Evaluation of Sorbent Injection for Mercury Control

Quarterly Technical Report
Reporting Period: April 1, 2005–June 30, 2005

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DISCLAIMER

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ABSTRACT

The power industry in the U.S. is faced with meeting new regulations to reduce the emissions of mercury compounds from coal-fired plants. These regulations are directed at the existing fleet of nearly 1,100 boilers. These plants are relatively old with an average age of over 40 years. Although most of these units are capable of operating for many additional years, there is a desire to minimize large capital expenditures because of the reduced (and unknown) remaining life of the plant to amortize the project. Injecting a sorbent such as powdered activated carbon into the flue gas represents one of the simplest and most mature approaches to controlling mercury emissions from coal-fired boilers.

The overall objective of the test program described in this quarterly report is to evaluate the capabilities of activated carbon injection at five plants with configurations that together represent 78% of the existing coal-fired generation plants. This technology was successfully evaluated in NETL's Phase I tests at scales up to 150 MW, on plants burning subbituminous and bituminous coals and with ESPs and fabric filters. The tests also identified issues that still need to be addressed, such as evaluating performance on other configurations, optimizing sorbent usage (costs), and gathering longer-term operating data to address concerns about the impact of activated carbon on plant equipment and operations. The four sites identified for testing are Sunflower Electric's Holcomb Station, AmerenUE's Meramec Station, AEP's Conesville Station, and Detroit Edison's Monroe Power Plant. In addition to tests identified for the four main sites, baseline and parametric testing at Missouri Basin Power Project's Laramie River Station Unit 3 was made possible through additional cost-share participation targeted by team members specifically for tests at Holcomb or a similar plant.

This is the seventh quarterly report for this project. Testing at Monroe Station was conducted during this reporting period. Preliminary results from baseline and parametric testing are included in this report. Planning information for the final test site, Conesville, is also included. In general, quarterly reports are used to provide project overviews, project status, and technology transfer information. Topical reports will be prepared for each test site and these will include detailed technical information. The topical report for evaluations conducted at Holcomb Station was submitted to DOE during this reporting period.

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INTRODUCTION

The overall objective of this test program is to evaluate the capabilities of activated carbon injection at five plants with configurations that together represent 78% of the existing coal-fired generation plants. Activated carbon injection was successfully evaluated in NETL's Phase I tests at scales up to 150 MW, on plants burning subbituminous and bituminous coals and with ESPs and fabric filters. The tests also identified issues that still need to be addressed, such as evaluating performance on other configurations, optimizing sorbent usage (costs), and gathering longer-term operating data to address concerns about the impact of activated carbon on plant equipment and operations. A summary of the key descriptive parameters for the host sites can be found in Table 1. Laramie River Station was added as the fifth site in the program during 4Q04.

The technical approach that is being followed during this program allows the team to: 1) effectively evaluate activated carbon and other viable sorbents on a variety of coals and plant configurations, and 2) perform long-term testing at the optimum condition for at least one month. These technical objectives will be accomplished by following a series of technical tasks:

Task 1. Design and Fabrication of Sorbent Injection System

Task 2. Site-Specific Activities including Field-Testing

Task 3. Technology Transfer

Task 4. Program Management and Reporting

Tasks 1, 3, and 4 are intended to support the overall direction, implementation, technology transfer, and management of the program. Task 2 will be repeated for each test site with subtasks designed to address the specific configurations, needs, and challenges of that site. Task 2 is the heart of the program and contains subtasks to address each important component of the testing. A summary of the Field-Testing subtasks (Task 2) is presented in Table 3.

Table 1. Host Site Key Descriptive Information.

	Holcomb	Meramec	Laramie River	Monroe	Conesville
Test Period	3/04–8/04	8/04–11/04	2/05–3/05	3/05–6/05	3/06–5/06
Unit	1	2	3	4	5 or 6
Size (MW)	360	140	550	785	400
Coal	PRB	PRB	PRB	PRB/Bit blend	Bituminous
Particulate Control	Joy Western Fabric Filter	American Air Filter ESP	ESP	ESP	Research-Cottrell ESP
SCA (ft^2/kacfm)	NA	320	599	258	301
Sulfur Control	Spray Dryer Niro Joy Western	Compliance Coal	Spray Dryer	Compliance Coal	Wet Lime FGD
Ash Reuse	Disposal	Sold for concrete	Disposal	Disposal	FGD Sludge Stabilization
Test Portion (MWe)	180 and 360	70	140	196	400
Typical Inlet Mercury (μg/dNm^3)	10–12	10–12	10–12	8–10	15–20
Typical Native Mercury Removal	0–13%	15–30%	<20%	10–30%	50%

A detailed topical report will be prepared for tests conducted at each test site. Quarterly reports will be used to provide project overviews, status, and technology transfer information.

EXECUTIVE SUMMARY

This five-site project is part of an overall program funded by the Department of Energy's National Energy Technology Laboratory (NETL) and industry partners to obtain the necessary information to assess the feasibility and costs of controlling mercury from coal-fired utility plants. Host sites that will be tested as part of this program are shown in Tables 1 and 2. These host sites reflect a combination of coals and existing air pollution control configurations representing 78% of existing coal-fired generating plants and, potentially, a significant portion of new plants. These host sites will allow documentation of sorbent performance on the following configurations:

Table 2. Host Sites Participating in the Sorbent Injection Demonstration Project.

	Coal/Options	APC	Capacity MW/ Test Portion	Current Hg Removal (%)
Sunflower Electric's **Holcomb Station**	PRB and Blend	SDA – Fabric Filter	360/180 and 360/360	<15
AmerenUE's **Meramec Station**	PRB	ESP	140/70	15–30
American Electric Power's (AEP) **Conesville Station**	Bituminous Blend	ESP + Wet FGD	400/400	50
Detroit Edison's **Monroe Power Plant**	PRB/Bit Blend	SCR + ESP	785/196	10–30
Missouri Basin Power Project's **Laramie River Station**	PRB	SDA – ESP	550/140	<20

During the seventh reporting period, April through June 2005, progress on the project was made in the following areas:

Sunflower Electric Power Corporation, Holcomb Station

- Holcomb Topical Report completed and submitted to DOE
    - Presented results at AWMA Annual Meeting

AmerenUE, Meramec

- Completed Meramec Draft Topical Report
- Presented results at AWMA Annual Meeting

MBPP, Laramie River Station

- Completed coal and ash analysis
- Preparing Laramie River Draft Topical Report

Detroit Edison, Monroe

- Completed baseline (SCR On) testing
- Completed parametric (SCR On) testing
- Conducted long-term testing
- Conducted team meeting to discuss project status and results from Monroe tests (6/28/05)

AEP, Conesville

- Completed Host Site Agreement with AEP for testing at Conesville
- AEP installed sampling ports (6/10/05) and completed design of silo foundation
- REI conducting flow modeling of Conesville ESP inlet

EXPERIMENTAL

The overall objective of this test program is to evaluate the capabilities of activated carbon injection at five plants with configurations that together represent 78% of the existing coal-fired generation plants. ADA-ES and the project team will evaluate activated carbon and other viable sorbents on a variety of coals and plant configurations, and perform long-term testing at the optimum condition for up to six weeks. The technical approach is outlined in a series of four technical tasks.

Task 1. Design and Fabrication of Sorbent Injection System

ADA-ES, the primary test contractor, will provide the majority of the process equipment that will travel from site to site. This equipment is sized and designed to cover the expected range of plant sizes (70–500 MW) and flue gas conditions, and has the flexibility for both baghouse and ESP applications.

Task 2. Site-Specific Activities Including Field-Testing

This task has seven subtasks. All subtasks will be repeated at each host site, except long-term testing which was not conducted at Laramie River Station. A summary of these subtasks is presented in Table 3. The five sites identified for testing are Sunflower Electric's Holcomb Station, AmerenUE's Meramec Station, Missouri Basin Power Project's Laramie River Station, Detroit Edison's Monroe Power Plant, and AEP's Conesville Station. Testing at Laramie River Station was limited to baseline and a short-term series of parametric tests. Testing during this quarter was conducted at Monroe Power Plant. Descriptions of Holcomb, Meramec, and Laramie River Station were included in previous quarterly reports. A description of Monroe Power Plant is included in this report. A description of Conesville Station will be included when results are presented.

Table 3. Task 2 Subtasks (to be repeated at each test site).

Subtask	Description
2.1	Host site kickoff meeting, Test Plan, and QA/QC plan
2.2	Design and install site-specific equipment
2.3	Field-tests
2.3.1	Sorbent selection
2.3.2	Sample and data coordination
2.3.3	Baseline tests
2.3.4	Parametric tests
2.3.5	Long-term tests *(no long-term tests conducted at Laramie River)*
2.4	Data analysis
2.5	Sample evaluation
2.6	Economic analysis
2.7	Site (topical) report

DTE Energy's Monroe Station Unit 4

Monroe Power Plant is located in Monroe County, Michigan. The test unit (Unit 4) is a load-following super-critical 785-MW (gross) pulverized coal, wall fired, electric generating unit with a horizontal shaft Ljungström® air preheater. The unit typically burns a 60/40 blend of PRB and eastern bituminous coals. The unit is capable of firing blends of up to 75% PRB coal while incurring a load reduction. The unit is equipped with four ESPs in a piggyback configuration, with two boxes on top and two boxes on bottom, operating in parallel for particulate removal. Each ESP has five electrical fields in series and twelve hoppers: three front to back and four side to side. Other air pollution control equipment used by Monroe Unit 4 includes an SCR used for NO_x control during ozone season and SO_3 injection for flue gas conditioning.

For sorbent injection testing with injection upstream of the ESP, only one-quarter of the 785-MW flue gas stream will be treated. A sketch showing one-half of the Unit 4 flue gas path is shown in Figure 1. Tests will be conducted to determine the mercury removal efficiency when injecting sorbent across the ESP with and without the SCR in operation. Data will also be available to determine the amount of mercury captured in-flight prior to entering the ESP. Key operating parameters for Monroe Unit 4 are shown in Table 4.

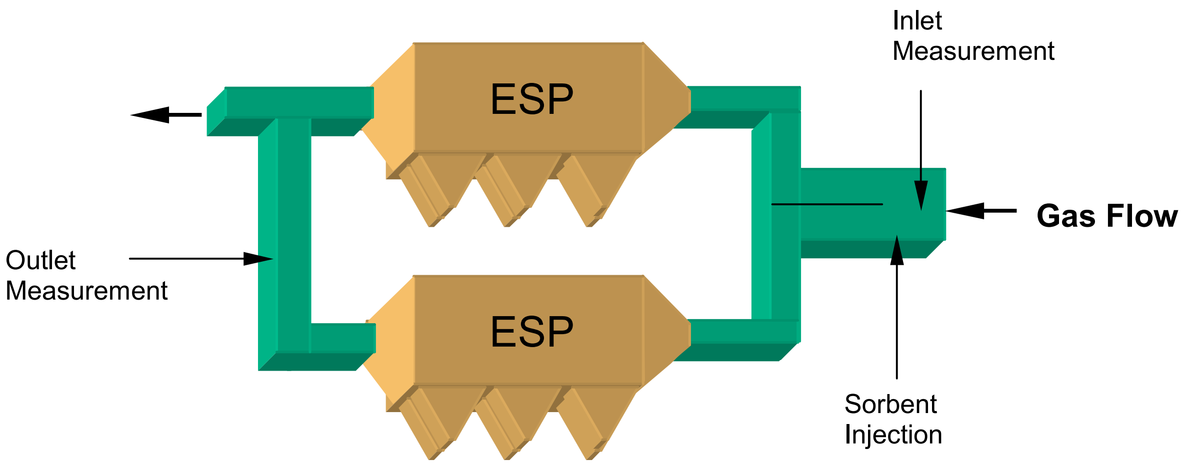

Figure 1. Sketch of Lower South ESP of Monroe Unit 4 Testing Layout.

Table 4. Monroe Key Operating Parameters.

Unit	4	
Size (MW)	785	
Test Portion (MWe)	196	
Coal	PRB – Eastern Bituminous Blend (60/40)	
	PRB	Bit
Heating Value (as received)	8,700	12,319
Sulfur (% by weight)	.04	.72
Chlorine (%)	~0.01	.05
Mercury (µg/g)	0.056	.08
Particulate Control	Cold-Side ESP SCA = 258 ft^2/kacfm	
Sulfur Control	Coal Blending	
Air Preheater	Ljungström Horizontal Shaft	
Ash Reuse	Disposed to Ash Pond	

Subtask 2.1. Host Site Planning and Coordination

Efforts within this subtask include planning the site-specific tests with the host site utility, DOE/NETL, and contributing team members. The planning process includes meeting with plant personnel, corporate, and environmental personnel to discuss and agree upon the overall scope of the program, the potential impact on plant equipment and operation, and to gather preliminary information necessary to develop a detailed draft Test Plan and scope of work. Efforts include identifying any permit requirements, developing a quality assurance/quality control plan, finalizing the site-specific scope for each of the team members, and putting subcontracts in place for manual flue gas measurements, including Ontario Hydro mercury measurement services.

Field-testing was conducted at Monroe Power Plant during this reporting period. Testing at Conesville has been delayed until spring 2006. Progress was made on the ESP inlet flow model by REI. Data from the flow model will be used to design the injection lances.

Subtask 2.2. Design, Fabricate, and Install Equipment

During this subtask, equipment will be identified, designed, fabricated when necessary, and installed at the host site. Some components are site-specific such as the sorbent distribution manifold and sorbent injectors (if possible, these components will be reused at multiple sites). This equipment must be sized, designed, and fabricated for the specific plant arrangements and ductwork configurations. Required site support includes installation of the injection and sampling ports (if not available), installation of required platforms and scaffolding, compressed air, electrical power, wiring plant signals including boiler load to the injection skid and control trailer, and the balance-of-plant engineering. The host utility will be responsible for all permitting and any variance requirements.

Subtask 2.3. Field-Testing

Field-tests are accomplished through a series of five steps. A summary of these steps is presented below.

2.3.1 Sorbent Selection

A key component of the planning process for these evaluations is identifying potential sorbents for testing. To assist in the sorbent selection process, a sorbent screening device (SSD) designed by ADA-ES was used at each site except Laramie River to compare the performance of candidate sorbents. A description of the device was included in the 2Q04 quarterly report.

2.3.2 Sample and Data Coordination

ADA-ES engineers coordinate with plant personnel to retrieve the necessary plant operating data files and determine appropriate samples to collect during baseline, parametric, and long-term testing periods. Samples are collected based upon a Sample and Data Management Plan developed for the sites. An example of the sampling schedule for Meramec and additional descriptions of the sample management protocol were included in the 2Q04 quarterly report.

2.3.3 Baseline Testing

Baseline mercury measurements, consisting of Ontario Hydro testing in conjunction with SCEM measurement, are typically made at each site for at least one week prior to beginning parametric mercury control tests. Baseline measurements were conducted at Holcomb, Meramec, Laramie, and Monroe, and are planned for Conesville. During testing at Laramie River Station, sorbent traps were used for comparison tests with the SCEMs. Additional tests, such as EPA M26a or EPA M29 measurements have also been conducted at Holcomb, Meramec, and Monroe, and are planned for Conesville.

2.3.4 Parametric Testing

A series of parametric tests is conducted at each site to determine the optimum operating conditions for several levels of mercury control. Evaluations of NORIT's DARCO® Hg and other sorbents chosen by the test team are typically included. Additional tests, such as coal blending or the introduction of additives onto the coal, may also be included. A summary of parametric tests conducted or planned at each site is shown below.

Sorbent Injection

(Descriptions of most sorbents tested are included in previous quarterly reports.)

- DARCO® Hg (formerly known as FGD): All sites
- DARCO® Hg-LH (formerly known as FGD-E3): Holcomb, Meramec, Laramie River, Monroe
- Calgon 208CP: Holcomb
- NORIT XTR (low-activity, lignite-based activated carbon): Monroe
- NEST PHg-1 (non-carbon-based material from Northeastern Energy and Environmental Technologies; chosen based on positive results from tests at Meramec): Monroe
- Sorbent(s) to be finalized: Conesville

Coal Blending

- PRB and western bituminous: Holcomb, Laramie River
- PRB and eastern bituminous: Monroe

Coal Additives

- ALSTOM's KNX: Holcomb, Meramec, Laramie River
- EERC's SEA2: Meramec (conducted with AmerenUE funds)

SCR ON/Bypass

- Monroe

2.3.5 Long-Term Testing

Thirty-day "long-term" testing has been completed at Holcomb and Meramec, was conducted during this reporting period at Monroe, and is planned for Conesville. The sorbents used during the long-term test period are chosen by the test team based upon performance during parametric testing and a review of the material costs and availability. The goal of the 30-day test phase is to obtain operational data on mercury removal efficiency, the effects on the particulate control device, effects on byproducts and impacts to the balance-of-plant equipment, to prove viability of the process, and determine the economics. During these tests, Ontario Hydro measurements are conducted at the inlet and outlet of the particulate control device at least once.

Subtask 2.4. Data Analysis

Data collection and analysis for this program are designed to measure the effect of sorbent injection on mercury control and the impact on the existing pollution control equipment. The mercury levels and plant operation are characterized without sorbent injection, during coal blending or coal additive testing, and with various injection rates and possible combustion modifications, as defined by the final Site Test Plan.

Subtask 2.5. Coal and Byproduct Evaluation

Coal and combustion byproduct samples collected throughout the program are analyzed in this task. During all field test phases, samples of coal and fly ash are collected. At a minimum, ultimate and proximate analyses will be performed and mercury, chlorine, and sulfur levels will be determined in a representative set of the coal samples. Activated carbon injection will result in the fly ash and scrubber materials being mixed with a certain amount of the mercury-containing sorbent. The ash samples will be analyzed at a minimum for mercury and LOI. It is expected that more than 100 samples will be collected at each site. A subset of these samples will be analyzed.

Subtask 2.6. Economic Analysis

After completion of testing and analysis of the data at each plant, the requirements and costs for full-scale permanent commercial implementation of the selected mercury control technology will be determined. The program team will meet with the host utility plant and engineering personnel to develop plant-specific design criteria. Process equipment will be sized and designed based on test results and the plant-specific requirements (reagent storage capacity, plant arrangement, retrofit issues, winterization, controls interface, etc.). A conceptual design document will be developed. Finally, a budget cost estimate will be developed to implement the control technology.

Subtask 2.7. Site (Topical) Report

A site (topical) report will be prepared documenting measurements, test procedures, analyses, and results obtained in Task 2. This report is intended to be a stand-alone document providing a comprehensive review of the testing that will be submitted to the host utility.

Task 3. Technology Transfer

Technology transfer activities include participation in DOE/NETL-sponsored meetings, presentations at conferences, and publication of technical papers. A summary of results from Holcomb, Laramie River, and Meramec was presented at the AWMA annual meeting in June 2005. A presentation is planned for the DOE Contractors Review meeting in July 2005.

Task 4. Program Management and Reporting

The final task provides time for overall program management and time to complete DOE's reporting requirements. This task will also support periodic meetings with DOE to discuss progress and obtain overall direction of the program from the DOE project manager. In addition to the standard financial and technical reports, additional deliverables will include topical reports for each site tested. The Project Schedule and Milestones are presented in Table 5.

Table 5. Project Schedule and Milestones.

Activity	Target Date	Actual Date
Holcomb		
Site Kickoff Meeting	12/16/03	12/16/03
Complete Sorbent Screening Tests	3/4/04	3/2/04
Complete Equipment Installation	5/21/04	4/21/04
Complete Baseline Testing	5/21/04	5/20/04
Initiate Parametric Testing	5/24/04	5/22/04
Complete Parametric Testing	6/11/04	6/11/04
Initiate Long-Term Testing	7/7/04	7/7/04
Complete Team Meeting and Site Tour	7/21/04	7/21/04
Complete Long-Term Test	8/6/04	8/6/04
Complete Economic Analysis	5/31/05	2/28/05
Complete Byproduct Analysis Evaluations	5/31/05	5/31/05
Complete Site (Topical) Report	6/30/05	6/27/05
Meramec		
Site Kickoff Meeting	4/20/04	4/20/04
Complete Pre-Baseline Testing	6/25/04	6/23/04
Complete Sorbent Screening Tests	10/18/04	10/08/04
Complete Equipment Installation	9/5/04	8/23/04
Complete Baseline Testing	9/5/04	8/27/04
Initiate Parametric Testing	9/6/04	8/30/04
Complete Parametric Testing	10/17/04	9/27/04
Complete Team Meeting and Site Tour	12/17/04	10/27/04
Initiate Long-Term Testing	10/18/04	10/14/04
Complete Long-Term Test	12/17/04	11/17/04
Complete Economic Analysis	8/31/05	
Complete Byproduct Analysis Evaluations	8/31/05	
Complete Site (Topical) Report	9/30/05	
Laramie River		
Site Kickoff Meeting	1Q05	1/20/05
Initiate Field-Testing	2Q05	2/21/05
Complete Field-Testing	2Q05	3/8/05
Monroe		
Site Kickoff Meeting	4Q04	1/11/05
Initiate Field-Testing	3Q05	3/22/05
Complete Field-Testing	4Q05	7/1/05
Conesville		
Site Kickoff Meeting	2Q05	3/1/05
Initiate Field-Testing	1Q06	
Complete Field-Testing	1Q06	

There are more than 100 individual team members from 27 organizations participating in this program. Current project co-funding is provided by:

- ADA-ES, Inc.
- ALSTOM
- AmerenUE*
- American Electric Power*
- Arch Coal
- Detroit Edison*
- Dynegy Generation
- EPRI
- Kennecott Coal
- MidAmerican
- NORIT Americas
- Ontario Power Generation and partners
  - EPCOR
  - Babcock & Wilcox
- Peabody Coal
- Southern Company
- Sunflower Electric Power Corporation* and partners
  - Associated Electric Coop
  - City of Sikeston
  - Empire District Electric Company
  - Kansas City Board of Public Utilities (KCKBPU)
  - Kansas City Power and Light
  - Kennecott Coal
  - Missouri Basin Power Project*
  - Nebraska Public Power District
  - PacifiCorp
  - Peabody Coal
  - Southern Minnesota Municipal Power Agency
  - Tri-State Generation & Transmission
  - TransAlta Utilities
  - TransAlta Energy.
  - Westar Energy
  - Western Fuels Association
  - Wisconsin Public Service
- Tennessee Valley Authority

** Indicates host site*

Key members of the test team include:

- ADA-ES, Inc.
  - Project Manager: Sharon Sjostrom
  - Site Manager: Travis Starns
  - SCEM Lead: Jerry Amrhein
- DOE/NETL
  - Project Manager: Andrew O'Palko
- EPRI
  - Project Manager: Ramsay Chang
- Reaction Engineering International
  - Coal and byproduct analysis interpretation: Connie Senior
- ALSTOM
  - Scrubber operation and coal additive injection parameters: Leif Lindau

To facilitate information sharing, a project Web site is maintained for the project. The project Web site is password protected and available only to project participants. Information available through the Web site includes all presentations, papers, reports, planning documents, schedules, and other information related to the project.

A schedule showing field-tests planned and completed at each test site is shown in Table 6.

Table 6. Field-Testing Schedule.

	2004				2005					
Site	May	Jul	Sep	Nov	Jan	Mar	May	Jul	Sep	Nov
Holcomb										
Meramec										
Laramie River										
Monroe										
Conesville Spring '06										

RESULTS AND DISCUSSION

Task 1. Design and Fabrication of Sorbent Injection System

Design and fabrication of the sorbent injection system used at Holcomb, Meramec, and Monroe Power Plant was completed during the January–March 2004 reporting period.

Task 2. Site-Specific Activities Including Field-Testing

Baseline and parametric testing at Monroe Power Plant with the SCR bypassed were completed during the January–March 2005 reporting period. Baseline and parametric testing with the SCR in-service were completed during the current reporting period (April–June 2005). Long-term testing at Monroe was also begun during this period. Results from baseline and parametric tests with and without the SCR are included under this task heading.

Subtask 2.3. Field-Testing

2.3.2 Sample and Data Coordination

Data analysis and coal and byproduct evaluation is ongoing for all sites where field-testing was conducted. Details will be included in the topical reports.

2.3.3 Baseline Testing – Monroe Power Plant

Baseline testing with the SCR bypassed was conducted March 22–24, 2005, and baseline testing with the SCR in-service was conducted May 16–20, 2005. Throughout these periods, mercury measurements were made at the ESP inlet and outlet with mercury analyzers (SCEM). During two days of each baseline test period, Ontario Hydro mercury measurements were also conducted at the inlet and outlet of the ESP.

SCR OFF Baseline Results

On March 23 and 24, Unit 4 was held steady at full-load conditions 24 hours/day. The coal blend ratio during this period was 15% low-sulfur bituminous/60% western subbituminous/ 25% mid-sulfur bituminous. The mercury removal measured on March 23 and 24 using the SCEM and Ontario Hydro methods are presented in Table 7. The average vapor-phase mercury removal efficiency measured with the SCEMs was less than 10%, compared to 35% measured with the Ontario Hydro method. The inlet mercury with the two methods matched within 13%, which is considered good for this comparison. The outlet mercury concentration measured with the two methods differed by 39%. It is probable that both methods are correct and the baseline mercury removal varied across the ESP due to temperature variations. To assist in troubleshooting this measurement discrepancy, thermocouples were installed at the inlet to the ESP. During the week of March 28, the average temperature at the inlet to the ESP varied from 275 to 235ºF. The average temperature in-line with the SCEM at the outlet of the ESP was 273ºF. The average temperature in-line with the single port used for Ontario Hydro measurements was 245ºF. The run sheets for the Ontario Hydro indicate the average temperature at the outlet during testing was 250ºF, which is close to the temperature measured at the upstream thermocouple installed at the inlet of the ESP. It is likely that the capacity of the fly ash for mercury is higher at lower temperatures. If so, the mercury removal measured in the cooler portion of the ESP where the Ontario Hydro was conducted could have been higher than in the warmer portion where the SCEM was installed.

The fraction of elemental mercury as measured using the SCEM was less than 50% of the overall vapor-phase mercury. The Ontario Hydro measurements suggest that 20% of the mercury was in the elemental form. It is possible that vapor-phase mercury was being oxidized across the fly ash captured on the Ontario Hydro sampling filter.

Table 7. Preliminary Baseline Results SCR OFF.

	ESP Inlet			**ESP Outlet**			
	Particulate Mercury (µg/Nm^3)	Elemental Mercury (µg/Nm^3)	Total Mercury (µg/Nm^3)	Particulate Mercury (µg/Nm^3)	Elemental Mercury (µg/Nm^3)	Total Mercury (µg/Nm^3)	% Removal
SCEM	0.8	4.3	9.5		1.9	8.8	7.4
OH	1.8	1.7	8.3	0.1	2.1	5.4	35
% Difference	*116.4*	*-61.0*	*-12.6*		*14.1*	*-38.9*	

SCR ON Baseline Results

During the baseline SCR ON tests, May 16–19, 2005, Unit 4 was held steady at full-load conditions with a coal blend ratio of 35% bituminous/65% western subbituminous. The average vapor-phase mercury removal efficiency according to the SCEM was 28%, compared to 29% overall removal measured with the Ontario Hydro method. These data are presented in Table 8. The mercury removal efficiency measurements as determined by the SCEM and the Ontario Hydro method compare well.

The fraction of oxidized mercury at the inlet to the ESP increased to over 90% with the SCR ON as compared to nominally 50% during the SCR OFF period, suggesting that the SCR is effective at enhancing mercury oxidation.

Table 8. Baseline Results SCR ON.

	ESP Inlet			**ESP Outlet**			
	Particulate Mercury (µg/Nm^3)	Elemental Mercury (µg/Nm^3)	Total Mercury (µg/Nm^3)	Particulate Mercury (µg/Nm^3)	Elemental Mercury (µg/Nm^3)	Total Mercury (µg/Nm^3)	% Removal
SCEM	NA	0.20	6.5		0.26	4.7	28
OH	1.46	0.16	9.00	0.01	0.16	6.43	29
% Difference	*NA*	*-13.4*	*29.0*		*-82.3*	*23.9*	

Note: Values reported are not corrected to 3% oxygen.

Duplicate sorbent traps were also performed at the ESP outlet during each Ontario Hydro run. Data are not yet available.

In the fall of 2004, the Energy and Environmental Research Center (EERC) tested Monroe Station Unit 1 for mercury emissions. Their primary focus was to characterize the effect of the SCR on mercury speciation and emissions. During testing, the blend ratio was 60% western subbituminous and 40% mid-sulfur eastern bituminous.

Results from testing in 2004 also indicate the SCR was very effective at increasing the amount of oxidized mercury entering the ESP. With the flue gas flowing through the SCR system, greater than 90% of the vapor-phase mercury entering the ESP was in an oxidized state. This is similar to the speciation seen during testing in 2005 at Monroe Station. Testing in 2004 was conducted on Unit 1 which similar in design to Unit 4 (i.e., SCR/ESP). With the SCR OFF, only 57% of the vapor-phase mercury entering the ESP was oxidized. For comparison, these results are shown in Figure 2.

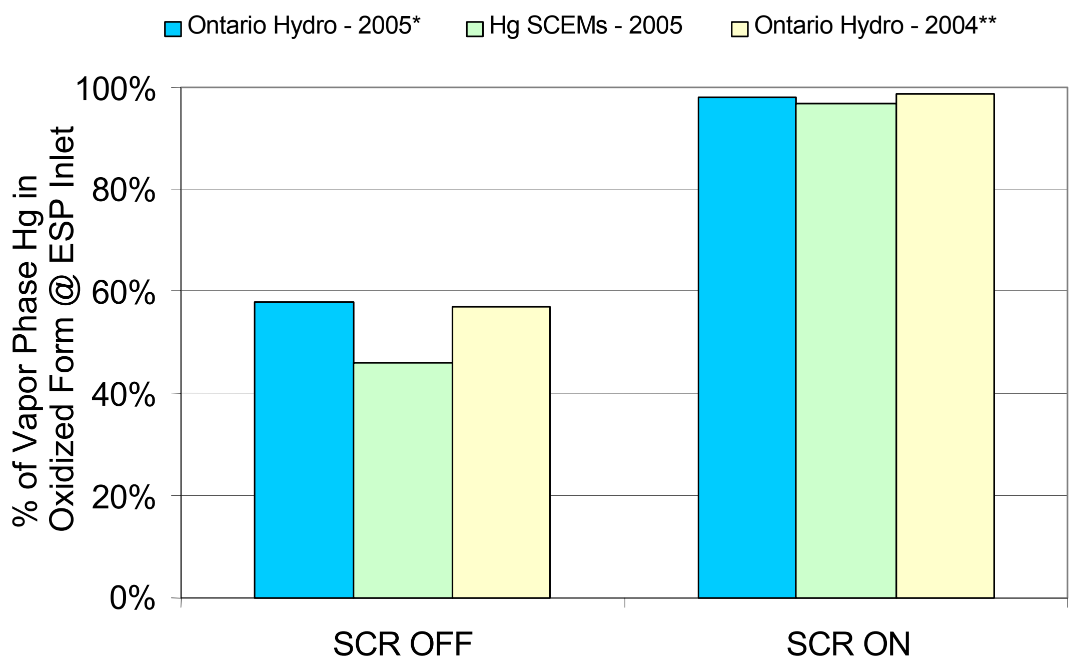

Figure 2. Effect of SCR on Mercury Speciation at the ESP Inlet.

Parametric Testing Results

Parametric testing with the SCR OFF was conducted March 29–31 and April 21, 2005. Testing with the SCR ON was conducted May 23–26, 2005. During these parametric tests, sorbents were injected at various rates to develop a relationship between sorbent injection rate and mercury removal efficiencies across the ESP.

SCR OFF

The DARCO® Hg and DARCO® Hg-LH sorbents were evaluated March 29–31, 2005, with the SCR OFF. The coal blend ratio for these tests was 65% western subbituminous, 15% low sulfur bituminous, and 20% mid-sulfur bituminous coal. Results from these tests show similar performance between the DARCO® Hg and DARCO® Hg-LH with the SCR OFF. Vapor-phase mercury capture across the ESP was greater than 80% while injecting the DARCO® Hg sorbent at an injection concentration of 6 lb/MMacf. Because of a tube leak on April 1, 2005, the DARCO® Hg-LH sorbent was not tested at this higher injection concentration (6 lb/MMacf). For reference, the percentage change in outlet mercury concentration, noted as incremental removal in Figure 3, is also shown.

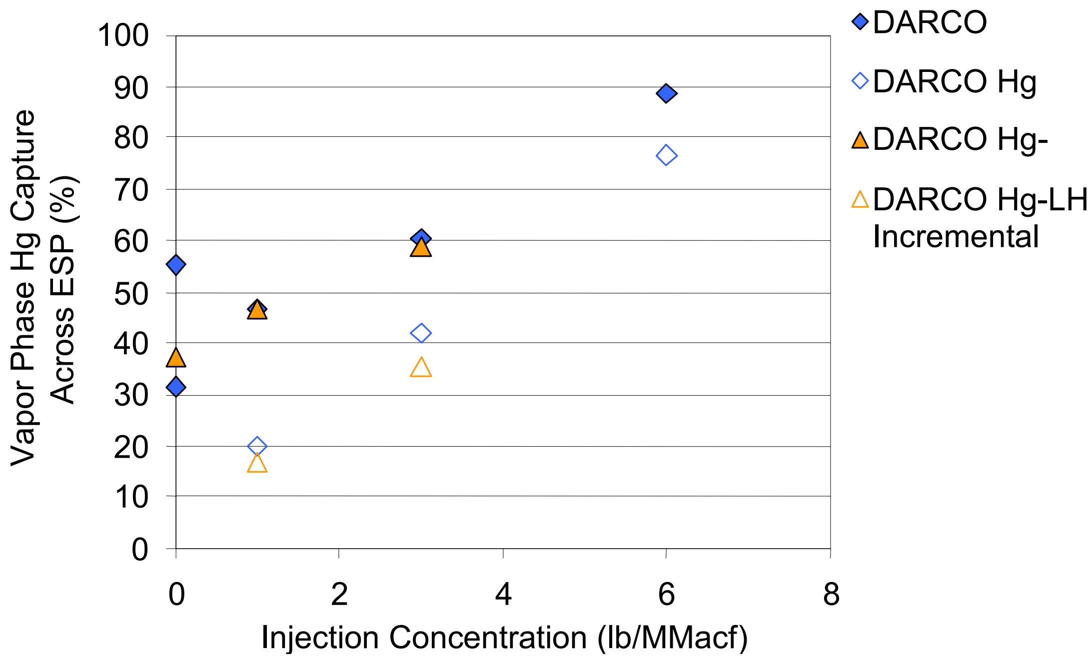

Figure 3. Sorbent Injection Results during SCR OFF Parametric Testing.

Coal Blending

Late on March 24, the blend ratio was adjusted to 65% western subbituminous and 35% mid-sulfur eastern bituminous. No significant change in the mercury concentration or speciation resulted from the change in coal. At approximately midnight on March 25, the blend ratio was adjusted to 70% western subbituminous and mid-sulfur bituminous. The mercury concentration at the outlet of the ESP began to decrease when the blend ratio was adjusted and load was dropped for this blend test. The elemental mercury concentration at the outlet of the ESP did not change, however, indicating a decrease in the fraction of oxidized mercury at the outlet of the ESP. The mercury concentration and speciation at the inlet of the ESP remained the same late into the evening March 25 before the change in blend ratio. An attempt was made for a 75% western subbituminous, 25% mid-sulfur bituminous blend ratio at midnight on March 26. This was aborted after a few hours because of combustion concerns and the blend ratio was returned to 70/30.

During the coal blend tests, the fraction of oxidized mercury increased with bituminous coal content. At a blend ration of 60/40 PRB to bituminous coal, 53% of the vapor-phase mercury at the ESP inlet was in the oxidized state. When the blend ratio was adjusted to 65/35, oxidized mercury decreased to 51% of the total vapor-phase mercury, while at the 70/30 blend ration, the vapor-phase oxidized mercury made up only 37% of the total vapor-phase mercury, as shown in Figure 4. This result was expected, as the chlorine content in PRB coals is generally less than that of bituminous coals. These data are summarized in Table 9.

Table 9. Average Vapor-Phase Mercury Concentrations during Coal Blending.

Blend Ratio (PRB/Bit)	ESP Inlet Total Vapor-Phase Mercury (µg/dNm)	ESP Inlet Vapor-Phase Oxidized Mercury (µg/dNm)	% ESP Inlet Vapor-Phase Oxidized Mercury
60/40	12.12	6.36	52
65/35	11.11	5.65	51
70/30	13.35	4.98	37

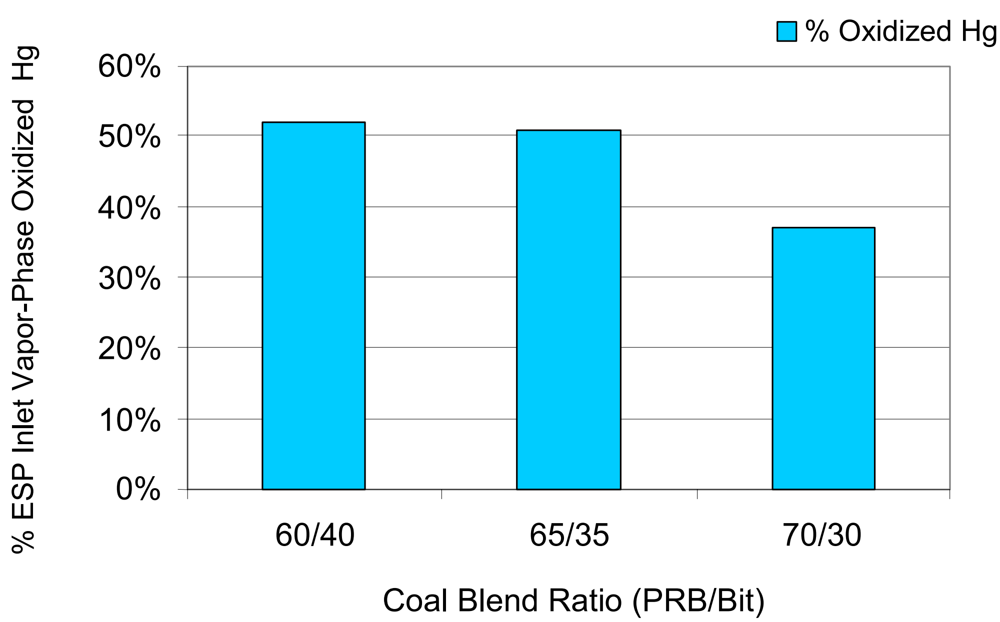

Figure 4. Average Vapor-Phase Mercury Concentrations during Coal Blending.

SCR ON

During the parametric testing series with the SCR ON, a total of three sorbents were evaluated: DARCO® Hg, DARCO® XTR, and NEST. The coal blend ratio during these tests was held fairly steady at 65% PRB and the balance of coal was mid-sulfur eastern bituminous. Each injection rate tested was held steady for a minimum of two hours to allow each test condition to reach equilibrium.

The DARCO® Hg sorbent demonstrated a vapor-phase mercury capture greater than 80% at an injection concentration of 6 lb/MMacf with the SCR ON. Thus, the performance of DARCO® Hg was similar whether the SCR was ON or OFF. A summary of the sorbent injection results during parametric testing, except for the NEST sorbent, is shown in Figure 5.

The final two days of parametric testing with the SCR ON evaluated the performance of a low-activity sorbent (DARCO® XTR) and a non-carbon-based material (NEST). The DARCO® XTR was evaluated at 3 and 6 lb/MMacf. Results suggest 49% mercury removal at 3 lb/MMacf compared to 61% for DARCO® Hg. At the higher injection concentration, 66% mercury removal was achieved with the DARCO® XTR compared to 81% with the DARCO® Hg. The baseline mercury removal during these tests was nominally 18%. The NEST tests indicated that there was a 5% decrease in mercury emissions at an injection concentration of 5 lb/MMacf.

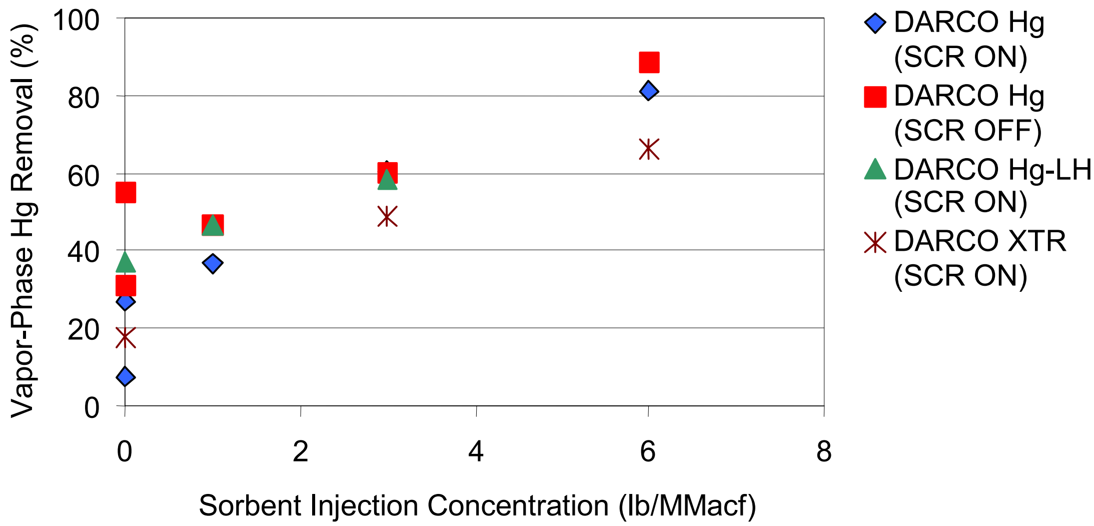

Figure 5. Preliminary Results from Parametric Testing at Monroe Unit 4.

2.3.4 Parametric Testing – Laramie River Station

Following the baseline test period, a series of parametric tests were conducted to evaluate various mercury control technologies. The parametric tests were conducted at full-load conditions to document performance of coal blending, sorbent injection, and coal additive addition (with and without ACI) for control of mercury in stack emissions. This task was completed at Laramie River Station during the January–March 2005 reporting period and preliminary results are included in this quarterly report.

Coal Blending

During the coal blending tests, two types of western bituminous coals were evaluated. The plant typically fires 100% PRB coal; however, during the coal blend tests, a blend of approximately 80% PRB and 20% western bituminous was used.

Western Bituminous Blend 1

The first western bituminous coal was tested at two different blend ratios: 80/20 and 75/25. While testing at the 80/20 ratio, the average total vapor-phase mercury concentrations at the SDA inlet and ESP outlet were 9.2 and 9.3 $\mu g/Nm^3$ respectively. Mercury speciation at both locations was consistent with baseline measurements, where approximately 2% of the vapor-phase mercury at the SDA inlet and 8% at the ESP outlet was oxidized.

Coal samples were collected at the mine and sent to ADA-ES. A composite sample was sent to an outside lab for analysis. Results from the coal analyses will be included in the topical report.

Immediately following the 80/20-blend test, the amount of western bituminous coal added to the Unit 3 boiler was increased to 25%. Average vapor-phase mercury concentrations at the SDA inlet and ESP outlet for this blend were 8.6 and 8.2 $\mu g/Nm^3$ respectively. During both blends, total vapor-phase mercury removal was less than 10%.

Western Bituminous Blend 2

The second coal blend test was conducted with a different western bituminous coal, at a coal blend ratio of approximately 84% PRB and 16% western bituminous. During the transition to the second blend, total coal flow into the boiler decreased while the gross generation increased. This is likely due to the higher heating value of the western bituminous coal.

Coal samples were collected at the mine and sent to ADA-ES. A composite sample was sent to an outside lab for analysis and to help calculate an expected coal quality for the blended coal. Results from the coal analyses will be included in the topical report.

A few hours before the second coal blend test, the total vapor-phase mercury removal across the system was approximately 22%. This is higher than during baseline testing and may be attributed to the residual effects of sorbent injection conducted before the coal blending tests. During coal blend tests, total vapor-phase mercury removal efficiency increased up to 30%, indicating a slight improvement in mercury removal with coal blending.

Sorbent Injection Testing

Sorbent injection tests began on February 28, 2005. Two sorbents were evaluated at Laramie River: the non-treated benchmark sorbent, DARCO® Hg, and the bromine-treated sorbent, DARCO® Hg-LH.

The vapor-phase mercury removal efficiency with DARCO® Hg appeared to be limited to nominally 50% at injection concentrations up to 6.2 lb/MMacf. Data from other cold-side ESP sites burning low-rank coals (PRB or North Dakota lignite) also show limitations in mercury capture when injecting DARCO® Hg, as shown in Figure 6. Halogens, such as HCl, must be present for effective mercury capture by untreated activated carbon. It is speculated that activated carbon injection concentrations of 3 to 10 lb/MMacf are sufficient to absorb the available halogens so that subsequent increases in injection concentrations are ineffective.

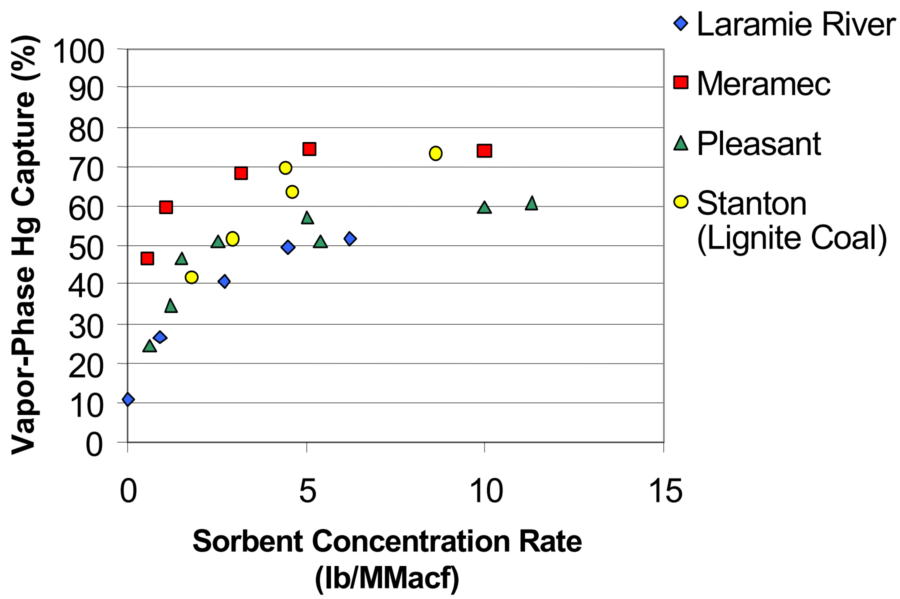

Figure 6. Summary of DARCO® Hg Results on Cold-Side ESPs.

When the halogen concentration in the flue gas is low, an activated carbon treated with a halogen can be used for higher mercury capture. When DARCO® Hg-LH sorbent was injected upstream of the SDA, 79% mercury removal was achieved at an injection concentration of 2.7 lb/MMacf, and 92% removal was achieved at 4.5 lb/MMacf. The results of DARCO® Hg and DARCO® Hg-LH sorbent injection are presented in Figure 7.

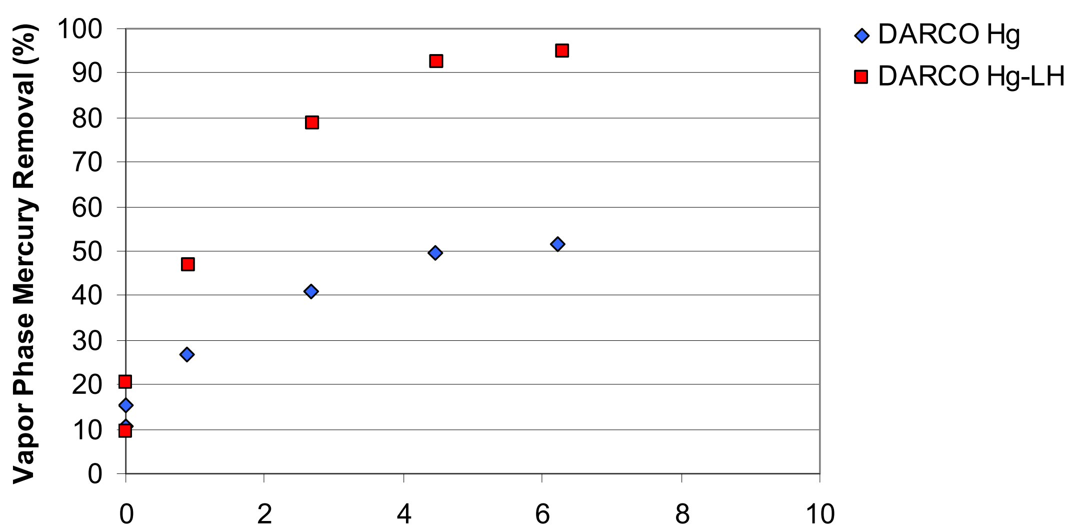

Figure 7. Results from Sorbent Injection Tests at Laramie River.

The in-situ fly ash sampler was used to evaluate in-flight mercury capture (by measuring mercury that ended up in the particulate phase). At baseline conditions, (no sorbent injection) the particulate-phase mercury was found to be less than 10% of the total mercury present at the inlet of the SDA. At sorbent injection concentrations of up to 6.3 lb/MMacf, a vapor-phase mercury removal rate of up to 40% was measured for DARCO® Hg and DARCO® Hg-LH.

Coal Additive Testing

Another option for introducing halogens into the flue gas stream is to treat the coal before it enters the boiler rather than injecting treated carbons. The coal additive tested was KNX, a proprietary mercury control technology from ALSTOM Power.

Unit 3 is equipped with a wall-fired boiler fed by seven coal feeders. KNX was applied to the coal at feeders 3B and 3C, which supply the lower burner elevations on each side of the boiler. At this chemical injection location, the treated coal reached the burner within seconds. The KNX additive was applied to the coal at injection rates up to 2.7 gph.

Prior to the start of KNX testing, the fraction of oxidized mercury at the SDA inlet was 2.4%. Injecting the KNX additive onto the coal at a rate of 0.7 gph resulted in a 2% increase in oxidized mercury at the SDA inlet. It should be noted that due to the pump's flow capacity, chemical flow less than 1 gph was unsteady and may have slightly deviated from the target set point. Increasing the KNX flow rate to 2.7 gph resulted in a 14% increase in speciation from baseline levels at the SDA inlet. Mercury speciation data from KNX testing are presented in Figure 8.

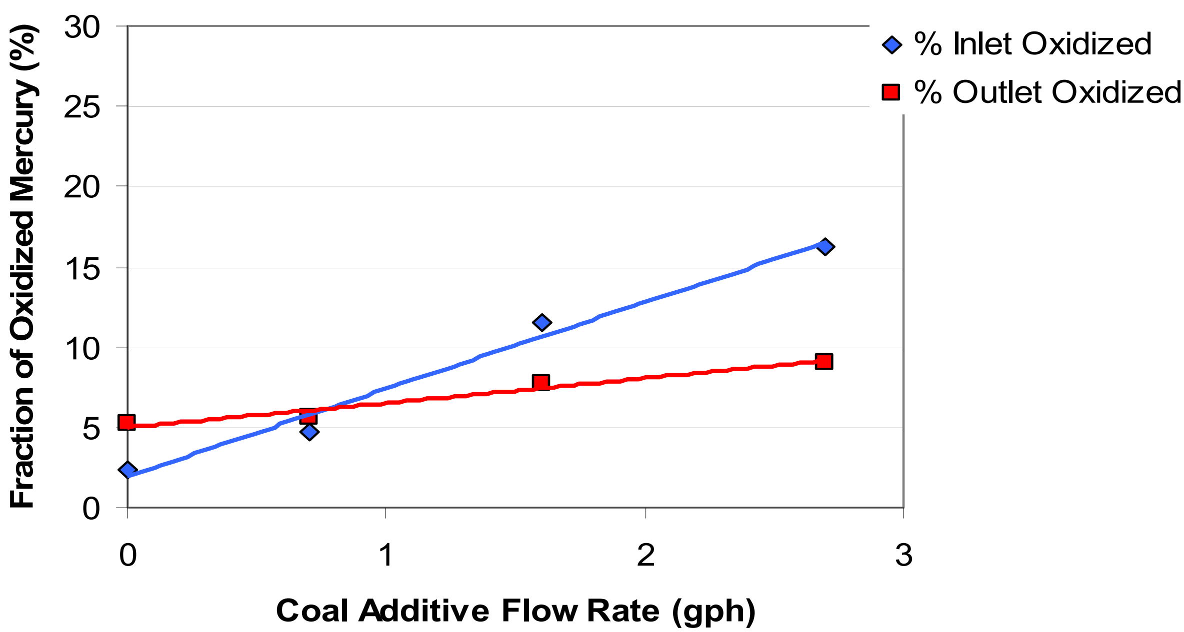

Figure 8. Mercury Speciation Results during KNX Testing.

Although the fraction of oxidized mercury at the inlet of the SDA increased, mercury removal across the system was limited to less than 20%, and the fraction of oxidized mercury at the outlet of the ESP was lower than at the SDA inlet. These data suggest that either the KNX addition resulted in a sampling artifact that biased the elemental mercury measurement at the SDA inlet, or the SDA-ESP configuration was reducing oxidized mercury back to the elemental form. This same phenomenon has been seen on other PRB/SDA units during KNX testing.

The final day of KNX testing included the injection of the DARCO® Hg sorbent at the SDA inlet at 4.5 lb/MMacf in conjunction with KNX addition at 1.6 gph. The resulting total mercury capture across the system was 94% compared to 50% with DARCO® Hg alone (no KNX). These data, shown in Figure 9, clearly indicate the improved performance of DARCO® Hg when halogens are added to the flue gas stream.

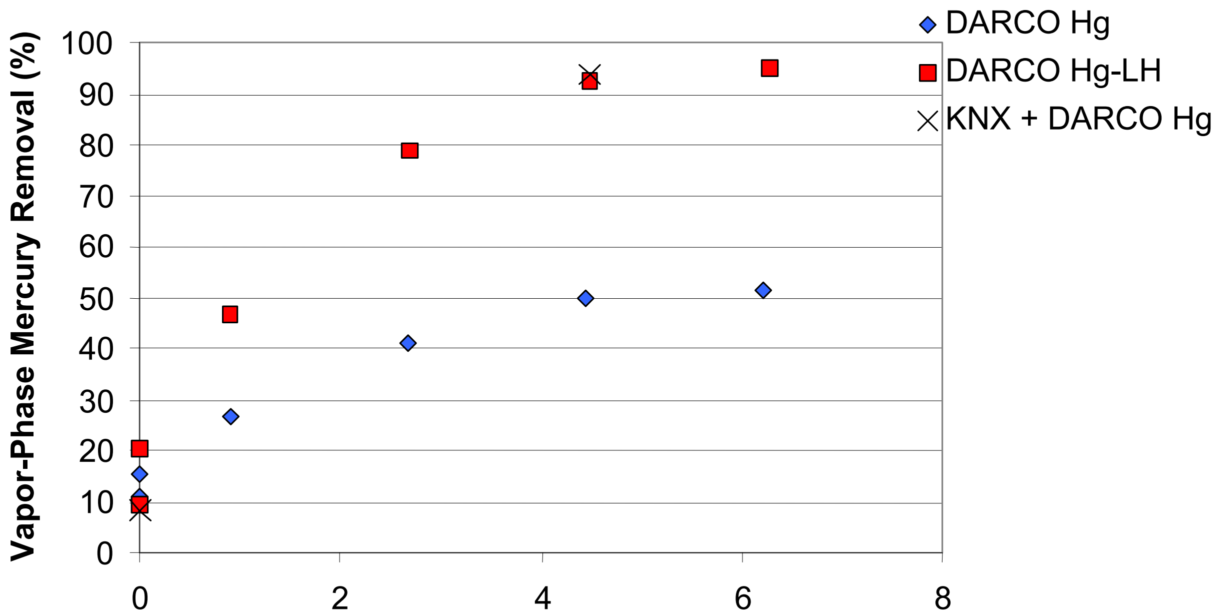

Figure 9. Impact of Coal Additive on DARCO® Hg Performance.

2.3.5 Long-Term Testing

No long-term tests were conducted at Laramie River Station.

<u>Subtask 2.4. Data Analysis</u>

Data collected from Meramec Station, Laramie River Station, and Monroe Power Plant are currently being reviewed.

<u>Subtask 2.5. Coal and Byproduct Evaluation</u>

Hundreds of samples are typically collected from each test site. Most of the ash samples, several coal samples, and at least one of all other sample types will be analyzed for mercury. Additional analyses, including coal ultimate and proximate analyses, and coal and ash chlorine analyses, are being conducted. Results from these tests are being reviewed and will be summarized in the topical report for the site.

CONCLUSIONS

Field-testing has been completed at Holcomb, Meramec, and Laramie River Station. Preliminary results from Laramie River tests were reported in this quarterly report.

Results from Holcomb, Meramec, and Laramie River provide information about options for mercury control at plants firing PRB coals. Options evaluated include coal-blending, introduction of additives onto the coal, and sorbent injection. General conclusions and observations from these tests include:

- Coal Blending
    - Testing at Laramie River Station (SDA + ESP) indicates no significant increase in mercury removal was achieved with two different western bituminous coals at blend ratios up to 80/20 (PRB/bituminous).
    - Up to 80% mercury removal was achieved during short-term testing at Holcomb (SDA + FF) at blend ratios up to 76/14 (PRB/bituminous).
    - Additional tests are required to confirm this result.
    - Blending tests are planned at Monroe (ESP).
- Coal Additives
    - >80% mercury removal was achieved at Holcomb and Laramie River using a combination of DARCO® Hg injection and coal additive.
    - >80% removal was achieved at Meramec without carbon injection (plant configuration and high LOI may have contributed to removal).
- Treated Activated Carbon Injection (DARCO® Hg-LH)
    - High removal (>90%) was achieved at Holcomb and Meramec during the long-term test periods and at Holcomb, Meramec, and Laramie River during parametric testing (no long-term tests were conducted at Laramie River).
    - No adverse balance-of-plant impacts were noted at either site.
    - Treated sorbents will be considered for testing at the remaining test sites.
- Other Balance-of-Plant Concerns
    - SGLP analyses from ash collected during the long-term test periods at Holcomb and Meramec were below the detection limit for mercury. Historical data suggest that no measurable mercury will leach from collected ash.
    - Flue-gas bromine measurements were made at Holcomb and Meramec during long-term testing of DARCO® Hg-LH. No levels of bromine in excess of those expected for plants firing PRB coals were measured.
    - Trace amounts of activated carbon can be detrimental to ash quality for cement use. Options to protect ash for sales include TOXECON™ and TOXECON II™. TOXECON II™ tests are scheduled to begin this fall on a separate DOE contract.

Specific conclusions and observations from testing at Laramie River include:

- Two technologies were demonstrated to enhance the performance of standard activated carbon:
    1. Chemical Addition to the Coal: Mercury removal of 94% was measured at a carbon injection concentration of 4.5 lb/MMacf and a KNX injection rate of 1.6 gph. (KNX is a proprietary chemical developed by ALSTOM Power.)
    2. Chemically Enhanced Sorbent: Mercury removal in excess of 90% was achieved at DARCO® Hg-LH injection concentrations of 4.5 lb/MMacf. (DARCO® Hg-LH is a proprietary product of NORIT Americas.)
- Co-firing PRB and up to 20% western bituminous coals was ineffective at significantly increasing the native mercury capture. Two different western bituminous coals were evaluated. No change in the baseline mercury removal was noted with the first western bituminous coal tested, and the increase in mercury capture was limited to 10% with the second western bituminous coal.
- No measurable increase in stack opacity was observed during parametric testing.
- No change in ESP operating performance was noted as a result of parametric testing.

LIST OF ACRONYMS AND ABBREVIATIONS

ACI	Activated carbon injection
APC	Air pollution control
B&W	Babcock & Wilcox
COC	Chain of Custody
DARCO® Hg	Sorbent manufactured by NORIT Americas. Formerly known as DARCO® FGD
DARCO® Hg-LH	Sorbent manufactured by NORIT Americas. Formerly known as DARCO® FGD-E3
DOE	Department of Energy
ESP	Electrostatic precipitator
FGD	Flue gas desulfurization
ID Fan	Induced draft fan
kacfm	Thousand actual cubic feet per minute
kW	Kilowatt
MW	Megawatt
NETL	National Energy Technology Laboratory
O&M	Operating and Maintenance
PAC	Powdered activated carbon
PC	Pulverized coal
PRB	Powder River Basin
SCA	Specific collection area
SCR	Selective Catalytic Reduction
SCEM	Semi-continuous emission monitor
SDA	Spray dryer absorber
SGLP	Synthetic groundwater leaching procedure
SSD	Sorbent screening device
TCLP	Toxicity characteristic leaching procedure