WRI 07-R015

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

FINAL REPORT TASK 31 PHASE 1

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ABSTRACT

The Subbituminous Energy Coalition (SEC) identified a need to re-test stack gas emissions from power plants that burn subbituminous coal relative to compliance with the EPA mercury control regulations for coal-fired plants. In addition, the SEC has also identified the specialized monitoring needs 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 executed in two phases; Phase I of the project covered mercury emission testing programs at ten (10) subbituminous coal-fired plants. Phase II compared the performance of continuous emission monitors for mercury at subbituminous coal-fired power plants and is reported separately. Western Research Institute and a number of SEC members have partnered with Etaa Energy and Air Pollution Testing to assess the Phase I objective.

Results of the mercury (Hg) source sampling at ten (10) power plants burning subbituminous coal concluded Hg emissions measurements from Powder River Basin (PBR) coal-fired units showed large variations during both ICR and SEC testing. Mercury captures across the Air Pollution Control Devices (APCDs) present much more reliable numbers (i.e., the mercury captures across the APCDs are positive numbers as one would expect compared to negative removal across the APCDs for the ICR data). Three (3) of the seven (7) units tested in the SEC study had previously shown negative removals in the ICR testing.

The average emission rate is 6.08 lb/TBtu for seven (7) ICR units compared to 5.18 lb/TBtu for ten (10) units in the SEC testing. Out of the ten (10) SEC units, Nelson Dewey Unit 1, burned a subbituminous coal and petcoke blend thus lowering the total emission rate by generating less elemental mercury. The major difference between the ICR and SEC data is in the APCD performance and the mercury closure around the APCD. The average mercury removal values across the APCDs are 2.1% and 39.4% with standard deviations (STDs) of 1990 and 75%, respectively for the ICR and SEC tests. This clearly demonstrates that variability is an issue irrespective of using “similar” fuels at the plants and the same source sampling team measuring the species. The study also concluded that elemental mercury is the main Hg specie that needs to be controlled. 2004 technologies such as activated carbon injection (ACI) may capture up to 60% with double digit lb/MMacf addition of sorbent. PRB coal-fired units have an Hg input of 7-15 lb/TBtu; hence, these units must operate at over 60% mercury efficiency in order to bring the emission level below 5.8 lb/TBtu**.** This was non-achievable with the best technology available as of 2004. Other key findings include:

- Conventional particulate collectors, such as Cold-side Electro-Static Precipitators (CESPs), Hot-side Electro-Static Precipitator (HESP), and Fabric Filter (FF) remove nearly all of the particulate bound mercury,

- CESPs perform better highlighting the flue gas temperature effect on the mercury removal. Impact of speciation with flue gas cooling is apparent,
- SDA's do not help in enhancing adsorption of mercury vapor species, and
- Due to consistently low chlorine values in fuels, it was not possible to analyze the impact of chlorine.

In summary, it is difficult to predict the speciation at two plants that burn the same fuel. Non-fuel issues, such as flue gas cooling, impact the speciation and consequently mercury capture potential.

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ABBREVIATIONS

APCD - Air Pollution Control Device

CESP - Cold side Electrostatic Precipitator

DFGD- Dry Flue Gas Desulfurization

F- Normalized gas flow factor, Fc (carbon-based) and Fd (total flue gas)

FF - Fabric Filter

FG- Flue Gas

HESP - Hot side Electrostatic Precipitator

Hg – Mercury

Hg-E Mercury –Elemental

Hg-O Mercury – Oxidized

Hg-P Mercury-Particulate

ICR – Information Collection Request

MMBtu/hr – Fuel Use, Millions of British Thermal Units Per Hour

MWe-G – MegaWattts-Gross

MWe-N- MegaWatts-Net

PM – Particulate Matter

QA/QC- Quality Assurance/Quality Control

SEC – Subbituminous Energy Coalition

WFGD- Wet Flue Gas Desulfirization

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

µg/dscm – Mercury Concentration, Micrograms Per Dry Standard Cubic Meter

EXECUTIVE SUMMARY

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. The Subbituminous Energy Coalition (SEC) has identified a need to re-test stack gas emissions from power plants that burn subbituminous coal relative to compliance with the EPA mercury control regulations for coal-fired plants. In addition, the SEC, has identified the specialized monitoring needs associated with mercury continuous emissions monitors (CEM) and with the development and demonstration of control technologies for high elemental mercury flue gases.

The overall objectives of the program were to develop and demonstrate solutions for the unique emission characteristics found when burning subbituminous coals. The program is executed in two phases; Phase I of the project covered mercury emission testing programs at ten (10) subbituminous coal-fired plants. Phase II compared the performance of continuous emission monitors for mercury at subbituminous coal-fired power plants.

Western Research Institute (WRI) in conjunction with Several SEC members have partnered with Etaa Energy and Air Pollution Testing to conduct testing of mercury emissions at ten (10) power plants burning subbituminous coals. This report summarizes the data from that testing.

Results of the mercury (Hg) source sampling are summarized in the Tables E-1 and E-2 below. Even within PRB coal-fired units, the measurements show large variations during both ICR and SEC tests. However, the mercury captures across the air pollution control devices (APCDs) present more reliable numbers (i.e., the mercury captures across the APCDs are positive numbers as one would expect compared to prior negative removal across the APCDs). Three (3) of the seven (7) units tested in the SEC study had previously shown negative removals in the ICR testing.

The average emission rate of 6.08 lb/TBtu for seven (7) ICR units compared to 5.18 lb/TBtu for ten (10) units in the SEC testing. Out of the ten (10) SEC units, Nelson Dewey Unit 1 burned a subbituminous coal and petcoke blend thus lowering the total emission rate by generating less elemental mercury. The major difference between the ICR and SEC data is in the APCD performance and the mercury closure around the APCD. As shown in Table E-1, the average mercury removal values across the APCDs are 2.1% and 39.4% with standard deviations (STDs) of 1990 and 75% respectively for the ICR and SEC tests. This clearly demonstrates that variability is an issue irrespective of using "similar" fuels at the plants and the same source sampling team measuring the species.

Table E-1 SEC and ICR Test Data Summary

Plant Type	Unit Name	Hg removal Across APCD		Hg Emission	
		SEC	ICR	SEC	ICR
		%	%	lb/GWh	lb/GWh
CESP	Dave Johnston - Unit 2	74.7		0.023	
DFGD- FF	Rawhide - Unit 101	7.9	31.8	0.056	0.082
DGFD-CESP	Laramie - Unit 3	0.0	-78.5	0.087	0.035
FF	Pawnee - Unit 1	54.1		0.052	
FF	Sheldon - Unit 2	79.9		0.014	
HESP	Columbia - 1	31.5	11.9	0.095	0.109
HESP	Nelson Dewey - Unit 1	15.6	-9.0	0.041	0.022
HESP	Platte - Unit 1	10.7	-3.0	0.076	0.112
CESP-WFGD	Jim Bridger - 4	58.1	9.6	0.081	0.050
CESP-WFGD	Laramie - Unit 1	59.6	51.6	0.030	0.039
Average		*39.2*	*2.1*	*0.055*	*0.064*
STD Deviation		*29.5*	*41.1*	*0.028*	*0.037*
% STD Dev		*75.3*	*1989.7*	*51*	*57*
Note: *These emission data exceed 0.0614 lb/GWh (5.8 lb/TBtu).					

Table E-2 Species Distribution Before and After APCD (ICR and SEC)

Parameter	Hg-P -In	Hg-O-In	Hg-E-In	Hg -in Total	Hg-P -Out	Hg-O-Out	Hg-E-Out	Hg -Out Total
	µg/dscm (@ 3% O2)				µg/dscm (@ 3% O2)			
Average - ICR (7 units)	0.63	1.77	8.54	10.94	0.03	0.75	7.68	8.47
STD Dev- ICR	0.95	1.26	4.39	5.12	0.03	0.89	4.08	4.83
% STD Dev-ICR	151	71	51	47	100	119	53	57
Average - SEC (10 units)	3.68	1.33	7.79	12.79	0.12	1.26	5.83	7.21
STD Dev- SEC	3.04	1.12	6.02	5.98	0.08	1.70	4.05	3.65
% STD Dev-SEC	83	84	77	47	63	135	69	51

The study also concluded that elemental mercury is the main Hg specie that needs to be controlled (Figure E1). Technologies as of 2004, such as activated carbon injection (ACi0, may capture up to 60% with double digit lb/MMacf addition of sorbent. PRB coal-fired units have a Hg input of 7-15 lb/TBtu; hence, these units must operate at over 60% mercury efficiency in order to bring the emission level below 5.8 lb/TBtu. This was non-achievable with the best technology available as of 2004

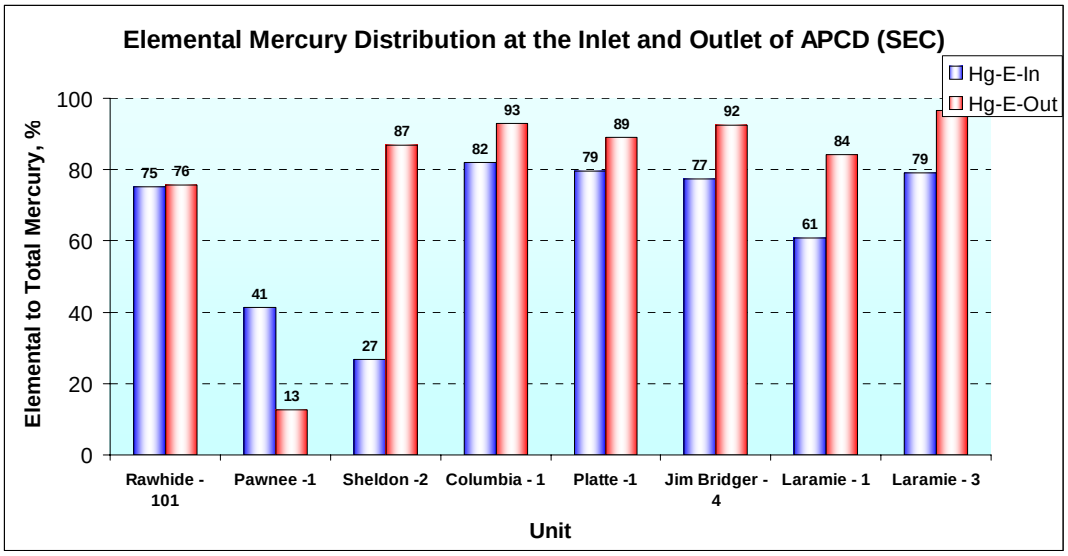


Figure E-1 Elemental Mercury's Dominance in the Species Distribution

Other key findings include:

- Conventional particulate collectors, such as Cold-side Electro Static Precipitators (CESPs). Hot-side Electro-Static Precipitator (HESP), and Fabric Filter (FF) remove nearly all of the particulate bound mercury.
- CESPs perform better highlighting the flue gas temperature effect on the mercury removal. Impact of speciation with flue gas cooling is apparent.
- SDA's do not help in enhancing adsorption of mercury vapor species, and
- Due to consistently low chlorine values in fuels, it was not possible to analyze the impact of chlorine.

In summary, it is difficult to predict the speciation at two plants that burn the same fuel. Non-fuel issues, such as flue gas cooling, impact the speciation and consequently mercury capture potential.

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. In support of developing emission regulatory guidelines, the U.S. EPA collected information on the mercury capture across the post combustion Air Pollution Control Devices (APCD). These data are currently used to develop mercury emission regulations from coal-fired utilities. The regulatory mercury emission limit determination is expected to be announced in late 2004 for compliance most likely starting in Jan 2007.

The Information Collection Request (ICR) data covered 81 boiler units representing all coal types and conventional coal-fired systems (Table 1.1.1) (EPA, 2002). Of these 81 units, 31 boilers burned subbituminous coal as the main fuel. The ICR data included the total and speciated mercury species at the inlet and outlet. It provided the current knowledge on the Hg species generated in the combustion process and the potential of the APCDs to capture them.

Table 1.1.1 Distribution of Mercury Emission Test Data by Boiler and Coal Types

Boiler Type	Fuel Type				
	Bit	Subbit	Lignite	Fuel Blends	Subtotal (by combustion mode)
PC-fired	26	29	9	1	65
Cyclone-fired	3	2	2		7
FBC	1	0	2	2	5
Stoker-fired	2	0	0	0	2
IGCC	2	0	0	0	2
Subtotal (by fuel)	34	31	13	3	81

Note: PC = Pulverized Coal FBC =Fluidzed Bed Combustion; IGCC = Integrated Coal Gasification Combined Cycle Unit; Bit =Bituminous coal; Subbit = Subbituminous coal; APCD = Air Pollution Control Device for particulate and flue gas desulfurization

Due to the impact of many processes and product design variables on the speciation and capture of mercury, the data were mostly qualitative in nature. Quantification of the trends was not possible for most cases. Specifically, the distribution of mercury species in the flue gas stream varied considerably between the bituminous and subbituminous/lignite coal types. About 40% of the plants showed negative removals across the plant and/or the APCDs (Table 1.1.2). The variations are more pronounced in the case of subbituminous and lignite-fired units. More

than 50% of the subbituminous coal–fired units showed negative removal compared to only 20% in the case of bituminous coal-fired units. This corroborates the large variability in measurement and control of the mercury species in subbituminous coal-fired systems. These variations are traced to the low concentration of the mercury species and attendant inaccuracies involved in the measurements. Thus, the use of the mercury emission data for developing emission control guidelines appears to have limitations.

Table 1.1.2 Distribution of ICR Negative Mercury Removal Data by Fuel Type

Parameter	Fuel Type				
	Bit	Subbit	Lignite	Fuel Blends	Subtotal
Plants Tested	34	31	13	3	81
Data Showing Negative Removal	7	17	6	1	31
Percentage of Plants with Negative Removal	20.6	54.8	46.2	33.3	38.3
Negative Removal -Coal-Stack only	4	5	3		12
Negative Removal -Across APCD only		9	2	1	12
Negative Removal in both Categories	3	3	1		7

1.2 Objectives

To supplement the ICR data and also to enhance the understanding of the mercury species distribution and total mercury emission in subbituminous coal-fired plants, Western Research Institute has organized, in conjunction with Basin Electric Power Cooperative, a Subbituminous Energy Coalition (SEC) or Subbituminous Coal Producers and Users Group, with the purpose of exchanging information and developing solutions to the specific needs of industry. This program will help to identify the parameters that impact the emission variations even within the subbituminous plants and develop suitable mercury reduction process parameters.

In the first phase of the program, the re-tested mercury emissions data from seven (7) units were compared with those of the ICR data; three (3) additional plants were also included to validate the findings on APCDs' performance on mercury capture.

2.0 SUMMARY OF THE TEST PROGRAM

2.1 Plant Selection

Phase I (Yr 1) of the program covered a mercury emissions testing program at ten (10) subbituminous coal-fired power plants. The plants were selected to represent different emission control equipment as well as those included previously under the 1999 EPA Information Collection Request (ICR) for mercury emissions. Some of the eighty (80) ICR plants showed negative mercury removals too. Table 2.1.1 summarizes the list of subbituminous plants selected

for mercury emission testing. The data includes the plant capacity, combustion mode, type of Air Pollution Control Device (APCD) and whether the plant was included under the EPA ICR.

Table 2.1.1 SEC Plant Selection for Mercury Emission Testing

Sl. No	Plant /Unit	Utility	Plant Capacity, MWe	Combustion Mode	Particulate Control	Desulfurization Unit	Included in ICR?
1	Jim Bridger Station - Unit 4	Pacific Corp	556-G	PC	CESP	WFGD	Yes
2	Columbia - Unit 1	Alliant Energy	550-G	PC	HESP		Yes
3	Dave Johnston - Unit 2	Pacific Corp	112-G	PC	CESP		
4	Nelson Dewey - Unit 1	Alliant Energy	100-G	PC	HESP		
5	Laramie River Station - Unit 1	Basin Electric Power Coop.	550-G	PC	CESP	WFGD	Yes
6	Laramie River Station - Unit 3	Basin Electric Power Coop.	550-G	PC	CESP	SDA	Yes
7	Pawnee - Unit 1	Xcel Energy	547-G	PC	FF		No
8	Platte River - Unit 1	City of Grand Island	100-N	PC	HESP		Yes
9	Rawhide - Unit 101	Platte River Power Authority	295-G	PC	FF	SDA	Yes
10	Sheldon Station - Unit 2	Nebraska Public Power District	120-G	CF	FF		No

Note: G=Gross MWe; N= Net MWe

2.2. Description of the Sampling Locations

The mercury species, particulate matter, and gas samples were taken at the inlet and outlet of the APCDs as shown in the Figure 2.2.1a. If two types of APCDs are used to control dust and SO_2, the samples were taken at the inlet of the first APCD and at the outlet of the second APCD (Fig. 2.2.1b). Details of the individual plant sampling locations are given in the Appendix.

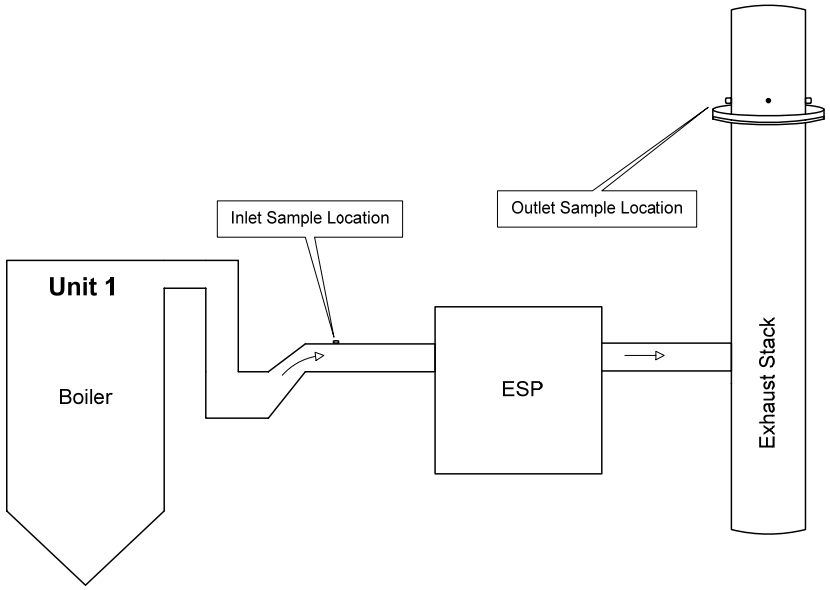


Figure 2.2.1a Location of the Mercury Species Sample Collection Ports (typ) – one APCD Only.

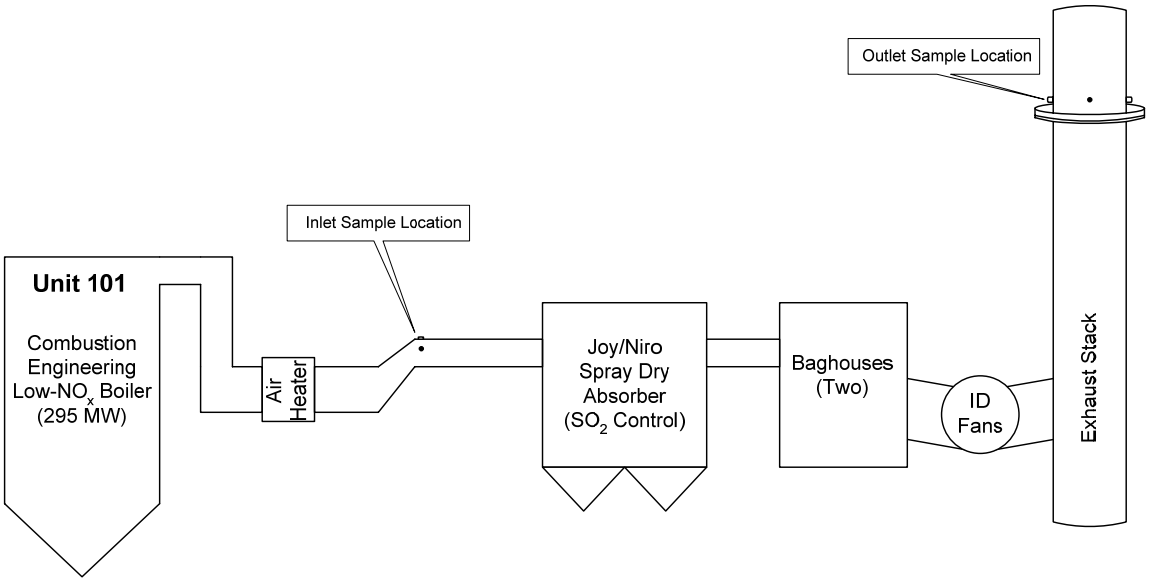


Figure 2.2.1b Location of the Mercury Species Sample Collection Ports (typ) – Two APCDs in series

2.3 Sampling and Analytical Procedures

Standard methodologies were used to collect the samples. Table 2.3.1 summarizes the type of standard sampling and analytical methods used during sample collection.

Table 2.3.1 Sampling Methods and Analytical Procedures

Parameter	Sampling Method	Analytical Method	Laboratory
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT 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	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	Cold Vapor Atomic Absorption (CVAAS)	PSC Analytical Burlington, Ontario

A single contractor (Air Pollution Testing (APT) of Wheat Ridge, Colorado) and a single analytical laboratory (Philip Analytical Services (PAS) of Burlington, Ontario) were used for the emission testing and analysis for all ten (10) units. 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 American Society for Testing and Materials (ASTM) and the EPA. Table 2.3.2 shows the sample or data collected and the procedure used to obtain and/or analyze the same.

APT 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 2.3.2 Summary of 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)

Sampling Details

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). A summary of the testing parameters is provided in *Appendices.*

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 (O_2 and CO_2) analysis using a Fyrite instrument. Additionally, carbon dioxide (CO_2) 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see the *Appendices.*

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 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.

All of 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 (µg/dscm), trillion British thermal units (lb/TBtu), and lb/hr.

2.4 Internal QA/QC Activities

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

Pre-Mobilization Quality Assurance Samples

Prior to departure for the emissions source sampling program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1 - N - HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; no mercury contamination was detected. An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. No mercury was detected in any reagent fraction.

On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. No mercury was detected in the blank train collected at the inlet sampling location. Mercury was detected in the blank train collected at the outlet location, but at less than one percent of the average emission sample level. For pollutant sample fractions with “not detected” mercury values, the detection limits were used for calculations. No blank corrections were performed. This strategy provided maximum possible mercury values for all emissions samples.

2.5 Mercury Emission Calculation Procedures

SEC:

For pollutant sample fractions with “not detected” mercury values, 50% of the detection limits were used for calculations. No blank corrections were performed. This strategy provides the most reasonable mercury values for all emissions samples.

Mercury emissions in units of pounds per trillion British thermal units (lb/TBtu) were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with a fuel factor (F_c) of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and plant CEMS CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant in accordance with *40 CFR 60* requirements.

The oxygen values were calculated from the CO_2 data and the correction procedure recommended by the Method 19. The mercury species concentration was normalized to 3% O_2 in flue gas using the corrected O_2 values. This strategy provided a sound basis for comparing the performance of the APCDs at each plant.

ICR:

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with a fuel factor (F_d) factor of 9840 dry standard cubic feet of exhaust gas per million British thermal units. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant in accordance with *40 CFR 60* requirements.

There are small differences in the use of F_c and F_d factors in reporting the emission data and these differences do not call for any change in the understanding or evaluating the performance of the APCD units' emission performance.

3.0 SUMMARY AND DISCUSSION OF THE TEST RESULTS

3.1 Fuel Data

Out of the ten (10) units tested, only one unit, Nelson Dewey, burned a blend of subbituminouos coal and petcoke (Table 3.1.1). All other units burned subbituminous coal as the primary fuel source. A key feature of the Nelson Dewey fuel is that the sulfur content is almost three times higher than the other fuel sources. Most of the chlorine data were reported to be less than the detectible limit of 100 parts per million on a wet basis (ppmw). The concentration of the species was taken to be 50% of the detectible limit. The Jim Bridger fuel had nearly twice as much ash of the other samples.

Table 3.1.1 Fuel Data (SEC-2003)

Plant Name	HHV*	M	A*	Cl*	Hg*	S*
	Btu/lb	%	%	ppmw	ppmw	%
Columbia-1	12114	31.20	6.11	50	0.13	0.55
Jim Bridger-4	11622	19.96	12.72	31	0.10	0.62
Laramie-Unit 1	13615	30.00	6.48	36	0.10	0.48
Laramie -Unit 3	13171	30.0	7.35	36	0.11	0.45
Platte - Unit 1	11913	28.30	6.78	35	0.09	0.37
Rawhide - Unit 101	12040	24.50	6.13	33	0.06	0.30
Pawnee	11798	29.85	6.58	36	0.12	0.60
Sheldon -Unit 2	11740	27.25	6.33	34	0.13	0.31
Dave Johnston-Unit 2	11715	28.11	6.96	35	0.12	0.60
Average	*12192*	*28*	*7.27*	*36*	*0.11*	*0.48*
Standard Deviation	*707*	*4*	*2.08*	*5.25*	*0.02*	*0.13*
% Std Dev	*6*	*13*	*29*	*15*	*20*	*27*
Nelson Dewey-Unit 1	11241	21.97	4.20	78	0.07	1.80

Note: *=Dry basis; Nelson Dewey is blend of subbituminous coal and petcoke.

3.2 Mercury in Input Coal

Figure 3.2.1 shows the distribution of the mercury data. The concentration of mercury in the subbituminous coals used in the ten (10) power plants varied from 0.06 ppmw to 0.13 ppmw resulting in an average value of 0.1035 ppmw with a standard deviation of 0.024 ppmw. Three (3) samples were taken at each unit and the average is represented by the bars. Table 3.2.2 presents the minimum and maximum of the three values and the average value.

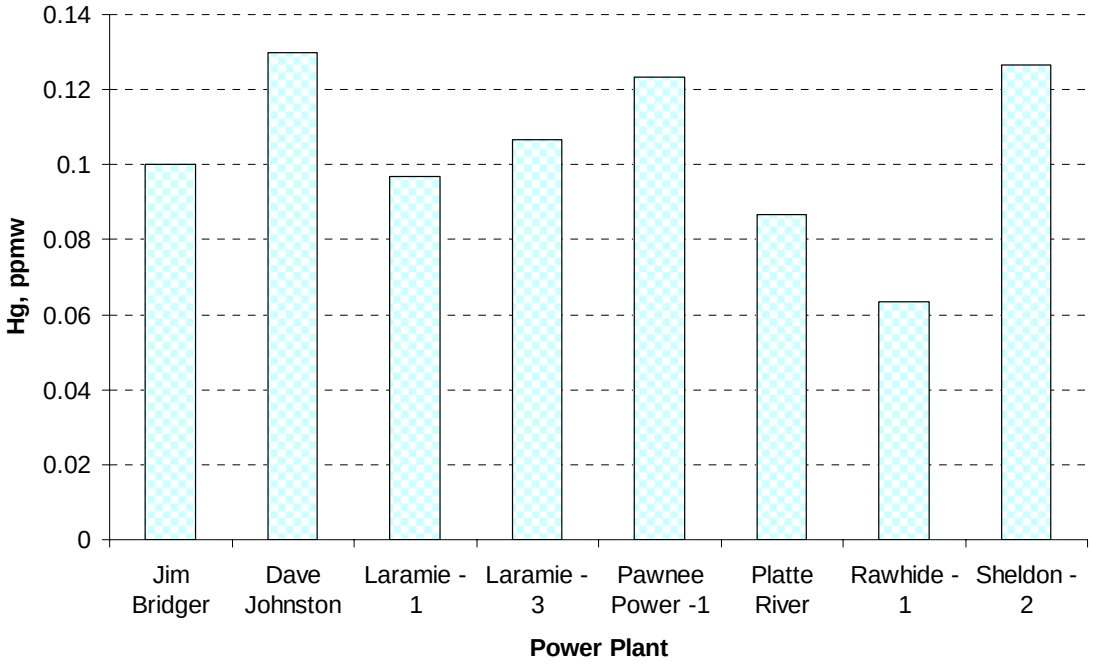


Figure 3.2.1 Mercury Concentration in Feed Coal (SEC-2003)

Table 3.2.2 Distribution of Mercury in the Feed Subbituminous Coals (SEC – 2003)

Plant	Min	Max	Ave
Jim Bridger	0.09	0.11	0.1
Dave Johnston	0.13	0.13	0.13
Laramie - 1	0.06	0.14	0.097
Laramie - 3	0.15	0.08	0.107
Pawnee Power -1	0.07	0.18	0.123
Platte River	0.08	0.09	0.087
Rawhide -1	0.04	0.1	0.063
Sheldon -2	0.05	0.22	0.127

3.3 Mercury Species Generated by the Boilers

Eight (8) of the ten (10) boilers were of tangential or wall-fired pulverized coal (PC) units and the remaining two (2) were cyclone-fired units. The emissions source sampling team measured the mercury species and the particulate matter concentration at the inlet and outlet of the APCDs.

Figure 3.3.1 below gives the three mercury species in micrograms per dry standard cubic meter (μg/dscm) normalized to 3% O_2 concentration and the Figure 3.3.2 presents species fractions in percentage of the total. The average value of the SEC mercury concentration at the APCD inlet is 12.79 μg/dscm with a STD of 6 μg/dscm. The concentration of oxidized mercury was less than 21% in all cases considered whereas the elemental mercury has gone up to 82% during the SEC sampling. These data corroborate the earlier findings that the elemental fraction is very high in subbituminous coal-fired units and the primary focus of any mercury capture technology should be the elemental mercury fraction for subbituminous coal-fired applications.

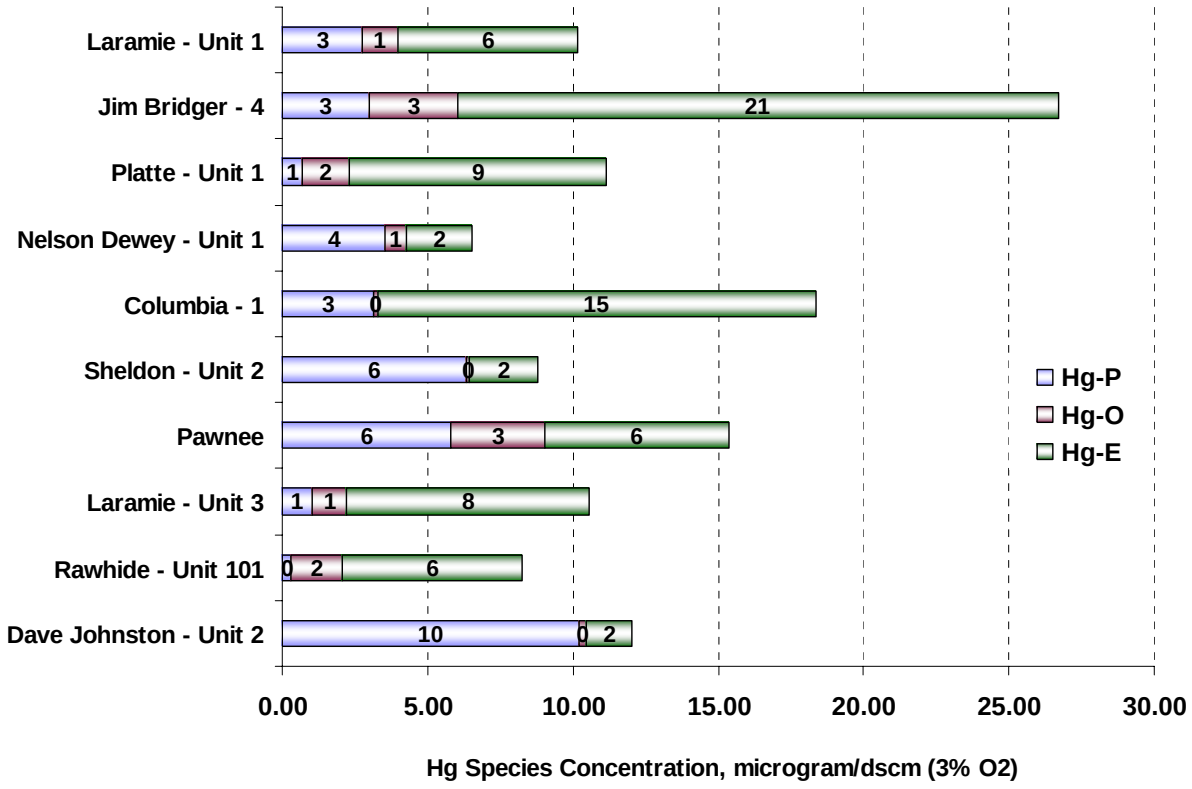


Figure 3.3.1 Mercury Species Concentration at the APCD Inlet, μg/dscm

3.4 APCDs' Mercury Capture Performance

Six (6) types of APCDs were used by the units in the program. The performance summary of all the APCD types is presented in this chapter. A detailed performance review of each APCD type is discussed in Sections 3.7 and 3.8. Figure 3.4.1 compares the performance of the six types of APCD combinations; the mercury removal efficiencies of the APCDs at the ten (10) boiler units are plotted against the total mercury concentration at the APCD inlet. From the SEC data, one can infer the directional trend of the mercury capture potential of APCD types.

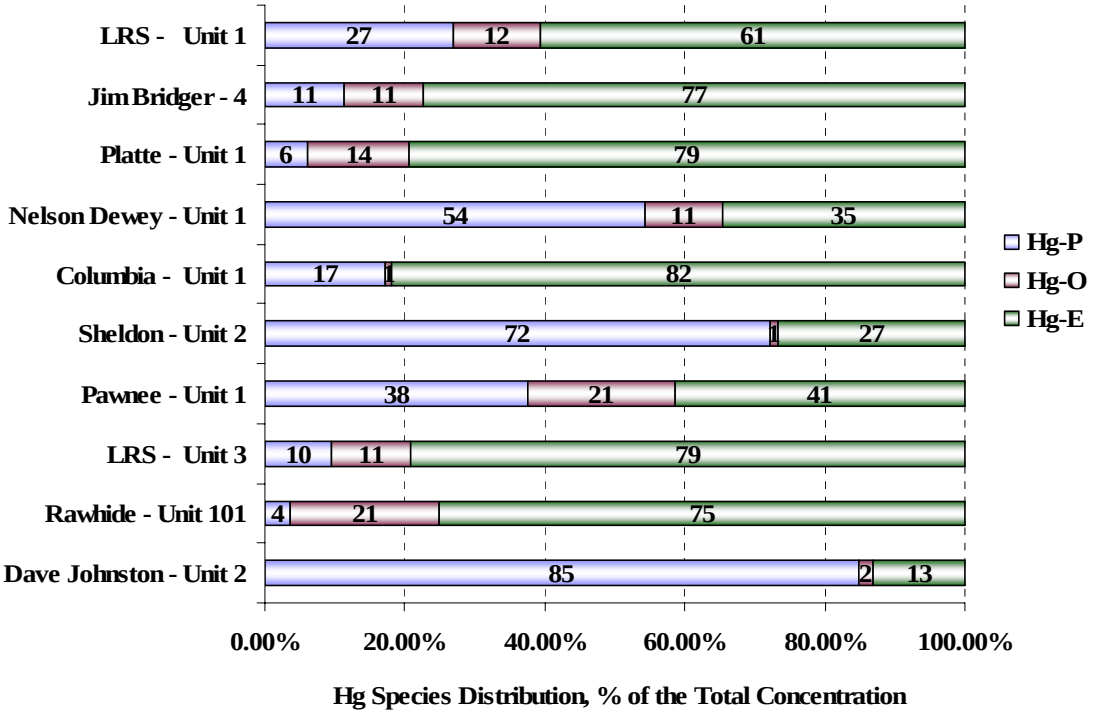


Figure 3.3.2 Total Mercury Species Concentration at the APCD Inlet Normalized to 100%

Fabric filters (FF) perform better than hot-side electro-static precipitators (HESP) while cold-side ESP systems are better than hot side ESPs. The dry flue gas desulfurization (FGD) equipped units do not remove any more Hg than other units. In these elemental mercury (Hg-E) constitutes more than 75% of the incoming mercury. Irrespective of the particulate removal system, the Hg removal is very poor (<10%).

Hot-side ESPs, as expected, are poor performers with mercury removal. It appears that the mercury species attach to the ash particles as the flue gas is cooled along its path and oxidize elemental species leading to better Hg removal by the cold-side ESPs. Hence, any post combustion technology must also address the issues relating to the conversion of Hg species below 600ºF and the potential interaction with cooler dust particles in adsorbing the Hg-O and Hg-E.

At Pawnee Station and Sheldon Station, the FFs perform better with the combined Hg-P and Hg-O fractions of above 59% of the total concentration. At the Rawhide facility, the combined Hg-P and Hg-O concentrations was only 25% resulting in very poor Hg capture. Though Hg-P and Hg-O fractions were lower than 50%, the CESP-WFGD combination has demonstrated 60% total Hg removal.

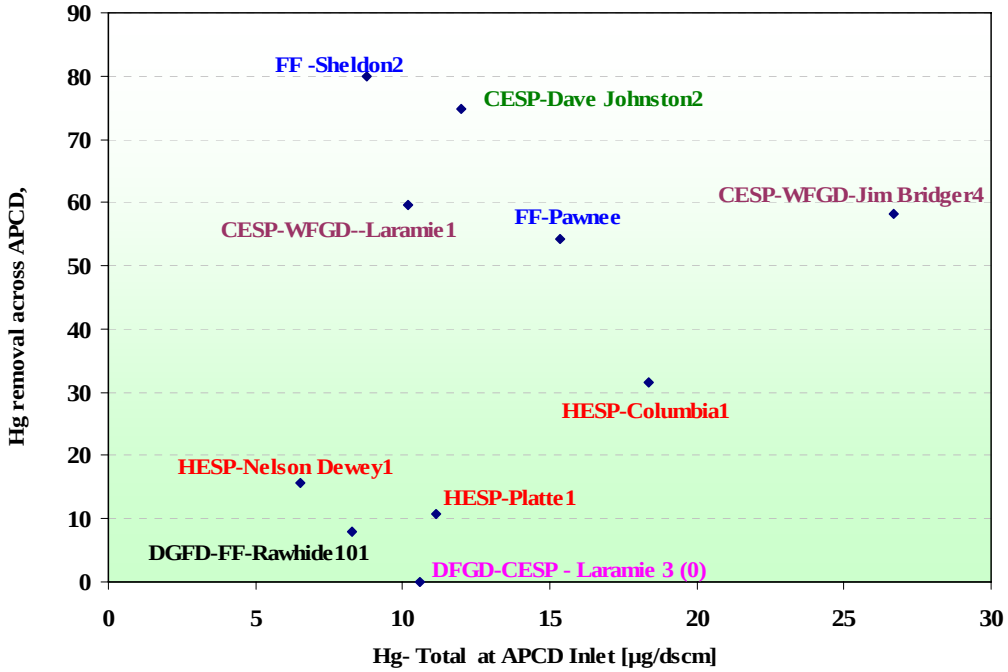


Figure 3.4.1 Mercury Capture Performance of APCDs

3.5 Mercury Species Leaving the APCDs

The Figure 3.5.1 shows the mercury species concentration at the outlet of the APCDs. Irrespective of the distribution of the species at the APCD inlet shown in Figure 3.3.1, the outlet stream contains mostly elemental mercury. The percentages of mercury species in each stream are given in Figure 3.5.2.

3.6 Mercury Emission from Subbituminous Coal-Fired Units

Mercury emissions from the stack in pounds per gigawatt hour (lb/GWh) were computed assuming a plant efficiency of 32.2% and using the total mercury concentration at the APCD outlet and F_c factor (EPA Method 19). The ICR data used the F_d factor. Though they are expected to result in the same emission rate (lb/MMBtu), WRI's check showed minor inconsistencies in the lb/MMBtu data because of the differences in fuel factors. F_c is the CO_2 based factor and F_d is the O_2 based factor. The differences are not discussed further in this report. F_c was used in SEC data analysis as recommended by the Air Pollution Testing, Inc.

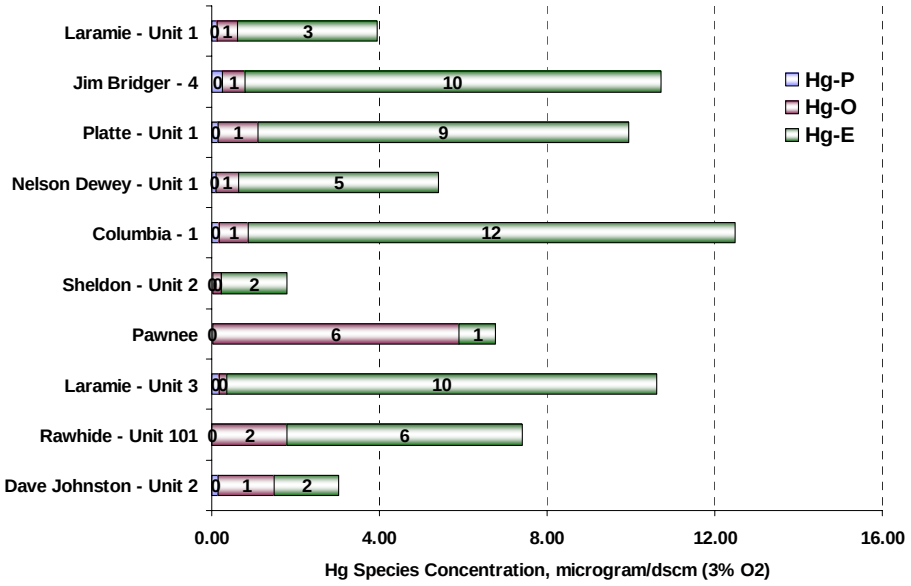


Figure 3.5.1 Mercury Species Concentration at the APCD Outlet, μg/dscm

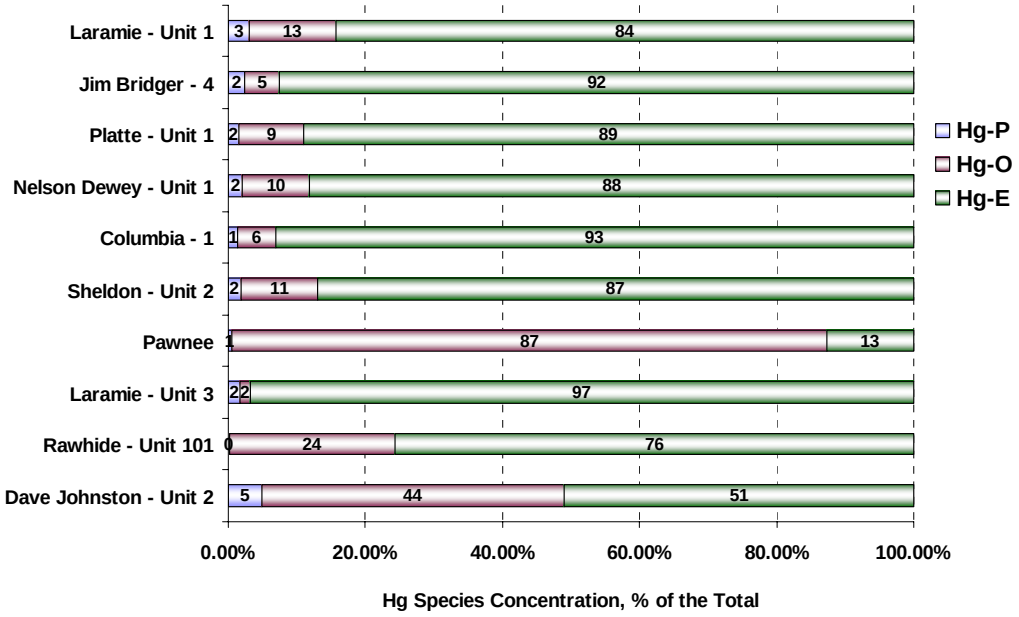


Figure 3.5.2 Total Mercury Species Concentration at the APCD Outlet Normalized to 100%

Both the ICR and the SEC data are directionally consistent but the magnitude varies in all cases highlighting the variability in the data. This corroborates the earlier stand of the power plant operators that data variability is an issue. Hence, the regulatory guidelines must account for the variability, specifically in the case of subbituminous coal due to its higher fraction of elemental mercury exiting the furnace**. One of the options under consideration for regulating**

the mercury emission proposes an emission limit of 5.8 lb/MMBtu which corresponds to 0.0615 lb/GWh.

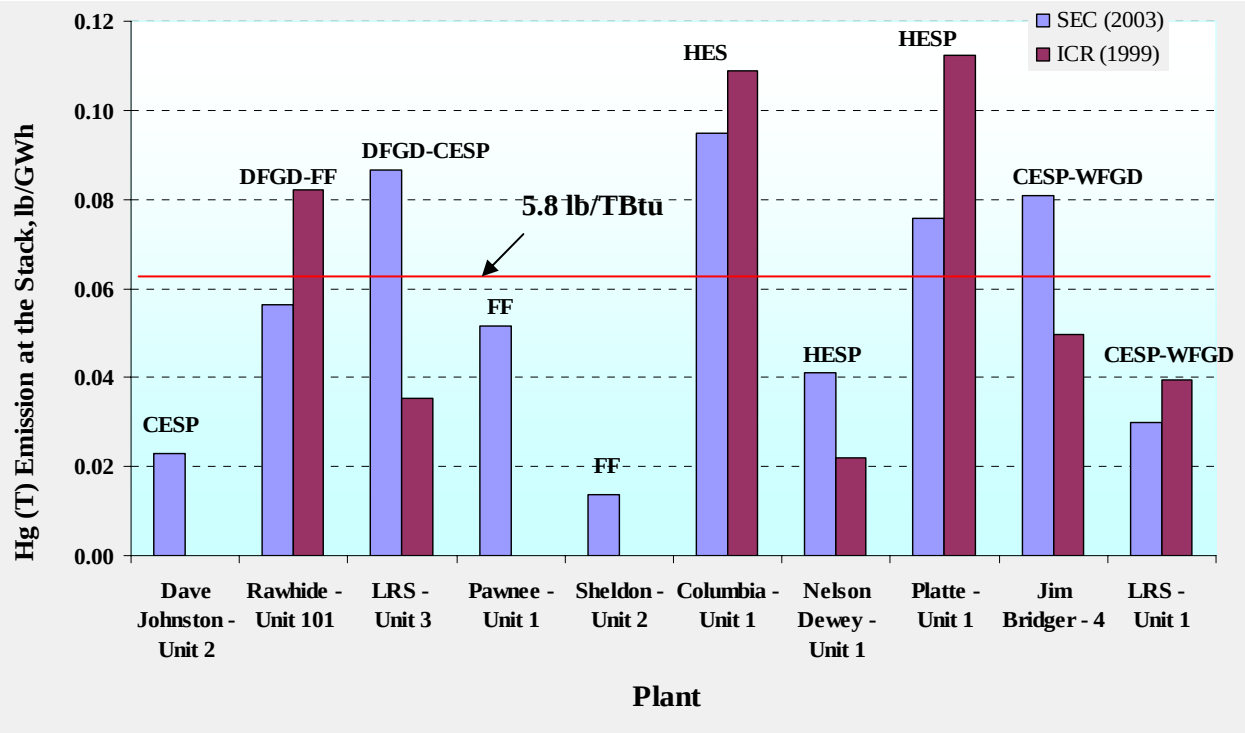


Figure 3.6.1 Mercury Emission at the Stack (ICR and SEC Data)

3.7 Particulate Capture Across APCDs

The particulate removal efficiency across the APCDs was well above 98% except at two ESP plants where it was 98.15% (HESP) and 98.5% (CESP). The excellent performance of the APCDs in removing the particulate plays an important role in the removal of particulate bound mercury (Hg-P) and, to a certain extent, the oxidized mercury (Hg-O). Although it is not possible to resolve with these data the Hg-E oxidation potential of the residual and accumulating filter ash layers or the adsorption of Hg-O or Hg-E, it is demonstrated clearly that the Hg-P is almost fully trapped by the APCDs. It also shows that the mercury adsorption is distributed among all the particle sizes; however, the adsorption bias between particle size is not analyzed in this Phase report.

Figures 3.7.1 and 3.7.2 show the PM concentration at the inlet and outlet of the APCDs. Three measurements taken at each point and the average are shown by the band and the red point respectively. The average dust concentrations at the inlet and outlet are 1.92 and 0.011 gr/dscf respectively. The Standard deviations for these values are 0.72 and 0.012 gr/dscf respectively.

Table 3.7.1 PM Concentration Data Summary at the Inlet and Outlet of APCDs

Plant	APCD	Scrubber	Inlet, gr/dscf			Outlet, gr/dscf			Particulate Removal Eff. %
			Min	Max	Average	Min	Max	Average	
Jim Bridger-4	CESP	WFGD	2.85	4.32	3.510	0.007	0.012	0.0097	99.72
Columbia-1	HESP		0.91	1.49	1.227	0.015	0.027	0.0270	98.18
Nelson Dewey-1	HESP		1.35	2.7	1.840	0.017	0.024	0.0210	98.84
Dave Johnston-2	CESP		1.54	3.13	2.24	0.013	0.072	0.0337	98.50
Laramie-1	CESP	WFGD	2.02	2.66	2.34	0.0009	0.0012	0.0010	99.96
Laramie-3	CESP	SDA	1.14	1.54	1.36	0.0021	0.0053	0.0031	99.77
Pawnee Power-1	FF		1.44	1.69	1.59	0.0006	0.001	0.0008	99.95
Platte River-1	HESP		2.06	2.25	2.18	0.0017	0.0111	0.0073	99.67
Rawhide-1	FF	SDA	1.65	2.08	1.92	0	0.0009	0.0004	99.97
Sheldon-2	FF		0.83	1.21	1.01	0.0019	0.0077	0.0040	99.61

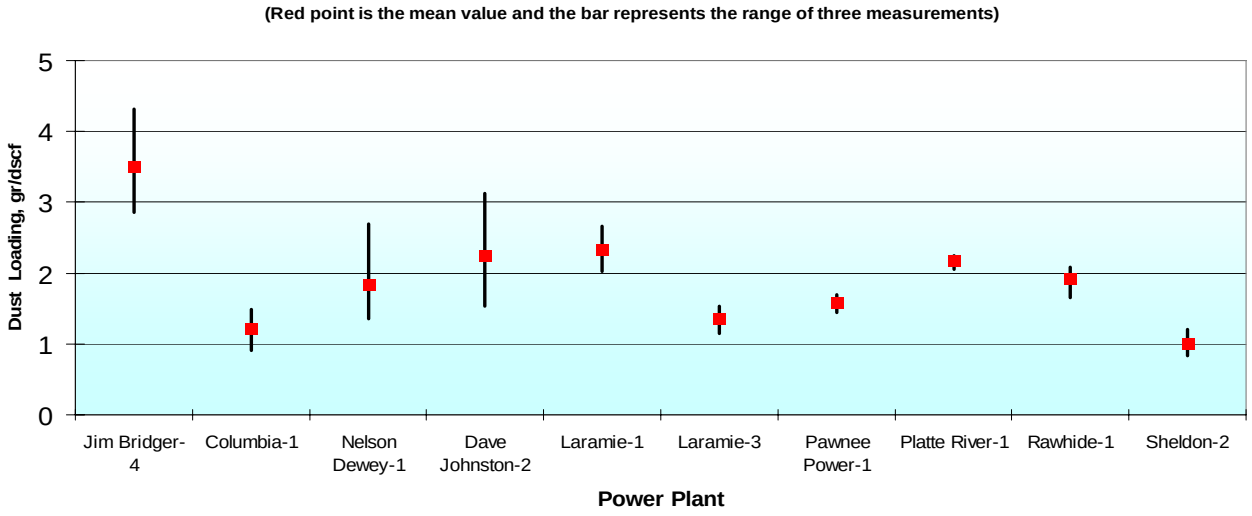


Figure 3.7.1 PM Concentration Data at the Inlet of APCDs

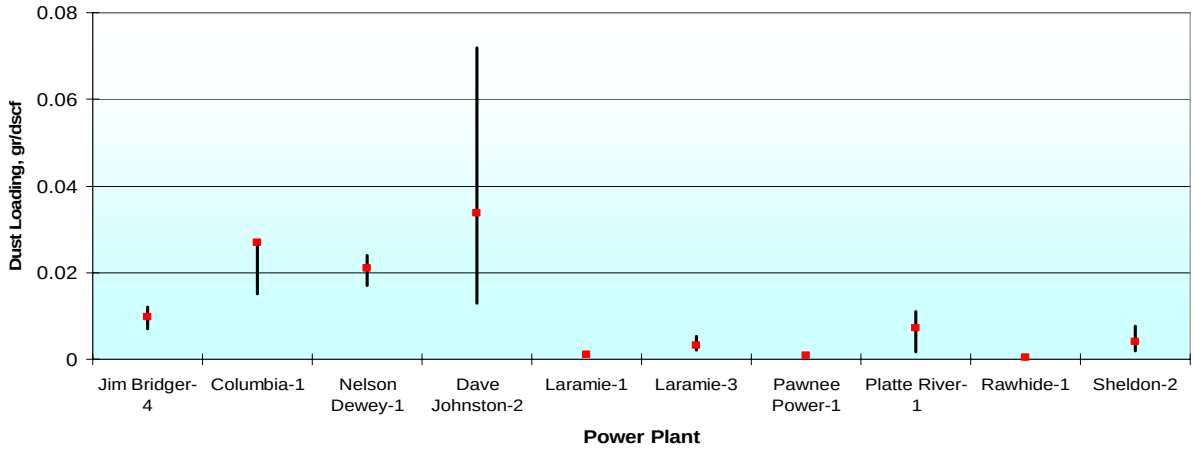


Figure 3.7.2 PM Concentration Data at the Outlet of APCDs

3.8 Mercury Capture Performance of Individual Units

The units are grouped under three categories, namely, CESP, HESP and FFDC systems. Secondary pollution control systems are not considered separately. Four units have CESP installations and other two categories have three units each.

The operating data consists of the fuel data, flue gas temperature and key gas species concentrations - moisture and oxygen that was directly measured during the ICR test and calculated from CO_2 data in the SEC tests. In addition, the sampling locations and mercury species concentrations at the inlet and outlet of the APCDs are given. The mercury species concentrations are normalized for 3% O_2 concentration by using the following equation

$$CorrectedValue = \frac{21\% - 3\%}{21\% - O_2\%actual}$$

Equation 1: Oxygen correction equation.

Also included are the mercury emission at the stack in lb/GWh and the mercury species removal efficiencies across the APCDs.

3.8.1 Cold-side ESP Units

There are four units in this category, namely, Jim Bridger Unit 4, Laramie Units 1 and 3, and Dave Johnston Unit 2. The following figures show the mercury sampling locations at these plants.

At the Jim Bridger unit, the inlet concentration of the Hg is almost four times higher during the SEC test compared to the values reported by the EPA (ICR data-1999). With fuel mercury concentration remaining the same, it is unlikely that the Hg species in flue gas would have been that high. **This data point appears to be suspect.**

As expected the elemental mercury is predominant (Fig. 3.8.1.2) and the CESP and WFGD combination is ineffective at capturing the elemental mercury. Due to a large fraction of elemental mercury both at the inlet and the outlet, it is not possible to resolve whether there is any re-conversion of the oxidized mercury into elemental mercury across the WFGD.

The system behavior at Laramie River Unit 1 is similar to that at the Jim Bridger Unit 4. The total mercury emission in the stack at Jim Bridger Unit 4 is 150% more than the Laramie Unit 1 though the Hg-E capture efficiency is very low (< 50%) in the SEC test at Laramie Unit 1. **This is most likely due to the higher inlet concentration to the APCD at Jim Bridger Unit 4.**

The performance of the Dave Johnston Unit 2 differs from the others in the following areas:

- Rock Springs, WY coal and not PRB coal is burned in this unit.

- The fraction of Hg-P is substantially higher (85%) compared to 10-27% in the other three units. This helps in higher Hg removal across the APCD since particulate capture is nearly 100%.

- The flue gas temperature at the stack is 148°C (298°F) compared to much lower value of 69°C (156°F) in the other three units. The high temperature has not impacted on the Hg removal efficiency.

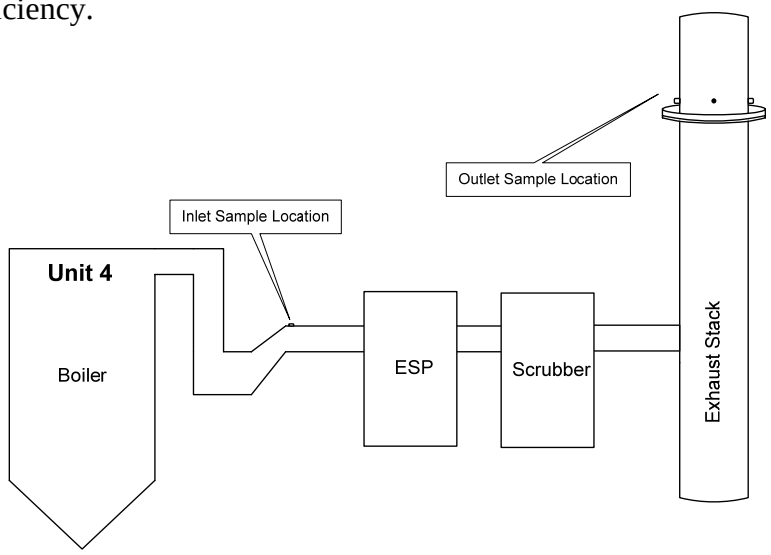


Figure 3.8.1.1 Schematic of Boiler and Pollution Control Equipment – Jim Bridger Unit 4

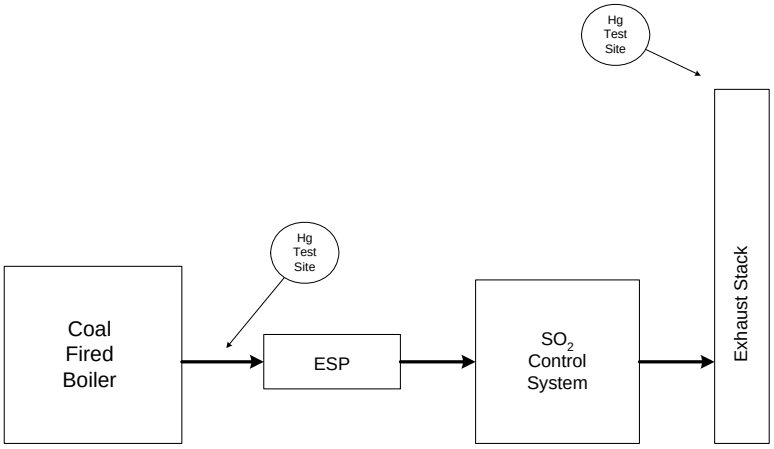


Figure 3.8.1.2 Schematic of Boiler and Pollution Control Equipment – Laramie Unit 1

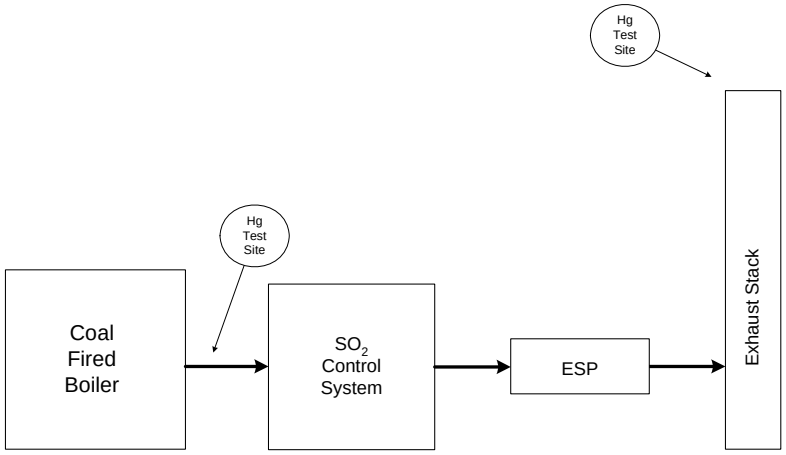


Figure 3.8.1.3 Schematic of Boiler and Pollution Control Equipment – Laramie Unit 3

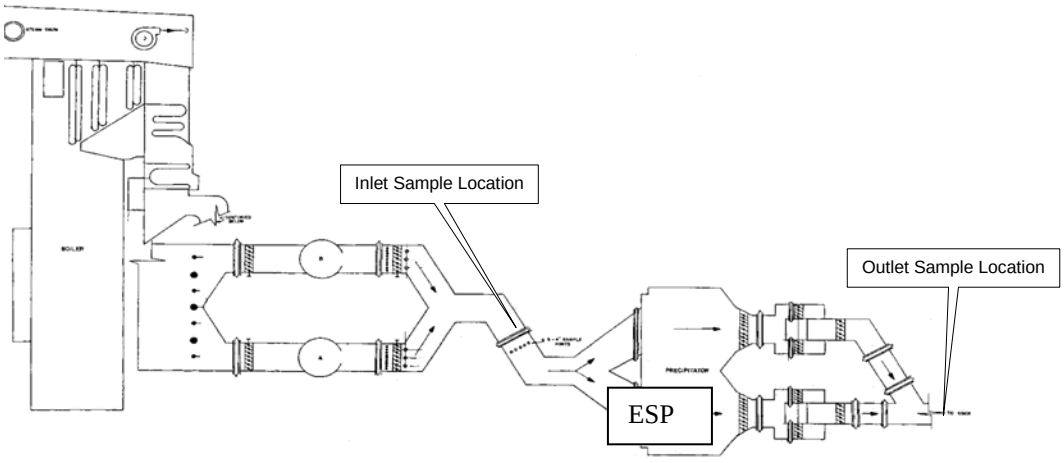


Figure 3.8.1.4 Schematic of Boiler and Pollution Control Equipment – Dave Johnston Unit 2

Tables 3.8.1.1 and 3.8.1.2 show the plant operating data and mercury species capture efficiencies and stack emission.

Table 3.8.1.1 Jim Bridger-4, Laramie 1 and 3 and Dave Johnston 2 Plant Operating Data

Plant Name-	Run	S	M	A	Cl	Hg	FG Temp. - In	FG Moist- In	FG O2- In	FG Temp. - Out	FG Moist- Out	FG O2- Out
Unit #		%	%	%	ppmw	ppmw	Deg C	%	%	Deg C	%	%
Jim Bridger-4 - CESP+WFGD												
ICR	1	0.71	19.0	11.8	ND(100)	0.08	147	9.6	5.8	54	12.8	5.8
	2	0.64	19.5	11.5	ND(100)	0.08	146	9.0	6.0	53	14.1	5.8
	3	0.69	19.6	10.9	ND(100)	0.06	145	9.1	5.8	54	13.4	5.8
Average		0.68	19.4	11.4	50	0.07	146	9.2	5.9	54	13.4	5.8
SEC	1	0.62	19.7	12.4	31	0.10	142	8.7	5.6	58	13.9	5.6
	2	0.59	20.0	13.4	31	0.09	137	8.3	5.2	56	13.2	5.2
	3	0.64	20.1	12.4	31	0.11	134	9.7	5.4	57	13.9	5.4
Average		0.62	20.0	12.7	31	0.10	138	8.9	5.4	57	13.7	5.4
Laramie -1 - CESP+WFGD												
ICR	1	0.52	31.1	7.8	87	0.10	141	12.8	10	64	15.2	10.5
	2	0.52	31.2	7.6	78	0.11	138	11.9	10.1	63	14.9	10.0
	3	0.54	31.3		57	0.14	136	11.6	10.1	63	15.7	7.8
Average		0.53	31.2	7.9	74	0.12	139	12.1	10.1	64	15.3	9.4
SEC	1	0.47	30.0	5.3	36	0.14	148	11.5	6.0	69	15.6	6.0
	2	0.49	30.0	5.2	36	0.08	144	9.5	6.0	68	13.8	6.0
	3	0.49	30.0	9.0	36	0.09	149	11.5	6.0	68	17.7	6.0
Average		0.48	30.0	6.5	36	0.10	147	10.8	6.0	69	15.7	6.0
Laramie -3 - DFGD+CESP												
ICR	1	0.49	30.8	7.4	86	0.12	138	10.4	9.9	78	15.3	10.0
	2	0.49	30.8	7.5	66	0.14	141	10.6	9.9	79	14.8	10
	3	0.47	31.0	7.1	79	0.11	136	10.6	10.1	79	14.9	9.8
Average		0.48	30.9	7.3	77	0.12	138	10.5	9.97	79	15.0	9.9
SEC												
	1	0.44	30.0	7.9	36	0.09	138	10.8	6.0	81	14.5	6.0
	2	0.47	30.0	5.8	36	0.08	147	10.2	6.0	82	14.5	6.0
	3	0.44	30.0	8.3	36	0.15	143	11.7	6.0	82	14.8	6.2
Average		0.45	30.0	7.3	36	0.11	143	10.9	6.0	82	14.6	6.1
Dave Johnston-2 - CESP												
SEC	1	0.60	29.8	7.0	36	0.13	147	11.3	4.9	142	11	4.9
	2	0.60	24.6	6.9	33	0.11	149	11.6	4.9	143	11.6	4.9
	3	0.60	29.9	7.0	36	0.13	148	11.4	4.9	143	11.3	4.9
Average		0.60	28.1	7.0	35	0.12	148	11.43	4.9	142	11.30	4.9

Table 3.8.1.2 Jim Bridger-4, Laramie 1 and 3, Dave Johnston-2 APCD Mercury Capture Performance

Plant Name-	Run	Hg-P -In	Hg-O-In	Hg-E-In	Hg -in Total	F-Factor lb/TBtu at APCD Inlet	Hg-P - Out	Hg-O-Out	Hg-E-Out	Hg -Out Total	Hg - Out Stack	Hg-P Rem. Eff.	Hg-O Rem. Eff.	Hg-E Rem. Eff.	Hg-T Rem. Eff.
Unit #		◊g/dscm (@ 3% O2)					◊g/dscm (@ 3% O2)				lb/hr*10^2	%	%	%	%
Jim Bridger Unit 4 - CESP+WFGD															
ICR	1	0.05	2.49	5.21	7.74	5.56	0.063	0.25	6.63	6.95	2.828	-32.5	89.9	-27.3	10.3
	2	0.44	2.04	5.46	7.94	5.70	0.046	0.29	6.37	6.71	2.666	89.6	85.6	-16.7	15.5
	3	0.07	1.78	4.33	6.18	4.44	0.033	0.20	5.77	6.00	2.412	53.3	88.8	-33.1	3.0
Average		0.19	2.10	5.00	7.29	5.23	0.047	0.25	6.26	6.55	2.635	36.8	88.1	-25.7	9.6
SEC	1	5.83	0.60	9.43	15.85	11.38	0.357	0.35	4.60	5.31	2.01	93.9	41.4	51.2	66.5
	2	1.71	7.20	40.78	49.69	35.66	0.199	0.83	18.01	19.04	6.62	88.4	88.5	55.8	61.7
	3	1.55	1.23	11.46	14.24	10.22	0.192	0.48	6.99	7.66	2.67	87.6	60.7	39.1	46.2
Average		3.01	3.03	20.66	26.70	19.09	0.249	0.56	9.91	10.72	3.84	89.9	63.5	48.7	58.1
Laramie River Unit 1- CESP+WFGD															
ICR	1	0.25	3.14	7.52	10.91	7.85	0.000	0.29	4.86	5.15	1.575	100.0	90.7	35.3	52.8
	2	0.04	2.16	8.35	10.54	7.59	0.000	0.12	5.73	5.85	1.808	100.0	94.5	31.4	44.5
	3	0.02	3.08	7.53	10.63	7.65	0.000	0.03	4.48	4.51	1.702	100.0	99.1	40.5	57.6
Average		0.10	2.79	7.80	10.70	7.70	0.000	0.14	4.99	5.13	1.696	100.0	94.8	35.7	51.6
SEC	1						0.152	0.59	3.27	4.02	1.71				
	2						0.143	0.45	3.35	3.94	1.69				
	3						0.071	0.47	3.38	3.92	1.60				
Average		2.74	1.25	6.18	10.17	7.30	0.122	0.50	3.33	3.96	1.67	95.6	59.9	46.0	59.6
Laramie River Unit 3 - DFGD+CESP															
ICR	1	0.03	0.22	0.63	0.88	0.63	0.026	0.10	3.87	4.00	1.427	0.4	56.3	-514.9	-355.3
	2	1.69	0.52	8.53	10.75	7.73	0.028	0.04	4.52	4.58	1.715	98.3	92.8	47.1	57.4
	3	4.55	0.44	9.28	14.27	10.27	0.033	0.04	5.27	5.34	1.941	99.3	91.2	43.2	62.5
Average		2.07	0.39	6.13	8.60	6.21	0.029	0.06	4.56	4.65	1.694	66.0	80.1	-141.5	-78.5
SEC															
	1						0.163	0.12	9.62	9.90	4.58				
	2						0.219	0.19	10.75	11.16	5.27				
	3						0.144	0.21	10.40	10.75	5.00				
Average		1.01	1.19	8.37	10.57	7.59	0.175	0.17	10.25	10.60	4.95	82.7	85.5	-22.6	-0.3
Dave Johnston Unit 2 - CESP															
SEC	1	9.59	0.29	1.50	11.38	8.16	0.141	1.34	1.58	3.06	0.27	98.5	-361.5	-5.2	73.1
	2	9.25	0.19	2.19	11.63	8.35	0.164	1.32	1.48	2.96	0.27	98.2	-594.1	32.7	74.5
	3	11.78	0.21	1.04	13.03	9.35	0.135	1.35	1.58	3.07	0.28	98.9	-536.8	-51.6	76.5
Average		10.21	0.23	1.58	12.01	8.62	0.147	1.34	1.54	3.03	0.27	98.5	-497.5	-8.1	74.7

Figures 3.8.1.5 – 3.8.1.12 show the mercury capture efficiencies of the APCDs with CESP for particulate removal in all cases, followed by WFGD at Jim Bridger Unit 4 and Laramie Unit 1. In the case of Laramie Unit 1, dry FGD system is ahead of the CESP to control the SO2.

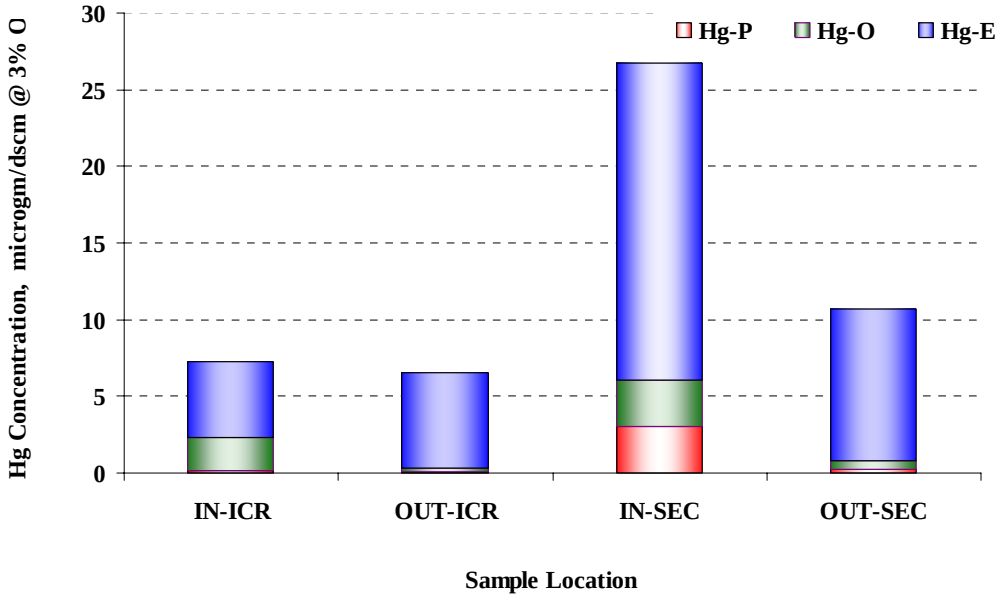


Figure.3.8.1.5. Jim Bridger Unit 4 – Hg Species Concentration at Inlet and Outlet of the CESP-WFGD.

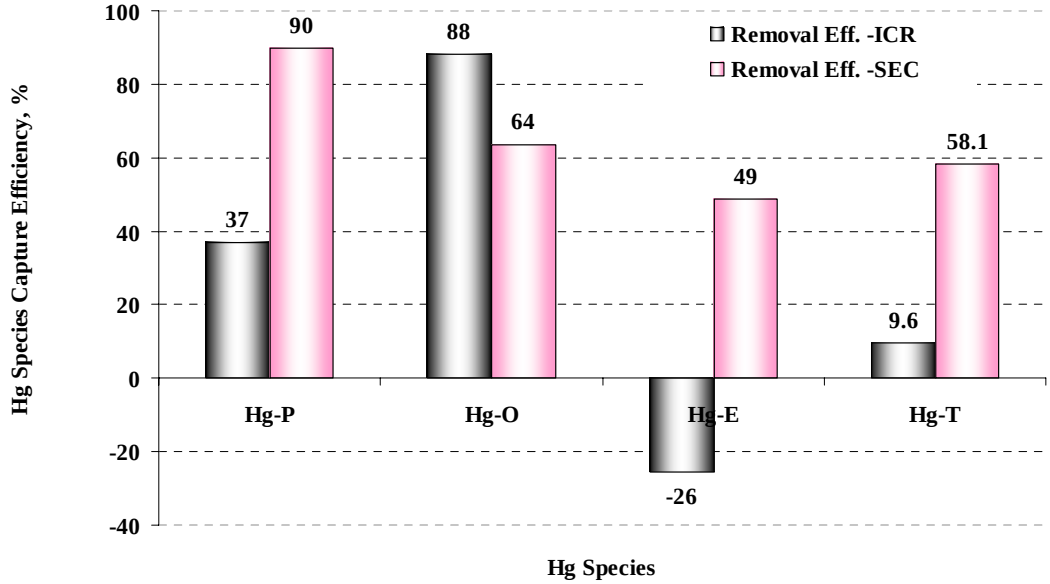


Figure 3.8.1.6 Jim Bridger Unit 4 – Hg Species Removal Across CESP-WF GD

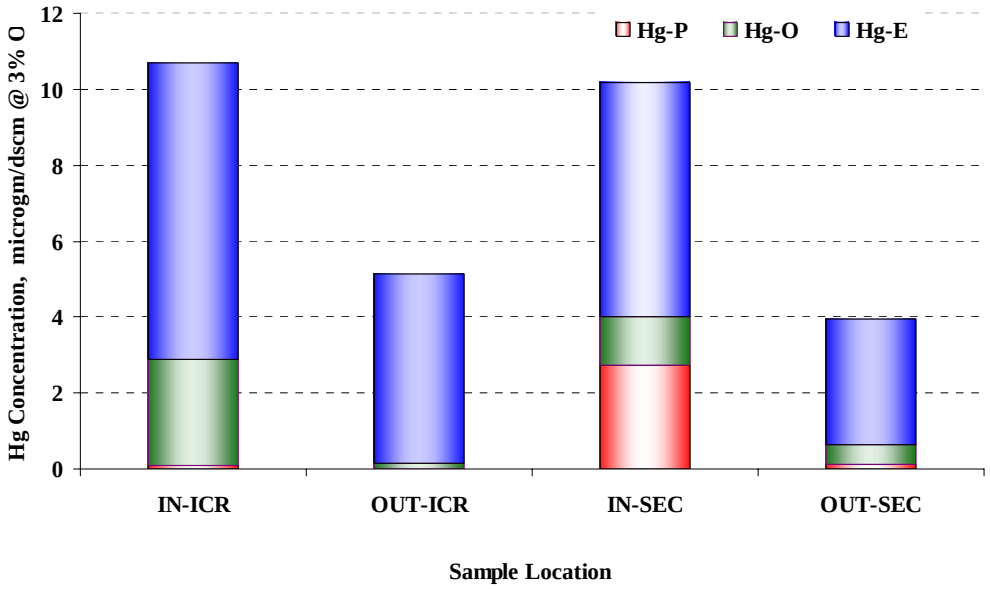


Figure 3.8.1.7 Laramie Unit 1 – HG Species Concentration at Inlet and Outlet of CESP-WFGD

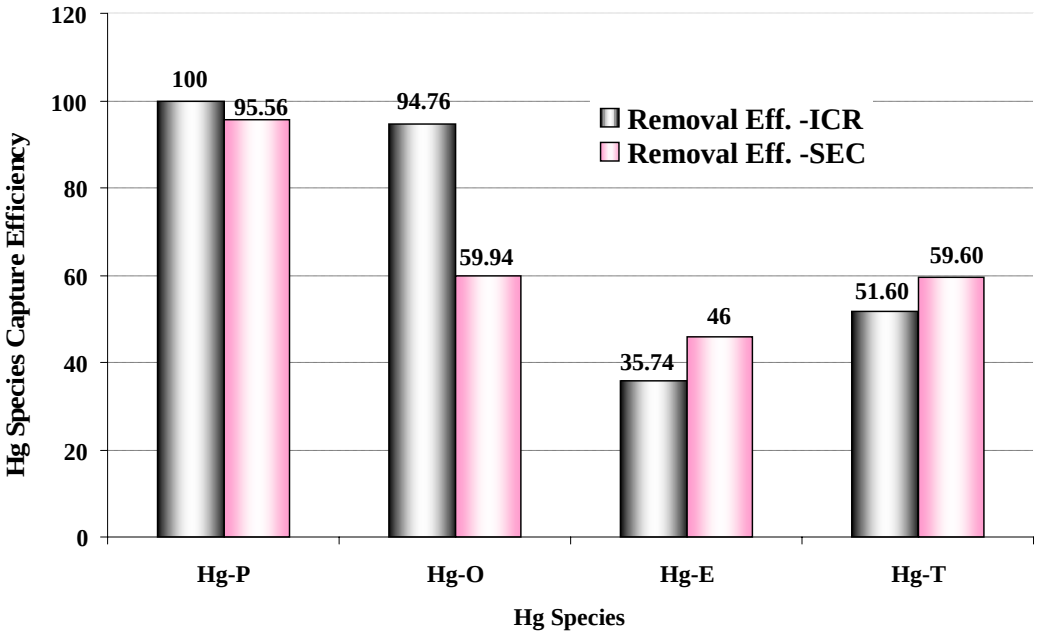


Figure 3.8.1.8 Laramie Unit 1 – Hg Species Removal Across CESP-WFGD

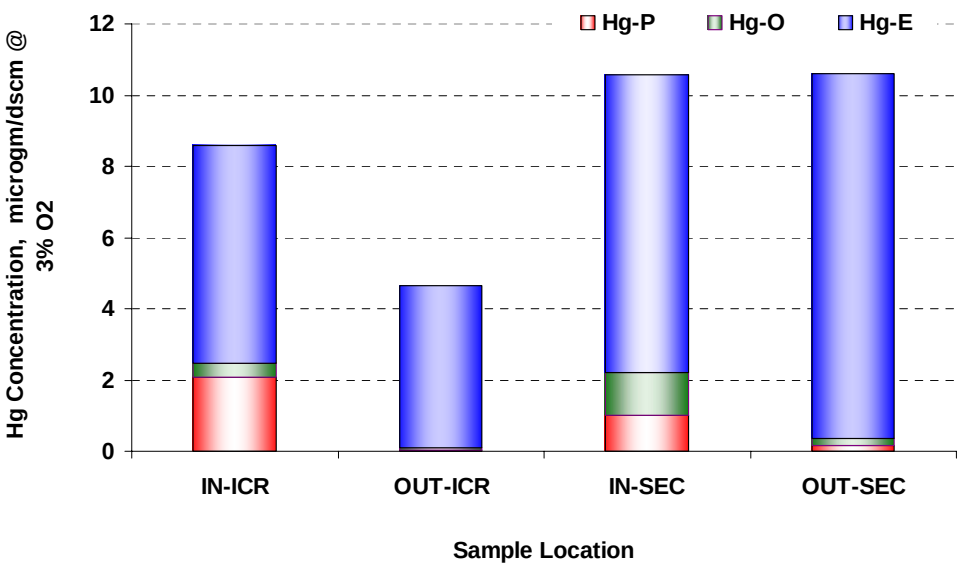


Figure 3.8.1.9 Laramie Unit 3 – Hg Species Concentration at Inlet and Outlet of DFGD+CESP

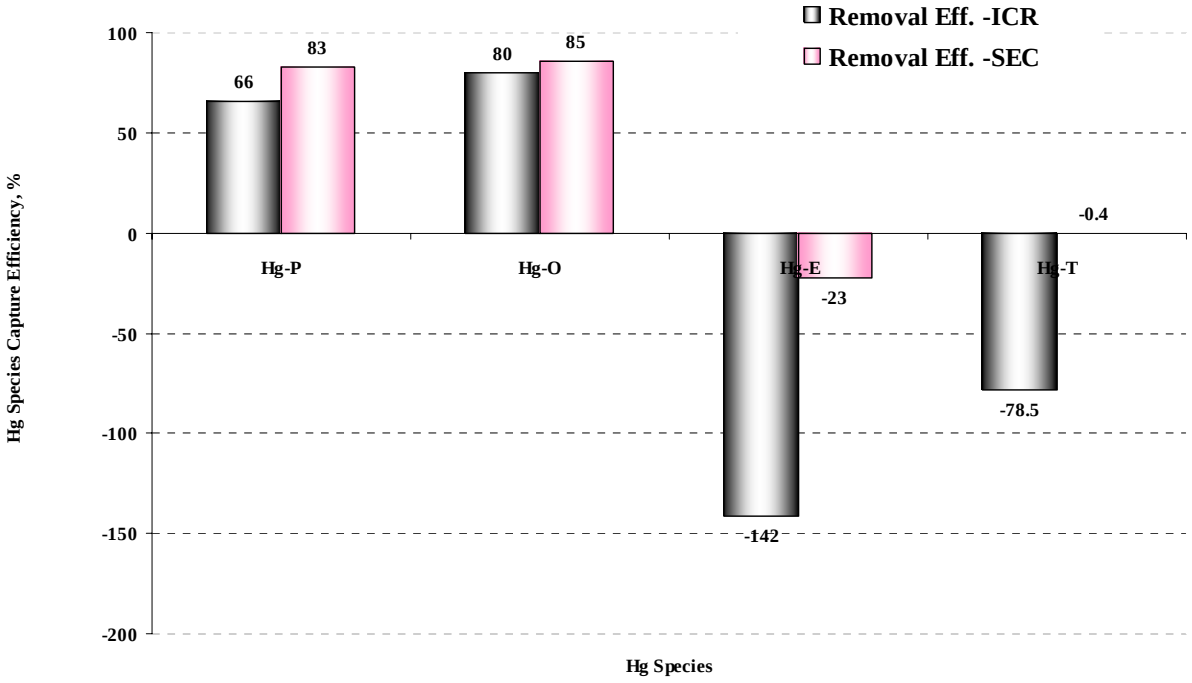


Figure 3.8.1.10 Laramie Unit 3 – Hg Species Removal Across DFGD+CESP

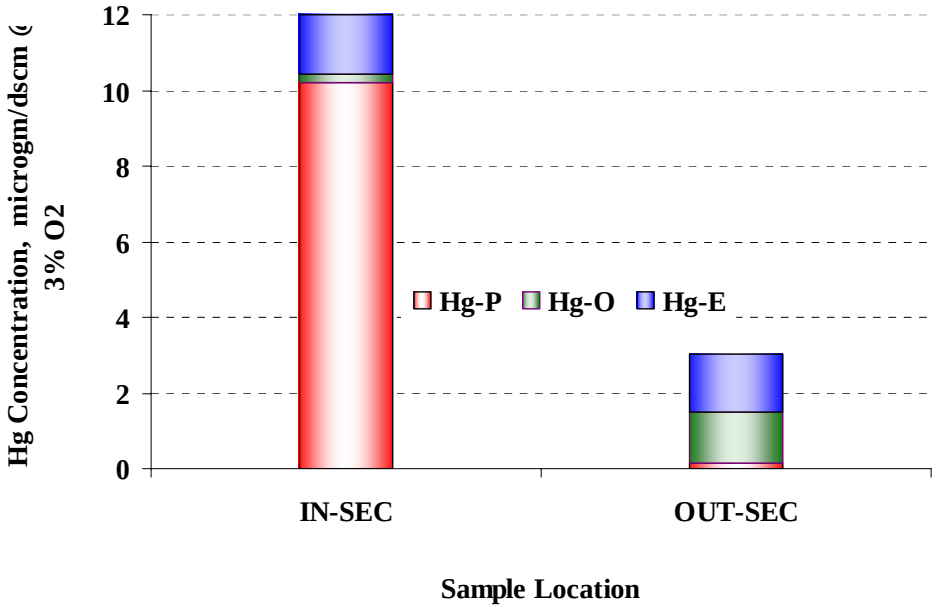


Figure 3.8.1.11 Dave Johnston Unit 2 – Hg Species Concentration at Inlet and Outlet of CESP

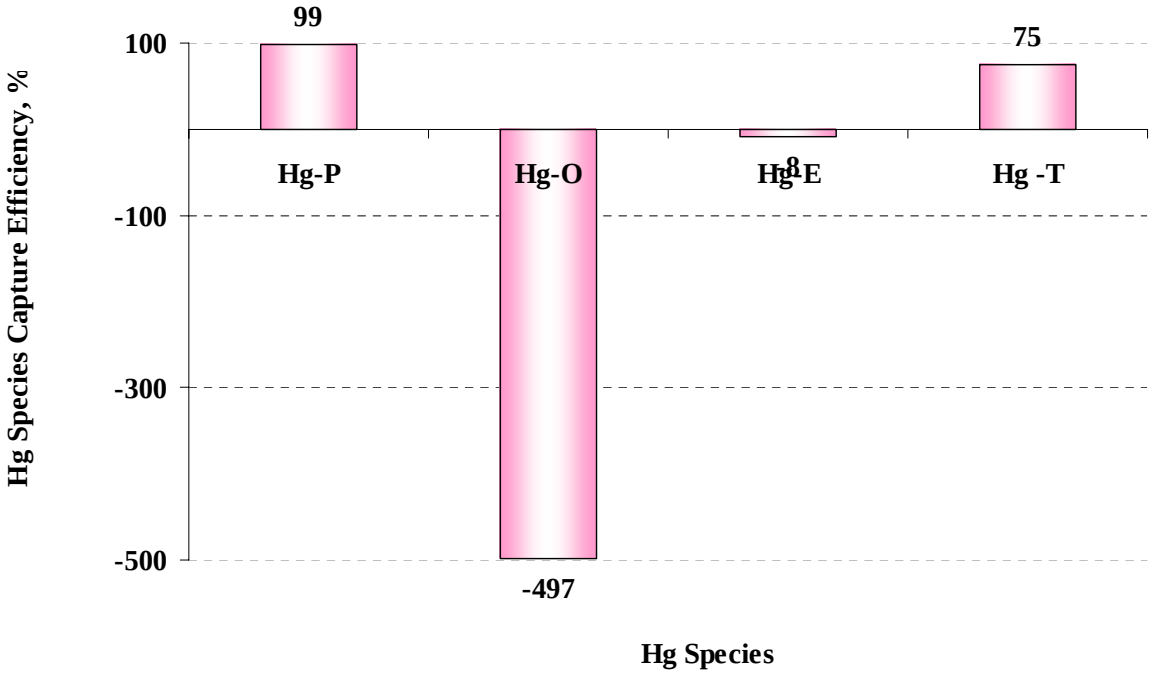


Figure 3.8.1.12 Dave Johnston Unit 2 – Hg Species Removal Across CESP

3.8.2 Hot-side ESPs

The mercury capture performance of three units - Columbia Unit 1, Nelson Dewey Unit 1, and Platte River Unit 1 - are illustrated and discussed in this section. The following three figures illustrate the emissions source sampling points of each unit.

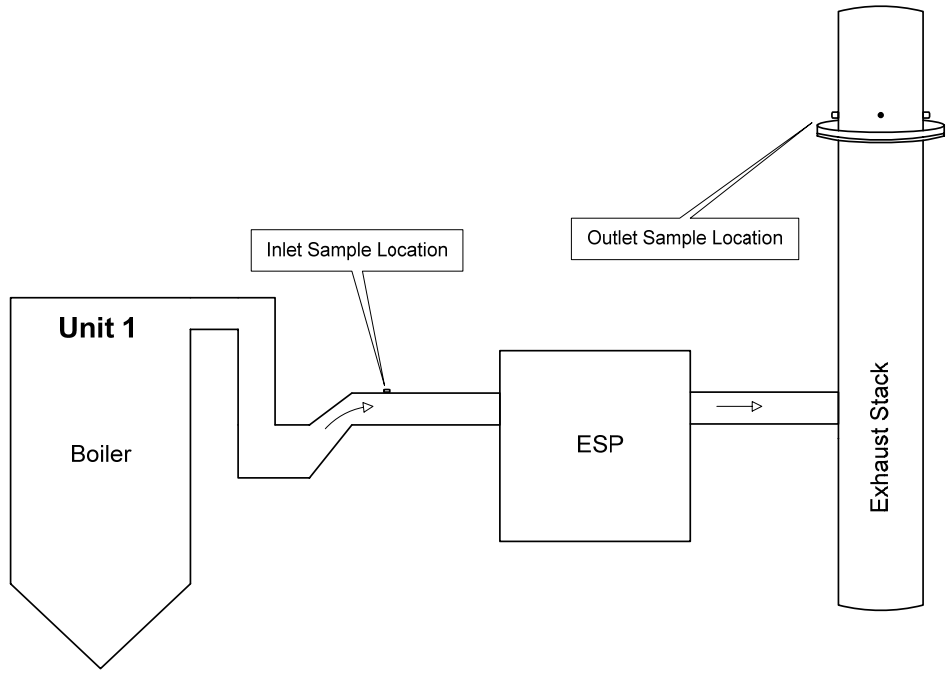


Figure 3.8.2.1 Schematic of Boiler and Pollution Control Equipment – Columbia Unit 1

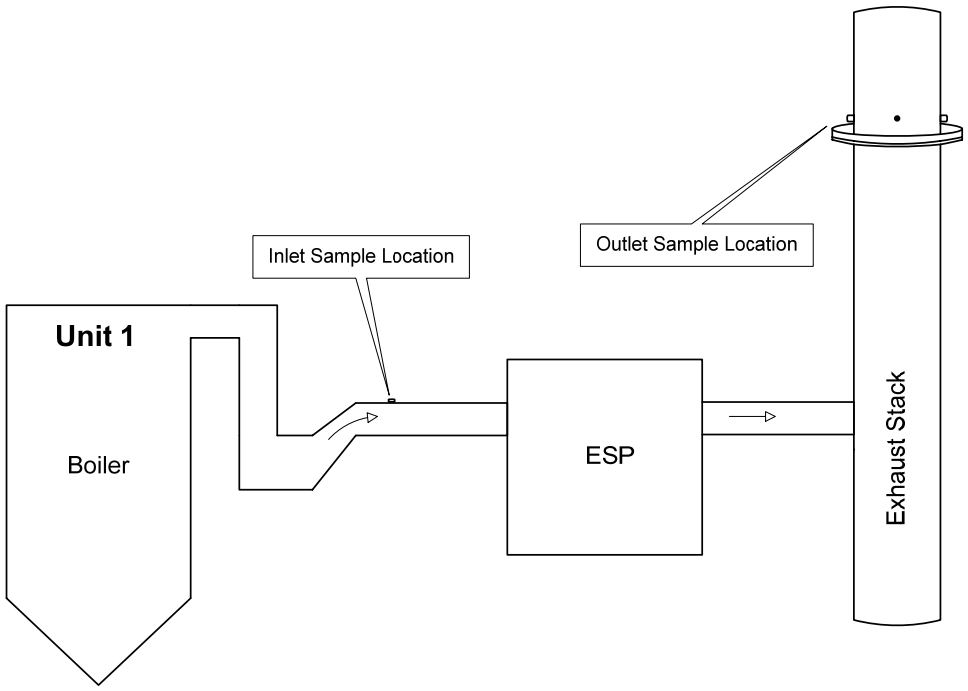


Figure 3.8.2.2 Schematic of Boiler and Pollution Control Equipment – Nelson Dewey Unit 1

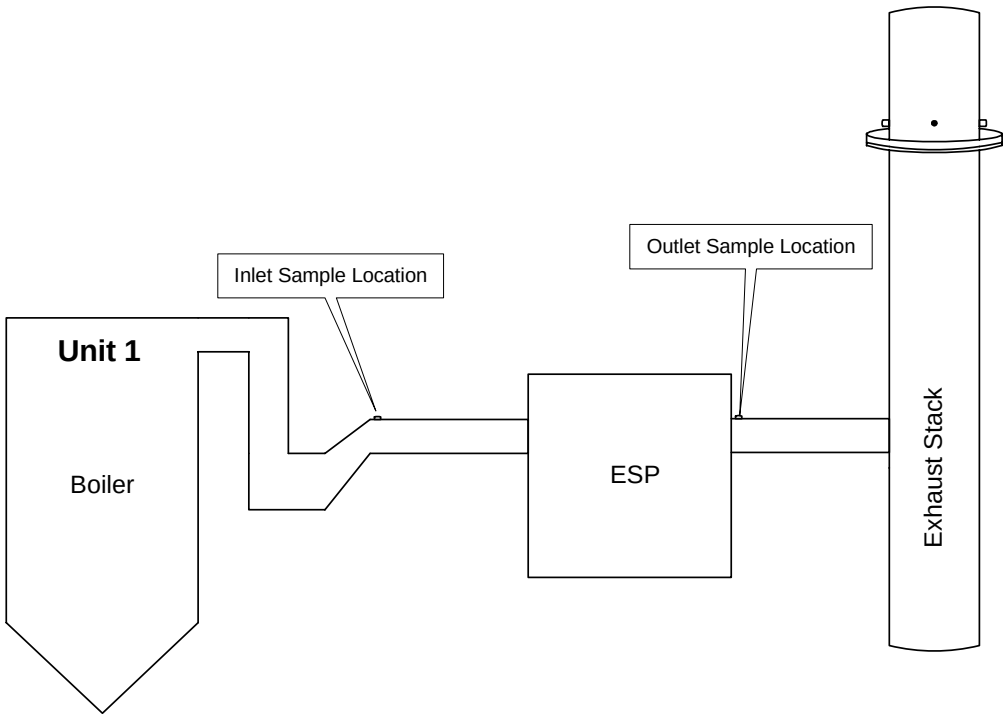


Figure 3.8.2.3 Schematic of Boiler and Pollution Control Equipment – Platte River Unit 1

Table 3.8.2.1 Columbia -1, Nelson Dewey 1, and Platte River -1 Plant Operating Data

Plant Name-	Run	S	M	A	Cl	Hg	FG Temp. - In	FG Moist- In	FG O2- In	FG Temp. - Out	FG Moist- Out	FG O2- Out
Unit #		%	%	%	ppmw	ppmw	Deg C	%	%	Deg C	%	%
Columbia-1 -HESP												
ICR	1	0.43	30.4	6.5	292	0.10	406	13.5	3.8	149	11.7	6.0
	2	0.43	29.1	6.2	347	0.10	403	13.9	4.0	156	11.9	5.8
	3	0.42	29.8	5.4	303	0.10	409	11.9	4.2	157	11.9	6.0
Average		0.43	29.8	6.0	314	0.10	406	13.1	4.0	154	11.8	5.9
SEC	1	0.59	32.0	6.1	76	0.10	403	12.4	7.8	149	10.1	7.9
	2	0.53	30.4	6.1	36	0.13	404	12.6	7.8	157	11.2	7.8
	3	0.54	31.2	6.1	36	0.15	404	13.4	7.8	161	11.6	7.8
Average		0.55	31.2	6.1	50	0.13	404	12.8	7.8	156	11.0	7.8
Nelson Dewey -1 -HESP												
ICR	1	1.48	22.4	5.0	141	0.06	254	10.8	4.4	258	11.1	4.2
	2	1.37	21.5	4.8	151	0.06	257	10.3	4.3	258	10.8	4.2
	3	1.35	23.6	4.9	95	0.06	260	10.3	3.8	264	10.9	3.8
Average		1.40	22.5	4.9	129.00	0.06	257	10.5	4.17	260	10.9	4.1
SEC	1	1.86	21.6	4.3	89	0.07	257	10.9	4.0	255	11.2	3.6
	2	1.86	21.5	4.2	78	0.07	257	11.3	4.0	260	10.7	3.8
	3	1.68	22.8	4.2	65	0.07	258	11.1	4.0	270	11.1	3.8
Average		1.80	22.0	4.2	78	0.07	257	11.1	4.0	262	11.0	3.7
Platte - 1 - HESP												
ICR	1	0.45	31.7	7.6	177	0.11	412	12.4	4.5	153	12.2	5.9
	2	0.43	29.1	6.9	174	0.09	413	13.6	4.2	158	14.2	5.7
	3	0.42	31.2	7.1	191	0.07	416	15.1	2.9	152	13.4	5.9
Average		0.43	30.7	7.2	181	0.09	414	13.7	3.9	155	13.3	5.8
SEC	1	0.35	27.9	6.1	35	0.09	406	11.9	6.7	135	11.0	6.7
	2	0.41	28.7	6.4	35	0.08	412	9.4	6.7	141	11.1	6.7
	3	0.35	28.3	7.8	35	0.09	414	11.5	6.7	142	10.7	6.7
Average		0.37	28.3	6.8	35	0.09	410	10.9	6.7	139	10.9	6.7

Table 3.8.2.2 Columbia -1, Nelson Dewey 1, and Platte River -1 APCD Mercury Capture Performance

Plant Name-	Run	Hg-P -In	Hg-O-In	Hg-E-In	Hg -in Total	F-Factor lb/TBtu at	Hg-P -Out	Hg-O-Out	Hg-E-Out	Hg -Out Total	Hg - Out Stack	Hg-P Rem. Eff.	Hg-O Rem. Eff.	Hg-E Rem. Eff.	Hg-T Rem. Eff.	F factor lb/TBtu	lb/GWh at APCD Outlet-
Unit #		◊g/dscm (@ 3% O2)				APCD	◊g/dscm (@ 3% O2)				lb/hr*10^2	%	%	%	%	at APCD	From
Columbia-1 -HESP																	
ICR	1	0.02	0.93	14.27	15.23	10.92	0.005	2.74	11.71	14.45	5.812	77.1	-193.8	18.0	5.1	10.376	0.10995
	2	0.03	5.82	13.40	19.26	13.82	0.005	2.16	11.82	13.98	5.619	85.1	63.0	11.8	27.4	10.035	0.10633
	3	0.04	0.46	14.65	15.15	10.87	0.005	2.65	11.99	14.64	5.809	88.8	-475.6	18.2	3.3	10.514	0.11141
Average		0.03	2.41	14.11	16.55	11.87	0.005	2.51	11.84	14.36	5.747	83.7	-202.1	16.0	11.9	10.308	0.10923
SEC	1	4.09	0.14	16.61	20.84	14.98	0.343	0.71	12.34	13.40	3.43	91.6	-424.5	25.7	35.7	9.63	0.10203
	2	0.39	0.19	15.27	15.85	11.39	0.109	0.73	11.35	12.20	3.20	72.4	-285.7	25.6	23.1	8.76	0.09286
	3	4.96	0.15	13.28	18.40	13.22	0.082	0.63	11.14	11.84	3.13	98.4	-318.2	16.2	35.6	8.51	0.09017
Average		3.15	0.16	15.06	18.36	13.20	0.177	0.69	11.61	12.48	3.25	87.5	-342.8	22.5	31.5	8.97	0.09500
Nelson Dewey -1 -HESP																	
ICR	1	0.02	0.49	3.20	3.71	2.66	0.049	0.26	3.33	3.64	0.274	-102.9	47.3	-4.2	2.0	2.610	0.02766
	2	0.02	0.24	2.19	2.44	1.75	0.019	0.16	2.40	2.58	0.193	-7.1	32.2	-9.7	-5.6	1.851	0.01961
	3	0.02	0.12	2.06	2.20	1.58	0.018	0.25	2.44	2.71	0.212	8.4	-118.2	-18.3	-23.3	1.942	0.02058
Average		0.02	0.28	2.48	2.78	2.00	0.029	0.22	2.72	2.97	0.226	-33.9	-12.9	-10.7	-9.0	2.135	0.02262
SEC	1	3.72	1.89	2.53	8.15	5.85	0.073	1.31	4.46	5.84	0.50	98.1	31.0	-76.4	28.3	4.19	0.04439
	2	2.22	0.18	3.44	5.84	4.19	0.073	0.04	4.73	4.85	0.49	96.7	76.8	-37.5	17.1	3.48	0.03683
	3	4.69	0.10	0.83	5.61	4.02	0.178	0.24	5.12	5.53	0.48	96.2	-152.2	-519.9	1.3	3.97	0.04206
Average		3.55	0.72	2.26	6.53	4.69	0.108	0.53	4.77	5.41	0.49	97.0	-14.8	-211.3	15.6	3.88	0.04110
Platte - 1 -																	
ICR	1	0.03	4.15	9.82	14.00	10.04	0.026	1.45	8.76	10.24	0.765	19.9	64.9	10.8	26.8	7.353	0.07791
	2	0.03	1.92	11.31	13.26	9.52	0.027	0.78	16.86	17.66	1.298	15.8	59.5	-49.0	-33.2	12.679	0.13435
	3	0.03	4.39	11.63	16.04	11.50	0.023	1.51	14.90	16.44	1.224	24.1	65.5	-28.2	-2.5	11.800	0.12504
Average		0.03	3.50	10.94	14.48	10.35	0.025	1.25	13.52	14.79	1.096	19.9	63.3	-22.1	-2.9	10.611	0.11243
SEC	1	0.65	0.23	10.27	11.15	8.01	0.299	1.20	9.15	10.64	0.88	54.1	-427.8	10.9	4.5	7.64	0.08100
	2	0.95	4.23	6.23	11.41	8.20	0.107	0.83	9.11	10.05	0.70	88.7	80.3	-46.2	11.9	7.22	0.07647
	3	0.44	0.37	10.08	10.89	7.82	0.063	0.78	8.33	9.17	0.70	85.8	-113.8	17.4	15.8	6.59	0.06980
Average		0.68	1.61	8.86	11.15	8.01	0.156	0.94	8.86	9.95	0.76	76.2	-153.8	-5.9	10.7	7.15	0.07576

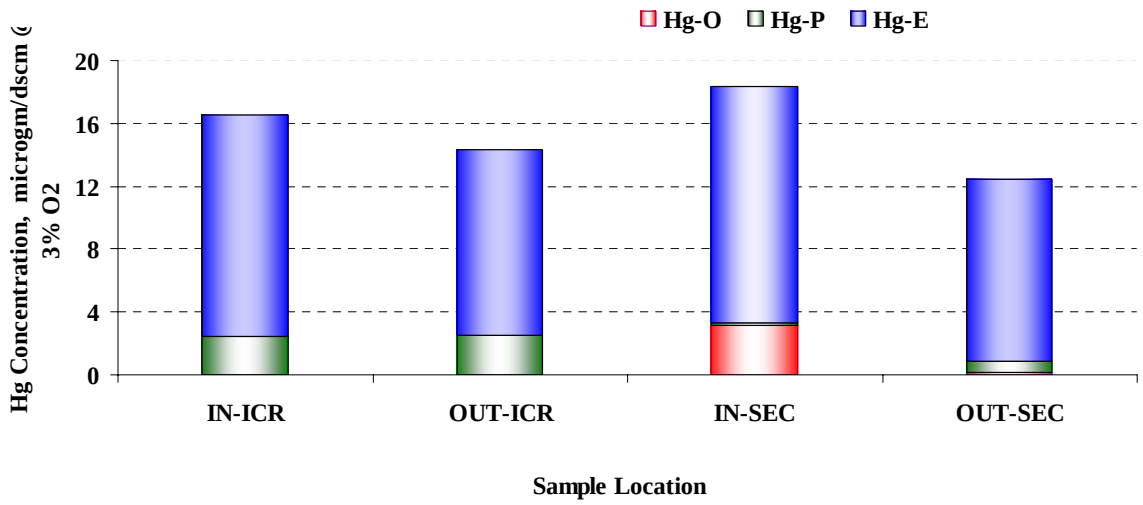


Figure 3.8.2.4 Columbia Unit 1 – Hg Species Concentration at Inlet and Outlet of HESP

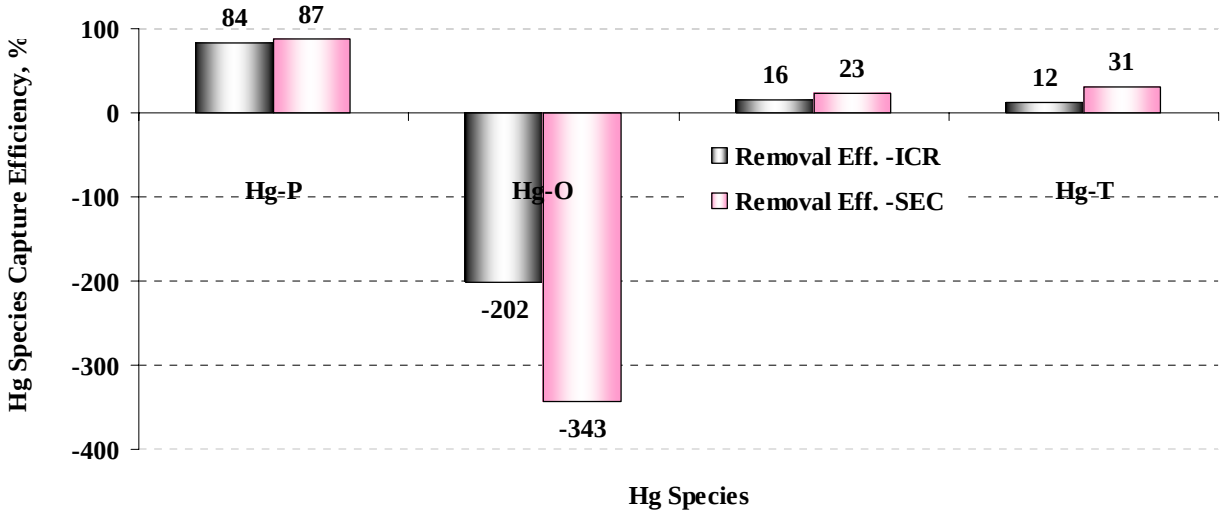


Figure 3.8.2.5 Columbia Unit 1 – Hg Species Removal Across HESP

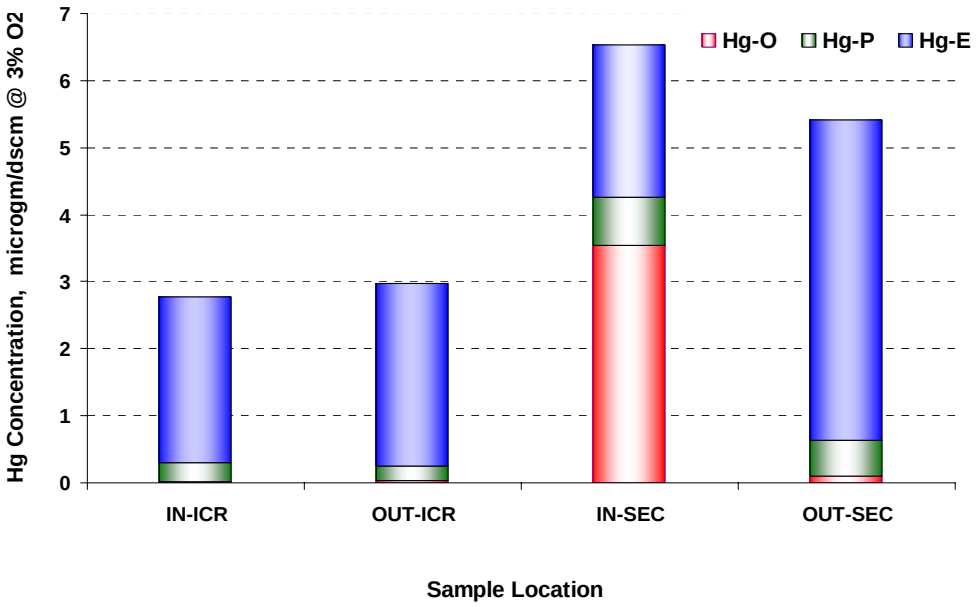


Figure 3.8.2.6 Nelson Dewey Unit 1 – Hg Species Concentration at Inlet and Outlet of HESP

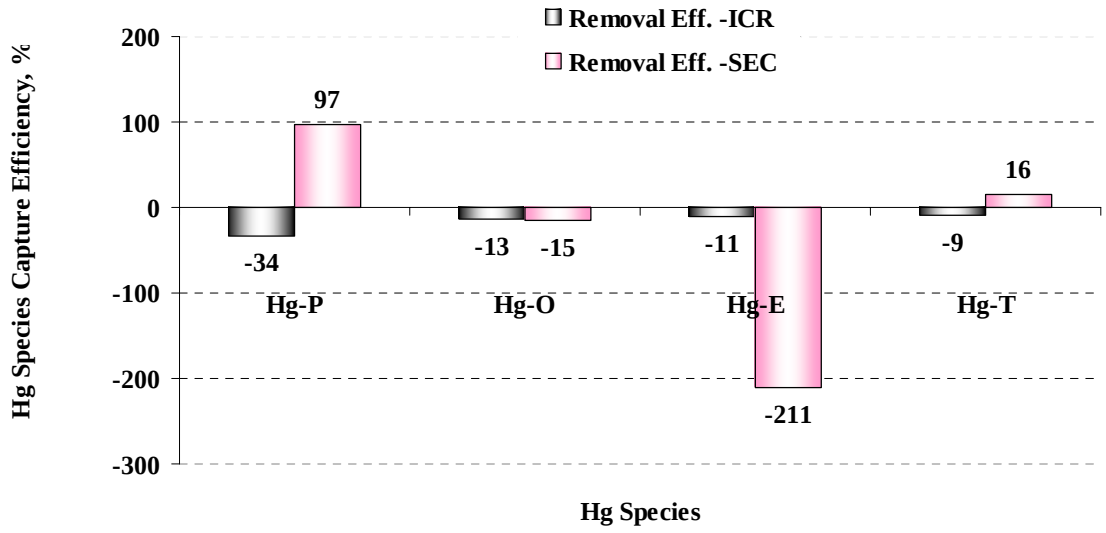
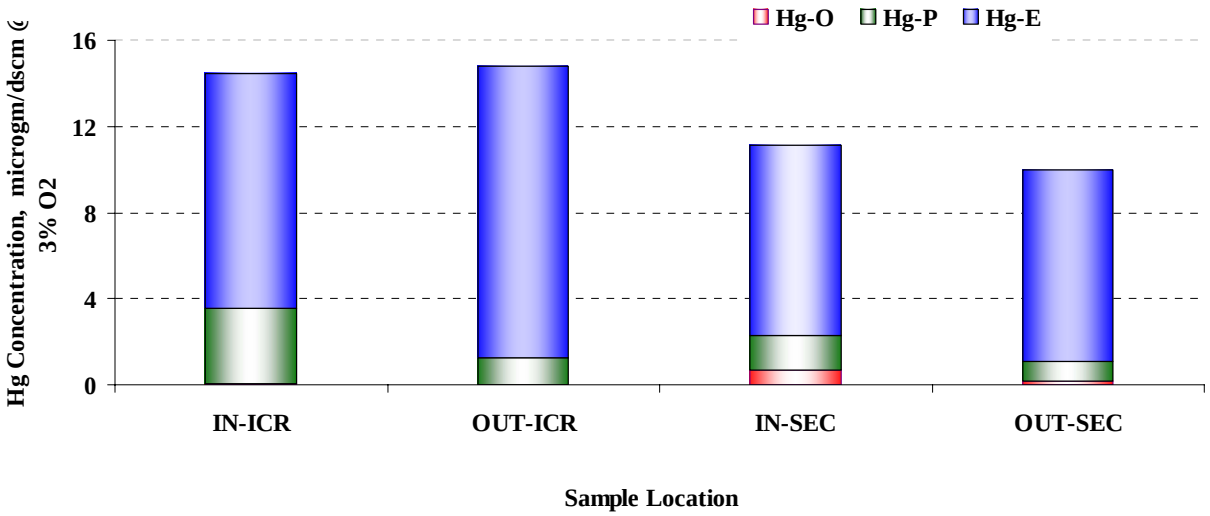
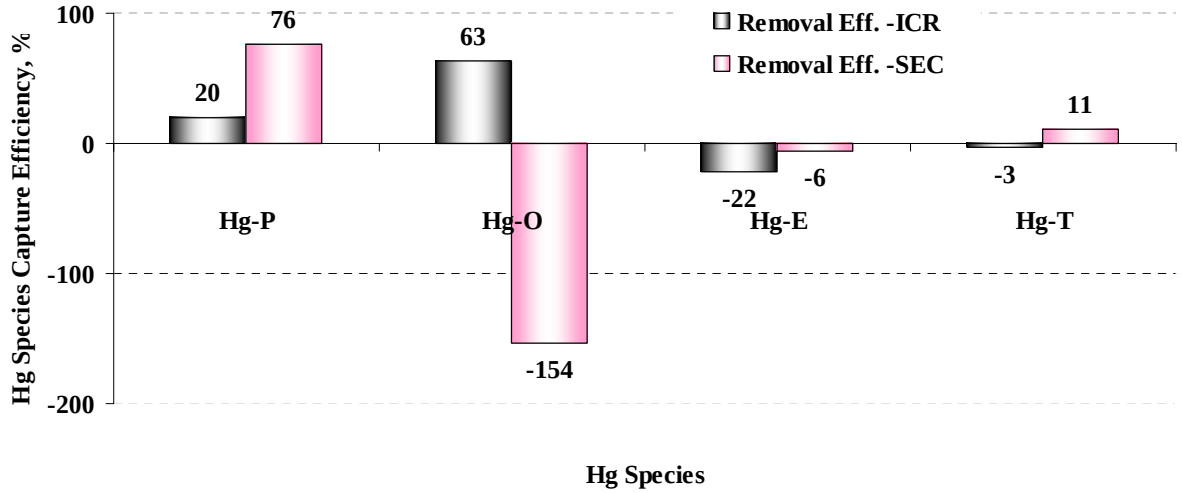


Figure 3.8.2.7 Nelson Dewey Unit 1 – Hg Species Removal Across HESP



Figures 3.8.2.8 Platte Unit 1 – Hg Species Concentration at Inlet and Outlet of HESP



Figures 3.8.2.9 Platte Unit 1 – Hg Species Removal Across HESP

Hot-side ESPs (HESP) have typically performed poorly in mercury removal. Two (2) of the three (3) units showed negative removal in the ICR data though all three have shown to be capturing 11-31% of the incoming mercury during SEC tests. The flue gas temperature effect is apparent in two (2) units except the Nelson Dewey unit, which burns a blended fuel. The reason for the over 100% increase in Hg-E quantity (2.26 μg/dscm to 4.77 μg/dscm) across the APCD is not clear. This HESP operates at about 257°C (495°F) compared to the operating temperature of 404-410°C (760-770°F) of the other two HESPs.

3.8.3 FF and DFGD+FF Unit Performance

Three units- Pawnee Unit 1, Sheldon Unit 2 and Rawhide Unit 101, have FFDC installations. Sampling points are shown in Figures 3.8.3.1 to 3.8.3.3.

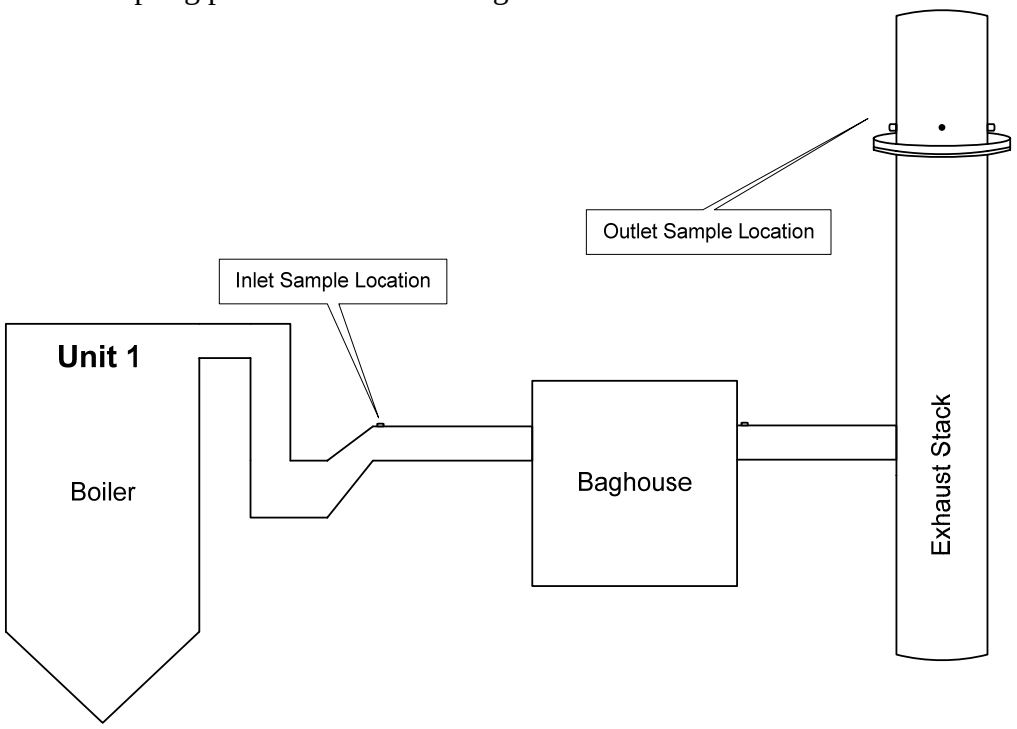


Figure 3.8.3.1 Schematic of Boiler and Pollution Control l Equipment – Pawnee Unit 1

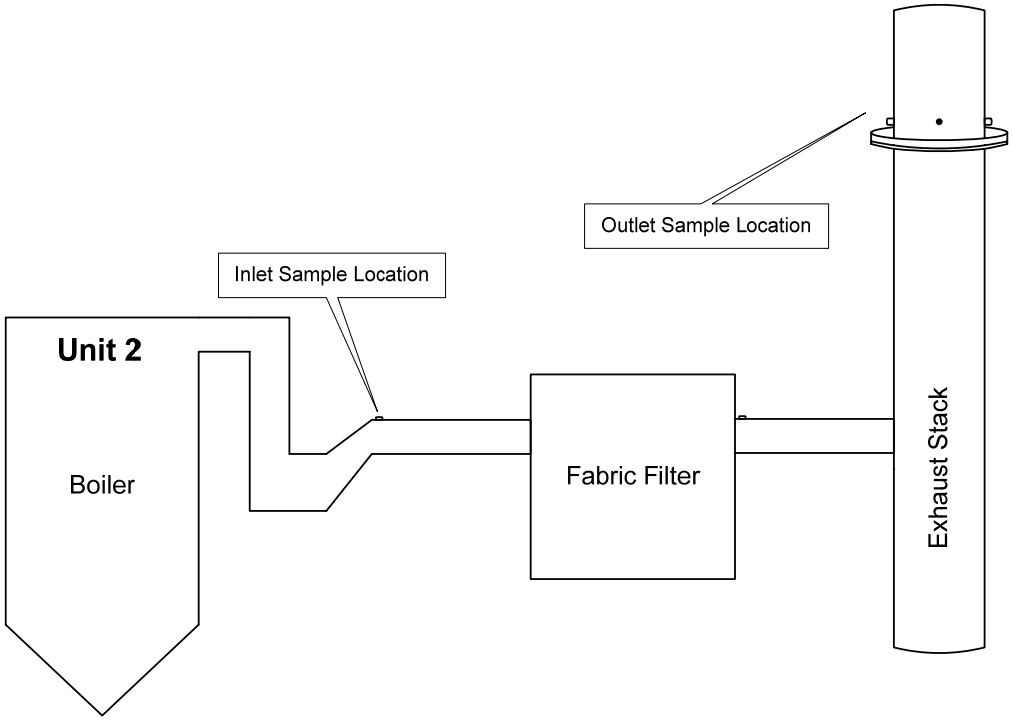


Figure 3.8.3.2 Schematic of Boiler and Pollution Control Equipment – Sheldon Unit 2

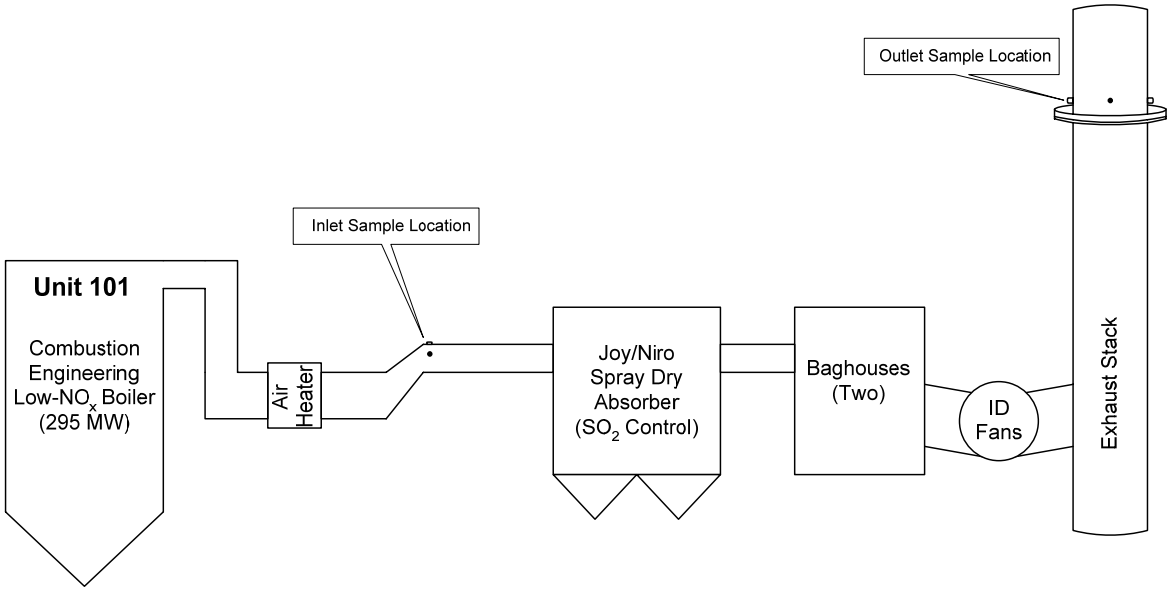


Figure 3.8.3.3 Schematic of Boiler and Pollution Control Equipment – Rawhide Unit 101

Table 3.8.3.1 Rawhide Unit 101, Pawnee Unit 1 and Sheldon Unit 2 Plant Operating Data

Plant Name-	Run	S	M	A	Cl	Hg	FG Temp. - In	FG Moist- In	FG O2- In	FG Temp. - Out	FG Moist- Out	FG O2- Out
Unit #		%	%	%	ppmw	ppmw	Deg C	%	%	Deg C	%	%
Rawhide -101 -SDA+FF												
ICR	1	0.31	20.5	7.3	133	0.07	171	12.65	5.1	104	12.78	6.0
	2	0.3	25.6	7.3	118	0.07	171	12.86	4.2	105	16.27	5.5
	3	0.3	23.4	7.5	129	0.08	171	12.27	5.6	103	16.19	6.0
Average		0.30	23.2	7.4	127	0.07	171	12.6	4.97	104	15.08	5.8
SEC	1	0.29	25.1	5.9	33	0.10	157	10.6	3.8	98	13.3	5.5
	2	0.29	23.9	6.6	33	0.05	156	10.3	3.8	99	13	5.5
	3	0.30	24.5	5.9	33	0.04	156	10.1	3.8	99	13	5.5
Average		0.30	24.5	6.1	33	0.06	156	10.3	3.8	99	13.10	5.5
Pawnee -1- FF												
SEC	1	0.64	30.2	6.6	36	0.18	157	10.1	6.4	149	10.7	6.4
	2	0.58	29.8	6.7	36	0.12	157	10.5	6.4	148	10.4	6.4
	3	0.58	29.5	6.4	35	0.07	162	11.1	6.4	156	11.7	6.4
Average		0.60	29.9	6.6	36	0.12	159	10.6	6.4	151	10.93	6.4
Sheldon - 2 -FF												
SEC	1	0.33	27.5	6.2	34	0.05	153	10.5	7.2	158	9.8	7.2
	2	0.31	28.3	6.4	35	0.11	154	10.1	7.2	152	10	7.2
	3	0.30	26.0	6.4	34	0.22	153	10	7.2	152	9.6	8.3
Average		0.31	27.3	6.3	34	0.13	153	10.2	7.2	154	9.80	7.6

Of the three units, Rawhide Unit 101 has DFGD ahead of the FFDC. There is increase in PM concentration at the FFDC inlet due to the operation of the DFGD. Pawnee Unit 1 shows a similar Hg species capture performance with identical quantities of Hg vapor (Hg-O and Hg-E) fraction. In addition, the Rawhide APCD operates with a 50 ºC (90 ºF) lower flue gas temperature than Sheldon Unit 2. Both lower gas temperature and, most likely, higher PM concentration does not seem to help Hg capture. Performance data are shown in Figures 3.8.3.4 - 3.8.3.9.

The Hg-O concentration at Pawnee Unit 1 increases across the FFDC most likely due to oxidation of the elemental species across the filter cake. Also, there is no Hg-O capture by the FFDC.

Table 3.8.3.2 Rawhide Unit 101, Pawnee Unit 1 and Sheldon Unit 2 APCD Mercury Capture Performance

Plant Name	Run	Hg-P -In	Hg-O-In	Hg-E-In	Hg -in Total	F-Factor lb/TBtu at APCD Inlet	Hg-P -Out	Hg-O-Out	Hg-E-Out	Hg -Out Total	Hg - Out Stack	Hg-P Rem. Eff.	Hg-O Rem. Eff.	Hg-E Rem. Eff.	Hg-T Rem. Eff.	F factor lb/TBtu at APCD Outlet	lb/GWh at APCD Outlet-From Concentration
Unit #		◊g/dscm (@ 3% O2)					◊g/dscm (@ 3% O2)				lb/hr*10^2	%	%	%	%		
Rawhide Unit 101 - SDA+FF																	
ICR	1	0.25	1.38	12.46	14.09	10.11	0.240	0.76	10.80	11.80	2.359	3.6	45.3	13.4	16.3	8.469	0.08974
	2	1.92	0.83	12.85	15.59	11.18	0.006	0.69	9.91	10.60	2.123	99.7	17.0	22.9	32.0	7.606	0.08060
	3	3.76	0.46	14.79	19.01	13.64	0.060	0.98	9.00	10.04	1.971	98.4	-115.9	39.1	47.2	7.211	0.07641
Average		1.96	0.89	13.34	16.19	11.65	0.101	0.81	9.90	10.81	2.151	67.2	-17.9	25.1	31.8	7.762	0.08225
SEC	1	0.22	3.05	7.59	10.86	7.79	0.007	3.43	5.25	8.69	1.78	96.8	-12.6	30.8	20.0	6.24	0.06611
	2	0.27	0.48	5.65	6.40	4.59	0.007	1.03	5.91	6.95	1.48	97.5	-114.8	-4.7	-8.6	4.99	0.05288
	3	0.37	1.75	5.38	7.51	5.38	0.007	0.92	5.64	6.56	1.42	98.1	47.8	-4.8	12.6	4.71	0.04988
Average		0.29	1.76	6.21	8.26	5.92	0.007	1.79	5.60	7.40	1.56	97.5	-26.5	7.1	8.0	5.31	0.05629
Pawnee Unit 1- FF																	
SEC	1	3.93	0.53	9.35	13.81	9.91	0.081	7.56	0.95	8.59	3.09	97.9	-1327.9	89.9	37.8	6.17	0.06538
	2	7.00	5.89	6.30	19.19	13.78	0.016	4.79	0.95	5.76	2.08	99.8	18.6	84.9	70.0	4.13	0.04381
	3	6.41	3.30	3.43	13.13	9.43	0.012	5.26	0.69	5.96	2.15	99.8	-59.3	80.0	54.6	4.28	0.04533
Average		5.78	3.24	6.36	15.38	11.04	0.037	5.87	0.86	6.77	2.44	99.2	-456.2	84.9	54.1	4.86	0.05151
Sheldon Unit 2 -FF																	
SEC	1	5.48	0.10	2.93	8.52	6.12	0.043	0.20	1.64	1.88	0.17	99.2	-87.5	44.0	77.9	1.35	0.01432
	2	6.41	0.09	2.50	9.00	6.47	0.034	0.21	1.47	1.72	0.15	99.5	-128.6	41.1	80.9	1.23	0.01306
	3	7.14	0.09	1.62	8.85	6.36	0.023	0.20	1.56	1.78	0.14	99.7	-118.0	3.3	79.8	1.28	0.01359
Average		6.34	0.10	2.35	8.79	6.31	0.034	0.20	1.56	1.79	0.15	99.5	-111.4	29.5	79.6	1.29	0.01366

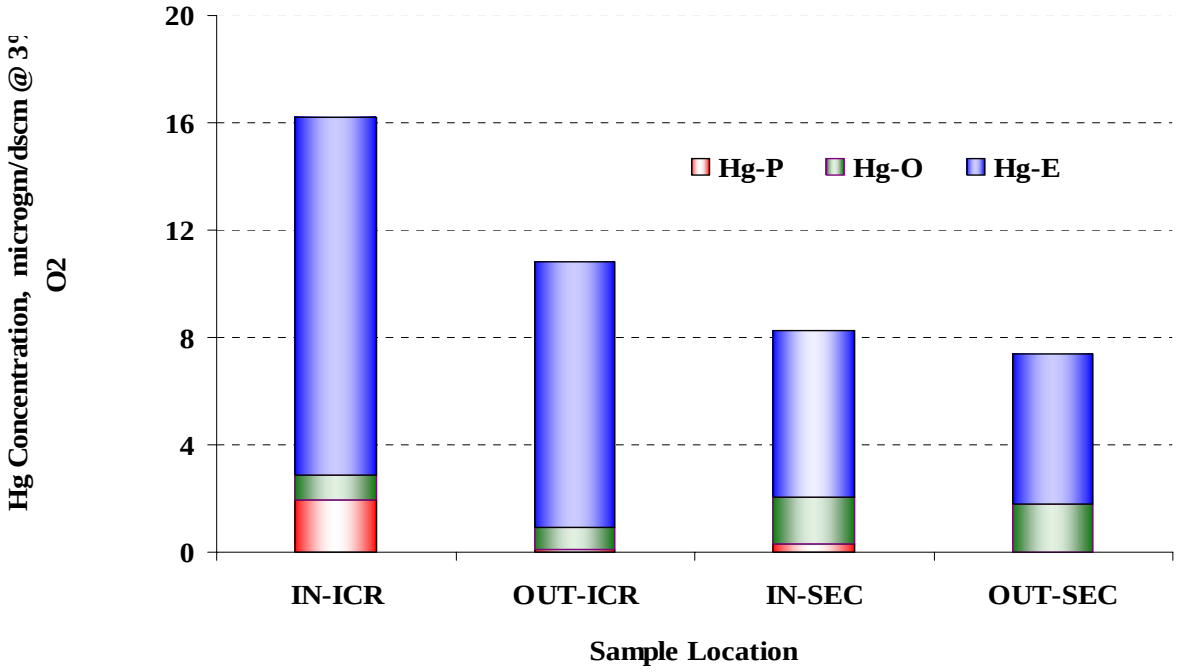


Figure 3.8.3.4 Rawhide Unit 101 – Hg Species Concentration at the Inlet and Outlet of DFGD+FF

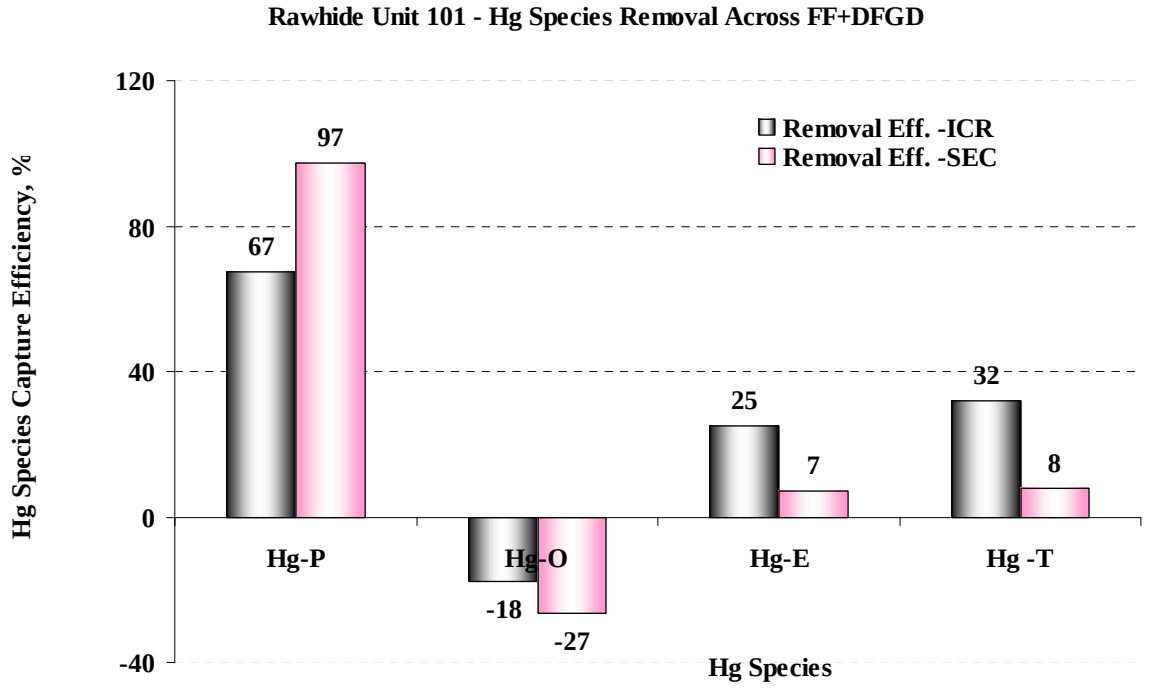


Figure 3.8.3.5 Rawhide Unit 101 – Hg Species Removal Across FF+DFGD

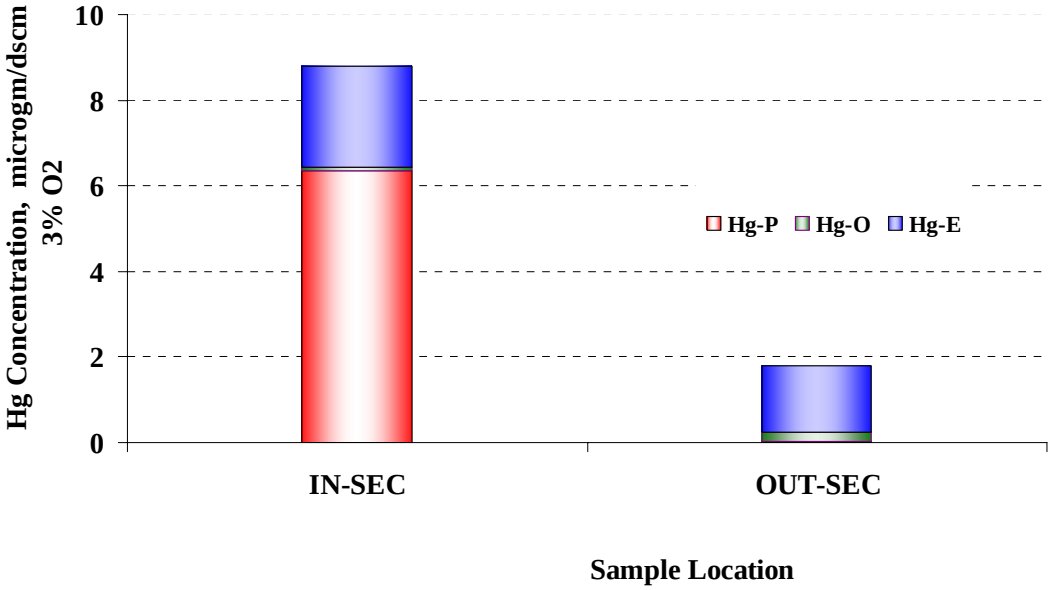


Figure 3.8.3.6 Sheldon Unit 2 – Hg Species Concentration at Inlet and Outlet of FF

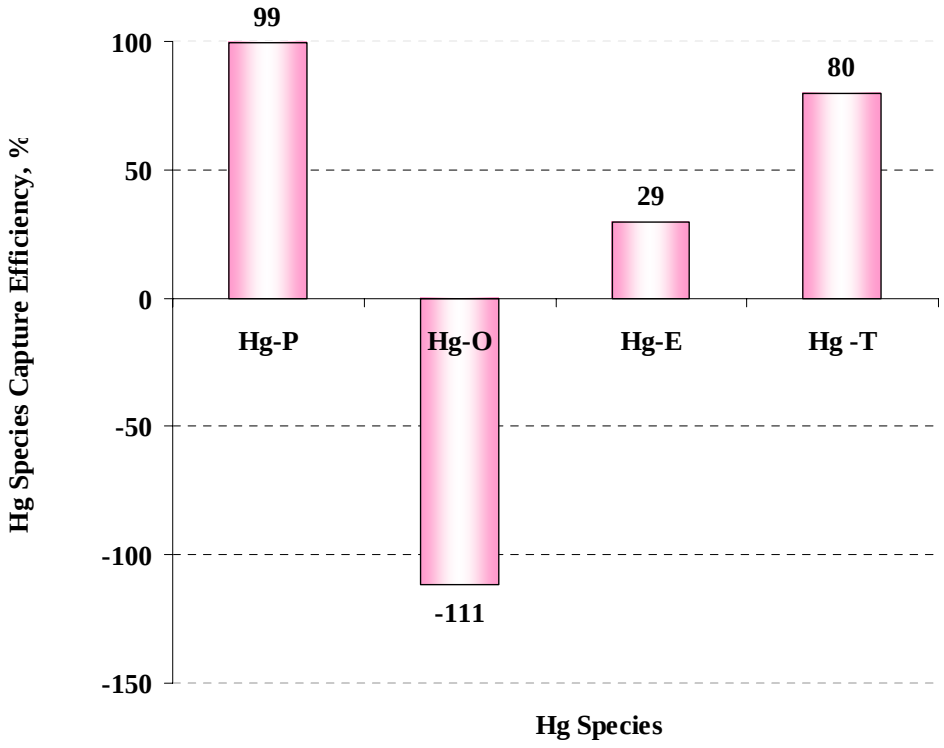


Figure 3.8.3.7 Sheldon Unit 2 – Hg Species Concentration at Inlet and Outlet of FF

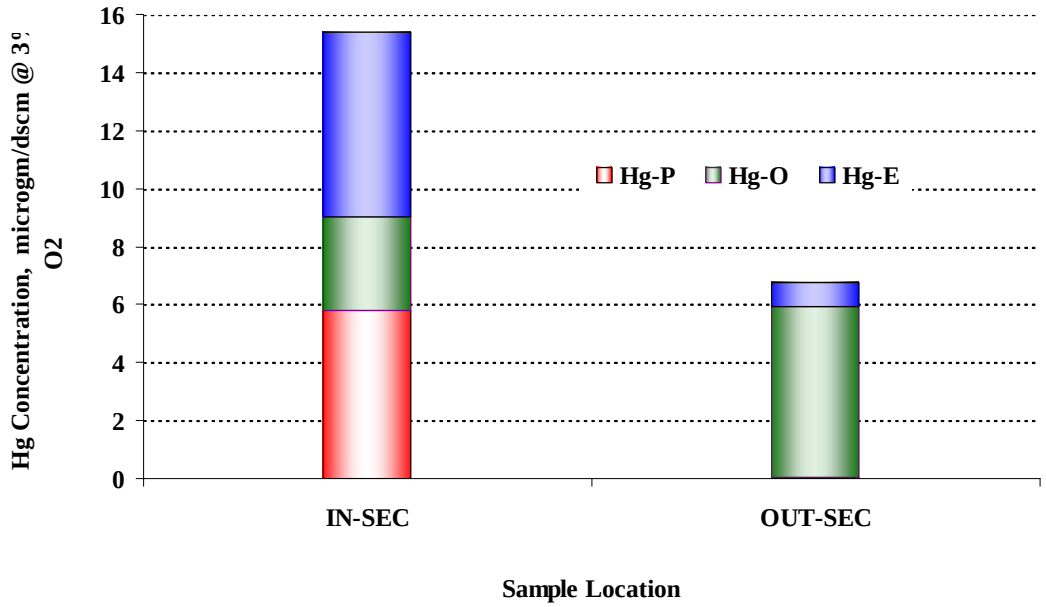


Figure 3.8.3.8 Pawnee – Hg Species Concentration at Inlet and Outlet of Fabric Filter

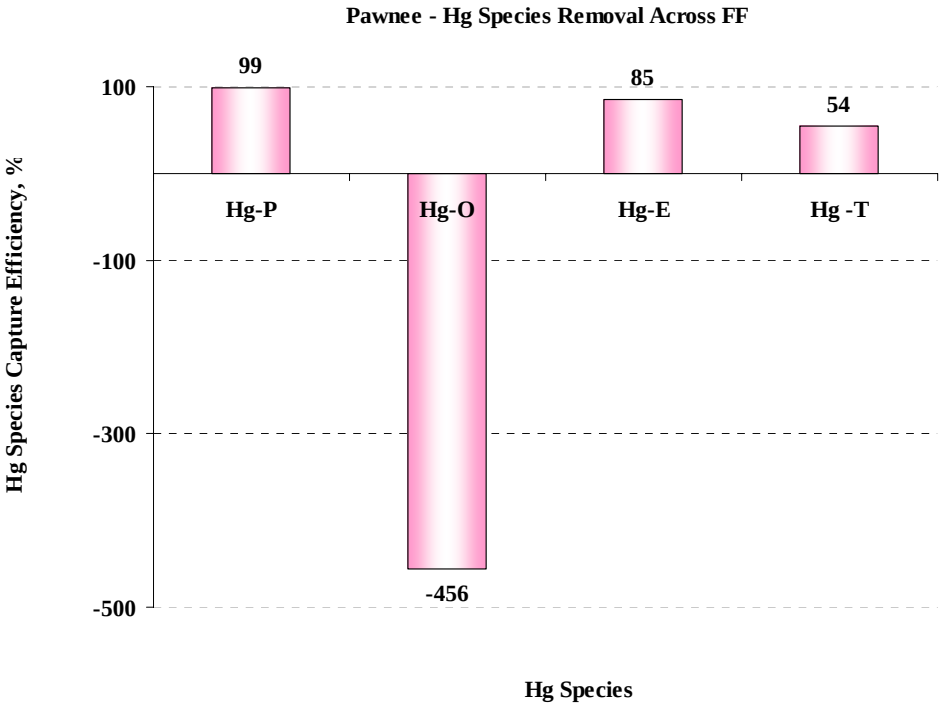


Figure 3.8.3.9 Pawnee Unit 1 – Hg species removal across the FF

4.0 COMPARISON OF ICR AND SEC DATA

4.1 Mercury Species Generation and Emission

Tables 4.1.1 and 4.1.2 show the mercury species distribution at the APCD inlet and outlet for both ICR and SEC tests**.**

Table 4.1.1 Hg Species Generation and Emission Data Summary

Plant Type	Unit Name	Hg removal Across APCD		Hg Emission	
		SEC	ICR	SEC	ICR
		%	%	lb/GWh	lb/GWh
CESP	Dave Johnston - Unit 2	74.7		0.023	
DFGD- FF	Rawhide - Unit 101	7.9	31.8	0.056	0.082
DGFD-CESP	Laramie - Unit 3	0.0	-78.5	0.087	0.035
FF	Pawnee - Unit 1	54.1		0.052	
FF	Sheldon - Unit 2	79.9		0.014	
HESP	Columbia - 1	31.5	11.9	0.095	0.109
HESP	Nelson Dewey - Unit 1	15.6	-9.0	0.041	0.022
HESP	Platte - Unit 1	10.7	-3.0	0.076	0.112
CESP-WFGD	Jim Bridger - 4	58.1	9.6	0.081	0.050
CESP-WFGD	Laramie - Unit 1	59.6	51.6	0.030	0.039
Average		*39.2*	*2.1*	*0.055*	*0.064*
STD Deviation		*29.5*	*41.1*	*0.028*	*0.037*
% STD Dev		*75.3*	*1989.7*	*51*	*57*

Note: *These emission data exceed 0.0614 lb/GWh (5.8 lb/TBtu), a limit under consideration for subbituminous coal-fired PC and cyclone units.

Table 4.1.2 ICR and SEC Data Spread Analysis Summary

Parameter	Hg-P -In	Hg-O-In	Hg-E-In	Hg -in Total	Hg-P -Out	Hg-O-Out	Hg-E-Out	Hg -Out Total
	µg/dscm (@ 3% O2)				µg/dscm (@ 3% O2)			
Average - ICR (7 units)	0.63	1.77	8.54	10.94	0.03	0.75	7.68	8.47
STD Dev- ICR	0.95	1.26	4.39	5.12	0.03	0.89	4.08	4.83
% STD Dev-ICR	151	71	51	47	100	119	53	57
Average - SEC (10 units)	3.68	1.33	7.79	12.79	0.12	1.26	5.83	7.21
STD Dev- SEC	3.04	1.12	6.02	5.98	0.08	1.70	4.05	3.65
% STD Dev-SEC	83	84	77	47	63	135	69	51

4.2 Mercury Capture Performance of APCDs

Fig. 4.2.1 presents a comparison of the APCDs' mercury removal performance during the ICR and SEC tests. Total mercury removal across the APCD is discussed. Of the seven (7) units that were tested during the SEC source sampling program, only one (1) unit showed a negative removal (-0.4%) of insignificant magnitude

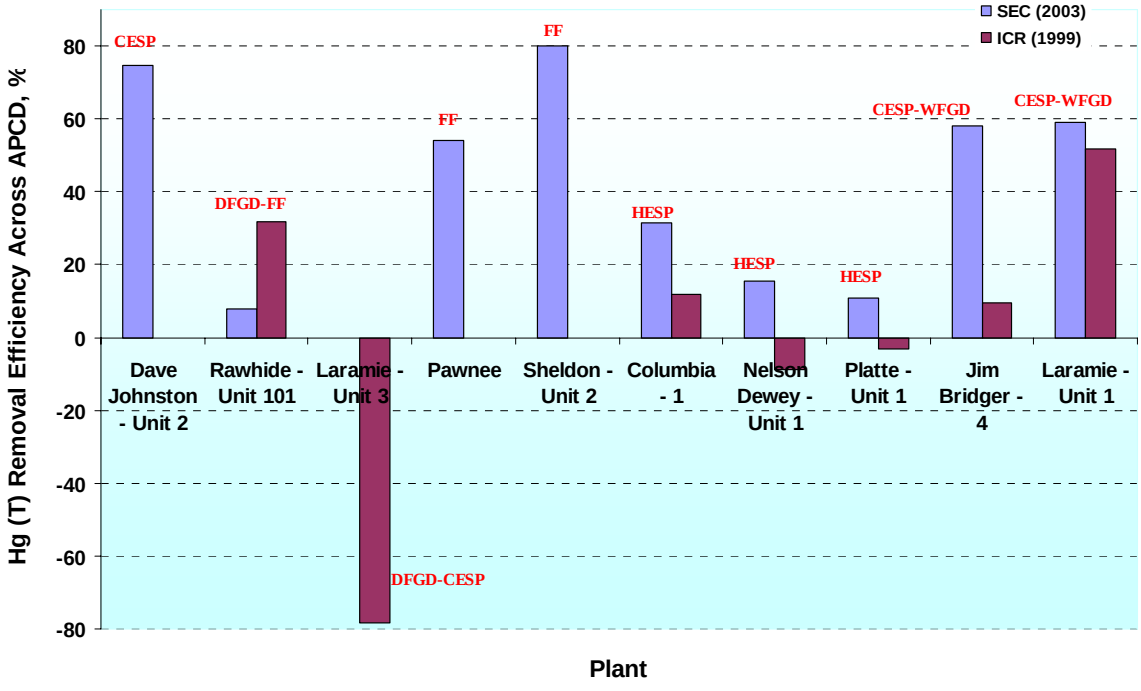


Figure 4.2.1 Mercury Capture Across the APCDs – ICR and SEC Data Comparison

compared to three (3) out of the seven (7) plants showing a substantial amount (up to 79%) of negative removal during ICR source sampling. In addition, similar types of APCDs showed better consistency in the performance data (i.e. there was positive removal of the mercury species). This is significant; the data confirm the improved reliability in the measurements and gives credence to using the SEC data for further analysis and MACT floor setting. It must, however, be acknowledged that the SEC data also demonstrates inconsistency in Hg species generation by the boiler and attendant APCD performance if one chooses fuel type as the only significant parameter for regulatory determination.

4.3 Variability in Generation, Capture and Emission

The current data (from SEC measurements) confirms that the concentrations of the mercury species, when measured by different teams, may lead to different mercury emission levels. Keeping all other conditions equal, the differences emanate from variability in fuel quality, measuring environment and unit operation. SEC used only one test team and the same lab services to analyze samples and to enhance the consistency in the emission data. This has been demonstrated by improved Hg closure around the APCD (i.e. there are no negative removals across the APCDs compared to three out of seven units which showed negative removals across the APCDs in the ICR data). Table 4.1.2 presents the averages of the normalized Hg species concentrations at the inlet and outlet of the APCDs both in ICR and SEC databases. There are no significant differences in the averages or the standard deviations. However, there seems to be a trend toward less variability in the SEC data with an average standard deviation (STD) of 52% in ICR compared to 49% in the SEC data. **(former numbers couldn't be found)**

The average emission rate is 6.08 lb/TBtu in the ICR data from seven (7) units compared to 5.18 lb/TBtu in ten (10) units in the SEC data. Out of the ten (10) SEC units, only Nelson Dewey Unit 1 burned a subbituminous coal and petcoke blend thus lowering the total emission rate by generating less than a fraction of the elemental mercury. The major difference in the ICR and SEC data is in the APCD performance and the mercury closure around the APCD. As shown in Section 4.1, the average mercury capture values are 2.1% and 39.4% with STDs of 1990 and 75, respectively for the ICR and SEC tests. These results clearly demonstrate the enhanced credibility of the SEC data and ongoing improvements in measurements and analysis.

The key finding is that elemental mercury is the main component that needs to be controlled (Figure 4.3.1). Current technologies such as Activated Carbon Injection may capture up to 60% with a heavy dose of the sorbent. PRB coal-fired units have an Hg input of 7-15 lb/TBtu; hence these units must operate at over 60% mercury efficiency in order to bring down the emission level below 5.8 lb/TBtu. **This is a non-achievable limit with the best technology available as of April 2004.**

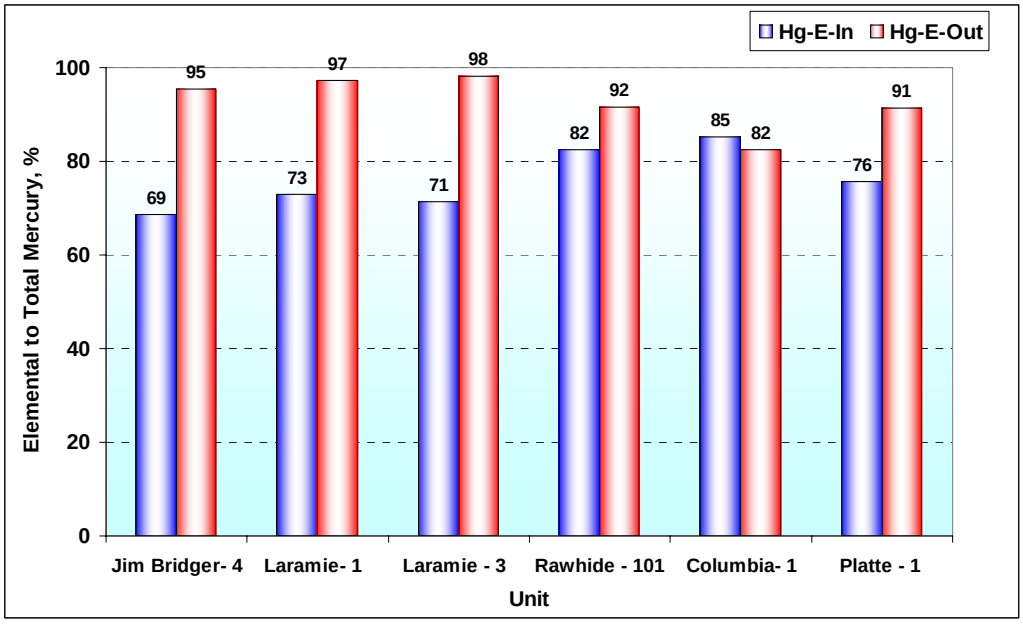


Figure 4.3.1 Elemental Mercury's Dominance in the Species Distribution

5.0 KEY FINDINGS AND CHARCTERICS TO BE CONSIDERED IN HG CONTROL TECHNOLOGY DEVELOPMENT

The units are categorized under six different types, namely CESP+WFGD, CESP+DFGD, CESP, FF+DFGD, FF and HESP. In Phase I of the program, the species distribution at the inlet and outlet of the APCDs and the species removal efficiencies are reported. The next phase of the work will review the adequacy of the APCDs to achieve specified Hg emission target levels.

The key findings of Phase I include the following:

- SEC data provides better closure of the data than the ICR data
- Variability in the results is an issue irrespective of using "similar" fuels at the plants and the same source sampling team measuring the species
- Elemental mercury forms a substantial portion, in most cases, at both the inlet and outlet of the APCDs
- Conventional particulate collectors (CESP, HESP, FF) remove nearly all of the particulate bound mercury
- CESPs perform better highlighting of the flue gas temperature effect on the mercury removal. Impact of speciation with flue gas cooling is apparent.
- SDA's do not help in enhancing adsorption of mercury vapor species.

- Due to consistently low chlorine values in fuels, it is not possible to analyze the impact of chlorine.
- It is difficult to predict the speciation at two plants that burn the same fuel. Non-fuel issues, such as flue gas cooling, impact the speciation and consequently mercury capture potential.

The findings of this study (Phase I) will enhance the understanding of the complexities involved in the application of new technologies on a commercial scale.

6.0 REFERENCES

"Control of Mercury Emissions from Coal-Fired Electric Utility Boilers: Interim Report Including Errata Dated 3-21-2002," US EPA, EPA-600/R-01-109, April 2002

APPENDIX A
Testing Reports

Alliant Energy Columbia Plant, Unit #1

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Alliant Energy Columbia Plant in Portage, Wisconsin.

The purpose of the testing program was to determine the operating efficiency of the Unit #1 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the Unit #1 inlet and exhaust stack on June 12, 2003. Inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program **Alliant Energy Columbia Plant, Unit #1** **Emissions Testing Program Contact Personnel**		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386, 307-721-2256 fax
Mr. Steve Jackson	Alliant Energy 4902 North Biltmore Lane P.O. Box 77007 Madison, Wisconsin 53707	608-458-5704, 608-458-0136
Ms. Ancy Sebastian	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Clint Yeagley	Air Pollution Testing, Inc. 5530 Marshall St. Arvada, Colorado 80002	303-420 5949, 303-420 5920 fax

2. Methods

APT tested in accordance with the following United States Environmental Protection Agency (USEPA) and ASTM International source emissions test methods. Methods 1 through 4 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

Method 3 – Gas Analysis for the Determination of Dry Molecular Weight

Method 4 – Determination of Moisture Content in Stack Gases

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Columbia Unit #1 is a pulverized coal-fired boiler with a nameplate rating of 550 GMW (gross megawatts). Emissions from Unit #1 are controlled with an electrostatic precipitator (ESP). Figure 3.1 provide schematics of the processes, including pollution control equipment.

3.2. Sampling Locations

At Unit 1, the ESP inlet sampling location was a horizontal duct measuring 72’ by 13.5’ with two sampling ports arranged along the top. Sampling was conducted over a 24-point grid across the stack cross section. The Unit 1 stack sampling location consisted of a vertical, round stack with an inside diameter of 21’. Sampling was conducted over a 24-point grid from four ports arranged 90 degrees apart.

Figure 3.1 provides a schematic of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

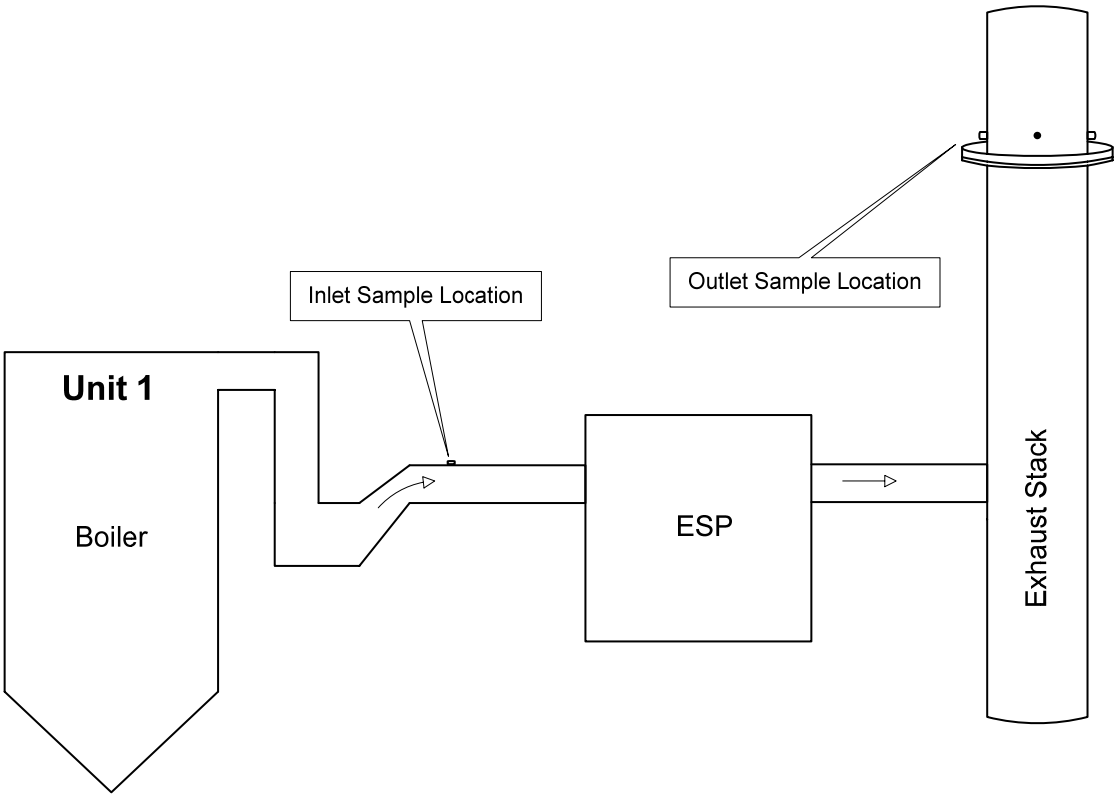


Figure 3.1: Schematic of Boiler and Pollution Control Equipment (Unit 1)

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE - Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program Alliant Energy Columbia Plant, Unit #1 Sampling and Analytical Methods Summary			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT 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	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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 Teflon-coated nozzle and heated Teflon probe liner, through a heated, out of stack filter, and through a series of eight impingers.

Integrated gas samples were collected in Tedlar bags during each run for diluent (O_2 and CO_2) analysis using an Orsat instrument; these 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), lb/TBtu (trillion British thermal units), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; while mercury contamination was detected, it was in a quantity below the Method Detection Limit (MDL).

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. Any mercury detected in any reagent fraction was below the MDL.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. Mercury was detected in quantities less than the MDL in the blank trains collected at the inlet and outlet sampling locations of Unit #1.

4.3. Calculations

For pollutant sample fractions with "not detected" mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1 and 5.2. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligrams per kilogram

Table 5.1: Emissions Testing Results Summary, Unit 1

WRI/DOE - Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program
Alliant Energy Columbia Plant, Unit #1
Speciated Mercury and Particulate Matter Test Results

	Inlet				Stack				ESP Control Efficiency
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**	**Average**	
Date	6/12	6/12	6/12		6/12	6/12	6/12		
Start time	8:30	12:00	15:30		8:30	12:00	15:30		
Stop time	10:35	14:05	17:35		10:35	14:05	17:35		
Load (GMW)	532	531	530	531	532	531	530	531	
Coal Use (MMBtu/hr)	5124	5380	5391	5298	5124	5380	5391	5298	
PM (gr/dscf)	1.28	1.49	0.91	1.22	0.027	0.025	0.015	0.022	
PM (lb/hr)	14106	17072	10375	13851	215.59	204.48	124.96	181.68	**98.2%**
PM (lb/MMBtu)	2.86	3.33	2.02	2.74	0.061	0.056	0.034	0.050	
PM Hg (ug/dscm)	3.01	0.29	3.65	2.32	0.25	0.08	0.06	0.13	
PM Hg (lb/hr)	1.45E-2	1.46E-3	1.83E-2	1.14E-2	8.62E-4	3.00E-4	2.19 E-4	4.60E-4	**94.4%**
Oxidized Hg (ug/dscm)	0.10	0.14	0.11	0.12	0.52	0.54	0.46	0.50	
Oxidized Hg (lb/hr)	5.03E-4	7.10E-4	5.57E-4	5.90E-4	1.82E-3	1.91E-3	1.64E-3	1.79E-3	**-323.2%**
Elemental Hg (ug/dscm)	<12.22	<11.23	9.77	<11.07	9.00	8.35	8.19	8.52	
Elemental Hg (lb/hr)	<5.90E-2	<5.62E-2	4.90E-2	<5.47E-2	3.16E-2	2.98E-2	2.95E-2	3.03E-2	**23.1%**
Total Hg (ug/dscm)	15.33	11.66	13.53	13.51	9.77	8.97	8.71	9.15	**32.3%**
Total Hg (lb/hr)	7.40E-2	5.84E-2	6.79E-2	6.68E-2	3.43E-2	3.20E-2	3.13E-2	3.25E-2	
Total Hg (lb/TBtu) †	14.99	11.39	13.23	13.20	9.63	8.77	8.51	8.97	
Total Hg (lb/TBtu) ‡	14.45	10.85	12.59	12.63	6.69	5.95	5.81	6.15	

† Calculated using Method 19.
‡ Calculated using plant coal use data.

Table 5.2: Coal and Ash Analysis Summary

WRI/DOE – Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program **Alliant Energy Columbia Plant, Unit #1** **Coal and Ash Analysis**				
	Unit 1			
Date	6/12	6/12	6/12	**Average**
Start time	8:30	12:00	15:30	
Stop time	10:35	14:05	17:35	
Hg Coal Feeder (mg/kg)	0.10	0.13	0.15	**0.13**
Cl Coal Feeder (%)	0.0052	<0.0050	<0.0050	**<0.0051**
Hg Bottom Ash (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Bottom Ash (%)	<0.0050	<0.0050	<0.0050	**<0.0050**

PacifiCorp Dave Johnston Generating Station, Unit #2

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Dave Johnston Generating Station in Glenrock, Wyoming.

The purpose of the testing program was to determine the operating efficiency of the Unit #2 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the Electrostatic Precipitator (ESP) inlet and outlet ducts on February 14, 2003. Inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program **Dave Johnston Generating Station, Unit #2** **Emissions Testing Program Contact Personnel**		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386 307-721-2256 fax
Mr. Alan Dugan	PacifiCorp Dave Johnston Generating Station 1591 Tank Farm Road Glenrock, Wyoming 82637	307-436-2046
Ms. Shari Typer	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Craig Kormylo	Air Pollution Testing, Inc. 12421 West 49th Avenue, Unit 2 Wheat Ridge, Colorado 80033	303-420 5949, 303-420 5920 fax

2. Methods

APT 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S 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 Matter from Stationary Sources

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Dave Johnston Generating Station Unit #2 is a front wall-fired pulverized coal boiler with a name plate rating of 112 GMW (gross megawatts). Emissions are controlled with a cold side ESP.

Figure 3.1 provides a schematic of the process, including pollution control equipment.

3.2. Sampling Locations

The ESP inlet sampling location was a horizontal rectangular duct measuring 11’-0” across and 13’-0” tall. The outlet sampling location consisted of a vertical, cylindrical stack with an inside diameter of 11 feet. Sampling at the inlet was conducted using a 20-point grid from five

sampling ports located along the top of the duct, with the outlet using a 16-point grid from four sampling ports located at the sampling platform of the exhaust stack.

Figure 3.1 provides a schematic of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

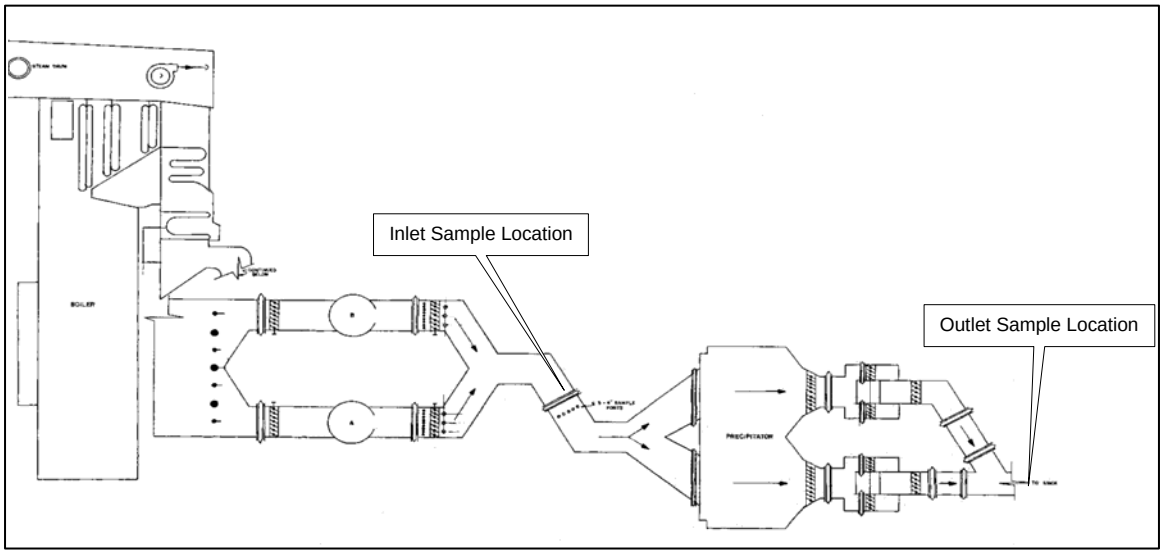


Figure 3.1: Schematic of Boiler and Pollution Control Equipment

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE – Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program Dave Johnston Generating Station, Unit #2 Sampling and Analytical Methods Summary			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT On-Site
O_2 / CO_2	Method 3	wet chemical -Fyrite instrument	
Moisture (H_2O)	Method 4	gravimetric	
Particulate Matter	Method 17 (inlet) or Method 5 (outlet)	gravimetric	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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 (O_2 and CO_2) analysis using a Fyrite instrument. Additionally, carbon dioxide 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), trillion British thermal units (lb/TBtu), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; no mercury contamination was detected.

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. No mercury was detected in any reagent fraction.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. No mercury was detected in the blank train collected at the inlet sampling location. Mercury was detected in the blank train collected at the outlet location, but at less than one percent of the average emission sample level.

4.3. Calculations

For pollutant sample fractions with "not detected" mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and plant CEMS CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1 and 5.2. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligrams per kilogram

Table 5.1: Emissions Testing Results Summary

WRI/DOE - Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program
Dave Johnston Generating Station, Unit #2
Speciated Mercury and Particulate Matter Test Results

	ESP Inlet				ESP Outlet				**ESP Control Efficiency**
Date	14-Feb-03	14-Feb-03	14-Feb-03	Average	14-Feb-03	14-Feb-03	14-Feb-03	Average	
Start time	7:20	10:40	13:30		7:20	10:40	13:30		
Stop time	9:26	12:46	15:42		9:26	12:46	15:36		
Load (GMW)	--	--	--		107.0	107.4	107.7	**107.4**	
Coal Use (MMBtu/hr)	--	--	--		1,371	1,371	1,371	**1,371**	
PM (gr/dscf)	3.13	1.54	2.06	**2.24**	1.33 e-2	7.42 e-2	1.60 e-2	**3.39 e-2**	**98.5%**
PM (lb/hr)	6,923	3,318	4,301	**4,847**	30.6	166.2	37.2	**78.0**	
PM (lb/MMBtu) (1)	5.67	2.76	3.71	**4.05**	2.41 e-2	1.30 e-1	2.88 e-2	**6.11 e-2**	
PM Hg (ug/dscm)	8.574	8.269	10.534	**9.126**	<1.26 e-1	<1.47 e-1	<1.21 e-1	**<1.31 e-1**	**98.6%**
PM Hg (lb/hr)	8.29 e-3	7.82 e-3	9.61 e-3	**8.57 e-3**	<1.27 e-4	<1.48 e-4	<1.23 e-4	**<1.32 e-4**	
Oxidized Hg (ug/dscm)	0.26	0.17	0.19	**0.21**	1.20	1.18	1.21	**1.20**	**-478.9%**
Oxidized Hg (lb/hr)	2.47 e-4	1.63 e-3	1.75 e-4	**1.95 e-4**	1.21 e-3	1.18 e-3	1.23 e-3	**1.21 e-3**	
Elemental Hg (ug/dscm)	1.34	1.96	0.93	**1.41**	1.41	1.32	1.41	**1.38**	**2.1%**
Elemental Hg (lb/hr)	1.30 e-3	1.85 e-3	8.44 e-3	**1.33 e-3**	1.41 e-3	1.33 e-3	1.44 e-3	**1.39 e-3**	
Total Hg (ug/dscm)	10.17	10.40	11.65	**10.74**	2.74	2.65	2.75	**2.71**	**74.8%**
Total Hg (lb/hr)	9.83 e-3	9.84 e-3	1.06 e-2	**1.01 e-2**	2.75 e-3	2.66 e-3	2.79 e-3	**2.73 e-3**	
Total Hg (lb/TBtu) (1)	8.05	8.18	9.16	**8.46**	2.17	2.08	2.16	**2.13**	
Total Hg (lb/TBtu) (2)	7.17	7.18	7.76	**7.37**	2.00	1.94	2.04	**1.99**	

(1) – calculated using plant CEMS CO_2 data and Method 19
(2) – calculated using plant coal use data

Table 5.2: Coal and Ash Analysis Summary

WRI/DOE – Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program **Dave Johnston Generating Station, Unit #2** **Coal and Ash Analysis**				
Date	14-Feb-03	14-Feb-03	14-Feb-03	**Average**
Start time	7:20	10:40	13:30	
Stop time	9:26	12:46	15:42	
Hg Mills Ash (mg/kg)	0.13	0.11	0.13	**0.12**
Cl Mills Ash (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Bottom Ash (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Bottom Ash (%)	<0.005	<0.005	0.0062	**<0.005**

PacifiCorp Jim Bridger Generating Station, Unit #4

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Jim Bridger Generating Station in Point of Rocks, Wyoming.

The purpose of the testing program was to determine the operating efficiency of the Unit #4 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the Electrostatic Precipitator (ESP) inlet and exhaust stack on April 2, 2003. Inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program Jim Bridger Generating Station, Unit #4 Emissions Testing Program Contact Personnel		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386 307-721-2256 fax
Mr. Dale Gillespie	Jim Bridger Generating Station P.O Box 158 Point of Rocks, Wyoming 82942	307-352-4281 307-352-4417 fax
Ms. Shari Typer	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Craig Kormylo	Air Pollution Testing, Inc. 12421 West 49th Avenue, Unit 2 Wheat Ridge, Colorado 80033	303-420 5949, 303-420 5920 fax

2. Methods

APT 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S 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 Matter from Stationary Sources

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Jim Bridger Generating Station Unit #4 is a tangential-fired pulverized coal boiler with a nameplate rating of 556 GMW (gross megawatts). Emissions are controlled with a cold ESP and sodium based flue gas de-sulfurization unit.

Figure 3.1 provides a schematic of the process, including pollution control equipment.

3.2. Sampling Locations

The ESP inlet sampling location was two horizontal rectangular ducts measuring 41'-0" across and 13'-0" tall each. The outlet sampling location consisted of a vertical, cylindrical stack with an inside diameter of 32'-9 ½". Sampling at the inlet was conducted using a 24-point grid from six sampling ports located along the top of the duct, with the outlet using a 16-point grid from four sampling ports located at the sampling platform on the exhaust stack.

Figure 3.1 provides a schematic of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

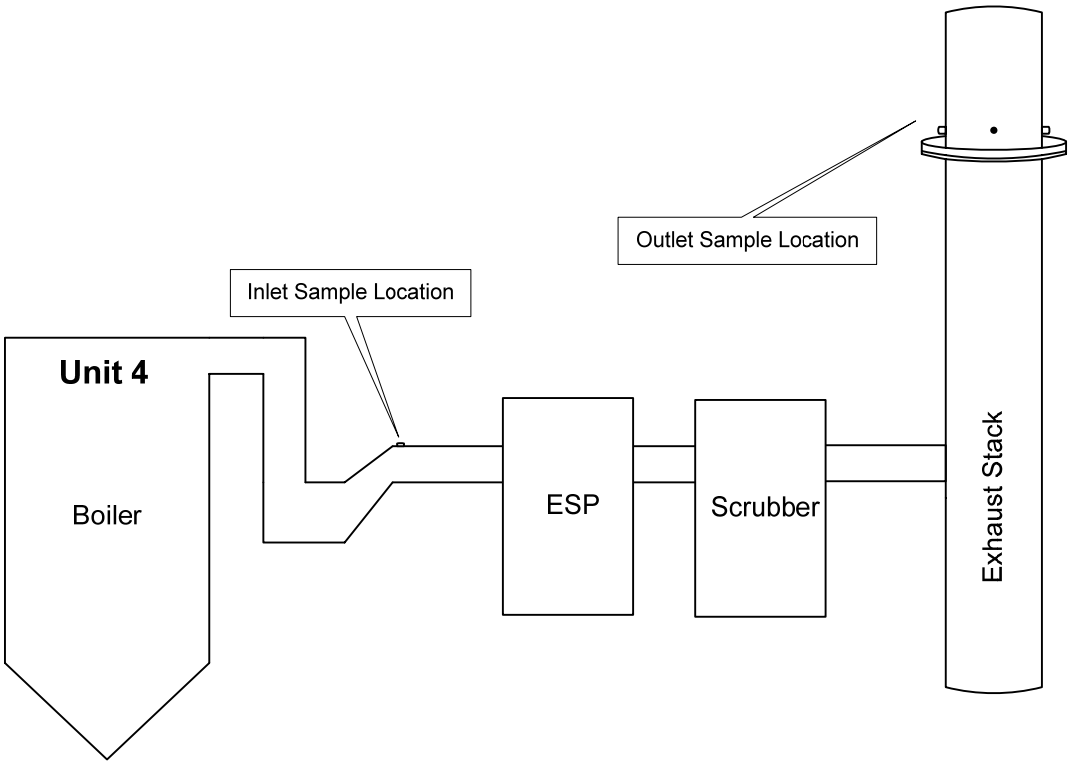


Figure 3.1: Schematic of Boiler and Pollution Control Equipment

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE – Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program Jim Bridger Generating Station, Unit #4 Sampling and Analytical Methods Summary			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT On-Site
O_2 / CO_2	Method 3	wet chemical -Fyrite instrument	
Moisture (H_2O)	Method 4	Gravimetric	
Particulate Matter	Method 17 (inlet) or Method 5 (outlet)	Gravimetric	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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 (O_2 and CO_2) analysis using a Fyrite instrument. Additionally, carbon dioxide 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium

permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), trillion British thermal units (lb/TBtu), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; no mercury contamination was detected.

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. No mercury was detected in any reagent fraction.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. Mercury was detected in the blank trains collected at both the inlet and outlet locations, but at less than one percent of the average emission sample level at the inlet and less that three percent at the outlet.

4.3. Calculations

For pollutant sample fractions with “not detected” mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and plant CEMS CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1 and 5.2. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligrams per kilogram

Table 5.1: Emissions Testing Results Summary

WRI/DOE – Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program
Jim Bridger Generating Station, Unit #4
Speciated Mercury and Particulate Matter Test Results

	ESP Inlet				Stack Outlet				**ESP Control Efficiency**
Date	02-Apr-03	02-Apr-03	02-Apr-03	Average	02-Apr-03	02-Apr-03	02-Apr-03	Average	
Start time	09:07	12:25	15:40		09:07	12:25	15:40		
Stop time	11:28	14:38	18:00		11:28	14:40	17:52		
Load (GMW)	--	--	--		496.1	443.5	447.8	**462.5**	
Coal Use (MMBtu/hr)	--	--	--		4,989	4,542	4,496	**4,676**	
PM (gr/dscf)	3.36	4.32	2.85	**3.51**	1.20 e-2	1.03 e-2	7.04 e-3	**9.79 e-3**	**99.7%**
PM (lb/hr)	71,141	86,344	53,372	**70,286**	121.4	93.6	64.6	**93.2**	
PM (lb/MMBtu) (1)	6.60	8.41	5.51	**6.84**	2.36 e-2	2.01 e-2	1.36 e-2	**1.91 e-2**	
PM Hg (ug/dscm)	4.99	1.50	1.34	**2.61**	0.306	0.174	0.167	**0.216**	**91.7%**
PM Hg (lb/hr)	4.62 e-2	1.31 e-2	1.10 e-2	**2.34 e-2**	1.35 e-3	6.93 e-4	6.69 e-4	**9.04 e-4**	
Oxidized Hg (ug/dscm)	0.51	6.30	1.07	**2.63**	0.299	0.726	0.421	**0.482**	**81.7%**
Oxidized Hg (lb/hr)	4.74 e-3	5.51 e-2	8.75 e-3	**2.29 e-2**	1.32 e-3	2.89 e-3	1.69 e-3	**1.96 e-3**	
Elemental Hg (ug/dscm)	8.07	35.69	9.96	**17.91**	3.94	15.76	6.07	**8.59**	**52.0%**
Elemental Hg (lb/hr)	7.48 e-2	3.12 e-1	8.16 e-2	**1.56 e-1**	1.74 e-2	6.26 e-2	2.44 e-2	**3.48 e-2**	
Total Hg (ug/dscm)	13.57	43.49	12.37	**23.15**	4.55	16.66	6.66	**9.29**	**59.9%**
Total Hg (lb/hr)	1.26 e-1	3.80 e-1	1.01 e-1	**2.02 e-1**	2.01 e-3	6.62 e-2	2.67 e-2	**3.77 e-2**	
Total Hg (lb/TBtu) (1)	11.65	37.03	10.46	**19.71**	3.90	14.18	5.63	**7.90**	
Total Hg (lb/TBtu) (2) (3)	--	--	--	**--**	4.02	14.58	5.95	**8.18**	

(3) – calculated using plant CEMS CO_2 data and Method 19
(4) – calculated using plant coal use data
(5) – probable significant bias on inlet values due to poor flow measurements

Table 5.2: Coal and Ash Analysis Summary

WRI/DOE – Subbituminous Coal-Fired Utilities Mercury Emissions Testing Program **Jim Bridger Generating Station, Unit #4** **Coal and Ash Analysis**				
Date	02-Apr-03	02-Apr-03	02-Apr-03	**Average**
Start time	09:07	12:25	15:40	
Stop time	11:28	14:38	18:00	
Hg Coal Feeder (mg/kg)	0.10	0.090	0.11	**0.10**
Cl Coal Feeder (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Fly Ash (mg/kg)	0.21	0.090	0.070	**0.12**
Cl Fly Ash (%)	<0.005	<0.005	<0.005	**<0.005**

Alliant Energy Nelson Dewey Plant Unit 1

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Alliant Energy Nelson Dewey Plant in Cassville, Wisconsin.

The purpose of the testing program was to determine the operating efficiency of the Unit #1 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the Unit #1 inlet and exhaust stack on June 10, 2003. Inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Alliant Energy Nelson Dewey Plant, Unit #1 Emissions Testing Program Contact Personnel		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386, 307-721-2256 fax
Mr. Steve Jackson	Alliant Energy 4902 North Biltmore Lane P.O. Box 77007 Madison, Wisconsin 53707	608-458-5704, 608-458-0136
Ms. Shari Typer	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Clint Yeagley	Air Pollution Testing, Inc. 5530 Marshall St. Arvada, Colorado 80002	303-420 5949, 303-420 5920 fax

2. Methods

APT tested in accordance with the following United States Environmental Protection Agency (USEPA) and ASTM International source emissions test methods. Methods 1 through 4 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

Method 3 – Gas Analysis for the Determination of Dry Molecular Weight

Method 4 – Determination of Moisture Content in Stack Gases

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Nelson Dewey Unit #1 is a pulverized coal-fired boiler with a nameplate rating of X GMW (gross megawatts). Emissions from Unit #1 are controlled with an electrostatic precipitator (ESP). Figure 3.1 provides a schematic of the process, including pollution control equipment.

3.2. Sampling Locations

At Unit 1, the ESP inlet sampling location consisted of two horizontal, rectangular ducts measuring 32" by 216" with six sampling ports arranged along one 216" side. Sampling was conducted over a 24-point grid across the stack cross section. The Unit 1 outlet sampling location consisted of two horizontal, rectangular ducts measuring 32" by 216". Sampling was conducted over a 24-point grid from six sampling ports.

Figure 3.1 provides a schematic of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

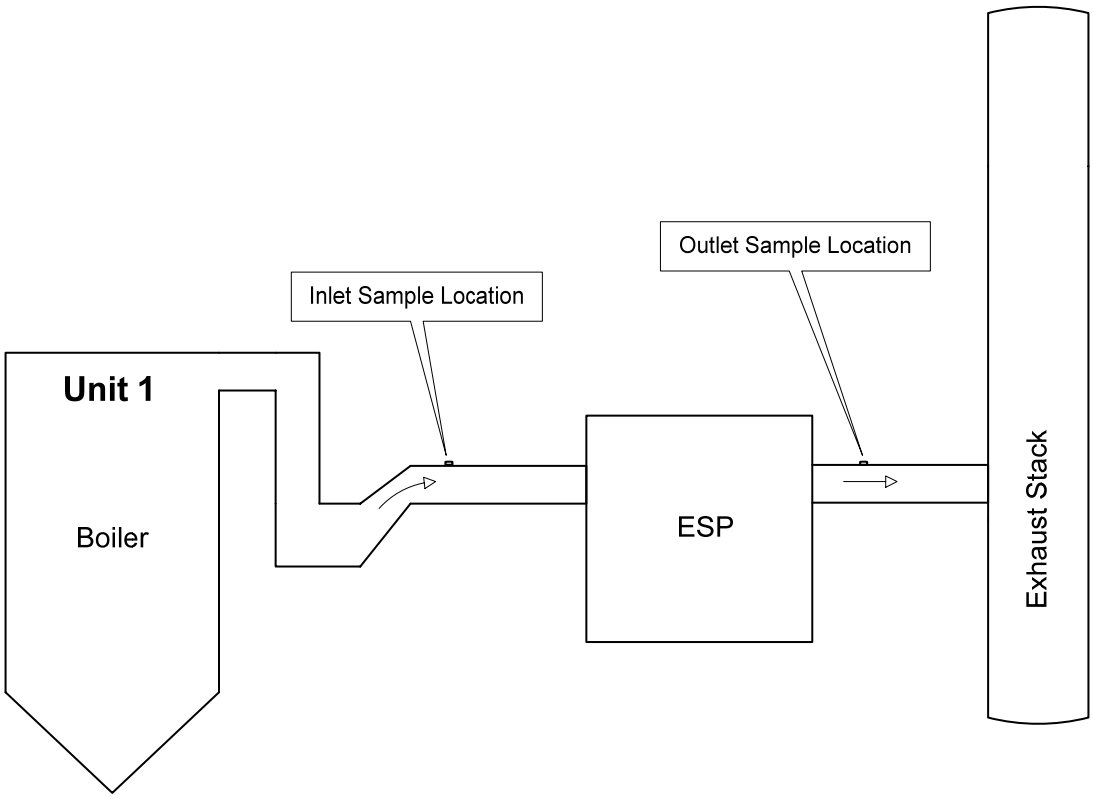


Figure 3.1: Schematic of Boiler and Pollution Control Equipment (Unit 1)

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Alliant Energy Nelson Dewey Plant, Unit #1 Sampling and Analytical Methods Summary			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT 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	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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 Teflon-coated nozzle and heated Teflon probe liner, through a heated, out of stack filter, and through a series of eight impingers.

Integrated gas samples were collected in Tedlar bags during each run for diluent (O_2 and CO_2) analysis using an Orsat instrument; these 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), lb/TBtu (trillion British thermal units), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; while mercury contamination was detected, it was in a quantity below the Method Detection Limit (MDL).

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. Any mercury detected in any reagent fraction was below the MDL.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. Mercury was detected in quantities less than the MDL in the blank trains collected at the inlet and outlet sampling locations of Unit #1.

4.3. Calculations

For pollutant sample fractions with “not detected” mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and CO_2 data. Second, the emissions were

calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1 and 5.2. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligrams per kilogram

Table 5.1: Emissions Testing Results Summary, Unit 1

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program
Alliant Energy Nelson Dewey Plant, Unit #1
Speciated Mercury and Particulate Matter Test Results

	Inlet				Stack				
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**	**Average**	**ESP Control Efficiency**
Date	6/10	6/10	6/10		6/10	6/10	6/10		
Start time	8:55	12:17	15:47		8:55	12:17	15:47		
Stop time	11:07	14:38	18:07		11:14	14:35	18:05		
Load (GMW)	110	101	112	108	110	101	112	108	
Coal Use (MMBtu/hr)	1056	997	1100	1051	1056	997	1100	1051	
PM (gr/dscf)	1.47	1.35	2.70	1.84	0.023	0.017	0.024	0.021	
PM (lb/hr)	2709	2548	4901	3386	45.62	40.00	49.84	45.15	**98.8%**
PM (lb/MMBtu)	2.55	2.35	4.69	3.20	0.039	0.028	0.042	0.036	
PM Hg (ug/dscm)	3.52	2.10	4.43	3.35	0.07	0.07	0.17	0.10	
PM Hg (lb/hr)	2.84E-3	1.73E-3	3.52E-3	2.70E-3	6.14E-5	7.40E-5	1.53E-4	9.60E-5	**96.9%**
Oxidized Hg (ug/dscm)	1.79	0.17	0.09	0.68	1.26	0.04	0.23	0.51	
Oxidized Hg (lb/hr)	1.44E-3	1.44E-4	7.30E-5	5.52E-4	1.11E-3	4.68E-5	2.07E-4	4.55E-4	**25.1%**
Elemental Hg (ug/dscm)	<2.39	<3.25	<0.78	<2.14	4.30	<4.53	<4.90	<4.58	
Elemental Hg (lb/hr)	<1.93E-3	<2.68E-3	<6.23E-4	<1.74E-4	3.79E-3	<4.77E-3	<4.40E-3	<4.32E-3	**-113.6%**
Total Hg (ug/dscm)	7.69	5.53	5.31	6.18	5.63	4.65	5.30	5.19	
Total Hg (lb/hr)	6.21E-3	4.56E-3	4.22E-3	4.99E-3	4.97E-3	4.89E-3	4.76E-3	4.87E-3	**16.0%**
Total Hg (lb/TBtu) †	5.84	4.20	4.03	4.69	4.19	3.48	3.97	3.88	
Total Hg (lb/TBtu) ‡	5.88	4.57	3.83	4.76	4.70	4.91	4.33	4.65	

† Calculated using Method 19.
‡ Calculated using plant coal use data.

Table 5.2: Coal and Ash Analysis Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program **Alliant Energy Nelson Dewey Plant, Unit #1** **Coal and Ash Analysis**				
	Unit 1			
Date	6/10	6/10	6/10	**Average**
Hg Coal Feeder A (mg/kg)	0.05	0.08	0.06	**0.06**
Cl Coal Feeder A (%)	0.0061	<0.0050	<0.0050	**<0.0054**
Hg Coal Feeder B (mg/kg)	0.06	0.07	0.10	**0.08**
Cl Coal Feeder B (%)	0.0078	0.0072	0.0050	**0.0067**
Hg Coal Feeder C (mg/kg)	0.11	0.06	0.06	**0.08**
Cl Coal Feeder C (%)	0.0071	0.0062	0.0051	**0.0061**
Hg Slag (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Slag (%)	<0.0050	<0.0050	<0.0050	**<0.0050**
Hg Fly Ash (mg/kg)	0.11	<0.04	0.12	**<0.09**
Cl Fly Ash (%)	0.0090	0.0057	0.0054	**0.0067**

Basin Electric Power Cooperative Laramie Station Unit 1 and 3

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Basic Electric Power Cooperative Laramie River Station in Wheatland, Wyoming.

The purpose of the testing program was to determine the operating efficiency of the Unit #1 and #3 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the Unit #3 Scrubber inlet and exhaust stack on February 11, 2003. Identical testing was performed at the Unit #1 electrostatic precipitator (ESP) inlet and exhaust stack on February 12, 2003. At both units, inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program **Basin Electric Power Cooperative, Laramie River Station, Units #1 and #3** **Emissions Testing Program Contact Personnel**		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386 307-721-2256 fax
Mr. Terry Archbold	Basin Electric Power Cooperative Laramie River Station PO Box 489 Wheatland, Wyoming 82201	307-322-9601 307-322-7199 fax
Ms. Shari Typer	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Craig Kormylo	Air Pollution Testing, Inc. 12421 West 49th Avenue, Unit 2 Wheat Ridge, Colorado 80033	303-420 5949, 303-420 5920 fax

2. Methods

APT tested in accordance with the following USEPA and ASTM source emissions test methods. Methods 1 through 4 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

Method 3 – Gas Analysis for the Determination of Dry Molecular Weight

Method 4 – Determination of Moisture Content in Stack Gases

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Laramie River Units #1 and #3 are pulverized coal-fired boilers with name plate ratings of 550 GMW (gross megawatts). Emissions from Unit #1 are controlled with an ESP and wet SO_2 scrubber. Emissions from Unit #3 are controlled with a dry SO_2 scrubber and an ESP. Figures 3.1 and 3.2 provide schematics of the processes, including pollution control equipment.

3.2. Sampling Locations

At Unit 1, the ESP inlet sampling location was a set of three horizontal rectangular ducts measuring 26'-6" across and 11'-10" tall. Sampling was conducted over a 24-point grid from three sampling ports located along the top of each duct. One 120-minute sample was collected from each inlet duct; volumetric flow rates from each run were summed to approximate total volumetric flow and mass emission rates for the control device inlet. The Unit 1 stack sampling location consisted of a round, vertical stack with a 375.6" inside diameter. Sampling was conducted over a 16-point grid from four ports arranged 90 degrees apart.

At Unit 3, the scrubber inlet sampling location was a set of three horizontal rectangular ducts measuring 26'-6" across and 11'-10" tall. Sampling was conducted over a 24-point grid from three sampling ports located along the top of each duct. One 120-minute sample was collected from each inlet duct; volumetric flow rates from each run were summed to approximate total volumetric flow and mass emission rates for the control device inlet. The Unit 3 stack sampling location consisted of a round, vertical stack with a 340.8" inside diameter. Sampling was conducted over a 16-point grid from four ports arranged 90 degrees apart.

Figures 3.1 and 3.2 provide schematics of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

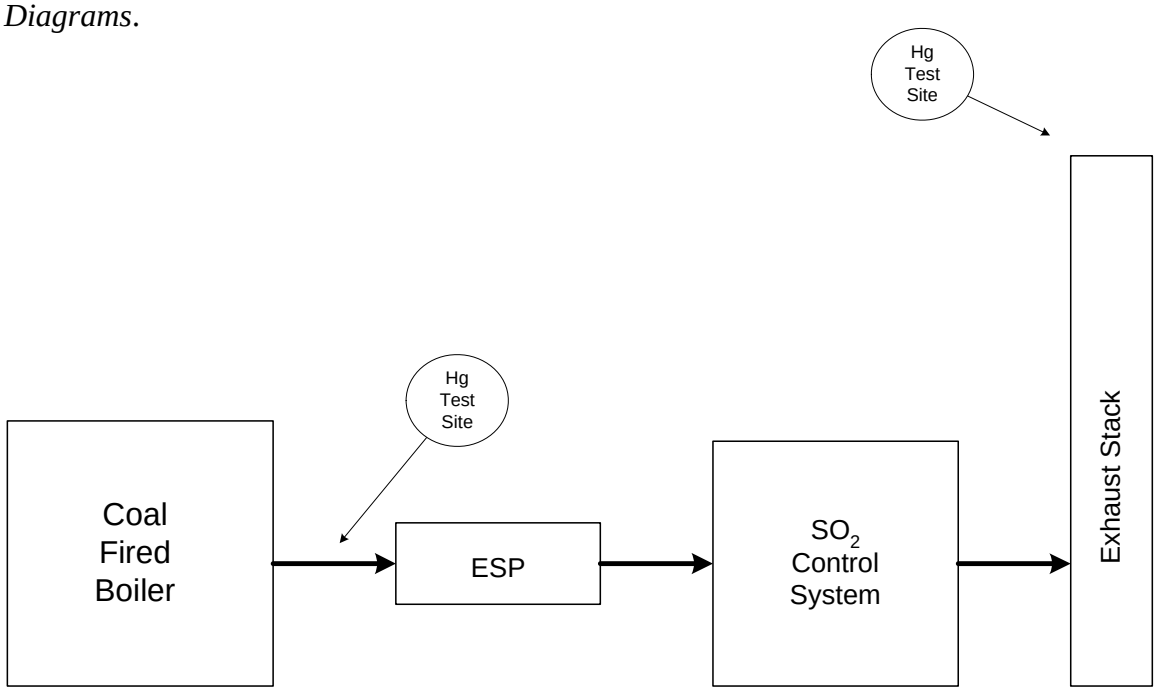


Figure 3.1: Schematic of Boiler and Pollution Control Equipment (Unit 1)

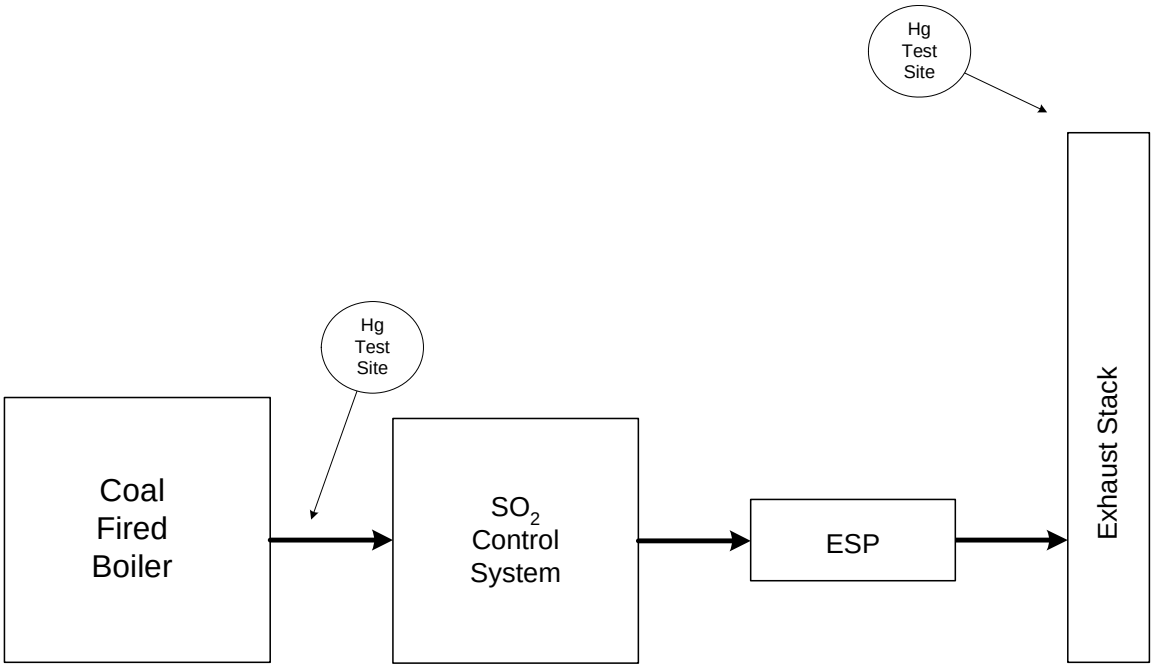


Figure 3.2: Schematic of Boiler and Pollution Control Equipment (Unit 3)

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Basin Electric Power Cooperative, Laramie River Station, Units #1 and #3 Sampling and Analytical Methods Summary			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT On-Site
O_2 / CO_2	Method 3	wet chemical -Fyrite instrument	
Moisture (H_2O)	Method 4	gravimetric	
Particulate Matter	Method 5 (Outlets) or 17 (Inlets)	gravimetric	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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 inlets, 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 outlets, the gas sample passed through a Teflon-coated nozzle and heated Teflon probe liner, through a heated, out of stack filter, and through a series of eight impingers.

Integrated gas samples were collected in Tedlar bags during each run for diluent (O_2 and CO_2) analysis using a Fyrite instrument. Additionally, carbon dioxide 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), lb/TBtu (trillion British thermal units), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; no mercury contamination was detected.

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. No mercury was detected in any reagent fraction.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. No mercury was detected in the blank trains collected at the inlet and outlet sampling locations of Unit #1. Mercury was detected in the blank train collected at the inlet location of Unit #3, but at about one percent of the average emission sample level.

4.3. Calculations

For pollutant sample fractions with "not detected" mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and plant CEMS CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1, 5.2, and 5.3. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligrams per kilogram

Table 5.1: Emissions Testing Results Summary, Unit 1

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program
Basin Electric Power Cooperative, Laramie River Station, Unit #1
Speciated Mercury and Particulate Matter Test Results

	Inlet				Stack				**ESP and Scrubber Control Efficiency**
	North	Middle	South	Average*	Run 1	Run 2	Run 3	Average	
Date	12-Feb-03	12-Feb-03	12-Feb-03		12-Feb-03	12-Feb-03	12-Feb-03		
Start time	9:30	15:40	18:30		9:30	15:40	18:30		
Stop time	14:30	17:50	20:54		14:30	17:50	20:54		
Load (GMW)					584.9	589.9	582.9	585.9	
Coal Use (MMBtu/hr)					6248.0	6299.2	6259.2	6268.8	
PM (gr/dscf)	2.02	2.33	2.66	2.33	9.04 e-4	1.16 e-3	9.25 e-4	9.95 e-4	
PM (lb/hr)	10,797	16,466	13,827	41,090	10.59	13.70	10.38	11.56	**100%**
PM (lb/MMBtu)	3.86	4.52	4.91	4.44	1.73 e-3	2.24 e-3	1.71 e-3	1.89 e-3	
PM Hg (ug/dscm)	4.25	0.43	2.77	2.28	0.13	0.12	0.06	0.10	**95.6%**
PM Hg (lb/hr)	9.94 e-3	1.32 e-3	6.30 e-3	1.76 e-2	6.45 e-4	6.15 e-4	2.89 e-4	5.16 e-4	
Oxidized Hg (ug/dscm)	0.49	0.79	1.93	1.04	0.49	0.37	0.39	0.42	**60.0%**
Oxidized Hg (lb/hr)	1.15 e-3	2.45 e-3	4.39 e-3	7.99 e-3	2.49 e-3	1.94 e-3	1.90 e-3	2.11 e-3	
Elemental Hg (ug/dscm)	1.74	8.79	3.64	5.13	2.72	2.78	2.81	2.77	**46.0%**
Elemental Hg (lb/hr)	4.06 e-3	2.71 e-2	8.29 e-3	3.95 e-2	1.40 e-2	1.44 e-2	1.38 e-2	1.41 e-2	
Total Hg (ug/dscm)	6.48	10.01	8.34	8.45	3.34	3.28	3.25	3.29	**61.1%**
Total Hg (lb/hr)	1.52 e-2	3.09 e-2	1.90 e-2	6.50 e-2	1.71 e-2	1.70 e-2	1.60 e-2	1.67 e-2	
Total Hg (lb/TBtu) †	5.41	8.48	6.74	7.03	2.78	2.78	2.63	2.73	
Total Hg (lb/TBtu) ‡	7.28	14.72	9.10	10.80	2.74	2.70	2.55	2.66	

* For the inlet, mass emissions (lb/hr) are presented as sums. Inlet concentrations are presented as flow-weighted averages.
† Calculated using plant CEMS CO_2 data and Method 19.
‡ Calculated using plant coal use data.

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program
Basin Electric Power Cooperative, Laramie River Station, Unit #3
Speciated Mercury and Particulate Matter Test Results

	Inlet				Stack				
	North	Middle	South	Average*	Run 1	Run 2	Run 3	Average	**ESP and Scrubber Control Efficiency**
Date	11-Feb-03	11-Feb-03	11-Feb-03		11-Feb-03	11-Feb-03	11-Feb-03		
Start time	8:30	12:55	16:35		8:30	12:55	16:35		
Stop time	11:00	15:36	18:56		11:00	15:36	18:56		
Load (GMW)					587.4	587.7	587.7	587.5	
Coal Use (MMBtu/hr)					6312.1	6244.4	6271.5	6276.0	
PM (gr/dscf)	1.40	1.14	1.54	1.33	2.13 e-3	2.05 e-3	5.27 e-3	3.15 e-3	**99.8%**
PM (lb/hr)	7456	8200	7967	23624	27.07	26.61	68.12	40.60	
PM (lb/MMBtu)	2.74	2.26	3.04	2.63	4.16 e-3	4.06 e-3	1.04 e-2	6.22 e-3	
PM Hg (ug/dscm)	0.99	0.38	1.33	0.84	0.14	0.18	0.12	0.15	**82.8%**
PM Hg (lb/hr)	2.31 e-3	1.21 e-3	3.02 e-3	6.54 e-3	7.52 e-4	1.03 e-3	6.72 e-4	8.19 e-4	
Oxidized Hg (ug/dscm)	0.57	0.49	2.11	0.99	0.10	0.16	0.17	0.14	**85.7%**
Oxidized Hg (lb/hr)	1.33 e-3	1.55 e-3	4.79 e-3	7.67 e-3	5.34 e-4	9.20 e-4	9.49 e-4	8.01 e-4	
Elemental Hg (ug/dscm)	6.18	8.19	6.02	6.95	7.99	8.93	8.57	8.50	**-22.3%**
Elemental Hg (lb/hr)	1.44 e-2	2.58 e-2	1.36 e-2	5.38 e-2	4.45 e-2	5.08 e-2	4.84 e-2	4.79 e-2	
Total Hg (ug/dscm)	7.74	9.06	9.47	8.78	8.22	9.27	8.86	8.78	**0.0%**
Total Hg (lb/hr)	1.80 e-2	2.86 e-2	2.15 e-2	6.81 e-2	4.58 e-2	5.27 e-2	5.01 e-2	4.95 e-2	
Total Hg (lb/TBtu)†	6.63	7.86	8.18	7.58	7.04	8.04	7.65	7.58	
Total Hg (lb/TBtu)‡	8.58	13.72	10.26	10.84	7.25	8.45	7.98	7.89	

* For the inlet, mass emissions (lb/hr) are presented as sums. Inlet concentrations are presented as flow-weighted averages.
† Calculated using plant CEMS CO_2 data and Method 19.
‡ Calculated using plant coal use data.

Table 5.2: Emissions Testing Results Summary, Unit 3

Table 5.3: Coal and Ash Analysis Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program **Basin Electric Power Cooperative, Laramie River Station, Units #1 and #3** **Coal and Ash Analysis**				
	Unit 1			
Date	12-Feb-03	12-Feb-03	12-Feb-03	**Average**
Start time	9:30	15:40	18:30	
Stop time	14:30	17:50	20:54	
Hg Coal Feeder (mg/kg)	0.14	0.08	0.09	**0.10**
Cl Coal Feeder (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Bottom Ash (mg/kg)	0.07	0.15	<0.04	**0.09**
Cl Bottom Ash (%)	0.023	0.021	0.016	**0.020**
	Unit 3			
Date	11-Feb-03	11-Feb-03	11-Feb-03	**Average**
Start time	8:30	12:55	16:35	
Stop time	11:00	15:36	18:56	
Hg Coal Feeder (mg/kg)	0.090	0.080	0.15	**0.11**
Cl Coal Feeder (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Bottom Ash (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Bottom Ash (%)	0.017	0.016	0.020	**0.018**

City of Grand Island Platte Station

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Platte Generating Station in Grand Island, Nebraska.

The purpose of the testing program was to determine the operating efficiency of the Unit #1 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the Electrostatic Precipitator (ESP) inlet and outlet ducts on February 18, 2003. Inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Platte Generating Station, Unit #1 Emissions Testing Program Contact Personnel		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386 307-721-2256 fax
Mr. Dave Kuhlman	Platte Generating Station 1035 West Wildwood Dr. Grand Island, Nebraska 68802	308-385-5497 308-385-5353 fax
Ms. Shari Typer	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Craig Kormylo	Air Pollution Testing, Inc. 12421 West 49th Avenue, Unit 2 Wheat Ridge, Colorado 80033	303-420 5949, 303-420 5920 fax

2. Methods

APT 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S 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 Matter from Stationary Sources

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Platte Generating Station Unit #1 is a pulverized coal-fired boiler with a name plate rating of 100 NMW (net megawatts). Emissions are controlled with a hot side ESP.

Figure 3.1 provides a schematic of the process, including pollution control equipment.

3.2. Sampling Locations

The ESP inlet sampling location was a horizontal rectangular duct measuring 27'-9" across and 6'-6" tall. The outlet sampling location consisted of a horizontal rectangular stack measuring 9'-6" by 10'-0". Sampling was conducted at each location over a 20-point grid from five sampling ports located along the top of each duct.

Figure 3.1 provides a schematic of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

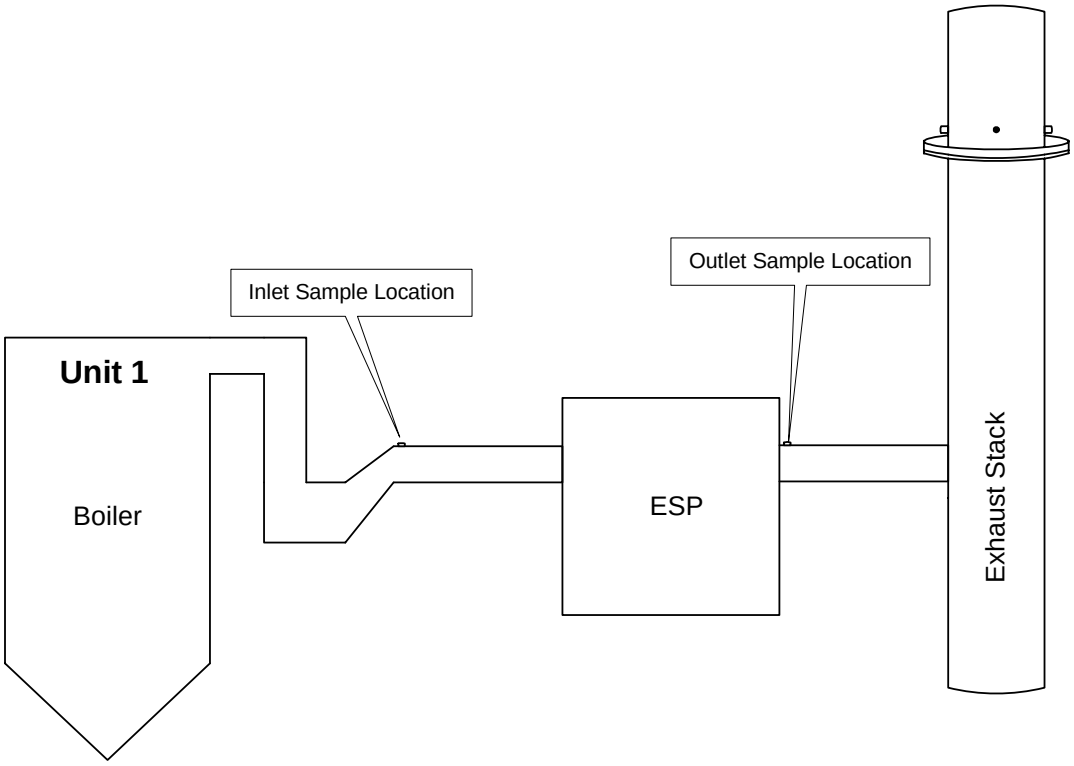


Figure 3.1: Schematic of Boiler and Pollution Control Equipment

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Platte Generating Station, Unit #1 Sampling and Analytical Methods Summary			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT On-Site
O_2 / CO_2	Method 3	wet chemical -Fyrite instrument	
Moisture (H_2O)	Method 4	gravimetric	
Particulate Matter	Method 17 (inlet) or Method 5 (outlet)	gravimetric	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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 (O_2 and CO_2) analysis using a Fyrite instrument. Additionally, carbon dioxide 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), lb/TBtu (trillion British thermal units), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; no mercury contamination was detected.

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. No mercury was detected in any reagent fraction.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. No mercury was detected in the blank train collected at the outlet sampling location. Mercury was detected in the blank train collected at the inlet location, but at less than one percent of the average emission sample level.

4.3. Calculations

For pollutant sample fractions with “not detected” mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and plant CEMS CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1 and 5.2. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligram per kilogram

Table 5.1: Emissions Testing Results Summary

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program
Platte Generating Station, Unit #1
Speciated Mercury and Particulate Matter Test Results

	ESP Inlet				ESP Outlet				**ESP Control Efficiency**
Date	18-Feb-03	18-Feb-03	18-Feb-03	Average	18-Feb-03	18-Feb-03	18-Feb-03	Average	
Start time	9:00	12:15	15:40		9:00	12:15	15:40		
Stop time	11:15	14:33	18:00		11:15	14:33	18:00		
Load (GMW)	--	--	--		102.9	102.9	102.9	**102.9**	
Coal Use (MMBtu/hr)	--	--	--		1,019	1,014	1,015	**1,016**	
PM (gr/dscf)	2.25	2.06	2.23	**2.18**	9.02 e-3	1.11 e-2	1.74 e-3	**7.30 e-3**	**99.7%**
PM (lb/hr)	4629	4219	4558	**4468**	21.6	22.2	3.8	**15.9**	
PM (lb/MMBtu) (1)	4.87	4.42	4.85	**4.71**	1.95 e-2	2.39 e-2	3.79 e-3	**1.57 e-2**	
PM Hg (ug/dscm)	0.516	0.755	0.352	**0.541**	0.237	0.085	0.050	**0.124**	**77.1%**
PM Hg (lb/hr)	4.64 e-4	6.75 e-4	3.15 e-4	**4.85 e-4**	2.48 e-4	7.38 e-5	4.83 e-5	**1.23 e-4**	
Oxidized Hg (ug/dscm)	0.18	3.35	0.29	**1.27**	0.95	0.66	0.62	**0.74**	**41.5%**
Oxidized Hg (lb/hr)	1.60 e-4	3.00 e-3	2.58 e-4	**1.14 e-3**	9.91 e-4	5.78 e-4	6.01 e-4	**7.23 e-4**	
Elemental Hg (ug/dscm)	8.14	4.94	7.99	**7.03**	7.25	7.22	6.60	**7.03**	**0.0%**
Elemental Hg (lb/hr)	7.32 e-3	4.42 e-3	7.14 e-3	**6.29 e-3**	7.59 e-3	6.30 e-3	6.35 e-3	**6.75 e-3**	
Total Hg (ug/dscm)	8.84	9.05	8.63	**8.84**	8.44	7.97	7.28	**7.89**	**10.7%**
Total Hg (lb/hr)	7.94 e-3	8.10 e-3	7.72 e-3	**7.92 e-3**	8.82 e-3	6.95 e-3	7.00 e-3	**7.59 e-3**	
Total Hg (lb/TBtu) (1)	8.35	8.48	8.2	**8.34**	7.97	7.47	6.91	**7.45**	
Total Hg (lb/TBtu) (2)	7.79	7.99	7.60	**7.79**	8.66	6.86	6.89	**7.47**	

(6) – calculated using plant CEMS CO_2 data and Method 19
(7) – calculated using plant coal use data

Table 5.2: Coal and Ash Analysis Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program **Platte Generating Station, Unit #1** **Coal and Ash Analysis**				
Date	18-Feb-03	18-Feb-03	18-Feb-03	Average
Start time	9:00	12:15	15:40	
Stop time	11:15	14:33	18:00	
Hg Precip Ash (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Precip Ash (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Pyrites (mg/kg)	0.81	0.81	0.81	**0.81**
Cl Pyrites (%)	0.008	0.008	0.008	**0.008**
Hg Coal Feeder (mg/kg)	0.09	0.08	0.09	**0.09**
Cl Coal Feeder (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Economizer (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Economizer (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Bottom Ash (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Bottom Ash (%)	<0.005	<0.005	<0.005	**<0.005**

Nebraska Public Power District Sheldon Unit #2 Unit

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Sheldon Station in Hallam, Nebraska.

The purpose of the testing program was to determine the operating efficiency of the Unit #2 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the Fabric Filter inlet and outlet ducts on February 20, 2003. Inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Sheldon Station, Unit #2 Emissions Testing Program Contact Personnel		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386 307-721-2256 fax
Mr. Doug Sorensen	Sheldon Station 4500 West Pella Road Hallam, Nebraska 68368-0088	402-787-5270 402-787-5246 fax
Ms. Shari Typer	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Craig Kormylo	Air Pollution Testing, Inc. 12421 West 49th Avenue, Unit 2 Wheat Ridge, Colorado 80033	303-420 5949, 303-420 5920 fax

2. Methods

APT 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S 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 Matter from Stationary Sources

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Sheldon Station Unit #2 is a cyclone-fired El Paso style pulverized coal boiler with a name plate rating of 120 GMW (gross megawatts). Emissions are controlled with a jet-pulse fabric-filter bag house.

Figure 3.1 provides a schematic of the process, including pollution control equipment.

3.2. Sampling Locations

The fabric filter inlet sampling location was a horizontal rectangular duct measuring11’-4” across and 15’-0” tall. The outlet sampling location consisted of a vertical, cylindrical stack with an inside diameter of 11’-7 3/8”. Sampling at the inlet was conducted using a

20-point grid from 2 sampling ports located along the top of the duct, with the outlet using a 16-point grid from four sampling ports located at the sampling platform on the exhaust stack.

Figure 3.1 provides a schematic of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

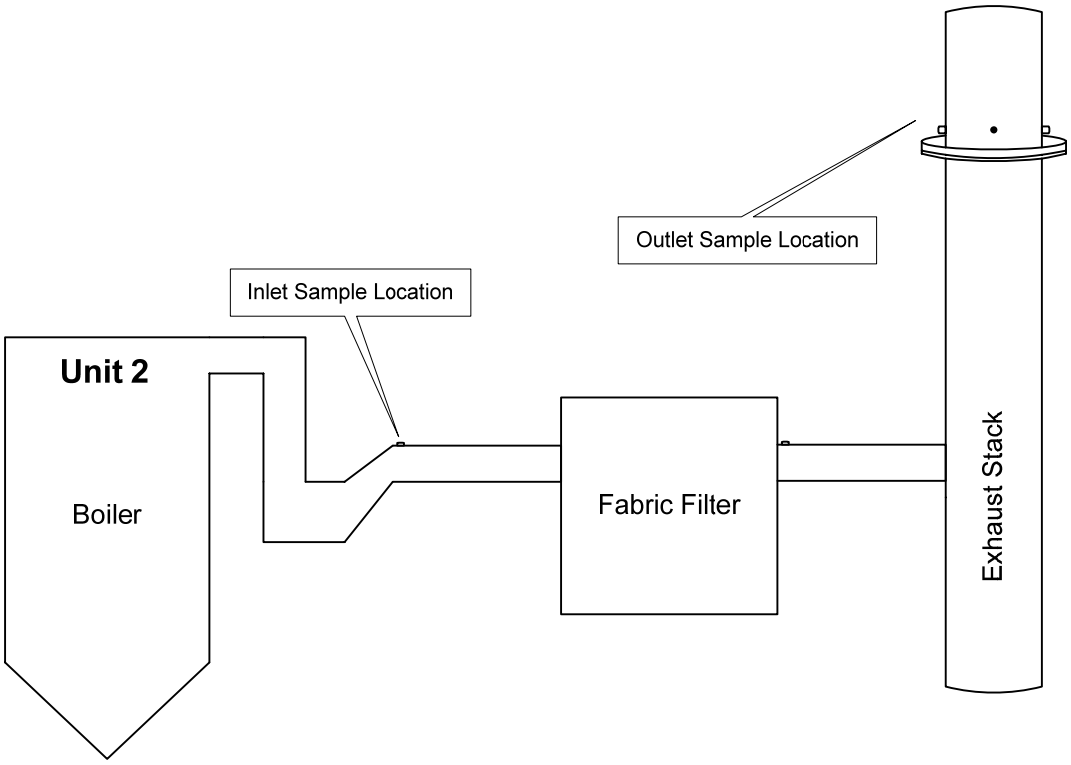


Figure 3.1: Schematic of Boiler and Pollution Control Equipment

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Sheldon Station, Unit #2 Sampling and Analytical Methods Summary			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT On-Site
O_2 / CO_2	Method 3	wet chemical -Fyrite instrument	
Moisture (H_2O)	Method 4	gravimetric	
Particulate Matter	Method 17 (inlet) or Method 5 (outlet)	gravimetric	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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 (O_2 and CO_2) analysis using a Fyrite instrument. Additionally, carbon dioxide 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), trillion British thermal units (lb/TBtu), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; no mercury contamination was detected.

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. No mercury was detected in any reagent fraction.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. No mercury was detected in either of the blank trains collected at the inlet and outlet sampling locations.

4.3. Calculations

For pollutant sample fractions with “not detected” mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and plant CEMS CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1 and 5.2. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligram per kilogram

Table 5.1: Emissions Testing Results Summary

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program
Sheldon Station, Unit #2
Speciated Mercury and Particulate Matter Test Results

	Fabric Filter Inlet				Fabric Filter Outlet				**ESP Control Efficiency**
Date	20-Feb-03	20-Feb-03	20-Feb-03	Average	20-Feb-03	20-Feb-03	20-Feb-03	Average	
Start time	9:32	13:35	16:50		9:32	13:35	16:50		
Stop time	12:17	15:42	19:00		12:17	15:42	19:00		
Load (GMW)	--	--	--		115	115	115	**115**	
Coal Use (MMBtu/hr)	--	--	--		1,312	1,244	1,274	**1,276**	
PM (gr/dscf)	0.83	1.00	1.21	**1.01**	7.69 e-3	1.94 e-3	2.42 e-3	**4.02 e-3**	**99.6%**
PM (lb/hr)	1,668	1,939	2,374	**1,994**	20.7	5.0	6.1	**10.6**	
PM (lb/MMBtu) (1)	1.61	1.97	2.38	**1.98**	1.50 e-2	3.82 e-3	4.80 e-3	**7.87 e-3**	
PM Hg (ug/dscm)	4.206	4.917	5.479	**4.867**	0.033	0.026	0.016	**0.025**	**99.5%**
PM Hg (lb/hr)	3.69 e-3	4.17 e-3	4.71 e-3	**4.19 e-3**	3.89 e-5	2.94 e-5	1.81 e-5	**2.88 e-5**	
Oxidized Hg (ug/dscm)	0.08	0.07	0.07	**0.07**	0.15	0.16	0.14	**0.15**	**-108.2%**
Oxidized Hg (lb/hr)	7.44 e-5	5.72 e-5	5.75 e-5	**6.30 e-5**	1.79 e-4	1.78 e-4	1.60 e-4	**1.72 e-4**	
Elemental Hg (ug/dscm)	2.25	1.92	1.24	**1.80**	1.26	1.13	1.10	**1.16**	**35.4%**
Elemental Hg (lb/hr)	1.97 e-3	1.63 e-3	1.06 e-3	**1.56 e-3**	1.48 e-3	1.27 e-3	1.22 e-3	**1.32 e-3**	
Total Hg (ug/dscm)	6.54	6.90	6.78	**6.74**	1.44	1.32	1.26	**1.34**	**80.1%**
Total Hg (lb/hr)	5.74 e-3	5.86 e-3	5.83 e-3	**5.81 e-3**	1.70 e-3	1.47 e-3	1.40 e-3	**1.52 e-3**	
Total Hg (lb/TBtu) (1)	5.53	5.93	5.84	**5.77**	1.23	1.13	1.09	**1.15**	
Total Hg (lb/TBtu) (2)	4.38	4.71	4.58	**4.56**	1.29	1.18	1.10	**1.19**	

(8) – calculated using plant CEMS CO_2 data and Method 19
(9) – calculated using plant coal use data

Table 5.2: Coal and Ash Analysis Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program **Sheldon Station, Unit #2** **Coal and Ash Analysis**				
Date	20-Feb-03	20-Feb-03	20-Feb-03	**Average**
Start time	9:32	13:35	16:50	
Stop time	12:17	15:42	19:00	
Hg Coal Feeder Ash (mg/kg)	0.05	0.11	0.22	**0.13**
Cl Coal Feeder Ash (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Bottom Ash (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Bottom Ash (%)	0.013	<0.005	<0.005	**<0.007**

Platte River Power Authority Rawhide Station, Unit #1

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Platte River Power Authority Rawhide Energy Station in Wellington, Colorado.

The purpose of the testing program was to determine the operating efficiency of the Unit #1 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the spray dry absorber (SDA) inlet and exhaust stack on March 6 and 7, 2003. Inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Platte River Power Authority Rawhide Station, Unit #1 Emissions Testing Program Contact Personnel		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386 307-721-2256 fax
Mr. Paul Schulz	Platte River Power Authority – Rawhide 2000 East Horsetooth Road Wellington, Colorado 80525	970-229-1762 970-229-5244 fax
Ms. Shari Typer	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Craig Kormylo	Air Pollution Testing, Inc. 12421 West 49th Avenue, Unit 2 Wheat Ridge, Colorado 80033	303-420 5949, 303-420 5920 fax

2. Methods

APT tested in accordance with the following USEPA and ASTM source emissions test methods. Methods 1 through 4 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

Method 3 – Gas Analysis for the Determination of Dry Molecular Weight

Method 4 – Determination of Moisture Content in Stack Gases

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Rawhide Unit #1 is a pulverized coal-fired boiler with a name plate rating of 295 GMW (gross megawatts). Emissions are controlled with a spray dry absorber, two side-by-side baghouses, and low NO_X concentric firing burners and over-fire air.

Figure 3.1 provides a schematic of the process, including pollution control equipment.

3.2. Sampling Locations

The SDA inlet sampling location was a horizontal rectangular duct measuring 20'0" across and 18'10" tall. Sampling was conducted over a 20-point grid from four sampling ports located along the top of the duct.

The stack sampling location consisted of a round, vertical stack with a 240" inside diameter. Sampling was conducted over a 16-point grid from four ports arranged 90 degrees apart.

Figure 3.1 provides a schematic of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

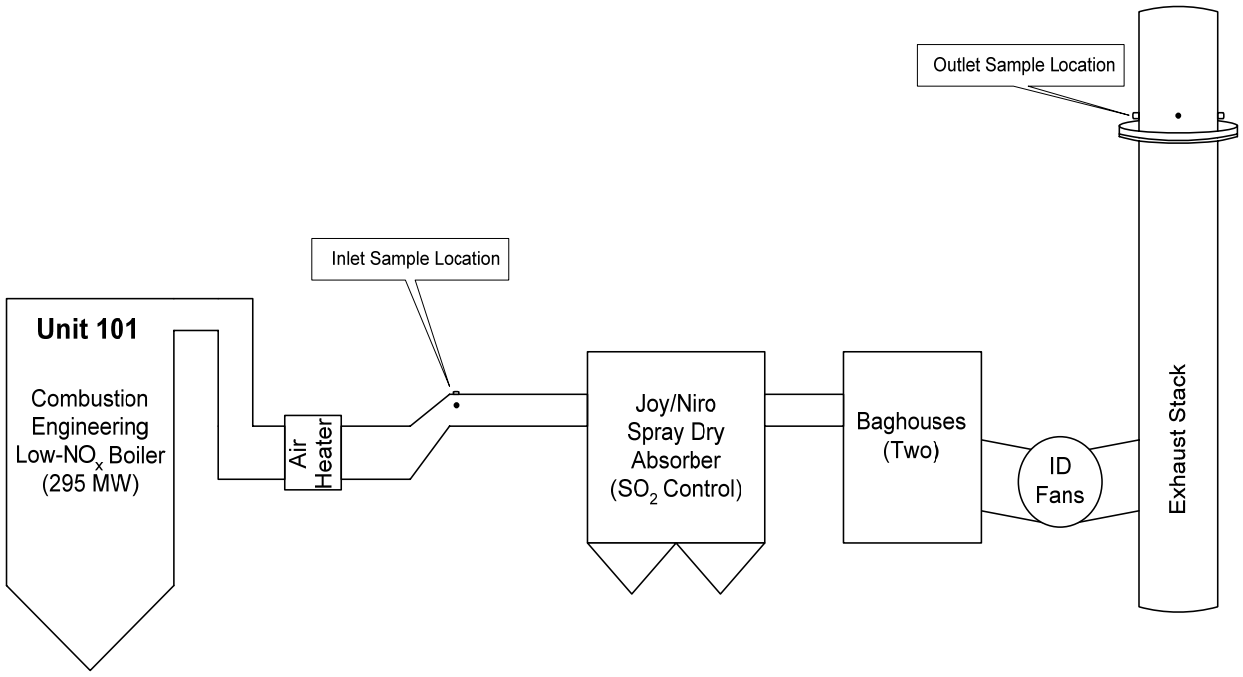


Figure 3.1: Schematic of Boiler and Pollution Control Equipment

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Platte River Power Authority Rawhide Station, Unit #1 Sampling and Analytical Methods Summary			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT On-Site
O_2 / CO_2	Method 3	wet chemical -Fyrite instrument	
Moisture (H_2O)	Method 4	gravimetric	
Particulate Matter	Method 17	gravimetric	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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. 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.

Integrated gas samples were collected in Tedlar bags during each run for diluent (O_2 and CO_2) analysis using a Fyrite instrument. Additionally, carbon dioxide 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), lb/TBtu (trillion British thermal units), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; no mercury contamination was detected.

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. No mercury was detected in any reagent fraction.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. No mercury was detected in the blank train collected at the outlet sampling location. Mercury was detected in the blank train collected at the inlet location, but at ½ of 1 percent of the average emission sample level.

4.3. Calculations

For pollutant sample fractions with “not detected” mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and plant CEMS CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant in accordance with *40 CFR 60* requirements.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1 and 5.2. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligram per kilogram

Table 5.1: Emissions Testing Results Summary

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program
Platte River Power Authority Rawhide Station, Unit #1
Speciated Mercury and Particulate Matter Test Results

	SDA Inlet				Stack				**SDA and Baghouse Control Efficiency**
Date	6-Mar-03	7-Mar-03	7-Mar-03	Average	6-Mar-03	7-Mar-03	7-Mar-03	Average	
Start time	16:00	09:05	12:10		16:00	09:05	12:10		
Stop time	18:47	11:09	14:15		18:47	11:25	14:17		
Load (GMW)	--	--	--		294	294	294	294	
Coal Use (MMBtu/hr)	--	--	--		2,817	2,783	2,794	2,798	
PM (gr/dscf)	2.03	1.65	2.08	1.92	9.43 e-4	2.47 e-4	1.34 e-4	4.41 e-4	**100.0%**
PM (lb/hr)	11,134	9,485	11,665	10,761	5.13	1.39	0.77	2.43	
PM (lb/MMBtu)	3.40	2.78	3.50	3.23	1.58 e-3	4.16 e-4	2.25 e-4	7.41 e-4	
PM Hg (ug/dscm)	0.213	0.261	0.358	0.277	<6.17 e-3	<5.96 e-3	<6.11 e-3	<6.08 e-3	**>97.8%**
PM Hg (lb/hr)	5.11 e-4	6.56 e-4	8.78 e-4	6.82 e-4	<1.47 e-5	<1.47 e-5	<1.53 e-5	<1.49 e-5	
Oxidized Hg (ug/dscm)	2.92	0.46	1.68	1.68	2.96	0.89	0.79	1.55	**8.0%**
Oxidized Hg (lb/hr)	7.00 e-3	1.15 e-3	4.12 e-3	4.09 e-3	7.05 e-3	2.20 e-3	1.99 e-3	3.75 e-3	
Elemental Hg (ug/dscm)	7.27	5.41	5.15	5.94	4.53	5.10	4.86	4.83	**18.7%**
Elemental Hg (lb/hr)	1.75 e-2	1.36 e-2	1.26 e-2	1.46 e-2	1.08 e-2	1.26 e-2	1.22 e-2	1.18 e-2	
Total Hg (ug/dscm)	10.40	6.13	7.19	7.90	7.50	6.00	5.66	6.39	**19.2%**
Total Hg (lb/hr)	2.50 e-2	1.54 e-2	1.76 e-2	1.93 e-2	1.79 e-2	1.48 e-2	1.42 e-2	1.56 e-2	
Total Hg (lb/TBtu) (1)	7.62	4.50	5.29	5.80	5.50	4.41	4.16	4.69	
Total Hg (lb/TBtu) (2)	8.86	5.53	6.31	6.90	6.34	5.31	5.08	5.58	

(10) – calculated using plant CEMS CO_2 data and Method 19
(11) – calculated using *40 CFR 60* plant coal use data

Table 5.2: Coal and Ash Analysis Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program **Platte River Power Authority Rawhide Station, Unit #1** **Coal and Ash Analysis**				
Date	6-Mar-03	7-Mar-03	7-Mar-03	**Average**
Start time	16:00	09:05	12:10	
Stop time	18:47	11:09	14:15	
Hg Coal Feeder (mg/kg)	0.10	0.05	0.04	**0.06**
Cl Coal Feeder (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Bottom Ash (mg/kg)	<0.04	<0.04	<0.04	**<0.04**
Cl Bottom Ash (%)	<0.005	<0.005	<0.005	**<0.005**
Hg Fly Ash (mg/kg)	0.05	0.04	0.05	**0.05**
Cl Fly Ash (%)	0.029	0.027	0.028	**0.028**

Xcel Energy Pawnee Generating Station, Unit #1

1. Introduction

Air Pollution Testing, Inc. (APT) was contracted by Western Research Institute (WRI) to conduct a series of source emission tests at the Pawnee Generating Station in Brush, Colorado.

The purpose of the testing program was to determine the operating efficiency of the Unit #1 control equipment for removal of particulate matter (PM), elemental, oxidized, particle-bound and total mercury (Hg) from the flue gas.

The data are a part of an ongoing assessment of mercury emissions from sub-bituminous coal-fired utilities being conducted jointly with WRI and the Department of Energy (DOE).

Triplicate 120-minute sampling periods were conducted at the baghouse inlet duct and exhaust stack on March 4-5, 2003. Inlet and outlet testing was conducted simultaneously. The following table provides key project personnel, company affiliations, telephone and fax numbers.

Table 1.1: Emissions Testing Program Contact Personnel

WRI/DOE - Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program Pawnee Generating Station, Unit #1 Emissions Testing Program Contact Personnel		
Name, Title	*Company, Affiliation Address*	*Telephone, Facsimile*
Dr. Alan Bland	Western Research Institute 365 North 9th Street Laramie, Wyoming 82072	307-721-2386 307-721-2256 fax
Mr. Gary Magno	Xcel Energy 4653 Table Mountain Drive Coors Technology Center Golden, Colorado 80403	720-497-2112
Ms. Shari Typer	Philip Analytical Services 5555 North Service Road Burlington, Ontario L7L 5H7 Canada	905-332 8788 x 255, 905-332 9165 fax
Mr. Craig Kormylo	Air Pollution Testing, Inc. 12421 West 49th Avenue, Unit 2 Wheat Ridge, Colorado 80033	303-420 5949, 303-420 5920 fax

2. Methods

APT 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 on the World Wide Web at *www.epa.gov/ttn/emc/prelim.html*.

Method 1 – Sample and Velocity Traverses for Stationary Sources

Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S 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 Matter from Stationary Sources

Method 17 – Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

PRE 3 – Draft Method - Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in the Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

3. Test Program Summary

The test program determined all parameters detailed in Table 3.1. At each sampling location, integrated samples were collected during 120-minute sample periods for off-site analysis to determine the speciated Hg and PM content of the gas streams. All samples were collected by APT personnel and delivered to PSC Analytical Services in Ontario, Canada via overnight delivery.

3.1. Process Description

Pawnee Station Unit #1 is a pulverized coal wall-fired boiler with a name plate rating of 547 gross megawatts (GMW). Particulate emissions are controlled by a baghouse with oxides of nitrogen (NO_X) emissions being controlled by low NO_X burners with over-fire air.

Figure 3.1 provides a schematic of the process, including pollution control equipment.

3.2. Sampling Locations

The baghouse inlet sampling location was a horizontal rectangular duct measuring 30’ across and 37’-11/12” tall. The outlet sampling location consisted of a vertical circular

stack measuring 24'-9.6" in diameter. Sampling at the inlet was conducted using a 24-point grid from 3 sampling ports located along the top of the duct, with the outlet using a 16-point grid from four sampling ports located at the exhaust stack.

Figure 3.1 provides a schematic of the sampling locations. For schematics of the sampling locations, sampling points and sampling trains, please see *Appendix 4 – Diagrams*.

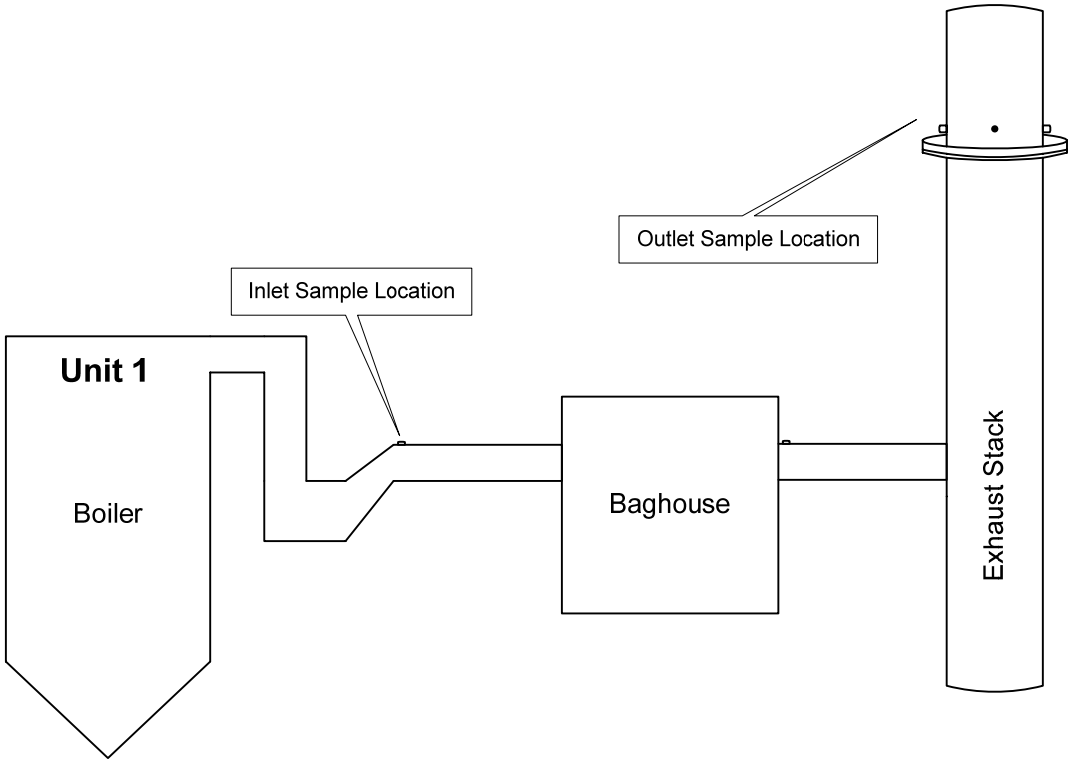


Figure 3.1: Schematic of Boiler and Pollution Control Equipment

Table 3.1: Sampling and Analytical Methods Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program **Pawnee Generating Station, Unit #1** **Sampling and Analytical Methods Summary**			
Parameter	*Sampling Method*	*Analytical Method*	*Laboratory*
Gas Flow	Methods 1 and 2	draft gauge, S-type pitot tube	APT On-Site
O_2 / CO_2	Method 3	wet chemical -Fyrite instrument	
Moisture (H_2O)	Method 4	Gravimetric	
Particulate Matter	Method 17 (inlet) or Method 5 (outlet)	Gravimetric	APT Wheat Ridge, CO
Speciated Mercury	Ontario Hydro Method	cold vapor atomic absorption (CVAAS)	PSC Analytical Burlington, Ontario

4. Sampling and Analysis Details

4.1. Sampling Details

Gas flow rate, PM, and speciated Hg levels were determined in accordance with EPA Methods 1, 2, 3, 4, 5 or 17, and PRE 3 – Ontario Hydro Method. A summary of the testing parameters is provided in *Appendix 1 - Testing Parameters / Sample Calculations*. Copies of the field and laboratory data sheets are located in *Appendix 2 - Field Data* and *Appendix 3 – Laboratory Data*.

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 (O_2 and CO_2) analysis using a Fyrite instrument. Additionally, carbon dioxide 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 (HNO_3/H_2O_2). The fifth, sixth, and seventh impingers were each seeded with 100 ml of acidified potassium permanganate ($KMnO_4$). The eighth impinger was seeded with approximately 250 grams of dried silica gel. For a schematic of the sampling train, please see *Appendix 4 – Diagrams*.

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 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.

All of 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 (µg/dscm), trillion British thermal units (lb/TBtu), and lb/hr.

4.2. Quality Control / Quality Assurance

A mobile analytical trailer prepared and dedicated for the project was provided to maintain a clean, temperature controlled environment for sample train preparation and sample recovery.

4.2.1. Pre-Mobilization Quality Assurance Samples

Prior to departure for the test program, all glassware was washed in accordance with the Ontario Hydro Method recommended procedures. Following this washing, a final rinse was conducted with 0.1N HNO_3. This final rinse solution was recovered and analyzed by PSC Analytical; no mercury contamination was detected.

An aliquot of all sampling and recovery reagents was analyzed for mercury prior to departure to the test site. No mercury was detected in any reagent fraction.

4.2.2. On-Site Quality Assurance Samples

Field train blanks were collected at the inlet and outlet sampling locations during the testing campaign. Field blank collection procedures were as detailed in the Ontario Hydro Method. Mercury was detected in both of the blank trains collected at the inlet and outlet sampling location. The inlet blank train contained one fraction with a significant level of mercury, possibly due to some residue background glassware contamination. This value was used for inlet blank corrections as deemed appropriate. The outlet blank train also contained some measurable mercury in one of its fractions, but at a much lower level that that of the inlet. No blank corrections were made at the outlet.

4.3. Calculations

For pollutant sample fractions with "not detected" mercury values, the detection limits were used for calculations. No blank corrections were performed. This provides maximum possible mercury values for all pollutant samples.

Mercury emissions in units of pounds per trillion British thermal units were calculated two ways, with both results provided in the results table. First, the emissions were calculated using EPA Method 19 with an F_c of 1,800 dry standard cubic feet of exhaust gas per million British thermal units and plant CEMS CO_2 data. Second, the emissions were calculated using the measured mercury emission rate in pounds per hour and the coal consumption as measured by the plant.

5. Test Results Summary

The results of the testing program are summarized in Tables 5.1 and 5.2. Any emission parameters not found in the tables can be found in *Appendix 1 – Testing Parameters and Sample Calculations.* The following abbreviations are used in the tables:

GMW – gross megawatts

MMBtu/hr – fuel use, millions of British thermal units per hour

PM – particulate matter

lb/hr – mass emission rate, pounds per hour

lb/MMBtu – mass emission rate, pounds per million British thermal units

gr/dscf – particulate concentration, grains per dry standard (68° F, 1 atmosphere) cubic foot

Hg – mercury

µg/dscm – mercury concentration, micrograms per dry standard cubic meter

lb/TBtu – mass emission rate, pounds per trillion British thermal units

mg/kg – milligram per kilogram

Table 5.1: Emissions Testing Results Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program
Pawnee Generating Station, Unit #1
Speciated Mercury and Particulate Matter Test Results

	Baghouse Inlet[4]				Baghouse Outlet				**Baghouse Control Efficiency[5]**
Date	04-Mar-03	05-Mar-03	05-Mar-03	Average	04-Mar-03	05-Mar-03	05-Mar-03	Average	
Start time	11:05	08:25	12:02		11:05	08:25	12:02		
Stop time	13:00	11:20	14:15		13:00	11:05	14:15		
Load (GMW)	--	--	--		535	535	535	**535**	
Coal Use (MMBtu/hr)	--	--	--		5,281	5,281	5,281	**5,281**	
PM (gr/dscf)	1.44	1.64	1.69	**1.59**	1.02 e-3	7.77 e-4	6.22 e-4	**8.06 e-4**	**99.9%**
PM (lb/hr)	27,332	32,179	33,048	**30,853**	10.3	7.91	6.31	**8.19**	
PM (lb/MMBtu) [1]	2.91	3.32	3.43	**3.22**	2.06 e-2	1.57 e-3	1.26 e-3	**1.63 e-3**	
PM Hg (ug/dscm)	3.19	5.68	5.20	**4.69**	0.066	0.013	0.010	**0.030**	**99.4%**
PM Hg (lb/hr)	2.65 e-2	4.88 e-2	4.44 e-2	**3.99 e-2**	2.92 e-4	5.86 e-5	4.31 e-5	**1.31 e-5**	
Oxidized Hg (ug/dscm)	0.43	4.78	2.68	**2.63**	6.14	3.89	4.24	**4.77**	**-81.1%**
Oxidized Hg (lb/hr)	3.60 e-3	4.11 e-2	2.29 e-2	**2.25 e-2**	2.73 e-2	1.73 e-2	1.90 e-2	**2.12 e-2**	
Elemental Hg (ug/dscm)	7.59	5.11	2.78	**5.16**	0.769	0.771	0.556	**0.699**	**86.5%**
Elemental Hg (lb/hr)	6.31 e-2	4.39 e-2	2.37 e-2	**4.36 e-2**	3.41 e-3	3.43 e-3	2.47 e-3	**3.10 e-3**	
Total Hg (ug/dscm)	11.21	15.58	10.66	**12.48**	6.98	4.67	4.84	**5.49**	**56.0%**
Total Hg (lb/hr)	9.32 e-2	1.34 e-1	9.10 e-2	**1.06 e-1**	3.10 e-2	2.08 e-2	2.15 e-2	**2.44 e-2**	
Total Hg (lb/TBtu) [1]	9.92	13.8	9.43	**11.1**	6.17	4.13	4.28	**4.86**	
Total Hg (lb/TBtu) [2][3]	--	--	--	**--**	5.86	3.94	4.07	**4.62**	

(12) – calculated using plant CEMS CO_2 data and Method 19
(13) – calculated using plant coal use data
(14) – probable significant positive bias on inlet values due to poor flow measurements
(15) – possible PM, PM Hg break through on inlet run 1 due to slight tear in filter
(16) – potential negative bias on speciated inlet Hg measurements, see EPA Research and Development report for discussion on inherent problems with OH method at locations down stream of PM control device (Control of Mercury Emissions from Coal Fired Electric Utility boilers, EPA-600/R-01-109, April 2002, Page ES-5)

Table 5.2: Coal and Ash Analysis Summary

WRI/DOE – Sub-bituminous Coal-Fired Utilities Mercury Emissions Testing Program **Pawnee Generating Station, Unit #1** **Coal and Ash Analysis**				
Date	04-Mar-03	05-Mar-03	05-Mar-03	Average
Start time	11:05	08:25	12:02	
Stop time	13:00	11:20	14:15	
Hg Coal Feeder (mg/kg)	0.18	0.12	0.070	**0.12**
Cl Coal Feeder (%)	<0.0050	<0.0050	<0.0050	<0.0050
Hg Bottom Ash (mg/kg)	<0.04	<0.04	0.10	**<0.06**
Cl Bottom Ash (%)	0.16	0.15	0.064	**0.12**