Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas

Final Project Report

Prepared by:

Dr. Carl Richardson
Katherine Dombrowski
Douglas Orr

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URS Group, Inc.
P.O. Box 201088
Austin, TX 78720-1088

Prepared for:

Pierina Noceti
Contracting Officer's Representative (COR)
U.S. Department of Energy
P.O. Box 880
Morgantown, WV 26508-0880

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Introduction

This project Final Report is submitted to the U.S. Department of Energy (DOE) as part of Cooperative Agreement DE-FC26-03NT41987, “Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas.” Sorbent injection technology is targeted as the primary mercury control process on plants burning low/medium sulfur bituminous coals equipped with ESP and ESP/FGD systems. About 70% of the ESPs used in the utility industry have SCAs less than 300 ft^2/1000 acfm. Prior to this test program, previous sorbent injection tests had focused on large-SCA ESPs.

This DOE-NETL program was designed to generate data to evaluate the performance and economic feasibility of sorbent injection for mercury control at power plants that fire bituminous coal and are configured with small-sized electrostatic precipitators and/or an ESP-flue gas desulfurization (FGD) configuration. EPRI and Southern Company were co-funders for the test program. Southern Company and Reliant Energy provided host sites for testing and technical input to the project. URS Group was the prime contractor to NETL. ADA-ES and Apogee Scientific Inc. were sub-contractors to URS and was responsible for all aspects of the sorbent injection systems design, installation and operation at the different host sites.

Full-scale sorbent injection for mercury control was evaluated at three sites: Georgia Power's Plant Yates Units 1 and 2 [Georgia Power is a subsidiary of the Southern Company] and Reliant Energy's Shawville Unit 3. Georgia Power’s Plant Yates Unit 1 has an existing small-SCA cold-side ESP followed by a Chiyoda CT-121 wet scrubber. Yates Unit 2 is also equipped with a small-SCA ESP and a dual flue gas conditioning system. Unit 2 has no SO_2 control system. Shawville Unit 3 is equipped with two small-SCA cold-side ESPs operated in series. All ESP systems tested in this program had SCAs less than 250 ft^2/1000 acfm.

Short-term parametric tests were conducted on Yates Units 1 and 2 to evaluate the performance of low-cost activated carbon sorbents for removing mercury. In addition, the effects of the dual flue gas conditioning system on mercury removal performance were evaluated as part of short-term parametric tests on Unit 2. Based on the parametric test results, a single sorbent (e.g., RWE Super HOK) was selected for a 30-day continuous injection test on Unit 1 to observe long-term performance of the sorbent as well as its effects on ESP and FGD system operations as well as combustion byproduct properties.

A series of parametric tests were also performed on Shawville Unit 3 over a three-week period in which several activated carbon sorbents were injected into the flue gas duct just upstream of either of the two Unit 3 ESP units. Three different sorbents were evaluated in the parametric test program for the combined ESP 1/ESP 2 system in which sorbents were injected upstream of ESP 1: RWE Super HOK, Norit's DARCO Hg, and a 62:38 wt% hydrated lime/DARCO Hg premixed reagent. Five different sorbents were evaluated for the ESP 2 system in which activated carbons were injected upstream of ESP 2: RWE Super HOK and coarse-ground HOK, Norit's DARCO Hg and DARCO Hg-LH, and DARCO Hg with lime injection upstream of ESP 1. The hydrated lime tests were conducted to reduce SO_3 levels in an attempt to enhance the mercury removal performance of the activated carbon sorbents.

The Plant Yates and Shawville studies provided data required for assessing carbon performance and long-term operational impacts for flue gas mercury control across small-sized ESPs, as well as for estimating the costs of full-scale sorbent injection processes.

This Final Report contains the results from each site testing program organized in three volumes as follows:

Volume 1 – Yates Unit 1
Volume 2 – Yates Unit 2
Volume 3 – Shawville Unit 3

Volume 1

Yates Unit 1

Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas

Site Report – Yates Unit 1

Prepared by:
Dr. Carl Richardson

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Cooperative Agreement Number: DE-FC26-03NT41987

URS Group, Inc.
P.O. Box 201088
Austin, TX 78720-1088

Prepared for:

Lynn Brickett
Contracting Officer's Representative (COR)
U.S. Department of Energy
P.O. Box 880
Morgantown, WV 26508-0880

Disclaimer

Abstract

This site report summarizes results from the project entitled "Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas" being managed by URS Group, Inc. as part of part of Cooperative Agreement DE-FC26-03NT41987. The objective of this project is to demonstrate the ability of various activated carbon sorbents to remove mercury from coal-combustion flue gas across full-scale units configured with small ESPs. The project is funded by the U.S. DOE National Energy Technology Laboratory under this Cooperative Agreement. EPRI, Southern Company, and Georgia Power are project co-funders. URS Group is the prime contractor.

Various sorbent materials were injected upstream of low SCA ESP systems at Georgia Power's Plant Yates Unit 1 and Unit 2. Both Unit 1 and Unit 2 fire a low sulfur bituminous coal. Unit 1 is equipped with a JBR wet FGD system downstream of the ESP for SO_2 control. Unit 2 is not equipped with downstream SO_2 controls; however, a dual flue gas conditioning system is used to enhance ESP performance. This site report focuses on the result from the Unit 1 test program. A separate site report will be issued for Unit 2.

Short-term parametric tests were conducted on Unit 1 to evaluate the mercury removal performance of activated carbon sorbents. Based on the results from these parametric tests, a continuous month-long carbon injection test was performed with RWE Rheinbraun's Super HOK sorbent. The mercury removal performance and balance of plant impacts were evaluated. The results of this study provide data required for assessing the performance, long-term operational impacts, and costs of full-scale sorbent injection processes for flue gas mercury removal.

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Executive Summary

URS Group, in conjunction with EPRI, Southern Company, Georgia Power, and ADA-ES evaluated sorbent injection for mercury control upstream of small-SCA ESPs in flue gas derived from low-sulfur Eastern bituminous fuel. The project was funded by DOE-NETL. Full-scale tests were performed at Georgia Power's Plant Yates Unit 1 [George Power is a subsidiary of The Southern Company] to evaluate the effectiveness of sorbent injection as a mercury control technology. Plant Yates Unit 1 burns low sulfur Eastern bituminous coal and is equipped with a small-SCA (173 ft^2/kacfm) cold-side ESP followed by a Chiyoda CT-121 wet scrubber.

Sorbent injection technology is targeted as the primary mercury control process on plants burning low/medium sulfur bituminous coals equipped with ESP and ESP/FGD systems. Approximately 38,000 MW of generating capacity exists for bituminous coal-fired power plants with high-efficiency particulate control devices followed by wet lime/limestone FGD. In addition, about 70% of the ESPs used in the utility industry have SCAs less than 300 ft^2/1000 acfm. Prior to this test program, previous sorbent injection tests had focused on large-SCA ESPs.

Sorbent was injected upstream of the cold-side ESP at Plant Yates Unit 1. Flue gas mercury concentrations were monitored with mercury SCEMs at the ESP inlet, ESP outlet, and scrubber outlet. Mercury removal performance as well as balance of plant impacts were measured and evaluated. Baseline mercury measurements indicated 4 to 7 $\mu g/Nm^3$ Hg (at 3%O_2) at the ESP inlet, 2 to 3.5 $\mu g/Nm^3$ Hg at the ESP outlet, and 2 to 3 $\mu g/Nm^3$ at the FGD outlet. Baseline removal across the ESP was variable, averaging about 35%.

The test program at Plant Yates Unit 1 was comprised of two components: a parametric test program in which various sorbents were evaluated in short-term tests, and a month-long continuous injection test conducted with a single sorbent. The following sorbents were evaluated in a round of parametric tests conducted in Spring 2004: RWE Rheinbruan's Super HOK, Ningxia Huahui's iodated activated carbon, and Norit Darco Hg. The three carbons performed similarly with respect to mercury removal performance. The maximum achieved percent reduction at the ESP outlet as a result of carbon injection was about 40-45% at 8 lb/Macf. Increasing the injection rate did not result in higher flue gas mercury removal.

A second series of parametric tests were conducted in January 2005. The following sorbents were evaluated: Norit's Darco Hg as a reference sorbent, coarsely ground HOK, Norit Darco Hg-LH, and a 50/50 mixture of PRB derived fly ash and Darco Hg. The coarse HOK performed similarly to the finer Super HOK tested in Spring 2004. The three Norit Darco sorbents/sorbent-ash combinations performed better than the Norit Darco Hg tested in Spring 2004. A mercury reduction of 60% was achieved at the ESP outlet with 10 lb/Macf of Norit Darco Hg-LH. The higher mercury removal achieved during January 2005 testing may be partly attributed to the lower ESP inlet temperatures experienced during that injection testing period.

The month-long continuous injection test was scheduled for November/December 2004, so the selection of the sorbent for the month-long injection test was based only on the Spring 2004 parametric test results. RWE Rheinbraun's Super HOK sorbent was selected based on its performance and low cost relative to Norit America's Darco Hg, and the paucity of "long-term" data available for sorbents other than Darco Hg. Injection of Super HOK increased the vapor-phase mercury removal across the Yates Unit 1 ESP from a nominal baseline value of 50% to almost 90% at times. Injection rates ranging between 4 and 10 lb/Macf were tested over the thirty-day period. Increasing the carbon injection rate above 4.5 lb/Macf did not provide significant improvements in the vapor phase mercury removal across the ESP. The vapor phase mercury removal across the ESP was highly variable, with values ranging from 60 to 90%.

Several balance of plant impacts were noted for the sorbent injection process. Carbon breakthrough at the outlet of the ESP was noted in both Method 17 particulate filters and in JBR scrubber samples. The inerts concentration of the JBR solids increased from a normal baseline of less than 2% to a high of 18%. Carbon injection caused an increase in the arc rate of the ESP at low load conditions, as compared to baseline arcing. While no physical damage to the ESP was noted at the end of the thirty-day injection test, it is unclear what effect the increased arcing will have on the mechanical integrity of the ESP over longer time periods. These test results indicate that the sorbent injection process will need to be evaluated on full-scale units (especially for those units equipped with low-SCA ESPs) for longer periods of time in order to better understand the impact of carbon injection on ESP performance and integrity.

1.0 Introduction

This Site Report is submitted to the U.S. Department of Energy (DOE) as part of Cooperative Agreement DE-FC26-03NT41987, "Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas". This project evaluated full-scale sorbent injection for mercury control at two sites with low-SCA ESPs, burning low sulfur Eastern bituminous coals. Full-scale tests were performed at Georgia Power's Plant Yates Units 1 and 2 [Georgia Power is a subsidiary of The Southern Company] to evaluate sorbent injection performance. Georgia Power's Plant Yates Unit 1 has an existing small-SCA cold-side ESP followed by a Chiyoda CT-121 wet scrubber. Unit 2 is also equipped with a small-SCA ESP and a dual flue gas conditioning system. Unit 2 has no SO_2 control system. This Site Report presents results from the testing conducted on Unit 1.

The sorbent injection tests consisted of two phases of testing: parametric tests in which various sorbents were screened in two to three hour tests, and a month-long continuous injection test with one sorbent. The sorbent injection equipment was installed upstream of the ESP at Unit 1. Flue gas mercury concentrations were monitored at the ESP inlet, ESP outlet, and scrubber outlet. Mercury removal performance as well as balance of plant impacts were measured and analyzed.

Sorbent injection technology is targeted as the primary mercury control process on plants burning low/medium sulfur bituminous coals equipped with ESP and ESP/FGD systems. Approximately 38,000 MW of generating capacity exists for bituminous coal-fired power plants with high-efficiency particulate control devices followed by wet lime/limestone FGD. In addition, about 70% of the ESPs used in the utility industry have SCAs less than 300 ft^2/1000 acfm. Full-scale testing of sorbent injection systems on ESP systems has shown promising results; however, all previous tests have been conducted for large-SCA ESP systems. Therefore, the data from this sorbent injection project are applicable to a large portion of the market and fill a data gap for the application of sorbent injection to small-SCA ESP systems.

The project team includes URS Group, Inc. as the prime contractor. EPRI, a team member and a major co-funder of the project, has funded and managed mercury emissions measurement and control research since the late 1980's. ADA-ES was a sub-contractor to URS and was responsible for all aspects of the sorbent injection system design, installation and operation. Southern Company and Georgia Power were team members and provided co-funding, technical input, and the host sites for testing.

Report Organization

Previous quarterly reports submitted to DOE by URS Group, Inc. covered selected results from this project. This report includes these previously reported results, as well as any additional information and analyses available since these quarterly reports were issued. The report is organized into five sections. Following this introduction, Section 2 discusses the project experimental approach and describes the full-scale sorbent injection system and other equipment and flue gas test methods used in the project. Section 3 presents and discusses project results. Section 4 provides the conclusions that can be made from the results of the sorbent injection test program, and Section 5 lists the references cited in the previous sections of the report.

2.0 Experimental

The experimental methods and procedures used to conduct the activated carbon injection evaluation at Plant Yates are described in this section. A description of the plant, the measurement locations, and injection location is given. The carbon injection equipment used in the parametric and long-term tests is described. The executed test matrices for the parametric and long-term testing are also provided in this section.

2.1 Facility Information

Yates Unit 1 is a 100 MW (gross) Eastern bituminous coal-fired plant equipped with a cold-side ESP (SCA = 173 ft^2/kafcm) for particulate control and a Chiyoda CT-121 scrubber for SO_2 control. The Chiyoda scrubber is a jet bubbling reactor (JBR) and will be referred to as the JBR or the scrubber.

Additional characteristics of Unit 1 are summarized in Table 2-1. Figure 2-1 illustrates the basic plant configuration, sorbent injection points, and flue gas sample locations for Unit 1.

Table 2-1. Yates Unit 1 Configuration

	Yates Unit 1
Boiler	
Type	CE Tangential Fired
Nameplate (MW)	100
Coal	
Type	Eastern Bituminous
Sulfur (wt %, dry)	0.8 - 1.5
Mercury (mg/kg, dry)	0.05 - 0.15
Chloride (mg/kg, dry)	100 - 600
ESP	
Type	Cold-Side
ESP Manufacturer	Buell (1971 vintage, refurbished in 1997)
Specific Collection Area (ft^2/kafcm)	173
Plate Spacing (in.)	11
Plate Height (ft)	30
Electrical Fields	4
Mechanical Fields	3
ESP Design Inlet Temp. (°F)	310
ESP Design Flow Rate (ACFM)	490,000
NO_x Controls	Low NOx Burners
SO_2 Controls	Chiyoda CT-121 wet scrubber (JBR)
Flue Gas Conditioning	None

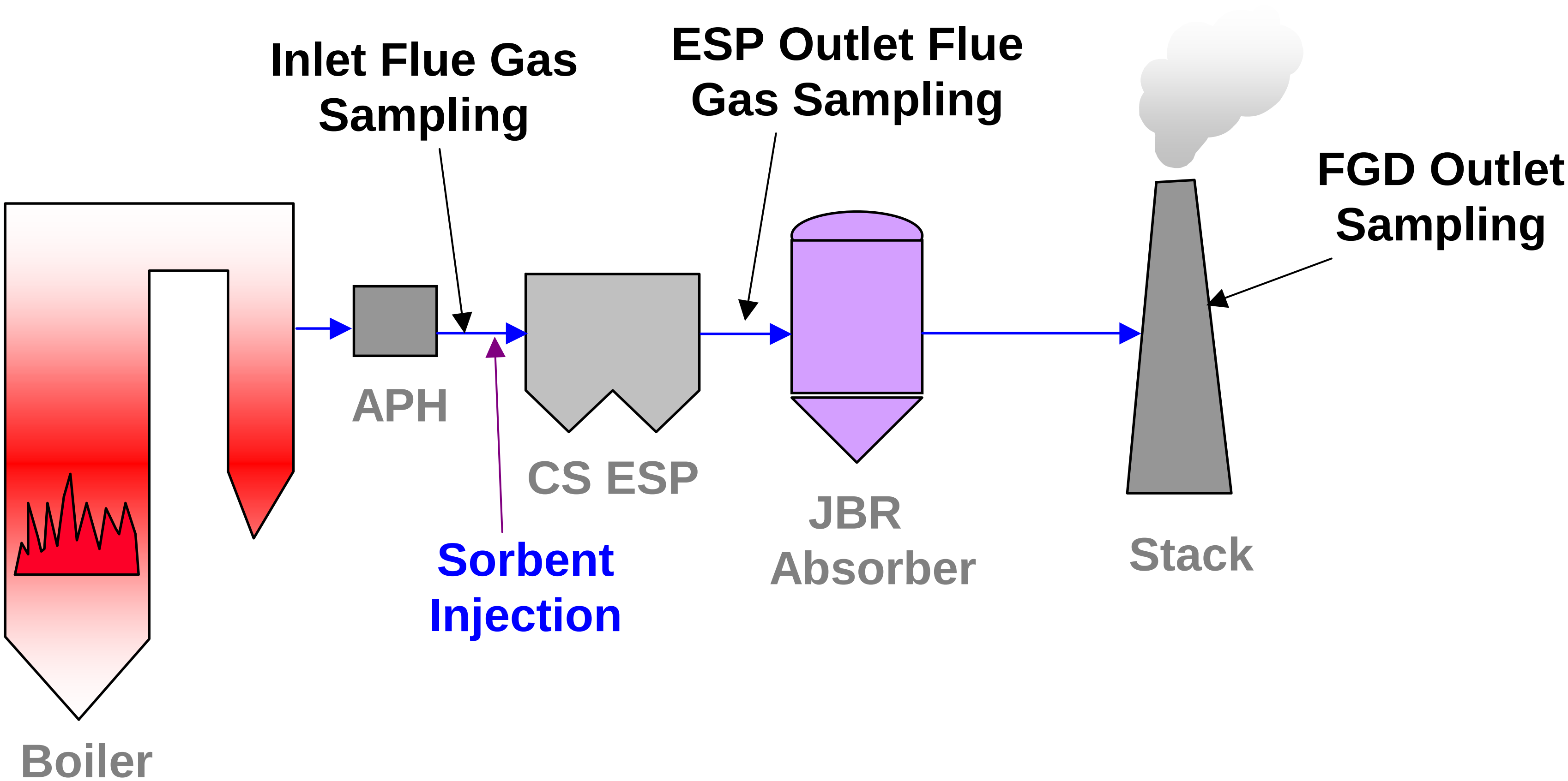

Figure 2-1. Yates Unit 1 Configuration and Flue Gas Sample Locations

2.2 Sampling and Analytical Methods

The mercury measurements for baseline and injection testing were performed with mercury semi-continuous analyzers, which are described below in more detail. During baseline testing, Ontario Hydro measurements were taken. This method is not explained further, as it is considered a standard EPA method. Coal, ash, and JBR byproduct samples were gathered regularly and analyzed by the methods described in this section.

2.2.1 Solid/Liquid Sampling Methods

The Unit 1 ESP consists of four electrical fields (Figure 2-2). Hoppers labeled 1-4 are under A and B fields. Hoppers labeled 5-8 are under the C and D fields. Hoppers 2, 3, 6, and 7 are the only hoppers equipped for ash sampling. Ash samples were gathered by Plant Yates personnel. The ash samples were only gathered on weekdays, because of the reduced staffing of plant personnel on weekends and holidays.

For the long-term injection test and the January 2005 parametric tests, the daily ash samples were taken as follows:

- One composite sample was taken from hoppers 2 and 3 (50% from hopper 2; 50% from hopper 3).
- One composite sample was taken from hoppers 6 and 7 (50% from hopper 6; 50% from hopper 7).

During the Spring 2004 baseline and parametric tests, ash samples were gathered as a weighted composite from the four hoppers (2, 3, 6, and 7).

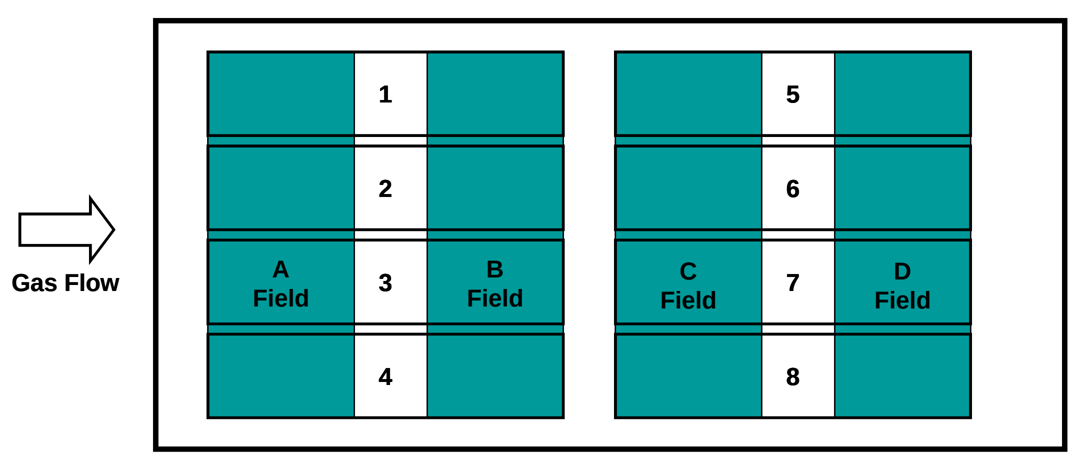

Figure 2-2. Diagram of Yates Unit 1 ESP

The Unit 1 furnace is fed with coal from four pulverizers. Coal samples were taken as a composite from the coal feeders just upstream of the pulverizers that were in service. Coal samples were gathered by both Plant Yates and URS personnel.

Approximately two times per week, URS collected FGD slurry samples for sulfite analysis and to filter for mercury solids and liquid analyses.

2.2.2 Solid/Liquid Analytical Methods

Solid samples, including coal and ESP hopper fly ash, were collected and analyzed for mercury content. Coal samples were also analyzed for chloride content. Coal samples were digested with ASTM 3684 and analyzed for mercury by CVAA. The coal was digested by ASTM D4208 and analyzed for chloride by ion chromatography (EPA Method 300). Ash samples and FGD solid samples were digested by a standard hydrofluoric acid digestion and analyzed for mercury by CVAA. All liquid samples were prepared by EPA Method 7470 and analyzed by CVAA. Fly ash LOI was determined by method ASTM D3174.

2.2.3 EPRI SCEM Mercury Analyzer

Additional details regarding the SCEM mercury analyzer are provided in this section since it is not standard EPA method. This section describes the operation of the SCEM. Appendix A describes how vapor phase mercury concentrations are calculated from the data recorded by the SCEMs. Flue gas vapor-phase mercury analyses were made using EPRI semi-continuous analyzers depicted in Figure 2-3. At each sample location, a sample of the flue gas is extracted at a single point from the duct and then drawn through an inertial gas separation (IGS) filter to remove particulate matter. This IGS filter consists of a heated stainless steel tube lined with sintered material. A secondary sample stream is pulled across the sintered metal filter and then is directed through the mercury analyzer at a rate of approximately 1-2 L/min thus providing near real-time feedback during the various test conditions. The analyzer consists of a cold vapor atomic absorption spectrometer (CVAAS) coupled with a gold amalgamation system (Au-CVAAS). Since the Au-CVAAS measures mercury by using the distinct lines of the UV absorption characteristics of elemental mercury, the non-elemental fraction is converted to elemental mercury prior to analysis using a chilled reduction solution of acidified stannous chloride. Several impingers containing alkaline solutions are placed downstream of the reducing impingers to remove acidic components from the flue gas; elemental mercury is quantitatively transferred through these impingers.

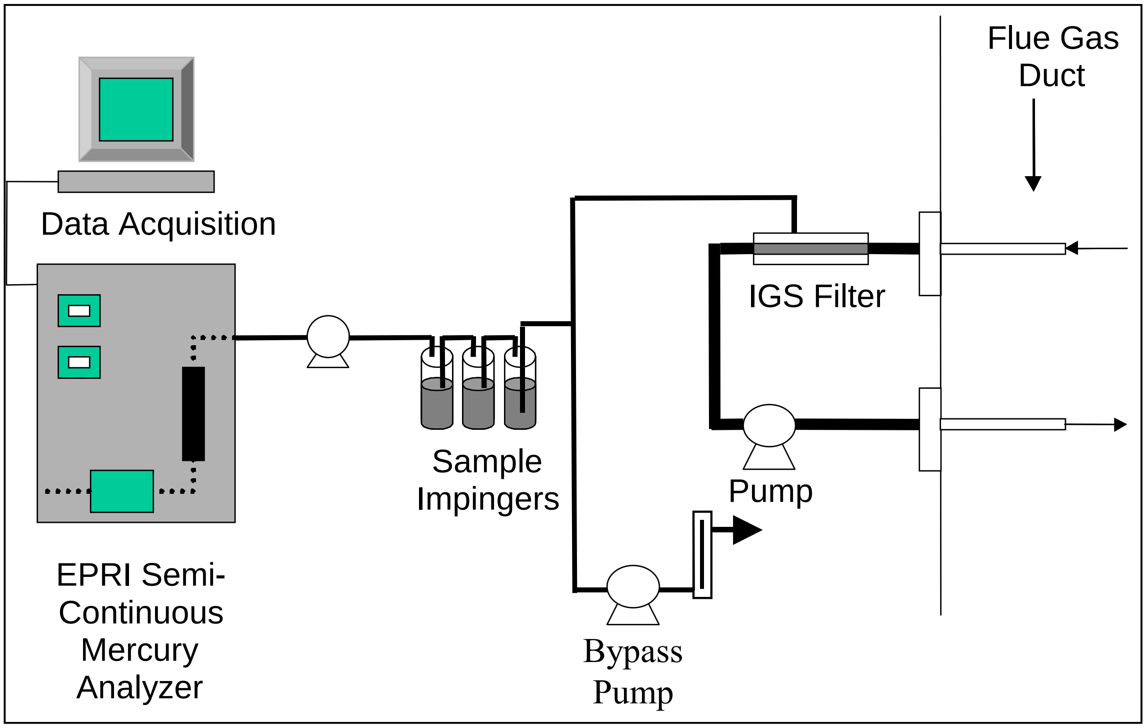

Figure 2-3. Semi-Continuous Mercury Analyzer

Gas exiting the impingers flows through a gold amalgamation column where the mercury in the gas is adsorbed (<60°C). After adsorbing mercury onto the gold for a fixed period of time (typically 1 minute), the mercury concentrated on the gold is thermally desorbed (>400°C) in nitrogen or air, and sent as a concentrated mercury stream to a CVAAS for analysis. Therefore, the total flue gas mercury concentration is measured semi-continuously with a 1-minute sample time followed by a 2-minute analytical period.

To measure elemental mercury only, an impinger containing either 1M potassium chloride (KCl) or 1M Tris Hydroxymethyl (aminomethane) and EDTA is placed upstream of the alkaline solution impingers to capture oxidized mercury. Oxidized forms of mercury are subsequently captured and maintained in the KCl or Tris impingers while elemental mercury passes through to the gold amalgamation system. Comparison of "total" and "elemental" mercury measurements yields the extent of mercury oxidation in the flue gas.

2.3 Activated Carbon Injection System Design

ADA-ES, under subcontract to URS Group, provided all of the injection process equipment used during testing at Plant Yates, installed the equipment on-site, and operated the equipment during testing.

For the short-term parametric tests conducted on Unit 1, a Port-a-Pac dosing system, supplied by Norit Americas, was used. This dry injection system, similar to the one shown in Figure 2-4, pneumatically conveys a predetermined and adjustable amount of sorbent from bulk bags into the flue gas stream. The unit consists of two eight-foot tall sections. The lower (or base) section consists of a small hopper with level detector, volumetric screw feeder, and pneumatic eductor. The upper or top section consists of an electric hoist and monorail to handle bulk bags of sorbent of up to 1000 pounds. When fully assembled, the system has a total height of 16-feet. Powdered activated carbon is metered using a volumetric feeder into a pneumatic eductor, where the air supplied from the regenerative blower provides the motive force needed to transport the carbon to the flue gas duct via six sorbent injection lances. The sorbent injection system can deliver approximately 20 – 350 lb/hr of activated carbon or other sorbents. The sorbent injection feed rate was verified with daily calibrations and trending of the bag emptying rate.

Figure 2-4. Port-a-Pac Dosing Unit Similar to the One Used in Parametric Testing

For the month-long continuous injection test, a large quantity of carbon was needed so a silo was used for storage. The silo and feed train for the Unit 1 long-term test are pictured in Figure 2-5. The silo was 10 feet in diameter, with a sidewall height of 32 ft. The silo had a volume of 2500 ft^3, and accommodated up to 60,000 lb of HOK carbon (the silo could store only 40,000 lb of Norit Darco Hg, because of the density difference between the two sorbents). The carbon injection system consisted of a bulk-storage silo and twin blower/feeder trains. Sorbent 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 subsequent motive force to carry the sorbent to the injection point. Regenerative blowers provided the conveying air. Flexible hoses carried the sorbent from the feeders to dual distribution manifolds located on the ESP inlet duct. Each manifold supplied six injectors for a total of twelve injectors. Each of the six port flanges contained two injector lances, inserted at different lengths into the duct. The feeding system was calibrated prior to commencement of the long-term injection test. The calibration was verified throughout the injection test by means of level and weight sensors on the silo.

Figure 2-5. Carbon Injection Storage Silo/Feeder Train (Long-Term Testing)

The injection lances were fabricated from 1-inch pipe and were placed across the width of the duct. Figure 2-6 shows the injection lance configuration in the Unit 1 ESP inlet duct. Each lance projected horizontally into the 8.5-foot deep duct and ended approximately 4 feet into the duct. The duct is approximately 60 feet wide at this location. Each lance was open-ended with no orifices along the length of the lance. The pneumatically conveyed sorbent exited the lance end and mixed with the flue gas flowing vertically in the duct before entering the ESP.

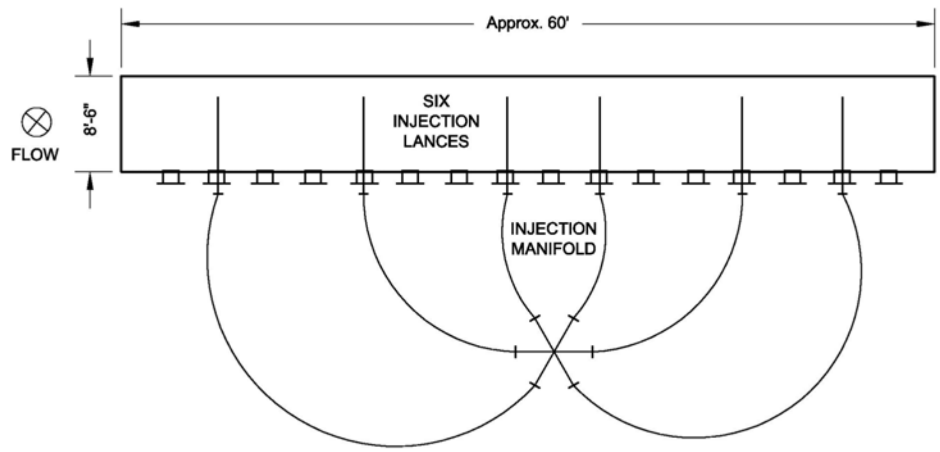

Figure 2-6. Unit 1 ESP Inlet Sorbent Injection Port Configuration During Parametric Tests (long-term tests used two lances per port)

2.4 Sorbent Selection

This section describes the properties of the sorbent materials selected for the test program. Testing was composed of two phases: (1) a parametric test program in which various sorbents were screened in two to three hour tests and (2) a long-term continuous injection program in which a single sorbent was injected into the Unit 1 ESP inlet duct for one month.

The purpose of the parametric testing was to evaluate various sorbents in order to select a single sorbent for the long-term injection test. Parametric testing consisted of evaluating the mercury removal performance of each sorbent at a range of injection rates. Three different sorbents were evaluated in initial Unit 1 parametric tests during Spring 2004. As listed in Table 2-2, the three carbons tested in the initial parametric tests were Norit's Darco-Hg, RWE Rheinbraun's Super HOK, and Ningxia Huahui's iodated NH Carbon.

Table 2-2. Sorbents Selected for Test Program

Carbon Name	Manufacturer	Description	Cost ($/lb)
Darco-Hg (formerly Darco FGD™)	Norit Americas	Lignite-derived activated carbon; baseline carbon (19 µm mean particle size)	0.44 [a]
Super HOK	RWE Rheinbraun	German lignite-derived activated carbon (23 µm mean particle size)	0.29 [b]
NH Carbon	Ningxia Huahui Activated Carbon Co. LTD (HHAC)	Chinese iodated bituminous-derived activated carbon (24 µm mean particle size)	0.88

a FOB Marshall, TX
b FOB east coast ports

The Darco-Hg (formerly Norit's Darco FGD™) carbon served as the benchmark sorbent since it had been used in numerous other sorbent injection test programs and its performance characteristics were well defined. The RWE Rheinbraun Super HOK sorbent is a German lignite-derived activated carbon selected for its cost, performance in previous tests and availability in quantities necessary for this test program. The third sorbent, a Chinese iodated activated carbon, was not originally included in the test plan, but was made available at no cost to the project and tested over a two-day period on Unit 1 when the Super HOK carbon did not arrive on-site as planned. The project team made the decision to test this chemically treated activated carbon because total vapor-phase mercury removal for the Darco-Hg activated carbon showed a plateau at about 70 percent removal during tests conducted on both the Unit 1 and Unit 2 ESP earlier in March 2004. The Chinese carbon offered the potential for removal greater than 70 percent, although the cost is twice that of the benchmark Darco-Hg carbon.

RWE Rheinbraun's Super HOK sorbent was selected for the long-term tests on Unit 1. The sorbent was selected because of its comparable performance and low cost relative to Norit America's Darco Hg (formerly known as Darco FGD™), and the paucity of "long-term" data available for sorbents other than Darco Hg.

Following the long-term injection tests, the project team decided to evaluate additional sorbents in parametric testing on Unit 1. These sorbents were selected for various reasons, including potential lower cost and the potential to overcome the plateau in removal performance seen in the Spring 2004 tests with the Darco Hg and Super HOK. The three new sorbents tested in this additional round of parametric tests are listed in Table 2-3. The sorbents were RWE Rheinbraun's coarsely ground HOK, Norit's Darco Hg-LH (a brominated carbon, formerly known as Norit E-3), and a sorbent/PRB ash mixture prepared by Southern Company. In addition, Norit's Darco Hg was tested again to compare its performance to the Spring 2004 results and to the sorbent/ash mixture.

Table 2-3. Additional Sorbents Selected for Parametric Test Program

Carbon Name	Manufacturer	Description	Cost ($/lb)
HOK-coarse	RWE Rheinbraun	German lignite-derived activated carbon (63 µm mean particle size)	0.265 [a]
Darco Hg-LH	Norit Americas	Brominated, lignite-derived activated carbon; (19 µm mean particle size)	0.65 [b]
PRB/Darco Hg		Mixture that is 50/50 PRB ash from Southern Company's Miller Station and Darco Hg sorbent	0.23[c]

a FOB east coast ports
b FOB Marshall, TX
c Estimated cost, based on raw material cost of Norit Darco Hg ($0.44/lb) and PRB ash ($0.0175/lb); does not include cost to mix the materials

The HOK carbon used in these parametric tests had the same composition as the carbon tested during the long-term evaluation in November/December 2004; however, for these tests the HOK carbon had a larger (coarser) particle size. RWE Rheinbraun had evidence from other testing that suggested the coarser HOK might provide nearly equivalent mercury removal as the finely ground HOK but at a lower cost.

Testing of Norit's Darco Hg-LH at low-chloride coal sites had shown the sorbent to have higher mercury removal than untreated activated carbons. It was desired to determine if a brominated carbon would have comparable relative performance in higher chloride flue gas, such as the flue gas at Plant Yates.

The sorbent/ash mixture consisted of Darco-Hg carbon and Plant Miller PRB fly ash in a 50/50 mixture. An ash/sorbent mixture has a potential cost advantage over pure activated carbon, due to the low cost of the raw ash material. Per pound of injected material, a 50/50 mixture of carbon/ash may provide removals comparable to injection of 100% activated carbon. For example, a 50/50 carbon/ash mixture injected at 5 lb/Mmacf (that is, 2.5 lb/Mmacf activated carbon) may have the same mercury removal as injection of pure activated carbon at 5 lb/Mmacf. It is believed that the alkaline nature of the PRB ash (due to the high calcium content in the PRB ash relative to the calcium content of the ash formed from the bituminous coal burned at Yates) may work synergistically with the activated carbon. The 50/50 combination has been tested at

Southern Company's Plant Gaston, producing mercury removals close to pure carbon material (Berry 2004).

2.5 Executed Testing Matrix and Sample Schedule

Figure 2-1, shown previously, identifies the sampling locations for the various gaseous streams. The type and frequency of measurements conducted at each sample location during the parametric and long-term tests are described below.

Table 2-4. Schedule of Testing for Yates Unit 1

Activity	Dates
Parametric Tests – Round 1	
Baseline	2/25 – 2/27/2004
Ontario Hydro #1	2/26/2004
Darco Hg	3/1 – 3/4/2004
NH Carbon	3/29 – 3/30/2004
Super HOK	4/6 – 4/7/2004
Long-term Tests	
Baseline	11/13 – 11/15/2004
Injection	11/15 – 12/14/2004
Ontario Hydro #2	12/1 – 12/2/2004
Method 17 Traverses	11/30 – 12/1/2004 and 12/7 – 12/9/2004
Parametric Tests – Round 2	
Baseline	1/17/2005
Coarse HOK	1/18/2005
Darco Hg/Miller PRB Ash	1/19/2005
Darco Hg-LH	1/20/2005
Darco Hg	1/21/2005

There were three distinct phases of the test program at Plant Yates Unit 1. In the first phase, baseline (no carbon injection) and first-round parametric testing were conducted in Spring 2004.

In the second phase, one sorbent was selected for month-long testing. This testing was conducted November/December 2004. In the third phase of this test program, follow-up parametric injection tests were conducted with additional sorbents in January 2005.

2.5.1 Parametric Tests – Spring 2004

Table 2-5 summarizes the sample types, frequency, and analyses conducted for samples gathered for the short-term baseline and parametric tests. Three mercury SCEMs were operated continuously during the Unit 1 tests: one to service the ESP inlet, one for the ESP outlet, and one at the JBR outlet. Ontario Hydro flue gas measurements were conducted once (i.e., one set of 3 samples) during baseline. Method 26a was conducted during baseline testing to characterize the HCl and Cl_2 content of the flue gas. The filters collected from the Method 26a traverses were used to quantify the baseline ESP particulate emissions. Single point Method 17 measurements were taken at the ESP outlet during each parametric injection rate in order to evaluate particulate breakthrough. Single point M17 measurements were taken (rather than a full traverse) because of time limitations associated with the short-term parametric tests. Full traverses of the ESP outlet duct particulate emissions were conducted during the long-term injection tests.

Grab samples of raw coal were collected from each pulverizer feed chute after the weigh belt. Daily composite grab samples were collected during both the baseline and parametric ACI test periods. Coal samples were analyzed for mercury, chloride, and ultimate/proximate parameters. ESP fly ash samples were collected from selected fields of the ESP during the baseline and ACI tests. The field samples were combined into a single composite sample. ESP fly ash samples were analyzed for mercury and LOI.

Table 2-5. Sample Collection and Analyses for Unit 1 Short-Term Baseline and Parametric Tests (Spring 2004)

Location	Sample Method	Parameter(s)	Frequency Per Test Condition
ESP Inlet	SCEM	Speciated Hg	Continuous
	Ontario Hydro	Speciated Hg	One Set, baseline only
	Method 26a	HCl, Cl_2	One Set, baseline only
ESP Outlet	SCEM	Speciated Hg	Continuous
	Ontario Hydro	Speciated Hg	One Set, baseline only
	Method 26a	HCl, Cl_2	One Set, baseline only
	Method 5	Particulate loading-traverse	One Set, baseline only
	Method 17	Particulate loading- single point	Once per injection condition
JBR Outlet	SCEM	Speciated Hg	Continuous
Coal	Grab Composite	Hg, Cl, Ult/Prox, HHV	Once per test day
ESP Fly Ash	Grab Composite	Hg, LOI	Once per test day
	Grab Composite	Waste Characterization	3 five gal. buckets, baseline only

Tables 2-6 through 2-9 show the sample times for each of the collected samples.

Table 2-6. Unit 1 Baseline Test Schedule

	2/25/04						2/26/04						2/27/04					
Time	8am	10am	12pm	2pm	4pm	6pm	8am	10am	12pm	2pm	4pm	6pm	8am	10am	12pm	2pm	4pm	6pm
								Duct A		Duct B		Duct B						
ESP Inlet:																		
Ontario Hydro								↔	↔	↔	↔	↔						
SCEM				←	—	—	—	—	—	—	—	—	—	→	Duct A			
M26A		↔	↔	↔	↔	↔	Duct B											
ESP Outlet:																		
Ontario Hydro								↔	↔	↔	↔	↔						
SCEM		←	—	—	—	—	—	—	—	—	—	—	→					
M26A and Loading		↔	↔	↔	↔	↔												
Stack Outlet:																		
SCEM			←	—	—	—	—	—	—	—	—	—	→					
Coal:																		
Grab Composite		●	●					●		●			●		●			
ESP Fly Ash:																		
Grab Composite		●		●				●							●			
DOE Characterization		●	●					●						●				
JBR FGD Gypsum:																		
Grab Composite										●								
Makeup Water:																		
Grab Composite											●							
Limestone:																		
Grab Composite										●								
Bottom Ash:																		
Grab Composite										●								

Table 2-7. Unit 1 Parametric Sorbent Injection Test Schedule for Darco Hg Activated Carbon

	3/1/04			3/2/04			3/3/04						3/4/04					
Test Condition	BL	SI	BL	BL	SI	BL	BL	SI	SI	SI	SI	BL	BL	SI	SI	SI	SI	BL
Begin/End Time (EST)	8:35 – 9:06	9:10 - 18:00	18:30 – 19:15	7:45 – 10:30	10:30 - 14:47	15:36 – 16:13	1:00 – 9:05	9:08 – 12:33	12:33 – 13:43	13:43 – 15:00	15:00 – 17:45	17:52 – 19:10	9:35 – 10:03	10:03 – 12:29	12:29 – 15:25	15:25 – 17:50	17:50 – 18:45	19:05 – 19:55
Injection Rate (lb/MMacf)	0	6.3	0	0	12.7	0	0	2.1	4.2	2.1	3.1	0	0	5.2	7.3	9.4	12.7	0
Injection Rate (lb/h)	0	180	0	0	365	0	0	60	120	60	90	0	0	150	210	270	365	0
ESP Inlet SCEM	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
ESP Outlet SCEM	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
ESP Outlet M17		X			X			X	X						X	X		
Stack SCEM	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Coal	-	10:00, 13:05	-	9:30	13:05	-	-	9:30	13:10	-	-	-	9:10	-	13:00	-	-	-
ESP Fly Ash	-	11:00	-	-	13:30	-	-	-	13:35	-	-	-	-	-	13:00	-	-	-

C = Indicates continuous SCEM operation during test period. Other entries indicate the times (EST) that samples were collected.
BL = Baseline (no injection)
SI = Sorbent Injection

Table 2-8. Field Test Conditions for the Unit 1 Super HOK Parametric Tests

Date	Day 1 4/6/04		Day 2 4/7/04			
Injection Time Period (EST)	10:35-11:01	11:01-12:45	12:55-14:47	14:47-16:45	16:45-19:09	19:09-20:00
Actual Injection Rate (lb/MMacf)	17.0	12.9	3.3	6.0	8.8	10.2
Actual Injection Rate (lb/hr)	496	372	95	174	253	293
ESP Inlet						
SCEM	C	C	C	C	C	C
ESP Outlet						
SCEM	C	C	C	C	C	C
M17	X		X	X	X	
Stack						
SCEM	C	C	C	C	C	C
Coal	10:00	13:20	9:30, 13:30			
ESP Fly Ash		13:30	13:20			

C = Indicates continuous SCEM operation during test period. Other entries indicate the times (EST) that samples were collected.

Table 2-9. Field Test Conditions for the Unit 1 NH Activated Carbon Parametric Tests

Date	Day 1 3/29/04		Day 2 3/30/04	
Injection Time Period (EST)	12:02-14:10	14:10-19:02	9:00-11:05	11:05-12:45
Actual Injection Rate (lb/MMacf)	4.2	6.3	8.3	12.5
Actual Injection Rate (lb/hr)	120	180	240	360
ESP Inlet				
SCEM	C	C	C	C
ESP Outlet				
SCEM	C	C	C	C
M17	X	X	X	X
Stack				
SCEM	C	C	C	C
Coal	9:30, 13:10		9:20	13:20
ESP Fly Ash	13:20			13:20

C = Indicates continuous SCEM operation during test period. Other entries indicate the times (EST) that samples were collected.

2.5.2 Parametric Tests – January 2005

Additional parametric tests were carried out during the week of January 17th, 2005. The sorbents tested in the second round of parametric tests included RWE Rheinbraun's coarse grind HOK, Norit's Darco Hg-LH (a brominated carbon, formerly known as Norit E-3), and a sorbent/PRB ash mixture prepared by Southern Company. In addition, Norit's Darco Hg was tested again to compare its performance to the Spring 2004 results and to the sorbent/ash mixture.

Tables 2-10 summarizes the sample types and frequency of collection for this second round of parametric tests and Table 2-11 shows the executed testing schedule.

Table 2-10. Sample Collection and Analyses for Unit 1 Parametric Tests (January 2005)

Location	Sample Method	Parameter(s)	Frequency Per Test Condition
ESP Inlet	SCEM	Speciated Hg	Continuous
ESP Outlet	SCEM	Speciated Hg	Continuous
	Method 26	HCl, Cl_2	Once per Darco Hg-LH test condition, baseline
JBR Outlet	SCEM	Speciated Hg	Continuous
Coal	Grab Composite	Hg, Cl, Ult/Prox, HHV	Once per test day
ESP Fly Ash	Grab Composite	Hg, LOI	Once per test day

Table 2-11. Field Test Conditions for the Unit 1 Baseline and ACI Parametric Tests

	Baseline, Full Load	Coarse HOK Carbon Injection, Full Load					Darco Hg™-Miller Ash Blend, Full Load		
	Day 1	Day 2					Day 3		
	1/17/05	1/18/05					1/19/05		
Injection Time Period (EST)	N/A	10:35 – 12:35	12:35 – 14:27	14:27 – 16:27	16:27 – 17:50	17:50 – 18:15	10:23 – 12:23	12:23 – 14:40	14:40 – 16:40
Actual Injection Rate (lb/MMacf)	0	5.0	6.9	10.4	13.9	16.2	2.5*	3.5*	5.2*
Actual Injection Rate (lb/hr)	0	143	200	300	400	467	143	200	300

* Injection Rates are lb carbon/macf. The actual total sorbent injection rate is twice this value, because the sorbent was composed of 50 wt % Darco Hg carbon and 50 wt %.

	Darco Hg-LH™ Carbon Injection, Full Load					Darco Hg™ Carbon Injection, Full Load	
	Day 4					Day 5	
	1/20/05					1/21/05	
Injection Time Period (EST)	10:20 – 12:35	12:40 – 15:15	15:15 – 16:11	16:11 – 18:30	18:30 – 20:00	10:55 – 12:55	12:55 – 18:30
Actual Injection Rate (lb/MMacf)	5.0	6.9	10.4	2.4	11.7	2.4	5.2
Actual Injection Rate (lb/hr)	143	200	300	70	337	70	150

2.5.3 Long-Term Test – November/December 2004

A month-long, activated carbon injection test was conducted at Plant Yates Unit 1 with RWE Rheinbraun's Super HOK activated carbon. The long-term injection test started on November 15, 2004, and ended on December 14, 2004. Baseline (no injection) vapor phase mercury measurements were made during three days prior to the month-long injection test.

For the majority of the injection test, Unit 1 operated at a load set by grid demand. This load was typically 55 MW. During one week of the test, Unit 1 operated at full load (107 MW) during the 6 am – 6 pm time period, and operated at reduced load overnight. The carbon injection rate ranged from 3 to 17 lb/Macf during the month-long test, with most of the test carried out at rates between 4 and 9 lb/Macf. Carbon injection rates were selected based on near-real type feedback of vapor phase mercury removal performance and observed balance of plant impacts

Table 2-11 summarizes the sample collections for the long-term test. Not all collected samples were analyzed for the parameters listed.

Table 2-11. Sample Collection and Analyses for Unit 1 Long-term Injection Test

Location	Sample Method	Parameter(s)	Frequency of Sampling
ESP Inlet	SCEM	Speciated Hg	Continuous
ESP Outlet	SCEM	Speciated Hg	Continuous
	Ontario Hydro	Speciated Hg	One set
	Method 5	Particulate loading	One set
	Method 17	Particulate loading-traverse	
JBR Outlet	SCEM	Speciated Hg	Continuous
	Ontario Hydro	Speciated Hg	One set
Coal	Grab Composite	Hg, Cl, Ult/Prox, HHV	Once per test day
ESP Fly Ash	Grab Composite	Hg, LOI	Once per test day
	Grab Composite	Waste Characterization	3 five gal. buckets
JBR Slurry	Grab sample	Hg, SO_3, SO_4, wt% solids	Twice weekly

Ontario Hydro testing was conducted during the week of November 30th, 2004 at the ESP outlet and JBR outlet. In previous Ontario Hydro campaigns, the evaluation points were the ESP inlet and ESP outlet. In these previous campaigns, the reactivity of the fly ash captured on the particulate filter created a bias in the partitioning of the mercury between solid and particulate phases. Furthermore, the vortex-like flow at the ESP inlet made iso-kinetic sampling impossible. It was decided for the final Ontario Hydro campaign that the ESP inlet site be omitted in favor of the stack location.

Method 17 traverses were conducted at the ESP outlet during the weeks of November 30th and December 7th, 2004 in order to evaluate how load and carbon injection rate affect ESP particulate emissions.

During the long-term injection test, coal and ash samples were collected on a daily basis. The coal sample was a composite sample from all the mills in service. Ash samples were collected as a composite of the first two fields and a composite of the second two fields. FGD samples were collected on a semi-weekly basis.

3.0 Results and Discussion

The results of the sorbent injection tests from Plant Yates Unit 1 are discussed in this section. First the parametric test results are presented, followed by the long-term test results. For each test period the following topics are discussed: flue gas mercury speciation and removal, coal and byproduct analyses, and impacts of sorbent injection on plant operations.

Two different metrics are used in this report to discuss the mercury removal performance of the sorbents. The first metric is the vapor phase mercury removal across a device. This metric compares the outlet vapor phase mercury concentration to the inlet vapor phase mercury concentration. The mercury removal can be calculated across the ESP, across the JBR FGD, or across the ESP/JBR system. The generic calculation for the vapor phase mercury removal is

$$\text{Percent Removal} = [1 - O/I] \times 100$$

where,

O = average SCEM total mercury concentration at the device outlet (either ESP outlet or stack) for the injection rate test period, and

I = average SCEM total mercury concentration at the inlet to the device or set of devices (either ESP inlet or ESP outlet).

The second metric used in this section is the percent reduction of vapor phase mercury at the exit of a device. Because the baseline system mercury removal was quite high, the amount of mercury reduction attributed to carbon injection was estimated by calculating the percent reduction in average total vapor-phase mercury levels at the ESP outlet and stack locations compared to average baseline levels (i.e., native levels). The percent reduction in total mercury concentration for a given injection rate is calculated as follows:

$$\text{Percent Reduction} = [1 - (O / BL)] \times 100$$

where,

O = average SCEM total mercury concentration at the ESP outlet or stack for the injection rate test period, and

BL = average SCEM total mercury concentration at the ESP outlet or stack for the baseline test period calculated based on the concentrations measured at the beginning and end of each test day.

Each datum point of percent removal or percent reduction of mercury represents an average of the data collected over a multi-hour test period. For the parametric tests, each injection rate was tested for two to four hours. Average mercury concentrations measured at each location were determined starting from the time the mercury concentrations at the sample locations had steadied until the injection rate was changed. These average mercury concentrations were then input into the calculations for percent mercury removal and percent mercury reduction. For the long-term tests, averages were computed on an hourly basis. Appendix A further explains how the raw data from the SCEM was treated to obtain the results provided in this report.

3.1 Parametric Tests

Various mercury sorbents were evaluated in parametric tests. These parametric tests were conducted in two phases. The first test phase occurred in Spring 2004, and the results were used to select a sorbent for the long-term injection test. The second phase occurred in January 2005, after the long-term injection test, for evaluation of additional sorbents. This section discusses the results from the two phases of parametric tests, first presenting the mercury removal results then discussing balance of plant impacts. Plots of the SCEM measurements for each day of parametric testing are provided in Figures B-1 through B-11 in Appendix B.

3.1.1 Plant Process Conditions

During both the Spring 2004 and January 2005 parametric tests, the unit increased operation to its full-load set point of approximately 106 MW before each baseline and sorbent injection test period and held the load constant throughout each test. The unit load affects duct temperatures, which ultimately affects flue gas mercury concentrations and in-flight removal of mercury. In general, the temperature of the duct and mercury concentration of the flue gas increased with increasing load. The correlation between duct temperatures, load, and mercury concentration is explored in detail in the section on long-term injection results because more data were available for analysis from that test period.

3.1.2 Phase I of Parametric Testing - Spring 2004

The first phase of parametric testing on Unit 1 consisted of four weeks of testing: a baseline (no injection) test week and three weeks of sorbent testing (one week each for Darco Hg, Super HOK, and NH Carbon). The mercury removal results from these three carbons were compared in order to choose a carbon for the long-term injection test.

Baseline Characterization Tests - Mercury Removal Results –Spring 2004

Baseline characterization of the mercury concentrations in the flue gas at the ESP inlet, ESP outlet, and stack locations were conducted over a three-day period from 2/25/04 through 2/27/04. During this period, semi-continuous data were collected for total vapor-phase mercury and elemental mercury using three SCEM analyzers. In addition, simultaneous Ontario Hydro mercury speciation measurements were conducted at the ESP inlet and ESP outlet during full-load conditions to compare to the SCEM analyzer results. The objectives of this series of tests were (1) to measure the native mercury concentrations at the various flue gas sample locations, and (2) to measure the variability in flue gas mercury concentrations over time.

The variability in total vapor-phase mercury concentrations was greatest at the ESP inlet location, where total vapor-phase mercury concentrations increased from 1 to 3 $\mu g/Nm^3$ at reduced load to 4 to 7 $\mu g/Nm^3$ during full-load conditions. At the ESP outlet location at full load, the mercury concentration varied from 2 to 3.5 $\mu g/Nm^3$, with approximately 35% oxidation. At the stack at full load, the mercury concentration varied from 2 to 3 $\mu g/Nm^3$, with almost all of the vapor phase mercury present as elemental mercury. The baseline removal across the ESP was approximately 35%.

These baseline data represent only 48 hours of operation, therefore, they do not represent the range in coal compositions that the unit experiences. Throughout the rest of the test program, baseline data were intermittently gathered. In viewing all of these data together, the baseline mercury profile across the Unit 1 can vary greatly.

During the parametric injection tests, a set of baseline mercury measurements with no injection was obtained at the beginning and at the end of each sorbent injection test day. The mercury concentrations and speciation measured at the three locations were very similar to the range measured during the baseline characterization in February 2004. The mercury removal across the ESP ranged from 25-50% during these baseline periods, with only a few points outside this range. The mercury removal across the JBR saw even greater variation, with data ranging between 20 and 60% baseline removal. The baseline mercury removal across the combined ESP/JBR system typically ranged from 60 to 75%.

At the ESP inlet location, the percentage of the total mercury present as oxidized mercury remained essentially unchanged between daily baseline and sorbent injection tests periods, with values generally in the range of 40 to 60 percent. These values were consistent with SCEM data obtained during the baseline characterization period of 2/25/04 through 2/27/04.

Sorbent Injection Tests – Mercury Removal Results – Spring 2004

Three sorbents were evaluated in the Spring 2004 parametric testing: Norit's Darco Hg, RWE's Super HOK, and Ningxia Huahui's activated carbon (NH carbon). Tables 3-1, 3-3, and 3-5 provide summaries of the average total vapor-phase mercury and mercury speciation data obtained for the sorbent injection tests. In these tables, the oxidized mercury concentration is calculated by difference using the total and elemental mercury measurements. Mercury removal performance of the ESP, JBR FGD and combined ESP/JBR FGD controls for the various tests are tabulated in Tables 3-2, 3-4, and 3-6.

Total vapor-phase mercury removal across the ESP (i.e., ESP inlet compared to ESP outlet) is plotted as a function of sorbent injection rate in Figure 3-1 for the various sorbents. This calculation does not account for removal of particulate mercury across the ESP. Like the baseline characterization tests on 2/25/04 through 2/27/04, relatively high native removals of total vapor-phase mercury were observed without sorbent injection at the beginning and end of each sorbent injection test day. Native removal of total vapor-phase mercury across the ESP ranged from 25 to 50 percent, which probably resulted from the high carbon content (7-15 % LOI) of the ash generated by Unit 1. For all three activated carbons, sorbents mercury removal across the ESP plateaued between 50 and 70% for injection rates greater than 8 lb/MMacf (these removal percentages include baseline removal of mercury across the ESP).

Figure 3-2 shows the vapor phase mercury removal across the JBR for each of the three carbons. The Darco Hg carbon appeared to negatively impact the mercury removal across the JBR as the injection rate increased. The Super HOK carbon had only a small, but perhaps negative, impact on the mercury removal across the JBR. In contrast, the mercury removal across the JBR increased with increasing NH carbon injection rate.

Figure 3-3 shows the vapor phase mercury removal across the ESP/JBR system. The mercury removal across the ESP/JBR system plateaued between 70 and 85% at injection rates greater than 8 lb/MMacf for all carbons.

Table 3-1. Average SCEM Mercury Measurements for Unit 1 During Baseline and Injection of Darco Hg™ Activated Carbon

Date	Injection Rate (lb/MMacf)	ESP Inlet, μg/Nm^3			ESP Outlet, μg/Nm^3			Stack, μg/Nm^3		
		Total	Hg^o	Percent Oxidized	Total	Hg^o	Percent Oxidized	Total	Hg^o	Percent Oxidized
3/1/04	0	7.3	2.5	66	3.8	2.3	40	1.8	1.8	1
	6.3	5.2	-	-	2.2	1.5	32	0.91	0.82	10
	0	5.2	-	-	3.8	-	-	1.2	-	-
3/2/04	0	6.9	3.6	47	3.3	2.4	25	2.5	2.3	8
	12.7	6.4	3.3	49	1.9	1.3	29	1.9	1.8	3
	0	5.9	2.8	52	3.2	-	-	2.7	-	-
3/3/04	0	7.8	3.6	54	4.3	1.9	57	2.6	2.0	23
	2.1	7.8	3.6	54	3.4	1.8	49	2.3	2.3	1
	4.2	6.9	3.3	52	2.9	-	-	2.2	-	-
	2.1	7.0	-	-		1.6	-	2.4	-	-
	3.1	7.2	3.3	55	3.1	1.5	52	1.9	2.2	0
	0	5.8	-	-	4.3	-	-	2.1	-	-
3/4/04	0	5.9	3.0	49	3.5	1.8	49	2.3	1.9	21
	5.2	6.2	3.0	51	2.4	1.3	48	1.8	1.7	2
	7.3	5.8	2.9	51	2.2	1.3	42	1.1	1.8	0
	9.4	5.5	3.1	43	2.0	1.2	40	1.6	1.7	0
	12.7	5.5	-	-	2.0	-	-	1.9	-	-
	0	5.8	3.1	46	4.0	-	-	3.1	-	-

Note: All concentrations normalized to 3% oxygen.

Table 3-2. Summary of Measured Vapor-Phase Mercury Removals for the Unit 1 ESP and JBR FGD During Injection of Darco Hg Activated Carbon

Date	Injection Rate, lb/MMacf	Hg Removal Across ESP, %	Hg Removal Across JBR FGD, %	Hg Overall Removal Across ESP/JBR FGD, %
		Total	Total	Total
3/1/04	0	48	53	75
	6.3	58	58	82
	0	26	68	76
3/2/04	0	53	24	64
	12.7	71	0	71
	0	46	15	54
3/3/04	0	45	40	67
	2.1	57	32	70
	4.2	58	24	68
	2.1	-	-	66
	3.1	57	38	73
	0	26	51	64
3/4/04	0	42	33	61
	5.2	61	26	71
	7.3	62	49	81
	9.4	64	21	71
	12.7	63	8	66
	0	30	24	47

Table 3-3. Average SCEM Mercury Measurements for Unit 1 During Baseline and Injection of Super HOK Carbon

		ESP Inlet			ESP Outlet			Stack		
Date	Rate (lb/MMacf)	Total Hg	Hg^0	% Oxidized	Total Hg	Hg^0	% Oxidized	Total Hg	Hg^0	% Oxidized
4/6/2004	0.0		2.3		3.1			2.5	2.6	-3%
	12.9	6.4	3.8	40%	2.2	0.8	62%	1.9	1.8	8%
	0.0				3.3			2.6		
4/7/2004	0.0				3.3			2.3		
	3.3	6.1			2.9			2.3		
	6.0				2.1			1.8		
	8.8	5.1			1.6	1.0	36%	1.4	1.5	-9%
	10.2	5.4			1.3			1.4		
	0.0	5.2			2.1			2.0		

Note: All concentrations are in units of μg/Nm^3 and are normalized to 3% oxygen.

Table 3-4. Summary of Measured Percent Removal of Vapor Phase Mercury Across ESP, JBR, and Combined ESP/JBR During Injection of Super HOK Carbon

		% Removal of Total Vapor Phase Hg		
Date	Rate (lb/MMacf)	Across ESP	Across JBR	Across ESP/JBR
4/6/2004	0.0	51%	20%	60%
	12.9	66%	13%	70%
	0.0	48%	22%	59%
4/7/2004	0.0	47%		
	3.3	52%	21%	62%
	6.0	59%	13%	64%
	8.8	69%	9%	72%
	10.2	75%	-4%	74%
	0.0	59%	6%	61%

Table 3-5. Average SCEM Mercury Measurements for Unit 1 During Baseline and Injection of NH Carbon

		ESP Inlet			ESP Outlet			Stack		
Date	Rate (lb/MMacf)	Total Hg	Hg^0	% Oxidized	Total Hg	Hg^0	% Oxidized	Total Hg	Hg^0	% Oxidized
3/29/2004	0.0		2.7	55%	4.1	1.9	53%	1.9	2.0	-6%
	4.2	5.9	2.4	60%	3.3			1.2		
	6.3	7.0			2.8	1.9	29%	1.1	1.2	-4%
	0.0	7.1			4.4			2.1		
3/30/2004	0.0				4.1	2.1	48%	1.9	1.6	11%
	8.3	5.5			2.7			0.9	0.9	2%
	12.5	4.9			2.4			0.7		
	0.0	4.7			4.0			1.4	1.4	2%

Note: All concentrations are in units of μg/Nm^3 and are normalized to 3% oxygen.

Table 3-6. Summary of Measured Percent Removal of Vapor Phase Mercury Across ESP, JBR, and Combined ESP/HBR During Injection of NH Carbon

Date	Rate (lb/MMacf)	% Removal of Vapor Phase Hg Across ESP	Across JBR	Across ESP/JBR
3/29/2004	0.0	30%	54%	68%
	4.2	44%	37%	80%
	6.3	61%	59%	84%
	0.0	38%	53%	71%
3/30/2004	0.0	25%	55%	66%
	8.3	50%	68%	84%
	12.5	51%	73%	87%
	0.0	16%	64%	70%

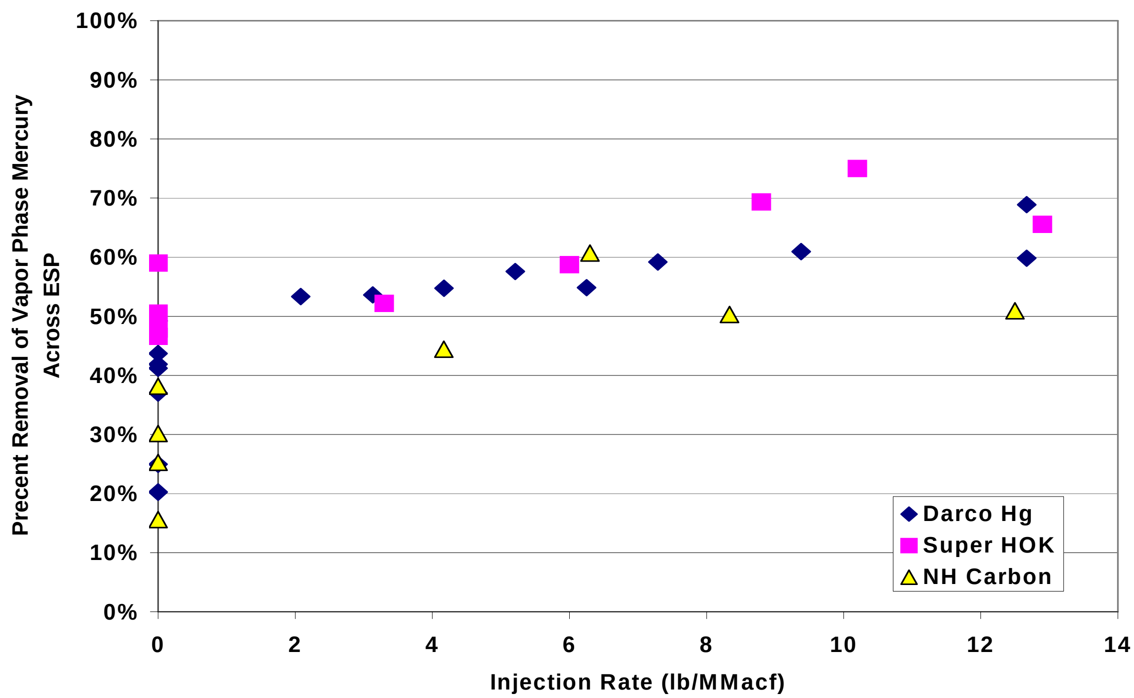

Figure 3-1. Comparison of Mercury Removal Efficiency Across the ESP for Darco Hg, Super HOK, and NH Carbon

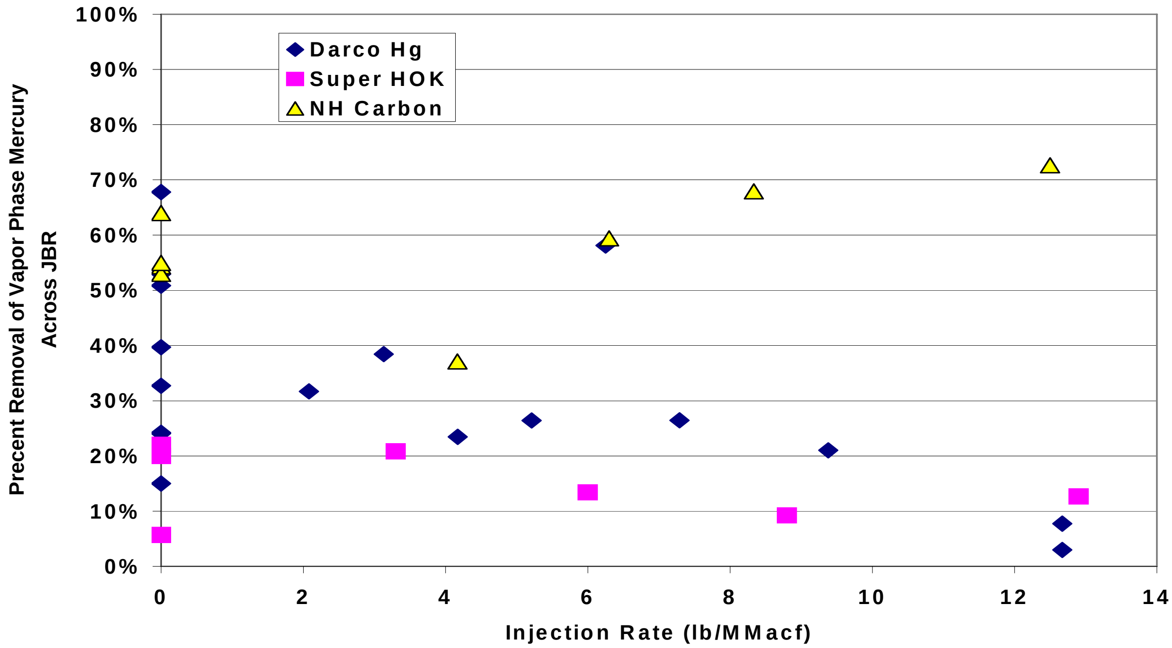

Figure 3-2. Comparison of Mercury Removal Efficiency Across the JBR for Darco Hg, Super HOK, and NH Carbon

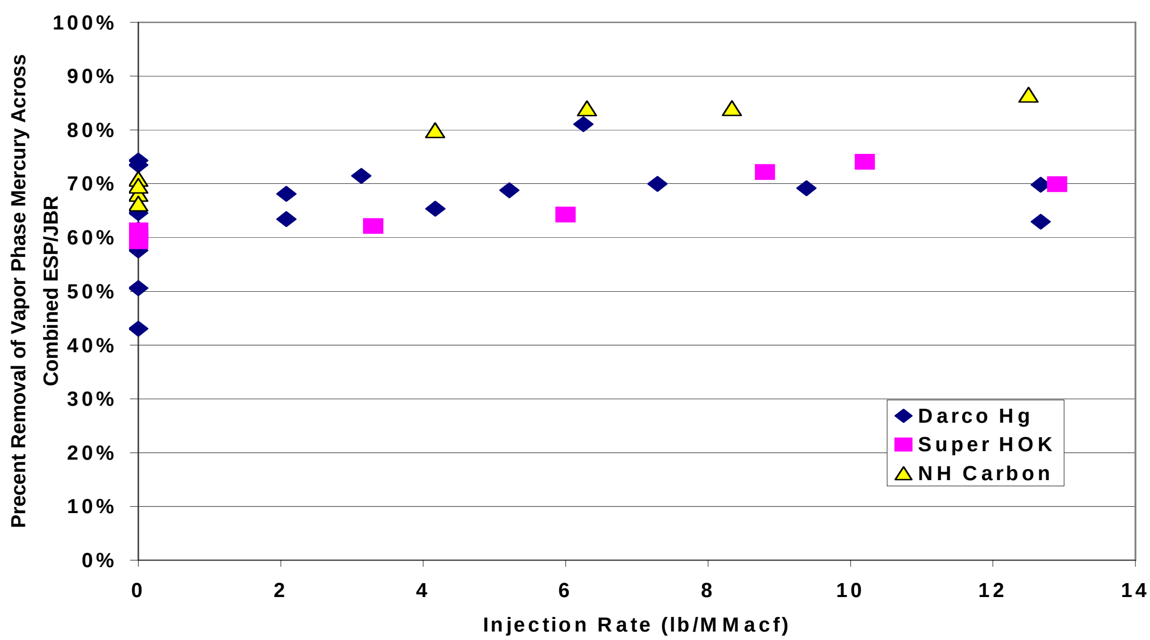

Figure 3-3. Comparison of Mercury Removal Efficiency Across the Combined ESP/JBR for Darco Hg, Super HOK, and NH Carbon

Because the baseline mercury removal was quite high, the amount of mercury reduction attributed to carbon injection was estimated by calculating the percent reduction in average total vapor-phase mercury levels at the ESP outlet and stack locations compared to average baseline levels. For the Unit 1 ESP, Figure 3-4 indicates a 10 to 45 percent reduction in total vapor-phase mercury concentrations at the ESP outlet compared to baseline concentrations over the range of sorbent injection rates tested. At the stack, Figure 3-5 shows a 10 to 50 percent reduction in total vapor-phase mercury concentrations compared to baseline concentrations over the range of sorbent injection rates tested. Both Figures 3-4 and 3-5 show that additional mercury removal from sorbent injection plateaus around 8 lb/MMacf.

For the three carbons, the maximum achieved percent reduction of mercury at the ESP outlet as a result of carbon injection was about 45%. The ESP mercury removal curves for the Darco Hg and the NH carbon are nearly identical, and the Super HOK curve is just slightly lower. At the stack, the NH carbon resulted in the highest combined removal across the ESP/JBR. However, the native removal across the ESP/JBR system was higher during the NH Carbon injection testing than during the other injection tests.

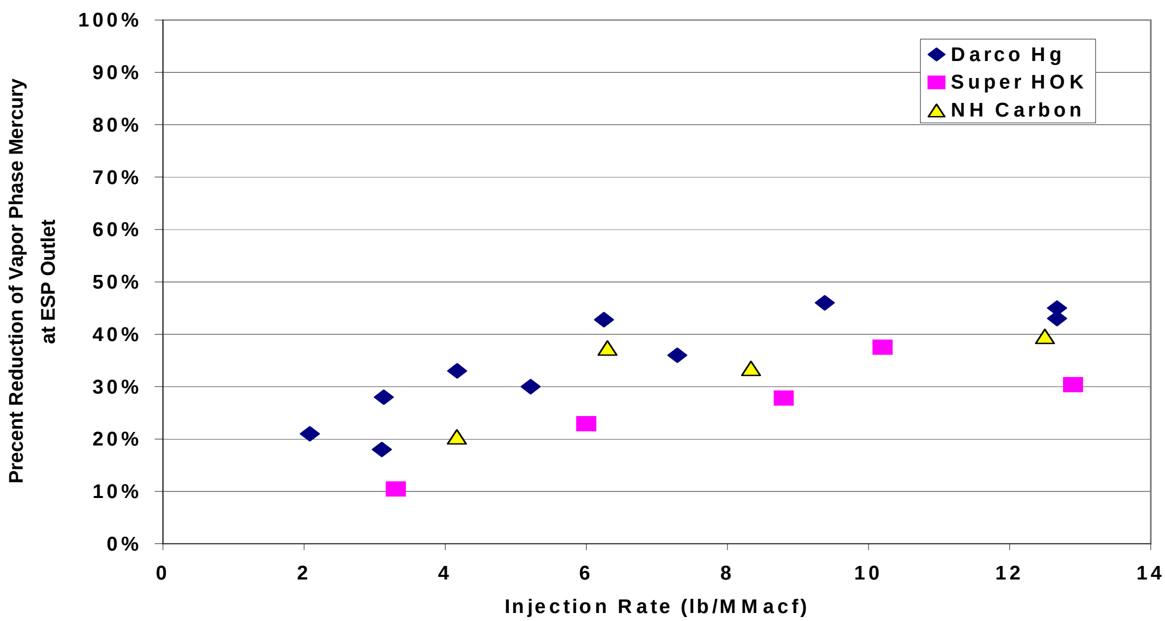

Figure 3-4. Comparison of Mercury Reduction at the ESP Outlet for Darco Hg, Super HOK, and NH Carbon

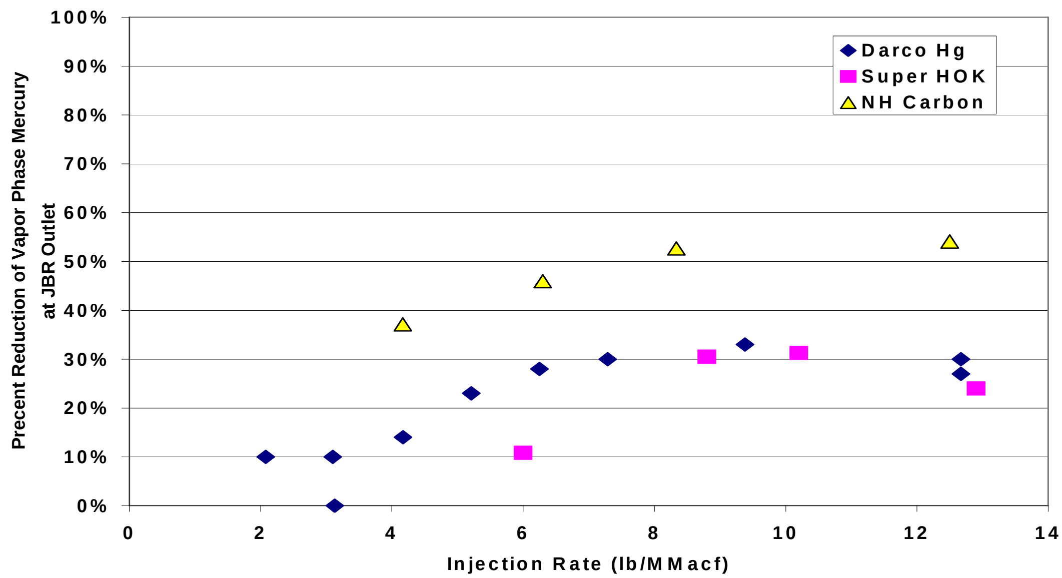

Figure 3-5. Comparison of Mercury Reduction at the JBR Outlet for Darco Hg, Super HOK, and NH Carbon

Figure 3-6 shows the total vapor-phase mercury emissions, expressed as lb/trillion Btu input, at the ESP outlet as a function of carbon injection rate. Without carbon injection, the ESP outlet emissions ranged from 2.1 to 2.9 lb/trillion Btu. At an injection rate of 6 lb/MMacf, all three sorbents were capable of bringing the Unit 1 ESP emissions below 2 lb/trillion Btu.

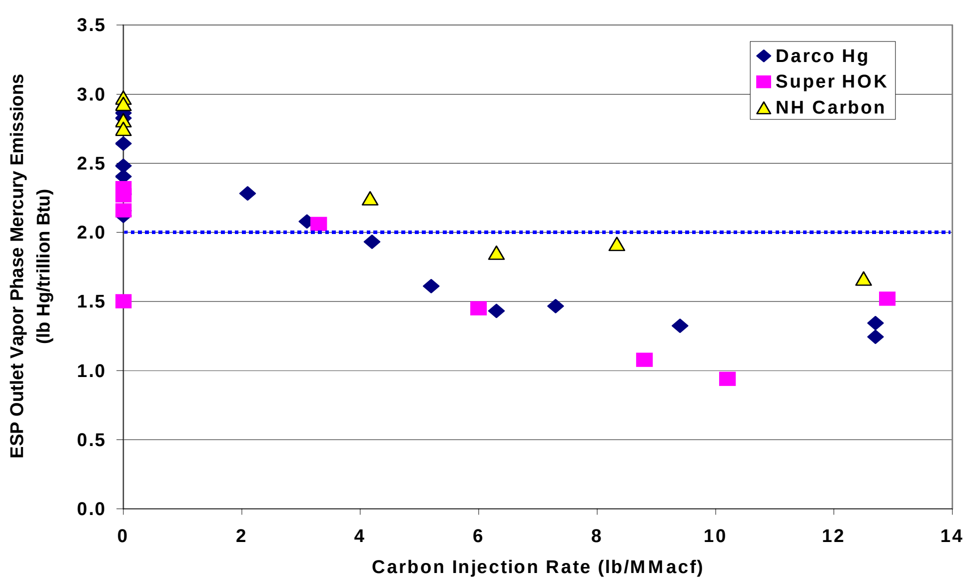

Figure 3-6. ESP Outlet Mercury Emissions in lb Hg/trillion Btu for Darco Hg, Super HOK, and NH Carbon

Balance of Plant Impacts – Spring 2004 Parametric Tests

Because of the short-term nature of the parametric tests, only limited conclusions can be drawn about the effect of carbon injection on balance of plant operations. A more detailed analysis of balance of plant impacts is conducted with the long-term injection data, which is covered in a subsequent section of this chapter. The primary impact that sorbent injection had on Unit 1 was related to the ESP operation.

The impact of sorbent injection on the ESP performance was quantified by taking Method 17 particulate samples at a single point in the duct during each injection rate and by monitoring the arc rate in each electrical field. The flue gas particulate concentration was measured at the ESP outlet during baseline and injection testing. During baseline testing, a Method 5 filter was used in conjunction with Method 26 traverses. During injection testing, Method 17 was employed at a single point in the duct.

Figure 3-7 shows the Unit 1 ESP outlet particulate concentrations measured during baseline and injection testing. During baseline conditions (sorbent injection rate = 0 lb/MMacf), the ESP outlet particulate concentration ranged from 0.024 to 0.052 grains/dscf at 3% O_2, with an average of 0.036 gr/dscf. For the tested carbon injection rates of 2 to 17 lb/MMacf, the measured outlet particulate concentrations were mostly within or below the range of concentrations measured during baseline testing. It should be noted that baseline measurements were taken as a traverse, while the injection test measurements are single points within the duct. Single point measurements cannot be used to quantify the emissions from the entire duct. They were used, in this case, to look at relative differences between injection rates at a common point in the duct. These measurements did not show an increase in particulate emissions with injection rate at the selected measurement point. Conversely, some of the Method 17 traverses conducted during the long-term injection test did show carbon breaking through the ESP.

Very low ESP spark rates were observed throughout the testing period. Although the spark rate remained fairly low, the arcing behavior of the Unit 1 ESP often exceeded 10 arc/minute (apm). This behavior was noted during both baseline and sorbent injection test periods, making it difficult to isolate the effect of carbon injection on the arc rate. The arcing behavior of the Unit 1 ESP caused some concern because it appeared to be influenced by sorbent injection and exceeded typical guidelines.

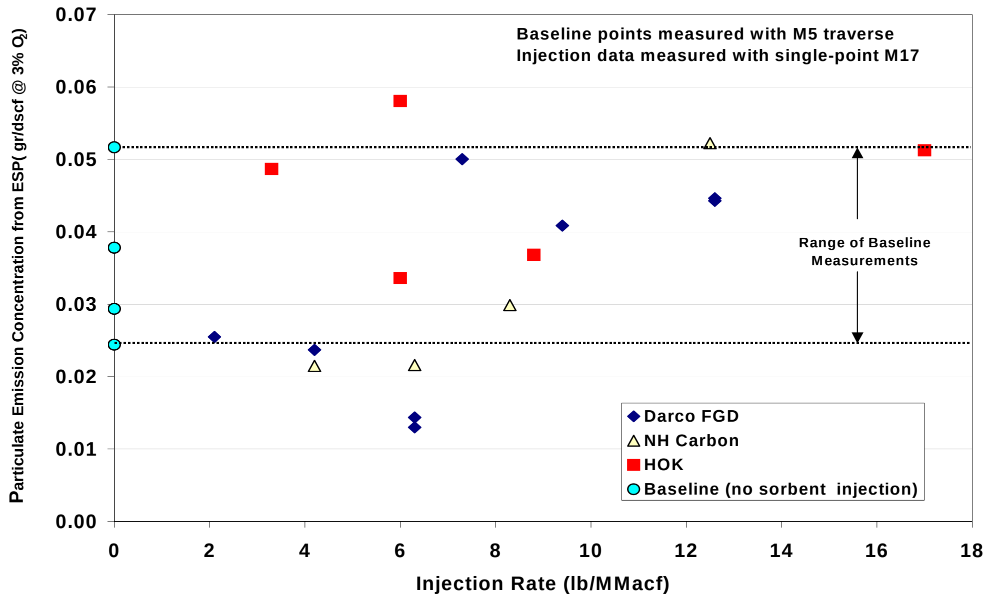

Figure 3-7. ESP Outlet Particulate Emissions Measured During Spring 2004 Unit 1 Parametric Carbon Injection Tests

In the time that elapsed between the parametric tests and the long-term injection tests, the Unit 1 ESP underwent rigorous inspection and maintenance. The stand-off insulators at the bottom of the high voltage frame were found damaged or broken. It is unclear when this damage occurred (i.e., whether the damage is related to activated carbon injection or to the LOI content of the ash). It is believed that the presence of broken insulators would lead to erratic arcing and sparking behavior in the ESP, as was observed in the Spring 2004 testing. A visual inspection of the insulators revealed that carbon was "baked" onto the surface of the insulators. This can be clearly seen in Figure 3-8.

Figure 3-8. Damaged Insulator from Yates Unit 1 ESP

Prior to commencement of the long-term injection test, the insulators on the Unit 1 ESP were replaced. Replacement of the insulators provided for a baseline operation with little arcing and allowed for a clearer comparison between injection and baseline conditions. The ESP performance data from the long-term test are discussed in Section 3.2 covering long-term testing results. As will be discussed in that section, the ESP is clearly subjected to higher arcing during carbon injection at low load conditions.

Coal, Ash, and FGD Byproducts – Spring 2004 Parametric Tests

Coal

Table 3-7 shows the analytical results for as-fired coal samples. Composite samples of the Unit 1 coal were collected twice per day downstream of the coal pulverizers and were analyzed in triplicate for mercury; an average of the triplicate analyses is reported in the table. Ultimate/proximate and chlorine analyses were performed on selected samples, and these results are also shown. For the test days on which the as-fired coal was not analyzed, the proximate analyses are for the as-bunkered coal samples are given. These as-bunkered data were provided by Plant Yates.

As the coal Hg content increased, the measured vapor phase mercury at the ESP inlet increased, as shown by Figure 3-9. This plot does not account for particulate phase mercury, which could not be measured due to severe cyclonic flow at the sampling location.

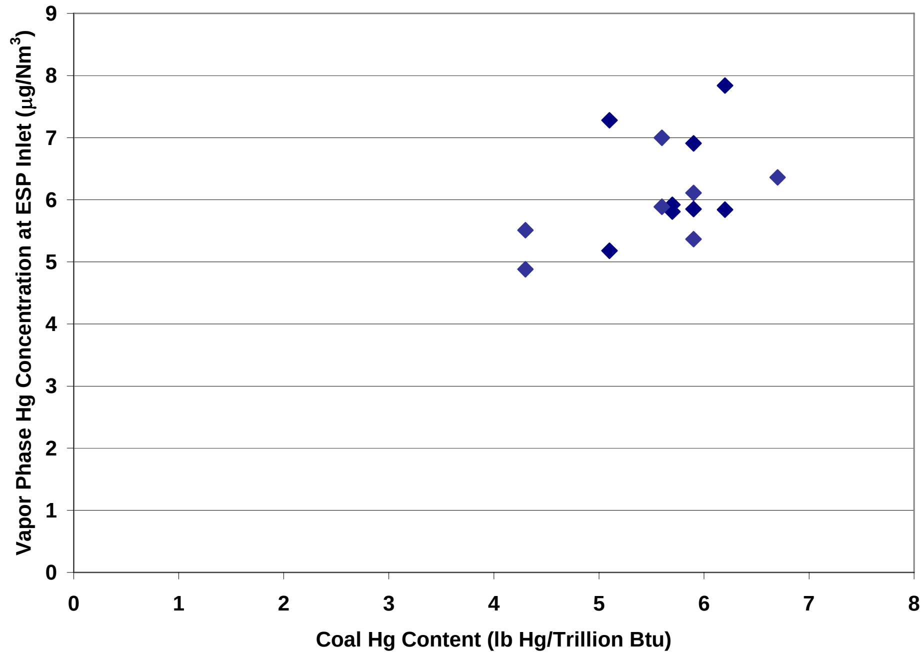

Figure 3-9. ESP Inlet Vapor Phase Mercury Concentration as a Function of Coal Mercury Content

Table 3-7. Unit 1 - Coal Analyses for Baseline and Carbon Injection Tests (Spring 2004)

Date	**2/24**	**2/25**	**2/25**	**2/26**	**2/26**	**2/27**	**2/27**	**3/1**	**3/1**	**3/2**	**3/2**	**3/3**	**3/3**	**3/4**	**3/4**
Sample Time	**13:30**	**9:20**	**12:30**	**9:20**	**13:00**	**9:00**	**12:10**	**10:00**	**13:05**	**9:30**	**13:05**	**9:30**	**13:10**	**9:10**	**13:00**
Test Condition [a]	**BL**	**BL**	**BL**	**BL**	**BL**	**BL**	**BL**	**Darco-Hg**	**Darco-Hg**	**Darco-Hg**	**Darco-Hg**	**Darco-Hg**	**Darco-Hg**	**Darco-Hg**	**Darco-Hg**
Proximate, wt % as received [b]															
Moisture	6.67	-	6.65	-	7.22	-	6.5	-	6.04	-	5.38	-	5.16	-	5.89
Ash	12.64	-	13.27	-	13.04	-	10.16	-	11.64	-	10.63	-	11.12	-	10.99
Volatile Matter	28.32	-	27.86	-	27.4	-	28.43	-	27.91	-	28.94	-	28.80	-	28.05
Fixed Carbon	52.38	-	52.23	-	52.33	-	54.90	-	54.41	-	55.05	-	54.92	-	55.07
Sulfur	0.76	-	0.73	-	0.91	-	1.29	-	0.93	-	0.95	-	0.93	-	1.16
Ultimate, wt % as received															
Moisture	-	-	3.62	-	-	-	-	-	-	-	-	-	4.40	-	-
Carbon	-	-	72.64	-	-	-	-	-	-	-	-	-	72.49	-	-
Hydrogen	-	-	4.66	-	-	-	-	-	-	-	-	-	4.69	-	-
Nitrogen	-	-	1.40	-	-	-	-	-	-	-	-	-	1.36	-	-
Sulfur	-	-	0.87	-	-	-	-	-	-	-	-	-	0.99	-	-
Oxygen	-	-	5.82	-	-	-	-	-	-	-	-	-	5.01	-	-
Ash	-	-	10.99	-	-	-	-	-	-	-	-	--	11.06	-	-
Heating Value (Btu/lb, as received)	12253[b]	13102	12196	-	12218[b]	-	12803[b]	-	12651[b]	-	12849[b]	-	12993	-	12730[b]
Mercury (µg/g, dry)	0.062	0.062	0.063	0.059	0.062	0.075	0.086	0.084	0.064	0.071	0.076	0.065	0.081	0.073	0.11
Mercury (lb/trillion Btu)	5.1	4.7	5.2		5.1	-	6.7	-	5.1	-	5.9	-	6.2	5.7	8.6
Chloride (mg/Kg, dry)		274	237		362	-	-	-	285	-	-	-	128	-	-

[a] BL = baseline characterization, Darco-Hg = Norit's Darco Hg™ carbon sorbent injection; NH = NH carbon sorbent injection; HOK = HOK sorbent injection

[b] Represents Plant Yates analysis of as-bunkered fuel samples. Mercury analysis was done on separate Unit 1 as-fired coal samples.

Table 3-7. Unit 1 - Coal Analyses for Baseline and Carbon (Spring 2004) (continued)

Date	3/29	3/29	3/30	3/30	4/6	4/6	4/7	4/7	4/8
Sample Time	9:30	13:10	9:20	13:20	10:00	13:20	9:30	13:30	9:30
Test Condition [a]	NH	NH	NH	NH	HOK	HOK	HOK	HOK	HOK
Proximate, wt % as received [b]									
Moisture	-	5.5	-	7.19	-	5.67	-	5.86	-
Ash	-	12.27	-	11.86	-	11.22	-	11.16	-
Volatile Matter	-	28.26	-	27.82	-	26.95	-	26.52	-
Fixed Carbon	-	53.97	-	53.14	-	56.16	-	56.45	-
Sulfur	-	0.86	-	0.86	-	0.89	-	0.89	-
Ultimate, wt % as received									
Moisture	-	-	-	5.28	-	-	-	6.21	-
Carbon	-	-	-	71.75	-	-	-	69.31	-
Hydrogen	-	-	-	4.61	-	-	-	4.36	-
Nitrogen	-	-	-	1.49	-	-	-	1.31	-
Sulfur [b]	-	-	-	1.03	-	-	-	0.93	-
Oxygen	-	-	-	4.86	-	-	-	5.68	-
Ash	-	-	-	10.98	-	-	-	12.20	-
Heating Value (Btu/lb, as received)	-	12606[b]	-	12933	-	12789[b]	-	12467	-
Mercury (µg/g, dry)	-	.071	-	.056	-	.086	-	.073	0.119
Mercury (lb/trillion Btu)	-	5.6	-	4.3	-	6.7	-	5.9	-
Chloride (mg/Kg, dry)	-	201	-	-	-	452	-	-	-

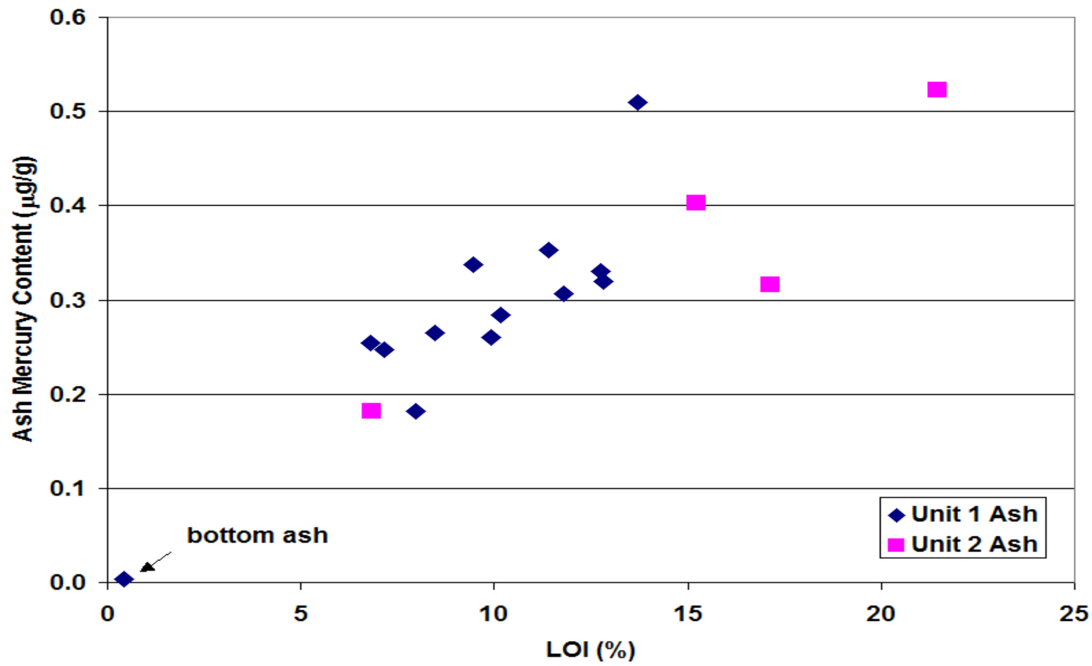

Figure 3-10. Ash Mercury Content as a Function of the Ash LOI Content

Table 3-8. Unit 1 – Bottom Ash and ESP Fly Ash Analyses for Baseline Characterization and Sorbent Injection (SI) Tests

Date	Time	Sample Type	Test Condition	Injection Rate (lb/MMacf)	Mercury (µg/g)	LOI (%)
2/24	13:15	ESP ash	Baseline	0	0.31	11.8
2/25	9:46	ESP ash	Baseline	0	0.26	9.9
2/25	13:10	ESP ash	Baseline	0	0.28	10.2
2/26	10:00	ESP ash	Baseline	0	0.33	12.8
2/26	13:00	Bottom Ash	Baseline	0	0.003	0.44
3/1	11:00	ESP ash	Darco Hg™ SI	6.3	0.32	12.8
3/2	13:30	ESP ash	Darco Hg™ SI	12.7	0.25	7.2
3/3	13:35	ESP ash	Darco Hg™ SI	4.2	0.27	8.5
3/4	13:30	ESP ash	Darco Hg™ SI	7.3	0.25	6.8
3/29	13:20	ESP ash	NH Carbon SI	4.2	0.182	7.97
3/30	13:20	ESP ash	NH Carbon SI	12.5	0.337	9.46
4/6	13:30	ESP ash	Super HOK SI	12.9	0.510	13.71
4/7	13:20	ESP ash	Super HOK SI	3.3	0.353	11.41

FGD Byproducts

During baseline (on 2/26/2004), a sample of FGD slurry was obtained and the liquor and solids were analyzed for mercury. The liquor had a concentration of 15 μg Hg/L, and the solid had a concentration 0.166 μg Hg/g. The limestone feed and pond water recycle were also measured for mercury content. The mercury concentration in the limestone feed was 0.02 μg Hg/g and in the recycled pond water was 1.17 μg Hg/L.

No scrubber samples were obtained during the parametric carbon injection tests because the test periods were too short for the scrubber to equilibrate.

3.1.3 Phase II of Parametric Testing - January 2005

A second round of parametric carbon injection tests were conducted because several additional sorbents were identified as having promise for controlling mercury emissions. There was inadequate time to test these newly identified sorbents prior to the long-term injection test. Instead, the second round of parametric tests was conducted at the conclusion of the long-term tests, in January 2005. The results of these additional parametric tests are described in this section. Figures B-12 through B-15 in the appendix show the SCEM measurements for each day of parametric testing.

The tested sorbents included a coarse-ground HOK, a brominated activated carbon (Darco Hg-LH™), a mixture of Darco Hg™ and Miller (PRB) ash, and Darco Hg™ for reference. For each carbon tested, a set of baseline mercury measurements with no injection was obtained at the beginning of each sorbent injection test day to provide a benchmark for the sorbent injection tests. Elemental mercury measurements were obtained at the beginning and at the end of each sorbent injection test day. As a result, there are elemental mercury data points that correspond with the baseline mercury measurements as well as the measurements associated with the final sorbent injection rate tested each day. Elemental mercury measurements were not obtained for every test condition because of the limited time frame in which to conduct each test.

Unit 1 Process Operations – January 2005 Parametric Tests

Unit 1 load was increased to its full-load set point of approximately 106 MW before each baseline and sorbent injection test period and held constant throughout each test. Flue gas temperatures at the air heater outlet (ESP inlet) A-side and ESP outlet, as measured by plant instrumentation, are shown in Figure 3-11. Flue gas temperatures at the ESP inlet and ESP outlet locations increased 40-50°F when Unit 1 load was increased from low load to full load. On the first three days of testing, the A-side ESP inlet temperature ranged from 260 to 275°F during the injection test period. Flue gas temperatures were about 10 to 15°F higher during the final two days (1/20/05 and 1/21/05) of full-load sorbent injection test periods compared to the earlier in the week. This can most likely be attributed to the considerably warmer weather experienced in the latter part of the testing period. A 30 to 35°F decrease in temperature was observed from the ESP inlet to the ESP outlet measurement location, presumably due to air in-leakage across the ESP and gas cooling in the approximately 50-foot run of duct between the outlet of the ESP and the outlet temperature measurement point.

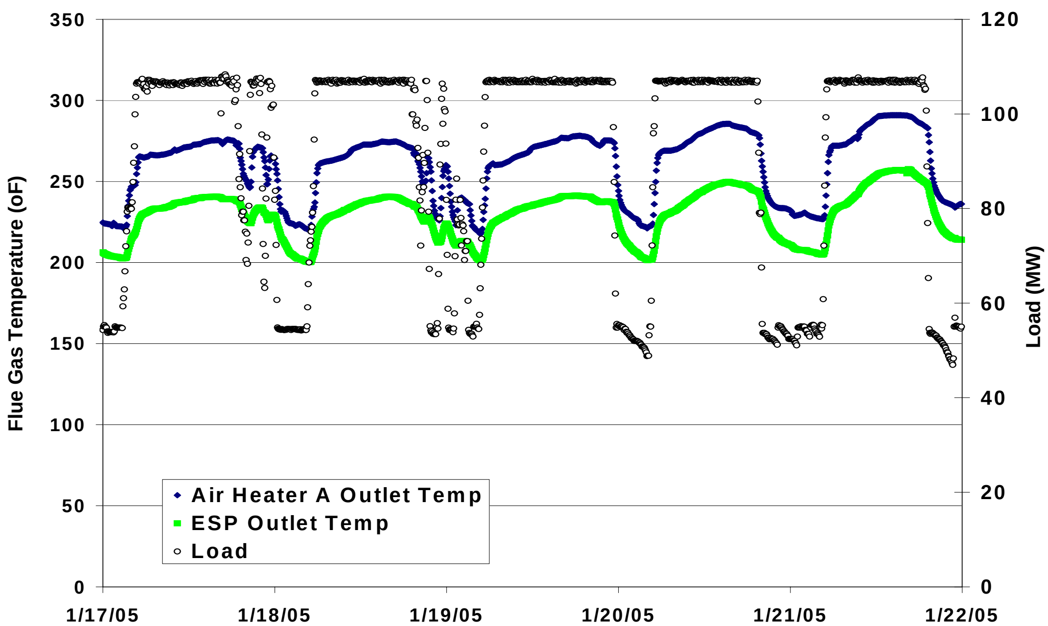

Figure 3-11. Unit 1 Air Heater Outlet and ESP Outlet Flue Gas Temperature During Baseline and Sorbent Injection Tests in January 2005

Mercury Speciation and Removal Data – January 2005 Parametric Tests

Sorbent Injection Tests – Coarse HOK Carbon

Table 3-9 provides a summary of the average total vapor-phase mercury concentration and mercury speciation data obtained for the Coarse HOK carbon injection test using the SCEM mercury analyzer.

Table 3-9. Average SCEM Mercury Measurements for Unit 1 During Baseline and Injection of Coarse HOK Carbon

Date	Injection Rate (lb/MMacf)	ESP Inlet, µg/Nm^3			ESP Outlet, µg/Nm^3			Stack, µg/Nm^3		
		Total	Hg^0	Percent Oxidized	Total	Hg^0	Percent Oxidized	Total	Hg^0	Percent Oxidized
1/18/05	0	8.6	4.9	43	4.2	2.14	50	2.8	2.2	24
	5.0	7.9	-	-	3.9	-	-	2.8	-	-
	6.9	8.5	-	-	3.7	-	-	2.7	-	-
	10.4	9.2	4.5	51	3.0	1.25	58	2.5	-	-
	13.9	10.7	-	-	2.7	-	-	-	-	-
	16.2	12.3	-	-	2.8	-	-	-	-	-

Note: All concentrations are in units of µg/Nm^3 and are normalized to 3% oxygen

Removal performance of the ESP, JBR FGD and combined ESP/JBR FGD controls for the various tests, calculated based on the average SCEM results from Table 3-9, are provided in Table 3-10. Baseline removal of total vapor-phase mercury across the ESP was 51 percent, which may be attributed to the high carbon content of the ash (13.9 percent LOI during the Coarse HOK carbon injection test period) generated by Unit 1. Removal of mercury across the ESP steadily increased to 77 percent at an injection rate of 16.2 lb/MMacf. This removal percentage includes the native removal of mercury across the ESP.

The baseline mercury removal value across the ESP/JBR FGD system was 67 percent. There appeared little change in the overall removal as injection rate increased. A slight increase in total mercury removal across the ESP/JBR FGD system was observed during the Coarse HOK activated carbon injection tests when compared to baseline. Incomplete total vapor-phase mercury data from the stack prevented calculation of an overall system removal for the two highest sorbent injection rates. According to the acquired data, total mercury removal values were increasing and had reached 73 percent at a sorbent injection rate of 10.4 lb/MMacf. This removal percentage includes the native removal of mercury across the ESP and JBR scrubber.

Table 3-10. Summary of Measured Vapor-Phase Mercury Removals for the Unit 1 ESP and JBR FGD During Injection of Coarse HOK Carbon

Date	Injection Rate (lb/MMacf)	Removal Across ESP, %	Removal Across JBR FGD, %	Overall Removal Across ESP/JBR FGD, %
1/18/05	0	51	33	67
	5.0	51	29	65
	6.9	57	27	68
	10.4	68	16	73
	13.9	74	-	-
	16.2	77	-	-

Because the native mercury removal was quite high, the amount of mercury reduction attributed to solely the Coarse HOK carbon injection was estimated by calculating the percent reduction in average total vapor-phase mercury levels at the ESP outlet location compared to average baseline levels. For the Unit 1 ESP, a 6 to 25 percent reduction in total vapor-phase mercury concentrations at the ESP outlet (compared to baseline concentrations) was observed over the range of sorbent injection rates tested.

Sorbent Injection Tests – Darco Hg™ Carbon-Miller Ash Blend

Table 3-11 provides a summary of the average total vapor-phase mercury concentration and mercury speciation data obtained for the Darco Hg™ Carbon-Miller ash injection test using the SCEM mercury analyzer. The Darco Hg™ Carbon-Miller ash blend consisted of, by weight, 50% activated carbon and 50% Plant Miller PRB ash. This blend was tested to identify whether the PRB ash demonstrated a synergistic effect when combined with the activated carbon. An effective sorbent blend of ash and carbon would provide a significant reduction in sorbent cost.

The injection rate for the ash/sorbent blend is reported in terms of the lb/MMacf of actual carbon injected, which is half the total lb/MMacf of the blend. For example, if 10 lb/MMacf of the ash-sorbent blend were injected for a test, the plots and tables would list 5 lb/MMacf. This convention is used to make simplify comparisons to the case where 100% Darco Hg was injected.

Table 3-11. Average SCEM Mercury Measurements for Unit 1 During Baseline and Injection of Darco Hg™ Carbon-Miller Ash

Date	Injection Rate* (lb carbon/MMacf)	ESP Inlet, μg/Nm^3			ESP Outlet, μg/Nm^3			Stack, μg/Nm^3		
		Total	Hg^0	% Oxid.	Total	Hg^0	% Oxid.	Total	Hg^0	% Oxid.
1/19/05	0	9.5	4.0	57	3.8	1.6	59	1.8	1.7	9
	2.5	8.6	-	-	3.0	-	-	2.0	-	-
	3.5	9.0	-	-	2.8	-	-	1.9	-	-
	5.2	9.2	-	-	2.4	1.2	48	1.8	-	-

Note: All concentrations are in units of μg/Nm^3 and are normalized to 3% oxygen. Injection rate refers to the carbon-only portion of the injected blend.

* Sorbent injection rate is double the carbon injection rate because sorbent composed of 50 wt % carbon and 50 wt % ash.

Removal performance of the ESP, JBR FGD and combined ESP/JBR FGD controls for the various tests, calculated based on the average SCEM results from Table 3-11, are provided in Table 3-12. Baseline removal of total vapor-phase mercury across the ESP was 60 percent.

Removal of mercury across the ESP increased to 74 percent at an injection rate of 5.2 lb/MMacf of carbon.

The baseline mercury removal across the ESP/JBR FGD system was 81 percent. There appeared to be no significant change in overall removal as a function of injection rate. For the Unit 1 ESP, a 21 to 38 percent reduction in total vapor-phase mercury concentrations at the ESP outlet (compared to baseline concentrations) was observed over the range of sorbent injection rates tested.

Table 3-12. Summary of Measured Vapor-Phase Mercury Removals for the Unit 1 ESP and JBR FGD During Injection of Darco Hg™ Carbon-Miller Ash

Date	Injection Rate* (lb carbon/MMacf)	Removal Across ESP, %	Removal Across JBR FGD, %	Overall Removal Across ESP/JBR FGD, %
1/19/05	0	60	52	81
	2.5	65	35	77
	3.5	69	30	78
	5.2	74	22	80

* Sorbent injection rate is double the carbon injection rate because sorbent composed of 50 wt % carbon and 50 wt % ash.

<u>Sorbent Injection Tests – Darco Hg-LH™ Carbon</u>

Table 3-13 provides a summary of the average total vapor-phase mercury concentration and mercury speciation data obtained for the Darco Hg-LH™ carbon injection test using the SCEM mercury analyzer.

Table 3-13. Average SCEM Mercury Measurements for Unit 1 During Baseline and Injection of Darco Hg-LH™ Carbon

Date	Injection Rate (lb/MMacf)	ESP Inlet, μg/Nm^3			ESP Outlet, μg/Nm^3			Stack, μg/Nm^3		
		Total	Hg^0	Percent Oxidized	Total	Hg^0	Percent Oxidized	Total	Hg^0	Percent Oxidized
1/20/05	0	11.1	5.1	54	5.0	1.8	64	2.8	2.5	8
	2.4	9.9	4.4	56	3.1	1.0	67	2.8	2.1	24
	5.0	9.7	-	-	2.7	-	-	2.5	-	-
	6.9	10.7	-	-	2.3	-	-	2.4	-	-
	10.4	9.8	-	-	1.8	-	-	1.9	-	-
	11.7	11.3	-	-	2.1	-	-	2.2	-	-

Note: All concentrations are in units of μg/Nm^3 and are normalized to 3% oxygen

Removal performance of the ESP, JBR FGD and combined ESP/JBR FGD controls for the various tests, calculated based on the average SCEM results from Table 3-13, are provided in

Table 3-14. Baseline removal of total vapor-phase mercury across the ESP was 55 percent. Removal of mercury across the ESP appeared to plateau at 82 percent at an injection rate of 10.4 lb/MMacf.

Table 3-14. Summary of Measured Vapor-Phase Mercury Removals for the Unit 1 ESP and JBR FGD During Injection of Darco Hg-LH™ Carbon

Date	Injection Rate (lb/MMacf)	Removal Across ESP, %	Removal Across JBR FGD, %	Overall Removal Across ESP/JBR FGD, %
1/20/05	0	55	44	75
	2.4	68	10	72
	5.0	72	6	74
	6.9	79	-4	78
	10.4	82	-4	81
	11.7	82	-8	80

The baseline mercury removal value across the ESP/JBR FGD system was 75 percent. A slight increase in total mercury removal across the ESP/JBR FGD system was observed during the Darco Hg-LH™ carbon injection tests when compared to baseline. According to the acquired data, total mercury removal value across the ESP/JBR reached a plateau at 81 percent at a sorbent injection rate of 10.4 lb/MMacf. This removal percentage includes the native removal of mercury across the ESP. For the Unit 1 ESP, a 37 to 64 percent reduction in total vapor-phase mercury concentrations at the ESP outlet (compared to baseline concentrations) was observed over the range of sorbent injection rates tested.

Sorbent Injection Tests – Darco Hg™ Carbon

Table 3-15 provides a summary of the average total vapor-phase mercury concentration and mercury speciation data obtained for the Darco Hg™ carbon injection test using the SCEM mercury analyzer.

Table 3-15. Average SCEM Mercury Measurements for Unit 1 During Baseline and Injection of Darco Hg™ Carbon

Date	Injection Rate (lb/MMacf)	ESP Inlet, μg/Nm^3			ESP Outlet, μg/Nm^3			Stack, μg/Nm^3		
		Total	Hg^0	Percent Oxidized	Total	Hg^0	Percent Oxidized	Total	Hg^0	Percent Oxidized
1/21/05	0	10.8	-	-	6.4	1.8	72	2.2	-	-
	2.4	10.7	-	-	4.4	-	-	1.5	-	-
	5.2	11.8	-	-	3.6	-	-	1.7	-	-

Note: All concentrations are in units of μg/Nm^3 and are normalized to 3% oxygen

Removal performance of the ESP, JBR FGD and combined ESP/JBR FGD controls for the various tests, calculated based on the average SCEM results from Table 3-15, are provided in Table 3-16. Baseline removal of total vapor-phase mercury across the ESP was 40 percent. Removal of mercury across the ESP increased to 69 percent at an injection rate of 5.2 lb/MMacf.

Table 3-16. Summary of Measured Vapor-Phase Mercury Removals for the Unit 1 ESP and JBR FGD During Injection of Darco Hg™ Carbon

Date	Injection Rate (lb/MMacf)	Removal Across ESP, %	Removal Across JBR FGD, %	Overall Removal Across ESP/JBR FGD, %
1/21/05	0	40	66	80
	2.4	59	65	86
	5.2	69	53	85

The baseline mercury removal value across the ESP/JBR FGD system was 80 percent. A slight increase in total mercury removal across the ESP/JBR FGD system was observed during the Darco Hg™ carbon injection tests when compared to baseline. According to the acquired data, vapor-phase mercury removal across the ESP/JBR system reached a plateau of 86 percent at a sorbent injection rate of 2.4 lb/MMacf. For the Unit 1 ESP, a 32 to 43 percent reduction in total vapor-phase mercury concentrations at the ESP outlet (compared to baseline concentrations) was observed over the range of sorbent injection rates tested.

Comparison of Sorbent Performance

Figures 3-12 through 3-14 are composites of data presented earlier in this report. Figures 3-12 and 3-13 show the percent mercury removal across the ESP and ESP/JBR combination, respectively. The vapor-phase mercury removals for Darco Hg™, Darco Hg-LH™, and the Darco Hg™ Carbon-Miller ash were within ±10% of each other over the range of injection rates, which may be within the variability of process conditions and the measurement uncertainty. Figure 3-14 shows the percent reduction of mercury at the ESP outlet.

Figure 3-15 shows the percent mercury removal across the ESP for all of the Darco Hg™ sorbents tested on Unit 1. This plot combines the performance of the Darco Hg sorbent tested in March 2004 and January 2005, along with the Darco Hg-Miller ash blend and the brominated Darco Hg-LH. The Darco Hg™ tested in January 2005 showed significantly better performance when compared to the Darco Hg™ tested in March 2004. At an injection rate of approximately 5 lb/MMacf, the Darco Hg™ tested in March 2004 provided a mercury removal of 58%, whereas the Darco Hg™ tested in January 2005 provided a mercury removal of 69% at the same injection rate. The high mercury removal during January 2005 may be partly attributed to the relatively lower ESP inlet temperatures experienced during that injection testing period. During the January 2005 testing, the AHO temperature ranged from 275 to 290 ºF; whereas, during the March 2004 testing the AHO temperature ranged from 303 to 306 ºF. During the January 2005 tests, the Darco Hg and Darco Hg-LH appeared to perform similarly over the range of rates tested, indicating that a halogenated carbon may not provide improved mercury removal.

Figure 3-16 shows the percent mercury removal across the ESP for the two HOK sorbents tested on Unit 1. This plot combines the performance of the Super HOK carbon tested in March 2004 with that of the Coarse HOK carbon tested in January 2005. The Coarse HOK demonstrated a maximum mercury removal similar to that of the Super HOK.

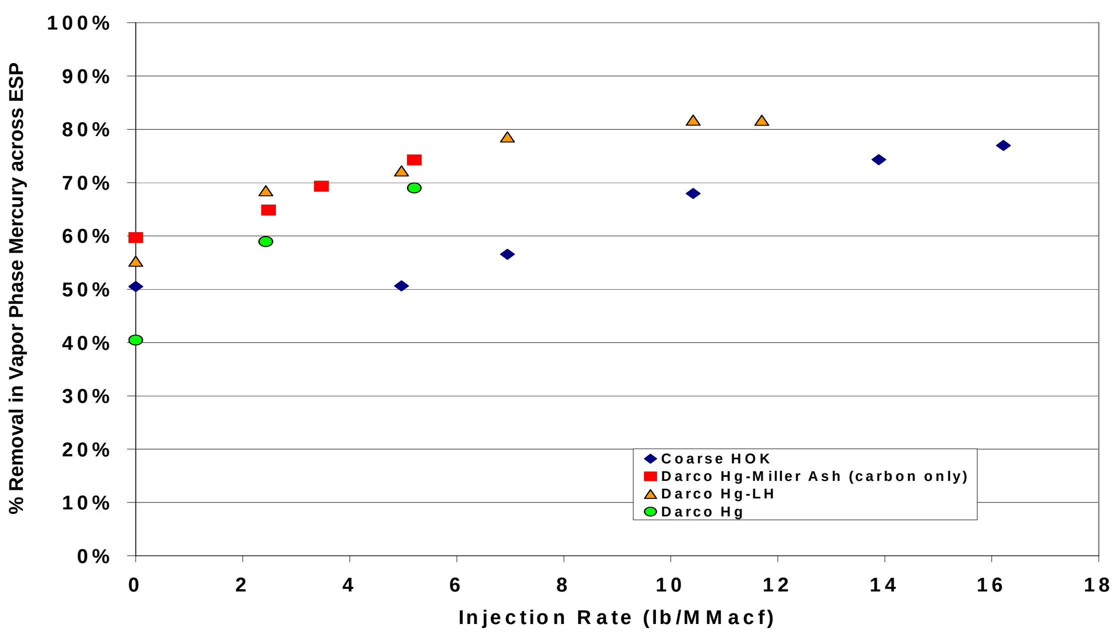

Figure 3-12. Percent Removal of Vapor-Phase Mercury Across the ESP for the Sorbents Tested on Unit 1 in January 2005

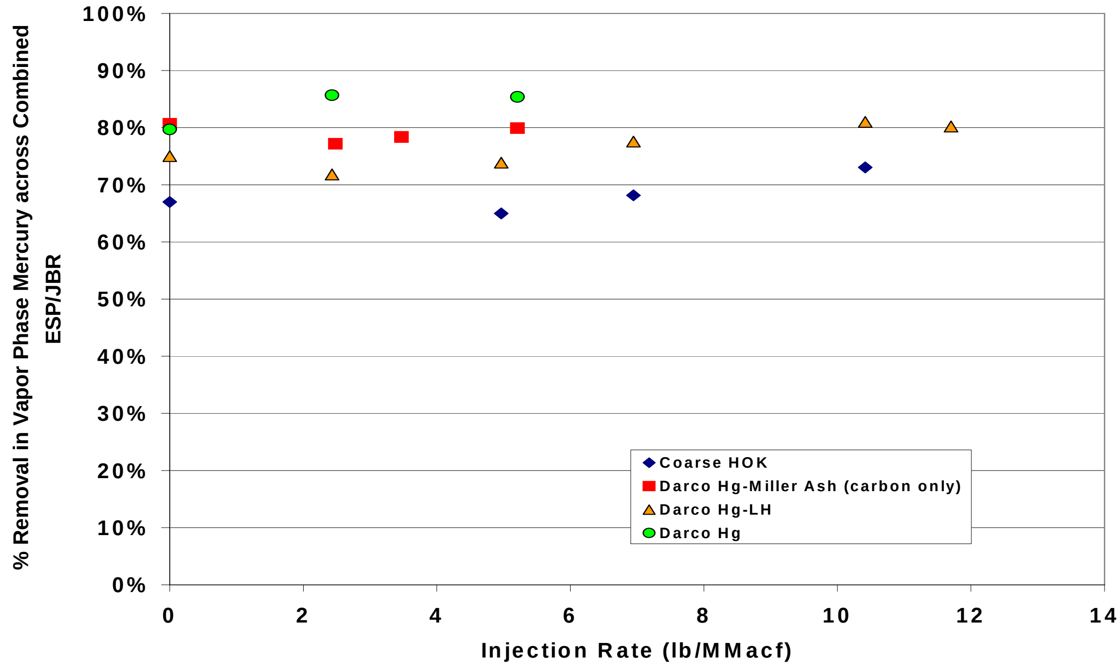

Figure 3-13. Percent Removal of Vapor-Phase Mercury Across the Combined ESP/JBR for the Sorbents Tested on Unit 1 in January 2005

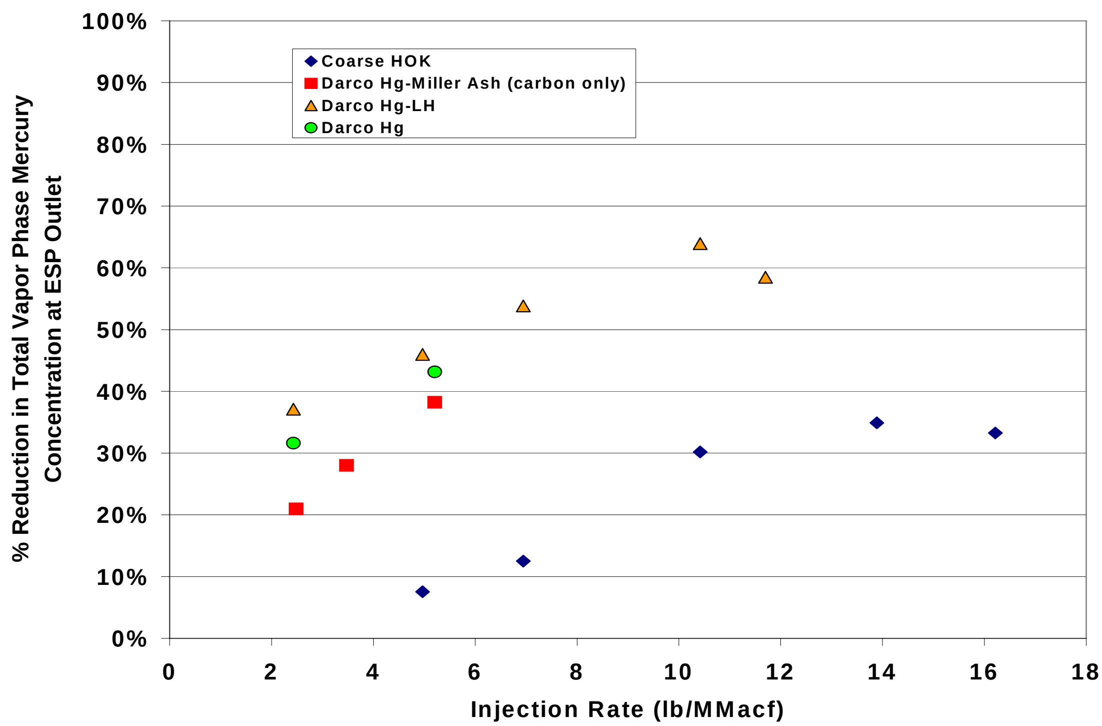

Figure 3-14. Percent Reduction of Total Vapor-Phase Mercury Concentration at the ESP Outlet Relative to Baseline for the Sorbents Tested on Unit 1 in January 2005

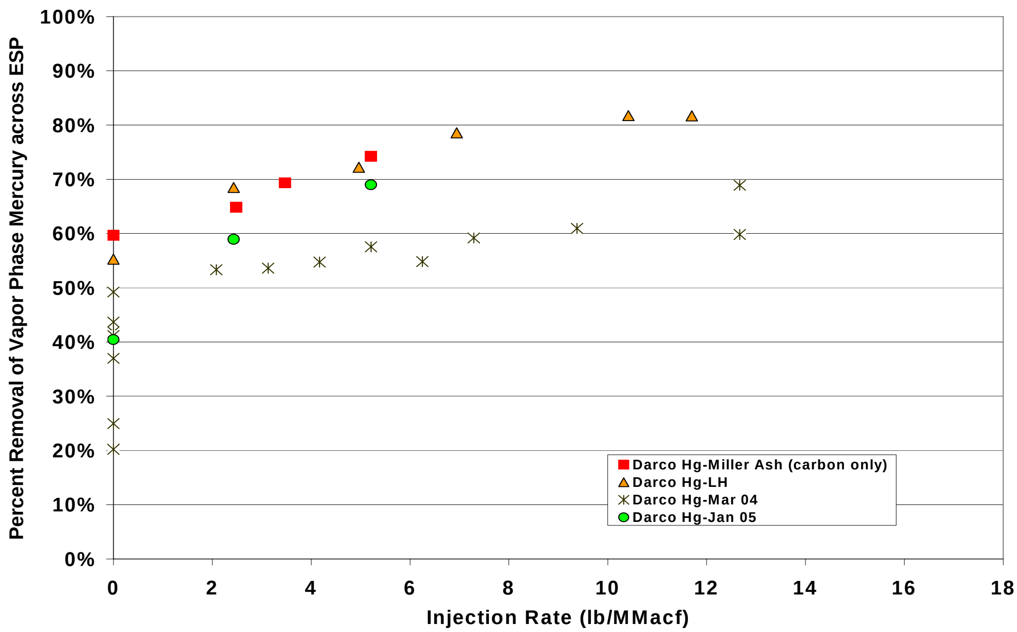

Figure 3-15. Percent Removal of Vapor Phase Mercury Across the ESP for all of the Darco Hg Sorbents Tested on Unit 1

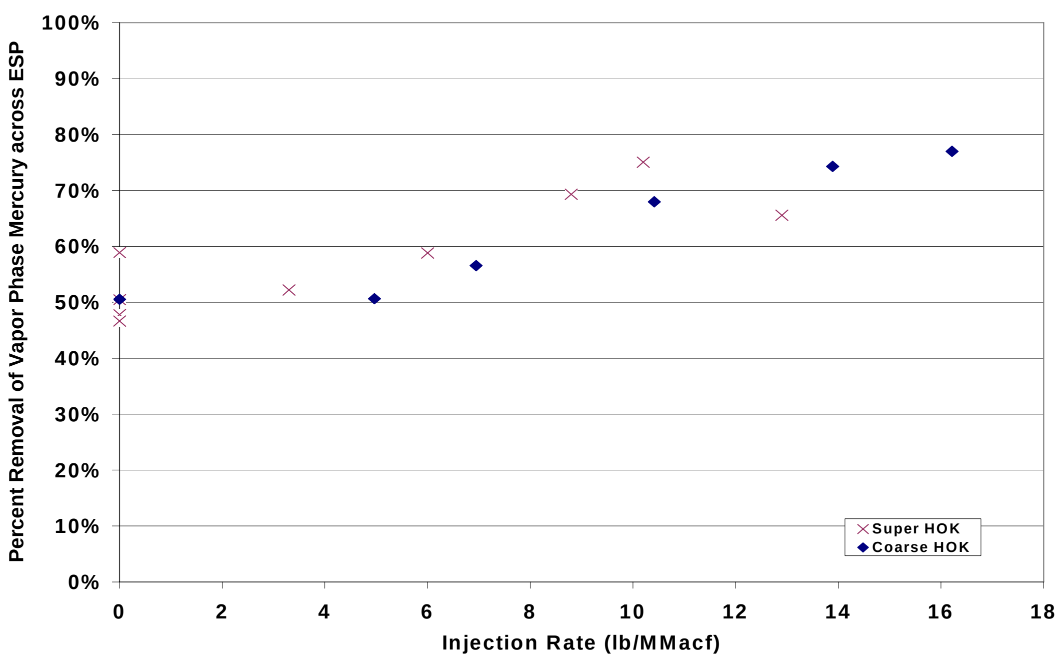

Figure 3-16. Percent Removal of Vapor Phase Mercury across the ESP for all of the HOK Sorbents Tested on Unit 1

Coal, Fly Ash, JBR FGD Byproducts, and Other Process Streams- January 2005

Coal

Table 3-17 shows the analytical results for the as-fired coal samples gathered during the January 2005 parametric tests. Composite samples of the Unit 1 coal were collected once daily upstream of the coal pulverizers and were analyzed in triplicate for mercury; an average of the triplicate analyses is reported in the table. Ultimate/proximate and chlorine analyses were performed on selected samples, and these results are also shown.

Table 3-17. Unit 1 – Coal Analyses for Baseline and ACI Parametric Tests

Date	**1/17/05**	**1/18/05**	**1/19/05**	**1/20/05**	**1/2l/05**
Sample Time (EST)	**17:00**	**10:33**	**n/a**	**14:30**	**10:00**
Test Condition [a]	**BL**	**HOK**	**Darco-Hg/Miller ash Blend**	**Darco Hg-LH**	**Darco Hg**
Proximate, wt % as received					
Moisture	8.75	6.49		5.47	
Ash	13.08	12.04		12.50	
Volatile Matter				32.12	
Fixed Carbon				49.91	
Ultimate, wt % as received					
Carbon				68.85	
Hydrogen				4.47	
Nitrogen				1.54	
Sulfur	1.07	1.39		1.47	
Oxygen				5.70	
Heating Value (Btu/lb, as received)	11790	12293		12330	
Mercury (μg/g, dry)	0.077	0.137	0.090	0.130	0.099
Mercury (lb/trillion Btu)	6.5	11.2		10.6	
Chlorine (mg/kg, dry)	290			272	

Fly Ash

Table 3-18 shows the results for mercury and LOI analyses of the ESP fly ash samples. Composite fly ash samples were obtained during the baseline characterization and sorbent injection test periods. The carbon content of the ESP fly ashes, as measured by percent LOI, were very similar during the injection testing, but there was no ESP ash collected during the baseline to compare to the injection test results.

Table 3-18. Unit 1 – ESP Fly Ash Analyses for Sorbent Injection Tests

Date	Time (EST)	Sample Type	Test Condition	Injection Rate (lb/MMacf)	Mercury (μg/g)	LOI (%)
1/18/05	~12:30	ESP Ash	Coarse HOK	5.0	0.64	13.9
1/19/05	~12:30	ESP Ash	Darco Hg™-Miller	5.0	0.54	12.2
1/20/05	~12:30	ESP Ash	Darco Hg™-LH	5.0	0.62	12.0
1/21/05	~12:30	ESP Ash	Darco Hg™	2.4	0.77	11.6

Method 26 Flue Gas Measurement Results from January 2005 Parametric Tests

Method 26 measurements were performed during the initial baseline test period as well as during the Darco Hg-LH™ carbon injection test period. Measured flue gas concentrations of HCl and Cl_2, HBr and Br_2, and HF at the ESP outlet are summarized in Table 3-19 and Table 3-20. During the Darco Hg-LH™ injection, there was a significant increase in the level of HBr in the flue gas downstream of the injection point relative to baseline. Since Darco Hg-LH™ is a brominated carbon, this suggests that a portion of the bromine associated with the carbon desorbed during injection. Furthermore, these data imply that the amount of bromine desorbed into the flue gas is related to the injection rate of the brominated carbon. Injection of the brominated carbon resulted in a five-fold increase in the amount of HBr in the flue gas. For a 100 MW unit, 1 ppm of HBr in the flue gas is equivalent to 10 ton/yr of HBr emissions. Units equipped with scrubbers would most likely remove the flue gas HBr.

Table 3-19. Unit 1 – Method 26A Data at ESP Outlet for Baseline Characterization Tests

Injection Rate (lb/hr)	HCl (ppmv)	Cl_2 (ppmv)	HBr (ppmv)	Br_2 (ppmv)	HF (ppmv)
Baseline	25.71	<0.08	0.18	<0.36	12.73

* All concentrations corrected to 3% O_2

Table 3-20. Unit 1 – Method 26A Data at ESP Outlet for Darco Hg-LH Characterization Tests

Injection Rate (lb/hr)	HCl (ppmv)	Cl_2 (ppmv)	HBr (ppmv)	Br_2 (ppmv)	HF (ppmv)
143	18.71	0.13	0.86	<0.39	13.31
200	17.95	0.40	1.20	<0.46	12.02

* All concentrations corrected to 3% O_2

3.2 Long-Term Carbon Injection Test Results

A month-long activated carbon injection test was conducted at Plant Yates Unit 1 with RWE Rheinbraun's Super HOK activated carbon. For the majority of the injection test, Unit 1 operated at a load set by grid demand. This load was typically 55 MW. During one week of the test, Unit 1 operated at full load (107 MW) during the 6 am – 6 pm time period, and operated at reduced load overnight.

Figure 3-17 shows the mercury concentrations measured at each of the SCEM locations, along with the carbon injection rate. The mercury concentrations are represented in μg/dry Nm^3 at 3% O_2. The carbon injection rate is in lb/Macf. The data are plotted as hourly averages (the SCEM generates data every 3 to 4 minutes). Figure 3-17 spans the entire month of the injection test as well as baseline data taken both prior and subsequent to the injection test.

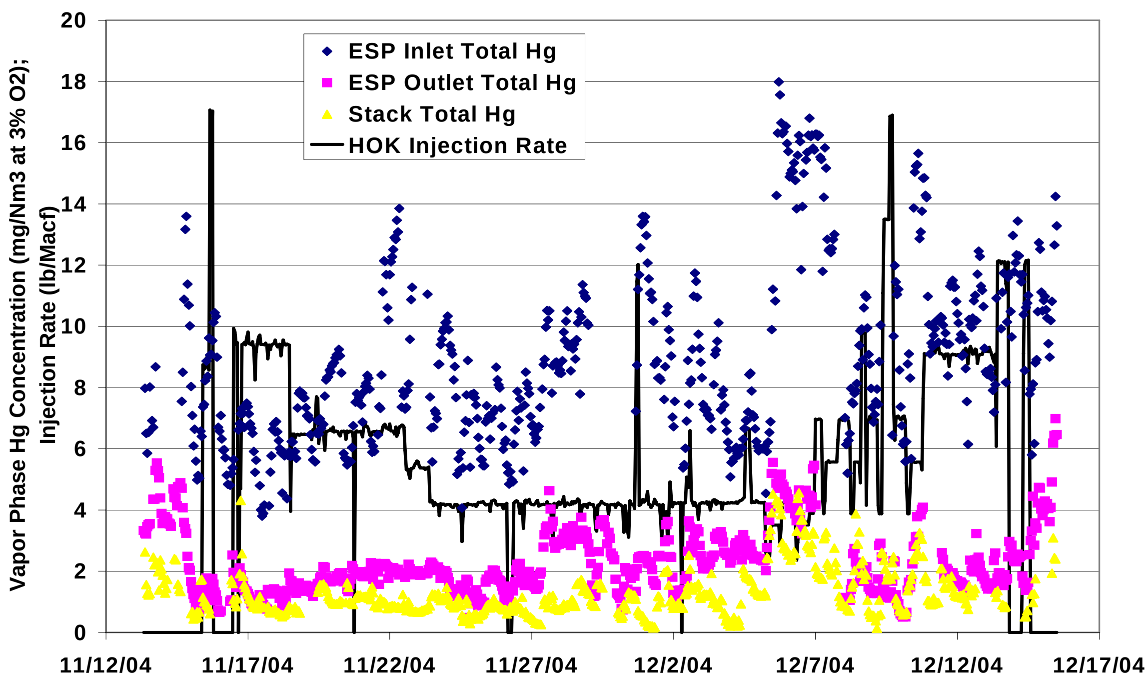

Figure 3-17. Vapor Phase Mercury Concentrations Measured at the ESP Inlet, ESP Outlet, and Stack During Long-Term Injection Test

Figure 3-18 shows the percent vapor phase mercury removals that were calculated from these data. Two removal values are charted: the vapor phase mercury removal across the ESP, and the vapor phase removal across the ESP/JBR scrubber system.

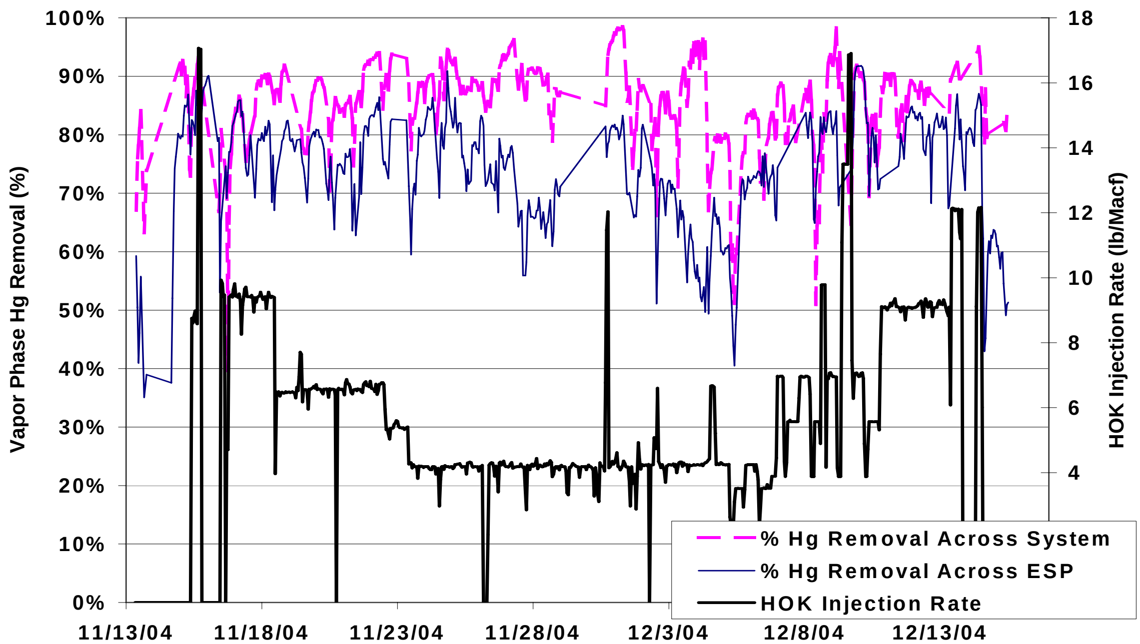

Figure 3-18. Vapor-Phase Mercury Removals Measured Across ESP and Across ESP/JBR System During Long-Term Test

Baseline mercury removal across the Unit 1 gas path was characterized before the start of the long-term injection test and again at the end of the test. Because the HOK carbon was injected downstream of the ESP inlet measurement location, the ESP inlet values were not affected by the carbon injection. The ESP inlet mercury concentration ranged from 5 - 13 $\mu g/Nm^3$ during baseline and injection testing, with 60-75% oxidation.

At the ESP outlet, the baseline vapor phase mercury concentration ranged from 3 - 7 $\mu g/Nm^3$, with 55-80% oxidation. At the stack, the baseline vapor phase mercury concentration ranged from 1.5 to 3 $\mu g/Nm^3$. Baseline removal across the ESP was nominally 50%, and baseline removal across the system (ESP+JBR scrubber) was 70-80%. The baseline mercury removal measured across the ESP is in agreement with results measured during the baseline testing in Spring 2004. The baseline removal across the system was higher during the Fall 2004 testing than during the Spring 2004 tests. The mercury oxidation levels at the both the ESP inlet and outlet were also higher, indicating a possible explanation for the higher overall removal.

The carbon feed rate was adjusted throughout the injection test, in order to investigate the effect on outlet mercury concentrations. The effective carbon feed rates varied somewhat throughout the test period because of these manual adjustments and because of load, flow, and temperature variations during the testing. Because the flue gas flow rate changes with load, the carbon injection rate (lb/hr) was adjusted to maintain a constant volumetric-based injection rate (lb/Macf).

During the month-long test period, there were a few periods each consisting of several hours where the carbon injection rate dropped to zero. The carbon feeding occasionally stopped because of mechanical or electrical problems that occurred with the feed skid during the night and were not fixed until staff arrived on-site the following morning. For other short periods, the carbon injection rate was raised to as high as 16 lb/Macf in order to evaluate the effect on the ESP outlet particulate emissions. Excluding these brief periods of zero- and high-injection rates, the carbon injection rate was typically between 4 and 10 lb/Macf during the long-term test period.

Table 3-21 shows the range of vapor phase mercury removals measured across the ESP and across the system. As seen in Table 3-21 and Figure 3-18, there was significant variability in the mercury removal performance achieved during the test. Mercury removal across the ESP ranged from 50 to 91%, with the majority of the data concentrated between 65 and 85%. The mercury removal across the ESP/JBR scrubber system ranged from 70 to 94%. From Table 3-21, it appears that increases in the carbon injection rate above 4.5 lb/Macf did not result in significant changes in the range of mercury removals measured.

Table 3-21. Range of Vapor Phase Mercury Removals Measured During Long-Term Injection Test

Injection Rate (lb/Macf)	Time Period	Range of Vapor Phase Hg Removals Measured across ESP (%)	Range of Vapor Phase Hg Removals Measured across System (%)
0	Pre and post long-term test	~50	70 - 80
4.5	11/23 17:00 – 12/5 5:00	50 – 91*	71 – 96
6.5	11/18 17:00 – 11/22 12:00	64 – 86	71 – 94
9.5	11/16 17:00 – 11/18 11:00; 12/11 0:00 – 12/13 4:00	67 – 86	75 – 92

* For the mercury removal across the ESP at an injection rate of 4.3 lb/Macf, 91 % removal was measured during one single hour; otherwise, the highest measured vapor phase mercury removal was 86%.

In Figure 3-19, the vapor phase mercury concentrations at the ESP outlet and the stack are plotted in lb Hg/trillion Btu. As seen in this plot, with no carbon injection, the ESP outlet concentration was between 2 and 3.5 lb/trillion Btu, while the stack mercury concentration was between 0.7 and 1.7 lb/trillion Btu. With carbon injection, the ESP outlet mercury concentration ranged from 0.5 to 3.6 lb/trillion Btu. Figure 3-20 shows the vapor phase mercury concentrations in units of 10^{-6} lb/MWh.

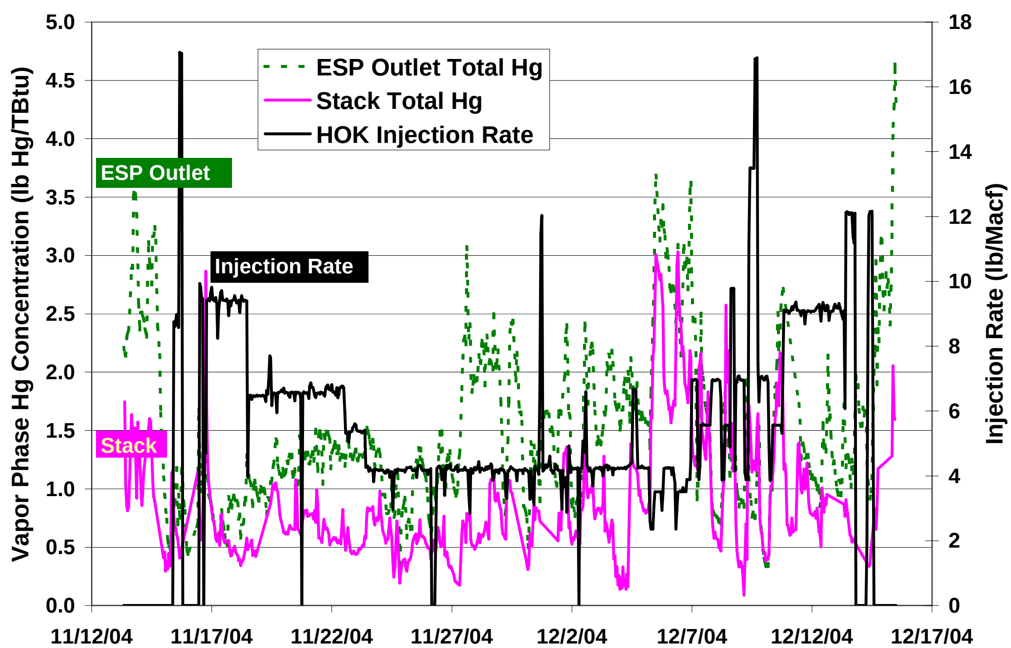

Figure 3-19. ESP Outlet and Stack Mercury Emissions in lb/trillion Btu

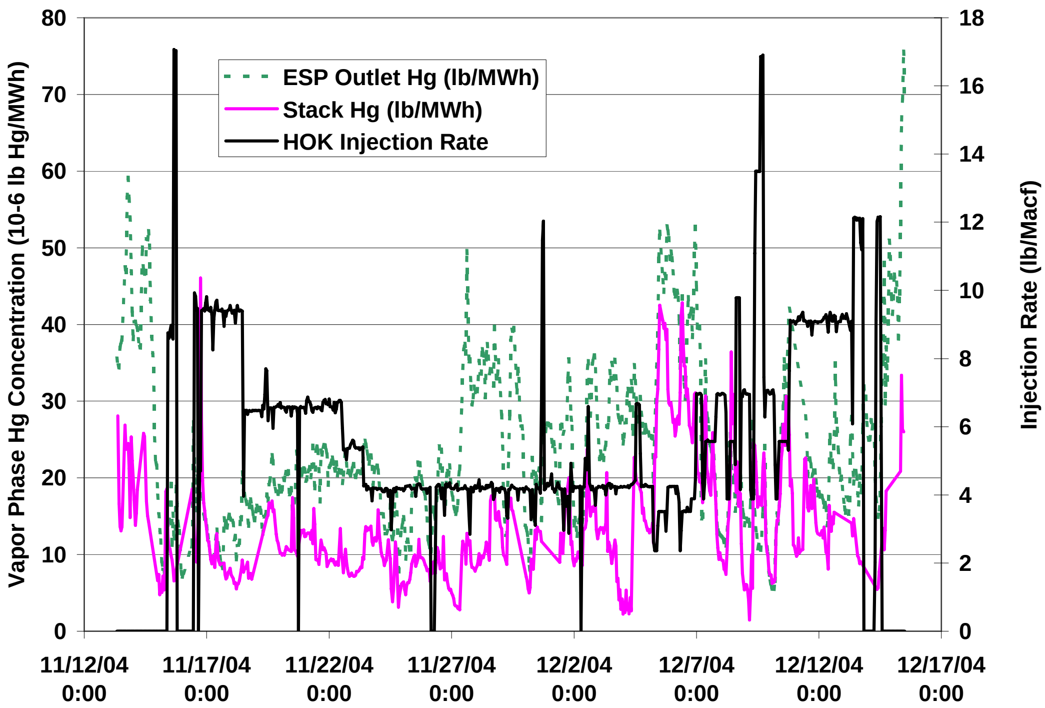

Figure 3-20. ESP Outlet and Stack Mercury Emissions in 10^{-6} lb Hg/MWh

Effect of Load on Mercury Removal

The effect of high versus low load on mercury removal performance was evaluated. Low load was defined as an hourly average load less than 60 MW, while high load was defined as an hourly average load greater than 95 MW. The hourly mercury removal data from the month-long injection test were sorted by injection rate and average load. Appendix A describes the mathematical approach for how the average mercury removal for each injection rate/load condition was determined.

Figure 3-21 shows the removal of vapor phase mercury across the ESP by the Super HOK activated carbon. It compares the low load and high load data from the long-term tests to the Spring 2004 parametric tests. The Spring 2004 tests were conducted at full load. The error bars on Figure 3-21 represent ± one standard deviation. The error bars for the lower injection rates are larger than the error bars at the higher injection rates; however, significantly more data were collected at the lower injection rates. Higher removal across the ESP was achieved during the long-term tests as compared to the parametric tests.

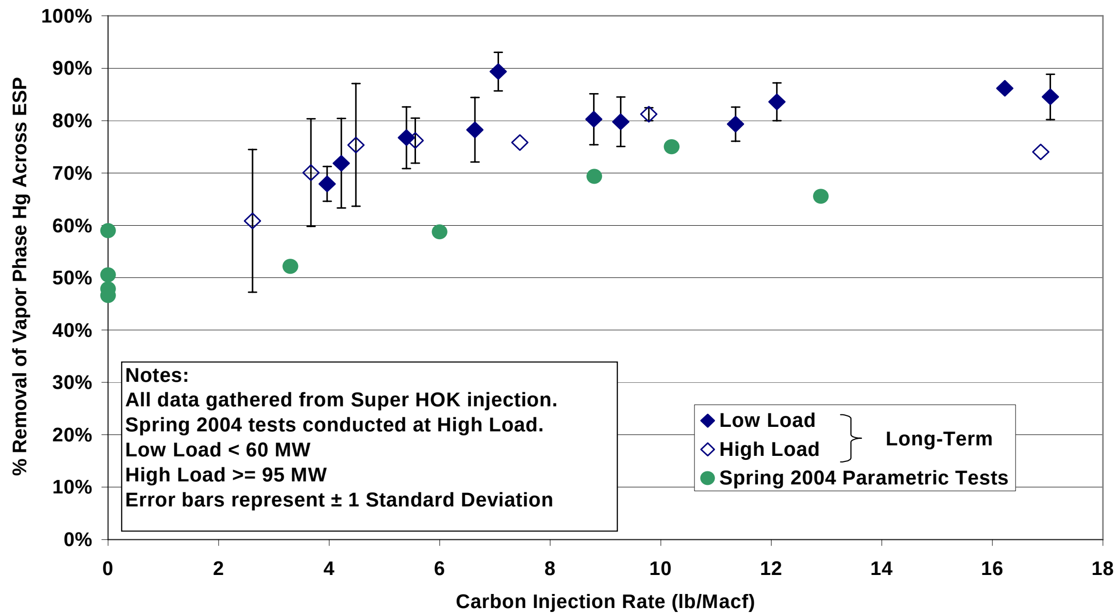

Figure 3-21. Comparison of Vapor-Phase Mercury Removal by Super HOK Across ESP for Parametric and Long-Term Injection Tests

From the long-term test data in Figure 3-21, it appears that operation at high load versus low load does not affect the mercury removal across the ESP. In Figure 3-22, the mercury removal across the ESP/JBR system is compared to the carbon injection rate at high and low loads. In this case, the system mercury removal is consistently lower at the high load condition.

Figure 3-23 is provided in order to compare the ESP removal to the system removal for the two load conditions. The long-term data from Figures 3-21 and 3-22 are combined to make this plot. At the low load condition, there is a significant increase in the overall system removal as compared to the ESP removal. However, for the high load condition, the overall system removal is either equal to or only slightly greater than the ESP removal, indicating little overall mercury removal by the scrubber at high load. Figure 3-24 shows that at high load the mercury removal across the JBR is less than 20%. There are three data points at high load and injection rates > 10 lb/Macf that appear to indicate negative removal of total mercury across the JBR scrubber. These three points were gathered on the same day. It is possible that there is some system performance or measurement bias for that day, so these data should not be given significant consideration in comparison to the rest of the data. The JBR performance data at high load appear to correlate very well with the Spring 2004 parametric test data, excluding the three data points at the highest injection rates.

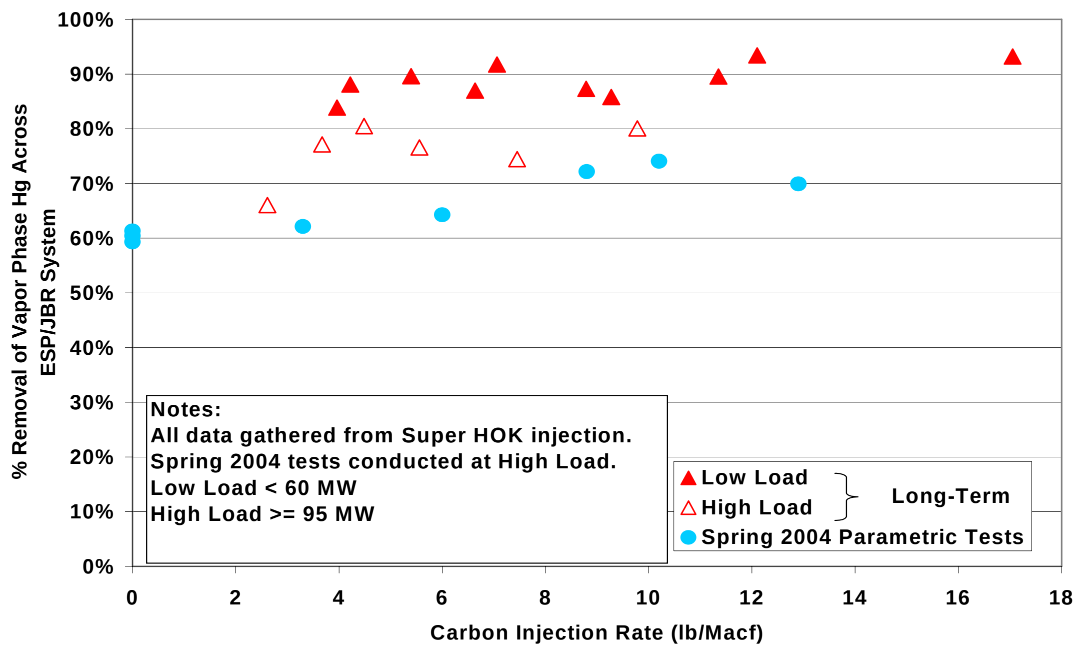

Figure 3-22. Comparison of Vapor-Phase Mercury Removal by Super HOK Across ESP/JBR System for Parametric and Long-Term Injection Tests

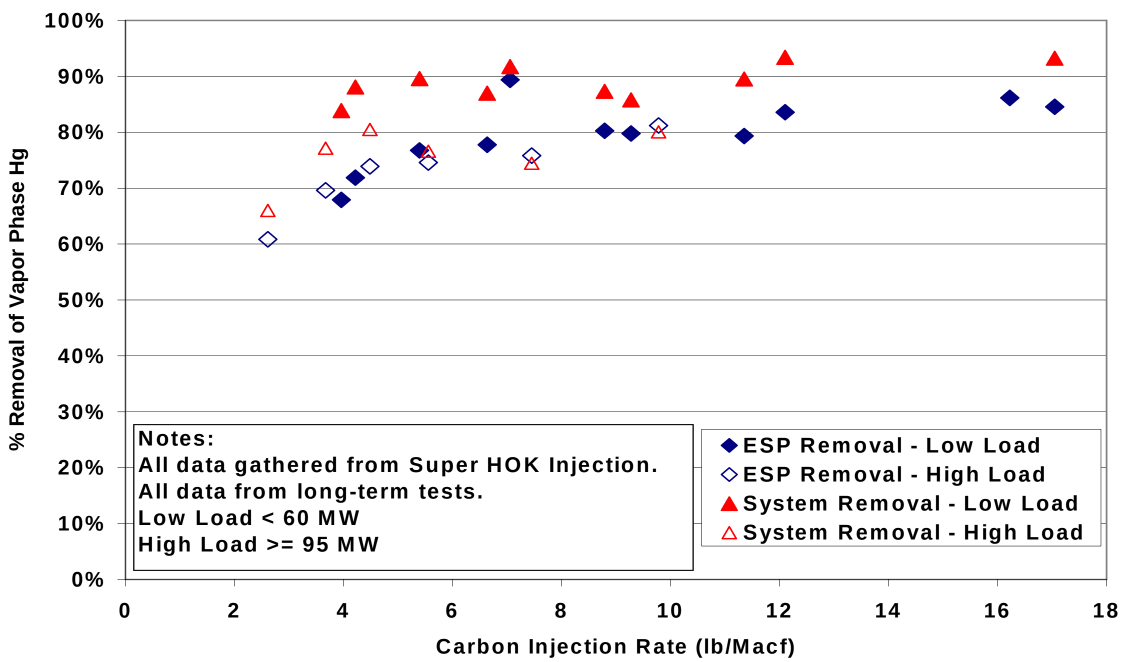

Figure 3-23. Comparison of Vapor-Phase Mercury Removal by Super HOK Across ESP and Across ESP/JBR System

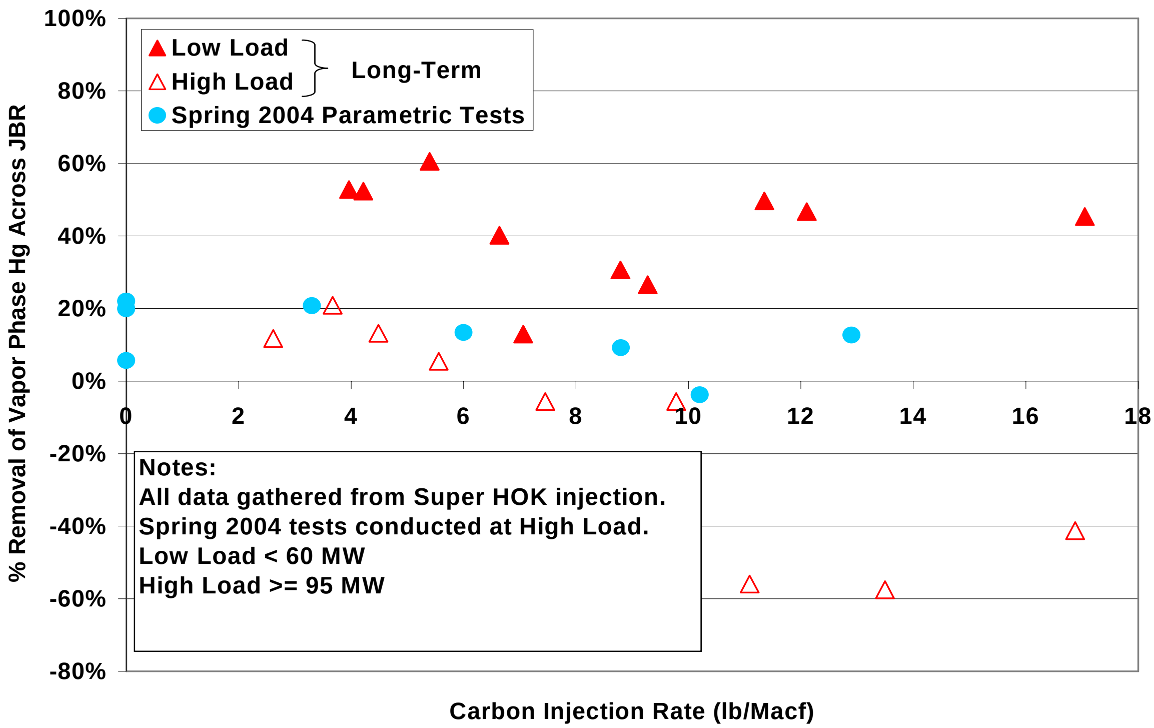

Figure 3-24. Vapor-Phase Mercury Present as Oxidized Mercury at ESP Inlet and Outlet

The total mercury removal by the scrubber is affected by two main components: (1) the removal of soluble oxidized mercury by the scrubber and (2) the possibility of re-emissions of elemental mercury. Therefore, the effect of load on system mercury removal may be related to the following parameters: variations with load in scrubber efficiency for removal of oxidized mercury, changes in the oxidation state of mercury in the inlet scrubber gas, and scrubber re-emissions. These three parameters were evaluated, as discussed below.

When the SO_2 removal efficiency was plotted against the load for the time period of the long-term test, a marked decrease was observed in removal efficiency as load increased. A similar trend might be expected for other gas phase species such as oxidized mercury, thus inhibiting total mercury removal at high loads. However, it should be noted that the SO_2 removal efficiency was still at least 90% at the highest load condition. In contrast, the oxidized mercury removal ranged from 40 to 98% at low load, and 40 to 90% at high load.

The decrease in system removal at high load might be explained by a lower fraction of oxidized mercury at the JBR inlet during high load conditions. The oxidation state of the vapor phase mercury was plotted versus the injection rate and load condition, as shown in Figure 3-25. At the ESP outlet, the fraction of vapor phase mercury present as oxidized mercury is only slightly lower at high versus low load. The small decrease in oxidation state of the ESP outlet gas mercury from low to high load is not large enough to account for the marked decrease in total mercury removal across the scrubber at high load. However, there does not appear to be sufficient data to draw a general conclusion on the effect of load on ESP outlet oxidation.

It should be noted that the overall set of JBR-related mercury data does not point to either re-emissions or removal of elemental mercury by the scrubber. Figure 3-26 shows the hourly averages of the difference between the inlet and outlet elemental mercury concentrations across the scrubber. Positive values indicate elemental mercury removal while negative values indicate re-emissions. With no re-emissions, the difference should be equal zero. The average of the differences plotted in Figure 3-26 is 0.1±0.3 μg/Nm^3, which is within the detection limit of the sampling system.

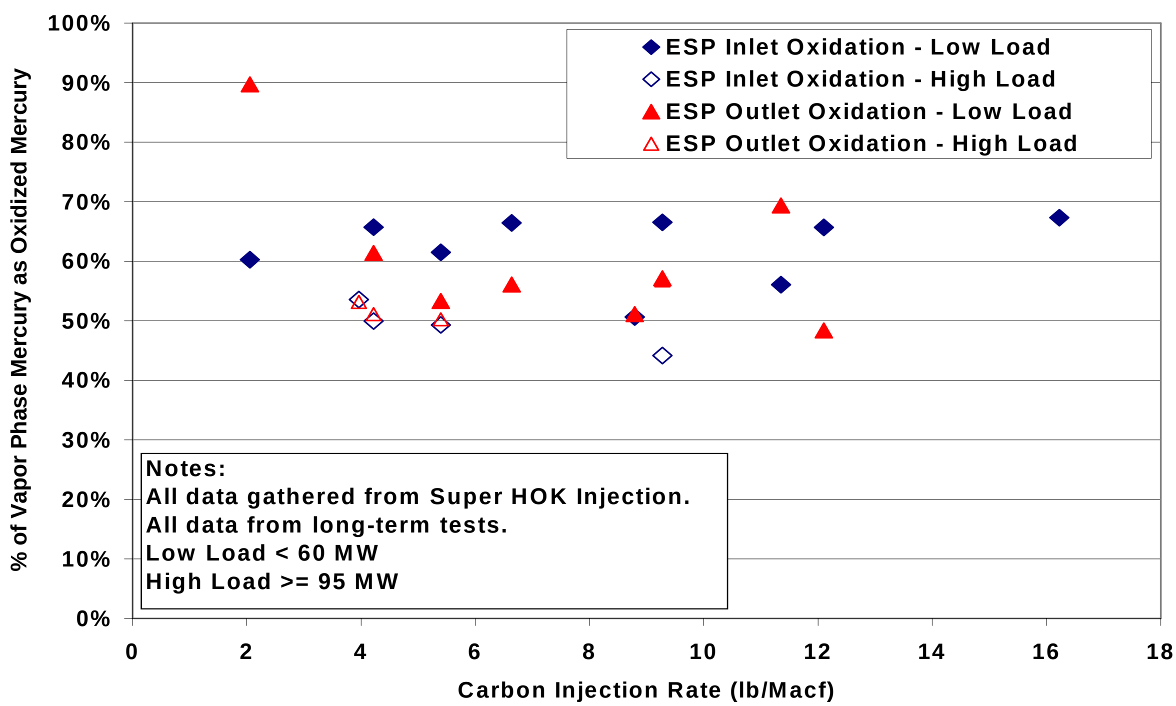

Figure 3-25. Vapor-Phase Mercury Removal Across the JBR at High and Low Load Conditions

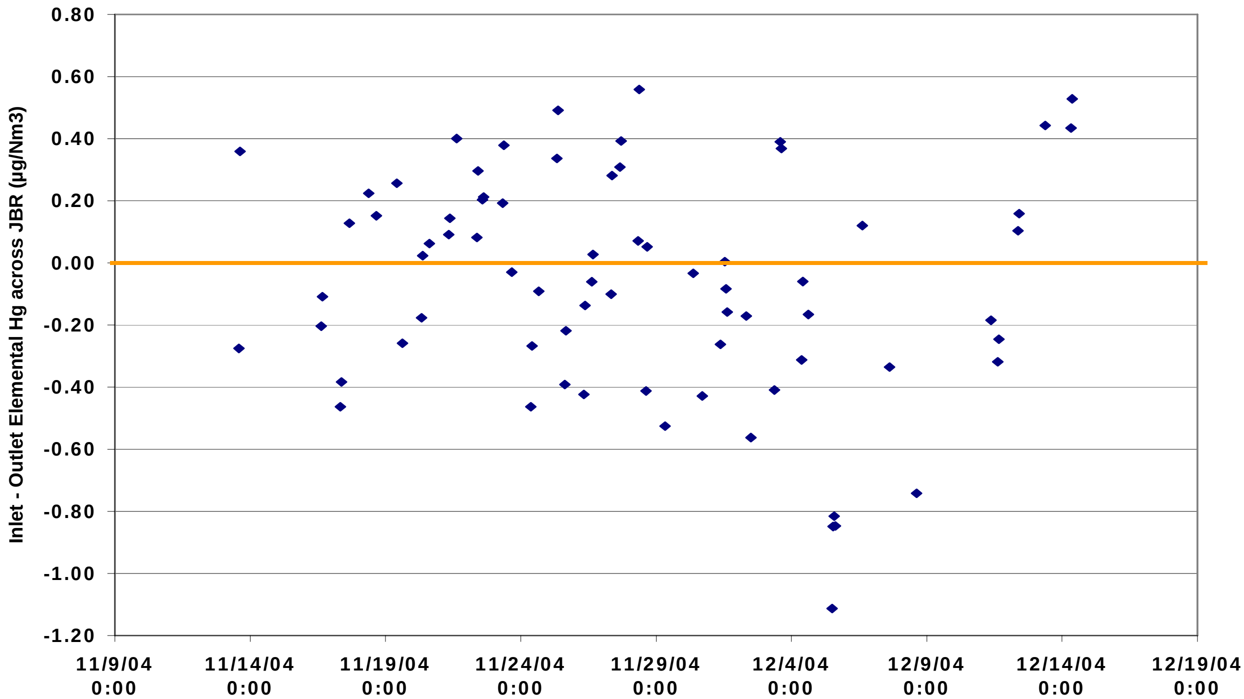

Figure 3-26. Difference Between JBR Inlet and Outlet Elemental Mercury Concentrations

More data are needed to draw a definitive conclusion about how an increase in load results in lower total mercury removal across the system.

Effect of Temperature on Mercury Removals Measured in Long-Term Test

In laboratory, fixed-bed tests, the adsorption capacity of activated carbon decreases with increasing temperature. In the full-scale application of ACI, the activated carbon does not reach equilibrium with the flue gas mercury; however, it is reasonable to expect the duct temperature to affect the reactivity of the carbon with the flue gas mercury.

The operating temperature of the ESP is a function of the unit load, as shown in Figure 3-27. Temperatures at high load are approximately 30°F higher than at low load. The A-side of the ESP inlet operates at approximately 30°F higher temperature than the B-side. The two sides combine in the ESP and have a common outlet, which is 40-50°F lower than the A side. Carbon injection occurs across both sides of the inlet to the ESP; however, mercury measurements are only made on the A-side of the inlet duct and the common outlet duct.

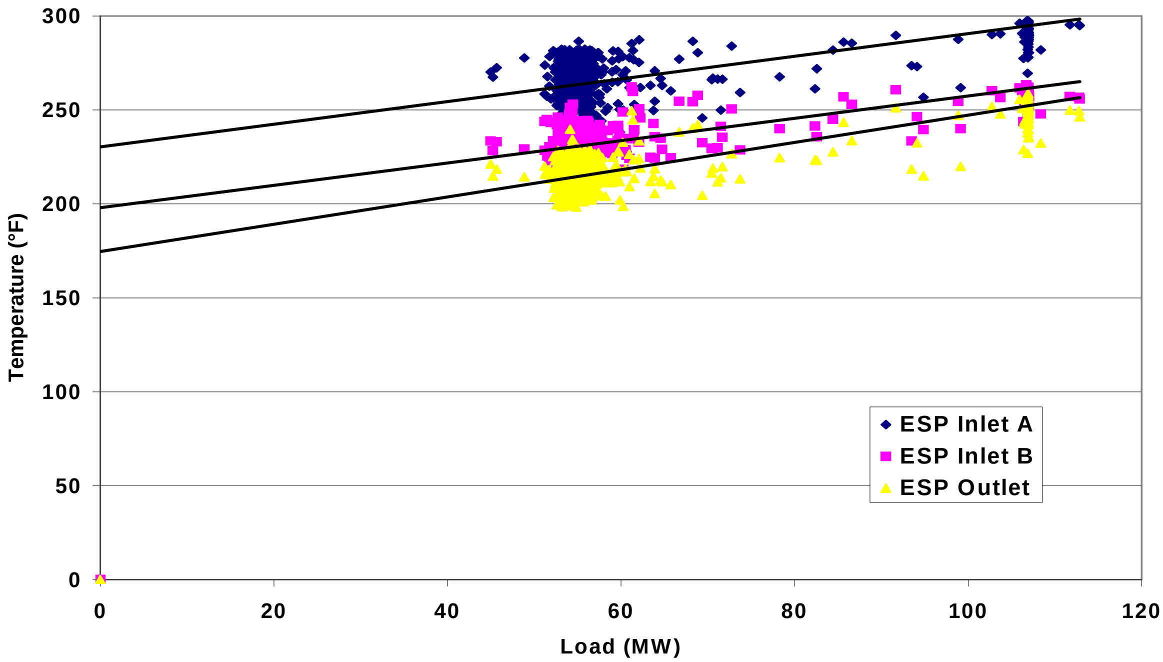

Figure 3-27. Effect of Unit Load on Unit 1 Duct Temperatures

Figure 3-28 shows the mercury removal across the ESP as a function of temperature, with the load and carbon injection rate identified for each point. Carbon injection rates (in lb/MMacf) are indicated by the different legend symbols. For the purposes of this analysis, high load was considered to be greater than 95 MW, while low load was between 50 and 60 MW. All data above 285°F are from the high load operating condition and are indicated by the dashed circle. This plot does not show a strong correlation between mercury removal and the ESP operating temperature.

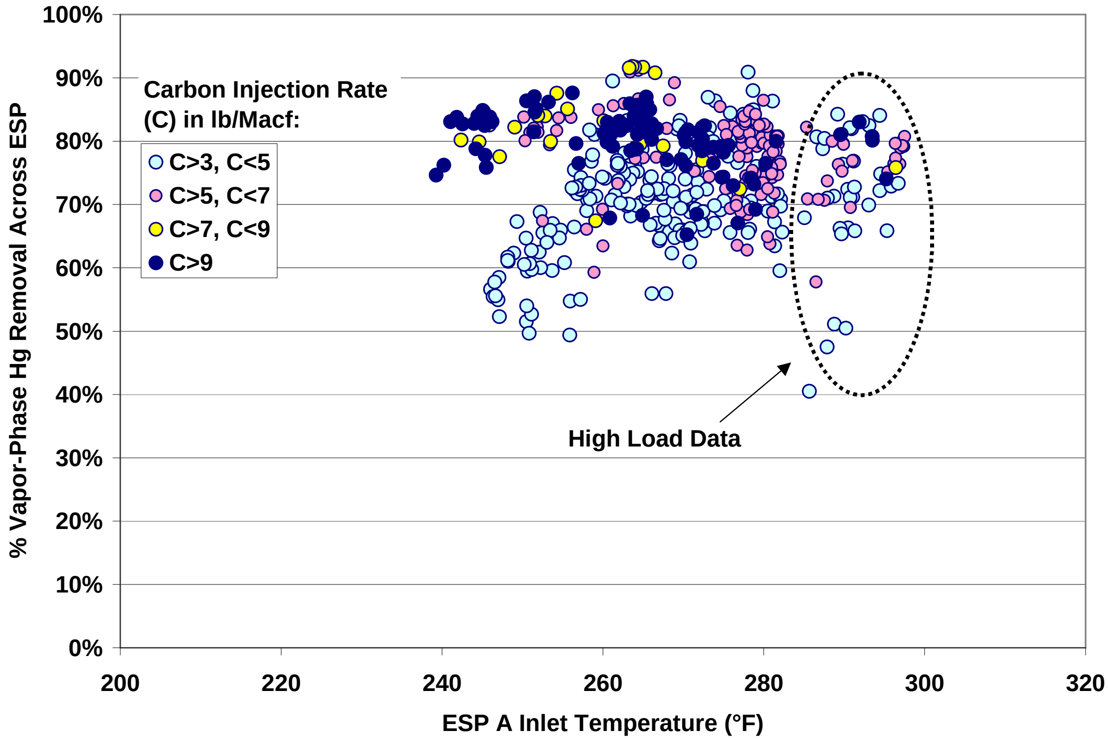

Figure 3-28. Effect of Temperature on Vapor-Phase Removal of Mercury Across the ESP

Collection and Analysis of Solids Samples

Coal, ash, and FGD byproduct samples were collected during the long-term injection test and analyzed. Table 3-22 shows the coal ultimate/proximate results, and Table 3-23 shows the mercury and chloride values measured for selected coal samples. The coal mercury concentrations were used to predict the flue gas mercury concentration (in $\mu g/Nm^3$) exiting the boiler, assuming that all coal mercury converted to vapor-phase mercury. Figure 3-29 compares the coal mercury predictions to the ESP inlet vapor phase mercury concentrations measured by the SCEM. There is good correlation between the two sets of values.

Table 3-22. Coal Ultimate/Proximate Results from Long-Term Test

Date	11/14/04	11/19/04	11/29/04	12/5/04	12/10/04
Sample Time	**12:50**	**8:40**	**8:00**	**NA**	**12:55**
Test Condition[a]					
Proximate, wt % as received [b]					
Moisture	5.27	4.44	5.93	5.16	6.28
Ash	11.05	10.73	11.11	10.93	11.65
Volatile Matter	38.83	32.10	32.36	31.55	31.64
Fixed Carbon	44.85	52.73	50.60	52.36	50.43
Sulfur	1.36	1.22	1.17	1.24	1.30
Ultimate, wt % as received					
Moisture	5.27	4.44	5.93	5.16	6.28
Carbon	70.13	70.4	68.56	69.80	68.30
Hydrogen	4.61	4.82	4.79	4.75	4.70
Nitrogen	1.53	1.52	1.45	1.47	1.44
Sulfur	1.36	1.22	1.17	1.24	1.30
Oxygen	6.05	6.87	6.99	6.65	6.33
Ash	11.05	10.73	11.11	10.93	11.65
Heating Value (Btu/lb, as received)	12609	12851	12535	12774	12385
Mercury (µg/g, dry)	0.097	0.068	0.090	0.101	0.180
Mercury (lb/trillion Btu input)	7.5	5.1	6.8	7.5	14.5

Table 3-23. Coal Hg and Cl Values for Selected Samples from Long-Term Test

Coal Sample Date	Coal Hg (ug/g)	Coal Cl (mg/kg)
11/3/2004	0.055	-
11/13/2004	0.099	-
11/14/2004	0.097	-
11/17/2004	0.078	112
11/19/2004	0.068	-
11/22/2004	0.037	-
11/24/2004	0.059	-
11/27/2004	0.091	-
11/29/2004	0.090	-
11/30/2004	0.054	119
12/5/2004	0.101	-
12/6/2004	0.068	-
12/8/2004	0.052	-
12/9/2004	0.046	-
12/10/2004	0.180	122
12/12/2004	0.103	-
12/15/2004	0.163	-

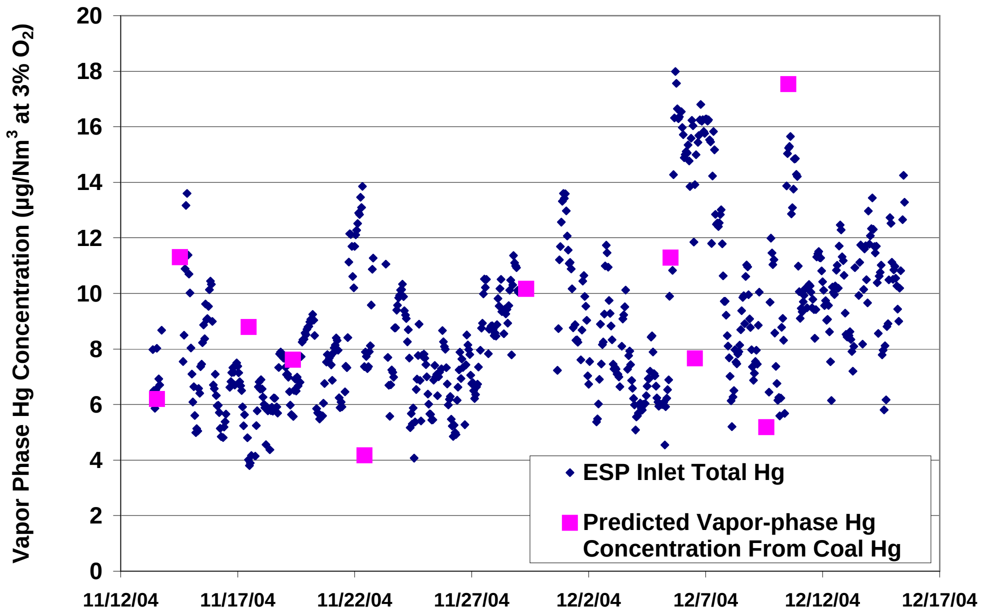

Figure 3-29. Comparison of Coal Hg Concentration to Measured ESP Inlet Vapor Phase Hg Concentration

Table 3-24 shows the ash mercury and LOI contents for selected samples. A diagram of ESP is shown in Figure 3-30. The ESP is equipped to allow sampling from hoppers 2, 3, 6, and 7. A composite sample was taken of hoppers 2 and 3, with 50% of the ash coming from each hopper. Likewise, a composite sample was taken of hoppers 6 and 7. In general, the mercury concentration of ash from Hoppers 6/7 was higher than Hopper 2/3. There does not appear to be a consistent trend in the relative LOI concentration between the two sets of hoppers.

On 12/1/04, separate samples were taken from each of the four hoppers. All four samples were analyzed to note differences in composition between hoppers 2 and 3 and between hoppers 6 and 7. The difference in mercury content between hoppers 2 and 3 is within the range of mercury concentrations measured throughout the test. A similar conclusion is drawn from the hopper 6 and 7 samples on 12/1/04.

Table 3-24. Ash Hg and LOI for Selected Samples from Long-Term Test

Sample ID	Hg (ug/g)		% LOI	
	Hopper 2/3	Hopper 6/7	Hopper 2/3	Hopper 6/7
11/15/2004	0.44	0.66	10.1	9.7
11/19/2004	0.57	0.57	13.5	12.1
11/29/2004	0.35	0.74	5.3	6.4
12/1/04, Hopper 2	0.26		6.1	
12/1/04, Hopper 3	0.36		9.9	
12/1/04, Hopper 6		0.53		8.8
12/1/04, Hopper 7		0.60		14.1
12/6/2004	0.43	0.70	11.2	14.2
12/10/2004	0.29		17.4	
12/13/2004	0.64	0.54	12.5	18.3

Table 3-25 shows the mercury concentrations of the FGD liquors and FGD solids sampled during the long-term test. The FGD liquor mercury concentration showed variability and ranged from 2.4 µg/L to 31 µg/L during the long-term injection test. The FGD liquor from parametric baseline (2/26/2004) testing had a mercury concentration of 15 µg/L and the mercury concentration of the liquor from the baseline day (11/14/2004) just prior to the long-term test was 13.6 µg/L. The FGD solids mercury concentration ranged from 0.125 to 2.2 µg/g. The baseline values measured were 0.166 µg/g (2/26/2004) and 0.37µg/g (11/14/2004).

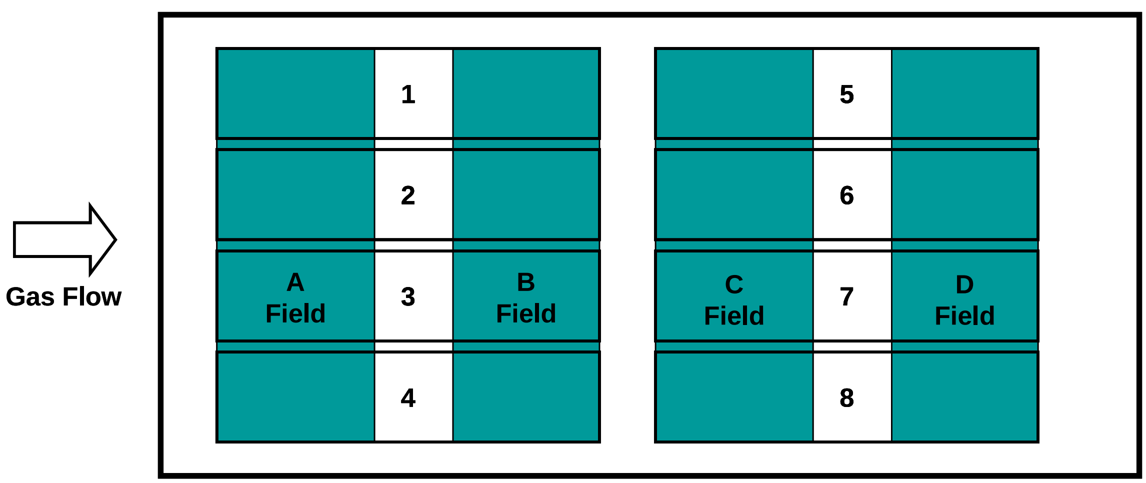

Figure 3-30. Diagram of Yates Unit 1 ESP

Table 3-25. Hg Concentrations in FGD Scrubber Liquor and FGD Scrubber Solids for Selected Samples from Long-Term Test

Sample Date	FGD Liquor Hg (μg/L)	FGD Solids Hg (μg/g)
11/14/2004 (BL)	13.6	0.37
11/17/2005	-	0.58
11/19/2004	3.0	0.125
11/25/2004	10.4	0.23
11/26/2004	2.4	2.0
11/30/2004	21.9	1.13
12/5/2004	23.5	2.2
12/10/2004	9.3	1.9
12/15/2004	31.2	0.25

Effect of Carbon Injection on ESP Operation

The injection of activated carbon upstream of an ESP has the potential to cause problems with the operation of the ESP. Firstly, rapping of the ESP plates could cause re-entrainment of the activated carbon, eventually leading to carbon emissions from the ESP. Secondly, the presence of carbon in the ESP may increase the potential for arcing and potentially damage the ESP over a prolonged period of operation. During the carbon injection tests at Plant Yates Unit 1, both carbon emissions from the ESP and increased arcing were noted. An analysis of these observations in provided in this section.

During parametric carbon injection testing in Spring 2004, erratic ESP arcing behavior was observed. The baseline (no injection) behavior of the ESP was also erratic, so it was not possible to correlate the ESP arcing with carbon injection rate. In the time that elapsed between the parametric tests and the long-term injection tests, the Unit 1 ESP underwent rigorous inspection and maintenance. The stand-off insulators at the bottom of the high voltage frame were found damaged or broken. It is unclear when this damage occurred (i.e., whether the damage is related to activated carbon injection during Spring 2004). It is believed that the presence of broken insulators would lead to erratic arcing and sparking behavior in the ESP, as was observed in the Spring 2004 testing. A visual inspection of the insulators revealed that carbon was "baked" onto the surface of the insulators.

In October 2004, some maintenance repairs were performed during a scheduled maintenance outage. During this outage the standoff insulators were either replaced or cleaned. This work was completed one month prior to the start of the continuous, long-term injection test.

Thus, it was possible to study the ESP electrical behavior prior to carbon injection, during carbon injection, and post-injection.

The methodology and results of the ESP arcing analysis are described below. As will be seen from the analysis, arcing in the ESP was related in part to the injection of activated carbon. The ESP was inspected approximately two months after the conclusion of the long-term carbon injection tests. No visible signs of damage were observed. No damage to the standoff insulators, like the ones found in the October 2004 inspection, was found.

Methodology for ESP Arcing Analysis

Figure 3-30 showed the layout of the Unit 1 ESP. It is composed of four fields, labeled A, B, C, and D. When arcing at the Yates Unit 1 ESP occurs, it is highest in the first (A) field, then less in each subsequent field. Furthermore, arcing in the B and C field does not occur unless there is significant arcing in field A. For the analysis presented here, data for only the A field are presented.

Raw data were obtained from the Unit 1 ESP in six-minute averages. These data spanned the time frame from 10/13/04 (the first day of ESP operation after the ESP overhaul) to 2/1/05 (approximately 1.5 months after the end of the long-term injection test). The data consisted of the unit load, ESP primary and secondary currents and voltages, arc rate, and spark rate for each field. These data were reduced to hourly averages, which were used for plotting purposes.

It was desired to evaluate the effect of load and carbon injection rate on the arcing rate in the first field of the ESP. Yates Unit 1 operated at two primary load ranges during the long-term injection test: low load (which ranged from 50 to 60 MW) and high load (which ranged from 95 to 107 MW). The ESP data were sorted by carbon injection rate and load in order to compute average arcing rates for various operational conditions. The average arcing rate was computed by averaging all the six-minute arc rates for which the load and injection rate met the specified criteria.

Pre-test injection behavior was analyzed with data covering the time period 10/13/04 to 11/15/04. Data prior to 10/13/04 were not analyzed because of the ESP overhaul that was conducted in early October. Post-injection test behavior was analyzed with data starting on 12/18/04, which is three days after injection was stopped, in order to allow for a return to baseline behavior. The ending date for the post-injection analysis was 1/17/05 because a second series of parametric carbon injection tests started on 1/18/05.

The ESP behavior before, during, and after the January 2005 parametric tests was also evaluated. For these analyses the time frame from January 8, 2005 to January 31, 2005 was analyzed.

Results of ESP Arcing Analysis

Figure 3-31 shows the arc rates for the first field of row 1 in the Unit 1 ESP. It also includes the load and carbon injection rate. While arcing in the first field was as high as 35 apm, no sparking was observed during the entire test period and so is not included in the plot. This plot covers the time period 10/13/04 through 1/17/05. Several observations can be made from this plot and from a companion plot (Figure 3-32), which shows the average arc rates during various load and carbon injection rates.

(1) First field arcing during the carbon injection test period is higher than during non-injection periods. Prior to the long-term injection testing, the average arc rate at low load was 0.5 apm. During the long-term injection test, the average arc rate ranged from 4 to 5 apm at low load.

(2) The arc rate is higher at high load that at low load. For a carbon injection rate of 4-5 lb/Macf, at low load the arc rate was 4 apm, while at high load the average arc rate was 17 apm. The increase in arcing at full load is seen for both injection and baseline cases.

(3) At low load, the magnitude of the arcing does not appear to trend with the magnitude of the carbon injection rate. For example, the arc rate for injection rates between 3 and 4 lb/Macf was 4.6 apm, while the arc rate for injection rates greater than 7 lb/Macf was 5.2 apm. However, at high load, there may be an increase in arc rate with carbon injection rate (with data at either 3-4 or 4-5 lb/Macf excepted).

(4) The ESP appears to have recovered from the carbon injection test to nearly pre-test arcing rates at low load. Pre-test arcing at low load was 0.5 apm, while post-test arcing at low load was 1.2 apm. However, given the volume of data available meeting the low load condition (561 hours of six-minute averages pre-test and 625 hours of six-minute averages post-test), this doubling of arc rate may be statistically significant.

(5) Very little high load baseline data were available during the pre and post-test periods (only 12 hours of six-minute averages per-test and 18 hours of six-minute average post-test). Therefore, it is not possible to draw statistically prudent conclusions about the high load arcing in the ESP at baseline.

(6) The opacity monitor at the ESP outlet is not a certified monitor, as it is used only for process information. The opacity monitor for Unit 1 measures 10% opacity when the unit is off-line. At low load, the opacity monitor also reads about 10%. No change in the

opacity was noted during carbon injection at low load. At high load baseline conditions, the opacity monitor reads 5 percentage points higher. For carbon injection rates less than 5 lb/Macf and high load, no further change in opacity was noted. For carbon injection rates greater than 5 lb/Macf and high load, a few percentage points increase in opacity was noted.

(7) Method 17 traverses were conducted in the ESP outlet duct to quantify ESP outlet particulate emissions during the month-long injection test. A handful of the data collected exceeded the baseline (no injection) ESP outlet emissions measured in three Method 5 traverses from Spring 2004. Furthermore, a few data points exceeded the compliance limit for Yates Unit 1 (0.24 lb/MMBtu); however, the unit itself was in compliance because the downstream JBR removed the broken-through particulate matter (see next section for further discussion). There were visible signs of carbon on the Method 17 filters, confirming the breakthrough of carbon from the ESP. Figure 3-33 shows the ESP particulate emissions versus the carbon injection rate.

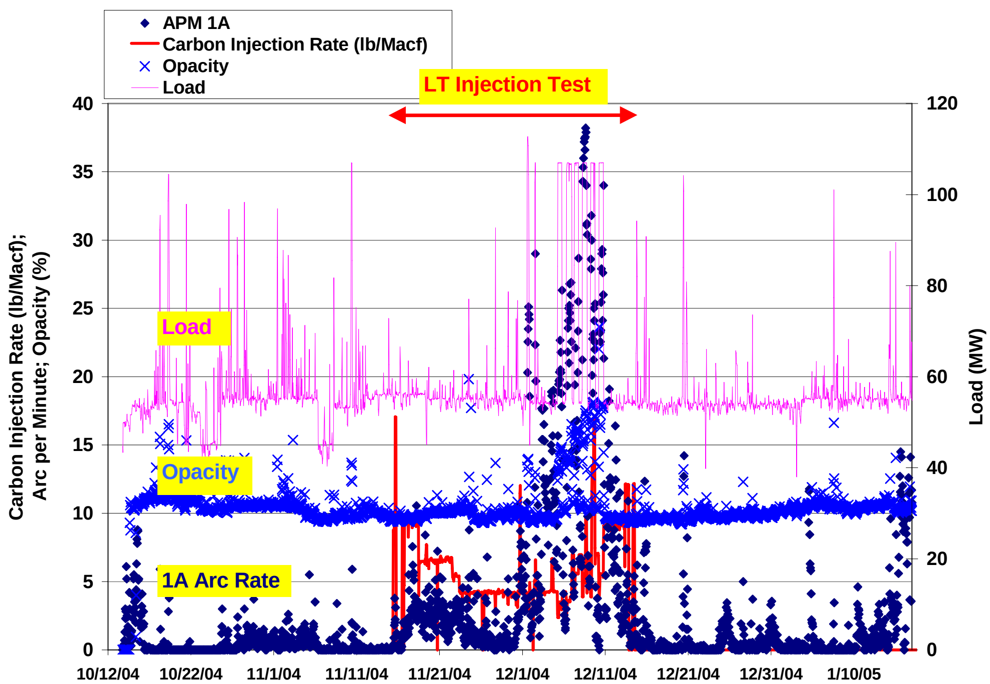

Figure 3-31. ESP, Load, and Carbon Injection Rate Data Previous, During, and Post Long-Term Injection Test

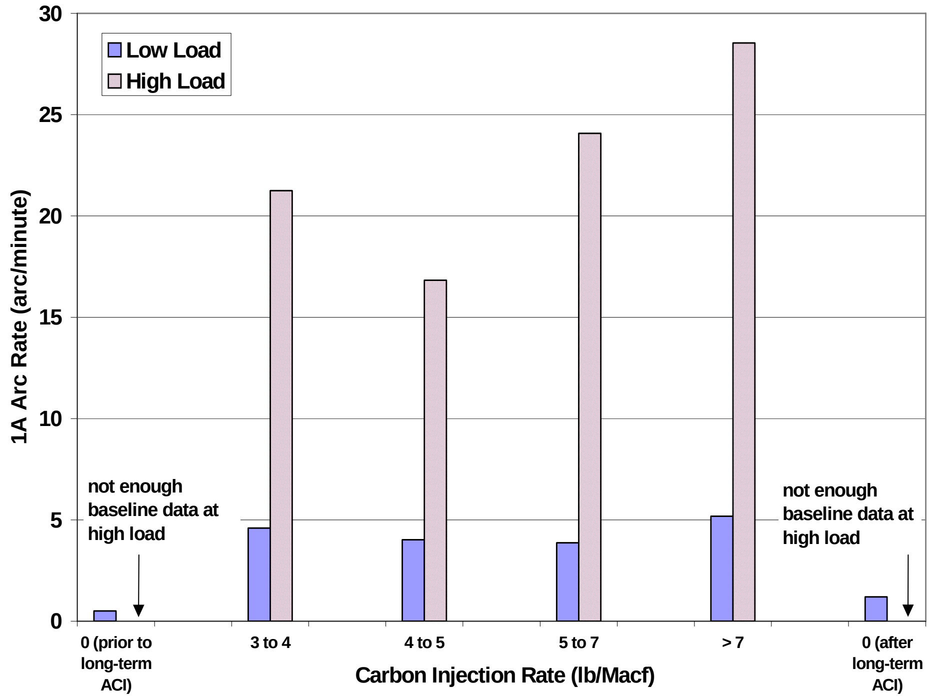

Figure 3-32. Average First Field Arc Rates at Various Carbon Injection Rates and Load Conditions

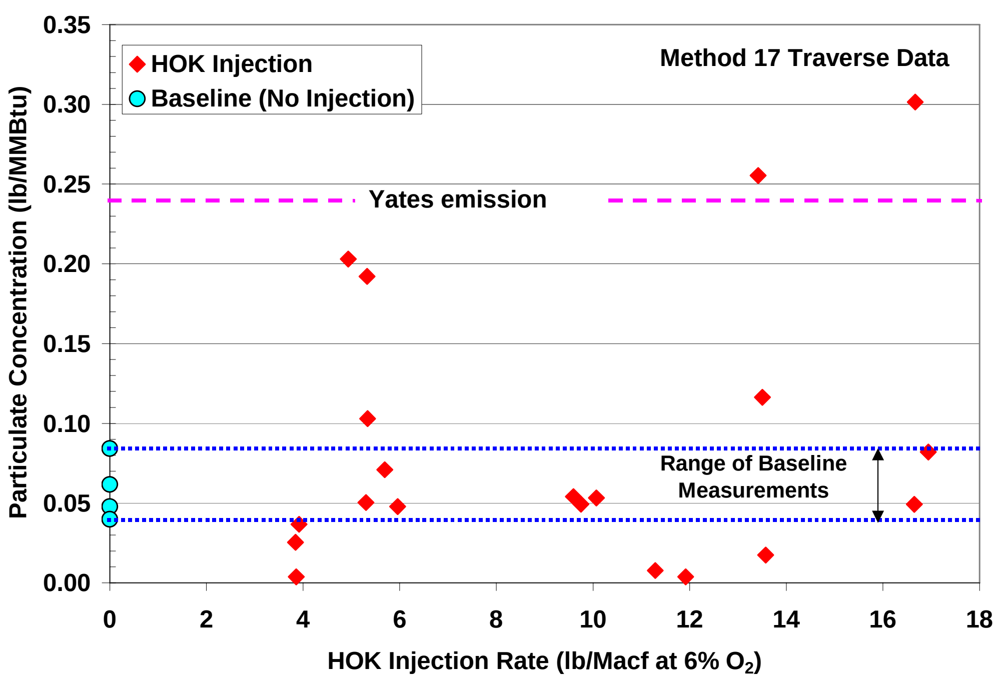

Figure 3-33. Method 17 Particulate Measurements versus Carbon Injection Rate

A second round of Unit 1 parametric carbon injection testing was conducted the week of January 18th, 2005. This testing began one month after the long-term carbon injection test had ended. Figure 3-34 shows the Unit 1, row 1 ESP arc rates for the first two fields, load, and carbon injection rate. The plot spans the time period January 8 through January 31, 2005. The following observations can be made from Figure 3-34.

(1) From the period January 8 through January 14, the arc rate in the first field was low. Starting January 14, the arc rate began to increase, and continued to do so through January 18, the start of the parametric carbon injection test. Some of this arcing behavior may be attributable to spikes in the load condition. No arcing was seen in the second field prior to the January carbon parametric tests.

(2) On January 17, the unit was operated at full load and the first field arc rate was as high as 15 apm. On January 18, carbon injection began (once again full load) and the first field arc rate increased to as high as 35 apm. On January 19, the same high arcing behavior was seen.

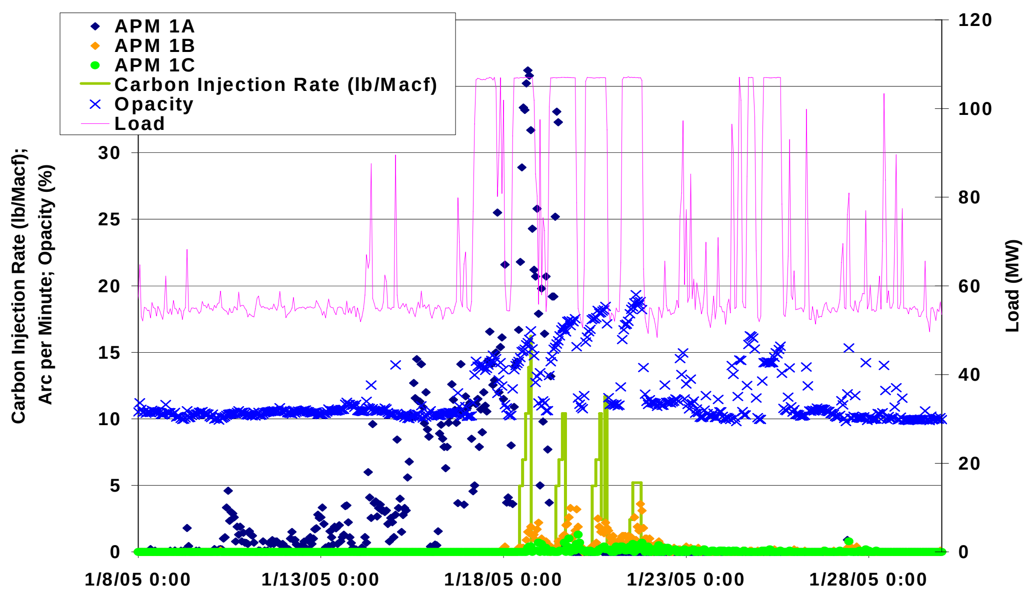

Figure 3-34. ESP, Load, and Carbon Injection Data Previous, During, and Post January Parametric Testing

(3) On January 19, 2005 at 12:51 the arc rate in the first field abruptly dropped from 35 apm to 0 apm. The arc rates in the second and third fields remain elevated. It is unclear why the arc rate in the first field fell to zero; neither the carbon injection rate nor the load caused this change. This type of abrupt change in arcing behavior was not noted during the long-term injection tests, where arcing rates from 25 to 40 apm were seen over the course of a six-day period of high load operation. At the end of the high load operation

during the long-term test, the arc rate gradually reduced to 10 apm, and at the end of carbon injection the arc rate gradually reduced to 1 apm.

(4) The arc rate in the first field remained at zero for the remainder of carbon injection test and through the end of this data set (January 31, 2005). Meanwhile, arcing was still seen in the second and third fields throughout the carbon injection test.

Effect of Carbon Injection on Scrubber Operation

As mentioned in the previous section, activated carbon broke through the ESP during the long-term test period. This carbon was observed in samples of the JBR scrubber slurry. During the period of 25 November through 10 December the scrubber slurry was observed to be either black or dark in color. During this time period, the carbon injection rate typically ranged from 4 - 6 lb/Macf (with a few, brief periods at higher rates). Prior to and subsequent to this time period, the scrubber slurry did not show any visual evidence of carbon contamination. After December 10, the carbon injection rate was as high as 12 lb/Macf, yet no further darkening was observed. From this limited set of data, it does not appear that the breakthrough of carbon to the JBR scrubber is directly related to the magnitude of the carbon injection rate. The darkening of the scrubber slurry is confirmed by measurements of the inert concentration of the JBR solids. The Yates JBR typically has an inert concentration less than 2%. During the period in which the JBR solids were visibly darkened, the inert concentration ranged from 3 to18% (see Figure 3-35).

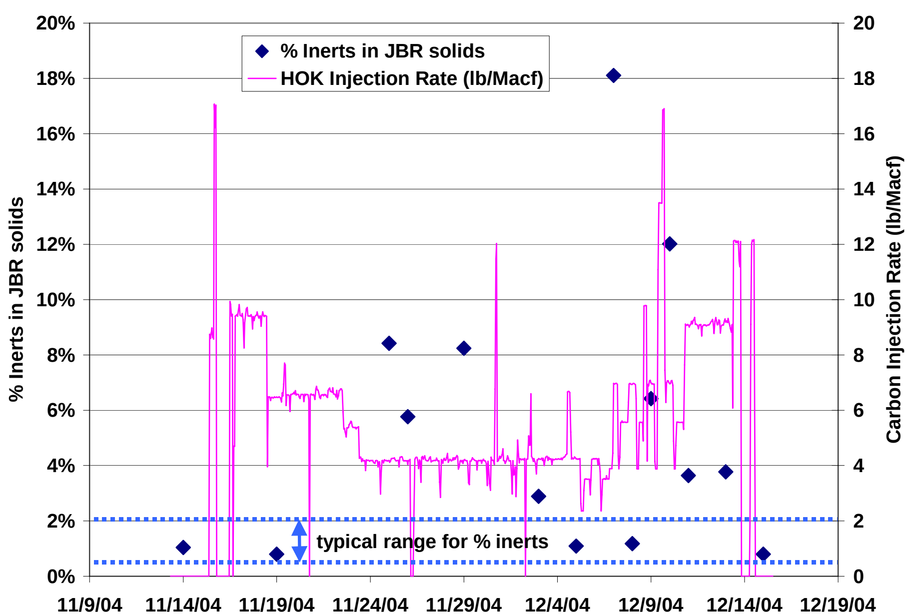

Figure 3-35. JBR Solids Inert Concentration During Long-Term ACI Test

3.3 Ontario Hydro Measurement Results

Three separate Ontario Hydro measurement campaigns were carried out during the carbon injection test program at Plant Yates. The purpose of these campaigns was to conduct the Ontario Hydro method testing side-by-side with the mercury SCEMs to validate the SCEM performance. The three Ontario Hydro campaigns were conducted during the following time periods:

(1) Unit 1 Baseline Testing: February 25-27, 2004
(2) Unit 2 Baseline Testing: March 18, 2004
(3) Unit 1 Long-term Carbon Injection Testing: December 1-2, 2004

The results from the two Unit 1 campaigns are discussed in this section. The Unit 2 results are provided in the Site 2 Report. Tables 3-26 and 3-27 summarize the Ontario Hydro measurements.

Table 3-26. Ontario Hydro Results from February 2004

	ESP Inlet			ESP Outlet		
	Run 1	**Run 2**	**Run 3**	**Run 1**	**Run 2**	**Run 3**
Date	26-Feb-04	26-Feb-04	26-Feb-04	26-Feb-04	26-Feb-04	26-Feb-04
Time	10:33-12:33	14:32-16:32	17:02 - 19:02	10:33-12:33	14:30-16:30	17:02 - 19:02
Gas Volume (dscf)	80.907	85.251	83.599	101.743	76.219	76.104
Moisture (%)	6.91	6.57	6.81	5.71	5.64	5.84
Oxygen (%)	9.5	8.5	8.0	8.0	8.0	8.0
Mercury Found (μg/sample)						
Probe and Nozzle Rinse	0.06*	0.11*	0.10*	<0.05	<0.04	<0.06
Filter	0.10	0.27	0.51	0.01	<0.01	0.04
Ash (analyzed separately)	0.13	0.32	0.30	--	--	--
Potassium Chloride	10.49	3.94	4.11	3.41	2.71	2.09
Nitric Acid Impinger	<0.20	<0.20	<0.20	<0.23	<0.20	<0.24
Permanganate Impinger	1.70	<0.67	<0.73	10.18	2.51	2.41
Totals (μg/sample)						
Particulate Mercury	0.28*	0.70*	0.92*	<0.06	<0.04	<0.10
Oxidized Mercury	10.49	3.94	4.11	3.41	2.71	2.09
Elemental Mercury	1.70	<0.87	<0.93	10.18	2.51	2.41
Total Mercury	12.48	4.64	5.03	13.59	5.22	4.50
Concentration (μg/Nm3), corrected to 3% O_2						
Particulate Mercury	0.21*	0.45*	0.58*	<0.03	<0.03	<0.07
Oxidized Mercury	7.72	2.53	2.59	1.76	1.87	1.45
Elemental Mercury	1.25	<0.56	<0.58	5.26	1.73	1.66
Total Mercury	9.18	2.98	3.16	7.02	3.60	3.11

*Isokinetic sampling was not possible at the ESP inlet because of vortex-like flows. The particulate values reported may be inaccurate, so these values are not carried forward in subsequent tables..

Table 3-27. Ontario Hydro Results from December 2004

	ESP Outlet			Stack Outlet		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
Date	1-Dec-04	2-Dec-04	2-Dec-04	1-Dec-04	2-Dec-04	2-Dec-04
Time	0	0	0	0	0	0
Gas Volume (dscf)	60.684	60.018	86.354	69.196	66.552	92.223
Moisture (%)	5.30	5.50	6.00	7.90	7.70	7.00
Oxygen (%)	9.9	9.8	8.9	10.7	8.3	12.4
Mercury Found (µg/sample)						
Probe and Nozzle Rinse	<0.03	<0.04	<0.04	<0.05	0.17	<0.04
Filter	0.02	0.01	0.02	0.01	0.01	0.05
Ash (analyzed separately)	--	--	--	--	--	--
Potassium Chloride	1.00	1.78	2.14	<0.34	<0.37	0.21
Nitric Acid Impinger	0.17	0.11	0.23	0.08	0.20	0.10
Permanganate Impinger	1.87	1.09	3.94	2.51	0.99	3.04
Totals (µg/sample)						
Particulate Mercury	<0.05	<0.05	<0.06	<0.06	0.18	<0.09
Oxidized Mercury	1.00	1.78	2.14	<0.34	<0.37	0.21
Elemental Mercury	2.03	1.21	4.17	2.59	1.19	3.14
Total Mercury	3.04	2.99	6.31	2.59	<1.74	3.35
Concentration (µg/Nm3), corrected to 3% O_2						
Particulate Mercury	<0.05	<0.05	<0.04	<0.06	0.14	<0.08
Oxidized Mercury	1.02	1.82	1.40	<0.33	<0.30	0.18
Elemental Mercury	2.07	1.23	2.73	2.49	0.96	2.72
Total Mercury	3.09	3.05	4.13	2.49	<1.41	2.90

For the first Ontario Hydro campaign, conducted during baseline testing, the Ontario Hydro measurements were made at the ESP inlet and ESP outlet locations. The average total and elemental mercury concentrations measured by the SCEM during the course of each two-hour Ontario Hydro run are compared in Table 3-28. The SCEM ESP inlet concentrations ranged between 3.92 and 4.12 µg/Nm^3 at 3% O_2, with an average of 4.02 µg/Nm^3. The three Ontario Hydro runs measured 8.97, 2.53, and 2.99 µg/Nm^3 at the ESP inlet. At the ESP outlet, the SCEM measured 3.49, 2.26, and 2.18 µg/Nm^3, while the Ontario Hydro runs measured 7.02, 3.60, and 3.11 µg/Nm^3. The vapor phase mercury concentrations obtained from the first Ontario Hydro run at both the ESP inlet and outlet are significantly higher than the second two runs and significantly higher than the SCEM results.

Particulate mercury concentrations are not available at the ESP inlet since the ESP inlet sampling location was nestled between two sharp turns in the ductwork, making iso-kinetic sampling infeasible. The ESP outlet particulate mercury concentrations, as determined by the Ontario Hydro method, were less than the detection limit of <0.03 µg/Nm^3.

The Ontario Hydro data indicate that the inlet stream is 88% oxidized, while the SCEM indicate 51% oxidation at the inlet. In Ontario Hydro, a particulate filter is placed upstream of the impingers, allowing for intimate contact between the gas and the collected particulate matter. The SCEM method uses a self-cleaning filter, which minimizes the accumulation of particulate matter and minimizes the possibility of bias. These data indicate that the passage of flue gas through the Ontario Hydro particulate filter may have resulted in oxidation of sampled mercury. This hypothesis is further validated with the outlet data, in which the oxidation percentages of the Ontario Hydro and SCEM agree. At the ESP outlet, the flue gas had a very low particulate concentration, so the bias caused by collection of particulate on the filter was reduced.

Table 3-28. Unit 1 - Comparison of Average SCEM and Ontario Hydro Mercury Measurements During Baseline Characterization on 2/26/04

	Run No.	Sampling Period (ET)	Vapor Phase			
			Elemental	Oxidized	Percent Oxidized	Total
ESP Inlet, µg/Nm^3						
SCEM	1	10:33-12:33	2.06	1.96	49	4.02
OH	1		1.25	7.72	86	8.97
SCEM	2	14:32-16:32	1.92	2.20	53	4.12
OH	2		<0.56	2.53	89	2.53
SCEM	3	17:02-19:02	1.89	2.03	52	3.92
OH	3		<0.58	2.59	86	2.59
ESP Outlet, µg/Nm^3						
SCEM	1	10:33-12:33	2.16	1.33	38	3.49
OH	1		5.26	1.76	25	7.02
SCEM	2	14:30-16:30	1.48	0.78	35	2.26
OH	2		1.73	1.87	51	3.60
SCEM	3	17:02-19:02	1.38	0.80	37	2.18
OH	3		1.66	1.45	47	3.11
Removal, %						
SCEM	1	10:33-12:33				13
OH	1					22
SCEM	2	14:32-16:32				45
OH	2					-42
SCEM	3	17:02-19:02				44
OH	3					-20

Note: All data normalized to 3% oxygen. Oxidized mercury for SCEM calculated as difference between measured total and elemental mercury. Total mercury for OH calculated as sum of measured elemental and oxidized mercury.

It should be noted that while the average of the SCEM and Ontario Hydro inlet data are within 18% of each other, each individual run shows larger disparity. The first run is of particular concern. Both the inlet and outlet first run Ontario Hydro values are at least twice as high as their counterpart SCEM measurements. Furthermore, the first run Ontario Hydro values are 2-3 times as high as the two subsequent Ontario Hydro runs (while the SCEM showed more constant mercury concentrations over the same time period). The plant operational data do not indicate any reason to expect the large change in mercury concentration seen in the Ontario Hydro data. A mass balance was computed by comparing the inlet coal mercury rate to the rate of mercury exiting in the fly ash and the flue gas. When this mercury balance is computed with first run of Ontario Hydro flue gas data, a 161% closure is obtained. From this result, the first run Ontario Hydro measurements do not appear reasonable in comparison to the mercury measured in the fly ash and the coal. A mass balance computed with the average of the second two runs of Ontario Hydro data indicate 109% closure.

A similar mass balance across the boiler/ESP system indicates 99% closure when performed with the average of the three runs of SCEM ESP outlet data. A review of the QC spike recovery data (Appendix E) for the SCEM method does not indicate any problem with these data.

The second Unit 1 Hydro campaign for the Yates ACI project was conducted December 1-2, 2004, in the middle of the long-term carbon injection test. Ontario Hydro measurements were made at the ESP outlet and the stack. Ontario Hydro measurements were not made at the ESP inlet, because of cyclonic flow problems that made iso-kinetic sampling impossible and a reactive ash that adsorbed mercury in previous Ontario Hydro testing (as discussed for Verification #1, conducted in February 2004).

An unexpected boiler tuning was carried out during the Ontario Hydro campaign, so load varied during the runs. As shown in previous process data, the unit load has a direct and immediate impact on the flue gas mercury concentration. Variations in mercury concentration across the sample time impact the Ontario Hydro and SCEM data in different ways. For the Ontario Hydro method, there are separate impingers to collect the elemental and oxidized mercury fractions. The flue gas mercury concentrations derived from these impinger catches represent an average of the entire time period of sampling. In contrast, the SCEM alternates between total and elemental mercury concentration measurements. For these Ontario Hydro verification runs, which typically lasted 2 hours per run, total mercury concentration was measured continuously for 1 to 1.5 hours in the period, followed by elemental mercury concentration was measured from 0.5 to 1 hour.

Due to the alternation between total and elemental mercury measurements, it was often the case that the SCEM elemental mercury measurements were obtained during one load and the SCEM total mercury measurements were obtained at a different load. This situation led to incongruous disparities between the total and elemental mercury concentrations measured by the SCEM. For example in Run 1 at the stack, the total mercury measurement, taken at a low load, indicated a lower mercury concentration than the elemental mercury measurement, which was taken at a higher load.

The average total and elemental mercury concentrations measured by the SCEM during the course of each two-hour Ontario Hydro run are reported in Table 3-29. The average of the three runs is not reported, because process conditions varied too much from run to run for an average to be meaningful. Instead, run-by-run comparisons were made between the Ontario Hydro and SCEM data.

Both SCEM and Ontario Hydro show the same trends in variation of total mercury concentration from run to run at both locations; however, the relative difference between the values for any given run ranges from 13 to 55 %. The oxidized mercury concentrations measured by the two methods showed more agreement, with very good agreement at the scrubber outlet where little oxidized mercury is present. At the ESP outlet, the fraction of oxidized mercury matched well between SCEM and Ontario Hydro for runs 1 and 2. For run 3 at the ESP outlet, the SCEM measured higher oxidation than the Ontario Hydro (load ramping is not the reason, as load was at its highest when SCEM elemental mercury was measured).

Most of the data gathered with the SCEM and Ontario Hydro methods indicate 20 to 30% total removal across the scrubber.

Both SCEM and Ontario Hydro indicate possibly a small amount of re-emission of elemental mercury across the JBR scrubber. However, at the low concentrations being measured, the differences in elemental mercury concentration across the scrubber are within the measurement uncertainty (especially for Ontario Hydro).

Table 3-29. Unit 1 - Comparison of Average SCEM and Ontario Hydro Mercury Measurements During Long-Term Sorbent Injection; December 2004

	Run No.	Sampling Period (CST)	Vapor Phase Hg Concentration			
			Elemental	Oxidized	Percent Oxidized	Total
ESP Outlet, µg/Nm^3						
SCEM	1	12/1/04 11:30-13:30	1.39	1.09	44	2.48
OH	1		2.07	1.02	34	3.09
SCEM	2	12/2/04 7:05-9:06	0.53	0.88	63	1.41
OH	2		1.23	1.82	61	3.05
SCEM	3	12/2/04 11:20-13:30	1.51	2.02	57	3.53
OH	3		2.73	1.40	34	4.13
Stack µg/Nm^3						
SCEM	1	12/1/04 11:30-13:30	1.32	-0.31*	0	1.32*
OH	1		2.49	<0.33	<12	2.49
SCEM	2	12/2/04 7:05-9:06	0.70	0.40	36	1.10
OH	2		0.96	<0.30	<12	<1.26
SCEM	3	12/2/04 11:20-13:30	2.08	0.30	13	2.38
OH	3		2.72	0.18	9	2.90
Removal*, %**						
SCEM	1	12/1/04 11:30-13:30	5	100	NA	47
OH	1		-20	68	NA	19
SCEM	2	12/2/04 7:05-9:06	-32	55	NA	22
OH	2		21	84	NA	>59
SCEM	3	12/2/04 11:20-13:30	-38	85	NA	33
OH	3		0	81	NA	30

Note: All data normalized to 3% oxygen. Oxidized mercury for SCEM calculated as difference between measured total and elemental mercury. Total mercury for OH calculated as sum of measured elemental and oxidized mercury. Because of changing load conditions from run to run, an average of the three runs is not an appropriate value to evaluate.
*Total mercury concentration measured by SCEM at Stack for Run 3 was lower than elemental mercury concentration because of load change in middle of run, hence the negative value for oxidized mercury. The elemental mercury value was used in computation of total mercury removal across scrubber.

3.4 Mercury Mass Balance

An overall mass balance for mercury was estimated based on the measured concentrations of mercury in the coal, bottom ash, ESP fly ash, JBR FGD slurry blowdown liquor and solids (gypsum), limestone, JBR FGD makeup water, and stack outlet gas on 2/26/04. As an additional data check, mass balances for mercury were computed around the boiler and the ESP as well as around the JBR. A mass balance around the ESP was not possible because the poor sampling location at the ESP inlet precluded iso-kinetic sampling. Therefore, particulate loading measurements were not possible.

Mass balance results for the baseline period are shown in Table 3-30. Process stream flow rates used in the mass balance calculations were estimated based on plant process data or calculated as indicated in the table. All mercury vapor concentrations listed in Table 3-30 are at actual oxygen levels. Mercury balance closure for the entire plant was 130 percent. The mass balance around the boiler/ESP system was (99%) indicating good agreement between coal mercury levels and outlet levels measured in the ESP fly ash and ESP outlet flue gas (SCEM). However, the balance around the JBR was 180%, which increased the uncertainty in the overall balance. The estimated mercury rates exiting in the slurry blowdown appear high. The pond water recycle flow rate was estimated as the difference between the required saturation water rate and the measured makeup water flow rate. This estimation may introduce additional error into the mass balance around the JBR. This preliminary mass balance indicates that approximately 60 percent of the mercury input with the coal was captured in the ESP fly ash.

3.5 Activated Carbon Injection Process Economics

A primary objective of this test program has been to develop the information required to predict activated carbon usage for a future full-scale installation. Based on the data collected at Plant Yates Unit 1, process costs can now be estimated.

The economics have been developed for a single, hypothetical 500-MW plant that fires bituminous coal and is located in the Southeastern U.S. The plant is equipped with a small-SCA ESP. This economic analysis is focused on mercury removal across the ESP; the hypothetical plant under consideration is not equipped with downstream SO_2 controls. The characteristics of the plant are summarized in Table 3-31.

Table 3-30. Unit 1 – Mercury Mass Balance Results for Baseline Characterization on 2/26/04

Stream	Flow Rate	Mercury Concentration[c]	Mercury Rate (g/hr)
Coal [a]	100,520 wet lb/hr	0.0604 dry µg/g	2.553
Bottom Ash [a]	2,622 lb/hr	0.003 µg/g	0.004
ESP Outlet Vapor [a] (SCEM)	8,472 dry Nm^3/min	1.86 µg/ Nm^3	0.946
ESP Outlet Particulate [a] (OH)	8,472 dry Nm^3/min	0.008 µg/Nm^3	0.004
ESP Captured Fly Ash [a]	10,420 lb/hr	0.331 µg/g	1.564
Limestone [ae]	3,133 lb/hr	0.02 µg/g	0.028
Pond Water Recycle [a]	90 gpm	1.17 µg/L	0.024
Slurry Blowdown – Liquid [b]	136 gpm	15.07 µg/L	0.449
Slurry Blowdown – Solids [b]	5,964 lb/hr	0.166 µg/g	0.449
Stack Vapor [b] (SCEM)	9,170 dry Nm^3/min	1.63 µg/Nm^3	0.897
Mass Balance Around Boiler and ESP			
		Boiler/ESP In	2.553
		Boiler/ESP Out	2.517
		Closure [d]	99 %
Mass Balance Around JBR FGD System			
		JBR FGD In	1.002
		JBR FGD Out	1.795
		Closure [d]	179%
Overall Mass Balance			
		Total In	2.605
		Total Out	3.3362
		Closure [d]	**129%**

[a] Estimated stream flow rate
[b] Measured stream flow rate
[c] Mercury vapor concentrations at the actual flue gas oxygen content.
[d] Closure (%) = (Out/In) x 100

Table 3-31. Process Parameters for Hypothetical Plant

Parameter	Value
Coal Type	Bituminous
Environmental Controls	Small-SCA ESP, no SO_2 controls
Net Unit Load	500 MW
Net Heat Rate	10,500 Btu/kwh
Unit Capacity Factor	0.8
Flue Gas Temperature at ESP Inlet	280°F
Flue Gas Flow Rate at ESP Inlet	1.92×10^6 acfm
Vapor Phase Hg Concentration at ESP Inlet	7.0 µg/Nm^3 at 3% O_2
Baseline Hg Removal across ESP	40%
Vapor Phase Hg Concentration at ESP Outlet	4.2 µg/Nm^3 at 3% O_2

The mercury concentrations and removals measured at Plant Yates were used to develop the baseline mercury profile for the hypothetical plant. Large variations in the baseline mercury profile were measured at Plant Yates, so median operating values were used. An ESP inlet vapor phase mercury concentration of 7.0 $\mu g/Nm^3$ (at 3% O_2) and a baseline removal of 40% of the vapor phase mercury across the ESP were assumed. Therefore, the ESP outlet vapor phase mercury concentration for the theoretical plant would be 4.2 $\mu g/Nm^3$.

Bituminous coal produces a higher LOI ash compared to sub-bituminous coals (PRB). However, the LOI is often below the ASTM limit of 6% and below the practical marketing limit of 3.5 – 4.0%. The predominant use for bituminous ashes (Class F) and PRB ashes (Class C) is for ready-mix concrete. Both carbon level and consistency of carbon level are important to the marketability of ash for this application. Therefore, the impact on ash sales is considered as a sensitivity case. This sensitivity case assumes that the plant sold its fly ash to the concrete industry prior to implementation of the carbon injection process, and the plant can no longer sell its fly ash once carbon injection is implemented.

The cost assumptions associated with the capital equipment and the activated carbons are summarized in Tables 3-32 and 3-33. The capital equipment cost was estimated for different injection rate scenarios. The details of the capital cost calculation are shown in Table 3-34.

Table 3-32. Cost Assumptions for Economic Analysis

Parameter	Value
New Plant Equipment Economic Life	15
New Plant Equipment Capital Recovery Factor	0.12
Activated Carbon Delivery Cost	$0.15/ton/mile

Table 3-33. Cost Assumptions for Activated Carbons

Carbon Name	Manufacturer	Bulk Carbon Cost ($/lb f.o.b.)*	Shipping Point	Distance to Plant from Shipping Point (miles)
Super HOK	RWE Rheinbraun	$0.29	Savannah, GA	250
Darco Hg	Norit Americas	$0.45	Marshall, TX	600
Darco Hg-LH	Norit Americas	$0.85	Marshall, TX	600
NH Carbon	Ningxia-Huahui	$0.88	Los Angeles, CA	2200

*Prices as of August 21, 2005

Table 3-34. Capital Cost Parameters

Injection Rate	(lb/Mmacf)	3	6	9
Carbon Feed at Full Load	(lb/hr)	345	690	1035
Feeder size	(lb/hr)	550	550	550
Feeder type	volumetric/gravimetric	volumetric	volumetric	volumetric
# Total feeders (incl. Spare)		2	3	4
15 day storage capacity	(lb)	124,247	248,494	372,741
Silo Capacity	(lb)	124,200	231,840	186,300
# Silos needed		1	1	2
Separate control building?	yes/no	no	no	no
Total Capital Cost	($)	$1,720,000	$1,830,000	$2,220,000
Capital Equipment Amortization	($/yr)	$206,400	$219,600	$266,400

According to the NETL Solicitation DE-PS26-03NT41718 (Large-scale Mercury Control Technology Field Testing Program – Phase II), the minimum mercury control percentage was specified as 80% for bituminous coal. This percentage represents a mercury removal increase beyond the “baseline” removal for the plant being considered.

The minimum mercury control objective of 80% was not achieved by any of the activated carbons tested in the parametric testing program at Plant Yates. Injection rates between 3 and 13 lb/Macf were tested; mercury reductions at the ESP outlet tended to plateau at injection rates between 6 and 10 lb/Macf. During the Spring 2004 parametric tests, the highest mercury reduction achieved was 45% at an injection rate of 10 lb/Macf of Darco Hg. Super HOK and NH Carbon produced slightly less mercury reductions at the same injection rate.

During the January 2005 parametric tests, approximately 60% mercury reduction was achieved with 10 lb/Macf of Darco Hg-LH. The Darco Hg was not tested at this high of an injection rate in January 2005; however, results at lower injection rates of 3 to 6 lb/Macf indicated nearly equal performance to the Darco Hg-LH.

It appears that the Darco Hg was more effective for mercury removal in the January 2005 tests, as compared to the Spring 2004 tests. The economic analysis is presented with results based on both sets of Darco Hg data to show the impact of the variability of the activated carbon performance on the economic analysis.

The ACI performance curves developed during the parametric testing were used to estimate the amount of carbon needed to achieve a specified mercury reduction at the ESP outlet. Four specified mercury reductions were evaluated: 20%, 35%, 45%, and 60%. The annual operating cost and installed capital cost for each control scenario were then calculated, using the assumed parameters from the above tables. The results presented here are "first-year" costs, meaning the sorbent costs are presented in 2005 dollars while capital costs have been amortized over fifteen years.

Figure 3-36 shows the annual cost of the carbon injection process for the four tested carbons to achieve a targeted mercury reduction of 35%. The annual cost is composed of three components: the sorbent cost, transportation for the sorbent, and capital equipment amortization. Annual operating and maintenance costs are not included, and would be expected to be small. For all sorbents, the sorbent cost comprises more than 75% of the total annual cost.

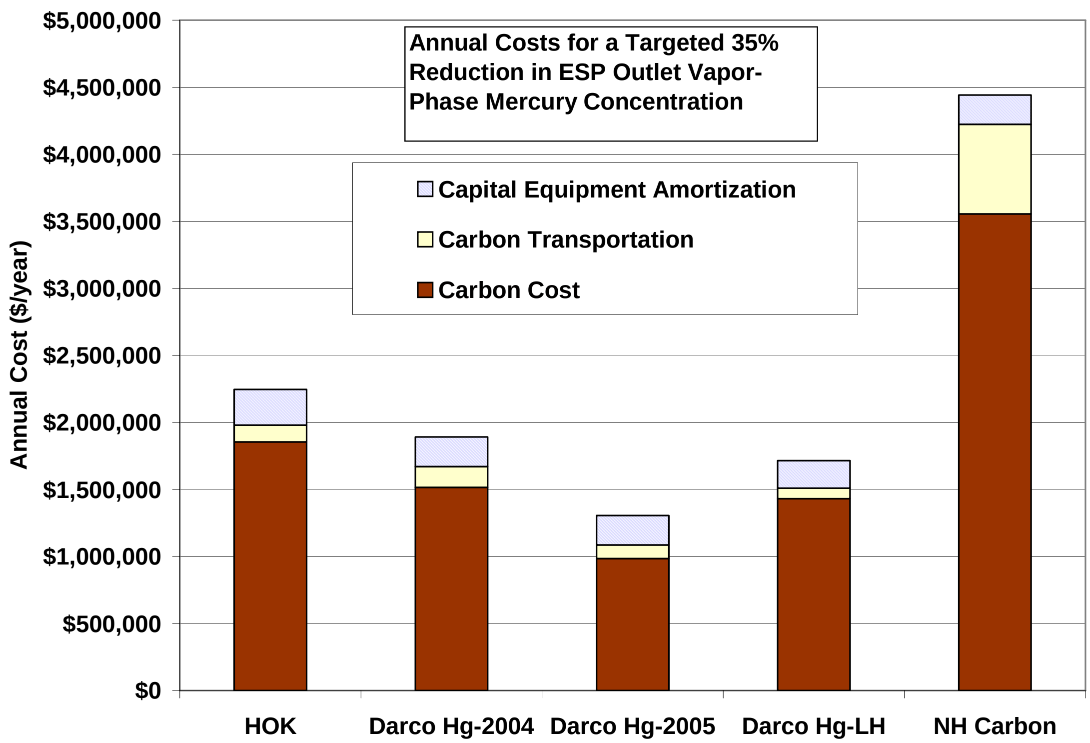

Figure 3-36. Annual Cost for Carbon Injection Process to Achieve a Targeted 35% Reduction in ESP Outlet Mercury Concentration

For a control level of 35% the NH carbon has the highest annual cost at $4.6M, which is more than double the cost of the other carbons that were tested. The NH carbon has the highest sorbent cost because it had the highest unit cost, while its mercury removal performance was no better than the other carbons. The annual cost for the Darco Hg sorbent was calculated based on both the Spring 2004 and January 2005 test results since the Darco Hg performed much better in the January 2005 tests. The annual cost for a 35% mercury reduction using the Darco Hg results from Spring 2004 is $1.9M; the annual cost decreases by one-third to $1.3M when the January 2005 results are used to estimate cost. The annual cost for the Super HOK was $2.2M. The Darco Hg-LH has an annual cost ($1.7M) that is slightly higher than the Darco Hg, based on 2005 results. This is because the two carbons performed similarly, but the Darco Hg-LH has a higher unit cost.

Figure 3-37 shows the annual cost for the sorbents at various mercury control levels, in terms of $/lb Hg removed. The cost for mercury control is reported in dollars per pound of mercury removed by the ACI process, which does not include mercury removed naturally by the ESP. The sorbent costs for achieving mercury reductions up to 50% is less than $80,000/lb Hg removed for all sorbents except the NH carbon.

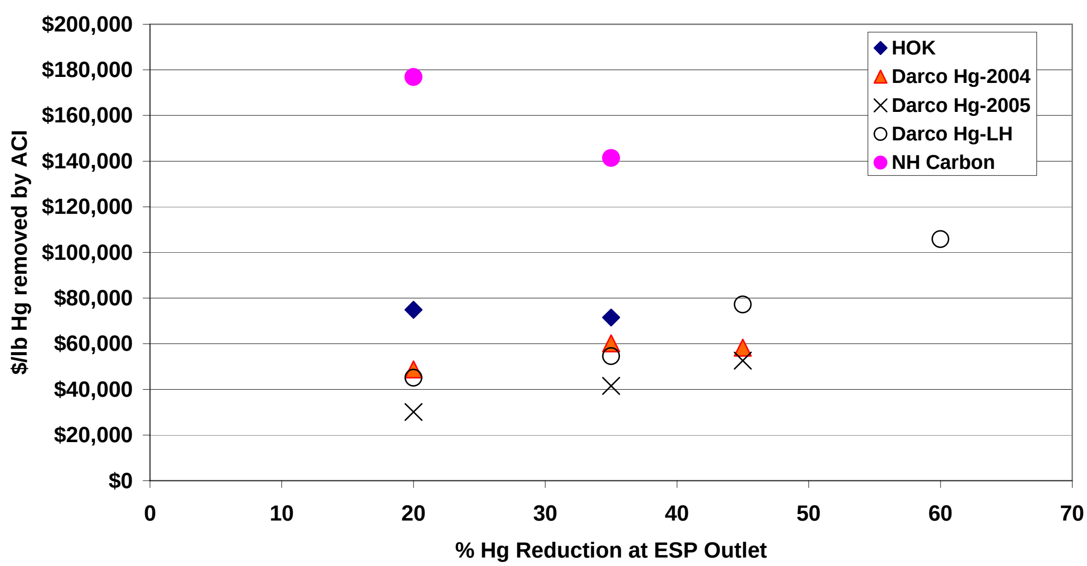

Figure 3-37. Normalized Cost of the Sorbent Injection Process (in $/lb mercury removed by ACI) for the Various Sorbents Tested in the Plant Yates Test Program

At a targeted mercury reduction of 20%, the cost for controlling mercury with the Super HOK sorbent is more than 50% higher than the Norit Darco carbons that were tested, even though its sorbent unit cost is approximately one-third lower than the Darco Hg sorbent. However, at a targeted mercury reduction of 35%, the cost for controlling mercury with the Super HOK is closer to that of the three Norit Darco sorbents.

It should be noted that the Super HOK appeared to show higher removals of vapor phase Hg across the ESP during the long-term tests than during the Spring 2004 parametric tests. However, the costs are calculated with the parametric test results because the baseline removal of the system was characterized for each day's test shown in the mercury removal performance curve. It was not possible to characterize the baseline mercury removal across the ESP during the long-term injection test; therefore, it is difficult to isolate the effect of the carbon on mercury removal. It is also possible that the other carbons to which the Super HOK is compared would show a similar increase in mercury removal during a long-term injection test, thereby decreasing the system operating costs.

A sensitivity case is considered in which it is assumed that the plant currently sells its fly ash. The sensitivity case was conducted for the Darco Hg sorbent, based on the January 2005 test results, at three levels of mercury control: 20%, 35%, and 45%. In this sensitivity case it was assumed that prior to implementation of the carbon injection process, the plant had been selling its fly ash to the concrete industry for $5/ton ash. With carbon injection in operation, the fly ash is no longer usable by the concrete industry. The plant will not only lose the income from selling fly ash, but will also incur the cost of fly ash disposal (estimated as $10/ton).

The loss of fly ash sales more than doubles the cost of sorbent injection as a mercury control option for all levels of mercury control studied. It has the largest cost impact at the lower mercury control scenarios (Figure 3-38). For a targeted reduction of 20% in vapor phase mercury, the impact of lost fly ash sales and landfilling quintuples the cost of carbon injection. For targeted reductions of 35% the impact of lost fly sales and landfilling almost triples the cost of carbon injection to $110,000/lb Hg removed, while at a control efficiency of 45% the cost increase is about double to $105,000/lb Hg removed.

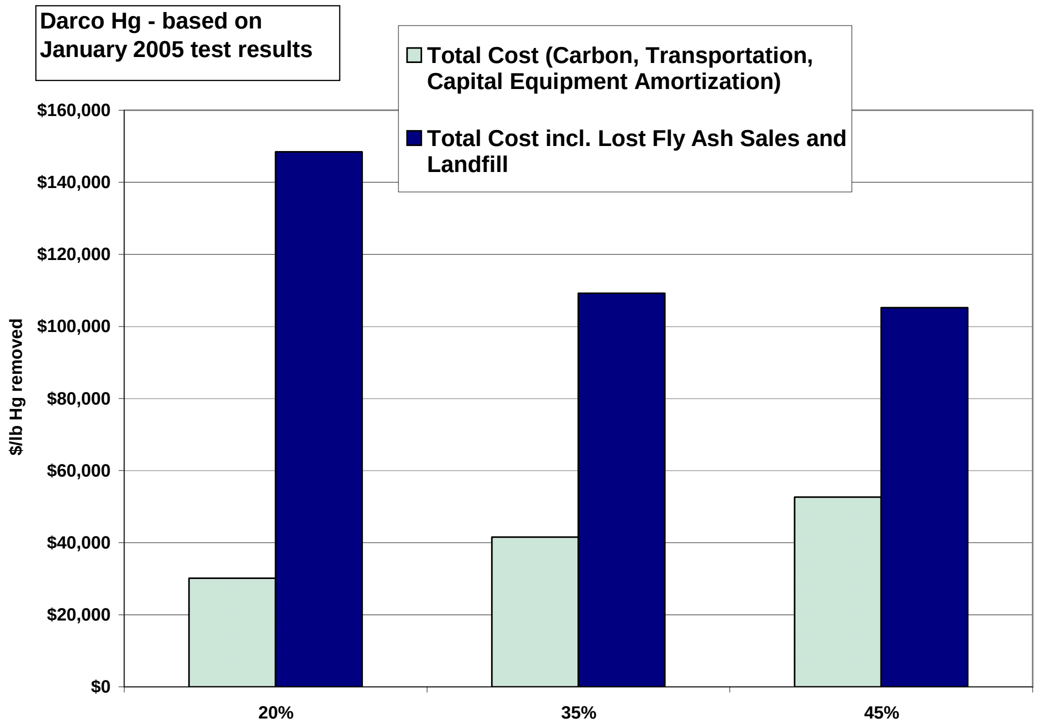

Figure 3-38. Impact of Lost Fly Ash Sales on Cost of Implementing Sorbent Injection for Norit Darco Hg Sorbent (based on January 2005 test results)

4.0 Conclusions and Recommendations

URS Group, in conjunction with EPRI, Southern Company, Georgia Power, and ADA-ES evaluated sorbent injection for mercury control upstream of small-SCA ESPs in flue gas derived from low-sulfur Eastern bituminous fuel. The project was funded by DOE-NETL. Full-scale tests were performed at Georgia Power's Plant Yates Unit 1 [George Power is a subsidiary of The Southern Company] to evaluate the effectiveness of sorbent injection as a mercury control technology. Plant Yates Unit 1 burns low sulfur Eastern bituminous coal and is equipped with a small-SCA (173 ft^2/kacfm) cold-side ESP followed by a Chiyoda CT-121 wet scrubber.

Sorbent injection technology is a promising mercury control option for plants burning low/medium sulfur bituminous coals equipped with ESP and ESP/FGD (without SCR) systems. Approximately 38,000 MW of generating capacity exists for bituminous coal-fired power plants with high-efficiency particulate control devices followed by wet lime/limestone FGD. In addition, about 70% of the ESPs used in the utility industry have SCAs less than 300 ft^2/1000 acfm. Prior to this test program, previous sorbent injection tests had focused on large-SCA ESPs.

Sorbent was injected upstream of the cold-side ESP at Plant Yates Unit 1. Flue gas mercury concentrations were monitored with mercury SCEMs at the ESP inlet, ESP outlet, and scrubber outlet. Mercury removal performance as well as balance of plant impacts were measured and evaluated. Baseline mercury measurements indicated 4 to 7 $\mu g/Nm^3$ Hg (at 3%O_2) at the ESP inlet, 2 to 3.5 $\mu g/Nm^3$ Hg at the ESP outlet, and 2 to 3 $\mu g/Nm^3$ at the FGD outlet. Baseline removal across the ESP was variable, averaging about 35%.

The test program at Plant Yates Unit 1 was comprised of two components: a parametric test program in which various sorbents were evaluated in short-term tests, and a month-long continuous injection test conducted with a single sorbent. The following sorbents were evaluated in a round of parametric tests conducted in Spring 2004: RWE Rheinbruan's Super HOK, Ningxia Huahui's iodated activated carbon (NH IAC), and Norit Darco Hg. The percent mercury removal across the ESP was somewhat similar for all three sorbents. A maximum vapor mercury removal across the ESP was about 70 to 75% at 10 lb/Macf injection. The vapor mercury removal across the ESP-JBR was about 80% at 10 lb/Macf. It appears that most of the mercury removal had occurred across the ESP. The ESP outlet mercury emissions could be maintained below 2 lb/TBtu at a carbon injection rate of >5 lb/Macf.

A second series of parametric tests were conducted in January 2005. The following sorbents were evaluated: Norit's Darco Hg as a reference sorbent, coarsely ground HOK, Norit Darco Hg-LH, and a 50/50 mixture of PRB derived fly ash and Darco Hg. The coarse HOK had the lowest mercury removal effectiveness, while the three Norit Darco sorbents/sorbent-ash combinations performed similarly and had about 10 to 20% higher removal than the coarse HOK. The ash-carbon mixture did not appear to improve the mercury removal effectiveness compared to carbon only at the same injection concentration. A maximum vapor mercury reduction of about 80% was achieved across the ESP outlet at ~10 lb/Macf with Darco Hg-LH. The higher mercury removal achieved during January 2005 testing may be partly attributed to the lower ESP inlet temperatures experienced during that injection testing period.

The month-long continuous injection test was scheduled for November/December 2004, so the selection of the sorbent for the month-long injection test was based only on the Spring 2004 parametric test results. RWE Rheinbraun's Super HOK sorbent was selected based on its performance (slightly lower than Darco Hg) and lower cost ($0.35/lb versus $0.45/lb for Darco Hg) relative to Norit America's Darco Hg, and the paucity of "long-term" data available for sorbents other than Darco Hg. Injection of Super HOK increased the vapor-phase mercury removal across the Yates Unit 1 ESP from a nominal baseline value of 50% to almost 90% at times. Injection rates ranging between 4 and 10 lb/Macf were tested over the thirty-day period. Increasing the carbon injection rate above 4.5 lb/Macf did not provide significant improvements in the vapor phase mercury removal across the ESP. The vapor phase mercury removal across the ESP was highly variable, with values ranging from 60 to 90%.

Several balance of plant impacts were noted for the sorbent injection process. Carbon breakthrough at the outlet of the ESP was noted in both Method 17 particulate filters and in JBR scrubber samples. The inerts concentration of the JBR solids increased from a normal baseline of less than 2% to a high of 18%. Carbon injection caused an increase in the arc rate of the ESP at low load conditions, as compared to baseline arcing. While no physical damage to the ESP was noted at the end of the thirty-day injection test, it is unclear what effect the increased arcing will have on the mechanical integrity of the ESP over longer time periods. These test results indicate that sorbent injection will need to be further evaluated on full-scale units (especially for small SCA ESPs) for longer periods of time in order to better understand the impact of carbon injection on ESP performance and integrity.

Relevancy of Test Program Results

The results from this test program have shown that achieving consistently high efficiency mercury removal with sorbent injection on Yates Unit 1 ESP as it is currently configured may not be possible. In other test programs, sorbent injection into ESPs for units burning eastern bituminous coal has produced mercury removals up to at least 80%.[1] Such high mercury removals were not achieved during the parametric evaluation of carbon on Yates Unit 1. Furthermore, during the thirty-day continuous injection test period, the mercury removal across the ESP varied from 60 to 90%. Increases in injection rate above 4 lb/Macf did not provide increased or more consistent mercury removal. The small size of the ESP may be a limiting factor for achieving higher mercury removals at Yates Unit 1. Furthermore, the small size of the ESP may have contributed to the increased acing and carbon breakthrough noted during the long-term injection test. These observations have not been recorded in previous test programs at other sites. The previous test sites were equipped with significantly larger ESPs.

Limitations in the mercury removal performance of the tested sorbents and limitations in the electrical and mechanical performance of the ESP posed challenges to achieving high mercury removal. As this is the first test sorbent injection test program to be conducted on a small SCA (< 300 ft^2/kacfm) ESP, it is unclear whether these results are specific to Yates Unit 1 or whether these challenges will manifest in similarly designed units. As 70% of the ESPs used in the utility industry have SCAs less than 300 ft^2/kacfm, further testing of sorbent injection on small SCA ESPs is warranted.

Results from the parametric tests on Yates Unit 1 indicate that use of a brominated carbon may not provide increased mercury removal over the standard, non-chemically treated activated carbons. Tests at other bituminous-fired units have indicated that brominated carbons may provide some limited improvement in mercury removal. This behavior is distinctly different from that of brominated sorbents in low-chloride flue gas (such as PRB or North Dakota lignite), where the use of a brominated sorbent can achieve greater than 90% mercury removal, while non-treated carbon are limited to 50-60% removal.[2] The higher concentrations of SO_3 in bituminous-derived flue gas is believed to be the cause of the lower mercury removals achieved by sorbent injection at bituminous-fired plants.

5.0 References

1. Berry, M. et al. “Mercury Control Research: Activated Carbon Injection Programs.” Air Quality V. Arlington, VA. 21 September 2005.
2. Dombrowski, K. et al. “Chemically Treated Activated Carbon Injection for Mercury Control in Flue Gases Derived from North Dakota Lignite and PRB.” Air and Waste Management Association Annual Conference.

Appendix A
SCEM Data Analysis Methodology

Methodology for Generating Mercury Concentrations in units of μg/Nm^3 at 3% O_2

This section explains how vapor phase mercury concentrations are obtained from the mercury SCEMs.

As described in Chapter 2 the mercury SCEMs use a gold amalgamation column coupled with a CVAA. The flue gas is conditioned to remove the acid gas constituents (which can harm the gold's ability to adsorb mercury). It is also conditioned to either convert all the mercury to the elemental phase or to remove the oxidized mercury, leaving just the elemental phase. The CVAA can only detect the elemental form of mercury.

A measured flow rate of conditioned flue gas is passed over the gold amalgamation column for a fixed period of time. The flow rate is measured by a mass flow meter. The flow meter is calibrated to generate flow rates in the units of normal cubic meters (Nm^3), where normal means the gas flow has been corrected to 32°F.

As the flue gas passes over the gold, the mercury in the flue gas adsorbs to the gold. Once a measured quantity of flue gas has passed over the gold, the gold is heated to desorb the mercury. This desorbed mercury is detected by the CVAA. The size of the peak generated by the CVAA correlates to a mass of mercury, as determined by a calibration curve. To produce the mercury concentration in μg/Nm^3, the mass of mercury is divided by the volume of flue gas sampled.

These mercury measurements are initially calculated at the actual O_2 concentration in the duct. For each mercury concentration, an oxygen concentration is measured. The mercury data are corrected to a 3% O_2 basis in order to account for dilution effects from location to location. The calculation for conversion to 3% O_2 is:

$$Hg\ [\mu g/Nm^3 \text{ at } 3\%\ O_2] = Hg\ [\mu g/Nm^3 \text{ at } x\%\ O_2] * (20.9-3) / (20.9-x)$$

where x represents the actual O_2 concentration measured.

Each mercury SCEM produces a datum point every three to seven minutes, depending on the sample time needed to collect a detectable amount of mercury on the gold. The sample time increases as the flue gas mercury concentration decreases.

Methodology for Data Analysis of Parametric Results

This appendix explains how the raw data gathered by the mercury SCEMs are manipulated to produce the vapor phase mercury removal results for the parametric test conditions. A parametric test condition consists of a carbon type and carbon injection rate.

Mercury SCEMs were employed at the ESP inlet, ESP outlet, and stack locations. An average mercury concentration was calculated for each location at each test condition. Each test condition lasted from two to three hours. During each test period, flue gas mercury concentrations were measured by the SCEMs. The test period was run long enough for the mercury concentrations to reach a steady state. At each location the steady state data were averaged to generate an average mercury concentration for the test condition. Mercury removals across the ESP, JBR, and ESP/JBR system were calculated for each injection rate using these average mercury concentrations.

Methodology for Data Analysis of Long-Term Results

The long-term carbon injection test was run for a one-month period. Over this time period, mercury SCEM data were collected every three to seven minutes at the ESP inlet, ESP outlet, and stack locations. Because of the huge volume of data, the mercury concentrations were reduced to one-hour averages. These one-hour averages were used for the plots in this report, and for calculations of percent removal across the ESP and JBR

Appendix B

SCEM and Carbon Injection Rate Data for Baseline and Parametric Tests

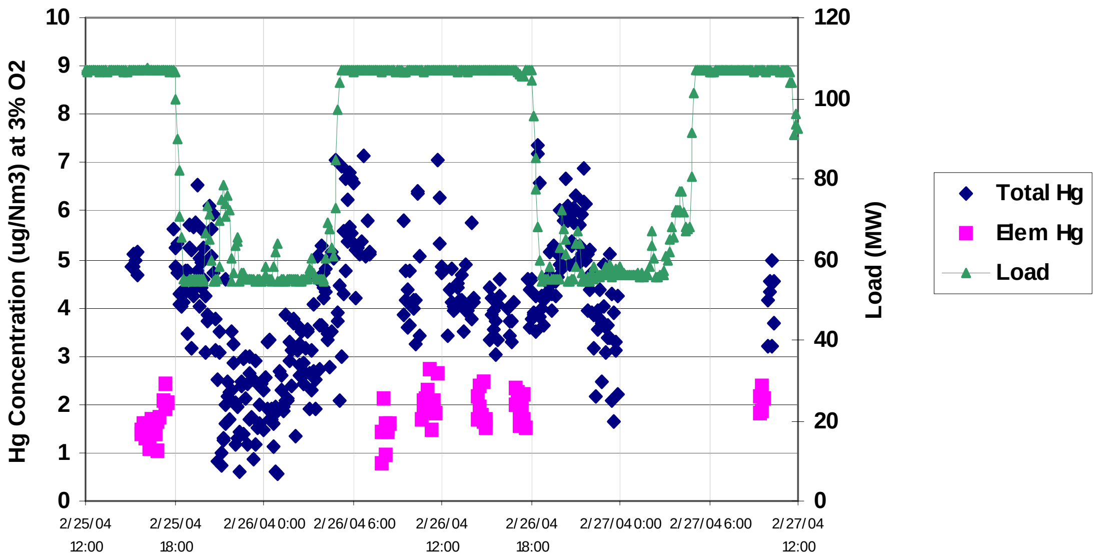

Figure B-1. Unit 1 – SCEM Mercury Measurements at the ESP Inlet for the Baseline Characterization Test Periods

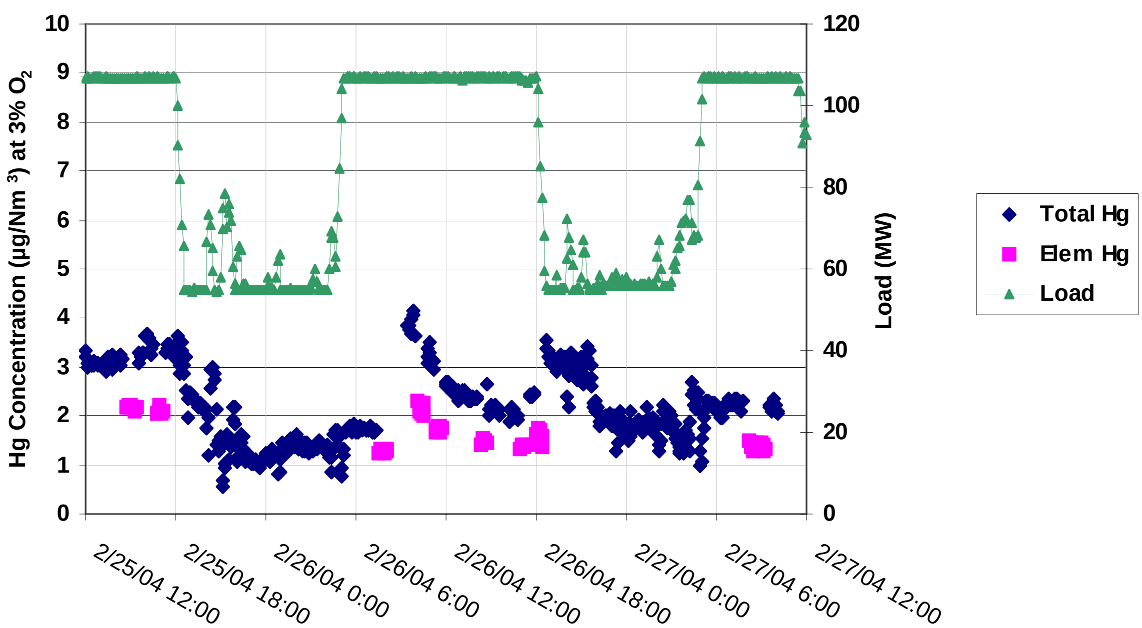

Figure B-2. Unit 1 – SCEM Mercury Measurements at the ESP Outlet for the Baseline Characterization Test Periods

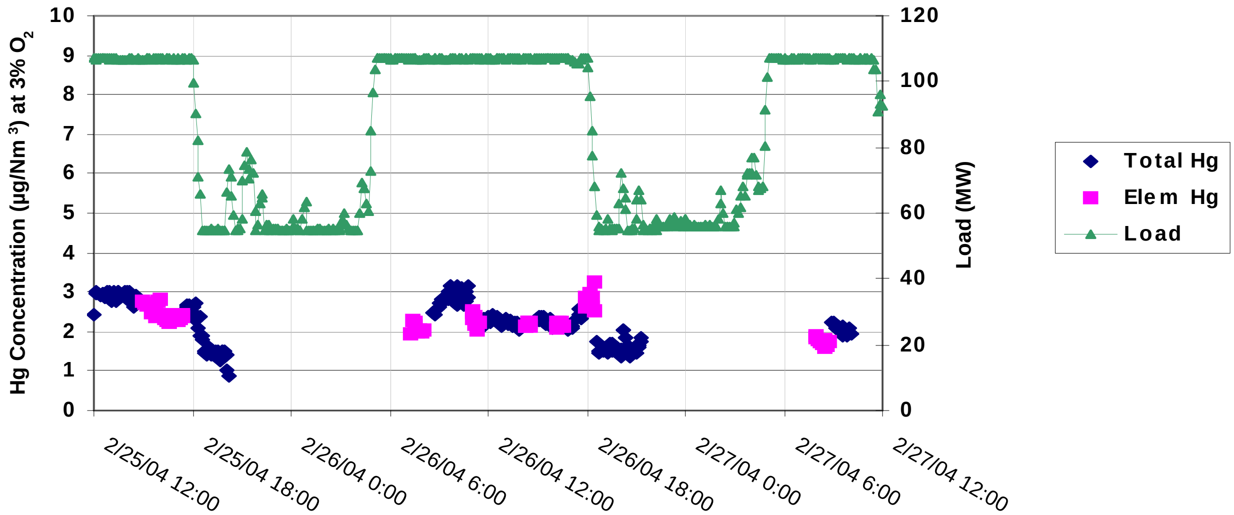

Figure B-3. Unit 1 – SCEM Mercury Measurements at the Stack for the Baseline Characterization Test Periods

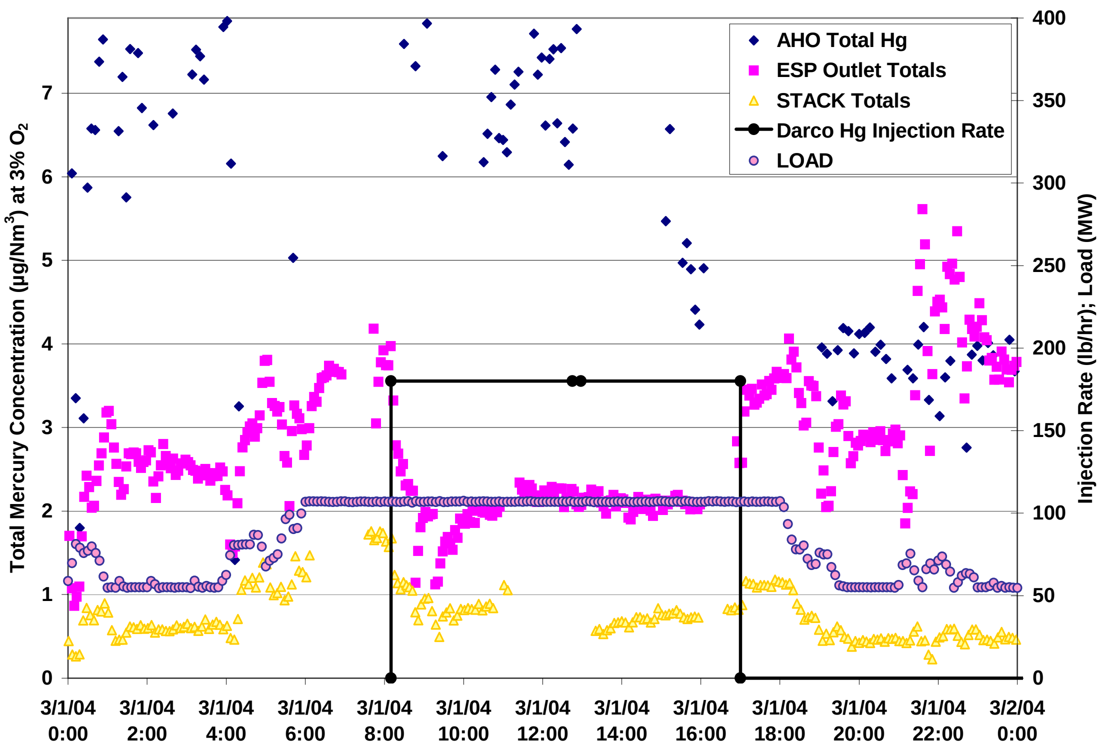

Figure B-4. Vapor Phase Mercury Concentrations measurements at Air Heater Outlet, ESP Outlet, and Stack during Day 1 of Darco Hg Injection Testing

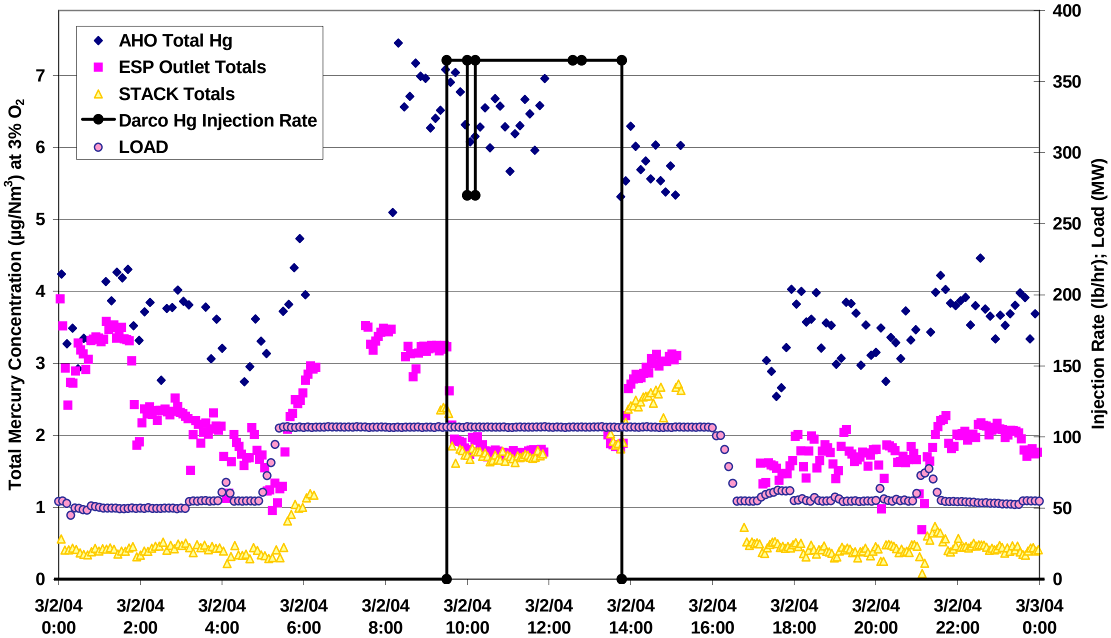

Figure B-5. Vapor Phase Mercury Concentrations measured at Air Heater Outlet, ESP Outlet, and Stack during Day 2 of Darco Hg Injection Testing

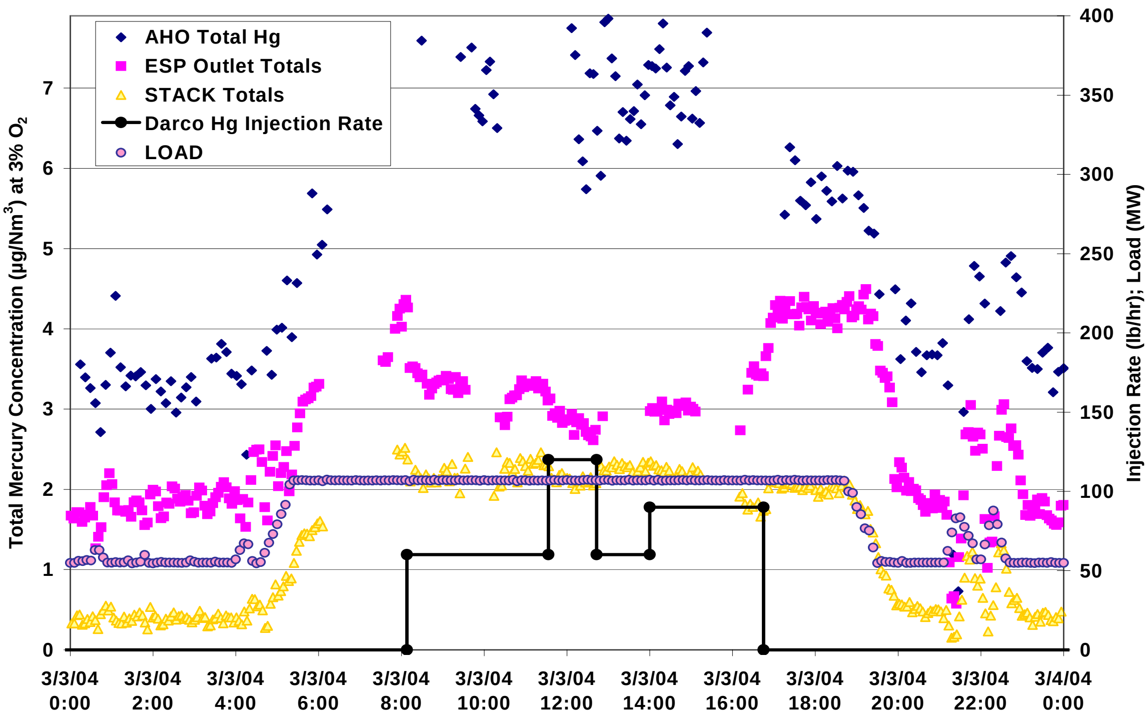

Figure B-6. Vapor Phase Mercury Concentrations measured at Air Heater Outlet, ESP Outlet, and Stack during Day 3 of Darco Hg Injection Testing

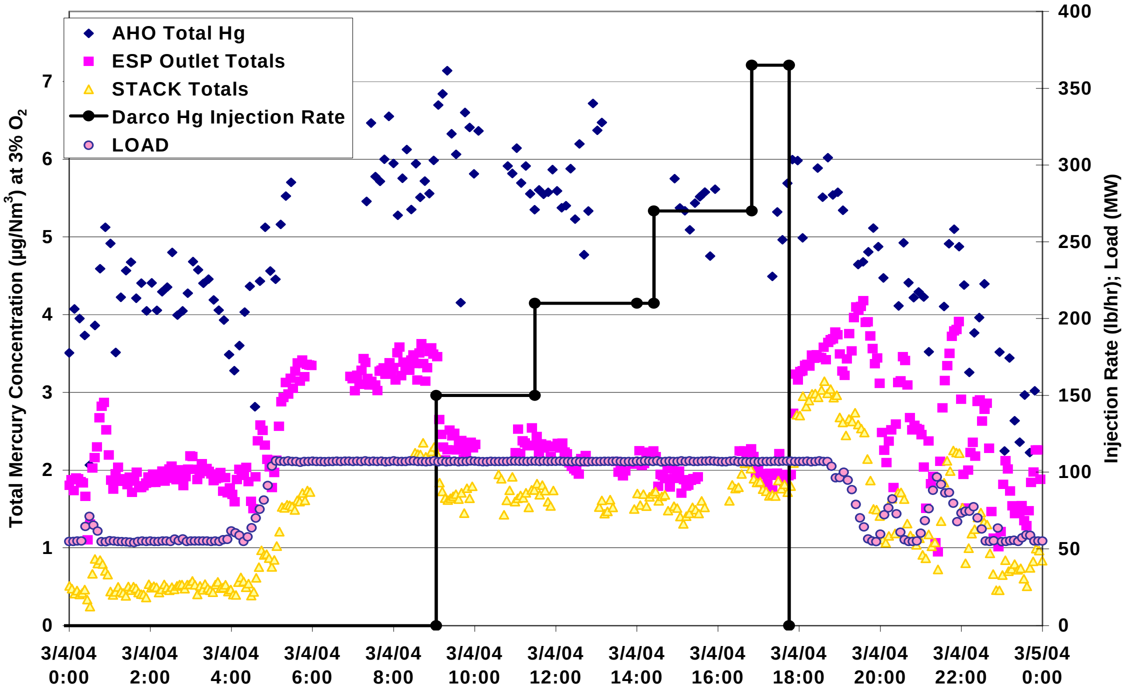

Figure B-7. Vapor Phase Mercury Concentrations measured at Air Heater Outlet, ESP Outlet, and Stack during Day 4 of Darco Hg Injection Testing

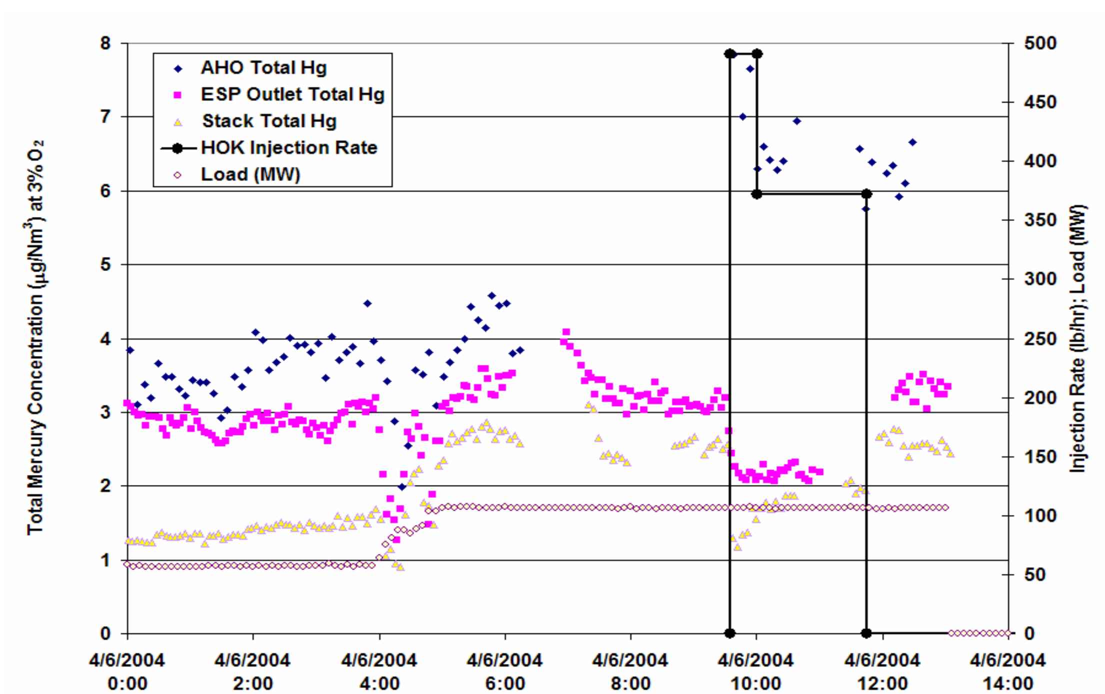

Figure B- 8. Vapor Phase Mercury Concentrations measured at Air Heater Outlet, ESP and Stack during Day 1 of Super HOK Injection Testing

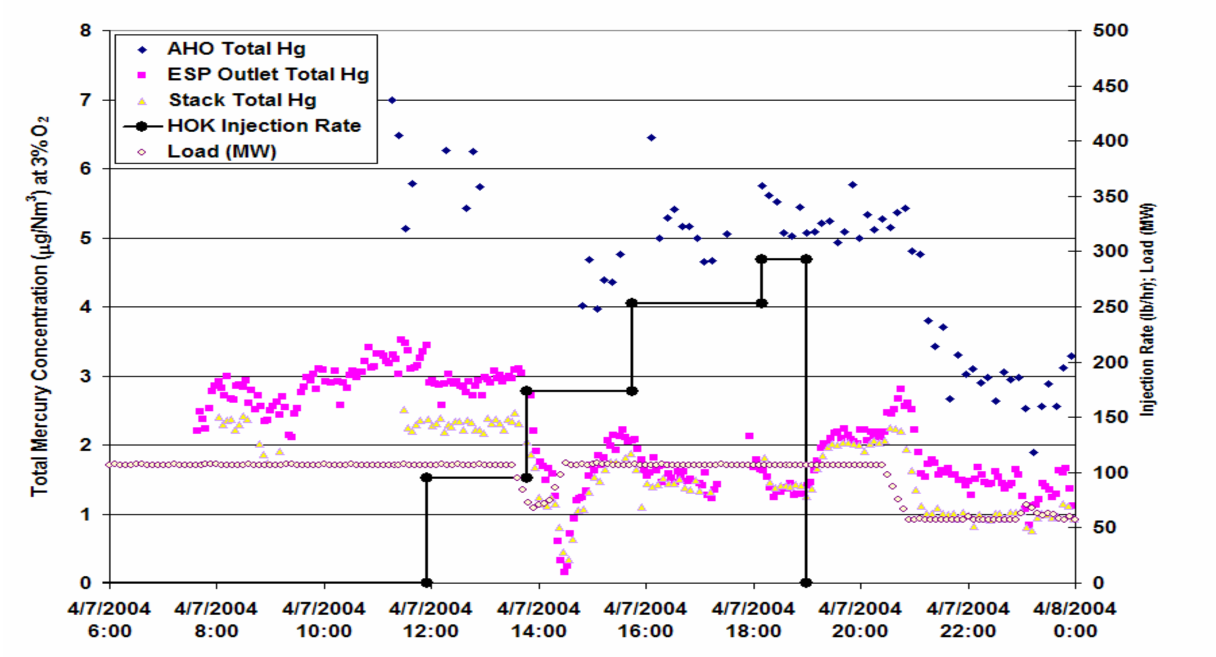

Figure B-9. Vapor Phase Mercury Concentrations measured at Air Heater Outlet, ESP Outlet, and Stack during Day 2 of Super HOK Injection Testing

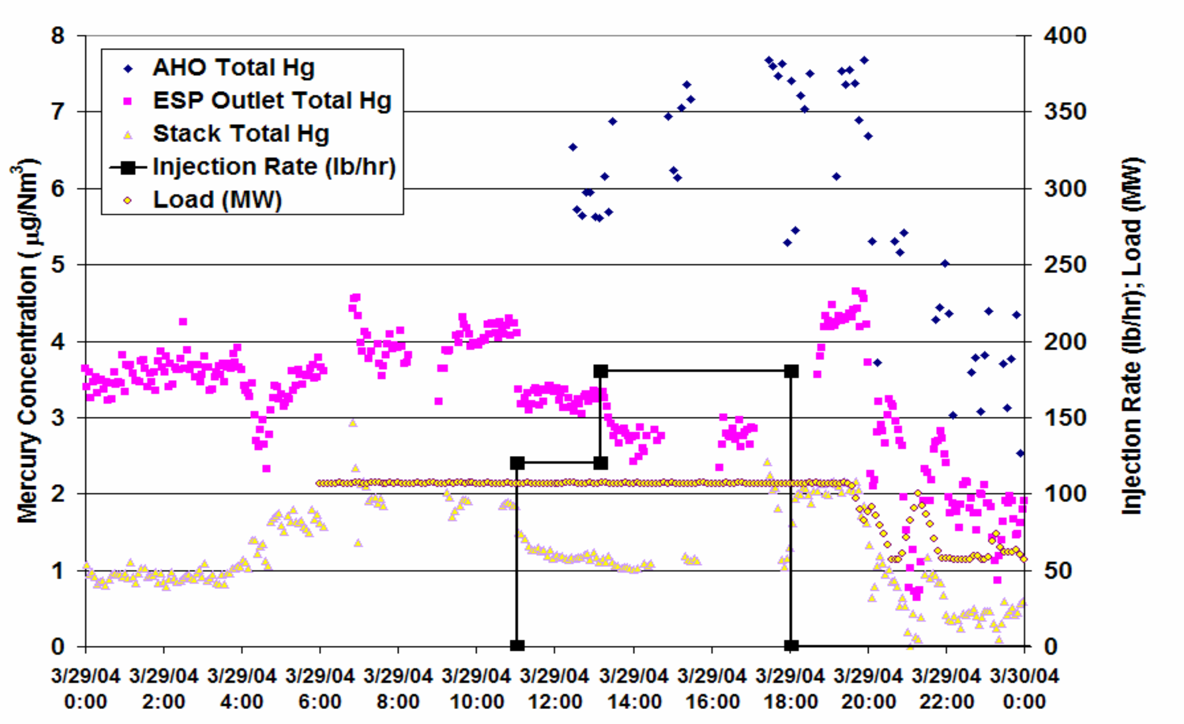

Figure B-10. Vapor Phase Mercury Concentrations measured at Air Heater Outlet, ESP Outlet, and Stack during Day 1 of NH Carbon Injection Testing

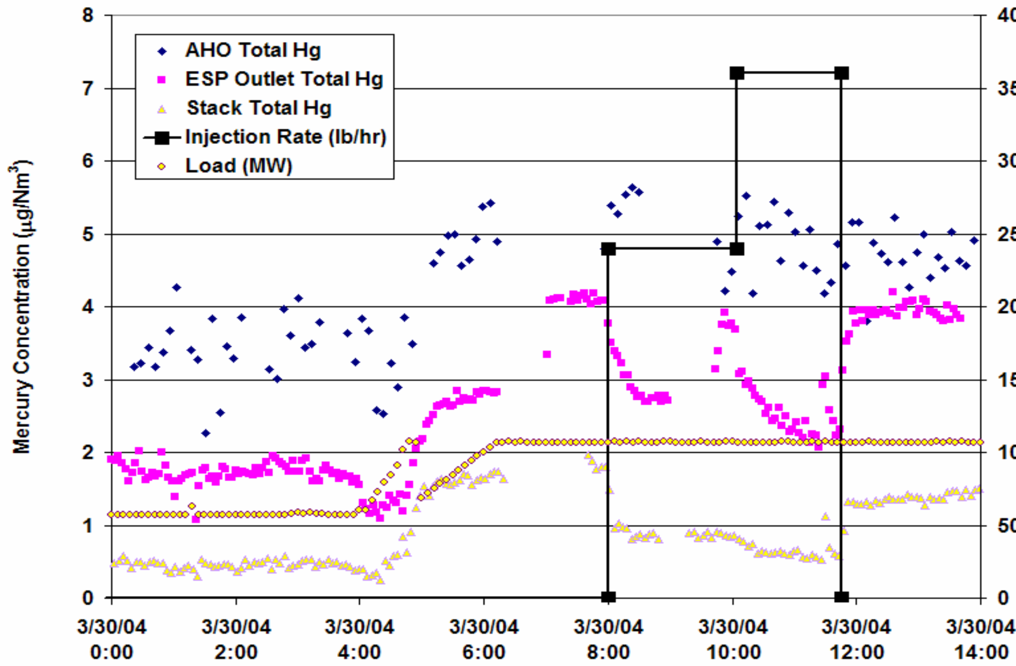

Figure B-11. Vapor Phase Mercury Concentrations measured at Air Heater Outlet, ESP Outlet, and Stack during Day 2 of NH Carbon Injection Testing

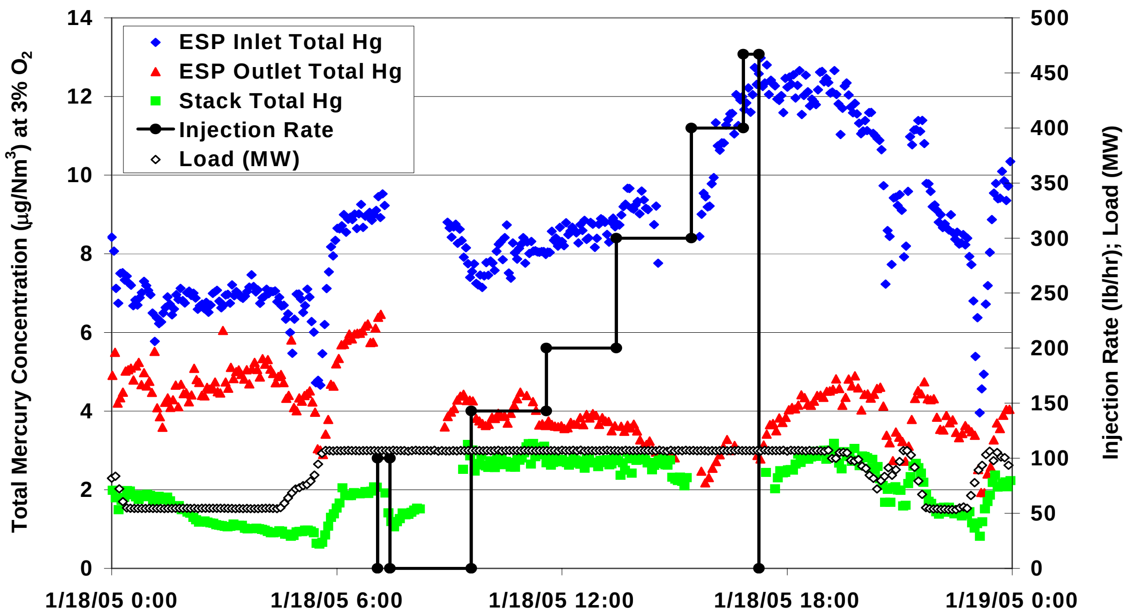

Figure B-12. Vapor-Phase Mercury Concentrations measured at ESP Inlet, ESP Outlet, and Stack during Coarse HOK Injection Testing

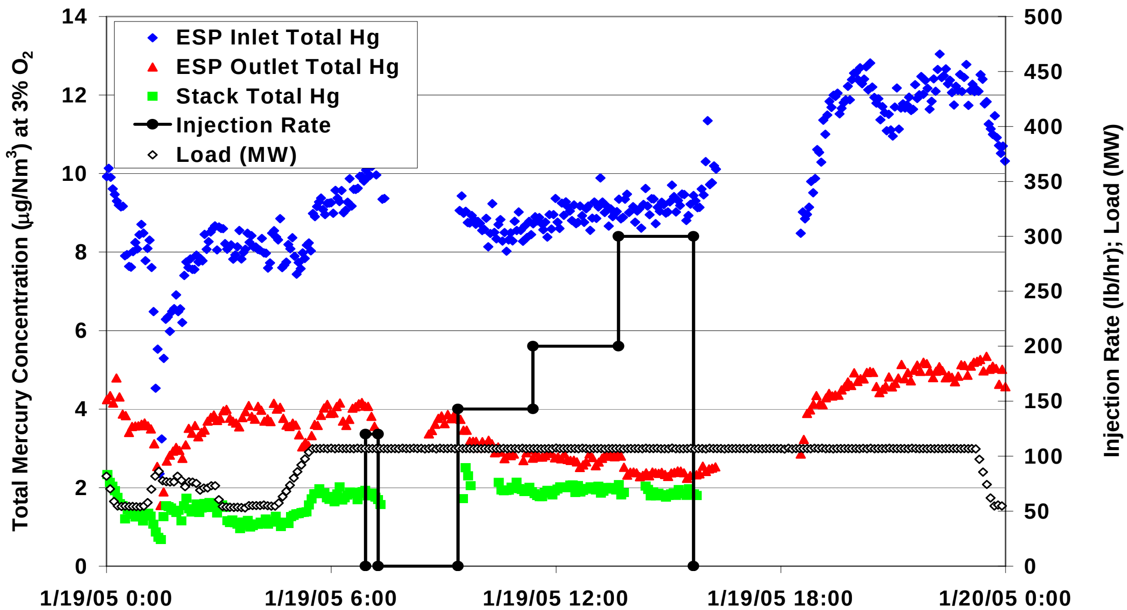

Figure B-13. Vapor-Phase Mercury Concentrations measured at ESP Inlet, ESP Outlet, and Stack during Darco Hg™-Miller Ash Blend Injection Testing

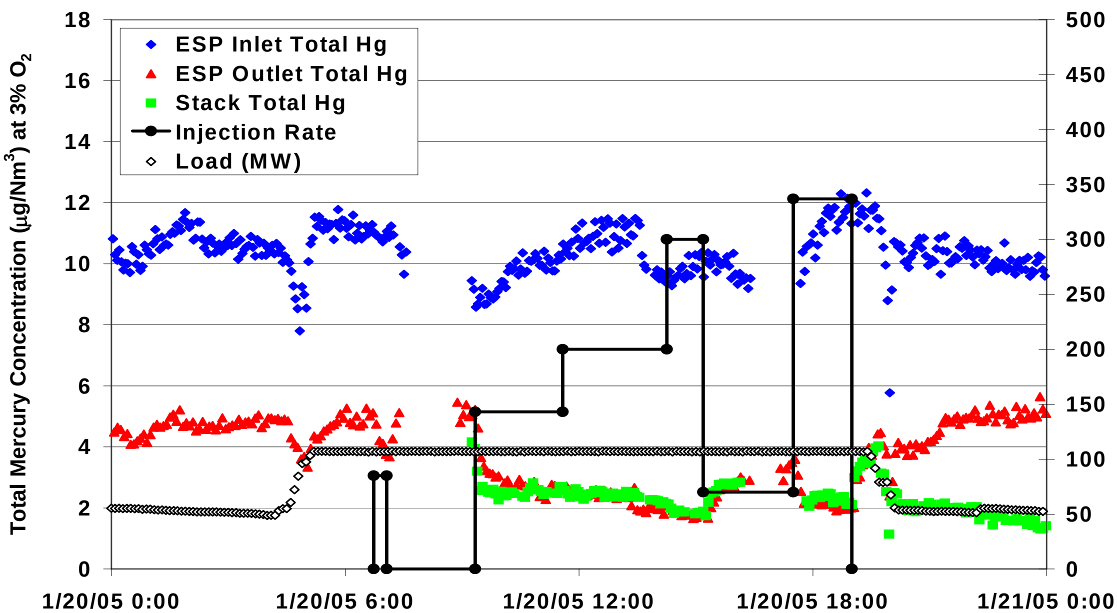

Figure B-14. Vapor-Phase Mercury Concentrations measured at ESP Inlet, ESP Outlet, and Stack during Darco Hg-LH™ Injection Testing

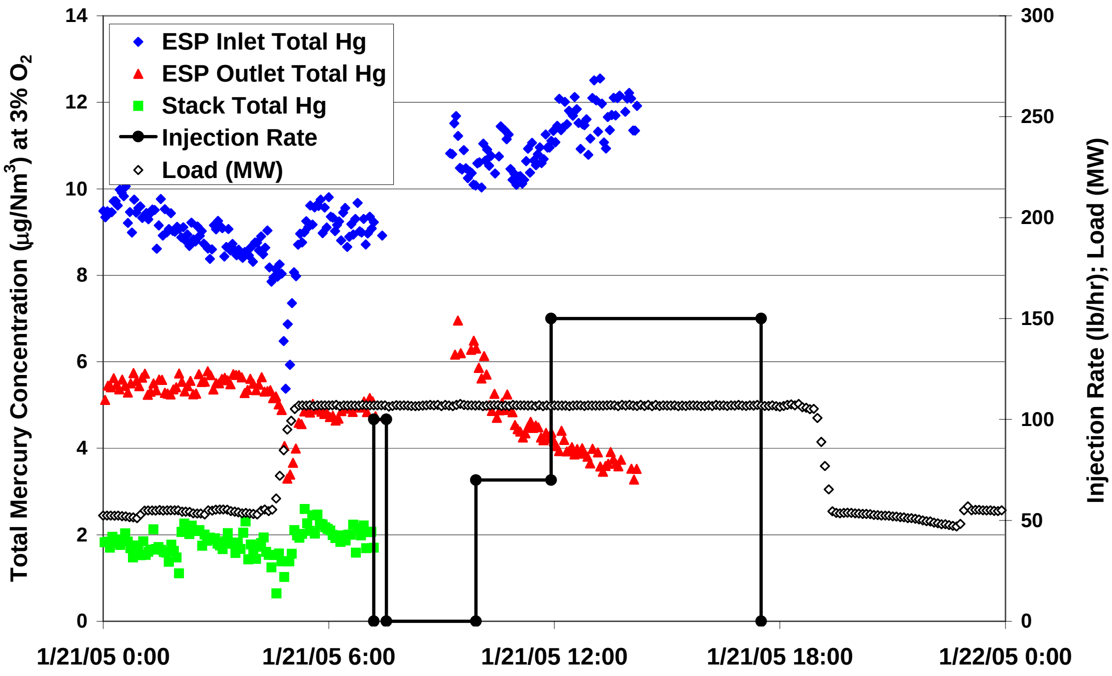

Figure B-15. Vapor-Phase Mercury Concentrations measured at ESP Inlet, ESP Outlet, and Stack during Darco Hg™ Injection Testing

Appendix C
Carbon Injection Rate Data (lb/hr) for Long-Term Test

Date and Time	Rate (lb/hr)
11/15/04 9:50	0
11/15/04 9:50	145
11/15/04 15:30	145
11/15/04 15:30	435
11/15/04 15:50	435
11/15/04 15:50	290
11/15/04 18:00	290
11/15/04 18:00	0
11/16/04 11:20	0
11/16/04 11:20	160
11/16/04 15:15	160
11/16/04 15:15	0
11/16/04 16:30	0
11/16/04 16:30	160
11/16/04 17:00	160
11/16/04 17:00	0
11/16/04 17:30	0
11/16/04 17:30	160
11/18/04 11:15	160
11/18/04 11:15	0
11/18/04 11:45	0
11/18/04 11:45	110
11/22/04 11:43	110
11/22/04 11:43	100
11/22/04 13:07	100
11/22/04 13:07	90
11/23/04 8:48	90
11/23/04 8:48	70
11/26/04 3:00	70
11/26/04 3:00	0
11/26/04 7:25	0
11/26/04 7:25	70
11/30/04 15:40	70
11/30/04 15:40	200
11/30/04 17:50	200
11/30/04 17:50	70
12/1/04 13:45	70
12/1/04 13:45	146

Date and Time	Rate (lb/hr)
12/1/04 14:30	146
12/1/04 14:30	114
12/1/04 18:05	114
12/1/04 18:05	70
12/2/04 11:40	70
12/2/04 11:40	140
12/2/04 13:45	140
12/2/04 13:45	108
12/2/04 13:58	108
12/2/04 13:58	150
12/2/04 14:10	150
12/2/04 14:10	70
12/3/04 16:00	70
12/4/04 12:10	70
12/4/04 12:10	110
12/4/2004 16:31	110
12/4/2004 16:31	70
12/5/2004 9:18	70
12/5/2004 9:18	104
12/5/2004 17:30	104
12/5/2004 17:30	70
12/6/2004 8:34	70
12/6/2004 8:34	104
12/6/2004 18:00	104
12/6/2004 18:00	115
12/7/2004 7:45	115
12/7/2004 7:45	165
12/7/2004 18:00	165
12/7/2004 18:00	115
12/8/2004 8:00	115
12/8/2004 8:00	165
12/8/2004 13:00	165
12/8/2004 13:00	0
12/8/2004 13:30	0
12/8/2004 13:30	290
12/8/2004 18:00	290
12/8/2004 18:00	115
12/9/2004 8:15	115

Date and Time	Rate (lb/hr)
12/9/2004 8:15	400
12/9/2004 13:50	400
12/9/2004 13:50	500
12/9/2004 17:10	500
12/9/2004 17:10	165
12/9/2004 18:00	165
12/9/2004 18:00	115
12/10/2004 8:30	115
12/10/2004 8:30	165
12/10/2004 17:30	165
12/10/2004 17:30	150
12/13/2004 7:47	150
12/13/2004 7:47	0
12/13/2004 8:30	0
12/13/2004 8:30	200
12/13/2004 19:10	200
12/13/2004 19:10	0
12/14/2004 6:40	0
12/14/2004 6:40	100
12/14/2004 7:30	100
12/14/2004 7:30	200
12/14/2004 12:35	200
12/14/2004 12:35	0

.

Appendix D

Long-term Data in Hourly Averages from SCEM, Carbon Injection Skid, and Plant

Symbol	Definition
†	Vapor Phase Concentrations from Hg SCEMs
*	Calculated Result from SCEM data
‡	Injection Rate calculated from injection skid lb/hr carbon feed and calculated flue gas flow rate
§	Plant Data
&	Flue gas flow rate calculated from Yate's reported unit load and a correlation of Flow Rate versus Load developed from flue gas flow measurements performed by URS Stack Sampling Crew

Note: Blanks in a datum cell indicate datum point was not available. Actual zeros are indicated with a numerical zero.

Date/Time	ESP Inlet Total Hg (μg/Nm^3, 3% O_2) †	ESP Outlet Total Hg (μg/Nm^3, 3% O_2) †	Stack Total Hg (μg/Nm^3, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/13 8:00		3.3			2.2					0.0	56.1	254.5	239.4	216.5	283219
11/13 9:00	8.0	3.2	2.6	5.3	2.2	1.7	59%	19%	67%	0.0	56.1	254.2	239.1	216.9	283253
11/13 10:00	6.5	3.2	1.6	4.3	2.1	1.0	50%	52%	76%	0.0	56.6	254.6	239.1	217.3	285269
11/13 11:00	5.9	3.5	1.3	3.9	2.3	0.8	41%	63%	78%	0.0	56.1	258.0	241.9	219.0	282958
11/13 12:00	6.5	3.5	1.2	4.3	2.3	0.8	46%	65%	81%	0.0	56.1	259.8	243.1	220.9	283320
11/13 13:00	8.0	3.6	1.3	5.3	2.4	0.8	56%	64%	84%	0.0	56.0	260.4	242.9	221.9	282706
11/13 14:00										0.0	54.5	260.8	243.0	221.6	276522
11/13 15:00	6.9			4.6						0.0	52.6	260.2	243.7	221.2	268798
11/13 16:00	6.7	4.4	2.5	4.5	2.9	1.6	35%	43%	63%	0.0	51.2	258.5	243.9	220.2	262835
11/13 17:00		4.4	2.2		2.9	1.5		49%		0.0	55.2	256.3	241.7	219.1	279226
11/13 18:00	8.7	5.3	2.3	5.8	3.5	1.5	39%	57%	74%	0.0	56.2	255.1	238.3	217.5	283528
11/13 19:00		5.5	2.3		3.7	1.5		59%		0.0	56.1	257.4	240.0	217.6	283255
11/13 20:00		5.3	2.0		3.5	1.3		62%		0.0	56.1	256.8	239.7	217.3	282946
11/13 21:00		5.1	1.4		3.4	0.9		73%		0.0	55.9	255.3	239.1	216.4	282490
11/13 22:00		4.4	2.4		2.9	1.6		46%		0.0	56.0	251.9	236.6	214.6	282693
11/13 23:00		3.9	2.1		2.6	1.4		47%		0.0	55.9	251.9	236.5	213.4	282159
11/14 0:00		3.6	1.9		2.4	1.2		47%		0.0	56.0	251.9	237.7	213.4	282636
11/14 1:00		3.8	1.6		2.5	1.1		57%		0.0	56.3	254.1	239.4	214.4	284095
11/14 2:00		3.8	1.3		2.5	0.9		66%		0.0	56.3	254.0	239.6	214.6	283993
11/14 3:00		3.7	1.4		2.5	1.0		61%		0.0	56.1	254.5	240.9	214.6	283044
11/14 4:00		3.7	1.7		2.5	1.1		53%		0.0	56.2	254.0	240.2	214.7	283373
11/14 5:00		3.6			2.4					0.0	56.1	252.9	238.9	213.6	283311
11/14 6:00		3.5			2.4					0.0	61.5	252.9	239.4	213.6	305687
11/14 7:00		3.5			2.3					0.0	56.6	252.8	239.8	213.2	285124

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/14 8:00										0.0	56.2	253.6	239.0	213.2	283718
11/14 9:00		4.7			3.1					0.0	56.5	251.7	237.7	212.7	284983
11/14 10:00		4.4	2.4		2.9	1.6		45%		0.0	56.2	252.5	238.4	212.9	283349
11/14 11:00		4.4	2.4		2.9	1.6		46%		0.0	56.1	255.3	240.7	214.7	283092
11/14 12:00		4.1			2.7					0.0	56.1	256.0	241.5	216.2	282989
11/14 13:00		4.8	1.6		3.2	1.0		67%		0.0	54.7	255.6	241.2	216.6	277468
11/14 14:00		4.8	1.4		3.2	0.9		70%		0.0	55.7	257.1	242.7	217.9	281411
11/14 15:00		4.9	1.3		3.2	0.9		73%		0.0	56.3	258.8	243.1	219.2	283832
11/14 16:00	7.5	4.7		5.0	3.1		38%			0.0	56.2	259.6	243.4	220.1	283516
11/14 17:00	8.5	4.1		5.6	2.7		52%			0.0	57.6	258.4	242.2	219.6	289279
11/14 18:00	10.9	3.6		7.2	2.4		67%			0.0	56.2	257.6	242.1	218.4	283459
11/14 19:00	13.2	3.4		8.7	2.3		74%			0.0	55.9	255.3	241.4	216.5	282129
11/14 20:00	13.6	3.2		9.0	2.1		76%			0.0	58.5	251.2	239.0	214.0	293002
11/14 21:00	11.4	2.5		7.6	1.6		78%			0.0	71.5	249.9	241.3	214.0	347138
11/14 22:00	10.7	2.1		7.1	1.4		80%			0.0	63.7	249.7	242.8	214.7	314824
11/14 23:00	10.0	2.0		6.7	1.4		80%			0.0	57.2	247.1	240.1	211.2	287510
11/15 0:00	8.0	1.7	0.6	5.3	1.1	0.4	79%	63%	92%	0.0	56.4	245.5	237.4	208.7	284361
11/15 1:00	7.1	1.4	0.7	4.7	1.0	0.5	80%	52%	90%	0.0	56.1	245.1	237.9	207.8	283259
11/15 2:00	6.1	1.2	0.4	4.0	0.8	0.3	80%	64%	93%	0.0	56.0	243.8	237.2	206.8	282802
11/15 3:00	6.6	1.1	0.6	4.4	0.7	0.4	83%	49%	91%	0.0	56.1	242.9	236.5	205.4	282927
11/15 4:00	5.6	0.8	0.5	3.7	0.6	0.3	85%	44%	92%	0.0	55.7	247.2	240.4	207.8	281428
11/15 5:00	5.0	0.8	0.7	3.3	0.5	0.4	85%	11%	86%	0.0	56.7	239.4	232.5	203.8	285573
11/15 6:00	5.1	0.8	0.5	3.4	0.5	0.3	85%	33%	90%	0.0	59.9	238.2	231.4	202.1	298848
11/15 7:00	5.0	0.7	0.7	3.3	0.4	0.4	87%	-1%	87%	0.0	57.7	244.1	238.2	204.5	289971

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/15 8:00	6.6		1.7	4.4		1.1			74%	0.0	56.1	239.6	234.6	203.8	283142
11/15 9:00	6.4	1.5	1.7	4.3	1.0	1.2	77%	-16%	73%	0.0	55.9	241.2	235.7	204.4	282373
11/15 10:00	7.4	1.3	1.2	4.9	0.9	0.8	83%	11%	84%	8.7	54.4	245.9	241.1	208.2	276221
11/15 11:00	7.5	1.3	1.0	4.9	0.9	0.7	82%	23%	86%	8.6	55.6	249.1	241.2	211.8	281064
11/15 12:00	8.2	1.5	1.0	5.5	1.0	0.7	81%	35%	88%	8.8	54.1	251.4	243.4	214.1	274625
11/15 13:00	8.9	1.8	0.9	5.9	1.2	0.6	80%	49%	90%	9.0	52.8	253.5	246.1	217.0	269241
11/15 14:00	8.4	1.0	0.9	5.6	0.7	0.6	88%	17%	90%	8.6	55.3	254.3	244.2	218.5	279724
11/15 15:00	9.6	1.4	0.8	6.4	1.0	0.5	85%	47%	92%	8.6	55.8	255.6	243.8	219.3	281775
11/15 16:00	9.1	1.1	0.6	6.0	0.7	0.4	88%	45%	93%	17.1	56.1	256.2	244.4	220.0	283206
11/15 17:00	9.1	1.3		6.0	0.8		86%			16.2	59.7	253.3	241.7	219.0	297901
11/15 18:00	9.5	1.8		6.3	1.2		81%			17.0	56.2	251.4	239.5	215.0	283700
11/15 19:00	10.1	1.6		6.7	1.0		84%			0.0	56.5	249.1	238.2	212.3	284934
11/15 20:00	10.4	1.3		6.9	0.9		87%			0.0	56.2	248.6	238.4	210.6	283380
11/15 21:00	10.3	1.2		6.9	0.8		88%			0.0	56.3	246.7	238.1	209.2	284119
11/15 22:00	9.0	1.0		6.0	0.7		88%			0.0	56.1	244.0	236.7	207.6	283065
11/15 23:00	6.7	0.7		4.5	0.5		89%			0.0	56.2	241.3	236.2	205.7	283649
11/16 0:00	6.6	0.7		4.4	0.4		90%			0.0	56.0	240.5	235.2	204.4	282837
11/16 1:00	7.1	0.7		4.7	0.5		90%			0.0	55.9	239.4	234.8	203.2	282332
11/16 2:00	6.3			4.2						0.0	56.5	238.9	235.2	202.6	284991
11/16 3:00	6.0			4.0						0.0	56.0	238.8	234.0	202.5	282754
11/16 4:00	6.0			4.0						0.0	55.9	239.2	234.5	202.2	282172
11/16 5:00	5.7			3.8						0.0	56.6	238.2	234.2	202.1	285151
11/16 6:00	5.1			3.4						0.0	69.4	245.8	232.6	204.6	338271
11/16 7:00	4.8			3.2						0.0	57.7	268.8	236.8	213.5	289878

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/16 8:00										0.0	53.9	266.3	227.4	212.4	274154
11/16 9:00	4.8	1.0		3.2	0.7		79%			0.0	53.4	266.1	226.1	211.0	271881
11/16 10:00	5.2	1.1	1.7	3.4	0.7	1.1	80%	-62%	67%	0.0	54.5	267.0	226.6	212.8	276566
11/16 11:00	5.4	2.5	1.6	3.6	1.7	1.1	53%	37%	70%	0.0	53.8	270.8	229.0	216.1	273457
11/16 12:00	5.7	2.0	1.1	3.8	1.3	0.7	65%	45%	81%	9.9	52.6	270.5	227.1	217.1	268527
11/16 13:00		1.8	1.0		1.2	0.6		48%		9.8	53.3	273.0	229.0	219.0	271476
11/16 14:00		1.5	0.8		1.0	0.6		43%		9.4	56.2	274.0	229.6	221.0	283454
11/16 15:00		1.9	1.1		1.3	0.7		42%		9.5	55.7	276.3	230.8	222.7	281550
11/16 16:00	6.6	1.7		4.4	1.1		75%			0.0	55.5	277.4	231.2	224.1	280475
11/16 17:00	6.8	2.1	1.9	4.5	1.4	1.3	69%	9%	72%	4.7	56.2	274.6	229.7	222.6	283613
11/16 18:00	7.2	1.9	4.3	4.7	1.3	2.9	74%	-128%	40%	4.7	56.2	271.8	228.3	219.8	283676
11/16 19:00	7.3	1.7	2.6	4.9	1.1	1.7	77%	-53%	65%	9.4	56.2	269.7	226.8	217.5	283589
11/16 20:00	7.2	1.6	1.8	4.8	1.1	1.2	77%	-12%	74%	9.4	56.0	268.0	225.8	215.9	282895
11/16 21:00	6.7	1.4	1.6	4.4	0.9	1.0	79%	-10%	77%	9.5	55.7	264.0	223.8	213.0	281642
11/16 22:00	7.4	1.4	1.5	4.9	0.9	1.0	82%	-7%	80%	9.4	56.2	264.9	223.4	212.3	283706
11/16 23:00	7.5	1.4	1.3	5.0	0.9	0.9	82%	1%	82%	9.6	54.6	266.7	223.8	211.4	276859
11/17 0:00	7.4	1.3	1.2	4.9	0.8	0.8	83%	3%	83%	9.8	53.3	266.1	223.5	211.0	271649
11/17 1:00	7.1	1.2	1.1	4.7	0.8	0.7	84%	6%	85%	9.4	56.0	264.6	223.1	210.8	282673
11/17 2:00	6.8	1.1	1.1	4.5	0.7	0.7	84%	0%	84%	9.4	56.1	265.2	223.8	210.9	283044
11/17 3:00	6.7	1.0	1.0	4.4	0.6	0.7	86%	-4%	85%	9.4	56.3	264.3	223.7	210.5	283818
11/17 4:00	6.5	0.9	0.9	4.3	0.6	0.6	86%	5%	87%	9.5	55.5	265.5	224.8	210.9	280696
11/17 5:00	5.9	0.8	0.8	3.9	0.6	0.5	86%	1%	86%	9.3	57.2	263.3	223.5	210.4	287513
11/17 6:00	5.2	0.9	0.9	3.5	0.6	0.6	83%	-1%	83%	8.3	65.7	260.1	224.5	210.4	323123
11/17 7:00	5.6	0.9	0.9	3.7	0.6	0.6	84%	-3%	83%	9.2	58.1	263.9	227.6	211.2	291300

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/17 8:00			0.8			0.5				9.4	56.0	267.9	227.5	212.7	282875
11/17 9:00			1.0			0.7				9.7	54.4	271.3	229.7	215.6	276018
11/17 10:00	4.8	1.2	1.2	3.2	0.8	0.8	74%	4%	75%	9.7	54.0	274.8	231.8	219.0	274548
11/17 11:00	4.0	1.1	0.9	2.7	0.7	0.6	73%	15%	77%	9.4	56.1	276.2	232.9	221.9	283265
11/17 12:00	3.8	1.0	0.9	2.5	0.7	0.6	73%	16%	77%	9.4	56.2	278.8	234.2	224.4	283393
11/17 13:00	3.9	0.9	0.8	2.6	0.6	0.5	77%	11%	79%	9.4	56.1	280.2	235.1	226.4	283275
11/17 14:00	4.2	0.8	0.8	2.8	0.6	0.5	80%	1%	80%	9.4	56.3	281.5	235.4	227.8	283757
11/17 15:00		0.8			0.5					9.5	55.8	282.3	235.9	228.7	281986
11/17 16:00		0.8			0.5					9.4	56.4	282.0	235.6	229.1	284512
11/17 17:00		1.4	0.8		0.9	0.6		40%		8.9	59.7	277.2	233.4	227.7	298188
11/17 18:00	4.1	1.3	0.7	2.7	0.8	0.5	69%	45%	83%	9.4	56.3	279.0	232.8	225.0	283938
11/17 19:00	5.2	1.4	0.6	3.5	0.9	0.4	74%	53%	88%	9.2	57.4	278.5	232.2	223.8	288482
11/17 20:00	5.8	1.3	0.7	3.8	0.8	0.4	78%	48%	89%	9.4	56.3	275.0	231.2	221.9	283931
11/17 21:00	6.6	1.4	0.7	4.4	0.9	0.5	79%	48%	89%	9.4	56.1	275.7	230.9	220.9	283110
11/17 22:00	6.8	1.4	0.7	4.5	0.9	0.5	79%	49%	89%	9.4	56.0	274.7	230.8	219.8	282627
11/17 23:00	6.6	1.4	0.8	4.4	0.9	0.5	79%	44%	88%	9.6	55.1	273.8	229.8	219.0	279105
11/18 0:00	6.9	1.4	0.7	4.6	0.9	0.5	80%	50%	90%	9.4	56.1	272.4	229.1	217.9	283146
11/18 1:00	6.6	1.4	0.7	4.4	0.9	0.4	79%	51%	90%	9.3	56.7	271.8	229.4	217.2	285802
11/18 2:00	6.3	1.3	0.6	4.2	0.9	0.4	79%	51%	90%	9.4	56.3	272.9	228.8	216.6	283897
11/18 3:00	6.0	1.1	0.6	4.0	0.7	0.4	81%	48%	90%	9.4	56.1	271.9	228.2	216.2	283250
11/18 4:00	5.9	1.2	0.6	3.9	0.8	0.4	80%	49%	90%	9.0	59.0	270.3	228.2	215.7	295022
11/18 5:00	4.6	0.9	0.5	3.0	0.6	0.3	81%	41%	89%	9.4	56.3	270.1	231.5	215.8	283969
11/18 6:00	5.9	1.0	0.6	3.9	0.7	0.4	82%	45%	90%	9.6	55.1	272.6	229.7	216.1	279002
11/18 7:00	5.8	1.1	0.6	3.8	0.7	0.4	82%	45%	90%	9.4	56.1	270.6	229.0	215.5	283070

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O₂) †	ESP Outlet Total Hg (µg/Nm³, 3% O₂) †	Stack Total Hg (µg/Nm³, 3% O₂) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O₂) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
11/18 8:00		1.1	0.6		0.7	0.4		42%		9.4	56.3	270.2	228.6	215.6	283962
11/18 9:00	4.4	1.4		2.9	0.9		68%			9.4	56.1	271.7	230.6	217.1	282954
11/18 10:00	5.8	1.4	0.8	3.8	0.9	0.5	76%	44%	87%	9.4	56.2	273.7	231.4	219.3	283371
11/18 11:00	5.9	1.9	0.9	3.9	1.3	0.6	67%	55%	85%	9.4	56.3	276.8	232.8	222.1	283873
11/18 12:00	5.8	1.7	0.7	3.8	1.1	0.5	71%	58%	87%	4.0	56.3	278.4	233.5	224.2	283938
11/18 13:00	6.2	1.7	0.8	4.1	1.1	0.5	73%	54%	88%	6.5	56.0	279.9	234.5	226.0	282855
11/18 14:00	6.2	1.6	0.8	4.1	1.1	0.5	74%	52%	88%	6.5	56.1	281.1	235.0	227.3	283019
11/18 15:00		1.6			1.1					6.5	56.0	281.7	235.3	227.6	282697
11/18 16:00	5.9		0.8	3.9		0.6			86%	6.4	57.4	280.6	234.3	227.3	288474
11/18 17:00	5.7	1.3	0.6	3.8	0.8	0.4	78%	49%	89%	6.5	56.3	277.9	232.9	225.1	283865
11/18 18:00	7.3	1.5	0.7	4.9	1.0	0.5	79%	56%	91%	6.5	56.1	277.9	232.7	224.4	283166
11/18 19:00	7.8	1.6	0.7	5.2	1.1	0.5	79%	56%	91%	6.4	56.4	277.3	232.4	223.7	284302
11/18 20:00	7.9	1.5	0.6	5.2	1.0	0.4	81%	58%	92%	6.5	56.4	277.2	232.2	223.1	284211
11/18 21:00	7.7	1.5		5.1	1.0		81%			6.5	56.0	277.0	232.0	222.6	282652
11/18 22:00	7.8	1.4		5.2	0.9		82%			6.5	56.2	276.1	231.3	222.0	283596
11/18 23:00	7.7	1.3		5.1	0.9		82%			6.5	56.1	275.0	230.8	221.3	283300
11/19 0:00	7.7	1.5		5.1	1.0		81%			6.5	56.0	275.4	230.5	220.7	282851
11/19 1:00	7.3	1.5		4.9	1.0		79%			6.5	56.2	275.2	230.3	220.3	283562
11/19 2:00	7.1	1.5		4.7	1.0		79%			6.5	56.2	274.4	229.9	219.7	283411
11/19 3:00	7.1	1.5		4.7	1.0		79%			6.5	56.0	274.6	230.1	219.3	282734
11/19 4:00	7.0	1.5		4.6	1.0		78%			6.5	56.1	274.4	230.0	219.2	283292
11/19 5:00	6.5	1.5		4.3	1.0		77%			6.4	56.5	273.4	229.0	218.7	284844
11/19 6:00	6.0	1.3		4.0	0.9		78%			6.3	58.0	272.3	227.8	218.1	291100
11/19 7:00	5.6	1.2		3.7	0.8		79%			6.6	54.5	272.4	228.9	217.5	276664

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/19 8:00		1.4			0.9					6.5	55.6	268.7	225.9	216.4	281221
11/19 9:00	5.6			3.7						6.9	51.5	267.7	225.5	216.6	264156
11/19 10:00	6.5	1.3		4.3	0.9		79%			7.7	45.2	267.5	228.3	214.8	238071
11/19 11:00	6.9	1.6	1.3	4.6	1.1	0.9	77%	18%	81%	7.6	45.7	272.4	233.1	218.4	239878
11/19 12:00	6.5	1.6	1.4	4.3	1.1	1.0	75%	11%	78%	6.2	59.4	271.4	230.6	221.0	297011
11/19 13:00	7.0	1.8	1.6	4.6	1.2	1.0	75%	12%	78%	6.6	55.3	277.8	231.7	222.6	279701
11/19 14:00	6.7	1.8	1.5	4.4	1.2	1.0	73%	15%	77%	6.6	55.3	275.6	229.9	222.6	279714
11/19 15:00			1.5			1.0				6.6	55.3	277.6	231.3	223.3	279781
11/19 16:00	6.8	2.1	1.6	4.5	1.4	1.1	68%	26%	77%	6.5	55.7	278.0	231.7	223.8	281340
11/19 17:00	7.7	2.1	1.5	5.1	1.4	1.0	72%	30%	81%	6.0	62.1	275.3	232.7	224.2	307974
11/19 18:00	8.2	1.8	1.5	5.5	1.2	1.0	78%	19%	82%	6.6	55.1	280.8	235.4	225.6	279027
11/19 19:00	8.3	1.7	1.3	5.5	1.2	0.9	79%	23%	84%	6.6	55.2	279.2	232.1	224.5	279343
11/19 20:00	8.4	1.7	1.2	5.5	1.1	0.8	80%	30%	86%	6.6	54.9	279.7	232.1	224.3	278220
11/19 21:00	8.6	1.7	1.1	5.7	1.1	0.7	80%	35%	87%	6.6	54.8	279.9	232.7	224.6	277630
11/19 22:00	8.5	1.7	1.1	5.7	1.1	0.7	81%	35%	87%	6.7	54.3	279.7	233.2	224.8	275617
11/19 23:00	8.7	1.8	1.0	5.8	1.2	0.7	80%	43%	88%	6.6	54.9	280.0	232.8	225.1	278075
11/20 0:00	8.8	1.7	0.9	5.8	1.1	0.6	81%	44%	89%	6.7	53.7	280.8	233.2	225.4	273290
11/20 1:00	8.8	1.7	0.9	5.9	1.1	0.6	81%	44%	89%	6.5	55.3	281.5	233.9	225.8	279942
11/20 2:00	9.0	1.7	0.9	6.0	1.1	0.6	81%	46%	90%	6.6	55.0	281.8	234.5	226.4	278442
11/20 3:00	9.1	1.9	0.9	6.0	1.2	0.6	80%	49%	90%	6.6	55.1	281.8	234.4	226.5	279083
11/20 4:00	9.0	1.8	0.9	6.0	1.2	0.6	80%	50%	90%	6.6	55.2	281.4	234.8	226.2	279296
11/20 5:00	9.2	1.9	1.0	6.1	1.3	0.7	79%	49%	89%	6.5	56.1	280.7	234.7	226.1	282949
11/20 6:00	9.0	2.0	1.0	6.0	1.3	0.7	78%	47%	89%	6.4	56.6	281.6	234.0	226.0	285390
11/20 7:00	8.5	1.9	1.0	5.6	1.3	0.7	78%	47%	88%	6.6	55.1	276.9	231.4	224.1	278912

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/20 8:00		2.0	1.0		1.3	0.7		49%		6.6	55.1	276.9	231.5	223.5	279131
11/20 9:00	5.8	1.7		3.9	1.1		72%			6.6	55.0	276.8	231.5	223.5	278708
11/20 10:00	5.7	1.7		3.8	1.1		71%			6.6	55.2	276.6	231.0	224.0	279264
11/20 11:00	5.7	1.8	1.0	3.8	1.2	0.6	69%	45%	83%	6.3	57.8	277.2	233.0	224.7	290346
11/20 12:00	5.5	1.4	1.6	3.6	0.9	1.1	74%	-15%	70%	6.6	55.0	280.1	235.7	226.9	278381
11/20 13:00	5.6	1.3	1.5	3.7	0.9	1.0	76%	-11%	74%	6.5	55.4	280.2	234.2	226.9	280302
11/20 14:00	5.6	1.6	1.0	3.7	1.0	0.7	72%	37%	82%	6.6	55.1	281.3	234.8	227.5	278921
11/20 15:00	5.6	1.7	1.0	3.7	1.2	0.6	69%	44%	83%	6.6	55.1	281.1	234.5	227.6	279048
11/20 16:00	6.0	2.2	0.9	4.0	1.5	0.6	64%	57%	84%	6.6	55.2	280.8	234.5	227.5	279532
11/20 17:00	6.8	2.1	0.9	4.5	1.4	0.6	69%	56%	86%	6.4	57.0	278.2	233.5	226.8	286801
11/20 18:00										#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
11/20 19:00	7.5	1.9	1.1	5.0	1.3	0.7	75%	41%	85%	6.6	55.3	281.5	234.0	226.4	279721
11/20 20:00	7.8	2.0	1.2	5.2	1.3	0.8	75%	40%	85%	6.6	54.9	281.7	234.0	226.5	278096
11/20 21:00	7.6	1.9	1.2	5.0	1.3	0.8	75%	35%	84%	6.6	55.2	280.1	232.8	225.9	279593
11/20 22:00	7.7	1.9	1.2	5.1	1.3	0.8	75%	38%	84%	6.6	55.3	280.5	232.9	225.4	279672
11/20 23:00	7.7	2.0	1.2	5.1	1.3	0.8	74%	38%	84%	6.6	55.1	280.1	233.0	225.8	279019
11/21 0:00	7.4	2.0	1.2	4.9	1.3	0.8	73%	42%	84%	6.5	55.5	279.9	233.1	225.4	280829
11/21 1:00	6.9	1.8	1.2	4.6	1.2	0.8	73%	37%	83%	6.4	57.0	277.7	234.7	225.4	286928
11/21 2:00	7.9	1.8	1.2	5.2	1.2	0.8	77%	36%	85%	6.8	53.2	282.0	233.8	225.7	271034
11/21 3:00	8.0	1.9	1.2	5.3	1.3	0.8	76%	39%	85%	6.9	52.2	281.5	233.5	225.2	266963
11/21 4:00	8.1	1.9	1.2	5.4	1.3	0.8	76%	39%	85%	6.7	53.5	280.2	232.7	225.0	272252
11/21 5:00	8.4	2.0	1.2	5.6	1.3	0.8	76%	40%	86%	6.7	53.5	282.1	233.3	225.3	272446
11/21 6:00	8.3	1.9	1.1	5.5	1.2	0.7	78%	40%	87%	6.6	54.4	280.5	232.9	225.2	276120
11/21 7:00	8.0	2.0	1.2	5.3	1.3	0.8	75%	38%	85%	6.5	56.2	278.9	232.7	224.9	283433

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
11/21 8:00	6.2	2.3	1.1	4.1	1.5	0.7	64%	53%	83%	6.4	56.7	276.7	233.4	224.7	285520
11/21 9:00	5.9		1.5	3.9		1.0			75%	6.5	55.4	279.3	233.0	224.5	280381
11/21 10:00	6.1	1.7	1.3	4.0	1.1	0.9	72%	25%	79%	6.6	55.2	279.7	232.4	224.6	279527
11/21 11:00	5.9	2.2	0.9	3.9	1.5	0.6	63%	60%	85%	6.6	55.2	277.9	231.9	223.9	279278
11/21 12:00		2.3	0.9		1.5	0.6		62%		6.5	55.6	277.7	231.8	223.9	281040
11/21 13:00		2.2	0.9		1.5	0.6		60%		6.6	55.0	277.7	231.8	223.5	278632
11/21 14:00	6.5	2.0	0.8	4.3	1.3	0.5	69%	59%	87%	6.6	55.3	275.8	230.5	222.0	279897
11/21 15:00	7.4	1.6		4.9	1.0		79%			6.6	55.2	275.2	229.7	220.1	279339
11/21 16:00	7.3	2.2	1.1	4.9	1.5	0.7	70%	50%	85%	6.5	55.9	276.6	230.5	220.6	282269
11/21 17:00	8.4	2.1	1.1	5.6	1.4	0.7	74%	51%	87%	6.5	56.2	275.0	231.3	221.0	283573
11/21 18:00	11.1	2.2	1.0	7.4	1.5	0.7	80%	56%	91%	6.7	53.7	278.4	231.3	221.7	273000
11/21 19:00	12.1	2.2	1.0	8.1	1.5	0.7	81%	55%	92%	6.8	53.1	278.5	230.6	221.7	270644
11/21 20:00	12.1	2.2	1.0	8.0	1.5	0.6	82%	57%	92%	6.8	52.8	276.8	229.1	221.1	269589
11/21 21:00	11.7	2.2	0.9	7.8	1.5	0.6	81%	57%	92%	6.7	54.1	278.2	230.7	221.9	274671
11/21 22:00	10.6	2.1	0.8	7.0	1.4	0.5	80%	64%	93%	6.7	54.0	278.5	231.4	222.1	274480
11/21 23:00	10.2	1.8	0.8	6.8	1.2	0.5	83%	54%	92%	6.6	54.4	277.6	231.2	222.1	276003
11/22 0:00	11.7	2.0	0.8	7.8	1.3	0.6	83%	57%	93%	6.8	52.7	279.1	231.0	222.3	269132
11/22 1:00	12.1	2.0	0.9	8.0	1.3	0.6	83%	58%	93%	6.6	54.9	277.7	230.7	222.3	278319
11/22 2:00	12.3	2.0	0.9	8.1	1.4	0.6	83%	57%	93%	6.6	55.0	277.3	230.9	222.3	278458
11/22 3:00	12.5	2.1	0.9	8.3	1.4	0.6	83%	60%	93%	6.6	55.2	277.7	231.4	222.6	279325
11/22 4:00	12.9	2.1	0.9	8.6	1.4	0.6	84%	58%	93%	6.5	56.0	277.5	231.2	222.8	282577
11/22 5:00	12.8	2.0	0.8	8.5	1.3	0.5	85%	58%	94%	6.7	53.7	278.2	231.7	222.8	272965
11/22 6:00	13.5	2.0	0.8	8.9	1.3	0.5	85%	59%	94%	6.4	56.8	274.6	228.8	221.8	286102
11/22 7:00	13.1	2.1	0.8	8.7	1.4	0.6	84%	59%	94%	6.5	55.7	279.0	236.6	224.5	281287

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
11/22 8:00	13.9	1.9	0.8	9.2	1.2	0.5	86%	56%	94%	6.7	53.6	280.0	232.9	224.5	272889
11/22 9:00		2.0	0.8		1.3	0.5		59%		6.7	53.6	280.4	232.7	224.6	272639
11/22 10:00	7.4			4.9						6.8	53.1	280.8	232.7	224.9	270819
11/22 11:00	7.9	1.9	1.2	5.2	1.3	0.8	76%	35%	84%	6.8	53.2	281.0	233.0	225.4	270901
11/22 12:00	7.7	1.9	0.9	5.1	1.3	0.6	75%	52%	88%	6.7	53.7	281.0	233.2	226.0	273246
11/22 13:00	7.3	1.8	0.8	4.8	1.2	0.6	75%	53%	88%	5.9	55.4	278.6	233.1	225.2	280169
11/22 14:00	7.4	1.9	0.7	4.9	1.3	0.5	74%	63%	90%	5.3	55.8	278.1	235.4	225.6	281929
11/22 15:00	7.9			5.2						5.3	55.6	280.6	234.4	226.2	280863
11/22 16:00	8.1	2.2	1.0	5.4	1.5	0.7	73%	55%	88%	5.2	57.4	280.5	233.8	226.4	288346
11/22 17:00	9.6	2.1	0.9	6.4	1.4	0.6	78%	58%	91%	5.0	59.7	281.2	239.9	228.2	297922
11/22 18:00	10.9	1.9	0.8	7.2	1.3	0.5	82%	60%	93%	5.4	55.3	280.4	234.4	224.2	279864
11/22 19:00	11.3	2.0	0.7	7.5	1.3	0.5	83%	64%	94%	5.4	55.3	280.0	233.3	222.5	279661
11/22 20:00		1.9	0.7		1.3	0.4		65%		5.4	55.2	280.0	233.3	221.7	279201
11/22 21:00		1.9	0.7		1.2	0.4		64%		5.5	53.8	280.2	233.2	222.2	273772
11/22 22:00		1.9	0.7		1.3	0.5		64%		5.5	53.3	280.4	232.8	222.7	271399
11/22 23:00		2.0	0.7		1.3	0.4		66%		5.6	52.4	280.8	232.7	223.0	267765
11/23 0:00		2.0	0.7		1.3	0.4		67%		5.6	52.7	280.8	232.2	223.4	269005
11/23 1:00		1.9	0.7		1.3	0.4		65%		5.4	54.6	279.6	232.9	223.7	277036
11/23 2:00		1.9	0.7		1.2	0.5		64%		5.4	55.1	279.3	232.8	224.0	278921
11/23 3:00		1.9	0.7		1.3	0.5		62%		5.4	55.1	278.8	232.8	224.2	278804
11/23 4:00		1.9	0.7		1.3	0.5		63%		5.4	55.2	278.9	233.1	224.3	279384
11/23 5:00		1.9	0.7		1.3	0.5		62%		5.4	55.1	279.6	233.5	224.6	278804
11/23 6:00		1.9	0.8		1.3	0.5		61%		5.3	55.8	278.9	233.0	225.0	281717
11/23 7:00		1.9	0.8		1.3	0.5		59%		5.4	55.1	276.4	232.8	224.3	279042

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
11/23 8:00	11.1	1.9	0.8	7.3	1.3	0.5	83%	60%	93%	5.4	55.1	279.4	233.4	225.2	278936
11/23 9:00		2.1	0.9		1.4	0.6		56%		5.4	54.7	280.0	233.4	225.7	277497
11/23 10:00	7.7	2.2	0.9	5.1	1.5	0.6	71%	61%	89%	4.3	53.8	281.0	233.9	226.1	273692
11/23 11:00	6.7	2.3	1.2	4.4	1.5	0.8	66%	49%	82%	4.3	53.1	282.3	234.5	226.9	270854
11/23 12:00	5.6	2.3	1.3	3.7	1.5	0.8	60%	44%	77%	4.3	53.2	282.0	234.6	227.5	271012
11/23 13:00	6.7	2.2	1.2	4.5	1.5	0.8	67%	44%	82%	4.1	55.7	281.3	234.9	228.2	281668
11/23 14:00	7.2	2.1	1.2	4.8	1.4	0.8	71%	41%	83%	4.2	54.1	282.1	235.9	228.9	274821
11/23 15:00	7.2	2.0	1.2	4.8	1.3	0.8	72%	39%	83%	4.2	55.2	281.7	235.1	227.8	279263
11/23 16:00	7.0	2.1		4.6	1.4		70%			4.2	55.3	282.1	235.0	222.7	279625
11/23 17:00	8.8	2.1	1.3	5.8	1.4	0.8	76%	40%	85%	4.2	55.1	281.2	234.2	222.4	278899
11/23 18:00	8.8	2.1	1.1	5.8	1.4	0.7	77%	45%	87%	3.8	61.5	276.7	234.8	223.5	305384
11/23 19:00	9.4	1.8	1.0	6.2	1.2	0.7	81%	41%	89%	4.2	54.7	278.9	233.7	223.8	277330
11/23 20:00	9.6	1.9	1.1	6.4	1.3	0.7	80%	42%	88%	4.2	55.1	277.6	231.7	222.9	278802
11/23 21:00	9.8	2.0	1.1	6.5	1.3	0.8	80%	43%	88%	4.2	54.9	277.7	231.6	223.0	278151
11/23 22:00	9.9	2.0	1.1	6.6	1.3	0.7	80%	45%	89%	4.2	55.0	278.9	232.1	223.9	278395
11/23 23:00	10.1	2.0	1.1	6.7	1.3	0.8	80%	43%	89%	4.2	55.5	280.3	233.5	225.1	280681
11/24 0:00	10.1	2.0	1.5	6.7	1.3	1.0	81%	25%	85%	4.2	55.1	286.6	240.4	229.5	279148
11/24 1:00	10.3	1.8	1.2	6.9	1.2	0.8	83%	33%	88%	4.2	55.1	279.0	232.5	226.9	279033
11/24 2:00	9.9	1.7	1.1	6.6	1.1	0.7	83%	35%	89%	4.2	55.2	277.7	230.9	224.8	279274
11/24 3:00	9.4	1.4	1.0	6.2	0.9	0.6	85%	33%	90%	4.2	55.1	278.4	230.9	224.4	278917
11/24 4:00	9.2	1.4	0.9	6.1	1.0	0.6	84%	36%	90%	4.1	56.1	278.6	232.3	224.8	283237
11/24 5:00	9.1	1.4	0.9	6.0	1.0	0.6	84%	38%	90%	4.1	56.6	277.5	232.4	225.4	285073
11/24 6:00	8.3	1.3	0.8	5.5	0.9	0.5	84%	37%	90%	4.1	56.6	275.9	232.7	224.8	285329
11/24 7:00	8.7	1.2	0.8	5.8	0.8	0.6	86%	29%	90%	4.2	55.2	281.1	237.8	227.7	279185

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
11/24 8:00	7.7	1.2	0.9	5.1	0.8	0.6	85%	28%	89%	4.2	55.0	278.7	233.7	226.8	278726
11/24 9:00	5.2			3.4						4.2	55.3	277.6	233.4	221.4	279654
11/24 10:00	5.7		1.1	3.8		0.7			80%	4.0	59.0	276.2	232.5	217.6	295176
11/24 11:00	5.3	1.3	1.0	3.5	0.8	0.6	76%	23%	82%	4.1	56.1	279.1	237.8	220.8	283093
11/24 12:00	5.9	1.5	0.9	3.9	1.0	0.6	74%	43%	85%	4.1	55.9	278.1	233.2	220.5	282333
11/24 13:00	4.1	1.3	0.6	2.7	0.8	0.4	69%	55%	86%	3.0	82.6	272.0	235.8	223.2	393020
11/24 14:00	5.4	1.1	0.4	3.6	0.8	0.2	79%	68%	93%	3.8	62.1	287.3	250.6	233.6	308071
11/24 15:00	6.5	1.2	0.5	4.3	0.8	0.3	82%	58%	92%	4.2	55.2	278.0	233.2	226.0	279237
11/24 16:00	6.9	1.5		4.6	1.0		78%			4.2	55.0	277.7	232.1	224.2	278658
11/24 17:00	7.8	1.7	1.1	5.2	1.2	0.7	78%	37%	86%	4.1	56.5	275.6	230.9	223.1	284759
11/24 18:00	8.9	1.7	0.9	5.9	1.1	0.6	81%	44%	89%	4.2	54.6	276.6	231.6	222.8	276813
11/24 19:00	6.9	1.2	0.6	4.6	0.8	0.4	82%	53%	92%	4.2	55.0	275.8	233.3	223.2	278654
11/24 20:00	5.4	0.5	0.3	3.6	0.3	0.2	91%	41%	95%	4.2	55.1	278.0	231.2	223.4	279101
11/24 21:00	7.8	0.9	0.4	5.2	0.6	0.3	88%	54%	94%	4.2	55.0	278.7	231.2	223.6	278737
11/24 22:00	7.7	1.2	0.5	5.1	0.8	0.3	85%	55%	93%	4.2	55.4	278.7	230.9	223.7	280310
11/24 23:00	7.8	1.3	0.6	5.2	0.8	0.4	84%	54%	93%	4.2	55.1	278.1	231.5	222.8	279164
11/25 0:00	7.7	1.3	0.6	5.1	0.9	0.4	83%	55%	92%	4.2	55.1	277.5	230.9	221.7	278979
11/25 1:00	7.4	1.4	0.6	4.9	0.9	0.4	81%	57%	92%	4.1	56.1	276.1	230.1	220.6	283271
11/25 2:00	7.0	1.3	0.5	4.6	0.8	0.3	82%	60%	93%	4.2	55.4	273.3	229.1	217.5	280214
11/25 3:00	6.4	0.9	0.4	4.2	0.6	0.3	86%	49%	93%	4.3	54.0	274.0	229.1	216.5	274442
11/25 4:00	6.0	1.1	0.6	4.0	0.7	0.4	82%	49%	91%	4.2	54.0	272.4	228.4	214.7	274540
11/25 5:00	5.7	1.1	0.6	3.8	0.7	0.4	80%	47%	90%	4.3	53.9	271.1	227.6	212.9	273816
11/25 6:00	5.6	1.0	0.6	3.8	0.7	0.4	82%	43%	90%	4.3	53.9	269.2	226.0	211.2	273814
11/25 7:00	5.4	1.0	0.6	3.6	0.6	0.4	82%	36%	89%	4.3	53.6	265.6	222.5	209.3	272814

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
11/25 8:00	5.5	1.0	0.7	3.6	0.7	0.5	82%	28%	87%	4.2	54.6	264.8	222.2	207.9	276897
11/25 9:00	6.9	1.6	0.8	4.6	1.1	0.5	76%	50%	88%	4.2	55.4	264.0	224.1	208.7	280129
11/25 10:00	7.4	1.7	0.9	4.9	1.2	0.6	76%	50%	88%	4.2	55.1	263.6	223.0	209.2	279090
11/25 11:00	7.0	1.7	0.9	4.6	1.2	0.6	75%	48%	87%	4.2	55.1	264.3	223.5	208.6	279052
11/25 12:00	7.1	1.9	0.9	4.7	1.2	0.6	74%	50%	87%	4.2	55.0	265.9	224.7	209.9	278510
11/25 13:00	6.3	1.9	0.8	4.2	1.2	0.5	70%	57%	87%	4.0	59.0	264.8	226.8	211.3	295097
11/25 14:00	7.0	1.8	0.8	4.6	1.2	0.6	74%	54%	88%	4.3	53.3	268.2	227.6	212.5	271500
11/25 15:00	7.2	2.0	0.9	4.8	1.4	0.6	72%	57%	88%	4.3	53.2	267.2	225.9	212.0	271209
11/25 16:00		1.9	1.1		1.2	0.7		41%		4.3	52.9	267.1	226.0	211.7	269793
11/25 17:00	7.3	2.0	0.9	4.8	1.3	0.6	72%	55%	88%	4.3	53.1	265.9	225.7	211.3	270775
11/25 18:00	8.7	1.9	0.9	5.8	1.3	0.6	78%	53%	90%	4.2	54.9	264.7	225.1	210.7	278219
11/25 19:00	8.3	1.8	0.9	5.5	1.2	0.6	78%	51%	89%	4.2	55.4	264.7	224.7	210.3	280257
11/25 20:00	8.1	1.7	0.9	5.4	1.1	0.6	79%	49%	89%	4.2	55.2	264.7	224.3	209.8	279197
11/25 21:00	8.0	1.7	0.9	5.3	1.1	0.6	79%	50%	89%	4.2	55.2	264.9	224.1	209.2	279278
11/25 22:00	7.3	1.6	0.8	4.9	1.1	0.5	78%	51%	89%	4.2	55.3	264.0	223.3	208.4	279680
11/25 23:00	6.7	1.5	0.8	4.5	1.0	0.5	78%	48%	88%	4.2	55.1	263.4	223.2	207.7	279076
11/26 0:00	6.0	1.4	0.7	4.0	0.9	0.5	77%	46%	88%	4.0	57.4	258.6	220.5	206.1	288639
11/26 1:00	6.2	1.1	0.7	4.1	0.7	0.5	82%	32%	88%	4.2	55.1	260.6	221.9	205.4	278882
11/26 2:00	6.3	1.1	0.7	4.2	0.7	0.5	83%	29%	88%	4.2	55.2	263.0	223.3	206.3	279399
11/26 3:00	5.5	0.9	0.6	3.6	0.6	0.4	83%	35%	89%	4.2	54.4	262.2	225.6	207.3	276214
11/26 4:00	5.2	1.0	0.7	3.5	0.6	0.5	82%	27%	87%	0.0	55.6	262.3	224.7	206.8	281068
11/26 5:00	4.8	1.2	0.7	3.2	0.8	0.5	75%	42%	85%	0.0	55.2	262.1	225.6	207.1	279451
11/26 6:00	5.3	1.5	0.8	3.5	1.0	0.6	71%	44%	84%	0.0	56.1	263.2	226.1	207.5	283129
11/26 7:00	5.0	1.4	0.7	3.3	0.9	0.5	72%	48%	85%	0.0	54.9	264.3	227.3	208.0	278324

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/26 8:00	4.9	1.4	0.7	3.3	0.9	0.5	72%	48%	86%	2.1	55.2	263.9	226.2	208.3	279244
11/26 9:00	6.2			4.1						4.2	54.4	261.6	223.6	207.9	275991
11/26 10:00	6.6	1.7	1.0	4.4	1.1	0.7	75%	39%	85%	4.3	53.6	263.8	225.5	209.5	272879
11/26 11:00	7.2	2.0	1.0	4.8	1.4	0.6	72%	53%	87%	4.3	53.2	266.4	227.2	212.1	271050
11/26 12:00	7.9	2.2	0.8	5.2	1.5	0.5	72%	63%	90%	4.3	53.3	267.4	228.2	214.0	271646
11/26 13:00	6.9	2.0	0.8	4.6	1.3	0.5	71%	62%	89%	4.2	55.0	265.8	227.0	214.7	278552
11/26 14:00	7.6	2.3	0.8	5.1	1.5	0.5	70%	64%	89%	3.9	60.2	268.8	228.9	217.2	300105
11/26 15:00	7.3	1.8	0.8	4.9	1.2	0.5	76%	57%	89%	4.2	54.8	271.7	230.0	218.4	277800
11/26 16:00		1.6	1.2		1.1	0.8		29%		4.2	55.5	272.6	228.9	219.0	280462
11/26 17:00	5.3	1.8	0.7	3.5	1.2	0.4	67%	63%	88%	3.4	70.6	267.0	229.4	219.0	343242
11/26 18:00	7.4	1.5	0.6	4.9	1.0	0.4	79%	59%	91%	4.3	53.3	272.8	234.0	218.8	271534
11/26 19:00	8.5	1.9	0.7	5.6	1.2	0.5	78%	63%	92%	4.3	52.9	270.3	227.2	216.2	269694
11/26 20:00	8.1	1.9	0.6	5.4	1.3	0.4	76%	69%	93%	4.2	54.3	268.4	225.9	214.1	275696
11/26 21:00	8.0	1.9	0.5	5.3	1.2	0.3	76%	73%	94%	4.3	53.3	268.1	224.9	212.9	271557
11/26 22:00	7.8	2.0	0.5	5.2	1.3	0.3	74%	75%	94%	4.4	52.4	266.1	224.0	211.0	267969
11/26 23:00	7.1	1.8	0.5	4.7	1.2	0.3	74%	72%	93%	4.2	54.7	263.3	222.7	209.4	277293
11/27 0:00	6.7	1.7	0.5	4.5	1.1	0.3	75%	73%	93%	4.2	55.1	262.6	221.6	208.1	279107
11/27 1:00	6.8	1.6	0.4	4.5	1.1	0.3	76%	73%	94%	4.2	55.2	262.2	221.6	207.5	279189
11/27 2:00	6.5	1.5	0.4	4.3	1.0	0.3	77%	74%	94%	4.2	55.3	261.9	221.4	206.9	279773
11/27 3:00	6.2	1.5	0.3	4.1	1.0	0.2	76%	79%	95%	4.2	54.7	261.8	221.6	206.3	277337
11/27 4:00	6.4	1.4	0.3	4.2	0.9	0.2	78%	78%	95%	4.3	53.6	258.7	218.9	204.8	272857
11/27 5:00	6.6	1.5	0.3	4.4	1.0	0.2	78%	79%	95%	4.3	53.0	262.7	221.3	204.9	270344
11/27 6:00	6.7	1.6	0.3	4.5	1.0	0.2	77%	82%	96%	4.1	56.0	261.8	220.4	206.1	282618
11/27 7:00	7.4	1.9	0.3	4.9	1.3	0.2	74%	86%	96%	4.2	55.5	260.3	220.1	206.3	280720

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/27 8:00		2.0	0.3		1.3	0.2		87%		4.2	55.2	261.5	221.2	207.6	279499
11/27 9:00	8.0			5.3						4.2	55.2	263.7	222.6	209.2	279397
11/27 10:00	8.8	2.8	0.9	5.8	1.9	0.6	68%	67%	89%	4.2	55.0	263.5	222.6	210.5	278456
11/27 11:00	8.9	3.2	1.1	5.9	2.1	0.7	64%	66%	88%	4.2	55.2	267.0	224.6	211.8	279253
11/27 12:00	10.0	3.4	1.0	6.6	2.3	0.7	66%	70%	90%	4.2	55.1	268.3	225.8	213.5	278799
11/27 13:00	10.5	3.5	1.0	7.0	2.3	0.7	67%	70%	90%	4.3	53.7	269.0	225.4	214.1	273313
11/27 14:00	10.2	3.4	0.8	6.8	2.2	0.5	67%	76%	92%	4.2	54.9	266.6	223.1	212.0	278225
11/27 15:00	10.5	4.6	1.2	7.0	3.1	0.8	56%	74%	89%	4.2	55.4	267.9	225.0	211.8	280275
11/27 16:00		4.0			2.7					4.2	55.3	269.6	226.1	214.3	279649
11/27 17:00	7.8	3.5	1.1	5.2	2.3	0.7	56%	68%	86%	3.4	70.5	266.1	229.7	216.5	342752
11/27 18:00	8.7	3.6	1.2	5.8	2.4	0.8	58%	67%	86%	2.8	86.6	285.5	253.0	233.7	409784
11/27 19:00	8.8	3.0	0.8	5.8	2.0	0.6	66%	71%	90%	4.2	54.5	278.3	235.7	226.9	276297
11/27 20:00	8.8	2.8	0.8	5.9	1.8	0.5	69%	72%	91%	4.2	55.2	270.8	226.9	218.9	279342
11/27 21:00	8.8	2.9	0.8	5.9	1.9	0.5	68%	73%	91%	4.1	56.7	267.8	225.4	216.0	285535
11/27 22:00	8.7	3.0	0.8	5.8	2.0	0.5	66%	75%	91%	4.2	54.4	269.9	225.6	215.0	275868
11/27 23:00	8.5	2.9	0.7	5.6	1.9	0.5	66%	75%	91%	4.3	53.8	269.9	225.0	214.7	273529
11/28 0:00	8.6	2.9	0.8	5.7	1.9	0.5	66%	74%	91%	4.2	55.0	269.6	225.1	214.6	278660
11/28 1:00	8.5	2.9	0.8	5.6	1.9	0.5	66%	73%	91%	4.2	54.7	270.4	225.6	214.7	277199
11/28 2:00	8.9	3.0	0.8	5.9	2.0	0.6	66%	72%	90%	4.3	53.3	272.7	227.2	215.3	271674
11/28 3:00	9.8	3.2	0.9	6.5	2.1	0.6	67%	71%	91%	4.4	51.2	273.9	228.5	215.7	262910
11/28 4:00	9.5	3.1	0.8	6.3	2.1	0.5	67%	74%	91%	4.1	56.2	272.4	227.6	215.7	283514
11/28 5:00	10.2	3.1	0.9	6.8	2.1	0.6	69%	72%	91%	4.2	55.1	271.6	227.1	215.3	279088
11/28 6:00	10.5	3.4	0.9	7.0	2.3	0.6	67%	73%	91%	4.2	54.3	272.2	226.5	215.0	275563
11/28 7:00	9.3	3.4	0.9	6.2	2.2	0.6	64%	74%	90%	4.2	54.8	270.9	225.3	214.1	277697

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/28 8:00		3.3			2.2					4.2	55.2	267.2	223.3	212.8	279510
11/28 9:00	8.6	2.8	1.0	5.7	1.9	0.7	67%	65%	88%	4.2	55.1	265.9	222.6	211.8	278916
11/28 10:00	9.4	3.3	1.1	6.3	2.2	0.7	65%	68%	89%	4.3	53.7	267.1	222.7	212.4	273090
11/28 11:00	9.3	3.5	1.0	6.2	2.3	0.7	62%	70%	89%	4.2	54.8	268.6	223.4	213.7	277575
11/28 12:00	9.4	3.3	1.0	6.3	2.2	0.6	65%	71%	90%	4.3	53.6	268.9	225.1	214.5	272630
11/28 13:00	8.9	3.1	0.9	5.9	2.1	0.6	65%	72%	90%	4.2	54.3	269.9	226.3	215.4	275669
11/28 14:00	9.6	3.2	1.6	6.4	2.1	1.0	67%	50%	84%	4.3	53.4	272.2	227.4	217.0	271850
11/28 15:00	10.1	3.1	1.6	6.7	2.1	1.1	69%	48%	84%	4.4	52.3	272.5	227.3	218.0	267168
11/28 16:00	10.5			7.0						4.3	52.9	272.1	227.1	217.9	270023
11/28 17:00	7.8	3.0	1.6	5.2	2.0	1.1	61%	46%	79%	3.9	60.5	270.8	228.9	218.7	301561
11/28 18:00	10.3	3.8	1.7	6.8	2.5	1.1	63%	54%	83%	3.9	59.1	281.4	241.6	224.9	295519
11/28 19:00	11.4	3.3	1.4	7.5	2.2	0.9	71%	59%	88%	4.2	55.5	275.0	229.5	220.7	280596
11/28 20:00	11.1	3.1	1.3	7.4	2.0	0.9	72%	56%	88%	4.2	55.0	272.9	226.7	217.7	278690
11/28 21:00	11.0	3.1	1.4	7.3	2.1	0.9	71%	54%	87%	4.1	55.8	271.1	227.3	216.7	281984
11/28 22:00	10.9	3.3	1.5	7.3	2.2	1.0	70%	56%	87%	4.2	55.1	273.9	226.7	216.5	278841
11/28 23:00	10.1	3.1	1.4	6.7	2.0	0.9	69%	56%	87%	4.1	56.8	269.8	224.7	214.9	285868
11/29 0:00	10.0	2.9	1.3	6.7	1.9	0.8	71%	56%	87%	4.2	54.8	270.4	224.7	213.4	277741
11/29 1:00		2.6	1.2		1.7	0.8		53%		4.2	54.5	268.5	223.2	212.4	276490
11/29 2:00		2.2	1.0		1.5	0.7		55%		4.2	55.1	268.3	224.0	211.8	279043
11/29 3:00		1.5	0.9		1.0	0.6		40%		4.2	55.1	267.2	221.8	210.0	279057
11/29 4:00		1.4	0.9		0.9	0.6		33%		4.2	55.2	266.8	221.7	209.2	279321
11/29 5:00		1.2	0.9		0.8	0.6		26%		4.1	57.2	263.9	219.8	207.9	287763
11/29 6:00		1.2	0.9		0.8	0.6		30%		3.4	71.1	266.5	229.9	211.8	345557
11/29 7:00		1.9	1.6		1.2	1.0		17%		3.3	72.8	283.9	250.5	226.6	352268

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
11/29 8:00		2.1			1.4					4.2	55.4	274.6	233.3	221.6	280399
11/29 9:00		2.6			1.8					4.2	55.6	272.6	230.8	218.2	280988
11/29 10:00		3.5	1.6		2.3	1.1		54%		4.2	54.6	273.3	232.3	219.6	276750
11/29 11:00		3.6	1.5		2.4	1.0		60%		4.3	53.5	277.4	234.8	222.0	272454
11/29 12:00		3.6	1.5		2.4	1.0		60%		4.2	54.2	278.9	234.6	223.9	275366
11/29 13:00		3.7			2.4					4.2	54.5	278.4	233.6	224.6	276309
11/29 14:00		3.5			2.3					4.2	55.0	279.2	234.5	225.6	278558
11/29 15:00										4.2	55.1	280.9	235.8	227.1	279151
11/29 16:00		2.9			1.9					4.2	55.3	280.5	234.7	227.0	279662
11/29 17:00		3.3			2.2					3.8	60.9	277.7	234.8	226.4	303256
11/29 18:00		3.1			2.0					4.2	55.5	278.5	235.4	225.9	280467
11/29 19:00		2.6			1.7					4.2	55.1	274.1	229.0	221.1	278824
11/29 20:00		2.5			1.7					4.2	55.2	272.3	229.6	219.2	279226
11/29 21:00		2.5			1.7					4.2	55.2	271.3	228.2	217.9	279426
11/29 22:00		2.4			1.6					4.2	55.0	272.7	227.9	217.2	278505
11/29 23:00		1.7			1.2					4.1	56.7	274.0	232.0	218.4	285624
11/30 0:00		1.3			0.9					4.2	55.1	268.1	224.4	215.5	278920
11/30 1:00		1.3	0.7		0.8	0.4		47%		4.2	54.3	266.0	221.6	212.1	275627
11/30 2:00		1.2	0.6		0.8	0.4		49%		4.2	55.2	264.5	220.3	210.8	279306
11/30 3:00		1.1	0.5		0.7	0.3		53%		4.2	55.2	266.4	222.2	210.5	279239
11/30 4:00		0.8	0.5		0.5	0.3		41%		4.1	55.7	264.5	221.6	211.0	281651
11/30 5:00		0.7	0.5		0.5	0.4		28%		4.1	57.0	262.8	220.7	210.2	286717
11/30 6:00		1.5	0.9		1.0	0.6		38%		3.3	73.7	259.3	228.7	213.3	356326
11/30 7:00		2.1	0.9		1.4	0.6		59%		4.2	55.6	279.2	238.0	221.2	280920

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
11/30 8:00		2.0	0.8		1.3	0.5		61%		3.9	60.6	266.1	225.9	217.3	302016
11/30 9:00		1.4			0.9					3.4	71.7	266.3	235.4	219.8	347890
11/30 10:00		2.1	1.3		1.4	0.9		36%		3.1	78.3	267.6	240.0	224.6	375189
11/30 11:00		1.9	1.1		1.2	0.7		41%		4.3	53.2	274.2	238.3	225.3	271003
11/30 12:00		1.8	1.3		1.2	0.8		28%		4.2	55.0	268.1	226.0	219.2	278644
11/30 13:00		1.9	1.2		1.3	0.8		37%		4.2	54.8	270.9	227.3	219.3	277866
11/30 14:00		2.0	1.2		1.3	0.8		39%		4.2	55.0	272.2	227.5	219.9	278536
11/30 15:00		1.8	1.2		1.2	0.8		33%		4.0	57.3	271.7	227.7	220.7	288258
11/30 16:00	7.2	1.3	1.1	4.8	0.9	0.7	81%	19%	85%	6.8	54.5	270.2	226.8	219.8	276408
11/30 17:00	8.7	2.1		5.8	1.4		76%			11.5	57.9	270.3	227.3	220.4	290686
11/30 18:00	11.2	2.4		7.4	1.6		78%			12.0	54.6	272.3	228.7	220.7	277090
11/30 19:00	11.7	2.5		7.8	1.6		79%			4.1	55.6	273.8	229.3	222.1	281238
11/30 20:00	12.6	2.4		8.3	1.6		81%			4.2	55.1	276.0	230.7	223.2	279150
11/30 21:00	13.3	2.5		8.8	1.7		81%			4.2	54.1	277.7	232.0	224.5	274990
11/30 22:00	13.6	2.5		9.0	1.7		82%			4.3	52.6	278.7	232.2	224.9	268590
11/30 23:00	13.4	2.5		8.9	1.7		81%			4.3	53.9	277.3	231.4	224.6	273841
12/1 0:00	13.6	2.5		9.0	1.6		82%			4.3	53.2	277.8	231.5	222.1	270917
12/1 1:00	13.0	2.5		8.6	1.6		81%			4.4	51.8	278.5	230.5	218.1	265196
12/1 2:00	12.1	2.3		8.0	1.5		81%			4.6	48.9	277.6	229.2	214.5	253110
12/1 3:00	11.6	2.2		7.7	1.5		81%			4.2	55.1	273.1	227.1	214.8	278975
12/1 4:00	11.1	2.3		7.4	1.5		79%			4.2	55.2	274.2	227.5	215.5	279258
12/1 5:00	11.1	2.2		7.4	1.5		80%			4.1	56.8	273.7	227.2	215.4	285852
12/1 6:00	10.9	2.0		7.2	1.4		81%			4.1	55.8	270.5	225.0	213.6	281906
12/1 7:00	10.2	1.7		6.7	1.1		83%			4.2	54.6	269.6	223.4	211.8	276777

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/1 8:00	8.8	1.6		5.8	1.1		82%			4.4	52.4	270.2	223.1	210.7	267898
12/1 9:00		1.5			1.0					4.3	53.6	264.9	222.4	209.8	272627
12/1 10:00	8.9		0.8	5.9		0.6			91%	4.2	55.2	262.7	222.3	209.0	279511
12/1 11:00	8.3	2.5	1.2	5.5	1.7	0.8	70%	52%	86%	4.2	55.3	264.1	224.0	210.4	279947
12/1 12:00	8.3	2.5	1.2	5.5	1.7	0.8	70%	54%	86%	4.2	55.3	263.0	223.4	210.6	279711
12/1 13:00	8.2	2.5	1.0	5.5	1.6	0.6	70%	61%	88%	3.7	63.4	263.1	224.8	212.0	313466
12/1 14:00										3.0	108.4	281.9	247.9	232.4	500150
12/1 15:00										4.2	112.9	294.9	255.8	246.4	518775
12/1 16:00	7.6		2.0	5.1		1.3			74%	3.7	112.8	295.4	256.7	249.6	518431
12/1 17:00	8.7	3.0	2.0	5.8	2.0	1.3	66%	34%	77%	3.7	111.7	295.3	257.2	249.9	514132
12/1 18:00	10.4	3.5	2.0	6.9	2.3	1.3	66%	43%	81%	4.0	103.7	290.5	256.5	247.8	480816
12/1 19:00	10.6	3.6	2.0	7.1	2.4	1.4	66%	44%	81%	2.9	85.6	286.1	256.9	243.5	405776
12/1 20:00	9.9	3.0	1.6	6.6	2.0	1.0	69%	49%	84%	3.9	60.2	278.4	248.8	232.8	300177
12/1 21:00	9.5	2.5	1.0	6.3	1.6	0.7	74%	59%	89%	4.9	45.0	270.3	233.5	221.3	236967
12/1 22:00	9.0	2.5	1.1	6.0	1.6	0.7	73%	56%	88%	4.4	51.8	262.6	223.0	213.2	265102
12/1 23:00	7.0	1.8	0.9	4.7	1.2	0.6	74%	51%	87%	4.1	56.4	259.9	220.5	209.2	284425
12/2 0:00	6.7	1.3	0.8	4.5	0.8	0.5	81%	38%	88%	4.2	54.1	259.0	220.6	207.0	274996
12/2 1:00	7.6	1.4	0.9	5.0	0.9	0.6	82%	37%	88%	4.2	54.2	258.4	219.1	205.2	275298
12/2 2:00		1.3	0.8		0.8	0.6		33%		4.2	54.7	257.4	218.5	203.9	277197
12/2 3:00		1.1	0.9		0.8	0.6		23%		4.2	54.3	259.8	220.7	204.8	275756
12/2 4:00		1.3	1.0		0.9	0.6		27%		4.2	54.2	256.5	217.7	203.3	275292
12/2 5:00		1.4	0.9		0.9	0.6		31%		4.2	54.8	256.4	218.2	202.4	277567
12/2 6:00		1.4	0.9		0.9	0.6		37%		4.3	54.0	258.1	219.7	202.6	274255
12/2 7:00														#DIV/0!	

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
12/2 8:00	5.4	1.3	0.8	3.6	0.9	0.5	75%	40%	85%	4.2	54.3	256.5	218.0	202.7	275627
12/2 9:00	5.5	1.4	1.2	3.6	0.9	0.8	74%	12%	77%	4.2	54.3	257.3	218.7	203.2	275541
12/2 10:00	6.0	1.7	1.2	4.0	1.1	0.8	71%	29%	80%	4.2	54.3	259.1	220.0	205.3	275450
12/2 11:00	6.9	1.8	1.3	4.6	1.2	0.9	73%	30%	81%	5.1	61.0	261.9	224.2	209.2	303419
12/2 12:00	8.9	2.7	1.5	5.9	1.8	1.0	70%	42%	83%	4.7	106.4	277.4	243.8	228.9	491958
12/2 13:00	7.5	3.6	2.5	5.0	2.4	1.7	51%	31%	66%	4.7	106.5	288.8	251.8	242.5	492545
12/2 14:00	8.2	3.4	2.1	5.4	2.3	1.4	58%	40%	75%	6.6	68.3	286.5	254.4	240.5	333653
12/2 15:00	8.3	2.8	1.5	5.5	1.9	1.0	66%	47%	82%	4.3	52.8	275.8	233.9	228.5	269220
12/2 16:00	9.3	2.6	1.4	6.1	1.7	0.9	72%	46%	85%	4.3	54.0	271.7	229.2	222.0	274220
12/2 17:00	11.0	3.0	1.5	7.3	2.0	1.0	72%	52%	87%	4.1	55.6	267.6	227.5	218.7	281135
12/2 18:00	11.7	3.2	1.5	7.8	2.1	1.0	72%	54%	87%	4.2	54.0	266.8	225.4	215.5	274527
12/2 19:00	11.5	3.3	1.5	7.6	2.2	1.0	71%	56%	87%	4.1	55.6	265.4	224.6	213.6	281185
12/2 20:00	10.9	3.4	1.5	7.3	2.2	1.0	69%	55%	86%	4.1	57.0	267.6	226.5	213.9	286870
12/2 21:00	9.7	3.3	1.6	6.5	2.2	1.1	66%	52%	84%	3.7	63.9	270.9	235.8	218.7	315540
12/2 22:00	9.3	2.8	1.2	6.2	1.9	0.8	69%	57%	87%	4.2	54.7	269.7	226.9	215.5	277410
12/2 23:00	8.8	2.5	1.1	5.9	1.7	0.7	72%	55%	87%	4.2	54.6	265.6	223.7	212.0	276982
12/3 0:00	8.3	2.3	1.2	5.5	1.5	0.8	72%	49%	86%	4.2	54.0	265.6	222.4	209.9	274564
12/3 1:00	7.5	2.1	1.2	4.9	1.4	0.8	72%	41%	83%	4.2	54.2	268.7	226.3	211.0	275081
12/3 2:00	7.3	2.2	1.3	4.8	1.4	0.8	70%	42%	83%	4.2	54.4	263.3	221.7	208.7	275888
12/3 3:00	7.3	2.1	1.2	4.9	1.4	0.8	72%	41%	83%	4.2	54.3	261.5	220.3	206.5	275446
12/3 4:00	7.3	2.1	1.2	4.8	1.4	0.8	71%	41%	83%	4.3	53.7	261.1	221.0	205.9	273160
12/3 5:00	7.1	2.1	1.2	4.7	1.4	0.8	71%	43%	83%	4.2	55.1	258.1	218.7	204.4	278783
12/3 6:00	7.1	2.2	1.2	4.7	1.5	0.8	69%	44%	83%	4.3	53.9	258.0	219.1	203.6	274082
12/3 7:00	7.0	2.3	1.3	4.6	1.5	0.9	67%	42%	81%	4.0	58.2	249.3	229.4	204.1	291961

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/3 8:00	6.6	2.5	1.9	4.4	1.7	1.3	62%	23%	71%	4.2	55.0	252.1	241.0	208.0	278571
12/3 9:00		2.5	1.0		1.6	0.6		61%		4.3	53.2	248.5	237.1	207.9	271232
12/3 10:00	8.1	2.5	1.1	5.4	1.7	0.7	69%	58%	87%	4.3	52.8	252.2	240.5	210.6	269410
12/3 11:00	9.1	3.1	1.0	6.0	2.1	0.7	65%	67%	89%	4.3	52.8	252.6	241.7	213.0	269394
12/3 12:00	9.2	3.0	0.9	6.1	2.0	0.6	67%	70%	90%	4.2	55.0	253.7	239.9	214.1	278580
12/3 13:00	9.5	3.2	0.8	6.3	2.2	0.5	66%	75%	91%	4.3	53.3	254.8	240.0	215.0	271604
12/3 14:00	10.1		0.9	6.7		0.6			91%	4.2	54.3	255.5	240.8	215.4	275587
12/3 15:00		3.1			2.0					4.2	54.2	256.2	241.5	216.5	275100
12/3 16:00	7.3	3.3	1.1	4.8	2.2	0.7	55%	66%	85%	4.2	54.1	255.9	240.8	216.5	274936
12/3 17:00	7.8	3.1	1.0	5.2	2.1	0.7	60%	67%	87%	4.0	57.6	253.7	239.4	216.1	289551
12/3 18:00	7.9	3.0	0.6	5.3	2.0	0.4	63%	80%	92%	4.2	54.2	251.1	237.0	213.3	275432
12/3 19:00	7.4	2.6	0.6	4.9	1.7	0.4	65%	76%	91%	4.2	54.6	250.5	236.2	211.6	276893
12/3 20:00	6.9	2.6	0.4	4.6	1.7	0.3	62%	85%	95%	4.2	54.6	248.9	235.5	210.1	276817
12/3 21:00	6.6	2.5	0.5	4.4	1.7	0.3	62%	80%	92%	4.2	54.4	248.2	235.3	209.1	276236
12/3 22:00	6.2	2.6	0.3	4.1	1.7	0.2	58%	90%	96%	4.2	54.1	247.1	235.5	208.1	274842
12/3 23:00	6.0	2.6	0.4	4.0	1.7	0.3	57%	85%	94%	4.2	54.4	246.0	235.0	207.4	275869
12/4 0:00	5.1	2.3	0.2	3.4	1.5	0.1	55%	91%	96%	4.2	54.3	246.4	236.5	206.8	275651
12/4 1:00	5.6	2.3	0.4	3.7	1.6	0.2	58%	85%	94%	4.2	54.1	246.6	235.8	206.8	274913
12/4 2:00	5.6	2.5	0.2	3.7	1.7	0.2	55%	91%	96%	4.2	54.2	247.0	236.4	207.1	275325
12/4 3:00	5.7	2.5	0.5	3.8	1.7	0.3	56%	80%	91%	4.2	54.3	246.7	236.9	207.3	275703
12/4 4:00	6.0	2.8	0.3	4.0	1.9	0.2	52%	91%	96%	4.2	54.3	247.1	237.6	207.4	275509
12/4 5:00	6.0	2.9	0.3	4.0	1.9	0.2	51%	89%	95%	4.3	53.8	250.5	238.2	208.2	273454
12/4 6:00	5.9	2.8	0.2	3.9	1.8	0.1	53%	92%	96%	4.2	54.6	251.2	237.5	208.4	276937
12/4 7:00	5.8	2.7	0.4	3.8	1.8	0.3	54%	85%	93%	4.3	53.8	250.5	237.2	208.0	273450

Date/Time	ESP Inlet Total Hg (µg/Nm^3, 3% O_2) †	ESP Outlet Total Hg (µg/Nm^3, 3% O_2) †	Stack Total Hg (µg/Nm^3, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
12/4 8:00	6.0	3.0	0.2	4.0	2.0	0.2	50%	92%	96%	4.3	53.2	250.8	235.1	207.7	271125
12/4 9:00		2.9	0.9		1.9	0.6		68%		4.3	53.2	251.1	237.1	208.6	270891
12/4 10:00	6.0	2.4		4.0	1.6		61%			4.3	52.6	255.2	242.1	213.0	268791
12/4 11:00	6.3	3.2	2.1	4.2	2.1	1.4	49%	35%	67%	4.4	51.9	255.9	243.3	215.2	265825
12/4 12:00	6.7	3.0	1.9	4.4	2.0	1.3	55%	35%	71%	4.4	51.5	257.2	244.9	216.7	263954
12/4 13:00	6.9	2.8	1.8	4.6	1.9	1.2	59%	35%	73%	6.7	54.2	258.9	243.8	218.4	275062
12/4 14:00	6.9	2.5	1.8	4.6	1.7	1.2	63%	29%	74%	6.7	54.0	260.0	243.3	219.4	274530
12/4 15:00	7.2			4.8						6.7	54.1	259.5	242.9	219.6	274770
12/4 16:00	8.4	2.6	1.8	5.6	1.7	1.2	69%	32%	79%	6.6	54.4	260.0	242.8	219.8	276273
12/4 17:00	8.5	2.9	1.7	5.6	1.9	1.2	66%	40%	80%	5.2	57.2	258.0	241.2	219.1	287844
12/4 18:00	7.9	2.6	1.7	5.2	1.8	1.1	66%	37%	79%	4.2	54.2	256.4	242.3	217.0	275100
12/4 19:00	7.1	2.5	1.4	4.7	1.7	0.9	65%	43%	80%	4.3	53.6	254.6	241.2	214.8	272607
12/4 20:00	7.0	2.4	1.5	4.7	1.6	1.0	66%	38%	79%	4.2	54.1	253.4	239.5	213.2	274828
12/4 21:00	6.7	2.4	1.3	4.4	1.6	0.9	64%	44%	80%	4.3	54.0	253.1	239.3	212.3	274415
12/4 22:00	6.2	2.5	1.3	4.1	1.7	0.9	60%	47%	79%	4.3	53.1	252.3	239.2	211.5	270765
12/4 23:00	6.1	2.4	1.3	4.0	1.6	0.8	60%	48%	79%	4.3	53.5	250.8	239.1	210.6	272503
12/5 0:00	5.9	2.4	1.2	3.9	1.6	0.8	59%	49%	79%	4.2	54.2	250.6	238.3	209.8	275049
12/5 1:00	6.0	2.4	1.2	4.0	1.6	0.8	60%	49%	79%	4.2	54.1	251.2	238.9	209.9	275000
12/5 2:00	6.0	2.4	1.2	4.0	1.6	0.8	61%	50%	80%	4.2	54.3	250.9	238.3	209.6	275475
12/5 3:00	6.0	2.4	1.2	4.0	1.6	0.8	61%	48%	80%	4.2	54.2	250.2	237.0	209.1	275048
12/5 4:00	6.0	2.3	1.2	4.0	1.6	0.8	61%	48%	80%	4.2	54.4	248.2	234.8	207.3	276007
12/5 5:00	6.1	2.4	1.3	4.0	1.6	0.9	61%	45%	78%	4.3	54.0	248.2	235.3	207.2	274373
12/5 6:00	4.5	2.0	1.2	3.0	1.3	0.8	55%	41%	74%	2.6	94.9	256.8	239.5	214.9	444042
12/5 7:00	5.9	2.8	2.4	3.9	1.8	1.6	53%	12%	59%	2.4	107.0	280.5	255.6	235.5	494454

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O₂) †	ESP Outlet Total Hg (µg/Nm³, 3% O₂) †	Stack Total Hg (µg/Nm³, 3% O₂) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O₂) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
12/5 8:00	6.2	3.2	2.4	4.1	2.1	1.6	49%	24%	61%	2.4	106.9	282.1	256.2	240.1	493888
12/5 9:00	6.5	3.7	3.2	4.3	2.4	2.1	44%	13%	51%	2.4	106.9	283.5	257.3	242.4	494248
12/5 10:00	6.9	4.1	3.4	4.6	2.7	2.2	41%	18%	51%	3.1	106.8	285.7	258.0	245.0	493823
12/5 11:00	9.9	5.2	3.9	6.6	3.5	2.6	47%	25%	60%	3.5	106.9	287.9	257.8	247.4	494138
12/5 12:00	11.2	5.6	4.5	7.4	3.7	3.0	50%	19%	60%	3.5	106.9	290.2	257.1	249.2	493845
12/5 13:00										3.5	106.8	290.8	257.5	250.2	493654
12/5 14:00	10.8			7.2						3.5	107.0	291.2	257.6	250.9	494282
12/5 15:00	14.3	4.9	4.3	9.5	3.2	2.9	66%	12%	70%	3.5	106.9	291.3	257.8	251.3	493908
12/5 16:00	16.3	4.7	4.2	10.8	3.1	2.8	71%	11%	74%	3.5	107.0	291.1	257.7	251.1	494338
12/5 17:00	18.0	5.0	4.3	11.9	3.3	2.8	72%	14%	76%	3.5	106.9	290.4	256.7	249.9	494222
12/5 18:00	17.6	4.9	4.0	11.7	3.3	2.7	72%	17%	77%	2.9	106.9	289.6	256.5	248.5	493973
12/5 19:00	16.6	5.2	3.8	11.1	3.4	2.6	69%	26%	77%	3.5	68.9	280.5	257.8	242.2	336098
12/5 20:00	16.3	4.9	2.9	10.8	3.2	1.9	70%	40%	82%	4.2	54.4	262.2	242.2	225.7	276201
12/5 21:00	16.4	4.8	2.8	10.9	3.2	1.8	71%	42%	83%	4.2	54.3	258.4	238.8	218.9	275530
12/5 22:00	16.5	4.5	2.7	11.0	3.0	1.8	73%	39%	83%	4.2	54.0	257.5	238.5	216.6	274517
12/5 23:00	16.5	4.6	2.8	11.0	3.1	1.8	72%	40%	83%	4.2	54.2	256.5	239.2	215.8	275278
12/6 0:00	16.0	4.5	2.7	10.6	3.0	1.8	72%	41%	83%	4.3	54.0	256.9	238.8	215.2	274492
12/6 1:00	15.7	4.4	2.5	10.4	2.9	1.7	72%	42%	84%	4.2	54.1	257.5	240.4	214.1	275026
12/6 2:00	14.9	4.1	2.6	9.9	2.7	1.7	72%	38%	83%	4.3	54.0	257.2	239.9	213.6	274433
12/6 3:00	15.0	4.0	2.4	10.0	2.7	1.6	73%	42%	84%	4.2	54.2	257.3	239.6	214.1	275049
12/6 4:00	15.1	4.1	2.5	10.0	2.7	1.6	73%	40%	84%	4.0	57.5	256.6	239.0	214.4	289050
12/6 5:00	15.1	4.1	2.6	10.0	2.7	1.7	73%	38%	83%	4.2	54.1	256.2	239.5	214.2	274633
12/6 6:00	15.3	4.1	2.6	10.2	2.7	1.8	73%	36%	83%	4.0	57.3	258.3	240.2	215.7	288120
12/6 7:00	14.8	3.9	2.6	9.8	2.6	1.7	74%	33%	83%	3.8	62.2	262.0	245.7	219.1	308573

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
12/6 8:00	13.8	3.7	3.3	9.2	2.4	2.2	74%	9%	76%	2.4	106.9	280.5	251.0	235.2	494165
12/6 9:00	15.6	4.2	4.4	10.4	2.8	2.9	73%	-5%	72%	2.9	106.5	286.3	257.2	244.1	492271
12/6 10:00	16.2	4.7	4.6	10.8	3.1	3.0	71%	2%	72%	3.5	107.0	288.7	258.4	247.5	494398
12/6 11:00	16.0	3.8	4.0	10.6	2.5	2.6	76%	-5%	75%	3.5	107.0	289.8	259.2	249.3	494395
12/6 12:00	11.9	3.4	3.7	7.9	2.3	2.4	71%	-7%	69%	3.5	106.2	290.8	260.3	250.9	491307
12/6 13:00	13.9	3.2	3.7	9.2	2.1	2.4	77%	-14%	74%	3.5	106.9	291.2	259.7	251.7	494157
12/6 14:00	15.0		3.3	10.0		2.2			78%	3.5	106.9	292.9	260.8	252.7	493937
12/6 15:00			3.3			2.2				3.6	102.8	290.2	260.2	251.8	476847
12/6 16:00	15.4	4.6	3.2	10.2	3.1	2.1	70%	32%	79%	3.5	106.8	293.1	259.6	253.0	493493
12/6 17:00	15.7	4.4	2.9	10.4	2.9	1.9	72%	34%	82%	3.5	106.8	294.4	261.1	254.0	493444
12/6 18:00	16.2	4.4	2.8	10.8	2.9	1.9	73%	36%	83%	3.5	106.7	295.8	262.6	255.3	493347
12/6 19:00	16.8	4.5	2.7	11.2	3.0	1.8	73%	39%	84%	3.9	106.7	296.7	263.4	256.0	493216
12/6 20:00	16.2	4.1	2.6	10.8	2.7	1.7	75%	36%	84%	3.9	106.7	294.5	261.4	255.2	493387
12/6 21:00	16.3	4.4	2.9	10.8	2.9	1.9	73%	35%	82%	3.9	106.7	291.3	257.9	253.0	493241
12/6 22:00	15.8	5.3	3.3	10.5	3.5	2.2	66%	38%	79%	3.9	106.7	289.5	256.2	251.6	493014
12/6 23:00	15.8	5.5	3.2	10.5	3.6	2.1	65%	41%	80%	4.4	91.7	289.7	260.8	251.2	430828
12/7 0:00	16.3	4.2	2.1	10.8	2.8	1.4	74%	48%	87%	7.0	54.1	273.2	251.4	239.8	274987
12/7 1:00	16.3	3.7	1.9	10.8	2.4	1.3	77%	47%	88%	6.9	54.3	266.6	243.4	230.8	275838
12/7 2:00	16.2	3.7	1.9	10.8	2.4	1.3	77%	48%	88%	7.0	54.2	265.0	241.3	227.6	275400
12/7 3:00	16.3	3.7	1.8	10.8	2.5	1.2	77%	51%	89%	7.0	54.1	264.0	241.4	225.9	274790
12/7 4:00	15.5	3.3	1.8	10.3	2.2	1.2	79%	45%	88%	7.0	54.1	264.0	241.4	224.9	274957
12/7 5:00	15.5	1.4	1.8	10.3	0.9	1.2	91%	-32%	88%	6.9	54.6	264.4	241.6	224.5	276740
12/7 6:00	11.8	1.5	1.7	7.8	1.0	1.2	87%	-13%	85%	4.3	94.1	273.1	246.5	232.5	440909
12/7 7:00	14.2	2.5	3.1	9.4	1.7	2.0	82%	-23%	78%	3.9	106.9	293.1	257.7	249.4	494000

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/7 8:00	15.8	2.5	3.1	10.5	1.7	2.1	84%	-24%	80%	4.3	106.9	294.4	258.8	253.7	494005
12/7 9:00	15.2	3.8	3.3	10.1	2.5	2.2	75%	13%	78%	5.6	107.0	295.4	259.3	255.0	494255
12/7 10:00	12.8	3.0	2.3	8.5	2.0	1.5	76%	25%	82%	5.6	107.0	296.9	261.3	256.6	494329
12/7 11:00	12.5	2.9	2.2	8.3	2.0	1.4	76%	26%	83%	5.6	105.9	296.2	261.7	255.7	490025
12/7 12:00	12.5	2.8	2.1	8.3	1.9	1.4	77%	27%	84%	5.6	107.0	296.4	260.5	255.6	494290
12/7 13:00	12.4	2.6	2.0	8.2	1.7	1.3	79%	25%	84%	5.6	106.9	297.0	261.0	256.9	494109
12/7 14:00	12.5	2.5	1.9	8.3	1.7	1.3	80%	26%	85%	5.6	106.9	297.0	260.9	257.4	494071
12/7 15:00	12.8	2.5		8.5	1.6		81%			5.6	106.8	297.5	261.1	258.1	493644
12/7 16:00	13.0	2.7	2.8	8.6	1.8	1.8	79%	-2%	79%	5.6	106.9	297.4	261.7	258.7	494179
12/7 17:00	11.8	2.4	2.3	7.8	1.6	1.5	79%	6%	81%	5.6	106.9	297.2	262.1	258.7	494198
12/7 18:00	10.6	2.2	2.0	7.1	1.4	1.3	80%	6%	81%	5.6	106.9	296.4	261.5	258.0	494074
12/7 19:00	9.7	1.7	1.6	6.4	1.1	1.0	82%	9%	84%	6.3	61.2	285.3	262.2	249.6	304401
12/7 20:00	9.7	1.3	1.2	6.4	0.9	0.8	87%	10%	88%	6.9	54.4	268.3	245.7	234.4	276005
12/7 21:00	9.2	1.2	1.0	6.1	0.8	0.7	87%	18%	89%	7.0	54.1	264.4	242.6	227.6	274973
12/7 22:00	8.5	1.2	0.9	5.6	0.8	0.6	86%	27%	90%	7.0	54.3	262.6	241.4	224.1	275600
12/7 23:00	8.1	1.2	1.0	5.4	0.8	0.6	86%	19%	88%	6.9	54.5	261.3	240.3	221.9	276643
12/8 0:00	7.7	1.2	0.9	5.1	0.8	0.6	85%	24%	89%	6.9	54.4	259.4	239.0	219.5	276202
12/8 1:00	7.0	1.1	0.9	4.7	0.8	0.6	84%	25%	88%	7.0	54.1	256.0	237.5	216.9	274859
12/8 2:00	6.1	1.1	0.9	4.1	0.7	0.6	82%	24%	86%	7.0	54.1	254.3	238.1	215.1	274927
12/8 3:00	5.2	1.1	0.7	3.5	0.7	0.5	79%	30%	86%	7.0	54.3	253.4	237.9	213.9	275694
12/8 4:00	6.3	1.1	0.7	4.2	0.7	0.5	82%	34%	88%	6.9	54.6	251.9	236.5	212.9	276901
12/8 5:00	6.5	1.1	0.7	4.3	0.7	0.5	84%	33%	89%	6.4	59.8	250.2	236.2	211.8	298638
12/8 6:00	8.0	1.4	1.1	5.3	0.9	0.7	82%	20%	86%	3.9	106.8	269.5	247.9	227.0	493828
12/8 7:00	7.5	1.6	1.5	5.0	1.1	1.0	79%	7%	80%	3.9	106.9	277.8	256.5	237.8	494025

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/8 8:00	7.5	2.6	1.6	5.0	1.7	1.1	66%	37%	78%	3.9	106.9	278.1	257.7	239.8	494194
12/8 9:00	7.8	2.7	2.0	5.2	1.8	1.3	65%	26%	74%	5.6	106.9	280.5	258.7	243.0	494149
12/8 10:00	7.9	2.3	3.9	5.2	1.5	2.6	71%	-68%	51%	5.6	106.9	285.5	256.3	245.9	494018
12/8 11:00	8.1	2.1	2.9	5.4	1.4	1.9	74%	-35%	64%	5.6	106.9	287.9	256.9	248.2	494187
12/8 12:00	8.7	2.1	2.9	5.8	1.4	1.9	76%	-40%	67%	5.6	107.0	289.3	257.1	249.6	494295
12/8 13:00	9.4	2.2	3.3	6.2	1.4	2.2	77%	-52%	65%	5.6	106.9	291.0	256.3	251.0	494032
12/8 14:00	9.9	1.7	2.2	6.5	1.1	1.5	83%	-35%	77%	4.9	106.9	292.3	255.5	252.3	494075
12/8 15:00	9.9	1.9	1.9	6.6	1.3	1.3	81%	-1%	81%	9.8	107.0	293.5	256.6	253.4	494345
12/8 16:00	8.9	1.8	2.4	5.9	1.2	1.6	80%	-33%	74%	9.8	106.9	293.5	256.9	253.5	494053
12/8 17:00	10.6	1.8	1.7	7.0	1.2	1.2	83%	4%	84%	9.8	106.9	291.9	255.6	252.2	493934
12/8 18:00	11.0	2.1	1.9	7.3	1.4	1.3	81%	7%	82%	9.8	106.9	289.5	254.1	249.4	494110
12/8 19:00	11.0	2.1	1.9	7.3	1.4	1.2	80%	12%	83%	4.2	98.9	287.5	254.5	247.1	460733
12/8 20:00	10.0	1.8	1.1	6.6	1.2	0.7	82%	41%	89%	6.9	54.5	267.9	253.1	234.2	276374
12/8 21:00	9.1	1.5	0.7	6.0	1.0	0.5	84%	53%	92%	6.9	55.0	254.5	239.8	221.8	278430
12/8 22:00	8.8	1.4	0.6	5.8	0.9	0.4	84%	58%	93%	7.1	53.3	252.8	238.7	216.7	271358
12/8 23:00	8.0	1.3	0.5	5.3	0.8	0.3	84%	61%	94%	7.1	53.1	251.9	237.3	214.6	270594
12/9 0:00	7.4	1.4	0.6	4.9	0.9	0.4	81%	59%	92%	7.0	54.0	250.9	236.3	212.7	274335
12/9 1:00	6.9	1.4	0.6	4.6	0.9	0.4	80%	59%	92%	7.0	54.3	250.3	236.0	212.2	275778
12/9 2:00	7.1	1.3	0.5	4.7	0.9	0.3	81%	62%	93%	7.0	54.2	252.0	237.8	212.5	275297
12/9 3:00	7.5	1.4	0.4	5.0	0.9	0.3	82%	72%	95%	6.9	54.4	251.4	237.0	212.4	276100
12/9 4:00	8.0	1.3	0.1	5.3	0.8	0.1	84%	89%	98%	6.9	54.3	251.8	237.6	212.9	275833
12/9 5:00	7.5	1.8	0.6	4.9	1.2	0.4	76%	68%	93%	4.2	99.1	261.9	240.0	219.9	461805
12/9 6:00	8.9	2.8	1.1	5.9	1.9	0.7	68%	63%	88%	3.9	106.9	285.1	256.1	239.6	494217
12/9 7:00	10.0	2.9	0.6	6.7	1.9	0.4	71%	80%	94%	3.9	106.8	287.9	257.0	245.8	493681

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O₂) †	ESP Outlet Total Hg (µg/Nm³, 3% O₂) †	Stack Total Hg (µg/Nm³, 3% O₂) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O₂) ‡	Load (MW) §	A AHO Temp (ºF) §	B AHO Temp (ºF) §	ESP Out Temp (ºF) §	Estimated Flow Rate (acfm, 6% O2) &
12/9 8:00		2.5	2.6		1.6	1.7		-6%		3.9	106.9	290.9	258.6	249.8	494111
12/9 9:00		1.7	2.6		1.1	1.7		-56%		11.1	106.9	291.8	258.4	251.5	494117
12/9 10:00		1.4	2.4		1.0	1.6		-64%		13.5	106.9	291.8	258.3	250.3	493943
12/9 11:00		1.3	2.1		0.9	1.4		-54%		13.5	106.8	292.6	259.3	246.0	493695
12/9 12:00		1.1	1.7		0.8	1.1		-51%		13.5	106.9	292.5	259.6	249.3	494046
12/9 13:00		1.2	1.9		0.8	1.2		-55%		13.5	106.9	293.0	260.1	251.5	494238
12/9 14:00		1.1	1.9		0.8	1.2		-63%		13.5	106.9	292.9	259.9	252.3	494227
12/9 15:00		1.1	1.8		0.7	1.2		-56%		16.9	106.9	294.7	258.0	252.9	494126
12/9 16:00		1.3	1.7		0.9	1.2		-31%		16.9	106.9	295.6	256.7	253.7	494112
12/9 17:00	6.4	1.7	2.3	4.3	1.1	1.5	74%	-36%	65%	16.9	106.7	295.2	257.3	254.1	493046
12/9 18:00	9.7	2.3	2.5	6.4	1.6	1.6	76%	-6%	74%	7.5	106.9	296.4	257.7	253.3	493929
12/9 19:00	12.0	2.3	1.9	8.0	1.5	1.2	81%	18%	84%	6.3	61.4	281.7	259.8	244.8	305094
12/9 20:00	11.5	1.2	1.1	7.6	0.8	0.7	89%	10%	90%	7.0	54.1	268.9	247.6	230.2	274668
12/9 21:00	11.0	1.0	1.0	7.3	0.7	0.6	91%	5%	91%	7.1	53.3	266.5	244.8	224.7	271507
12/9 22:00	11.2	0.9	0.9	7.4	0.6	0.6	92%	3%	92%	7.1	53.2	265.0	243.9	222.6	271155
12/9 23:00	8.6	0.7	0.7	5.7	0.5	0.5	92%	-4%	91%	7.0	53.8	264.0	242.4	222.2	273506
12/10 0:00	7.4	0.6	0.7	4.9	0.4	0.5	92%	-13%	91%	7.0	54.3	263.7	242.0	221.7	275470
12/10 1:00	6.8	0.6	0.7	4.5	0.4	0.5	92%	-22%	90%	7.0	54.1	264.8	242.7	222.2	274995
12/10 2:00	6.2	0.5	0.6	4.1	0.3	0.4	92%	-14%	91%	7.1	53.3	263.7	242.2	222.0	271420
12/10 3:00	6.3	0.5	0.6	4.2	0.4	0.4	92%	-18%	90%	7.1	53.1	263.3	242.0	221.1	270862
12/10 4:00	5.6	0.5	0.6	3.7	0.3	0.4	91%	-17%	89%	6.9	54.8	263.4	241.8	221.1	277837
12/10 5:00	6.2	0.7	0.7	4.1	0.4	0.5	89%	-5%	89%	4.9	82.4	261.2	241.4	223.4	392142
12/10 6:00	8.8	1.4	1.4	5.8	0.9	0.9	84%	1%	84%	3.9	106.9	289.2	256.7	243.3	494226
12/10 7:00	9.1	1.6	1.5	6.0	1.1	1.0	82%	6%	83%	3.9	106.9	290.9	257.7	249.1	494072

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/10 8:00	8.3	1.5	1.5	5.5	1.0	1.0	82%	-3%	82%	4.7	106.9	290.7	257.9	250.0	494242
12/10 9:00	5.7	1.7	1.7	3.8	1.1	1.2	70%	0%	69%	5.6	106.9	290.8	258.0	250.8	494089
12/10 10:00		2.2	1.9		1.5	1.3		15%		5.6	106.9	290.2	257.9	251.0	493871
12/10 11:00	13.9	2.8	2.4	9.2	1.9	1.6	80%	15%	83%	5.6	106.8	289.9	257.6	250.4	493820
12/10 12:00	15.0	2.8	2.5	10.0	1.9	1.7	81%	11%	83%	5.6	107.0	289.7	257.1	250.0	494480
12/10 13:00	15.2	3.1	2.9	10.1	2.1	1.9	80%	8%	81%	5.6	107.0	289.9	257.1	250.2	494389
12/10 14:00	15.3	3.8	2.6	10.2	2.5	1.7	75%	31%	83%	5.6	106.9	289.7	256.4	249.9	494205
12/10 15:00	15.7	3.1	2.6	10.4	2.1	1.7	80%	18%	84%	5.6	106.9	288.5	255.7	248.3	494134
12/10 16:00	12.9		3.3	8.5		2.2			75%	5.6	106.9	288.0	253.6	245.7	493964
12/10 17:00	13.1	3.8	3.1	8.7	2.6	2.0	71%	21%	77%	5.6	107.0	287.5	252.5	245.6	494372
12/10 18:00	13.8	4.0	3.1	9.1	2.7	2.0	71%	24%	78%	5.3	107.0	286.8	252.4	245.2	494263
12/10 19:00	14.8	4.1	2.5	9.9	2.7	1.7	72%	39%	83%	7.6	66.7	277.0	254.6	238.3	327195
12/10 20:00	14.9		1.8	9.9		1.2			88%	9.1	54.0	259.4	239.3	222.3	274284
12/10 21:00	14.3		1.8	9.5		1.2			87%	9.1	54.1	255.3	236.0	216.2	274864
12/10 22:00	14.2		1.7	9.4		1.1			88%	9.1	54.3	254.2	235.0	213.3	275670
12/10 23:00	11.0		1.0	7.3		0.7			91%	9.1	54.0	252.1	234.7	210.1	274557
12/11 0:00	10.1		1.0	6.7		0.7			90%	9.1	54.2	250.4	234.2	208.7	275222
12/11 1:00	9.1		1.0	6.0		0.6			89%	9.0	54.8	249.1	234.6	208.0	277557
12/11 2:00	9.5		0.9	6.3		0.6			90%	9.1	54.2	248.2	233.2	206.6	275098
12/11 3:00	9.3		0.9	6.2		0.6			90%	9.1	54.1	249.7	234.6	206.7	274804
12/11 4:00	9.7		1.1	6.4		0.7			88%	9.2	53.2	255.1	239.5	210.4	271126
12/11 5:00	9.9		0.9	6.6		0.6			90%	9.1	53.9	246.3	231.3	206.6	273823
12/11 6:00	10.2		1.0	6.8		0.6			90%	9.2	53.0	246.2	231.4	205.0	270421
12/11 7:00	10.2		1.0	6.8		0.6			90%	9.3	52.8	246.6	231.4	204.8	269473

Date/Time	ESP Inlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Outlet Total Hg ($\mu g/Nm^3$, 3% O_2) †	Stack Total Hg ($\mu g/Nm^3$, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/11 8:00	9.5		1.0	6.3		0.6			90%	9.4	52.3	243.3	229.7	203.4	267142
12/11 9:00										9.1	54.0	243.7	229.9	203.0	274474
12/11 10:00	10.3		2.1	6.9		1.4			80%	9.1	53.9	243.8	234.3	203.7	274188
12/11 11:00	10.3	2.6	2.1	6.8	1.7	1.4	75%	19%	80%	9.1	54.1	239.3	242.7	204.2	274906
12/11 12:00	10.0	2.4	1.8	6.7	1.6	1.2	76%	26%	82%	9.1	54.4	240.2	248.0	205.7	275994
12/11 13:00	9.5	1.9	1.5	6.3	1.2	1.0	80%	20%	84%	8.9	55.2	242.4	237.7	205.3	279437
12/11 14:00	9.8	2.1	1.5	6.5	1.4	1.0	79%	30%	85%	9.1	54.1	244.2	236.2	204.8	274882
12/11 15:00	9.4	2.1		6.3	1.4		78%			9.1	54.1	245.4	237.4	205.7	274871
12/11 16:00	8.4	2.0	1.8	5.6	1.3	1.2	76%	13%	79%	9.1	54.1	245.5	238.1	206.1	274662
12/11 17:00	9.4	1.9	1.5	6.3	1.3	1.0	80%	21%	84%	8.7	57.2	244.6	237.2	206.4	287687
12/11 18:00	11.3	1.9	1.5	7.5	1.3	1.0	83%	20%	87%	9.0	54.6	244.7	237.7	205.9	277082
12/11 19:00	11.4	2.0	1.8	7.6	1.3	1.2	83%	6%	84%	9.1	54.3	245.4	237.7	206.6	275594
12/11 20:00	11.5	1.9	1.5	7.6	1.3	1.0	83%	23%	87%	9.1	54.1	246.2	237.5	207.0	274867
12/11 21:00	11.3	1.8	1.3	7.5	1.2	0.9	84%	28%	88%	9.1	54.2	245.9	237.4	206.9	275437
12/11 22:00	11.3	1.7	1.2	7.5	1.1	0.8	85%	30%	89%	9.1	54.2	245.2	236.8	206.6	275262
12/11 23:00	10.8	1.6	1.2	7.2	1.1	0.8	85%	28%	89%	9.1	54.4	245.0	236.9	206.2	276167
12/12 0:00	10.4	1.7	1.2	6.9	1.1	0.8	84%	31%	89%	9.1	54.3	245.1	237.3	206.5	275449
12/12 1:00	10.1	1.6	1.2	6.7	1.1	0.8	84%	28%	89%	9.1	54.2	244.4	236.5	206.1	275318
12/12 2:00	9.6	1.6	1.2	6.3	1.1	0.8	83%	28%	88%	9.1	54.2	244.0	237.3	205.7	275369
12/12 3:00	9.7	1.6	1.2	6.5	1.1	0.8	83%	26%	88%	9.1	54.0	245.0	237.9	206.3	274514
12/12 4:00	9.0	1.6	1.1	6.0	1.1	0.7	82%	29%	88%	9.1	53.8	245.3	237.9	206.8	273504
12/12 5:00	9.1	1.5	1.3	6.0	1.0	0.8	84%	16%	86%	9.2	53.3	244.4	238.1	207.0	271541
12/12 6:00	9.6	1.6	1.1	6.4	1.0	0.7	84%	29%	88%	9.2	53.2	241.9	236.0	205.3	270973
12/12 7:00	8.6	1.5	0.9	5.7	1.0	0.6	83%	36%	89%	9.3	52.7	242.6	236.7	204.7	269146

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/12 8:00	7.5	1.3	0.9	5.0	0.8	0.6	83%	27%	88%	9.1	54.2	241.1	235.8	204.5	275187
12/12 9:00	6.1	1.4	0.8	4.1	0.9	0.5	78%	45%	88%	8.8	56.5	247.2	233.6	205.2	284847
12/12 10:00	10.2		1.5	6.8		1.0			85%	9.2	53.2	255.8	230.4	207.1	270940
12/12 11:00	10.0	2.4	1.3	6.7	1.6	0.9	76%	43%	87%	9.4	52.3	257.0	229.5	208.5	267365
12/12 12:00	10.0	2.0	1.2	6.6	1.3	0.8	80%	41%	88%	9.2	53.0	256.7	228.5	209.1	270285
12/12 13:00	10.3	2.1	1.4	6.8	1.4	0.9	80%	33%	87%	9.1	54.1	260.5	231.2	211.0	274954
12/12 14:00	10.8	2.0	1.3	7.2	1.3	0.9	82%	34%	88%	9.1	54.1	262.2	233.1	213.6	274780
12/12 15:00	11.0	2.4	1.4	7.3	1.6	1.0	79%	39%	87%	9.3	52.9	263.5	234.0	214.6	269851
12/12 16:00	10.2	3.2		6.8	2.1		68%			9.2	53.1	264.9	235.2	216.3	270551
12/12 17:00	11.7	2.4		7.8	1.6		80%			8.8	56.4	264.6	234.5	216.9	284331
12/12 18:00	12.5	2.5		8.3	1.6		80%			9.0	54.6	266.1	235.6	216.7	276791
12/12 19:00	12.3	2.2		8.2	1.5		82%			9.1	54.3	265.6	233.8	216.0	275524
12/12 20:00	11.3	2.0		7.5	1.3		83%			9.1	54.2	264.8	232.8	215.1	275150
12/12 21:00	11.2	1.8		7.4	1.2		84%			9.1	54.2	264.2	232.4	214.4	275293
12/12 22:00	10.7	1.9		7.1	1.2		82%			9.2	53.2	263.0	231.6	213.7	271220
12/12 23:00	9.3	1.7		6.2	1.2		81%			9.3	52.7	260.1	229.4	211.5	268939
12/13 0:00	8.5	1.6		5.7	1.1		81%			9.2	53.5	260.7	229.7	210.9	272300
12/13 1:00	8.4	1.5		5.6	1.0		82%			9.2	53.1	261.4	230.7	211.3	270849
12/13 2:00	8.4	1.4		5.6	0.9		83%			9.2	53.5	262.1	231.2	211.9	272515
12/13 3:00	8.5	1.6		5.6	1.1		81%			9.3	52.5	260.9	230.6	211.4	268311
12/13 4:00	8.6	1.6		5.7	1.1		81%			9.2	53.4	260.6	229.5	211.1	272103
12/13 5:00	8.3	1.4		5.5	0.9		83%			9.1	54.2	260.6	229.2	210.5	275418
12/13 6:00	7.9	1.6		5.3	1.1		80%			9.0	55.2	260.7	229.2	210.0	279304
12/13 7:00	7.2	2.3		4.8	1.6		67%			8.8	56.1	259.1	228.8	209.6	283257

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/13 8:00	8.1	2.6	1.3	5.4	1.7	0.9	68%	50%	84%	9.1	54.1	260.9	229.9	210.2	274839
12/13 9:00	10.9		1.2	7.3		0.8			89%	6.1	53.9	260.1	229.5	210.6	274054
12/13 10:00		1.8	1.4		1.2	0.9		23%		12.1	54.1	263.4	232.6	211.9	274934
12/13 11:00		1.9			1.3					12.1	54.0	262.9	231.6	212.4	274452
12/13 12:00		1.9			1.3					12.1	54.1	264.0	232.2	213.1	274766
12/13 13:00	9.9	1.9		6.6	1.2		81%			12.1	54.5	264.3	232.9	212.8	276410
12/13 14:00	11.1	1.7	0.9	7.4	1.1	0.6	85%	46%	92%	12.1	54.2	265.8	233.9	213.5	275179
12/13 15:00	11.7	1.5	0.9	7.8	1.0	0.6	87%	42%	92%	12.1	54.4	265.4	233.5	213.7	276161
12/13 16:00		1.9	0.8		1.3	0.5		57%		12.1	54.2	264.7	233.4	214.1	275161
12/13 17:00	8.2	1.7	0.9	5.4	1.1	0.6	79%	50%	90%	11.4	58.4	261.2	230.3	213.2	292518
12/13 18:00	10.1	1.8		6.7	1.2		83%			11.2	59.6	265.1	233.8	214.0	297800
12/13 19:00	11.6	2.5		7.7	1.6		79%			12.1	54.2	264.2	229.6	212.1	275407
12/13 20:00	11.7	3.0		7.8	2.0		75%			0.0	54.3	263.5	228.5	210.5	275507
12/13 21:00	10.5	2.8		7.0	1.9		73%			0.0	55.0	262.4	227.8	210.2	278588
12/13 22:00	9.7	2.8		6.4	1.9		70%			0.0	54.5	261.9	227.9	209.9	276667
12/13 23:00	13.0	2.5		8.6	1.7		80%			0.0	54.4	260.2	226.6	208.4	275993
12/14 0:00	11.8	2.3		7.8	1.6		80%			0.0	54.1	262.5	228.4	209.3	274948
12/14 1:00	12.1	2.3		8.0	1.5		81%			0.0	54.2	256.0	224.1	206.1	275058
12/14 2:00	12.3	2.3		8.2	1.5		81%			0.0	54.2	254.1	222.3	203.7	275350
12/14 3:00	13.4	2.6		8.9	1.7		81%			0.0	54.2	254.5	221.6	202.4	275175
12/14 4:00	12.3	2.4		8.2	1.6		80%			0.0	54.1	253.5	221.0	201.9	274867
12/14 5:00	11.7	2.5		7.8	1.7		79%			0.0	53.6	252.6	220.8	201.0	272857
12/14 6:00	11.5	2.5		7.6	1.7		78%			0.0	55.7	253.9	220.9	201.1	281411
12/14 7:00	11.7	1.8		7.8	1.2		84%			2.0	53.5	254.9	222.9	202.3	272149

Date/Time	ESP Inlet Total Hg (µg/Nm^3, 3% O_2) †	ESP Outlet Total Hg (µg/Nm^3, 3% O_2) †	Stack Total Hg (µg/Nm^3, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/14 8:00	10.4	1.6		6.9	1.1		85%			9.1	54.0	251.5	219.7	200.8	274331
12/14 9:00	8.6		0.5	5.7		0.3			94%	12.0	54.7	251.5	220.1	201.0	277351
12/14 10:00	10.6	1.4	0.5	7.0	0.9	0.3	87%	62%	95%	12.2	54.0	251.5	221.4	201.1	274322
12/14 11:00	10.8	1.5	0.7	7.1	1.0	0.5	86%	51%	93%	12.1	54.1	250.5	221.5	201.1	274938
12/14 12:00	11.0	1.6		7.3	1.1		85%			12.2	53.9	251.7	222.3	201.2	274042
12/14 13:00	7.8	2.5		5.2	1.7		67%			6.0	54.7	252.5	222.8	202.0	277510
12/14 14:00	8.0	3.0		5.3	2.0		62%			0.0	54.0	254.7	224.8	203.1	274321
12/14 15:00	5.8	3.3	1.2	3.9	2.2	0.8	43%	62%	79%	0.0	54.2	255.9	226.2	204.4	275195
12/14 16:00	8.1	4.5	1.0	5.4	3.0	0.7	45%	78%	88%	0.0	53.5	256.6	227.1	205.1	272346
12/14 17:00	6.2	2.9	1.3	4.1	1.9	0.8	54%	56%	80%	0.0	63.9	254.6	224.3	205.6	315520
12/14 18:00	8.8	3.6	1.8	5.8	2.4	1.2	59%	51%	80%	0.0	64.6	266.8	235.0	212.6	318300
12/14 19:00	8.9	3.4		5.9	2.3		62%			0.0	93.5	273.6	233.5	218.5	438380
12/14 20:00	10.5	4.2		7.0	2.8		60%			0.0	84.4	281.8	245.1	227.7	400737
12/14 21:00	12.7	4.7		8.5	3.1		63%			0.0	54.3	264.7	230.6	216.9	275824
12/14 22:00	12.5	4.7		8.3	3.1		62%			0.0	64.8	263.0	229.0	211.9	319055
12/14 23:00	11.1	4.0		7.4	2.7		64%			0.0	53.0	256.7	225.1	207.1	270072
12/15 0:00	10.5	3.8		7.0	2.5		64%			0.0	53.4	253.4	220.8	202.7	271811
12/15 1:00	10.8	4.0		7.2	2.7		63%			0.0	53.7	252.5	218.7	200.7	273188
12/15 2:00	11.0	4.3		7.3	2.9		61%			0.0	52.6	252.3	218.9	199.5	268555
12/15 3:00	10.5	4.1		7.0	2.7		61%			0.0	54.0	251.7	217.8	199.0	274579
12/15 4:00	10.3	4.2		6.8	2.8		59%			0.0	53.2	252.0	218.2	198.5	271031
12/15 5:00	9.4	4.0		6.3	2.7		57%			0.0	54.8	249.9	217.5	198.3	277866
12/15 6:00	9.0	3.6		6.0	2.4		60%			0.0	60.3	249.9	218.4	198.7	300372
12/15 7:00	10.2	4.1		6.8	2.7		60%			0.0	54.1	251.8	220.7	199.4	274960

Date/Time	ESP Inlet Total Hg (µg/Nm³, 3% O_2) †	ESP Outlet Total Hg (µg/Nm³, 3% O_2) †	Stack Total Hg (µg/Nm³, 3% O_2) †	ESP Inlet Hg (lb/Tbtu) *	ESP Outlet Hg (lb/TBtu) *	Stack Hg (lb/TBtu) *	% Hg Removal across ESP *	% Hg Removal across JBR *	% Hg Removal across System *	Carbon Injection (lb/Macf, 6% O_2) ‡	Load (MW) §	A AHO Temp (°F) §	B AHO Temp (°F) §	ESP Out Temp (°F) §	Estimated Flow Rate (acfm, 6% O2) &
12/15 8:00	10.8	4.9	1.9	7.2	3.3	1.3	55%	61%	82%	0.0	53.6	252.2	220.3	199.1	272598
12/15 9:00		6.2	3.1		4.1	2.1		50%		0.0	54.0	251.9	219.2	199.5	274340
12/15 10:00	12.7	6.4	2.4	8.4	4.3	1.6	49%	62%	81%	0.0	54.1	254.3	221.0	200.9	274660
12/15 11:00	14.2	7.0	2.4	9.5	4.6	1.6	51%	66%	83%	0.0	53.0	257.2	223.8	203.6	270262
12/15 12:00	13.3	6.5		8.8	4.3		51%			0.0	55.6	256.4	223.2	205.7	281129

Appendix E

QA/QC Results

The quality assurance measures implemented for this project are summarized in this appendix. The QA/QC measures addressed the following critical measurement parameters: 1) total and speciated mercury in flue gas at air heater outlet, ESP outlet, and JBR FGD outlet; 2) mercury content in the coal and byproducts solids; and 3) HCl concentrations in the flue gas at the various sample locations.

Specific quantitative data quality objectives established for the project, expressed as precision, accuracy and completeness, are summarized in Table E-1.

Table E-1. Quality Assurance Objectives for Critical Measurement Parameters

Critical Parameter (Method)	Sampling Method	Experimental Conditions	Precision	Accuracy	Completeness [1]
Mercury in Flue Gas (Method 7470 Digestion; CVAA Analysis)	Ontario Hydro Method	Matrix Spike and Duplicates	20% Relative Percent Difference	80-120% Recovery	100%
HCl in Flue Gas	Method 26A	Matrix Spike and Duplicates	15% Relative Percent Difference	80-120% Recovery	100%
Mercury in Flue Gas ($KCl/SnCl_2$ Impingers, CVAA Analysis)	Semi-continuous Gas Analyzer	Matrix Spike (Method of Standard Additions)/ Replicate Assays/ Relative Accuracy Testing	20% Relative Percent Difference	80-120% Recovery	80%
Mercury in Coal, ESP fly ash, FGD solids (ASTM 3684 HF Digestion (solids); EPA 7471 CVAA Analysis) [1]	Grab Sample Composites	Matrix Spike and Duplicates	25% Relative Percent Difference	70-130% Recovery	100%
		Coal and Fly Ash NIST Standard Reference Materials	NA	80-120% Recovery	
		FGD Reference Material [2]	NA	80-120% Recovery	

[1] Completeness is defined as the percentage of planned samples actually collected.

QA/QC measures conducted prior to and during the field test program included calibrations of the sorbent injection and sampling systems, as well as internal quality control checks related to analytical instruments and measurements. Each of these topics is discussed in the following sections.

Calibration of Injection and Sampling Equipment

The following calibration procedures were used for the sorbent injection and source sampling equipment during the course of the project. Records of all manufacturer calibration and field calibrations for all injection and sampling equipment are maintained in the URS and ADA-ES project files.

Sorbent Injection System

The accuracy and consistency of volumetric feeding of dry sorbents are susceptible to changes due to material density, moisture, and plugging. Two methods were used to confirm the feed rate of the sorbent: (1) the feed system was calibrated over a range of expected sorbent injection rates and (2) the rate of loss-of-weight for the loaded sorbent was computed. For the parametric tests, a portable injection system was used, and the primary method of determining the sorbent feed rate was based on a pre- and post-test calibration of the feed system. The sorbent bag-emptying rate was used to confirm these calibrations. For the long-term tests, a silo was used that was equipped with a load cell. The real-time loss-of-weight load cell system gave the operators rapid indication of any significant change in feed-rate during the test period.

Source Sampling Equipment

Various components of the source sampling equipment were calibrated prior to use in the field test program. These calibrations are summarized below:

- Type S pitot tube calibration – design and construction of pitot tube according to EPA document 600/4-77-027b. Inspection per the requirements of EPA Method 2.
- Sample nozzle calibration – clean, inspect and calibrate according to EPA document 600/4-77-027b. Calibration per EPA Method 5.
- Temperature measuring devices – calibrated and linearity checked using a traceable precision voltage generator.
- Dry gas meter and orifice – calibrated semi-annually against calibrated orifice and calibration checked before and after field use.]

SCEM Analyzers

The analyzers were calibrated for elemental mercury, sample flow rate, and oxygen concentration following installation at the test sites and periodically throughout the testing program. The calibration of both the Au-CVAAS analyzer, which measures the mass of mercury desorbed, and the mass flow meter in the monitor, which measures the total sample volume through the analyzer, were checked daily during testing. The analyzer was calibrated by introducing a spike of vapor phase elemental mercury standard into the analyzer upstream of the gold wire or just upstream of the impinger solutions. These quality control samples are important for ensuring proper transport of mercury through the various flow lines. The mercury vapor for the spike was taken from the air space in a vial containing liquid elemental mercury. The mercury spike concentration is calculated from the vapor pressure of mercury and the temperature of the vial. The vial temperature was measured with a precision thermometer.

QA/QC results for SCEM analyzer measurements, including elemental mercury calibration spikes, are summarized in the following table. These QA/QC results are detailed in Tables E-2, E-3 and E-4.

	Spike Recovery		**Replicate Analysis**	
Location	**Average Recovery (%)**	**Percent of Determinations Meeting 80-120% Recovery**	**Average Relative Standard Deviation (%)**	**Percent of RSD Determinations Meeting 0-20%**
ESP Inlet/Air Heater Outlet	91.3	70.2	11.6	90.7
ESP Outlet	96.5	79.4	8.8	89.9
Stack	93.5	61.1	11.0	84.8

Typically, corrective actions, as shown in Table E-2, E-3, and E-4 were implemented for spike recoveries below 75%. These usually required a repair, or instrument adjustment. Typically the emissions data were corrected for recoveries in excess of 125%.

The calibration of the mass flow meter was checked by connecting the operating meter in series with a pre-calibrated dry cal meter and verifying measured flow rates across the range expected during testing. Oxygen sensor calibration and linear response were checked in the laboratory before the instruments were shipped to the field test site. During field-testing, oxygen sensor readings were periodically compared to the data obtained from Orsat measurements.

Documentation of analyzer calibration and any system maintenance was recorded in the project notebook. Verification of computerized analyzer calculations was conducted manually on a periodic basis. ***Any data collected during periods of suspect analyzer operation were flagged as questionable data.***

Table E-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
2/25/04	17:30	Spike before gold	flue gas	79	7.4%	none
	17:35	Spike before gold	flue gas	89		none
	17:40	Spike before gold	flue gas	91		none
		average of day's QC's		**86**		
2/26/04	8:30	Spike before gold	air	71	21.6%	none
	8:35	Spike before gold	air	112		none
	8:40	Spike before gold	air	95		none
	8:45	Spike before gold	air	72		none
	8:50	Spike before gold	air	110		none
	10:15	Spike before gold	flue gas	95	3.8%	none
	10:20	Spike before gold	flue gas	90		none
	11:30	Spike before gold	flue gas	85		none
	13:45	Spike before gold	flue gas	79	13.7%	none
	13:50	Spike before gold	flue gas	100		none
	13:55	Spike before gold	flue gas	101		none
	16:00	Spike before gold	air	86	5.7%	none
	16:05	Spike before gold	air	94		none
	18:30	Spike before gold	air	90	10.1%	none
	18:35	Spike before gold	air	74		none
	18:40	Spike before gold	air	80		none
		average of day's QC's		**90**		
2/27/04	9:00	Spike before gold	air	98	0.7%	none
	9:05	Spike before gold	air	97		none
		average of day's QC's		**97**		
3/1/04	10:00	Spike before gold	air	103	9.6%	none
	10:05	Spike before gold	air	86		none
	10:10	Spike before gold	air	90		none
	19:30	Spike before gold	air	110	13.1%	none
	19:35	Spike before gold	air	126		none
	19:40	Spike before gold	air	143		none
		average of day's QC's		**110**		

Table E-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/2/04	7:30	Spike before gold	air	79	3.5%	none
	7:35	Spike before gold	air	84		none
	7:40	Spike before gold	air	80		none
	7:45	Spike before gold	air	71		none
	16:00	Spike before gold	air	83	14.5%	none
	16:05	Spike before gold	air	96		none
	16:10	Spike before gold	air	111		none
	16:15	Spike through impingers	air	100		none
		average of day's QC's		**88**		
3/3/04	7:00	Spike before gold	air	88	3.1%	none
	7:05	Spike before gold	air	92		none
	16:08	Spike before gold	air	104	1.3%	none
	16:13	Spike before gold	air	106		none
		average of day's QC's		**98**		
3/4/04	6:30	Spike before gold	flue gas	96	9.0%	none
	6:45	Spike before gold	air	109		none
	16:51	Spike before gold	air	116	5.4%	none
	16:56	Spike before gold	air	114		none
	17:01	Spike before gold	air	126		none
		average of day's QC's		**112**		
3/28/04	16:00	Spike before gold	air	108	6.0%	none
	16:05	Spike before gold	air	99		none
		average of day's QC's		**104**		
3/29/04	7:15	Spike before gold	air	88	12.2%	none
	7:20	Spike before gold	air	82		none
	7:25	Spike before gold	air	83		none
	7:30	Spike before gold	air	102		none
	7:35	Spike before gold	air	88		none
	7:40	Spike before gold	air	110		none
	9:30	Spike through impingers	air	31		none
	13:40	Spike through impingers	air	80	3.8%	none
	13:45	Spike through impingers	air	84		none
	13:50	Spike through impingers	air	78		none
		average of day's QC's		**83**		

Table E-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/30/04	7:05	Spike before gold	air	82	14.9%	none
	7:10	Spike before gold	air	66		recalibrate
	13:00	Spike before gold	flue gas	97	3.1%	none
	13:05	Spike before gold	flue gas	101		none
		average of day's QC's		**86**		
4/6/04	10:15	Spike before gold	flue gas	121		none
	11:57	Spike before gold	flue gas	101		none
	13:00	Spike before gold	air	67		recalibrate
		average of day's QC's		**96**		
4/7/04	7:50	Spike through impingers	air	-		none
	9:45	Spike through impingers	air	48		replace impingers
	15:38	Spike before gold	flue gas	101		none
	17:15	Spike before gold	flue gas	112		none
		average of day's QC's		**87**		
11/13/04	15:28	Spike before gold	flue gas	74	28.3%	none
	15:32	Spike before gold	flue gas	111		recalibrate
		average of day's QC's		**93**		
11/14/04	13:27	Spike before gold	flue gas	97	21.5%	none
	13:32	Spike before gold	flue gas	135		none
	13:37	Spike before gold	flue gas	150		none
	14:56	Spike through impingers	air	70	7.6%	none
	15:03	Spike through impingers	air	78		none
		average of day's QC's		**106**		
11/15/04	15:11	Spike before gold	flue gas	103		none
		average of day's QC's		**103**		
11/16/04	11:32	Spike before gold	flue gas	145	3.5%	none
	11:40	Spike before gold	flue gas	138		recalibrate
		average of day's QC's		**142**		

Table E-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
11/17/04	12:27	Spike before gold	flue gas	57	34.7%	none
	12:31	Spike before gold	flue gas	94		none
	12:51	Spike before gold	flue gas	88	6.1%	none
	12:55	Spike before gold	flue gas	96		none
	13:11	Spike before gold	flue gas	70		replace column
	16:24	Spike before gold	air	55	17.6%	none
	16:31	Spike before gold	air	53		none
	16:35	Spike before gold	air	65		none
	16:38	Spike before gold	air	77		recalibrate
		average of day's QC's		**73**		
11/18/04	7:21	Spike before gold	air	106	4.1%	none
	7:24	Spike before gold	air	100		none
	8:06	Spike before gold	flue gas	75	5.4%	none
	8:11	Spike before gold	flue gas	81		none
	9:24	Spike before gold	flue gas	68	10.5%	none
	9:27	Spike before gold	flue gas	83		none
	9:31	Spike before gold	flue gas	81		none
	11:20	Spike through impingers	air	83		none
		average of day's QC's		**85**		
11/19/04	10:42	Spike before gold	flue gas	71	22.8%	none
	10:46	Spike before gold	flue gas	110		none
	10:49	Spike before gold	flue gas	108		none
		average of day's QC's		**96**		
11/20/04	12:59	Spike before gold	flue gas	63	16.0%	none
	13:03	Spike before gold	flue gas	82		none
	13:07	Spike before gold	flue gas	86		none
		average of day's QC's		**77**		
11/21/04	10:13	Spike before gold	flue gas	48	10.9%	none
	10:17	Spike before gold	flue gas	56		recalibrate
	13:19	Spike before gold	flue gas	59	19.6%	none
	13:23	Spike before gold	flue gas	78		none
	14:01	Spike before gold	flue gas	98		none
	15:06	Spike before gold	flue gas	92		none
		average of day's QC's		**72**		

Table E-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
11/22/04	13:13	Spike before gold	flue gas	98	6.2%	none
	13:22	Spike before gold	flue gas	107		none
	15:10	Spike before gold	flue gas	101		none
		average of day's QC's		**102**		
11/23/04	9:46	Spike before gold	flue gas	106		none
	13:10	Spike before gold	flue gas	93		none
		average of day's QC's		**100**		
11/24/04	8:58	Spike before gold	flue gas	74	7.6%	none
	9:05	Spike before gold	flue gas	86		none
	9:09	Spike before gold	flue gas	82		none
	10:41	Spike through impingers	air	32	66.6%	none
	10:49	Spike through impingers	air	89		none
		average of day's QC's		**73**		
11/25/04	12:13	Spike before gold	flue gas	79	15.3%	none
	12:16	Spike before gold	flue gas	105		none
	12:20	Spike before gold	flue gas	104		none
		average of day's QC's		**96**		
11/26/04	11:59	Spike before gold	flue gas	94	11.7%	none
	12:02	Spike before gold	flue gas	116		none
	12:05	Spike before gold	flue gas	97		none
		average of day's QC's		**102**		
11/27/04	10:06	Spike before gold	flue gas	82	9.4%	none
	10:10	Spike before gold	flue gas	91		none
	10:13	Spike before gold	flue gas	99		none
		average of day's QC's		**91**		
11/28/04	13:06	Spike before gold	flue gas	92	4.7%	none
	13:09	Spike before gold	flue gas	96		none
	13:12	Spike before gold	flue gas	101		none
		average of day's QC's		**96**		
11/30/04	15:03	Spike before gold	flue gas	91		none
		average of day's QC's		**91**		
12/1/04	10:38	Spike before gold	flue gas	91	2.3%	none
	10:41	Spike before gold	flue gas	94		none
	14:36	Spike through impingers	air	90	3.1%	none
	14:48	Spike through impingers	air	94		none
		average of day's QC's		**92**		

Table E-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
12/2/04	8:20	Spike before gold	flue gas	93	29.5%	none
	8:23	Spike before gold	flue gas	78		none
	8:29	Spike before gold	flue gas	76		none
	8:32	Spike before gold	flue gas	148		none
	8:41	Spike before gold	flue gas	136		none
	8:44	Spike before gold	flue gas	92		none
		average of day's QC's		**104**		
12/4/04	9:15	Spike before gold	air	86	10.6%	none
	9:18	Spike before gold	air	100		none
		average of day's QC's		**93**		
12/5/04	8:53	Spike before gold	flue gas	77	8.3%	none
	8:56	Spike before gold	flue gas	91		none
	8:59	Spike before gold	flue gas	84		none
		average of day's QC's		**84**		
12/6/04	10:03	Spike before gold	flue gas	63	3.4%	none
	10:06	Spike before gold	flue gas	60		recalibrate
	10:48	Spike before gold	air	115	8.5%	none
	10:52	Spike before gold	air	102		none
	12:08	Spike before gold	flue gas	77	2.7%	none
	12:11	Spike before gold	flue gas	80		none
	12:27	Spike before gold	flue gas	81		none
		average of day's QC's		**83**		
12/7/04	9:50	Spike before gold	flue gas	96	18.5%	none
	9:53	Spike before gold	flue gas	133		none
	10:00	Spike before gold	flue gas	100		none
		average of day's QC's		**110**		
12/8/04	7:11	Spike before gold	air	106	7.7%	none
	7:14	Spike before gold	air	95		none
	9:22	Spike before gold	flue gas	107	0.7%	none
	9:28	Spike before gold	flue gas	108		none
		average of day's QC's		**104**		
12/9/04	14:04	Spike before gold	air	46	13.8%	none
	14:07	Spike before gold	air	43		none
	14:17	Spike before gold	air	35		none
	14:33	Spike through impingers	air	129		replace column
		average of day's QC's		**63**		

Table E-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
12/10/04	11:13	Spike before gold	flue gas	94	17.5%	none
	11:19	Spike before gold	flue gas	133		none
	11:25	Spike before gold	flue gas	110		none
		average of day's QC's		**112**		
12/11/04	9:25	Spike before gold	air	100	7.4%	none
	9:28	Spike before gold	air	111		none
	10:37	Spike before gold	flue gas	92	3.0%	none
	10:40	Spike before gold	flue gas	96		none
		average of day's QC's		**100**		
12/12/04	9:17	Spike before gold	air	97	8.9%	none
	9:20	Spike before gold	air	110		none
	9:54	Spike before gold	flue gas	94	3.1%	none
	9:57	Spike before gold	flue gas	90		none
		average of day's QC's		**98**		
12/13/04	8:15	Spike before gold	air	96	2.9%	none
	8:18	Spike before gold	air	100		none
	13:00	Spike before gold	flue gas	85	2.5%	none
	13:03	Spike before gold	flue gas	81		none
	13:10	Spike before gold	flue gas	84		none
		average of day's QC's		**89**		
12/14/04	8:43	Spike before gold	air	89	5.6%	none
	8:46	Spike before gold	air	95		none
	8:49	Spike before gold	air	85		none
	10:56	Spike before gold	flue gas	52	14.6%	none
	11:00	Spike before gold	flue gas	64		recalibrate
		average of day's QC's		**77**		
12/15/04	11:31	Spike before gold	flue gas	94	2.9%	none
	11:34	Spike before gold	flue gas	98		none
		average of day's QC's		**96**		
1/17/05	14:02	Spike before gold	flue gas	106	2.6%	none
	14:08	Spike before gold	flue gas	110		none
	16:31	Spike before gold	flue gas	98	2.1%	none
	16:35	Spike before gold	flue gas	101		none
		average of day's QC's		**104**		

Table E-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
1/18/05	7:50	Spike before gold	flue gas	104	4.9%	none
	7:54	Spike before gold	flue gas	97		none
	14:20	Spike before gold	flue gas	107	4.1%	none
	14:24	Spike before gold	flue gas	101		none
		average of day's QC's		**102**		
1/19/05	7:15	Spike before gold	flue gas	107	15.4%	none
	7:18	Spike before gold	flue gas	86		none
	9:02	Spike before gold	air	91	4.5%	none
	9:05	Spike before gold	air	97		none
	14:00	Spike before gold	flue gas	100		none
	16:46	Spike before gold	flue gas	10	115.7%	none
	16:50	Spike before gold	air	100		none
	17:03	Spike through impingers	air	0		replace impingers
	18:12	Spike before gold	flue gas	68	21.0%	none
	18:15	Spike before gold	flue gas	97		none
	18:28	Spike before gold	flue gas	103		none
		average of day's QC's		**78**		
1/20/05	7:17	Spike before gold	flue gas	99	5.5%	none
	7:20	Spike before gold	flue gas	107		none
	13:50	Spike before gold	flue gas	104	10.2%	none
	13:53	Spike before gold	flue gas	90		none
		average of day's QC's		**100**		
1/21/05	7:15	Spike before gold	flue gas	76	1.5%	none
	7:18	Spike before gold	flue gas	74		none
	7:21	Spike before gold	flue gas	76		replace column
	8:46	Spike before gold	air	109		none
	10:22	Spike before gold	flue gas	104	11.9%	none
	10:28	Spike before gold	flue gas	121		none
	10:37	Spike before gold	flue gas	96		none
	13:50	Spike before gold	flue gas	108		none
		average of day's QC's		**96**		

Table E-3. SCEM Quality Control Results – ESP Outlet

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
2/25/04	10:00	Spike before gold	air	88	1.8%	none
	10:05	Spike before gold	air	85		none
	10:10	Spike before gold	air	86		none
	11:00	Spike before gold	flue gas	99		none
	15:00	Spike before gold	flue gas	89	5.4%	none
	15:05	Spike before gold	flue gas	93		none
	15:45	Spike before gold	flue gas	99		none
		average of day's QC's		**91**		
2/26/04	8:09	Spike before gold	air	73	1.9%	none
	8:14	Spike before gold	air	75		recalibrate gold
	9:00	Spike before gold	air	106		none
	9:53	Spike before gold	flue gas	93		none
	11:30	Spike before gold	flue gas	114		none
	15:19	Spike before gold	flue gas	86	8.5%	none
	15:24	Spike before gold	flue gas	97		none
	15:35	Spike through impingers	air	114		none
		average of day's QC's		**95**		
2/27/04	7:50	Spike before gold	air	94	7.7%	none
	7:55	Spike before gold	air	109		none
	8:10	Spike before gold	flue gas	106		none
		average of day's QC's		**103**		
2/29/04	15:45	Spike before gold	air	blow by		replace column
		average of day's QC's		**-**		
3/1/04	11:30	Spike before gold	flue gas	78	10.9%	none
	11:35	Spike before gold	flue gas	91		none
		average of day's QC's		**85**		
3/2/04	7:30	Spike before gold	air	108	1.6%	none
	7:35	Spike before gold	air	105		none
	7:45	Spike through impingers	air	88		none
	14:00	Spike before gold	flue gas	79	11.9%	none
	14:05	Spike before gold	flue gas	70		none
	14:10	Spike before gold	flue gas	68		none
	14:15	Spike before gold	flue gas	82		none
	14:20	Spike before gold	flue gas	94		none
	14:25	Spike before gold	flue gas	81		replace column
		average of day's QC's		**86**		

Table E-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/3/04	8:00	Spike before gold	flue gas	111	7.4%	none
	8:05	Spike before gold	flue gas	100		none
	9:30	Spike before gold	flue gas	89		none
	12:45	Spike before gold	flue gas	84	3.3%	none
	12:50	Spike before gold	flue gas	88		none
	15:45	Spike before gold	air	78	8.2%	none
	15:50	Spike before gold	air	92		none
	15:55	Spike before gold	air	81		none
	16:00	Spike before gold	air	92		none
	16:05	Spike before gold	air	90		none
	16:10	Spike before gold	air	97		none
		average of day's QC's		**91**		
3/4/04	6:05	Spike before gold	air	90	0.8%	none
	6:10	Spike before gold	air	89		none
	9:00	Spike before gold	flue gas	89	0.8%	none
	9:05	Spike before gold	flue gas	88		none
	10:10	Spike before gold	air	107	5.5%	none
	10:15	Spike before gold	air	99		none
	13:30	Spike before gold	flue gas	87	8.4%	none
	13:35	Spike before gold	flue gas	98		none
	15:40	Spike before gold	air	106	0.0%	none
	15:45	Spike before gold	air	106		none
		average of day's QC's		**96**		
3/28/04	12:45	Spike before gold	air	99	0.5%	none
	12:50	Spike before gold	air	100		none
		average of day's QC's		**100**		

Table E-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/29/04	6:30	Spike before gold	air	104	0.7%	none
	6:35	Spike before gold	air	105		none
	8:00	Spike before gold	flue gas	87	1.6%	none
	8:05	Spike before gold	flue gas	89		none
	10:45	Spike before gold	flue gas	94	11.1%	none
	10:50	Spike before gold	flue gas	110		none
	13:30	Spike before gold	flue gas	113	2.7%	none
	13:35	Spike before gold	flue gas	116		none
	13:40	Spike before gold	flue gas	110		none
	15:00	Spike before gold	air	95		none
	17:00	Spike before gold	flue gas	44	64.1%	none
	17:05	Spike before gold	flue gas	117		none
		average of day's QC's		**99**		
3/30/04	8:45	Spike before gold	flue gas	88	13.8%	none
	8:50	Spike before gold	flue gas	107		none
	9:15	Spike before gold	air	97	8.2%	none
	9:20	Spike before gold	air	109		none
	12:15	Spike before gold	flue gas	103	2.0%	none
	12:20	Spike before gold	flue gas	102		none
	12:25	Spike before gold	flue gas	106		none
		average of day's QC's		**102**		
4/5/04	17:30	Spike before gold	air	103		none
		average of day's QC's		**103**		
4/6/04	6:30	Spike before gold	air	75	16.6%	none
	6:35	Spike before gold	air	104		none
	6:40	Spike before gold	air	98		none
	9:15	Spike before gold	flue gas	90		none
	10:45	Spike before gold	flue gas	69		none
	11:15	Spike before gold	flue gas	85	1.7%	none
	11:20	Spike before gold	flue gas	83		none
	11:45	Spike before gold	air	99	1.1%	none
	11:50	Spike before gold	air	101		none
	11:55	Spike before gold	air	99		none
	14:00	Spike before gold	air	98		none
		average of day's QC's		**86**		

Table E-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
4/7/04	6:45	Spike before gold	air	102	8.1%	none
	6:50	Spike before gold	air	91		none
	9:00	Spike before gold	flue gas	93		none
	12:10	Spike before gold	flue gas	85	3.3%	none
	12:15	Spike before gold	flue gas	89		none
	15:45	Spike before gold	flue gas	84	2.5%	none
	15:50	Spike before gold	flue gas	87		none
		average of day's QC's		**90**		
11/13/04	15:55	Spike before gold	flue gas	118	2.4%	none
	16:00	Spike before gold	flue gas	122		recalibrate gold
		average of day's QC's		**120**		
11/14/04	8:52	Spike before gold	flue gas	78	5.7%	none
	8:57	Spike before gold	flue gas	72		recalibrate gold
	13:34	Spike before gold	flue gas	103		none
		average of day's QC's		**84**		
11/15/04	12:49	Spike before gold	flue gas	208	43.0%	recalibrate gold
	15:55	Spike before gold	flue gas	111		none
		average of day's QC's		**160**		
11/16/04	11:45	Spike before gold	flue gas	163	7.4%	none
	11:56	Spike before gold	flue gas	181		recalibrate gold
		average of day's QC's		**172**		
11/17/04	12:30	Spike before gold	flue gas	74	14.8%	none
	12:35	Spike before gold	flue gas	60		none
	12:54	Spike before gold	flue gas	107	11.4%	none
	12:59	Spike before gold	flue gas	91		none
		average of day's QC's		**83**		
11/18/04	9:05	Spike before gold	flue gas	82		none
	14:37	Spike before gold	flue gas	73	4.0%	none
	14:42	Spike before gold	flue gas	69		recalibrate gold
		average of day's QC's		**75**		

Table E-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
11/19/04	7:12	Spike before gold	flue gas	129	2.2%	none
	7:16	Spike before gold	flue gas	125		none
	11:04	Spike before gold	flue gas	132		recalibrate gold
	13:58	Spike before gold	flue gas	110		none
		average of day's QC's		**124**		
11/20/04	12:50	Spike before gold	flue gas	123	3.5%	none
	12:55	Spike before gold	flue gas	117		recalibrate gold
	14:02	Spike before gold	flue gas	114		none
		average of day's QC's		**118**		
11/21/04	9:00	Spike before gold	air	115	8.1%	none
	9:03	Spike before gold	air	129		recalibrate gold
	9:45	Spike before gold	air	-		none
	9:54	Spike before gold	air	93		none
		average of day's QC's		**112**		
11/22/04	13:36	Spike before gold	flue gas	95	11.0%	none
	13:41	Spike before gold	flue gas	111		none
		average of day's QC's		**103**		
11/23/04	14:06	Spike before gold	flue gas	56	46.1%	none
	14:11	Spike before gold	flue gas	172		none
	14:21	Spike before gold	flue gas	101		none
	14:31	Spike before gold	flue gas	92		none
		average of day's QC's		**105**		
11/24/04	8:05	Impinger Spike	air	103	8.6%	none
	8:14	Impinger Spike	air	89		none
	8:22	Impinger Spike	air	89		none
	9:56	Impinger Spike	air	111	15.8%	none
	10:03	Impinger Spike	air	77		none
	10:11	Impinger Spike	air	96		none
	10:18	Impinger Spike	air	86		none
	14:46	Spike before gold	flue gas	98	1.4%	none
	14:51	Spike before gold	flue gas	100		none
		average of day's QC's		**94**		
11/25/04	13:17	Spike before gold	flue gas	108	1.3%	none
	13:22	Spike before gold	flue gas	106		none
		average of day's QC's		**107**		

Table E-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
11/26/04	9:35	Spike before gold	flue gas	93	2.2%	none
	9:40	Spike before gold	flue gas	91		none
	9:45	Spike before gold	flue gas	95		none
		average of day's QC's		**93**		
11/27/04	13:29	Spike before gold	flue gas	80	20.2%	none
	13:34	Spike before gold	flue gas	69		none
	13:39	Spike before gold	flue gas	53		recalibrate gold
		average of day's QC's		**67**		
11/28/04	10:08	Spike before gold	flue gas	120	5.3%	none
	10:13	Spike before gold	flue gas	108		none
	10:18	Spike before gold	flue gas	115		none
		average of day's QC's		**114**		
11/29/04	10:48	Spike before gold	flue gas	87	1.1%	none
	10:53	Spike before gold	flue gas	89		none
	10:58	Spike before gold	flue gas	88		none
		average of day's QC's		**88**		
11/30/04	12:18	Spike before gold	flue gas	95	7.0%	none
	12:23	Spike before gold	flue gas	86		none
	13:35	Spike before gold	flue gas	84	2.5%	none
	13:40	Spike before gold	flue gas	87		none
		average of day's QC's		**88**		
12/2/04	10:33	Spike before gold	flue gas	61	24.5%	none
	10:39	Spike before gold	flue gas	87		none
	10:44	Spike before gold	flue gas	60		none
	10:59	Spike before gold	flue gas	97		none
	15:35	Spike before gold	air	67	23.2%	none
	15:38	Spike before gold	air	108		none
	15:41	Spike before gold	air	94		none
		average of day's QC's		**82**		
12/3/04	12:37	Spike before gold	air	98	2.1%	none
	12:40	Spike before gold	air	101		none
		average of day's QC's		**100**		
12/4/04	14:59	Spike before gold	air	105	5.6%	none
	15:02	Spike before gold	air	97		none
		average of day's QC's		**101**		

Table E-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
12/5/04	9:25	Spike before gold	flue gas	88	8.0%	none
	9:29	Spike before gold	flue gas	75		none
	9:33	Spike before gold	flue gas	82		none
		average of day's QC's		**82**		
12/6/04	12:22	Spike before gold	flue gas	blowby		none
	12:26	Spike before gold	flue gas	blowby		replace column
		average of day's QC's		**-**		
12/7/04	10:28	Spike before gold	flue gas	113	20.0%	none
	14:59	Spike before gold	flue gas	85		none
		average of day's QC's		**99**		
12/8/04	7:08	Spike before gold	air	83	25.8%	none
	7:11	Spike before gold	air	104		none
	7:14	Spike before gold	air	130		none
	7:16	Spike before gold	air	118		none
	7:19	Spike before gold	air	166		recalibrate
	8:39	Spike before gold	flue gas	102	2.1%	none
	8:48	Spike before gold	flue gas	99		none
		average of day's QC's		**115**		
12/9/04	7:56	Spike before gold	air	69		recalibrate
	15:24	Spike before gold	air	90		none
		average of day's QC's		**80**		
12/10/04	11:36	Spike before gold	flue gas	124	20.5%	none
	11:45	Spike before gold	flue gas	122		none
	11:55	Spike before gold	air	84		recalibrate
		average of day's QC's		**110**		
12/11/04	10:27	Spike before gold	air	87	3.2%	none
	10:30	Spike before gold	air	91		none
	13:20	Spike before gold	flue gas	95	10.3%	none
	13:25	Spike before gold	flue gas	110		none
		average of day's QC's		**96**		
12/12/04	9:54	Spike before gold	air	97	0.0%	none
	9:57	Spike before gold	air	97		none
	13:00	Spike before gold	flue gas	86	4.0%	none
	13:06	Spike before gold	flue gas	91		none
		average of day's QC's		**93**		

Table E-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
12/13/04	8:57	Spike before gold	air	94	0.7%	none
	9:00	Spike before gold	air	95		none
	12:39	Spike before gold	flue gas	94	3.1%	none
	12:45	Spike before gold	flue gas	90		none
	13:57	Spike before gold	flue gas	87	5.5%	none
	14:02	Spike before gold	flue gas	94		none
		average of day's QC's		**92**		
12/14/04	9:19	Spike before gold	air	107	6.5%	none
	9:22	Spike before gold	air	106		none
	9:25	Spike before gold	air	95		none
	10:37	Spike before gold	flue gas	94	14.2%	none
	10:44	Spike before gold	flue gas	115		none
		average of day's QC's		**103**		
12/15/04	10:55	Spike before gold	flue gas	68	28.3%	none
	11:04	Spike before gold	flue gas	102		none
		average of day's QC's		**85**		
1/17/05	8:19	Spike before gold	air	62	18.8%	none
	8:22	Spike before gold	air	81		none
	13:37	Spike before gold	flue gas	86	1.6%	none
	13:46	Spike before gold	flue gas	88		none
	16:01	Spike before gold	flue gas	93		none
		average of day's QC's		**82**		
1/18/05	8:39	Spike before gold	air	66		none
	10:58	Spike before gold	flue gas	78	5.7%	none
	11:08	Spike before gold	flue gas	72		none
	13:29	Spike before gold	flue gas	79		none
		average of day's QC's		**74**		
1/19/05	7:50	Spike before gold	flue gas	96		none
	8:10	Spike before gold	air	101		none
	11:02	Spike before gold	flue gas	92		none
	15:39	Spike before gold	flue gas	110		none
		average of day's QC's		**100**		

Table E-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
1/20/05	7:29	Spike before gold	air	101	0.7%	none
	7:32	Spike before gold	air	100		none
	8:19	Spike before gold	flue gas	98		none
	12:53	Spike before gold	flue gas	106	10.0%	none
	13:07	Spike before gold	flue gas	92		none
	16:17	Spike before gold	flue gas	90		none
		average of day's QC's		**98**		
1/21/05	7:22	Spike before gold	air	104	4.6%	none
	7:25	Spike before gold	air	113		none
	7:28	Spike before gold	flue gas	105		none
	9:05	Spike before gold	flue gas	113		none
	9:43	Spike before gold	flue gas	114		none
	13:50	Spike before gold	flue gas	115		none
		average of day's QC's		**111**		

Table E-4. SCEM Quality Control Results – Stack

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
2/25/04	11:30	Spike before gold	air	109		none
	14:30	Spike before gold	flue gas	126	2.2%	none
	14:35	Spike before gold	flue gas	130		none
	16:00	Spike before gold	flue gas	82	24.9%	none
	16:05	Spike before gold	flue gas	117		none
		average of day's QC's		**113**		
2/26/04	8:10	Spike before gold	air	68	23.4%	none
	8:15	Spike before gold	air	87		none
	8:20	Spike before gold	air	87		none
	8:25	Spike before gold	air	131		none
	8:30	Spike before gold	air	117		none
	8:45	Spike before gold	flue gas	95		none
	13:35	Spike before gold	flue gas	94		none
	14:50	Spike before gold	flue gas	112		none
	17:30	Spike before gold	flue gas	137	4.8%	none
	17:35	Spike before gold	flue gas	127		none
	17:40	Spike before gold	flue gas	139		none
		average of day's QC's		**109**		
2/27/04	8:08	Spike before gold	flue gas	93		none
		average of day's QC's		**93**		
2/29/04	15:30	Spike before gold	air	93	13.8%	none
	15:35	Spike before gold	air	116		none
	15:40	Spike before gold	air	121		recalibrate gold
		average of day's QC's		**110**		
3/1/04	10:50	Spike before gold	flue gas	78	0.0%	none
	10:55	Spike before gold	flue gas	78		none
		average of day's QC's		**78**		
3/2/04	7:30	Spike before gold	flue gas	68	9.7%	none
	7:35	Spike before gold	flue gas	78		replace column
	14:52	Spike before gold	flue gas	111	3.8%	none
	14:57	Spike before gold	flue gas	118		none
	15:02	Spike before gold	flue gas	119		none
	16:00	Spike before gold	air	-		recalibrate gold
	16:30	Spike before gold	air	96		none
		average of day's QC's		**98**		

Table E-4. SCEM Quality Control Results – Stack (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/3/04	6:45	Spike before gold	air	-		recalibrate gold
	8:15	Spike before gold	flue gas	100		none
	12:45	Spike before gold	flue gas	83		none
	16:32	Spike before gold	flue gas	98		none
		average of day's QC's		**94**		
3/4/04	7:00	Spike before gold	air	-		recalibrate gold
	14:51	Spike before gold	flue gas	105		none
		average of day's QC's		**105**		
3/28/04	6:00	Spike before gold	air	101	0.7%	none
	6:05	Spike before gold	air	102		none
		average of day's QC's		**102**		
3/29/04	7:50	Spike before gold	flue gas	131	5.2%	none
	7:55	Spike before gold	flue gas	119		none
	8:00	Spike before gold	flue gas	121		none
	9:30	Spike before gold	flue gas	132		recalibrate
	14:10	Spike before gold	flue gas	107		none
	15:53	Spike before gold	flue gas	108	3.2%	none
	15:58	Spike before gold	flue gas	113		none
		average of day's QC's		**119**		
3/30/04	7:00	Spike before gold	air	115	2.9%	none
	7:05	Spike before gold	air	113		none
	7:10	Spike before gold	air	109		none
	13:00	Spike before gold	air	94	0.2%	none
	13:05	Spike before gold	air	94		none
		average of day's QC's		**105**		
4/5/04	15:00	Spike before gold	air	72	22.2%	none
	15:05	Spike before gold	air	53		replace column
		average of day's QC's		**62**		
4/6/04	6:45	Spike before gold	flue gas	97		none
	8:00	Spike before gold	flue gas	103		none
	9:04	Spike before gold	flue gas	112		none
	11:40	Spike before gold	flue gas	113	11.0%	none
	11:51	Spike before gold	flue gas	132		none
		average of day's QC's		**111**		

Table E-4. SCEM Quality Control Results – Stack (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
4/7/04	6:45	Spike before gold	air	117	5.0%	none
	6:50	Spike before gold	air	125		recalibrate
	7:30	Spike before gold	air	111	7.4%	none
	7:35	Spike before gold	air	100		none
	8:15	Spike before gold	flue gas	74		none
	8:35	Spike before gold	flue gas	112	22.7%	none
	8:40	Spike before gold	flue gas	81		none
	9:00	Spike before gold	flue gas	79	5.6%	none
	9:05	Spike before gold	air	73		replace column
	12:00	Spike before gold	flue gas	83		none
	13:41	Spike before gold	flue gas	70		none
	15:28	Spike before gold	flue gas	77		none
	17:03	Spike before gold	flue gas	62		none
	17:55	Spike before gold	air	100		none
		average of day's QC's		**90**		
4/8/04	6:00	Spike before gold	air	112		none
		average of day's QC's		**112**		
11/14/04	7:24	Spike before gold	flue gas	50	75.5%	none
	7:27	Spike before gold	flue gas	5		none
	7:34	Spike before gold	flue gas	37		recalibrate gold
		average of day's QC's		**31**		
11/15/04	15:42	Spike before gold	flue gas	94		none
		average of day's QC's		**94**		
11/16/04	13:57	Spike before gold	flue gas	81	2.7%	none
	14:01	Spike before gold	flue gas	78		none
		average of day's QC's		**80**		
11/17/04	13:16	Spike before gold	flue gas	79	30.5%	none
	13:22	Spike before gold	flue gas	51		recalibrate gold
		average of day's QC's		**65**		
11/18/04	10:08	Spike before gold	flue gas	87		none
	13:34	Spike before gold	flue gas	101		none
	14:21	Spike before gold	flue gas	94		none
		average of day's QC's		**94**		
11/19/04	14:16	Spike before gold	flue gas	94		none
		average of day's QC's		**94**		
11/20/04	13:34	Spike before gold	flue gas	86		none
		average of day's QC's		**86**		

Table E-4. SCEM Quality Control Results – Stack (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
11/21/04	9:35	Spike before gold	flue gas	74	6.0%	none
	9:41	Spike before gold	flue gas	68		recalibrate gold
	13:22	Spike before gold	flue gas	69	32.0%	none
	13:28	Spike before gold	flue gas	82		none
	13:34	Spike before gold	flue gas	62		none
	13:41	Spike before gold	flue gas	35		none
	14:49	Spike before gold	flue gas	50		recalibrate gold
		average of day's QC's		**63**		
11/22/04	13:18	Spike before gold	flue gas	86	16.3%	none
	13:24	Spike before gold	flue gas	119		none
	13:30	Spike before gold	flue gas	98		none
	13:36	Spike before gold	flue gas	85		none
		average of day's QC's		**97**		
11/23/04	9:07	Spike before gold	flue gas	56	11.6%	none
	9:13	Spike before gold	flue gas	66		replace column
	15:58	Spike before gold	flue gas	84	25.0%	none
	16:04	Spike before gold	flue gas	120		none
		average of day's QC's		**82**		
11/24/04	10:07	Spike before gold	flue gas	115	17.7%	none
	10:13	Spike before gold	flue gas	148		none
	14:31	Impinger spike	air	61	17.3%	none
	14:39	Impinger spike	air	78		none
	15:21	Spike before gold	flue gas	99		none
		average of day's QC's		**100**		
11/25/04	12:16	Spike before gold	flue gas	90	8.9%	none
	12:23	Spike before gold	flue gas	74		none
	12:29	Spike before gold	flue gas	90		none
		average of day's QC's		**85**		
11/26/04	10:01	Spike before gold	flue gas	81	8.3%	none
	10:07	Spike before gold	flue gas	72		none
		average of day's QC's		**77**		
11/27/04	13:01	Spike before gold	flue gas	58	3.6%	none
	13:08	Spike before gold	flue gas	61		recalibrate gold
		average of day's QC's		**60**		
11/28/04	10:30	Spike before gold	flue gas	81	0.0%	none
	10:37	Spike before gold	flue gas	81		none
		average of day's QC's		**81**		

Table E-4. SCEM Quality Control Results – Stack (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
11/29/04	10:45	Spike before gold	flue gas	108	8.8%	none
	10:52	Spike before gold	flue gas	88		none
	10:58	Spike before gold	flue gas	105		none
		average of day's QC's		**100**		
11/30/04	10:59	Spike before gold	air	69	1.2%	none
	11:02	Spike before gold	air	68		none
	11:05	Spike before gold	air	67		recalibrate gold
		average of day's QC's		**68**		
12/1/04	14:58	Impinger spike	air	103	3.5%	none
	15:06	Impinger spike	air	98		none
	16:14	Spike before gold	air	103	9.5%	none
	16:17	Spike before gold	air	90		none
		average of day's QC's		**99**		
12/2/04	15:02	Spike before gold	flue gas	88	9.4%	none
	15:08	Spike before gold	flue gas	77		none
	15:25	Spike before gold	flue gas	89	8.9%	none
	15:31	Spike before gold	flue gas	101		none
		average of day's QC's		**89**		
12/3/04	14:24	Spike before gold	flue gas	43	14.7%	none
	14:31	Spike before gold	flue gas	53		recalibrate gold
		average of day's QC's		**48**		
12/6/04	10:54	Spike before gold	flue gas	71		none
	11:19	Spike before gold	flue gas	102		none
		average of day's QC's		**87**		
12/7/04	9:50	Spike before gold	flue gas	111		none
		average of day's QC's		**111**		
12/8/04	15:25	Spike before gold	flue gas	116		none
		average of day's QC's		**116**		
12/9/04	7:17	Spike before gold	air	101	7.4%	none
	7:20	Spike before gold	air	91		none
		average of day's QC's		**96**		
12/10/04	8:07	Spike before gold	air	105	10.9%	none
	8:10	Spike before gold	air	90		none
	14:24	Spike before gold	flue gas	90	14.4%	none
	14:30	Spike before gold	flue gas	120		none
	14:36	Spike before gold	flue gas	111		none
		average of day's QC's		**103**		

Table E-4. SCEM Quality Control Results – Stack (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
12/11/04	13:24	Spike before gold	flue gas	82	1.7%	none
	13:31	Spike before gold	flue gas	84		none
		average of day's QC's		**83**		
12/12/04	9:29	Spike before gold	flue gas	98	11.0%	none
	9:32	Spike before gold	flue gas	122		none
	9:35	Spike before gold	flue gas	109		none
	12:55	Spike before gold	flue gas	101	1.4%	none
	13:01	Spike before gold	flue gas	103		none
		average of day's QC's		**107**		
12/13/04	9:09	Spike before gold	flue gas	90	3.2%	none
	9:13	Spike before gold	flue gas	86		none
		average of day's QC's		**88**		
12/14/04	9:28	Spike before gold	flue gas	--		none
	9:31	Spike before gold	flue gas	111		recalibrate gold
		average of day's QC's		**111**		
1/17/05	10:58	Spike before gold	air	112	13.3%	none
	11:01	Spike before gold	air	145		none
	11:04	Spike before gold	air	139		none
		average of day's QC's		**132**		
1/18/05	17:07	Spike before gold	flue gas	69	2.0%	none
	17:15	Spike before gold	flue gas	71		none
		average of day's QC's		**70**		
1/19/05	13:52	Spike before gold	flue gas	68	5.2%	none
	13:56	Spike before gold	flue gas	73		none
	14:01	Spike before gold	flue gas	66		none
	14:10	Spike before gold	air	84	7.2%	none
	14:13	Spike before gold	air	93		none
	17:15	Spike before gold	air	77	14.9%	none
	17:18	Spike before gold	air	83		none
	17:21	Spike before gold	air	102		none
		average of day's QC's		**81**		

Table E-4. SCEM Quality Control Results – Stack (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
1/20/05	8:33	Spike before gold	air	90	11.0%	none
	8:37	Spike before gold	air	77		recalibrate gold
	10:24	Spike before gold	flue gas	139	10.4%	none
	10:28	Spike before gold	flue gas	120		none
	11:13	Spike before gold	flue gas	133	8.0%	none
	11:17	Spike before gold	flue gas	149		none
	13:37	Spike before gold	flue gas	117	7.0%	none
	13:41	Spike before gold	flue gas	106		none
	14:46	Spike before gold	flue gas	108	13.5%	none
	14:50	Spike before gold	flue gas	88		none
	14:54	Spike before gold	flue gas	115		none
	16:12	Spike before gold	flue gas	87	2.4%	none
	16:16	Spike before gold	flue gas	90		none
		average of day's QC's		**109**		
1/21/05	9:06	Spike before gold	flue gas	44	22.9%	none
	9:10	Spike before gold	flue gas	61		replace column
		average of day's QC's		**53**		

Internal Quality Control Checks

Quality control procedures were also included in this test program for both sampling and analytical activities. In most instances, strict adherence to prescribed method-defined procedures for each sampling and analytical effort is the most applicable QC check. However, in some cases specific QC samples were planned to assess overall measurement data quality. QC samples planned for the critical measurement parameters are summarized in Table E-5.

The QC analyses conducted during the testing program were designed to provide a quantitative assessment of the measurement system data. The two aspects of data quality that are of primary concern are precision and accuracy. Accuracy reflects the degree to which the measured value represents the actual or "true" value for a given parameter and includes elements of both bias and precision. Precision is a measure of the variability associated with the measurement system.

Precision

EPA defines precision as "a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions." For this project, precision estimates will be based on conditions that encompass as many components of variability as are feasible, which includes variability in the sample matrix itself, as well as imprecision in sample collection, preparation, and analysis. Precision data are reported for analytical duplicate samples.

Where estimated from duplicate (two) results, precision is expressed in terms of relative percent difference (RPD) between results for analytical duplicates. RPD is calculated as follows:

$$\text{RPD} = \frac{|X_1 - X_2|}{\text{Mean}} \text{ x } 100$$

RPD is related to percent CV by (RPD = CV x $\sqrt{2}$).

Where estimated from triplicate (three) results, precision is expressed in terms of relative standard deviation (RSD) between results for analytical replicates. RSD is calculated as follows:

$$\text{RSD} = \frac{|\text{Standard Deviation}}{\text{Mean}} \text{ x } 100$$

These terms are independent of the error (bias) of the analyses and reflect only the degree to which the measurements agree with one another, not the degree to which they agree with the "true" value for the parameter measured.

Accuracy

Accuracy, according to EPA's definition is "the degree of agreement of a measurement (or an average of measurements of the same thing), X, with an accepted reference or true value, T." Accuracy includes components of both bias (systematic error) and imprecision (random error). Bias may be estimated from the average of a set of individual accuracy measurements.

For this project, accuracy objectives are expressed in terms of individual measurements. Individual measurements were compared with the objectives presented previously in Table E-1. In the final analysis, the average accuracy (i.e., bias), calculated as percent recovery, are reported and used to assess the impact on project objectives. Percent recovery is calculated as follows:

$$\% \text{ Recovery} = \frac{\text{Measured Value}}{\text{Reference Value}} \times 100$$

In the case of matrix spiked samples, measured value in the above equation represents the difference between the spiked sample measurement result and the unspiked sample results. The reference value represents the amount of spike added to the sample.

Table E-5. QC Samples for Critical Measurement Parameters

Parameter	Field Blank	Trip (reagent) Blank	Matrix Spike and Duplicate	Standard Material Analysis
Mercury in Flue Gas (Ontario Hydro method)	1 per batch of $KMnO_4$ reagent	1 per batch of $KMnO_4$ reagent	1 per sample location	-
Mercury in Flue Gas (semi-continuous analyzer)	-	-	1 per day	-
HCl/chlorine in Flue Gas	1 per day	1 per day	1 per sample location	-
Mercury in Coal, ESP fly ash, FGD solids	-	-	1 per 10 samples per matrix type	1 per 10 samples per matrix type

Ontario Hydro

Source sampling field data for the three Ontario Hydro verification tests conducted during baseline and long term test phases are summarized in Appendix A. Percent isokenetics, a measure of sample representativeness, were within acceptable limits for all test runs.

QA/QC results for reagent blanks, field blanks, matrix spikes, replicate analyses, and calibration curve checks from the three Ontario Hydro verification trips are provided in Tables E-6 and E-7, respectively. With a few exceptions, all results were within the data quality objectives of the test program and the results as a whole do not indicate a significant background contributions or bias in the analytical results for the Ontario Hydro method samples. Note that field blank impinger solutions are used to perform a matrix matched instrument calibration to reduce potential bias in the analytical results. Reagent blanks are typically not analyzed unless appreciable mercury is detected in the field blank matrix matched calibration process. Filters from both the reagent blank and the field blank are analyzed for mercury to quantify background contributions.

Table E-6. QA/QC Results for Mercury Analyses of Ontario Hydro Impinger Solutions – Verification Trip #1 (February 2004), Unit 1

QA Check	Sample	Objective	Ontario Hydro Sample Fractions				
			$KMnO_4$	KCl	H_2O_2	Filter	PNR/Nitric Rinse
Method Blank	All	<DL	<DL	<DL	<DL	<DL	<DL
DI Water Blank	All	<DL	<DL	<DL	<DL	<DL	<DL
Reagent Blank	All	<DL	--	--	--	--	--
Field Blank	All	<DL	--	--	--	--	--
Lab QC Standard Recovery[1]	Inlet & Outlet	80-120%	99.0-101.7	98.0-102.4	85.4-89.9	98.9-101.3	95.0-99.2
Matrix Spike[2]	Inlets	80 120%	100.4	91	96.6	89.2 [3]	99
Replicate Analysis RPD	Inlets	<20%	NC [4]	2.4	NC	2.4	NC
Matrix Spike[2]	Outlets	80–120%	99.3	90	98.8	NA[5]	104
Replicate Analysis RPD	Outlets	<20%	15	1.3	NC	NA	NC

[1] The lab QC percentages encompass the range of QC values obtained per batch analyzed containing the three runs.

[2] One matrix spike was performed per set of 3 inlets and each set of 3 outlets in a batch. Each batch contained 3 inlet runs and 3 outlet runs.

[3] Filter samples are not amenable to replicate analysis or spikes. The spike and duplicate were performed on a sample of the ash removed from the filter.

[4] NC = not calculated. At least one result was non-detect. RPD cannot be calculated.

[5] NA – Not Applicable. Filter samples are not amenable to replicate analysis or spikes.

Table E-7. QA/QC Results for Mercury Analyses of Ontario Hydro Impinger Solutions – Verification Trip #2 (December 2004), Unit 1

QA Check	Sample	Objective	Ontario Hydro Sample Fractions				
			$KMnO_4$	KCl	H_2O_2	Filter	PNR/ Nitric Rinse
Method Blank	All	<DL	<DL	<DL	<DL	<DL	<DL
DI Water Blank	All	<DL	<DL	<DL	<DL	<DL	<DL
Reagent Blank	All	<DL	--	--	--	--	--
Field Blank	All	<DL	--	--	0.078 µg/sample [6]	--	--
Lab QC Standard Recovery[7]	ESP Outlet & Stack	80-120%	103.3-104.6	102.5-103.1	81.9-88.7	96.6-97.8	92.6-96.6
Matrix Spike[8]	ESP Outlet	80-120%	104.0	101.4	95.6	NA[9]	71.0
Replicate Analysis RPD	ESP Outlet	<20%	3.9	5.4	27	NA	NC [10]
Matrix Spike	Stack	80-120%	102.5	100.1	91.2	NA	83.2
Replicate Analysis RPD	Stack	<20%	2.3	19	14	NA	NC

[6] This result is of similar magnitude to the nitric acid and hydrogen peroxide impinger solutions from the field samples. Those results are considered to have a positive bias. The mass of mercury found in the nitric acid/hydrogen peroxide impinger is summed with the result from the potassium permanganate impinger to develop a total for elemental mercury. In all cases, the mass of mercury found in the nitric acid/hydrogen peroxide is significantly less than the mass found in the permanganate fraction, and the bias in the nitric acid/hydrogen peroxide impinger samples has a negligible impact on the overall determination of elemental mercury.

[7] The lab QC percentages encompass the range of QC values obtained per batch analyzed containing the three runs.

[8] One matrix spike was performed per set of 3 inlets and each set of 3 outlets in a batch. Each batch contained 3 inlet runs and 3 outlet runs.

[9] NA – Not Applicable. Filter samples are not amenable to replicate analysis or spikes.

[10] NC = not calculated. At least one result was non-detect. RPD cannot be calculated.

Method 26A

Source sampling field data for the Method 26A measurements conducted during the baseline phase are summarized in Appendix A. Percent isokenetics, a measure of sample representativeness, were within acceptable limits for all test runs.

Table E-8 provides a summary of the QA/QC results for Method 26A samples. With two minor exceptions, all QA/QC results were within the data quality objectives of the test program. The two outliers were RPD on one duplicate pair, and one matrix spike with a slightly low recovery. These outliers have no impact on the interpretation of the results.

Table E-8. QA/QC Results for Chloride Analyses of Method 26A Impinger Solutions

Sample Batch Analysis Date	Sample	Method Blank	MS [11] Recovery	Duplicate RPD [12] (%)	Field Blank	CCV [13] Recovery (%)
	Objective→	**<DL [14]**	**80–120%**	**<15%**	**NA**	**80–120**
10 March 2004	Field Blank	-	-	-	<0.2 mg	-
	Method Blanks	<DL	-	-	-	-
	Continuing Calibration Verification (acid impingers)	-	-	-	-	94.9-103.3
	Continuing Calibration Verification (alkaline impingers)	-	-		-	98.3-104.6
	Duplicate Analyses (acid impingers)			0.2-2.1		
	Duplicate Analyses (alkaline impingers)			0.9-17.0		
	Matrix Spike - Outlet Run 4 – Acid Impinger		102.3, 103.2			
	Matrix Spike – Outlet Run 1 – Alkaline Impinger		81.1, 78.3			

[11] MS = Matrix Spike

[12] RPD = Relative Percent Difference

[13] CCV = continuing Calibration Verification

[14] DL = Detection Limit

Mercury in Coal and Byproduct Solids

QA/QC results for the various coal and byproduct samples, including analytical method blanks, matrix spikes, duplicates and standard reference materials, are summarized in Tables E-8, E-9, and E-10 for coal, ash and other byproduct streams, respectively. With a few exceptions, results were within the data quality objectives of the test program and the results as a whole do not indicate a significant bias in the analytical results for the coal or byproducts solids samples.

Table E-8. QA/QC Results for Mercury Analyses of Coal Samples

Sample Analysis Batch Date	Sample	Method Blank	MS Recovery	RSD [15]	Reference Coal Recovery	Lab Check Sample
	Objective→	**<DL**	**70–130%**	**<25%**	**80–120%**	**80–120%**
Analysis on 3/3/04 Samples from 2/24/04, 2/25/04 (9:20), 2/25/04 (12:30), 2/26/04 (9:20), 2/26/04 (13:00), 2/27/04 (9:00)	DI Water Blank	<DL	-	-	-	-
	Bomb Blank	<DL	100.5	-	-	-
	NIST Coal 1632b [16,17]	-	-	-	105.4	-
	Lab Check Sample Range	-	-	-	-	100.0-104.4
	Replicate Analysis Range			2.1-18.5		
	Matrix Spike (Coal from 2/25/04 (9:20))				92.7	
Analysis on 3/17/04 Samples from 2/27/04 (12:10), 3/1/04 (10:00), 3/1/04 (13:05), 3/2/04 (9:30), 3/2/04 (13:05), 3/3/04 (9:30), 3/3/04 (13:10), 3/4/04 (9:10), 3/4/04 (13:00)	DI Water Blank	<DL	-	-	-	-
	Bomb Blank	<DL	105.1	-	-	-
	NIST Coal 1632b	-	-	-	112.7	-
	Lab Check Sample Range	-	-	-	-	102.3-103.3
	Replicate Analysis Range			0.5-13.1		
	Matrix Spike (Coal from 3/2/04 (13:05))		107.2			
Analysis on 4/17/04 Samples from 3/29/04 (13:10), 3/30/04 (13:20), 4/6/04 (13:20), 4/7/04 (13:30)	DI Water Blank	<DL	-	-	-	-
	Bomb Blank	<DL	102.7	-	-	-
	NIST Coal 1632b	-	-	-	109.5	-
	Lab Check Sample Range	-	-	-	-	102.7-103.0
	Replicate Analysis Range			1.9-5.1		

[15] RSD = Relative Standard Deviation

[16] NIST = National Institute of Standards and Technology

[17] NIST Coal 1632b has an uncertified mercury value of 0.07 μg/g

Table E-8. QA/QC Results for Mercury Analyses of Coal Samples (continued)

Sample Analysis Batch Date	Sample	Method Blank	MS Recovery	RSD	Reference Coal Recovery	Lab Check Sample
	Objective→	**<DL**	**70–130%**	**<25%**	**80–120%**	**80–120%**
Analysis on 1/14/05 Samples from 11/3/04, 11/14/04, 11/17/04, 11/19/04, 11/22/04, 11/29/04, 12/05/04, 12/06/04	DI Water Blank	<DL	-	-	-	-
	Bomb Blank	<DL	100.5	-	-	-
	NIST Coal 1632c	-	-	-	102.6	-
	Lab Check Sample Range	-	-	-	-	100.1-102.3
	Replicate Analysis Range			1.9-14.2		
	Matrix Spike (Coal from 11/29/04)	-	102	8.4	-	-
Analysis on 1/14/05 Samples from 12/9/04, 12/10/04	DI Water Blank	<DL		-	-	-
	Bomb Blank	<DL	87.5	-	-	-
	NIST Coal 1632c	-	-	-	106.6	-
	Lab Check Sample Range	-	-	-	-	102.5-102.8
	Replicate Analysis Range			1.6-3.2		
	Matrix Spike (Coal from 11/29/04)		106.4			
Analysis on 3/10/05 Samples from 1/17/05, 1/18/05, 1/19/05, 1/21/05	DI Water Blank	<DL	-	-	-	-
	Bomb Blank	<DL	106.1	-	-	-
	NIST Coal 1632c	-	-	-	110.7	-
	Lab Check Sample Range	-	-	-	-	99.5-100.5
	Replicate Analysis Range			0.4-19.2		
	Matrix Spike (Coal from 1/18/05)		102.8			
Analysis on 1/28/05 Sample from 1/20/05	DI Water Blank	<DL	-	-	-	-
	Bomb Blank	<DL	103.1	-	-	-
	NIST Coal 1632c	-	-	-	105.5	-
	Lab Check Sample Range	-	-	-	-	95.3-97.7
	Replicate Analysis Range			4.8		
	Matrix Spike (Coal from 1/18/05)		85.4			

Table E-9. QA/QC Results for Mercury Analyses of Ash

Sample Batch Analysis Date	Sample	Method Blank	MS [18] Recovery	Relative Percent Difference	Reference Material Recovery	Lab Check Sample
	Objective→	**<DL [19]**	**80–120%**	**<25%**	**80–120%**	**80–120%**
Analysis on 2/25/05 Samples from 11/15/04, 11/19/04, 11/29/04, 12/6/04, 12/10/04, 12/13/04, 1/21/05	DI Water Blank	<DL				
	Method Blank	<DL				
	NIST Ash 1633b [20,21]				112.7-114.1	
	Lab Check Sample Range					99.4-103.6
	Replicate Analysis Range			0.3-0.5		
	Matrix Spike (Ash from 11/19 (Hoppers 2&3) and 1/21)		96.3-103.3			
Analysis on 2/28/05 Samples from 12/1/04 (Hopper 6), 12/1/04 (Hopper 2), 1/18/05, 1/19/05, 1/20/05	DI Water Blank	<DL				
	Method Blank	<DL				
	NIST Ash 1633b				114.1	
	Lab Check Sample Range					95.4-97.8
	Replicate Analysis Range			0.2-5.2		
	Matrix Spike (Ash from 12/1 (Hopper 6)			101.4		
Analysis on 4/21/04 Samples from 2/27/04, 3/30/04, 4/6/04, 4/7/04	Method Blank	<DL				
	Lab Check Sample Range					101.7-102.6
	NIST Ash 1633b				101.5	
	Replicate Analysis Range				1.4	
	Matrix Spike (Samples from 4/6)			91.5		

[18] MS – Matrix Spike

[19] DL – Detection Limit

[20] NIST = National Institute of Standards and Technology

[21] 1633b ash, certified Hg = 0.141 µg/g ± 10%

Table E-9. QA/QC Results for Mercury Analyses of Ash (continued)

Sample Batch Analysis Date	Sample	Method Blank	MS [22] Recovery	Relative Percent Difference	Reference Material Recovery	Lab Check Sample
	Objective→	<DL [23]	80–120%	<25%	80–120%	80–120%
Analysis on Samples from 2/24/04, 2/25/04 (0946), 2/25/04 (1310), 2/26/04	DI Water Blank	<DL				
	Method Blank	<DL				
	NIST Ash 1633b				32.9	
	Lab Check Sample Range					100.0-107.0
	Replicate Analysis Range			5.3		
	Matrix Spike (Sample from 2/26)			96		
Analysis on 3/8/04 Samples from 2/24/04, 2/25/04 (0946), 2/25/04 (1310), 2/26/04	DI Water Blank	<DL				
	Method Blank	<DL				
	NIST Ash 1633b					
	Lab Check Sample Range					100.0-107.0
	Replicate Analysis Range			5.3		
	Matrix Spike (Sample from 2/26)		96			
Analysis on 4/8/04 Samples from 3/1/04, 3/2/04, 3/3/04, 3/4/04, 3/29/04	DI Water Blank	<DL				
	Method Blank	<DL	110.8			
	NIST Ash 1633b		102.0		106.3	
	Lab Check Sample Range					99.6-101.1
	Replicate Analysis Range			0.8 [24]		
	Matrix Spike (Sample from 3/26)		97.6			

[22] MS – Matrix Spike

[23] DL – Detection Limit

[24] This is relative standard deviation. Sample was analyzed in triplicate.

Table E-9. QA/QC Results for Mercury Analyses of Ash (continued)

Sample Batch Analysis Date	Sample	Method Blank	MS [22] Recovery	Relative Percent Difference	Reference Material Recovery	Lab Check Sample
	Objective→	**<DL [23]**	**80–120%**	**<25%**	**80–120%**	**80–120%**
Analysis on 3/4/05 Samples from 12/1/04 (Hopper 7), 12/1/04 (Hopper 3)	DI Water Blank	<DL				
	Method Blank	<DL				
	NIST Ash 1633b				104.9	
	Lab Check Sample Range					98.5-98.9
	Replicate Analysis Range			1.7		
	Matrix Spike (Sample from 12/1 Hopper 3)			98.6		
Analysis on 6/30/05 Samples from 11/16/04, 11/17/04, 11/23/04, 12/2/04, 12/7/04, 12/8/04 12/15/04	DI Water Blank	<DL				
	Method Blank	<DL				
	NIST Ash 1633b				142.4	
	Lab Check Sample Range					88.7-96.7
	Replicate Analysis Range			0.7		
	Matrix Spike (Sample from 11/23)			104.8		

Table E-10. QA/QC Results for Mercury Analyses of FGD Samples

Sample Batch Analysis Date	Sample	Method Blank	MS [25] Recovery	Relative Percent Difference	Reference Material Recovery	Lab Check Sample
	Objective→	**<DL [26]**	**80–120%**	**<25%**	**80–120%**	**80–120%**
Analysis on 3/22/04 Samples from 2/26/04	DI Water Blank	<DL				
	Method Blank	<DL				
	Lab Check Sample Range					98.7-102.8
	Replicate Analysis Range			1.2, 5.7 [27]		
	Matrix Spike (Gypsum sample from 2/26/04))		101.4			
Analysis on 3/17/05 Samples from 11/30/05, 1/17/05	DI Water Blank	<DL				
	Method Blank	<DL				
	QC Gypsum Sample [28]				99.7	
	Lab Check Sample Range					100.7-101.4
	Replicate Analysis Range			1.4		
	Matrix Spike (Sample from 1/17)		103.3			
Analysis on 3/23/05 Samples from 11/14/04, 11/17/04, 11/19/04, 11/25/04, 11/26/04, 11/30/04, 12/5/04, 12/10/04	DI Water Blank	<DL				
	Method Blank	<DL	104.3			
	Lab Check Sample Range					98.5-102.4
	QC Gypsum Sample		105.6, 100.3		101.4, 94.6	
	Replicate Analysis Range			0.4-16.5		
	Matrix Spike (Samples from 11/26, 12/05, 12.15)			91-111		
	Matrix Spike (Sample from 12/1 Hopper 3)			98.6		

[25] MS – Matrix Spike

[26] DL – Detection Limit

[27] This is relative standard deviation. Sample was analyzed in triplicate.

[28] Standardized Gypsum sample repeatedly analyzed by URS. Standardized value is 0.352 μg/g

Volume 2

Yates Unit 2

Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas

Site Report – Yates Unit 2

Cooperative Agreement Number: DE-FC26-03NT41987

Prepared by:

Dr. Carl Richardson
URS Group, Inc.
P.O. Box 201088
Austin, TX 78720-1088

Prepared for:

Lynn Brickett
Contracting Officer's Representative (COR)
U.S. Department of Energy
P.O. Box 880
Morgantown, WV 26508-0880

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Disclaimer

Abstract

This site report document summarizes results from the project entitled "Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas" being managed by URS Group, Inc. as part of part of Cooperative Agreement DE-FC26-03NT41987. The objective of this project is to demonstrate the ability of various activated carbon sorbents to remove mercury from coal-combustion flue gas across full-scale units configured with small ESPs. The project is being funded by the U.S. DOE National Energy Technology Laboratory under this Cooperative Agreement. EPRI, Southern Company, and Georgia Power are project co-funders. URS Group is the prime contractor.

Various sorbent materials were injected upstream of low SCA ESP systems at Georgia Power's Plant Yates Unit 1 and Unit 2. Both Unit 1 and Unit 2 fire a low sulfur bituminous coal. Unit 1 is equipped with a JBR wet FGD system downstream of the ESP for SO_2 control. Unit 2 is not equipped with downstream SO_2 controls; however, a dual flue gas conditioning system is used to enhance ESP performance. This site report focuses on the results from the Unit 2 test program. A separate site report was issued for Unit 1.

Short-term parametric tests were conducted on Unit 2 to evaluate the performance of an activated carbon sorbent. In addition, the effects of the dual flue gas conditioning system on mercury removal performance were evaluated as part of the short-term parametric test on Unit 2. The results of this study will provide data required for assessing the performance, long-term operational impacts, and estimating the costs of full-scale sorbent injection processes for flue gas mercury removal.

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EXECUTIVE SUMMARY

This Site Report is submitted to the U.S. Department of Energy (DOE) as part of Cooperative Agreement DE-FC26-03NT41987, "Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas". This project has evaluated full-scale sorbent injection for mercury control at two sites with small-SCA ESPs, burning low sulfur Eastern bituminous coals. Full-scale tests have been performed at Georgia Power's Plant Yates Units 1 and 2 [Georgia Power is a subsidiary of the Southern Company] to evaluate sorbent injection performance. Georgia Power's Plant Yates Unit 1 has an existing small-SCA cold-side ESP followed by a Chiyoda CT-121 wet scrubber. Unit 2 is also equipped with a small-SCA ESP and a dual flue gas conditioning system. Unit 2 has no SO_2 control system. This Site Report presents results from the testing conducted on Unit 2.

Sorbent injection equipment was installed upstream of the ESP at Unit 2 with the sorbent injection lances located between the ammonia and SO_3 injection points associated with the dual flue gas conditioning system. One week of short-term baseline and parametric tests were conducted at Unit 2 in March 2004 using Norit Americas' Darco-Hg (formerly Dacro FGD™) activated carbon. The sorbent injection rate was varied in an attempt to achieve mercury removal rates between 40 and 90%. The primary goals of the project were (1) to measure native mercury removal across the small-SCA ESP; (2) to measure the variability in flue gas mercury concentrations at the ESP inlet and outlet locations; (3) to measure mercury removal performance of the Darco-Hg activated carbon over a range of injection rates with the conditioning system both on and off; and (4) to observe the effects of sorbent injection on the operation of the ESP system and on the properties of the ESP fly ash.

Native removal of total vapor-phase mercury across the Unit 2 ESP (SCA = 144 ft^2/1000 acfm), with the dual flue gas conditioning system in service, generally ranged from 20 to 36 percent during the baseline characterization period. Material balance results for the full baseline test period indicate approximately 31 percent of the mercury input with the coal was removed with the ESP ash. Total vapor-phase mercury concentrations at the ESP inlet, as measured by SCEM, ranged from 4.1 to 7.6 $\mu g/Nm^3$ and total mercury concentrations at the ESP outlet ranged from 1.9 to 4.4 $\mu g/Nm^3$ (dry, at 3% oxygen).

Parametric tests showed that injection of the benchmark Darco-Hg activated carbon upstream of ESP resulted in total vapor-phase mercury removals ranging from 43 to 73 percent at injection rates ranging from 2.3 to 12.7 lb/MMacf. The removal curve was relatively flat at about

70 percent for injection rates greater than approximately 6 lb/MMacf. The incremental mercury removal attributed to carbon injection (i.e., the reduction in mercury beyond native removal levels) ranged from 30 to 40 percent.

Total vapor phase mercury emissions at the ESP outlet were calculated on a lb/trillion Btu input basis and a lb/MWh output basis. Without carbon injection, total vapor phase mercury emissions ranged from 1.5 to 3.5 lb/trillion Btu. Mercury emissions in the range of 2.5 to 1.5 lb/trillion Btu were measured during the carbon injection tests for injection rates in the range of 2.1 to 12.5 lb/MMacf. On a lb/MWh output basis, the mercury emissions ranged between 21 and 40 10^{-6} lb/MWh at baseline, and from 28 to 14 10^{-6} lb/MWh for carbon injection rates ranging from 2.1 to 12.5 lb/MMacf.

The use of the dual flue gas conditioning system on Unit 2 had no impact on the ability of Darco-Hg carbon to remove vapor-phase mercury across the ESP. Parametric carbon injection tests conducted using various combinations of NH_3 and SO_3 injection rates showed no difference in the mercury removal performance of the ESP.

Because of the short-term nature of the parametric tests conducted on Unit 2, data were inconclusive regarding the effect of sorbent injection on ESP performance. Data from additional longer-term tests, such as those conducted on the Unit 1 ESP system, have also been analyzed and more definitive conclusions can be made based on this larger data set. Refer to the Unit 1 Site Report for additional information regarding Unit 1 ESP performance during sorbent injection.

The mercury content of the Unit 2 ESP fly ash increased with increasing LOI during both baseline and Darco Hg™ carbon injection tests. LOI for the ESP fly ash samples ranged from 7.7 to 22 percent during the baseline and from 6.9 to 17.1 percent during the carbon injection tests. Mercury concentrations in the ESP ash ranged from 0.21 to 0.25 μg/g for the baseline tests and from 0.18 to 0.40 μg/g for the carbon injection tests.

1.0 Introduction

This Site Report is submitted to the U.S. Department of Energy (DOE) as part of Cooperative Agreement DE-FC26-03NT41987, "Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas." This project has evaluated full-scale sorbent injection for mercury control at two sites with small-SCA ESPs, burning low sulfur Eastern bituminous coals. Full-scale tests have been performed at Georgia Power's Plant Yates Units 1 and 2 [Georgia Power is a subsidiary of The Southern Company] to evaluate sorbent injection performance. Georgia Power's Plant Yates Unit 1 has an existing small-SCA cold-side ESP followed by a Chiyoda CT-121 wet scrubber. Unit 2 is also equipped with a small-SCA ESP and a dual flue gas conditioning system. Unit 2 has no SO_2 control system. This site report covers the testing performed on Unit 2.

The sorbent injection equipment was installed upstream of the ESP at Unit 2. One week of short-term parametric tests were conducted at Unit 2 using Norit Americas' Darco-Hg activated carbon. The sorbent injection rate was varied in attempt to achieve mercury removal rates between 40 and 90%. In addition to mercury removal, various unit process parameters, such as particulate emissions, ash LOI and ash Hg concentrations, were evaluated. Unit 2 shares a stack with Unit 3. The combined stack prevented a full analysis of the effect of carbon injection on stack opacity (except for a two day period during the test program when Unit 3 was not in operation).

Sorbent injection technology is targeted as the primary mercury control process on plants burning low/medium sulfur bituminous coals equipped with an ESP. About 70% of the ESPs used in the utility industry have SCAs less than 300 ft^2/1000 acfm. Current full-scale testing of sorbent injection systems on ESP systems has shown promising results; however, all of these tests have been conducted for large-SCA ESP systems. Therefore, the data from this sorbent injection project are applicable to a large portion of the market and fill a data gap for the application of sorbent injection to small-SCA ESP systems.

Previous EPRI testing at a plant firing PRB/bituminous blend showed that dual flue gas conditioning could have a significant impact on ACI mercury removal. Flue gas conditioning appeared to inhibit mercury removal across the residence time chamber. In the absence of sorbent, 35 to 45% mercury removal was measured across the residence time chamber when testing on the non-flue-gas-conditioned duct while 0% mercury removal was measured on the conditioned duct. With sorbent injection, the mercury removal was similar for both cases. Thus, it is important to assess the impact of SO_3 and ammonia on ACI mercury control. The DOE/EIA-767 survey indicates that 245 individual units are equipped with flue gas conditioned cold-side ESPs.

The project team includes URS Group, Inc. as the prime contractor. EPRI, a team member and a major co-funder of the project, has funded and managed mercury emissions measurement and control research since the late 1980's. ADA-ES was a sub-contractor to URS and was responsible for all aspects of the sorbent injection system design, installation and operation. Southern Company and Georgia Power were team members and provided co-funding, technical input, and the host sites for testing.

1.1 Process Overview

Yates Unit 2 is a 100 MW facility firing Eastern bituminous coal and is configured with a cold-side ESP (SCA = 144 ft^2/1000afcm) for particulate control. Unit 2 is also equipped with a dual NH_3/SO_3 flue gas conditioning system to enhance ESP performance.

Figure 1-1 shows the basic plant configuration, sorbent injection points, and flue gas sample locations for Unit 2.

1.2 Report Organization

Previous quarterly reports submitted to DOE by URS Group, Inc. covered selected results from this project[1,2,3,4,5]. This report includes these previously reported results, as well as additional information and analyses available since these quarterly reports were issued. The report is organized into five sections. Following this introduction, Section 2 discusses the project experimental approach and describes the full-scale sorbent injection system and other equipment and flue gas test methods used in the project. Section 3 presents and discusses project results. Section 4 provides the conclusions that can be made from the results of the ACI test program, and Section 5 lists the references cited in the report

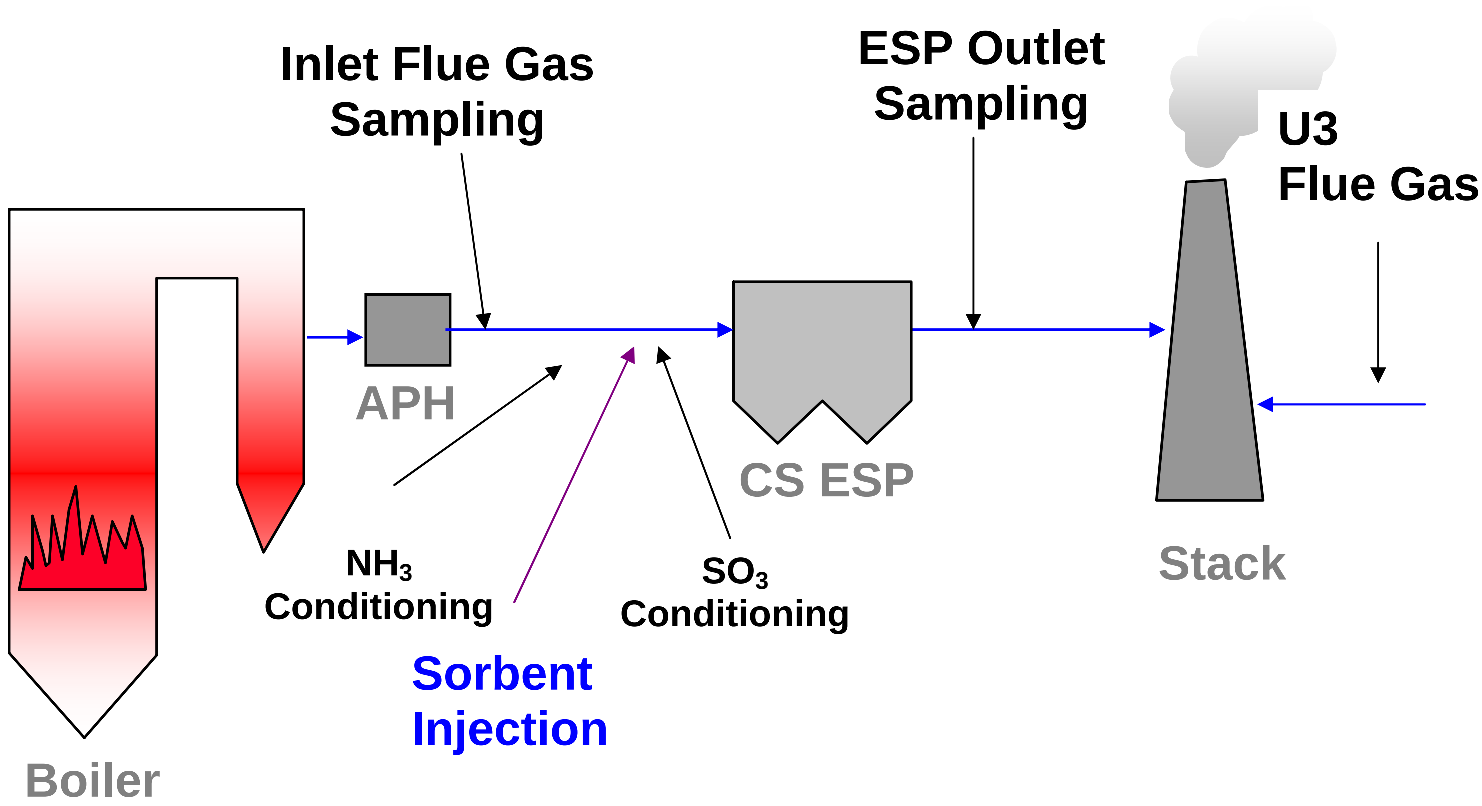

Figure 1-1. Yates Unit 2 Configuration and Flue Gas Sample Locations

2.0 Summary of Experimental Activities

2.1 Facility Information and Process Description

Basic characteristics of Unit 2 and design of the activated carbon injection system are described in the following sections.

2.1.1 Plant Characteristics

Yates Unit 2 is a 100 MW Eastern bituminous coal-fired plant equipped with a cold-side ESP (SCA = 144 ft^2/1000afcm) for particulate control. Unit 2 is also equipped with a dual NH_3/SO_3 flue gas conditioning system to enhance ESP performance. Additional characteristics of Unit 2 are summarized in Table 2-1. Figure 1-1, shown previously, illustrates the basic plant configuration, sorbent injection points, and flue gas sample locations for Unit 2.

Table 2-1. Yates Unit 2 Configuration

	Yates Unit 2
Boiler	
Type	CE Tangential Fired
Nameplate (MW)	100
Coal	
Type	Eastern Bituminous
Sulfur (wt %, dry)	1.0
Mercury (mg/kg, dry)	0.07 – 0.14
Chloride (mg/kg, dry)	300-1400
ESP	
Type	Cold-Side
ESP Manufacturer	Buell (1968 and 1971 vintage, refurbished in 1997)
Specific Collection Area (ft^2/1000afcm)	144
Plate Spacing (in.)	11
Plate Height (ft)	30
Electrical Fields	4
Mechanical Fields	3
ESP Inlet Temp. (°F)	300
ESP Design Flow Rate (ACFM)	420,000
NO_x Controls	None
SO_2 Controls	None
Flue Gas Conditioning	Dual NH_3/SO_3

2.1.2 Activated Carbon Injection System Design

ADA-ES, under subcontract to URS Group, provided all of the injection process equipment used during testing at Yates, installed the equipment on-site, and operated the equipment during testing.

For the short-term parametric tests conducted on Unit 2, a Port-a-Pac dosing system, supplied by Norit Americas, was used. This dry injection system, shown in Figure 2-1, pneumatically conveyed a predetermined and adjustable amount of sorbent from bulk bags into the flue gas stream. The unit consisted of two eight-foot tall sections. The lower or base section consisted of an iris isolation valve, small hopper with level detector, volumetric screw feeder, and pneumatic eductor. The upper or top section consisted of an electric hoist and monorail to handle bulk bags of sorbent of up to 1000 pounds. When fully assembled, the system had a total height of 16-feet. PAC was metered using a volumetric feeder into a pneumatic eductor, where the air supplied from the regenerative blower provided the motive force needed to transport the carbon to the flue gas duct via six sorbent injection lances. The sorbent injection system could deliver from approximately 20 to 350 lb/hr of activated carbon sorbent.

Figure 2-1. Port-a-Pac Dosing Unit

Flexible hoses carried the sorbent from the feeders to distribution manifolds located on the ESP inlet duct, feeding the injection probes as shown in Figure 2-2. During the site survey visit, engineers determined the port configurations and injection skid locations. This information was used to by ADA-ES to design the injection manifolds and lances.

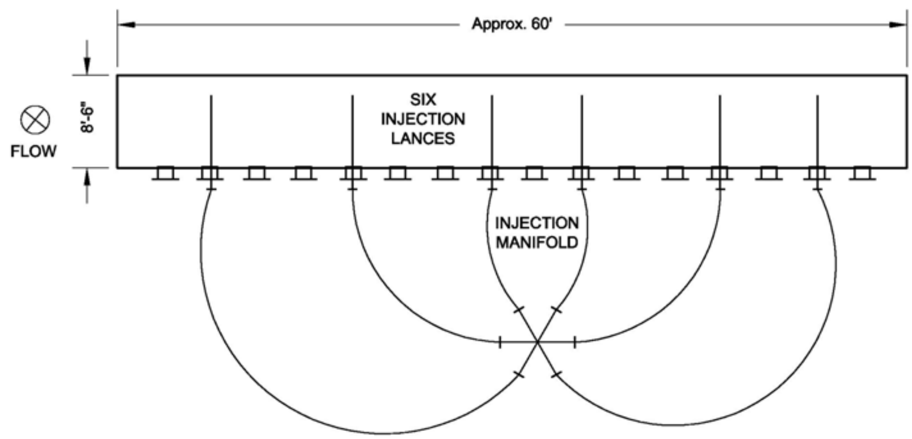

Figure 2-2. Unit 2 – ESP Inlet Sorbent Injection Port Configuration

The six injection lances fabricated from 1-inch pipe were placed at equal spacing across the width of the duct. Each lance projected horizontally into the 8.5-foot deep duct and ended approximately 4 feet into the duct. The duct was approximately 60 feet wide at this location. Each lance was open-ended with no orifices along the length of the lance. The pneumatically conveyed sorbent exited the lance end and mixed with the flue gas flowing vertically in the duct before entering the ESP.

The dual flue gas conditioning system for Unit 2 was located in the same run of duct used for sorbent injection. The sorbent injection point was located downstream of the NH_3 injection point and upstream of the SO_3 injection point.

2.2 Test Matrix and Sampling Locations

This section describes the properties of the sorbent materials selected for the test program and describes the text matrix and sample locations used to characterize the system.

2.2.1 Sorbent Selection

A single sorbent, Darco-Hg activated carbon, was selected for the short-term parametric testing at Unit 2. Darco-Hg carbon has been tested at a number of other coal-fired plants and serves as a benchmark sorbent. Characteristics for the selected sorbent are summarized in Table 2-2. The Darco-Hg sorbent was also tested on the Unit 1 ESP, a similar small-SCA ESP system at Plant Yates.

Table 2-2. Sorbent Tested on Unit 2

Sorbent Identifier	Manufacturer	Average Particle Size (μm)	Description	Price [a] ($/lb)
Darco-Hg (formerly Darco FGD™)	Norit Americas	19	Lignite-derived activated carbon; baseline carbon	$0.44

[a] FOB Marshall, TX.

2.2.2 Test Matrix

Testing for Unit 2 consisted of 3 days of baseline tests and 5 days of parametric tests to determine the effect of dual flue gas conditioning on sorbent injection performance. Figure 1-1, shown previously, identifies the sampling locations for the various gaseous process streams.

Tables 2-3 and 2-4 summarize the sample types and frequency of collection for the short-term baseline and parametric tests, respectively. Short-term baseline tests were conducted the week of March 15, 2004 and parametric activated carbon injection tests were the week of March 22, 2004. The goal of these tests was to measure the effects of sorbent injection at different addition rates for the benchmark Darco-Hg carbon and observe the effects of sorbent injection with the flue gas conditioning system both on and off. Two mercury SCEMs were operated continuously during the Unit 2 tests: one to service the ESP inlet and one for the ESP outlet.

Injection rates for the parametric tests were selected based on results of the Unit 1 injection tests for the Darco-Hg carbon. Ontario Hydro flue gas measurements were conducted once (e.g., one set of 3 samples) during the initial full baseline condition as specified in Table 2-3. Grab samples of raw coal were collected from each pulverizer feed chute after the weigh belt. Daily composite grab samples were collected during both the baseline and parametric carbon injection test periods. ESP fly ash samples were also collected from each field of the ESP during the baseline and carbon injection tests. Bulk samples of ESP ash for DOE waste characterization tests were collected as shown in Table 2-3 and held for future analysis as part of a separate DOE-sponsored project. The unit was down during the day of March 17; therefore, no solid samples were taken that day.

Table 2-5 shows the type of analyses conducted for each sample type. Coal samples were analyzed for mercury, chloride, and ultimate/proximate parameters. ESP fly ash samples were analyzed for mercury and LOI.

2.3 Sampling and Analytical Methods

Sampling and analytical methods for flue gas and process solids, including coal and ESP fly ash are described in this section.

2.3.1 Coal and ESP Ash

Composite samples of the Unit 2 coal were collected once per day upstream of the coal pulverizers. Composite fly ash samples were obtained by collecting and combining ash from each field of the ESP during the baseline characterization and sorbent injection test periods. Coal and fly ash samples were digested with ASTM 3684 and analyzed for mercury by CVAA. The coal was digested by ASTM D4208 and analyzed for chloride by ion exchange chromatography (EPA Method 300).

2.3.2 Flue Gas

The flue gas mercury measurements for baseline and injection testing were performed with mercury semi-continuous analyzers, which are described below in more detail. During baseline testing Ontario Hydro measurements were conducted. This method is not explained further, as it is considered a standard EPA method.

Table 2-3. Unit 2 – Baseline Test Schedule

	3/17/04						3/18/04						3/19/04					
Time:	8am	10am	12pm	2pm	4pm	6pm	8am	10am	12pm	2pm	4pm	6pm	8am	10am	12pm	2pm	4pm	6pm
ESP Inlet:																		
Ontario Hydro								↔	↔		↔							
SCEM						←	—	—	—	—	—	—	—	—	—	—	—	→
M26A						↔	↔							↔				
ESP Outlet:																		
Ontario Hydro								↔	↔		↔							
SCEM						←	—	—	—	—	—	—	—	—	—	—	—	→
Coal:																		
Grab Composite								●	●					●	●			
ESP Fly Ash:																		
Grab Composite									●						●			
DOE Characterization Sample									●						●			

Table 2-4. Unit 2 – Parametric Sorbent Injection Test Schedule for Darco Hg™ Activated Carbon

Date	**3/22/04**				**3/24/04**				
Test Condition	BL	SI	SI	BL	BL	SI	SI	SI	BL
Begin/End Time (EST)	10:32 - 11:45	11:45 - 15:25	15:25 - 16:30	16:30 – 20:39	8:20 - 13:25	13:25 - 16:11	16:11 - 17:14	17:14 - 18:11	18:11- 18:31
Injection Rate (lb/MMacf)	0	2.1	4.2	0	0	6.3	8.3	12.7	0
Flue Gas Conditioning [a]	Full	Full	Full	Full	Full	Full	Full	Full	Full
ESP Inlet SCEM	C	C	C	C	C	C	C	C	C
ESP Outlet SCEM M17 Loading	C	C	C X	C	C	C X	C X	C X	C
Coal	9:45	13:30	-	-	13:20	-	-	-	-
ESP Fly Ash	-	13:30	-	-	13:20	-	-	-	-

Date	**3/25/04**						**3/26/04**					
Test Condition	BL	SI	SI	SI	BL	BL	BL	SI	SI	SI	SI	BL
Begin/End Time (EST)	8:22 - 9:57	9:57 - 13:11	13:11 - 16:00	16:00 - 17:30	17:30 - 18:14	18:14 - 18:54	8:23 - 9:57	9:57 - 12:46	12:46 - 14:30	14:30 - 15:40	15:40 - 16:15	16:15 - 20:25
Injection Rate (lb/ MMacf)	0	2.1	4.2	4.2	4.2	0	0	4.2	4.2	4.2	4.2	0
Flue Gas Conditioning [a]	None	None	None	Half	None	None	Full	Full	Half	Full	Low NH_3	Full
ESP Inlet SCEM	C	C	C	C	C	C	C	C	C	C	C	C
ESP Outlet SCEM M17 Loading	C	C X	C X	C	C	C	C	C X	C X	C	C	C
Coal	-	-	13:20	-	-	-	-	-	13:21	-	-	-
ESP Fly Ash	-	-	13:30	-	-	-	-	-	13:30	-	-	-

[a] Full = NH_3 ~ 6 ppm, SO_3 ~ 10 ppm;
Half = NH_3 ~ 3 ppm, SO_3 ~ 5 ppm;
Low NH_3 = NH_3 ~ 2 ppm, SO_3 ~ 10 ppm; and
None = Conditioning System Off
C = Indicates continuous SCEM operation during test period. Other entries indicate the times (EST) that samples were collected.
BL = Baseline, SI = Sorbent Injection

Table 2-5. Sample Analyses Plan for Unit 2 Short-Term Baseline and Parametric Tests

Location	Sample Method	Parameter(s)
ESP Inlet	SCEM	Speciated Hg
	Ontario Hydro	Speciated Hg
	Method 26A	HCl/Cl_2
ESP Outlet	SCEM	Speciated Hg
	Ontario Hydro	Speciated Hg
Coal	Grab Composite	Hg, Cl, Ult/Prox, HHV
ESP Fly Ash	Grab Composite	Hg, LOI
	Grab Composite	Waste Characterization [a]

[a] Bulk five-gallon bucket samples were collected for additional waste characterization tests to be conducted as part of a separate DOE-sponsored project.

EPRI SCEM Mercury Analyzer

Additional details regarding the SCEM mercury analyzer are provided in this section since it is not standard EPA method. Flue gas vapor-phase mercury analyses were made using EPRI semi-continuous analyzers depicted in Figure 2-3. At each sample location, a sample of the flue gas is extracted from the duct and then drawn through an inertial gas separation (IGS) filter to remove particulate matter. This IGS filter consists of a heated stainless steel tube lined with sintered material. A secondary sample stream is pulled across the sintered metal filter and then is directed through the mercury analyzer at a rate of approximately 1-2 L/min thus providing near real-time feedback during the various test conditions. The analyzer consists of a cold vapor atomic absorption spectrometer (CVAAS) coupled with a gold amalgamation system (Au-CVAAS). Since the Au-CVAAS measures mercury by using the distinct lines of the UV absorption characteristics of elemental mercury, the non-elemental fraction is converted to elemental mercury prior to analysis using a chilled reduction solution of acidified stannous chloride. Several impingers containing alkaline solutions are placed downstream of the reducing impingers to remove acidic components from the flue gas; elemental mercury is quantitatively transferred through these impingers.

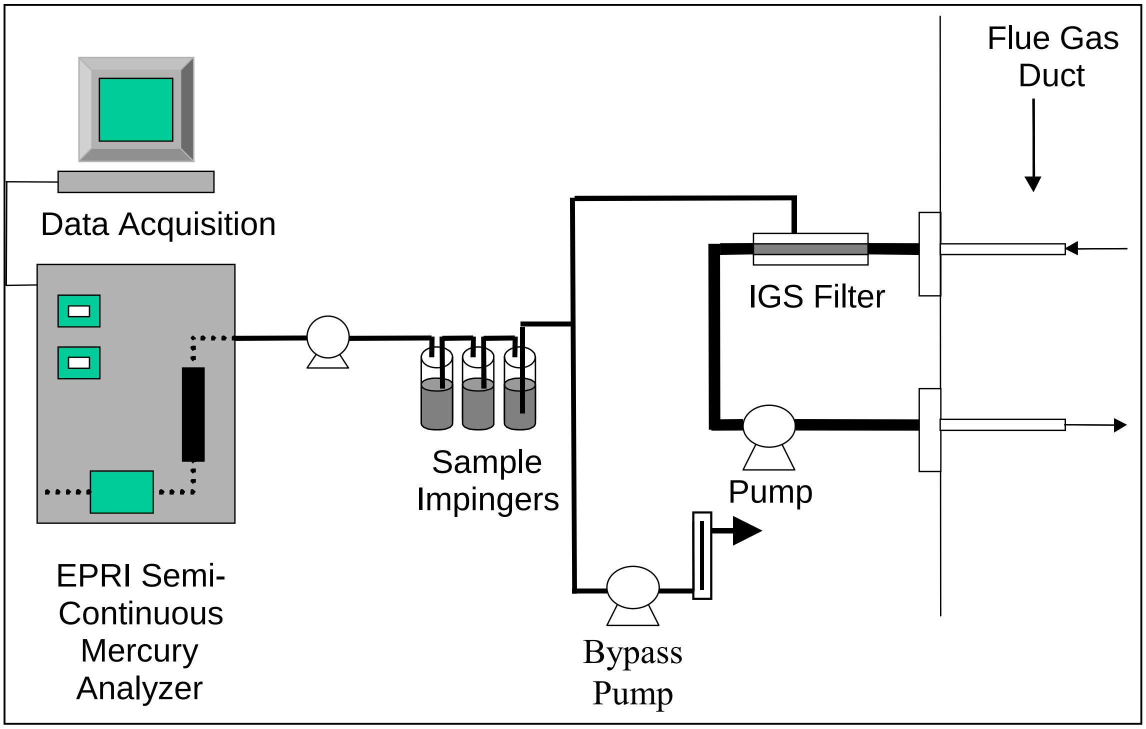

Figure 2-3. Semi-Continuous Mercury Analyzer

Gas exiting the impingers flows through a gold amalgamation column where the mercury in the gas is adsorbed (<60° C). After adsorbing mercury onto the gold for a fixed period of time (typically 1 minute), the mercury concentrated on the gold is thermally desorbed (>400° C) in nitrogen or air, and sent as a concentrated mercury stream to a CVAAS for analysis. Therefore, the total flue gas mercury concentration is measured semi-continuously with a 1-minute sample time followed by a 2-minute analytical period.

To measure elemental mercury only, an impinger containing either 1M potassium chloride (KCl) or 1M Tris Hydroxymethyl (aminomethane) and EDTA is placed upstream of the alkaline solution impingers to capture oxidized mercury. Oxidized forms of mercury are subsequently captured and maintained in the KCl or Tris impingers while elemental mercury passes through to the gold amalgamation system. Comparison of “total” and “elemental” mercury measurements yields the extent of mercury oxidation in the flue gas.

3.0 Results and Discussion

The results of the baseline and Darco-Hg activated carbon injection tests for Unit 2 are discussed in this section. The following topics are discussed: flue gas mercury speciation and removal, coal and byproduct analyses, additional flue gas characterization testing, and impacts of sorbent injection on plant operations. Field test conditions for each test phase are summarized in Table 3-1.

3.1 Flue Gas Mercury Speciation and Removal

Baseline

Baseline characterization of the vapor-phase mercury concentrations in the flue gas at the ESP inlet and ESP outlet were conducted over a three-day period from 3/17/04 through 3/19/04. During this period, semi-continuous data were collected for total vapor-phase mercury and elemental mercury (oxidized mercury calculated by difference) using two SCEM analyzers. The objectives of this series of tests were (1) to measure the native mercury concentrations at the various flue gas sample locations; (2) to quantify any baseline native mercury removal; (3) to measure the variability in flue gas mercury concentrations over time; and (4) to compare the performance of the SCEM analyzers with results from the Ontario Hydro standard reference method.

Total and elemental vapor-phase mercury concentrations, as measured by the SCEM, are shown for each sample location over the entire baseline characterization period in Figure 3-1 to illustrate variability in the mercury concentrations and speciation over time. During the baseline evaluation, the ESP inlet (air heater outlet) and ESP outlet total vapor-phase mercury concentrations varied from 4.1 to 7.6 $\mu g/Nm^3$ at the ESP inlet and 1.9 to 4.4 $\mu g/Nm^3$ at the ESP outlet, at 3% O_2. Methodology for normalization of mercury measurement data from actual duct conditions to 3% O_2 is described in Appendix A.

Table 3-1. Field Test Conditions for the Unit 2 Baseline and Darco-Hg Carbon Injection Tests

Date	Baseline, Full Load			Darco-Hg Carbon Injection, Full Load												
	Day 1	**Day 2**	**Day 3**	**Day 4**		**Day 5**			**Day 6**				**Day 7**			
	3/17/04	**3/18/04**	**3/19/04**	**3/22/04**		**3/24/04**			**3/25/04**				**3/26/04**			
Sorbent Injection Time Period (EST)	NA	NA	NA	11:45 – 15:25	15:25 – 16:30	13:25 – 16:11	16:11 – 17:14	17:14 – 18:11	9:57 – 13:11	13:11 – 16:00	16:00 – 17:30	17:30 – 18:14	9:57 – 12:46	12:46 – 14:30	14:30 – 15:40	15:40 – 16:15
Sorbent Injection Rate (lb/MMacf)	0	0	0	2.1	4.2	6.3	8.3	12.7	2.1	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Sorbent Injection Rate (lb/hr)	0	0	0	60	120	180	240	365	60	120	120	120	120	120	120	120
Dual Flue Gas Injection (NH_3 ppmv/SO_3 ppmv)	6/10	6/10	6/10	6/10	6/10	6/10	6/10	6/10	0/0	0/0	3/5	0/0	6/10	3/5	6/10	2/10

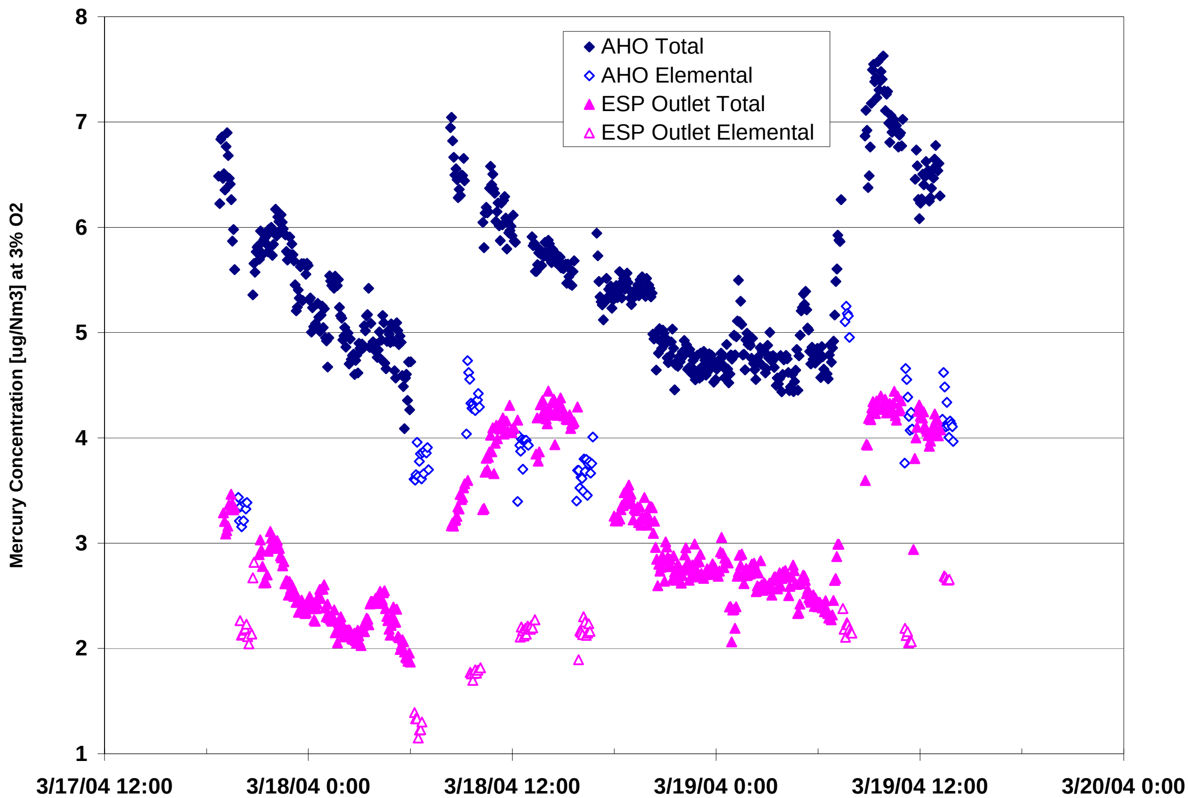

Figure 3-1. Baseline SCEM Mercury Characterization at the Unit 2 ESP Inlet and ESP Outlet Locations, Conditioning System On

Sorbent Injection with Darco-Hg Activated Carbon

Table 3-2 provides the average SCEM mercury measurement data obtained during the various Darco-Hg carbon sorbent injection test periods. A plot of total vapor-phase mercury removal across the ESP system during sorbent injection tests is provided in Figure 3-2 to illustrate overall mercury removal. Here, removal is calculated based on the simultaneous average SCEM vapor-phase total mercury concentrations obtained at the ESP inlet and ESP outlet locations.

Native removals across the ESP, measured daily before and after sorbent injection periods, ranged from 20 to as high as 66 percent, with the majority of values for non-injection periods concentrated between 20 and 30 percent. These removals compare favorably to the value of 36 percent removal measured during the week of baseline characterization.

Native removals of 56 and 66 percent were measured during the morning and afternoon of one single test day (3/24/04). These native removals were higher than native removals during the rest of the week. The mercury content (0.52 µg/g) and percent LOI (21.5%) for the ESP ash sample collected during the daily baseline test period on 3/24/04 were also the highest values measured during the Unit 2 tests and tend to support the higher native removals observed on this day. The highest injection rates were tested on the day of the highest native removal.

For the ESP system, the removal curve flattens out near 70 percent for sorbent injection rates of 6 lb/MMacf and above. Total vapor-phase mercury removal across the ESP was 73% at the highest tested injection rate of 12.7 lb/MMacf.

To illustrate the additional reduction in total vapor-phase mercury removal attributed to sorbent injection (i.e., reduction beyond native levels), the percent reduction in average total vapor-phase mercury concentrations at the ESP outlet relative to average baseline (i.e. native) concentrations are plotted in Figure 3-3, for each sorbent injection test condition. The percent reduction in total mercury concentration for a given injection rate is calculated as follows:

$$\text{Percent Reduction} = [1 - (I / BL)] \times 100$$

Where, I = average SCEM total mercury concentration at the ESP outlet for the injection rate test period, and

BL = average SCEM total mercury concentration at the ESP outlet for the baseline test period calculated based on the concentrations measured at the beginning and end of each test day.

These short-term test data indicate an additional 30 to 40 percent reduction in total vapor-phase mercury was achieved at an injection rate of 2 lb/MMacf. No additional reduction in ESP outlet total mercury concentrations was observed at higher injection rates up to 13 lb/MMacf. Figure 3-3 also indicates the set points for the dual flue gas conditioning system during each test period. The dual flue gas conditioning system had no effect on total vapor-phase mercury reduction at the ESP outlet.

Figure 3-4 shows the total vapor-phase mercury emissions, expressed as lb/trillion Btu input, at the ESP outlet as a function of the carbon injection rate. Without injection, the ESP outlet emissions ranged from 1.5 to 3.5 lb/trillion Btu, with the predominance of values falling in the 2.5 to 3.5 lb/trillion Btu range. Figure 3-5 shows an analogous plot in terms of lb/MWh output.

Table 3-2. Unit 2 – Average SCEM Mercury Measured for Injection Tests of Darco-Hg Activated Carbon

Date	Injection Rate (lb/MMacf)	Conditioning [a]	ESP Inlet, μg/Nm³			ESP Outlet, μg/Nm³			Total Hg Removal Across ESP, %
			Total	Hg^o	% Oxidized	Total	Hg^o	% Oxidized	
3/22/04	0	Full	7.1	2.4	67	5.3	2.1	60	25
	2.1	Full	-	-	-	3.7	1.8	52	48[b]
	4.2	Full	-	-	-	2.9	1.6	45	50[b]
	0	Full	5.7	-	-	4.6	-	-	19
3/24/04	0	Full	6.3	-	-	2.8	-	-	56
	6.3	Full	6.6	-	-	2.0	-	-	70
	8.3	Full	6.6	3.9	41	2.0	-	-	70
	12.7	Full	6.7	4.3	37	1.8	-	-	73
	0	Full	6.8	-	-	2.3	-	-	66
3/25/04	0	None	7.5	4.4	42	5.2	2.4	54	31
	2.1	None	6.4	4.2	34	3.4	-	-	47
	4.2	None	6.2	4.0	36	3.3	-	-	47
	4.2	Half	6.6	4.0	39	3.3	2.1	37	50
	4.2	None	6.5	-	-	3.5	-	-	46
	0	None	-	3.9	-	3.9	-	-	-
3/26/04	0	Full	5.4	-	-	4.3	1.9	56	20
	4.2	Full	5.5	3.4	37	2.7	-	-	51
	4.2	Half	4.8	-	-	2.6	-	-	46
	4.2	Full	4.7	2.9	39	2.6	-	-	45
	4.2	Low NH_3	-	3.1	-	2.7	-	-	43[b]
	0	Full	4.6	-	-	3.7	-	-	20

Note: All concentrations normalized to 3% oxygen.

[a] Full = 6 ppm HN_3, 10 ppm SO_3
Half = 3 ppm HN_3, 5 ppm SO_3
Low NH_3 = 2 ppm HN_3, 10 ppm SO_3
None = 0 ppm HN_3, 0 ppm SO_3

[b] The corresponding ESP inlet concentration was not available. Removal was calculated based on the nearest ESP inlet measurement.

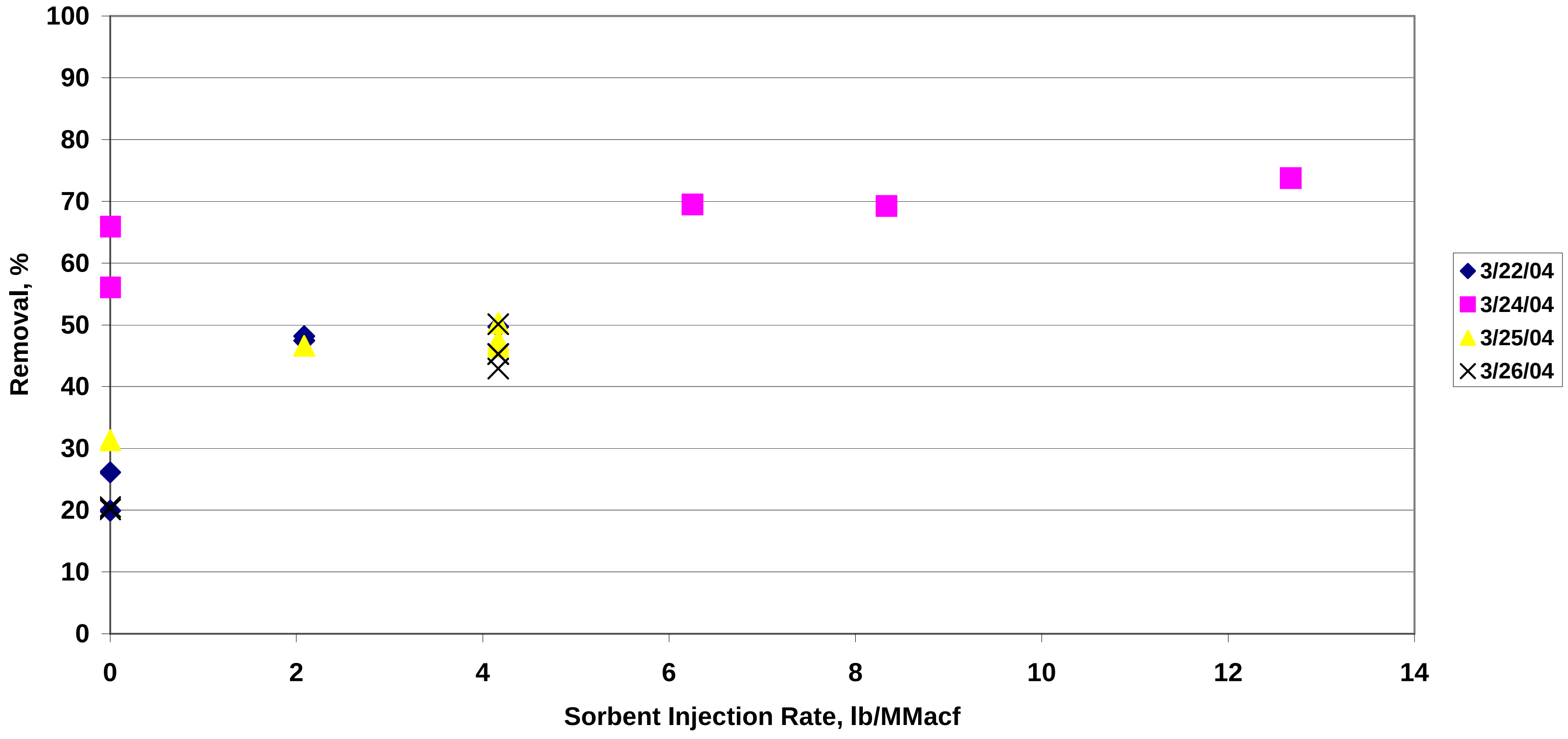

Figure 3-2. Unit 2 –Total Vapor-phase Mercury Removal Across the ESP for Darco-Hg Activated Carbon Injection Tests

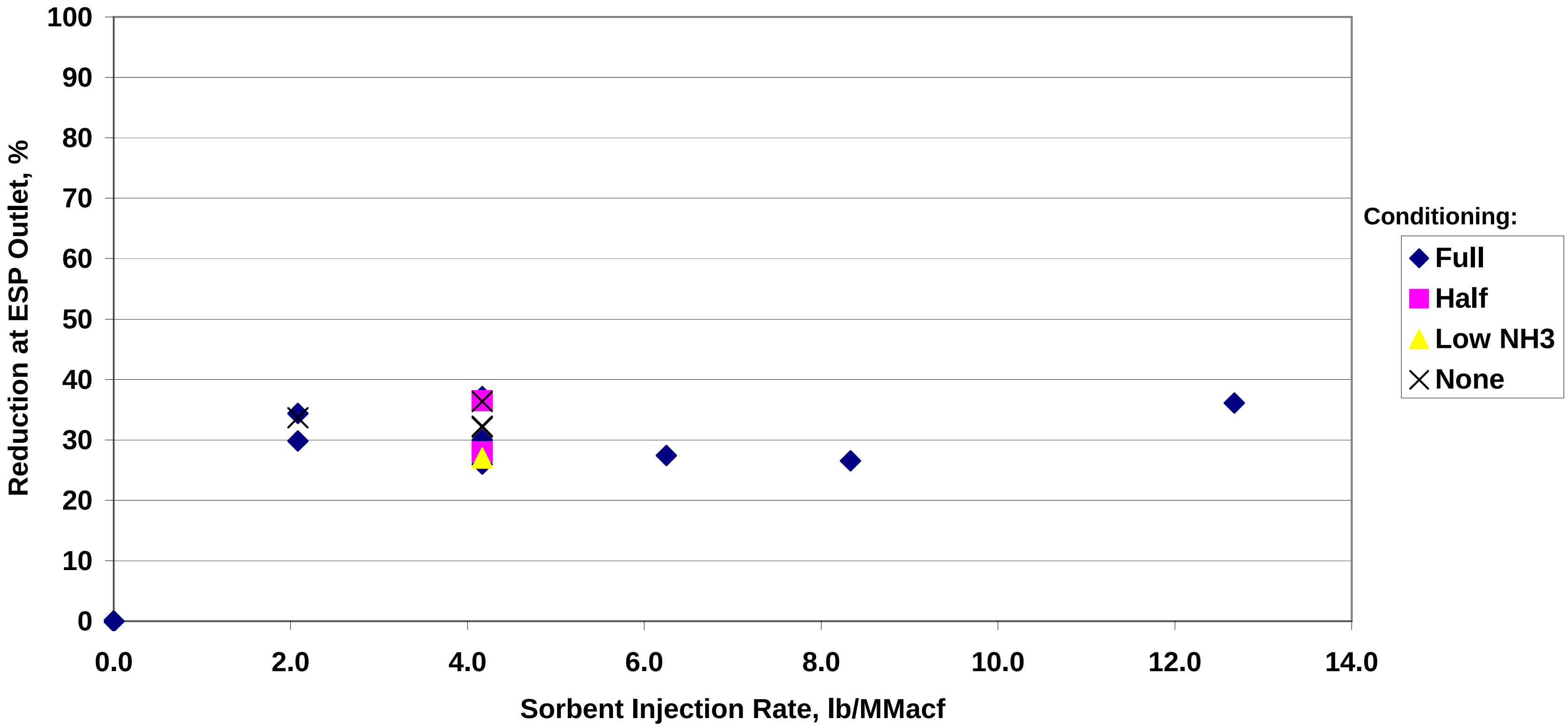

Figure 3-3. Unit 2 – Reduction in Total Vapor-phase Mercury Concentrations at the ESP Outlet Relative to Baseline During-Hg Carbon Injection

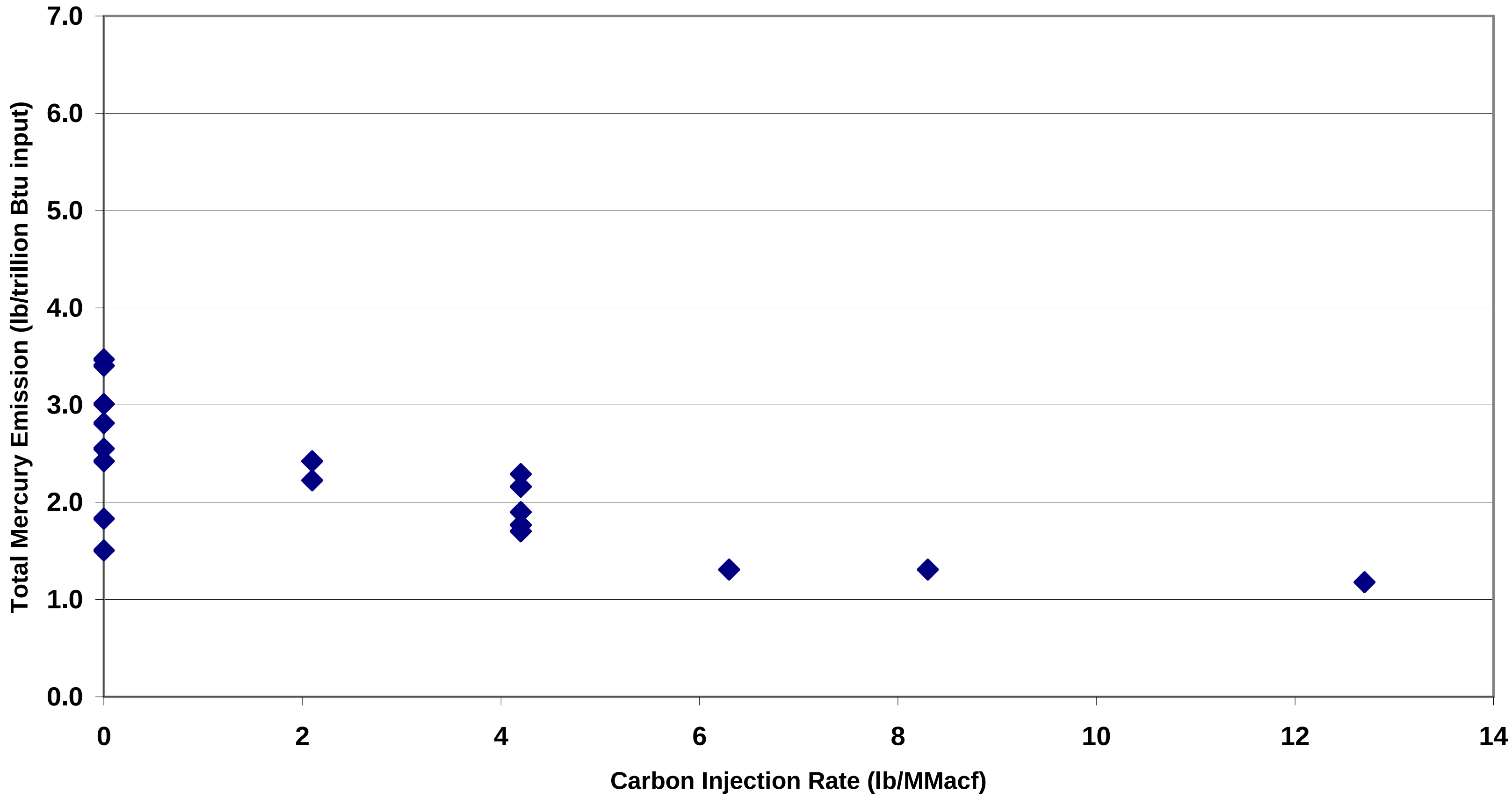

Figure 3-4. Unit 2 ESP Outlet Mercury Emissions During Baseline and Darco-Hg Carbon Injection Tests (expressed as lb/trillion Btu input)

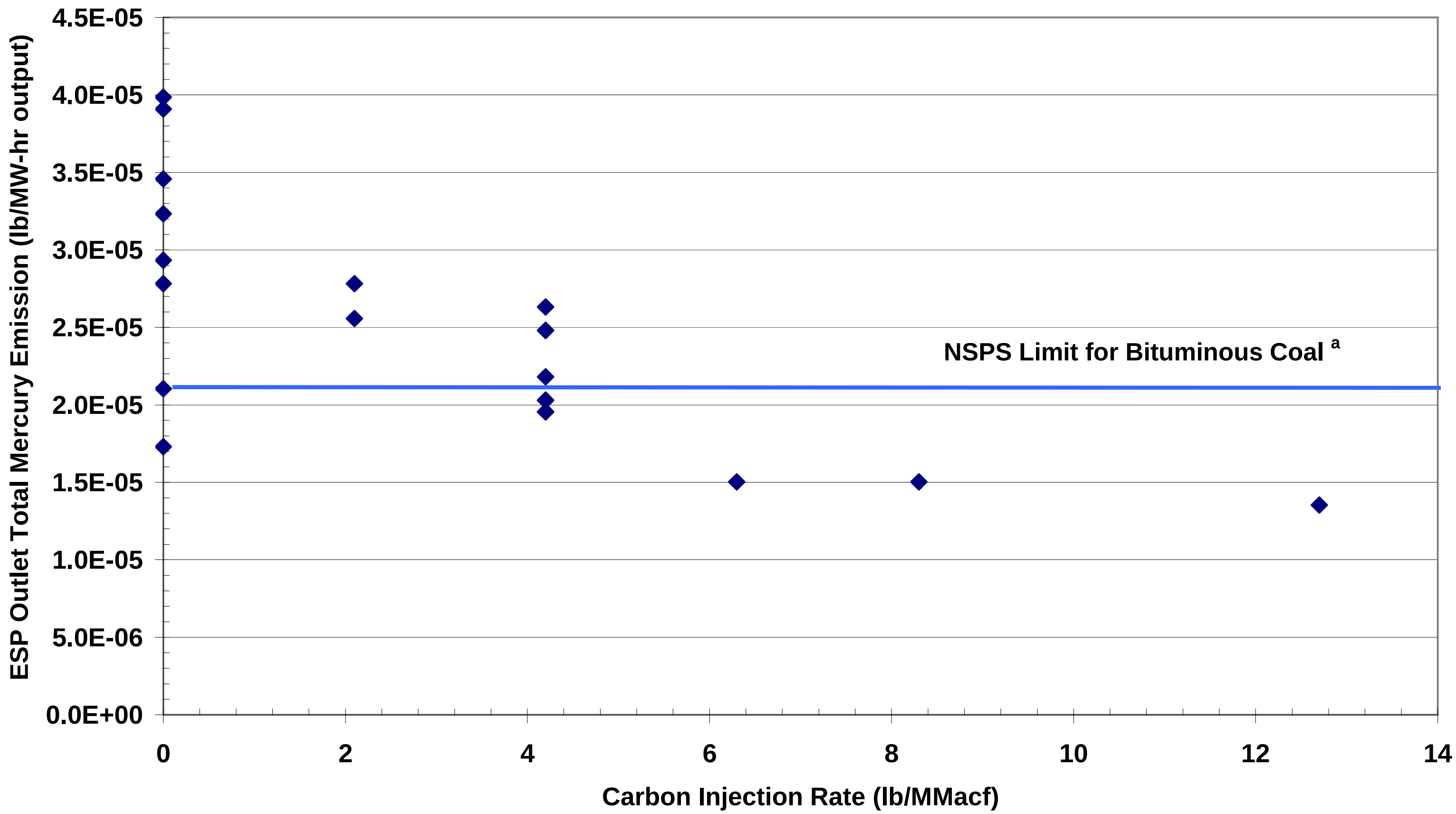

Figure 3-5. Unit 2 ESP Outlet Mercury Emissions During Baseline and Darco-Hg Carbon Injection Tests (expressed as lb/MWh output)

3.2 Coal and Byproduct Analyses

Coal

Table 3-3 shows the analytical results for as-fired coal samples. Coal samples were taken as a composite from the coal feeders just upstream of the pulverizers that were in service. They were analyzed in triplicate for mercury and an average of the triplicate analyses is reported in the Table 3-4. Results from the ultimate and proximate analyses are also shown.

Coal mercury content of the samples ranged from 0.069 to 0.14 µg/g, dry basis (5.4 to 10.8 lb/trillion Btu). Coal chloride levels ranged from 152 µg/g to 436 µg/g, dry basis. Other coal properties showed little variation over the parametric test period.

Fly Ash

Table 3-4 shows the results for mercury and LOI analyses of the ESP fly ash samples. Composite fly ash samples were obtained by collecting and combining ash from each field of the ESP during the baseline characterization and sorbent injection test period. The LOI results for Unit 2 are plotted in Figure 3-6 and show a general trend of higher mercury concentrations at higher LOI.

Fly ash samples were gathered in five-gallon buckets for the DOE waste characterization study. These samples are listed in Appendix B.

Mercury Mass Balance

Table 3-5 shows an overall mass balance for mercury estimated based on the measured concentrations of mercury in the coal, ESP fly ash, and ESP outlet gas on 3/18/04. A mass balance around the ESP was not possible because the sampling location at the ESP inlet precluded isokinetic particulate loading measurements. Mercury balance closure for the entire unit was 76 percent, using SCEM data for the ESP outlet. This mass balance indicates that approximately 31 percent of the mercury input with the coal was captured in the ESP fly ash.

Table 3-3. Unit 2 – Coal Analyses for Baseline and Carbon Injection Tests

Date	3/15/04	3/15/04	3/16/04	3/18/04	3/19/04	3/22/04	3/24/04	3/25/04	3/26/04
Sample Time	**9:40**	**13:40**	**9:30**	**13:20**	**13:10**	**13:30**	**13:20**	**13:20**	**13:21**
Test Condition [a]	**BL**	**BL**	**BL**	**BL**	**BL**	**Darco-Hg**	**Darco-Hg**	**Darco-Hg**	**Darco-Hg**
Proximate, wt % as received [b]									
Moisture	-	5.48	5.54	5.69	6.02	5.23	-	5.51	5.68
Ash	-	10.4	11.5	11.8	11.0	11.1	-	11.1	10.2
Volatile Matter	-	29.3	28.6	28.0	28.9	28.5	-	29.0	29.8
Fixed Carbon	-	54.9	54.3	54.6	54.0	55.2	-	54.4	54.3
Sulfur	-	1.24	1.00	0.96	1.41	1.12	-	0.91	0.86
Ultimate, wt % as received									
Moisture	3.81	-	-	-	-	-	4.60	-	-
Carbon	72.7	-	-	-	-	-	72.5	-	-
Hydrogen	4.70	-	-	-	-	-	4.63	-	-
Nitrogen	1.39	-	-	-	-	-	1.37	-	-
Sulfur [b]	0.99	-	-	-	-	-	1.10	-	-
Oxygen	5.60	-	-	-	-	-	5.32	-	-
Ash	10.8	-	-	-	-	-	10.5	-	-
Heating Value (Btu/lb, as received)	13,136	12,858[b]	12,724[b]	12,647[b]	12,713[b]	12,811[b]	13,072	12,754[b]	12,841[b]
Mercury (µg/g, dry)	-	0.081	0.069	0.074	0.137	0.083	0.073	0.071	0.096
Mercury (lb/trillion Btu)	-	6.3	5.4	5.9	10.8	6.5	5.6	5.6	7.5
Chloride (mg/Kg, dry)	-	-	-	436	277	356	-	152	-

[a] BL = baseline characterization, Darco-Hg = Darco-Hg activated carbon sorbent injection

[b] Represents Plant Yates analysis of as-bunkered fuel samples. Mercury analysis was done on separate Unit 2 as-fired coal samples.

Table 3-4. Unit 2 – ESP Fly Ash Analyses for Baseline Characterization and Darco Hg Activated Carbon Injection Tests

Date	Time	Sample Type	Test Condition	Injection Rate (lb/MMacf)	Mercury (µg/g)	LOI (%)
3/18/04	NA	ESP ash	Baseline	0	0.25	7.7
3/19/04	NA	ESP ash	Baseline	0	0.21	9.0
3/22/04	13:30	ESP ash	Darco-Hg	2.1	0.18	6.9
3/24/04	13:20	ESP ash	Daily Baseline [a]	0	0.52[b]	21.5[b]
3/25/04	13:30	ESP ash	Darco-Hg	4.2	0.40	15.2
3/26/04	13:30	ESP ash	Darco-Hg	4.2	0.32	17.1

[a] Sample collected during the 5-hr daily baseline period prior to the start of the sorbent injection test at 6 lb/MMacf.

[b] The reported mercury concentration for this baseline sample appears to be an outlier when compared to the typical LOI and Hg concentrations measured in the fly ash. The native removal of mercury across the ESP was higher than normal on this day.

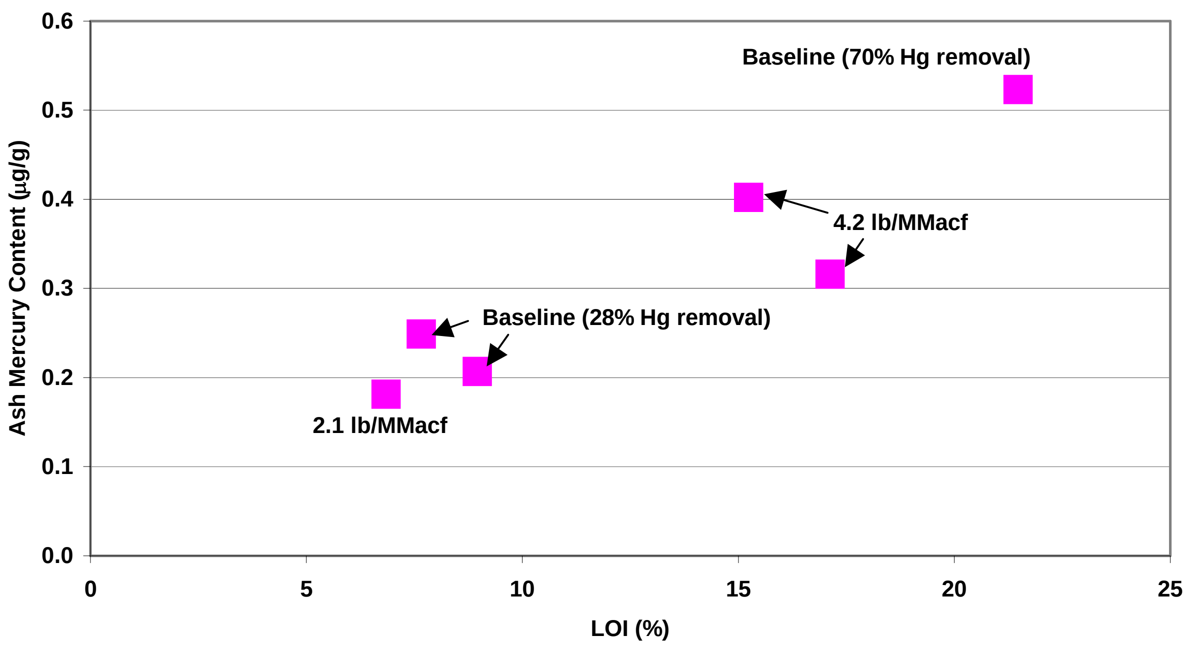

Figure 3-6. Unit 2 – Fly Ash Mercury Content and Ash LOI

Table 3-5. Unit 2 – Mercury Mass Balance Results for Baseline Characterization on 3/18/04

Stream	Flow Rate	Mercury Concentration [b]	Mercury Rate (g/hr)
Coal [a]	84,704 dry lb/hr	0.074 dry µg/g	2.84
Bottom Ash [a]	1,906 lb/hr	0.0030 µg/g	0.003
ESP Outlet Vapor [a] (SCEM)	490,240 dry Nm^3/hr	2.66 µg/Nm^3	1.30
ESP Outlet Particulate [a] (OH)	490,240 dry Nm^3/hr	< 0.0114 µg/Nm^3	< 0.006
ESP Captured Fly Ash [a]	7,622 lb/hr	0.249 µg/g	0.86
Overall Mass Balance			
		Total In	2.84
		Total Out	2.16
		Closure [c]	**76%**

[a] Estimated stream flow rate
[b] Mercury vapor concentrations at the actual flue gas oxygen content.
[c] Closure (%) = (Out/In) x 100

3.3 Additional Flue Gas Characterization

Additional flue gas characterization data for HCl/Cl_2 and particulate loading are summarized in this section. Appendix C provides the raw source sampling data collected for these methods.

Ontario Hydro

Average mercury concentrations from the SCEM analyzer for the ESP inlet and ESP outlet locations during the full-load baseline test period are summarized in Table 3-2. SCEM mercury concentrations reported in Table 3-6 are average values for the corresponding Ontario Hydro source sampling test periods on 3/18/04. For these baseline tests, the dual flue gas conditioning system was turned on with operating set-points of approximately 6 ppm NH_3 and 10 ppm SO_3 (i.e., "Full" condition). The SCEM measured total mercury concentrations at the ESP inlet between 5.6 and 6.5 µg/Nm^3 at 3% O_2, with an average of 6.0 µg/Nm^3. The Ontario Hydro runs measured an average concentration of 7.0 µg/Nm^3 at the ESP inlet. At the ESP outlet, the SCEM averaged 3.9 µg/Nm^3, while the Ontario Hydro runs averaged 8.2 µg/Nm^3. Based on the SCEM data, average total vapor-phase mercury removal across the ESP on 3/18/04 was 36 percent during baseline conditions. An increase in mercury oxidation from 34% to 48% was observed across the Unit 2 ESP.

Particulate mercury concentrations are not available at the ESP inlet since the ESP inlet sampling location was nestled between two sharp turns in the ductwork, making isokinetic sampling infeasible. The ESP outlet particulate mercury concentrations, as determined by the Ontario Hydro method, was less than 0.017 $\mu g/Nm^3$.

The inlet SCEM and Ontario Hydro data for the ESP inlet are within 13% of each other. However, the Ontario Hydro data indicate that the inlet stream is 75% oxidized, while the SCEM data indicate 35% oxidation at the inlet. In Ontario Hydro a particulate filter is placed upstream of the impingers, allowing for intimate contact between the gas and the collected particulate matter. The SCEM method uses a self-cleaning filter that minimizes the accumulation of particulate matter and minimizes the possibility of bias. These data indicate that the passage of flue gas through the Ontario Hydro particulate filter may have resulted in oxidation of sampled mercury. This hypothesis is further validated with the outlet data, in which the oxidation percentages of the Ontario Hydro and SCEM are in better agreement. At the ESP outlet, the flue gas had a very low particulate concentration, so that bias caused by collection of particulate on the filter was reduced. These same patterns in oxidation results were seen in the Yates Unit 1 baseline data comparison between Ontario Hydro and SCEM.

While the inlet total vapor phase mercury data show reasonable agreement between the Ontario Hydro and SCEM data, the outlet SCEM and Ontario Hydro data are not in good agreement for total mercury concentration. A mercury balance was performed around the boiler/ESP combined system as discussed in Section 3.2. A closure of 100% indicates that the input and output values are equal. A closure less than 100% indicates that the outputs were less than the inputs. A mercury balance using ESP outlet values measured with SCEM indicates 76% closure around the boiler/ESP combination. Using the Ontario Hydro values in the mass balance (rather than SCEM data) results in 170% closure, indicating that the SCEM data are more in line with the mercury content of the coal and ash.

The QA/QC results for the Ontario Hydro and SCEM methods are given in Appendix D.

Table 3-6. Unit 2 – Average SCEM and Ontario Hydro Mercury Measurements During Baseline Characterization on 3/18/04, NH_3/SO_3 Conditioning System On

Method	Run No.	Sampling Period (EST)	Vapor Phase			
			Elemental	Oxidized	Percent Oxidized	Total
			ESP Inlet, µg/Nm^3			
SCEM	1	9:15-11:15	4.37	2.16	33	6.54
OH	1		1.93	5.67	75	7.61
SCEM	2	12:15-14:15	3.88	2.11	35	5.99
OH	2		1.93	5.63	74	7.56
SCEM	3	15:40-17:40	3.65	1.95	35	5.60
OH	3		0.82	4.85	86	5.67
SCEM	Avg		3.97	2.07	34	6.04
OH	Avg		1.56	5.38	75	6.95
			ESP Outlet, µg/Nm^3			
SCEM	1	9:15-11:22	1.77	1.58	47	3.35
OH	1		5.50	3.04	36	8.54
SCEM	2	12:15-14:15	2.18	1.93	47	4.11
OH	2		4.61	2.84	36	7.45
SCEM	3	15:40-17:40	2.16	2.07	49	4.22
OH	3		5.12	3.56	41	8.68
SCEM	Avg		2.04	1.86	48	3.89
OH	Avg		5.08	3.14	37	8.22
			Removal, %			
SCEM	Avg		NC	NC	NA	36
OH			NC	NC	NA	-18

Note: All data normalized to 3% oxygen. Vapor phase oxidized mercury for the SCEM was computed as the difference between the total and elemental measurements.
NA = Not applicable. NC = Not calculated.

Method 26A

Method 26A flue gas characterization data were collected during the initial baseline characterization test period at the ESP inlet. Measured flue gas concentrations of HCl and Cl_2 are summarized in Table 3-7. HCl levels at the ESP inlet, ranging from 12 to 32 ppmv, are consistent with the chloride levels measured in the coal.

Table 3-7. Unit 2 – Method 26A Data for Baseline Characterization Tests

Location	Date/Time	HCl (ppmv)	Cl_2 (ppmv)
ESP Inlet	3/17/04 8:13 – 9:13	31.9	< 0.06
	3/18/04 7:15 – 8:15	17.1	< 0.07
	3/19/04 9:25 - 10:25	12.3	< 0.05
	Average	20.4	< 0.06

Particulate Loading

Particulate loading measurements were obtained at the ESP outlet during baseline and sorbent injection test periods, as shown in Table 3-8. For baseline tests, particulate loading was determined from the Ontario Hydro samples runs from 3/18/04; for the sorbent injection tests, Method 17 was used to determine particulate loading. Note that the Ontario Hydro samples were collected using a full-traverse of the duct cross section over a period of approximately 2 hours for each sample run, whereas, the Method 17 samples were collected at a single point of average velocity in the duct over a period of approximately 1 hour. The Method 17 data were intended to provide an indication of trends in particulate loading between the various injection rate tests rather than providing a "compliance" type particulate emission measurement. Because the baseline and injection loading data were obtained using two different methods it is not valid to make a quantitative comparison of particulate loading for baseline and sorbent injection tests. The particulate measurements are explored further in the next section on the effect of sorbent injection on ESP performance.

Table 3-8. Unit 2 – ESP Outlet Particulate Loading Measurements

Sample Method	Sorbent Injection Rate (lb/MMacf)	Date/Time	Particulate Loading (gr/dscf @ 3% O_2)
Ontario Hydro (full traverse)	0 (baseline)	3/18/04 / 9:15 – 11:22	0.016
	0 (baseline)	3/18/04 / 12:45 – 14:15	0.018
	0 (baseline)	3/18/04 / 15:40 – 17:40	0.026
		Average	0.020
Method 17 (single point)	4.2	3/23/04 / 15:03 – 16:01	0.010
	6.3	3/24/04 / 13:05 – 15:10	0.0098
	8.3	3/24/04 / 15:27 – 16:08	0.011
	12.7	3/24/04 / 16:30 - 17:09	0.012
	2.1	3/25/04 / 9:15 - 10:01	0.012
	4.2	3/25/04 / 12:45 – 14:01	0.015
	4.2	3/26/04 / 9:34 - 10:17	0.011
	4.2	3/26/04 / 12:02 - 13:01	0.0099

3.4 Impacts of ACI on Plant Operations

Plant process data are summarized in figures in Appendix E. Unit 2 load was increased to its full-load set point of approximately 105-110 MW before each baseline and sorbent injection test period and held constant throughout each test.

Unit 2 ESP Performance

The impact of sorbent injection on the ESP performance was monitored in the following ways:

(1) Single point particulate loading measurements at the ESP outlet during each activated carbon injection test (Table 3-8, Figure 3-7),

(2) Monitoring plant opacity data for the common Unit 2/Unit 3 stack (Figure 3-8), and

(3) Monitoring the arc rate in each field of the ESP (Figure 3-9)

The flue gas particulate concentration was measured at the ESP outlet during both baseline and injection testing as shown previously in Table 3-8.

Figure 3-7 shows the Unit 2 ESP outlet particulate concentrations measured during baseline and injection testing. During baseline conditions (no sorbent injection), the ESP outlet particulate concentration ranged from 0.016 to 0.026 grains/dscf (gr/dscf) at 3% O_2, with an average of 0.020 gr/dscf, as determined from the Ontario Hydro full-traverse particulate samples. For carbon injection rates of 2 to 13 lb/MMacf, the measured particulate concentrations at the ESP outlet were slightly below this level, as measured by single-point Method 17. As discussed in the previous section, a quantitative comparison of particulate loading for baseline and injection tests is not valid because different sampling methods were used. However, qualitatively, these results suggest that there was little variation in particulate loading during sorbent injection tests with injection rates in the range of 2 to 13 lb/MMacf. The conditioning system was turned on during the collection of the test data shown in Figure 3-7, except as noted.

Opacity data from the combined Unit 2/Unit 3 stack were also examined over the course of each injection test to determine if sorbent injection resulted in changes in opacity. During typical operation, Units 2 and 3 share a common stack making it impossible to isolate opacity data for Unit 2; however, Unit 3 was taken offline at 9:22 AM on 3/25/04 and remained offline during the remainder of injection testing on Unit 2, so it was possible to examine opacity data from this time period to observe changes during sorbent injection. Figure 3-8 shows a plot of stack opacity as a function of time during the periods when Unit 3 was off-line. The various sorbent injection rates and Unit 2 load are noted on the plot.

On 3/25/04, this plot clearly shows that near the end of the 4.2 lb/MMacf sorbent injection period, Unit 2 stack opacity began to increase sharply. These changes in opacity, if due to increased particulate loading, would not have been reflected in the Method 17 single point measurements since the Method 17 measurements were conducted from 9:00-10:00 and 12:45-14:00 when opacity levels were relatively steady at about 4-5%. The data also show that stack opacity continued to increase after sorbent injection was discontinued at approximately 17:15. At approximately 20:00, load was dropped to 50% capacity on Unit 2. Figure 3-9 shows a clear relationship between increased arcing in the Unit 2 ESP and sorbent injection on 3/25/04.

Opacity data from 3/26/04 show a different trend during sorbent injection periods. All injection tests on 3/26/04 were conducted at 4.2 lb/MMacf with various conditioning system settings. Injection began at approximately 9:00 and continued until 15:15. Unlike the data from 3/25/04, opacity levels decreased for approximately 6 hours after sorbent injection began (from about 10% at the beginning of the test to a low of about 5.5% at 14:00). After 14:00, opacity levels began to rise and continued to rise after injection was discontinued at 15:15. ESP arc rate data from 3/26/04, shown in Figure 3-9, do not clearly indicate a correlation between sorbent injection and increased arc rate. The reason for the apparent difference in ESP operation for the two injection tests days is not known.

Data from these short-term tests are inconclusive regarding the effect of sorbent injection on ESP behavior. Data from additional longer-term tests, such as those conducted on the Unit 1 ESP system, have also been analyzed and more definitive conclusions can be made based on this larger data set. Refer to the Unit 1 Site Report for additional information regarding Unit 1 ESP performance during sorbent injection.

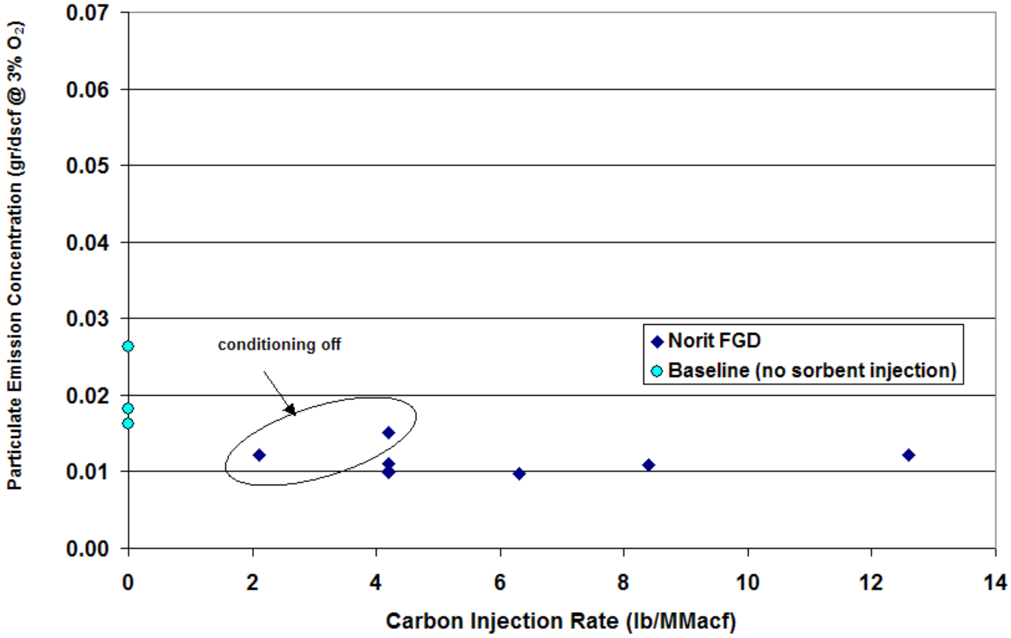

Figure 3-7. Unit 2 – ESP Outlet Particulate Loading

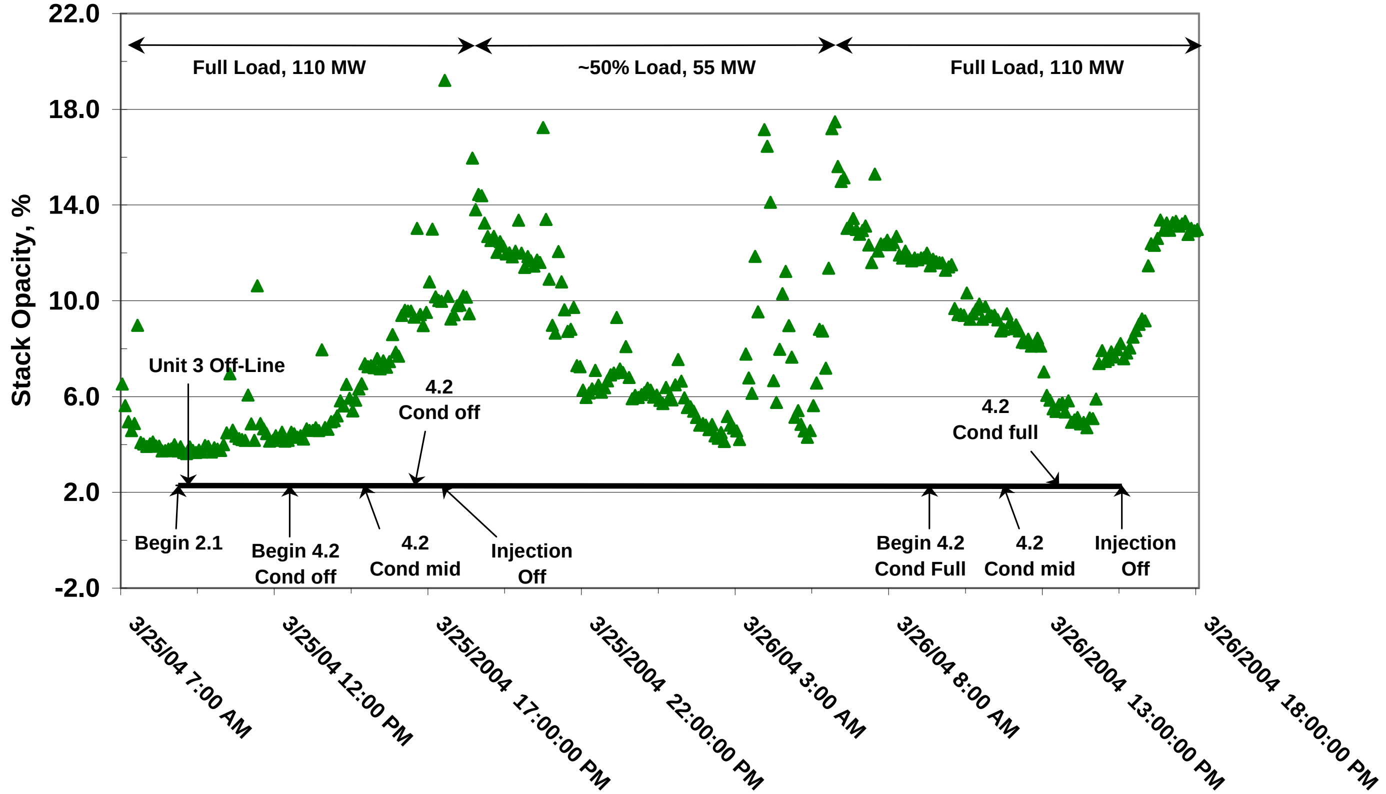

Figure 3-8. Unit 2 – Stack Opacity for Selected Darco-Hg Sorbent Injection Test Periods

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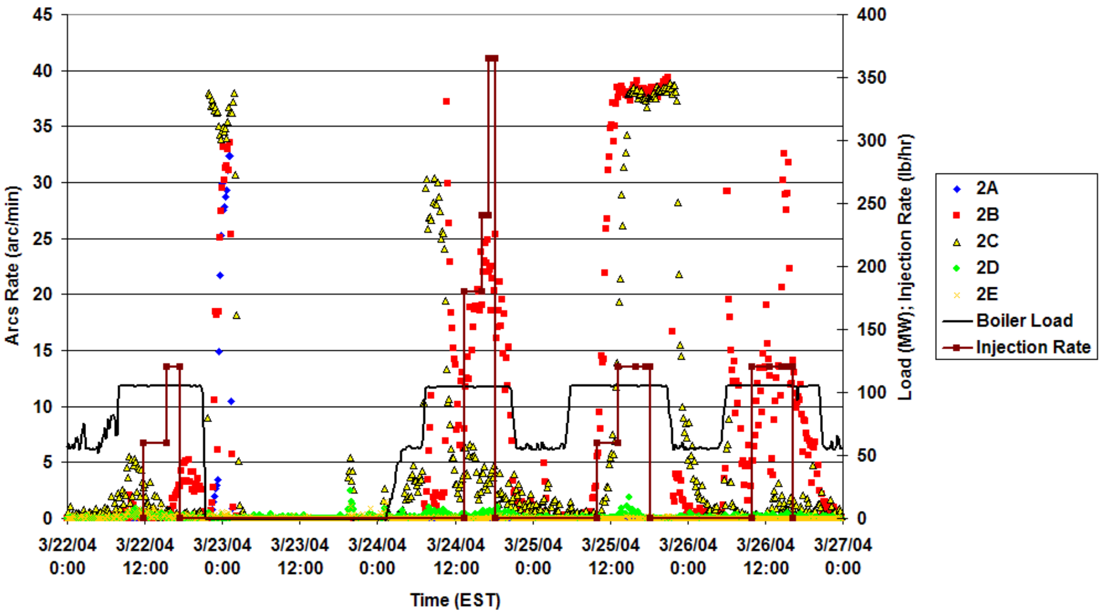

Figure 3-9. Arc Rates for Individual Fields in Unit 2 ESP During Darco-Hg Injection Testing

4.0 Conclusions and Recommendations

The primary goals of the project were (1) to measure native mercury removal across the small-SCA ESP; (2) to measure the variability in flue gas mercury concentrations at the ESP inlet and outlet locations; (3) to measure mercury removal performance of the Norit's Darco-Hg activated carbon over a range of injection rates with the conditioning system both on and off; and (4) to observe the effects of sorbent injection on the operation of the ESP system and on the properties of the ESP fly ash.

Native removal of total vapor-phase mercury across the Unit 2 ESP (SCA = 144 ft^2/1000 acfm), with the dual flue gas conditioning system in service, generally ranged from 20 to 36 percent during the baseline characterization period. Material balance results for the full baseline test period indicate approximately 31 percent of the mercury input with the coal was removed with the ESP ash. Total vapor-phase mercury concentrations at the ESP inlet, as measured by SCEM, ranged from 4.1 to 7.6 µg/Nm^3 and total mercury concentrations at the ESP outlet ranged from 1.9 to 4.4 µg/Nm^3 (at 3% oxygen).

Parametric tests showed that injection of the benchmark Darco-Hg activated carbon upstream of the ESP resulted in total vapor-phase mercury removals across the ESP ranging from 43 to 73 percent at injection rates ranging from 2.3 to 12.7 lb/MMacf. The removal curve was relatively flat at about 70 percent for injection rates greater than approximately 6 lb/MMacf. Percent reduction in total mercury at the ESP outlet attributed to carbon injection (i.e., the reduction in mercury beyond native removal levels) ranged from 30 to 40 percent.

During the baseline tests, total vapor phase mercury emissions at the ESP outlet ranged from 1.5 to 3.5 lb/trillion Btu input, with the predominance of value between 2.5 and 3.5 lb/trillion Btu (21-40 10^{-6} lb/MWh). Mercury emissions in the range of 2.5 to 1.5 lb/trillion Btu (28 to 14 10^{-6} lb/MWh) were measured during the carbon injection tests for injection rates in the range of 2.1 to 12.5 lb/MMacf.

The use of the dual flue gas conditioning system on Unit 2 had no impact on the ability of Darco-Hg carbon to remove vapor-phase mercury across the ESP. Parametric carbon injection tests conducted using various combination of NH_3 and SO_3 injection rates showed no difference in the mercury removal performance of the ESP.

Because of the short-term nature of the parametric tests conducted on Unit 2, data were inconclusive regarding the effect of sorbent injection on ESP performance. Data from additional longer-term tests, such as those conducted on the Unit 1 ESP system, have also been analyzed and more definitive conclusions can be made based on this larger data set. Refer to the Unit 1 Site Report for additional information regarding Unit 1 ESP performance during sorbent injection.

The mercury content of the Unit 2 ESP fly ash increased with increasing LOI during both baseline and Darco Hg™ carbon injection tests. LOI for the ESP fly ash samples ranged from 7.7 to 22 percent during the baseline and from 6.9 to 17 percent during the carbon injection tests. Mercury concentrations in the ESP ash ranged from 0.21 to 0.25 µg/g for the baseline tests and from 0.18 to 0.40 µg/g for the carbon injection tests.

Relevancy of Test Program Results

This two-week test program on Yates Unit 2 generated data characterizing the baseline mercury removal for the unit and a performance curve for Darco Hg injection for the ESP. The results from the Unit 2 test program were comparable to the Yates Unit 1 testing, indicating about 35% native removal of mercury across the ESP and limitations in the activated carbon being able to achieve a high level of mercury removal.

In other test programs, sorbent injection into ESPs for units burning eastern bituminous coal has produced mercury removals greater than 80%. Such high mercury removals were not achieved during the parametric evaluation of carbons on Yates Unit 2. The small size of the ESP may be a limiting factor for achieving higher mercury removals. Similar behavior was observed on Yates Unit 1, which has an identically sized ESP.

The Yates Unit 2 ESP was equipped with dual flue gas conditioning, allowing for evaluation of the effect of SO_3 on mercury removal. No effect of NH_3 and SO_3 conditioning was observed on either the baseline removal of mercury nor on the sorbent performance; however, baseline SO3 levels in the Unit 2 flue gas (due to sulfur content of the coal) may have been high enough to mask the additional of SO3 conditioning. Flue gas SO_3 measurements were not made to validate this hypothesis.

5.0 References

1. Richardson, C., Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas, Quarterly Technical Progress Report for the period October 1, 2003 – December 31, 2004, URS Group, Inc. February 2004.

2. Richardson, C., Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas, Quarterly Technical Progress Report for the period January 1 – March 31, 2004, URS Group, Inc. April 2004.

3. Richardson, C., Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas, Quarterly Technical Progress Report for the period April 1 – June 30, 2004, URS Group, Inc. July 2004.

4. Richardson, C., Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas, Quarterly Technical Progress Report for the period July 1 – September 30, 2004, URS Group, Inc. October 2004.

5. Richardson, C., Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas, Quarterly Technical Progress Report for the period October 1 – December 31, 2004, URS Group, Inc. January 2004.

Appendix A

SCEM Calculation Methodology

Methodology for Generating Mercury Concentrations in μg/Nm^3 at 3% O_2

This section explains how vapor phase mercury concentrations are obtained from the mercury SCEMs.

As described in Section 2.3.2, the mercury SCEMs use a gold amalgamation column coupled with a CVAA. The flue gas is conditioned to remove the acid gas constituents (which can harm the gold's ability to adsorb mercury). It is also conditioned to either convert all the mercury to the elemental phase or to remove the oxidized mercury, leaving just the elemental phase. The CVAA can only detect the elemental form of mercury.

A measured flow rate of conditioned flue gas is passed over the gold amalgamation column for a fixed period of time. The flow rate is measured by a mass flow meter. The flow meter is calibrated to generate flow rates in the units of normal cubic meters (Nm^3), where normal means the gas flow has been corrected to 32°F.

As the flue gas passes over the gold, the mercury in the flue gas adsorbs to the gold. Once a measured quantity of flue gas has passed over the gold, the gold is heated to desorb the mercury. This desorbed mercury is detected by the CVAA. The size of the peak generated by the CVAA correlates to a mass of mercury, as determined by a calibration curve. To produce the mercury concentration in μg/Nm^3, the mass of mercury is divided by the volume of flue gas sampled.

These mercury measurements are initially calculated at the actual O_2 concentration in the duct. For each mercury concentration, an oxygen concentration is measured. The mercury data are corrected to a 3% O_2 basis in order to account for dilution effects from location to location. The calculation for conversion to 3% O_2 is:

$$\text{Hg } [\mu g/Nm^3 \text{ at } 3\% \ O_2] = \text{Hg } [\mu g/Nm^3 \text{ at } x\% \ O_2] * (20.9-3) / (20.9-x)$$

Where:

x = actual O_2 concentration measured in the flue gas

Each mercury SCEM produces a datum point every three to seven minutes, depending on the sample time needed to collect a detectable amount of mercury on the gold. The sample time increases as the flue gas mercury concentration decreases.

Methodology for Data Analysis of Parametric Results

This section explains how the raw data gathered by the mercury SCEMs are manipulated to produce the vapor phase mercury removal results for the parametric test conditions. A parametric test condition consists of a carbon type and carbon injection rate. Each test condition lasted from two to three hours.

Mercury SCEMs were employed at the ESP inlet and ESP outlet locations. The test period was long enough for the mercury concentrations to reach a steady state. At each location the steady state data were averaged to generate an average mercury concentration for the test condition. Mercury removals across the ESP system were calculated for each injection rate using these average mercury concentrations, normalized to 3% O_2.

Appendix B

Waste Characterization Sample Log

Samples of Unit 2 ESP fly ash solids were collected and archived for future waste characterization analyses during the baseline period. Table B-1 documents the sample collection dates for the baseline samples.

Table B-1. Unit 2 – Samples Collected for Future DOE Byproduct Characterization During Baseline Conditions

Sample Type	Test Conditions	Date Collected	No. of Buckets
ESP Fly Ash	BL	3/18/04	1
ESP Fly Ash	BL	3/19/04	1

BL = no sorbent injection

Appendix C

Source Sampling Data for Ontario Hydro, Method 26A, and Method 17

Table C-1. Ontario Hydro – ESP Inlet Baseline

Date	3/18/2004	3/18/2004	3/18/2004
Location/Condition	ESP Inlet	ESP Inlet	ESP Inlet
Run	1	2	3
Worksheet Tab Name	**ESP Inlet R1**	**ESP Inlet R2**	**ESP Inlet R3**
Start Time	9:15	12:15	15:40
End Time	11:15	14:15	17:40
Source Area (ft^2)	NA	NA	NA
Nozzle Diameter (")	NA	NA	NA
DGM Calibration Factor (Y_D)	1	1	1
ΔH@	1.8779	1.8779	1.8779
Pitot (Cp)	0.84	0.84	0.84
Stack Barometric Pressure ("Hg)	30.10	30.10	30.10
Static Pressure ("H_2O)	-7.00	-7.00	-7.00
Test Duration (min)	120	120	120
Minutes per point	5	5	5
Meter Volume x DGMCF (ft^3)	77.656	79.586	82.208
Impinger Mass Gain (g)	112.6	114.9	105.9
Meter Temperature (R)	547.3	559.1	563.1
Average ΔH (in H_2O)	1.88	1.88	1.88
Meter Pressure ("Hg)	30.24	30.24	30.24
% H_2O at saturation	101.1	101.1	101.1
% H_2O	6.6	6.7	6.0
% CO_2	11.0	11.0	11.0
% O_2	8.0	8.0	8.0
% N_2	81.0	81.0	81.0
Dry Molecular Weight (mw_{dry})	30.1	30.1	30.1
Source Molecular Weight (mw_g)	29.3	29.3	29.4
Avg. SQRT Delta P	NA	NA	NA
Avg. Source Temperature (R)	716.4	723.1	727.3
Avg. Source Pressure ("Hg)	29.59	29.59	29.59
Gas Velocity (ft/s)*	20.8	20.8	20.8
Stack Gas Flow Rate (acfm)*	15,670	15,670	15,670
Stack Gas Flow Rate (dscfm)*	10,316	10,316	10,316
Standard Sample Volume (dscf)	75.674	75.907	77.857
Average Isokinetic %	NA	NA	NA
Average sqrt(ΔH)	1.37	1.37	1.37
Y(qa)	1.154	1.138	1.105
ΔY (± 5%)	**15.4%**	**13.8%**	**10.5%**

Table C-2. Ontario Hydro – ESP Outlet Baseline

Date	3/18/2004	3/18/2004	3/18/2004
Location/Condition	AH Outlet	AH Outlet	AH Outlet
Run	1	2	3
Worksheet Tab Name	**AH Outlet R1**	**AH Outlet R2**	**AH Outlet R3**
Start Time	9:15	12:15	15:40
End Time	11:22	14:15	17:40
Source Area (ft^2)	NA	NA	NA
Nozzle Diameter (")	NA	NA	NA
DGM Calibration Factor (Y_D)	1.005	1.005	1.005
ΔH@	1.717	1.717	1.717
Pitot (Cp)	0.84	0.84	0.84
Stack Barometric Pressure ("Hg)	30.10	30.10	30.10
Static Pressure ("H_2O)	-5.80	-5.80	-5.80
Test Duration (min)	120	120	120
Minutes per point	5	5	5
Meter Volume x DGMCF (ft^3)	88.390	97.836	89.144
Impinger Mass Gain (g)	128.6	136.3	141.7
Meter Temperature (R)	531.5	538.6	543.5
Average ΔH (in H_2O)	1.82	1.72	1.72
Meter Pressure ("Hg)	30.23	30.23	30.23
% H_2O at saturation	100.8	100.8	100.8
% H_2O	6.4	6.2	7.1
% CO_2	11.0	11.0	12.0
% O_2	8.5	8.0	9.0
% N_2	80.5	81.0	79.0
Dry Molecular Weight (mw_{dry})	30.1	30.1	30.3
Source Molecular Weight (mw_g)	29.3	29.3	29.4
Avg. SQRT Delta P	NA	NA	NA
Avg. Source Temperature (R)	773.8	764.2	767.8
Avg. Source Pressure ("Hg)	29.67	29.67	29.67
Gas Velocity (ft/s)*	20.8	20.8	20.8
Stack Gas Flow Rate (acfm)*	15,670	15,670	15,670
Stack Gas Flow Rate (dscfm)*	10,316	10,316	10,316
Standard Sample Volume (dscf)	88.669	96.834	87.433
Average Isokinetic %	NA	NA	NA
Average sqrt(ΔH)	1.39	1.31	1.31
Y(qa)	1.061	0.913	1.003
ΔY (± 5%)	**5.6%**	**-9.2%**	-0.2%

Table C-3. Method 26A – ESP Inlet Baseline

Date	3/17/2004	3/18/2004	3/19/2004
Location/Condition	M5_26 Inlet	M5_26 Inlet	M5_26 Inlet
Run	1	2	3
Worksheet Tab Name	**M5_26 Inlet R1**	**M5_26 Inlet R2**	**M5_26 Inlet R3**
Start Time	8:13	7:15	9:25
End Time	9:13	8:15	10:25
Source Area (ft^2)	NA	NA	NA
Nozzle Diameter (")	NA	NA	NA
DGM Calibration Factor (Y_D)	1.0023	1.0023	1.0023
ΔH@	1.8779	1.8779	1.8779
Pitot (Cp)	0.84	0.84	0.84
Stack Barometric Pressure ("Hg)	29.93	29.93	29.93
Static Pressure ("H_2O)	-7.00	-7.00	-7.00
Test Duration (min)	60	60	60
Minutes per point	5	5	5
Meter Volume x DGMCF (ft^3)	43.668	39.213	39.624
Impinger Mass Gain (g)	70.7	64.7	57.0
Meter Temperature (R)	543.3	536.4	549.3
Average ΔH (in H_2O)	1.72	1.88	1.88
Meter Pressure ("Hg)	30.06	30.07	30.07
% H_2O at saturation	101.7	101.7	101.7
% H_2O	7.3	7.3	6.6
% CO_2	11.0	11.0	11.0
% O_2	8.0	7.0	8.5
% N_2	81.0	82.0	80.5
Dry Molecular Weight (mw_{dry})	30.1	30.0	30.1
Source Molecular Weight (mw_g)	29.2	29.2	29.3
Avg. SQRT Delta P	NA	NA	NA
Avg. Source Temperature (R)	684.9	712.8	717.9
Avg. Source Pressure ("Hg)	29.42	29.42	29.42
Gas Velocity (ft/s)*	20.8	20.8	20.8
Stack Gas Flow Rate (acfm)*	15,670	15,670	15,670
Stack Gas Flow Rate (dscfm)*	10,316	10,316	10,316
Standard Sample Volume (dscf)	42.609	38.771	38.256
Average Isokinetic %	NA	NA	NA
Average sqrt(ΔH)	1.26	1.37	1.37
Y(qa)	0.942	1.137	1.138
ΔY (± 5%)	**-6.0%**	**13.5%**	**13.5%**

Table C-4. Method 17 Particulate Loading – ESP Outlet Sorbent Injection

Date	3/23/2004	3/24/2004	3/24/2004	3/24/2004	3/25/2004	3/25/2004	3/26/2004	3/26/2004
Location/Condition	ESP Out	ESP Out	ESP Out	ESP Out	ESP Out	ESP Out	ESP Out	ESP Out
Run	1	2	3	4	5	6	7	8
Worksheet Tab Name	**ESP Out R1**	**ESP Out R2**	**ESP Out R3**	**ESP Out R4**	**ESP Out R5**	**ESP Out R6**	**ESP Out R7**	**ESP Out R8**
Start Time	15:03	13:05	15:27	16:30	9:15	12:45	9:34	12:02
End Time	16:01	15:10	16:08	17:09	10:01	14:01	10:17	13:01
Source Area (ft^2)	129.39	129.39	129.39	129.39	129.39	129.39	129.39	129.39
Nozzle Diameter (")	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215
DGM Calibration Factor (Y_D)	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
$\Delta H@$	1.908	1.908	1.908	1.908	1.908	1.908	1.908	1.908
Pitot (Cp)	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Stack Barometric Pressure ("Hg)	29.57	29.76	29.76	29.76	29.77	29.77	29.77	29.77
Static Pressure ("H_2O)	-14.00	-14.00	-14.00	-14.00	-14.00	-14.00	-14.00	-14.00
Test Duration (min)	58	125	41	39	46	76	43	59
Minutes per point	58	125	41	39	46	76	43	59
Stack Temperature (R)	764	736	755	768	750	772	771	757
Meter Volume x DGMCF (ft^3)	44.208	92.931	32.306	30.968	33.767	57.899	33.097	44.708
Impinger Mass Gain (g)	253.1	253.1	253.1	253.1	229.5	229.5	229.5	229.5
Meter Temperature (R)	515.7	459.7	459.7	459.7	517.7	459.7	459.7	459.7
Average ΔH (in H_2O)	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
Meter Pressure ("Hg)	29.71	29.90	29.90	29.90	29.91	29.91	29.91	29.91
% H_2O at saturation	104.84	104.14	104.14	104.14	104.11	104.11	104.11	104.11
% H_2O	5.68	5.68	5.68	5.68	5.94	5.94	5.94	5.94
% CO_2	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
% O_2	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
% N_2	79.0	79.0	79.0	79.0	79.0	79.0	79.0	79.0
Dry Molecular Weight (mw_{dry})	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4
Source Molecular Weight (mw_g)	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Avg. SQRT Delta P	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13

Table C-4. Method 17 Particulate Loading – ESP Outlet Sorbent Injection (continued)

Date	3/23/2004	3/24/2004	3/24/2004	3/24/2004	3/25/2004	3/25/2004	3/26/2004	3/26/2004
Location/Condition	ESP Out	ESP Out	ESP Out	ESP Out	ESP Out	ESP Out	ESP Out	ESP Out
Run	1	2	3	4	5	6	7	8
Worksheet Tab Name	**ESP Out R1**	**ESP Out R2**	**ESP Out R3**	**ESP Out R4**	**ESP Out R5**	**ESP Out R6**	**ESP Out R7**	**ESP Out R8**
Avg. Source Temperature (R)	763.7	735.7	754.7	767.7	749.7	771.7	770.7	756.7
Avg. Source Pressure ("Hg)	28.54	28.73	28.73	28.73	28.74	28.74	28.74	28.74
Gas Velocity (ft/s)	76.9	76.0	76.5	76.8	76.4	77.0	77.0	76.3
Stack Gas Flow Rate (acfm)	597,363	589,699	593,636	596,170	593,455	598,133	597,553	592,299
Stack Gas Flow Rate (dscfm)	371,377	383,072	375,921	371,133	377,404	369,535	369,655	373,184
Standard Sample Volume (dscf)	44.920	92.694	30.825	29.682	34.409	58.771	32.868	45.079
Average Isokinetic %	107.0	99.3	102.6	105.2	101.7	107.4	106.1	105.1
Average sqrt(ΔH)	1.382	1.382	1.382	1.382	1.382	1.382	1.382	1.382
Y(qa)	0.952	0.919	0.867	0.860	0.987	0.896	0.887	0.901
ΔY (± 5%)	-4.6%	**-7.9%**	**-13.1%**	**-13.8%**	-1.1%	**-10.2%**	**-11.1%**	**-9.7%**

Appendix D

QA/QC Results

The quality assurance measures implemented for this project are summarized in this appendix. The QA/QC measures addressed the following critical measurement parameters: 1) total and speciated mercury in flue gas at the ESP inlet and ESP outlet; 2) mercury content in the coal and ESP fly ash solids; and 3) HCl concentrations in the flue gas at the various sample locations.

Specific quantitative data quality objectives established for the project, expressed as precision, accuracy and completeness, are summarized in Table D-1.

Table D-1. Quality Assurance Objectives for Critical Measurement Parameters

Critical Parameter (Method)	Sampling Method	Experimental Conditions	Precision	Accuracy	Completeness[1]
Mercury in Flue Gas (Method 7470 Digestion; CVAA Analysis)	Ontario Hydro Method	Matrix Spike and Duplicates	10% Relative Percent Difference	85-115% Recovery	100%
HCl in Flue Gas (Ion Chromotography)	Method 26A (mini sampler)	Matrix Spike and Duplicates	15% Relative Percent Difference	85-115% Recovery	100%
Mercury in Flue Gas ($KCl/SnCl_2$ Impingers, CVAA Analysis)	Semi-continuous Gas Analyzer (SCEM)	Matrix Spike (Method of Standard Additions)/ Replicate Assays/ Relative Accuracy Testing	20% Relative Percent Difference	80-120% Recovery	80%
Mercury in Coal, ESP fly ash, and FGD solids (ASTM 3684 HF Digestion (solids); EPA 7471 CVAA Analysis) [1]	Grab Sample Composites	Matrix Spike and Duplicates	25% Relative Percent Difference	70-130% Recovery	100%
		Coal and Fly Ash NIST Standard Reference Materials	NA	80-120% Recovery	
		FGD Reference Material	NA	80-120% Recovery	

Other QA objectives include representativeness and comparability. Representativeness is primarily a function of sampling strategy. Representative samples will be collected by following specified methods, where available, and by only sampling under stable and/or normal operating conditions. Comparability of project data with similar studies conducted by URS and others will be ensured by adherence to standard methods and materials.

[1] Completeness is defined as the percentage of planned samples actually collected.

QA/QC measures conducted prior to and during the field test program included calibrations of the sorbent injection and sampling systems, as well as internal quality control checks related to analytical instruments and measurements. Each of these topics is discussed in the following sections.

Calibration of Injection and Sampling Equipment

The following calibration procedures were used for the sorbent injection and source sampling equipment during the course of the project. Records of all manufacturer calibration and field calibrations for all injection and sampling equipment are maintained in the URS and ADA-ES project files.

Sorbent Injection System

The accuracy and consistency of volumetric feeding of dry sorbents is susceptible to changes due to material density, moisture, and plugging. Before the testing program began on Unit 2, the sorbent injection system was calibrated over the range of expected sorbent injection rates to ensure accurate delivery of sorbent to the duct injection points. Prior to the start of each injection test the specific feed-rate desired was confirmed by timed catch and weight of the sorbent at the eductor inlet location. This calibration was repeated at the completion of the test to determine if any significant shift in feed-rate may have occurred during the test period. The sorbent bag emptying rate was monitored for consistency with the calibrated feed rates.

Source Sampling Equipment

Various components of the source sampling equipment were calibrated prior to use in the field test program. These calibrations are summarized below:

- Type S pitot tube calibration – design and construction of pitot tube according to EPA document 600/4-77-027b. Inspection per the requirements of EPA Method 2.
- Sample nozzle calibration – clean, inspect and calibrate according to EPA document 600/4-77-027b. Calibration per EPA Method 5.
- Temperature measuring devices – calibrated and linearity checked using a traceable precision voltage generator.
- Dry gas meter and orifice – calibrated semi-annually against calibrated orifice and calibration checked before and after field use.

SCEM Analyzers

The analyzers were calibrated for elemental mercury, sample flow rate, and oxygen concentration following installation at the test sites and periodically throughout the testing program. The calibration of both the Au-CVAAS analyzer, which measures the mass of mercury desorbed, and the mass flow meter in the monitor, which measures the total sample volume through the analyzer, were checked daily during testing. The analyzer was calibrated by introducing a spike of vapor phase elemental mercury standard into the analyzer upstream of the gold wire or just upstream of the impinger solutions. These quality control samples are important for ensuring proper transport of mercury through the various flow lines. The mercury vapor for the spike was taken from the air space in a vial containing liquid elemental mercury. The mercury spike concentration is calculated from the vapor pressure of mercury and the temperature of the vial. The vial temperature was measured with a precision thermometer.

QA/QC results for SCEM analyzer measurements, including elemental mercury calibration spikes, are summarized in the following table. These QA/QC results are detailed in Tables D-2 and D-3.

Location	Spike Recovery		Replicate Analysis	
	Average Recovery (%)	**Percent of Determinations Meeting 80-120% Recovery**	**Average Relative Standard Deviation (%)**	**Percent of RSD Determinations Meeting RSD <20%**
ESP Inlet/Air Heater Outlet	97.4	73.8	8.7	100
ESP Outlet	100.9	64.8	4.6	100

Typically, corrective actions, as shown in Table D-2, and D-3 were implemented for spike recoveries below 75%. These usually required a repair, or instrument adjustment. Typically the emissions data were corrected for recoveries in excess of 125%.

The calibration of the mass flow meter was checked by connecting the operating meter in series with a pre-calibrated dry cal meter and verifying measured flow rates across the range expected during testing. Oxygen sensor calibration and linear response were checked in the laboratory before the instruments were shipped to the field test site. During field-testing, oxygen sensor readings were periodically compared to the data obtained from Orsat measurements.

Documentation of analyzer calibration and any system maintenance was recorded in the project notebook. Verification of computerized analyzer calculations was conducted manually on a periodic basis. ***Any data collected during periods of suspect analyzer operation were flagged as questionable data.***

Table D-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/16/2004	8:35	Spike before gold	air	87.8	4.8%	none
	8:40	Spike before gold	air	82		none
	8:45	Spike before gold	air	80.16		none
		Daily Average		**83**		
3/17/2004	15:07	Spike before gold	air	114.3	1.1%	none
	15:12	Spike before gold	air	116.8		none
	15:17	Spike before gold	air	114.8		none
		Daily Average		**115**		
3/18/2004	7:30	Spike before gold	air	160.7	15.8%	none
	7:35	Spike before gold	air	118.7		none
	7:40	Spike before gold	air	130.6		recalibrate
		Daily Average		**137**		
3/19/2004	7:45	Spike before gold	air	96.4	2.5%	none
	7:50	Spike before gold	air	92.9		none
	7:55	Spike before gold	air	97.4		none
		Daily Average		**96**		
3/21/2004	7:45	Spike before gold	flue gas	71	9.3%	none
	7:50	Spike before gold	flue gas	81		none
		Daily Average		**76**		

Table D-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/22/2004	7:00	Spike before gold	air	77	11.5%	none
	7:05	Spike before gold	air	97		none
	7:10	Spike before gold	air	89		none
	7:22	Spike through impingers	air	91		none
	8:00	Spike before gold	air	100	0.0%	none
	8:05	Spike before gold	air	100		none
	8:15	Spike through impingers	air	99.6		none
	11:48	Spike before gold	air	110	10.3%	none
	11:53	Spike before gold	air	95		none
	11:58	Spike through impingers	air	66		none
	12:15	Spike through impingers	air	72		replace impinger train
	12:35	Spike through impingers	air	54		replace filter
	12:55	Spike through impingers	air	58		replace 3/8" line
	13:15	Spike through impingers	air	75		none
	13:35	Spike before gold	air	79		replace column
	15:00	Spike through impingers	air	174		none
	15:20	Spike through impingers	air	93		none
	15:40	Spike through impingers	air	167		none
	16:00	Spike through impingers	air	134		change cal kit needle
	16:20	Spike through impingers	air	103		none
	16:40	Spike through impingers	air	148		none
	18:00	Spike through impingers	air	134		none
		Daily Average		**101**		
3/23/2004	6:20	Spike before gold	air	137	16.1%	none
	6:25	Spike before gold	air	109		none
		Daily Average		**123**		
3/24/2004	6:20	Spike before gold	air	125	6.6%	none
	6:25	Spike before gold	air	137		recalibrate
	7:00	Spike before gold	air	101		none
	9:27	Spike before gold	flue gas	88		none
	12:11	Spike before gold	flue gas	82	19.1%	none
	12:16	Spike before gold	flue gas	59		none
	12:21	Spike before gold	flue gas	61		replace column
	17:35	Spike before gold	air	101	0.1%	none
	17:40	Spike before gold	air	101		none
		Daily Average		**95**		

Table D-2. SCEM Quality Control Results – ESP Inlet/Air Heater Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/25/2004	6:45	Spike before gold	air	128	14.2%	none
	6:50	Spike before gold	air	97		none
	6:55	Spike before gold	air	108		none
	7:00	Spike through impingers	air	112		none
	7:45	Spike before gold	flue gas	96		none
	9:00	Spike before gold	flue gas	107		none
	10:00	Spike before gold	flue gas	99		none
	12:15	Spike before gold	flue gas	103		none
	13:00	Spike before gold	flue gas	84	7.1%	none
	13:05	Spike before gold	flue gas	76		none
	13:15	Spike before gold	air	95		none
	13:20	Spike before gold	air	111		none
	13:25	Spike before gold	air	100		none
	13:30	Spike before gold	air	86		none
	13:35	Spike before gold	air	96		none
	14:30	Spike before gold	flue gas	74	11.4%	none
	14:35	Spike before gold	flue gas	87		none
	15:30	Spike before gold	flue gas	85	7.2%	none
	15:35	Spike before gold	flue gas	96		none
	15:40	Spike before gold	flue gas	97		none
	16:10	Spike before gold	flue gas	69	10.7%	none
	16:15	Spike before gold	flue gas	76		none
	16:20	Spike before gold	flue gas	86		none
	16:25	Spike before gold	flue gas	69		none
	17:35	Spike before gold	flue gas	87	11.5%	none
	17:40	Spike before gold	flue gas	78		none
	17:45	Spike before gold	flue gas	69		replace column
		Daily Average		**92**		
3/26/2004	6:45	Spike before gold	air	90	6.7%	none
	6:50	Spike before gold	air	99		none
	7:30	Spike before gold	flue gas	95		none
	13:45	Spike before gold	flue gas	96	2.3%	none
	13:50	Spike before gold	flue gas	93		none
	13:55	Spike before gold	flue gas	92		none
	14:00	Spike before gold	flue gas	91		none
	16:00	Spike before gold	flue gas	85	14.0%	none
	16:05	Spike before gold	flue gas	112		none
	16:10	Spike before gold	flue gas	95		none
		Daily Average		**95**		

Table D-3. SCEM Quality Control Results – ESP Outlet

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/16/2004	8:45	Spike before gold	air	88	8.7%	none
	8:50	Spike before gold	air	78		recalibrate
		Daily Average		**83**		
3/17/2004	15:20	Spike before gold	air	95	2.0%	none
	15:25	Spike before gold	air	97		none
		Daily Average		**96**		
3/18/2004	7:07	Spike before gold	air	76	7.7%	none
	7:12	Spike before gold	air	84		recalibrate
	16:42	Spike before gold	air	122	1.9%	none
	16:47	Spike before gold	air	119		recalibrate
		Daily Average		**100**		
3/19/2004	8:20	Spike before gold	air	94	3.2%	none
	8:25	Spike before gold	air	89		none
		Daily Average		**91**		
3/22/2004	8:00	Spike before gold	air	105	4.8%	none
	8:05	Spike before gold	air	115		none
	8:10	Spike before gold	air	113		none
	16:23	Spike before gold	air	130		replace column
		Daily Average		**116**		
3/23/2004	8:00	Spike before gold	air	90	7.0%	none
	8:05	Spike before gold	air	103		none
	8:10	Spike before gold	air	100		none
		Daily Average		**98**		

Table D-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/24/2004	7:30	Spike before gold	air	106	3.3%	none
	7:35	Spike before gold	air	111		none
	9:15	Spike before gold	air	78		replace column
	10:30	Spike before gold	air	-		none
	11:15	Spike before gold	flue gas	75		none
	13:00	Spike before gold	flue gas	82	0.0%	none
	13:05	Spike before gold	flue gas	82		none
	14:15	Spike before gold	air	138		none
	14:20	Spike before gold	air	139		none
	14:25	Spike before gold	air	126		none
	14:30	Spike before gold	air	107		none
	14:35	Spike before gold	air	132		recalibrate
	15:00	Spike before gold	flue gas	75	0.0%	none
	15:05	Spike before gold	flue gas	75		none
	15:10	Spike before gold	flue gas	75		none
		Daily Average		**100**		
3/25/2004	7:30	Spike before gold	air	117		none
	8:10	Spike before gold	flue gas	103		none
	10:05	Spike before gold	flue gas	95	18.2%	none
	10:10	Spike before gold	flue gas	123		none
	13:14	Spike before gold	flue gas	91	16.0%	none
	13:19	Spike before gold	flue gas	122		none
	13:24	Spike before gold	flue gas	122		none
	13:45	Spike before gold	air	143		recalibrate
	14:17	Spike before gold	flue gas	85		none
	14:56	Spike before gold	flue gas	91	2.4%	none
	15:01	Spike before gold	flue gas	88		none
	18:12	Spike before gold	flue gas	80	1.8%	none
	18:17	Spike before gold	flue gas	78		replace column
	19:15	Spike before gold	flue gas	102	1.0%	none
	19:20	Spike before gold	flue gas	101		none
		Daily Average		**103**		

Table D-3. SCEM Quality Control Results – ESP Outlet (continued)

	Time	QC Type	Gas Matrix	Recovery (%)	Relative Standard Deviation	Action Taken
3/26/2004	6:30	Spike before gold	air	-		recalibrate
	7:45	Spike before gold	flue gas	98	5.5%	none
	7:50	Spike before gold	flue gas	106		none
	9:57	Spike before gold	flue gas	100	0.0%	none
	10:02	Spike before gold	flue gas	100		none
	11:20	Spike before gold	flue gas	103	1.7%	none
	11:25	Spike before gold	flue gas	101		none
	16:00	Spike before gold	flue gas	100	2.1%	none
	16:05	Spike before gold	flue gas	103		none
		Daily Average		**101**		

Internal Quality Control Checks

Quality control procedures were also included in this test program for both sampling and analytical activities. In most instances, strict adherence to prescribed method-defined procedures for each sampling and analytical effort is the most applicable QC check. However, in some cases specific QC samples were planned to assess overall measurement data quality. QC samples planned for the critical measurement parameters are summarized in Table D-4.

Table D-4. QC Sample Frequency for Critical Measurement Parameters

Parameter	Field Blank [2]	Trip (reagent) Blank [3]	Matrix Spike and Duplicates	Replicates	Standard Material Analysis
Mercury in Flue Gas (Ontario Hydro method)	1 per batch of $KMnO_4$ reagent	1 per batch of $KMnO_4$ reagent	1 per sample location	Duplicate, 1 per sample location	-
Mercury in Flue Gas (semi-continuous analyzer)	-	-	1 per day	Duplicate, 1 per day	-
HCl/chlorine in Flue Gas	1 per day	1 per day	1 per sample location		
Mercury in Coal, ESP fly ash, and FGD solids	-	-	1 per 10 samples per matrix type		1 per 10 samples per matrix type

[2] Field blank impinger solutions are used to perform a matrix matched instrument calibration to compensate for possible background contribution in the blank sampling train and to compensate for matrix interference.

[3] Analysis of the reagent blank is not generally conducted unless appreciable amounts of mercury are noted in the field blank.

The QC analyses conducted during the testing program were designed to provide a quantitative assessment of the measurement system data. The two aspects of data quality that are of primary concern are precision and accuracy. Accuracy reflects the degree to which the measured value represents the actual or "true" value for a given parameter and includes elements of both bias and precision. Precision is a measure of the variability associated with the measurement system.

Precision

EPA defines precision as "a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions." For this project, precision estimates will be based on conditions that encompass as many components of variability as are feasible, which includes variability in the sample matrix itself, as well as imprecision in sample collection, preparation, and analysis. Precision data are reported for analytical duplicate samples.

Where estimated from duplicate (two) results, precision is expressed in terms of relative percent difference (RPD) between results for analytical duplicates. RPD is calculated as follows:

$$\text{RPD} = \frac{|X_1 - X_2|}{\text{Mean}} \times 100$$

RPD is related to percent CV by (RPD = CV x $\sqrt{2}$).

Where estimated from triplicate (three) results, precision is expressed in terms of relative standard deviation (RSD) between results for analytical replicates. RSD is calculated as follows:

$$\text{RSD} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

These terms are independent of the error (bias) of the analyses and reflect only the degree to which the measurements agree with one another, not the degree to which they agree with the "true" value for the parameter measured.

Accuracy

Accuracy, according to EPA's definition is "the degree of agreement of a measurement (or an average of measurements of the same thing), X, with an accepted reference or true value, T." Accuracy includes components of both bias (systematic error) and imprecision (random error). Bias may be estimated from the average of a set of individual accuracy measurements.

For this project, accuracy objectives are expressed in terms of individual measurements. Individual measurements were compared with the objectives presented previously in Table D-1. In the final analysis, the average accuracy (i.e., bias), calculated as percent recovery, are reported and used to assess the impact on project objectives. Percent recovery is calculated as follows:

$$\%\ \text{Recovery} = \frac{\text{Measured Value}}{\text{Reference Value}} \text{ x } 100$$

In the case of matrix spiked samples, measured value in the above equation represents the difference between the spiked sample measurement result and the unspiked sample results. The reference value represents the amount of spike added to the sample.

Ontario Hydro

Source sampling field data for the three Ontario Hydro verification tests conducted during baseline and long term test phases are summarized in Appendix A. Percent isokinetics, a measure of sample representativeness, were within acceptable limits for all test runs.

QA/QC results for reagent blanks, field blanks, matrix spikes, replicate analyses, and calibration curve checks from the Ontario Hydro testing in Table D-5. With a few exceptions, all results were within the data quality objectives of the test program and the results as a whole do not indicate a significant background contributions or bias in the analytical results for the Ontario Hydro method samples. Note that field blank impinger solutions are used to perform a matrix matched instrument calibration to reduce potential bias in the analytical results. Reagent blanks are typically not analyzed unless appreciable mercury is detected in the field blank matrix matched calibration process. Filters from both the reagent blank and the field blank are analyzed for mercury to quantify background contributions.

Table D-5. QA/QC Results for Mercury Analyses of Ontario Hydro Impinger Solutions – Baseline 3/18/04

QA Check	Sample Loc.	Objective	Ontario Hydro Sample Fractions				
			$KMnO_4$	KCl	H_2O_2	Filter	PNR/Nitric Rinse
NIST 1633b	All	85-115%	NA[4]	NA	NA	123% [5]	NA
Method Blank	All	<DL and 85-115% recovery	NA	NA	NA	0.03 µg/L	NA
DI Water Blank	All	<DL	<DL	<DL	<DL	<DL	<DL
Reagent Blank	All	NA	NA	NA	NA	<0.006 µg	NA
Field Blank	ESP Inlet	NA	NA	NA	NA	0.042 µg	NA
Lab QC Standard [6]	All	85-115%	110-112	100-103	99-102	103-107	98-101
Matrix Spike	ESP Inlet	85 – 115%	99.0	90.0	109.7	NA	104.4
RPD	ESP Inlet	<10%	4.9 –18	0.7-2.8	26.7 [7]	NA	0
Matrix Spike	ESP Outlet	85 – 115%	102	98	103.9	NA	104.4
RPD	ESP Outlet	<10%	6.1-6.3	2.9-3.2	13.3 [b]	0	0

Method 26A

Source sampling field data for the Method 26A measurements conducted during the baseline phase are summarized in Appendix A. Percent isokinetics, a measure of sample representativeness, were within acceptable limits for all test runs.

Table D-6 provides a summary of the QA/QC results for Method 26A samples. All results were within the data quality objectives of the test program.

[4] NA – Not Applicable

[5] The NIST ash standard is certified at 0.141 µg/g $\pm$ 10%. 123% recovery is calculated based on a certified value of 0.141 µg/g; however, if the upper end of the certified range is used (0.155 µg/g), the recovery is 112% and within the target range.

[6] QC calibration check run every 5 samples.

[7] The analytical result was near the lower calibration range of the instrument. Variability is typically larger in this area of the calibration curve and RPD values greater than 10% are not indicative of a problem with sample values

Table D-6. QA/QC Results for Mercury Analyses of Method 26A Impinger Solutions – ESP Inlet

Sample Batch Analysis Date	Sample	Method Blank	MS/MSD [8] Recovery	Duplicate RPD	Background Blanks	CCV [9] Recovery (%)
	Objective→	**<DL [10]**	**85–115%**	**<15%**	**NA**	**85–115%**
4/23/04	Field Blank	-	-	0	<0.24 mg	-
	Reagent Blank	-	-	0	<DL	-
Chloride (HCl) Analysis	Method Blanks	<DL	-	-	-	-
	QC Lab Standards	-	-	-	-	97.6 - 103.5
	ESP inlet	-	96.8, 113.1	1.2 - 3.6	-	-
4/21/04	Method Blanks	<DL	-	-	-	-
	ESP inlet	-	87.4, 124.7	-	-	-
Chlorine (Cl_2) Analyses	Field Blank	-	-	-	<0.24 mg	-
	Reagent Blank	-	-	-	<0.04 mg	-

Mercury in Coal and Byproduct Solids

QA/QC results for the various coal and byproduct samples, including analytical method blanks, matrix spikes, duplicates and standard reference materials, are summarized in Tables D-7 and D-8, respectively. All results were within the data quality objectives of the test program.

[8] MS = Matrix Spike; MSD = Matrix Spike Duplicate
[9] CCV = continuing Calibration Verification
[10] DL = Detection Limit

Table D-7. QA/QC Results for Mercury Analyses of Coal Samples

Sample Analysis Batch Date	Sample	Blanks	MS [11] Recovery	Relative Percent Difference	Reference Coal Recovery	Lab QC Sample
	Objective→	**<DL [12]**	**80–120%**	**<25%**	**80–120%**	**80–120%**
Analysis on 4/15/04 Samples from 3/18/04, 3/19/04, 3/20/04, 3/24/04	DI Water Blank	<DL	-	-	-	-
	Blank	<DL	103.1	-	-	-
	NIST Coal 1632b [13,14]	-	-	-	108.6	-
	Lab Check Sample Range	-	-	-	-	95.3 - 97.7
	Duplicate Analysis Range	-	-	12.3	-	-
	Triplicate Analysis Range			0.5-2.7 [15]		
	Matrix Spike (Sample from 3/24)	-	-93.0		-	-
Analysis on 4/17/04 Samples from 3/16/04, 3/22/04, 3/25/04, 3/26/04, 3/29/04, 3/30/04	DI Water Blank	<DL	-	-	-	-
	Blank	<DL	102.7	-	-	-
	Lab Check Sample Range	-	-		-	102.8–104.0
	Replicate Analysis Range	-	-	1.5-7.2	-	-
	Matrix Spike (Sample from 3/26)	-	104.5		-	-

[11] MS – Matrix Spike
[12] DL – Detection Limit
[13] NIST = National Institute of Standards and Technology
[14] NIST Coal 1632b has an uncertified mercury value of 0.07 µg/g
[15] This is relative standard deviation. Samples were analyzed in triplicate.

D-8. QA/QC Results for Mercury Analyses of ESP Fly Ash Solids Samples

Sample Batch Analysis Date	Sample	Method Blank	MS [16] Recovery	Relative Percent Difference	Reference Material Recovery	Lab Check Sample
	Objective→	<DL [17]	80–120%	<25%	80–120%	80–120%
Analysis on 4/8/04 Samples from 3/22/04, 3/25/04, 3/26/04	DI Water Blank	<DL				
	Method Blank	<DL	110.8			
	NIST Ash 1633b [18,19]		102.0		106.3	
	Lab Check Sample Range					99.6-101.1
Analysis on 6/7/04 Samples from 3/18/04	DI Water Blank	<DL				
	Method Blank	<DL	102.3			
	NIST Ash 1633b		95.2		104.9	
	Replicate Analysis Range			0.4		
	Lab Check Sample Range					102.4-103.5
	Matrix Spike (Sample from 3/18)		93.6			
Analysis on 6/9/04 Samples from 3/19/04	DI Water Blank	<DL				
	Method Blank	<DL	107			
	NIST Ash 1633b		98.4		114.1	
	Replicate Analysis Range			7.1		
	Lab Check Sample Range					98.8-100.4
	Matrix Spike (Sample from 3/19)		91.8			

[16] MS – Matrix Spike
[17] DL – Detection Limit
[18] NIST = National Institute of Standards and Technology
[19] 1633b ash, certified Hg = 0.141 µg/g ± 10%

Appendix E

Unit 2 Process Data

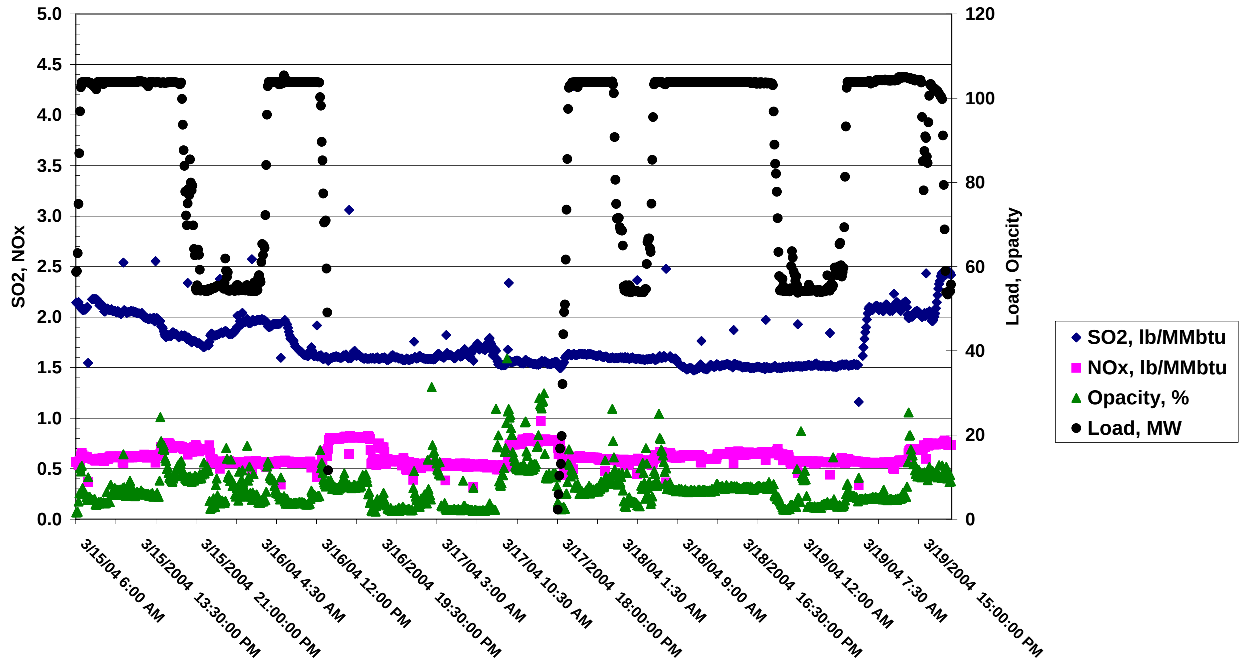

Figure E-1. Plant Process Data for Unit 2 Baseline Test Period

Note: Stack emissions data represent common stack for both Units 2 and 3

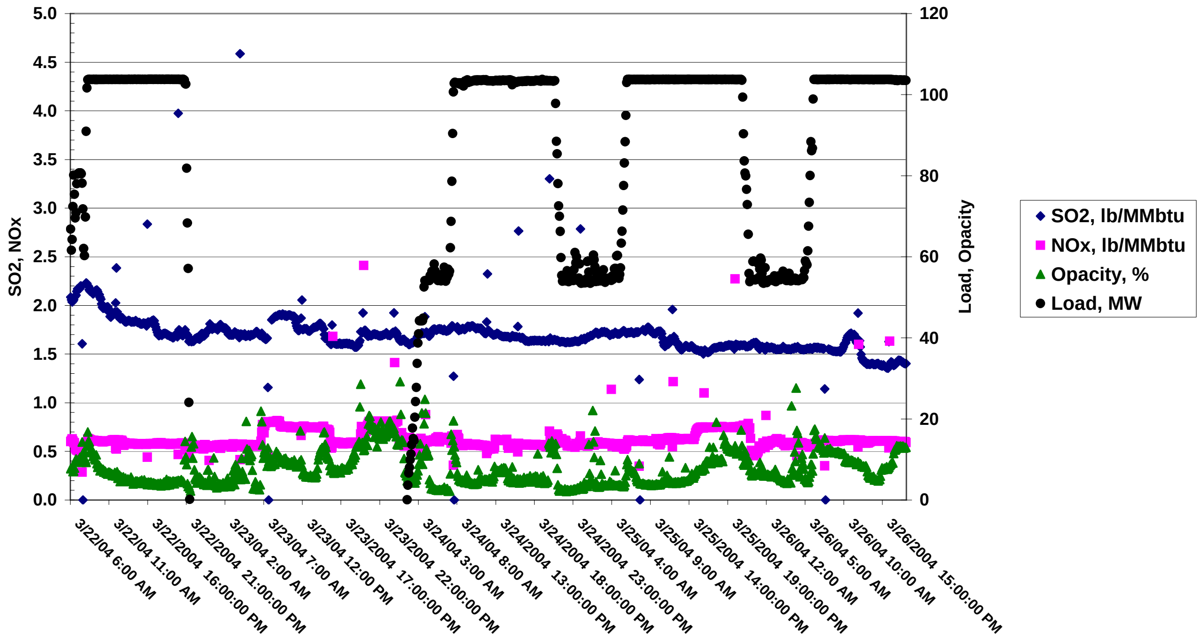

Figure E-2. Plant Process Data for Unit 2 Sorbent Injection Test Period

Note: Stack emissions data represent common stack for both Units 2 and 3 prior to 9:22 AM on 3/25/04 when Unit 3 was taken off-line

Volume 3

Shawville Unit 3

Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas

Site Report – Shawville Unit 3

Prepared by:

Doug Orr
Katherine Dombrowski
Dr. Carl Richardson

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Cooperative Agreement Number: DE-FC26-03NT41987

URS Group, Inc.
P.O. Box 201088
Austin, TX 78720-1088

Prepared for:

Pierina Noceti
Contracting Officer's Representative (COR)
U.S. Department of Energy
P.O. Box 880
Morgantown, WV 26508-0880

Disclaimer

Abstract

This site report document summarizes results from the project entitled “Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas” being managed by URS Group, Inc. as part of part of Cooperative Agreement DE-FC26-03NT41987. The objective of this project is to demonstrate the ability of various activated carbon sorbents to remove mercury from coal-combustion flue gas across full-scale units configured with small ESPs. The project is funded by the U.S. DOE National Energy Technology Laboratory under this Cooperative Agreement. EPRI, Southern Company, and Georgia Power are project co-funders. URS Group is the prime contractor.

All project objectives, as outlined in the initial Statement of Project Objectives, have been met. Mercury sorbents were injected upstream of low SCA ESP units at Southern Company’s Georgia Power Plant Yates Units 1 and 2. Both units fire a low sulfur bituminous coal. Unit 1 is equipped with a JBR wet FGD system downstream of the ESP for SO_2 control. Unit 2 is equipped with a dual flue gas conditioning system used to enhance ESP performance; it does not have an installed FGD system. Separate site reports have been prepared for each unit.

The tests at Plant Yates were successfully executed at lower-than-expected costs due to a number of factors, including an extremely trouble-free test program (requiring no contingency) and lower than expected sorbent costs. URS and NETL determined that sufficient project funds remained to conduct additional tests focused on meeting the primary objectives of this program. The project team identified Reliant Energy’s Shawville Station Unit 3 as a suitable host site to perform additional activated carbon injection tests.

This site report focuses on the additional sorbent injection tests conducted at the Shawville Station Unit 3 which fires eastern bituminous coal and is configured with two sequential small-sized ESPs. Short-term parametric tests and an extended 48-hour injection test were conducted on Unit 3 in July and August of 2006 to evaluate the mercury removal performance of activated carbon sorbents, including Norit America’s DARCO Hg and DARCO Hg-LH; RWE Rheinbraun’s Super HOK; and various hydrated lime/activated carbon injection configurations. Mercury removal performance and balance of plant impacts were evaluated. The results of this study provide data required for assessing the performance, longer-term operational impacts, and costs of full-scale sorbent injection processes for flue gas mercury removal.

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EXECUTIVE SUMMARY

This Site Report is submitted to the U.S. Department of Energy (DOE) as part of Cooperative Agreement DE-FC26-03NT41987, “Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas.” Sorbent injection technology is targeted as the primary mercury control process on plants burning low/medium sulfur bituminous coals equipped with ESP and ESP/FGD systems. About 70% of the ESPs used in the utility industry have SCAs less than 300 ft^2/1000 acfm. Prior to this test program, previous sorbent injection tests had focused on large-SCA ESPs.

This project has evaluated full-scale sorbent injection for mercury control at three sites with small-SCA ESPs, burning low sulfur Eastern bituminous coals. Full-scale tests have been performed at Georgia Power's Plant Yates Units 1 and 2 [Georgia Power is a subsidiary of the Southern Company] and at Reliant Energy's Shawville Unit 3 to evaluate sorbent injection performance. Georgia Power’s Plant Yates Unit 1 has an existing small-SCA cold-side ESP followed by a Chiyoda CT-121 wet scrubber. Yates Unit 2 is also equipped with a small-SCA ESP and a dual flue gas conditioning system. Unit 2 has no SO_2 control system. Shawville Unit 3 is equipped with two small-SCA cold-side ESPs operated in series. This Site Report presents results from the testing conducted on Shawville Unit 3.

A series of tests were performed on Shawville Unit 3 over a three-week period in which several activated carbon sorbents were injected into the flue gas duct just upstream of either of the two Unit 3 ESP units. Three different sorbents were evaluated in the parametric test program for the combined ESP 1/ESP 2 system in which sorbents were injected upstream of ESP 1: RWE Rheinbraun’s Super HOK, Norit’s DARCO Hg, and a 62:38 wt% hydrated lime/DARCO Hg premixed reagent. Five different sorbents were evaluated for the ESP 2 system in which activated carbons were injected upstream of ESP 2: RWE Rheinbraun’s Super HOK and coarse-ground HOK, Norit’s DARCO Hg and DARCO Hg-LH, and DARCO Hg with lime injection upstream of ESP 1. Flue gas injection rates ranging from 3 to 15 lbs/MMacf were tested. The hydrated lime tests were conducted to reduce SO_3 levels in an attempt to enhance the mercury removal performance of the activated carbon sorbents.

Flue gas measurements were made to determine the effectiveness of the carbons to remove mercury. Additional measurements were made to evaluate ESP performance for particulate removal during the ACI tests. A nominal 48-hour continuous injection test was also performed to evaluate longer-term performance over a period when the unit experienced several anticipated changes in load. The primary goals of the project were (1) to measure native mercury removal across the small-SCA ESPs; (2) to measure vapor-phase mercury removal performance of the sorbents over a range of injection rates; (3) to examine possible enhancement of ACI performance by reducing the levels of SO_3 present in the Unit 3 flue gas; (4) to observe the effect of ESP size on ACI mercury removal performance by conducting similar tests upstream of both (sequential) Unit 3 ESP; and (5) to observe the effects of sorbent injection on the operation of the ESP system and on the properties of the ESP fly ash.

The native removal of total vapor-phase mercury across the Unit 3 combined ESP 1/ESP 2 system (ESP 1 SCA = 83 ft^2/1000 acfm, ESP 2 SCA = 230 ft^2/1000 acfm), with the SNCR system in service, ranged from 10 – 30 percent during the test program. Average vapor-phase mercury removal was 22 percent for ESP 1 and 5 percent for ESP 2. Total vapor-phase mercury concentrations at the ESP 2 outlet during the initial baseline characterization period were typically in the range of 26 to 43 µg/Nm^3 (dry, at 3% oxygen). Material balance results for the initial baseline test period indicate approximately 16 percent of the mercury input with the coal was removed with the combined ESP 1 and ESP 2 fly ash.

Parametric carbon-only injection tests showed that Darco Hg injected upstream of ESP 1 resulted in the highest total vapor-phase mercury removals ranging from 62 to 87 percent at injection rates ranging from 6.7 to 15 lb/MMacf. The removal curve was relatively flat at about 85 to 87 percent for injection rates greater than approximately 12 lb/MMacf. The incremental mercury removal attributed to carbon injection (i.e., the reduction in mercury beyond native removal levels) ranged from 52 to 85 percent. Injection of Darco Hg-LH, a brominated carbon, showed no mercury removal advantage in this Eastern bituminous flue gas matrix.

Both injection configurations using hydrated lime in combination with Darco Hg carbon (premix injection at the ESP 1 inlet, and staged injection using lime upstream of ESP 1 and Darco Hg upstream of ESP 2) resulted in a reduction in flue gas SO_3 levels compared to baseline and improved vapor-phase mercury removal performance. Flue gas SO_3 concentrations decreased with increasing lime injection rates. Injection of premixed hydrated lime/DARCO Hg upstream of ESP 1 resulted in slightly better mercury removal performance compared to staged injection. The 72% vapor-phase mercury reduction at the ESP 2 outlet for the premix injection upstream ESP 1 at 5.5 lb/MMacf was comparable to that observed for injection of DARCO Hg only at a rate of nearly 11 lb/MMacf.

Operation of the SNCR system did not have a significant impact on the baseline SO_3 concentrations measured at the ESP 2 outlet; all baseline SO_3 levels were low, in the range of 1.6 to 1.7 ppmv regardless of whether the SNCR system was on or off.

Mercury reduction performance for carbons injection across ESP 1 and across ESP 2 were not significantly different, indicating that the larger SCA of the ESP 2 system did not have a significant impact on vapor-phase mercury removal performance of the carbons.

Finally, several balance of plant impacts were noted. First, the mercury content of the Unit 3 ESP fly ash increased with increasing LOI during the carbon injection tests. LOI for the ESP 2 fly ash samples collected during the 48-hr HOK injection at the ESP 2 inlet was approximately 10% during baseline and ranged from 11%-12% during the 48-hr HOK injection test at 11 lb/MMacf. Mercury concentrations in the ESP 2 ash ranged from 0.9 to 1.2 µg/g for the baseline period and from 1.8 to 2.2 µg/g for the 48-hr HOK test. Second, because of the short-term nature of the parametric tests conducted on Unit 3, data were limited regarding the long-term effects of sorbent injection on ESP performance; however, parametric test results generally indicated an increase in particulate loading at the outlet of ESP 2 for the higher injection rates upstream of ESP 1 and an increase in particulate loading for nearly all sorbents injected upstream of ESP 2, including the longer-term 48 hour HOK injection test. These test results, along with those generated from the Yates Unit 1 long-term test program and described in a separate Yates Unit 1 site report, indicate that the sorbent injection process will need to be evaluated on full-scale units (especially for those units equipped with low-SCA ESPs) for longer periods of time in order to better understand the impact of carbon injection on ESP performance and integrity. Additional ACI testing in conjunction with alternative reagents for SO_3 control may also be warranted.

1.0 Introduction

This document describes tests conducted to evaluate activated carbon injection (ACI) for reducing mercury emissions at Reliant Energy's Shawville Station Unit 3. Unit 3 is fueled with Pennsylvania bituminous coal and is equipped with two sequential electrostatic precipitators (ESPs) for particulate control. The proposed tests were conducted as part of DOE-NETL Cooperative Agreement Number DE-FC26-03NT41987 titled "Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas".

Tests were conducted at Shawville Unit 3 to determine the feasibility of using activated carbon injection for mercury control at a plant firing bituminous coal and configured with a small-sized ESP; ESPs are considered small if they have a specific collection area (SCA) of less than 300 ft^2/1000 afcm. Results of these tests provide indication of the level of mercury emission reduction feasible with ACI for units possessing small ESPs, such as Shawville.

A series of tests were performed over a three-week period in which several activated carbon sorbents were injected into the flue gas duct just upstream of either of the two Unit 3 ESP units. Flue gas measurements were made to determine the effectiveness of the carbons to remove mercury. Additional measurements were made to evaluate ESP performance for particulate removal during the ACI tests. Short-term parametric tests were conducted to determine the effectiveness of several carbon sorbents injected into the flue gas at rates ranging from 3 to 15 lbs/MMacf. A nominal 48-hour continuous injection test was also performed to evaluate longer-term performance over a period when the unit experienced several anticipated changes in load. Additional tests were also performed in which hydrated lime was injected upstream of the first ESP to reduce SO_3 levels in an attempt to enhance the mercury removal performance of the activated carbon sorbents.

Results of the ACI tests were compared to those collected during normal (baseline) operation to determine the true impact of the ACI process. Additional solid by-product characterizations were made to evaluate the ACI impact on Unit 3 fly ash properties including carbon and mercury levels. Mercury material balance calculations were made by comparing the results of coal, fly ash, and flue gas mercury measurements.

Background

The following section recounts the DOE-NETL program background as well as the current status of ACI injection for mercury removal from flue gas.

NETL Project Background

This DOE-NETL program is designed to generate data to evaluate the performance and economic feasibility of sorbent injection for mercury control at power plants that fire bituminous coal and are configured with small-sized electrostatic precipitators and/or an ESP-flue gas desulfurization (FGD) configuration. EPRI and Southern Company are co-funding the test program. URS Corporation is the prime contractor to NETL. As part of this program, tests have been performed to evaluate the performance of activated carbon technology for mercury control at Southern Company's Georgia Power Plant Yates Units 1 and 2 (Newnan, GA); both units fire a low-sulfur bituminous coal and are equipped with ESPs having SCAs less than 200 ft^2/1000 afcm.

Short-term parametric tests were conducted on Yates Units 1 and 2 to evaluate the performance of low-cost activated carbon sorbents for removing mercury. In addition, the effects of the dual flue gas conditioning system on mercury removal performance were evaluated as part of short-term parametric tests on Unit 2. Based on the parametric test results, a single sorbent (e.g., RWE Super HOK) was selected for a 30-day continuous injection test on Unit 1 to observe long-term performance of the sorbent as well as its effects on ESP and FGD system operations as well as combustion byproduct properties. The results from the Plant Yates ACI tests showed that mercury removals ranging from 50-70% were achievable across the small-sized ESPs with activated carbon; overall mercury removals across the entire flue gas path ranged from 70-90%. The Plant Yates study provided data required for assessing carbon performance and long-term operational impacts, as well as for estimating the costs of full-scale sorbent injection processes for flue gas mercury removal.

All originally planned project objectives have been met. NETL and EPRI subsequently agreed to use remaining project budget to perform additional tests at Shawville Unit 3 focused on meeting the project objectives. Shawville Unit 3 fires eastern bituminous coal and is configured with two sequential ESPs with specific collection areas of approximately 83 and 230-ft^2/1000 acfm, respectively. Therefore, Unit 3 possesses an appropriate configuration for further evaluating ACI performance across small-sized ESPs.

Objectives for Shawville Testing

Tests were conducted to determine the viability of ACI as a mercury control process at Reliant Energy's Shawville Unit 3 focusing on performance of the technology as well as its impact on ESP operation. Specifically, tests were conducted to evaluate the following:

- The level of mercury control that can be achieved by the addition of varying amounts of different commercial activated carbons to the Unit 3 flue gas.
- The effect of ESP size on ACI mercury removal performance by conducting similar tests upstream of both (sequential) Unit 3 ESPs.
- The effect of activated carbon addition rate on the particulate matter removal performance of the Unit 3 ESPs to determine if their limits are on the amount of carbon that can be added to the flue gas at Shawville.
- The impact of the ACI process on the Unit 3 fly ash properties, including carbon content and total mercury content.
- The performance of low-cost activated carbons compared to a halogen-impregnated carbon.
- Enhancement of ACI performance by reducing the levels of SO_3 present in the Unit 3 flue gas.
- The cost of implementing and operating an ACI process for controlling mercury at Shawville Unit 3.

2.0 Experimental

A summary of the sorbent injection test matrix conducted at Reliant Energy's Shawville Station are presented in this section, including a description of the plant, measurement locations, injection locations, sorbents evaluated, and carbon injection equipment used. In addition, the experimental methods and analytical procedures used to conduct the activated carbon injection evaluation at Shawville are also described.

2.1 Description of Injection/Measurements Locations

Shawville Unit 3 is a 175 MW coal-fired unit that burns eastern bituminous coal. The unit, depicted in Figure 2-1, is equipped with two ESPs in series. The first has a specific collection area (SCA) of 82.5 ft^2/kacfm and the second ESP has an SCA of 229 ft^2/kacfm. Each ESP is split into two halves as designated by "A" and "B." The carbon injection tests were conducted on the "A" side. Unit 3 also uses a SNCR system, located upstream of the air preheaters, for NO_x control. With the exception of one testing day, the SNCR system was turned on during the ACI test program.

The schematic shown in Figure 2-1 shows the sampling and injection locations used during the testing.

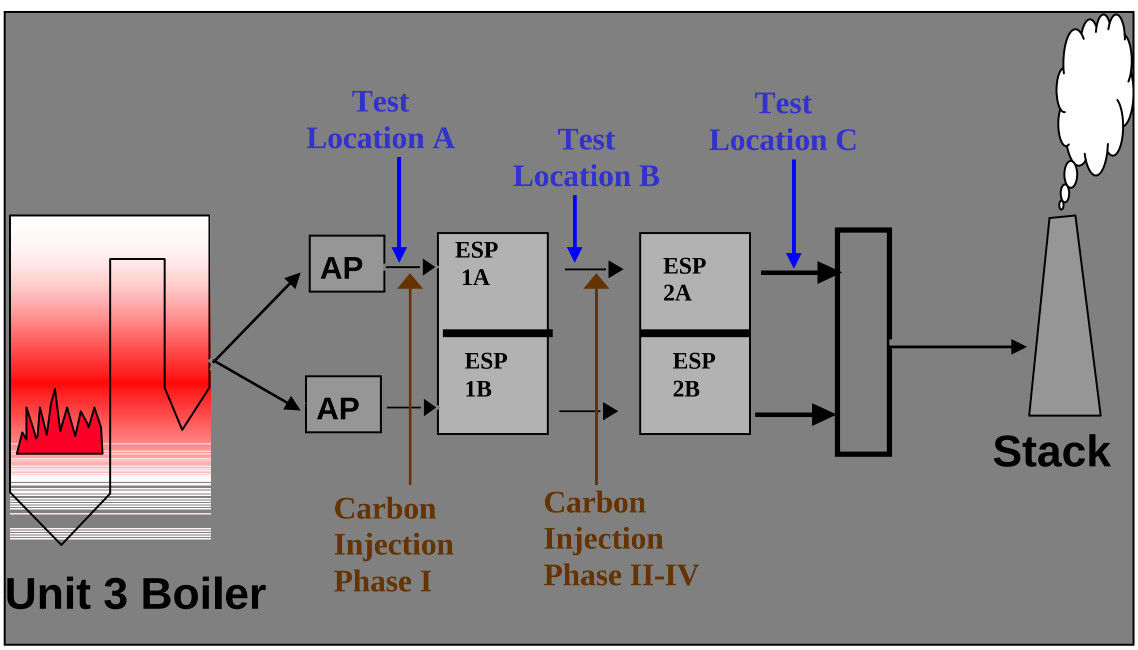


Figure 2-1. Shawville Unit 3 Configuration and Sampling Locations

Table 2-1 lists the sorbent materials evaluated during this program. RWE's Super HOK was evaluated in tests conducted across both ESPs. One additional version of the HOK sorbent was also evaluated. The two HOK carbons differed in the extent of sample grinding (i.e., particle size characteristics). Thus, the tests for these two HOK carbons were used to provide indication of the effect of sorbent particle size on mercury removal performance. Two Norit Americas activated Texas lignite carbons were evaluated; DARCO Hg (formerly known as FGD Carbon) and DARCO Hg-LH. DARCO Hg-LH is a bromine-impregnated version of Harco Hg. Several tests were conducted with high-calcium hydrated lime being injected upstream of ESP 1 to decrease the flue gas SO_3 concentrations and potentially improve the mercury removal performance of the DARCO Hg carbon.

Table 2-1. Sorbents Evaluated at Shawville Unit 3

Sorbent	Vendor	Description
HOK	RWE (Germany)	Super HOK activated German lignite; d_{50} = 24 µm
HOK-coarse	RWE (Germany)	Coarse grind of Super HOK; d_{50} = 63 µm
DARCO Hg	Norit Americas (Marshall, TX)	Activated carbon derived from Texas lignite; d_{50} = 19 µm
DARCO Hg-LH	Norit Americas (Marshall, TX)	Bromine activated carbon derived from Texas lignite; d_{50} = 19 µm
DARCO Hg / High Calcium Hydrated Lime [a]	Chemical Lime (Dallas, TX)	High surface area hydrated lime; added to reduce flue gas SO_3 levels; carbon d_{50} = 19 µm, lime d_{50} = 80 µm

[a] In Phase I, a premixed lime/carbon reagent (62% lime: 38% DARCO Hg carbon) was injected at various rates upstream of ESP 1. In Phase IV tests, hydrated lime was injected upstream of ESP 1 and DARCO Hg carbon was injected upstream of ESP 2.

2.2 Test Matrix and Objectives

A series of tests were performed over a three-week period in which the carbon sorbents described above were injected into the flue gas duct just upstream of each of the two Unit 3 ESP units. Short-term parametric tests were conducted to determine the effectiveness of several carbon sorbents injected into the flue gas at rates ranging from 3 to 15 lbs/MMacf. A nominal 48-hour continuous injection test was also performed to evaluate longer-term performance over a period when the unit experienced several anticipated changes in load. Additional test were also performed in which hydrated lime was injected upstream of the first ESP to reduce SO_3 levels in an attempt to enhance the mercury removal performance of the activated carbon sorbents. Flue gas measurements were made to determine the effectiveness of the carbons to remove mercury.

Additional measurements were made to evaluate ESP performance for particulate removal during the ACI tests.

Table 2-2 lists list the parametric tests conducted at Shawville Unit 3. The test program was broken into four distinct phases:

Phase I:	Parametric injection of Super HOK, DARCO Hg, and a DARCO Hg/Lime mixture upstream of the ESP 1.
Phase II:	Parametric injection upstream of ESP 2 to evaluate DARCO Hg-LH, Super HOK, and HOK Coarse.
Phase III:	Injection of HOK sorbent for a 48-hour period to observe longer-term performance.
Phase IV:	Parametric evaluation of alkali sorbent injection upstream of ESP 1 combined with activated carbon injection upstream of ESP 2 and staged injection of DARCO Hg at both ESP 1 and ESP 2 inlet location.

Each test was conducted for approximately four hours. Mercury measurements were made across both ESPs to characterize emissions across the entire gas path during Phase I tests. For Phase II-IV tests, flue gas mercury SCEM measurements were conducted at the ESP 1 outlet and ESP 2 outlet locations. Particulate measurements were made downstream of ESP 2 to evaluate the impact of sorbent type and injection rate on ESP performance.

Table 2-3 summarizes the various measurements conducted and process solids samples collected during each test day, including SCEM mercury, Method 17 particulate matter, mercury sorbent tubes, coal, and ESP fly ash samples.

Table 2-2. Sorbent Injection Testing Schedule at Shawville Unit 3

Date	Start Time (CT) [a]	End Time (CT)	Sorbent(s)	Injection Location(s)	Carbon Injection Rate [b]		Lime Injection Rate (lb/hr)
					(lb/MMacf)	(lb/hr)	
Phase I – Baseline and Parametric ACI Tests for ESP 1 Inlet Injection							
7/19/06 – 7/22/06	12:30	7:39	Baseline	-	0	0	0
7/22/06	9:00	12:40	HOK	ESP 1A Inlet	3.2	63	0
7/22/06	13:10	16:45	HOK	ESP 1A Inlet	11.8	233	0
7/23/06	8:50	12:15	HOK	ESP 1A Inlet	7.2	141	0
7/23/06	14:15	16:21	DARCO Hg	ESP 1A Inlet	6.7	133	0
7/24/06	12:06	15:56	DARCO Hg	ESP 1A Inlet	11.7	230	0
7/25/06	9:30	12:23	HOK	ESP 1A Inlet	15.0	296	0
7/25/06	13:45	16:19	DARCO Hg	ESP 1A Inlet	14.6	288	0
7/26/06	11:33	14:03	DARCO Hg/ Lime Premix	ESP 1A Inlet	3.5	70	117 (5.9 lb/MMacf)
7/26/05	14:34	17:34	DARCO Hg/ Lime Premix	ESP 1A Inlet	5.5	109	181 (9.2 lb/MMscf)
Phase II – Parametric Tests for ESP 2 Inlet Injection							
7/27/06	8:49	11:27	DARCO Hg-LH	ESP 2A Inlet	6.7	131	0
7/27/06	12:00	16:03	DARCO Hg-LH	ESP 2A Inlet	9.8	192	0
7/28/06	9:00	11:45	HOK Coarse	ESP 2A Inlet	11.0	217	0
7/28/06	12:15	15:30	HOK Coarse	ESP 2A Inlet	14.7	289	0
7/29/06	9:00	11:58	HOK	ESP 2A Inlet	6.7	131	0
7/29/06	12:30	15:30	HOK	ESP 2A Inlet	11.2	221	0
7/30/06	9:53	11:34	HOK	ESP 2A Inlet	13.4	263	0
8/4/06	9:10	10:11	DARCO Hg	ESP 2 Inlet	14.9	293	0
8/4/06	10:41	11:02	DARCO Hg	ESP 2 Inlet	11.7	231	0
Phase III –Extended ACI Tests for ESP 2 Inlet Injection							
7/30/06	12:04	16:30	HOK 48 hour	ESP 2A Inlet	10.8	212	0
7/30/06	16:30	2:40	HOK 48 hour	ESP 2A Inlet	10.3	202	0
7/31/06	2:40	11:50	HOK 48 hour	ESP 2A Inlet	10.3	203	0
7/31/06	11:50	6:57	HOK 48 hour	ESP 2A Inlet	11.0	217	0
7/30/06 – 8/1/06	12:04	6:57	HOK 48 hour (extended avg)	ESP 2A Inlet	10.6	208	0
Phase IV –Parametric Lime ESP 1/Carbon ESP 2 Injection; Staged Carbon Injection							
8/1/06	12:30	14:36	DARCO Hg	ESP 1A Inlet	9.7	191	0
8/2/06	9:15	10:00	Lime	ESP 2A Inlet	0	0	50 [e] (2.5 lb/MMacf)
8/2/06	10:30	11:05	Lime	ESP 2A Inlet	0	0	100 [e] (5.1 lb/MMacf)
8/2/06	11:35	13:15	Lime DARCO Hg	ESP 1A Inlet ESP 2A Inlet	3.8	75	50 [e] (2.5 lb/MMacf)

Table 2-3. (continued)

Date	Start Time (CT) [a]	End Time (CT)	Sorbent(s)	Injection Location(s)	Carbon Injection Rate [b]		Lime Injection Rate (lb/hr)
Phase IV –Parametric Lime ESP 1/Carbon ESP 2 Injection; Staged Carbon Injection (continued)							
8/2/06	13:45	15:00	Lime DARCO Hg	ESP 1A Inlet ESP 2A Inlet	7.0	137	50 [e] (2.5 lb/MMacf)
8/3/06	10:00	11:25	Baseline (SNCR off)	-	0	0	0
8/3/06	11:55	13:11	DARCO Hg (SNCR off)	ESP 2A Inlet	4.8	95	0
8/3/06	13:41	15:25	Lime DARCO Hg (SNCR off)	ESP 1A Inlet ESP 2A Inlet	4.9	95	100 [e] (5.1 lb/MMacf)
8/3/06	15:55	16:45	Lime DARCO Hg (SNCR off)	ESP 1A Inlet ESP 2A Inlet	4.9	96	200 [e] (10.2 lb/MMacf)
8/3/06	17:15	17:30	Lime DARCO Hg (SNCR back on)	ESP 1A Inlet ESP 2A Inlet	4.9	95	200 [e] (10.2 lb/MMacf)
8/3/06	18:00	8:40	Baseline	-	0	0	0
8/4/06	11:02	11:46	Lime DARCO Hg	ESP 1A Inlet ESP 2A Inlet	11.7	231	100 [e] (5.1 lb/MMacf)
8/4/06	12:16	13:35	Lime DARCO Hg	ESP 1A Inlet ESP 2A Inlet	11.7	231	200 [e] (10.2 lb/MMacf)
8/4/06	14:25	15:32	DARCO Hg (staged)	ESP 1A Inlet ESP 2A Inlet	5.3 [c]	104	0
8/4/06	15:45	16:14	DARCO Hg [d]	ESP 1 Inlet	7.3	144	0
8/4/06	16:44	18:00	DARCO Hg (staged)	ESP 1A Inlet ESP 2A Inlet	6.7 [c]	132	0
8/4/06	18:30	19:40	DARCO Hg [d]	ESP 1A Inlet	14.6	288	0
8/4/06	20:10	11:00	Baseline	-	0	0	0

[a] Start and end times represent the beginning and end of the data averaging period. Sorbent injection began approximately 30 minutes prior to the indicated start times.

[b] Injection rates are based on an average flue gas flow rate of 327,923 acfm as measured by URS velocity traverses at the ESP 1A outlet and ESP 2A outlet locations.

[c] Staged injection. Rate shown is the injection rate at each injection location.

[d] During these tests, two open-ended hoses were used to feed carbon to the ESP 1A inlet injection point. Fabricated lances with distribution points along the length of the lance were used upstream of ESP 2A and for all other injections upstream of ESP 1A.

[e] Nominal target lime injection rate.

Table 2-3. Sample Collection Matrix for Shawville Unit 3

Test Runs				Measurements and Samples Collected A = ESP 1A Inlet, B = ESP 1A Outlet (ESP 2A Inlet), C = ESP 2A Outlet					
Date	**Start Time (CT)** [a]	**End Time (CT)**	**Sorbent(s)**	**SCEM Hg**	**Method 17 Particulate**	**Sorbent Tube Hg**	**CCS SO_3**	**Coal**	**ESP Fly Ash Composite**
Phase I – Baseline and Parametric ACI Tests for ESP 1 Inlet Injection									
7/19/06 – 7/22/06	12:30	7:39	Baseline	A, B, and C	C	C		10:05 7/20 9:45 7/21 7:00 7/22	14:00 7/21
7/22/06	9:00	12:40	HOK	A, B, and C	C				11:15 12:30
7/22/06	13:10	16:45	HOK	A, B, and C	C	C			16:45
7/23/06	8:50	12:15	HOK	A, B, and C				8:00	11:00
7/23/06	14:15	16:21	DARCO Hg	A, B, and C	C	C			16:00
7/24/06	12:06	15:56	DARCO Hg	A, B, and C	C (baseline and injection)	C		8:30	13:00
7/25/06	9:30	12:23	HOK	A, B, and C	C	C	C (baseline)	8:00	13:00
7/25/06	13:45	16:19	DARCO Hg	A, B, and C	C	C			15:45
7/26/06	11:33	14:03	DARCO Hg/ Lime Premix	A, B, and C	C	C	C (baseline and injection)	12:15	13:45
7/26/05	14:34	17:34	DARCO Hg/ Lime Premix	A, B, and C	C	C	C		16:30
Phase II – Parametric Tests for ESP 2 Inlet Injection									
7/27/06	8:49	11:27	DARCO Hg-LH	B and C	C	C			10:45
7/27/06	12:00	16:03	DARCO Hg-LH	B and C	C	C	C	12:25	14:30
7/28/06	9:00	11:45	HOK Coarse	B and C	C	C		7:55	11:00
7/28/06	12:15	15:30	HOK Coarse	B and C	C	C			15:20
7/29/06	9:00	11:58	HOK	B and C	C	C		6:30	11:45
7/29/06	12:30	15:30	HOK	B and C	C	C			15:45
7/30/06	9:53	11:34	HOK	B and C	C			6:30	11:45
8/4/06	9:10	10:11	DARCO Hg	B and C	C	C		7:50	9:40
8/4/06	10:41	11:02	DARCO Hg	B and C					

Table 2-3. (continued)

Test Runs				Measurements and Samples Collected A = ESP 1A Inlet, B = ESP 1A Outlet (ESP 2A Inlet), C = ESP 2A Outlet					
Date	**Start Time (CT)** [a]	**End Time (CT)**	**Sorbent(s)**	**SCEM Hg**	**Method 17 Particulate**	**Sorbent Tube Hg**	**CCS SO_3**	**Coal**	**ESP Fly Ash Composite**
Phase III –Extended ACI Tests for ESP 2 Inlet Injection									
7/30/06	12:04	16:30	HOK 48 hour	B and C					
7/30/06	16:30	2:40	HOK 48 hour	B and C					
7/31/06	2:40	11:50	HOK 48 hour	B and C	C	C		8:15	
7/31/06	11:50	6:57	HOK 48 hour	B and C	C	C			15:30 7/31 6:45 8/1
7/30/06 – 8/1/06	12:04	6:57	HOK 48 hour (extended avg)	B and C				6:20 8/1	
Phase IV –Parametric Lime ESP 1/Carbon ESP 2 Injection; Staged Carbon Injection									
8/1/06	12:30	14:36	DARCO Hg	B and C	B (baseline and injection)				14:15
8/2/06	9:15	10:00	Lime	B and C			C		
8/2/06	10:30	11:05	Lime	B and C					
8/2/06	11:35	13:15	Lime DARCO Hg	B and C			C	11:20	
8/2/06	13:45	15:00	Lime DARCO Hg	B and C			C		15:00
8/3/06	10:00	11:25	Baseline (SNCR off)	B and C			C		
8/3/06	11:55	13:11	DARCO Hg (SNCR off)	B and C			C		
8/3/06	13:41	15:25	Lime DARCO Hg (SNCR off)	B and C			C	15:00	16:00
8/3/06	15:55	16:45	Lime DARCO Hg (SNCR off)	B and C			C		
8/3/06	17:15	17:30	Lime DARCO Hg (SNCR back on)	B and C					
8/3/06	18:00	8:40	Baseline	B and C					
8/4/06	11:02	11:46	Lime DARCO Hg	B and C					

Table 2-3. (continued)

Test Runs				Measurements and Samples Collected A = ESP 1A Inlet, B = ESP 1A Outlet (ESP 2A Inlet), C = ESP 2A Outlet					
Date	**Start Time (CT)** [a]	**End Time (CT)**	**Sorbent(s)**	**SCEM Hg**	**Method 17 Particulate**	**Sorbent Tube Hg**	**CCS SO_3**	**Coal**	**ESP Fly Ash Composite**
8/4/06	12:16	13:35	Lime DARCO Hg	B and C	C	C			
8/4/06	14:25	15:32	DARCO Hg (staged)	B and C	C				
8/4/06	15:45	16:14	DARCO Hg [d]	B and C					
8/4/06	16:44	18:00	DARCO Hg (staged)	B and C					
8/4/06	18:30	19:40	DARCO Hg [d]	B and C					
8/4/06	20:10	11:00	Baseline	B and C					

[a] Start and end times represents the beginning and end of the data averaging period. Sorbent injection began approximately 30 minutes prior to the indicated start times. Sample times for process solids are shown in Central time.

2.2 Description of Carbon Injection Equipment

Two portable dosing systems were used to feed activated carbon to the Unit 3 flue gas. One injection system was supplied by EPRI and the other was supplied by Norit Americas. This type of dry injection system, shown in Figure 2-2, pneumatically conveys a predetermined and adjustable amount of sorbent from bulk bags into the flue gas stream. Each sorbent injection system can deliver approximately 20 – 400 lb/hr of activated carbon. During the test program, the sorbent injection feed rate from each system was verified with a daily calibration.

Each unit consists of two eight-foot tall sections. The lower or base section consists of a small hopper with level detector, volumetric screw feeder, and pneumatic eductor. The upper or top section consists of an electric hoist and monorail to handle bulk bags of sorbent of up to 2000 pounds. When fully assembled, the system has a total height of 16-feet. Powdered activated carbon is metered using a volumetric feeder into a pneumatic eductor, where the air supplied from a regenerative blower provides the motive force needed to transport the carbon.

Figure 2-2. Norit Port-a-Pac Carbon Feeding System

The injection lances were fabricated from 1 1/4-inch pipe and were placed at equal spacing across the width of the “A”-side ducts entering the Unit 3 ESPs. Each lance projected 8 feet horizontally into the ducts. Each lance was close-ended with six orifices along the length of the lance. Six lances were used at the ESP 1A inlet and three lances were used at the ESP 2A inlet. The pneumatically conveyed sorbent exited the lance and mixed with the flue gas flowing vertically in the duct before entering the ESP.

2.3 Description of Sampling and Analytical Methods

The following describes the methods used during the evaluation of ACI for Shawville Unit 3 for both flue gas and solid process samples.

2.3.1 Flue Gas

Flue gas sampling and analytical methods are described below.

Mercury SCEM

The analyzer consisted of a cold vapor atomic absorption spectrometer (CVAAS) coupled with a gold amalgamation system (Au-CVAAS). Since the Au-CVAAS measures mercury by using the distinct lines of the UV absorption characteristics of elemental mercury, the non-elemental fraction is converted to elemental mercury prior to analysis using a chilled reduction solution of acidified stannous chloride. Several impingers containing alkaline solutions are placed downstream of the reducing impingers to remove acidic components from the flue gas; elemental mercury is quantitatively transferred through these impingers.

Gas exiting the impingers flows through a gold amalgamation column where the mercury in the gas is adsorbed (<60°C). After adsorbing mercury onto the gold for a fixed period of time (typically one to five minutes, depending on the mercury concentration in the gas), the mercury concentrated on the gold is thermally desorbed (>400°C) in nitrogen or air, and sent as a concentrated mercury stream to a CVAAS for analysis. Therefore, the total flue gas mercury concentration is measured semi-continuously with a 1- to 5-minute sample time followed by a 2-minute analytical period.

To measure elemental mercury only, an impinger containing either 1M potassium chloride (KCl) or 1M Tris Hydroxymethyl (aminomethane) and EDTA is placed upstream of the alkaline solution impingers to capture oxidized mercury. Oxidized forms of mercury are subsequently captured and maintained in the KCl or Tris impingers while elemental mercury passes through to the gold amalgamation system. Comparison of "total" and "elemental" mercury measurements yields the extent of mercury oxidation in the flue gas.

Description of Data Obtained from SCEMs

Each SCEM can measure total vapor-phase mercury concentration and elemental mercury concentration, although not simultaneously. Because the two measurements require different wet chemistry, the analyzer alternates between measuring each type of mercury. A single data point is generated every three to seven minutes, depending on the concentration of mercury in the flue gas. Data for a sampling event were averaged to determine the average total mercury concentration and average elemental mercury concentration. When reducing the SCEM data sets, data from the first 30 minutes of each injection period were excluded from analyses to ensure that only data from steady state conditions were included in the analyses. Oxidized mercury concentrations were determined as the difference between the measured total mercury concentration and the measured elemental mercury concentration. The percent of total vapor-phase mercury present in the oxidized form within the flue gas at any given sampling location was calculated as follows:

Percent Vapor-Phase Mercury in Oxidized Form = [(Total Hg Concentration – Elemental Hg Concentration)/Total Hg Concentration] × 100

Method 17

Particulate matter measurements were made using EPA Method 17 single point measurements at the ESP 1 outlet and ESP 2 outlet locations as indicated in Table 2-3. Method 17 uses an in-duct filter to collect particulate matter. These measurements were conducted to measure the effect of the sorbent injection on particulate matter loading at the ESP 2 outlet; however, they were not intended to provide compliance-type PM emission data since they were single point measurements rather than a full traverse of the duct.

Controlled Condensation System (CCS)

Flue gas SO_2 and SO_3 levels were measured and analyzed per the CCS method for ESP 2A outlet location during selected tests as shown in Table 2-3.

Mercury Sorbent Tubes

Sorbent tubes were used to measure total flue gas mercury concentrations at the ESP 2A outlet location during various tests as shown above in Table 2-3. The tubes sampled gas that was filtered by the same IGS filter used for the SCEM measurements. Samples were collected at a flow rate of 0.5 liters/minute or less over a period of approximately 1 hour using heated, small two-bed traps supplied by Frontier GeoSciences. These smaller traps are designed for use in day-long sample collection periods. Third bed spikes were not used. Tube temperature was recorded every 10 minutes, leak checks were conducted at the beginning of each test run and O_2 levels in the sample gas were monitored throughout the sample period to detect leaks across the sample system. The carbon tube sample media was digested in a 25:75 HCl:HNO_3 solution and analyzed by AF with dual gold amalgamation. All sample preparation and analyses were conducted in URS laboratories.

2.3.2 Coal and Fly Ash Solids Samples

Coal and ESP fly ash samples were collected daily as indicated in Table 2-3. The configuration of the ESP 1 and ESP 2 ash hoppers is shown in Figure 2-3. Approximately 80% of the total fly ash is collected in ESP 1 and the other 20% is collected in ESP 2. With the exception of baseline tests on 7/21/06 and HOK injection tests on 8/1/06, samples of fly ash were collected from ESP 1 hoppers 5 and 6, and from ESP 2 hoppers 1 and 2. For the baseline characterization test on 7/21/06, ash samples were also collected from ESP 1 hoppers 1 and 2. Each individual hopper sample from 7/21/06 (baseline) and 8/1/06 (48-hour HOK) was analyzed for mercury and LOI. Five-gallon bucket samples were also collected during the 48-hour HOK injection test to obtain sufficient ash for additional chemical and physical characterization tests.

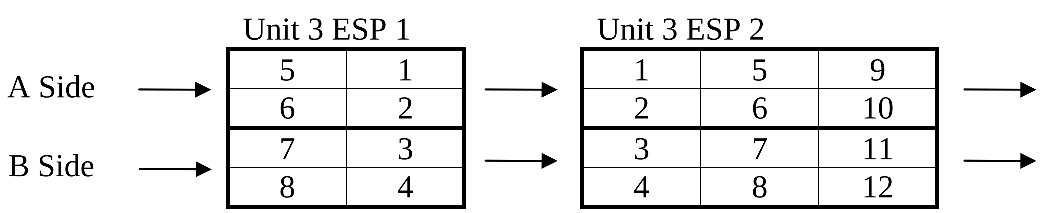


Figure 2-3. Unit 3 ESP 1 and ESP 2 Fly Ash Hopper Numbering

All laboratory coal analyses were conducted by Consol, and all fly ash analyses were conducted at URS' Austin laboratories. Ash samples were digested by a standard hydrofluoric acid digestion and analyzed for mercury by CVAA. Fly ash LOI was determined by ASTM D3174.

2.3.3 Velocity Traverses

Velocity traverses were conducted at the ESP 1A outlet and ESP 2A outlet locations to identify flow patterns and quantify the flue gas flow rate. At the ESP 1A outlet, a nine-point traverse was conducted among the three ports not used for mercury sampling. At 12-point traverse was conducted at the ESP 2A outlet.

The carbon and lime injection rates were measured on the injection skids in lb/min and then expressed in terms of lb/MMacf using an average flue gas flow rate for the two traverse velocity locations according to the following equation:

$$\text{Injection Rate (lb/MMacf)} = \text{Injection Rate (lb/min)/Flue gas flow (acfm)} \times 10^6$$

3.0 Results and Discussion

This section presents the test results for the Shawville Unit 3 test program. The results of the sorbent injection tests from Plant Yates Unit 1 and Unit 2 are reported in their respective site reports.

A summary of the SCEM inlet and outlet total vapor phase mercury concentrations and the mercury removal performance for the initial baseline characterization and each of the sorbent injection tests are tabulated in Appendix C. The mercury removal performance of the sorbents was evaluated based on the vapor phase mercury removal across the ESP system(s). This metric compares the outlet vapor phase mercury concentration to the inlet vapor phase mercury concentration. The generic calculation for the vapor phase mercury removal is

$$\text{Percent Removal} = [1 - O/I] \times 100$$

where,

O = average SCEM total mercury concentration at the device outlet (either ESP 1 outlet or ESP 2 outlet) for the injection rate test period, and

I = average SCEM total mercury concentration at the inlet to the device or (either ESP 1 inlet or ESP 1 outlet)

As a second metric, the performance of each sorbent was evaluated in terms of percent reduction of vapor phase mercury at the exit of the control device. Mercury reduction results for each test are also tabulated in Appendix C. Because the baseline system mercury removal was quite high in some cases, the amount of mercury reduction attributed solely to carbon injection can be estimated by calculating the percent reduction in average total vapor-phase mercury concentrations at the ESP 1 and ESP 2 outlet location compared to average baseline concentrations (i.e., native concentrations). The percent reduction in total mercury concentration for a given injection rate is calculated as follows:

$$\text{Percent Reduction} = [1 - (O / BL)] \times 100$$

where,

O = average SCEM total mercury concentration at the ESP 1 or ESP 2 outlet for the injection rate test period, and

BL = average SCEM total mercury concentration at the ESP 1 or ESP 2 outlet for the baseline test period calculated from the concentrations measured at the beginning of each test day after daily SCEM instrument QA/QC checks and calibrations.

Each datum point in Appendix C represents an average of the data collected over a multi-hour test period. For the parametric tests, each injection rate was tested for two to four hours. Averages of the mercury concentrations measured at each location were taken starting from the time the mercury concentrations at the sample locations had steadied until the injection rate was changed. These average mercury concentrations were then input to the calculations for percent mercury removal and reduction. For the longer 48-hour HOK carbon injection test, hourly average mercury concentrations were calculated for both the ESP 2 inlet and ESP 2 outlet locations and an hourly average mercury removal for each data pair was then calculated. The overall average mercury removal across ESP 2 for the 48-hour test period was then estimated as the average of these hourly removal values. Hourly mercury reduction values were calculated in a similar manner using each hourly average ESP 2 outlet mercury value and the baseline concentration at the ESP 2 outlet measured at the beginning of the 48-hour test on 7/30/06.

3.1 Baseline Flue Gas Characterization

3.1.1 Flue Gas Flow Rates

Results of the velocity traverse conducted at the ESP 1A outlet and ESP 2A outlet locations are summarized in Table 3-1. The average measured flow in Unit 3 duct. A at the ESP 2 outlet was 344 kacfm. Doubling this flow to estimate the entire Unit 3 flow rate gives 688 kacfm, which compares well with expected 660 kacfm estimated by the plant.

The average of the ESP 1A and ESP 2A outlet flue gas measurements (328 kacfm) was used as the basis of all sorbent injection rate calculations presented in this report on a lb/MMacf basis.

Table 3-1. Flue Gas Flow Rate Measurement Results

Location	Date/Time (CT)	Average Temperature (F)	Flue Gas Flow Rate (acfm) [a]	Flue Gas Flow Rate (dscfm) [a]
ESP 1A Outlet	7/24/06 15:57 – 16:10	272	312,104	206,538
ESP 2A Outlet	7/27/06 11:02 – 11:20	285	343,742	224,651
Average			327,923	215,595

[a] At an average of 8.7% O_2 at the ESP 2 outlet location.

3.1.2 Baseline Mercury Characterization

Both comprehensive initial baseline and daily baseline mercury characterization were conducted over the course of the test program.

Comprehensive baseline (no injection) flue gas mercury measurements were made on the first two days of the test program, 7/20/06 through the morning of 7/22/06. The mercury concentrations at the ESP 1A inlet and ESP 2A outlet, as measured by SCEM, are shown in Figure 3-1. Mercury concentrations are reported in $\mu g/Nm^3$ normalized to 3% O_2. During the baseline test period, the inlet and outlet mercury concentrations were generally within ±10-20% of each other. Baseline mercury concentrations typically ranged from 26 to 43 $\mu g/Nm^3$ at full load. In general, 20-40% of the total mercury was present in the elemental form at the ESP 1A inlet location (60-80% in the oxidized form). At the ESP 2A outlet, only 10-20% of the total mercury was measured in the elemental form (80-90% in the oxidized form), indicating significant oxidization of mercury across the ESPs.

Daily baseline characterization periods were defined for a morning period on each day of parametric testing as shown in Table 3-2. These daily baseline periods were generally selected to be the period immediately following the morning SCEM instrument QA/QC checks and prior to the start of the first sorbent injection test. As shown in Table 3-2, there were significant variations in the daily total baseline mercury removal, particularly for the ESP 1 system where native removals on test days 7/22 through 7/26 were significantly higher than those measured during the initial comprehensive baseline characterization period. Average baseline vapor-phase mercury removal for ESP 1 for the entire test program was approximately 22% and the average baseline removal across ESP 2 was approximately 5 percent, assuming the negative removal values from ESP 2 are taken as zero in the average calculation. The lower baseline vapor-phase mercury removal for the ESP 2 system was expected because of the lower particulate loading of the flue gas entering the second ESP, resulting in less fly ash being available to remove mercury within the second ESP. Additional analyses of sorbent performance in terms of percent mercury reduction was conducted to account for daily variations in baseline (i.e., native) mercury removal.

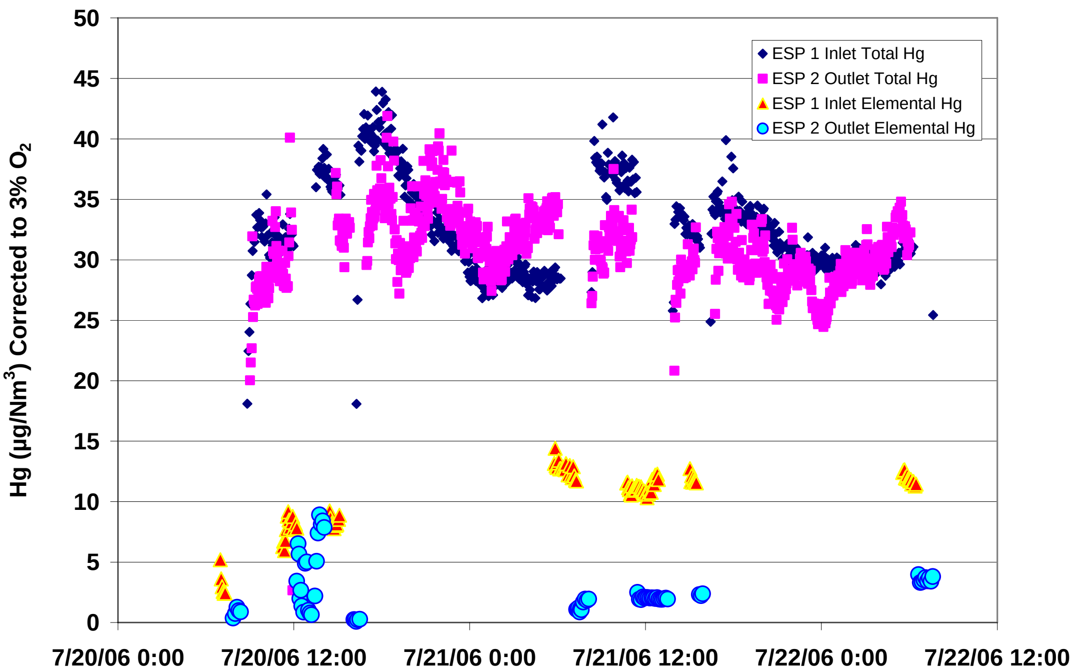


Figure 3-1. Baseline SCEM Flue Gas Mercury Concentrations

Table 3-2. Comprehensive and Daily Baseline Mercury Characterization Data

Baseline Period		Average SCEM Total Mercury Concentration (µg/Nm^3 at 3% O_2)			Total Vapor-Phase Mercury Removal (%)		
Start	Stop	ESP 1 Inlet	ESP 1 Outlet	ESP 2 Outlet	ESP 1	ESP 2	Overall
7/19/2006 12:30	7/22/2006 7:39	32.5	31.1	31.0	4.2	0.5	4.7
7/20/2006 9:00	7/20/2006 11:00	31.8	27.9	28.2	12	-1.0	11
7/21/2006 9:00	7/21/2006 11:00	37.3	34.9	31.8	6.5	8.9	15
7/22/2006 7:56	7/22/2006 8:39	30.7	23.5	25.8	24	-9.8	16
7/23/2006 7:35	7/23/2006 8:20	34.5	26.6	22.5	23	15	35
7/24/2006 7:58	7/24/2006 11:41	30.1	23.6	21.8	22	7.6	28
7/25/2006 7:34	7/25/2006 9:00	30.3	24.5	21.8	19	11	28
7/26/2006 7:30	7/26/2006 11:00	25.5	14.8	17.0	42	-15	34
7/27/2006 7:30	7/27/2006 8:15	NM	21.7	18.0	NC	17	NC
7/28/2006 7:30	7/28/2006 8:30	NM	18.1	21.6	NC	-19	NC
7/29/2006 7:30	7/29/2006 8:30	NM	16.8	15.7	NC	6.6	NC
7/30/2006 8:30	7/30/2006 9:00	NM	15.2	18.0	NC	-18	NC
8/1/2006 10:00	8/1/2006 12:00	NM	17.6	25.3	NC	-44	NC
8/2/2006 8:25	8/2/2006 8:45	NM	16.5	18.5	NC	-11.8	NC
8/3/2006 10:00	8/3/2006 11:25	NM	16.7	16.8	NC	-0.6	NC
8/4/2006 8:15	8/4/2006 8:35	NM	17.7	15.7	NC	11	NC
				Average	22	5.1	26

NM = Not measured. SCEM analyzer measurements were not planned at the ESP 1 inlet location during this phase of the test program.
NC = Not calculated.

3.2 ACI Injection Tests

Results of the various injection tests for the HOK (regular and coarse grind) and DARCO (Hg and Hg-LH) carbons are presented and discussed in this section. Results for each group of carbons are presented for the various injection locations, followed by a comparison of the mercury removal performance for all sorbents.

3.2.1 HOK Injection

HOK sorbent injection test results are discussed in this section. Tests included injection of HOK at the ESP 1A inlet, injection of HOK at the ESP 2A inlet, injection of coarse grind HOK at the ESP 2A inlet, and injection of the HOK at the ESP 2A inlet over a 48-hour period. Mercury removal performance for the HOK tests is shown in Figure 3-2 as a function of carbon injection rate.

In Figure 3-2, “ESP 1/2” refers to injection of HOK carbon upstream of ESP 1, with total mercury removal calculated based on the ESP 1 inlet and ESP 2 outlet total mercury concentrations. “ESP 1 only” refers to the mercury removal measured across ESP 1 calculated based on the ESP 1 inlet and ESP 1 outlet total mercury concentrations. “ESP 2” refers to tests in which HOK was injected at the ESP 2 inlet and removal was calculated based on the ESP 2 inlet and ESP 2 outlet total mercury concentrations.

Baseline mercury removal varied across ESP 1 from day-to-day, ranging from 15% to 35%. In contrast, the baseline vapor-phase mercury removal across ESP 2 was near zero. Therefore, results were also analyzed in terms of percent reduction in mercury (i.e., ESP outlet values compared to daily baseline ESP outlet values). Percent mercury reduction for various the HOK injection tests are shown in Figure 3-3.

Results for each injection location are discussed further below.

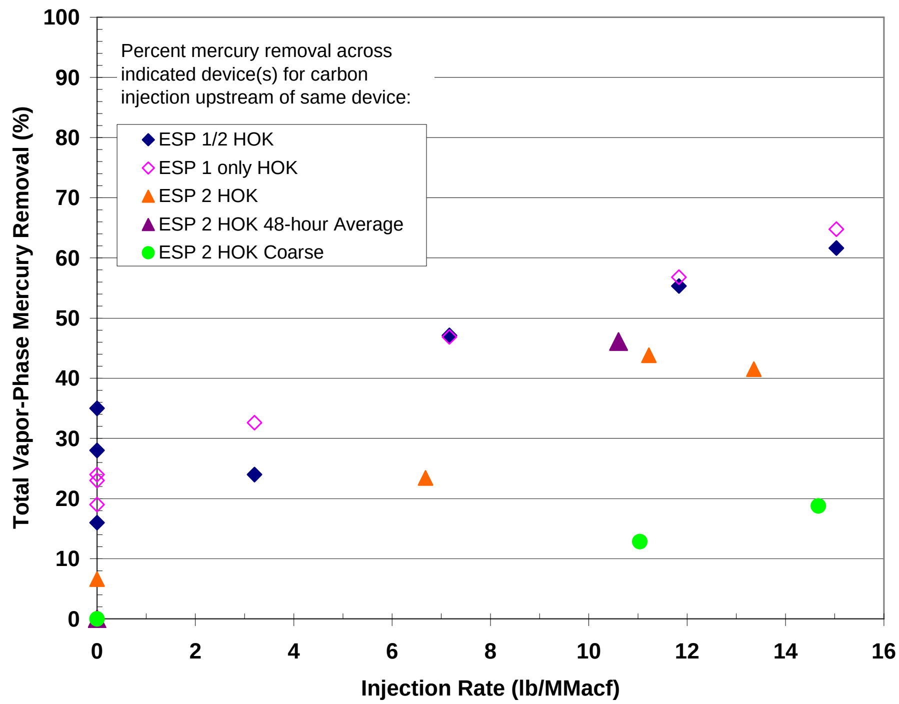


Figure 3-2. Mercury Removal Performance for the HOK and Coarse HOK Carbons

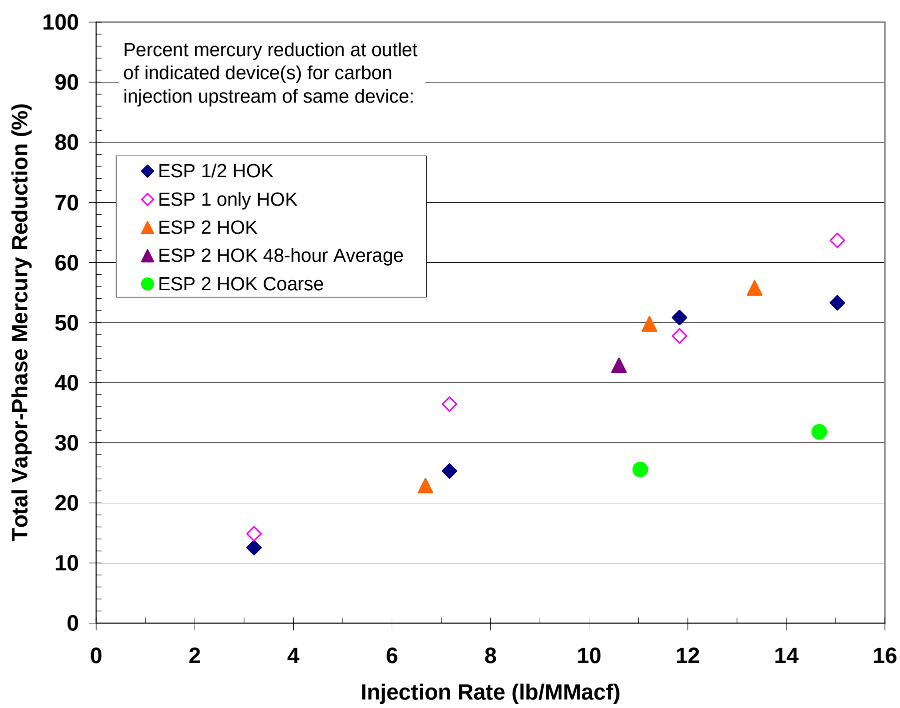


Figure 3-3. Mercury Reduction Performance for the HOK and Coarse HOK Carbons

Figures 3-2 and 3-3 show an increase in mercury removal across the combined ESP 1/ESP 2 system with increasing injection rates. Sixty-two percent removal (53% reduction) was obtained at an injection rate of 14.7 lb/MMacf. It is not known if a higher removal rate could have been obtained with carbon injection rates greater than 14.7 lb/MMacf; however, Figure 3-3 shows a plateau in performance being approached. All of the observed removal occurred across ESP 1 (SCA = 82.5 ft^2/1000 acfm), as shown by the overlap of the "ESP 1 only" data points with the "ESP 1/2" data points.

ESP 2 Inlet Injection - HOK and Coarse HOK

Upon completion of the HOK injection tests at the ESP 1A inlet location, Phase II tests were performed to compare the performance of the standard (d_{50} = 24 µm) and coarse grind (d_{50} = 63 µm) HOK carbons. During this test phase, sorbents were injected upstream of ESP 2 which has an SCA of 229 ft^2/1000 acfm. The standard HOK carbon was also injected upstream of ESP 2 over a 48-hour period to observe mercury removal and ESP performance over a longer injection period.

Figure 3-2 shows the results from the various Phase II HOK tests. The overall mercury removal performance across ESP 2 was significantly lower than that observed for ESP 1. The maximum percent mercury removal observed for the standard HOK carbon on ESP 2 was 44% at an injection rate of 11 lb/MMacf compared to about 56% at a comparable injection rate for ESP 1. However, the baseline mercury removal is significantly higher across ESP1. When performance is evaluated in terms of percent mercury reduction, as shown in Figure 3-3, HOK results were comparable for the ESP 1 and ESP 2 systems. Maximum percent mercury reduction for ESP 2 was 56% at 13.3 lb/MMacf compared to 53% for ESP 1 at 14.7 lb/MMacf. These results indicated that ESP size did not affect activated carbon mercury removal performance.

Mercury removal and reduction for the coarse grind HOK were lower that those for the standard HOK, with maximum removal of 19 percent (32 percent mercury reduction) at approximately 14.7 lb/MMacf. The data support the theory that the finer grind of the standard HOK provides greater surface area and thus better mercury removal.

Average total mercury removal across ESP 2 during the 48-hour HOK injection test was 46% (43% mercury reduction at the ESP 2 outlet) and was comparable to that observed during the shorter 4-hour injection test at a similar injection rate. Results for the 48-hour HOK test are discussed further below.

ESP 2 Inlet Injection - 48 Hour HOK

Hourly average total mercury removal across ESP 2 and percent mercury reduction at the ESP 2 outlet for the 48-hour HOK test are shown in Figure 3-4 and corresponding inlet and outlet SCEM data are presented in Figure 3-5. Hourly average removals shown in Figure 3-4 were calculated based on hourly average mercury concentrations developed from the SCEM data collected at the ESP 2 inlet and outlet locations. The overall average mercury removal, calculated as the average of the hourly removal values, was 46% during the 48-hour period.

The average hourly percent reduction values shown in Figure 3-4 were estimated based on an average baseline mercury concentration for the ESP 2 outlet. This average baseline value was calculated using ESP 2 outlet mercury data from the daily baseline period at the beginning of the 48-hour injection test on 7/30/06. The overall average vapor-phase mercury reduction at the ESP 2 outlet was 43% during the 48-hour period.

As shown in Figure 3-5, the ESP 2 outlet mercury concentration remained relatively constant at about 8 to 13 $\mu g/Nm^3$ despite the ESP 1 outlet (ESP 2 inlet) mercury concentration increasing from about 15 $\mu g/Nm^3$ at the beginning of the test on 7/30/06 to nearly 30 $\mu g/Nm^3$ at the end of the test period. This resulted in a steady increase in the estimated total mercury removal from 37% on 7/31/06 to 60 % on 8/1/06. The average HOK injection rate during the entire 48-hour period was 10.6 lb/MMacf. As shown in Figure 3-4, injection rates varied from approximately 190 lb/hr to 270 lb/hr. With the exception of the overnight period on 7/30/06, unit load remained steady at approximately 175 MW during the test period. Variations in the percent mercury reduction tend to track variations in the HOK injection rate as expected, particularly on the second day of the 48-hour test. Coal mercury concentrations for samples collected on 7/30/06 through 8/1/06 were not highly variable, ranging from 0.38 to 0.44 µg/g (dry).

Because the mercury reduction was calculated from a relatively steady outlet concentration and a single baseline average concentration, mercury reduction was more steady over the test period than the calculated hourly average removal across the ESP, although on average, mercury reduction did decrease slightly on 7/31/06.

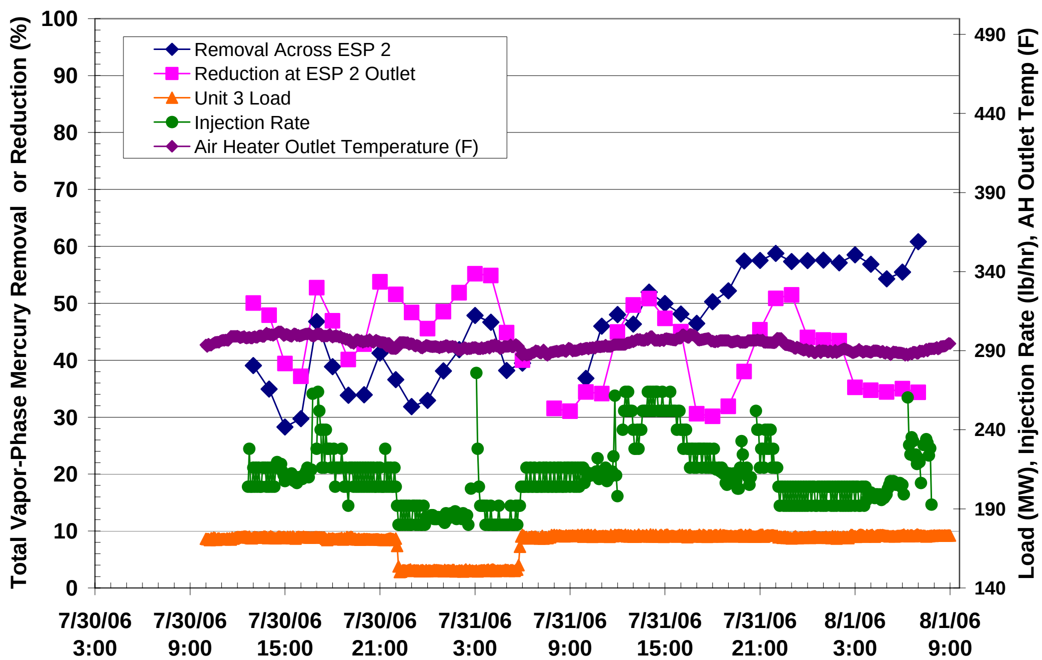


Figure 3-4. Hourly Average Total Mercury Removal and Reduction for the 48-Hour HOK Test on ESP 2

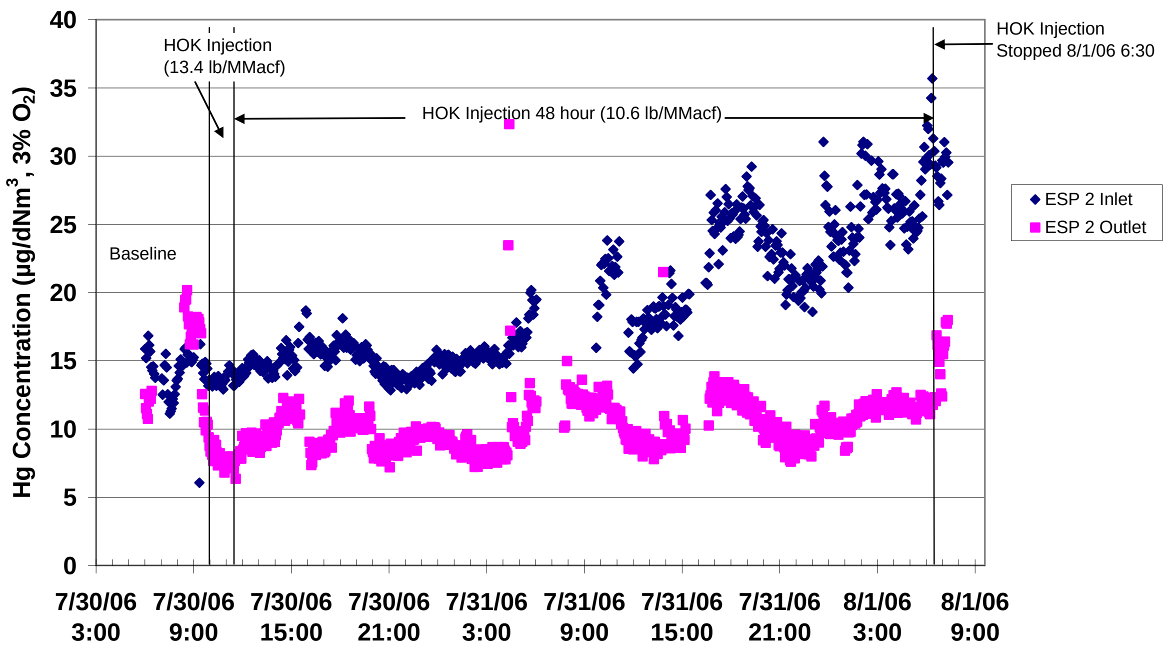


Figure 3-5. Total Mercury Concentrations at the ESP 2 Inlet and Outlet for the 48-Hour HOK Test

3.2.2 Injection of DARCO Carbons

Injection tests using both the DARCO Hg and DARCO Hg-LH carbons were conducted during Phase I and Phase II of the test program. Parametric tests were conducted for the DARCO-Hg sorbent by injecting at two different locations: upstream of ESP 1A (ESP 1 and ESP 2 performance measured) and upstream of ESP 2A (only ESP 2 performance measured). DARCO Hg-LH was also injected upstream of ESP 2A as part of Phase II tests. Staged injection tests in which DARCO Hg was injected simultaneously at both the ESP 1A and ESP 2A locations were also conducted during Phase IV of the program. DARCO carbon performance, expressed in terms of mercury removal and mercury reduction, are shown in Figures 3-6 and 3-7 as a function of injection rate, respectively. Results for each set of tests are discussed in the following sections.

ESP 1 Inlet Injection – DARCO Hg

As shown in Figures 3-6 and 3-7, sorbent performance was evaluated for both the combined ESP 1/ESP 2 system and for ESP 1 only based on SCEM measurements taken at the three flue gas sample locations. Results shown in Figure 3-6 indicate a maximum percent removal across the combined ESP 1/ESP 2 system of approximately 88% at an injection rate of 11.7 lb/MMacf, with no further increase in removal at 14.6 lb/MMacf. As with the HOK tests, nearly all the mercury removal occurred across ESP 1 as indicated by the overlap of the "ESP 1 only" data points with the "ESP 1/2" data points.

ESP 2 Inlet Injection – DARCO Hg and DARCO Hg-LH

Total mercury removal and reduction values for the DARCO Hg sorbent injection upstream of ESP 2 were generally slightly lower than those obtained when injecting upstream of ESP 1. In both cases, the mercury removal and reduction values at the highest injection rate were approximately 75 to 80 percent. Similar to the HOK carbon, the data suggest that the higher SCA of ESP 2 had little impact on total mercury removal performance for the DARCO carbons. Sorbent performance metrics for DARCO Hg and DARCO Hg-LH carbons injected upstream of ESP 2 were very similar, indicating that a brominated carbon does not offer an advantage for mercury removal in this Eastern bituminous flue gas.

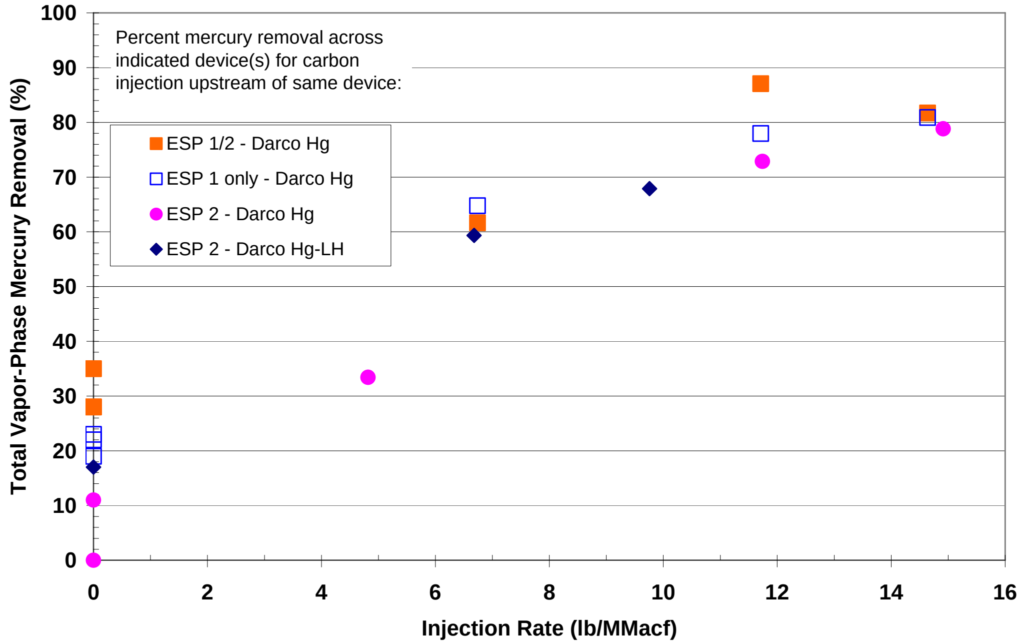


Figure 3-6. Mercury Removal Performance for the DARCO Hg and DARCO Hg-LH Carbons

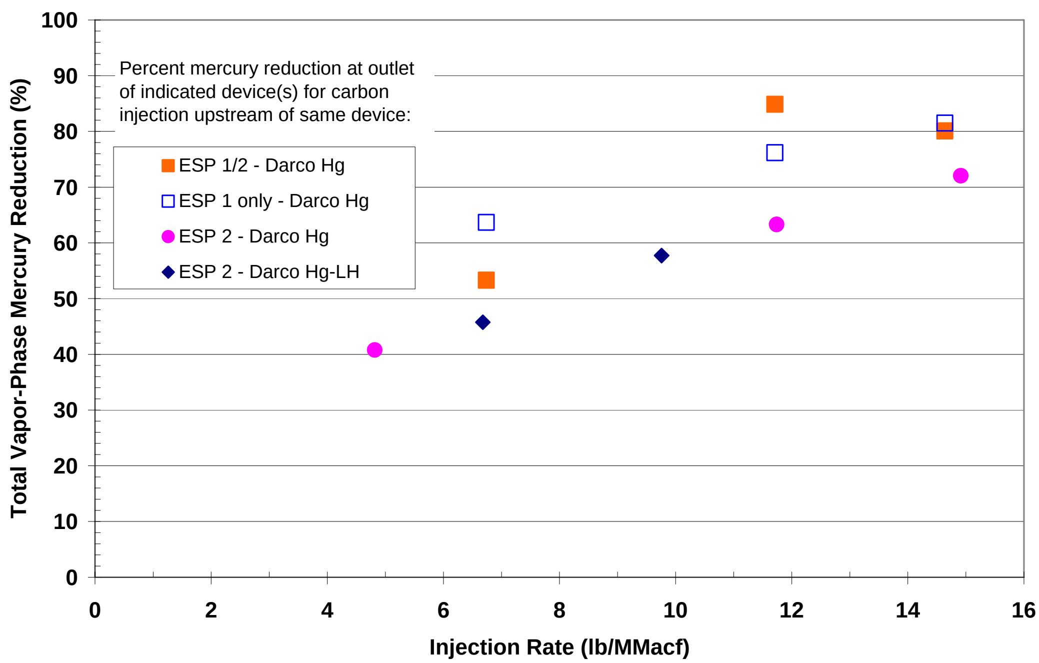


Figure 3-7. Mercury Reduction Performance for the DARCO Hg and DARCO Hg-LH Carbons

Staged Injection of DARCO Hg at ESP 1 and ESP 2 Inlet Locations

During these Phase IV tests, SCEM measurements were only conducted at the ESP 2 inlet and ESP 2 outlet locations. The inlet and outlet SCEM data for the two staged injection tests indicate 76-82 percent reduction of vapor phase mercury occurred across ESP 2, resulting in ESP 2 outlet vapor-phase mercury concentrations in the range of 3 to 4 $\mu g/Nm^3$ compared to the daily morning baseline concentration of 15.7 $\mu g/Nm^3$ at the ESP 2 outlet. Because SCEM mercury measurements were not planned at the ESP 1 inlet location during the staged injection tests, total mercury removal across the combined ESP1/ESP2 system could not be estimated. In Figure 3-8, mercury reduction at the ESP 2 outlet for the staged injection tests was compared to the results presented previously for DARCO Hg injection upstream of ESP 1 only. No significant difference in vapor-phase mercury reduction was observed for the two DARCO Hg injection configurations.

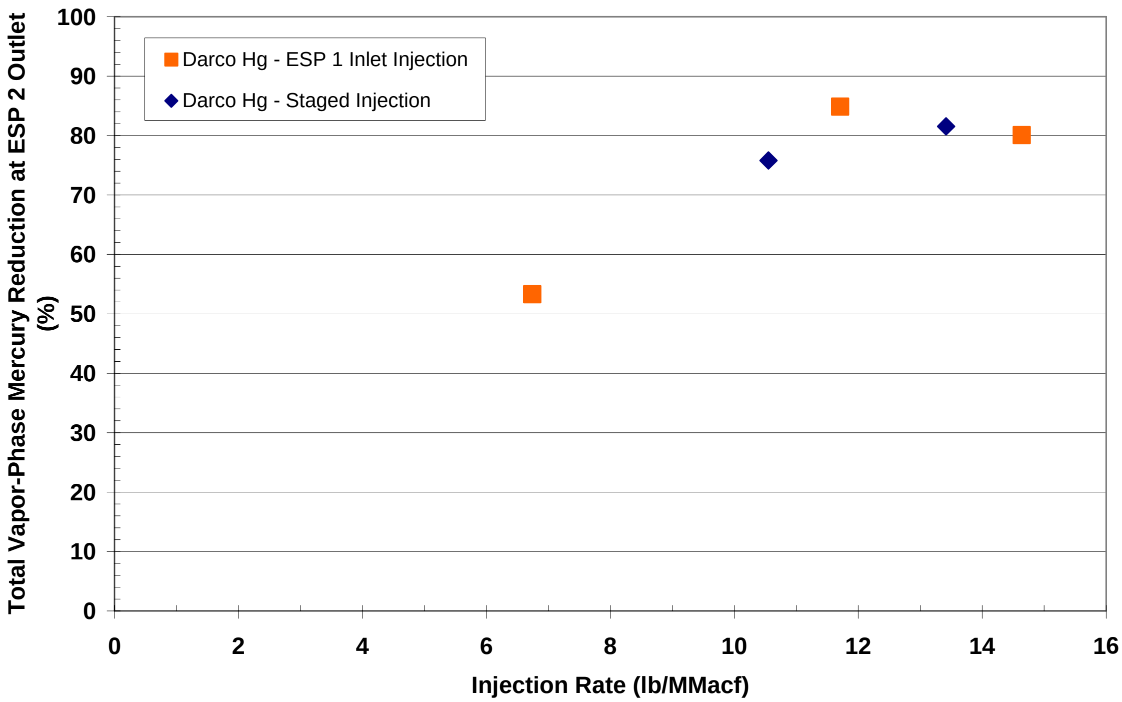


Figure 3-8. Vapor-Phase Mercury Reduction for Staged Injection of DARCO Hg Upstream of ESP 1 and ESP 2

3.2.3 Comparison of Carbon Performance

A comparison of the mercury reduction performance for all carbons injected upstream of ESP 2 is provided in Figure 3-9. Performance of the various carbons are compared in terms of percent mercury reduction since this is more consistent way to compare performance. As shown previously, similar results were obtained for injection upstream of ESP 1, so results for the various ESP 1 inlet injection tests are not repeated in Figure 3-9. Results for the DARCO Hg and DARCO Hg-LH were similar, and both the showed higher mercury reduction than the two HOK carbons over the range of injection rates tested. The best mercury reduction performance, 72%, was observed for the DARCO Hg carbon injected at 14.7 lb/MMacf. The highest percent mercury reduction for the HOK carbon, 56%, occurred at an injection rate of 13.3 lb/MMacf.

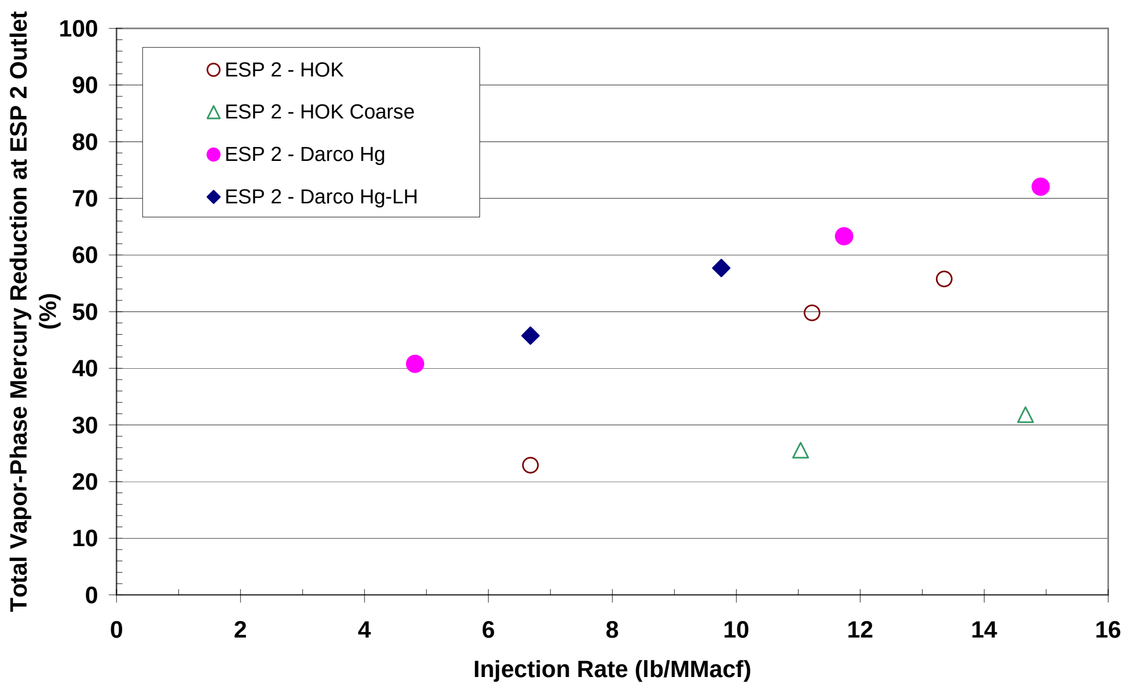


Figure 3-9. Comparison of Mercury Reduction Performance for All Carbon-Only Injection Configurations Across ESP 2

3.3 DARCO Hg with Hydrated Lime Injection

Lime injection is thought to improve mercury removal performance for the activated carbons by reducing the concentration of SO_3 in the flue gas, thus decreasing competition between mercury and SO_3 for adsorption sites on the carbon. For the Shawville tests, high injection rates (approximately a 35:1 molar ratio at the highest rate of 200 lb/hr) of a high surface area lime reagent were tested. The effects of using lime injection in conjunction with activated carbon were evaluated for two injection configurations at Shawville Unit 3. The first involved injection of a premixed DARCO Hg/lime reagent (62.5 wt% lime/37.5 wt% carbon) upstream of ESP 1A at two injection rates. The second involved staged injection of lime upstream of ESP 1A with simultaneous injection of DARCO Hg upstream of ESP 2A. Lime injection rates for this second series of tests were nominally 50, 100, and 200 lb/hr into ESP 1; DARCO Hg injection rates varied from 5 lb/MMacf to 12 lb/MMacf into ESP 2.

3.3.1 Effect of Lime and Carbon Injection on Flue Gas SO_3 Concentrations

SO_3 measurements were conducted at the ESP 2 outlet location during the baseline and lime/carbon premix tests, and during selected lime/carbon injection tests on August 2nd and August 3rd when lime was injected upstream of ESP 1 and DARCO Hg was injected upstream of ESP 2. Flue gas SO_3 concentrations on the order of 10 ppmv, typical of sites firing eastern bituminous coal, were anticipated for Shawville Unit 3 at the ESP 2 outlet; however, measured baseline SO_3 concentrations in the flue gas were only approximately 1.7 ppmv, as shown in Figure 3-10. Flue gas SO_3 concentrations measured at the ESP 2 outlet decreased with increasing lime injection rates. Even with low baseline SO_3 levels, lime injection resulted in a decrease in flue gas SO_3 concentrations; 0.3 ppmv SO_3 was measured during the highest lime injection rate of 200 lb/hr. The results also show that injection of Darco Hg carbon resulted in a decrease in SO_3 concentrations from 1.7 ppmv to 1.1 ppmv, illustrating how injection of carbon alone can reduce flue gas SO_3 concentrations.

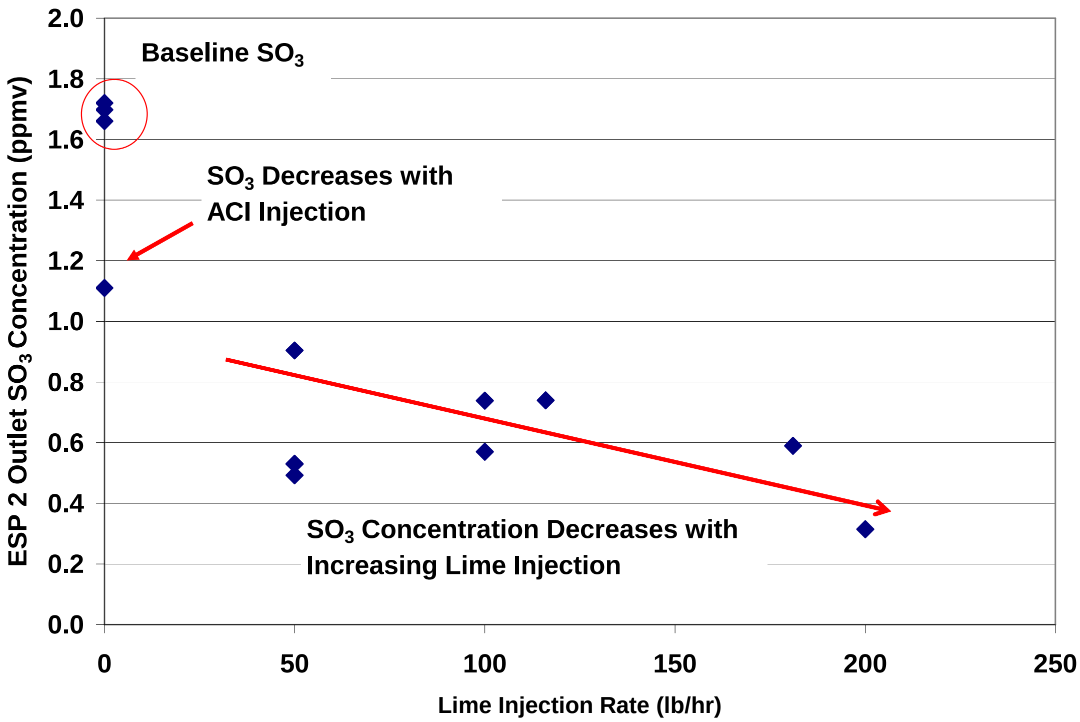


Figure 3-10. ESP 2 Outlet SO_3 Concentrations for Baseline and Lime Injection Tests

3.3.2 Effect of Lime Injection on Mercury Reduction Performance

Total vapor-phase mercury removal across the combined ESP 1/ESP 2 system (Phase I premix tests) and across ESP 2 (Phase IV tests) is plotted as function of ESP 2 outlet SO_3 concentrations in Figure 3-11 for selected tests where the carbon injection rate was similar (3.5 to 5.5 lb/MMacf). Additional flue gas SO_3 data are presented in Section 3.4. Total mercury reduction across the ESP systems for the DARCO Hg carbon increased with decreasing flue gas SO_3 levels for both injection configurations. Baseline SO_3 levels were similar with the SNCR system on and off, indicating SNCR had little effect on flue gas SO_3 levels.

Test data shown in Figure 3-11 also indicate that at lower carbon injection rates, slightly better total mercury reduction performance for the lime/DARCO Hg reagent combination was obtained for the premix configuration in which both lime and carbon were injected upstream of ESP 1, as opposed to lime injection at the ESP 1 inlet and carbon injection at the ESP 2 inlet. Mercury reduction of 72% was obtained at an carbon injection rate of approximately 5.5 lb/MMacf when the premixed reagent was injected upstream of ESP 1 at 181 lb/hr. As shown previously, when only DARCO Hg was injected upstream of ESP 1, an injection rate of nearly 11 lb/MMacf was needed to achieve comparable mercury removal. Two additional lime-only injection tests were conducted at ESP 1 inlet injection rates of 50 lb/hr and 100 lb/hr. For these tests, no mercury removal was observed across ESP 2 and SO_3 levels decreased to 0.9 ppmv and 0.74 ppmv, respectively. These test data indicate that it was the decrease in flue gas SO_3 concentrations, not mercury adsorption onto the lime that caused improvement in ACI vapor phase mercury removal performance.

Results for the lime injection tests are also plotted in Figure 3-10 where percent mercury reduction is shown as a function of the DARCO Hg carbon injection rate upstream of ESP 2. Each lime injection rate at the ESP 1 inlet location is identified with a separate data symbol. The results from the injection of DARCO Hg at the ESP 2 inlet were used as a baseline comparison for the lime injection tests and are shown as 0 lb/hr lime injection. Results indicate that at the lower DARCO Hg injection rate (4.9 lb/MMacf), mercury reduction performance across ESP 2 increased from 40% reduction for no lime injection to nearly 65% reduction for 200-lb/hr lime injection. At the 12 lb/MMacf DARCO Hg injection rate, lime injection also resulted in an enhancement in mercury removal performance; mercury reduction increased from 63% without lime injection to 83% for 200 lb/hr lime injection.

3.4 Additional Flue Gas Characterization Results

Additional flue gas characterization tests were conducted throughout the test program to provide supplemental data for evaluation the ACI technology and its impacts on the ESP system.

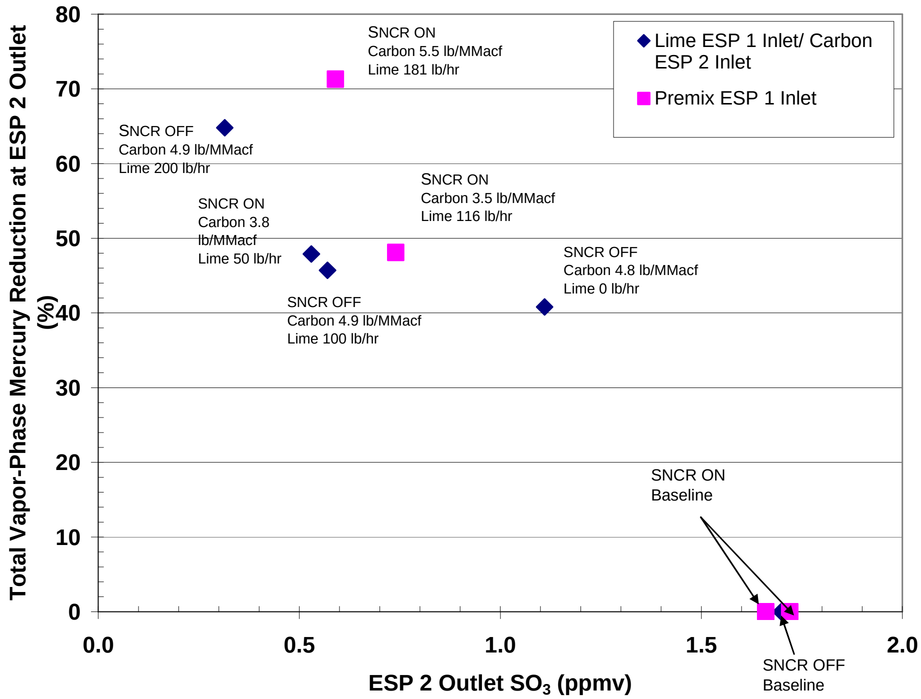


Figure 3-11. Mercury Reduction Performance as a Function of ESP 2 Outlet SO_3 Concentration – DARCO Hg

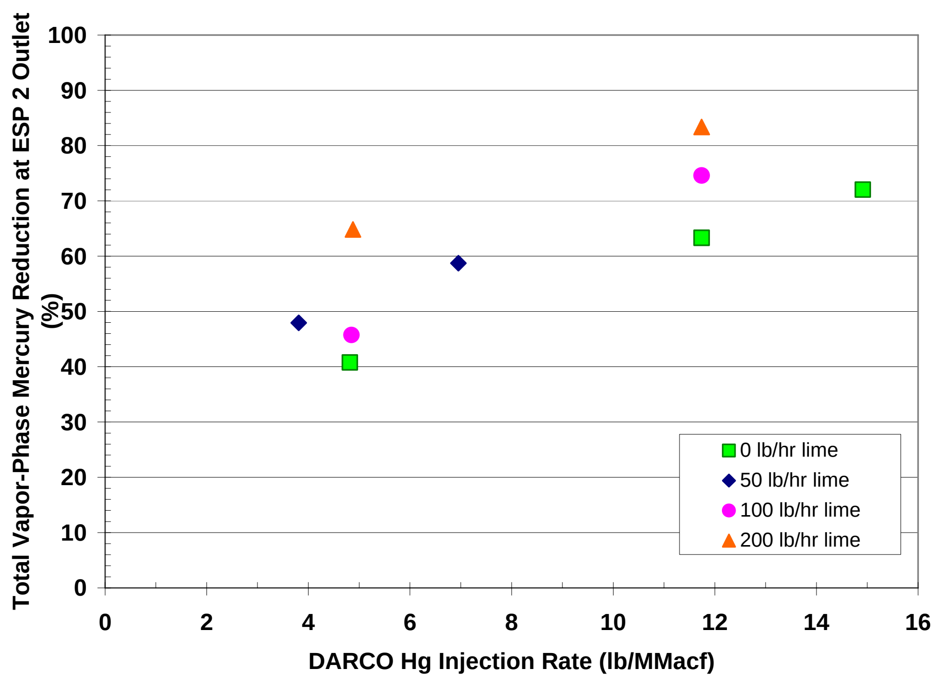


Figure 3-12. Mercury Reduction Performance for Staged Lime/Carbon Injection Tests: Lime Injection at ESP 1 Inlet, DARCO Hg Injection at ESP 2 Inlet

3.4.1 Sorbent Tube Mercury

Total vapor-phase mercury concentrations were measured at the ESP 2 outlet location using a sorbent tube sampling method for various SCEM test periods throughout the Shawville program. Sorbent tube results were consistently at least 50% lower than those obtained with the SCEM instrument with the exception of one sample collected on 7/29/06. The total vapor-phase mercury concentration measured by sorbents tubes at the ESP 2 outlet during the initial baseline characterization tests on 7/21/06 were 15 and 13 µg/Nm^3, whereas the total SCEM vapor-phase mercury concentration for corresponding sorbent tube sample periods were 32 and 29 µg/Nm^3. The estimated total (particulate plus vapor-phase) flue gas mercury concentration calculated based on the average coal mercury concentration of 0.44 µg/g was approximately 52 µg/Nm^3 at 3% O_2. SCEM values are more consistent with the predicted coal-based flue gas mercury value. A low bias is indicated for all of the sorbent tube flue gas mercury measurements; therefore, individual sorbent tube results are not presented in this report.

A review of the sorbent tube QC data did not indicate any problems with either the sampling or analytical procedures used for these samples. Third bed spikes, which can provide information needed to evaluate possible flue gas interferences, were not conducted as part of sorbent trap sampling at Shawville Unit 3.

3.4.2 Particulate Matter (Method 17)

Results for the Method 17 particulate matter samples are summarized in Table 3-3. All samples were collected at the ESP 2 outlet location with the exception of 8/1/06 when samples were collected at the ESP 1 outlet (ESP 2 inlet) using a thimble filer sample configuration. The particulate matter collection efficiency for ESP 1 and ESP 2, estimated based on the baseline Method 17 data, was 83% and 98%, respectively. This estimate is based on the following: a measured ash content of the coal (15%, dry basis), 80% of coal ash becomes fly ash, a coal heating value (12700 Btu/lb dry basis) and the standard F factor for bituminous coal (11419 MMBtu/dry scf at 3% O_2) resulting in a calculated ESP 1 inlet particulate loading of 7.2 grains/dscf at 3% O_2. Measured baseline Method 17 loading values of 1.2 grains/dscf at 3% O_2 at the ESP 1 outlet and 0.02 grains/dscf at 3% O_2 at the ESP 2 outlet were used.

Additional analyses of these results are found below in Section 3.7.

Table 3-3. Method 17 Particulate Matter Measurements

Sorbent - Injection Location	Carbon (lb/MMacf)	Lime (lb/hr)	Date	M17 Start (ET)	M17 End (ET)	Particulate Concentration (grains/dscf at 3% O_2)
ESP 2 Outlet Samples						
Baseline	0	0	7/20/2006	16:36	18:02	1.96E-02
Baseline	0	0	7/21/2006	7:52	8:52	1.31E-02
Baseline	0	0	7/21/2006	9:59	10:59	1.67E-02
HOK – ESP 1	3.2	0	7/22/2006	10:51	11:51	9.09E-03
HOK – ESP 1	11.8	0	7/22/2006	14:48	15:48	1.01E-02
DARCO Hg – ESP 1	6.7	0	7/23/2006	16:02	17:02	1.18E-02
Baseline	0	0	7/24/2006	11:27	12:27	1.55E-02
DARCO Hg – ESP 1	11.7	0	7/24/2006	15:18	16:18	1.73E-02
HOK – ESP 1	15	0	7/25/2006	11:06	12:06	1.85E-02
DARCO Hg – ESP 1	14.6	0	7/25/2006	15:31	16:31	2.30E-02
Lime/DARCO Hg Premix – ESP 1	3.5	116 (5.9 lb/MMacf)	7/26/2006	12:30	13:30	2.37E-02
Lime/DARCO Hg Premix – ESP 1	5.5	181 (9.2 lb/MMacf)	7/26/2006	17:12	18:12	2.48E-02
DARCO Hg-LH – ESP 2	6.7	0	7/27/2006	10:35	11:35	2.65E-02
DARCO Hg-LH – ESP 2	9.8	0	7/27/2006	14:30	15:30	3.81E-02
HOK coarse – ESP 2	11.0	0	7/28/2006	11:02	12:05	1.48E-02
HOK coarse – ESP 2	14.7	0	7/28/2006	14:24	15:27	1.99E-02
HOK – ESP 2	6.7	0	7/29/2006	11:31	12:31	1.67E-02
HOK – ESP 2	11.2	0	7/29/2006	15:05	16:05	2.38E-02
HOK – ESP 2	13.4	0	7/30/2006	11:29	12:29	2.04E-02
HOK 48hr – ESP 2	10.6	0	7/31/2006	7:15	8:15	2.50E-02
HOK 48hr – ESP 2	10.6	0	7/31/2006	14:17	15:17	2.93E-02
DARCO Hg – ESP 2	14.9	0	8/4/2006	10:05	11:05	1.25E-02
Lime – ESP 1 DARCO Hg – ESP 2	11.7	200 (10.2 lb/MMacf)	8/4/2006	13:30	14:30	2.15E-02
DARCO Hg – ESP 1 DARCO Hg – ESP 2	10.6	0	8/4/2006	15:30	16:30	2.72E-02
ESP 2 Inlet Samples						
Baseline (Thimble)	0	0	8/1/2006	11:05	12:05	9.85E-01
DARCO Hg – ESP 1 (Thimble)	9.7	0	8/1/2006	14:00	15:00	1.31E+00

3.4.3 SO_3/SO_2 (Controlled Condensation System)

CCS testing was done at the ESP 2A outlet to examine the effects of both sorbent and lime injection on the combined sulfur oxides present in the flue gas. The testing was performed on two consecutive days as shown in Table 3-4 with the SNCR system operating on Day 1 and the SNCR system off on Day 2. With SNCR turned off, baseline SO_3 levels of approximately 1.7 ppmv were measured (no injection). SNCR appeared to have minimal impact on the observed SO_3 levels. As expected, lowest SO_3 levels occurred during the 200-lb/hr lime injection test, where the SO_3 concentration decreased to about 0.3 ppmv.

Table 3-4. ESP 2 Outlet SO_3 Data

Date	Time (CT)	SNCR (on/off)	Injection Configuration	Inlet ESP 2A Inject DARCO Hg (lb/MMacf)	Inlet ESP1A Inject Lime (lb/hr)	ESP 2A Outlet SO_3 (ppmv)
7/25/06	7:15 – 8:51	ON	Baseline	0	0	1.72
7/26/06	7:01 – 8:37	ON	Baseline	0	0	1.66
7/26/06	12:50 – 13:53	ON	Premix Lime/DARCO Hg ESP 1	3.5	116	0.74
7/27/06	14:52 – 15:55	ON	Premix Lime/DARCO Hg ESP 1	5.5	181	0.59
8/2/2006	8:50-9:50	ON	Lime ESP 1	0	50	0.90
8/2/2006	10:05 - 11:05	ON	Lime ESP 1	0	100	0.74
8/2/2006	11:10 - 13:15	ON	Lime ESP 1 DARCO Hg ESP 2	3.8	50	0.53
8/2/2006	13:25 - 15:00	ON	Lime ESP 1 DARCO Hg ESP 2	7	50	0.49
8/3/2006	10:00 – 11:25	OFF	Baseline	0	0	1.70
8/3/2006	11:50 - 12:55	OFF	DARCO ESP 2	4.8	0	1.11
8/3/2006	13:35 - 14:35	OFF	Lime ESP 1 DARCO Hg ESP 2	4.9	100	0.57
8/3/2006	15:45 - 16:45	OFF	Lime ESP 1 DARCO Hg ESP 2	4.9	200	0.31

3.5 Coal and Fly Ash Analyses

Analytical results for coal and fly ash samples are presented in this section.

3.5.1 Coal

Unit 3 coal analyses for the test program are shown in Table 3-5. The average coal mercury concentration for the 2-week period was 0.44 mg/kg with relative standard deviation of 21%. Coal mercury concentrations varied by about a factor of two during the 2-week test period, with mercury concentrations of about 0.55 to 0.70 mg/kg (dry basis) at the beginning of the test program and concentrations of 0.35 to 0.45 mg/kg for samples collected over the last week of the test program. Other coal parameters remained relatively steady during the test program.

3.5.2 Fly Ash

Fly ash analyses for mercury and LOI are summarized in Table 3-6 for the baseline and 48-hour HOK injection tests. Results are shown for the various fields of each ESP system as defined previously in Figure 2-3. For the baseline tests, mercury concentrations for the fly ash collected in the front fields of ESP 2 were approximately 2 to 3 times higher than the mercury concentrations measured in the fly ash from the front fields of ESP 1. Percent LOI values were also correspondingly higher for the ESP 2 fly ash samples.

For HOK injection upstream of ESP 2, the ESP 2 fly ash mercury concentrations were higher than baseline values, consistent with the additional vapor-phase mercury removal observed during the HOK sorbent injection period. LOI values for the ESP 2 fly ash (11-12%) were also slightly higher than baseline ash LOI values (10%).

3.6 Mercury Mass Balance

An overall mass balance for mercury was estimated based on the measured concentrations of mercury in the coal, ESP 1 and ESP 2 fly ash, and ESP 2 outlet gas for the initial comprehensive baseline period (7/19 - 7/21/06). A mass balance was also estimated for the ESP 2 system during the 48-hour HOK injection test period (7/30 – 8/1/06) when HOK was injected at the inlet of ESP 2.

Table 3-5. Unit 3 Coal Analyses

Sample Date/Time (CT)	Total Moisture, %	Mercury, mg/kg dry basis	Wt. %, dry basis									Btu/lb, dry Basis
			Volatile Matter	Ash	Fixed Carbon	Total Carbon	Hydrogen	Nitrogen	Total Sulfur	Chlorine	Oxygen by difference	
7/20/06 10:05	6.16	0.553										
7/21/06 9:45	6.31	0.697	26.63	14.40	58.97	72.29	3.77	1.29	2.35	0.108	5.79	12,726
7/22/06 7:00	5.24	0.434										
7/23/06 8:00	5.04	0.461										
7/24/06 8:30	5.76	0.531										
7/25/06 8:00	5.32	0.407										
7/26/06 12:15	5.55	0.433	26.10	16.24	57.66	70.48	3.70	1.30	2.14	0.109	6.03	12,352
7/27/06 12:25	5.61	0.352										
7/28/06 7:55	5.72	0.354										
7/29/06 6:30	5.26	0.339	26.17	15.22	58.61	72.43	4.00	1.27	1.61		5.47	12,746
7/30/06 6:30	5.49	0.383										
7/31/06 8:15	5.42	0.444										
8/1/06 6:20	6.28	0.386	26.41	13.98	59.61	73.15	3.98	1.31	1.54	0.108	5.93	12,903
8/2/06 11:20	5.30	0.360	26.41	14.29	59.30	73.66	4.01	1.33	1.84		4.87	12,886
8/3/06 15:00	5.73	0.439										
8/4/06 7:50	5.78	0.456										
Average	5.6	0.44	26.3	14.8	58.8	72.4	3.9	1.3	1.9	0.11	5.6	12,723
Standard Deviation	0.38	0.092	0.21	0.91	0.75	1.21	0.15	0.02	0.35	0.00058	0.47	222

Table 3-6. ESP 1 and ESP 2 Fly Ash Analyses

Date	Sample Time (CT)	Injection Rate (lb/MMacf)	ESP No.	Field No.	Mercury (µg/g)	LOI (%)
Baseline						
7/21/06	14:00	0	1	5	0.465	4.5
			1	6	0.483	5.5
			1	1	0.864	5.5
			1	2	0.629	6.2
			2	1	1.20	9.9
			2	2	0.929	9.6
48-Hour HOK Injection at ESP 2 Inlet						
8/1/06	06:45	10.6	1	5	0.502	5.4
			1	6	0.443	5.6
			2	1	1.89	11.0
			2	2	1.64	11.2
8/1/06	14:15	10.6	1	5	0.557	5.4
			1	6	0.903	5.9
			2	1	1.81	11.1
			2	2	2.21	11.7
8/1/06	Average	10.6	1	5	0.53	5.4
			1	6	0.67	5.8
			2	1	1.85	11.0
			2	2	1.93	11.5

Mass balance results are shown in Table 3-7. Process stream flow rates used in the mass balance calculations were estimated based on plant process data or calculated as indicated in the table. All mercury vapor concentrations listed in Table 3-6 are at 3% oxygen levels. Baseline mercury balance closure for the entire plant was 75 percent indicating acceptable agreement between coal mercury levels and outlet levels measured in the ESP fly ashes and ESP outlet flue gas (SCEM). This mass balance indicates that approximately 16 percent of the mercury input with the coal was captured in the ESP 1 and ESP 2 fly ashes during baseline conditions. Mercury balance closure for the ESP 2 system during the 48-hour HOK injection test was 76 percent also indicating reasonable agreement between the inlet flue gas measurements (SCEM) and outlet levels measured in the ESP 2 fly ash and outlet flue gas (SCEM).

Table 3-7. Unit 3 – Mercury Mass Balance Results for Baseline Characterization (7/19 – 7/22/06) and 48-Hour HOK Injection (7/30 – 8/1/06)

Stream	Flow Rate	Mercury Concentration [c]	Mercury Rate (g/hr)
Baseline Characterization Period			
Coal [a]	104,000 dry lb/hr	0.44 dry µg/g	20.9
ESP 2 Outlet Vapor [a] (SCEM)	6,700 dry Nm^3/min	31 µg/ Nm^3	12.5
ESP 2 Outlet Particulate [a, b] (M17)	6,700 dry Nm^3/min	0.042 µg/Nm^3	0.02
ESP 1 and 2 Captured Fly Ash [d]	12,370 lb/hr	0.59 µg/g	3.3
Mass Balance Around Boiler and ESP 1 and 2 System			
		Boiler/ESP In	20.9
		Boiler/ESP Out	15.8
		Closure [e]	75 %
48-Hour HOK Injection across ESP 2			
ESP 2 Inlet Vapor [a] (SCEM)	6,700 dry Nm^3/min	19.5 µg/ Nm^3	7.8
ESP 2 Inlet Particulate [a, f] (M17)	6,700 dry Nm^3/min	1.2 µg/Nm^3	0.5
ESP 2 Outlet Vapor [a] (SCEM)	6,700 dry Nm^3/min	10.3 µg/ Nm^3	4.1
ESP 2 Outlet Particulate [a, g] (M17)	6,700 dry Nm^3/min	0.031 µg/Nm^3	0.01
ESP 2 Captured Fly Ash [h]	2,475 lb/hr	1.89 µg/g	2.1
Mass Balance Around ESP 2 System			
		ESP 2 In	8.3
		ESP 2 Out	6.2
		Closure [e]	76 %

[a] Estimated flow rates based on 175 MW, plant gross heat rate 7,620 Btu/KW-hr, standard F-factor for bituminous coal of 11,419 dscf/MMBtu @ 3% oxygen and average measured coal properties as shown in Table 3-5.

[b] Particulate loading based on single-point M17 measurements (0.016 gr/dscf). ESP 2 outlet particulate mercury composition assumed to be equal to the measured mercury composition of the ash collected in ESP 2 (1.06 dry µg/g).

[c] Vapor phase mercury vapor concentrations at 3% oxygen content.

[d] Estimated ash flow rates based 80/20 fly ash to bottom ash split. Bulk ash mercury composition for the combined ESP 1 and ESP 2 ash estimated based on analysis of the individual ESP field hoppers for ESP 1 and ESP 2, assuming 80% of ash is captured in ESP 1 and 20% is captured in ESP 2.

[e] Closure (%) = (Out/In) x 100

[f] Particulate loading based on single-point M17 measurement at ESP 2 inlet on 8/1/06 (0.985 gr/dscf). ESP 2 inlet particulate mercury composition assumed to be equal to the measured mercury composition of the ash collected in ESP 1 (0.47 dry µg/g).

[g] Particulate loading based on single-point M17 measurements during HOK injection (0.027 gr/dscf). ESP 2 outlet particulate mercury composition assumed to be equal to the measured mercury composition of the ash collected in ESP 2 (1.89 dry µg/g).

[h] Estimated ash flow rates based 80/20 fly ash to bottom ash split with 20% being captured in ESP 2.

3.7 Effect of Carbon Injection on ESP Operation

The injection of activated carbon upstream of an ESP has the potential to impact the operation of the ESP. The additional particulate loading can challenge the ESPs' performance. Increased loading can cause increased sparking in the first electrical field of the ESP that in turn reduces the power available to maintain electrostatic collection. The reduced performance of the first field "loads-up" the second field downstream and so forth, ultimately resulting in an overall reduction of ESP collection efficiency. In addition, the electrical characteristics of the added particulate matter can impact the ESP performance, yielding either a positive or negative result. Since the ESP is an electrical device, changing the electrical properties of the flue gas medium will affect ESP performance. Carbon is a conductive material and hence reduces the resistivity of the flue gas ash. However, as it rapidly picks-up the electrostatic charge and increases secondary current, it also gives-up its charge at the collecting plate and has a tendency to easily re-entrain into the flue gas during plate rapping thus "skipping" from collecting plate to collecting plate. As the carbon content of the flue gas ash increases, there is the potential for an increase in outlet particulate emissions caused by the carbon particles passing through the ESP as well as scouring ash off of collecting plates. In cases where an ESP operates at a high resistivity level the addition of carbon (in optimum amounts) may lower the ash resistivity and actually enhance ESP performance.

For ESPs that do not have digital controls, there is the potential to damage and ultimately break the emitter electrodes (wires) in the ESP. The increased sparking from the injection of particulate causes electrical erosion of the wire and will increase the chance of breakage. The broken wire will groundout the ESP electrical field and potentially cause an emissions violation (opacity). Digital controls currently available on many ESP systems control secondary current spikes much quicker thus eliminating wire breakage due to sparking. The Shawville Unit 3 ESPs use digital controls hence the concern for wire breakage is greatly reduced.

As shown in Figure 3-13, Shawville Unit 3 has two ESPs in series each fed by separate gas trains designated as Train A and Train B. The ACI test program at Shawville Unit 3 included injecting activated carbon sorbents upstream of ESP 1 and/or upstream of ESP 2 on Train A. There are "dust level index" monitors located in the ductwork downstream of ESP 2 for both Train A and Train B, designated by the plant as "Dust 3A" and "Dust 3B." As part of the ACI test program, single-point Method 17 particulate loading measurements were periodically conducted downstream of ESP 2 on gas Train A. Instantaneous readings from the in-duct dust monitors and key electrical readings from each field of the ESP 1 and ESP 2 system were also recorded by plant personnel at 2-hour intervals during the ACI test program.

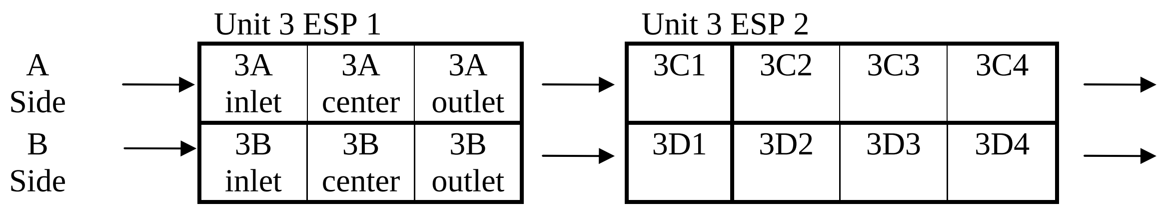


Figure 3-13. Electrical Fields for Shawville Unit 3 ESP 1 and ESP 2 Systems

To characterize the impact of sorbent injection on ESP performance, the electrical readings at the inlet fields of both ESPs and the outlet field of ESP 2 were analyzed. The data used for the ESP performance analysis included the average primary power (kw) and the spark rate (spark per minute, SPM). In addition, data obtained from the two dust monitors and the single-point Method 17 samples were analyzed. In each case, operating parameter values during baseline conditions were compared to values during the various sorbent injection tests to determine if there were significant changes in ESP field power and spark rate, or changes in flue gas particulate loading downstream of ESP 2.

Summary of Findings

ESP performance is affected by many factors. Coal type and quality affects the resistivity and ash loading to the ESP. Flue gas temperature affects ash resistivity. Boiler load and performance, air-in leakage, carbon carry-over (LOI) all effect ESP performance. It is difficult to positively identify which constituent is driving the ESP performance at any given time. For the Shawville ACI test, the available ESP performance data was limited to the electrical readings, unit load, outlet duct monitor and single-point Method 17 data. As such, this analysis is based on comparison of operational parameters during sorbent injection with operational parameters during baseline conditions for both the A and B gas trains.

From the ESP electrical data, it is apparent there is a native difference between the A and B gas trains and ESPs. Typically, the Train B ESPs operated at higher power levels and lower spark rates than Train A ESPs. However, Train B reads a higher dust level index than Train A. The dust index monitors are used to monitor relative changes in duct particulate levels within a given duct and are not intended to be compliance monitors; therefore, the difference in dust index between the two monitors may not be indicative of a true difference in outlet flue gas particulate levels between the A and B ducts. If the calibration of the dust monitors is sufficient to allow a ditect comparison between ducts, then clearly there are other parameters involved that may define the differences in these ESPs. It could be air in-leakage at hoppers on the B Train or a higher LOI ash on the B side. This information was not available. It is known that both Train A and Train B ESPs operate at approximately the same gas temperature (300˚F) so the ash resistivity is expected to be similar for both ESP systems.

As sorbents are introduced into the gas stream, they can either load-up the ESP and cause severe spark–down of power or can modify the resistivity of the ash. Either of these conditions can negatively impact electrical conditions. However, depending on the size and configuration of the ESP, the outlet emissions may or may not correlate directly with the electrical operating parameters. An ESP may have sufficient design margin to suffer through challenging conditions such as a powered-down electrical field. So while it is always good as a first cut to consider the impact on ESP electrical parameters, the real impact is the outlet particulate matter emissions or opacity.

Figure 3-14 provides a comparison of the various Method 17 single point particulate matter concentrations measured at the ESP 2 outlet location for baseline and sorbent injection tests. Data points are distinguished by both injection location and sorbent type. The 95% confidence interval (CI) for the measured baseline concentrations is show by the shaded region on the figure. The following general observations can be made regarding the impact of ACI on ESP performance at Shawville Unit 3 based on data shown in Figure 3-14 and analysis of other ESP operational data:

1. Particulate matter concentrations in the ESP 2 outlet generally increased with increasing sorbent injection rate for nearly every sorbent type tested.
2. Federal PSD/NSR review is triggered when there is an increase of 25 tons/year of total particulate matter (PM) or more, or an increase of 15 tons/year or more of PM10 per project per site. Use of sorbent injection for Shawville Unit 3 could potentially result in an emission increase greater than these limits that would trigger NSR requirements. For Unit 3, an increase in total particulate concentration of approximately 0.0028 grains/dscf corresponds to a 25-ton/year increase in emissions. For example, using the data shown in Figure 3-14 for the 48-hour HOK injection test, the estimated increase in particulate emissions is about 80 tons/year using the highest measured baseline particulate concentration of 0.02 grains/dscf and the highest measured particulate concentration of 0.0293 grains/dscf from the 48-hour injection test.

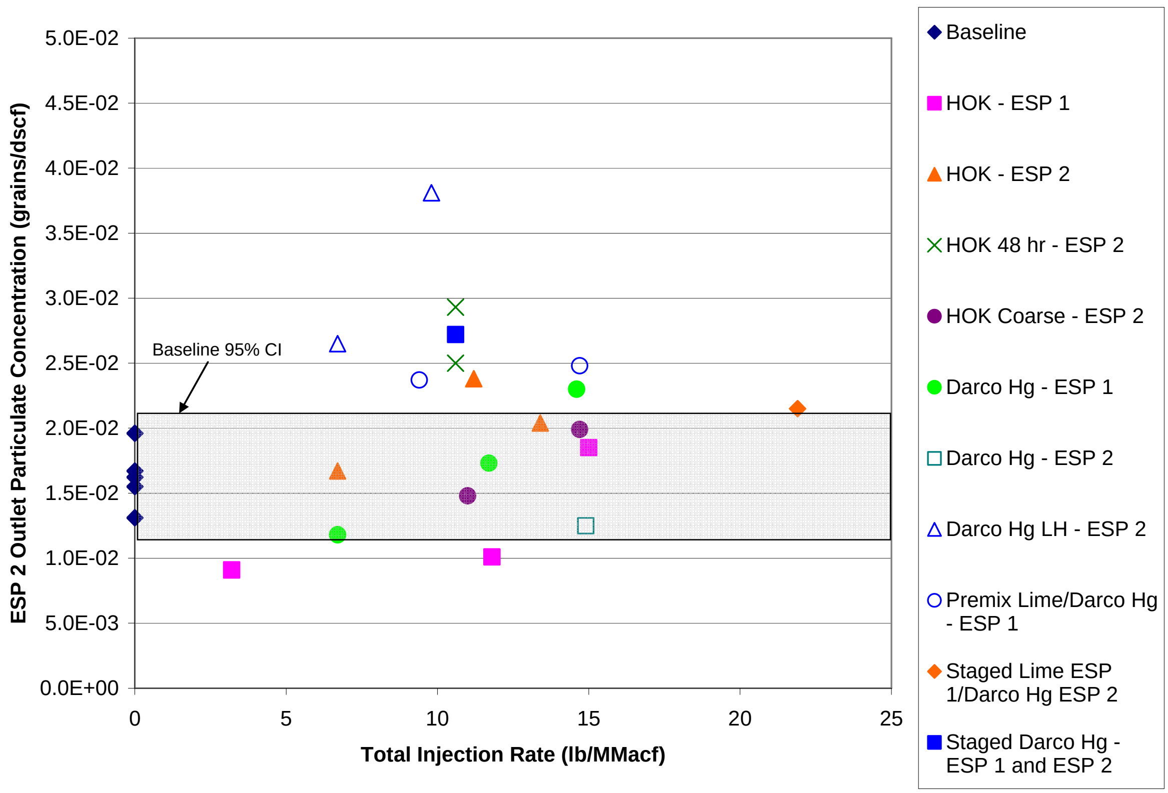


Figure 3-14. ESP 2 Outlet Particulate Matter Concentrations as Measured by Single-Point Method 17

3. Sorbents injected at the inlet of ESP 1, at rates less than approximately 11 lb/MMacf did not adversely affect particulate loading at the ESP 2 outlet (as measured by single-point Method 17 and in-duct dust index monitors) when compared to baseline conditions.

4. Most sorbents injected upstream of ESP 2 caused a negative impact on ESP 2 outlet particulate loading. Although the ESP inlet field (3C1) and outlet field (3C4) electrical data did not indicate a problem, there was a negative impact on particulate loading indicated by both the Method 17 and the in-duct dust monitor index data.

5. Injection of lime in combination with Darco Hg carbon caused a negative impact on ESP 2 outlet particulate loading for both the staged ESP 1/ESP 2 injection configuration and the premixed ESP 1 injection configurations. Although injection of lime enhanced the mercury removal performance of the ESPs by reducing flue gas SO_3 levels, it appeared to have a negative effect on particulate loading at the ESP 2 outlet. The presence of SO_3 can have a positive conditioning effect on ESP systems by reducing the fly has resistivity. Thus, a reduction in SO_3 levels as a result of lime injection can result in reduced particulate removal performance within ESP systems. This has been observed in other SO_3 control projects using lime injection. Alternative reagents, such as Trona or sodium

bisulfite (SBS), can be injected to control SO_3 levels without adversely affecting the resistivity properties of the fly ash.

5. During carbon injection upstream of ESP 1 or upstream of ESP 2, spark rates and power levels for the inlet field of each ESP were not significantly impacted compared to baseline conditions.

6. During sorbent injection upstream of ESP 2, decreased power levels relative to baseline were observed in the outlet field of ESP 2 (field 3C4) for many of the carbons and injection rates tested. However, corresponding spark rates for the ESP 2 outlet field did not appear to increase as might be expected with decreased power levels.

Given the short-term parametric nature of the injection tests for this program and the limitations posed by using a relatively small number of instantaneous readings for ESP operational data, additional longer-term injection testing with more frequent monitoring of ESP operational parameters would be required to fully understand the impact of ACI on performance of the Shawville Unit 3 ESP systems. Additional ACI testing in conjunction with alternative reagents for SO_3 control may also be warranted.

Details of the data analysis are presented in Appendix E.

3.8 Activated Carbon Injection Process Economics

A primary objective of this test program has been to develop the information required to predict activated carbon usage for a future full-scale installation. Based on the data collected at Shawville Unit 3, process costs specific to Unit 3 were estimated.

The economics have been developed for a single, hypothetical 175-MW plant that fires medium-sulfur eastern bituminous coal and is located in the Eastern U.S. The plant is equipped with dual small-SCA ESPs in series. The characteristics of the plant are summarized in Table 3-8.

Table 3-8. Process Parameters for Hypothetical Plant

Parameter	Value
Coal Type	Eastern Bituminous
Environmental Controls	Dual Small-SCA ESP in series, no SO_2 controls
Gross Unit Load	175 MW
Gross Heat Rate	7,620 Btu/kW-hr
Unit Capacity Factor	0.80
Flue Gas Temperature at ESP 1 Inlet	280°F
Flue Gas Flow Rate at ESP Inlet	660,000 acfm
Vapor Phase Hg Concentration at ESP 1 Inlet	30 µg/Nm^3 at 3% O_2
Baseline Hg Removal across ESP 1	22%
Baseline Hg Removal across ESP 2	5%
Baseline Hg Removal across Combined ESP 1/ESP 2	26%
Vapor Phase Hg Concentration at ESP Outlet	22 µg/Nm^3 at 3% O_2

The mercury concentrations and removals measured at Shawville Unit 3 were used to develop the baseline mercury profile for the hypothetical plant. Variations in the baseline mercury profile were measured for the Unit 3 ESP 1 so average operating values for each ESP system were used. In cases where the baseline ESP outlet concentration was higher than the ESP inlet concentration, a removal of zero was used in the calculation of the average value. An ESP 1 inlet vapor phase mercury concentration of 30 µg/Nm^3 (at 3% O_2) and average baseline removals of 22% and 5% vapor phase mercury across the ESP 1 and ESP 2 were assumed, respectively. Based on these assumptions, the ESP 2 outlet vapor phase mercury concentration for the theoretical plant would be 22 µg/Nm^3.

The cost assumptions associated with the capital equipment and the activated carbons are summarized in Tables 3-9 and 3-10. The capital equipment cost was estimated for different injection rate scenarios. All scenarios assume a single injection point located upstream of the first ESP. Staged carbon injection was not considered in the cost estimates since this configuration did not appear to offer any significant advantage in terms of mercury reduction for the Shawville Unit 3 ESP system. For the lime/carbon injection scenarios, the activated carbon was assumed to be DARCO Hg, since this was the only carbon tested in combination with lime injection. A capital cost of $1.3M was assumed for all of the carbon-only injection scenarios based on "study-level" capital cost estimates developed previously by the U.S. DOE for 6 plants where activated carbon injection has been tested [1]. The average capital cost for the 6 plants examined in the DOE study, ranging in size from 100 MW to 360 MW, was $1.3 MM for mercury removals in the range of 50% to 90%. For the lime/carbon case, a cost factor of 1.5 was

[1] *DOE/NETL's Phase II Mercury Control Technology Field Testing Program — Preliminary Economic Analysis of Activated Carbon Injection. April 2006.*

applied to the carbon-only case to account for the potential added capital cost for additional storage and feeder/injection equipment associated with lime injection. The details of the capital cost calculation are shown in Table 3-11.

Table 3-9. Cost Assumptions for Economic Analysis

Parameter	Value
New Plant Equipment Economic Life	15
New Plant Equipment Capital Recovery Factor	0.12
Activated Carbon Delivery Cost	$0.15/ton/mile
Hydrated Lime Delivery Cost	$0.15/ton/mile

Table 3-10. Cost Assumptions for Activated Carbons and Other Reagents

Reagent Name	Manufacturer	Bulk Reagent Cost ($/lb f.o.b.)[a]	Shipping Point	Distance to Plant from Shipping Point (miles)
Super HOK	RWE Rheinbraun	$0.29	Savannah, GA	780
DARCO Hg	Norit Americas	$0.50	Marshall, TX	1270
DARCO Hg-LH	Norit Americas	$0.85	Marshall, TX	1270
Hydrated Lime	Chemical Lime	$95/ton	Undefined	700

[a] Carbon prices as of December 14, 2006

Table 3-11. Estimated Capital and Reagent Costs for Various ACI Scenarios

	Units	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Target Total Vapor-Phase Mercury Reduction [a]	%	50	70	85 [b]	50	50 [b]	50	70
Reagent(s)		DARCO Hg	DARCO Hg	DARCO Hg	DARCO Hg-LH	HOK	DARCO Hg/Lime	DARCO Hg/Lime
Injection Location		ESP 1 Inlet	ESP 1 Inlet	ESP 1 Inlet	ESP 1 Inlet	ESP 1 Inlet	ESP 1 Inlet	ESP 1 Inlet
Carbon Injection Rate (lb/MMacf)	lb/MMacf	6	9.5	12	6	12	3.8	5.5
Lime Injection Rate (lb/MMacf)	lb/MMacf	0	0	0	0	0	6.4	9.2
Carbon Feed at Full Load	lb/hr	247	392	495	247	495	157	227
Lime Feed at Full Load	lb/hr	0	0	0	0	0	264	379
Annual Carbon Cost	$	$1,032,425	$1,634,673	$2,064,850	$1,639,479	$1,208,904	$598,945	$946,390
Annual Lime Cost	$	0	0	0	0	0	$185,007	$265,947
Total Capital Equipment Cost	$	$1,298,500	$1,298,500	$1,298,500	$1,298,500	$1,298,500	$1,947,750	$1,947,750
Capital Equipment Amortization	$/yr	$133,697	$133,697	$133,697	$133,697	$133,697	$200,546	$200,546
Total First Year Cost	$	$1,166,122	$1,768,370	$2,198,548	$1,773,176	$1,342,602	$984,498	$1,412,883
Normalized First Year Cost	$/lb reduced	$15,127	$16,385	$16,776	$23,001	$17,416	$12,771	$13,091

[a] Estimated percent mercury reduction at the ESP 2 outlet as the specified injection rate based on results of the present parametric testing program.

[b] Represents the maximum mercury reduction achieved for the carbon during the present test program.

[c] First year cost = annual reagent costs plus capital equipment amortization.

[d] Cost per pound of mercury reduction at the ESP 2 outlet.

According to the NETL Solicitation DE-PS26-03NT41718 (Large-scale Mercury Control Technology Field Testing Program – Phase II), the minimum mercury control percentage was specified as 80% for bituminous coal. This percentage represents a mercury removal increase beyond the "baseline" removal for the plant being considered. The minimum mercury control objective of 80% was only achieved for the DARCO Hg carbon which exhibited a maximum mercury reduction of 85% at an injection rate of 12 lb/MMacf. Beyond this injection rate, a plateau in performance was observed.

The ACI mercury reduction performance data, shown in Figure 3-15, were used to estimate the amount of carbon needed to achieve a specified mercury reduction at the ESP 2 outlet. Three specified vapor-phase mercury reductions were evaluated: 50%, 70%, and 85%. Cases 1 through 3 were included in the analysis for the DARCO Hg carbon at target reduction values of 50%, 70%, and 85% to cover the approximate range of injection rates and vapor-phase mercury reduction values from the Shawville test program. Performance data for the DARCO Hg-LH were comparable to that of the DARCO Hg carbon, so a single scenario, Case 4, was selected at the 50% mercury reduction target. A single cost scenario, Case 5, was included for the Super HOK carbon which exhibited a maximum mercury reduction of approximately 50% at an injection rate of 12 lb/MMacf. The final scenarios, Cases 6 and 7 are for the lime/DARCO Hg reagent mixture. Target reduction value of 50% and 70% were chosen for these scenarios to provide cost comparisons for the DARCO Hg 50% and 70% reduction target scenarios (Cases 2 and 3).

The annual reagent (carbon and lime) cost and installed capital cost for each control scenario were then calculated, using the assumed parameters from the above tables. The results presented here are "first-year" costs, meaning that reagent costs are presented in 2006 dollars while capital costs have been amortized over fifteen years.

Figure 3-16 shows the annual cost of the carbon injection process for the three tested carbons to achieve a targeted mercury reduction of 50%, assuming injection upstream of ESP 1. The annual cost is composed of three components: the reagent cost(s), transportation for the reagent(s), and capital equipment amortization. Other annual operating and maintenance costs are not included, and would be expected to be small relative to the annual cost for the reagents. For all of the carbon-only scenarios, the carbon accounts for more than 75% of the total annual cost. For the lime/carbon scenario, reagent costs (lime plus carbon) are approximately 60% of the total annual cost.

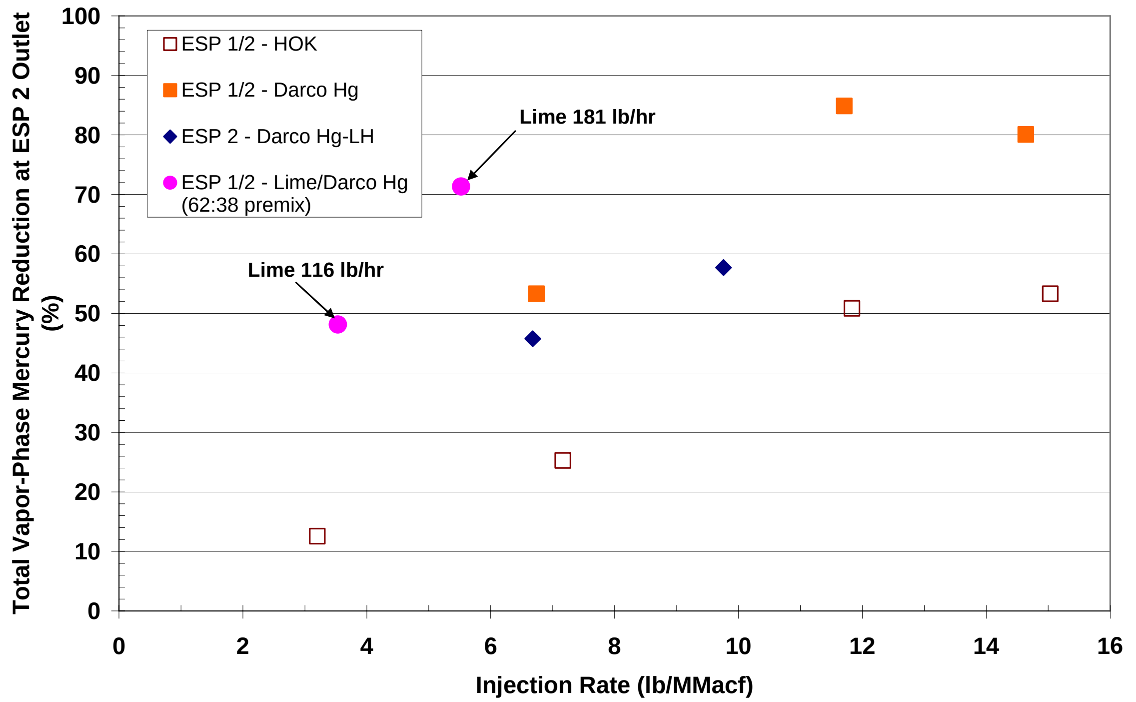


Figure 3-15. Mercury Reduction Performance Curves used for Cost Estimation

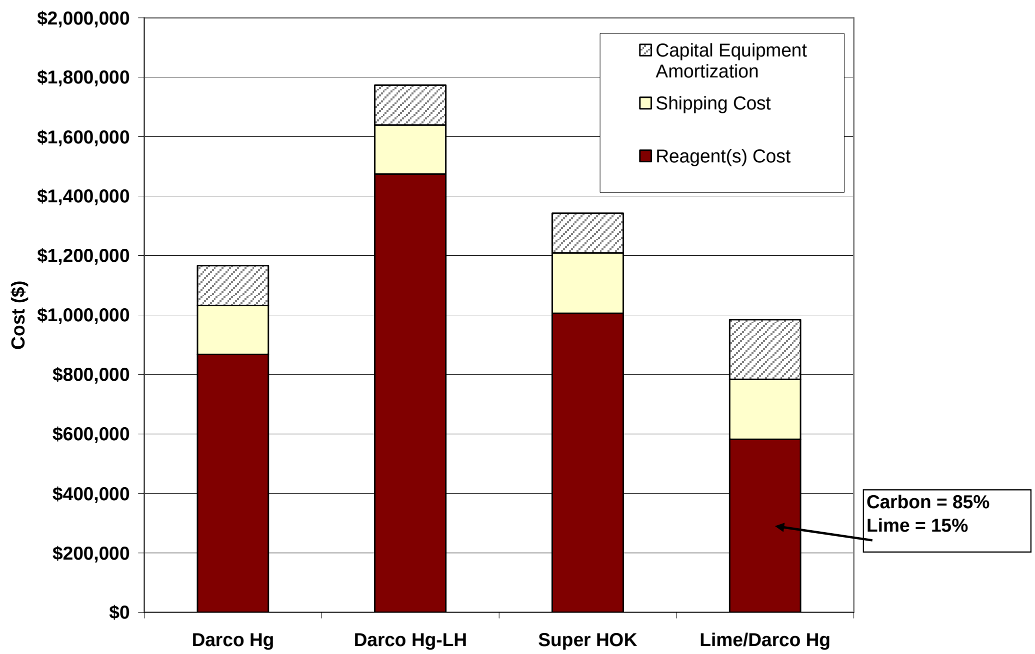


Figure 3-16. Annual Cost for Sorbent Injection Process Upstream of ESP 1 to Achieve a Targeted 50% Reduction in ESP 2 Outlet Mercury Concentration

For a control level of 50% the DARCO Hg-LH carbon has the highest annual cost at $1.8M, which is 1.4 to 1.8 times the cost of the other sorbents tested. This is because it has the highest unit sorbent cost, while its mercury removal performance was comparable to the DARCO Hg carbon. The annual cost for a 50% mercury reduction using the DARCO Hg carbon is $1.2M and the annual cost for the Super HOK was $1.3M. The lowest estimated cost was obtained for the lime/DARCO Hg mixture at $1.0M, since carbon injection rates are reduced from 6 lb/MMacf for DARCO Hg only to 3.8 lb/MMacf for the lime/DARCO Hg mixture. For the lime/carbon scenario, 85% of the total annual reagent cost is associated with the carbon and 15% is associated with the lime.

Figure 3-17 shows the annual cost for the sorbents at various mercury control levels, in terms of $/lb Hg reduction at the ESP 2 outlet. The cost for mercury control is reported in dollars per pound of mercury removed by the ACI process, which does not include mercury removed naturally by the ESPs. The total normalized annual costs for achieving mercury reductions up to 50% is less than $20,000/lb Hg removed for all sorbents except the DARCO Hg-LH. Normalized costs for achieving 85% reduction using DARCO Hg were approximately $17,000/lb Hg removed. Data from the parametric test program for lime/DARCO Hg carbon injection upstream of ESP 1 at a 62:38 weight percent ratio suggest that normalized costs in the range of $13,000/lb reduced are possible for mercury reductions between 50% to 70% percent.

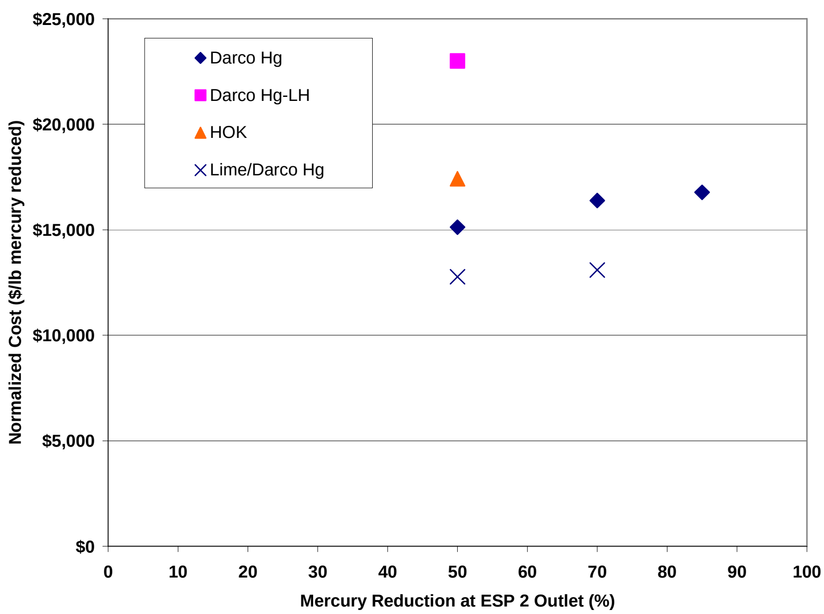


Figure 3-17. Normalized Cost of the Sorbent Injection Process Upstream of ESP 1 for the Various Sorbents Tested in the Shawville Unit 3 Program ($/lb mercury reduction by ACI)

4.0 Conclusions and Recommendations

A sorbent injection test program was conducted at Reliant Energy's Shawville Unit 3. Tests consisted of both activated carbon and lime/activated carbon injection at various injection point locations for the combined ESP 1/ESP 2 system, and a longer term 48-hour injection test for ESP 2. The purpose of the parametric tests was to compare the mercury removal efficiencies of various sorbents added over a range of injection rates. The purpose of the longer-term test was to evaluate the variability in mercury removal performance over an extended period of time and to collect data about the balance of plant impacts of sorbent injection.

Three different sorbents were evaluated in the parametric test program for the combined ESP 1/ESP 2 system in which sorbents were injected upstream of ESP 1: RWE Rheinbraun's Super HOK, Norit's DARCO Hg, and a 62:38 hydrated lime/DARCO Hg mixture. Five different sorbents were evaluated for the ESP 2 system in which activated carbons were injected upstream of ESP 2: RWE Rheinbraun's Super HOK and coarse-ground HOK, Norit's DARCO Hg and DARCO Hg-LH, and DARCO Hg with lime injection upstream of ESP 1. Analysis and interpretation of the data collected at Shawville Unit 3 support the following conclusions and recommendations:

Conclusions

- Based on the current data and observations from this test program, the most favorable option for mercury removal at Shawville Unit 3 appears to be injection of Darco Hg carbon upstream of ESP 1. For this sorbent, approximately 80% removal of vapor-phase mercury across the combined ESP 1/ESP 2 system can be expected at an injection rate 11 lb/MMacf without impacting ESP performance. This corresponds to overall coal-based mercury removal of approximately 92% to 96% for the range of measured coal mercury concentrations during the test program (0.34 µg/g to 0.7 µg/g, dry basis). For higher injection rates, or other configurations such as injection upstream of ESP 2 or staged injection the impact on particulate matter emissions may become significant. The cost analysis for ACI in combination with lime injection indicated this was potentially a lower cost option; however, significant impacts on PM emissions were indicated. Additional testing may identify other reagents to reduce SO_3 levels but not result in an increase in PM emissions, and if viable, the use of these reagents in combination with ACI could potentially provide a lower cost mercury control option.
- Baseline (i.e., native) mercury removal varied significantly from day to day, particularly for ESP 1, where initial baseline removals of 5-10% were indicated; however, baseline removals for subsequent test days were in the range of 20-40%.

Baseline mercury removal for ESP 2 was low, approximately 5%, presumably due to the lower flue gas particulate loading at the ESP 2 inlet.

- For the ACI tests on the combined ESP 1/ESP 2 system, the highest percent mercury removal (87%) was measured for the DARCO Hg at an injection rate of 11.7 lb/MMacf. Removal performance appeared to plateau at higher injection rates. By comparison, the percent mercury removal for the HOK carbon across the combined ESP 1/ESP 2 system at the same injection rate was 56 percent.
- No significant difference in percent mercury removal was observed between the DARCO Hg and DARCO Hg-LH carbons for ESP 1 or ESP 2, indicating the brominated carbon does not offer a mercury removal advantage in this Eastern bituminous flue gas matrix. Both carbons showed a plateau in mercury removal beyond an injection rate of approximately 12 lb/MMacf.
- Mercury reduction performance for carbons injection across ESP 1 and across ESP 2 were not significantly different, indicating that the larger SCA of the ESP 2 system did not have a significant impact on mercury removal performance of the carbons.
- All of the mercury removal observed for the combined ESP 1/ESP 2 systems occurred across the first ESP for baseline tests, and for both the DARCO Hg and HOK carbons.
- Injection of premixed hydrated lime/DARCO Hg upstream of ESP 1 resulted in a reduction in flue gas SO_3 levels and improved mercury removal performance at both carbon injection rates tested (3.5 and 5.5 lb/MMacf). The 72% mercury reduction at the ESP 2 outlet for the premix injection upstream ESP 1 at 5.5 lb/MMacf was comparable to that for injection of DARCO Hg only at a rate of nearly 11 lb/MMacf.
- Lime injection upstream of ESP 1 reduced the SO_3 levels in the flue gas, resulting in improved mercury removal performance for the DARCO Hg carbon when injected upstream of ESP 2. The improvement in percent mercury removal was more pronounced at the lower carbon injection rates (4.9 lb/MMacf): mercury reduction with 200 lb/hr lime injection was 65% compared to 40% with no lime injection upstream of ESP 1.
- PM emissions increased during co-injection of lime and activated carbon. While adding lime significantly improved ACI performance, this may not be feasible at Shawville Unit 3 unless the ESPs can be upgraded.
- Operation of the SNCR system did not have a significant impact on the baseline SO_3 concentrations measured at the ESP 2 outlet; all baseline SO_3 levels were low, in the range of 1.6 to 1.7 ppmv.
- Particulate emission data and ESP operational data suggest that carbon injection may adversely impact particulate emissions from Unit 3 ESPs, particularly when injected upstream of ESP 2.

Recommendations

- To achieve vapor phase mercury removals with ACI across the ESP of greater than 80% for Shawville, additional approaches may need to be considered.
  - On-site grinding of carbon reagents to reduce the particle size and reduce agglomeration prior to injection;
  - Optimize injection locations and nozzle configurations through CFD modeling; and
  - Test alternate SO_3 removal reagents such as Trona and SBS in combination with ACI.
- A longer term ACI test should be conducted for Unit 3 to monitor impacts on ESP operational performance over a 3 or 4 week period.
- ACI should be used to treat the full ESP system (i.e., injection across both the "A-side" and "B-side") at Shawville Unit 3 and a full-traverse of the Unit 3 stack should be conducted to monitor small changes in stack particulate emissions which could not be captured with the single point Method 17 sampling system used in the current test program. This should help determine if ACI affects PM emissions and whether the ESPs needs to be upgraded if ACI was selected as a mercury compliance option.
- The impact of lime injection on fly ash resistivity and ESP particulate removal performance should be investigated.

Appendix A

CCS Results

July 25, 2006							
Coil ID	Coil 1	Coil 2	Coil 3				Impingers
Injection Parameters	Baseline	Baseline	Baseline				
Start Time (ET)	8:15	8:47	9:20				
End Time (ET)	8:45	9:17	9:51				
ppm SO_3 @ 3%O2	**1.60**	**1.60**	**1.97**				
ppm SO_2 @ 3%O2							**1,331**

July 26, 2006							
Coil ID	Coil 1	Coil 2	Coil 3				Impingers
Injection Parameters	Baseline	Baseline	Baseline				
Start Time (ET)	8:01	8:35	9:07				
End Time (ET)	8:31	9:05	9:37				
ppm SO_3 @ 3%O2	**2.05**	**1.61**	**1.32**				
ppm SO_2 @ 3%O2							**1,428**

July 26, 2006							
Coil ID	Coil 1	Coil 2					Impingers
Injection Parameters	Premix 3.5 lb/MMacf carbon + 116 lb/hr lime	Premix 3.5 lb/MMacf carbon + 116 lb/hr lime					
Start Time (ET)	13:50	14:23					
End Time (ET)	14:20	14:53					
ppm SO_3 @ 3%O2	**0.88**	**0.59**					
ppm SO_2 @ 3%O2							**1,524**

July 26, 2006							
Coil ID	Coil 1	Coil 2					Impingers
Injection Parameters	Premix 5.5 lb/MMacf carbon + 181 lb/hr lime	Premix 5.5 lb/MMacf carbon + 181 lb/hr lime					
Start Time (ET)	15:52	16:25					
End Time (ET)	16:22	16:55					
ppm SO_3 @ 3%O2	**0.58**	**0.60**					
ppm SO_2 @ 3%O2							**1,386**

August 2, 2006							
Coil ID	Coil 1	Coil 2	Coil 3	Coil 4	Coil 5	Coil 6	Impingers
Condition	50 lbs/hr Lime	100 lbs/hr Lime	50 lbs/hr Lime + 3.8 lbs/MMacf DARCO Hg	50 lbs/hr Lime + 3.8 lbs/MMacf DARCO Hg	50 lbs/hr Lime + 7 lbs/MMacf DARCO Hg	50 lbs/hr Lime + 7 lbs/MMacf DARCO Hg	
Start Time (ET)	9:50	11:05	12:10	13:15	14:25	15:30	
End Time (ET)	10:50	12:05	13:10	14:15	15:25	16:00	
ppmv SO_3 @ 3% O2	**0.90**	**0.74**	**0.52**	**0.54**	**0.49**	**0.50**	
ppmv SO_2 @ 3% O2							**1,370**
August 3, 2006							
Coil ID	Coil 1	Coil 2	Coil 3	Coil 4	Coil 5	Coil 6	Impingers
Condition	Basleine SNCR Off	Baseline SNCR Off	SNCR Off + 4.8 lbs/MMacf DARCO Hg	SNCR Off + 4.8 lbs/MMacf DARCO Hg	SNCR Off + 100 lbs/hr Lime + 4.9 lbs/MMacf DARCO Hg	SNCR Off + 200 lbs/hr Lime + 4.9 lbs/MMacf DARCO Hg	
Start Time (ET)	11:00	11:35	12:50	13:25	14:35	16:45	
End Time (ET)	11:30	12:05	13:20	13:55	15:35	17:45	
ppmv SO_3 @ 3% O2	**1.50**	**1.89**	**1.15**	**1.07**	**0.57**	**0.31**	
ppmv SO_2 @ 3% O2							**1,330**

Appendix B

Method 17 Particulate Matter Data

Sorbent	Carbon (lb/MMacf)	Lime (lb/hr)	Date	Start (ET)	End (ET)	Mass per sample Grams	Mass per sample grains	Sample Volume (dscf)	O_2 (%)	Concentration (gr/dscf @ 3% O_2)
1 – BL	0	0	7/20/2006	16:36	18:02	0.0344	5.31E-01	285562	9.0	1.96E-02
2 - BL	0	0	7/21/2006	7:52	8:52	0.0218	3.36E-01	270462	9.2	1.31E-02
3 - BL	0	0	7/21/2006	9:59	10:59	0.0308	4.75E-01	287223	8.2	1.67E-02
1 - HOK C1	3.2	0	7/22/2006	10:51	11:51	0.0169	2.61E-01	293520	8.8	9.09E-03
HOK 9 lbs	11.8	0	7/22/2006	14:48	15:48	0.0203	3.13E-01	291794	8.2	1.01E-02
DARCO HG C1	6.7	0	7/23/2006	16:02	17:02	0.0209	3.23E-01	257132	8.0	1.18E-02
Baseline	0	0	7/24/2006	11:27	12:27	0.0216	3.33E-01	240739	10.5	1.55E-02
DARCO Hg 9 lbs	11.7	0	7/24/2006	15:18	16:18	0.0263	4.06E-01	250582	10.0	1.73E-02
HOK 12 lbs	15	0	7/25/2006	11:06	12:06	0.0302	4.66E-01	242871	9.0	1.85E-02
DARCO 12 lbs	14.6	0	7/25/2006	15:31	16:31	0.0347	5.36E-01	251606	10.0	2.30E-02
Carbon-Lime Premix 8 lbs.	3.5	116	7/26/2006	12:30	13:30	0.0373	5.76E-01	249625	9.5	2.37E-02
Carbon-Lime Premix 12 lbs.	5.5	181	7/26/2006	17:12	18:12	0.0427	6.59E-01	248324	8.5	2.48E-02
DARCO Hg LH 6 lbs.	6.7	0	7/27/2006	10:35	11:35	0.0454	7.01E-01	248005	8.5	2.65E-02
DARCO Hg LH 9 lbs.	9.8	0	7/27/2006	14:30	15:30	0.0647	9.98E-01	246599	8.5	3.81E-02
HOK coarse 9 lbs	11.0	0	7/28/2006	11:02	12:05	0.0267	4.12E-01	257045	8.5	1.48E-02
HOK coarse 12 lbs	14.7	0	7/28/2006	14:24	15:27	0.0350	5.40E-01	251006	8.5	1.99E-02
HOK 6 lbs	6.7	0	7/29/2006	11:31	12:31	0.0303	4.68E-01	245942	8.0	1.67E-02
HOK 9 lbs	11.2	0	7/29/2006	15:05	16:05	0.0403	6.22E-01	244027	8.5	2.38E-02
HOK 12 lbs	13.4	0	7/30/2006	11:29	12:29	0.0356	5.49E-01	249716	8.5	2.04E-02
1 - HOK 9 lbs	10.6	0	7/31/2006	7:15	8:15	0.0430	6.64E-01	257009	8.5	2.50E-02
2 - HOK 9 lbs	10.6	0	7/31/2006	14:17	15:17	0.0504	7.78E-01	258074	8.5	2.93E-02
2- Baseline thimble (ESP 1 outlet) [a]	0	0	8/1/2006	11:05	12:05	1.6644	2.57E+01	243244	8.5	9.85E-01
1 – DARCO 9 lbs thimble (ESP 1 outlet) [a]	9.7	0	8/1/2006	14:00	15:00	2.1634	3.34E+01	242575	8.5	1.31E+00
DARCO Hg	14.9	0	8/4/2006	10:05	11:05	0.0222	3.43E-01	258569	8.0	1.25E-02
Lime/DARCO Hg	11.7	200	8/4/2006	13:30	14:30	0.0380	5.86E-01	258224	8.0	2.15E-02
DARCO Hg - Staged	10.6	0	8/4/2006	15:30	16:30	0.0478	7.38E-01	258052	8.0	2.72E-02

[a] Sample collected at the ESP 1 outlet location. All other samples collected as the ESP 2 outlet.

Appendix C

Flue Gas Mercury Data for Shawville Unit 3 Sorbent Injection Tests

Table C-1. SCEM Mercury Speciation Data for Shawville Unit 3 Tests

Data Avg. Start Time (CT)	Data Avg. End Time (CT)	Sorbent	SNCR	Carbon		Mercury Concentration, $\mu g/Nm^3$ at 3% O_2					
				Injection Point	Rate (lb/ MMacf)	Inlet ESP 1		Outlet ESP 1		Outlet ESP 2	
						Total	Elemental	Total	Elemental	Total	Elemental
7/19/2006 12:30	7/22/2006 7:39	Initial Baseline	ON	-	0	32.48	10.43	31.11	11.53	30.96	2.58
7/22/2006 9:00	7/22/2006 12:40	HOK	ON	ESP 1 inlet	3.2	29.69	11.91	20.01	9.78	22.57	2.91
7/22/2006 13:10	7/22/2006 16:45	HOK	ON	ESP 1 inlet	11.8	28.40	10.47	12.27	7.45	12.69	2.73
7/23/2006 8:50	7/23/2006 12:15	HOK	ON	ESP 1 inlet	7.17	31.78	10.60	16.88	8.83	16.80	5.78
7/23/2006 14:15	7/23/2006 16:21	DARCO Hg	ON	ESP 1 inlet	6.74	27.38	10.45	9.65	5.70	10.50	-
7/24/2006 12:06	7/24/2006 15:56	DARCO Hg	ON	ESP 1 inlet	11.7	25.50	9.79	5.62	3.55	3.30	-
7/25/2006 9:30	7/25/2006 12:23	HOK	ON	ESP 1 inlet	15.0	29.35	-	10.41	-	11.20	-
7/25/2006 13:45	7/25/2006 16:19	DARCO Hg	ON	ESP 1 inlet	14.6	23.74	8.70	4.54	3.20	4.34	3.72

Table C-2. Mercury Removal Performance Data for Shawville Unit 3 Sorbent Injection Tests

Data Avg. Start Time (CT)	Data Avg. End Time (CT)	Sorbent	SNCR (on/off)	Carbon		Lime			Total Vapor Phase Mercury (μg/Nm^3 at 3% O_2)			Total Vapor-Phase Mercury Removal (%)		
				Injection Pt.	Rate (lb/MMacf)	Injection Pt.	Rate (lb/hr)	Rate (lb/MMacf)	ESP 1 Inlet	ESP 1 Outlet	ESP 2 Outlet	ESP 1	ESP 2	Overall
7/19/06 12:30	7/22/2006 7:39	Comprehensive Baseline (entire period)	ON		0			0	32.48	31.11	30.96	4.22	0.51	4.70
7/20/2006 9:00	7/20/2006 11:00	Comprehensive Baseline (AM)	ON		0			0	31.78	27.91	28.19	12.2	-1.0	11.3
7/21/2006 9:00	7/21/2006 11:00	Comprehensive Baseline (AM)	ON		0			0	37.30	34.89	31.77	6.5	8.9	14.8
7/22/2006 7:56	7/22/2006 8:39	Daily Baseline	ON		0			0	30.72	25.50	25.81	23.5	-9.8	16.0
7/22/06 9:00	7/22/2006 12:40	HOK	ON	ESP 1 inlet	3.20			0	29.69	20.01	22.57	32.62	-12.81	23.99
7/22/06 13:10	7/22/2006 16:45	HOK	ON	ESP 1 inlet	11.83			0	28.40	12.27	12.69	56.80	-3.42	55.33
7/23/06 7:35	7/23/06 8:20	Daily Baseline	ON		0			0	34.37	26.56	22.49	22.9	15.3	34.7
7/23/06 8:50	7/23/06 12:15	HOK	ON	ESP 1 inlet	7.17				31.78	16.88	16.80	46.87	0.48	47.13
7/23/06 14:15	7/23/2006 16:21	DARCO Hg	ON	ESP 1 inlet	6.74			0	27.38	9.65	10.50	64.78	-8.90	61.64
7/24/06 7:58	7/24/2006 11:41	Daily Baseline	ON		0			0	30.14	23.58	21.77	21.8	7.6	27.7
7/24/06 12:06	7/24/2006 15:56	DARCO Hg	ON	ESP 1 inlet	11.71			0	25.50	5.62	3.30	77.97	41.32	87.07
7/25/06 7:34	7/25/2006 9:00	Daily Baseline	ON		0			0	30.30	24.53	21.80	19.0	11.1	28.0
7/25/06 9:30	7/25/2006 12:23	HOK	ON	ESP 1 inlet	15.03			0	29.35	10.41	11.20	64.53	-7.58	61.84
7/25/06 13:45	7/25/2006 16:19	DARCO Hg	ON	ESP 1 inlet	14.64			0	23.74	4.54	4.34	80.88	4.39	81.72
7/26/06 7:30	7/26/2006 11:00	Daily Baseline	ON		0			0	25.53	14.75	16.99	42.2	-15.1	33.5
7/26/06 11:33	7/26/2006 14:03	Lime/DARCO Hg Premix	ON	ESP 1 inlet	3.53	ESP 1	116	5.9	22.85	5.92	8.81	74.10	-48.84	61.45
7/26/05 14:34	7/26/2006 17:34	Lime/DARCO Hg Premix	ON	ESP 1 inlet	5.52	ESP 1	181	9.2	22.07	2.32	4.87	89.49	-109.9	77.93
7/27/06 7:30	7/27/2006 8:15	Daily Baseline	ON		0			0	-	21.65	17.98	-	17	-

Table C-2. (continued)

Data Avg. Start Time (CT)	Data Avg. End Time (CT)	Sorbent	SNCR (on/off)	Carbon		Lime			Total Vapor Phase Mercury (µg/Nm^3 at 3% O_2)			Total Vapor-Phase Mercury Removal (%)		
				Injection Pt.	Rate (lb/MMacf)	Injection Pt.	Rate (lb/hr)	Rate (lb/MMacf)	ESP 1 Inlet	ESP 1 Outlet	ESP 2 Outlet	ESP 1	ESP 2	Overall
7/27/06 8:49	7/27/2006 11:27	DARCO Hg-LH	ON	ESP 2 inlet	6.68			0	-	23.99	9.75	-	59.35	-
7/27/06 12:00	7/27/2006 16:03	DARCO Hg-LH	ON	ESP 2 inlet	9.76			0	-	23.67	7.60	-	67.89	-
7/28/06 7:30	7/28/2006 8:30	Daily Baseline	ON		0			0		18.12	21.62	-	-19.3	-
7/28/06 9:00	7/28/2006 11:45	HOK coarse	ON	ESP 2 inlet	11.04			0	-	18.47	16.09	-	12.85	-
7/28/06 12:15	7/28/2006 15:30	HOK coarse	ON	ESP 2 inlet	14.67			0	-	18.15	14.74	-	18.78	-
7/29/06 7:30	7/29/2006 8:30	Daily Baseline	ON		0			0	-	16.75	15.65	-	6.6	
7/29/06 9:00	7/29/2006 11:58	HOK	ON	ESP 2 inlet	6.68			0	-	15.76	12.07	-	23.43	-
7/29/06 12:30	7/29/2006 15:30	HOK	ON	ESP 2 inlet	11.22			0	-	13.99	7.86	-	43.83	-
7/30/06 8:30	7/30/2006 9:00	Daily Baseline	ON		0			0	-	15.22	17.96	-	-18.0	-
7/30/06 9:53	7/30/2006 11:34	HOK	ON	ESP 2 inlet	13.36			0	-	13.58	7.94	-	41.51	-
7/30/06 12:04	7/30/2006 16:30	HOK 48-hour	ON	ESP 2 inlet	10.80			0	-	15.14	9.81	-	35.19	-
7/30/06 16:30	7/31/2006 2:40	HOK 48-hour	ON	ESP 2 inlet	10.28			0	-	14.89	9.25	-	37.85	-
7/31/06 2:40	7/31/2006 11:50	HOK 48-hour	ON	ESP 2 inlet	10.34			0	-	17.67	10.93	-	38.11	-
7/31/06 11:50	8/1/2006 6:57	HOK 48-hour	ON	ESP 2 inlet	11.01			0	-	23.58	10.68	-	54.71	-
8/1/06 10:00	8/1/2006 12:00	Daily Baseline	ON		0			0	-	17.55	25.52		-44.3	
8/1/06 12:30	8/1/2006 14:36	DARCO Hg	ON	ESP 1 inlet	9.70			0	-	5.96	6.21	-	-4.26	-
8/2/06 8:25	8/2/2006 8:45	Daily Baseline	ON		0			0	-	16.51	18.49	-	-11.8	-
8/2/06 9:15	8/2/2006 10:00	Lime	ON		0	ESP 1 inlet	50	2.5	-	15.74	15.86	-	-0.73	-
8/2/06 10:30	8/2/2006 11:05	Lime	ON		0	ESP 1 inlet	100	5.1	-	15.04	15.71	-	-4.48	-
8/2/06 11:35	8/2/2006 13:15	Lime - DARCO Hg	ON	ESP 2 inlet	3.81	ESP 1 inlet	50	2.5	-	17.01	9.61	-	43.49	-

Table C-2. (continued)

Data Avg. Start Time (CT)	Data Avg. End Time (CT)	Sorbent	SNCR (on/off)	Carbon		Lime			Total Vapor Phase Mercury (μg/Nm³ at 3% O_2)			Total Vapor-Phase Mercury Removal (%)		
				Injection Pt.	Rate (lb/MMacf)	Injection Pt.	Rate (lb/hr)	Rate (lb/MMacf)	ESP 1 Inlet	ESP 1 Outlet	ESP 2 Outlet	ESP 1	ESP 2	Overall
8/2/06 13:45	8/2/2006 15:00	Lime - DARCO Hg	ON	ESP 2 inlet	6.95	ESP 1 inlet	50	2.5	-	17.12	7.62	-	55.50	-
8/3/06 10:00	8/3/2006 11:25	Daily Baseline	OFF		0			0	-	16.73	16.84	-	-0.6	-
8/3/06 11:55	8/3/2006 13:11	DARCO Hg	OFF	ESP 2 inlet	4.82			0	-	14.98	9.97	-	33.42	-
8/3/06 13:41	8/3/2006 15:25	Lime - DARCO Hg	OFF	ESP 2 inlet	4.85	ESP 1 inlet	100	5.1	-	14.86	9.13	-	38.54	-
8/3/06 15:55	8/3/2006 16:45	Lime - DARCO Hg	OFF	ESP 2 inlet	4.88	ESP 1 inlet	200	10.2	-	16.10	5.92	-	63.23	-
8/3/06 17:15	8/3/2006 17:30	Lime - DARCO Hg	ON	ESP 2 inlet	4.85	ESP 1 inlet	200	10.2	-	14.61	11.58	-	20.73	-
8/4/06 8:15	8/4/2006 8:35	Daily Baseline	ON						-	17.74	15.73	-	11.3	-
8/4/06 9:10	8/4/2006 10:11	DARCO Hg	ON	ESP 2 inlet	14.91			0	-	20.76	4.40	-	78.82	-
8/4/06 10:41	8/4/2006 11:02	DARCO Hg	ON	ESP 2 inlet	11.74			0	-	21.29	5.77	-	72.88	-
8/4/06 11:02	8/4/2006 11:46	Lime - DARCO Hg	ON	ESP 2 inlet	11.74	ESP 1 inlet	100	5.1	-	19.39	3.99	-	79.40	-
8/4/06 12:16	8/4/2006 13:35	Lime - DARCO Hg	ON	ESP 2 inlet	11.74	ESP 1 inlet	200	10.2	-	22.90	2.62	-	88.57	-
8/4/06 14:05	8/4/2006 14:08	DARCO Hg	ON	ESP 2 inlet	11.74			0	-	13.13	3.54	-	73.02	-
8/4/06 14:25	8/4/2006 15:32	DARCO Hg (staged)	ON	ESP 1 inlet ESP 2 inlet	5.28 [a]			0	-	10.52	3.81	-	63.83	-
8/4/06 15:45	8/4/2006 16:14	DARCO Hg (no lances)	ON	ESP 1 inlet	7.32			0	-	8.78	4.67	-	46.83	-
8/4/06 16:44	8/4/2006 18:00	DARCO Hg (staged)	ON	ESP 1 inlet ESP 2 inlet	6.71 [a]			0	-	7.33	2.90	-	60.39	-
8/4/06 18:30	8/4/2006 19:40	DARCO Hg (no lances)	ON	ESP 1 inlet	14.64			0	-	5.95	6.04	-	-1.53	-
8/4/06 20:10	8/5/2006 11:00	Baseline	ON		0			0	-	12.74	12.83	-	-0.70	-

[a] Injection rate for each ESP inlet location.

Table C-3. Mercury Reduction Performance Data for Shawville Unit 3 Sorbent Injection Tests

Data Avg. Start Time (CT)	Data Avg. End Time (CT)	Sorbent	SNCR (on/off)	Carbon		Lime			Total Vapor Phase Mercury (µg/Nm^3 at 3% O_2)			Total Vapor-Phase Mercury Reduction (%)	
				Injection Pt.	Rate (lb/MMacf)	Injection Pt.	Rate (lb/hr)	Rate (lb/MMacf)	ESP 1 Inlet	ESP 1 Outlet	ESP 2 Outlet	ESP 1 Outlet	ESP 2 Outlet
7/19/06 12:30	7/22/2006 7:39	Comprehensive Baseline (entire period)	ON		0			0	32.48	31.11	30.96	-	-
7/20/2006 9:00	7/20/2006 11:00	Comprehensive Baseline (AM)	ON		0			0	31.78	27.91	28.19	-	-
7/21/2006 9:00	7/21/2006 11:00	Comprehensive Baseline (AM)	ON		0			0	37.30	34.89	31.77	-	-
7/22/2006 7:56	7/22/2006 8:39	Daily Baseline	ON		0			0	30.72	25.50	25.81	-	-
7/22/06 9:00	7/22/2006 12:40	HOK	ON	ESP 1 inlet	3.20			0	29.69	20.01	22.57	14.9	12.6
7/22/06 13:10	7/22/2006 16:45	HOK	ON	ESP 1 inlet	11.83			0	28.40	12.27	12.69	47.8	50.8
7/23/06 7:35	7/23/06 8:20	Daily Baseline	ON		0			0	34.37	26.56	22.49	-	-
7/23/06 8:50	7/23/06 12:15	HOK	ON	ESP 1 inlet	7.17				31.78	16.88	16.80	36.4	25.3
7/23/06 14:15	7/23/2006 16:21	DARCO Hg	ON	ESP 1 inlet	6.74			0	27.38	9.65	10.50	63.7	53.3
7/24/06 7:58	7/24/2006 11:41	Daily Baseline	ON		0			0	30.14	23.58	21.77	-	-
7/24/06 12:06	7/24/2006 15:56	DARCO Hg	ON	ESP 1 inlet	11.71			0	25.50	5.62	3.30	76.2	84.9
7/25/06 7:34	7/25/2006 9:00	Daily Baseline	ON		0			0	30.30	24.53	21.80	-	-
7/25/06 9:30	7/25/2006 12:23	HOK	ON	ESP 1 inlet	15.03			0	29.35	10.41	11.20	57.6	48.6
7/25/06 13:45	7/25/2006 16:19	DARCO Hg	ON	ESP 1 inlet	14.64			0	23.74	4.54	4.34	81.5	80.1
7/26/06 7:30	7/26/2006 11:00	Daily Baseline	ON		0			0	25.53	14.75	16.99	-	-
7/26/06 11:33	7/26/2006 14:03	Lime/DARCO Hg Premix	ON	ESP 1 inlet	3.53	ESP 1	116	5.9	22.85	5.92	8.81	59.9	48.1
7/26/05 14:34	7/26/2006 17:34	Lime/DARCO Hg Premix	ON	ESP 1 inlet	5.52	ESP 1	181	9.2	22.07	2.32	4.87	83.9	71.3
7/27/06 7:30	7/27/2006 8:15	Daily Baseline	ON		0			0	-	21.65	17.98	-	-
7/27/06 8:49	7/27/2006 11:27	DARCO Hg-LH	ON	ESP 2 inlet	6.68			0	-	23.99	9.75	-	45.8
7/27/06 12:00	7/27/2006 16:03	DARCO Hg-LH	ON	ESP 2 inlet	9.76			0	-	23.67	7.60	-	57.7

Table C-3. (continued)

Data Avg. Start Time (CT)	Data Avg. End Time (CT)	Sorbent	SNCR (on/off)	Carbon		Lime			Total Vapor Phase Mercury (µg/Nm³ at 3% O_2)			Total Vapor-Phase Mercury Reduction (%)	
				Injection Pt.	Rate (lb/MMacf)	Injection Pt.	Rate (lb/hr)	Rate (lb/MMacf)	ESP 1 Inlet	ESP 1 Outlet	ESP 2 Outlet	ESP 1 Outlet	ESP 2 Outlet
7/28/06 7:30	7/28/2006 8:30	Daily Baseline	ON		0			0		18.12	21.62	-	-
7/28/06 9:00	7/28/2006 11:45	HOK coarse	ON	ESP 2 inlet	11.04			0	-	18.47	16.09	-	25.5
7/28/06 12:15	7/28/2006 15:30	HOK coarse	ON	ESP 2 inlet	14.67			0	-	18.15	14.74	-	31.8
7/29/06 7:30	7/29/2006 8:30	Daily Baseline	ON		0			0	-	16.75	15.65	-	-
7/29/06 9:00	7/29/2006 11:58	HOK	ON	ESP 2 inlet	6.68			0	-	15.76	12.07	-	22.9
7/29/06 12:30	7/29/2006 15:30	HOK	ON	ESP 2 inlet	11.22			0	-	13.99	7.86	-	49.8
7/30/06 8:30	7/30/2006 9:00	Daily Baseline	ON		0			0	-	15.22	17.96	-	-
7/30/06 9:53	7/30/2006 11:34	HOK	ON	ESP 2 inlet	13.36			0	-	13.58	7.94	-	55.8
7/30/06 12:04	7/30/2006 16:30	HOK 48-hour	ON	ESP 2 inlet	10.80			0	-	15.14	9.81	-	45.4
7/30/06 16:30	7/31/2006 2:40	HOK 48-hour	ON	ESP 2 inlet	10.28			0	-	14.89	9.25	-	48.5
7/31/06 2:40	7/31/2006 11:50	HOK 48-hour	ON	ESP 2 inlet	10.34			0	-	17.67	10.93	-	39.1
7/31/06 11:50	8/1/2006 6:57	HOK 48-hour	ON	ESP 2 inlet	11.01			0	-	23.58	10.68	-	40.5
8/1/06 10:00	8/1/2006 12:00	Daily Baseline	ON		0			0	-	17.55	25.52	-	-
8/1/06 12:30	8/1/2006 14:36	DARCO Hg	ON	ESP 1 inlet	9.70			0	-	5.96	6.21	66.0	75.5
8/2/06 8:25	8/2/2006 8:45	Daily Baseline	ON		0			0	-	16.51	18.49	-	-
8/2/06 9:15	8/2/2006 10:00	Lime	ON		0	ESP 1 inlet	50	2.5	-	15.74	15.86	-	14.1
8/2/06 10:30	8/2/2006 11:05	Lime	ON		0	ESP 1 inlet	100	5.1	-	15.04	15.71	-	14.9
8/2/06 11:35	8/2/2006 13:15	Lime - DARCO Hg	ON	ESP 2 inlet	3.81	ESP 1 inlet	50	2.5	-	17.01	9.61	-	47.9
8/2/06 13:45	8/2/2006 15:00	Lime - DARCO Hg	ON	ESP 2 inlet	6.95	ESP 1 inlet	50	2.5	-	17.12	7.62	-	58.7
8/3/06 10:00	8/3/2006 11:25	Daily Baseline	OFF		0			0	-	16.73	16.84	-	-

Table C-3. (continued)

Data Avg. Start Time (CT)	Data Avg. End Time (CT)	Sorbent	SNCR (on/off)	Carbon		Lime			Total Vapor Phase Mercury (µg/Nm[3] at 3% O_2)			Total Vapor-Phase Mercury Reduction (%)	
8/3/06 11:55	8/3/2006 13:11	DARCO Hg	OFF	ESP 2 inlet	4.82			0	-	14.98	9.97	-	40.8
8/3/06 13:41	8/3/2006 15:25	Lime - DARCO Hg	OFF	ESP 2 inlet	4.85	ESP 1 inlet	100	5.1	-	14.86	9.13	-	45.7
8/3/06 15:55	8/3/2006 16:45	Lime - DARCO Hg	OFF	ESP 2 inlet	4.88	ESP 1 inlet	200	10.2	-	16.10	5.92	-	64.8
8/3/06 17:15	8/3/2006 17:30	Lime - DARCO Hg	ON	ESP 2 inlet	4.85	ESP 1 inlet	200	10.2	-	14.61	11.58		31.2
8/4/06 8:15	8/4/2006 8:35	Daily Baseline	ON						-	17.74	15.73	-	-
8/4/06 9:10	8/4/2006 10:11	DARCO Hg	ON	ESP 2 inlet	14.91			0	-	20.76	4.40	-	72.0
8/4/06 10:41	8/4/2006 11:02	DARCO Hg	ON	ESP 2 inlet	11.74			0	-	21.29	5.77	-	63.3
8/4/06 11:02	8/4/2006 11:46	Lime - DARCO Hg	ON	ESP 2 inlet	11.74	ESP 1 inlet	100	5.1	-	19.39	3.99	-	74.6
8/4/06 12:16	8/4/2006 13:35	Lime - DARCO Hg	ON	ESP 2 inlet	11.74	ESP 1 inlet	200	10.2	-	22.90	2.62	-	83.4
8/4/06 14:05	8/4/2006 14:08	DARCO Hg	ON	ESP 2 inlet	11.74			0	-	13.13	3.54	-	77.5
8/4/06 14:25	8/4/2006 15:32	DARCO Hg (staged)	ON	ESP 1 inlet ESP 2 inlet	5.28 [a]			0	-	10.52	3.81	-	75.8
8/4/06 15:45	8/4/2006 16:14	DARCO Hg (no lances)	ON	ESP 1 inlet	7.32			0	-	8.78	4.67	-	70.3
8/4/06 16:44	8/4/2006 18:00	DARCO Hg (staged)	ON	ESP 1 inlet ESP 2 inlet	6.71 [a]			0	-	7.33	2.90	-	81.5
8/4/06 18:30	8/4/2006 19:40	DARCO Hg (no lances)	ON	ESP 1 inlet	14.64			0	-	5.95	6.04	-	61.6
8/4/06 20:10	8/5/2006 11:00	Baseline	ON		0			0	-	12.74	12.83	-	-

[a] Injection rate for each ESP inlet location.

Appendix D

SCEM Data

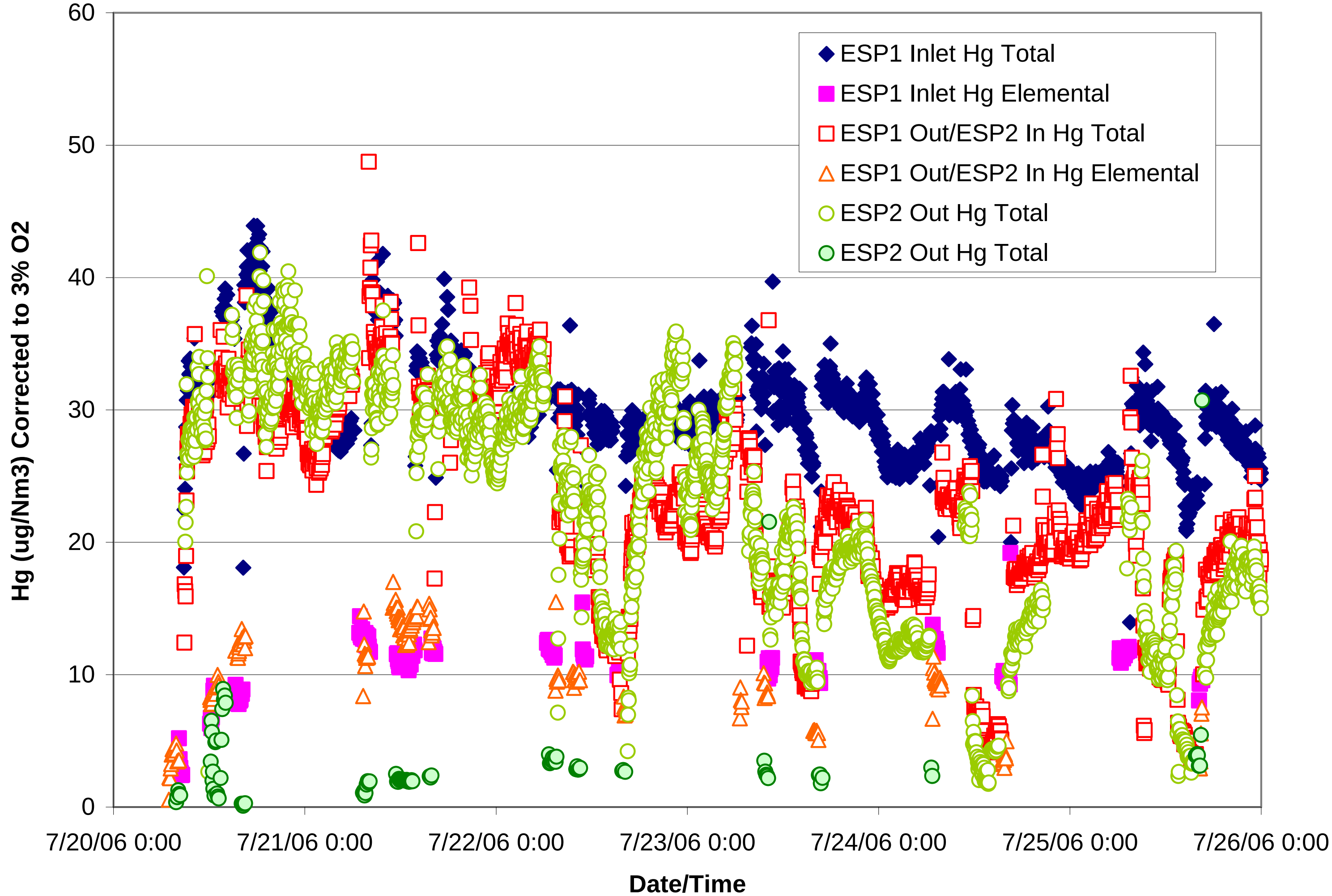


Figure D-1. SCEM Data – Week 1

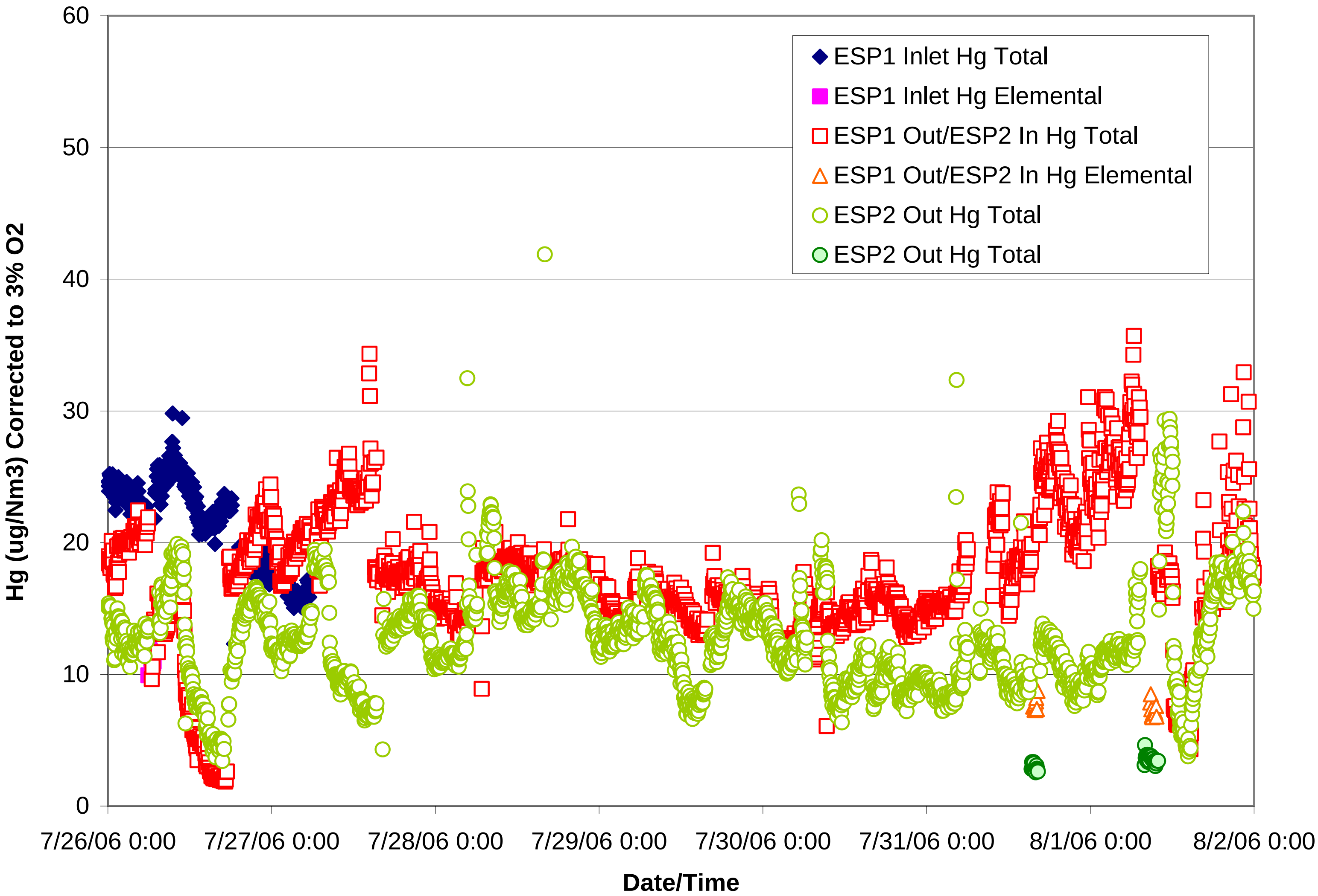


Figure D-2. SCEM Data – Week 2

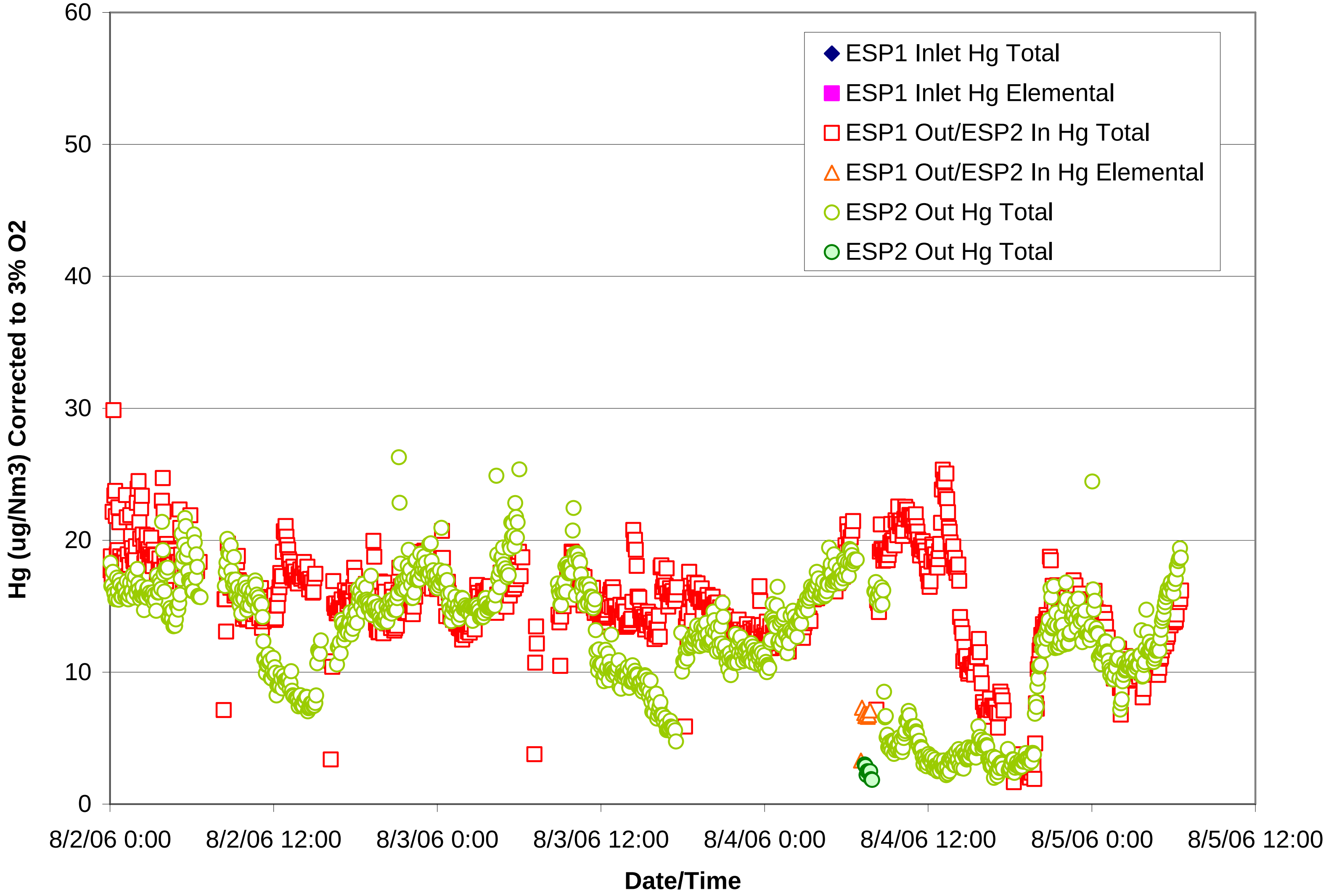


Figure D-3. SCEM Data – Week 3

Appendix E

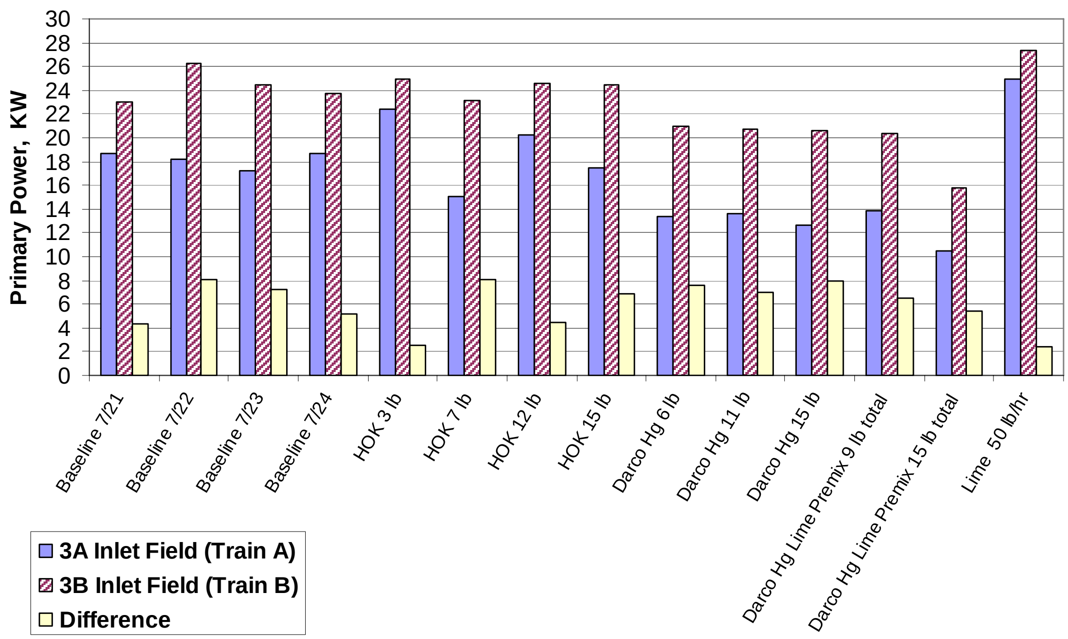
Analysis of Sorbent Injection Impacts on Unit 3 ESP Performance

1.0 ESP Electrical Impacts From ACI

ESP 1 Inlet Field Impacts

<u>ESP Primary Power</u>

From Figure E-1, it can be seen that there is a native difference between Trains A and B with Train B operating a higher overall power than A. In comparison with the baseline data and taking into account the native difference between trains, it can be seen that ESP power was slightly higher than baseline levels for 2 of the 4 HOK injection tests upstream of ESP 1. A decrease in ESP power compared to baseline was observed for the Darco Hg and Darco Hg with Lime tests; however, power levels for Train B (no ACI injection) during the corresponding time periods also decreased, suggesting the decrease may be attributed to a change in coal or other process that was driving the performance of the ESP at this time rather than carbon injection. Injection of lime only at the ESP 1 inlet at 50 lb/hr greatly enhanced ESP inlet power, but additional tests would be required to corroborate this effect.

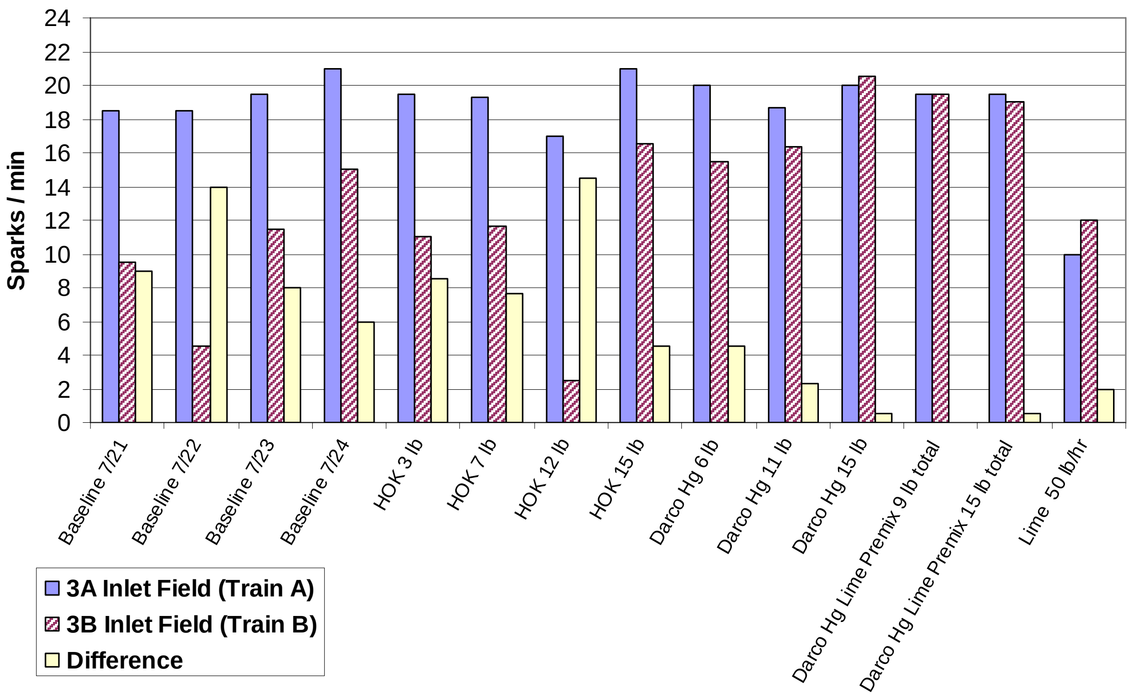


Note: "lb" indicates the injection rate for each test in lb/MMacf. Injection rate for the premix test is the combined lime plus carbon injection rate.

Figure E-1. ESP 1 Inlet Field Primary Power for ESP 1 Inlet Injection Tests

ESP Spark Rate

The spark rate will change with as a result of changes in flue gas resistivity and /or flue gas particulate loading. Figure E-2 illustrates native difference in the baseline spark rate between Trains A and B with Train A sparking higher than B. A comparison baseline data, taking into account the native difference between trains, shows that for all carbons and injection rates there was very little change from baseline conditions. Corresponding to the earlier shown increased ESP power, the spark rate for the lime only injection test decreased compared to baseline, consistent with the observed increase in primary power discussed previously.



Note: "lb" indicates the injection rate for each test in lb/MMacf. Injection rate for the premix test is the combined lime plus carbon injection rate.

Figure E-2. ESP 1 Inlet Field Spark Rate for ESP 1 Inlet Injection Tests

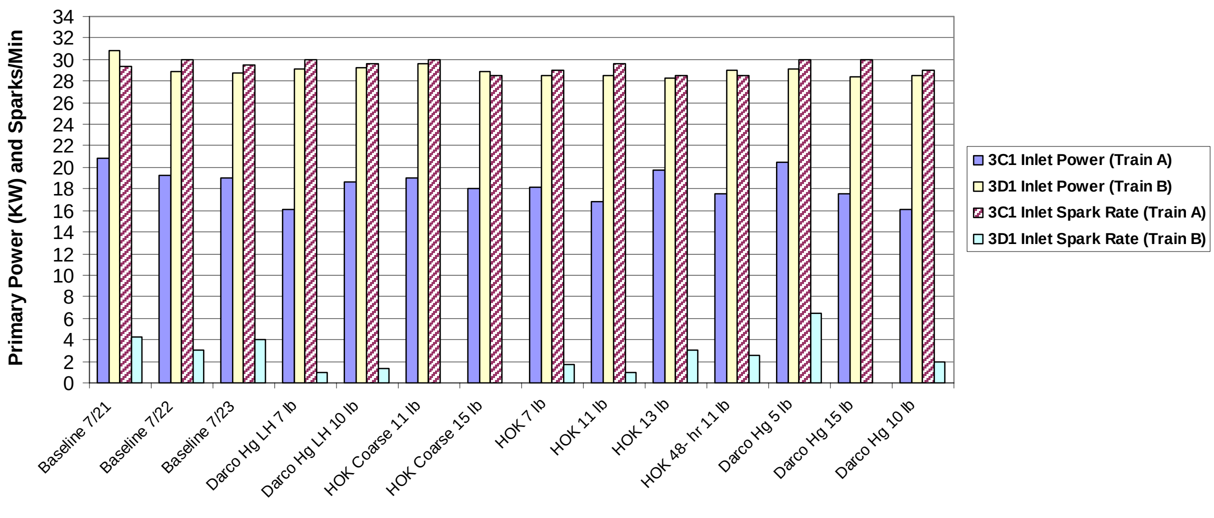
ESP 2 Inlet Field Impacts

ESP Primary Power

Similar to ESP 1, there is a native difference of ESP power between the A and B Trains in ESP 2. Train B operates at higher power levels than Train A. As shown in Figure D-3, overall there was little impact to ESP 2 inlet field power during injection of the various sorbents at the inlet to ESP 2.

ESP Spark Rate

The baseline data shown in Figure E-3 illustrate the native spark rate difference between the two gas trains. Train A operates at higher spark rates than Train B consistent with the lower primary power levels observed for Train A. As in the case of the ESP power, there was very little impact on the inlet field sparking rates during with the injection of sorbents.



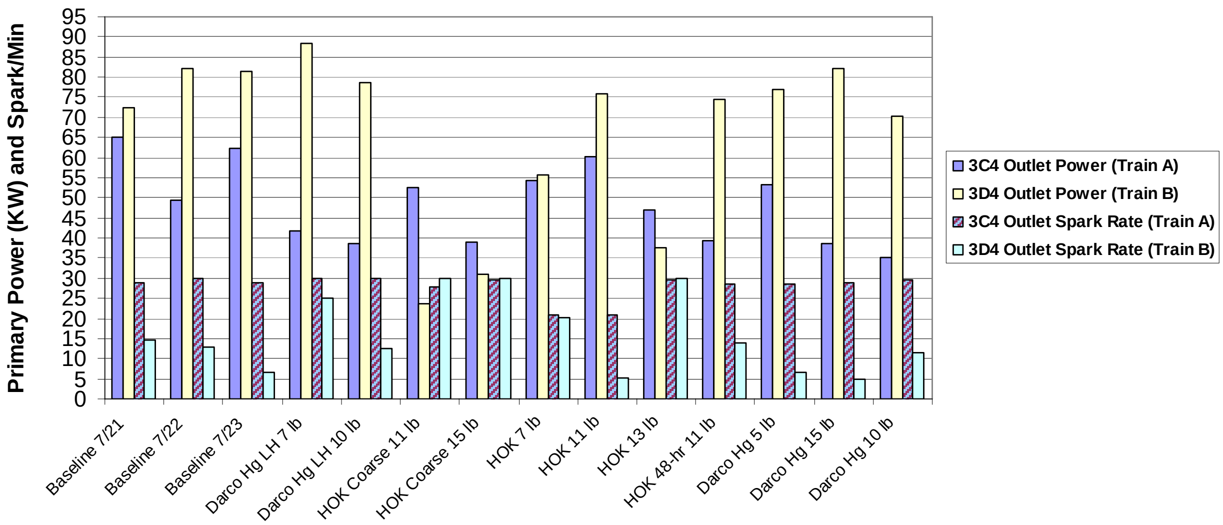
Note: "lb" indicates the injection rate for each test in lb/MMacf.

Figure E-3. ESP 2 Inlet Field 3C1 and 3D1 Primary Power and Spark Rate for ESP 2 Inlet Injection Tests

ESP 2 Outlet Field Impacts

ESP Primary Power

As shown in Figure E-4, the same native difference of ESP power exists for the ESP outlet field 3C4 between the A and B Trains. For the Darco Hg LH, the decrease in ESP power relative to baseline is consistent with the reduction noted at the ESP inlet field 3C1. For all sorbents injected, there was generally an overall decrease in ESP power when compared to the baseline and the Train B outlet field 3D4. During the HOK Coarse test, the Train B ESP outlet field 3D4 power also dropped significantly as a result of some other change process operations.



Note: "lb" indicates the injection rate for each test in lb/MMacf

Figure E-4. ESP 2 Outlet Field 3C4 and 3D4 Primary Power and Spark Rate for ESP 2 Inlet Injection Tests

ESP Spark Rate

Again, the baseline data shows a native difference between the two gas trains. Train A operates at higher spark rates than Train B consistent with the lower power levels observed for Train A. Overall the spark rate for the ESP 2 outlet field on Train A did not change much as a result of the various sorbents injected.

2.0 ESP Outlet Particulate Loading Impacts from ACI

Figure E-5 shows both the average Duct 3A dust index data and the single-point Method 17 particulate loading data. Data are group by baseline conditions, ESP 1A inlet injection tests and ESP 2A inlet injection tests. Both the Dust 3A and Method 17 measurements were obtained at the outlet of ESP 2 for gas Train A. Average Duct 3A dust index value are shown as shaded bars for each test period both during injection and during the corresponding daily non-injection baseline periods.

Although not shown in Figure E-5, the Duct 3B dust index data remained fairly constant throughout the test program but were consistently higher than the Duct 3A values, typically in the range of 0.09 to 0.12 for Duct 3B compared to 0.03 to 0.04 for Duct 3A during the baseline test period early in the test program, indicating a possible native difference in ESP 2 outlet particulate levels for Train A and Train B or simply a difference in the calibration of the two dust monitoring systems.

With the exception of a couple of data points, there is a correlation between the 3A Dust Index and the Method 17 single-point particulate loading values. The average baseline Method 17 particulate loading was 0.016 gr/dscf with values ranging from 0.013 to 0.02 gr/dscf.

In general, for carbon injection rates less than approximately 11 lb/MMacf at the inlet of ESP 1, there was no significant increase in the 3A dust index or in the Method 17 values when compared to the corresponding average daily baseline dust index or baseline Method 17 measurements. For most carbons injected at 11 lb/MMacf or greater there was an increase in 3A dust index compared to baseline. For both of the Darco Hg/Lime premix injection tests at the ESP 1 inlet, there was an increase in the 3A dust index relative to baseline. Method 17 particulate loading values were also outside the range of observed baseline values for both the Darco Hg/lime premix injection tests and the highest injection rates of Darco Hg.

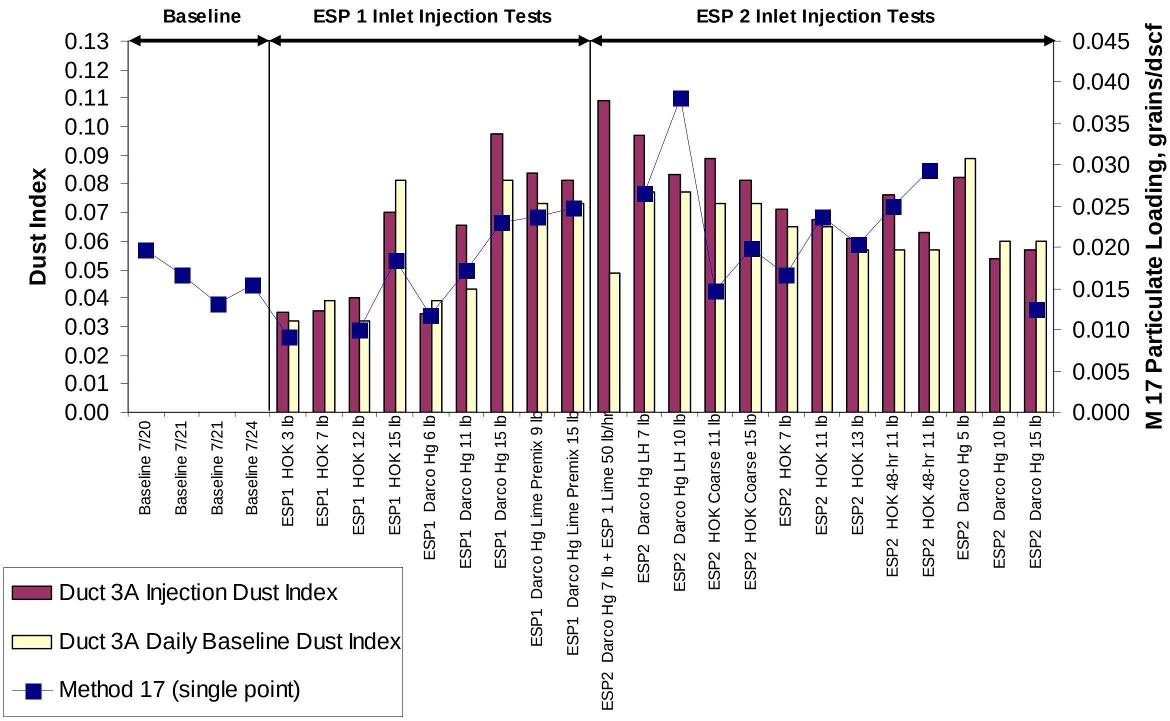


Figure E-5. ESP 2 Outlet Dust Index and Method 17 Particulate Measurements for Train A

For all sorbents (except Darco Hg) injected at the inlet of ESP 2 there was an increase in the 3A dust index compared to daily baseline. In particular, the data for the 48-hour HOK test, the best indicator of longer term impacts of ACI on ESP 2 performance from this test program, show that both the Dust 3A values and the Method 17 measurements were higher than the corresponding baseline value. Method 17 particulate loading values during the 48-hr injection period were as much as a factor of 1.5 higher than the highest baseline value (0.029 grains/dscf during HOK injection compared to the highest baseline value of 0.02 grains/dscf).

Finally, the largest average dust index value (0.11) was observed for the staged lime/Darco Hg injection test where the dust index value was 2 times the daily baseline value. This result is consistent with the higher dust index and Method 17 values observed for the lime/Darco Hg premix injection tests conducted at the ESP 1 inlet, suggesting that although the injection of lime in combination with activated carbon improved mercury removal performance of the ESP systems, it may also have a negative impact on particulate removal performance of the ESP systems. Lime removes SO_3 from the flue gas. The presence of SO_3 can have a positive conditioning effect on ESP systems by reducing the fly ash resistivity. Thus, a reduction in SO_3 levels as a result of lime injection can result in reduced particulate removal efficiency within ESP systems. This has been observed in other SO_3 control projects using lime injection. Alternative reagents, such as sodium bisulfite (SBS), can be injected to control SO_3 levels without adversely affecting the resistivity properties of the fly ash.

In summary, the impact of sorbent injection on ESP 2 outlet particulate loading was less when sorbent was injected upstream of both ESPs and at less than approximately 11 lb/MMacf. Although the short-term test data from the Shawville test program provide an indication of potential impacts of sorbent injection on ESP performance, additional longer term testing of ACI would be required to fully understand operational impacts of sorbent injection on the Shawville ESP system. Additional ACI testing in conjunction with alternative reagents for SO_3 control may also be warranted.