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

Quarterly Technical Report
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ABSTRACT

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

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

Short-term mercury removal levels in excess of 90% were achieved using the COHPAC® unit. The test also showed that activated carbon was effective in removing both forms of mercury–elemental and oxidized. However, a great deal of additional testing is required to further characterize the capabilities and limitations of this technology relative to use with baghouse systems such as COHPAC®. It is important to determine performance over an extended period of time to fully assess all operational parameters.

The project described in this report focuses on fully demonstrating sorbent injection technology at a coal-fired power generating plant that is equipped with a COHPAC® system. The overall objective is to evaluate the long-term effects of sorbent injection on mercury capture and COHPAC® performance. The work is being done on one-half of the gas stream at Alabama Power Company's Plant Gaston Unit 3 (nominally 135 MW). Data from the testing will be used to determine:

1. If sorbent injection into a high air-to-cloth ratio baghouse is a viable, long-term approach for mercury control; and
2. Design criteria and costs for new baghouse/sorbent injection systems that will use a similar, polishing baghouse (TOXECON™) approach.

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EXECUTIVE SUMMARY

ADA-ES began work on a Cooperative Agreement with the Department of Energy in September 2002 to fully evaluate Activated Carbon Injection (ACI) in conjunction with a high-ratio baghouse (COHPAC®) for mercury control. The work is being conducted at Alabama Power Company's Plant Gaston. During the two-year project, a powdered ACI system will be installed and tested at the plant for a continuous one-year period. ADA-ES' responsibilities for managing the project include engineering, testing, economic analysis, and information transfer functions.

During the eighth reporting quarter, April through June 2004, progress on the project was made in the following areas (Unit 3 was offline from mid-February until mid-April):

- Conducted short baseline test after outage.
- Completed long-term activated carbon injection tests on high-perm bags.
- Conducted a set of Ontario Hydro measurements.
- Conducted testing of alternative carbons.
- Made periodic measurements of hopper ash and LOI.
- Prepared for decommissioning of the test site.

INTRODUCTION

Cooperative Agreement No. DE-FC26-02NT41591 was awarded to ADA-ES to demonstrate Activated Carbon Injection (ACI) technology on a coal-fired boiler equipped with a COHPAC® baghouse. Under the contract, ADA-ES is working in partnership with DOE/NETL, Alabama Power, and EPRI.

A detailed topical report will be prepared at the end of the test. Quarterly reports will be used to provide project overviews and technology transfer information.

Test Schedule

- Baseline Period 1 (March 28 – April 21)
- Baseline Period 2 (May 28 – June 26)
- Optimization Period 1 (April 21 – May 27)
- Optimization Period 2 (June 26 – July 18)
- Long-Term Test on Original Bags (July 19 – November 25)
- Long-Term Test on High-Perm Bags (December 15 – June 4)
- Alternative Carbon Tests (June 7 – July 2)

Team Members

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

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

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

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

EXPERIMENTAL

Activated Carbon Injection Equipment

The activated carbon injection equipment was installed, field-tested, and continued to operate through the eighth quarter of the project.

Mercury Analyzer

The mercury analyzer is operating and measuring total vapor-phase mercury at the inlet and outlet of the COHPAC® baghouse.

A full equipment description can be found in DOE Report No. 41591R03.

RESULTS AND DISCUSSION

Significant progress was made during this reporting period to meet the overall objective of demonstrating long-term performance of carbon injection for mercury control. The original test plan was adapted to the operating conditions at the host site. These changes were documented in Report No. 41591R04, but primarily consisted of extending the baseline and optimization tests and modifying the injection scheme. The test plan for this program has five primary tasks:

1. Design and install an activated carbon injection system capable of continuous operation for up to one year.
2. Install a mercury analyzer capable of long-term, continuous operation. This analyzer is referred to as a Semi-Continuous Emissions Monitor (S-CEM).
3. Evaluate the long-term performance of carbon injection upstream of COHPAC® for mercury control. This task has two separate test periods:
   a. The first test (up to six months) was conducted using the existing set of bags.
   b. The second test (up to six months) was conducted on a set of new bags made from advanced fabrics.
4. Perform short-term tests of alternative sorbents.
5. Document test procedures and results, and complete reporting and management requirements.

Tasks 1, 2, 3a and 3b have been completed. This report documents activities from task 3b and 4. Task 5 is in progress.

High-Perm Bag Test (December 15 – June 4)

New high-permeability (high-perm) bags were installed December 4 through 8, 2003. The primary differences in design between these bags and the original bags are denier (an indication of fiber diameter; 2.7 versus 7.0 denier) and permeability (nominally 30 versus 130 cfm/ft^2 @ 0.5" H_2O).

The final schedule for the high-perm bag test was:

- Baseline Tests: December 15–January 5
- Optimization Tests: January 6–February 11
- Long-Term Test: April 20-June 4

Baseline Tests (April 20 – May 4)

The high-permeability (high-perm) bag tests began on December 15, 2003. The previous report presented data through February 11, when Unit 3 came off-line for an extended outage. During the outage, several maintenance tasks were scheduled for the hot-side ESP, including fixing TR sets and washing the plates and wires. Unit 3 was put back into service the weekend of April 17. ADA-ES began monitoring inlet and outlet mercury concentrations on April 20. Since April 17, there have been two additional short outages.

After an outage in which a hot-side ESP undergoes maintenance and washing, performance is generally much better than it was before the outage. Hot-side ESPs suffer from sodium depletion and washing the plates and wires removes high resistivity ash from these surfaces and allows power levels to increase to near-design conditions. In expectation of much improved ESP performance after the outage and lower inlet particulate loading, a period of baseline operation was planned to document COHPAC® performance under these new conditions. Unit 3B COHPAC® performance was monitored in baseline conditions, no carbon injection, from April 20 until May 4. Figure 1 presents data from this period. The graphs show inlet and outlet mercury concentrations, boiler load, mercury removal efficiency, ash LOI measurements, mass loading into both Unit 3B and 3A baghouses, and pulse frequency for Unit 3B.

Analysis and Interpretation of Figure 1:

- As can be seen in Figure 1, inlet mass loading into Unit 3B baghouse varied from 0.012 to greater than 0.25 gr/acf. Unit 3A mass loading was much lower and did not have the high excursions that 3B experienced.
- Although not shown, there was also a flow imbalance between the sides. At full-load, B-side was operating at about 580,000 acfm (air-to-cloth ratio of ~ 9.0 ft/min) while A-side was about 507,000 acfm (air-to-cloth ratio of ~ 7.9 ft/min). This significant difference in flow may be part of the reason that the hot-side ESP performance was so poor on B-side immediately after the outage.

- The relatively low cleaning frequency on the 3B baghouse, even with high loading and high air-to-cloth ratio, can be attributed to the recently installed high-perm bags that have low residual and dynamic pressure drop. If these conditions had occurred with the original bags, the baghouse would have been in a continuous clean.
- High inlet mass loading again resulted in variable, baseline mercury removal. During baseline testing, removal efficiency varied between 0 and 83%. Periods with mercury removal greater than 60% correlate with high inlet mass loading.
- LOI measurements (loss-on-ignition tests provide a good indication of carbon content in the ash) were made on hopper ash samples taken from the 3B COHPAC® hoppers. These measurements were made on-site using a hot-foil technique and can be seen in Figure 1. LOI values varied between 20 and 30%, with an average LOI of 25%.

Activated Carbon Injection (May 4 – June 4)

Carbon injection was started again on May 4. From May 4 through May 21, the injection system control logic was set to vary injection rate based on inlet loading. Table 1 presents the set-point for injection rates at different inlet mass loading conditions. On May 21, the system was set to inject continuously at 45 lbs/h (1.3 lbs/MMacf).

Table 1. Activated Carbon Injection Operating Parameters.

Inlet Loading (gr/scf)	Inlet Loading (gr/acf)	Injection Concentration (lbs/MMacf)	Carbon Injection Rate (lbs/h)
<0.1	~0.07	0.1.0 or 1.2	30 or 35
<0.2	~0.14	0.6	20
>0.2	~0.14	0	0

Performance and operating data with carbon injection can be seen in Figure 2. The graphs show inlet and outlet mercury concentrations, carbon injection rate, mercury removal efficiency, mass loading into both Unit 3B and 3A baghouses, and pulse frequency for Unit 3B.

Analysis and Interpretation of Figure 2 and Table 2:

- Inlet mass loading was highly variable during this period, with one episode of sustained, high inlet loading. When inlet loading was high, carbon injection rate varied between 0 and 30 lbs/h. Bag cleaning frequency increased to as high as 2.5 pulses/bag/h and was often near 2.0 pulses/bag/h.

- Average mercury removal from May 4 through May 21 at noon, when injection rate was varying with inlet loading, was 82%.

- Average mercury removal when the injection rate was held steady at 45 lbs/h (1.3 lbs/MMacf) was 92%, with a maximum hourly value of 98% and a minimum hourly value of 80%.
- Average mercury removal when the injection rate was held steady at 54 lbs/h (1.6 lbs/MMacf) was 91%, with a maximum hourly value of 98% and a minimum hourly value of 79%.
- The previous progress update included a table with average mercury removal at different injection rates. Table 2 presents these data again, plus the average mercury removal at 45 and 54 lbs/h, which were evaluated during this reporting period. Before the spring outage, mercury removal was held at greater than 90% at an injection rate of 35 lbs/h (1.1 lbs/MMacf). After the spring outage, it was difficult to maintain the same removal at the same injection rate, so the injection rate was increased to 45 lbs/h. As Table 2 shows, this did not increase the injection concentration by much because flow into the 3B baghouse was significantly higher after the outage. The injection rate was then raised to 54 lbs/hour (1.6 lbs/MMacf). There was no measurable difference in average mercury removal between the two conditions.

Table 2. Average mercury removal with carbon injection and high-perm bags before and after spring outage.

Injection Rate (lb/h)	Injection Concentration (lbs/MMacf)	Removal Efficiency Data collected before spring outage (%)	Removal Efficiency Data collected after spring outage (%)
20[a]	0.6[a]	87	
25[a]	0.8[a]	91	
30[a]	1.0[a]	94	
35[a]	1.1[a]	93	
45[b]	1.3[b]		92
55[b]	1.6[b]		91

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

Ontario Hydro Mercury Testing (May 26 and 27)

Weston Solutions, Inc., conducted the third and final set of Ontario Hydro testing on May 26 and 27. These tests included simultaneous inlet and outlet measurements of speciated mercury following the Ontario Hydro method, multiple metals sampling at the outlet, and hydrogen chloride sampling at the inlet. Measurement results have not yet been completed.

Alternative Carbon Tests (June 7 – July 2)

Evaluating carbons from different manufacturers is the final testing task of the program. This testing is included to broaden the options of suppliers and sorbents evaluated in this program. An invitation letter was sent to nine different sorbent suppliers asking them if they would like to participate in the Gaston program. Seven suppliers responded positively and two declined. Two companies provided more than one option. A summary of the company, product name, price of the sorbent for these tests, projected prices for commercial use and a brief product description can be found in Table 3. The product description in some cases includes sorbent characteristics such as particle size, molasses number, iodine number and density.

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

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

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

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

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

The test schedule is shown in Table 4.

For these tests, a portable feeder was installed next to the silo and attached to the existing transport hoses. This size feeder was used so that supersack quantities of materials could be used, instead of having to load the large silo with the alternative products. A PortaPac feeder was leased from NORIT.

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

Company	Product Name	Project Price	Projected Price	Product Description
RWE	Activated Lignite HOK Super	1 supersack free	~$0.35/lb	Besides its internal pore structure suitable for adsorption, this sorbent, as a result of the milling rate applied, has an extremely large outer surface area so that correspondingly high adsorption efficiencies can be attained
CARBOCHEM	MGF-20	$0.15/lb bulk or supersacks	$0.15/lb bulk or supersacks	None provided
	MC-40	$0.25/lb bulk or supersacks	$0.25/lb bulk or supersacks	None provided
	IMC-10	$0.49/lb bulk or supersacks	$0.49/lb bulk or supersacks	None provided
	IMS-10	$0.51/lb bulk or supersacks	$0.51/lb bulk or supersacks	None provided
Donau	Desorex DX 400C	$0.25/lb + freight (cost share)	~$0.34	Iodine #mg/g >400. Product supersedes Desorex HOK 300S. Bulk density ~33 lb/cu ft, particle size is 95% <325 mesh, adsorption capacity is in excess of 7 wt. %
Superior Adsorbents, Inc.	Merqsorb	5,000-10,000 lbs free (in supersacks) ADA-ES to pay freight	~$0.40	Same product as used at Brayton Point, P4, Gaston, etc. High kinetic rate of adsorption, easy flow, steam/thermal activation
General Technologies	PC-800 (FJ045)	$0.50/lb supersack	$0.34/lb supersack $0.37/lb truck	PAC made from bituminous coal. Iodine 800 mg/g
NORIT Americas	FGD-XTR	$0.27/lb supersack (cost share)	~$0.34/lb	Experimental, can be produced at lower costs and may perform as well for Hg removal in certain equipment configurations. Molasses decolorizing efficiency = 20 to 40, mesh size <325, Iodine #350-450, density 40-50 lbs/cu ft
	DARCO FGL	$0.27/lb	list price	Should be tested at this location because it may provide some cost advantages if it performs as well as DARCO FGD. Iodine #500 mg/g, sulfur % 0.6, density 0.63 g/mL lb/ cu ft
Barnebey Sutcliffe (Calgon)	Fluepac	$0.45/lb (ADA-ES provides supersack)	$0.38/lb supersack $0.32 bulk	Iodine #600
Amended Silicates	DECLINED			
Sorbtech	DECLINED			

Table 4. Alternative carbon test schedule.

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

Single day test schedule

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

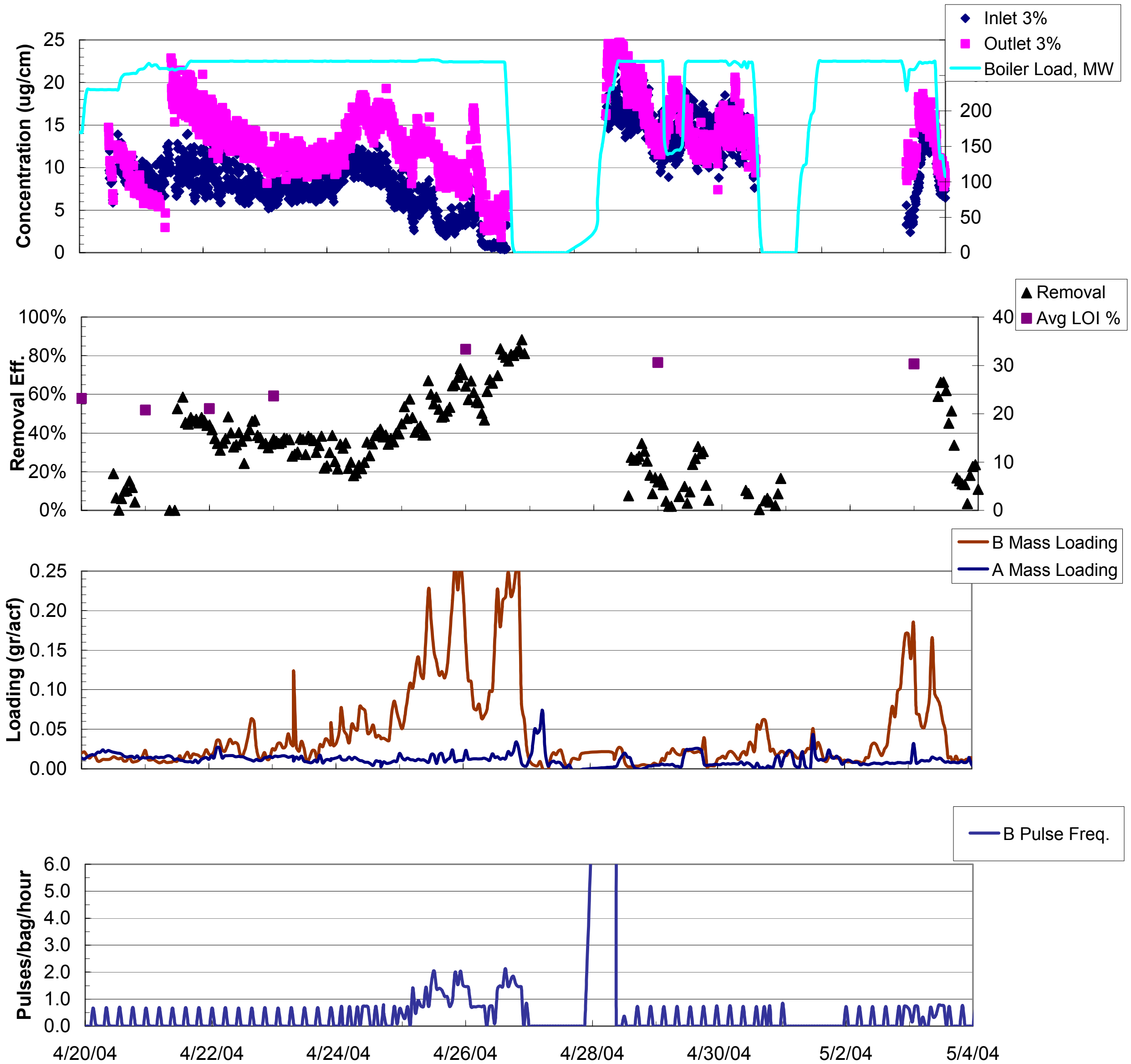

Figure 1. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, COHPAC® cleaning frequency and inlet mass loading on Unit 3 COHPAC® from December 15, 2003, through February 11, 2004.

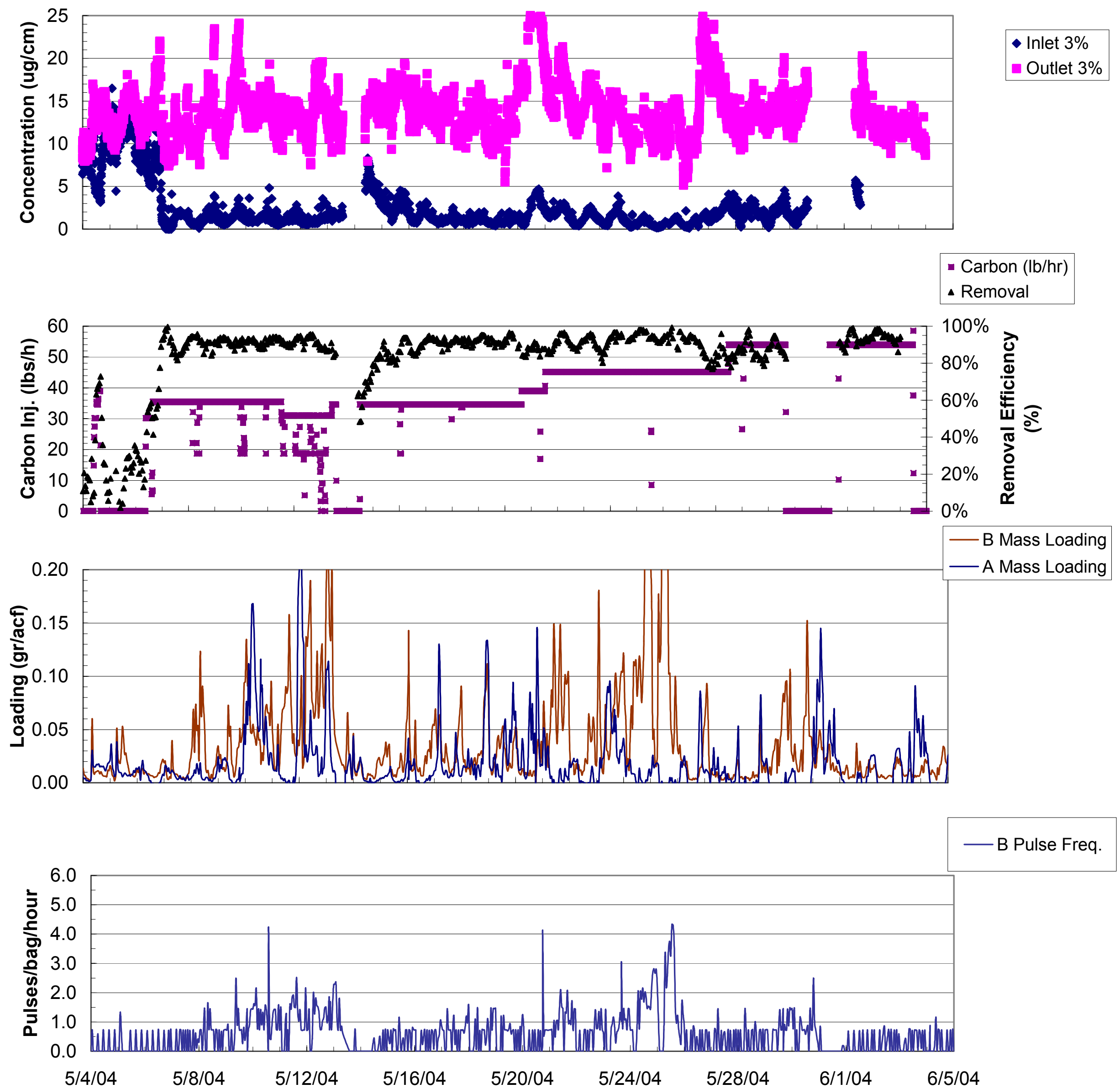

Figure 2 Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, COHPAC® cleaning frequency and inlet and outlet mass loading on Unit 3 COHPAC® from May 4, 2003, through June 4, 2004.