MERCURY CONTROL WITH THE ADVANCED HYBRID PARTICULATE COLLECTOR

Technical Progress Report

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MERCURY CONTROL WITH THE ADVANCED HYBRID PARTICULATE COLLECTOR

ABSTRACT

This project was awarded under U.S. Department of Energy (DOE) Program Solicitation DE-PS26-00NT40769 and specifically addresses Technical Topical Area 4 – Testing Novel and Less Mature Control Technologies on Actual Flue Gas at the Pilot Scale. The project team includes the Energy & Environmental Research Center (EERC) as the main contractor; W.L. Gore & Associates, Inc., as a technical and financial partner; and the Big Stone Power Plant operated by Otter Tail Power Company, which will host the field testing portion of the research.

Since 1995, DOE has supported development of a new concept in particulate control, called the advanced hybrid particulate collector (AHPC). The AHPC combines the best features of electrostatic precipitators (ESPs) and baghouses in a unique configuration, providing major synergism between the two collection methods, both in the particulate collection step and in the transfer of dust to the hopper. The AHPC provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emission with conventional ESPs, and it solves the problem of reentrainment and re-collection of dust in conventional baghouses. The AHPC appears to have unique advantages for mercury control over baghouses or ESPs as an excellent gas–solid contactor.

The objective of the three-task project is to demonstrate 90% total mercury control in the AHPC at a lower cost than current mercury control estimates. The approach includes bench-scale batch testing that ties the new work to previous results and links results with larger-scale pilot testing with real flue gas on a coal-fired combustion system, pilot-scale testing on a coal-fired combustion system with both a pulse-jet baghouse and an AHPC to prove or disprove the research hypotheses, and field demonstration pilot-scale testing at a utility power plant to prove scaleup and demonstrate longer-term mercury control.

This project, if successful, will demonstrate at the pilot-scale level a technology that would provide a cost-effective technique to accomplish control of mercury emissions and, at the same time, greatly enhance fine particulate collection efficiency. The technology can be used to retrofit systems currently employing inefficient ESP technology as well as for new construction, thereby providing a solution to a large segment of the U.S. utility industry as well as other industries requiring mercury control.

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AHPC	advanced hybrid particulate collector
A/C	air-to-cloth
BCI	bag-cleaning interval
CEM	continuous emission monitor
CVAA	cold-vapor atomic absorption
DOE	U.S. Department of Energy
EERC	Energy & Environmental Research Center
EPA	U.S. Environmental Protection Agency
ESP	electrostatic precipitator
IAC	iodine-impregnated activated carbon
PRB	Powder River Basin
PTC	particulate test combustor

MERCURY CONTROL WITH THE ADVANCED HYBRID PARTICULATE COLLECTOR

EXECUTIVE SUMMARY

Since 1995, the U.S. Department of Energy (DOE) has supported development of a new concept in particulate control, called the advanced hybrid particulate collector (AHPC). The AHPC combines the best features of electrostatic precipitators (ESPs) and baghouses in a unique configuration, providing major synergism between the two collection methods, both in the particulate collection step and in the transfer of dust to the hopper.

The objective of this project is to demonstrate 90% total mercury control with commercially available sorbents in the AHPC at a lower cost than current mercury control estimates. The approach includes three levels of testing: 1) bench-scale batch testing that ties the new work to previous results and links results with larger-scale pilot testing with real flue gas on a coal-fired combustion system, 2) pilot-scale testing on a previously proven combustion system with both a pulse-jet baghouse and an AHPC to prove or disprove the research hypotheses, and 3) field demonstration pilot-scale testing at a utility power plant to prove scaleup and demonstrate longer-term mercury control.

During the first quarter of the project, initial bench-scale testing was completed, and plans were made for an initial field test earlier than planned in the original schedule.

The bench-scale results were in good agreement with previous data. This means that the planned work based on the previous results is still valid and that no changes to the overall experimental approach are necessary at this time.

Results show that the SO_2 and NO_2 concentration effects are additive and have a significant effect on sorbent performance. This finding should facilitate predicting sorbent performance in real systems when the SO_2 and NO_2 concentrations are known.

Testing with the 2.5-MW AHPC at Big Stone was not scheduled to begin until early 2002 after completing the first pilot-scale tests. However, the project team decided to complete an initial field test the first week of November 2001 prior to the pilot-scale tests at the EERC. By doing initial testing in November, mercury sampling in the worst part of the winter could be avoided.

Results from the initial field test with the Big Stone AHPC showed that:

- The average inlet mercury speciation for seven samples was 55.4% particulate bound, 38.1% oxidized, and 6.4% elemental. The high level of particulate-bound mercury and oxidized mercury was somewhat surprising because for western PRB (Powder River Basin) coals lower levels of particulate-bound mercury and oxidized mercury are more typical. However, significant capture of mercury by the fly ash has been observed in previous EERC pilot tests as well as a number of coal-fired plants burning western

fuels. Possible factors that determine the level of particulate-bound and oxidized mercury include coal type, boiler type, HCl (as well as other flue gases), temperature, and amount of carbon in the fly ash. The current level of understanding of how these factors work together is insufficient to explain the observed mercury speciation for individual plants.

- A carbon injection rate of 1.5 lb/million acf corresponds to a carbon-to-mercury ratio of approximately 2500 for the measured inlet mercury. With this carbon injection rate, from 91% to 97% total mercury collection efficiency was achieved, compared to 49% removal for the baseline case. Even though the carbon addition rate was low, the carbon was highly effective at removing mercury. The data show that the carbon was effective at removing both elemental and oxidized mercury.

- These short-term tests are highly encouraging because they prove that excellent mercury removal can be achieved with very low addition rates of carbon injected upstream of the AHPC. Further testing is needed to demonstrate that the high level of mercury removal can be maintained over the longer term and that the carbon injection will not have any adverse effect on the longer-term operation of the AHPC.

During the last quarter, additional bench-scale tests as well as the first planned pilot-scale tests were completed. A key finding from the bench-scale tests was that the fixed-bed sorbent-screening tests using simulated flue gas were in good agreement with similar tests sampling real flue gas. This suggests that as long as the main flue gas components are duplicated, the bench-scale fixed-bed tests can be utilized to indicate sorbent performance in larger-scale systems.

In the pilot-scale tests, a baseline comparison was made between the AHPC and a pulse-jet baghouse in terms of the mercury speciation change across the device and the amount of mercury retained by the fly ash. Results showed that for both devices there was very little capture of mercury by the fly ash. There was some increase in oxidized mercury, but no significant differences were noted between the AHPC and pulse-jet modes of operation.

Even though the same coal was used in the pilot-scale tests and the field tests, there was a significant difference in inlet mercury speciation. For the pilot-scale tests, results were more similar to what is typically expected for Powder River Basin coals in that most of the mercury was elemental, with little mercury capture by the fly ash. In contrast, for the field test, there was much more oxidized than elemental mercury and significant mercury capture by the fly ash. Possible reasons for the difference include higher carbon in the field ash, somewhat higher HCl in the field flue gas, possible variation in the coal, cyclone firing for the field compared to pulverized coal firing for the pilot tests, longer residence time for the field tests, and a finer particle size for the field test.

MERCURY CONTROL WITH THE ADVANCED HYBRID PARTICULATE COLLECTOR

1.0 INTRODUCTION

This project was awarded under U.S. Department of Energy (DOE) Program Solicitation DE-PS26-00NT40769 and specifically addresses Technical Topic Area 4 – Testing Novel and Less Mature Control Technologies on Actual Flue Gas at the Pilot Scale. The project team includes the Energy & Environmental Research Center (EERC) as the main contractor; W.L. Gore & Associates, Inc., as a technical and financial partner; and the Big Stone Power Plant operated by Otter Tail Power Company, which is hosting the field testing portion of the research.

Since 1995, DOE has supported development of a new concept in particulate control, called the advanced hybrid particulate collector (AHPC). The AHPC combines the best features of electrostatic precipitators (ESPs) and baghouses in a unique configuration, providing major synergism between the two collection methods, both in the particulate collection step and in the transfer of dust to the hopper. The AHPC provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emissions with conventional ESPs, and it solves the problem of reentrainment and re-collection of dust in conventional baghouses. In Phase II of the DOE-funded AHPC project, a 2.5-MW-scale AHPC was designed, constructed, installed, and tested at the Big Stone Power Plant. For Phase III, further testing of an improved version of the 2.5-MW-scale AHPC at the Big Stone Power Plant was conducted to facilitate commercialization of the AHPC technology. The AHPC appears to have unique advantages for mercury control over baghouses or ESPs as an excellent gas–solid contactor.

The objective of this project is to demonstrate 90% total mercury control with commercially available sorbents in the AHPC at a lower cost than current mercury control estimates. The approach includes three levels of testing: 1) bench-scale batch testing that ties the new work to previous results and links results with larger-scale pilot testing with real flue gas on a coal-fired combustion system, 2) pilot-scale testing on a previously proven combustion system with both a pulse-jet baghouse and an AHPC to prove or disprove the research hypotheses, and 3) field demonstration pilot-scale testing at a utility power plant to prove scaleup and demonstrate longer-term mercury control.

2.0 EXPERIMENTAL

2.1 Objective and Goals

The overall project objective is to demonstrate 90% total mercury control with commercially available sorbents in the AHPC at a lower cost than current mercury control estimates.

Test goals include the following:

- Determine if the bench-scale mercury breakthrough results can be duplicated when real flue gas is sampled.
- Compare the level of mercury control with sorbents under similar conditions at the 55-kW pilot scale between the AHPC and a pulse-jet baghouse.
- Demonstrate 90% mercury capture for both a western subbituminous and an eastern bituminous coal.
- Demonstrate mercury capture with the 2.5-MW AHPC at Big Stone.
- Demonstrate 90% mercury capture over a longer time (3 months) with the 2.5-MW AHPC at Big Stone.

2.2 Planned Scope of Work

To meet the objectives, the work was organized into five tasks:

- Task 1: Project Management, Reporting, and Technology Transfer
- Task 2: Bench-Scale Batch Testing
- Task 3: Pilot-Scale Testing
- Task 4: Field Demonstration Pilot Testing
- Task 5: Facility Removal and Disposition

2.2.1 Task 1 – Project Management, Reporting, and Technology Transfer

Task 1 includes all of the project management requirements, including planning, coordination among team members, supervision of tests, review of results, meeting attendance, and all aspects of reporting.

2.2.2 Task 2 – Bench-Scale Batch Testing

The bench-scale tests are for the purpose of verifying previous results, expanding on the SO_2 and NO_2 concentrations effect, linking the synthetic gas results to the results with real flue gas, and for screening sorbents.

The 30 tests planned with the bench-scale unit are divided into three series that follow a logical progression. The purpose of the first series of tests is to ensure that results obtained by the EERC and others can be duplicated and, second, to include SO_2 and NO_2 as variables. Series 1 tests, shown in Table 1, are intended to verify the previous bench-scale work and expand on the SO_2 and NO_2 concentration effect. In previous work, no tests were completed in which both the SO_2 and NO_2 were reduced at the same time. In all of these tests, the inlet Hg^0 concentration is typically 15 $\mu g/m^3$ and each test is run for a duration of approximately 4 hr. The 150 mg of Norit Americas FGD activated carbon sorbent is equivalent to a sorbent-to-

Table 1. Bench-Scale Series 1 – SO_2 and NO_2 Concentration

Test No.	Sorbent Type	Temp., °C	Sorbent Concentration, mg	Flue Gas	SO_2, ppm	HCl, ppm	NO, ppm	NO_2, ppm
1	FGD	135	150	Simulated	1600	50	400	20
2	FGD	135	150	Simulated	500	50	400	20
3	FGD	135	150	Simulated	200	50	400	20
4	FGD	135	150	Simulated	1600	50	400	10
5	FGD	135	150	Simulated	500	50	400	10
6	FGD	135	150	Simulated	200	50	400	10
7	FGD	135	150	Simulated	1600	50	400	5
8	FGD	135	150	Simulated	500	50	400	5
9	FGD	135	150	Simulated	200	50	400	5
10	FGD	135	150	Simulated	Repeat test to be selected			

mercury ratio of 3700 after 3 hr of exposure. This concentration has been shown to provide consistent results in previous testing and is sufficient to accurately measure the amount of mercury in the spent sorbent for mass balance closure. The Series 1 tests are now all completed. Seven of the nine tests from the 3 × 3 matrix were previously completed and were reported in the July–September quarterly. Additional results with the fully completed test matrix are shown later in this report.

The second series of bench-scale tests (Table 2) is for the purpose of comparing the bench-scale fixed-bed results sampling real flue gas to those obtained with simulated flue gas. These comparisons will be made for both a western subbituminous and an eastern bituminous coal. The simulated flue gas concentrations will be matched to actual concentrations measured in the combustion tests. Since these results are critical, both the real flue gas and simulated flue gas tests will be duplicated. In addition, tests with lower sorbent concentrations will also be conducted with flue gases matched to the two coals to assist in selecting the best sorbent concentrations for the pilot-scale tests. The real flue gas tests will be completed as part of the first two pilot-scale tests in Task 3. These bench-scale tests will be conducted using a slipstream bench-scale system sampling flue gas from the particulate test combustor (PTC).

After the Series 2 tests, the data will be evaluated to determine if the simulated gas tests provide comparable results to the tests with real flue gas, in terms of initial breakthrough capacity and desorption after 100% breakthrough. If the results are comparable, it will provide confidence in proceeding with the pilot-scale mercury capture tests.

Tests 11–14 of the Series 2 tests have been completed and are discussed later in this report.

Table 2. Bench-Scale Series 2 – Real Flue Gas Comparison

Test No.	Sorbent Type	Temp., °C	Sorbent Concentration, mg	Flue Gas	SO_2, ppm	HCl, ppm	NO, ppm	NO_2, ppm
11	FGD	135	150	Real	Flue gas from western coal			
12	FGD	135	150	Real	Duplicate test western coal			
13	FGD	135	150	Simulated*	400	4	300	5
14	FGD	135	150	Simulated Duplicate*	400	4	300	5
15	FGD	135	50	Simulated*	400	4	300	5
16	FGD	135	150	Real	Flue gas from eastern coal			
17	FGD	135	150	Real	Duplicate test eastern coal			
18	FGD	135	150	Simulated*	1000	50	400	10
19	FGD	135	150	Simulated Duplicate*	1000	50	400	10
20	FGD	135	50	Simulated*	1000	50	400	10

* Simulated flue gases will be determined from actual flue gas measurements during combustion tests; values shown are estimates.

The third series of bench-scale tests (Table 3) is for the purpose of screening alternative sorbents. The iodine-impregnated activated carbon (IAC) sorbent was chosen because of the excellent results seen in some of the previous EERC pilot-scale tests, especially at higher temperatures from 121°–177°C (250°–350°F). The IAC also appears to be better at capturing Hg^0 than the FGD. However, since the IAC is more costly than FGD, it must be effective at lower concentrations than the FGD. The IAC will be evaluated with flue gas concentrations for both a subbituminous and a bituminous coal at two concentration levels and at two temperatures. Four additional screening tests will be conducted on other promising alternative sorbents to be selected based on new information and availability. The results from these tests will be used to prescreen alternative sorbents that have the potential to provide better mercury capture than the FGD. The most promising sorbent would then be further evaluated in pilot-scale testing in Task 3.

2.2.3 Task 3 – Pilot-Scale Testing

Six weeks of testing are planned under Task 3. A week of testing includes an 8-hr heatup period on gas and then approximately 100 hr of steady-state operation firing coal. This allows for four 24-hr test periods where the PTC is operated around the clock. The planned 6 weeks of tests are shown in Table 4. The first 2 weeks are for the purpose of generating baseline data without carbon injection for a bituminous and a subbituminous coal with both the pulse-jet baghouse and the AHPC. Each test is for a duration of approximately 48 hr. These tests will establish the amount of mercury capture by fly ash and will determine whether the amount of mercury capture is different between the pulse-jet baghouse and the AHPC. It will also establish the inlet and outlet speciated mercury concentrations and whether there is a change in mercury speciation

Table 3. Bench-Scale Series 3 – Sorbent Type

Test No.	Sorbent Type	Temp., °C	Sorbent Concentration, mg	Flue Gas	SO_2, ppm	HCl, ppm	NO, ppm	NO_2, ppm
21	IAC	135	150	Simulated*	400	4	300	5
22	IAC	135	50	Simulated*	400	4	300	5
23	IAC	135	150	Simulated*	1000	50	400	10
24	IAC	135	50	Simulated*	1000	50	400	10
25	IAC	163	150	Simulated*	400	4	300	5
26	IAC	163	150	Simulated*	1000	50	400	10
27	New No. 1**	135	150	Simulated*	400	4	300	5
28	New No. 2**	135	150	Simulated*	400	4	300	5
29	New No. 3**	135	150	Simulated*	400	4	300	5
30	New No. 4**	135	150	Simulated*	400	4	300	5

* Simulated flue gases will be determined from actual flue gas measurements during combustion tests; values shown are estimates.

** New sorbents would be selected based on background data and availability.

across both devices. A second purpose for these baseline tests is to provide flue gas to support the bench-scale testing with real flue gas under Task 2.

Weeks 3 and 4 are designed to prove the ability of the technology to control mercury at the 90% level with a western subbituminous coal. Week 5 is for the purpose of testing mercury control in the AHPC with an eastern bituminous coal.

Week 6 is for the purpose of testing alternative sorbents in the AHPC. The need for alternate sorbent testing will be somewhat dependent on the results with the FGD sorbent. If 90% mercury capture was already demonstrated with both coals at a low sorbent concentration (for example, less than 3000:1), then there may be no need to further evaluate other sorbents. In this case, Week 6 would be cancelled, and testing with the field AHPC would proceed. However, if results with the FGD sorbent have not met expectations and other sorbents look more promising or if other unanswered questions remain that could be tested in the pilot tests, Week 6 would be completed.

Of the pilot-scale test matrix listed in Table 4, the first three weeks of testing with a western subbituminous coal have all been completed (Tests 1-1, 1-2, 3-1, 3-2, 4-1, and 4-2). Results from the first week of testing are given later in this report. However, data reduction for the other two tests is still being completed and will be given in the next quarterly report.

Table 4. Task 3 – Pilot-Scale Testing

Week/ Test	Purpose	Coal	Collection Device	Sorbent Type	C:Hg Ratio	Injection Method
1-1	Baseline	WSB[1]	PJBH[2]	None	NA[3]	NA
1-2	Baseline	WSB	AHPC	None	NA	NA
2-1	Baseline	EB[4]	PJBH	None	NA	NA
2-2	Baseline	EB	AHPC	None	NA	NA
3-1	Hg capture, collection device	WSB	PJBH	FGD	3000[5]	Continuous
3-2	Hg capture, collection device	WSB	AHPC	FGD	3000[5]	Continuous
4-1	Hg capture, residence time	WSB	AHPC	FGD	3000[5]	Continuous
4-2	Hg capture, residence time	WSB	AHPC	FGD	3000[5]	Batch
5-1	Hg capture, residence time	EB	AHPC	FGD	3000[5]	Continuous
5-2	Hg capture, residence time	EB	AHPC	FGD	3000[5]	Batch
6-1	Sorbent type and concentration	WSB	AHPC	New No. 1[6]	3000[5]	Continuous[6]
6-2	Sorbent type and concentration	WSB	AHPC	New No. 1[6]	1000[5]	Continuous[6]
6-3	Sorbent type and concentration	WSB	AHPC	New No. 2[6]	3000[5]	Continuous[6]
6-4	Sorbent type and concentration	WSB	AHPC	New No. 2[6]	1000[5]	Continuous[6]

[1] Western subbituminous.
[2] Pulse-jet baghouse.
[3] Not applicable.
[4] Eastern bituminous.
[5] Estimated concentrations; actual concentration will be based on previous testing.
[6] To be selected.

2.2.4 Task 4 – Field Demonstration Pilot Testing

Demonstration of mercury control with the AHPC at the 2.5-MW scale at a utility power plant is the next logical step toward proving the commercial validity of this approach. A total of 5 months of field tests was originally planned. The first month was planned for baseline testing without sorbent injection to establish the mercury concentration, speciation, and amount of fly ash capture as well as to compare mercury emissions at the plant stack with the AHPC outlet.

The second month of field tests was planned for the purpose of establishing the sorbent addition rate to achieve 90% mercury control. Following the second month of field testing was a project decision point to determine if an acceptable level of mercury control has been achieved. If results are acceptable, field testing will continue. Depending on the level of success with the FGD sorbent in the field and the pilot-scale test results with alternative sorbents, the third month was planned for the purpose of evaluating alternative sorbents. If alternative sorbent testing is not necessary, then 3 months of longer-term testing with the FGD sorbent are to be completed. The longer-term operation will establish whether there are any longer-term problems associated with the sorbent injection such as bag-cleaning problems. If alternative sorbents are tested during Month 3, then the longer-term demonstration testing would last only 2 months.

According to the planned work, testing with the 2.5-MW AHPC at Big Stone Power Plant was not scheduled to begin until after completing the first pilot-scale tests. However, the project team decided to conduct an initial field test the first week of November 2001 prior to the pilot-scale tests at the EERC.

The field test at Big Stone was completed the week of November 5–10, 2001, with baseline testing on the first day, followed by carbon injection in both AHPC and pulse-jet operational modes for the remainder of the week. The starting carbon addition rate was set at 24 kg of carbon sorbent/million m^3 of flue gas (1.5 lb of carbon sorbent/million acf), with the plan that it could be increased if necessary to achieve good mercury control. However, over 90% mercury control was seen at this carbon addition rate so no testing was completed at higher carbon concentrations.

The results from the November field test were previously reported in the October–December quarterly. Additional field testing with the 2.5-MW field AHPC is expected to resume in the Summer of 2002.

2.2.5 Task 5 – Facility Removal and Disposition

The field AHPC will be dismantled and removed at the end of this project if no further testing is anticipated in support of subsequent work at the Big Stone Power Plant. If further testing were to be completed with the field AHPC at another site (funded by possible subsequent projects), the AHPC components would be moved to that site. If no other AHPC testing is anticipated, the salvageable AHPC components will be returned to the EERC, and the larger steel components will be disposed of as scrap steel. The site will then be restored to its original condition. The Big Stone Power Plant will be responsible for removing the 24-in. ductwork that breeches the plant ductwork, the electrical power lines, air supply lines, and communication lines once the project is complete.

3.0 RESULTS

3.1 Series 1 – Bench-Scale Tests

The nine tests for the Series 1 matrix are shown in Table 1. The other gas concentrations, which were held constant for all of the tests, are shown in Table 5. A key reason for completing these tests was to expand on the SO_2 and NO_2 concentration effects seen in previous work. The nine breakthrough curves for these tests are presented at constant SO_2 concentration with varying NO_2 and at constant NO_2 concentration with varying SO_2 concentration in Figures 1–6. For comparison, all nine are shown in Figure 7.

Table 5. Baseline Flue Gas Concentrations

Hg^0	15 µg/m^3
O_2	6%
CO_2	12%
H_2O	8%
N_2	Balance
HCl	50 ppm
NO	400 ppm
NO_2	Varied
SO_2	Varied

The breakthrough graphs show several effects of SO_2 and NO_2 concentration. First, the time until initial breakthrough decreases significantly with increasing SO_2 and NO_2 concentrations. At the higher concentrations breakthrough occurs after about 30 min and at the lower concentrations, breakthrough occurs after about 2.5 hr. This implies that a sorbent at the lower concentrations would have five times the mercury capacity of a sorbent exposed to the higher concentrations. This range is significant enough that it might dictate whether mercury control with carbon is practical for a given set of conditions. Since these are fixed-bed tests, the cumulative carbon-to-mercury ratio is infinite at the start of the test and decreases with exposure

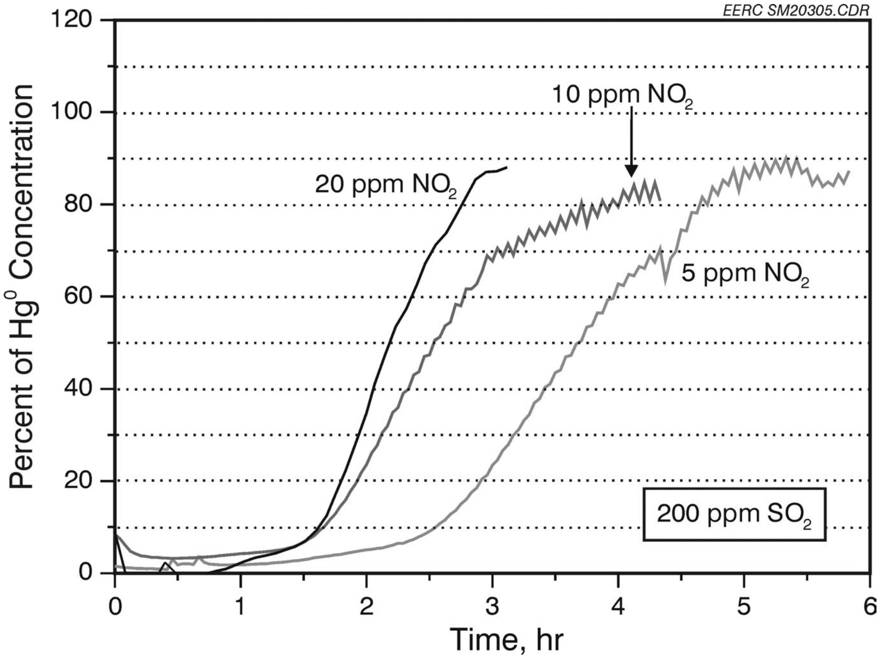

Figure 1. Breakthrough curve showing 200 ppm SO_2 concentration with varying NO_2 concentration.

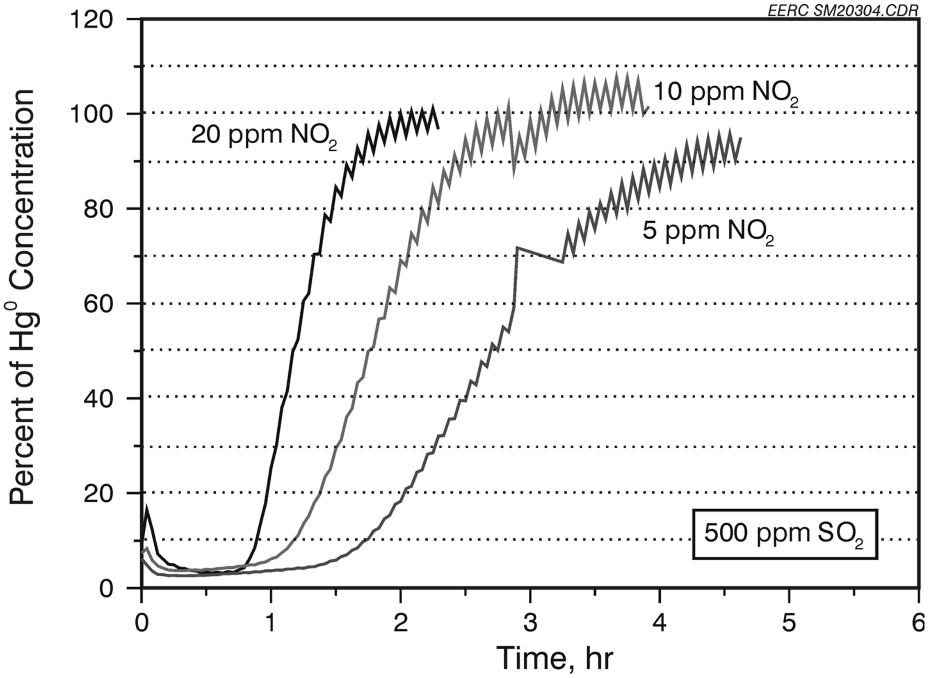

Figure 2. Breakthrough curve showing 500 ppm SO_2 concentration with varying NO_2 concentration.

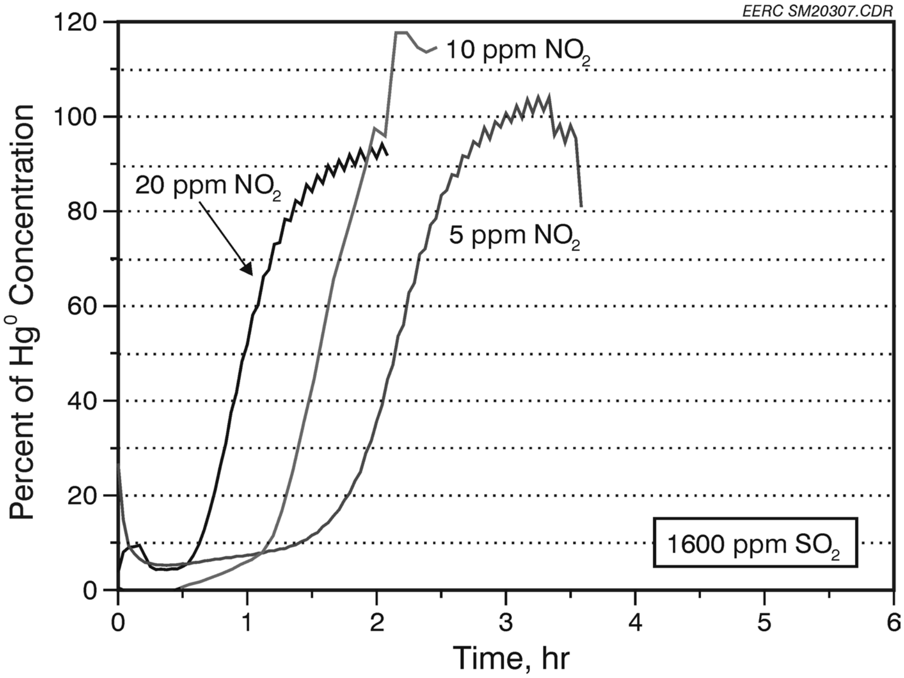

Figure 3. Breakthrough curve showing 1600 ppm SO_2 concentration with varying NO_2 concentration.

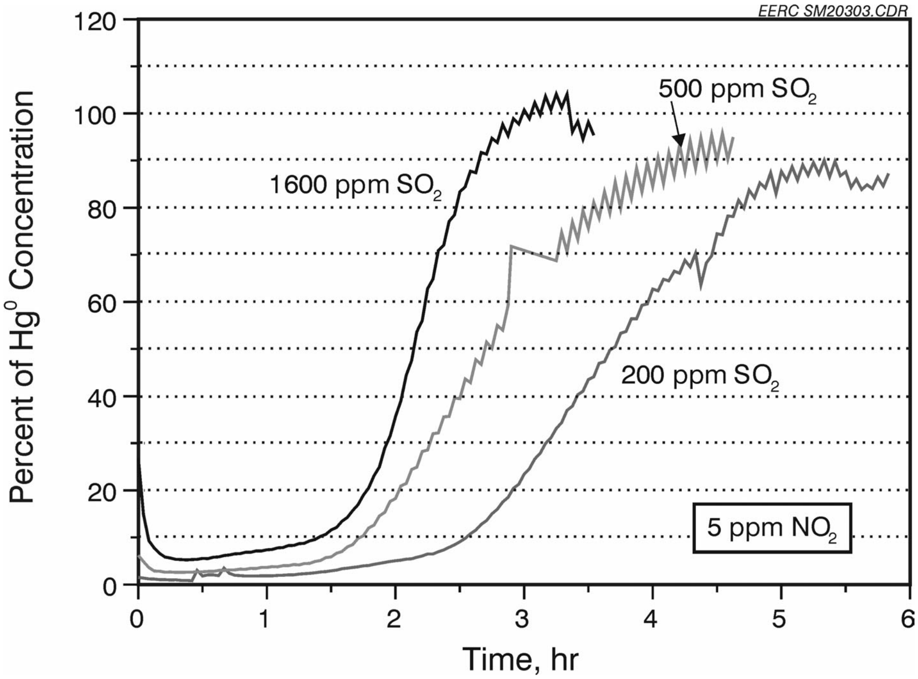

Figure 4. Breakthrough curve showing 5 ppm NO_2 concentration with varying SO_2 concentration.

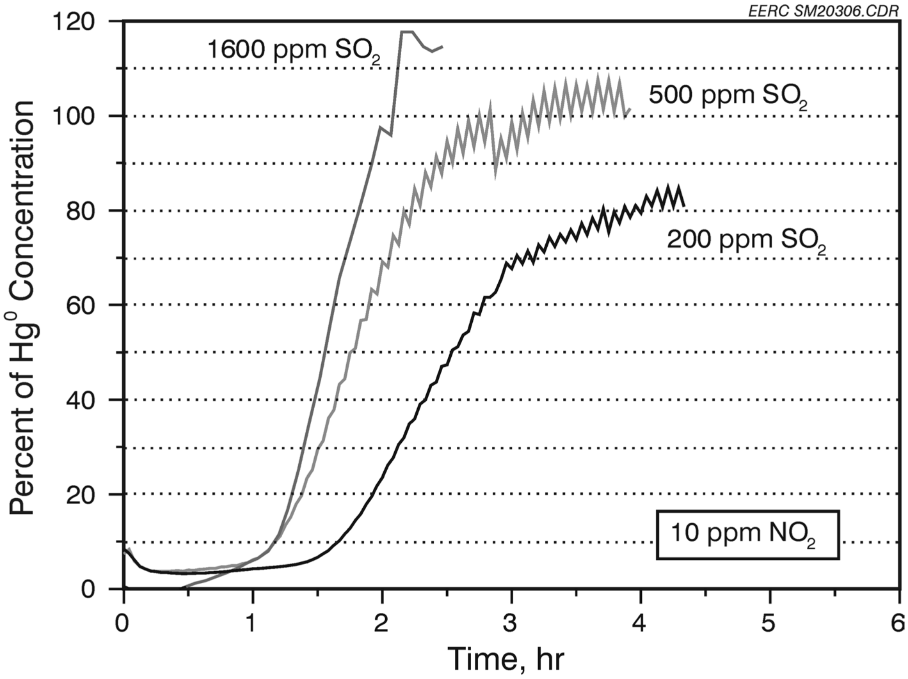

Figure 5. Breakthrough curve showing 10 ppm NO_2 concentration with varying SO_2 concentration.

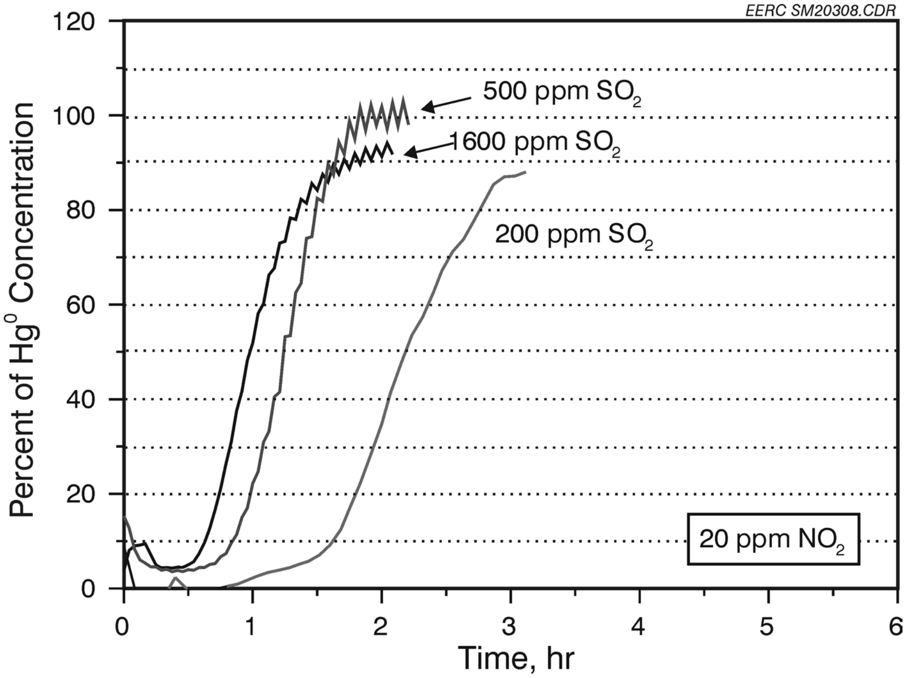

Figure 6. Breakthrough curve showing 20 ppm NO_2 concentration with varying SO_2 concentration.

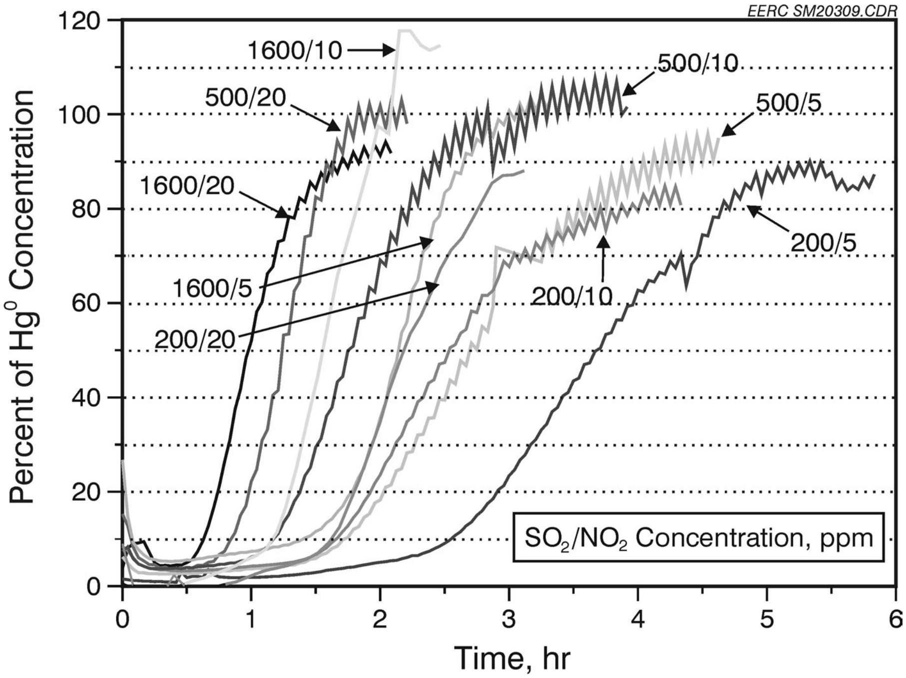

Figure 7. Breakthrough curve showing all nine tests of various NO_2 concentrations with various SO_2 concentrations.

time. After 3 hours of exposure, the calculated ratio is approximately 3700, which is considered a reasonable value for control. However, after only 30 min, the cumulative ratio is 22,200, which is likely too high to be considered for economical mercury control. If these data can be shown to be indicative of sorbent performance in real systems, they would appear to be valuable for initial screening of potential sorbents for a known set of flue gas conditions. At high SO_2 and NO_2 concentrations, the data suggest that effective elemental mercury control would be difficult to achieve at a reasonable carbon-to-mercury ratio.

The second obvious SO_2 and NO_2 concentration effect is that at lower concentrations the slope of the breakthrough curves is more gradual. This suggests that there is some additional sorbent capacity available for the lower SO_2 and NO_2 concentrations. However, even at the very lowest concentrations tested, the time from initial breakthrough until 50% breakthrough was extended by only about 1 hr, which upon integration yields only about a 20% increase in sorbent capacity.

A third conclusion from these tests is that both SO_2 and NO_2 concentration have a significant effect on breakthrough capacity and that the combined effect of both of these gases is additive, at least within the range of concentrations tested. These breakthrough tests are highly repeatable and appear to be quantitative to the extent that all of the midpoint tests fell between the respective low- and high-concentration test results.

These Series 1 tests are in agreement with previous bench-scale work conducted for other projects that shows the significance of SO_2 and NO_2 concentration on the elemental mercury capture ability of various sorbents (1). Most of the previous tests were completed with either a HCl concentration of 50 ppm, which would match a medium-chlorine bituminous coal, or with no HCl. The effect of NO_2 and SO_2 concentration at much lower HCl levels of 1–5 ppm, which are more typical of western subbituminous coals, has not previously been tested. While previous results have shown that higher NO_2 and SO_2 concentrations lead to poorer sorbent performance, the presence of 50 ppm HCl was shown to be beneficial to mercury capture. Even though low SO_2 and NO_2 concentrations with a subbituminous coal would be expected to result in good sorbent performance, the lower HCl may lead to poorer performance.

3.2 Series 2 – Bench-Scale Tests

The Series 2 tests (see Table 2) are being completed to specifically tie the bench-scale simulated flue gas results to results generated when sampling real flue gas from coal combustion. Tests 11–14 in Series 2 were planned for this objective for a western subbituminous coal and Tests 16–19 for an eastern bituminous coal. Each of these conditions was planned in duplicate. Tests 15 and 20 were planned to briefly evaluate sorbent concentration for both coals. During the pilot-scale Tests 1-1 and 1-2 (see Table 4), a total of three bench-scale breakthrough tests were completed on three different days of operation. These results are shown in Figure 8 along with a simulated flue gas test in which the gas concentrations were set according to the actual measured concentrations from the coal-fired tests (see Table 6).

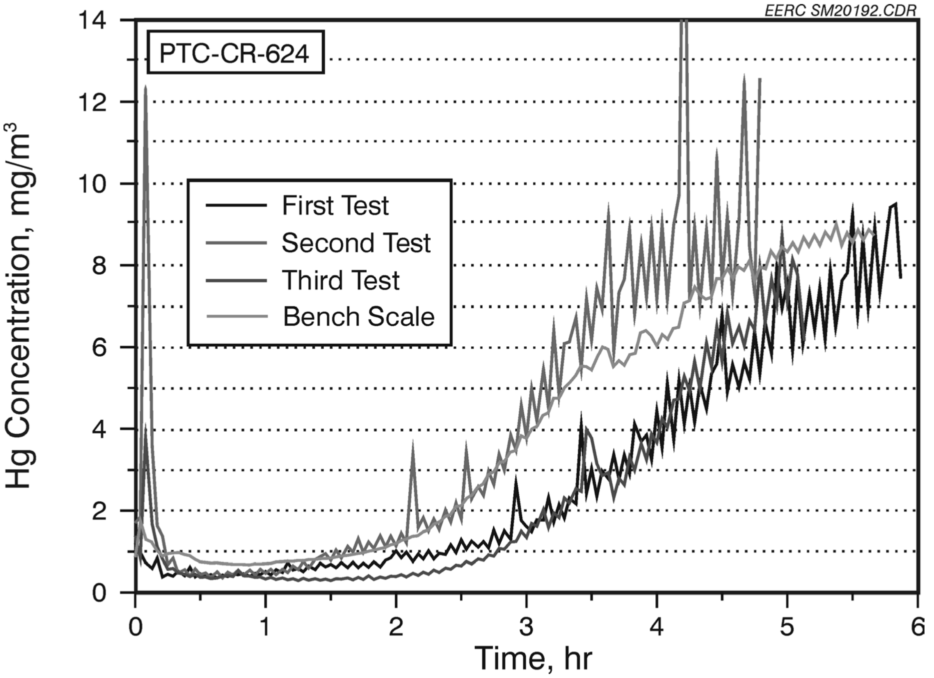

Figure 8. Bench-scale breakthrough tests, comparison of results using simulated gas with results using real flue gas.

Table 6. Flue Gas Concentrations for Bench-Scale Breakthrough Tests

Hg (total)	10 µg/m^3
O_2	5%
CO_2	12%
H_2O	10%
N_2	Balance
HCl	3 ppm
NO	598 ppm
NO_2	5 ppm
SO_2	267 ppm

From Figure 8, the simulated flue gas test is in good agreement with the results upon exposure to real flue gas since the simulated flue gas curve is within the range of the three actual flue gas curves. The results are also in reasonable agreement with the case of nearest SO_2 and NO_2 concentrations (500 ppm SO_2 and 5 ppm NO_2) from the Series 1 tests (see Figure 4), even though the mercury concentration and speciation were somewhat different. For the Series 1 bench-scale tests, the mercury concentration was 15 µg/m^3 of elemental mercury. The inlet mercury concentration from the pilot-scale tests averaged 11 $\mu g/m^3$, with about 75% elemental mercury. For the comparative simulated bench-scale test from Series 2, the mercury was set at 10 $\mu g/m^3$ but included only elemental mercury. Decreasing the mercury from 15 to 10 $\mu g/m^3$ would be expected to extend the time until breakthrough by 50%. For the Series 1 test at 500 ppm SO_2 and 5 ppm NO_2, breakthrough occurred after about 1.75 hr (see Figure 4), and for the simulated Series 2 test, breakthrough occurred at about 2.25 hr. The 2.25 hr is somewhat less than the 50% increase expected, but the lower HCl value for the Series 2 test may be the reason. Considering all of these effects, the simulated flue gas breakthrough curves appear to be in good agreement with results from real flue gas.

3.3 Pilot-Scale Tests

3.3.1 Test Conditions and Schedule

Tests 1-1 and 1-2 from the test matrix shown in Table 4 were completed with the EERC PTC and pilot-scale AHPC. The run was designated as PTC-CR-624. The system was operated continuously from Monday through Thursday evening, a total of four days. The coal burned for this test was Codero Rojo Complex Powder River Basin (PRB) subbituminous, which is the same coal burned at the Big Stone Power Plant during the November field test. In addition to providing real flue gas for the bench-scale tests, another purpose was to provide baseline mercury data with both the AHPC and a pulse-jet baghouse, with several different cleaning cycle configurations.

Upon starting on January 7, the system was operated at a 30-min bag-cleaning interval under a current level of 4.00 mA until January 8, 5:00 p.m. During this time period, the perforated plates, electrodes, and outside wall collection surface were rapped every 30 minutes and the hopper ash was also emptied once per 30 minutes to maintain the ash at a constant residence time level.

From January 8, 5:00 p.m., to January 10, 7:32 a.m., the unit operated at a constant pulse trigger pressure of 8.0 in. W.C. (2.0 kPa) while the current level was still kept at 4.00 mA, resulting in a bag-cleaning interval in the range of 4–6 hr. During the test period, the hopper ash was emptied twice (January 9, 3:16 p.m., and January 10, 8:16 a.m.), providing approximately 17–22 hr residence time of ash in the system.

The unit was next operated in a pulse-jet mode with a pulse trigger pressure of 8.0 in. W.C. (2.0 kPa) from 8:16 a.m. to 7:20 p.m. on January 10. Because of the high air-to-cloth (A/C) ratio of 12 ft/min (3.7 m/min), the bag-cleaning interval was around 3 min. The hopper ash was emptied once every 30 min.

During the first-day test, one pair of Method 101A and one pair of Ontario Hydro method measurements were carried out both at the AHPC inlet and outlet to measure mercury concentration in the system. A total of four Ontario Hydro mercury measurements were taken for each day during the rest of the test. A summary of the mercury, solids, and flue gas sampling is listed in Table 7.

3.3.2 Coal Sampling and Analysis

Approximate 5478 lb of Cordero Rojo Complex was burned during the 1-week test, and a coal sample was collected each day from the coal feed conveyor. The mercury analysis results are listed in Table 8, showing a mean value of 0.108 µg/g in the raw coal.

Table 7. Summary of Mercury, Gas, and Solids Samples Taken

Ontario Hydro
  Day 1 – One pair of simultaneous inlet and outlet
  Days 2–4 – Two pairs of simultaneous inlet and outlet
Method 101A
  Day 1 – One pair of simultaneous inlet and outlet
Mercury continuous emission monitor (CEM)
  Continuous sampling with one PS Analytical mercury CEM, one SemTech CEM, and Two Tekran CEMs on Days 1–4
HCl
  Two inlet samples on Days 2 and 4
SO_2, NO, NO_2, CO, CO_2, O_2
  Sampling at both inlet and outlet with portable Ecom gas analyzer at Days 2 and 4
Coal
  One sample per day
AHPC hopper ash
  One sample per day

Table 8. Coal Mercury Analysis

Sample	Hg Concentration, dry coal basis, µg/g
Day 1–3	0.114
Day 4	0.103
Mean	0.108

Proximate and ultimate analyses are listed in Table 9. From the ultimate analysis and the mercury content in raw coal (Table 8), a theoretical combustion calculation was completed to determine the theoretical mercury concentration in the inlet flue gas. From the combustion calculation, the coal should produce 96.8 scf of dry flue gas per lb normalized to 3.0% oxygen, which corresponds to a theoretical inlet mercury concentration of 13.4 $\mu g/m^3$ of dry flue gas at 3.0% O_2. The theoretical inlet mercury value is somewhat higher than the 9.2 to 12.1 $\mu g/m^3$ inlet total mercury concentrations measured by the Ontario Hydro method. Possible reasons for the difference are discussed later in this report.

Table 9. Coal Analysis for the PTC-CR-624 Test

	As Sampled	Moisture Free
Proximate Analysis, %		
Moisture Content	23.1	NA
Volatile Matter	36.43	47.37
Fixed Carbon	35.42	46.06
Ash	5.05	6.57
Ultimate Analysis, %		
Hydrogen	6.12	4.62
Carbon	52.53	68.31
Nitrogen	0.78	1.02
Sulfur	0.24	0.31
Oxygen	35.27	19.17
Ash	5.05	6.57
Heating Value, Btu/lb	9023	11733

3.3.3 Flue Gas Composition

The flue gas compositions, O_2, CO_2, CO, NO, NO_2, and SO_2, were monitored and daily average values calculated, listed in Table 10. Because of the low-sulfur Cordero Rojo coal, the SO_2 concentration in the flue gas was at a low level, ranging from 260 to 330 ppm. The NO and NO_2 concentrations in the flue gas were 549–695 ppm for NO and only 4–7 ppm for NO_2. The O_2 concentration was slightly increased from the inlet to the outlet because of some air leakage in the system. Gas concentrations are normalized to a 3% O_2 level and shown in Table 11. Two HCl samples (using EPA Method 26) were collected at the AHPC inlet at Day 2 and 4, shown in Tables 10 and 11.

Table 10. Summary of Flue Gas Compositions During PTC-CR-624 Sampling, dry basis

		O_2, %	CO_2, %	CO, ppm	NO, ppm	NO_2, ppm	SO_2, ppm	HCl, ppm
Day 1	In	4.5	13.4	7.0	653	–	299	–
	Out	5.2	–	–	601	–	269	–
Day 2	In	4.4	14.7	6.6	693	4	306	3.4
	Out	5.2	–	–	614	3	267	
Day 3	In	4.6	15.1	37.1	695	–	293	–
	Out	5.3			624	–	260	–
Day 4	In	4.4	15.1	43.5	630	5	331	2.4
	Out	5.1	–	–	549	7	271	–

Table 11. Summary of Flue Gas Compositions During PTC-CR-624 Sampling, dry basis normalized to 3% O_2

		O_2, %	CO_2, %	CO, ppm	NO, ppm	NO_2, ppm	SO_2, ppm	HCl, ppm
Day 1	In	3	14.6	7.6	712	–	326	–
	Out	3	–	–	685	–	306	–
Day 2	In	3	15.9	7.2	751	4.3	332	3.7
	Out	3	–	–	699	3.4	304	
Day 3	In	3	16.6	40.7	763	–	321	–
	Out	3			715	–	298	–
Day 4	In	3	16.4	47.2	683	5.4	359	2.6
	Out	3	–	–	621	7.9	307	–

3.3.4 Ontario Hydro Mercury Data Discussion

Ontario Hydro sampling trains were set up at the AHPC inlet and outlet, respectively, to measure mercury concentrations in the flue gas. The target sampling time was 2 hours. The flue gas was isokinetically pulled through the filtration system to remove fly ash from flue gas. The particle-free flue gas then passed through a series of impingers to capture elemental and oxidized mercury followed by a silica gel-filled impinger where the moisture and SO_2 were removed. The dry flue gas exiting the impinger was conveyed through a MISCO control box (Model 7200) to measure the flow rate and the gas temperature.

Since the Ontario Hydro method uses isokinetic sampling to measure mercury concentration in fly ash particles, it also provides information on the dust loading in the flue gas. The dust-loading measurement results at the inlet and outlet of the AHPC system (obtained from Ontario Hydro method) are listed in Table 12, and the corresponding particle collection efficiencies are also calculated and presented in Table 12. The overall particle collection efficiency varied from 99.984% to 99.996% during the first 3-day tests, showing excellent capture of fly ash particles in the AHPC mode under both short bag-cleaning interval (30 min) and long bag-cleaning interval (4–6 hr). When the unit was operated in pulse-jet mode for the Day 4 test, the overall particle collection efficiency was reduced to 99.0%–99.52%. The reason is that the unit was experiencing frequent pulsing (every 3 min), causing a high particle penetration through the filter bags as a result of a particle emission spike at each pulsing. The results confirm the AHPC technology is superior to a conventional baghouse and demonstrate that longer bag-cleaning intervals benefit particle emission reduction.

As discussed earlier, the Ontario Hydro sampling method provides mercury species information in flue gas as elemental mercury vapor, oxidized mercury, and mercury associated with particulate. All the results were presented in the form of $\mu g/Nm^3$ based on the cold-vapor atomic absorption (CVAA) analysis results of the impinger solutions, sampling of flue gas volume, and dust loading. All the measured mercury concentrations in the flue gas were corrected to the concentrations of moisture-free 3% O_2 level.

Table 12. Dust Loading at the AHPC Inlet and Outlet and the Calculated Collection Efficiency

	Inlet, gr/dscf	Outlet, gr/dscf	Collection Efficiency, %
Day 1-1	1.422	0.000058	99.996
Day 1-2	1.538	0.000079	99.995
Day 2-1	1.671	0.000187	99.989
Day 2-2	1.591	0.000249	99.984
Day 3-1	1.514	0.000112	99.993
Day 3-2	1.556	0.000186	99.988
Day 4-1	1.417	0.00680	99.520
Day 4-2	1.524	0.0152	99.000

A summary of Ontario Hydro method mercury analysis results during the 4-day test is listed in Table 13. The total mercury concentration in the flue gas (present as total mercury concentration at the AHPC inlet) varied from 9.2 to 12.1 μg/m^3, which is close to a theoretical value of 13.4 μg/m^3 obtained from the coal combustion calculation based on the coal analysis. The slight difference may be the result of uncertainty in the mercury coal analysis as well as additional process variability.

The mercury species distributions for Day 1–2 tests are plotted as a function of sampling location shown in Figure 9. The unit was operated under AHPC mode, with a 30-min bag-cleaning interval. The collection plates and electrodes were rapped every 30 min, and the hopper ash was also emptied every half hour during the testing period to keep the residence time of the fly ash in the chamber at approximate 30 minutes. At the AHPC inlet, oxidized mercury vapor varied from 2.1 to 3.7 μg/m^3, while the elemental mercury vapor was in the range of 6.8–9.8 μg/m^3. Mercury species associated with particulate was at a low level, ranging from 0.3–0.5 μg/m^3, showing little capture of mercury species by fly ash particles. Because of the excellent fly ash capture efficiency of the AHPC, particulate-associated mercury was completely removed from the flue gas. The total outlet gas-phase mercury, was at the same level as that at the AHPC inlet. However, the oxidized mercury vapor concentration at the AHPC outlet was always higher than the corresponding oxidized mercury vapor concentration measured at the AHPC inlet. This corresponded to a reduction in elemental mercury concentration.

A pair of Method 101A samples was taken at both the AHPC inlet and outlet simultaneously in the Day 1 test. The goal was to compare Method 101A with the results from the Ontario Hydro method being performed on the same day. Method 101A provides information on mercury associated with fly ash and total concentration of mercury vapor in flue gas but cannot differentiate mercury species in the vapor phase. As shown in Table 14, 11.3 μg/m^3 of mercury vapor and 0.3 μg/m^3 of particulate mercury were measured at the inlet, and 10.5 μg/m^{3}of mercury vapor was measured at the outlet. The results agree with the data obtained from the Ontario Hydro method.

Table 13. Summary of Ontario Hydro Mercury Results, dry flue gas at 3.0% O_2 (µg/Nm^3)

		Hg^0	Hg^+	Hg (Particulate)	Hg (Total)
Day 1	Inlet	9.8	2.1	0.3	12.1
	Outlet	9.1	6.2	0.0	15.2
Day 2	Inlet	6.8	3.7	0.5	11.0
		9.1	2.2	0.3	11.6
	Outlet	5.3	5.7	0.0	11.0
		6.6	5.9	0.0	12.5
Day 3	Inlet	8.0	2.2	0.1	10.3
		8.1	2.3	0.7	11.0
	Outlet	4.1	6.9	0	11.0
		4.4	7.1	0.0	11.5
Day 4	Inlet	5.0	5.1	1.5	11.6
		4.7	4.4	0.1	9.2
	Outlet	3.4	5.9	0.0	9.3
		3.8	5.1	0.0	8.9

Day 1 – AHPC mode, 30-min bag-cleaning interval
Day 2 – AHPC mode, 30-min bag-cleaning interval
Day 3 – AHPC mode, 8.0-in.-W.C. (2.0-kPa) pulse trigger pressure
Day 4 – Pulse-jet mode, 8.0-in.-W.C. (2.0-kPa) pulse trigger pressure

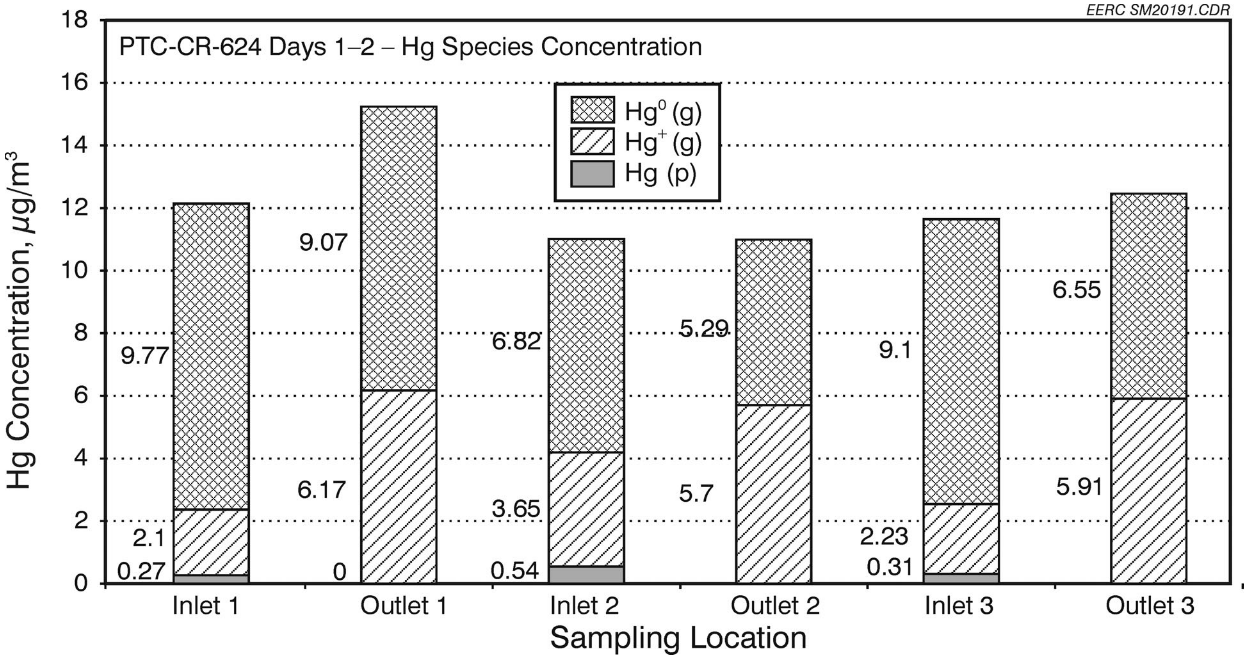

Figure 9. PTC-CR-624 Day 1–2 – mercury species concentration in flue gas at the AHPC inlet and outlet (AHPC mode, 30-min bag-cleaning interval).

Table 14. Summary of Method 101A Results, dry flue gas at 3.0% O_2)

		Hg (g)	Hg (Particulate)	Hg (Total)
Day 1	Inlet	11.3	0.3	11.5
	Outlet	10.5	0	10.5

To better clarify the transformation of mercury species across the AHPC unit, the average normalized mercury species distribution at the AHPC inlet is plotted in Figure 10. At the AHPC inlet, 75.3% of mercury was in elemental state, 21.7% was oxidized mercury vapor, and only 3.0% of total mercury was associated with fly ash particles. Since the particulate collection efficiency of the AHPC was 99.99%, the mercury associated with the inlet fly ash was all collected in the hopper. The mercury in the hopper ash was analyzed for comparison with mercury concentration on the Ontario Hydro inlet sampling filters (Table 15). The hopper ash mercury was added to the outlet vapor species and normalized to 100% for comparison with the inlet (Figure 10). Results show there was an increase in oxidized mercury from 21.7% to 43.1% across

the AHPC, while there was a corresponding decrease in elemental mercury from 75.3% at the inlet to 52.9% at the outlet. The results clearly demonstrate that elemental mercury vapor was oxidized across the AHPC, but very little was captured by the fly ash.

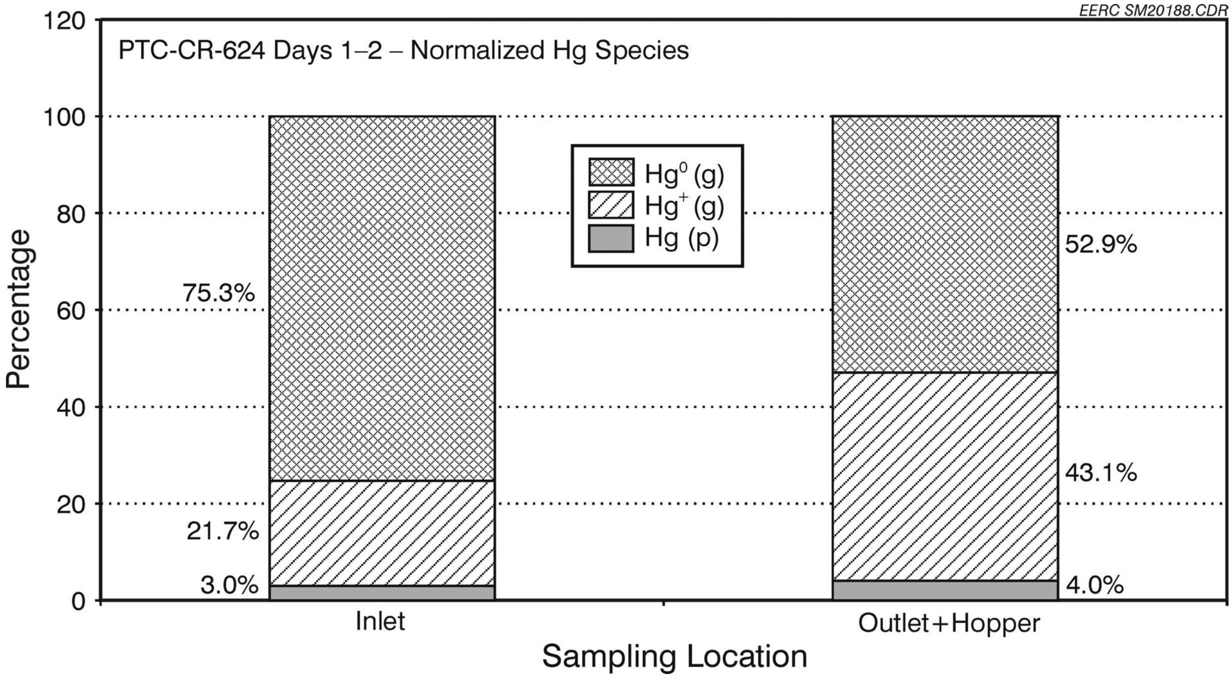

Figure 10. PTC-CR-624 Day 1–2 – normalized mercury species distribution in flue gas across the AHPC unit (AHPC mode, 30-min bag-cleaning interval).

Table 15. Mercury Concentration in Fly Ash

Test Day	Sample Type	Time Sample Taken	Hg Concentration, µg/g
Day 1	Inlet filter	15:05–16:05	0.0595
Day 1	Inlet filter	16:37–17:37	0.0581
Day 2	Inlet filter	11:00-13:00	0.109
Day 2	Inlet filter	15:00-17:00	0.0653
Day 2	Hopper ash	17:00	0.102
Day 3	Inlet filter	9:10-11:10	0.0311
Day 3	Inlet filter	12:17-14:17	0.148
Day 3	Hopper ash	15:06	0.182
Day 4	Inlet filter	10:17-12:17	0.396
Day 4	Inlet filter	14:00-16:00	0.025
Day 4	Hopper ash	19:30	0.337
Day 4	Outlet filter	10:17-12:17	0.944
Day 4	Outlet filter	14:00-16:00	0.233

For the Day 3 sampling test, the unit was operated in AHPC mode with an 8.0-in.-W.C. (2.0-kPa) pulse-trigger pressure, resulting in longer bag-cleaning intervals ranging from 4 to 6 hr. The hopper ash was emptied twice during the testing period, providing approximate 17–22 hr residence time of fly ash in the system. Two pairs of Ontario Hydro sampling were conducted at the AHPC inlet and outlet, respectively, and the data are plotted in Figure 11. The total mercury vapor concentrations at the AHPC inlet and outlet were at the same level, showing no capture of mercury vapor across the AHPC unit and a complete removal of mercury associated with fly ash. Again, oxidation of elemental mercury vapor to oxidized mercury vapor across the AHPC unit was observed.

Normalized mercury species distributions across the AHPC unit were calculated as mentioned above and plotted in Figure 12. At the AHPC inlet, elemental mercury was the dominant species, accounting for 75.4%, while the oxidized mercury vapor was 20.8%, and mercury associated with fly ash particles was 3.8%. The inlet mercury species distribution for the Day 3 test agrees very well with the results obtained for the Day 1–2 test. In the flue gas out of the AHPC unit, only 35.0% of the total mercury vapor was in the elemental state compared to the 52.9% measured for the Day 1–2 test. The oxidized mercury, on the other hand, increased to 58.2%. The mercury concentration associated with fly ash also increased slightly from 3.8% at the inlet to 6.8%. The presence of more ash in the AHPC chamber along with the extended residence time of fly ash in the AHPC unit may have promoted the increased mercury vapor oxidation compared to the Day 1–2 test where the residence time was limited to 30 min.

The AHPC unit was then operated in pulse-jet mode (no high-voltage power) for the Day 4 test. The A/C ratio was kept at 12 ft/min (3.7 m/min), resulting in a frequent bag pulse cleaning every 3 min caused by the high dust loading to the filter bags and severe fly ash reentrainment. The hopper ash was also emptied every half hour to keep a 30-min maximum residence time of fly ash in the system. The measured mercury species concentrations at the AHPC inlet and outlet are plotted in Figure 13. The mercury species concentrations at the AHPC inlet during this test are somewhat different from the previous tests in that more mercury vapor was already in an oxidized state at the AHPC inlet. The normalized mercury distributions at the inlet and outlet are plotted in Figure 14.

Because of the frequent bag-cleaning pulsing, a fraction of ultrafine fly ash was measured at the AHPC outlet. The ultrafine ash was also analyzed for mercury. However, based on the measured dust loading at the AHPC outlet, mercury associated with fly ash was only 0.01–0.1 $\mu g/m^3$, indicating a very low emission level of particulate mercury.

From Figure 14, there was also an increase in oxidized mercury across the pulse-jet baghouse, but not to the extent of the increase noted in either the short-residence-time AHPC test (Figure 10) or long-residence-time AHPC test (Figure 12). However, since the inlet oxidized mercury fraction was higher for the pulse-jet test, no conclusion can be drawn as to the reason. Some variation in inlet speciation is typically seen with the Ontario Hydro method, and the differences seen may simply be the effect of that variability. The data indicate no significant difference between the pulse-jet and AHPC in the level of oxidation of mercury across the device or in the amount of mercury retained by the fly ash.

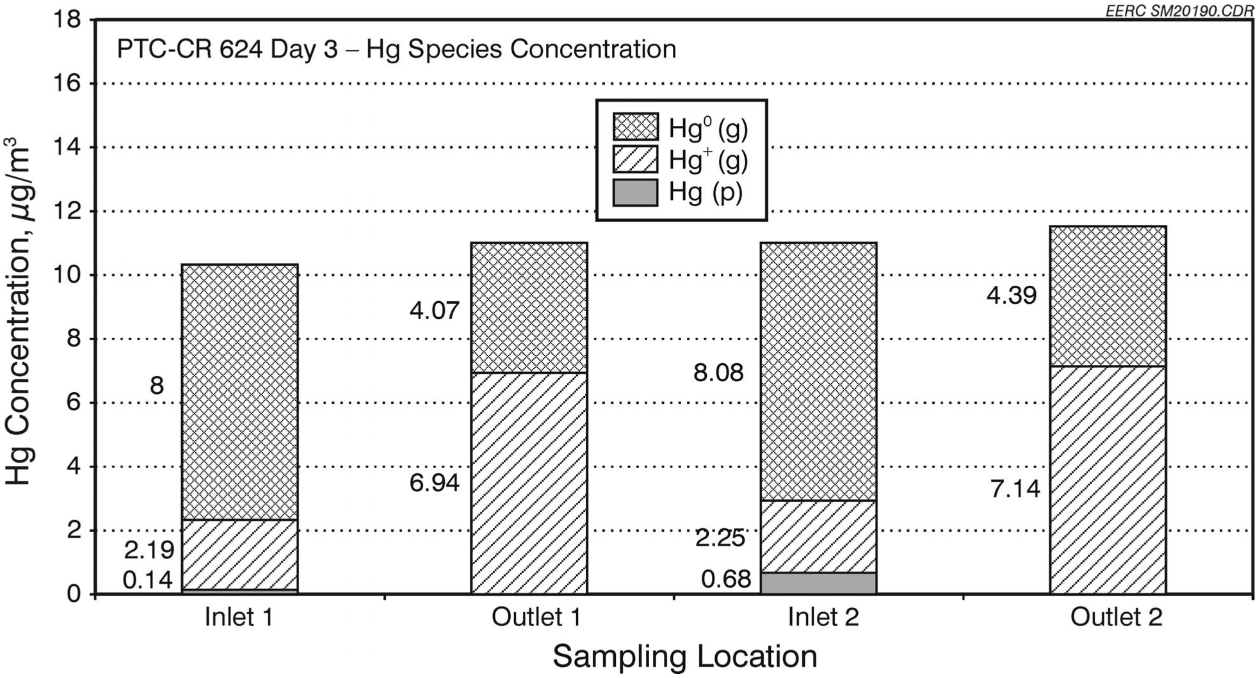

Figure 11. PTC-CR-624 Day 3 – mercury species concentration in flue gas at the AHPC inlet and outlet (AHPC mode, 8.0-in.-W.C. pulse-trigger pressure).

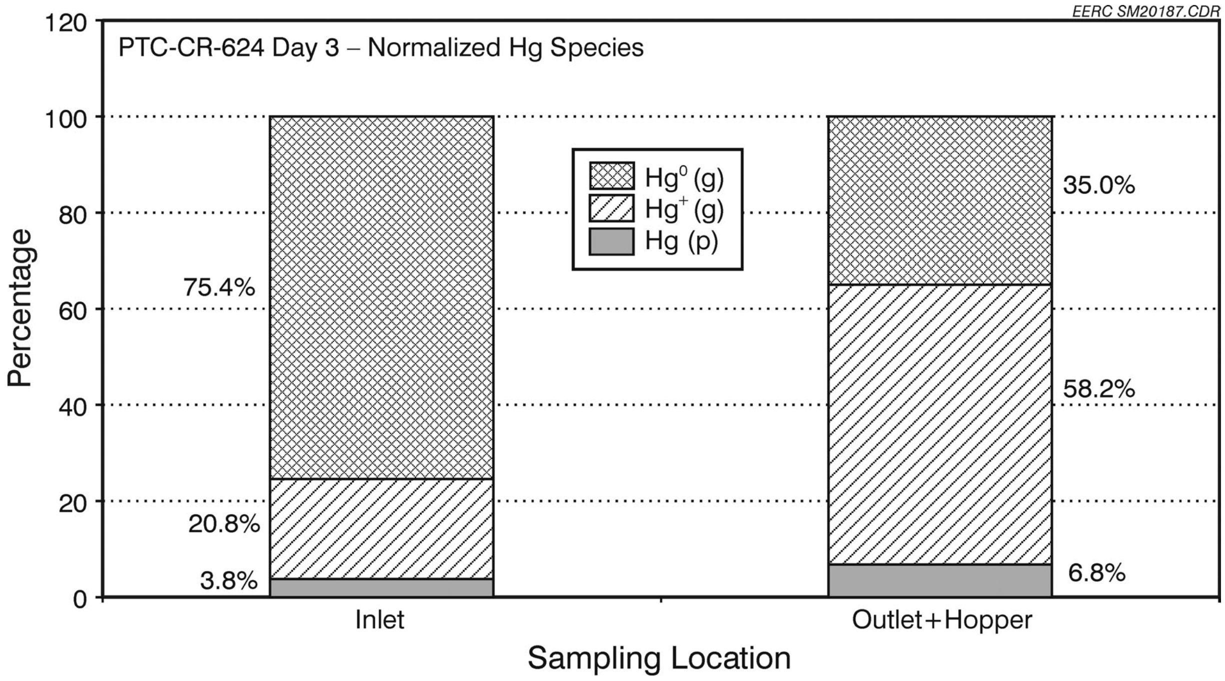

Figure 12. PTC-CR-624 Day 3 – normalized mercury species distribution in flue gas across the AHPC unit (AHPC mode, 8.0-in.-W.C. pulse-trigger pressure).

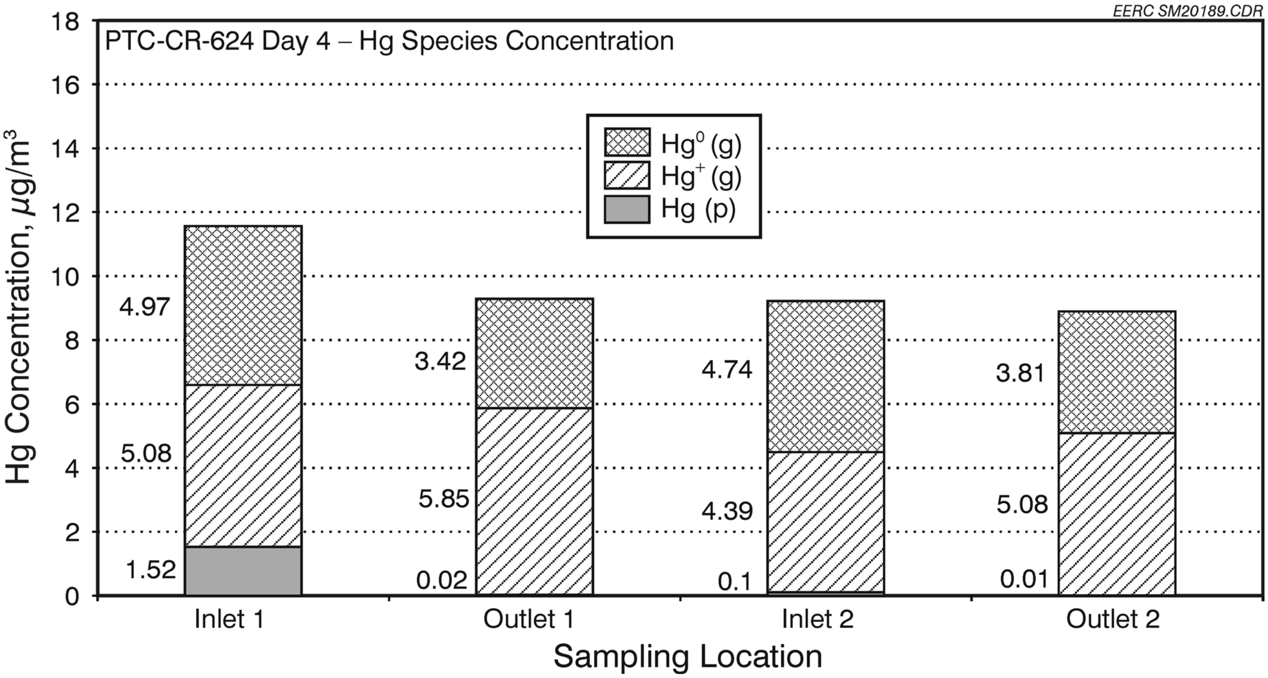

Figure 13. PTC-CR-624 Day 4 – mercury species concentration in flue gas at the AHPC inlet and outlet (pulse-jet mode, 8.0-in.-W.C. pulse-trigger pressure).

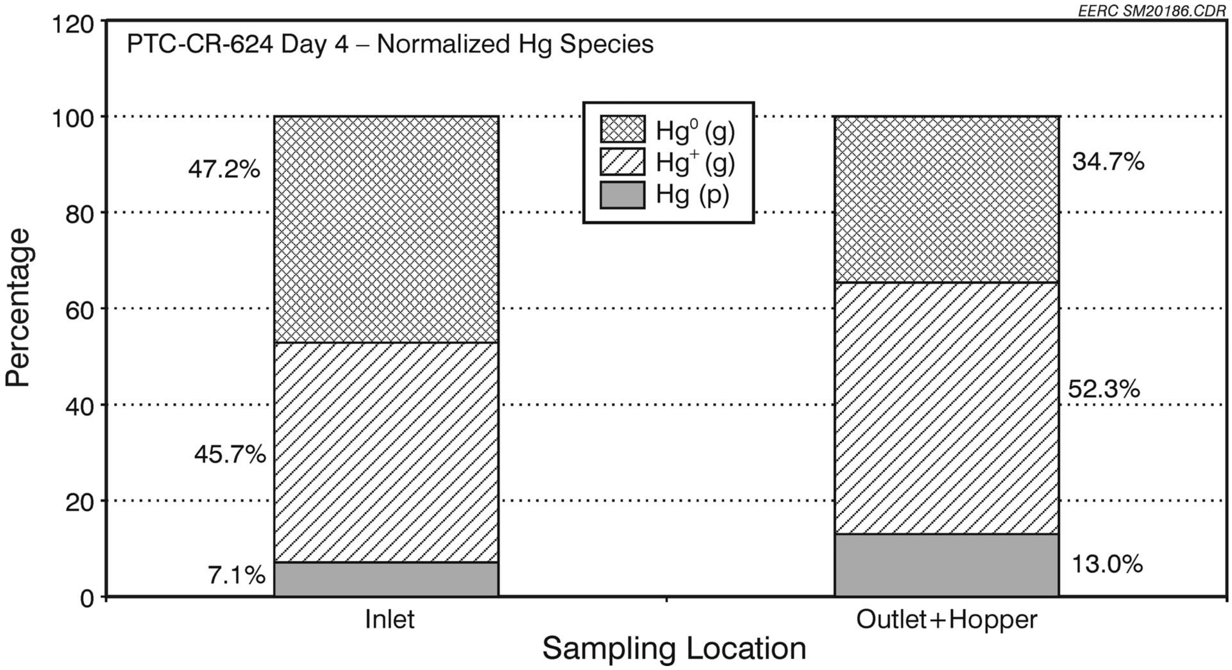

Figure 14. PTC-CR-624 Day 4 – normalized mercury species distribution in flue gas across the AHPC unit (pulse jet mode, 8.0-in.-W.C. pulse-trigger pressure).

Figures 15 and 16 show the comparison of the average of seven inlet mercury speciation tests for the field tests completed in November and the baseline pilot-scale tests. Even though the total values are similar within the margin of error, two very significant differences are obvious. For the field results, an average of 56% of the mercury was retained by the fly ash compared to only 5% for the pilot-scale tests. A second significant difference is the vapor-phase speciation. For the field results, 38% of the inlet total was oxidized mercury and only 6% was elemental mercury compared to 29% oxidized and 67% elemental for the pilot-scale tests.

A number of differences in conditions between the two tests could be responsible for the significant speciation difference. The HCl for the pilot-scale tests was measured by Method 26A to be 3 ppm in the flue gas compared to 9 ppm for the field test. The additional HCl in the field test may have come from the small percentage of waste tires that are cofired with coal at the Big Stone Power Plant. However, 9 ppm HCl is still a fairly low concentration compared to the 50–100 ppm level that is typically seen for bituminous coals.

Another possible reason for the difference is the amount of unburned carbon in the ash, which for the Big Stone baseline tests ranged from 0.5% to 1.9% (without carbon injection) compared to only 0.16% for the pilot-scale tests. Under some conditions carbon in the ash can be responsible for mercury retention as well as an oxidation surface.

Cyclone firing is known to produce a finer fly ash particle size than pulverized-coal firing, which could also lead to more mercury retention as well as oxidation. Other work has shown that mercury concentration is typically higher in the smaller fly ash fraction, and the higher surface area of the finer particles may also promote more oxidation.

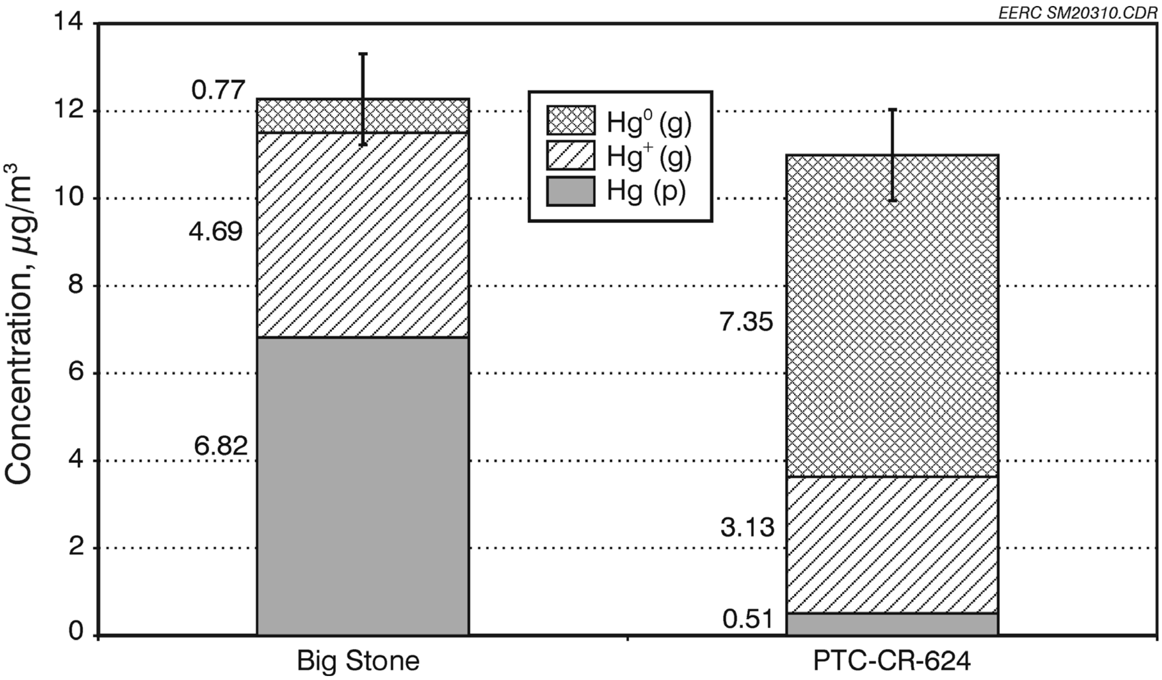

Figure 15. Comparison of Big Stone and PTC-CR-624 mercury speciation at the AHPC inlet, concentration basis.

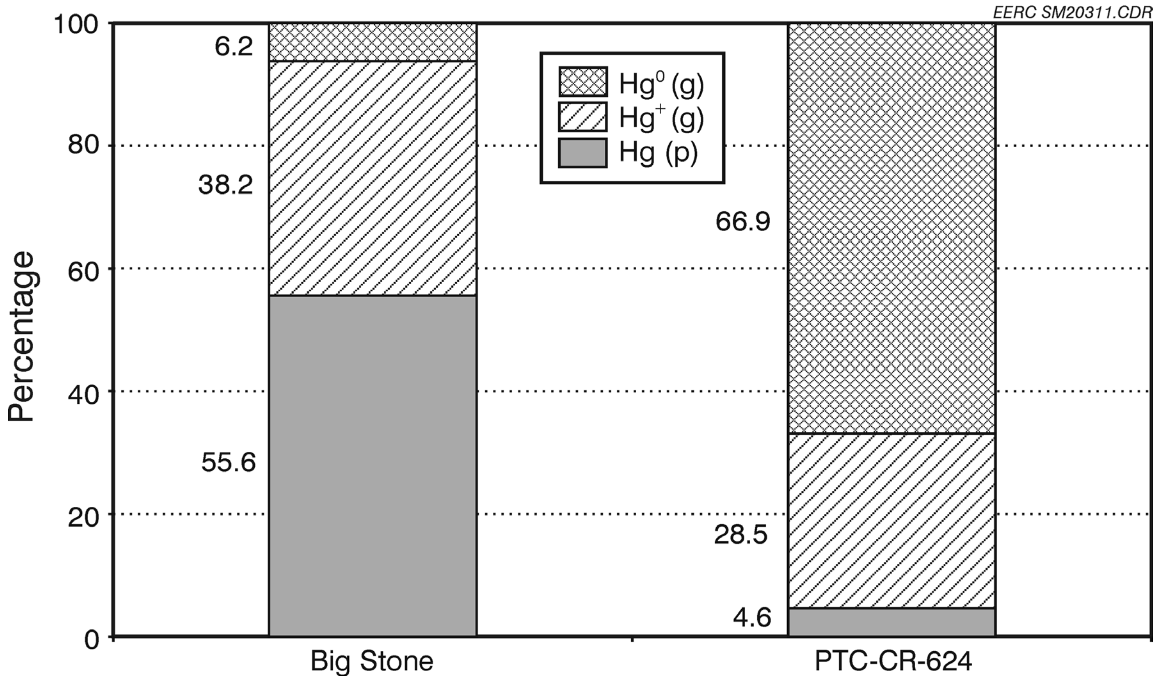

Figure 16. Comparison of Big Stone and PTC-CR-624 mercury speciation at the AHPC inlet, percentage basis.

Still further possible contributors to the differences are the longer residence time and exposure of the flue gas to the fly ash for a full-scale boiler and possible differences in the coal. The coal burned in the pilot-scale unit was from the Big Stone Power Plant and was from the same mine, but it was obtained over a month prior to the field test. The pilot-scale coal was taken from a point in the plant prior to mixing any waste fuel.

4.0 CONCLUSIONS

- Further bench-scale results confirm that the SO_2 and NO_2 concentration effects are additive and have a significant effect on sorbent performance. This finding should facilitate predicting sorbent performance in real systems when the SO_2 and NO_2 concentrations are known.

- Another key finding from the bench-scale tests was that the fixed-bed sorbent-screening tests using simulated flue gas were in good agreement with similar tests sampling real flue gas. This suggests that as long as the main flue gas components are duplicated, the bench-scale fixed-bed tests can be utilized to indicate sorbent performance in larger-scale systems.

- In the pilot-scale tests, a baseline comparison was made between the AHPC and a pulse-jet baghouse in terms of the mercury speciation change across the device and the amount of mercury retained by the fly ash. Results showed that for both devices there was very little capture of mercury by the fly ash, but there was some increase in oxidized mercury across the device. No significant differences were noted between the AHPC and pulse-jet modes of operation.

- Even though the same coal was used in the pilot-scale tests and the field tests, there was a significant difference in inlet mercury speciation. For the pilot-scale tests, results were more similar to what is typically expected for PRB coals in that most of the mercury was elemental with little mercury capture by the fly ash. In contrast, for the field test, there was much more oxidized than elemental mercury and significant mercury capture by the fly ash. Possible reasons for the difference include higher carbon in the field ash, somewhat higher HCl in the field flue gas, possible variation in the coal, cyclone firing for the field tests compared to pulverized coal firing for the pilot tests, longer residence time for the field tests, and a finer particle size for the field tests.

5.0 REFERENCES

1. Miller, S.J.; Dunham, G.E.; Olson, E.S.; Brown, T.D. Mercury Sorbent Development for Coal-Fired Boilers. In *Proceedings of the Air Quality: Mercury, Trace Elements, and Particulate Matter Conference*; McLean, VA, Dec 1–4, 1998.