MERCURY CONTROL WITH THE ADVANCED HYBRID PARTICULATE COLLECTOR

Technical Progress Report

For the period July 1 through September 30, 2004

Prepared for:

AAD Document Control

U.S. Department of Energy
National Energy Technology Laboratory
PO Box 10940, MS 921-107
Pittsburgh, PA 15236-0940

DOE NETL Cooperative Agreement DE-FC26-01NT41184; UND Fund 4498
Performance Monitor: William Aljoe

Prepared by:

Stanley J. Miller
Ye Zhuang
Jay Almlie

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

November 2004

EERC DISCLAIMER

LEGAL NOTICE This research report was prepared by the Energy & Environmental Research Center (EERC), an agency of the University of North Dakota, as an account of work sponsored by National Energy Technology Laboratory. Because of the research nature of the work performed, neither the EERC nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation by the EERC.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report is available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161; phone orders accepted at (703) 487-4650.

ACKNOWLEDGMENT

This report was prepared with the support of the U.S. Department of Energy (DOE) National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-01NT41184. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE.

MERCURY CONTROL WITH THE ADVANCED HYBRID PARTICULATE COLLECTOR

ABSTRACT

This project was awarded under U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) 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 included 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 Plant operated by Otter Tail Power Company, host for 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 has been licensed to W.L. Gore & Associates, Inc., and is marketed as the *Advanced Hybrid*™ filter by Gore. 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. The AHPC also appears to have unique advantages for mercury control over baghouses or ESPs as an excellent gas–solid contactor.

The objective of the original 5-task project was to demonstrate 90% total mercury control in the AHPC at a lower cost than current mercury control estimates. The approach included bench-scale batch tests, larger-scale pilot testing with real flue gas on a coal-fired combustion system, and field demonstration at the 2.5-MW scale at a utility power plant to prove scale-up and demonstrate longer-term mercury control.

The scope of work was modified to include an additional sixth task, initiated in April 2003. The objective of this task was to evaluate the mercury capture effectiveness of the AHPC when used with elemental mercury oxidation additives.

This project, which is now nearing completion, demonstrated at the pilot-scale level a technology that provides a cost-effective technique to control mercury and, at the same time, greatly enhances 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 for improved fine particulate control combined with effective mercury control for a large segment of the U.S. utility industry as well as other industries.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

AHPC	advanced hybrid particulate collector
COHPAC	compact hybrid particulate collector
CMM	continuous mercury monitor
DOE	U.S. Department of Energy
EB	eastern bituminous
EERC	Energy & Environmental Research Center
ESP	electrostatic precipitator
NETL	National Energy Technology Laboratory
PJBH	pulse-jet baghouse
PJFF	pulse-jet fabric filter
PRB	Powder River Basin
PTC	particulate test combustor
PTFE	polytetrafluoroethylene
SDA	spray dryer absorber
TDF	tire-derived fuel
WSB	western subbituminous

MERCURY CONTROL WITH THE ADVANCED HYBRID PARTICULATE COLLECTOR

EXECUTIVE SUMMARY

Since 1995, the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) has supported development of a new concept in particulate control called the advanced hybrid particulate collector (AHPC). The AHPC, licensed to W.L. Gore & Associates, Inc., is now marketed as the *Advanced Hybrid*™ filter by Gore. 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 Energy & Environmental Research Center's (EERC's) objective for this project, which is nearly complete, was to demonstrate 90% total mercury control with commercially available sorbents in the AHPC at a lower cost than current mercury control estimates. The approach included three levels of testing: 1) bench-scale batch testing that tied the new work to previous results and linked 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 and 3) field demonstration testing at the 2.5-MW scale at a utility power plant to prove scale-up and demonstrate longer-term mercury control.

Initial bench-scale results were in good agreement with previous data. Results showed 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.

An initial field test of the 2.5-MW AHPC at the Big Stone Plant was completed the first week of November 2001. Results showed that the average inlet mercury speciation for seven samples was 55.4% particulate bound, 38.1% oxidized, and 6.4% elemental. A carbon injection rate of 24 kg of carbon sorbent/million m^3 of flue gas (1.5 lb of carbon sorbent/million acf) resulted in 91% total mercury collection efficiency, compared to 49% removal for the baseline case.

Following the initial field test, 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 (PJBH) 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 and initial 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 (PRB) coals in that most of the mercury was elemental, with little mercury capture by the fly ash. In contrast, for the November 2001 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 due to the cofiring of tire-derived fuel (TDF), 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.

During April–June 2002, a number of baseline and carbon injection pilot-scale tests were completed with Belle Ayr PRB subbituminous coal, one of the coals burned at Big Stone. For the baseline case, approximately 70% of the inlet mercury was elemental, approximately 23% oxidized, and 2% or less was associated with particulate matter. Very little natural mercury was captured across the AHPC for the baseline tests, and the level of oxidized mercury increased only slightly across the AHPC during baseline operation.

With carbon injection, a comparison of short and long residence time in the AHPC showed that somewhat better mercury removal was achieved with longer residence time. No evidence of desorption of mercury from the carbon was seen upon continued exposure to flue gases up to 24 hours. This suggests that desorption of captured mercury from the carbon sorbent is not a significant problem under these flue gas conditions with the low-sulfur subbituminous coal.

At a carbon-to-mercury ratio of 3000:1, from 50% to 71% total mercury removal was achieved. When the ratio was increased to 6000:1, the removal range increased to 65%–87%, even for the difficult case with predominantly elemental mercury and very little natural capture of mercury by the fly ash.

A longer-term field test was completed with the 2.5-MW field AHPC August 6 through September 6, 2002. Carbon injection and CMM (continuous mercury monitor) measurements were continuous (24 hours a day) for the entire month except for an unplanned plant outage from August 29 to September 2. The primary goal of the work was to demonstrate longer-term mercury control with the AHPC and evaluate the effect of carbon injection on the AHPC operational performance. Another goal of the test was to evaluate the effect of supplemental TDF burning on the level of mercury capture for comparison with results from the previous test completed in November 2001.

The inlet mercury speciation during the August 2002 tests averaged 17% particulate bound, 32% oxidized, and 51% elemental. The significant difference in mercury speciation between the August and November 2001 field data is likely the effect of a higher rate of cofiring of TDF with the coal during the November test.

In the November 2001 tests, 49% mercury capture was seen for the baseline conditions without carbon injection. The August tests indicated only 0%–10% mercury capture with no carbon injection. Again, the most likely explanation is the much higher TDF cofiring rate and higher HCl in the flue gas for the November test.

Addition of activated carbon at a rate of 24 kg of carbon sorbent/million m^3 of flue gas (1.5 lb of carbon sorbent/million acf) resulted in an average of 63% mercury removal in the August tests without any TDF cofiring. A small TDF cofiring rate of about 23 tons a day resulted in an increase in mercury collection to 68%. At the highest TDF rate seen in the August tests of 150–177 tons a day, mercury removal of up to 88% was achieved. This compares with 91% removal seen during the November tests when the TDF feed rate was in the range from 90 to 250 tons a day. These results indicate that TDF cofiring has the effect of increasing the level of mercury control that can be achieved with a low carbon addition rate.

One of the main objectives of the August tests was to assess the effect of carbon injection on longer-term AHPC performance. When the carbon was started on August 7, there was no perceptible change in pressure drop or bag-cleaning interval. Similarly, there was no change in the K_2C_i value that relates to how well the ESP portion of the AHPC is working. These results indicate that low addition rates of carbon will have no perceptible effect on the operational performance of the AHPC.

Another short field test was completed with the 2.5-MW AHPC at the Big Stone Plant November 19–22, 2002, to coincide with the first test conducted at the inlet and stack of the full-scale *Advanced Hybrid*™ filter after it came online October 26, 2002. The primary purpose of the test was to evaluate the effect of injecting a small amount of HCl into the flue gas along with the activated carbon. Results showed that without supplemental HCl injection and a low carbon injection rate of 24 kg of carbon sorbent/million m^3 of flue gas (1.5 lb of carbon sorbent/million acf), from 65% to over 90% total mercury removal was achieved. This is somewhat better than the results seen in the monthlong continuous test in August 2002. Part of the reason could be the higher temperatures in the AHPC during August, which typically were in the range of 132°–143°C (270°–290°F) compared to 121°C (250°F) for the November 2002 tests.

Little or no effect was seen with the supplemental HCl injection. This is somewhat surprising because an extensive amount of bench-scale sorbent work has demonstrated the benefit of HCl for capturing elemental mercury in a simulated flue gas over the temperature range of 107°–188°C (225°–370°F). However, the benefit of additional HCl may be marginal in cases where there is already a sufficient amount of HCl present to achieve good mercury control.

During October–December 2002, a 5.7-m^3/min (200-acfm) pilot-scale test was also completed with Springfield bituminous coal. The purpose of this test was to evaluate mercury control with the AHPC with a high-sulfur bituminous coal. The Springfield bituminous coal produced a flue gas that was high in all of the acid gases including SO_3, and most of the inlet mercury was in an oxidized form. A number of short- and longer-term tests with the NORIT Americas DARCO® FGD carbon at temperatures ranging from 135° to 160°C (275° to 320°F) showed that this sorbent is completely ineffective at mercury control under these conditions. This is in contrast to the extensive testing conducted previously with the AHPC and

subbituminous coal, where up to 90% mercury capture was seen at a low carbon addition rate. The data are consistent with previous bench-scale testing that has shown that flue gas conditions are critical to the mercury capture ability of an activated carbon.

The previous field studies performed in November 2001 and August 2002 showed there was a correlation between Hg^{2+} concentration in the flue gas and the amount of TDF fed into the boiler. However, because of the variability of the TDF feed rate, it was difficult to quantify the TDF effect on mercury removal. A 1-week pilot-scale test was conducted on the 5.7-m^3/min (200-acfm) EERC AHPC where the coal feed rate and the TDF feed rate were precisely controlled.

Cofiring of TDF with the subbituminous coal had a significant effect on mercury speciation at the inlet to the AHPC. Firing 100% coal resulted in only 19% oxidized mercury at the inlet compared to 47% cofiring 5% TDF (mass basis) and 85% cofiring 10% TDF. The significant increase in oxidized mercury may be partly the result of increased HCl in the flue gas with the TDF. However, since the actual increase of measured HCl was only a few parts per million, other changes in combustion conditions or flue gas components may also be responsible for the increase in oxidized mercury.

The TDF not only enhances mercury oxidation in flue gas but also improves mercury capture when combined with FGD carbon injection. With 100% coal, test results have shown from 48% to 78% mercury removal at a relatively low FGD carbon addition rate of 24 kg of carbon/million m^3 (1.5 lb of carbon/million acf). Results showed from 88% to 95% total mercury removal with the same carbon addition rate while 5%–10% TDF was cofired. These results are consistent with previously reported results from the 2.5-MW pilot-scale AHPC.

W.L. Gore & Associates, Inc., initiated an innovative concept for control of mercury emissions in flue gas streams. Specifically, the configuration involves a mercury control filter placed inside the existing particulate control filter bag, essentially a bag-within-a-bag. This concept is attractive for use the AHPC, because of the much fewer number of bags required compared to conventional baghouses.

A week of testing was completed with two different cartridge filters on the 5.7-m^3/min (200-acfm) pilot-scale AHPC in March 2003. The filters were installed inside of the four cylindrical all-polytetrafluoroethylene (PTFE) bags in the AHPC unit. Operationally, the mercury filter elements did not appear to impair the pulse cleaning of the bags. Initial tests with these cartridges showed that nearly 100% mercury capture could be achieved, but early breakthrough results were observed. Another week of testing was planned, but Gore made the decision to discontinue development of this technology.

Another 1-month field test was completed during May–June 2003 with the 2.5-MW AHPC unit at the Big Stone Plant to demonstrate long-term mercury control with the AHPC and evaluate the impacts of various operating parameters such as filtration velocity, carbon feed rate, and carbon in-flight time on mercury control.

The inlet mercury vapor concentration in the flue gas during the May 2003 test ranged from 4.98 to 10.6 μg/m^3 with 20%–70% Hg^0. The variation in mercury speciation was likely caused by varying coal as well as the intermittent cofiring of TDF and waste seeds. The May 2003 test indicated 0%–30% mercury inherent capture with no carbon addition, typical for western subbituminous coal. At low carbon feed concentrations ranging from 1 to 3 lb/Macf, the AHPC demonstrated high overall mercury collection efficiencies from 65% to 95%. When compared with other research results, the AHPC clearly demonstrated higher mercury removal efficiency than an ESP under the same carbon feed rate. The overall Hg removal with the AHPC was similar to a baghouse or COHPAC (compact hybrid particulate collector).

An additional sixth task was added to the project, initiated in April 2003. The planned objectives for this task were to evaluate mercury capture enhancement by using elemental mercury oxidation additives with a spray dryer absorber and test the novel Gore baghouse inserts downstream of the AHPC or a fabric filter. The planned additional tests included 1) Hg oxidation upstream of a lime-based spray dryer fabric filter or AHPC combination in order to control mercury emissions using dry scrubbers and 2) field testing of mercury sorbent technology at a North Dakota power plant using a slipstream baghouse. However, planned field testing of the Gore mercury inserts was not completed because Gore discontinued their development.

A pilot-scale Niro spray dryer system was installed on the EERC particulate test combustor (PTC) upstream of a PJFF (pulse-jet fabric filter) or AHPC. Several additives and sorbent combinations were tested for mercury control while a Center, North Dakota, lignite was fired. Results showed that 95% mercury removal was seen with DARCO® FGD activated carbon when a sorbent enhancement additive was injected into the furnace, compared to only 37% control with the FGD sorbent alone or 54% removal with the additive alone.

The last planned experimental work for the project was a test completed this quarter (July–September 2004) to measure the amount of mercury collected by the perforated plates in the AHPC apart from any mercury control on the filter bags. To address this question, the 200-acfm pilot-scale AHPC was modified so that it included perforated plates totally surrounding the normal bag area, but with the filter bags removed. Mercury removal with this configuration using the Norit FGD carbon injected at 36 kg of carbon sorbent/million m^3 of flue gas (2 lb of carbon sorbent/million acf) was 66%, which was similar to previous results with the AHPC. However, using an EERC proprietary sorbent at the same carbon addition rate improved the mercury collection efficiency to 90%. For both tests, the particulate collection efficiency of the perforated plates alone was 98%. These are important results, because they prove that good gas–solid contact leading to excellent mercury removal can be achieved by collection of the activated carbon on the perforated plates alone, without a significant fraction of the carbon reaching the bags.

MERCURY CONTROL WITH THE ADVANCED HYBRID PARTICULATE COLLECTOR

1.0 INTRODUCTION

This project was awarded under U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) 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 Plant operated by Otter Tail Power Company, which hosted 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 has been licensed to W.L. Gore & Associates, Inc., and is now marketed as the *Advanced Hybrid*™ filter by Gore. 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 Plant. For Phase III, further testing of an improved version of the 2.5-MW-scale AHPC at the Big Stone Plant was conducted to facilitate commercialization of the AHPC technology. The AHPC also appears to have unique advantages for mercury control over baghouses or ESPs as an excellent gas–solid contactor. Mercury control with the AHPC is the focus of this project.

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 included 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 between the AHPC and a pulse-jet baghouse (PJBH) with sorbents under similar conditions at the 55-kW (200-acfm) pilot scale.

- Demonstrate 90% mercury capture for both a western subbituminous (WSB) and an eastern bituminous (EB) coal.

- Demonstrate mercury capture with the 2.5-MW (9000-acfm) AHPC at Big Stone.

- Demonstrate 90% mercury capture over a longer time (3 months) with the 2.5-MW (9000-acfm) AHPC at Big Stone.

- Evaluate the mercury capture effectiveness of the AHPC when used with elemental mercury oxidation additives and a spray dryer absorber (SDA).

2.2 Planned Scope of Work (revised February 2004)

To meet the objectives, the work was organized into six 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
- Task 6: Mercury Control Enhancement with Oxidation Additives

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 were for the purposes of verifying previous results, expanding on the SO_2 and NO_2 concentration effect, linking the synthetic gas results to the results with real flue gas, and screening sorbents.

Tests planned with the bench-scale unit were divided into three series. The purpose of the first series of tests was to ensure that results obtained by the EERC and others could be duplicated and to expand evaluation of the effects of SO_2 and NO_2 as variables.

The second series of bench-scale tests was for the purpose of comparing the bench-scale fixed-bed results sampling real flue gas to those obtained with simulated flue gas for both WSB and EB coals.

The third series of bench-scale tests was for the purpose of screening possible alternative or more advanced sorbents. Results from the completed bench-scale tests have been summarized in previous quarterly reports.

2.2.3 Task 3 – Pilot-Scale Testing

The originally planned 6 weeks of testing are shown in Table 1 along with two tests added later in the project. Results from the first 7 weeks of testing were given in previous quarterly reports. During the last quarter (July–September 2004), the last of the planned tests under Task 3 was completed.

Test 8 was originally planned to further evaluate the Gore mercury sorbent insert; however, since Gore discontinued development of this technology, Test 8 was completed to evaluate the amount of mercury collected on the perforated plates in the AHPC compared to the total mercury removal across the AHPC.

2.2.4 Task 4 – Field Demonstration Pilot Testing

The purpose of Task 4 was to demonstrate mercury control with the AHPC at a much larger scale by utilizing the 2.5-MW AHPC, which was previously installed on a slipstream at the Big

Table 1. Task 3 – Pilot-Scale Testing

Week/ Test	Purpose	Coal	Collection Device	Sorbent Type	C:Hg Ratio	Injection Method
1-1	Baseline	WSB	PJBH	None	NA[1]	NA
1-2	Baseline	WSB	AHPC	None	NA	NA
2-1	Baseline	EB	PJBH	None	NA	NA
2-2	Baseline	EB	AHPC	None	NA	NA
3-1	Hg capture, collection device	WSB	PJBH	FGD	3000[2]	Continuous
3-2	Hg capture, collection device	WSB	AHPC	FGD	3000[2]	Continuous
4-1	Hg capture, residence time	WSB	AHPC	FGD	3000[2]	Continuous
4-2	Hg capture, residence time	WSB	AHPC	FGD	3000[2]	Batch
5-1	Hg capture, residence time	EB	AHPC	FGD	3000[2]	Continuous
5-2	Hg capture, residence time	EB	AHPC	FGD	3000[2]	Batch
6-1	Sorbent type and concentration	WSB	AHPC	New No. 1[3]	3000[2]	Continuous[3]
6-2	Sorbent type and concentration	WSB	AHPC	New No. 1[3]	1000[2]	Continuous[3]
6-3	Sorbent type and concentration	WSB	AHPC	New No. 2[3]	3000[2]	Continuous[3]
6-4	Sorbent type and concentration	WSB	AHPC	New No. 2[3]	1000[2]	Continuous[3]
7	Sorbent type and concentration	WSB	AHPC	Gore[4]	NA	NA
8[5]	Plate capture vs. total capture	WSB	AHPC	FGD	3000[2]	Continuous[3]

[1] Not applicable.
[2] Estimated concentrations; actual concentration will be based on previous testing.
[3] To be selected.
[4] Bag insert within the AHPC.
[5] Newly added test.

Stone Power Station. Over the time from November 2001 through June 2003, four separate periods of testing were completed with the 2.5-MW AHPC, ranging from 1 week to 2 months in duration. Results from these Task 4 field tests have already been given in previous quarterly reports.

2.2.5 Task 5 – Facility Removal and Disposition

The plan was to dismantle and remove the 2.5-MW AHPC at the end of this project if no further testing was anticipated in support of subsequent work at the Big Stone Plant. However, the 2.5-MW AHPC has already been used in support of the full-scale AHPC at Big Stone, so the decision was made to leave the 2.5-MW AHPC in place at Big Stone until no further use of it is anticipated.

2.2.6 Task 6 – Mercury Control Enhancement with Oxidation Additives

Task 6 was added to the project to address the use of Hg^0 oxidation additives to the coal to enhance mercury control with sorbents for cases with a high percentage of elemental mercury. Specifically, the case of using a North Dakota lignite coal along with a spray dryer for SO_2 control was evaluated. Results from Task 6 were reported in the previous two quarterly reports.

3.0 RESULTS AND DISCUSSION

Test 8, the last planned test under Task 3, was completed this quarter. This test, designated as PTC-BA-650, consisted of a pilot-scale test with the EERC 200-acfm AHPC, which was modified to help answer the question of how much of the total mercury control with the AHPC occurs on the perforated plates.

Previous results with both the 200-acfm AHPC and the 2.5-MW AHPC showed that, over a range of conditions, from 50% to 95% mercury control was seen. Based on the rate of pressure drop increase in comparative tests without high-voltage power, the particulate collection efficiency of the perforated-plate ESP portion of the AHPC was calculated to be about 95%. If the injected carbon is collected at the same efficiency as the fly ash, then it can be assumed that most of the carbon was also collected on the plates rather than on the bags. It is important to show that good mercury control can be achieved by collection of the carbon on the perforated plates, because then the carbon addition rate can be adjusted as necessary to achieve the target mercury control level without concern of the effect of the carbon injection on pressure drop. While it could be inferred from previous tests that most of the mercury capture occurred before the flue gas reached the bags, the uncertainty over the exact amount of fly ash and injected carbon that was collected on the perforated plates made the conclusion tentative. Test 8 was set up to specifically determine the amount of mercury control across the perforated plates alone.

The 200-acfm AHPC was set up with perforated plates surrounding the bag area. The plates had approximately 50% open area with 0.75-in.-diameter holes. Directional discharge electrodes pointing toward the perforated plates were used to minimize any unwanted collection on the outside walls of the AHPC housing. To further facilitate collection of the dust on the

plates rather than the housing walls, the distance from the discharge electrodes to the plates was set at 5.25 in., while the distance from the discharge points to the outside housing walls was 8.25 in. Flue gas was introduced into the AHPC housing in the area between the discharge electrodes and the outside walls to make sure that all of the gas would pass through the plane of the discharge electrodes before reaching the perforated plates (see Figures 1 and 2). To minimize collection of any ash or carbon downstream from the perforated plates, the bags were removed. After the gas passed through the perforated plates, it exited through the open holes in the tube sheet into the clean air plenum and then out of the AHPC housing.

Three test conditions were evaluated with this configuration: baseline tests before each of the carbon injection tests and tests with two different carbon-based sorbents. The coal for the tests was Belle Ayr, which is one of the Powder River Basin subbituminous coals burned at the Big Stone Power Station and which was used for previous pilot-scale tests. Mercury was measured with two PS Analytical continuous mercury monitors (CMMs): one at the inlet upstream of the point of carbon injection and one at the AHPC outlet. Outlet particulate dust loadings were determined with EPA Method 5 during each of the two carbon injection tests.

For the first baseline test, the inlet CMM was not working properly, but the outlet CMM indicated about 10–11 μg/dNm^3 of mercury (dry gas corrected to 3% O_2), which is the expected inlet concentration based on previous tests with this coal. When the Norit FGD carbon was injected just upstream of the AHPC at a rate of at 36 kg of carbon sorbent/million m^3 of flue gas (2 lb of carbon sorbent/million acf), the outlet mercury concentration quickly dropped to

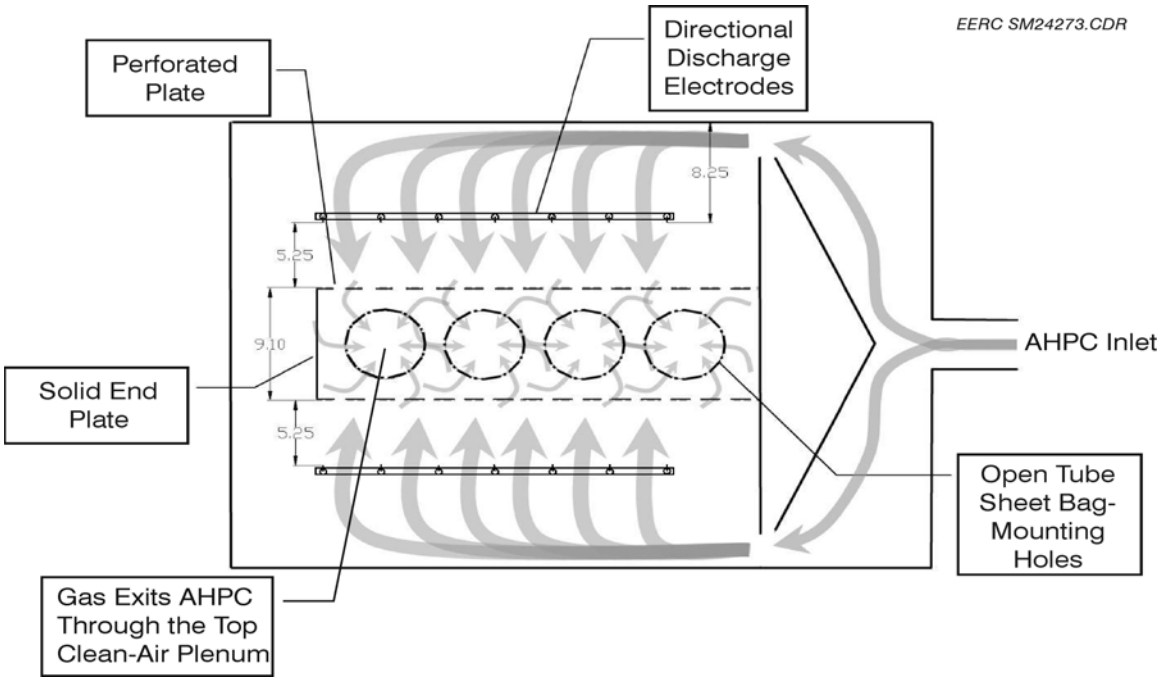

Figure 1. Top-view schematic of the AHPC showing the geometric arrangement and gas flow pattern.

Figure 2. Front view of AHPC with inlet cover removed.

3–4 μg/dNm^3 , corresponding to an average of 66% removal (Figures 3–5). This level of removal was similar to previous results with the AHPC using the NORIT FGD carbon and indicates that reasonably good mercury control can be achieved with carbon collected on the perforated plates alone. However, there was still the question of whether the mercury control was limited by the gas–solid contact geometry or by the mercury sorption ability of the injected carbon. During this test, the outlet dust loading measurement showed that the total particulate control removal across the perforated plates was 98.3%, so very little carbon bypassed the perforated plates (Figure 6).

To further evaluate the level of mercury control across the perforated plates, a second carbon injection test was conducted using an EERC-developed carbon that has performed better than the NORIT FGD sorbent. After reestablishing the baseline, the EERC carbon was injected upstream of the AHPC at the same carbon injection rate as in the FGD test. Immediately after starting injection, the outlet mercury dropped to about 1 μg/dNm^3, corresponding to an average mercury removal of 89.9% (Figures 3–5). Since the carbon injection rate and the particulate collection efficiency (Figure 6) were the same for both tests, the better mercury removal for the EERC carbon is attributed to superior mercury capture ability of the carbon rather than any difference in gas–solid contact exposure. These results provide convincing evidence that the geometry of the AHPC allows sufficient gas–solid contact for achieving excellent mercury control when most of the carbon is collected on the perforated plates. The data represent the minimum level of mercury control that would be expected. Any carbon that reaches the bags would only enhance the gas–solid contact and further improve the total mercury capture.

4.0 CONCLUSIONS

The last planned experimental work for the project was a test to measure the amount of mercury collected by the perforated plates in the AHPC apart from any mercury control on the

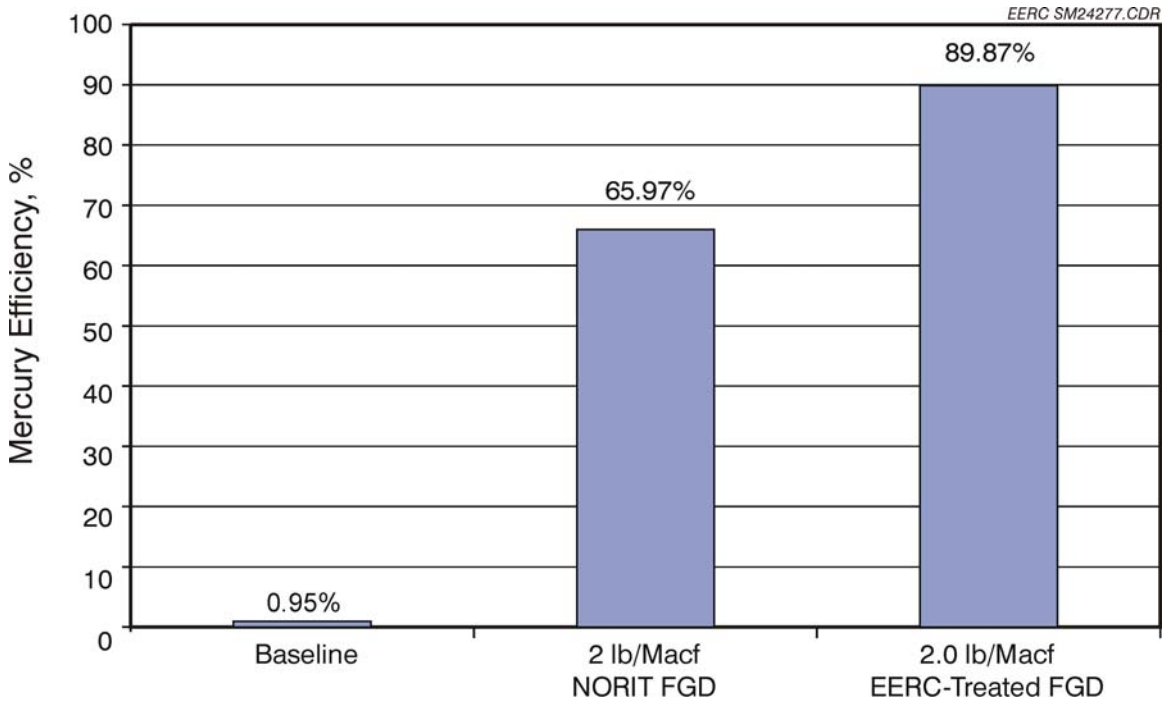

Figure 3. Average mercury removals for baseline and carbon injection tests.

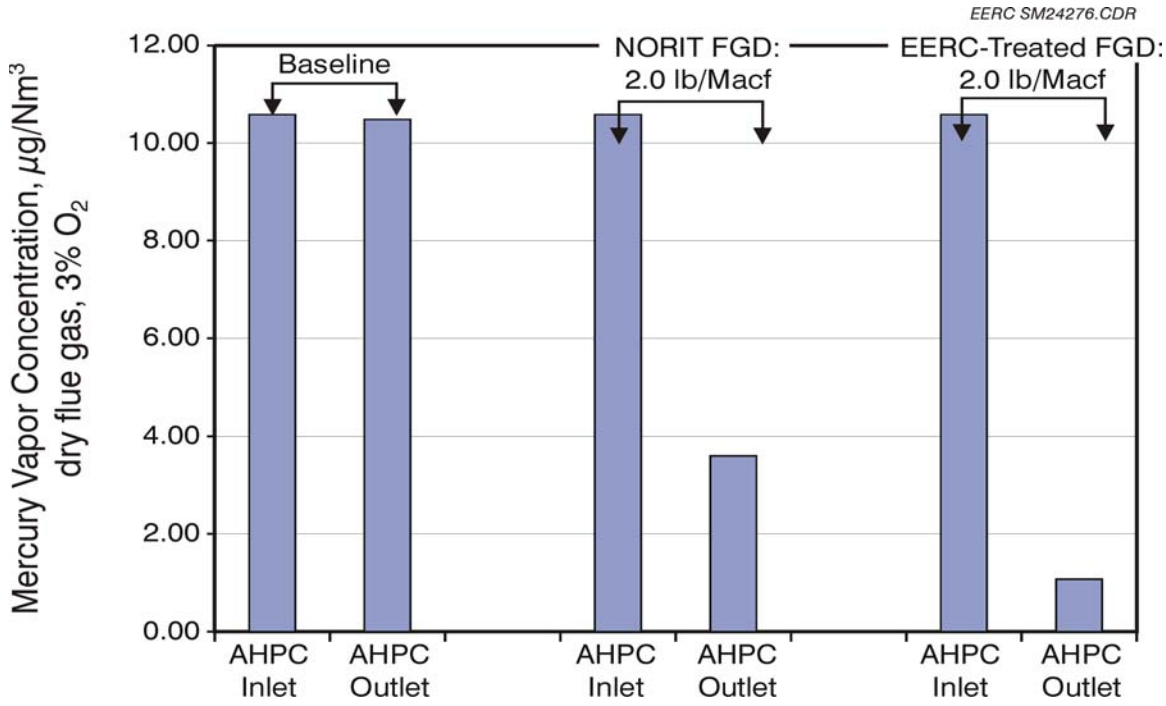

Figure 4. Average inlet and outlet mercury concentrations for baseline and carbon injection tests.

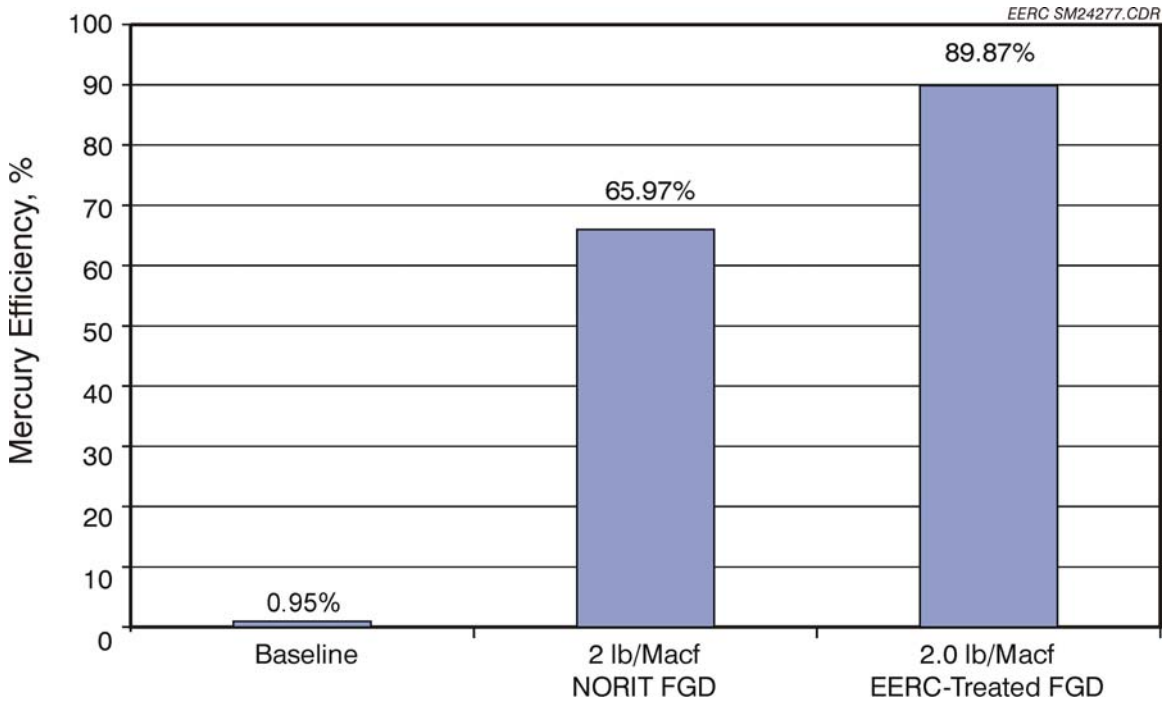

Figure 5. Average vapor-phase mercury removals for baseline and carbon injection tests.

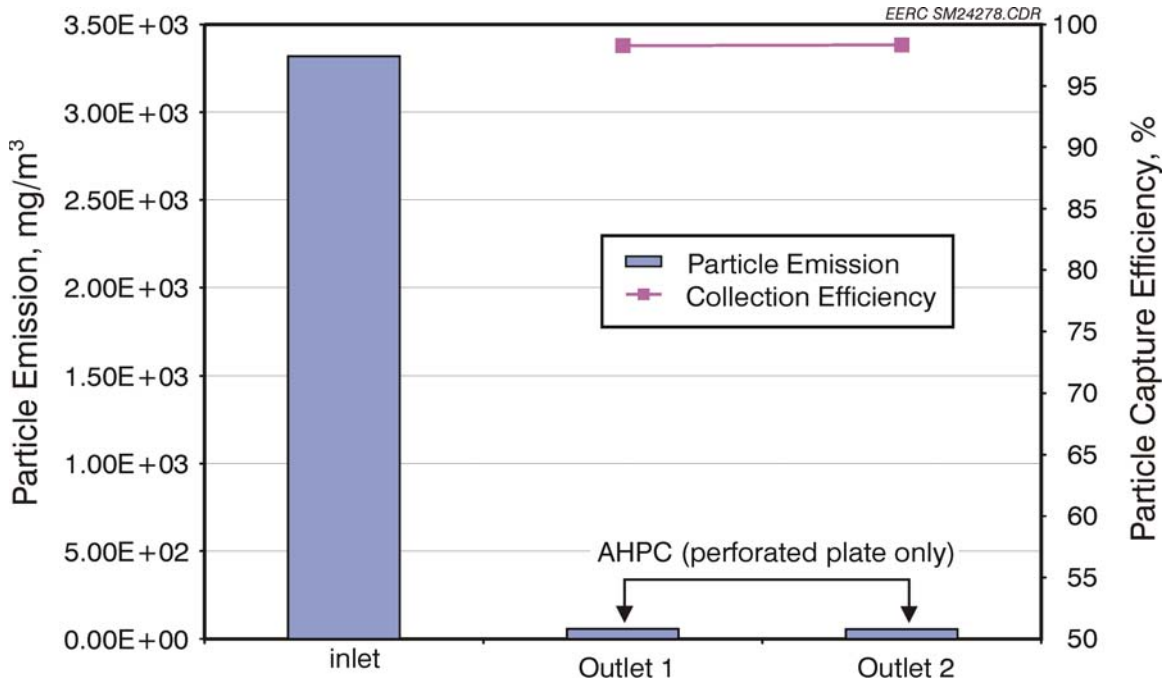

Figure 6. Outlet dust loadings and particulate collection efficiency for carbon injection tests.

filter bags. To address this question, the 200-acfm pilot-scale AHPC was modified so that it included perforated plates totally surrounding the normal bag area, but with the filter bags removed. Mercury removal with this configuration using the NORIT FGD carbon injected at 36 kg of carbon sorbent/million m^3 of flue gas (2 lb of carbon sorbent/million acf) was 66%, which was similar to previous results with the AHPC. These results indicate that good mercury control can be achieved with carbon collected on the perforated plates alone. However, using an EERC proprietary sorbent at the same carbon addition rate, the mercury collection efficiency improved to 90%. For both tests, the particulate collection efficiency of the perforated plates alone was 98%. These results are even more convincing because they prove that good gas–solid contact leading to excellent mercury removal can be achieved by collection of the activated carbon on the perforated plates alone, without a significant fraction of the carbon reaching the bags. It is important to show that good mercury control can be achieved by collection of the carbon on the perforated plates, because then the carbon addition rate can be adjusted as necessary to achieve the target mercury control level without concern of the effect of carbon injection on pressure drop. These results are consistent with previous pilot-scale and field data that have consistently shown that carbon injected upstream of the AHPC for mercury control has little or no effect on pressure drop.