Full-Scale Evaluation of Mercury Control with Sorbent Injection and COHPAC at Alabama Power E.C. Gaston

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ABSTRACT

The overall objective of this project was to determine the cost and impacts of mercury control using sorbent injection into a COHPAC baghouse at Alabama Power's Gaston Unit 3. This test is part of a program funded by the Department of Energy's National Energy Technology Laboratory (NETL) to obtain the necessary information to assess the costs of controlling mercury from coal-fired utility plants that do not have scrubbers for SO_2 control. The economics will be developed based on various levels of mercury control.

Gaston Unit 3 was chosen for testing because COHPAC represents a cost-effective retrofit option for utilities with existing electrostatic precipitators (ESPs). COHPAC is an EPRI patented concept that places a high air-to-cloth ratio baghouse downstream of an existing ESP to improve overall particulate collection efficiency. Dry sorbents such as activated carbons were injected upstream of COHPAC, downstream of the ESP to obtain performance and operational data. Residue hopper ash and carbon samples were collected to evaluate the impact ash properties. A series of parametric tests were conducted to determine the optimum operating conditions for several levels of mercury control up to 90% mercury removal. Based on results from these tests, a longer-term test with one sorbent and optimized conditions was conducted to assess impacts to COHPAC and auxiliary equipment.

INTRODUCTION

In December 2000 EPA announced their intent to regulate mercury emissions from the nation's coal-fired power plants. In anticipation of these regulations, a great deal of research has been conducted during the past decade to characterize the emission and control of mercury compounds from the combustion of coal. Much of this research was funded by the Department of Energy, EPA, and EPRI. The results are summarized in the comprehensive AWMA Critical Review Article[1]. As a result of these efforts, the following was determined:

1. Trace concentrations of mercury in flue gas can be measured relatively accurately;
2. Mercury is emitted in a variety of forms;
3. Mercury species vary with fuel source and combustion conditions; and
4. Control of mercury from utility boilers will be both difficult and expensive.

This latter point is one of the most important and dramatic findings from the research conducted to date. Because of the large volumes of gas to be treated, low concentrations of mercury, and presence of difficult to capture species such as elemental mercury, some estimates show that 90% mercury reduction for utilities could cost the industry as much as $5 billion per year[1]. Most of these costs will be borne by power plants that burn low-sulfur coal and do not have wet scrubbers as part of the air pollution equipment.

With regulations rapidly approaching, it is important to concentrate efforts on the most mature retrofit control technologies. Injection of dry sorbents such as powdered activated carbon (PAC) into the flue gas and further collection of the sorbent by ESPs and fabric filters represents the most mature and potentially most cost-effective control technology for power plants.

Under a DOE/NETL cooperative agreement, ADA-ES is working in partnership with PG&E National Energy Group (NEG), Wisconsin Electric, a subsidiary of Wisconsin Energy Corp., Alabama Power Company, a subsidiary of Southern Company, EPRI, and Ontario Power Generation on a field evaluation program of sorbent injection upstream of existing particulate control devices for mercury control[2]. The test program, which will take place at four different sites during 2001 and 2002, is described in detail in the July 2001 EM Journal[3]. Other organizations participating in this program as team members include EPRI, Apogee Scientific, URS Radian, Energy & Environmental Strategies, Reaction Engineering, Inc, Southern Research Institute, Hamon Research-Cottrell, and Norit Americas.

Gaston Unit 3 was chosen as the first test site because COHPAC represents a cost-effective retrofit option for utilities with electrostatic precipitators (ESPs). COHPAC is an EPRI patented concept that places a high air-to-cloth ratio baghouse downstream of an existing ESP to improve overall particulate collection efficiency. The advantages of this configuration are:

1. Sorbents are mixed with a small fraction of the ash (nominally 1%) which reduces the impact on ash reuse and waste disposal.
2. Pilot plant studies and theory[4] indicate that compared to ESPs, baghouses require one-tenth the sorbent to achieve similar removal efficiencies.
3. Capital costs for COHPAC are less than other options such as replacing the ESP with a baghouse or larger ESP.
4. COHPAC requires much less physical space than either a larger ESP or full-size baghouse system
5. Outage time can be significantly reduced with COHPAC systems in comparison to major ESP rebuilds/upgrades.

E.C. GASTON SITE DESCRIPTION

The E.C. Gaston Electric Generating Plant, located in Wilsonville, Alabama, has four 270 MW balanced draft and one 880 MW forced draft coal fired boilers. All units fire a variety of low-sulfur, washed, Eastern bituminous coals.

The primary particulate control equipment on all units are hot-side ESPs. Units #1 and #2 and Units #3 and #4 share common stacks. In 1996 Alabama Power contracted with Hamon Research-Cottrell to install COHPAC downstream of the hot-side ESP on Unit 3. This COHPAC system was designed to maintain Unit #3 and #4's stack opacity levels below 5% on a 6 minute average[5].

The COHPAC system is a hybrid pulse-jet type baghouse, designed to treat flue gas volumes of 1,070,000 acfm at 290°F (gross air-to-cloth ratio of 8.5 ft/min with on-line cleaning). The COHPAC baghouse consists of four (4) isolatable compartments, two compartments per air-preheater identified as either A- or B-Side. Each compartment consists of two bag bundles, each having a total of 544, 23-foot long, PPS felt filter bags, 18 oz/yd^2 nominal weight. This results in a total of 1,088 bags per compartment, or 2,176 bags per casing[5]. The evaluation was conducted on one-half of the gas stream, nominally 135 MW. The side chosen for testing was B-side. A-side was monitored as the control unit.

The hot-side ESP is a Research-Cottrell weighted wire design. The specific collection area (SCA) is 274 ft^2/1000 acfm. Depending on the operating condition of the hot-side ESP, nominally 97 to 99+% of the flyash is collected in the ESP. The remaining flyash is collected in the COHPAC system. The average inlet particulate mass concentration into COHPAC between 1/97 and 4/99 was 0.0413 gr/acf[5]. Hopper ash from both the ESP and baghouse are sent to a wet ash pond for disposal. A hydrovactor system delivers the flyash to the pond.

Figure 1 shows a diagram of the location of the various components of the air pollution control train. Design parameters for Gaston Unit 3 are presented in Table 1. For the mercury control program, carbon-based dry sorbents were injected upstream of COHPAC, downstream of the ESP over an eight week period.

Figure 1. Flow Schematic of Gaston Unit 3, Showing Injection and Measurement Locations

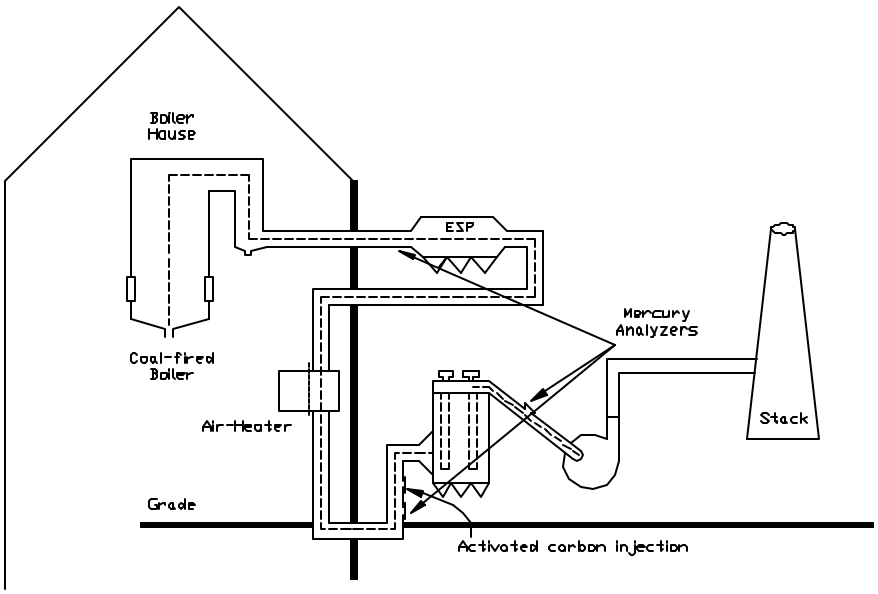


Table 1. Site Description Summary, Gaston Unit 3

Parameter Identification	Description
Boiler Manufacturer	**B&W wall-fired**
Burner Type	B&W XCL
Low NOx Burners	Yes
NOx Control (Post Combustion)	None
Temperature (APH Outlet)	290°F
Coal (Typical – this unit fires a variety of coals)	
Type	Eastern Bituminous
Heating Value (Btu/lb)	13,744
Moisture (%)	6.9
Sulfur (%)	0.9
Ash (%)	13.1
Hg (μg/g)	0.06
Cl (%)	0.03
Control Device	
Type	Hot-Side ESP with COHPAC
ESP Manufacturer	Research Cottrell
Design	Weighted Wire
Specific Collection Area (ft^2/1000afcm)	274
Flue Gas Conditioning	None
Baghouse Manufacturer	Hamon Research-Cottrell
Design	Pulse-Jet, Low Pressure – High Volume
Air-to-Cloth Ratio (acfm/ft^2)	8.5:1 (gross), On-Line Cleaning

SITE SPECIFIC EQUIPMENT

The critical elements of the program were the actual field tests and measurements, which relied upon accurate, rapid measurements of mercury concentration and an injection system that realistically represented commercially available technology.

Near real-time vapor phase mercury measurements were made using a Semi-Continuous Emissions Monitor (S-CEM) designed and operated by Apogee Scientific. This instrument was developed with EPRI funding to facilitate EPRI research and development efforts[6]. The locations of the analyzers are shown in Figure 1. The S-CEMs operated continuously for over seven weeks providing speciated, vapor phase mercury concentrations at the inlet and outlet of COHPAC.

Norit Americas' supplied a portable dilute phase pneumatic injection system that is typical of those used at Municipal Solid Waste (MSW) facilities for mercury control with activated carbon. ADA-ES designed the distribution and injection components of the system.

Sorbent requirements for various levels of mercury control were predicted based on empirical models developed through EPRI funding[4]. The values used were based on a uniform sorbent size of 15 microns and a bag cleaning frequency of 2 pulses/bag/hr (also assumed all bags were cleaned at the same time when in practice, the bags are cleaned in sections or rows). Rates used to design equipment for the Gaston test are presented in Table 2. The system was sized for a maximum injection rate of 100 lbs/h.

Table 2. Predicted Injection Rates for FGD Carbon on B-Side of COHPAC[3]

Target Hg Removal Efficiency (%)	Predicted Injection Concentration (lbs/MMacf)	Predicted Injection Rate[a] (lbs/h)
50	0.5	<30
75	1.5	45
90	3.0	90

a. Injection rate based on nominal flow at full load of 500,000 acfm.

Figure 2 is a picture of the portable injection skid supplied by Norit Americas and installed for use at Plant Gaston Unit 3B. Activated carbon delivered to the plant in 900 lb supersacks was loaded onto the skid by a hoist. The sorbent was metered by a variable speed screw feeder into an eductor that provided the motive force to carry the sorbent ~100 ft to the injection point.

Sorbent was pneumatically transported via flexible hose from the feeder to a distribution manifold at the injection level and injected into the flue gas through six injection probes (three/duct). Figure 3 is a photograph of the distribution manifold. The injection system operated without plugging while injecting carbon based products with D50 particle size of 18 micron. The distribution system plugged once while feeding a finer material with a D50 of 6-7 microns.

Figure 2. Carbon Injection Skid Installed at Plant Gaston

Figure 3. Distribution Manifold for Injection Lances at Plant Gaston

TEST RESULTS

Pre-Baseline Tests

The first field measurements were made prior to installing the injection equipment. The objectives for the pre-baseline tests were to:

1. Document mercury emissions across COHPAC; and
2. Perform screening tests for mercury adsorption characteristics of several activated carbons that were candidate sorbents for the full-scale tests.

Table 3 presents vapor phase mercury measurements during the pre-baseline tests in January on Unit 3. Two analyzers were used for these tests. The analyzers were set-up to measure simultaneously either across the hot-side ESP or COHPAC.

The results show that vapor phase mercury varied between 7 and 10 $\mu g/dNm^3$ at all three locations. There was no measurable removal of vapor phase mercury across either the hot-side ESP or COHPAC.

Table 3. Pre-Baseline Mercury Measurement Results (S-CEM)

Location	**Total Mercury mg/dNm^3 @ 3% O_2**	**Oxidized Mercury %**
ESP Inlet	7 – 10	5 - 33
ESP Outlet/COHPAC Inlet	7 – 10	29 – 51
COHPAC Outlet	7 – 10	52 - 76
Mercury Removal Across ESP	0%	
Mercury Removal Across COHPAC	0%	

These results are comparable to those made during ICR measurements on Unit 1 for total mercury concentrations and removal efficiencies. ICR measurements showed total mercury concentrations between 6.0 and 7.5 $\mu g/dNm^3$ and no mercury removal across the hot-side ESP[7].

No mercury removal was measured across COHPAC without the addition of sorbents. Review of data collected through the ICR at other plants shows that there was significant natural mercury capture on units with conventional type baghouses when firing bituminous coals[7]. This natural collection is assumed to occur because of exposure of the flue gas to ash on the bag dustcake. The ash at Gaston was tested for mercury adsorption capacity by URS Corporation. Analysis of the ash showed high carbon content throughout the total size distribution and an adsorption capacity that was reasonable

when compared to other ashes. However, since COHPAC is downstream of the hot-side ESP and the ESP was in excellent condition at the time of the tests, the inlet loading to COHPAC was very low (0.04 gr/acf on average and less than 0.01 during the tests), so there was a relatively small amount of ash present on the bags to react with the mercury.

The portion of vapor phase mercury in the oxidized state increased in the direction of flow. There was a greater percentage of elemental mercury at the hot-side inlet (economizer outlet) than there was at either the COHPAC inlet or outlet. The most significant oxidation occurred across the COHPAC baghouse. Similar phenomena have been documented across baghouses with fiberglass and PPS fabric bags[8].

Baseline Tests

After equipment installation and checkout, a set of baseline tests were conducted immediately prior to the first parametric test series to document current operating conditions. During this test boiler load was held steady at "full-load" conditions during testing hours, nominally 7:00 am to 7:00 pm. Mercury across B-Side of COHPAC was measured using two separate methods:

1. S-CEMs; and
2. Modified Ontario Hydro Method.

In addition to monitoring mercury removal, it was also important to document the performance of COHPAC during sorbent injection. The primary COHPAC performance indicator at this site was cleaning frequency. Pressure drop/drag is controlled by the cleaning frequency. It was expected that cleaning frequency would increase with the increased particulate loading from sorbent injection. Cleaning frequency was monitored before, during and after sorbent injection.

Results from the Ontario Hydro tests conducted by Southern Research Institute are presented in Table 4. Similar to pre-baseline measurements, there was no measurable mercury removal across COHPAC. The average of the inlet and outlet total mercury measurements was about 15 μg/dncm. Coal analyses showed mercury levels in the three coal samples varied between 0.06 and 0.17 μg/g. Since Gaston burns coals from several different coal sources each day it is difficult to correlate mercury level in the coal to a specific flue gas measurement; however, the higher coal mercury values correlate well with mercury measured in the flue gas.

The Ontario Hydro measurements also showed oxidation across COHPAC. At the inlet the average fraction of oxidized mercury was 61%, and increased to 77% at the outlet. Flue gas temperatures during this tests were nominally 255°F.

Table 4: Baseline Ontario Hydro Measurements at COHPAC Inlet and Outlet

Date/Location	Particulate (mg/dncm[1])	Oxidized (mg/dncm[1])	Elemental (mg/dncm[1])	Total (mg/dncm[1])	Percent Oxidized
3/6/01 Inlet	0.03	11.56	6.64	18.23	63
3/6/01 Inlet	0.03	8.01	7.02	15.05	53
3/7/01 Inlet	0.22	9.05	4.26	13.53	67
Average Inlet	0.09	9.54	5.97	15.60	61
3/6/01 Outlet	0.01	10.19	4.60	14.79	69
3/6/01 Outlet	0.02	12.48	2.99	15.48	81
3/7/01 Outlet	0.01	10.91	2.44	13.35	82
Average Outlet	0.01	11.19	3.34	14.54	77

1. Normal: T = 32°F

Parametric Tests

A series of parametric tests was conducted to determine the optimum operating conditions for several levels of mercury control up to 90% mercury removal, for several activated carbon products. To minimize permitting issues, only coal-based sorbents were considered at this site. Norit Americas lignite-based PAC, Darco FGD, was chosen as the benchmark sorbent. Sorbent type and injection concentration for the long-term tests were chosen based on results from these tests.

In all, 15 different parametric conditions were tested. The primary variables were carbon type and target mercury removal level. Other variables included COHPAC cleaning settings and flow through the baghouse. Although lower flue gas temperatures have been correlated with increased mercury removal, temperature was not a variable during these tests because normal operating temperatures at this plant were between 250°F and 270°F, which is cool enough for acceptable removal. A summary of the parametric tests is presented in Table 5. Unless noted, all tests were conducted with the boiler at full load conditions and COHPAC cleaning at a drag initiate setpoint of 0.6 inches w.c./ft/min. A description of the different carbons used in these tests is presented in Table 6.

Table 5. Summary of Parametric Test Conditions

Test Series	Carbon Name	Target Hg Removal Efficiency (%)	Non Standard Conditions
1-5	Darco FGD	50, 75 and 90	Standard
6-9	Norit PAC2B	50, 75, 90	Standard
10	None	Baseline	Standard
11	Darco Insul	90	Standard
12	HydroDarco-C	90	Standard
13 a-c	Darco FGD	75	Change to pressure drop initiate clean
14	Darco FGD	50	Lower A/C to 4 ft/min

15	Darco FGD	50	Compare to test 14 with A/C = 7 ft/min

Table 6. Description of Norit Carbons Used in Parametric Tests

Name	**Description**	**Particle Size Distribution[a]**		
		D95	**D50**	**D5**
Darco FGD	Lignite AC	52	15-20	<3
Norit PAC2B	Subbit/Bit Blend AC	52	15-20	<3
Darco Insul	Fine chemically washed specialty product	25	6-7	<2
HydroDarco-C	Coarser FGD	100	30	3

a. Percent of particles less than size in microns

Parametric testing measured mercury removal as a function of injection concentration and sorbent type, and the impact of sorbent injection on COHPAC performance. Feedback from the S-CEMs were invaluable in making timely, real-time decisions on test conditions. Examples of the data provided from the S-CEMs are presented in Figure 4. These data are from the first week of parametric tests, test numbers 1 – 5, with Darco FGD. Reduction in outlet mercury concentration can be seen to correlate with relative injection rates.

Figure 4. S-CEM Mercury Measurements During the First Week of Parametric Tests with Norit Darco FGD PAC

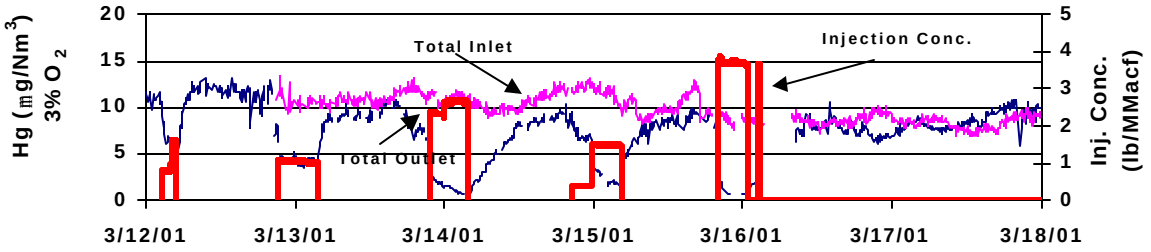
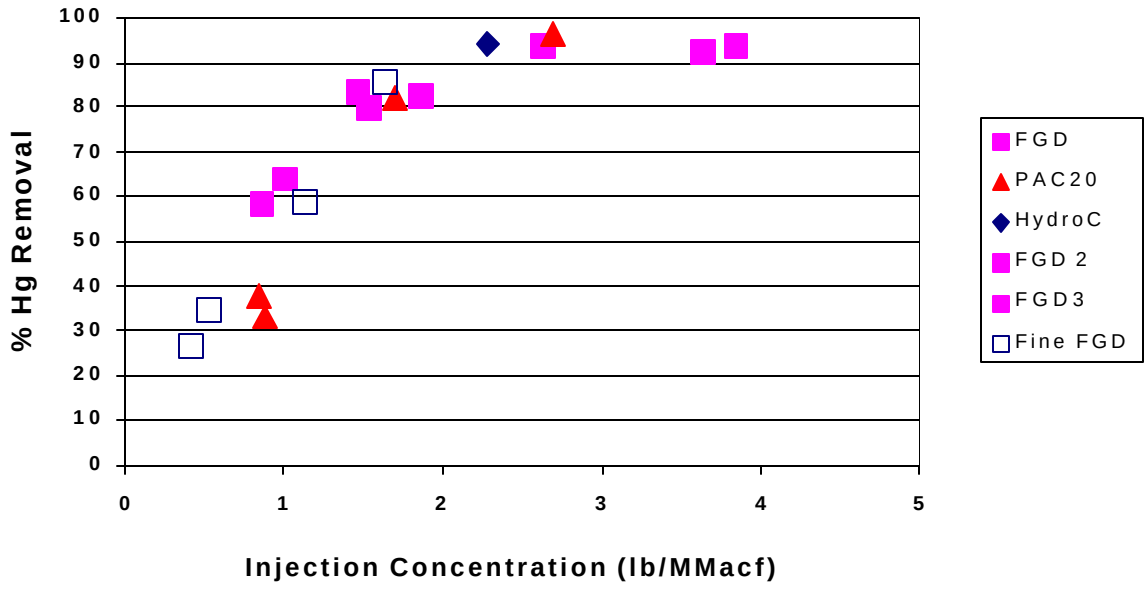


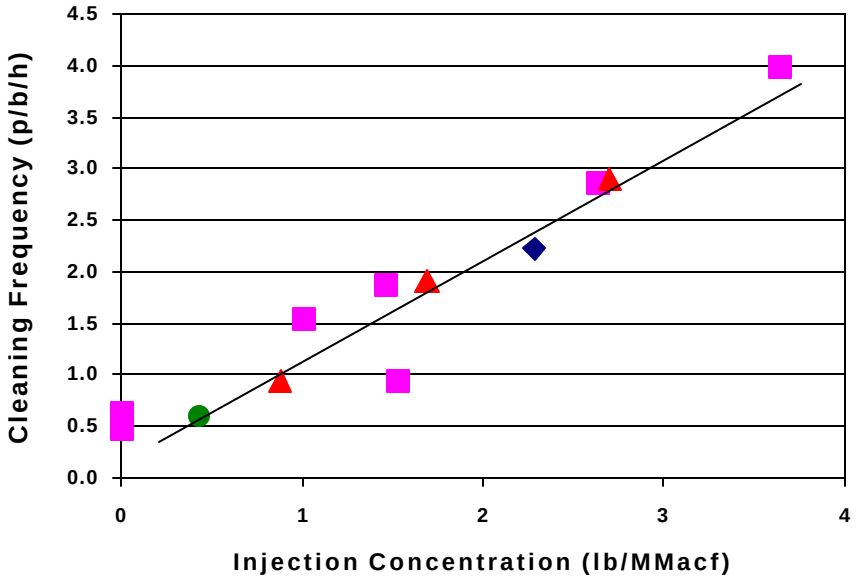
Figure 5 presents mercury removal efficiencies as activated carbon injection concentrations were varied during the parametric tests for several activated carbons (see Tables 5 and 6 for description of test conditions). This figure shows that mercury removal increased nearly linearly with injection rate up to 2 lbs/MMacf and then leveled off at about 90% removal with higher injection providing no additional benefit. This figure also shows that there was no measurable performance difference between the different PAC's.

Figure 5. Mercury Removal Trends Across COHPAC as a Function of PAC Injection Concentrations. Measurements Made During Parametric Tests, March 2001



Carbon injection significantly increased the cleaning frequency of the COHPAC baghouse. Figure 6 presents actual cleaning frequencies at different carbon injection concentrations. At an injection concentration of 2.0 lbs/MMacf the cleaning frequency increased from 0.5 to 2 pulses/bag/hour, or a factor of 4. Acceptable cleaning frequencies at this site has been set at 1.5 pulses/bag/hour, to maintain long-term bag life.

Figure 6. COHPAC Cleaning Frequency in Pulses/Bag/Hour as a Function of PAC Injection Concentration. Measurements Made During Parametric Tests, March 2001



Long-Term Tests

Long-term testing at "optimum" plant operating conditions as determined from the parametric tests, was planned to gather data on:

1. Mercury removal efficiency over time;
2. The effects on COHPAC and balance of plant equipment of sorbent injection; and
3. Operation of the injection equipment to determine the viability and economics of the process.

During these tests, carbon was injected continuously 24 hours per day, for 9 days. Based on results from the parametric tests, Darco FGD activated carbon was chosen as the sorbent for these tests. Injection rate was determined taking into consideration both mercury removal and the projected increase in COHPAC cleaning frequency. An injection concentration of 1.5 lbs/MMacf was chosen to maintain COHPAC cleaning frequency below 1.5 pulses/bag/hour.

Similar to the baseline test series, mercury was measured by both the S-CEMs and manual methods (Ontario Hydro). COHPAC performance, coal and ash samples, plant CEM data were collected. During these tests an EPA audit of the manual measurements was performed.

The long-term tests started on April 18 and carbon was injection continuously until April 26. Full load boiler conditions were held between the times of 0700 and 2000, with load following at other times for the first 5 days. During the three days when the Ontario Hydro tests were conducted, full load was maintained 24 hours/day. At the beginning of the tests time was needed to work out a COHPAC cleaning logic issue and there was a short period when load was lowered to fix a mill problem. The final 7 days of the test were conducted at the optimized PAC feedrate and COHPAC cleaning logic.

Three sets of Ontario Hydro measurements were made at three locations: 1) inlet of the hot-side ESP, 2) COHPAC inlet and 3) COHPAC outlet. Southern Research Institute conducted tests across COHPAC and Arcadis G&M Inc. made the measurements upstream of the hot-side ESP. The hot-side measurements were made using an experimental in-duct, quartz thimble to minimize sampling artifacts often seen with this method. Artifacts have been known to occur when the particulate collected on the filter captures vapor phase mercury, resulting in higher particulate phase mercury than is really present. Sampling artifacts from particulate on the filter were not as much of a concern at the other two locations because most of the particulate was already removed by either the hot-side ESP or COHPAC.

Table 7 presents the results from each of the Ontario Hydro measurements. These data show that the inlet to the hot-side ESP and the inlet to COHPAC have similar, average mercury concentrations and speciation, and that mercury is oxidized across COHPAC. The outlet mercury concentrations show the effect of carbon injection with overall low mercury emissions for all species. Table 8 presents average, speciated mercury removal across COHPAC. The overall average reduction in total mercury is 90%. At the outlet the predominate species of mercury is the oxidized form; however, it is still 85% less than what was present upstream of PAC injection.

Figure 7 presents inlet and outlet mercury concentrations as measured by the S-CEMs, boiler load, and PAC injection concentration during the last 5 days of the long-term test. Periods when Ontario Hydro measurements were made are also identified. The S-CEMs indicate that mercury removal was nominally 87, 90, and 88% during the Ontario Hydro tests. This correlates well with the manual measurements. However, it is important to note that the S-CEMs showed that the average mercury removal efficiency over the multi-day time period was 78%, with variations between 36% to over 90%. This difference is probably due to varying coal and operating conditions over time. Figure 7 also shows that during this 5-day period inlet mercury concentration varied by nearly a factor of five. Outlet concentrations can be seen to follow the inlet and there are times during these transitional periods when removal efficiencies are fairly low. During the period when the Ontario Hydro tests were run, inlet mercury levels were low and fairly steady. These tests were conducted under ideal conditions and may show the best case condition for mercury control at this injection rate.

During the test program sorbent was injected at a constant rate with no attempt to increase sorbent when the inlet mercury concentration increased. However, the data in Figure 7 highlight the importance of having CEMs to use as process control for a permanent mercury control system.

Table 7: Long-Term Ontario Hydro Measurements at Hot-Side ESP Inlet, COHPAC Inlet and COHPAC Outlet

Date/Location	Particulate (mg/dncm[1])	Oxidized (mg/dncm[1])	Elemental (mg/dncm[1])	Total (mg/dncm[1])	Percent Oxidized
4/24/01ESP Inlet[2]	0.51	2.90	5.59	9.01	32
4/25/01 ESP Inlet[2]	0.03	7.30	3.68	11.01	66
4/26/01 ESP Inlet[2]	0.07	6.17	3.04	9.27	66
Average ESP Inlet	0.20	5.46	4.10	9.76	55
4/24/01 COHPAC In	0.12	4.95	5.24	10.31	48
4/25/01 COHPAC In	0.41	5.60	3.36	9.37	60
4/26/01 COHPAC In	0.16	8.55	5.17	13.88	62
Average COHPAC Inlet	0.23	6.37	4.59	11.19	56
4/24/01 COHPAC Out	0.11	0.93	0.09	1.03	91
4/25/01 COHPAC Out	0.19	0.88	0.05	1.12	78
4/26/01 COHPAC Out	0.07	0.93	-0.05	1.00	93
Average COHPAC Outlet	0.12	0.91	0.03	1.05	87

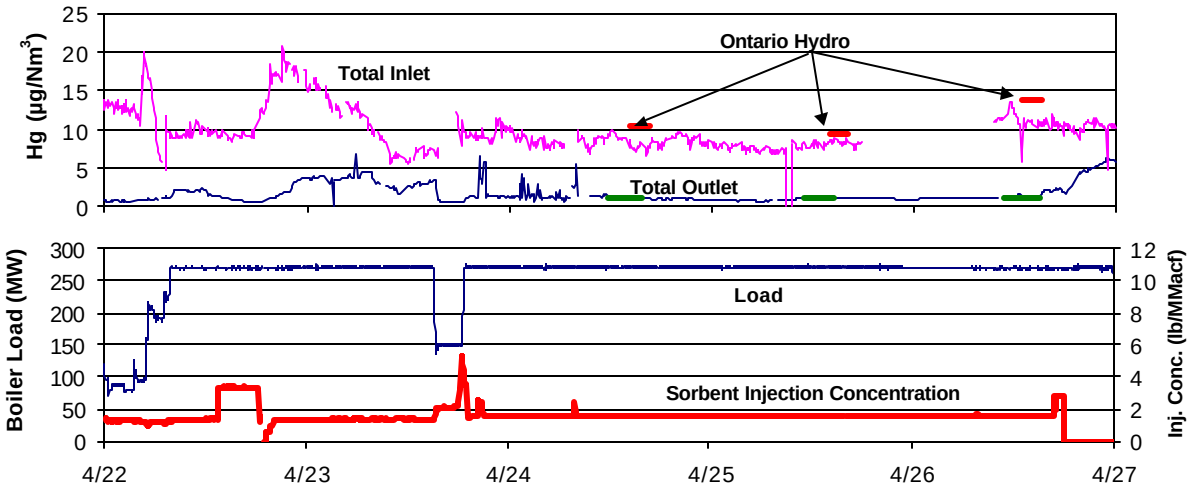
1. *Normal: T = 32°F*
2. *Tests conducted by Arcadis using an in-stack (heated) quartz thimble.*

Table 8: Average Mercury Removal Efficiencies Across COHPAC as Measured with Ontario Hydro Method

Sampling Location	Particulate (mg/dncm[1])	Oxidized (mg/dncm[1])	Elemental (mg/dncm[1])	Total (mg/dncm[1])
COHPAC Inlet	0.23	6.37	4.59	11.19
COHPAC Outlet	0.12	0.91	0.03	1.05
Removal Efficiency (%)	45.6	85.7	99.3	90.6

1. *Normal: T = 32°F*

Figure 7. Inlet and Outlet COHPAC Mercury Concentrations, Boiler Load and PAC Injection Concentration During Long-Term Tests, April 2001



The most challenging time for COHPAC performance was during the period with continuous full-load operation and PAC injection. The cumulative cleaning frequency increased to a high of 1.3 pulses/bag/hour, but was mostly maintained at levels less than 1.0 pulses/bag/hour.

Coal and Ash Characterization

Coal and ash samples were collected daily during the baseline, parametric and long-term tests. Gaston fires a variety of washed, low sulfur eastern bituminous coals. Because several different coals can be fired in a day, the daily coal samples provide relative mercury concentrations, but may not be representative of specific test periods. Standard ultimate and proximate analyses were conducted, plus measurements for mercury, chlorine, and sulfur.

Ash samples were collected from the hot-side ESP, control side (A-side) COHPAC, and test side (B-side) COHPAC hoppers. Ash generated from the E.C. Gaston Plant is impounded using a wet ash handling system. The ash is not currently beneficially reused, therefore ash characterization testing concentrated on measuring mercury and carbon content.

The mercury content of coal samples taken during the long-term tests varied between 0.09 and 0.21 µg/g. This is consistent with flue gas mercury measurements that showed considerable variability in

mercury concentration. This variability has implications on how mercury control technologies will be implemented.

The B-side ash, mixed with sorbent, showed about 30% carbon content as compared to 12% on the A-side ash. The sorbent-ash mixtures from the B-side had about 30 times the mercury of the A-side hopper ash, indicating removal of mercury by the sorbent across COHPAC.

COST ANALYSIS

The requirements and costs for full-scale, permanent, commercial implementation of the necessary equipment for mercury control using PAC injection technology are being finalized for Gaston Unit 3. Preliminary capital and sorbent costs for 80% mercury removal have been developed.

The estimated uninstalled cost for a sorbent injection system and storage silo for the 270 MW unit is about $500,000. Sorbent costs were estimated for nominally 80% mercury control based on the long-term PAC injection concentration of 1.5 lbs/MMacf. For Gaston Unit 3, this would require an injection rate of nominally 80 lbs/h. Assuming a unit capacity factor of 80% and a delivered cost of $0.50/lb for PAC, the annual sorbent cost for injecting PAC into the existing COHPAC baghouse would be about $300,000. Additional cost information is being developed for balance of plant impacts.

CONCLUSIONS

A full-scale evaluation of mercury control using activated carbon injection upstream of a COHPAC baghouse was conducted at Alabama Power Company's Plant Gaston Unit 3. Results and trends from these relatively short term tests were encouraging.

- Effective mercury removal, up to 90% efficiency, was obtained for short operating periods (8 hrs) by injecting powdered activated carbon upstream of COHPAC.
- A significant increase in the cleaning frequency of the COHPAC baghouse occurred with the injection of activated carbons. At this site, the maximum acceptable cleaning frequency and pressure drop limited the amount of sorbent that could be injected and therefore the maximum mercury removal actually achievable. Based on these results, it will be necessary to take into consideration the sorbent injection rate in the design of future COHPAC baghouses and perhaps design the baghouses more conservatively.
- On average, around 78% mercury removal was obtained when PAC was injected into COHPAC 24 hr/day during long-term tests. Mercury removal varied throughout the period and ranged from 36% to 90%.
- To verify S-CEM measurements during the long-term tests, mercury removal across COHPAC was measured following the draft Ontario Hydro method. Results show an average 90% removal for the three tests periods. These results confirm the high mercury removal measured with the S-CEMs.
- Actual mercury removals were in reasonably close agreement with theoretical model predictions for 80 to 90% removal (1.5 to 2 vs 3 lbs/MMacf) considering that the model is based on a uniform PAC particle size of 15 microns when in fact the actual FGD carbon used has a wide size distribution with significant numbers of particles below 15 microns. The model also assumed a cleaning frequency of 2 pulses/bag/hr (all bags cleaned at the same time) whereas the bags were actually cleaned at ~ 1 to 2 pulses/bag/hr (bags cleaned 15 (one row) at a time) during the tests.
- Additional testing over longer periods (up to a year) need to occur to determine the impact of carbon injection on bag life (pressure drop and bag strength) and outlet particulate emissions.

REFERENCES

1. Brown, T.D., D.N. Smith, R.A. Hargis and W.J. O'Dowd. "Mercury Measurement and Its Control: What We Know, Have Learned, and Need to Further Investigate," *J. Air & Waste Management Association*, pp. 1-97, June 1999.

2. Durham, M.D, C.J. Bustard, R. Schlager, C. Martin, S. Johnson, S. Renninger. "Field Test Program to Develop Comprehensive Design, Operating and Cost Data for Mercury Control Systems on Non Scrubbed Coal-Fired Boilers". Presented at the Air & Waste Management Association 2001 Annual Conference and Exhibition, June 24-28, 2001, Orlando, FL.

3. Durham, MD, C.J. Bustard, R. Schlager, C. Martin, S. Johnson, S. Renninger. "Controlling Mercury Emissions from Coal-Fired Utility Boilers: A Field Test" *EM, Air & Waste Management Association's Magazine for Environmental Managers, pp 27 – 33, July 2001*.

4. Meserole, F.B., R. Chang, T.R. Carey, J. Machac, and C.F. Richardson, "Modeling Mercury Removal by Sorbent Injection," J. Air & Waste Mange. Assoc., 49, 694-704, 1999.

5. Miller, Richard, W. Harrison, B. Corina, K. Cushing, R. Chang. "COHPAC (Compact Hybrid Particulate Collector) The Next Generation in Particulate Control Technology Alabama Power Company's E. C. Gaston Units #2 and #3 "A Success Story". Presented at the EPRI-DOE-EPA Combined Utility Air Pollution Control Symposium: The MEGA Symposium, Atlanta Georgia, August 16 – 20, 1999.

6. Sjostrom, S, T. Ebner, T. Ley, R. Slye, C. Richardson, T. Machalek, R. Richardson, R. Chang, F. Meserole. "Assessing Sorbents for Mercury Control in Coal-Combustion Flue Gas". Presented at the "A&WMA Specialty Conference on Mercury Emissions: Fate, Effects and Control," Chicago, IL, August 21 –23, 2001.

7. EPA website, http://www.epa.gov/ttn/atw/combust/utiltox/utoxpg.html.

8. Sjostrom, S.M., J. Bustard, M. Durham Ph.D, R. Chang Ph.D. *"Mercury Removal Trends in Full-Scale ESPs and Fabric Filters"*. Presented at the "A&WMA Specialty Conference on Mercury Emissions: Fate, Effects and Control," Chicago, IL, August 21 –23, 2001.

9. Hassett, D.J., D.F. Pflughoeft-Hassett, D.L. Laudal and J.H. Pavlish. "Mercury Release from Coal-Combustion By-Products to the Environment," Mercury in the Environment Specialty Conference, Minneapolis, MN, September 15-17, 1999.