

EMISSIONS, MONITORING, AND CONTROL OF MERCURY FROM SUBBITUMINOUS COAL-FIRED POWER PLANTS – PHASE II

TOPICAL REPORT

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Task 31

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ABBREVIATIONS

APCD -	Air Pollution Control Devices
CESP -	Cold-side Electrostatic Precipitator
ESP -	Electrostatic precipitator
F -	Normalized gas flow factor, F_c (carbon-based) and F_d (total flue gas)
FF -	Fabric Filter
HAP -	Hazardous Air Pollutants (i.e. Hg)
Hg –	Mercury
Hg⁰	Mercury –Elemental
Hg²⁺	Mercury – Oxidized
Hg^{PB}	Mercury-Particulate
Hg^T	Mercury-Total
MMBtu/hr –	Fuel Use, Millions of British Thermal Units Per Hour
MWe-G –	Megawatts-Gross
MWe-N -	Megawatts-Net
PM –	Particulate Matter
QA/QC -	Quality Assurance/Quality Control
SEC –	Subbituminous Energy Coalition
gr/dscf –	Particulate Concentration, Grains Per Dry Standard (68° F, 1 atm) Cubic Foot
lb/hr –	Mass Emission Rate, Pounds Per Hour
lb/MMBtu –	Mass Emission Rate, Pounds Per Million British Thermal Units
lb/TBtu –	Mass Emission Rate, Pounds Per Trillion British Thermal Units
mg/kg –	Milligrams Per Kilogram
ppb_a -	Parts per Billion, Dry Basis
µg/dscm –	Mercury Concentration, Micrograms per Dry Standard Cubic Meter

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DISCLAIMER

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EXECUTIVE SUMMARY

Western Research Institute (WRI), in conjunction with Western Farmers Electric Cooperative (WFEC), has teamed with Clean Air Engineering of Pittsburgh PA to conduct a mercury monitoring program at the WEFC Hugo plant in Oklahoma. Sponsored by US Department of Energy Cooperative Agreement DE-FC-26-98FT40323, the program included the following members of the Subbituminous Energy Coalition (SEC) as co-sponsors.

- Missouri Basin Power Project
- DTE Energy
- Entergy
- Grand River Dam Authority
- Nebraska Public Power District

This research effort had five objectives: (1) determine the mass balance of mercury for subbituminous coal-fired power plant; (2) assess the distribution of mercury species in the flue gas (3) perform a comparison of three different Hg test methods; (4) investigate the long-term (six months) mercury variability at a subbituminous coal-fired power plant; and (5) assess operation and maintenance of the Method 324 and Horiba CEMS utilizing plant personnel.

Mercury Mass Balance

Mercury testing and analysis was performed on process samples, (coal, coal pyrite rejects, fly ash, and bottom ash), as well as the flue gas at the facility's boiler exhaust stack and electrostatic precipitator (ESP) inlet (1 of 4 inlets) over the two day period of July 6 and 7, 2005. Flue gas sampling was performed using co-located, Ontario-Hydro or OH, (ASTM D6784-02) test trains at the facilities boiler exhaust stack as well as paired OH trains at one of the four inlets to the ESP. Hg concentrations and other flue gas characteristics were assumed the same for each ESP inlet. Three 2-hour Ontario-Hydro test runs were performed at each test location while process samples were collected. The three 2-hour Ontario-Hydro test runs indicated 93.8% total mercury closure across the ESP and 95.6% overall mass balance closure.

Mercury Species Distribution

Mercury speciation testing of showed 89.5% elemental Hg, 8.0% oxidized Hg and 2.5% particulate bound Hg at the inlet of the ESP and 75.7% elemental Hg, and 23.3% oxidized Hg at the stack. The Hg speciation results across the ESP can be seen in Figure 3.4.5. As expected, nearly all of the Hg^{PB} is removed across the ESP. Since Hg^{PB} constitutes only a minor fraction of the Hg^T present in the flue gas, there is little removal of Hg^T across the ESP. Also evident is the oxidation of some of the Hg⁰ to Hg²⁺.

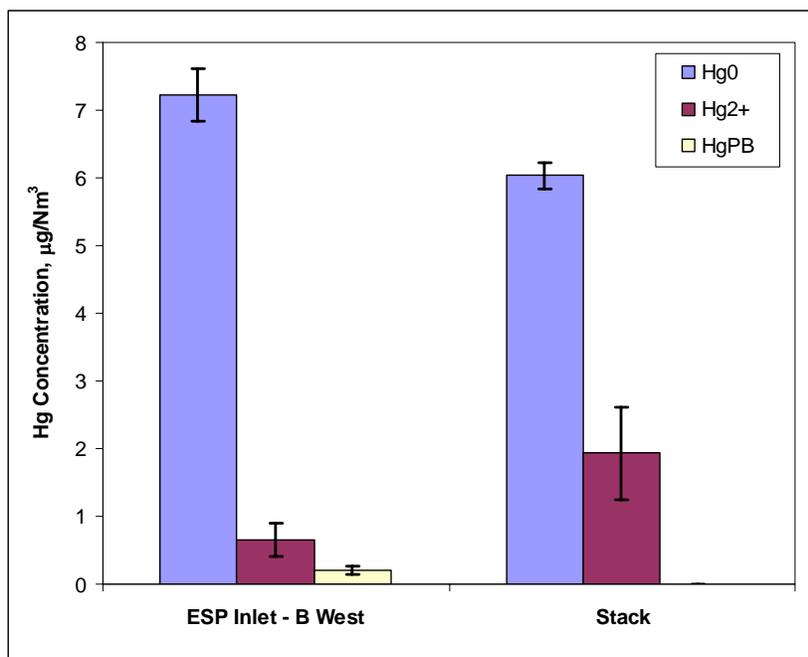


Figure ES-1. Hg speciation results.

Inter-Methods Comparison

Three different mercury test methods were concurrently performed and compared;

- Mercury continuous emissions monitoring system (Hg-CEMS);
- Former dry sorbent-tube based USEPA Method 324;
- Ontario Hydro (OH) test method (ASTM D6784-02).

In order to compare the results of different methods of measuring Hg concentrations in the flue gas, nine consecutive co-located Ontario-Hydro runs and Method 324 runs (with co-located sorbent traps) were performed simultaneously at the stack, while corresponding Horiba DM-6 mercury continuous emissions monitoring system using a vapor phase mercury monitor was used to monitor the Hg emissions in the flue gas at Hugo's exhaust stack. Testing was performed over the period of June 29-30 and July 6-7, 2005. The following results were established.

- All paired Ontario-Hydro sampling method test runs passed the minimum performance criteria for paired RM tests according to Performance Specification 12A (RD less than 10% for total gaseous Hg concentrations greater than $1.0 \mu\text{g}/\text{m}^3$). Particulate-bound Hg was negligible (non-detected).

- All Method 324 data pairs had a relative deviation (RD) of less than 5%. A field spike was recovered to 90% (80-120% limit).
- The relative accuracy (RA) of Method 324 with respect to Ontario-Hydro as reference method result was 10.4% (20.00% limit) with an absolute difference of $0.46\mu\text{g}/\text{m}^3$ (limit of $1\mu\text{g}/\text{m}^3$). As such, the Method 324 data passed the RATA.
- During the first week of testing, (June 29 and 30), the Horiba DM-6 Hg CEMS used at the stack provided data comparable to those obtained using the Ontario-Hydro and sorbent-based sampling method (10-22% lower with Run 2 not included).
- The relative accuracy of the Horiba DM-6-6 CEMS data showed a relative accuracy of 64.8% (limit of 20%) relative to the OH as the reference method and an absolute difference of $2.98\mu\text{g}/\text{m}^3$ (limit of $1\mu\text{g}/\text{m}^3$). As such, the Horiba DM-6 data does not pass the RATA.

Additional method comparisons continued over the first two months of the program using both Method 324 sorbent tubes and the Horiba Hg-CEMS. The sorbent tubes continued with weekly switch out of sorbent tubes. The mercury content of the coal, fly ash and bottom ash was also monitored over this period.

Long-Term Monitoring Operations and Maintenance

Plant personnel were trained on site on the use, care and maintenance of the sorbent tube sampling equipment and Hg-CEMS. The Horiba DM-6 Hg-CEMS and Method 324 sorbent tubes were maintained by plant personnel over a six month period.

There were several Method 324 auto sampler hardware and software, as well as sorbent trap recovery issues during the program. As a result, only one sorbent trap of each pair could be recovered successfully for the first five weeks. Nevertheless, after working through most of the issues that plagued the sorbent trap monitoring system for the first five weeks of the program, the operation and maintenance of the Method 324 sorbent traps when sampling sorbent traps on a weekly basis, required approximately 1-3 hours per week.

Maintenance of the Hg-CEMS included weekly calibration checks as well as daily inspections to ensure continued sampling. The six-month period covered emissions from June 24, 2005 until December 20, 2005. This included calibration checks and routine catalyst and filter replacements. The following Horiba DM-6 CEMS maintenance issues were observed.

- **Buildup of fly ash / particulate matter in the probe and filter.** The stack platform geometry required the use of a rather long (10 feet) probe with large internal diameter of the probe stinger. It is conceivable that particulate buildup along the stinger wall as well

as in the particulate filter adsorbed mercury contained in the flue gas causing a consistently low bias of the Horiba CEM readings.

- **Catalyst deactivation.** The catalyst used to convert all oxidized forms of mercury to their elemental state underwent a rather rapid deactivation with an average life expectancy of approximately 2-3 weeks per catalyst. As a result, the CEM mercury readings dropped slowly over the course of 2-3 weeks subsequent to its installation.
- **Cold spots / condensation in the probe.** Condensation was observed in several parts of the probe, in particular in the initially unheated / not-insulated calibration tee coupling. This became of particular concern during the colder months of the monitoring part of the project and may have resulted in the scrubbing of mercury from the sample gas stream.
- **Freezing of condensate in probe.** On several occasions during the colder months of the year the condensate originating from the Peltier cooler removing moisture from the sample gas froze in the cooler. This led to blockage of the sampling path and eventually to an automatic suspension of the sampling activity via the Horiba CEM controller.

In summary, although mercury emissions monitoring techniques are progressing to be able to meet the regulatory needs of the promulgated CAMR rules, there is room for improvement of Hg CEMS both in performance and in maintenance and operation by plant personnel.

1.0 INTRODUCTION

1.1. Background

The results of the 1990 Clean Air Act Amendments and the Environmental Protection Agency's (EPA) review of hazardous air pollutants has prompted development of technologies to remove mercury from coal or to capture mercury from the flue gases of coal-fired utilities. Wyoming's Powder River Basin (PRB) subbituminous coal resources are unique in their emissions characteristics, requiring special control and monitoring technologies. The Subbituminous Energy Coalition (SEC) identified the need (1) to re-test stack gas emissions from power plants that burn subbituminous coal relative to compliance with the EPA-proposed mercury control regulations for coal-fired plants, and (2) for specialized monitoring requirements associated with mercury continuous emissions monitors (CEM).

The overall objectives of the program were to develop and demonstrate solutions for the unique emission characteristics found when burning subbituminous coals. The program was to be executed in three phases: Phase I of the project covered mercury emission source sampling programs at ten (10) subbituminous coal-fired plants. Phase II compared the performance of continuous emission monitoring programs for mercury at subbituminous coal-fired power plants.

Western Research Institute (WRI) and Western Farmers Electric Cooperative and other SEC members have partnered with Clean Air Engineering to conduct a testing program that addresses the Phase II objectives. Phase II of the program, described herein, focused on obtaining a mass balance of mercury (Hg) both total and speciated mercury across the Western Farmers Electric Cooperative (WFEC) Hugo Station subbituminous coal-fired power plant, a comparison of Hg source sampling methods, investigation into the variability of Hg emissions, and the long-term performance of continuous emission monitoring strategies for mercury.

1.2 Objectives

Phase II of the program focused on the following objectives:

- Perform a total mercury (Hg) mass balance around the WFEC Generating Station,
- Investigate the distribution of Hg species across the air pollution control device (APCD) and at the stack,
- Compare Hg source sampling methods including RATA testing of Method 324 and Horiba DM-6 continuous emission monitoring system (CEMS),
- Assess long-term mercury variability at Hugo Generating Station, and
- Document the long-term operations and maintenance of Method 324 sorbent traps and the Horiba DM-6 Hg CEMS.

Long-term performance verification of Hg emissions monitoring was of direct interest to the sponsoring SEC members.

2.0 SITE DESCRIPTION AND METHODOLOGY

2.1 Site Description

Western Farmers Electric Cooperative (WFEC) produces power at the Hugo Generating Station located in Fort Towson, Oklahoma. The plant, Figure 2.1.1, is a base-loaded, front and rear fired unit (Unit 1) with a generating capacity of 450MW. The Hugo Station employs cold-side ESP for particulate control



Figure 2.1.1 Photograph of the WFEC Hugo Generating Station located near Hugo, Oklahoma.

Photographs of the stack and the ESPs are shown in Figure 2.1.2. A generalized process schematic of the Hugo Station is shown in side-view and layout-view in Figures 2.1.3 and 2.1.4.

Fly ash collected in the ESP hoppers is transported into storage silos and sold as concrete admixture. From the boiler, the flue gas ductwork splits into four smaller ducts which lead to parallel electrostatic precipitators (ESP).



Figure 2.1.2 Process Schematic and photograph of the Hugo plant layout

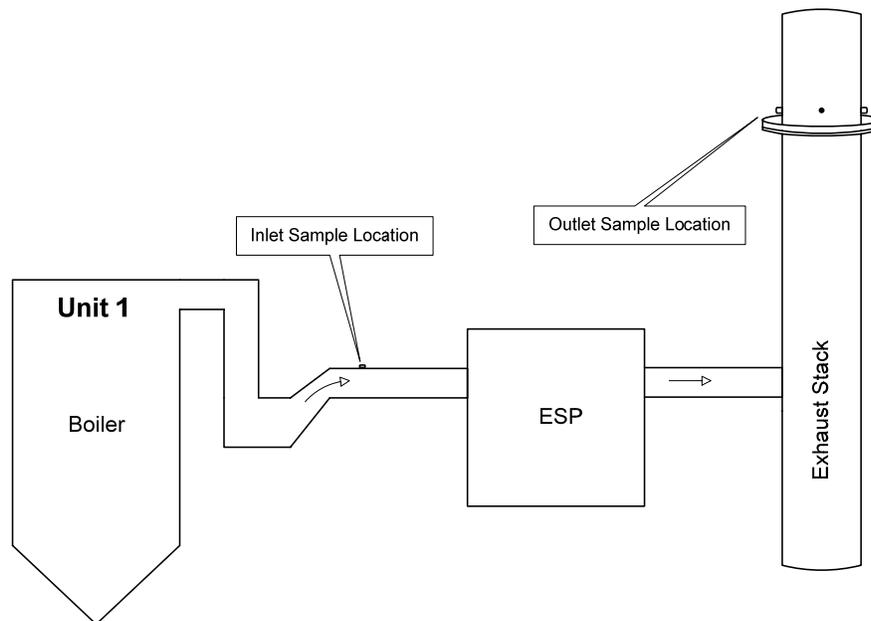


Figure 2.1.3 Schematic of plant configuration, side view.

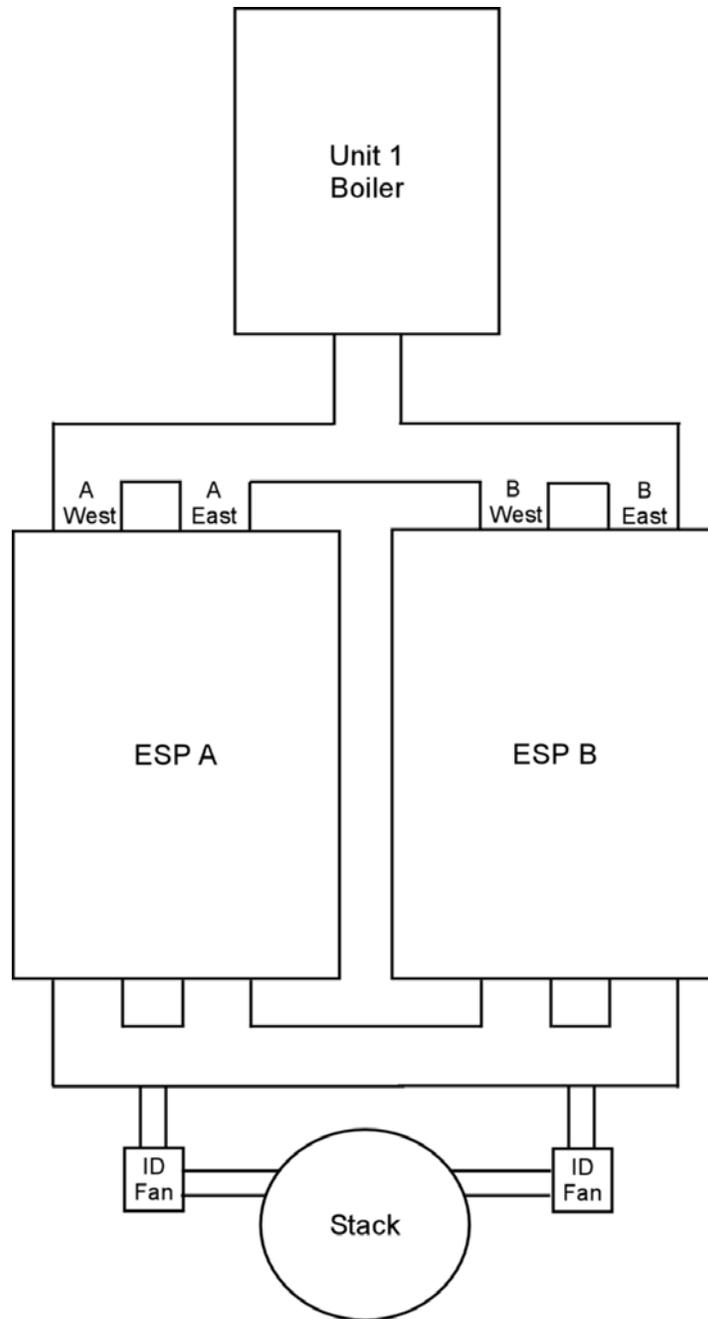


Figure 2.1.4 Schematic of the Hugo site, plan view.

The flue gas entering the ESPs each feeds a row of eight hoppers. From the ESPs, flue gas is pulled through two (2) induced draft fans and routed to the flue gas exhaust stack. The flue gas exhausts through an approximately 450 feet high stack that is 28.3 feet in diameter, equipped with an EPA testing platform that is located approximately 360 feet above ground level and which is accessible via an elevator.

The plant burns approximately 250 tons per hour of pulverized subbituminous low-sulfur coal originating from two mines in the Powder River Basin area near Gillette, Wyoming. The two coals have remarkably similar compositional characteristics as shown in Table 2.1.1.

Table 2.1.1 Summary of the coal analyses for Hugo’s two subbituminous coal sources.

	Mine A (Buckskin)	Mine B (Eagle Butte)
Proximate (wt.%)		
Moisture	30.01	30.75
Ash	4.77	4.67
Fixed Carbon	34.81	34.40
Volatile Matter	30.41	30.18
Ultimate Analysis (wt. %)		
C	49.25	49.18
H	3.19	3.07
N	0.64	0.60
Sulfur	0.33	0.21
Heating Value (Btu/lb, dry)	8405	???
Forms of Sulfur (wt. %)		
Sulfate	0.00	0.00
Organic	0.24	0.21
Pyritic	0.09	0.00
Mercury (ppm, dry)	0.068	0.070

2.2 Description of Sampling Locations

WRI and Clean Air Engineering of Pittsburgh, PA, installed a dry thermo-catalytic Horiba-NIC Model DM-6 Hg^T CEMS at the stack sampling location. A sorbent trap-based monitoring system was also installed at the sampling location. All inlet source sampling reported in this document was performed on one of the four ESP inlets. The inlet duct labeled ‘B-West’ was chosen for sampling as it was the most representative sampling location for flue gas constituents. All flue gas exhaust outlet sampling occurred at the stack sampling platform.

Traverse point 1 involved a port to point distance (in.) 109.77 inches; traverse point 2 involved a port to point distance of 65.82 inches, traverse point 3 involved a 35.56 inches and Travers point 4 involved a port to point distance of 10.97 inches. Duct diameters upstream from the flow disturbance (A) were 8.0 with a limit of 0.5; and duct disturbance downstream from the flow disturbance (B) was 8 with a limit of 2.0. A diagram of sampling points is shown in Figure 2.2.1 below.

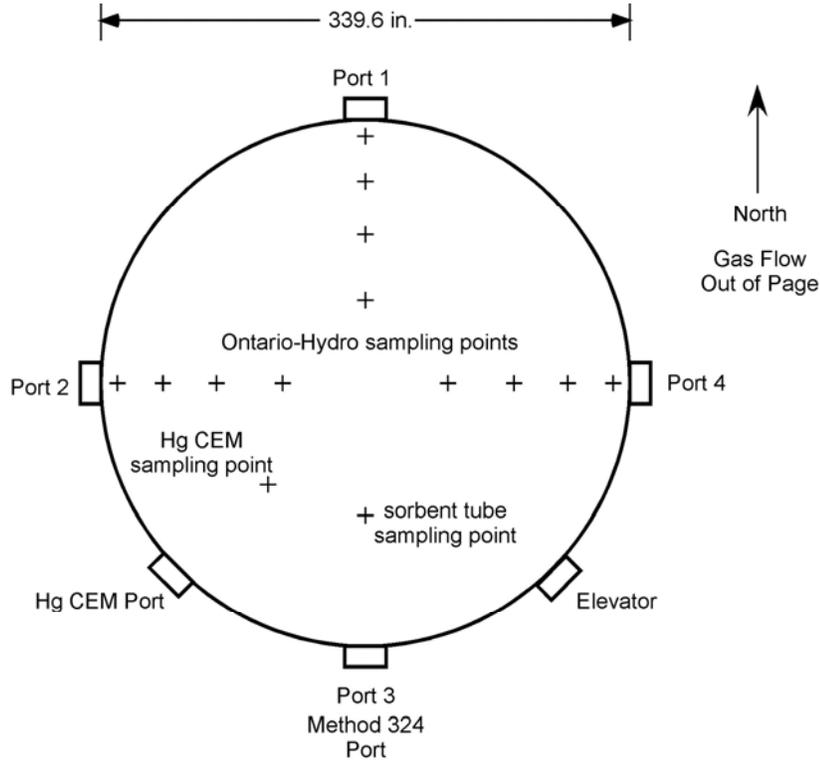


Figure 2.2.1 Diagram of emissions source sampling traverse points at exhaust stack.

Ontario Hydro testing at the ESP inlet B-West duct and stack were performed using paired trains. These trains were labeled A & B. Run 1A and 1B were voided due to a plant trip at the half-way point of the test run. The labeling of the stack test runs, 7 through 9, although different from the ESP inlet run numbering were indeed sampled simultaneously to the ESP inlet test runs. The stack test runs were part of the Hg test methods and monitoring inter-comparison in addition to Hg mass balance testing.

Sample points at the exhaust stack platform location conformed to EPA Method 1. The sorbent tube sampling point and Hg-CEMS sampling point at the stack sampling location were in accordance with the guidelines of EPA Performance Specification 12-A. All sampling at the ESP inlet location was also in accordance with EPA Method 1 as seen in Figure 2.2.2.

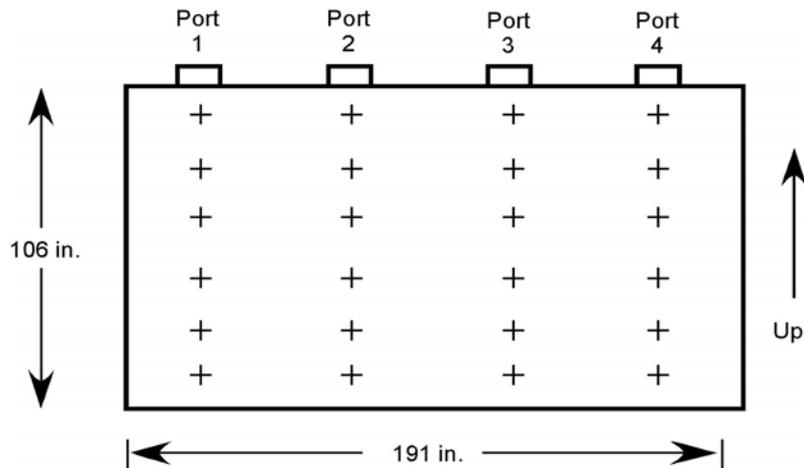


Figure 2.2.2 Diagram of emissions source sampling traverse points at the ESP inlet

Traverse point 1 involved a port to point distance (in.) 109.77 inches; traverse point 2 involved a port to point distance of 65.82 inches, traverse point 3 involved a 35.56 inches and traverse point 4 involved a port to point distance of 10.97 inches. Duct diameters upstream from the flow disturbance (A) were 8.0 with a limit of 0.5; and duct disturbance downstream from the flow disturbance (B) was 8 with a limit of 2.0. A diagram of sampling points is shown in Figure 2.2.2 above.

2.3 Mercury Measurement and Monitoring Methods

Three methods were used in the study to determine the mercury concentration in the flue gases at Hugo. These methods were installed at the ESP inlet B West duct as described earlier. These methods were ASTM 6784-02 (Ontario Hydro) that measures both total gaseous Hg emissions, as well as species of mercury; EPA Method 324 (carbon tube) that measures total gaseous mercury; and dry thermo-catalytic CEM (Horiba NIC DM 6) which also measures the total gaseous mercury.

2.3.1 Ontario-Hydro Mercury Speciation Method

Ontario Hydro method is a standard test method for speciated mercury measurement. The method measures particulate-bound mercury (HgP), elemental (Hg0), and oxidized forms (Hg2+). The Ontario Hydro provides good results with a level of sensitivity of $<0.5\text{mg/m}^3$. The measurements range from 0.5 to 100mg/m^3 . The Ontario Hydro method measurements are typically time integrated between 2-3 hours. The isokinetic gas sample volume ranges between 1000L to 2500L. The collected solutions from the impingers are analyzed off-site at a laboratory using cold-vapor atomic absorption spectroscopy (CVAAS) or cold-vapor atomic fluorescence spectroscopy (CVAFS). A schematic of the OH testing setup is shown in Figure 2.3.1.1.

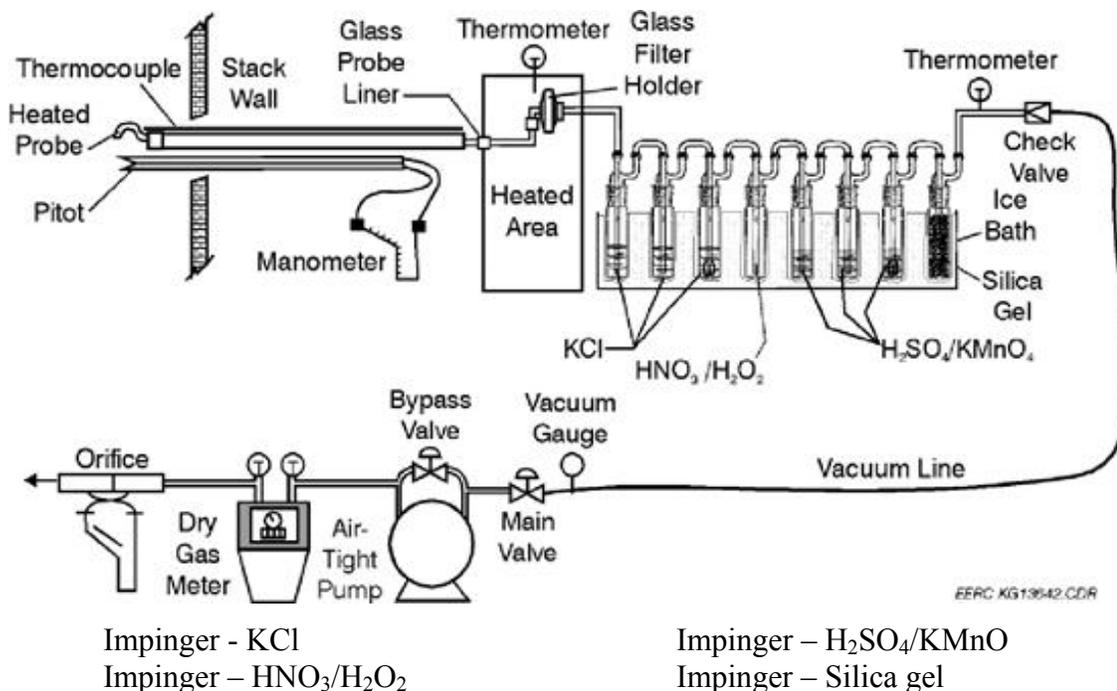


Figure 2.3.1.1 Schematic of the Ontario Hydro testing apparatus

Table 2.3.1.1 summarizes the type of standard sampling and analytical methods used during sample collection. A single contractor (Clean Air Engineering of Pittsburgh, PA) and a single analytical laboratory were used for the emission testing and analysis. This procedure reduced the inter-laboratory and contractor-related data variability. Both companies have extensive experience plant emission source sampling and mercury analyses. Samples and data were collected as per established procedures by the ASTM and the EPA. Table 2.3.1.2 shows the sample or data collected and the procedure used to obtain and/or analyze the same.

Table 2.3.1.1 Sampling Methods and Analytical Procedures

Parameter	Sampling Method	Analytical Method	Laboratory
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	Clean Air Engineering On-Site
O_2 / CO_2	Method 3	wet chemical -Orsat instrument	
Moisture (H_2O)	Method 4	gravimetric	
Particulate Matter	Method 5 (Outlet) or 17 (Inlet)	gravimetric	Clean Air Engineering Pittsburgh, PA
Speciated Mercury	Ontario Hydro Method	Cold Vapor Atomic Absorption (CVAAS)	Element One

OH testing was tested in accordance with the following USEPA and ASTM source emissions test methods. Methods 1 through 4, 5 and 17 are referenced in 40 CFR Part 60, Appendix A. The Ontario Hydro Method is a Preliminary Draft Test Method (designated as PRE 3) and may be found at www.epa.gov/ttn/emc/prelim.html.

Table 2.3.1.2 Summary of the Source Sampling Procedures

Method 1	Sample and Velocity Traverses for Stationary Sources
Method 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (S-Type Pitot Tube)
Method 3	Gas Analysis for the Determination of Dry Molecular Weight
Method 4	Determination of Moisture Content in Stack Gases
Method 5	Determination of Particulate Emissions from Stationary Sources
Method 17	Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration)
PRE 3	Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario-Hydro Method)

Gas flow rate, particulate matter (PM), and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 (the Ontario Hydro Method).

Each sampling period consisted of conducting a temperature and differential pressure traverse of the duct with a K-type thermocouple and an S-type pitot tube. Concurrently, a gas sample was extracted at an isokinetic flow rate for a 120-minute period. At the inlet, the gas sample passed through an in-stack Teflon-coated nozzle and filter holder assembly, through a heated Teflon probe liner and through a series of eight impingers. At the outlet, the gas sample passed through a heated Teflon-coated nozzle, through a heated Teflon probe and a heated filter, and through a series of eight impingers. Integrated gas samples were collected in Tedlar bags during each run for diluent (O₂ and CO₂) analysis using a Fyrite instrument. Additionally, carbon dioxide (CO₂) values taken from the plant CEMS (Continuous Emissions Monitoring System) data were used for Method 19 calculations.

Prior to sampling, the first three impingers were each seeded with 100 milliliters (ml) of potassium chloride (KCl). The fourth impinger was seeded with nitric peroxide (HNO₃/H₂O₂). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate (KMnO₄). The eighth impinger was seeded with approximately 250 grams of dried silica gel.

Following sampling, the moisture gain in the impingers was measured gravimetrically to determine the moisture content of the stack gas. The filters and a series of acetone rinses of the nozzle and sampling hardware upstream of the filters were quantitatively recovered for gravimetric analysis to determine the particulate matter (PM) and particulate Hg content of the

gas streams. The impinger contents were recovered according to the procedures provided in the Ontario Hydro Method to determine the oxidized and elemental Hg content of the gas streams.

The above data were combined to calculate the gas velocity and volumetric flow rate in units of feet per second (ft/sec), actual cubic feet per minute (acfm), dry standard cubic feet per minute (dscfm), and pounds per hour (lb/hr). The PM levels were calculated in units of grains per dry standard cubic foot (gr/dscf), pounds per million British thermal units (lb/MMBtu), and lb/hr. Each Hg fraction (particulate bound, oxidized, elemental and total) was calculated in units of micrograms per dry standard cubic meter ($\mu\text{g/dscm}$), trillion British thermal units (lb/TBtu), and lb/hr.

Photographs of the equipment used for the paired train at the stack are shown in Figures 2.3.1.2 and 2.3.1.3.



Figure 2.3.1.2 Photographs of the Ontario-Hydro probe at the stack



Figure 2.3.1.3 Photographs of the Ontario-Hydro rotameters and impingers at the stack

In addition, a paired train for the OH analysis was also installed and tested at the ESP inlet. A sampling rig was installed (see Figure 2.3.1.4) for testing at that location.



Figure 2.3.1.4 Photographs of installation of equipment and probes at the ESP inlet

2.3.2 Method 324 Mercury Monitoring

Method 324 measures gaseous mercury in low-dust applications. Gaseous mercury is trapped on iodine impregnated activated carbon traps and is then analyzed off-site by cold vapor atomic fluorescence spectrometry (CVAFS). The duration of sampling on a single trap is 30 minutes to 10 days. As such, it does not provide actual continuous analysis of the mercury in the flue gas, but rather an average of mercury in the flue gas over the sampling interval.

An automated sorbent trap-sampling system was installed to perform the sorbent trap monitoring. The sorbent trap monitoring was conducted in accordance with the now withdrawn previously proposed US EPA Method 324 (Determination of Vapor Phase Flue Gas Mercury Emissions from Stationary Sources Using Dry Sorbent Trap Sampling).

The complete system consisted of two independent gas sampling trains (designated A and B in this report) is illustrated in Figure 2.3.2.1. Each sampling train included an auto-sampler, a moisture removal system and a heated sample line. The only exception to this was a single probe accommodating both sorbent traps at a distance of approximately 1-inch. As a result, two samples were collected simultaneously from the same general spatial point in the flue gas stream. The insertion depth of the sampling probe into the stack was approximately 36 inches. The probe was not heated as the average temperature of the stack was well above 300 °F.

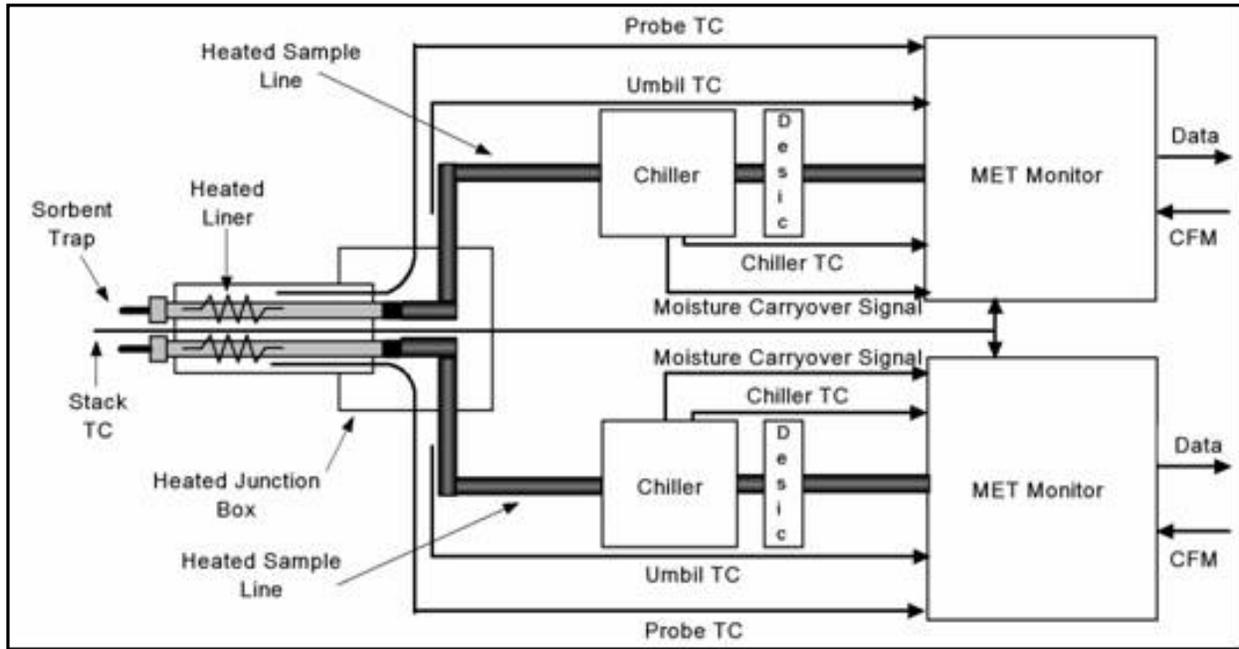


Figure 2.3.2.1 Sorbent trap sampling train schematic

The system (excluding the probe) was housed in a shelter at the main stack sampling platform (Figure 2.3.2.2).



Figure 2.3.2.2 Sampling system used at WFEH Hugo plant

Photographs of the details of the probe ends of the Method 324 equipment used in the Hugo testing is presented in Figure 2.3.2.4. and photographs of the installation of Method 324 equipment at the stack (Figure 2.3.2.5).

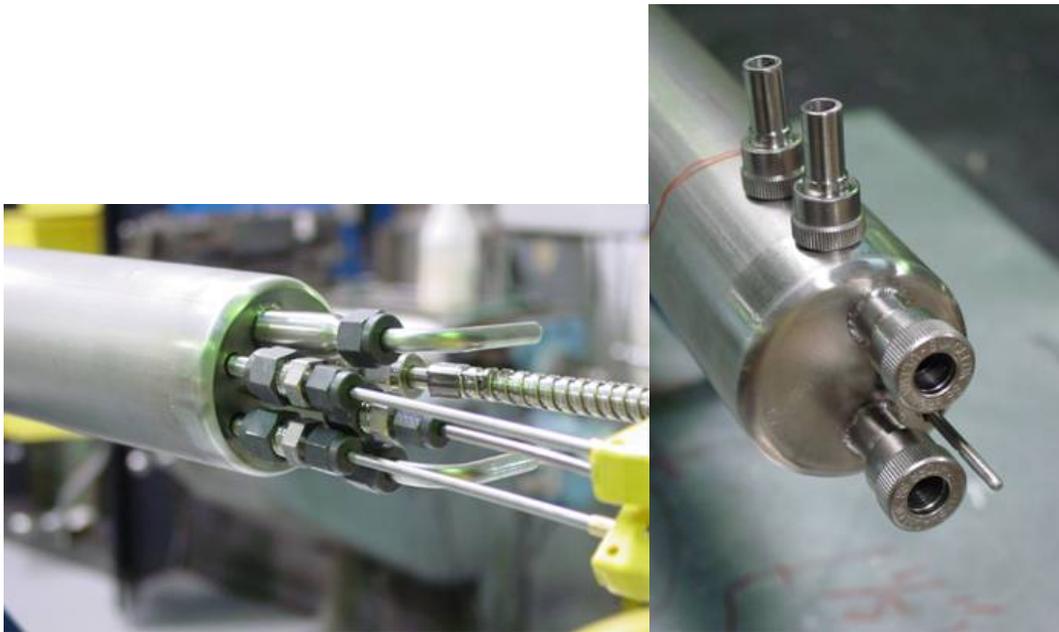


Figure 2.3.2.4 Photographs of the probe connections for the Method 324 equipment



Figure 2.3.2.5 Photographs of the Method 324 equipment and penetration at the stack

Data was continuously acquired and stored by both auto-samplers in 10-minute intervals and included:

- Stack temperature
- Sample vacuum pressure
- Probe temperature
- Barometric pressure
- Heated umbilical temperature
- Sample volume
- Sample flow rate
- Sample temperature
- Stack flow rate surrogate (4 – 20mA)

The moisture removal system used for this program consisted of a compressor-type gas conditioner in addition to a desiccant container downstream of the conditioner constituting the final stage of the moisture removal system.

Sorbent traps used for this study consisted of two equal-mass sections of iodinated activated carbon separated by a quartz-wool plug and were in accordance with US EPA Method 324 (67 FR 4467) (Figures 2.3.2.3a and b). The first section denoted the main section is exposed

to the flue gas sample, while the second section represents the backup or breakthrough section. All sorbent traps used in this study were obtained from Frontier Geosciences, Inc.



Figure 2.3.2.3a Photographs of the sorbent traps used in the study



Figure 2.3.2.3b Photographs of the sorbent traps used in the study

For sample quality control, Method 324 Section 9.0 required that the mercury mass loading of each breakthrough section did not exceed 2% of the mercury mass loaded onto the main section, in order for the sample to be considered valid. In addition to these QC criteria, the Method 324 (Table 324-2 Section 9.0) required that a known mass of gaseous, elemental mercury be spiked onto the first section of each third sorbent trap, constituting a field spike that was to be recovered in the laboratory to 80 – 120%. In the course of the monitoring part of this project, one sorbent trap was sampled and retrieved containing a spike on the first section being equal to three to four times the anticipated mercury loading of a regular sorbent trap. This spiked amount was suggested by Frontier Geosciences.

The analyses of each sorbent trap followed Method 324 protocol and employed acid digestion and cold vapor atomic fluorescence spectroscopy (CVAFS). All materials associated with each trap section were combined and analyzed together, i.e., any supporting substrate that the sample gas passed through prior to entering a media section (e.g., glass wool, etc.) was analyzed with that segment.

As specified in Section 8.2.4 of Method 324, the gas sampling was intended to be performed at a sampling rate that was proportional to the stack flow rate using an analog signal from the plant flow monitor. After an unexpected break down of the stack flow surrogate (4-20mA signal) supplied to the sorbent-trap sampling system, this approach was abandoned in favor of constant-flow sampling consistent with Section 8.2.3 of Method 324. The sample flow rate was set to approximate 0.4Lpm.

Initially, sorbent trap exchanges were scheduled to be performed on a weekly basis. However, due to unexpected sampling system problems and depending on plant personnel schedule, sampling duration ranged from 2 to 7 days.

2.3.3 Horiba DM-6 Mercury CEMS

The third mercury measurement and monitoring method is the dry thermo-catalytic continuous emission monitor (CEM) via the Horiba NIC DM 6. The Horiba Hg CEM measures the total gaseous mercury on a real-time basis. The method consists of pre-treatment unit (dry thermo-catalytic converter) and elemental mercury detector (CVAA). The pre-treatment probe is located at the stack. The detection unit with data acquisition system was located in the Hg CEM trailer. The two are connected via a heated sample line. The probe is powered via a detector unit and there is a separate data acquisition system. A schematic of the Horiba DM-6 CEMS is shown in Figure 2.3.3.1.

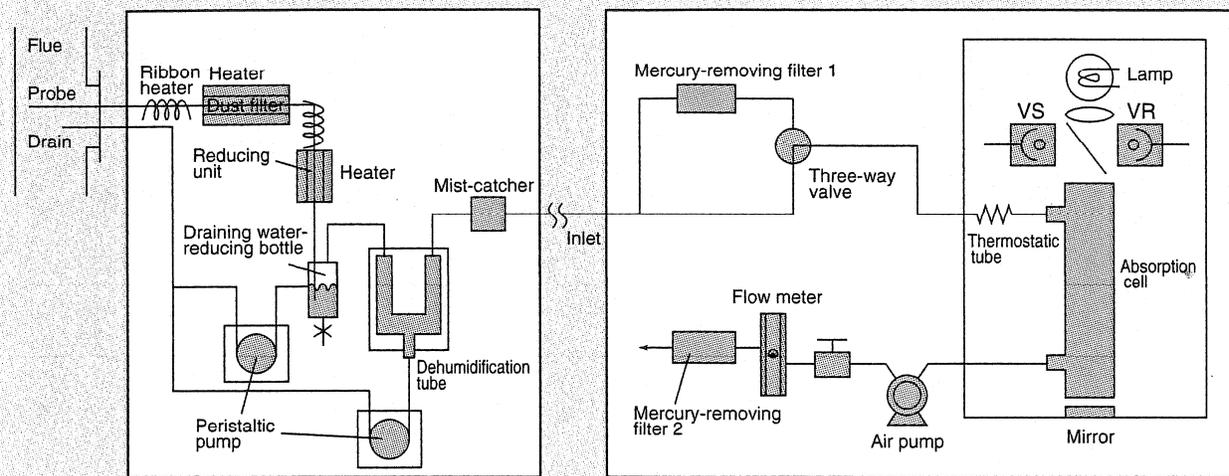


Figure 2.3.3.1 Schematic of the Horiba Hg CEM system

The Horiba's DM-6 detector is a cold-vapor atomic absorption (CVAA) instrument that is limited to measuring elemental mercury (Hg^0) only. Therefore, in order to determine the total gaseous Hg content in the flue gas, all ionic Hg forms (e.g., mercuric chloride) must be converted to the elemental state and the sample gas conditioned before being introduced into the detector. This is achieved through the instrument's pre-treatment system via a solid reducing catalyst followed by a liquid separator tube as well as thermo-electric cooling unit. The pre-

treatment system of the Horiba DM-6 was connected directly to the probe and installed at the stack testing platform (Figure 2.3.3.2).

Due to the peculiarities of the stack location, the mercury CEM probe was used in conjunction with a 10-foot heated Teflon stinger in order to penetrate the stack annulus and reach the flue gas. This Teflon stinger was extended into the flue gas by approximately 36 inches (Figure 2.3.3.3).



Figure 2.3.3.2 Hg-CEM system installation at stack test platform



Figure 2.3.3.3 Hg-CEM system penetration into the stack

The pre-treatment system was connected to the detector via a 450-ft sample line, which was heated to approximately 250 °F. Before entering the detector, the sample gas was passed through a 1N KOH solution for SO₂ removal, as SO₂ constitutes an interferant for the detection of gaseous elemental Hg via CVAAS (Figure 2.3.3.4).



Figure 2.3.3.4 Hg CEM flue gas conditioning unit

The detector was located in an environmentally-controlled trailer. All data acquisition was facilitated via a data logger (ESC Model 8816), which was connected to a laptop PC for

remote monitoring and frequent data back up. The setup of the CEM detector unit can be seen in Figure 2.3.3.5 and 2.3.3.6.

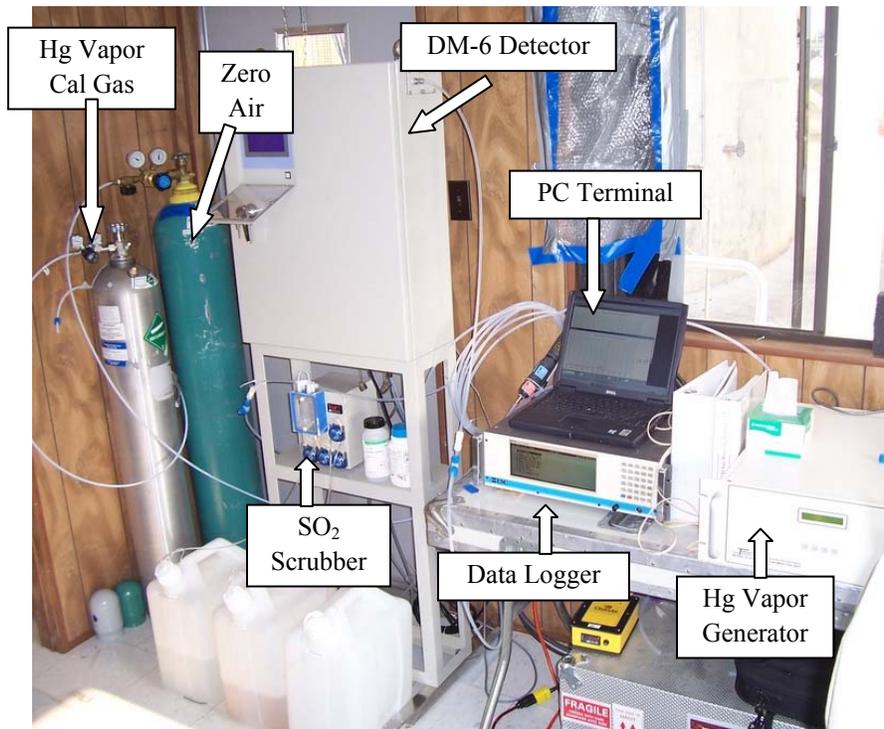


Figure 2.3.3.5 Hg-CEM detector and data acquisition system setup

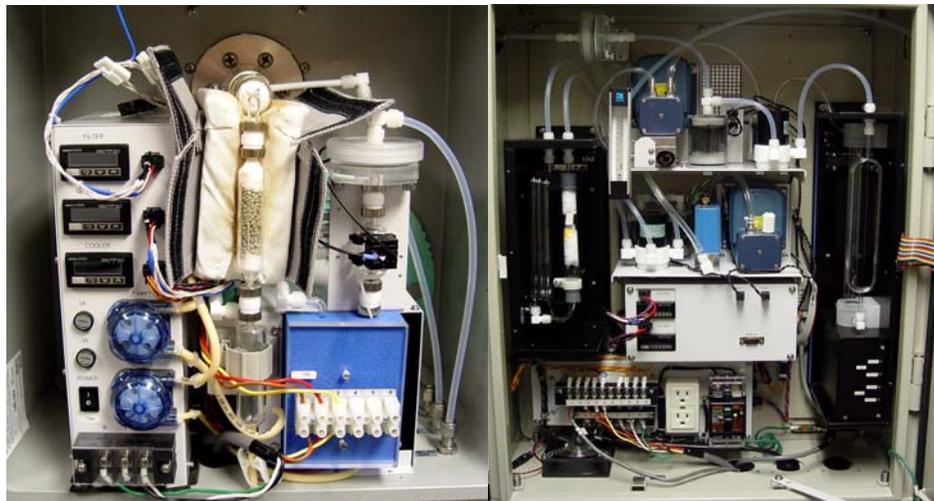


Figure 2.3.3.6 Photograph of the internals of the Horiba DM 6 unit

The mercury CEMS was initially calibrated using Tekran's Series 3310 mercury calibration unit. However, for subsequent span calibrations during the extended monitoring period, the mercury CEMS calibration was performed once a week by plant personnel using certified gas cylinders from Spectra Gases containing 5.5 g/Nm³ (±10%) of elemental mercury in a balance of nitrogen in conjunction with an all Teflon valve and rotameter.

2.4 Sampling Methods

2.4.1 Solids Sampling and Analyses

Daily fuel and ash sampling with weekly composite analysis were conducted concurrently with the Hg sampling. Coal from the plant's auto-sampler was used for coal analysis. The coal analyses included ultimate and proximate analyses, in addition to heating value forms of sulfur and mercury. The analytical methods for analysis of coal samples are presented in Table 2.4.1.1.

Fly ash was collected from the sampling ports in the conveyance piping from the ESP hoppers. During 07/06 - 07/07/2005, fly ash samples from the corresponding ESP hoppers were collected in the middle of each Ontario-Hydro method sampling run. For the remainder of the project, fly ash samples were targeted to be collected daily and analyzed as a weekly composite. The ash samples were tested according to ASTM D6721 in Table 2.4.1.1.

As for the bottom ash, sampling was taken from the ash sluicing hopper prior to conveyance during the actual mass balance testing. The coal pulverizer pyrite rejects were also sampled during initial testing.

Table 2.4.1.1 ASTM Methods Used for Coal Analyses

<u>Proximate Analysis</u>	ASTM D3180
Moisture	ASTM D3302
Ash	ASTM D3174
Fixed Carbon	ASTM D5142
Volatile Matter	ASTM D5142
<u>Ultimate Analysis (CHNS)</u>	ASTM D5373
<u>Heating Value</u>	ASTM D5865
<u>Forms of Sulfur</u>	ASTM D2492
<u>Mercury</u>	ASTM D6721
<u>Chlorine</u>	ASTM D2361

2.4.2 Emission Source Sampling and Analysis

During all emission source sampling, the procedures as detailed in U.S. EPA *Title 40, Code of Federal Regulations, Appendix A, Methods 1- 5 and 17, PS-12A, former Method 324, and ASTM D6784-02* were used. Table 2.4.2.1 summarizes the methods and their respective sources.

Table 2.4.2.1 Summary of source sampling methods and procedures at Hugo

Summary of Sampling Procedures	
Method 1	Sample and Velocity Traverses for Stationary Sources
Method 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (S-Type Pitot Tube)
Method 3	Gas Analysis for the Determination of Dry Molecular Weight
Method 4	Determination of Moisture Content in Stack Gases
Method 5	Determination of Particulate Emissions from Stationary Sources
Method 17	Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration) <i>Title 40 Code of Federal Regulations Part 60 Appendix A Test Methods</i>
PS-12A	Specifications and Test Procedures for Total Vapor Phase Mercury Continuous Emissions Monitoring Systems in Stationary Sources <i>Title 40 Code of Federal Regulations Part 60 Appendix B Performance Specifications (PS)</i>
Method 324	Determination of Vapor Phase Flue Gas Mercury Emissions from Stationary Sources Using Dry Sorbent Trap Sampling <i>Former US EPA Promulgated Test Method</i>
ASTM D6784-02	Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario-Hydro Method) <i>American Society for Testing and Materials (ASTM) Methods</i>

The methods in Table 2.4.2 appear in detail in the *Code of Federal Regulations (CFR)* and on the World Wide Web at <http://www.epa.gov/ttn/emc/promgate.html>.

Sampling protocol at the ESP inlet followed US EPA Method 17 (in-stack filtration). The in-stack filter was a quartz fiber thimble encased in a stainless-steel Siltek® coated thimble holder. The stainless steel nozzle at the probe tip was also coated. The flue gas sample remained above dew point temperatures using a heated Teflon jumper connection from the probe to the impinger train setup. The stack location source sampling used the out-of-stack US EPA Method 5 filtration setup.

Specific quality assurance and quality control (QA/QC) procedures as outlined in the individual methods and in the US EPA “*Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III Stationary Source-Specific Methods*”, EPA/600/R-94/038C were followed.

3.0 TEST RESULTS

3.1 Pre-Testing Assessment of Mercury Distribution

Prior to assessing the amount of sampling necessary to characterize the Hugo plant, an assessment of mercury distribution in the different areas of the plant was conducted. Representative samples of the coals, the plant's first and second ESP rows of both A and B side fly ash composite, economizer ash, pulverizer pyrite reject and plant's bottom ash. The mercury concentration in these samples is presented in Figure 3.1.1.

It is clear from the data that the mercury in the coals is essentially identical. There is little discernable difference in the mercury concentration in the ESP ashes. The economizer ash had a low mercury concentration and the mercury in the bottom ash was slightly less than the ESP ashes.

The coal pyrite rejects were also sampled during initial testing. The Hg concentration in the pyrites was relatively high. However, the quantity of the pyrites accumulated is very low. As a result, the Hg mass flow rate for this pathway was deemed insignificant and was not considered in the plant Hg mass balance.

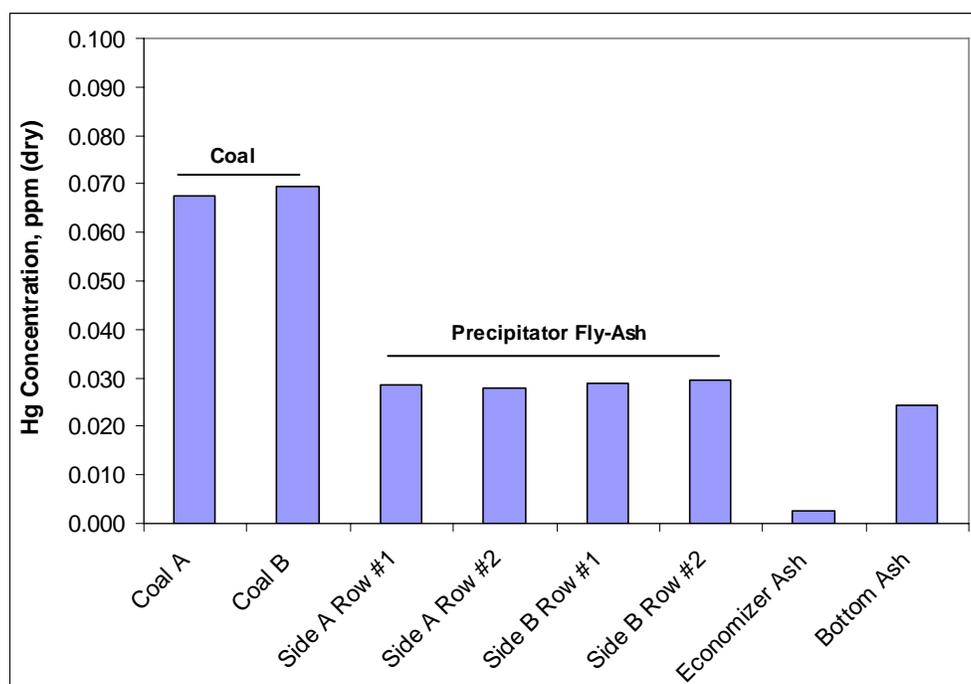


Figure 3.1.1 Pre-Hg balance test program coal and ash sample results

Mercury can leave the plant either through the stack or with the ash collected in the various hoppers along the process stream. It was decided based on initial test results (see Figure 3.1.1) that the main pathways of Hg leaving the system, besides through the stack, are with the ESP hopper ash and the bottom ash.

In order to obtain the rate of Hg leaving the system with the ESP hopper ash, the amount of fly ash removed was calculated on the basis of the actual ash content in the coal during the mass balance sampling and the expected partitioning of the resulting ash between fly ash and bottom ash. This partitioning depends on the boiler design. For the Hugo plant, it was assumed to be 80% fly ash and 20% bottom ash. Subsequently, the Hg leaving the system via the ESP was calculated based on the measured Hg concentrations in the ash. The same considerations were followed for determining the amount of Hg leaving the system via the bottom ash.

As a result of this analysis, it was decided that sampling of only one side of the ESP was adequate to meet project objectives. OH sampling efforts were only completed at one of the gas streams (B-West duct) assuming that the flue gas was well mixed and that concentrations for each Hg species were the same in each gas stream.

3.2 Mercury Balance Results

One of the primary objectives of the program was to assess the mercury mass balance for the Hugo plant and especially around the plant's cold-side ESP. In order to assess the mercury mass balance, flue gas Hg measurements using both Ontario-Hydro method (ASTM D 6784-02) and sorbent traps were completed at two locations: inlet to the electrostatic precipitator (ESP) and at the flue gas exhaust stack shown earlier (Figures 2.3.1.2 through 2.3.1.4).

The mercury mass balance was conducted by completing three (3) ASTM D6784-02 (OH) sample runs concurrently at the inlet and outlet locations. The arrangement of the paired probes at the stack was in accordance with specifications of US EPA Method 301 for co-located sampling. The inlet location also used paired probes but the probes could not be co-located due to test equipment and test location limitations. Sampling protocol at the ESP inlet followed US EPA Method 17 (in-stack filtration). The in-stack filter was a quartz fiber thimble encased in a stainless-steel Siltek® coated thimble holder. The stainless steel nozzle was also coated. The flue gas remained heated using a heated Teflon jumper connection from the probe to the impinger train setup. The stack location used an out-of-stack filtration setup. During the OH testing coal, fly ash and bottom ash samples were also collected and analyzed for total Hg.

3.2.1 Coal Analysis

The consistency of the coal feed during the plant mercury balance testing was conducted and presented in the following figures. Figure 3.2.1.1 show the variability of the ash content in the feed coal on a dry basis over the first two-week period. With the exception of the coal sample for July 7, 2005, the ash variability was relatively low $6.65\% \pm 0.95\%$ (1). The cause for the ash spike on July 7th is currently unknown.

Figure 3.2.1.2 show the variability of the feed coal's heating value over the testing period. The variability of the heating value content is remarkable constant with the exception of the low value for the July 7th sample.

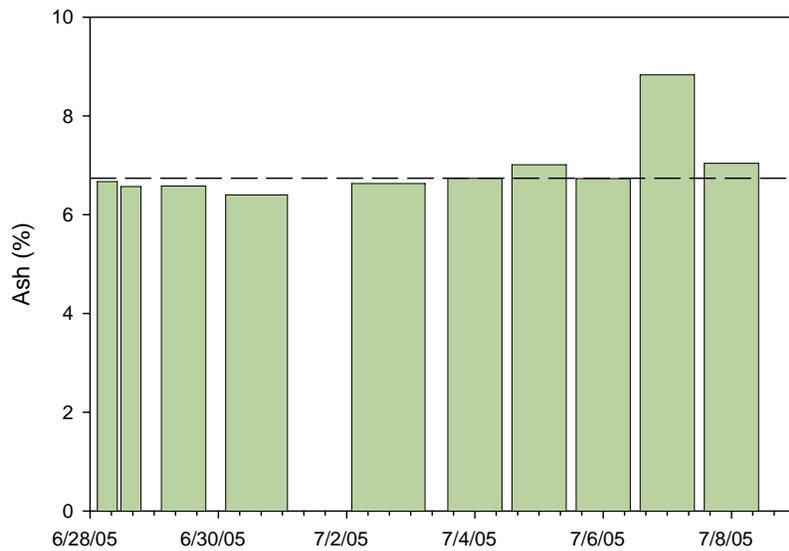


Figure 3.2.1.1 Ash variability of Hugo feed coal during inter-method comparison testing. (The line represents the value from the initial per-test evaluation.)

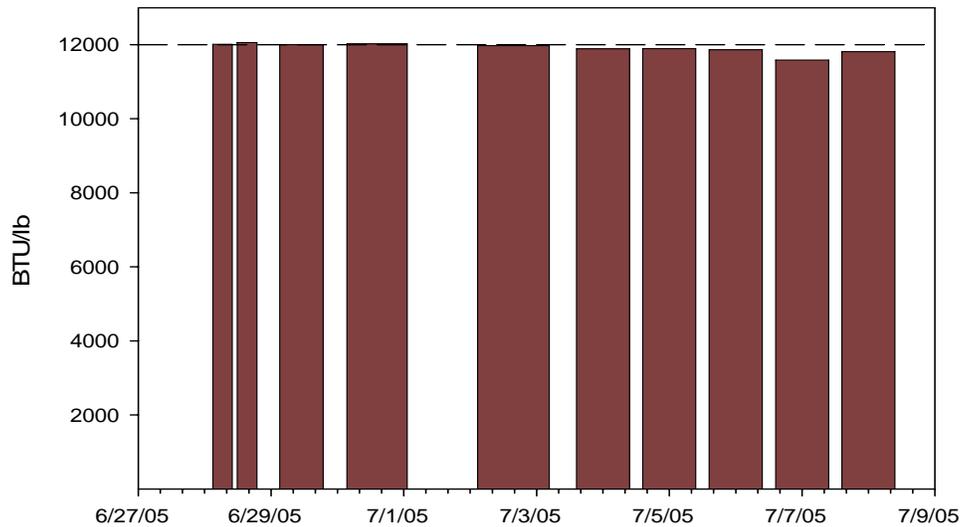


Figure 3.2.1.2 Heating value variability of Hugo feed coal during inter-method comparison testing. (The line represents the value from the initial per-test evaluation.)

Figure 3.2.1.3 shows the variability of the feed coal’s pyritic sulfur content over the first two-week period of testing. The pyritic sulfur content of the feed coal burned at Hugo is relatively low but highly variable $0.05\% \pm 0.03\%$ (1). Although the concentration of Hg in pyrite is relatively high, the small concentration of pyrite in the coal is assumed to have a limited impact on mercury variability in the feed coal.

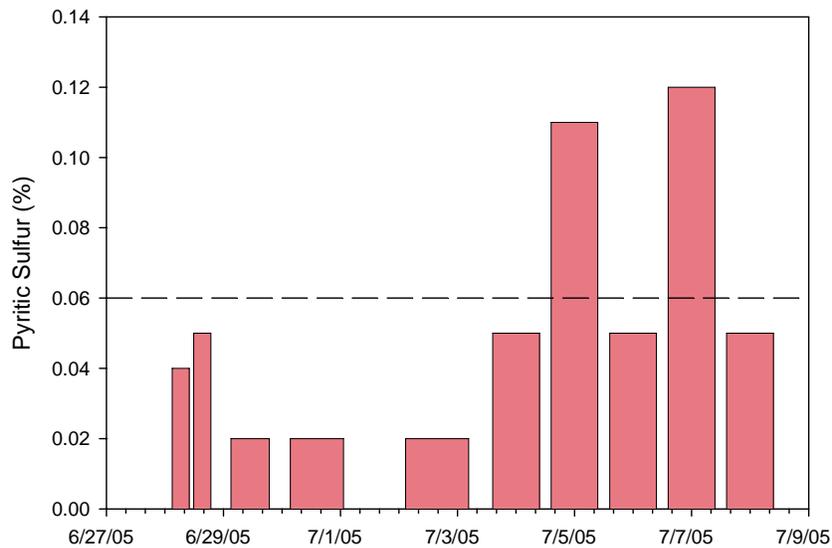


Figure 3.2.1.3 Pyritic sulfur variability of Hugo feed coal during inter-method comparison testing. (The line represents the value from the initial per-test evaluation)

Figure 3.2.1.4 shows the Hg content of the plant feed coal. Despite erratic Hg concentrations during the early testing, Hg concentrations in the coal seemed to stabilize during the days of the Hg mass balance testing (07/06 - 07/07/2005) with Hg concentrations similar to those found during the initial tests. The actual coal Hg concentration determined for each day was used to calculate the Hg mass balance. The average Hg concentration was **0.097 ppm ± 0.035ppm (1)**.

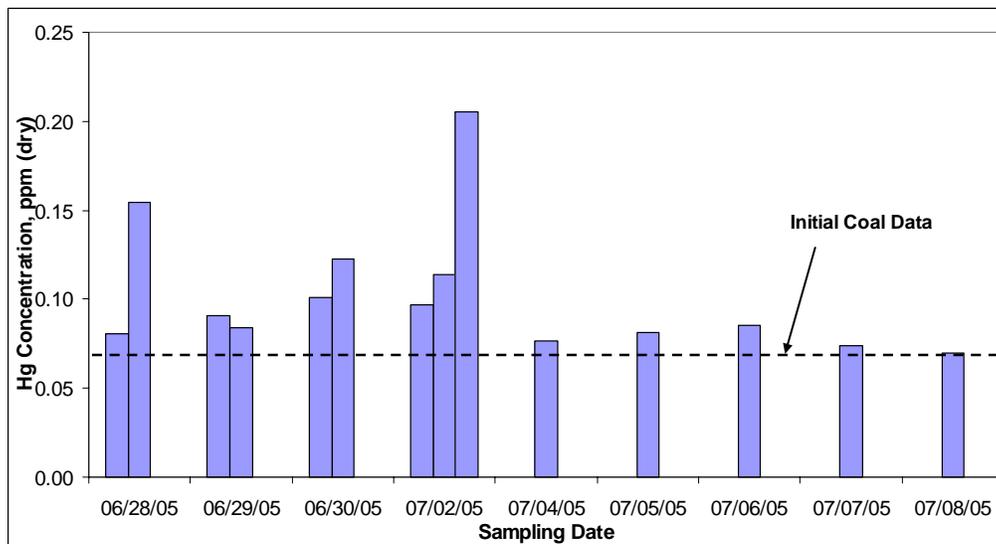


Figure 3.2.1.4 Coal Hg concentrations

3.2.2 Ash Analysis

Analysis results for the fly ash removed from the ESP hoppers are shown in Figure 3.2.2.1. For the duration of the Hg mass balance testing (07/06 - 07/07/2005), fly ash samples from the corresponding hoppers were collected in the middle of each Ontario-Hydro sampling method run. As can be seen in Figure 3.2.2.1, the high coal Hg concentrations during the early testing period (06/29 - 06/30/2005) were reflected in the fly ash mercury concentrations. The fly ash Hg concentration in the fly ash was **0.040ppm ± 0.034ppm (1σ)**.

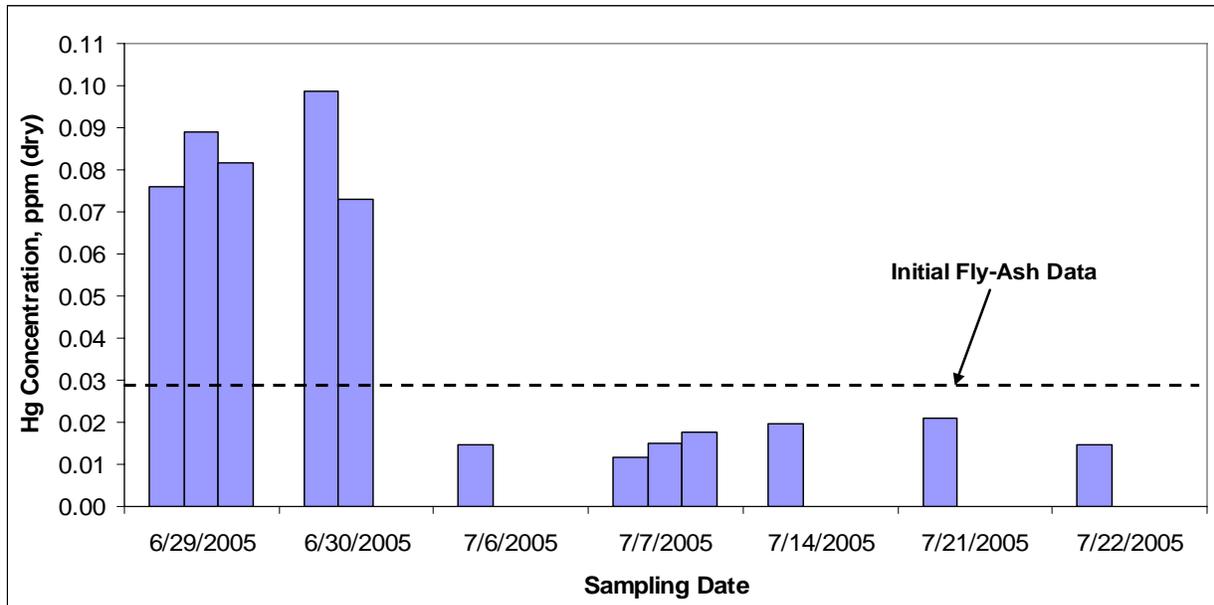


Figure 3.2.2.1 Ash sample analysis results

As for the bottom ash, sampling during mass balance testing yielded very little Hg concentrations: 4.5ppb and 2ppb (on a dry basis) for 07/06/2005 and 07/07/2005, respectively. Hg mass flow rates based on these results were insignificant and were therefore omitted in the Hg mass balance calculations. The average concentration in the bottom ash was 0.111ppm ± 0.197ppm (1σ).

3.2.3 Mercury Emissions Results

The Hg mass balances across the plant and ESP are presented in Table 3.2.3.1 and Table 3.2.3.2, respectively. The overall Hg mass balance closes to 95.6%, while the Hg mass balance across the ESP is 93.8%. A description of the details and calculations are presented in Appendix A.

Table 3.2.3.1 Hg mass flow rate across Hugo facility

Hg Mass Flow Rate (g/hr)	
Inlet Hg	
Hg from coal	15.8
Outlet Hg	
Hg exiting the stack	14.9
Hg in bottom ash	<0.1
Hg in ESP hopper ash	0.2
Outlet/Inlet Balance	95.6%

Note that Hg mass flow at the ESP inlet (16.1g/hr) is slightly higher than the calculated Hg mass flow entering the plant via the coal (15.8g/hr). However, considering the variation in Hg entering the system via the coal during the three mass balance Ontario-Hydro sampling method runs (15.8 g/hr \pm 1.4g/hr), these two values are essentially identical.

Table 3.2.3.2 Hg mass flow rate across ESP

Hg Mass Flow Rate (g/hr)	
Hg at the ESP inlet	16.1
Hg at the Stack	14.9
Hg in ESP hopper ash	0.2
Outlet/Inlet Balance	93.8%

The mercury mass balance closures are presented in Figure 3.2.3.3 and yield closures of 100% \pm 25% except for sampling during week 7. This low closure has been attributed to a two-day outage during which the monitoring system continued sampling at a constant rate, shifting the average mercury concentration for the sampling period to a lower value. In addition to above considerations, keep in mind that due to the nature of the coal sampling schedule, some of the mass balances were based on weekly coal sample composites, while others were based on monthly composites. Furthermore, considering the variability of the mercury content in coal, as evident from Figure 19, this variability alone could explain the mass balance discrepancy.

In Figure 3.2.3.3 values in the body of each column represent either the Relative Deviation (RD) or the field spike recovery (FS) in percent (%). Units are on a dry basis. In addition, total gaseous mercury concentrations for each sorbent trap pair are superimposed with the mercury mass balance closures based on the results per sampling run. Note that the plant went offline from 08/19/05 - 08/21/05 (week 7).

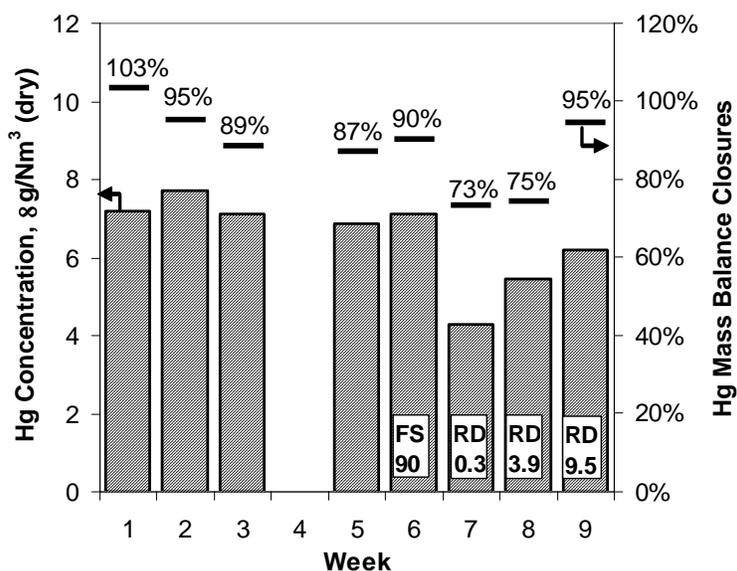


Figure 3.2.3.3 Average total mercury concentrations per sorbent trap sampling run

3.3 Mercury Speciation

A second objective of the project was to ascertain the speciation of the mercury in the Hugo plant. Specifically, the distribution between the elemental and the oxidized mercury exiting the boiler and exiting the stack. Ontario-Hydro is the method that allows for the determination of the species of mercury in the flue gas streams in the plant. This testing was conducted in order to confirm any changes in speciation as a result of the flue gas and mercury passing through the cold-side ESP.

The subbituminous coal burned at Hugo results in a high percentage of Hg^0 in the flue gas. At the ESP inlet, 89.5% of the total Hg was measured in the form of Hg^0 , while only 8.0% were present as Hg^{2+} . It should be noted that about 2.5% of the Hg at the ESP inlet was particulate-bound. Tables 3.3.1 and 3.3.2 detail the Hg speciation on a mass basis and concentration basis.

Table 3.3.1 Hg Speciation Mass Results

Hg Species	ESP Inlet (g/hr)	Stack (g/hr)	ESP Inlet (% of Total)	Stack (% of Total)
Hg^0	14.42	11.28	89.5	75.7
Hg^{2+}	1.30	3.61	8.0	24.3
Hg^{PB}	0.40	0.00	2.5	0.0

Table 3.4.2 shows the concentrations of Hg in the flue gas for the two sample locations. All Hg mass flow rates were based on these results. Note that each value is the average of three paired Ontario-Hydro sampling runs.

Table 3.3.2 Flue gas Hg concentrations

Hg Species	ESP Inlet (g/Nm ³ @7% O ₂)	Stack (g/Nm ³ @7% O ₂)
Hg ^T	8.08 (0.28)	7.97 (0.40)
Hg ⁰	7.23 (0.19)	6.03 (0.09)
Hg ²⁺	0.65 (0.12)	1.94 (0.34)
Hg ^{PB}	0.20 (0.03)	<0.01

(value) represents 1 standard deviation

The Hg speciation results across the ESP can be seen in Figure 3.3.1. As expected, nearly all of the Hg^{PB} is removed across the ESP. Since Hg^{PB} constitutes only a minor fraction of the Hg^T present in the flue gas, there is little removal of Hg^T across the ESP. Also evident is the oxidation of some of the Hg⁰ to Hg²⁺.

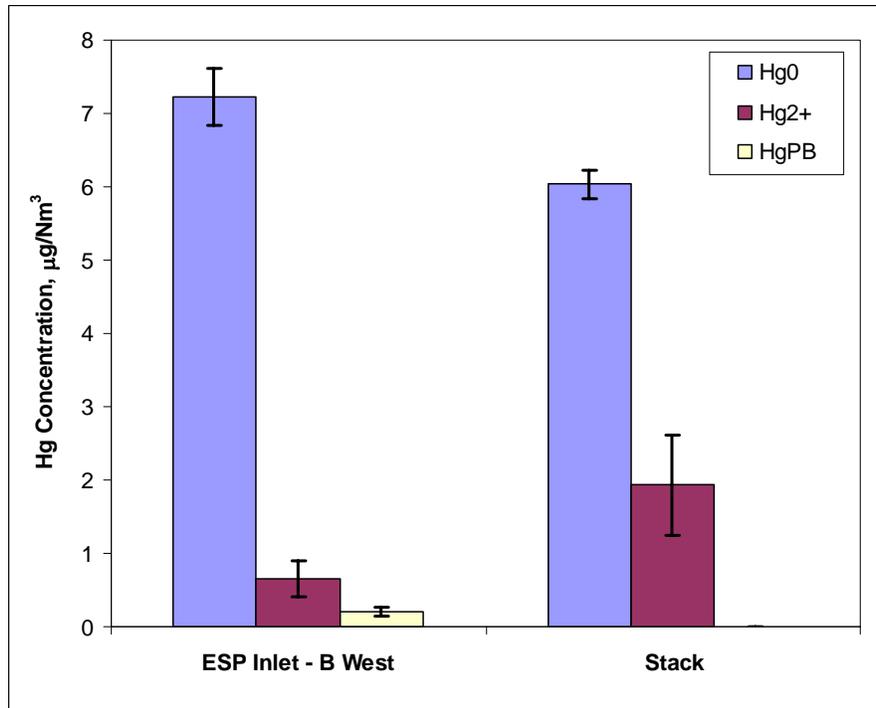


Figure 3.3.1 Hg speciation results

3.4 Inter-Method Comparison

A third objective of the project was to conduct an inter-method comparison, emissions source sampling included a Performance Specification (PS) 12A Relative Accuracy Test Audit (RATA) consisting of nine (9) paired OH reference method (RM) runs at the exhaust stack. In addition, nine consecutive paired sorbent-based US EPA Method 324 runs were performed simultaneously at the stack, and the corresponding mercury CEMS data were recorded.

3.4.1 PS12A Reference Method – Ontario Hydro

The minimum performance criteria for paired RM tests according to Performance Specification 12A required Relative Deviation (RD) of less than 10% for total gaseous Hg concentrations greater than $1.0 \mu\text{g}/\text{m}^3$. In order to establish the Ontario Hydro as the reference method requires an evaluation of the paired data for relative

The results of the Ontario-Hydro testing for the elemental and the oxidized mercury are presented in Figures 3.4.1.1 and 3.4.1.2 for the elemental and Figures 3.4.1.3 and 3.4.1.4 for the oxidized mercury.

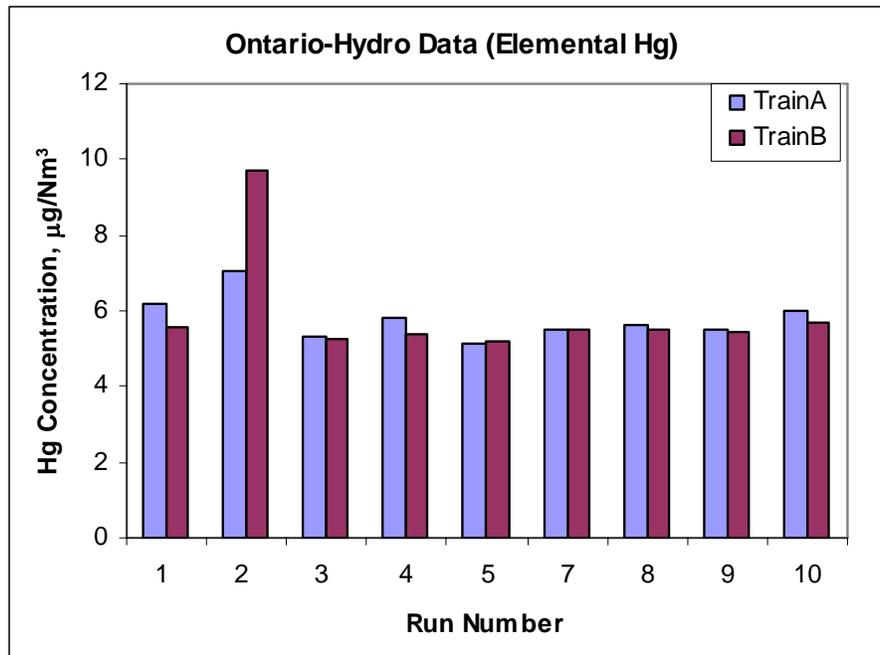


Figure 3.4.1.1 Ontario-Hydro– elemental Hg per train

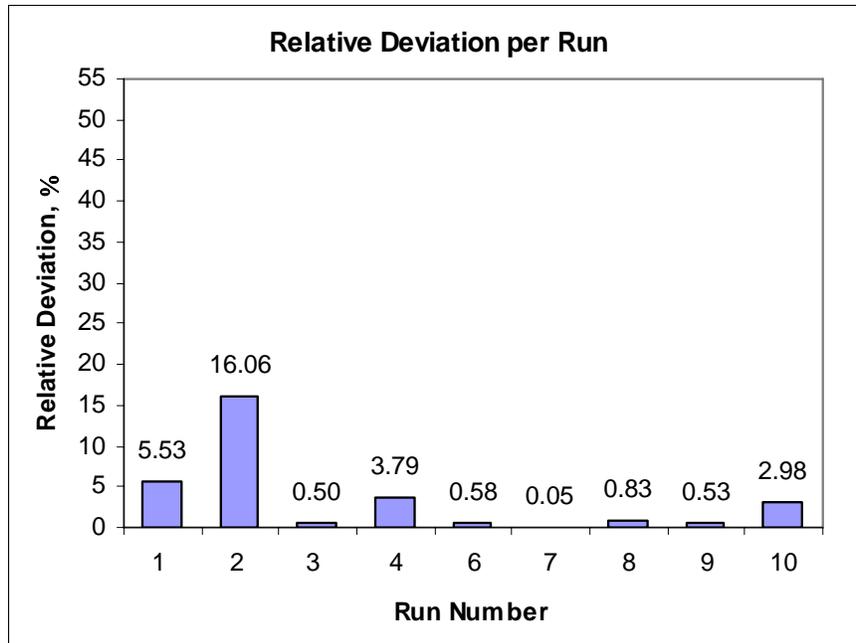


Figure 3.4.1.2 Ontario-Hydro – elemental Hg relative deviation per run

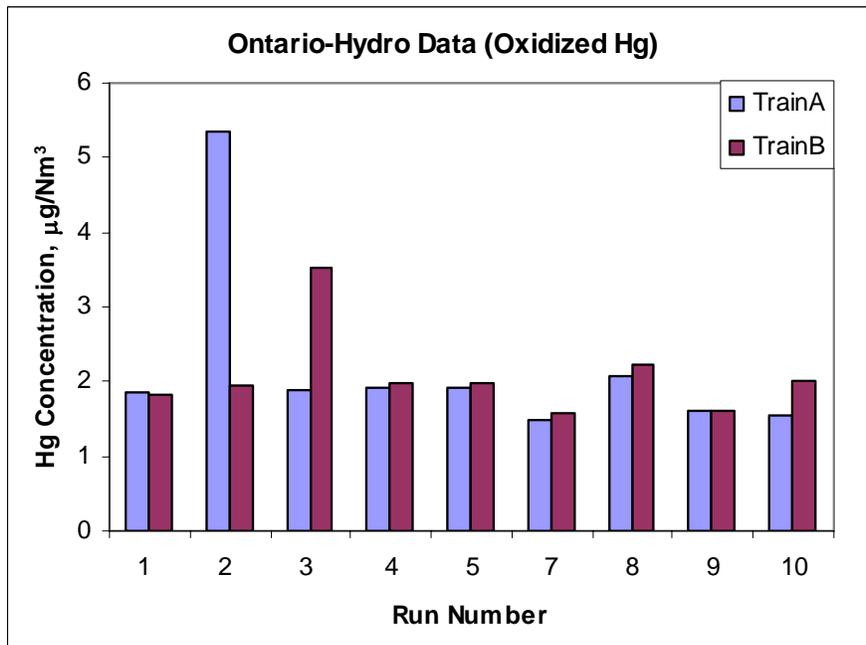


Figure 3.4.1.3 Ontario-Hydro– oxidized Hg per train

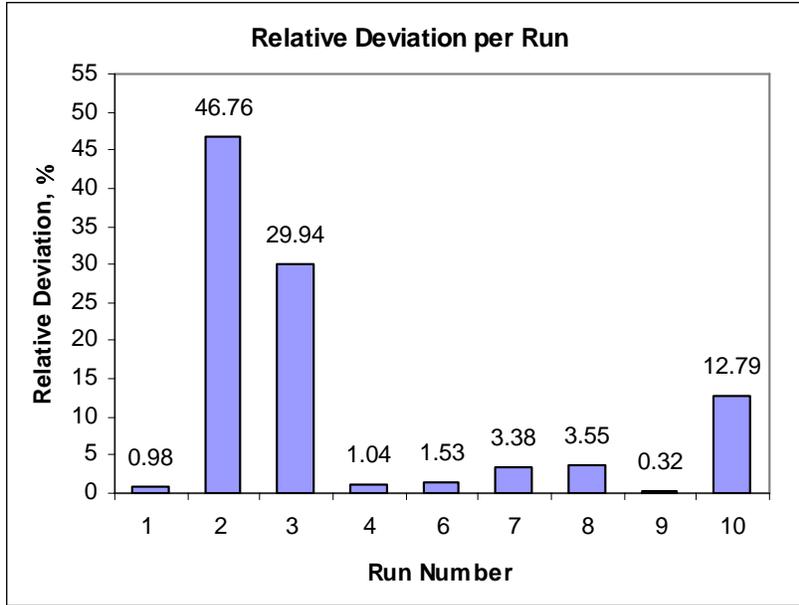


Figure 3.4.1.4 Ontario-Hydro – oxidized Hg relative deviation per run

The average total gaseous Hg results for each paired Ontario-Hydro test run are presented in Figure 3.4.1.5.

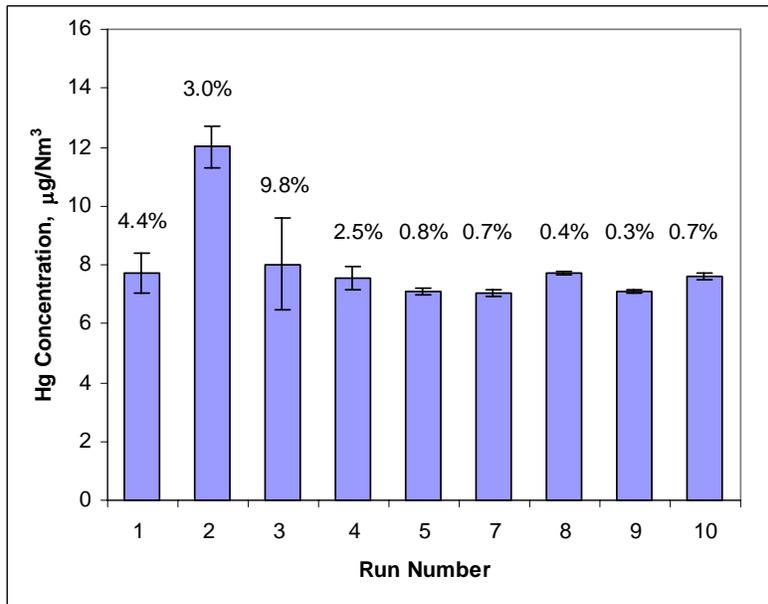


Figure 3.4.1.5 Average total gaseous Hg result for each paired Ontario-Hydro test run

All Ontario-Hydro sampling method runs satisfy the minimum performance criteria for paired reference method (RM) tests as specified in Performance Specification 12A. According to this criteria, the relative deviation (RD) for any data pair of the RM test runs must be less than 10% as long as the mean Hg concentration in the flue gas is greater than 1.0 µg/m³. Despite

satisfying these criteria, it is evident from Figure 3.4.1.6 that Run 2 should be considered an outlier and omitted from subsequent data correlations.

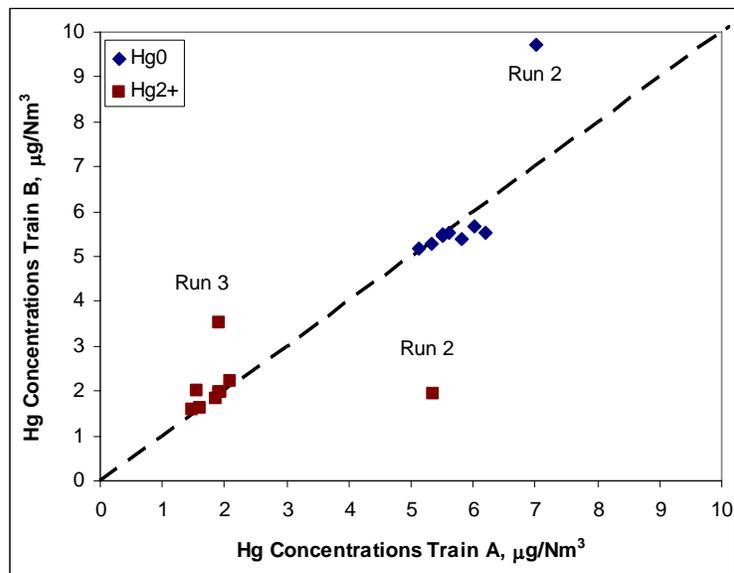


Figure 3.4.1.6 Hg results for each Ontario-Hydro train

The Hg^{2+} of Train A is almost three times the concentration of the results for Train B, while the Hg^0 of Train B is almost 40% higher than the corresponding result for Train A. The error bars represent the Relative Percent Difference (RPD) between the individual Ontario-Hydro method train results for each pair. The values on top of each column indicate the Relative Deviation (RD) for each data pair. The relative deviation for each run ranges from 0.03% to 9.8% as presented in Figure 3.4.1.5. Run 6 was omitted from the data set since it was interrupted by an unplanned plant outage.

3.4.2 Method 324 RATA

Table 324-2 of 67 FR 4467 requires pre- and post-sampling leak rate of less than 2% of prevalent sampling rate and sorbent trap backup section mercury loading less than 2% or, alternatively, 5ng/trap of the main section mercury loading. Further details on each of these can be found in Appendix A. Relative Accuracy Test Audit (RATA) for the Method 324 data requires the following:

- Field Spike Recovery: Spiked sorbent trap section mercury mass equal to 80-120% of original elemental mercury spike amount, and
- Paired Trap Agreement: Relative deviation (RD) between results of paired traps less than or equal to 10%.

Figures 3.4.2.1, 3.4.2.2 and 3.4.2.3 show the results for the corresponding sorbent-based Method 324 sampling.

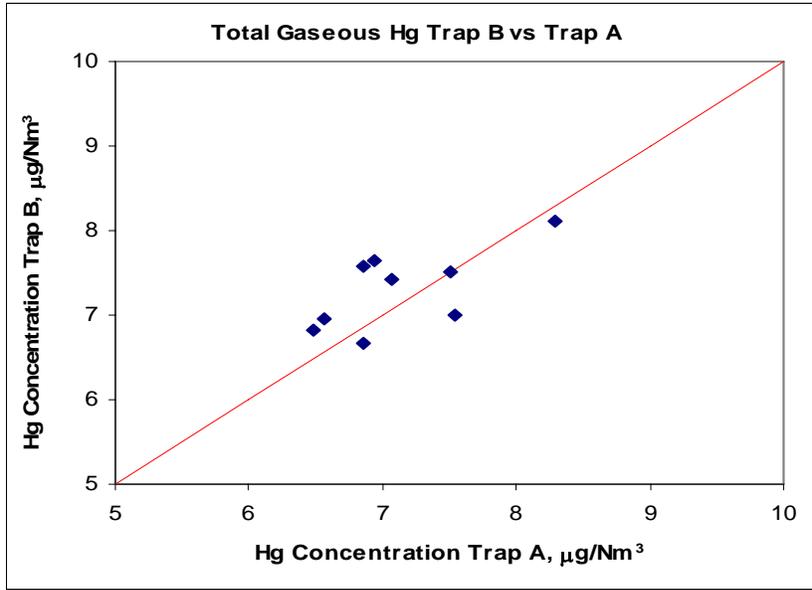


Figure 3.4.2.1 Hg results for each paired sorbent trap test

Included in the data set are the results for the field spike run. Field spike recovery was 90%.

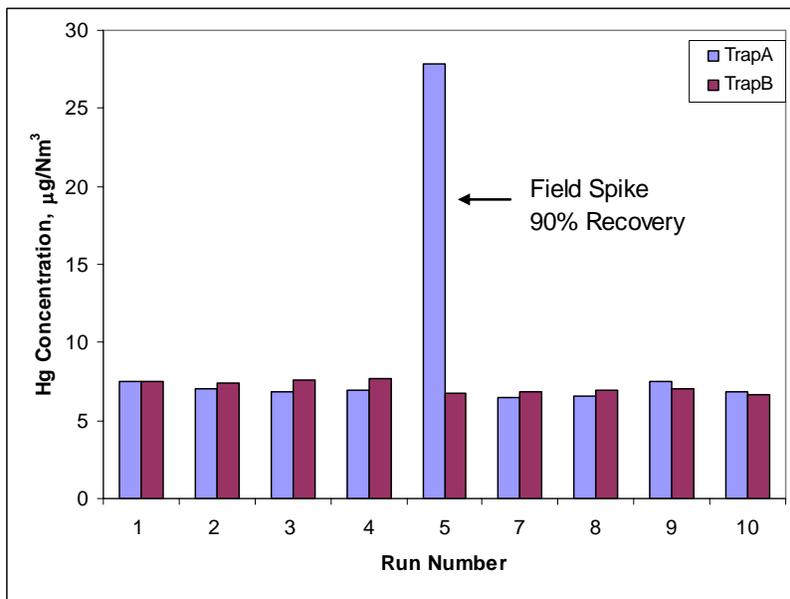


Figure 3.4.2.2 Hg results for each paired sorbent trap test run

The error bars represent the Relative Percent Difference (RPD) between the individual sorbent traps for each pair. The values on top of each column indicate the Relative Deviation (RD). Units are on a dry basis.

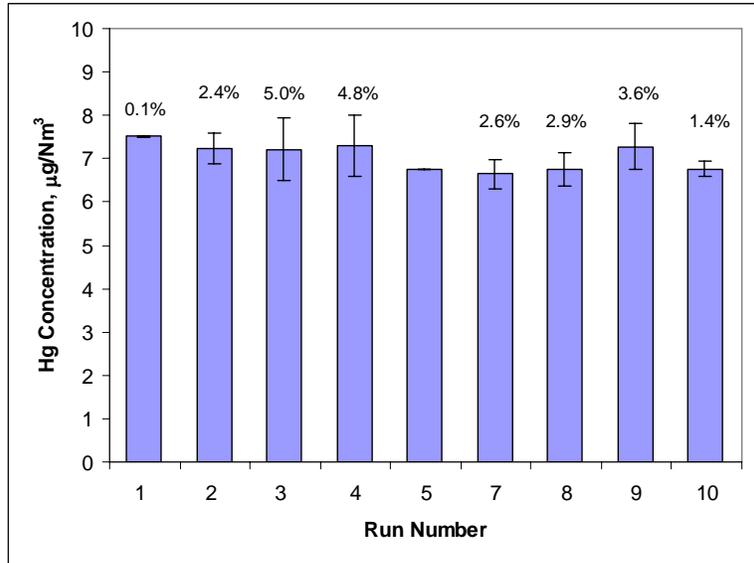


Figure 3.4.2.3 Average Hg result for each paired sorbent trap test run

For comparison of both method results, the total gaseous Hg concentrations obtained from the sorbent-based method were plotted against the total gaseous Hg concentrations of the Ontario-Hydro sampling method runs. Figure 3.4.2.4 indicates that results of both methods compare very favorably to each other except for Run 2.

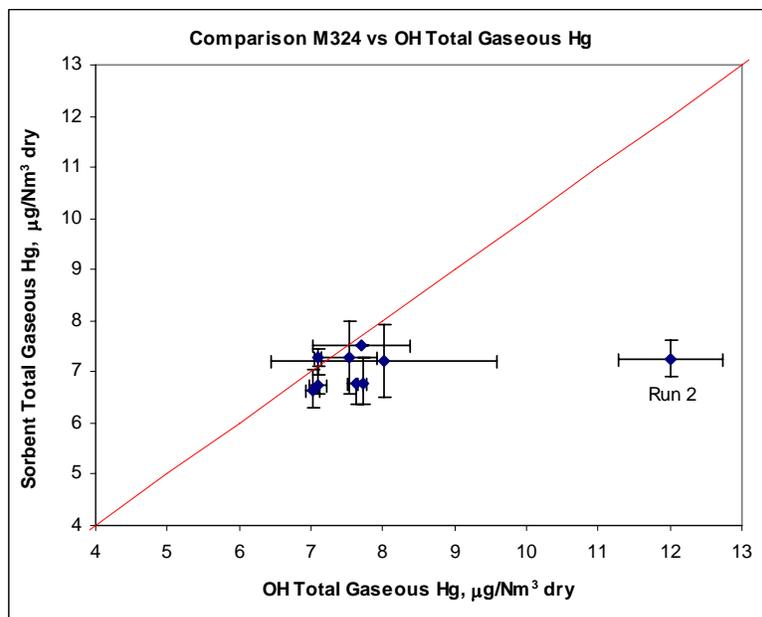


Figure 3.4.2.4 Sorbent trap results vs. Ontario-Hydro results

Using the Ontario-Hydro sampling method as the reference method (RM) and excluding Run 2 from the data set, a relative accuracy (RA) of 10.4% with respect to the RM is indicated. The error bars represent the RPD between both results of each data pair. All units are on a dry

basis. In summary, the Method 324 RATA showed a relative accuracy as a percent of OH as reference method was 10.4% (limit of 20%), and an absolute difference of $0.46\mu\text{g}/\text{m}^3$ (limit of $1\mu\text{g}/\text{m}^3$). As such, the Method 324 data passed the RATA.

3.4.3 Horiba DM-6 CEMS

In addition to the Ontario-Hydro and sorbent-based sampling method test runs, a Horiba DM-6 mercury CEMS was used to continuously monitor the total gaseous Hg concentrations at the stack. During the first week of testing, the mercury CEMS was generally reading 10-22% lower than the corresponding RM during the same time period, as can be seen in Figures 3.4.3.1 and 3.4.3.2. However, after several unplanned plant outages during which steam was vented through the stack and the unit was fired using oil, Hg concentrations reported by the DM-6 never recovered and were consistently lower by more than 50% with respect to the RM for the remainder of the testing. Nevertheless, after exchanging the unit's reducing catalyst, reported Hg concentrations returned to the levels seen during the first week. The reasons for this behavior as well as the short-term drifts of the instrument are currently under investigation.

Figures 3.4.3.1 and 3.4.3.2 show the comparison of OH, Method 324 and the Horiba data during the test periods of June 29 and 30, 2005. With the exception of run 2, the OH and Method 324 correlate well as expected from the RATA. The Horiba DM-6 data was consistently biased low.

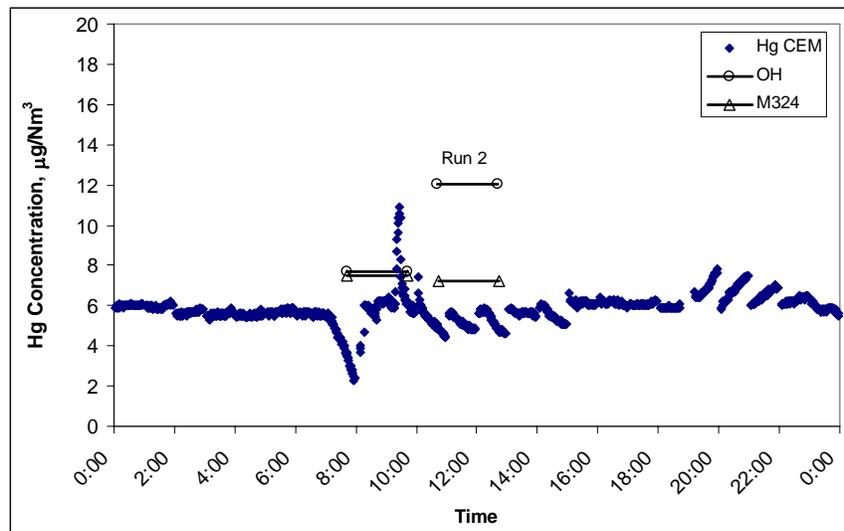


Figure 3.4.3.1 Hg-CEMS results vs. Ontario-Hydro results for June 29, 2005

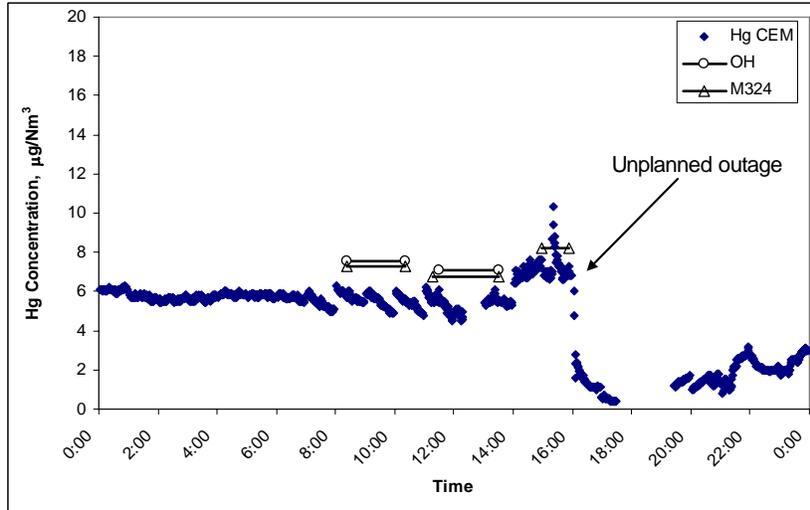


Figure 3.4.3.2 Hg-CEMS results vs. corresponding Ontario-Hydro results for June 30, 2005

The sudden drop in Hg concentrations around 16:00 hours was due to an unplanned plant outage. All data are adjusted for CEMS response time. A similar RATA conducted using the data from the Horiba DM-6 CEMS showed a relative accuracy as a % of the OH as the reference method of 64.8% (limit of 20%) and an absolute difference of $2.98\mu\text{g}/\text{m}^3$ (limit of $1\mu\text{g}/\text{m}^3$). As such, the Horiba DM-6 data does not pass the RATA.

The comparison of the three methods is shown graphically in Figure 3.4.3.3

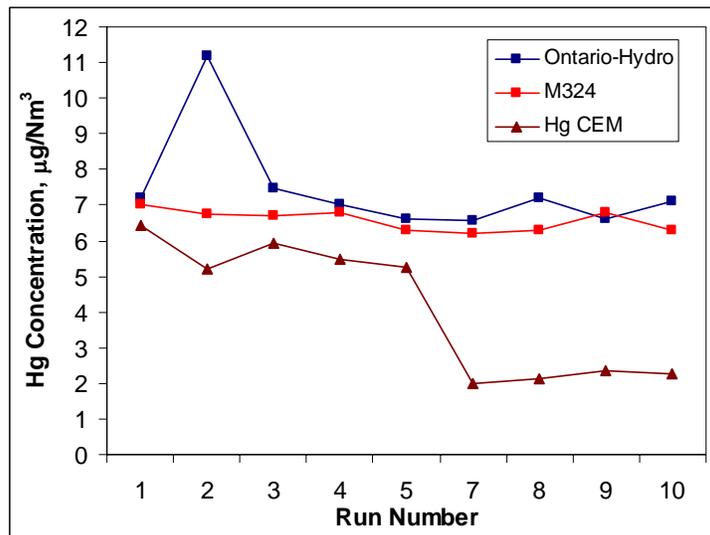


Figure 3.4.3.3 Ontario-Hydro vs. M324 (sorbent tube) vs. Hg-CEMS

In addition to the testing described above, inter-method comparison of the Method 324 and the Horiba CEMS continued through July and August 2005. Figures 3.4.4.1 and 3.4.4.2 shows the results of that testing. In general, the Horiba and M324 methods tracked each other,

but the Horiba showed a bias for a lower concentration. In addition there was a slow decline in the Horiba as a result of the slow deactivation of the catalyst.

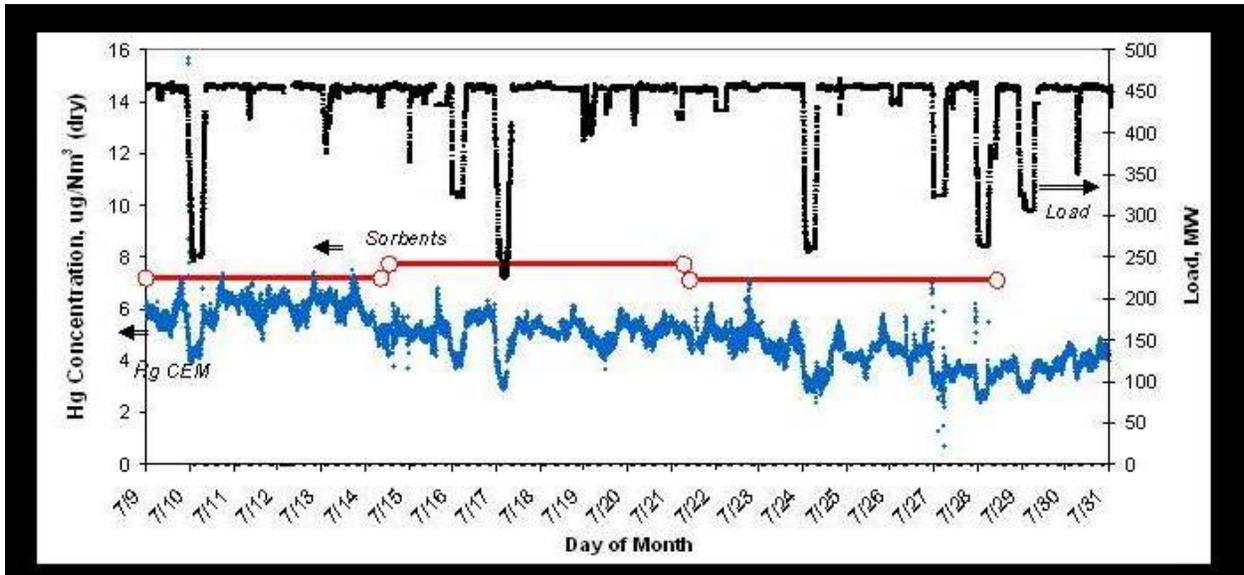


Figure 3.4.4.1 Mercury emissions and load for 7 July through 31 July 2005

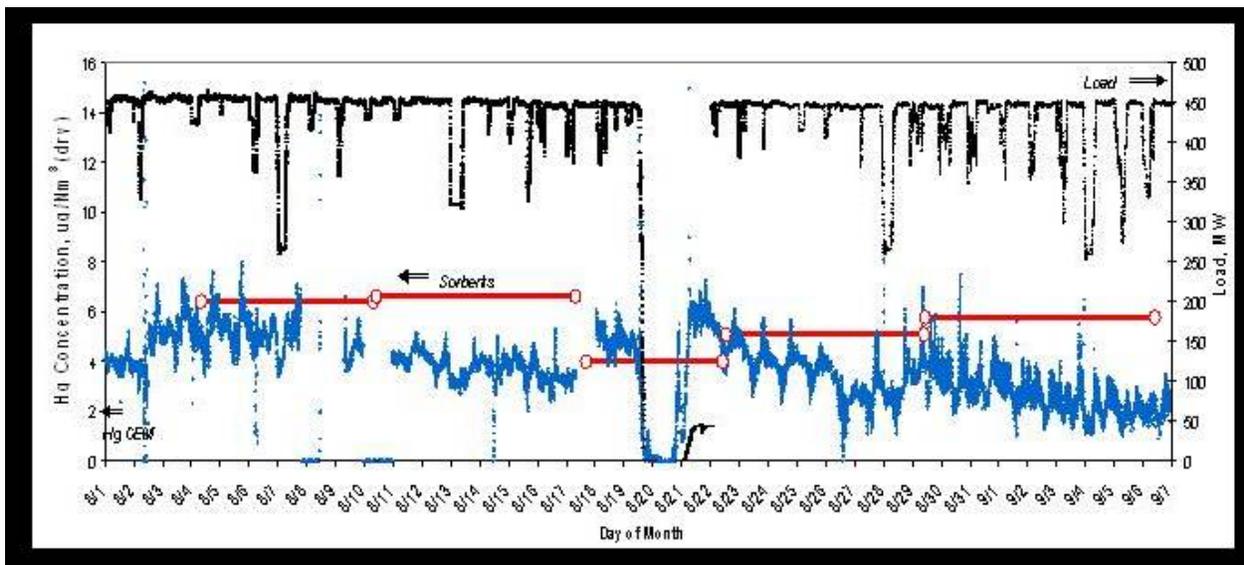


Figure 3.4.4.2 Mercury emissions and load for 1 August through 7 September 2005

The data shows a cyclic nature of the Horiba data with a continued decline in recorded concentration with time. This is considered to reflect the deactivation of the catalyst with time between replacement events.

3.4.4 Summary

In summary,

- All paired Ontario-Hydro sampling method test runs passed the minimum performance criteria for paired RM tests according to Performance Specification 12A (RD less than 10% for total gaseous Hg concentrations greater than $1.0\mu\text{g}/\text{m}^3$). Particulate-bound Hg was negligible (non-detected).
- All Method 324 data pairs had a relative deviation (RD) of less than 5%. A field spike was recovered to 90% (80-120% limit).
- The relative accuracy (RA) of Method 324 with respect to Ontario-Hydro as reference method result was 10.4% (20.00% limit) with an absolute difference of $0.46\mu\text{g}/\text{m}^3$ (limit of $1\mu\text{g}/\text{m}^3$). As such, the Method 324 data passed the RATA.
- During the first week of testing, (June 29 and 30), the Horiba DM-6 Hg CEMS used at the stack provided data comparable to those obtained using the Ontario-Hydro and sorbent-based sampling method (10-22% lower with Run 2 not included).
- The relative accuracy of the Horiba DM-6-6 CEMS data showed a relative accuracy of 64.8% (limit of 20%) relative to the OH as the reference method and an absolute difference of $2.98\mu\text{g}/\text{m}^3$ (limit of $1\mu\text{g}/\text{m}^3$). As such, the Horiba DM-6 data does not pass the RATA.

3.5 Long-Term Mercury Variability

As part of this study, an evaluation of long-term mercury variability was conducted. This evaluation extended beyond the period of the initial Ontario-Hydro method testing and continued throughout the remainder of the 6-month program. The evaluation examined the variability of the feed coal throughout this period, evaluation of the variability of the mercury in the ash, and the resultant variability in the mercury emissions at the stack.

3.5.1 Coal Analysis

All coal samples were analyzed for moisture, ash, carbon, sulfur, hydrogen, nitrogen, oxygen and mercury content. See the appropriate Appendix for other results. Coal mercury was performed using ASTM Method D6722-01. Figures 3.5.1.1 and 3.5.1.2 show the long-term variability in the coal ash content and the heating value (Btu/lb) over the 6-month period. It is clear that the coal quality parameters were very consistent. Average ash content was $6.40\% \pm 1.76\%$ (1σ).

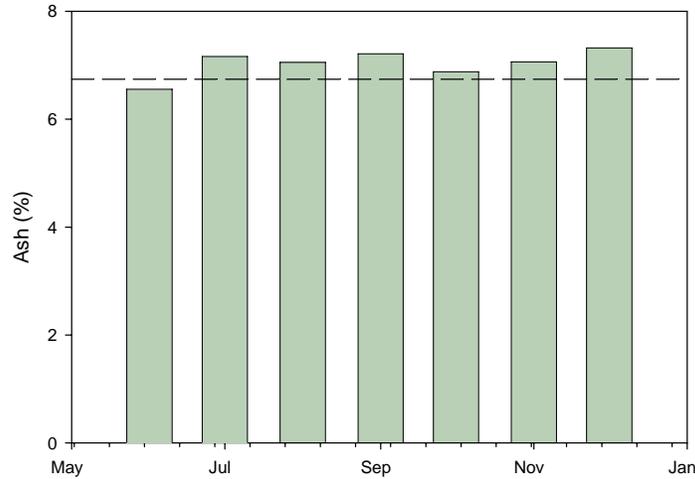


Figure 3.5.1.1 Ash content of the feed coals on a monthly basis over the 6-month monitoring period. (Line represents the values determined in the pre-test coals.)

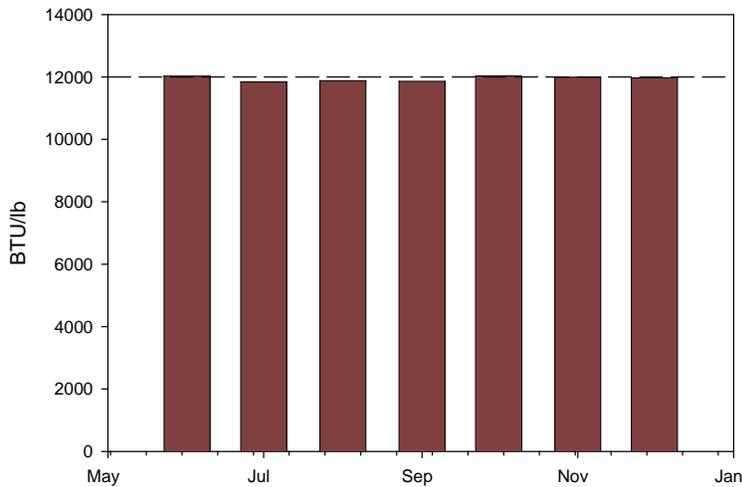


Figure 3.5.1.2 Heating value content of the feed coals on a monthly basis over the 6-month monitoring period. (Line represents the values determined in the pre-test coals.)

Figure 3.5.1.3 shows the Hg content as a monthly average of the feed coal for the 6-month period. The line represents the value determined in the pre-test coals (see Section 3.1). Unlike the ash and heating values, the Hg concentration varies considerably from a high of 0.12 ppm to a low of 0.06ppm in September 2005. For comparison, Figure 3.5.1.4 shows the individual Hg variability for the same period. As one can determine, even within a particular month variability of Hg is high. The average coal mercury concentration for the entire project duration was 0.096ppm \pm 0.032ppm (1σ) on a dry basis.

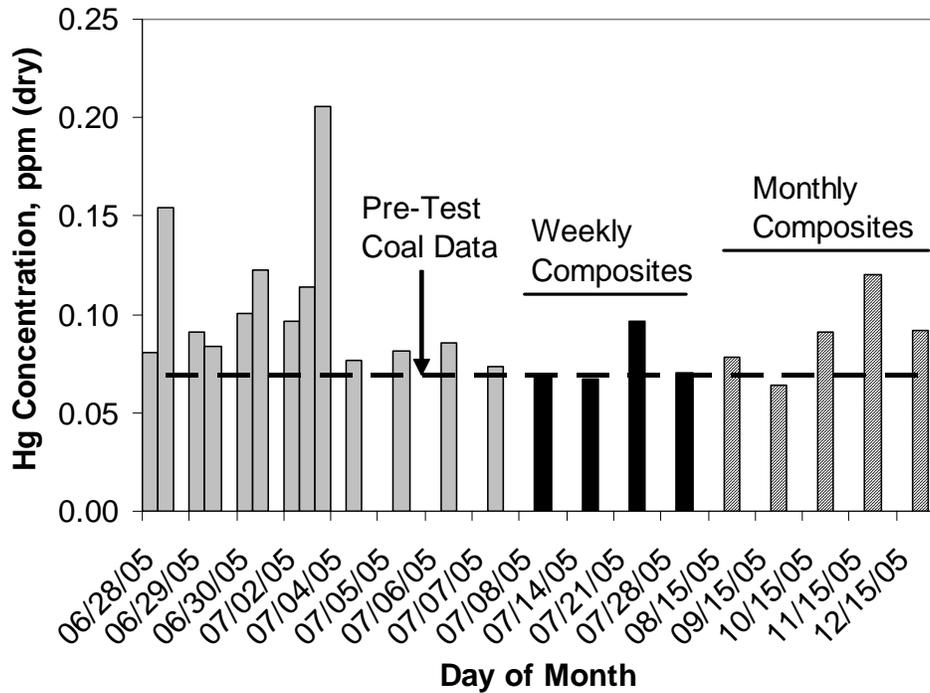


Figure 3.5.1.5 Coal Hg analysis results for the three testing period (daily, weekly and monthly)

Figure 3.5.1.5 summarizes the coal mercury over the 6-month period. Figure 3.5.1.6 shows the variability of pyritic sulfur content on the feed coal over the 6-month evaluation period. Like the Hg content the pyritic sulfur content ranging from 0.02% to 0.07% -average $0.05\% \pm 0.03\%$ (1σ). Both Hg and pyritic sulfur show a low in September 2005 and a high in the October-November timeframe. There is a correlation between the pyritic sulfur and the Hg contents in the feed coal.

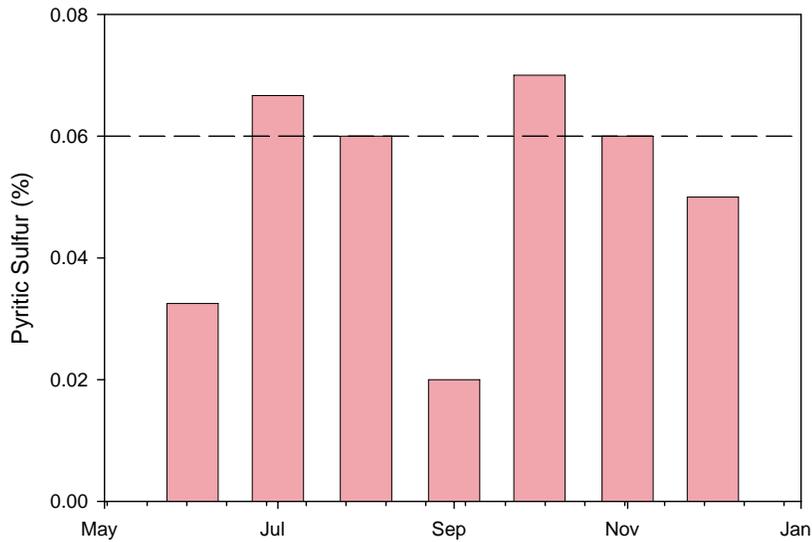


Figure 3.5.1.6 Pyritic sulfur content of the feed coals on a monthly basis over the 6-month monitoring period. (Line represents the values determined in the pre-test coals.)

One should keep in mind that there were coal shipment issues during the time of the testing resulting in the utility to go deeper into the coal pile and use some older stockpile coal. This could account for the feed coal variability shown in the data.

3.5.2 Ash Analyses

Mercury analysis results for the fly ash removed from the ESP hoppers are shown in Figure 3.5.2.1. For the initial part of the program (07/06 - 07/07/2005), fly ash samples from the corresponding ESP hoppers were collected in the middle of each Ontario-Hydro method sampling run. As can be seen in Figure 3.5.2.1, the high coal mercury concentrations during the early testing period (see results for dates 06/29 - 06/30/2005 in Figure 3.5.2.1) were reflected in the corresponding fly ash mercury concentrations. For the remainder of the project, fly ash samples were targeted to be collected daily and analyzed as a weekly composite. The average mercury content in the fly ash for the entire project duration was $0.042\text{ppm} \pm 0.023\text{ppm}$ (1σ) on a dry basis.

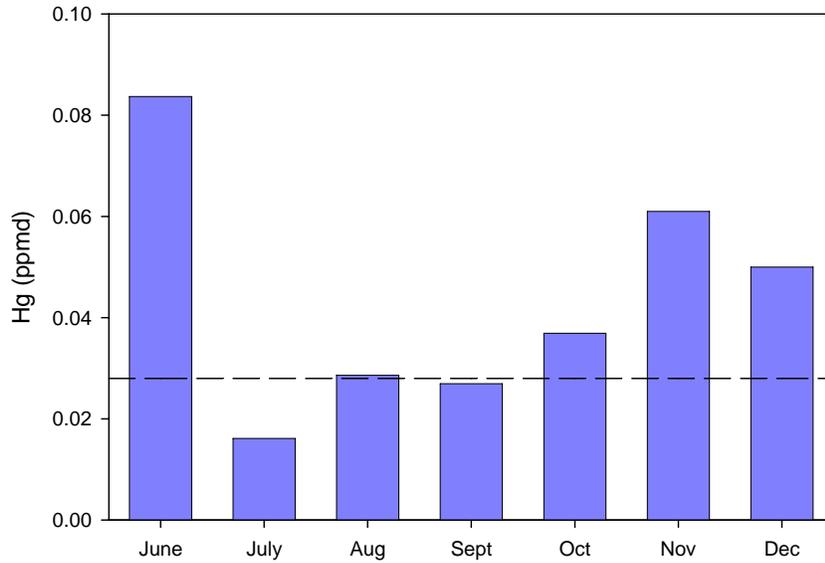


Figure 3.5.2.1 Monthly mercury results for the fly ash over the 6-month evaluation period. (Line represents the concentration determined from the pre-test samples.)

For the bottom ash, sampling during the actual mass balance testing yielded very low mercury concentrations: daily averages of 4.5ppb and 2ppb (on a dry basis) for the 07/06/2005 and 07/07/2005, respectively. However, as is evident from Figure 3.5.2.2, mercury concentrations in the bottom ash seemed to vary greatly (by several orders of magnitude) over the course of the project, raising concerns about the collection of representative bottom ash samples. The average mercury content of the bottom ash for the 6-month project duration was $0.065\text{ppm} \pm 0.198\text{ppm}$ (1σ).

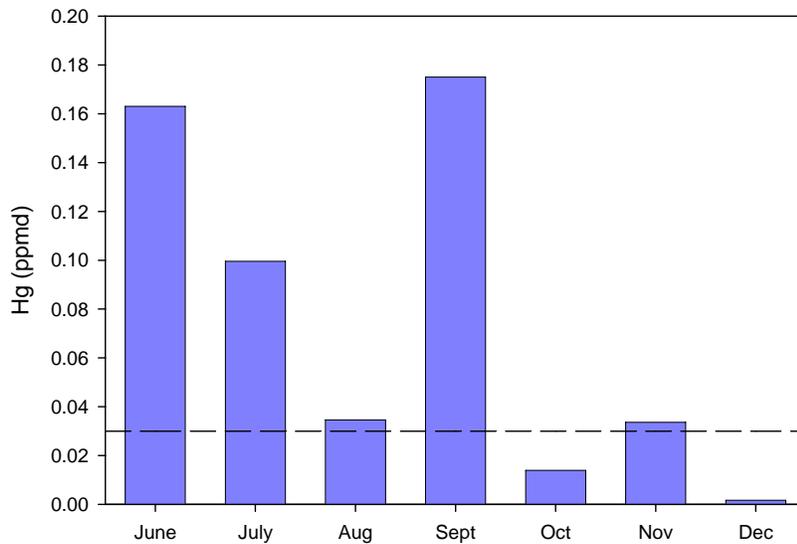


Figure 3.5.2.2 Monthly mercury content of the bottom ash samples

3.5.3 Mercury Emissions.

Concurrent with the coal and ash samples, the Horiba DM-6 mercury continuous emissions monitoring system and Method 324 sorbent tubes were used to monitor the Hg emissions in the flue gas at Hugo's exhaust stack over the six month evaluation period. Sorbent tube Method 324 sampling was performed during the first two of those six months and Horiba DM-6 CEMS monitored the stack gas emissions over the entire 6-month period. The Hg in the stack gas as measured by both or one of these methods is shown in Figures 3.5.3.1 through 3.5.3.6.

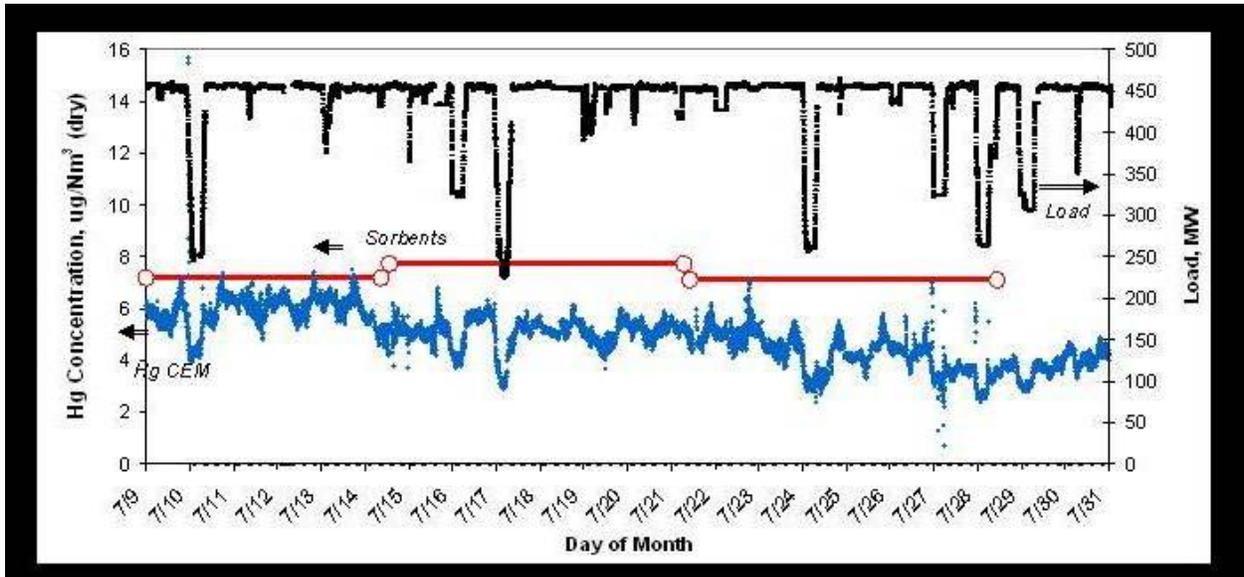


Figure 3.5.3.1 Mercury emissions and load for 7 July through 31 July 2005

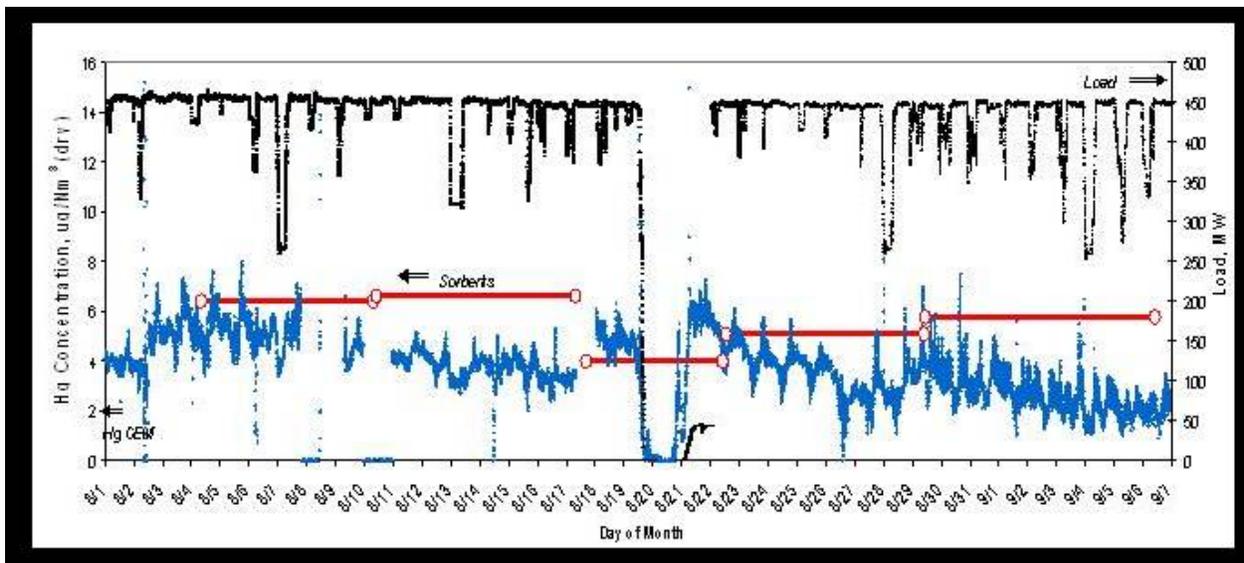


Figure 3.5.3.2 Mercury emissions and load for 1 August through 7 September 2005

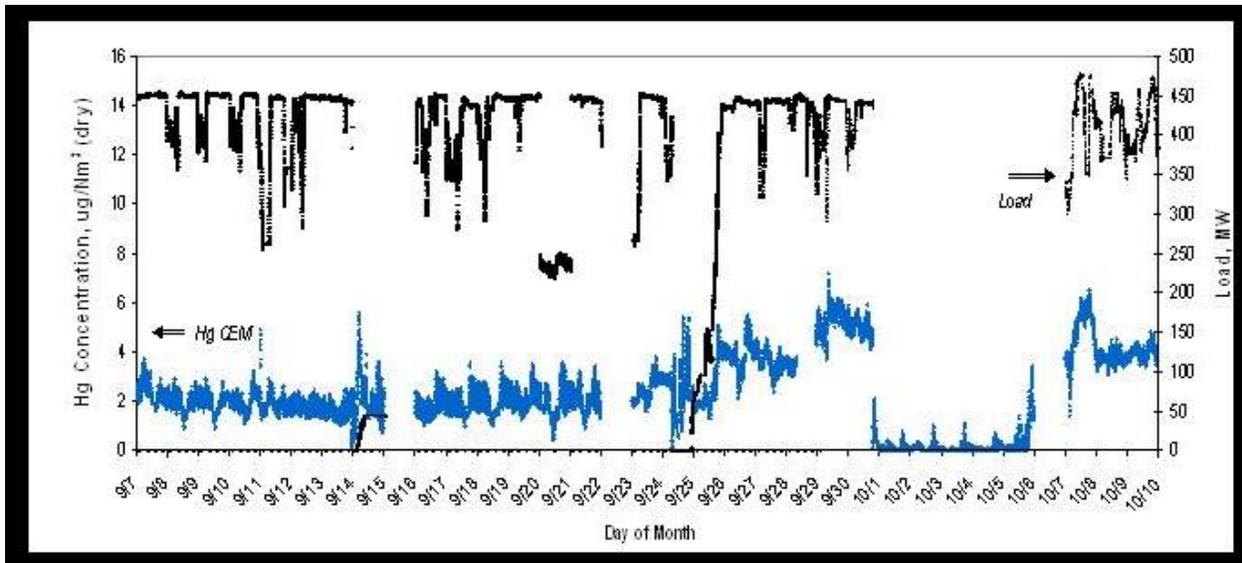


Figure 3.5.3.3 Mercury emissions and load for 8 September through 10 October 2005

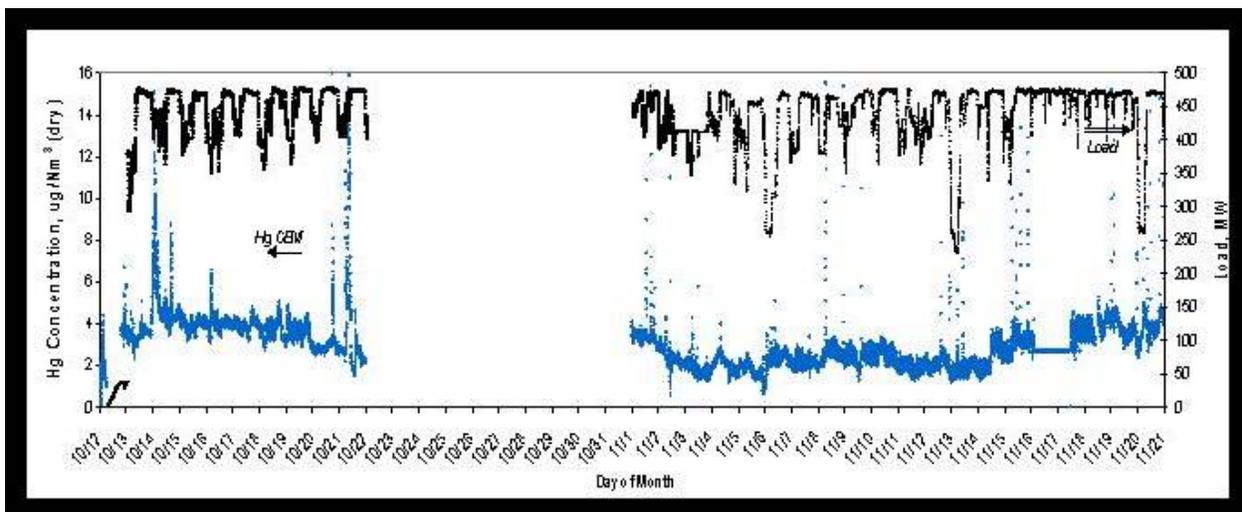


Figure 3.5.3.4 Mercury emissions and load for 11 October through 21 November 2005

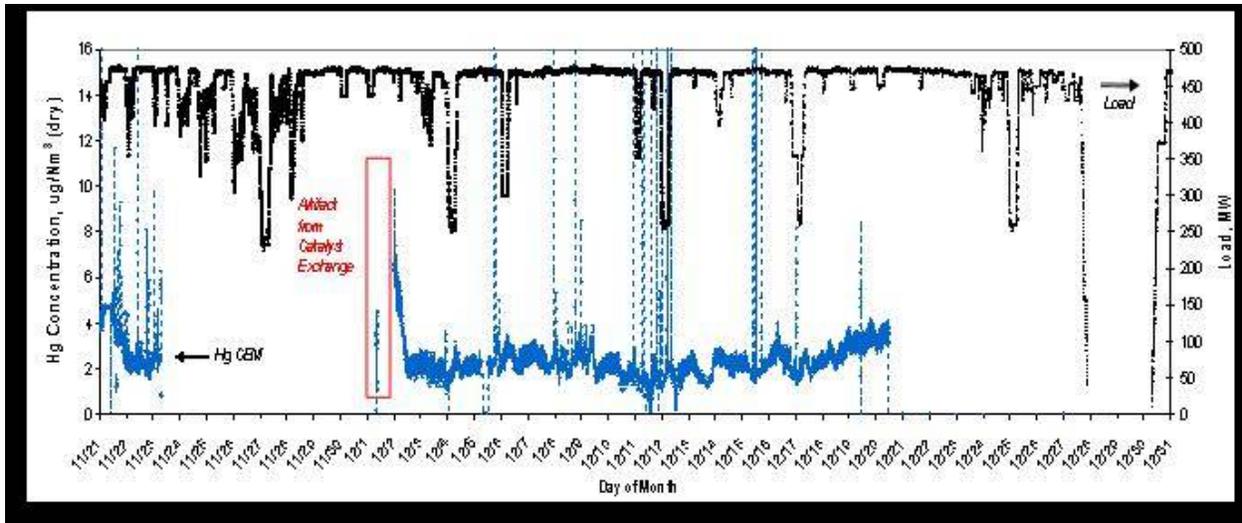


Figure 3.5.3.5 Mercury emissions and load for 21 November through 31 December 2005

It can be seen that there is a downward trend in the emissions Hg concentration with time as determined by the Horiba CEMS system. It is unclear that this is real or a deterioration of performance with time (see levels in August compared with levels in November and December).

3.6 Method 324 and Horiba CEMS Long-Term Operation and Maintenance Record

Plant personnel were trained on site on the use, care and maintenance of the sorbent tube sampling equipment and Hg-CEMS. Phone and email support was provided when requested. Several site visits over the six-month period for maintenance were also performed. The Horiba Hg-CEMS and sorbent tube were maintained by plant personnel over this six-month period. Horiba Hg-CEMS data files and facility boiler data were downloaded by plant personnel and emailed daily for data reduction and reporting. WFEC's CEMS and boiler data was provided for the six-month period showing boiler load levels, coal consumption, as well as sulfur dioxide, nitrogen oxides, and flue gas flow rates. Maintenance of the Horiba Hg-CEMS included weekly calibration checks, as well as daily inspections to ensure continued sampling. The six-month period covered emissions from June 24, 2005 until December 20, 2005.

3.6.1 Method 324 Operation and Maintenance.

Table 3.6.1.1 shows the results of gaseous mercury emissions of measured during the program. As can be seen in Table 3.7.1.1, there were several hardware, software as well as sorbent trap recovery issues during the first five weeks of the program. As a result, only one sorbent trap of each pair could be recovered successfully for the first five weeks. In addition, the sorbent trap results for the 4th week were deemed invalid for the same reason. The QA / QC for the sorbent trap method is presented in Appendix A.

Table 3.6.1.1 Summary of Test Results for Long-Term Sorbent Trap Monitoring

Start Date/ Start Time	Stop Date/ Stop Time	Hg Concentration ($\bar{g}/dscm$)		
		Trap A	Trap B	Average (A&B)
07/08/05 16:22	07/14/05 08:55	N/A ¹	6.70	N/A ¹
07/14/05 13:30	07/21/05 06:52	N/A ²	7.20	N/A ²
07/21/05 10:09	07/28/05 10:30	6.62	N/A ³	N/A ³
08/04/05 08:05	08/10/05 07:28	N/A ⁴	6.41	N/A ⁴
08/10/05 09:51	08/17/05 07:35	6.62	24.71 ⁵	N/A ⁵
08/17/05 16:30	08/22/05 09:53	3.98	4.01	4.00 ⁶
08/22/05 12:50	08/29/05 09:49	4.61 ⁷	5.57	5.09 ⁷
08/29/05 10:46	09/06/05 09:49	5.79	5.36	5.77

¹ Sorbent trap breakage during trap recovery

² Autosampler software malfunction and hardware failure

³ Autosampler hardware failure

⁴ Autosampler software malfunction

⁵ Sorbent trap with spike in the main section (field spike)

⁶ Plant went offline from 08/19/05 - 08/21/05

⁷ Sorbent trap breakage during recovery and subsequent loss of approximately 60% of the sorbent content of the backup section. Since capture of gaseous mercury occurs primarily in the front half of each section, the remainder of the backup section was recovered, analyzed and reported.

In addition to the sorbent trap breakage and autosampler malfunctions, the laboratory analysis of the sorbent faced issues as well. Table 3.6.1.2. shows the recoveries of the laboratory spikes and the certified reference materials (CRM). Recoveries of spikes range from 91% to 103% which is within the acceptable limits. However, the recovery from the NIST 1641d CRM range only between 82 and 105%. These percent recoveries fall outside of the allowed 90% – 110% range.

Table 3.6.1.2 Summary of the Laboratory Spike and CRM Recoveries

Sorbent Trap ID	Digestion Blanks ng/trap	MDL ¹ ng/trap	CRM ² (NIST 1641d) % Recovery	Laboratory Matrix Spike ³ % Recovery	Lab Matrix Duplicate RPD ⁴	Lab Matrix Spike Duplicate RPD
830	0.50	3.35	82.2%	101.6%	1.3%	0.4%
832, 833	2.70	1.93	83.3%	101.1%	6.6%	1.2%
838	0.14	0.42	96.7%	99.1%	0.6%	1.5%
839	2.70	1.93	83.3%	101.1%	6.6%	1.2%
828 ⁵	2.70	1.93	83.3%	100.4%	3.8%	6.5%
840, 841	0.10	0.09	103.0%	102.9%	7.1%	6.0%
842, 843, 844, 845	0.39	2.42	104.6%	91.4%	2.1%	10.6%

¹ Estimated Method Detection Limit (three times the standard deviation of successive digestion blank results)

² Certified Reference Material (CRM)

³ Average of duplicate analysis

⁴ Relative Percent Deviation (RPD)

⁵ Sorbent trap with spike in the main section (field spike)

Table 3.6.1.3 Sorbent Trap Breakthrough Performance

Start Date/ Start Time	Stop Date/ Stop Time	Backup Section Analysis (Breakthrough)				Paired Trap Agreement %RD
		Trap A ng	Trap B ng	Trap A % ⁷	Trap B % ⁷	
07/08/05 16:22	07/14/05 08:55	N/A ¹	1.94	N/A ¹	0.02%	N/A ¹
07/14/05 13:30	07/21/05 06:52	N/A ²	5.49	N/A ²	0.02%	N/A ²
07/21/05 10:09	07/28/05 10:30	3.89	N/A ³	0.01%	N/A ³	N/A ³
08/04/05 08:05	08/10/05 07:28	N/A ⁴	0.00	N/A ⁴	0.00%	N/A ⁴
08/10/05 09:51	08/17/05 07:35	0.00	0.24	0.00%	0.00%	N/A ⁵
08/17/05 16:30	08/22/05 09:53	0.28	0.12	0.00%	0.00%	0.34
08/22/05 12:50	08/29/05 09:49	1.01 ⁶	0.03	0.01% ⁶	0.00%	9.46
08/29/05 10:46	09/06/05 09:49	0.00	0.00	0.00%	0.00%	3.87

¹ Sorbent trap breakage during trap recovery

² Autosampler software malfunction and hardware failure

³ Autosampler hardware failure

⁴ Autosampler software malfunction

⁵ Sorbent trap with spike in the main section (field spike)

⁶ Sorbent trap breakage during recovery and subsequent loss of approximately 60% of the sorbent content of the backup section. Remainder of the backup section was recovered, analyzed and reported.

⁷ Percent recovery with respect to the main section.

Table 3.6.1.2 presents the analysis of the backup section of the sorbent traps as it relates to the comparison of the paired Method 324 sorbent traps. The high amount of trap breakage makes analysis difficult. However, where paired traps were available (August 17 through 8/29/2005 showed paired trap agreement of 0.34% to 9.46% were used.

The Method 324 plant personnel operations and maintenance summary contained herein includes only the major maintenance and operational events. The infrequent trips of the plant technicians up the stack in order to assess the system's state have not been included in this report, anticipating that future versions of sorbent trap-based monitoring equipment are enhanced with remote monitoring capabilities that make these trips redundant. In addition to the description and date of each major maintenance/operational event, Table 3.6.1.4 also includes an estimate of the duration of each event. Durations for logbook entries with missing time stamps were based on documented durations for similar tasks or time stamps of data files for subsequent sampling runs. Note that some time durations are not representative of the actual time spent to maintain or operate the system, since on several occasions plant personnel interrupted their tasks for several hours in order to devote their attention onto more pressing issues related to their daily duties.

Nevertheless, after working through most of the issues that plagued the sorbent trap monitoring system for the first five weeks of the program, the duration recorded for the operation and maintenance of the remainder of the program reflects the true effort for plant personnel. As such, when sampling sorbent traps on a weekly basis, the time spent on the sampling location is approximately 1-3 hours per week.

Table 3.6.1.4 Summary Log of Major Sorbent Trap Maintenance Events

Date	App. Duration	Description
07/08/05	1h Estimate (no logbook entry)	Sorbent trap pair installation (829 on sampler 68-324-1, 830 on sampler 68-324-2). Leak check and sampler startup. Samplers are configured for automatic flow control based on an externally provided 4-20mA stack flow signal.
07/11/05	0.5h Estimate based on data file entry	Both samplers performed automatic sampling shutdown since sample flow set point could not be reached. In addition, the 4-20mA source underwent a hardware malfunction, which resulted in the decision to switch to constant rate sampling in both sampling paths. Restart of sampling run.
07/14/05	3h Estimate based on log book entry	Leak check and sorbent trap recovery (trap 829 from sampler 68-324-1, trap 830 from sampler 68-324-2). Trap 829 broke upon removal. Cleansing of probe from glass debris and carbon remains. New sorbent trap pair installation (831 on sampler 68-324-1, 832 on sampler 68-324-2). Leak check and sampler startup.
07/19/05	1.25h Estimate based on log book entry	Autosampler 68-324-1 hung up. In addition, flow rate was uncontrolled (high) at the same sampler. Change of sampler 68-324-1 with 68-324-3. Condensate removal from condensate reservoir below chiller and desiccant exchange. Leak test of each sampling path and subsequent restart of sampling run.
07/21/05	3h Estimate based on log book entry	Leak check and sorbent trap recovery (trap 831 from sampler 68-324-3, trap 832 from sampler 68-324-2). Condensate removal, chiller maintenance and desiccant exchange. New sorbent trap pair installation (833 on sampler 68-324-3, 834 on sampler 68-324-2). Leak check and start of new sampling run.
07/28/05	3h Estimate (start time entry missing)	Leak check and sorbent trap recovery (trap 833 from sampler 68-324-3, trap 834 from sampler 68-324-2). Desiccant exchange. Technician noted that sampler 68-324-2 was not controlling the flow and had a very high sample flow rate. However, samplers were not exchanged. Instead, new sorbent trap pairs were installed (835 on sampler 68-324-3, 836 on sampler 68-324-2). Leak check and start of new sampling run.
08/02/05	1h Estimate (start time missing)	Technician observed uncontrolled high flow on sampler 68-324-3 in addition to 68-324-2. Removal of probe from stack and trouble shooting (leak checking). Exchange of sampler 68-324-3 with repaired sampler 68-324-1. Leak check and subsequent restart of sampling run.

Table 3.6.1.4 Summary Log of Major Sorbent Trap Maintenance Events (continued)

08/04/05	1.3h Estimate based on log book entry	Leak check and sorbent trap recovery (trap 835 from sampler 68-324-1, trap 836 from sampler 68-324-2). Desiccant exchange and chiller condensate removal. New sorbent trap pair installation (837 on sampler 68-324-1, 838 on sampler 68-324-2). O-Ring replacement on probe. Leak check and start of new sampling run.
08/08/05	1h Estimate (time entry missing)	Sampling run suspension. Desiccant exchange and chiller condensate removal. Leak check and restart of sampling run.
08/10/05	2h Estimate (time entry missing)	Leak check and sorbent trap recovery (trap 837 from sampler 68-324-1, trap 838 from sampler 68-324-2). Software malfunction on sampler 68-324-1. Exchange of sampler 68-324-1 with repaired 68-324-3. Desiccant exchange and chiller condensate removal. New sorbent trap pair installation (828 on sampler 68-324-3, 839 on sampler 68-324-2). Leak check and start of new sampling run.
08/17/05	2h Estimate (time entry missing)	Leak check and sorbent trap recovery (trap 828 from sampler 68-324-3, trap 839 from sampler 68-324-2). Desiccant exchange and chiller condensate removal. New sorbent trap pair installation (840 on sampler 68-324-3, 841 on sampler 68-324-2). Leak check and start of new sampling run.
08/22/05	3h Estimate based on time stamps of subsequent sampling files	Leak check and sorbent trap recovery (trap 840 from sampler 68-324-3, trap 841 from sampler 68-324-2). Desiccant exchange and chiller condensate removal. New sorbent trap pair installation (842 on sampler 68-324-3, 843 on sampler 68-324-2). Leak check and start of new sampling run.
08/29/05	1h Estimate based on time stamps of subsequent sampling files	Leak check and sorbent trap recovery (trap 842 from sampler 68-324-3, trap 843 from sampler 68-324-2). Breakage of sorbent trap 842. Loss of part of the backup section. Desiccant exchange and chiller condensate removal. New sorbent trap pair installation (844 on sampler 68-324-3, 845 on sampler 68-324-2). Leak check and start of new sampling run.
09/06/05	1h Estimate (time entry missing)	Leak check and sorbent trap recovery (trap 844 from sampler 68-324-3, trap 845 from sampler 68-324-2).

3.6.2 Horiba DM-6 CEMS Operation and Maintenance

Horiba CEMS maintenance report summary in Table 3.6.2.1 is based on the plant technician's logbook notes as well as service technician site visit reports.

Table 3.6.2.1 Summary Log of Major Hg-CEMS Maintenance Events

Date	App. Duration	Description
07/08/05	4h	<ul style="list-style-type: none"> • Catalyst and dust filter exchange at probe. • Replenishment of de-ionized water at the system probe. • System span calibration. New calibration factor: 0.9818.
07/14/05	1h	<ul style="list-style-type: none"> • System span calibration. New calibration factor: 1.0182.
07/21/05	1h	<ul style="list-style-type: none"> • Calibration attempt. Aborted due to use of wrong system mode.
07/22/05	1h	<ul style="list-style-type: none"> • Calibration setup maintenance. • Span calibration. New calibration factor: 1.0000.
07/25/05	0.5h	<ul style="list-style-type: none"> • Laptop failure due to disconnected power supply. Restart of Laptop.
07/26/05	2h	<ul style="list-style-type: none"> • Change of cal gas regulator. • System span calibration. New calibration factor: 1.0545.
08/02/05	2h	<ul style="list-style-type: none"> • System span calibration. New calibration factor: 0.7091.
08/09/05	1h	<ul style="list-style-type: none"> • System span calibration. New calibration factor: 0.9045.
08/17/05	4h	<ul style="list-style-type: none"> • Catalyst and dust filter exchange at probe. • Installation of Teflon (PFA) flowmeter / regulator at cal gas cylinder. • System span calibration. New calibration factor: 0.8181.
08/23/05	1h	<ul style="list-style-type: none"> • System span calibration. New calibration factor: 0.8000. • Replenishment of de-ionized water at the detector.
08/31/05	1h	<ul style="list-style-type: none"> • Unsuccessful calibration attempt. Calibration factor remains the same (0.8000) • Excessive zero drift observed during baseline adjust before span cal.
09/02/05	0.5h	<ul style="list-style-type: none"> • Setting Laptop time to match plant time.
09/07/05	2h	<ul style="list-style-type: none"> • System span calibration. New calibration factor: 0.9818. • Excessive zero drift observed during baseline adjust before span cal.
09/28/05	1.5h	<ul style="list-style-type: none"> • Catalyst and dust filter exchange at probe. • Discovery of brown residue in Teflon calibration T-coupling. Cleansing of coupling.
09/29/05	1h	<ul style="list-style-type: none"> • System span calibration. New calibration factor: 0.8181.
10/12/05	5h	<ul style="list-style-type: none"> • Extensive system maintenance: <ul style="list-style-type: none"> ○ Sample line leak check ○ Removal of probe from stack and cleansing of probe liner (deposits along the inside of the 10 feet liner) ○ Cleansing of Teflon calibration T-coupling from black residue. ○ Catalyst and dust filter exchange (new-style catalyst) ○ Replenishment of de-ionized water at probe • System span calibration. New cal factor: 0.8909 • Zero gas response check. $< 1 \mu\text{g}/\text{m}^3$

Table 3.6.2.1 Summary Log of Major Sorbent Trap Maintenance Events(continued)

10/27/05	1h	<ul style="list-style-type: none"> • Catalyst (original-style catalyst)
10/28/05	1h	<ul style="list-style-type: none"> • System span calibration. New cal factor: 1.2182
11/01/05	1.5h	<ul style="list-style-type: none"> • System span calibration. New cal factor: 1.2727
11/14/05	1h	<ul style="list-style-type: none"> • System span calibration. New cal factor: 0.9091
11/17/05	1.5h	<ul style="list-style-type: none"> • Horiba stopped due to ‘Probe Error’ (possibly due to freezing of condensate in some part of the probe). Restart and system span calibration. New cal factor: 0.9091
11/18/05	3h	<ul style="list-style-type: none"> • Maintenance at probe to remove condensate from probe liner. • Horiba stopped due to ‘Probe Error’ possibly due to freezing of condensate in some part of the probe, which is supported by a considerable vacuum pressure.
11/21/05	1h	<ul style="list-style-type: none"> • Troubleshooting
11/23/05	0.5h	<ul style="list-style-type: none"> • Erratic measurements with high vacuum pressure. • Shutdown of analyzer for preventive maintenance. • Preventive maintenance <ul style="list-style-type: none"> ○ Inspection and cleansing of probe liner and Teflon cal T-coupling from brown deposits and condensate.
12/01/05	4h	<ul style="list-style-type: none"> ○ Disassembly of dust filter (noticing water stains) ○ Maintenance of heated sample line ○ Additional insulation of probe penetrating the stack annulus as well as unheated sample line portion within the probe housing in order to prevent further formation and freezing of condensate.
12/02/05	0.5h	<ul style="list-style-type: none"> • System span calibration. New cal factor: 1.0727
12/09/05	0.5h	<ul style="list-style-type: none"> • System span calibration. New cal factor: 1.1273
12/16/05	0.5h	<ul style="list-style-type: none"> • System span calibration. New cal factor: 1.0000

Once again, only major maintenance and operational events are listed here. The infrequent trips of the plant technician up the stack and to the CEM shelter to visually assess state of the system components have not been included in this report. In addition to the description and date of each major maintenance/operational event, Table 3.6.2.1 also includes an estimate of the duration of each maintenance event. Durations for logbook entries with missing time stamps were based on documented durations for similar tasks as well as the judgment of the authors aiming to be as conservative as possible in the time estimate.

For reference to the reader, typical maintenance duties included the changing of the catalyst (Figure 3.6.2.1) and the changing of the filters depicted in Figure 3.6.2.2).

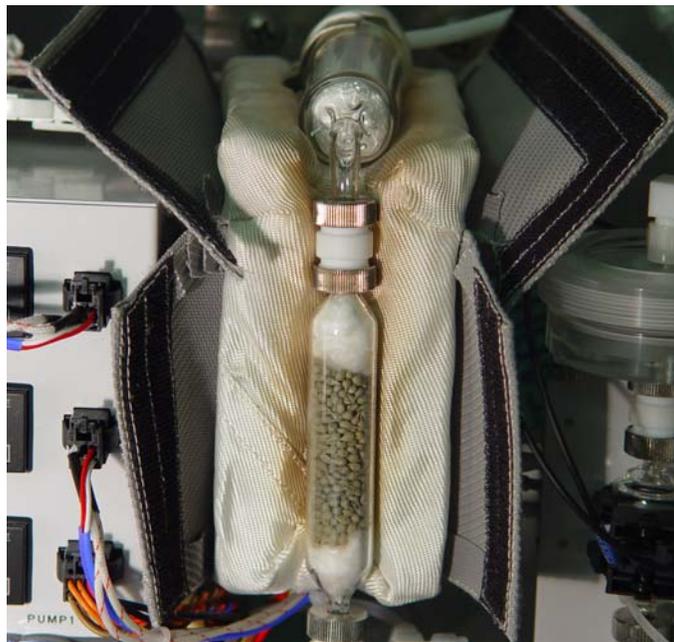
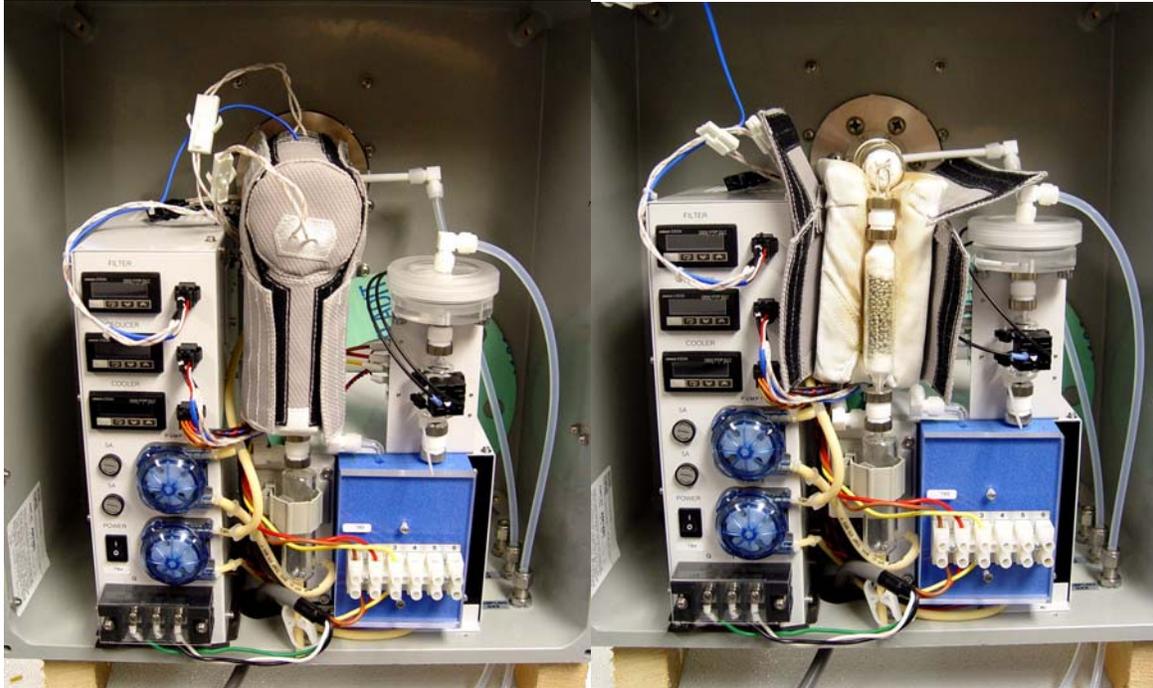


Figure 3.6.2.1 Photograph sequence of the changing of Horiba CEM catalysts

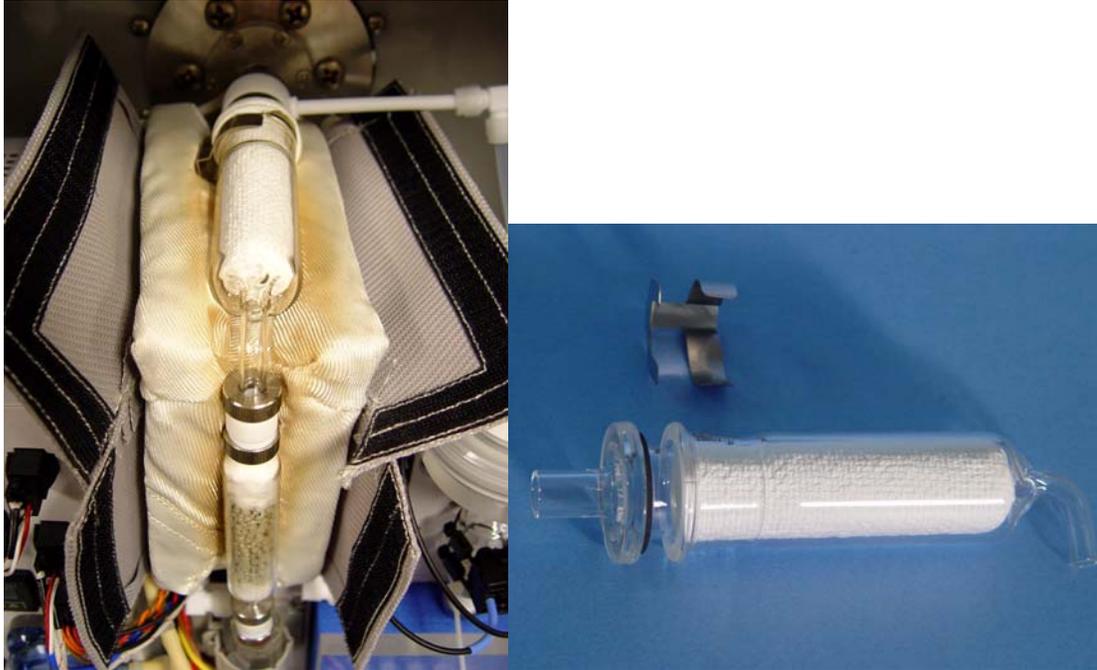


Figure 3.6.2.2 Photographs of changing of the filter

As can be seen earlier in Tables 3.6.2.1. the mercury Horiba CEM suffered from several shortcomings affecting the Horiba CEMS performance in various ways.

Buildup of fly ash / particulate matter in the probe and filter.

The stack platform geometry required the use of a rather long (10 feet) probe with large internal diameter of the probe stinger. It is conceivable that particulate buildup along the stinger wall as well as in the particulate filter adsorbed mercury contained in the flue gas causing a consistently low bias of the Horiba CEM readings.

Catalyst deactivation.

The catalyst in use to convert all oxidized forms of mercury to their elemental state underwent a rather rapid deactivation with an average life expectancy of approximately 2 – 3 weeks per catalyst. The reasons for this rapid deactivation are unknown. As a result, the CEM mercury readings dropped slowly over the course of 2 – 3 weeks subsequent to its installation. This can be seen in particular during the use of the first catalyst (07/08/05 - 08/17/05), which was kept installed over a longer period of time in order to assess the lifetime of a catalyst for the subsequent monitoring part of the program.

Cold spots / condensation in the probe.

As can be seen in the maintenance record, at several instances condensation was observed in several parts of the probe, in particular in the initially unheated / not-insulated calibration tee

coupling. This became of particular concern during the colder months of the monitoring part of the project and may have resulted in the scrubbing of mercury from the sample gas stream. Eventually, the probe penetrating the annulus as well as the unheated calibration tee coupling was insulated to prevent further condensation.

Freezing of condensate in probe.

On several occasions during the colder months of the year the condensate originating from the Peltier cooler removing moisture from the sample gas froze in the cooler. This led to blockage of the sampling path and eventually to an automatic suspension of the sampling activity via the Horiba CEM controller.

4.0 SUMMARY AND CONCLUSIONS

Western Research Institute (WRI), in conjunction with Western Farmers Electric Cooperative (WFEC, has teamed with Clean Air Engineering of Pittsburgh, PA to conduct a mercury monitoring program at the WEFC Hugo plant in Oklahoma. This research effort had five objectives: (1) determine the mass balance of mercury for subbituminous coal-fired power plant; (2) assess the distribution of mercury species in the flue gas (3) perform a comparison of three different Hg test methods; (4) investigate the long-term (six months) mercury variability at a subbituminous coal-fired power plant; and (5) assess operation and maintenance of the Method 324 and Horiba CEMS utilizing plant personnel.

4.1. Mercury Mass Balance

In order to establish the Hg mass balance across the plant, the rate of Hg entering the plant was compared to the rate of Hg leaving the plant. Mercury testing and analysis was performed on process samples, (coal, coal pyrite rejects, fly ash, and bottom ash), as well as the flue gas at the facility's boiler exhaust stack and electrostatic precipitator (ESP) inlet (1 of 4 inlets) over a two day period of July 6 and 7, 2005. Flue gas sampling was performed using co-located, Ontario-Hydro or OH, (ASTM D6784-02) test trains at the facilities boiler exhaust stack as well as paired OH trains at one of the four inlets to the ESP. Hg concentrations and other flue gas characteristics were assumed the same for each ESP inlet. The three 2-hour Ontario-Hydro test runs indicated 93.8% total mercury closure across the ESP and 95.6% overall mass balance closure.

4.2 Mercury Species Distribution.

Mercury speciation testing of showed 89.5% elemental Hg, 8.0% oxidized Hg and 2.5% particulate bound Hg at the inlet of the ESP and 75.7% elemental Hg, and 23.3% oxidized Hg at the stack. The Hg speciation results across the ESP can be seen in Figure 3.4.5. As expected, nearly all of the Hg^{PB} is removed across the ESP. Since Hg^{PB} constitutes only a minor fraction

of the Hg^{T} present in the flue gas, there is little removal of Hg^{T} across the ESP. Also evident is the oxidation of some of the Hg^0 to Hg^{2+} .

4.3 Inter-Methods Comparison

Three different mercury test methods were concurrently performed and compared, including: Hg continuous emissions monitoring system (Horiba Hg-CEMS), former dry sorbent-tube based USEPA Method 324, and Ontario Hydro (OH) test method (ASTM D6784-02). In order to compare the results of different methods of measuring Hg concentrations in the flue gas, nine consecutive co-located Ontario-Hydro runs and Method 324 runs (with co-located sorbent tubes) were performed simultaneously at the stack, while corresponding Horiba DM-6 mercury continuous emissions monitoring system using a vapor phase mercury monitor was used to monitor the Hg emissions in the flue gas at Hugo's exhaust stack. Testing was performed over the period of June 29-30 and July 6-7, 2005. In summary, the results include:

- All paired Ontario-Hydro sampling method test runs passed the minimum performance criteria for paired RM tests according to Performance Specification 12A (RD less than 10% for total gaseous Hg concentrations greater than $1.0 \mu\text{g}/\text{m}^3$). Particulate-bound Hg was negligible (non-detected).
- All Method 324 data pairs had a relative deviation (RD) of less than 5%. A field spike was recovered to 90% (80-120% limit).
- The relative accuracy (RA) of Method 324 with respect to Ontario-Hydro as reference method result was 10.4% (20.00% limit) with an absolute difference of $0.46 \mu\text{g}/\text{m}^3$ (limit of $1 \mu\text{g}/\text{m}^3$). As such, the Method 324 data passed the RATA.
- During the first week of testing, (June 29 and 30), the Horiba DM-6 Hg CEMS used at the stack provided data comparable to those obtained using the Ontario-Hydro and sorbent-based sampling method (10-22% lower with Run 2 not included).
- The relative accuracy of the Horiba DM-6-6 CEMS data showed a relative accuracy of 64.8% (limit of 20%) relative to the OH as the reference method and an absolute difference of $2.98 \mu\text{g}/\text{m}^3$ (limit of $1 \mu\text{g}/\text{m}^3$). As such, the Horiba DM-6 data does not pass the RATA.

Additional method comparisons continued over the first two months of the program using both Method 324 sorbent tubes and the Horiba Hg-CEMS. The sorbent tubes continued with weekly switch out of sorbent tubes. The mercury content of the coal, fly ash and bottom ash was also monitored over this period.

4.4 Long-Term Hg Monitoring Method Operation and Maintenance Record

Plant personnel were trained on site on the use, care and maintenance of the sorbent tube sampling equipment and Hg-CEMS. The Horiba DM-6 Hg-CEMS and Method 324 sorbent tubes were maintained by plant personnel over a six month period.

There were several Method 324 auto-sampler hardware and software, as well as sorbent trap recovery issues during the program. As a result, only one sorbent trap of each pair could be recovered successfully for the first five weeks. Nevertheless, after working through most of the issues that plagued the sorbent trap monitoring system for the first five weeks of the program, the operation and maintenance of the Method 324 sorbent traps when sampling sorbent traps on a weekly basis, required approximately 1-3 hours per week.

Maintenance of the Hg-CEMS included weekly calibration checks as well as daily inspections to ensure continued sampling. The six-month period covered emissions from June 24, 2005 until December 20, 2005. This included calibration checks and routine catalyst and filter replacements. The following Horiba DM-6 CEMS maintenance issues were observed.

- **Buildup of fly ash / particulate matter in the probe and filter.** The stack platform geometry required the use of a rather long (10 feet) probe with large internal diameter of the probe stinger. It is conceivable that particulate buildup along the stinger wall as well as in the particulate filter adsorbed mercury contained in the flue gas causing a consistently low bias of the Horiba CEM readings.
- **Catalyst deactivation.** The catalyst used to convert all oxidized forms of mercury to their elemental state underwent a rather rapid deactivation with an average life expectancy of approximately 2-3 weeks per catalyst. As a result, the CEM mercury readings dropped slowly over the course of 2-3 weeks subsequent to its installation.
- **Cold spots / condensation in the probe.** Condensation was observed in several parts of the probe, in particular in the initially unheated / not-insulated calibration tee coupling. This became of particular concern during the colder months of the monitoring part of the project and may have resulted in the scrubbing of mercury from the sample gas stream.
- **Freezing of condensate in probe.** On several occasions during the colder months of the year the condensate originating from the Peltier cooler removing moisture from the sample gas froze in the cooler. This led to blockage of the sampling path and eventually to an automatic suspension of the sampling activity via the Horiba CEM controller.

In summary, although mercury emissions monitoring techniques are progressing to be able to meet the regulatory needs of the promulgated CAMR rules, there is room for improvement of Hg CEMS both in performance and in maintenance and operation by plant personnel.

APPENDIX A

Ontario Hydro Run Data

APPENDIX A CONTENTS

- A-1 Ontario-Hydro Data**
- A-2 Ontario Hydro Mercury Species Balance**
- A-3 Ontario Hydro Mass Balance Calculations**
- A-4 Method 324 Data**
- A-5 Method 324 RATA**
- A-6 Method 324 QA/QC Description**
- A-7 Horiba DM-6 CEMS RATA**

A-1-1

Unit 1 ESP Inlet (B-West duct) – Ontario-Hydro, Runs 2A-4A

Run No.		2A	3A	4A	Average
Date (2005)		Jul 6	Jul 7	Jul 7	
Start Time (approx.)		13:30	09:32	12:40	
Stop Time (approx.)		16:07	11:56	15:37	
Process Conditions					
R _p	Coal Flow - (Ton/hour)	286	286	286	286
P ₁	Load Level - (MW)	459	459	458	458
F _c	Carbon dioxide-based F-factor (dscf/MMBtu)	1,800	1,800	1,800	1,800
Gas Conditions					
O ₂	Oxygen (dry volume %)	7.6	7.8	7.4	7.6
CO ₂	Carbon dioxide (dry volume %)	12.2	11.8	12.0	12.0
T _s	Sample temperature (°F)	331	324	328	328
B _w	Actual water vapor in gas (% by volume)	11.94	12.15	11.33	11.80
Gas Flow Rate					
Q _s	Volumetric flow rate, standard (scfm)	374,271	371,863	371,753	372,629
Q _{std}	Volumetric flow rate, dry standard (dscfm)	329,586	326,693	329,647	328,642
Total Mercury Results					
C _{sd}	Concentration (µg/dscm)	7.22	6.98	7.55	7.25
E _{lb/yr}	Rate (lb/yr)	78.11	74.86	81.67	78.22
E _{Fc}	Rate - Fc-based (lb/TBtu)	6.65	6.65	7.07	6.79
Particulate Bound Mercury Results					
C _{sd}	Concentration (µg/dscm)	0.181	0.206	0.212	0.199
E _{lb/yr}	Rate (lb/yr)	1.95	2.21	2.29	2.15
E _{Fc}	Rate - Fc-based (lb/TBtu)	0.166	0.196	0.198	0.187
Oxidized Mercury Results					
C _{sd}	Concentration (µg/dscm)	0.579	0.574	0.535	0.563
E _{lb/yr}	Rate (lb/yr)	6.27	6.15	5.79	6.07
E _{Fc}	Rate - Fc-based (lb/TBtu)	0.534	0.547	0.502	0.527
Elemental Mercury Results					
C _{sd}	Concentration (µg/dscm)	6.46	6.20	6.80	6.49
E _{lb/yr}	Rate (lb/yr)	69.89	66.50	73.59	69.99
E _{Fc}	Rate - Fc-based (lb/TBtu)	5.95	5.91	6.37	6.08
Total Gaseous Results					
C _{sd}	Concentration (µg/dscm)	7.04	6.78	7.34	7.05
E _{lb/yr}	Rate (lb/yr)	76.16	72.65	79.38	76.06
E _{Fc}	Rate - Fc-based (lb/TBtu)	6.49	6.45	6.87	6.60

Averages includes 3 runs.

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Unit 1 ESP Inlet (B-West duct) – Ontario-Hydro, Runs 2B-4B

Run No.		2B	3B	4B	Average
Date (2005)		Jul 6	Jul 7	Jul 7	
Start Time (approx.)		13:30	09:31	12:40	
Stop Time (approx.)		16:07	11:56	15:36	
Process Conditions					
R _p	Coal Flow - (Ton/hour)	286	286	286	286
P ₁	Load Level - (MW)	459	459	458	458
F _c	Carbon dioxide-based F-factor (dscf/MMBtu)	1,800	1,800	1,800	1,800
Gas Conditions					
O ₂	Oxygen (dry volume %)	7.4	7.8	7.6	7.6
CO ₂	Carbon dioxide (dry volume %)	12.2	11.8	12.0	12.0
T _s	Sample temperature (°F)	329	321	326	325
B _w	Actual water vapor in gas (% by volume)	11.61	12.07	11.34	11.67
Gas Flow Rate					
Q _s	Volumetric flow rate, standard (scfm)	372,560	374,220	373,537	373,439
Q _{std}	Volumetric flow rate, dry standard (dscfm)	329,295	329,048	331,178	329,841
Total Mercury Results					
C _{sd}	Concentration (µg/dscm)	7.15	7.43	6.88	7.16
E _{lb/yr}	Rate (lb/yr)	77.32	80.29	74.77	77.46
E _{Fc}	Rate - Fc-based (lb/TBtu)	6.59	7.08	6.44	6.71
Particulate Bound Mercury Results					
C _{sd}	Concentration (µg/dscm)	0.155	0.185	0.141	0.160
E _{lb/yr}	Rate (lb/yr)	1.68	1.99	1.54	1.74
E _{Fc}	Rate - Fc-based (lb/TBtu)	0.143	0.176	0.133	0.150
Oxidized Mercury Results					
C _{sd}	Concentration (µg/dscm)	0.577	0.763	0.449	0.596
E _{lb/yr}	Rate (lb/yr)	6.23	8.24	4.88	6.45
E _{Fc}	Rate - Fc-based (lb/TBtu)	0.531	0.727	0.421	0.560
Elemental Mercury Results					
C _{sd}	Concentration (µg/dscm)	6.42	6.49	6.29	6.40
E _{lb/yr}	Rate (lb/yr)	69.41	70.05	68.35	69.27
E _{Fc}	Rate - Fc-based (lb/TBtu)	5.92	6.18	5.89	6.00
Total Gaseous Results					
C _{sd}	Concentration (µg/dscm)	7.00	7.25	6.74	7.00
E _{lb/yr}	Rate (lb/yr)	75.65	78.29	73.23	75.72
E _{Fc}	Rate - Fc-based (lb/TBtu)	6.45	6.91	6.31	6.55

Averages include 3 runs.

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A-1-3

Unit 1 Stack – Ontario-Hydro, Runs 1A-3A

Run No.	1A	2A	3A	Average
Date (2005)	Jun 29	Jun 29	Jun 29	
Start Time (approx.)	08:51	11:51	15:26	
Stop Time (approx.)	10:51	13:51	17:26	
Process Conditions				
R _p Coal Flow - (Ton/hour)	217	215	219	217
P ₁ Load Level - (MW)	355	355	359	356
F _c Carbon dioxide-based F-factor (dscf/MMBtu)	1,800	1,800	1,800	1,800
Gas Conditions				
O ₂ Oxygen (dry volume %)	7.8000	7.6000	8.2000	7.8667
CO ₂ Carbon dioxide (dry volume %)	11.8000	11.7000	11.2000	11.5667
T _s Sample temperature (°F)	292.8750	295.9167	299.3750	296.0556
B _w Actual water vapor in gas (% by volume)	11.3566	10.7201	10.8852	10.9873
Gas Flow Rate				
Q _s Volumetric flow rate, standard (scfm)	1,296,884	1,296,468	1,318,327	1,303,893
Q _{std} Volumetric flow rate, dry standard (dscfm)	1,149,602	1,157,485	1,174,825	1,160,637
Q _{std7} Volumetric flow rate, dry std@7%O ₂ (dscfm)	1,083,438	1,107,522	1,073,401	1,088,120
Total Mercury Results				
C _{sd} Concentration (µg/dscm)	7.4990	11.5312	6.7407	8.5903
E _{T/yr} Rate (lb/yr)	282.9535	438.0830	259.9213	326.9859
E _{Rp} Rate - Production-based (lb/Ton-coal)	1.485E-04	2.321E-04	1.355E-04	1.720E-04
E _{Fc} Rate - Fc-based (lb/TBtu)	7.1434	11.0783	6.7650	8.3289
Particulate Bound Mercury Results				
C _{sd} Concentration (µg/dscm)	<4.645E-03	<4.619E-03	<4.600E-03	<4.621E-03
E _{T/yr} Rate (lb/yr)	<1.753E-01	<1.755E-01	<1.774E-01	<1.760E-01
E _{Rp} Rate - Production-based (lb/Ton-coal)	<9.200E-08	<9.299E-08	<9.245E-08	<9.248E-08
E _{Fc} Rate - Fc-based (lb/TBtu)	<4.425E-03	<4.438E-03	<4.617E-03	<4.493E-03
Oxidized Mercury Results				
C _{sd} Concentration (µg/dscm)	1.7326	4.9887	1.7710	2.8308
E _{T/yr} Rate (lb/yr)	65.3758	189.5259	68.2890	107.7303
E _{Rp} Rate - Production-based (lb/Ton-coal)	3.431E-05	1.004E-04	3.559E-05	5.678E-05
E _{Fc} Rate - Fc-based (lb/TBtu)	1.6505	4.7927	1.7774	2.7402
Elemental Mercury Results				
C _{sd} Concentration (µg/dscm)	5.7663	6.5425	4.9697	5.7595
E _{T/yr} Rate (lb/yr)	217.5778	248.5571	191.6322	219.2557
E _{Rp} Rate - Production-based (lb/Ton-coal)	1.142E-04	1.317E-04	9.988E-05	1.153E-04
E _{Fc} Rate - Fc-based (lb/TBtu)	5.4929	6.2855	4.9876	5.5887

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A-1-4

Unit 1 Stack – Ontario-Hydro, Runs 4A-7A

Run No.	4A	5A	7A	Average
Date (2005)	Jun 30	Jun 30	Jul 6	
Start Time (approx.)	09:30	12:40	13:30	
Stop Time (approx.)	11:30	14:40	16:03	
Process Conditions				
R _p Coal Flow - (Ton/hour)	N/A	N/A	286	286
P ₁ Load Level - (MW)	N/A	N/A	459	459
F _c Carbon dioxide-based F-factor (dscf/MMBtu)	1,800	1,800	1,800	1,800
Gas Conditions				
O ₂ Oxygen (dry volume %)	7.9333	8.0000	8.0000	7.9778
CO ₂ Carbon dioxide (dry volume %)	11.2333	11.4000	11.6000	11.4111
T _s Sample temperature (°F)	294.8750	318.6250	331.7083	315.0694
B _w Actual water vapor in gas (% by volume)	11.0605	11.4806	11.6553	11.3988
Gas Flow Rate				
Q _s Volumetric flow rate, standard (scfm)	1,351,935	1,505,688	1,473,871	1,443,832
Q _{std} Volumetric flow rate, dry standard (dscfm)	1,202,404	1,332,827	1,302,088	1,279,106
Q _{std7} Volumetric flow rate, dry std@7%O ₂ (dscfm)	1,121,667	1,236,940	1,208,412	1,189,006
Total Mercury Results				
C _{sd} Concentration (µg/dscm)	7.2038	6.5638	6.5017	6.7564
E _{T/yr} Rate (lb/yr)	284.3018	287.1413	277.8634	283.1021
E _{Rp} Rate - Production-based (lb/Ton-coal)	N/A	N/A	1.109E-04	1.109E-04
E _{Fc} Rate - Fc-based (lb/TBtu)	7.2084	6.4719	6.3001	6.6602
Particulate Bound Mercury Results				
C _{sd} Concentration (µg/dscm)	<4.440E-03	<4.467E-03	<4.666E-03	<4.524E-03
E _{T/yr} Rate (lb/yr)	<1.752E-01	<1.954E-01	<1.994E-01	<1.900E-01
E _{Rp} Rate - Production-based (lb/Ton-coal)	N/A	N/A	<7.956E-08	<7.956E-08
E _{Fc} Rate - Fc-based (lb/TBtu)	<4.443E-03	<4.405E-03	<4.521E-03	<4.456E-03
Oxidized Mercury Results				
C _{sd} Concentration (µg/dscm)	1.7939	1.7958	1.3765	1.6554
E _{T/yr} Rate (lb/yr)	70.7957	78.5572	58.8278	69.3936
E _{Rp} Rate - Production-based (lb/Ton-coal)	N/A	N/A	2.347E-05	2.347E-05
E _{Fc} Rate - Fc-based (lb/TBtu)	1.7950	1.7706	1.3338	1.6332
Elemental Mercury Results				
C _{sd} Concentration (µg/dscm)	5.4100	4.7681	5.1252	5.1011
E _{T/yr} Rate (lb/yr)	213.5060	208.5840	219.0356	213.7086
E _{Rp} Rate - Production-based (lb/Ton-coal)	N/A	N/A	8.739E-05	8.739E-05
E _{Fc} Rate - Fc-based (lb/TBtu)	5.4134	4.7013	4.9663	5.0270

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Unit 1 Stack – Ontario-Hydro, Runs 8A-10A

Run No.	8A	9A	10A	Average
Date (2005)	Jul 7	Jul 7	Jul 7	
Start Time (approx.)	09:31	12:40	16:52	
Stop Time (approx.)	11:52	15:34	18:52	
Process Conditions				
R _p Coal Flow - (Ton/hour)	286	286	285	286
P ₁ Load Level - (MW)	458	458	456	458
F _c Carbon dioxide-based F-factor (dscf/MMBtu)	1,800	1,800	1,800	1,800
Gas Conditions				
O ₂ Oxygen (dry volume %)	8.2000	8.4000	8.0000	8.2000
CO ₂ Carbon dioxide (dry volume %)	11.2000	11.4000	11.2000	11.2667
T _s Sample temperature (°F)	323.6250	330.2083	334.2917	329.3750
B _w Actual water vapor in gas (% by volume)	12.0935	12.0237	11.5306	11.8826
Gas Flow Rate				
Q _s Volumetric flow rate, standard (scfm)	1,457,525	1,470,029	1,546,707	1,491,421
Q _{std} Volumetric flow rate, dry standard (dscfm)	1,281,260	1,293,277	1,368,362	1,314,300
Q _{std7} Volumetric flow rate, dry std@7%O ₂ (dscfm)	1,170,648	1,163,019	1,269,918	1,201,195
Total Mercury Results				
C _{sd} Concentration (µg/dscm)	7.1638	6.6338	7.0491	6.9489
E _{T/yr} Rate (lb/yr)	301.2631	281.5918	316.5947	299.8165
E _{Rp} Rate - Production-based (lb/Ton-coal)	1.201E-04	1.125E-04	1.269E-04	1.198E-04
E _{Fc} Rate - Fc-based (lb/TBtu)	7.1897	6.5409	7.0746	6.9351
Particulate Bound Mercury Results				
C _{sd} Concentration (µg/dscm)	<4.778E-03	<4.720E-03	<4.460E-03	<4.653E-03
E _{T/yr} Rate (lb/yr)	<2.009E-01	<2.004E-01	<2.003E-01	<2.005E-01
E _{Rp} Rate - Production-based (lb/Ton-coal)	<8.008E-08	<8.007E-08	<8.027E-08	<8.014E-08
E _{Fc} Rate - Fc-based (lb/TBtu)	<4.795E-03	<4.654E-03	<4.477E-03	<4.642E-03
Oxidized Mercury Results				
C _{sd} Concentration (µg/dscm)	1.9398	1.5010	1.4496	1.6302
E _{T/yr} Rate (lb/yr)	81.5754	63.7165	65.1065	70.1328
E _{Rp} Rate - Production-based (lb/Ton-coal)	3.251E-05	2.546E-05	2.609E-05	2.802E-05
E _{Fc} Rate - Fc-based (lb/TBtu)	1.9468	1.4800	1.4549	1.6272
Elemental Mercury Results				
C _{sd} Concentration (µg/dscm)	5.2240	5.1328	5.5995	5.3188
E _{T/yr} Rate (lb/yr)	219.6878	217.8753	251.4882	229.6838
E _{Rp} Rate - Production-based (lb/Ton-coal)	8.756E-05	8.707E-05	1.008E-04	9.180E-05
E _{Fc} Rate - Fc-based (lb/TBtu)	5.2429	5.0609	5.6197	5.3078

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Unit 1 Stack – Ontario-Hydro, Runs 1B-3B

Run No.		1B	2B	3B	Average
Date (2005)		Jun 29	Jun 29	Jun 29	
Start Time (approx.)		08:51	11:51	15:26	
Stop Time (approx.)		10:51	13:51	17:26	
Process Conditions					
R _p	Coal Flow - (Ton/hour)	217	215	219	217
P ₃	Load Level - (MW)	355	355	359	356
F _c	Carbon dioxide-based F-factor (dscf/MMBtu)	1,800	1,800	1,800	1,800
Gas Conditions					
O ₂	Oxygen (dry volume %)	7.6000	7.6667	8.0000	7.7556
CO ₂	Carbon dioxide (dry volume %)	12.0000	11.6333	11.4000	11.6778
T _s	Sample temperature (°F)	293.0417	296.2500	300.0000	296.4306
B _w	Actual water vapor in gas (% by volume)	10.9849	10.7215	10.7846	10.8303
Gas Flow Rate					
Q _s	Volumetric flow rate, standard (scfm)	1,295,242	1,296,346	1,317,017	1,302,868
Q _{std}	Volumetric flow rate, dry standard (dscfm)	1,152,961	1,157,358	1,174,982	1,161,767
Q _{std7}	Volumetric flow rate, dry std@7%O ₂ (dscfm)	1,103,193	1,101,849	1,090,451	1,098,498
Total Mercury Results					
C _{sd}	Concentration (µg/dscm)	6.8606	10.8564	8.2047	8.6406
E _{T/yr}	Rate (lb/yr)	259.6245	412.4023	316.4174	329.4814
E _{Rp}	Rate - Production-based (lb/Ton-coal)	1.363E-04	2.185E-04	1.649E-04	1.732E-04
E _{Fc}	Rate - Fc-based (lb/TBtu)	6.4264	10.4898	8.0899	8.3353
Particulate Bound Mercury Results					
C _{sd}	Concentration (µg/dscm)	<4.483E-03	<4.513E-03	<4.627E-03	<4.541E-03
E _{T/yr}	Rate (lb/yr)	<1.696E-01	<1.714E-01	<1.784E-01	<1.732E-01
E _{Rp}	Rate - Production-based (lb/Ton-coal)	<8.904E-08	<9.085E-08	<9.299E-08	<9.096E-08
E _{Fc}	Rate - Fc-based (lb/TBtu)	<4.199E-03	<4.361E-03	<4.562E-03	<4.374E-03
Oxidized Mercury Results					
C _{sd}	Concentration (µg/dscm)	1.6990	1.8099	3.2849	2.2646
E _{T/yr}	Rate (lb/yr)	64.2961	68.7513	126.6822	86.5765
E _{Rp}	Rate - Production-based (lb/Ton-coal)	3.375E-05	3.643E-05	6.603E-05	4.540E-05
E _{Fc}	Rate - Fc-based (lb/TBtu)	1.5915	1.7487	3.2389	2.1930
Elemental Mercury Results					
C _{sd}	Concentration (µg/dscm)	5.1616	9.0466	4.9198	6.3760
E _{T/yr}	Rate (lb/yr)	195.3285	343.6510	189.7351	242.9049
E _{Rp}	Rate - Production-based (lb/Ton-coal)	1.025E-04	1.821E-04	9.889E-05	1.278E-04
E _{Fc}	Rate - Fc-based (lb/TBtu)	4.8349	8.7410	4.8510	6.1423

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Unit 1 Stack – Ontario-Hydro, Runs 4B-7B

Run No.	4B	5B	7B	Average
Date (2005)	Jun 30	Jun 30	Jul 6	
Start Time (approx.)	09:30	12:40	13:30	
Stop Time (approx.)	11:30	14:40	16:03	
Process Conditions				
R _p Coal Flow - (Ton/hour)	N/A	N/A	286	286
P ₁ Load Level - (MW)	N/A	N/A	459	459
F _c Carbon dioxide-based F-factor (dscf/MMBtu)	1,800	1,800	1,800	1,800
Gas Conditions				
O ₂ Oxygen (dry volume %)	8.0000	8.0000	8.0000	8.0000
CO ₂ Carbon dioxide (dry volume %)	11.0667	11.4000	11.6000	11.3556
T _s Sample temperature (°F)	294.7917	319.1250	331.8333	315.2500
B _w Actual water vapor in gas (% by volume)	10.9586	11.4339	11.7754	11.3893
Gas Flow Rate				
Q _s Volumetric flow rate, standard (scfm)	1,352,222	1,505,057	1,474,512	1,443,930
Q _{std} Volumetric flow rate, dry standard (dscfm)	1,204,037	1,332,969	1,300,882	1,279,296
Q _{std7} Volumetric flow rate, dry std@7%O ₂ (dscfm)	1,117,416	1,237,072	1,207,293	1,187,260
Total Mercury Results				
C _{sd} Concentration (µg/dscm)	6.8466	6.6756	6.5956	6.7059
E _{T/yr} Rate (Ton/yr)	270.5707	292.0620	281.6162	281.4163
E _{RP} Rate - Production-based (lb/Ton-coal)	N/A	N/A	1.124E-04	1.124E-04
E _{FC} Rate - Fc-based (lb/TBtu)	6.9541	6.5821	6.3911	6.6425
Particulate Bound Mercury Results				
C _{sd} Concentration (µg/dscm)	<4.413E-03	<4.408E-03	0.0027	<3.838E-03
E _{T/yr} Rate (lb/yr)	<1.744E-01	<1.929E-01	0.1150	<1.608E-01
E _{RP} Rate - Production-based (lb/Ton-coal)	N/A	N/A	4.589E-08	4.589E-08
E _{FC} Rate - Fc-based (lb/TBtu)	<4.483E-03	<4.346E-03	0.0026	<2.073E-03
Oxidized Mercury Results				
C _{sd} Concentration (µg/dscm)	1.8315	1.8514	1.4727	1.7185
E _{T/yr} Rate (lb/yr)	72.3785	81.0006	62.8802	72.0864
E _{RP} Rate - Production-based (lb/Ton-coal)	N/A	N/A	2.509E-05	2.509E-05
E _{FC} Rate - Fc-based (lb/TBtu)	1.8602	1.8255	1.4270	1.7043
Elemental Mercury Results				
C _{sd} Concentration (µg/dscm)	5.0151	4.8242	5.1202	4.9865
E _{T/yr} Rate (lb/yr)	198.1922	211.0614	218.6209	209.2915
E _{RP} Rate - Production-based (lb/Ton-coal)	N/A	N/A	8.722E-05	8.722E-05
E _{FC} Rate - Fc-based (lb/TBtu)	5.0939	4.7566	4.9615	4.9373

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Unit 1 Stack – Ontario-Hydro, Runs 8B-10B

Run No.		8B	9B	10B	Average
Date (2005)		Jul 7	Jul 7	Jul 7	
Start Time (approx.)		09:31	12:40	16:52	
Stop Time (approx.)		11:52	15:34	18:52	
Process Conditions					
R _P	Coal Flow - (Ton/hour)	286	286	285	286
P ₁	Load Level - (MW)	458	458	456	458
F _C	Carbon dioxide-based F-factor (dscf/MMBtu)	1,800	1,800	1,800	1,800
Gas Conditions					
O ₂	Oxygen (dry volume %)	8.2000	8.4000	8.0000	8.2000
CO ₂	Carbon dioxide (dry volume %)	11.0000	11.4000	11.2000	11.2000
T _s	Sample temperature (°F)	323.6667	329.5417	334.5417	329.2500
B _w	Actual water vapor in gas (% by volume)	12.1190	11.9846	11.2546	11.7861
Gas Flow Rate					
Q _s	Volumetric flow rate, standard (scfm)	1,458,281	1,470,528	1,545,564	1,491,458
Q _{std}	Volumetric flow rate, dry standard (dscfm)	1,281,552	1,294,291	1,371,617	1,315,820
Q _{std7}	Volumetric flow rate, dry std@7%O ₂ (dscfm)	1,170,914	1,163,931	1,272,940	1,202,595
Total Mercury Results					
C _{sd}	Concentration (µg/dscm)	7.2207	6.5889	7.1503	6.9866
E _{T/yr}	Rate (Ton/yr)	0.1519	0.1400	0.1610	0.1509
E _{Rp}	Rate - Production-based (lb/Ton-coal)	1.211E-04	1.119E-04	1.290E-04	1.206E-04
E _{Fc}	Rate - Fc-based (lb/TBtu)	7.3785	6.4967	7.1761	7.0171
Particulate Bound Mercury Results					
C _{sd}	Concentration (µg/dscm)	<4.809E-03	<4.736E-03	<4.496E-03	<4.680E-03
E _{T/yr}	Rate (Ton/yr)	<1.011E-04	<1.006E-04	<1.012E-04	<1.010E-04
E _{Rp}	Rate - Production-based (lb/Ton-coal)	<8.063E-08	<8.039E-08	<8.110E-08	<8.071E-08
E _{Fc}	Rate - Fc-based (lb/TBtu)	<4.914E-03	<4.669E-03	<4.512E-03	<4.699E-03
Oxidized Mercury Results					
C _{sd}	Concentration (µg/dscm)	2.0824	1.5106	1.8748	1.8226
E _{T/yr}	Rate (Ton/yr)	0.0438	0.0321	0.0422	0.0394
E _{Rp}	Rate - Production-based (lb/Ton-coal)	3.491E-05	2.564E-05	3.382E-05	3.146E-05
E _{Fc}	Rate - Fc-based (lb/TBtu)	2.1280	1.4895	1.8816	1.8330
Elemental Mercury Results					
C _{sd}	Concentration (µg/dscm)	5.1382	5.0783	5.2755	5.1640
E _{T/yr}	Rate (Ton/yr)	0.1081	0.1079	0.1187	0.1116
E _{Rp}	Rate - Production-based (lb/Ton-coal)	8.615E-05	8.621E-05	9.516E-05	8.917E-05
E _{Fc}	Rate - Fc-based (lb/TBtu)	5.2505	5.0072	5.2945	5.1841

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Ontario Hydro Mercury Species Distribution

Ontario-Hydro – Hg^{PB} Comparison & Balance

	Test Time	Mass Flow						Process Conditions	
		ESP Inlet - B West			Stack			Coal Flow (Ton/hr)	Load Level (MW)
		A (g/hr)	B (g/hr)	Avg (g/hr)	A (g/hr)	B (g/hr)	Avg (g/hr)		
Hg ^{PB}	13:30-16:07	0.101	0.087	0.094	-0.010	0.006	-0.002	286	459
	09:32-11:56	0.114	0.103	0.109	-0.010	-0.010	-0.010	286	459
	12:40-15:37	0.119	0.080	0.099	-0.010	-0.010	-0.010	286	458
Total Avg				0.101			-0.008	286	459
Total Stdev				0.015			0.007		

Hg ^{PB} Mass Flow ESP Inlet (4 Ducts):	0.40	±	0.03 g/hr
Hg ^{PB} Mass Flow Stack:	-0.01	±	0.01 g/hr

Ontario-Hydro - Hg²⁺ Comparison & Balance

	Test Time	Mass Flow						Process Conditions	
		ESP Inlet - B West			Stack			Coal Flow (Ton/hr)	Load Level (MW)
		A (g/hr)	B (g/hr)	Avg (g/hr)	A (g/hr)	B (g/hr)	Avg (g/hr)		
Hg ²⁺	13:30-16:07	0.324	0.323	0.324	3.046	3.255	3.150	286	459
	09:32-11:56	0.319	0.427	0.373	4.223	4.535	4.379	286	459
	12:40-15:37	0.300	0.253	0.276	3.299	3.322	3.311	286	458
Total Avg				0.324			3.613	286	459
Total Stdev				0.057			0.609		

Hg ²⁺ Mass Flow ESP Inlet (4 Ducts):	1.30	±	0.10 g/hr
Hg ²⁺ Mass Flow Stack:	3.61	±	0.61 g/hr

Ontario-Hydro - Hg⁰ Comparison & Balance

	Test Time	Mass Flow						Process Conditions	
		ESP Inlet - B West			Stack			Coal Flow (Ton/hr)	Load Level (MW)
		A (g/hr)	B (g/hr)	Avg (g/hr)	A (g/hr)	B (g/hr)	Avg (g/hr)		
Hg ⁰	13:30-16:07	3.618	3.594	3.606	11.340	11.318	11.329	286	459
	09:32-11:56	3.443	3.627	3.535	11.373	11.189	11.281	286	459
	12:40-15:37	3.810	3.539	3.674	11.280	11.169	11.224	286	458
Total Avg				3.605			11.278	286	459
Total Stdev				0.121			0.083		

Hg ⁰ Mass Flow ESP Inlet (4 Ducts):	14.42	±	0.21 g/hr
Hg ⁰ Mass Flow Stack:	11.28	±	0.08 g/hr

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Ontario Hydro Mass Balance Calculations

Ontario-Hydro - HgT Comparison & Balance

	Test Time	Mass Flow						Process Conditions	
		ESP Inlet - B West			Stack			Coal Flow (Ton/hr)	Load Level (MW)
		A (g/hr)	B (g/hr)	Avg (g/hr)	A (g/hr)	B (g/hr)	Avg (g/hr)		
Total	13:30-16:07	4.044	4.003	4.024	14.385	14.580	14.482	286	459
	09:32-11:56	3.876	4.156	4.016	15.597	15.724	15.660	286	459
	12:40-15:37	4.228	3.871	4.050	14.578	14.491	14.535	286	458
Total Avg				4.030			14.893	286	459
Total Stdev				0.145			0.600		

Total Mass Flow from Coal:	15.79		g/hr
Total Mass Flow ESP Inlet (4 Ducts):	16.12	±	0.25 g/hr
Total Mass Flow Stack:	14.89	±	0.60 g/hr
Total Mass Flow Fly Ash (ESP):	0.19		g/hr
Removal Efficiency across ESP:	7.6	±	4.0 %

Overall plant Hg material balance

Inlet Hg	Hg from coal	15.79 g/hr
Outlet Hg	Hg exiting the stack	14.89 g/hr
	Hg in ESP hopper ash	0.19 g/hr
Outlet/Inlet Balance		95.6 %

Hg mass flow rates across air pollution control devices

Hg at the ESP Inlet	16.12 g/hr
Hg at the outlet of the ESP	14.89 g/hr
Hg in ESP hopper ash	0.19 g/hr
Outlet/Inlet Balance	93.6 %

A-4
Method 324 Data

Method 324
Total Gaseous Mercury (Hg^{Total}) Results

Sorbent ID	1737		1738		1739		1740		1741		1742		1743		1744		Field Spike		1736		1745		1746		1747				
	Date (2005)	June 29	June 29	June 29	June 29	June 29	June 30	June 30	June 30	June 30	June 30	June 30	June 30	June 30	June 30	June 30	June 30	June 30	June 30	June 30									
Start Time (approx.)	09:52:51	09:52:29	12:52:56	12:52:33	16:30:41	16:30:19	09:33:58	09:33:37	12:25:19	12:27:20	16:06:20	16:05:59	11:52:47	11:52:24	14:52:47	14:52:47	18:31:03	18:30:39	11:31:52	11:31:31	14:41:38	14:41:14	17:02:40	17:02:19					
Stop Time (approx.)																													
Sampling Data																													
V _{mstd} Volume metered, standard (dscm)	42105.0260	42192.7933	39761.0680	44971.1078	47714.7669	39040.5400	42324.5715	39931.3557	45774.8123	50975.5663	19252.3428	19670.7523																	
Laboratory Data																													
m _n Total Mercury (ng/trap)	294.7320	295.2040	262.0770	311.2320	304.8180	275.5800	273.6400	284.4280	1186.2150	320.9490	148.7390	148.8470																	
Total Results																													
C _{sd} Concentration (µg/dscm)	6.9999	6.9966	6.5913	6.9207	6.3883	7.0588	6.4653	7.1229	25.9141	6.2961	7.7258	7.5669																	
C _{avg} Avg Concentration (µg/dscm)	6.9982		6.7560		6.7236		6.7941		Percent Recovery		7.6463																		
RD Relative Deviation (µg/dscm)	0.02		2.44		4.99		4.84		89.80 %		1.04																		
RD=ABS[C _A -C _B]/[C _A +C _B]									(volume adjusted)																				
RPD Relative Percent Difference (µg/dscm)	0.05		4.88		9.97		9.68				2.08																		
RPD=ABS[C _A -C _B]/AVG[C _A +C _B]																													

Ontario Hydro Results		A1	B1	A2	B2	A3	B3	A4	B4	A5	B5
C _{sd} Concentration (µg/dscm)		7.4990E+00	6.8606E+00	1.1531E+01	1.0856E+01	6.7407E+00	8.2047E+00	7.2038E+00	6.8466E+00	6.5638E+00	6.6756E+00
C _{avg} Avg Concentration (µg/dscm)		7.1798		11.1938		7.4727		7.0252		6.6197	
RD Relative Deviation (µg/dscm)		4.45		3.01		9.80		2.54		0.84	
RD=ABS[C _A -C _B]/[C _A +C _B]											
RPD Relative Percent Difference (µg/dscm)		8.89		6.03		19.59		5.08		1.69	
RPD=ABS[C _A -C _B]/AVG[C _A +C _B]											

A-5

Unit 1 Stack – Ontario-Hydro vs. Method 324 Sorbent Traps

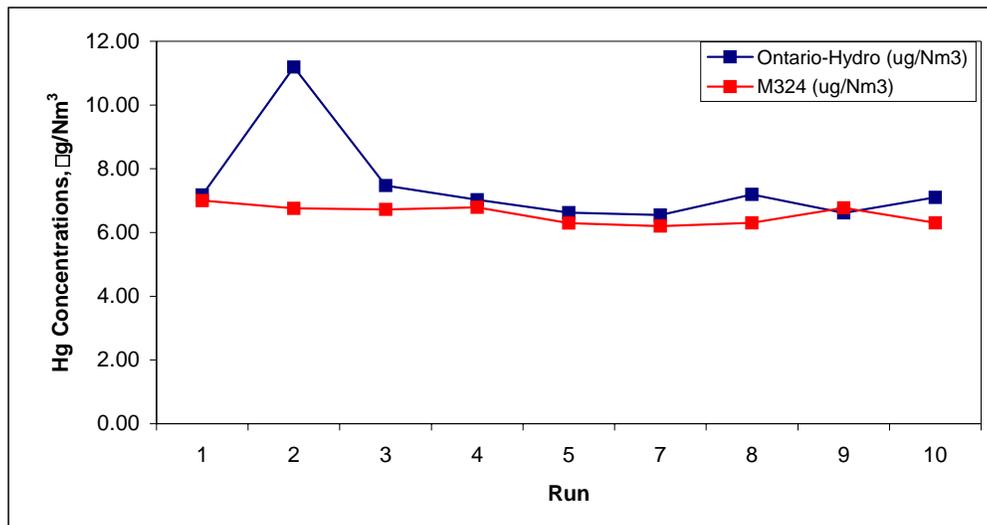
Run No.	Start Time	Date 2005	Ontario-Hydro (ug/Nm ³)	M324 (ug/Nm ³)	Difference (ug/m ³)	Percent Difference
1	9:52	Jun 29	7.18	7.00	0.18	2.53%
2	12:52	Jun 29	11.19	6.76	4.44	39.65% *
3	16:30	Jun 29	7.47	6.72	0.75	10.02%
4	9:33	Jun 30	7.03	6.79	0.23	3.29%
5	12:25	Jun 30	6.62	6.30	0.32	4.89%
7	13:31	Jul 6	6.55	6.20	0.35	5.36%
8	9:31	Jul 7	7.19	6.30	0.89	12.38%
9	12:41	Jul 7	6.61	6.78	-0.17	-2.52%
10	16:53	Jul 7	7.10	6.31	0.79	11.19%
Average			6.97	6.55	0.42	6.02%

RATA	
Standard Deviation	0.3626
Confidence Coefficient	0.3032
Relative Accuracy (as % of RM)	10.37%
Average Absolute Difference (ug/m ³)	0.4609
Limits	
20.00%	
1	

* Indicates that the run was not included in the RATA calculations.

8 Runs are being considered in the RATA calculations
1 Runs are being excluded from the RATA calculations

RM = Reference Method (Ontario-Hydro)
M324 = Sorbent-Based Monitoring System



A-6

Method 324 Quality Assurance and Quality Control Description

There are several QA/QC criteria specified in Table 324-2 of 67 FR 4467 that are applicable to the work performed in this program. The following QA/QC criteria were monitored during the course of the program:

1. Pre and Post Sampling Leak-check: Leak rate less than 2% of prevalent sampling rate.
2. Breakthrough: Sorbent trap backup section mercury loading less than 2% or, alternatively, 5ng/trap of the main section mercury loading.
3. Paired Trap Agreement: Relative deviation (RD) between results of paired traps less than or equal to 10%.
4. Field Spike Recovery: Spiked sorbent trap section mercury mass equal to 80-120% of original elemental mercury spike amount.

A field spike run was conducted from 08/10/05 – 08/17/05. During this sampling run a sorbent trap spiked with a known amount of gaseous elemental mercury (M_{ref}) onto the main section of the trap was sampled side-by-side with a regular two-section trap. Relating the mass of total gaseous mercury captured in both sections of the regular sorbent trap (M_1) to the mass of total gaseous mercury captured in both sections of the spiked sorbent trap (M_2) according to the following equation yields the percent spike recovery ($\%R$).

$$\%R = \frac{M_2 - M_1}{M_{ref}} \times 100$$

According to this equation, the field spike was recovered to 90%, passing the field spike QA/QC criteria of 80% to 120% recovery. Note that the mercury mass loadings are corrected for a slight difference in flue gas volumes sampled through each trap.

Table A6-1 summarizes how well these criteria were met during the test program. As is evident, all validated sorbent trap results met the breakthrough criteria. The same holds true for the paired sorbent trap agreement for the sampling runs that yielded two valid sorbent trap results.

Table A6-1. QA/QC Summary – Sorbent Trap Breakthrough Performance

Start Date/ Start Time	Stop Date/ Stop Time	Backup Section Analysis (Breakthrough)				Paired Trap Agreement %RD
		Trap A ng	Trap B ng	Trap A % ⁷	Trap B % ⁷	
07/08/05 16:22	07/14/05 08:55	N/A ¹	1.94	N/A ¹	0.02%	N/A ¹
07/14/05 13:30	07/21/05 06:52	N/A ²	5.49	N/A ²	0.02%	N/A ²
07/21/05 10:09	07/28/05 10:30	3.89	N/A ³	0.01%	N/A ³	N/A ³
08/04/05 08:05	08/10/05 07:28	N/A ⁴	0.00	N/A ⁴	0.00%	N/A ⁴
08/10/05 09:51	08/17/05 07:35	0.00	0.24	0.00%	0.00%	N/A ⁵
08/17/05 16:30	08/22/05 09:53	0.28	0.12	0.00%	0.00%	0.34
08/22/05 12:50	08/29/05 09:49	1.01 ⁶	0.03	0.01% ⁶	0.00%	9.46
08/29/05 10:46	09/06/05 09:49	0.00	0.00	0.00%	0.00%	3.87

¹ Sorbent trap breakage during trap recovery

² Autosampler software malfunction and hardware failure

³ Autosampler hardware failure

⁴ Autosampler software malfunction

⁵ Sorbent trap with spike in the main section (field spike)

⁶ Sorbent trap breakage during recovery and subsequent loss of approximately 60% of the sorbent content of the backup section. Remainder of the backup section was recovered, analyzed and reported.

⁷ Percent recovery with respect to the main section.

Table A6-2 summarizes the results for the analytical QA/QC, some of which are listed in Table 324-2 of US EPA Method 324, while others are presented in sections 11.6 – 11.14 of US EPA Method 324. All of the criteria are met except for the low recoveries of the Certified Reference Material (NIST 1641d) during the analysis of sorbent traps 830, 832, 833, 839 and 828. These percent recoveries fall outside of the allowed 90% – 110% range.

Table A6-2. QA/QC Summary – Analytical Criteria

Sorbent Trap ID	Digestion Blanks ng/trap	MDL¹ ng/trap	CRM² (NIST 1641d) % Recovery	Laboratory Matrix Spike³ % Recovery	Lab Matrix Duplicate RPD⁴	Lab Matrix Spike Duplicate RPD
830	0.50	3.35	82.2%	101.6%	1.3%	0.4%
832, 833	2.70	1.93	83.3%	101.1%	6.6%	1.2%
838	0.14	0.42	96.7%	99.1%	0.6%	1.5%
839	2.70	1.93	83.3%	101.1%	6.6%	1.2%
828 ⁵	2.70	1.93	83.3%	100.4%	3.8%	6.5%
840, 841	0.10	0.09	103.0%	102.9%	7.1%	6.0%
842, 843, 844, 845	0.39	2.42	104.6%	91.4%	2.1%	10.6%

¹ Estimated Method Detection Limit (three times the standard deviation of successive digestion blank results)

² Certified Reference Material (CRM)

³ Average of duplicate analysis

⁴ Relative Percent Deviation (RPD)

⁵ Sorbent trap with spike in the main section (field spike)

A-7

Horiba DM-6 CEMS RATA

Unit 1 Stack – Ontario-Hydro vs. Hg-CEMS

Run No.	Start Time	Date 2005	Ontario-Hydro (ug/Nm ³)	Hg CEMS (ug/Nm ³)	Difference (ug/Nm ³)	Percent Difference
1	9:52	Jun 29	7.18	6.41	0.77	10.73%
2	12:52	Jun 29	11.19	5.21	5.99	53.47% *
3	16:30	Jun 29	7.47	5.94	1.53	20.44%
4	9:33	Jun 30	7.03	5.50	1.53	21.76%
5	12:25	Jun 30	6.62	5.25	1.37	20.74%
6	13:31	Jul 6	6.55	2.01	4.54	69.37%
7	9:31	Jul 7	7.19	2.15	5.05	70.16%
8	12:41	Jul 7	6.61	2.37	4.24	64.15%
9	16:53	Jul 7	7.10	2.26	4.84	68.12%
Average			6.97	3.99	2.98	42.81%

RATA	
Standard Deviation	1.8294
Confidence Coefficient	1.5297
Relative Accuracy (as % of RM)	64.76%
Average Absolute Difference (ug/m ³)	2.9833
Limits	
	20.00%
	1

* Indicates that the run was not included in the RATA calculations.

8 Runs are being considered in the RATA calculations
1 Run is being excluded from the RATA calculations

RM = Reference Method (Ontario-Hydro)
 CEMS = Continuous Emissions Monitoring System (Hg-CEMS; DM-6)

