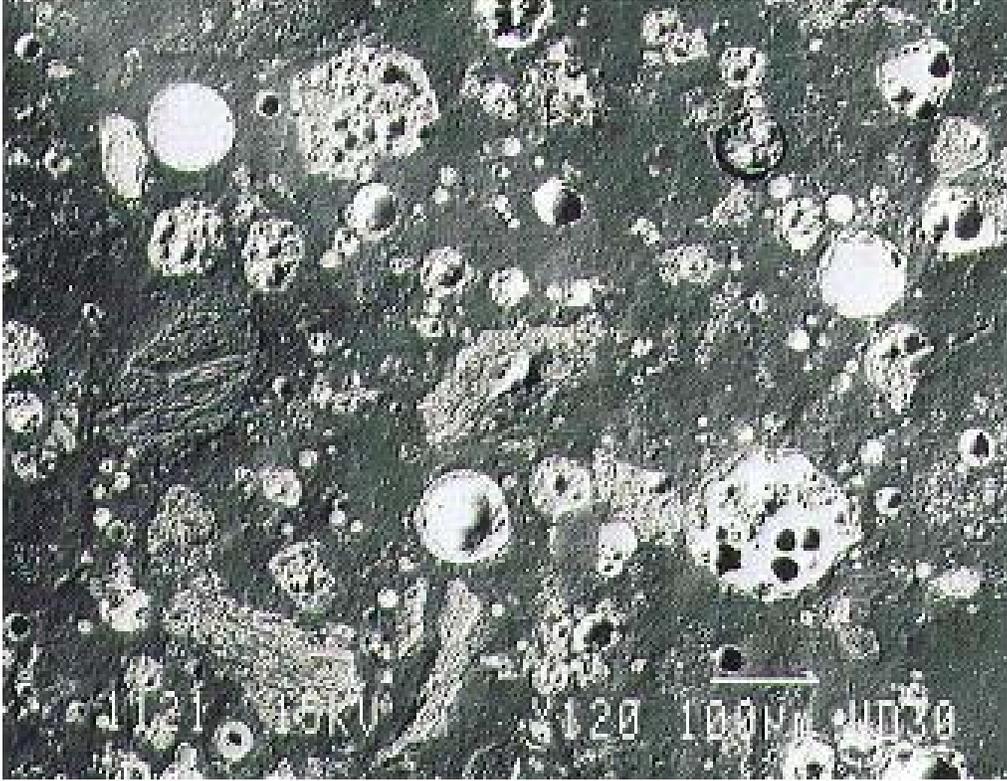


Figure 4. Polished cross-section of hot-side ESP ash (GAS00152), 4/26/01.

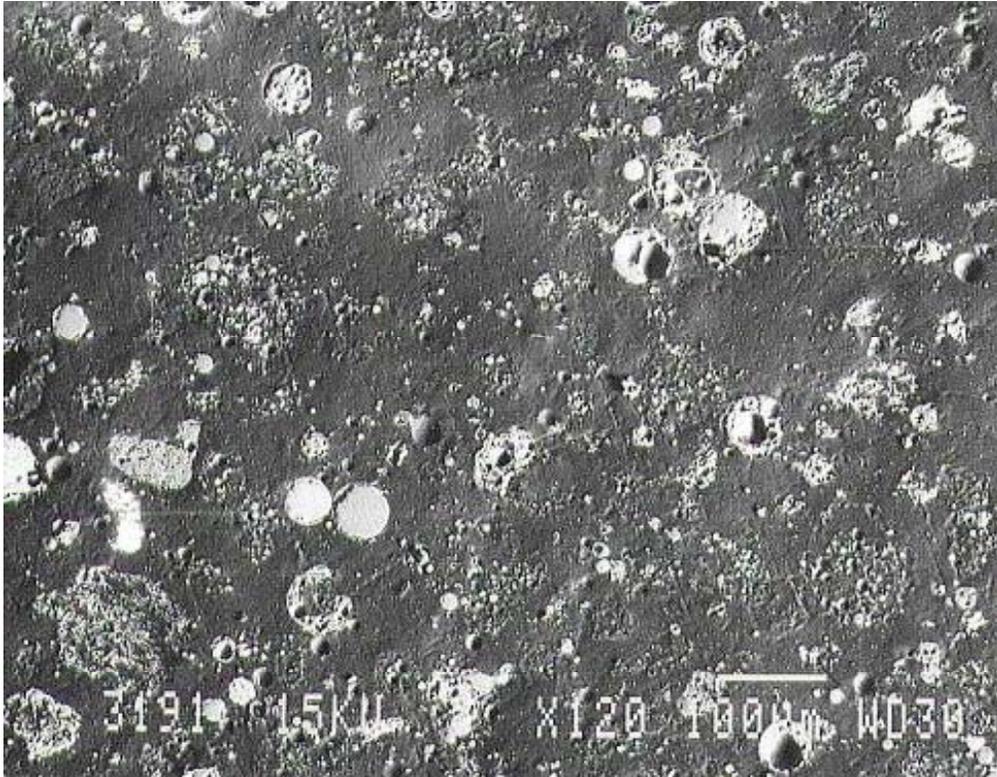


Figure 5. Polished cross-section of hot-side ESP ash (GAS00204), 4/2/03.

The hot-side ESP ash in 2003 does not differ greatly from the hot-side ESP ash from 2001 in terms of the carbon maceral content or particle size distribution. The surface area of the 2003 hot-side ESP ash is higher than in 2001.

As the particle size distributions indicate, the A-side ash is considerably finer than the hot-side ESP ash. This is illustrated in the photograph of the A-side ash in Figure 6. There are few of the large, bright spheres and only one large, unburned carbon particle (lower right quadrant).



Figure 6. Polished cross-section of A-side ash (GAS00153), 4/26/01.

Particle size distribution, surface area, carbon content and carbon maceral type are all distinct between the hot-side ESP samples and the baghouse ash samples, as summarized in Table 4. The A-side ash has a lower surface area than the hot-side ESP ash. Addition of activated carbon to the baghouse increases the surface area, as one would expect. The surface area of the A-side ash may be higher in 2001 than in 2003, though with only two samples analyzed for each year it is hard to reach a definitive conclusion. The hot-side ESP ash samples have a higher surface area in 2003 than in 2001, though the sample size is small.

The ratios of the major maceral types are distinct for the different ash samples. Table 4 gives the ratio of the anisotropic carbon to the total forms of carbon. The hot-side ash has more isotropic carbon, while the A-side ash has proportionately more anisotropic carbon. Hower et al.¹ have

¹ Hower, J.C, M.M. Maroto-Valer, D.N. Taulbee, T. Sakulpitakphon "Mercury Capture by Distinct Fly Ash Carbon Forms" *Energy Fuels* **1999**, 14 (1), 224-226.

speculated that anisotropic carbon in fly ash absorbs more mercury from flue gas because this type of carbon has the greatest surface area of the forms of carbon.

Table 4. Summary of ash properties.

Sample ID	MTI ID	Date/Time	Sample Location	Hg, ug/g (AR)	LOI, wt%	%C, dry	BET SA, m ² /g	Fraction Anisotropic Carbon
GAS00137	01-212	4/23/2001	HESP	3.08	16.2%			
GAS00140	01-113	4/24/2001	HESP	0.0024	10.4%			
GAS00141	01-114	4/24/2001	A-side BH	1.85	12.8%			
GAS00146	01-117	4/25/2001	HESP	1.33	13.1%		5.3	
GAS00147	01-118	4/25/2001	A-side BH	0.187	14.8%		4.15	
GAS00152	01-121	4/26/2001	HESP	1.48	11.9%	12.3%	7.14	0.38
GAS00153	01-122	4/26/2001	A-side BH	0.267	14.7%	7.9%	2.24	0.61
GAS00204	03-191	4/2/2003	HESP	0.334	13.6%	14.1%	12.45	0.38
GAS00205	03-192	4/2/2003	A-side BH	0.241	10.8%	5.3%	1.74	0.68
GAS00203	03-190	4/2/2003	B-side BH	5.38	17.8%	17.1%	10.74	0.46
GAS00267	03-201	5/14/2003	HESP	0.53	13.7%		8.31	
GAS00265	03-199	5/14/2003	A-side BH	0.894	16.5%		2.93	
GAS00266	03-200	5/14/2003	B-side BH	7.61	16.9%		8.72	

Conclusions

Particle size distribution, surface area, carbon content and carbon maceral type are all distinct between the hot-side ESP samples and the baghouse ash samples. The A-side ash has a lower surface area than the hot-side ESP ash, which may be due to differences in the distribution of carbon macerals in the ash. Addition of activated carbon to the baghouse increases the surface area, as one would expect.

The A-side ash has LOI values comparable to the hot-side ESP ash. However, the carbon content of the A-side ash is lower than the carbon content of the hot-side ESP ash. The measured amounts of LOI agree well with the measured amounts of carbon for the hot-side ESP ash and the B-side ash sample (containing activated carbon). The measured amount of carbon in the A-side ash is considerably lower than the LOI. Based on the ultimate analysis of the ash, the A-side ash has a significant amount of moisture, sulfur and oxygen, unlike the hot-side ash samples and the B-side sample. Based on two sets of samples, therefore, it appears that the LOI content of the A-side ash is misleading, in terms of the amount of carbon in the ash.

The hot-side ESP ash in 2003 does not differ greatly from the hot-side ESP ash from 2001 in terms of the carbon maceral content or particle size distribution. The surface area of the 2003 hot-side ESP ash is higher than in 2001. Thus, it is hard to determine if the boiler produced the same kind of ash in 2003 as in 2003. Since the number of samples measured was small (and different coals are burned in the boiler on a continually changing basis), it may be difficult to conclude with certainty that the combustion conditions are the same.

The A-side samples for 2003 are significantly different from the 2001 samples in that the former contain more large particles. The variability in the 2003 A-side ESP ash suggests that the hot-side ESP is not operating in a consistently efficient manner, and that more large particles are getting through the hot-side ESP in 2003 as compared to 2001.

APPENDIX F

GFTS Report No. 3789 Bag Analysis Before Sorbent Injection

Grubb Filtration Testing Services, Inc.

8006 Route 130 North
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Delran, NJ 08075

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Laboratory Report No. 3789

Date: March 13, 2004

RECEIVED

MAR 18 2004

Prepared For: ADA ENVIRONMENTAL SOLUTIONS, LLC
8100 SouthPark Way, Unit B
Littleton, Colorado 80120

Reference: ADA-ES Agreement No. 007-2002; Task Order No. 01-02-7004

Subject: GASTON UNIT 3B CARBON INJECTION / COHPAC TEST
DOE Cooperative Agreement DE-FC26-02NT41591
Baseline Filter Bag Analysis

Background

Prior to the initiation of the carbon injection test in Casing B of the Gaston Unit 3 COHPAC baghouse, an inspection of the bags was conducted during the Unit 3 outage in March 2003. Information about the bags that were in place at that time is given below. All of the bags were made of 2.7-denier Ryton felt made by Tex Tech Industries.

Modules	Front (3B10 & 3B20)	Rear (3B11 & 3B21)
Bag Supplier	Midwesco	BHA
Date Installed	11/4/00	11/30/01
Length of Service*	18,809 hr	9,678 hr

* Exposure Hours (hours bags exposed to flue gas including time when bypass damper partially opened) from Southern Research Institute summary through March 31, 2003, assuming continuous operation after the outage.

As previously reported by Southern Research Institute, only five "failed" bags were detected (of the 2,194 bags in this casing). Three bags had actually failed in 3B20, and two bags had slipped off their cages in 3B21.

Request and Sample Description

Two used bags, one each from a front and rear module, were submitted for analysis to determine their baseline condition prior to the carbon injection test. They had been removed on March 11, 2003.

<u>Module</u>	<u>Row-Bag</u>	<u>Condition</u>
3B20	15-43	Failed
3B21	8-4	Non-Failed

Bag B20 was a very poor sample for testing due to the massive failure 2-4 feet from its bottom.

Summary and Conclusions

The physical properties of Bag B21 were very similar to those obtained in 1998 on one of the OEM bags with a comparable length of service, as shown in Table 1. (No used bags from either Unit 3 replacement set have previously been tested.) Although the actual Mullen burst strength of the B21 fabric was 30% higher than that of previous used OEM bags from Gaston 3, the percent strength loss was about the same. This is due to the initial strength of the rear module replacement bag fabric, which was 23% greater than that of the OEM bag fabric (525 vs 428 psi, net, normalized to an 18 oz/yd² fabric weight).

Since the inside of Bag B20 was severely contaminated with ash due to the massive failure in its bottom, it was unsuitable for permeability and weight testing (except for washed samples). The actual Mullen burst strength of the fabric in this bag was about 15% lower than that of previous used OEM bags from Gaston 3. Since the initial strength of the front module replacement bag fabric was 14% greater than that of the OEM bag fabric (487 vs. 428 psi), the strength loss of the fabric in Bag B20 was even greater relative to that of the OEM bag fabric after a comparable length of service, as shown in Table 1. However, we cannot be certain that the fabric strength was not adversely affected by operation of this bag in its severely failed mode.

The dirty fabric pH (5g/100ml distilled H₂O) was considerably higher (less acidic) on both bags than on previous OEM bags after comparable periods of service.

Table 1

**GASTON UNIT 3 – USED BAG COMPARISON
 No Carbon Injection**

Bag Set	OEM	Replacement	OEM	Replacement
Date Test Bag Removed	2/20/98	3/11/03	1/26/99	3/11/03
GFTS Sample	#2587	#3789-B21	#2830-A	#3789-B20
Service Life	8650 hr	9678 hr	16,050 hr	18,809 hr
Module	B20	B21	A20 / B20	B20
Permeability (cfm/ft²):				
As Received	5.74	4.78	–	–
Vacuumed	21.2	18.8	–	–
Washed	41.8	35.4	–	–
Fabric Weight (oz/yd²):				
Washed	18.6	17.8	18.8	18.7
Residual Dust Load (oz/yd²):				
Removable by Vacuuming	6.1	6.4	–	–
Removable by Washing	3.0	3.0	–	–
Total (As-Received)	9.3	9.4	–	–
Bag Weight, as received (lb)	6.7	6.9	6.6	7.7
Residual Dust Weight (lb)	2.5	2.7	2.4	3.5
Mullen Burst Strength (psi, net):				
Average (actual)	318	396	322	271
Normalized to 18 oz/yd ²	308	400	309	261
% Loss (vs. new fabric*)	–28%	–24%	–28%	–46%
Fabric pH (5g/100 ml):	3.44	4.24	2.44	3.97

* Average values for new fabric were 428, 525, and 487 psi net (normalized) for the OEM bags, the B21 replacement bags, and the B20 replacement bags, respectively.

Observations and Data Profiles

Both bags had been cut into two pieces near their middle and slit open full-length for cage removal. The top sections of both bags were quite stiff (had been wet in service), especially Bag B20, and both had been mangled during removal. Both bags had been “wadded up” in a plastic bag for shipment. The dust cake on both bags was black, which is typical of Gaston ash (though it varies in its degree of blackness).

Bag B21 was in excellent condition with no wear evident, even at the top cuff, cage junction, and bottom reinforcement. The cage wire impressions on the inside of this bag were barely visible at the cage junction or in the bottom half.

Bag B20 had a massive failure and thus was badly contaminated with ash internally. The failure was a 29” long split starting 13½” up from the bottom disc. It was at vertical wire #2 (second from the midpoint of the cage, clockwise from the bag seam, top view). The wear at this cage wire, on the *outside* of the bag, was severe, and it extended several feet upward from the split. The bottom reinforcement of this bag was worn completely through, and the bag fabric was worn down to its scrim, at vertical wires #2 and #13, but not yet to the point of failure. The bag was not worn at the cage junction, and in fact the cage impressions were barely visible there.

Since the bags had been cut open and their tops mangled, length and flat width measurements were not possible. The circumference of Bag B21 was 15³/₁₆”, which is in the range that has been previously measured on numerous used Gaston 3 OEM bags. The circumference of Bag B20 was 15”, which is 1/16” less than the minimum measured on any previous Gaston 3 bag.

FABRIC WEIGHT AND RESIDUAL DUST LOAD PROFILE (oz/yd²)

Condition	Bag Section				Average	
	Top		Bottom			
Bag B21						
As-Received	31.7		22.8		27.2	
Vacuumed	23.7	(8.0)	18.0	(4.8)	20.8	(6.4)
Washed	18.6	(5.1)	17.1	(0.9)	17.8	(3.0)
Total Dust Load	13.1		5.7		9.4	

Values in () represent dust removed vs. the previous condition; i.e., by vacuuming as-received fabric and by washing vacuumed fabric.

Permeability Profile (cfm / ft² @ 0.5" WG)

Bag Section	As Received			Vacuumed			Washed
	Curved Portions	Flat Portions	Section Average	Curved Portions	Flat Portions	Section Average	
Bag B21							
Top	1.83 / 2.40	3.32 / 3.48	2.76	6.56 / 10.8	7.23 / 9.76	8.56	32.6
Middle	6.02 / 3.99	5.10 / 5.83	5.24	20.7 / 18.7	23.7 / 17.9	20.2	–
Bottom	6.08 / 7.74	6.41 / 5.21	6.36	26.7 / 25.9	29.0 / 23.2	26.2	38.2
Average	4.68	4.89	4.78	18.2	18.5	18.3	35.4

MULLEN BURST STRENGTH PROFILE (psi, net)

Bag Portion	Bag Section			Average
	Top	Middle	Bottom	
Bag B20				
Flat	253 / 274	273 / 235	266 / 292	265
Curved	276 / 339	260 / 226	270 / 289	277
Average	279	249	279	271
Bag B21				
Flat	393 / 390	380 / 417	409 / 405	399
Curved	398 / 400	375 / 382	409 / 392	393
Average	395	389	404	396

Gross Mullen burst values may be obtained by adding 35 psi (the diaphragm tare pressure) to the net values given above.

Bag Construction

The bags were constructed of 18 oz/yd², 2.7-denier Ryton felt, singed on both sides, according to the Hamon Research-Cottrell specifications for the Alabama Power Gaston bags. They had a separate, woven Ryton top cuff with a double-beaded snap band, an oval disk bottom with a 4 reinforcement (both self-material), and a lapped vertical seam sewn with triple needle chain stitching. Both bags were sewn with PTFE thread (blue Profilen) in their circumferential stitching. The vertical seam of Bag B20 (Midwesco) was sewn with multifilament PPS thread, and that of Bag B21 (BHA) with PTFE-coated glass thread.

APPENDIX G

GFTS Report No. 3919 Bag Analysis After Sorbent Injection

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Testing Services, Inc.**

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Laboratory Report No. 3919

Date: December 3, 2004

Prepared For: ADA ENVIRONMENTAL SOLUTIONS, LLC
8100 SouthPark Way, Unit B
Littleton, Colorado 80120

Reference: ADA-ES Agreement No. 007-2002; Task Order No. 01-02-7004

Subject: GASTON UNIT 3B CARBON INJECTION / COHPAC TEST
DOE Cooperative Agreement DE-FC26-02NT41591
Analysis of Used Filter Bags Removed at End of the
Long-Term Test on Original Bags (December 2003)

Background

Information about the bags that were in place at the beginning of the carbon injection test in Casing B of the Gaston Unit 3 COHPAC baghouse in March 2003 is given below. All of the bags were made of 2.7-denier Ryton felt made by Tex Tech Industries.

Modules	Front (3B10 & 3B20)	Rear (3B11 & 3B21)
Bag Supplier	Midwesco	BHA
Date Installed	11/4/00	11/30/01
Length of Service*	18,809 hr	9,678 hr

* Exposure Hours (hours bags exposed to flue gas including time when bypass damper partially opened) from Southern Research Institute summary through March 31, 2003, assuming continuous operation after the outage.

Two used bags, one each from a front and rear module, were removed on March 11, 2003, and submitted for analysis to determine their baseline condition prior to the carbon injection test. (Refer to GFTS Report No. 3789.) At that time, six (6) new bags were installed, three in Module B20 and three in Module B21. These were reported to be 6.0-denier PPS felt bags, "because there were no 2.7-denier bags available."

Request and Sample Description

At the end of the “Long-Term Test on Original Bags”, one bag of each type, as described above, was to be submitted for analysis. Five (5) bags were actually submitted (two by mistake), as listed below:

Module	Row-Bag	Length of Service	Condition	Disposition
3B20	14-24	25,075 hr	Mangled	Discarded
3B20	14-38	25,075 hr	Worn but “OK”	Tested
3B21	14-24	15,944 hr	OK	Tested
3B21	8-3	06,266 hr	Very stiff at top	Discarded
3B21	8-4	06,266 hr	Crusty/Stiff top	Tested

The bags that were tested are referred to as B20, B21, and 8-4 respectively in this report.

Summary and Conclusions

Except for having somewhat lower permeability values in both their dirty (as-received) and vacuumed conditions, the original replacement bags (B20 and B21) that were exposed to carbon injection during most of their final 6,266 hours of service had properties that were very similar to those of the Gaston 3 OEM bags tested in 1998-2000 after comparable lengths of service without carbon injection, as shown in Table 1 below.

In particular, the activated carbon has had no significant effect on either the fabric strength or pH values. Although the actual Mullen burst strength of the used replacement bags was nearly the same as that of comparably-aged OEM bags from Gaston 3, the percent strength loss was somewhat higher. This is due to the initial strength of the 2.7-denier Ryton replacement bag fabric, which was 14% or 23% greater than that of the 3.0-denier Ryton OEM bag fabric (for the B20 and B21 bags respectively).

Bag 8-4 (Installed in Module B21 in March 2003): This bag was *not a 6-denier PPS bag*, as reported (nor was Bag 8-3). Both were in fact 2.7-denier PPS felt bags from BHA (the same lot as the rear module replacement bags installed in 2001). In addition, portions of both of these bags were very stiff and/or crusty, obviously having been wet in service. The bags that were observed in this area during our March 2003 inspection were in a similar condition and had failed, which is the reason the new bags were installed in this location.

Although neither of these bags was really a suitable specimen, #8-4 seemed to be somewhat less stiff and was selected for testing. The results are given in Table 2 along with data on OEM bags tested after a comparable length of service (without carbon injection) in 1997-98. However, except for the Mullen burst strength, any comparison of the data on Bag 8-4 is probably meaningless due to its atypically stiff and crusty condition.

Table 1

GASTON UNIT 3 – USED BAG COMPARISON With and Without Carbon Injection

Bag Set	Replace.	OEM	Replace.	OEM	Replace.
Date Test Bag Removed	3/11/03	8/9/98	12/6/03	11/30/99	12/6/03
GFTS Sample	#3789-B21	#2725	#3919-B21	#3087	#3919-B20
Service Life	9678 hr	12,176 hr	15,944 hr	23,815 hr	25,075 hr
Carbon Injection?	No	No	Yes*	No	Yes*
Module	B21	A10	B21	A20/B20	B20
Permeability (cfm/ft²):					
As Received	4.78	4.48	3.07	3.60	3.21
Vacuumed	18.8	15.8	11.7	14.4	12.6
Washed	35.4	40.9	33.0	40.4	31.0
Fabric Weight (oz/yd²):					
Washed	17.8	18.6	18.2	19.4	19.2
Residual Dust Load (oz/yd²):					
Removable by Vacuuming	6.4	5.6	4.7	6.8	4.8
Removable by Washing	<u>3.0</u>	<u>5.3</u>	<u>6.0</u>	<u>7.1</u>	<u>4.2</u>
Total (As-Received)	9.4	10.9	10.7	13.9	9.0
Bag Weight, as received (lb)	6.9	6.8	6.6	7.4	6.4
Residual Dust Weight (lb)	2.7	2.6	2.4	3.1	2.2
Mullen Burst Strength (psi, net):					
Average (actual)	396	343	357	305	305
Normalized to 18 oz/yd ²	400	332	354	283	286
% Loss (vs. new fabric**)	-24%	-23%	-33%	-33%	-41%
Fabric pH (5g/100 ml):	4.24***	3.03	2.91	2.45	2.57

* During much of the final 6,266 hours of service

** Average values for new fabric were 428, 525, and 487 psi net (normalized) for the OEM bags, the B21 replacement bags, and the B20 replacement bags, respectively.

*** pH electrode malfunction suspected

Table 2

GASTON UNIT 3 – USED BAG COMPARISON With and Without Carbon Injection

Bag Set	OEM	Test Bag*	OEM
Date Test Bag Removed	10/3/97	12/6/03	2/20/98
GFTS Sample	#2460	#3919-8-4	#2587
Service Life	6,100 hr	6,266 hr	8,650 hr
Carbon Injection?	No	Yes	No
Module	A20	B21	B20
Permeability (cfm/ft ²):			
As Received	6.32	3.38	5.74
Vacuumed	18.6	13.2	21.2
Washed	42.7	32.4	41.8
Fabric Weight (oz/yd ²):			
Washed	18.1	18.1	18.6
Residual Dust Load (oz/yd ²):			
Removable by Vacuuming	3.4	7.15	6.1
Removable by Washing	3.8	14.2	3.0
Total (As-Received)	7.2	21.35	9.3
Bag Weight, as received (lb)	6.0	7.2	6.7
Residual Dust Weight (lb)	1.8	3.0	2.5
Mullen Burst Strength (psi, net):			
Average (actual)	358	357	318
Normalized to 18 oz/yd ²	357	355	308
% Loss (vs. new fabric**)	-17%	-32%	-28%
Fabric pH (5g/100 ml):	4.45	3.17	3.44

* Installed in March 2003 prior to initiation of the carbon injection test. This used bag was very stiff and crusty, atypical of Gaston 3 bags in general.

** Average values for new fabric were 428 and 525 psi net (normalized) for the OEM bags and the B21 test bag, respectively.

Bag Measurements and Construction

Used Bag	B20	B21	8-4
Length (inches)*	–	277 ^{3/8}	277 ^{1/4}
Flat Width (inches)	7 ^{3/8}	7 ^{7/16}	7 ^{7/16}
Circumference (inches)	14 ^{7/8}	14 ^{15/16} – 15	14 ^{15/16} – 15
Bag Weight (lb)	6.39	6.58	7.16

* Measured at the seam, from top of bag to the upper row of disc stitching. Bags cut in half as-received; sum of lengths of two pieces. Bag B20 too damaged during removal to measure accurately.

The bags were constructed of 18 oz/yd², 2.7-denier Ryton felt, singed on both sides, according to the Hamon Research-Cottrell specifications for the Alabama Power Gaston bags. They had a separate, woven Ryton top cuff with a double-beaded snap band, an oval disk bottom with a 4" reinforcement (both self-material), and a lapped vertical seam sewn with triple-needle chain stitching. Both bags were sewn with PTFE thread (blue Profilen) in their circumferential stitching. The vertical seam of Bag B20 (Midwesco) was sewn with multifilament PPS thread, and those of Bags B21 and 8-4 (BHA) were sewn with PTFE-coated glass thread.

Observations and Data Profiles

All of the bags had been cut into two pieces and slit open vertically near their middle for cage removal. The external dust cake on all bags was the same dark gray color, but it varied from bag to bag in its thickness and appearance.

Bag 8-3: This bag had a very nodular dust cake, and it was very stiff and crusty in its top 2^{1/2} feet. It was discarded.

Bag 8-4: This bag also had a very nodular dust cake, especially in its bottom half, but its top was not nearly as stiff as that of #8-3. The top 5-foot section of this bag was much stiffer than the rest of the bag, and it had blotchy staining (watermarks?). It was still very stiff and crusty even after vacuuming. There were no signs of excessive wear on this bag, either internally or externally. Internally, the bag was a light olive color, with not much of a color gradient from top to bottom (unusual for Gaston bags), and it appeared to be much newer than Bags B20 and B21 (as it was supposed to be). The cage pan impression, though somewhat indistinct, was $\approx 1\frac{1}{4}$ " above the bag disc.

Bag B21: This bag had a similar appearance to #8-4 except that it was not stiff. It had some soft crust externally, especially in the curved portions in its top half, but no hard nodules like #8-4. There were no signs of excessive wear, either internally or externally. This bag had more blotchy dust darkening internally than #8-4, especially in the flat portion of its bottom half. The cage pan impression was level with to slightly above the bag disc.

Bag B20: The external dust cake on this bag was more flaky, not crusty or nodular like the other bags. It had been mangled somewhat in its top cuff and near its middle during removal. *Its bottom reinforcement was badly worn*, completely through to the bag fabric in the flat portion on the seam side and down to the scrim of the bag fabric in one curved portion. Although the thread in the disc attachment stitching was worn away externally in that curved section, no actual dust leakage had occurred. This type of wear is common in certain areas of the front modules in this baghouse, where bags swing and bang together due to turbulent gas flow. The bag exhibited no excessive wear otherwise, either internally or externally. The cage pan impression was bottomed out in the bag disc.

The washed samples of all three bags were a light golden-brown color (with some carbon staining externally), typical of previous used Gaston bags. The washed samples from Bag B20 (the oldest bag) were only slightly darker in color.

Permeability Profiles

Used Bag		B20	B21	8-4
Permeability (cfm/ft² @ 0.5" WG):				
As Received,	Top	2.20	2.53	3.18
	Middle	3.78	3.00	3.43
	<u>Bottom</u>	<u>3.66</u>	<u>3.68</u>	<u>3.54</u>
	Average	3.21	3.07	3.38
Vacuumed,	Top	6.34	5.84	5.20
	Middle	15.0	11.5	15.5
	<u>Bottom</u>	<u>16.6</u>	<u>17.8</u>	<u>18.9</u>
	Average	12.6	11.7	13.2
Washed,	Top	29.2	29.8	32.3
	<u>Bottom</u>	<u>32.8</u>	<u>36.3</u>	<u>32.4</u>
	Average	31.0	33.0	32.4

Mullen Burst Profiles

Used Bag		B20	B21	8-4
Mullen Burst (psi, net):				
Vacuumed,	Top	296	359	362
	Middle	307	374	359
	<u>Bottom</u>	<u>324</u>	<u>346</u>	<u>422</u>
	Average	309	359	381

Fabric Weight and Residual Dust Load Profiles (oz/yd²)

Used Bag	B20	B21	38202
Weight (oz/yd²):			
As-Received, Top	30.1	32.0	47.4
<u>Bottom</u>	<u>26.3</u>	<u>25.9</u>	<u>31.5</u>
Average	28.2	28.95	39.45
Vacuumed, Top	25.4	26.7	41.3
<u>Bottom</u>	<u>21.4</u>	<u>21.8</u>	<u>23.3</u>
Average	23.4	24.25	32.3
Washed, Top	19.8	18.6	17.7
<u>Bottom</u>	<u>18.6</u>	<u>17.9</u>	<u>18.5</u>
Average	19.2	18.25	18.1
Residual Dust Load (oz/yd²):			
Removed by vacuuming, Top	4.7	5.3	6.1
<u>Bottom</u>	<u>4.9</u>	<u>4.1</u>	<u>8.2</u>
Average	4.8	4.7	7.15
Removed by washing, Top	5.6	8.1	23.6
<u>Bottom</u>	<u>2.8</u>	<u>3.9</u>	<u>4.8</u>
Average	4.2	6.0	14.2
Total Top	10.3	13.4	29.7
<u>Bottom</u>	<u>7.7</u>	<u>8.0</u>	<u>13.0</u>
Average	9.0	10.7	21.35

Fabric pH

pH was measured on samples of as-received (dirty) fabric from the middle of both bags (5 g per 100 ml distilled water). The values were 2.57, 2.91, and 3.17 for bags B20, B21 and 8-4 respectively.

APPENDIX H

NORIT Quote for ACI System



Cameron E. Martin
ADA Environmental Solutions LLC
8100 South Park Way Unit B-2
Littleton, CO 80120

NORIT Americas Inc.
5775 Peachtree Dunwoody
Suite #C250
Atlanta, GA 30342
Phone: 404-256-6150
Fax: 404-256-6199
www.norit-americas.com

September 13, 2002

Re: Southern Company Plant Gaston

Dear Cam;

Enclosed is our proposal for the Southern Company Plant Gaston PAC Storage and dosing system.

If you require any additional information or I can be of further assistance please contact me at (800) 641-9245 or by email at DPHall@norit-americas.com . Hard copies are on their way via Fed Ex.

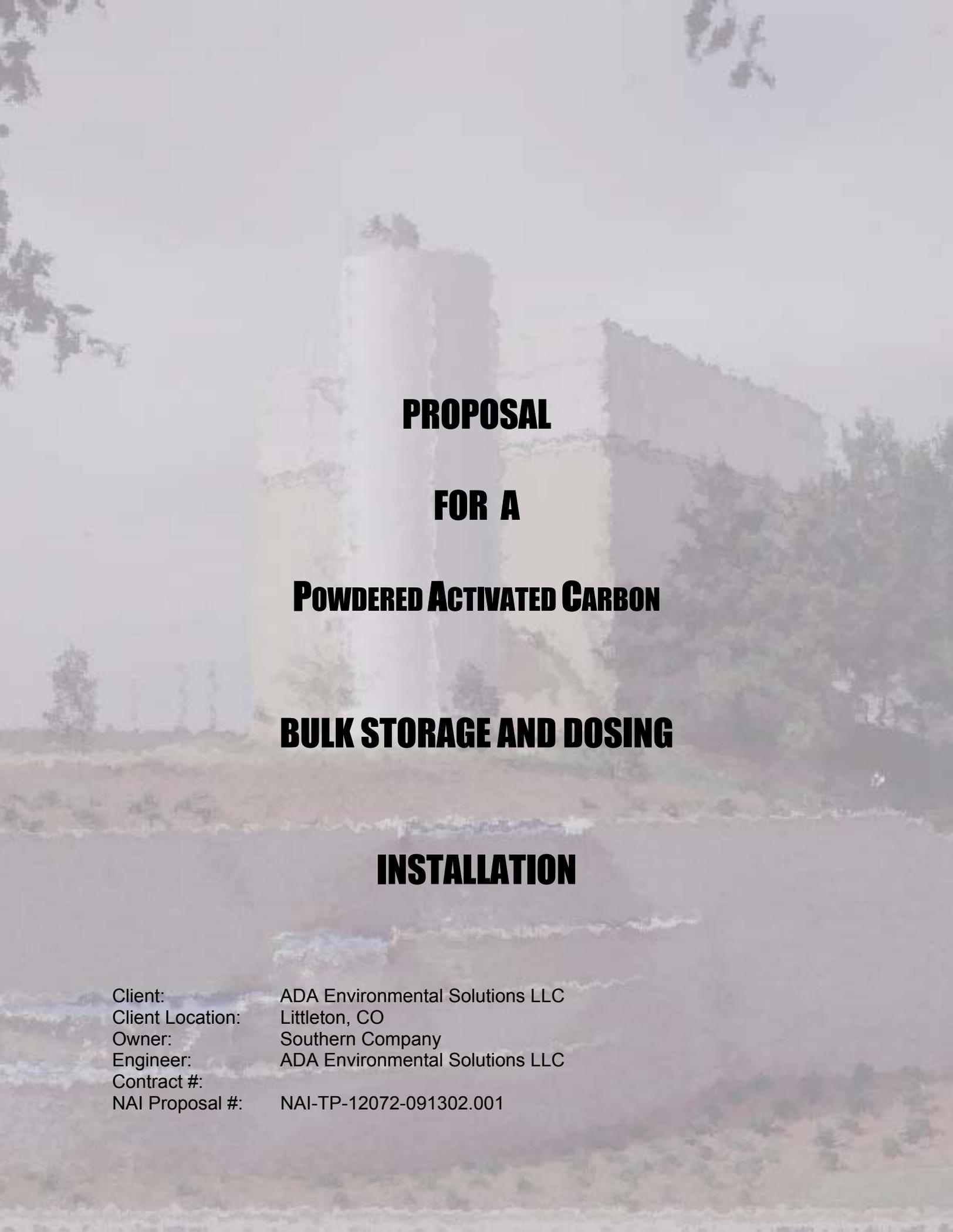
Regards,

A handwritten signature in black ink, enclosed within a hand-drawn oval. The signature is stylized and appears to read 'Donald P. Hall, Jr.'.

Donald P. Hall, Jr.
Systems & Services
DPHall@norit-americas.com

cc: / RKM / file

Attachments: Contract / NAI-TP-12072-091302.001



PROPOSAL

FOR A

POWDERED ACTIVATED CARBON

BULK STORAGE AND DOSING

INSTALLATION

Client: ADA Environmental Solutions LLC
Client Location: Littleton, CO
Owner: Southern Company
Engineer: ADA Environmental Solutions LLC
Contract #:
NAI Proposal #: NAI-TP-12072-091302.001

NORIT Americas Inc.

Most Choices + Precise Fit = Best Performance.

PROPOSAL

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PROPOSAL

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PROPOSAL

BENEFITS NORIT AMERICAS INC. SILO STORAGE & AUTOMATIC FEED SYSTEM

SYSTEM FEATURE	BENEFIT TO Southern Company
<i>PAC System Design from Worlds Largest PAC producer</i>	<ul style="list-style-type: none">• Experienced Team and Custom Design ensures reliability• Complete turnkey installation• The best system from the people who know PAC the best
<i>Automatic feed of PAC</i>	<ul style="list-style-type: none">• Easy start-up• Totally hands off operation which is <u>monitored</u> by the operator• Accurate PAC feedrate• No operator handling or exposure to carbon dust
<i>Prefabricated Components</i>	<ul style="list-style-type: none">• Fast Erection & Startup• Minimized plant interruption.
<i>Totally contained system</i>	<ul style="list-style-type: none">• <u>NO</u> carbon mess• Enhanced Reliability• Improved safety from cleaner work place
<i>(Optional) Remote telemetry reorder \$750 Adder</i>	<ul style="list-style-type: none">• No emergency orders of PAC• No danger of plant downtime from loss of carbon feed• No worry about when to reorder - it's automatic• Optimal inventory control



NORIT Americas Inc.

Most Choices + Precise Fit = Best Performance.

CONTRACT

NORIT Americas Inc. (hereinafter referred to as "Seller") does hereby propose to furnish to **ADA Environmental Solutions LLC** (hereinafter referred to as "Buyer"), whose address is **8100 South Park Way Unit B-2, Littleton, CO 80120** equipment and or activated carbon, as set forth below.

NORIT Bulk Storage and PAC Dosing System

US\$ 312,625.⁰⁰

Including, but not limited to 14' diameter PAC Storage Silo, Equipment Skid containing all equipment required for a self contained metering and dosing system to convey PAC to two independantly controllable dosing points at the rate of 30-750 #/hr., Prewired/Preprogrammed Control System panel, Level Indicators, Discharge Valve and Flow Control System delivered to site ofr erection by others. As described in NORIT Proposal attached as Exhibit A. FOB ExWorks.

Option	Accept	Decline	Description	Adjustment	Price
A.					
B.					
C.					
D.					
E.					
F.					

All work to be completed in a workmanlike manner according to standard practices and will comply with all local requirements for building permits and inspections. Any alteration or deviation from the above specifications involving extra costs will be executed only upon written orders, and will become an extra charge over and above the proposal. This proposal is valid for sixty (60) days from 9 December, 2005. Payment Terms 10% with Order, 10% with Approval Drawings, 50% with notice to ship, 20% upon erection, 10% upon startup and owner acceptance.

General Terms and Conditions on reverse shall govern

NORIT Americas Inc.

Dated 9 December, 2005

Authorized Signature _____

Authorized Signature _____

Acceptance of Proposal

The Above prices, specifications and conditions are hereby accepted. NORIT Americas Inc. is authorized to do the work as specified. Payment will be made as outlined above.

Date of Acceptance _____

ADA Environmental Solutions LLC

Signature _____

Signature _____



I GENERAL TERMS & CONDITIONS

The following terms and conditions of sale ("Terms") govern all quotations, offers, purchase orders, order acknowledgements, contracts, and deliveries for the sale and/or installation of all goods (the "goods") supplied by Norit Americas Inc. ("Seller") to the purchaser thereof ("Buyer"). All orders by Buyer for goods are subject to acceptance by Seller at its office in Atlanta, Georgia. Unless modifications or additions are expressly accepted in writing by Seller, these Terms are controlling and no other, inconsistent or additional provisions shall be of any effect, unless accepted by Seller in writing. Seller's acceptance of Buyer's order is expressly conditional on Buyer's assent to these Terms. These Terms and Conditions of Sale shall become effective, and are accepted by Buyer, at the latest upon Buyer's receipt and use of all or part of the goods sold hereunder.

SCOPE. Seller's written quotation and order confirmation, if any, and these Terms shall be conclusive in determining the rights and obligations of Seller and Buyer. Data, such as illustrations, drawings or specifications, shall be considered approximations, unless Seller has specifically stated otherwise in writing. Seller reserves the right to make changes in design and construction of the goods to be supplied, provided such changes do not impair the operation or durability of the goods and do not alter the price.

PURCHASE PRICE AND PAYMENT TERMS. Buyer shall, without offset or deduction, pay the purchase price for the goods, as well as all federal, state and local sales, use, excise or other similar taxes on the goods. Unless otherwise agreed in writing, payment of the purchase price shall be net F.O.B. origin of shipment and payment shall be made by Buyer at the latest within thirty (30) days from the date of Seller's invoice. On all amounts owed and remaining unpaid more than thirty days from the date of Seller's invoice, interest will automatically accrue and be charged to Buyer without further notice at the rate one percent (1%) per month (12% annually). In addition, Buyer agrees to pay all expenses of collection, including reasonable attorneys' fees, if amounts owing by Buyer are collected by or through an attorney at law. Time is of the essence as to the payment obligations of Buyer.

The terms of payment are subject to the approval of Seller prior to shipment, and Buyer agrees, with respect to its obligation for payment, that (a) if, in Seller's judgment, Buyer's financial condition or other conditions do not justify shipment, Seller may require full or partial payment in advance; (b) after the goods are shipped, it will pay to Seller the amount of the invoice in accordance with the terms of payment stated thereon.

Buyer agrees that all changes which it may request after approval of drawings and settlement of design details are subject to engineering charges and to factory charges on in-process work already completed and affected by the change. Such changes are to be initiated in writing by Buyer and are subject to acceptance by Seller. Buyer agrees that the value of all change order amounts is billable at 100% of face value due net 30 days.

PROPOSAL VALIDITY. The price in this proposal is valid for 60 days from 9 December, 2005, after which time NORIT Americas Inc. retains the right to review the individual items for price escalation.

DELIVERY. Unless otherwise agreed in writing, Seller will deliver the goods F.O.B. Seller's place of shipment upon receipt by Seller of any agreed upon downpayment, other payments, and all documents, permits and data deemed reasonably necessary by Seller for it to perform its contractual obligations. Partial shipments will be permitted and contract modifications will extend time of delivery for a period of time appropriate to permit compliance with same. The times for shipment, delivery, and start-up are Seller's best estimate and Seller will exert reasonable efforts to accomplish shipment, delivery, and start-up at such estimated times. Shipment dates are not guaranteed and are not binding in the event of unforeseen circumstances, including but not limited to acts of God, war, insurrection, labor disputes, delay of delivery of essential materials, and events beyond Seller's control. In the event of cancellation, anticipatory repudiation, nonperformance, breach or default by Buyer prior to shipment, Seller shall be entitled, without proof of actual damages, to liquidated damages equal to twenty-five percent (25%) of the contract price in lieu of actual damages. It is agreed that the liquidated damages referred to herein are not established as a penalty, but are calculated and agreed upon in advance based upon the difficulty, uncertainty and impossibility of determining the actual and consequential damages which would be incurred as a result of such cancellation, repudiation, nonperformance, breach or default by Buyer prior to shipment. This liquidated damages provision is not intended to apply to nonperformance, breach or default of the contract subsequent to shipment, nor, at Seller's option, to cancellation, repudiation, nonperformance, breach or default which gives rise to a remedy other than damages (such as specific performance), and Seller retains every other remedy it may have in connection therewith. In the event of Buyer's breach at the time of or subsequent to shipment, Seller shall be entitled to all reasonable attorneys' fees, collection costs, interest at the maximum rate allowable by law on the unpaid balance due, and all other legal and equitable remedies.

RISK OF LOSS AND ACCEPTANCE. The risk of loss passes to Buyer at the time of delivery to carrier, irrespective of whether Seller is required to render additional services under the contract, such as installation. Notwithstanding the passage of risk of loss to Buyer upon delivery of the goods to the carrier, title of the goods shall remain in Seller until delivery to Buyer. In the event of a delay in shipment for which the Buyer is responsible, the risk of loss passes to Buyer as of the date the goods are ready for shipment. Buyer is required to accept delivery of all goods shipped, without prejudice to its warranty rights. Buyer shall upon delivery receive, sign for and unload the goods and within seven (7) days of delivery inspect the goods, and shall within fifteen (15) days of delivery give written notice to Seller of any claim that the goods do not conform or are otherwise unacceptable. No attempt at notice of revocation of acceptance by Buyer shall be effective if not made in writing within fifteen (15) days after Buyer discovers or should have discovered, whichever is earlier, the ground for such revocation. Buyer shall make any claims in writing for shortage or error in filling its order within ten (10) business days after delivery of the goods.

SECURITY INTEREST. Until all amounts owed by Buyer to Seller with respect to the goods or services provided hereunder and under any other transaction between Seller and Buyer are paid in full, Seller retains security title to the goods and Buyer grants to Seller a lien upon and purchase money security interest in the goods under the Uniform Commercial Code all of which shall continue notwithstanding any attachment or affixation of the goods to real estate and Buyer agrees to execute all documents and to do and perform all other acts and things which Seller in good faith considers necessary, desirable or appropriate to further establish, perfect or protect Seller's security interest and Buyer authorizes all present and future officers of Seller to execute, and to file, in Buyer's name and on Buyer's behalf any and all financing statements, fixture filings or other documents deemed necessary by Seller to accomplish same.

WARRANTY, DISCLAIMER AND LIMITATION OF REMEDIES. NORIT Americas, Inc., Inc. (Seller warrants that, for a period of one (1) year from the date of start-up to the customers site, not to exceed eighteen (18) months after delivery to plant site, those equipment, materials and workmanship described above for the intended normal use and service will be free from defects in material and workmanship. Seller will assign to Buyer (to the extent assignable) all warranties or guarantees of goods of manufacturer other than its own that it sells in connection with the setup and the use of its goods. Notwithstanding the foregoing, Seller does not warrant against abrasion, corrosion or erosion. Seller's limited product warranty will not apply unless Buyer gives written notice to Seller of the specific defect within five (5) business days of discovery and Buyer has met its own obligations under the contract, including payment. Seller further warrants that those goods manufactured by Seller will be designed and manufactured so as to perform the mechanical functions expressly set forth in Seller's written specifications for the goods. This performance warranty shall be effective only if Buyer tests the goods promptly in accordance with the scheduling as agreed to by the parties, if any, notifies Seller in writing of any deficiency in performance within seventy-two (72) hours of the completion of such testing, delivers to Seller a written performance report within ten (10) days after the completion of such testing, and has met its own obligations under the contract, including payment. Seller shall be deemed to have fulfilled its performance warranty, if any, in the event that the applicable specifications can be achieved within 10% upon performance testing. Buyer expressly acknowledges that reloading of materials is required periodically during operation and that such requirement will result in discontinuous operation from time to time. Seller's warranties do not cover defects or deficiencies due to or arising out of (1) normal wear and tear or improper, abnormal, or negligent handling, operation, maintenance, overloading, or use; (2) improper foundation or installation, unless performed by Seller; (3) weather or other influences of nature; (4) tampering, alteration, or repair by Buyer or third parties without the prior written consent of Seller. Seller does not warrant components and parts not manufactured by Seller. Seller does not warrant services by anyone other than Seller, unless such services are provided by an authorized agent of Seller, in which event Seller warrants that the service will be performed in a workmanlike manner.

Buyer shall grant Seller a reasonable time and opportunity after Buyer's written notice to comply with warranty obligations and Seller reserves the right to make adjustments and design modifications to the goods prior to initial operation and during the warranty period to meet its warranties.

Seller shall absorb the costs of warranty repairs and replacements on an ex-works basis. Buyer shall be responsible for the costs of warranty transportation of the goods, outside charges, "back charges" and the expenses of warranty disassembly and installation. With respect to repaired or replaced goods serviced under Seller's product warranty, Seller's product warranty shall apply for the longer of (a) the initial product warranty period then remaining as to the repaired or replaced goods or (b) six (6) months from the date of notification by Seller to Buyer that the work has been completed, whichever is later. All replaced goods shall be the property of Seller.

THE WARRANTIES SET FORTH ABOVE ARE THE SOLE AND EXCLUSIVE WARRANTIES AND ARE EXPRESSLY IN LIEU OF ANY AND ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR ANY PARTICULAR PURPOSE, WHICH ARE HEREBY DISCLAIMED.

Buyer's sole and exclusive remedy for breach of warranty is limited to the repair or replacement at Seller's option of defective or deficient parts. In the event Seller is unable or otherwise fails to repair or replace within a reasonable time, Buyer's sole and exclusive remedy is limited to an amount not in any event to exceed the price actually paid for the goods upon return of the goods to Seller.

Except where expressly acknowledged in writing by an executive officer of Seller, no person or entity other than a corporate officer of Seller is authorized to assume for Seller any undertaking, obligation, liability, or warranty.

LIMITATION OF LIABILITY. Seller shall in no event be liable to Buyer for injury to persons or damage to property arising out of or in connection with the sale, delivery, assembly, disassembly, repair, use, installation, or employment of the goods, whether arising from any claim based upon contract, warranty, tort, products liability, strict liability, failure of essential purpose, or any other legal or equitable theory, for any amount in excess of the amount actually paid by Buyer to Seller for the goods. Except, however, in no event shall Seller be liable to Buyer in any manner for any special, indirect, incidental, or consequential damages including but not limited to damages or losses arising out of shut-downs, inoperability of the goods, operating labor, overhead, loss of production or raw materials, production of below-standard products, or loss of profits, whether arising from contract, warranty, tort, products liability, strict liability, failure of essential purpose, or any other legal or equitable theory.

INSTALLATION. If the contract provides for installation by Seller, Seller will commence such installation after the site has been made ready, foundations have been completely dried and set, and all construction and preliminary work has been entirely completed. Unless otherwise agreed, installation of the goods and all outside charges and "back charges" shall be carried out at the expense and risk of Buyer. If the contract requires Seller to install the goods and to provide labor, the labor supplied by Seller shall not be required to work overtime or to provide services except as expressly required under the contract, unless Buyer agrees to pay for such additional work against a separate invoice. Trial operations, performance testing and start-up shall be performed during normal working hours and operating materials shall be paid for by Buyer.

CONFIDENTIALITY. Seller retains ownership of and all intellectual property rights in and to all information, quotations, drawings, and documents (collectively "the property") furnished by Seller or produced in the performance of this contract.

SECURITY. All documents and information made available by either party to the other will be treated as confidential and used exclusively in cooperation with each other for the construction of the plant. NORIT Americas Inc. will abide by all requirements outlined in the previously signed Confidentiality Agreement. If documents and information are transmitted to third parties with the permission of the originator of such documents and information, it will be made binding on such third parties not to disclose documents or information received. If Client deems it necessary, confidentiality agreements will be placed with said third party.

CHOICE OF LAW AND JURISDICTION. The interpretation and enforcement of these Terms shall be exclusively governed by and construed in accordance with the substantive laws of Georgia without giving effect to the choice of law principles thereof. Buyer and Seller hereto specifically consent to jurisdiction in any federal or state court within Georgia, which courts shall together constitute the exclusive forum in which disputes under or in connection with this contract are to be resolved. Buyer specifically submits to personal jurisdiction and waives all objections to jurisdiction and venue and waives any claim of forum non conveniens and specifically consents to venue and jurisdiction in the state and federal courts of Georgia for any action instituted pursuant to this contract. Except, however, nothing contained herein shall prevent Seller from bringing any action or exercising any rights within any other state or other jurisdiction against Buyer and against the collateral and any properties or assets of Buyer as to any legal claim arising in connection with these Terms.

INFRINGEMENT. If notified promptly in writing of and given sole control of the defense, Seller shall indemnify and hold Buyer harmless from and against claims that the goods themselves infringe a United States patent. Buyer, however, shall defend, indemnify and hold harmless Seller from and against any loss, liability, claim or expense (including reasonable attorney's fees) arising out of a claim of patent or other intellectual property rights infringement made in connection with Buyer's business, its methods, systems or processes; except, there shall be no indemnity by Buyer where Seller's good are the sole cause of such claim.

MISCELLANEOUS. Buyer shall use and shall require its employees and others coming in contact with the goods to use safety measures and devices. Buyer shall provide proper warnings and use and require its employees and others coming in contact with the goods to use safe operating procedures around the goods and in operating the goods. Buyer specifically agrees to maintain the goods in compliance with all laws and regulations of any and all government agencies or authorities having jurisdiction with respect to the installation and use of the goods. Seller makes no representation that the goods do or will comply with any law, code, regulation or order of any authority or other governmental body and Seller does not undertake or have any obligation to obtain permits, licenses or approval from said authority or governmental body concerning the goods. If Buyer breaches any of the agreements or undertakings in this Agreement, Buyer shall indemnify and save Seller harmless from and against any claim, loss, liability, obligation or judgment, including expenses of litigation and reasonable attorneys' fees, incurred by Seller arising out of or in connection with injuries to person or damage to property directly or indirectly related to the purchase, installation, use or operation of the goods. Buyer further agrees to notify Seller promptly in writing, but in no event later than thirty days of any accident or malfunction involving the goods, which results in personal injury or damage to property and to at all times cooperate fully with Seller and others in investigating and determining the causes of such accident or malfunction.

This contract shall be binding upon and inure to the benefit of the respective successors and assigns of each of the parties hereto, but shall not be assigned by Buyer without the prior written consent of Seller.

Seller's waiver of any breach, or failure to enforce any of the terms and conditions of this contract at any time, shall not in any way affect, limit or waive Seller's right thereafter to enforce and compel strict compliance with every term and condition hereof.

Buyer shall reimburse Seller for all excise, use or sales taxes, or other charges which Seller may be required to pay to any government (national, state or local) upon, or measured by, the sale, transportation or use of any goods sold hereunder. Seller may at its option add to the price of goods sold hereunder the amount of any increase in transportation charges for shipments to Buyer.

All provisions of these Terms are severable and divisible and if any term or provision of the contract should be held invalid or unenforceable for any reason, such term or provision shall be void to the extent of such invalidity or illegality, without invalidating any of the remaining Terms. The headings contained herein are for convenience of reference only and shall not affect the meaning or interpretation of these Terms.

In the event that NORIT Americas, Inc. should be delayed in the completion of the work by reason of any act or omission of the purchaser or another contractor employed by the purchaser, the period within which the work is to be completed under this contract will be extended for the period resultant from such delay.

These Terms and the documents consistent with and governed by these Terms constitute the entire agreement and understanding between the parties with respect to its subject matter and shall not be modified or amended except by express written amendment signed by the duly authorized representatives of the parties.

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I INTRODUCTION

The NORIT Americas, Inc. silo storage and flue gas dosing system is the result of many years of experience in the design and installation of powdered activated carbon (PAC) dosing systems worldwide, as well as the experience gained by being one of the largest manufacturers of activated carbons in the world.

NORIT Americas Inc. proposes to design and supply a clean, reliable dosing/injection system, that will receive, store and feed bulk Powdered Activated Carbon (PAC) into the flue gas stream of a coal fired power boiler at the Gaston Plant of Alabama Power.

II DESCRIPTION OF THE SYSTEM

The NORIT bulk silo storage and feed system will receive bulk PAC in 40,000 pound batches, delivered by tanker trucks. The PAC is unloaded pneumatically into a dry welded steel storage silo where a combination of specially designed air fluidization valves and nozzles, located in the conical discharge section of the silo, pulse compressed air into the bulk of the carbon, promoting mass flow out of the flanged discharge connections. NORIT takes advantage of the natural tendency of fine powders to flow with liquid-like properties when fluidized by a gas, normally air, to move the PAC within the system. By separating the individual carbon particles with a gas, the normal resistance to bulk flow is greatly reduced and the carbon can easily be moved from the silo into the metering equipment.

Fluidized PAC is fed from the silo by a rotary valve into a volumetric feeder hopper where it is temporarily stored until conveyed by the feeder screw into the drop tube. The amount of carbon discharged from feeder is directly proportional to the speed of the feeder screw and an adjustable speed drive motor allows a wide range of carbon delivery rates from the screw. Carbon is fed through the drop tube directly into the eductor inlet, located below the feeder discharge.

The passing of motive air through the eductor nozzle produces a vacuum in the eductor inlet, which helps draw the carbon and air into the mixing zone directly downstream of the mouth. The carbon is transported through the piping system and is injected through a nozzle into the boiler exhaust gas stream.

A programmable logic controller (PLC), with input from remote sensors, controls the sequences of events throughout the system and also provides alarms and interlocks to annunciate problems and protect the system. The system is configured to feed a constant pounds per hour of carbon or to



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follow an analog signal provided by the customers equipment. During normal operation, operator attention is not required, as the system operates automatically once the mode of operation and the feed rates have been selected.

The equipment/system proposed will require a dry compressed air supply, a 480 VAC power supply and injection piping interfaces. All system components will be located under or attached to the storage silo, on the storage silo top deck and in the Power and Control Building. The footprint of the PAC storage silo will be 14 feet in diameter and will require an adjoining area for spotting a pneumatic road tanker for carbon filling. The footprint of the Power and Control Building will be 8 feet by 10 feet. This building will house the Motor Control Center, the Control Panel and the air storage tank.

III SCOPE OF WORK

NORIT Americas Inc. proposes to provide the following management, design, equipment, installation and support:

A. MANAGEMENT, DESIGN & SUPPORT

1. Project Management

NORIT will provide the services of a Project Manager to oversee the complete project including the following activities:

- a. System design.
- b. Project scheduling.
- c. Project submittals.
- d. Coordination between the Purchaser and NORIT for system details.
- e. Equipment Procurement.
- f. Supervision of fabrication shop for sub-assemblies.
- g. Technical support during equipment installation.
- h. System start-up.
- i. Development of the system O&M Manuals.

2. Design

NORIT will provide the following design documents and drawings:

- a. General arrangement drawings.



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- b. Piping Instrumentation Diagram.
- c. Mechanical Design/Layout Drawings.
- d. Electrical Schematics.
- e. Point to point wiring diagrams.
- f. Interconnect Diagram & Conduit Routing
- g. Allen Bradley PLC Ladder Logic Diagrams.
- i. I/O List.
- j. Equipment List.
- k. Motor data sheets.
- l. Foundation Loadings provided by the Silo Manufacturer.

3. Submittal

NORIT will provide four (4) copies of the following drawings and information, as a minimum, to the Purchaser for approval prior to purchase of equipment.

- a. Written Description of System Operation.
- b. Project Schedule.
- c. System P&ID's.
- d. System General Arrangement Drawings.
- e. System Plan Drawings.
- f. Electrical Schematic Drawings.
- g. Control Panel Layout Drawings.
- h. PLC Ladder Logic.
- i. Equipment Cut Sheets.

4. O&M Manuals

NORIT will provide four (4) copies of the O&M manuals prior to installation of the equipment and will provide as-built drawings upon completion of the project. The O&M Manuals will contain, as a minimum, the following information:

- a. Written Description of System Operation.
- b. System P&ID's.
- c. System General Arrangement Drawings.



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- d. System Plan Drawings.
- e. Electrical Wiring Diagrams.
- f. Control Panel Layout Drawings.
- g. PLC Ladder Logic.
- h. Equipment Operation & Installation Manuals.
- i. Silo Design Drawings & Foundation Loading Calculations.

5. Installation, Start-Up and Training Services

NORIT Americas will provide the services of the Project Manager for a period of two (2) weeks to assist the purchaser and his contractor with the installation of the equipment and to provide start-up services and operator training. Additional days on-site at the request of the purchaser will be billed at the standard rate of \$750 per day plus living and travel expenses.

B. CIVIL/STRUCTURAL

1. Storage Silo and Building Foundations

NORIT will provide the storage silo design loads to allow the Purchaser to design and install a suitable foundation for the PAC storage silo. NORIT will also provide the Power and Control Building loads to allow the Purchaser to design and install a suitable sub-base or foundation.

2. Power and Control Building

NORIT Americas will provide a concrete Power and Control Building that houses the Motor Control Center and the Control Panel. This building will have heating and air conditioning and will also contain the air storage tank.

3. Equipment Support Structure

The PAC feed equipment, blower, associated piping and instruments will be mounted on support skids fabricated from 3" A 500 square tubing with base plates for anchoring. The structural members will be of sufficient size to support the equipment without excessive deflection or vibration.

All external carbon steel surfaces will be blasted per SSPC SP6 commercial blast to obtain a 1.5 mil average profile, prime coated



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with Sherwin Williams Epoxy Mastic Aluminum II B62 S 100/B60 V 100 Primer (6.0 mils DFT) and finish coated with Sherwin Williams Aliphatic Polyurethane B65 T 104/B60 V2 (3.0 mils DFT) in "safety" blue.

C. MECHANICAL EQUIPMENT

1. Storage Silo

A welded carbon steel silo with support legs and load cells will be provided to receive and store the bulk PAC. The silo will be 14 feet in diameter with a working capacity of approximately 2,900 cubic feet. The silo deck will be sloped ten (10) degrees for drainage. The silo will be fabricated with a two (2) cone bottom, each with a 60 degree minimum slope. Each discharge cone will be fitted with a short section of 8" nominal pipe and an 8" flange

The silo will be designed to meet the most stringent of the following conditions:

- a. Per the Uniform Building Code, latest edition.
- b. A weight of 35 pounds per cubic foot for the material contained within the silo.
- c. Transportation, handling and erection loads.
- d. To support a 300 pound person walking on the roof and platform surfaces, in addition to the dead load weight of all equipment and appendages.
- e. A live load of 50 psf on the roof area and 100 psf on walking surfaces.

Anchor bolts will be designed and provided by the silo manufacturer.

The silo will be equipped with a 4" nominal, schedule 40 fill line, with a 48" radius elbow, which enters the silo tangentially, reducing dusting and lowering the demand on the silo vent filter. The fill line will be supported by brackets attached to the silo shell and will be equipped with a 4" male camlok fitting & cap located approximately 4½' above grade for the truck hose connection.

The silo roof deck will be equipped with a bag type vent filter for cleaning the conveying air from the delivery tankers, a 24" pressure and vacuum relieving manway, and a reflex-radar level transmitter to measure PAC Level.



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The silo will be equipped with three (3) each 1½" half couplings located in the sidewall for three (3) point level switches to monitor PAC level.

Each silo discharge pipe will be equipped with one (1) each 1" half coupling and each outlet transition section will be equipped with two (2) 1" half couplings to accommodate fluidizing nozzles. The upper silo discharge cone section will also be equipped with eight (8) each 2" half couplings to accommodate additional air fluidization nozzles near the circumference of the cone.

The silo will be primed with a polyamide epoxy primer over a commercial SSPC SP-6 blast on the exterior surfaces and inside the skirt. The exterior will be coated with an acrylic enamel topcoat of a color chosen from the manufacturer's standard color chart. The silo top deck will be painted with a FerroX non-skid coating.

The silo will be skirted with structural steel legs and load cells such that the weight of the PAC remaining in the silo can be measured at all times. The load cells will feed a weigh-indicator mounted in the Control Panel. The Weigh-Indicator will also provide input to the Allen Bradley PLC System.

A galvanized carbon steel OSHA approved ladder with integral safety cage and intermediate landing will be provided for access to the silo top deck, which will be enclosed with handrail and toe plate. The handrail will be aluminum pipe supported from galvanized carbon steel angle posts with galvanized steel toeboard.

Electrical Equipment installed under, on the side and on top of the silo will be suitable for use in Class II Division 2 Group F Environments.

2. Silo Vent Filter

A self-contained bag-type (Flex Kleen model 58BVBS-25 or approved equal) bin vent filter will be provided and mounted atop the PAC storage silo. The dust collector will be oriented to allow easy operator access of the filter elements for routine maintenance. The dust collector will be designed to provide a 3.3:1 air-to-cloth ratio based on 600 cfm of air volume from the truck mounted blower. The filter bags will be fabricated from 16 oz woven polypropylene material and will be 58 inches long.

The filter bags will be cleaned by a reverse pulse air jet type



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cleaning system which will require approximately seven (7) scfm of compressed air at 100 psig when operating. The vent filter timer board, which actuates the solenoid valves, will be located within a NEMA 4X enclosure mounted on the filter house. The unit will be primed and finish painted safety blue and will be flange mounted on the storage silo roof.

A Dwyer Series 1950 differential pressure switch and a Dwyer Series 2000 Magnahelic differential pressure indicator will be provided to monitor the pressure drop across the filter bags. An Off/Hand selector switch will be provided to control the filter bag cleaning cycle. The time between air pulses and the duration of the pulses are adjustable.

The particulate matter concentration in the effluent gas of the dust collector will not exceed an average of 0.02 grains per actual cubic foot. The guarantee is based on particles two microns and larger in diameter and on the equipment being properly installed and maintained according to the standard Flex Kleen instructions.

3. Manual Knifegate Valve

Each silo discharge cone will be equipped with an 8" DeZurik manual knifegate valve to isolate the PAC storage silo from the feed system below. All wetted parts will be of stainless steel construction.

4. Rotary Valve

Each silo discharge cone will be equipped with an 8" Rotolok Industries HD8 (OAE) rotary valve to control the flow of fluidized PAC from the silo into the volumetric feeder hopper. The valves will be constructed of cast iron with 8" ANSI flanged inlet and outlet connections and a closed rotor with a minimum of six pockets. The valves will feature externally mounted bearings to separate the product from the bearings. The rotary valve will turn at approximately 10 revolutions per minute, providing a theoretical maximum PAC feed rate of 110 cubic feet per hour to the volumetric feeder hopper. The unit will be located between the knifegate valve and the expansion joint. Each rotary valve will be driven by a 1/2 hp 480/3/60 single speed TEFC motor. The motor will be coupled to a gearbox that drives the valve rotor through a chain and sprocket arrangement encased inside an OSHA approved guard.



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5. Volumetric Feeder

Two (2) Acrison model 105Z auger type volumetric feeders, designed to deliver between 30 and 750 pounds per hour of PAC, will be provided to meter the PAC from the feeder hopper into the drop tubes. Each volumetric feeder will be equipped with an eleven (11) cubic foot stainless steel supply hopper with two (2) level switches for level control. All wetted surfaces of the feeders and the supply hoppers will be fabricated from stainless steel.

Each unit will be driven by a 1 hp variable speed DC motor and controlled by a Contrex M-Drive microprocessor controller located in the door of the main control panel. The digital speed controller will allow a 25:1 turndown ratio providing a wide range of dosing levels. The feeder controllers will be programmed to allow feeding of the carbon at a constant rate in pounds per hour or to follow a 4-20 mA analog signal from a remote location.

6. Drop Tube

A removable drop tube or hose will be installed between the volumetric feeder outlet and the inlet to the eductor. The drop tube is removed for calibration of the PAC Feeder.

7. Blower Package

Two (2) pneumatic motive air blowers: One (1) each blower installed on each feeder skid located under the silo. The blower will be a regenerative type Siemens blower, driven by a 460/3/60 TEFC motor operating at 1800 rpm. The drive motor will be direct coupled to the blower.

Each blower package will be mounted in a structure fabricated from carbon steel and will be equipped with an inlet silencer, pressure relief valve, pressure gauge and expansion joints.

Each blower will provide sufficient volume and pressure to maintain the minimum velocity to keep the PAC in suspension for a distance up to a maximum of 200 feet with an elevation change of 100 feet.

The sound level will not exceed 85 dBA at 3 feet from a single blower operating alone.

A Dwyer 3330 WP pressure switch will be used for sensing high and low pressure signals.



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8. Eductor

A 2" hardened carbon steel eductor will be installed at the outlet from the drop tube to convey the carbon/air mixture to the injection point.

9. Piping

Motive air piping from the blower to the eductor will be 1½" nominal schedule 40 304 stainless steel pipe with screwed fittings.

Carbon transfer piping or hoses from the eductors to the injection nozzles will be 2" and will be supplied by the Purchaser.

Compressed air piping from the Plant to the fluidizing system and to the silo vent filter will be ASTM B-88 Type K hard drawn copper pipe with solder joint fittings. The Purchaser will supply this piping.

Air fluidization tubing between the air fluidization solenoid valves and the air fluidization nozzles will be poly tubing with compression type fittings.

10. Air Receiver

One (1) air receiver will be provided to reduce the surge demand from the compressed air users in the system. The vessel will be 60 gallons rated for 200 psig @ 80°F. This receiver will have an ASME 'U' stamp, automatic drain valve, pressure switch, pressure relief valve and pressure indicator. The vessel will be primed and painted safety blue.

11. Air Fluidization Nozzles

Air fluidization nozzles will be placed in strategic locations on the silo discharge cones in the silo under-skirt area. The type and placement of fluidizing nozzles acts to promote reliable mass flow of the PAC from the silo.

D. POWER DISTRIBUTION

1. The PAC system 480 volt power distribution devices will be contained within a Motor Control Center (Allen Bradley Bulletin 2100 or equal MCC), including a main disconnect breaker, individual breakers, motor circuit protectors, motor starters and overloads. The MCC will also house the control power transformer and distribution panel for the PAC System.



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2. A main disconnect breaker will be provided in the power panel which will be utilized to protect and to de-energize the complete PAC system electrical system.
3. A motor circuit protector, a NEMA starter and solid state overload protection will be provided for each 480 volt AC motor.
4. A 480 volt AC to 120 volt AC transformer will furnished to provide 120 volt AC control power. The transformer will be rated at 15 KVA.
5. The 120-volt AC distributions panel will have a main breaker and individual single-phase breakers to feed the various control power loads.

E. CONTROL PANEL

1. The PAC system PanelView (HMI or Operator Interface), PLC, PLC power-supply, manual control devices, feeder speed controllers, control relays, terminal blocks, emergency stop buttons and feeder control switches will be contained within the control panel. All system equipment can be controlled manually from the main control panel.
2. Control wiring philosophy will meet the following requirements:
 - a. The control wiring philosophy will be such that all field control devices utilize normally closed contacts during normal operating condition.
 - b. A contact opening or an open circuit will result in an alarm condition for the specific device.
 - c. Loss of power to a control device will result in an alarm condition.

F. PANEL FEATURES

The power panel and control panel will be provided with the following items and/or features:

1. Panels will be constructed of 304 or 316 stainless steel and rated NEMA 4X.
2. The main control panel will contain a fluorescent work light and 15 amp 120 Volt GFI convenience receptacle.
3. Terminal blocks will be provided for termination of all "field run" cables.



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4. All PLC inputs and outputs will be wired to fused terminal blocks equal to Allen Bradley 1492-H6.
5. Terminal blocks for voltage of 120 volts and less will be equal to Allen Bradley 1492-W10 unless specified otherwise.
6. All selector switches, pilot lights, push buttons and other devices that are visible on the front of the control panels will have Lamacoid nameplates, which are white with black letters.
7. All wiring will be installed in Panduit or similar wireways and separate into categories (i.e., 480 volt power, 120 volt control, etc.) to the extent practical. AC or DC power wiring will not run in any raceway with any type instrument wiring. Wiring will be protected across panel hinges. All terminal strips for all wiring terminations will be numbered.
8. Wiring will be stranded copper, 600 volt, THHN insulated, extra flexible type. As a minimum wire size will be #12 AWG for all power wiring, #16 AWG for all control wiring and #18 AWG twisted shielded pair for analog signal conductors. Wiring will be color coded as follows:
 - a. Ground wiring will be green.
 - b. 120 volt ac and 480 volt ac wiring will be black.
 - c. Neutral wiring will be white.
 - d. 120 volt ac control wiring will be red.
 - e. 24 volt dc control wiring will be brown positive and orange negative.
 - f. 90 volt dc power wiring will be blue.
9. Wiring at all terminals within panels, junction boxes, and field devices will be numbered with shrink fit, machine printed labels.

G. ELECTRICAL COMPONENTS

1. 480 Volt Circuit Breakers: Molded case, thermal magnetic, minimum interrupting capacity of 10,000 amperes symmetrical at 480 volts AC. Acceptable manufacturers are Allen Bradley, General Electric, Siemens, Square D, or Cutler-Hammer.
2. Motor Circuit Protectors: 480 volt AC, three (3) phase, NEMA rated, motor circuit protectors for all 480 volt motors. Acceptable manufacturers are Square D or Cutler-Hammer (Westinghouse).
3. Starters: 480 volt AC, three phase, NEMA rated, with solid state



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overcurrent protection in each phase. Acceptable manufacturers are Allen-Bradley, Square D, General Electric, or Cutler-Hammer.

4. Power Distribution Blocks: Allen Bradley 1492-PD, Square D type LB or IIsco type PDB.
5. 120 Volt Circuit Breakers: Allen Bradley 1492-CB,
6. Control Relays: Allen Bradley type HA, Potter Brumfield type KRP or Square D type KP.
7. Selectors and Push buttons: 30.5 mm, heavy duty, NEMA 4X rated; contacts rated 10 amps continuous, 6 amps break at 120 VAC, equal to Allen-Bradley Type 800H.
8. Indicating Lights: 30.5 mm, heavy duty, NEMA 4X rated, 6 volt transformer type , equal to Allen-Bradley Type 800H.
9. Raceway: Galvanized rigid steel conduit, 3/4" minimum nominal diameter.

H. CONTROL COMPONENTS.

1. Programmable Logic Controller and Panel View (HMI)

A single PLC will be provided to control and monitor the PAC systems. A minimum of 10 percent spare memory capacity, a minimum of 10 percent spare I/O points, and interposing relays for external status/control signals will be provided. Complete software documentation including a ladder logic diagram printout with a complete set of comments and a narrative description of the sequence of operation will be provided. The PLC will be manufactured by Allen-Bradley and will be a Model SLC 5/04. The PanelView 1000 will have a color display and will also be manufactured by Allen-Bradley.

2. Feeder Speed Controller

The screw drive for each of the volumetric feeders will be controlled by a digital microprocessor controller providing finite local adjustment of the PAC feeding rate over a range of 5 to 100 pounds per hour. Based on the system operating mode, the controller will maintain a constant feedrate or will follow a 4-20 ma signal provided by the Purchaser. The feeder microprocessor controller will be a Contrex M-Drive.

3. Fluidizing Solenoid Valves

Solenoid valves will be brass body, soft-seated, with 120V AC solenoid coil. Solenoid operators will be molded coil in NEMA 9



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explosion proof enclosure. Maximum operating pressure differential capability will be 100 psig. Solenoid valves will not require a minimum pressure to either open or close. Valves will be two-way, energize-to-open. Valves will be ASCO Red Hat or approved equal.

4. Point Level Switches

Seven (7) Bindicator point level switches will be provided to control the volumetric feeder hopper fill cycles and to provide storage silo level indication on the main control panel. The units are of the tuning fork type and have local indicating LED lights to indicate when the switch is energized and the state of the switch. The units mount through 1½" half couplings and are easily removable for servicing. The units will be oscillating tuning fork type, of stainless steel construction, Bindicator Pulse Point model LPI-1-A-1-X-A-20-0.

5. Pressure Switches

The silo vent filter differential pressure switch will be a Dwyer series 1620. The eductor discharge pressure switch will be a Dwyer series 3000 Photohelic. The compressed air pressure switch and the motive air pressure switch will be Ashcroft B series, Square D Class 9012, or Allen Bradley Bulletin 836.

I. MONITORING DEVICES.

1. Continuous Level Sensor

A Krohne Reflex Radar level transmitter will be provided to continuously measure and display the level of the carbon within the silo. The transducer will be mounted on a 4" nozzle located in the center of the storage silo roof. A 4-20 mA signal will be provided to the PLC and level indication will be provided on the PanelView.

2. Differential Pressure Switch

The differential pressure across the silo vent filter will be displayed continuously at the vent filter by a Dwyer Magnahelic Series 2000 differential pressure indicator.

3. Pressure Indicators

Pressure indicators will be Bourdon tube type with solid front, phenolic plastic case and 4-1/2 inch dial. Indicators will be Ashcroft Duragauge Style 1279 or approved equal.



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4. Silo Weight Indicator/Transmitter

A BLH LCp-100 Weight Indicator/Transmitter and four (4) BLH Z-BLOK Weigh Modules will be provided to continuously monitor the weight of the carbon in the storage silo. The Weight Indicator will be mounted in the Control Panel in the Power and Control Building. A signal from the Weight Indicator will be provided to the PLC and will also be indicated on the PanelView.

J. STATUS LIGHTS

1. The following status lights will be located on the Motor Control Center for each individual feeder/eductator train:
 - a. Red – Blower Running.
 - b. Green – Blower Off.
 - c. Red – Rotary Valve Running.
 - d. Green – Rotary Valve Off.
2. The following silo alarm lights will be located on the Silo Unloading Panel:
 - a. Amber - Silo Level High - Stop Fill.
 - b. Amber - Silo Level Low - OK to Fill.
 - c. Amber - Compressed Air Pressure Low – Stop Fill.
 - d. Amber - Silo Filter DP High – Stop Fill.

K. CONTROL SWITCHES

1. The following control switches will be located on the control panel:
 - a. Emergency Stop pushbutton for each Feed System.
 - b. Hand/Off/Auto Control switches for each Feeder.
2. The following control switches will be located on the Motor Control Center:
 - a. Hand/Off/Auto Control switches for each Blower.
 - b. Hand/Off/Auto Control switches for each Rotary Valve.
3. The following control switches will be located on the Silo Unloading Panel:
 - a. Off/Hand selector switch for the Vent Filter on the silo.



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L. CONTROLS AND INDICATORS

1. The following controls and indicators will be located on the control panel:
 - a. Contrex M-Drive microprocessor speed controller for each Feeder
 - b. BLH Weigh Indicator to indicate the PAC weight remaining.

IV SYSTEM OPERATION

The PAC dosing system will consist of three (3) independent control loops: (1) silo level monitoring and filling; (2) feeder hopper level monitoring and filling and (3) carbon feed/injection.

A. SILO LEVEL MONITORING AND FILLING.

1. The PAC level in the silo will be monitored continuously by a reflex radar level transmitter. The level signal will be provided to the PLC and PanelView. The silo weight will also be monitored continuously by a Weigh-Indicator mounted in the control panel. The weight signal will be provided to the PLC and PanelView.
2. The PAC level in the storage silo will also be monitored at two points by “tuning fork” type level switches. When ample volume exists in the silo to accept a complete truckload of PAC (~40,000 pounds), the silo low point level switch will be uncovered by the PAC. The contact opening will activate the SILO LEVEL LOW - OK TO FILL light on the silo unloading panel. The silo low point level switch will not stop operation of the PAC feed system, which will operate independently of the PAC level in the silo.
3. The PAC storage silo will be filled by pneumatic road tankers, which will employ a trailer mounted blower to pneumatically transfer the PAC from the tanker into the silo. When the PAC level covers the silo high point level switch, the switch will activate the SILO LEVEL HIGH - STOP FILL alarm and light on the silo unloading panel.
4. During silo filling, the air that is utilized to pneumatically convey the PAC into the silo will be discharged to the atmosphere through the “bag” type silo vent filter. The bags will be sequentially cleaned by pulses of air flowing in the reverse direction through the bags on a preset timed basis (HAND). Filter



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operation will be designated as HAND or OFF via a HO selector switch located on the silo control panel. In the HAND mode, the dust collector will sequentially pulse the bags with cleaning air on a preset time interval continuously as long as the HO switch is in the HAND position. If the vent filter bags are not being cleaned properly, the vent filter differential pressure switch will initiate an alarm on the silo unloading panel to stop filling.

B. FEEDER HOPPER LEVEL MONITORING AND FILLING.

1. Two level switches are used to monitor the PAC level in each feeder supply hopper. With the rotary valve HOA switch in the AUTO position, the low level switch will start the rotary valve and the high level switch will stop the rotary valve. When the rotary valve begins to turn, PAC is fed from the silo into the feeder hopper.
2. With the Fluidizing control in AUTO, the silo fluidizing cycle will also be initiated when the rotary valve motor is started. Under certain conditions it may be advantageous to manually fluidize the silo PAC prior to placing a feeder in service. Manual operation of the fluidizing system will be provided through the PanelView interface.
3. If the hopper low-level switch is uncovered for more than 5 minutes, a feeder hopper level low alarm will be initiated and feeder operation will be terminated.
4. After the rotary valve has been started, the time required to cover the hopper high-level switch is monitored and alarmed if it exceeds 5 minutes. This alarm is called the hopper fill malfunction alarm.

C. CARBON FEED

1. Train 1 and Train 2 can be operated independently or together to feed the same boiler. Each Train will require its own dedicated feed piping or hose and injection points.
2. Terminals for a remote contact permissive will be available if it is desirable to add a permissive, such as ID Fan operating, to limit the PAC injection operation. These terminals will be identified on the drawings.
3. A HAND/OFF/AUTO selector switch for each blower is located on the Motor Control Center. This switch controls the



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blower-operating mode. When placed in HAND, the blower will start. When placed in AUTO, the PanelView touch-keys will start the blower and motive air will be provided to the injection system. The control panel also has lights to indicate blower-operating status.

4. After the blower has started, the system controls will allow ten (10) seconds for motive air pressure to be established via the motive air pressure switch, otherwise the low motive air pressure alarm will be initiated and the feeder will not start until the problem is resolved and the alarm is cleared. Also, a pressure switch connected to the eductor drop tube must indicate a small negative pressure (-3" H²O) to verify that the eductor is functioning properly.
5. With the Feeder HOA switch in the AUTO position, the volumetric feeder will begin feeding PAC into the drop tube thirty (30) seconds after motive airflow and pressure have been established. With the Feeder HOA switch in the HAND position, the Feeder can be operated without the blower operating for feeder calibration.
6. Control of the PAC feed rate will be selected on the PanelView. Control selection is either "M-Drive" or "PanelView". In the M-Drive Control mode, the operator will manually set a fixed PAC feed rate in pounds per hour via the feeder controller or M-Drive. The feeder controller will display the feed rate in pounds per hour. In the PanelView Control mode, the feed rate will be set and controlled by PanelView input.
7. If a feeder high speed, low speed or speed deviation condition is detected when the PAC feeder is running, a FEEDER MALFUNCTION alarm will be initiated and the feeder will stop operation.
8. The system will inject PAC into the flue gas stream until stopped by the PLC/PanelView, HOA switches switched to OFF or the Emergency Stop button is depressed. A normal shutdown by the PLC/PanelView will stop the blower thirty (30) seconds after the feeder has been stopped to clear the injection piping of PAC. HOA and E-STOP shutdown will not purge the injection piping of PAC.
9. If an alarm condition has terminated the operation of the system, the alarm must be reset to restart the system.



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D. ALARMS.

The alarm sequence will operate essentially the same for all alarms. When an alarm is initiated, the alarm condition will be displayed on the PanelView Screen. These alarms will also be ACKNOWLEDGED on the PanelView.

1. Silo Level High (Do Not Fill): The silo level high alarm will activate on the silo unloading panel and on PanelView when the silo is full and filling operations should be terminated. This alarm will not have any effect on the filling operations or normal system operation, other than to provide an alarm, and will automatically clear once the PAC level in the silo has fallen below the high point level probe.
2. Silo Level Low (OK To Fill): The silo level low alarm will activate on the silo unloading panel and on the PanelView when the PAC level in the storage silo has fallen below the low point level probe. The silo low-level alarm will indicate sufficient volume in the silo to receive a bulk trailer load of PAC. This alarm will not have any effect on normal system operation, other than to provide an alarm, and will automatically clear once the PAC level in the silo has covered the low point level probe.
3. Blower Discharge Pressure High: The blower discharge pressure high alarm will be initiated on the PanelView when the blower discharge pressure switch is enabled. The alarm will immediately terminate feeder and blower operation and must be ACKNOWLEDGED on the PanelView to restart the system.
5. Silo Vent Filter DP High – Stop Fill: The differential pressure across the vent filter bags will be monitored at all times by a differential pressure switch mounted on the silo deck. If the high differential pressure switch remains in the high differential state for a period of fifteen (15) seconds, the silo vent filter DP high alarm will be initiated on the silo unloading panel and the PanelView. This alarm will not effect the filling operation or normal system operation and will automatically clear when the differential pressure returns to normal.
6. Compressed Air Pressure Low – Stop Fill: A pressure switch mounted on the air receiver will monitor the air system pressure continuously. The compressed air pressure low alarm will be initiated on the silo unloading panel and the PanelView when the air pressure has fallen below a pre-set pressure of 80 psig. The low air pressure alarm will automatically clear when adequate air



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pressure is restored.

7. Motive Air Pressure Low: The motive air pressure low alarm will be initiated on the PanelView when the motive air pressure falls below a pre-set value (approximately 10 psig). Operation of the feeder will be stopped when the alarm is initiated, however, the blower will not be stopped and the alarm will be automatically cleared when adequate air pressure is established. Feeder operation will be automatically restored when the alarm is cleared.
8. Feeder Malfunction - The M-Drive will be configured to provide a feeder malfunction alarm to the PanelView based on a minimum speed, a maximum speed and a speed error condition. The feeder malfunction alarm will immediately stop operation of the feeder. ACKNOWLEDGING the alarm on the PanelView will clear the alarm.
9. Feeder Hopper Fill Malfunction - The feeder hopper fill malfunction alarm will be initiated on the PanelView if the time to cover the hopper high level probe, after the rotary valve has been given a start signal, exceeds five (5) minutes. The feeder hopper fill malfunction alarm will not stop operation of the feeder, the rotary valve or the fluidization system. The alarm will automatically clear when the feeder high-level switch is covered with PAC.
10. Feeder Hopper Level Low - The feeder hopper level low alarm will be initiated on the PanelView if the feeder hopper low level probe is uncovered for more than 5 minutes. The feeder hopper level low alarm will stop operation of the feeder, the rotary valve and the fluidization system until the alarm is cleared. The alarm will automatically clear when the feeder low-level switch is covered with PAC

V PURCHASER'S SCOPE OF WORK

The following items are not included in this offering and shall be supplied by the Purchaser if required:

- A. FOUNDATIONS - The Purchaser shall design and install all foundations for the PAC dosing system from load data provided by the Seller. The Silo Supplier will provide the foundation anchor bolts for the Silo.
- A. ERECTION AND ASSEMBLY OF EQUIPMENT – The Purchaser shall receive and install the equipment provided by the Seller. Installation is not included in this proposal.



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- B. AREA LIGHTING – The Purchaser shall furnish and install area lighting. Seller will provide light fixtures for the area under the storage silo and for the roof. Also, Seller will provide and install the lighting in the Power and Control Building
- C. COMPRESSED AIR SUPPLY - The Purchaser shall provide dry instrument quality compressed air source capable of delivering 10 scfm at 100 psig. The Purchaser shall install compressed air piping to the fluidizing air header and to the vent filter on top of the silo.
- D. ELECTRICAL POWER SUPPLY - The Purchaser shall provide a single electrical power feed capable of delivering 60 amps of three (3) phase sixty (60) cycle power at 460 volts AC. The Purchaser shall install the power feed and terminate the power feed within the MCC.
- E. INTERCONNECTING CABLE & CONDUIT - The Purchaser shall provide and install all interconnecting cable and conduit (including fittings) to connect the MCC and control panel to the furnished equipment. Conduit and wiring between the Control Panel and the MCC will be provided and installed by the Seller prior to delivery of the Building.
- F. POWDERED ACTIVATED CARBON (PAC) - The Purchaser shall provide the initial and all subsequent fills of carbon.
- G. DELIVERY PIPING - The Purchaser shall provide the design and installation of the conveying piping, hoses and injection nozzles.

VI SPARE PARTS

The following spare parts have been included in this proposal:

- A. Eductor.
- B. Bindicator point level probe.
- C. Silo fluidizing air solenoid valve.
- D. Silo vent filter bags (set).
- E. Feeder speed controller (M-Drive).
- F. Feeder drive motor speed pick-up.
- G. Feeder drive motor.
- H. Feeder auger and gasket.



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- I. Three (3) each blower inlet air filters.

VII PRICING

Engineer, Procure and Deliver Silo System Equipment

Pricing for the above-described Silo Dosing System delivered to Gaston, Alabama for erection by Purchaser:

Three Hundred Twelve Thousand Six Hundred Twenty Five Dollars.

US\$ 312,625.00

Donald P. Hall
Engineering Sales
Systems and Services
NORIT Americas Inc.

David A. Perry
Executive Vice President
NORIT Americas Inc.

Robert W. Edwards
Sales Director
NORIT Americas Inc.



APPENDIX I

Levelized Costs for ACI System

Levelized Costs for ACI System

<i>Capital Costs</i>			
Description	Units	Value	Notes
ACI Storage and Injection System	\$	\$320,000	
Piping, Manifolds, and Lances	\$	\$25,000	
Foundations and Steel (installed)	\$	\$55,000	
Electrical Supply Upgrades	\$	\$25,000	
Miscellaneous Utilities, Lighting		\$20,000	
Controls Integration	\$	\$20,000	
Subtotal		\$465,000	
Taxes	\$	\$27,900	
Freight	\$	<i>incl</i>	
Purchased Equipment Cost Subtotal	\$	\$492,900	
Installation of Process Equipment	\$	\$90,000	
<i>Total Direct Cost</i>	\$	\$582,900	
Indirects			
General Facilities	10%	\$58,290	
Engineering Fees	10%	\$58,290	
Project Contingency	15%	\$87,435	
Process Contingency	5%	\$29,145	
Total Plant Cost (TPC)	\$	\$816,060	
<i>Allow. for Funds During Constr. (AFDC)</i>	\$		\$0 Construction period < 1yr.
Total Plant Investment (TPI)	\$	\$816,060	
<i>Preproduction Costs</i>	\$	\$0	
<i>Inventory Capital</i>	\$	\$0	
Total Capital Requirement (TCR)	\$	\$816,060	
	\$/kW	\$3.15	
Variable O&M and Costs			
	<i>Cost Basis (Year)</i>	2003	
Sorbent Costs		\$245,280	
Waste Disposal Costs		\$0	
Power Consumption	kW	25	
Power Cost (\$0.05/kW)		\$7,665	
Operating Labor (4 hours/day, \$45/hr)		\$65,700	
Maintenance Costs		\$17,250	
Periodic Replacement Items		\$10,000	
COHPAC [®] Bag Replacement Increase*		\$108,800	
Total	\$	\$454,695	
\$/kW	\$/kW	\$1.76	
mills/kW-hr	mills/kW-hr	\$0.29	

* Without ACI, bag life was estimated at 4 years; with ACI, bag life is 2 years.

Economic Factors		
Net Generating Capacity	MW	259
Annual Capacity Factor	%	70%
Power Costs	\$/kw	\$0.05
Operating Labor Rate	\$/hr	\$45
Cost Basis - Year Dollars	Year	2003
Capital Esc During Construction	%	1.5%
Construction Years		0.5
Annual Inflation	%	2.5%
Discount Rate, % (MAR) =	%	9.2%
AFUDC Rate	%	10.8%
First Year Fixed Charge Rate, Current\$	%	22.3%
First Year Fixed Charge Rate, Const\$	%	15.7%
Lev Fixed Charge Rate, Current\$ (FCR) =	%	16.9%
Lev Fixed Charge Rate, Const\$ (FCR) =	%	11.7%
Service Life (years) =	Years	20
Escalation Rates :		
Consumables (O&M) =	%	3.0%
Fuel =	%	5.0%
Power =	%	3.0%
		Current\$ Basis
		Constant \$ Basis
P/A Factor		9.00
A/P Factor		0.11
P/AE Factors		
Consumables (O&M)		11.45
Power		11.45
Levelizing Factors		
Consumables (O&M)		1.27
Power		1.27
First Year Costs		
		Current\$ Basis
		Constant \$ Basis
Fixed Costs		\$128,121
Variable O&M (minus bag replacement cost)		\$345,895
Total First Year Costs	\$	\$474,016
\$/kw	\$/kW	\$2.25
	mills/kW-hr	\$0.37
20-Year Annual Levelized Costs		
		Current \$ Basis
		Constant \$ Basis
Fixed Costs		\$95,479
Operating Costs		
Reagent		\$312,104
Waste Disposal		\$0
Power		\$9,753
Labor		\$83,599
Maintenance		\$21,950
Increase in Bag Replacement Costs		\$138,442
Spare Parts		\$12,724
Total Annual 20-Year Levelized Costs	\$/year	\$674,051
\$/kW	\$/kW	\$2.60
	mills/kW-hr	\$0.42