

**FOSSIL ENERGY RESEARCH CORP.**  
23342C South Pointe, Laguna Hills, CA 92653 (949) 859-4466

March 6, 2000  
FERCo-R745tl2

Mr. William Grimley  
USEPA, EMC Building, Room 108  
4930 Old Page Road  
Durham, NC 27709

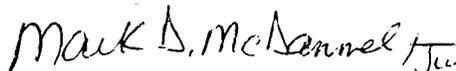
Dear Mr. Grimley,

Enclosed are five bound copies and one unbound copy of Fossil Energy Research Corp.'s Report No. FERCo R745 entitled "**Mercury Speciation Stack Sampling Test Report: Navajo Unit 3.**"

We are submitting these copies on behalf of Salt River Project to meet the requirements of the information collection request.

Sincerely,

Fossil Energy Research Corp.



Mark D. McDannel, P.E.

MDM/jw

cc: Paul Ostapuk, SRP Navajo  
Dan Casiraro, SRP

# MERCURY SPECIATION STACK SAMPLING TEST REPORT: NAVAJO UNIT 3

March 2000

**Prepared by**

Fossil Energy Research Corp.  
23342 C South Pointe  
Laguna Hills, CA 92653

**Principal Investigator**

Mark D. McDannel, P.E.

**Prepared for**

Salt River Project  
Page, Arizona

Electric Power Research Institute  
Palo Alto, California



# TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
<b>1 INTRODUCTION .....</b>	<b>1-1</b>
1.1 Summary of Test Program .....	1-1
Purpose of Test .....	1-1
Test Unit .....	1-1
Test Measurements .....	1-2
Responsible Organizations .....	1-2
Dates of Test .....	1-2
Document Description .....	1-2
1.2 Key Personnel .....	1-3
<b>2 PLANT AND SAMPLING LOCATION DESCRIPTIONS .....</b>	<b>2-1</b>
2.1 Process and Control Equipment Description and Operation .....	2-1
2.2 Flue Gas Sampling Locations .....	2-3
Inlet Locations .....	2-3
Stack Location .....	2-3
2.3 Coal Sampling Location .....	2-4
<b>3 SUMMARY AND DISCUSSION OF TEST RESULTS .....</b>	<b>3-1</b>
3.1 Objectives and Test Matrix .....	3-1
Objectives .....	3-1
Test Matrix .....	3-1
3.2 Field Test Changes and Problems .....	3-1
Change of Analytical Method and Laboratory for Mercury in Coal .....	3-1
3.3 Presentation of Results .....	3-3
<b>4 SAMPLING AND ANALYTICAL PROCEDURES .....</b>	<b>4-1</b>
4.1 Test Methods .....	4-1
Sample Recovery .....	4-4
Sample Digestion and Analysis .....	4-4
Ash Sample (Containers 1 and 2) .....	4-4
KCl Impingers (Container 3) .....	4-5
KNO <sub>3</sub> -H <sub>2</sub> O <sub>2</sub> Impinger (Container 4) .....	4-5
H <sub>2</sub> SO <sub>4</sub> -KMnO <sub>4</sub> Impingers (Container 5) .....	4-5
Analysis .....	4-5

**Table of Contents (continued)**

Handling of Non Detects.....	4-7
Auxiliary Flue Gas Measurements.....	4-7
Stack Moisture.....	4-7
Inlet Flow Determination .....	4-7
Stack Flow Determination.....	4-8
Comparative Flow Rate Calculations.....	4-8
Alternate Methodology for O <sub>2</sub> /CO <sub>2</sub> Determination .....	4-8
Determination of Scrubber Efficiency .....	4-8
Scrubber Efficiency Determination.....	4-8
4.2 Process Data.....	4-9
<b>5 INTERNAL QA/QC ACTIVITIES.....</b>	<b>5-1</b>
5.1 QA/QC Problems.....	5-1
5.2 QA Audits and Data Quality Objectives.....	5-1
5.3 Comparison Analyses .....	5-2
<b>APPENDIX A. RESULTS AND CALCULATIONS.....</b>	<b>A-1</b>
<b>APPENDIX B. RAW FIELD DATA AND CALIBRATION DATA SHEETS .....</b>	<b>B-1</b>
<b>APPENDIX C. CHAIN-OF-CUSTODY RECORDS.....</b>	<b>C-1</b>
<b>APPENDIX D. ANALYTICAL LAB REPORTS .....</b>	<b>D-1</b>
<b>APPENDIX E. AUDIT DATA SHEETS.....</b>	<b>E-1</b>
<b>APPENDIX F. LIST OF PARTICIPANTS.....</b>	<b>F-1</b>
<b>APPENDIX G. ADDITIONAL INFORMATION.....</b>	<b>G-1</b>

# LIST OF TABLES

<u>SECTION</u>	<u>PAGE</u>
Table 1-1. Test Program Organization and Responsibilities.....	1-4
Table 2-1. Summary of Navajo Unit 3 Operation.....	2-2
Table 2-2. Navajo Unit 3 Sampling Location Descriptions.....	2-4
Table 3-1. Test Matrix for Mercury ICR Tests at Navajo 3.....	3-2
Table 3-2. Navajo 3 Sampling Times.....	3-3
Table 3-3. Navajo Unit 3 Sample Gas Conditions.....	3-4
Table 3-4. Navajo Unit 3 Mercury Speciation Results .....	3-5
Table 3-5. Navajo Unit 3 Mercury Removal Efficiency.....	3-6
Table 4-1. Sample Train Components - Method 17 Configuration .....	4-3
Table 4-2. Sample Train Components - Method 5 Configuration .....	4-3
Table 5-1. Audit Samples for Ontario Hydro Mercury Speciation.....	5-2
Table 5-2. Data Quality Objectives for Flue Gas Mercury Analyses .....	5-2
Table 5-3. Results Evaluation and Verification Checklist.....	5-3
Table 5-4. Navajo 3 Sample Fraction Mercury Measurements .....	5-4
Table 5-5. Results of Independent QA Analyses of Navajo 3 Samples.....	5-4

# LIST OF FIGURES

<u>SECTION</u>	<u>PAGE</u>
Figure 1-1. Project Organization Chart.....	1-5
Figure 2-1. Navajo Unit 3 Schematic.....	2-1
Figure 2-2. Navajo Unit 3 Inlet Location.....	2-5
Figure 2-3. Navajo Unit 3 Stack Sample Location .....	2-6
Figure 3-1. Mercury Speciation Across Navajo Unit 3 Scrubber .....	3-7
Figure 4-1. Schematic of the Mercury Speciation Sample Train (Method 5 option as used at the stack is shown; Method 17 in-stack filtration was used for the Inlet on Navajo 3) .....	4-2
Figure 4-2. Sample Recovery Scheme for the Mercury Sampling Train.....	4-6

# 1

## INTRODUCTION

---

### 1.1 Summary of Test Program

#### *Purpose of Test*

The United States Environmental Protection Agency (EPA) has implemented an Information Collection Request (ICR) aimed at characterizing mercury emissions from coal-fired power plants in the United States. As part of this ICR, the operators of selected coal-fired boilers were required to collect and analyze flue gas samples for particulate, elemental, and oxidized mercury.

Salt River Project's (SRP's) Navajo Unit 3 was selected at random by the EPA to provide speciated mercury emissions data, which will then be used to develop emission factors for boilers in its class.

Measurements collected were speciated mercury emissions at the stack, speciated mercury concentrations at the scrubber inlet, and fuel mercury, chlorine, moisture, sulfur, ash, and heating value.

#### Test Unit

The test unit is Navajo 3. This unit is operated by Salt River Project (SRP), and is located in Page, Arizona. The unit was selected by the EPA as part of the following category:

- Fuel type: subbituminous
- SO<sub>2</sub> control type: wet scrubber
- Particulate control type: hot side electrostatic precipitator

The unit is rated at 750 MW net. Navajo 3 is a tangentially-fired Combustion Engineering boiler, with no NO<sub>x</sub> controls. It fires subbituminous coal. SO<sub>2</sub> emissions are controlled by a wet limestone scrubber with two absorber modules. There is no scrubber bypass; all of the flue gas passes through the scrubbers.

#### Test Measurements

The program included the following tests, with triplicate sets of measurements performed simultaneously at each test location:

- Particulate, oxidized, and elemental mercury emissions at the stack per the Ontario Hydro mercury speciation method.
- Particulate, oxidized, and elemental mercury concentrations at the inlet of Scrubber B, one of two scrubbers on the unit. This location, referred to as the “inlet”, is downstream of the hot side electrostatic precipitators and upstream of the wet scrubber.
- Mercury and chlorine content of representative coal samples collected from the coal feeders.
- Coal moisture, sulfur, ash, and heating content.

## Responsible Organizations

Responsible organizations for this project are:

- Test site operator: Salt River Project
- Program sponsor: Electric Power Research Institute (EPRI)
- Sampling team: Fossil Energy Research Corp. under contract to EPRI, with Delta Air Quality Services as a major subcontractor
- Sample analysis: Philip Analytical Services (flue gas mercury, coal chlorine), Commercial Testing and Engineering (coal HHV, S, ash, moisture), Frontier Geosciences (coal mercury), University of North Dakota Energy and Environmental Research Center (QA analyses on splits of flue gas samples)

## Dates of Test

The test program was conducted on October 25-26, 1999. Daily activities included:

- October 25: set up and conducted Run 1; conducted stack field blank.
- October 26: conducted Runs 2 and 3; conducted inlet field blank.

## Document Description

This document is the test report for the Navajo Unit 3 mercury ICR testing. It has been prepared in accordance with Emission Measurement Center Guideline Document GD-043, as required in the ICR.

The work described here is based on the Navajo Unit 3 Test Plan (Report No. FERCo R676), the Navajo Unit 3 Quality Assurance Plan (Report No. FERCo R699), and the Navajo Unit 3 Test Plan Addendum (Report No. FERCo R724). These reports are available from SRP, the EPA or FERCo.

The Test Plan Addendum was prepared in response to initial EPA review of the Test Plan. The Test Plan Addendum was approved by Mr. William Grimley of the EPA. The QA Plan was approved by Ms. Lara Autry of the EPA prior to testing. EPA comments on the draft QA Plan were incorporated into the final version of the QA Plan.

## 1.2 Key Personnel

Table 1-1 lists the test program organization and key individuals with responsibilities, phone numbers, and e-mail addresses. A program organizational chart is shown in Figure 1-1.

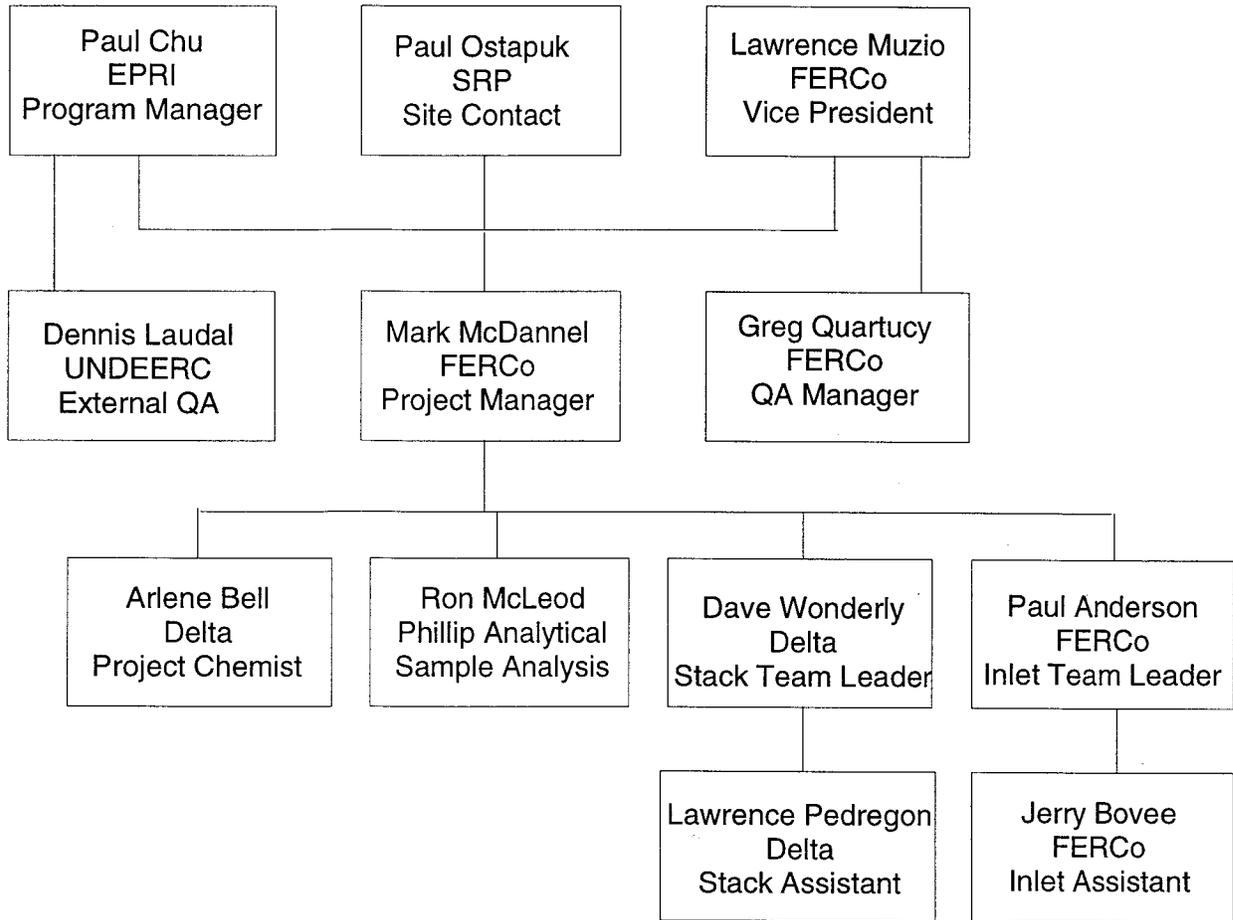
The program was jointly funded by SRP and EPRI. FERCo was under contract to EPRI. The Project Quality Assurance Officer was Greg Quartucy of FERCo, who reported directly to Larry Muzio, FERCo's Vice President. External QA activities were performed by Dennis Laudal of UNDEERC. Mr. Laudal reported directly to Paul Chu of EPRI. Both UNDEERC and FERCo are contractors to EPRI. The reporting function from Mr. Laudal to Mr. Chu is considered to be external to FERCo's project.

Mr. Ostapuk, Mr. McDannel, and Ms. Bell were all on-site for the testing.

Testing was observed by two USEPA contractors. Ms. Abra Bennett of Battelle observed process operation and coal sampling, and Mr. Tony Underwood of ETS (under subcontract to Battelle) observed sampling and sample recovery.

**Table 1-1. Test Program Organization and Responsibilities**

Organization	Individual	Responsibility	Reports To	Phone Number	Fax Number	E-mail Address
Project Management and Oversight						
EPRJ	Paul Chu	EPRJ Project Manager	N/A	(650) 855-2812	(650) 855-2619	pchu@epri.com
FERCo	Lawrence Muzio	Vice President	N/A	(949) 859-4466	(949) 859-7916	lmuzio@ferco.com
FERCo	Greg Quartucy	QA Manager	Lawrence Muzio	(949) 859-4466	(949) 859-7916	gquartucy@ferco.com
Host Utility						
Salt River Project	Paul Ostapuk	Program Coordinator and Site Contact	Bob Candelaria	(520) 645-6577	(520) 645-6234	pmostapu@srpnet.com
FERCo/Delta Sampling Team						
FERCo	Mark McDannel	Program Manager	Paul Chu	(949) 859-4466	(949) 859-7916	mmcdannel@ferco.com
Delta	Arlene Bell	Project Chemist	Mark McDannel	(714) 279-6777	(714) 279-6781	deltaaqs@aol.com
Philip Environmental	Ron McLeod	Sample Analyses	Mark McDannel	(905) 332-8788	(905) 332-9169	rmcleod@philipinc.com
External QA/QC						
UNDEERC	Dennis Laudal	External QA/QC	Paul Chu	(701) 777-5138	(701) 777-5181	dlaudal@eerc.und.nodak.edu



**Figure 1-1. Project Organization Chart**



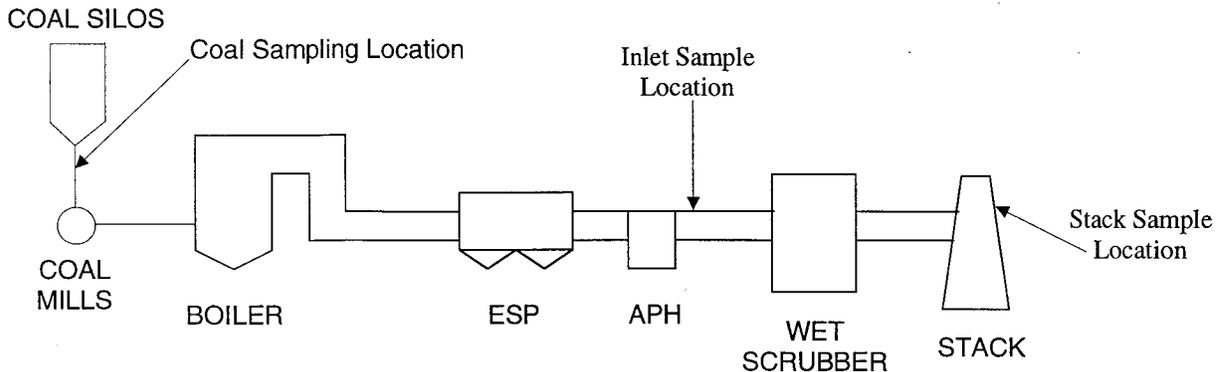
# 2

## PLANT AND SAMPLING LOCATION DESCRIPTIONS

---

### 2.1 Process and Control Equipment Description and Operation

Navajo 3 is a tangentially-fired Combustion Engineering boiler rated at 750 MW net. Figure 2-1 shows a schematic of the boiler and pollution control equipment, including sample points.



**Figure 2-1. Navajo Unit 3 Schematic**

Key unit parameters include:

- Unit capacity: 750 MW net
- Boiler type: Combustion Engineering, tangentially-fired, balanced draft
- Fuel type: subbituminous
- SO<sub>2</sub> control: wet scrubber, two modules, limestone forced oxidation system, 97-99% removal.
- Particulate control: hot side ESP, 99.1-99.5% removal.
- NO<sub>x</sub> control: none. Boiler is operated to meet 0.45 lb/MMBtu annual limit; typical emissions are 0.38 lb/MMBtu.

Fuel samples were collected at the coal feeders ahead of the boiler, inlet samples were collected at the inlet to one of two wet scrubbers, and outlet samples were collected at the stack.

The sample gas at the inlet is approximately 310°F. At the stack, the gas temperature is approximately 120°F and is saturated with moisture.

Unit operation during testing was at or near nominal full load, at steady state operation. Coal type, boiler operation, and control device operation were all within normal operating ranges.

Table 2-1 presents a summary of unit operation during the tests. Additional detailed unit data is included in Appendix G.

**Table 2-1. Summary of Navajo Unit 3 Operation**

	Run 1	Run 2	Run 3
Date, 1999	25-Oct	26-Oct	26-Oct
Start time	1500	0755	1130
Stop time	1727	1015	1353
Unit load, MW gross	796	808	808
Coal mills out of service	B,E*	E	E
Coal flow, klb/hr	690	696	700
Boiler O <sub>2</sub> , A side/B side	3.4/3.4	3.4/3.4	3.3/3.4
CEMS data			
CO <sub>2</sub> , % wet	11.9	12.0	11.9
SO <sub>2</sub> , lb/MMBtu	0.041	0.043	0.043
NO <sub>x</sub> , lb/MMBtu	0.35	0.38	0.36
Stack gas flow, kwscfh	120	122	122
Stack gas temperature, F	114	112	115
ESP data			
Power level, kW	1,287	1,523	1,526
Sections in service	48	48	48
Sections out of service	0	0	0
Scrubber data			
Slurry feed density, % solids	24.8	25.8	25.8
Limestone feed, klb/hr			
A scrubber	29.5	35.4	33.7
B scrubber	34.1	30.2	31.1
Pressure drop			
A scrubber	2.4	2.3	2.4
B scrubber	2.5	2.5	2.5
pH			
A scrubber	5.6	5.6	5.6
B scrubber	5.6	5.6	5.6
* Note- Mill B placed in service half way through Run 1.			

## 2.2 Flue Gas Sampling Locations

Table 2-2 presents a summary of key inlet and stack sample location parameters. Individual discussions of the two locations are presented below.

### ***Inlet Locations***

The inlet samples were collected at the inlet of one of the two absorber modules on Navajo 3. A drawing of this location is shown in Figure 4-2. Flue gas from the boiler exits through two air preheaters, two induced draft fans per absorber and then to the absorber modules. The sample ports are located in the duct between the ID fan outlet and the scrubber module inlet.

Because of the number and location of the inlet ducts, it was not feasible to sample both ducts simultaneously with the stack sample without adding an additional sample team. Because mercury speciation is not expected to be stratified, and because the cost of an additional crew is not considered to be consistent with the intent of the ICR, inlet sampling was conducted in one duct. This approach is consistent with ICR guidelines, and should adequately characterize mercury speciation at the inlet.

Although the duct is 22 feet deep, a 16-foot long sample probe was used. This approach is consistent with information posted on the EPA/RTI web site under “Frequently Asked Questions” for stack sampling. The top four points from an EPA Method 1 grid of six points per port were used.

The sample traverse scheme for Navajo Unit 3 inlet was:

6 ports x 4 points/port x 5 minutes/point = 120 minutes.

This location does not meet the requirements of EPA Method 1. A cyclonic flow check was done before testing. The average yaw angle was less than 5 degrees, with all points having an angle of 5 degrees or less.

### ***Stack Location***

The stack samples were collected at the existing stack sample ports. A schematic and cross section of the stack location is shown in Figure 2-3.

This location meets the requirements of EPA Method 1. A cyclonic flow check was done before testing. The average flow angle was 4 degrees, with no angles higher than 8 degrees.

The sample traverse scheme for the Navajo 1 stack was:

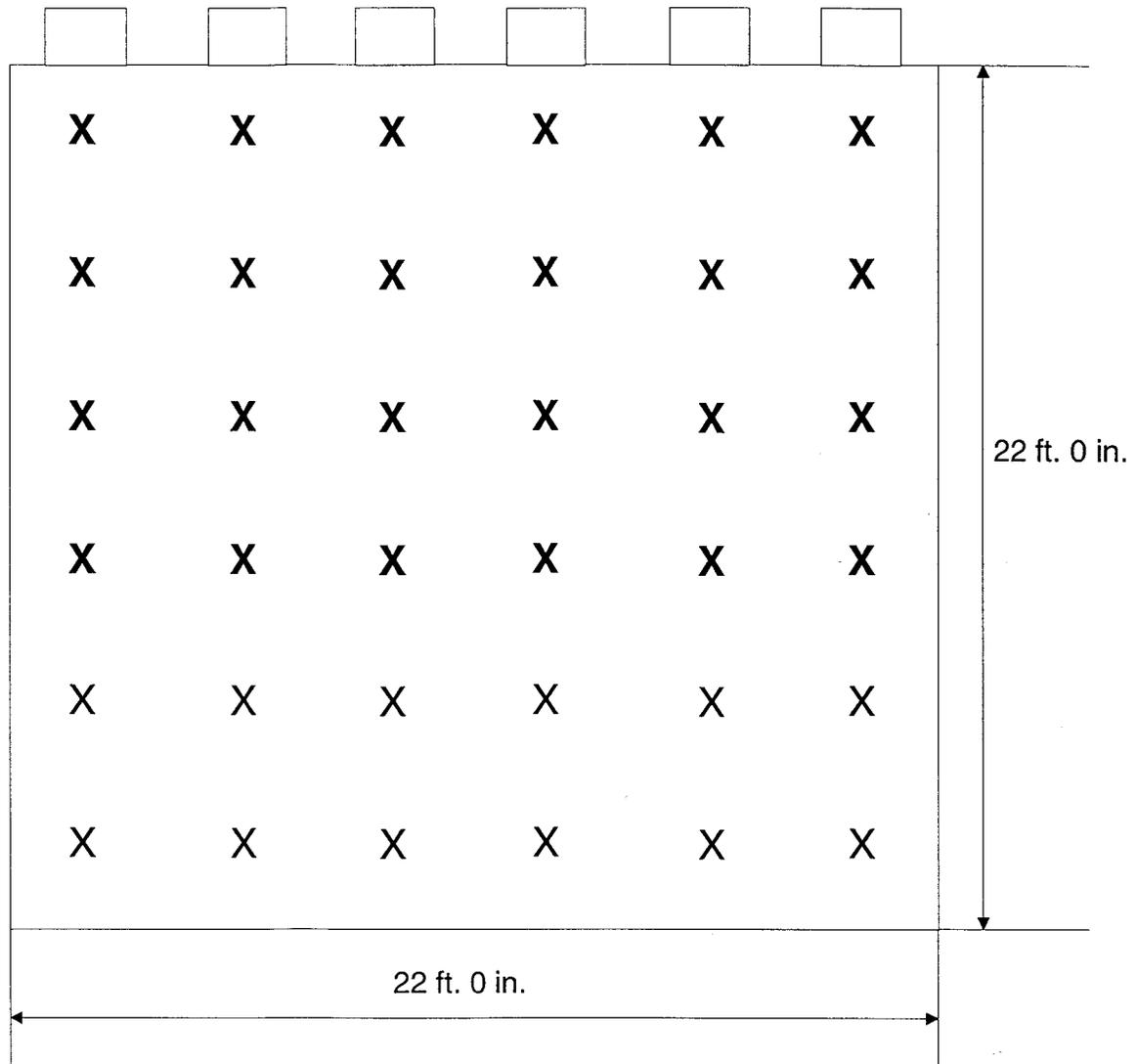
4 ports x 3 points/port x 10 minutes/point = 120 minutes.

**Table 2-2. Navajo Unit 3 Sampling Location Descriptions**

	<b>Inlet</b>	<b>Stack</b>
Description	Module B inlet	Stack platform
Elevation	Approximately 100'	496'
Physical access	Elevator, stairs	Elevator
Side or top access	Top	Side
Round or rectangular	Rectangular	Round
Port length (outside of port to inner stack wall)	18"	6"
Number/type of ports	Six 4-inch w/ flanges	Four 6-inch w/ flanges
Inside dimensions	22' 0" deep x 22' 0" wide Equivalent diameter 22.0'	34' 9" ID
Nearest upstream disturbance		
Disturbance	Bend in duct	Duct entrance
Distance, ft	25'	300'
Distance, diameters	1.1	>8
Nearest downstream disturbance		
Disturbance	Scrubber inlet	Stack exit
Distance, ft	18'	280'
Distance, diameters	0.8	8

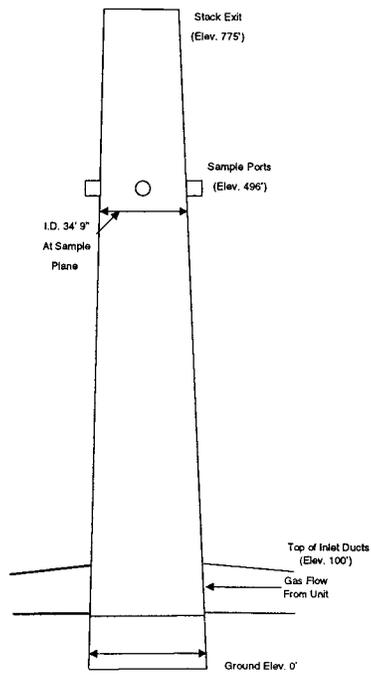
### **2.3 Coal Sampling Location**

Coal samples were collected from the silo just above the coal feeders to each individual mill. One one-pint scoop was collected from each operating mill during the first and last hour of each test run, and all samples were composited. The estimated lag time for coal from the sample location to the boiler is a few minutes. Samples were collected by Mark McDannel of FERCo.

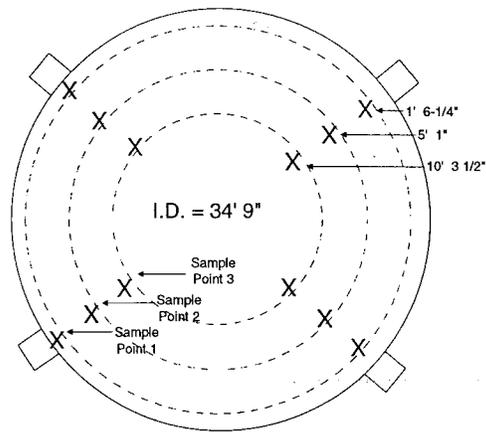


Note - only the top four points were sampled. See text for discussion.

**Figure 2-2. Navajo Unit 3 Inlet Location**



a. Diagram of Stack



b. Cross-Section of Sample

Figure 2-3. Navajo Unit 3 Stack Sample Location

# 3

## SUMMARY AND DISCUSSION OF TEST RESULTS

---

### 3.1 Objectives and Test Matrix

#### *Objectives*

The objective of the program is to collect the information and measurements required by the EPA Mercury ICR. Specific objectives are:

- Quantify speciated mercury concentrations at the stack.
- Quantify speciated mercury concentrations in the flue gas at the scrubber inlet.
- Quantify fuel mercury and chlorine content during the stack and inlet tests.
- Provide the above information for use in developing boiler-, fuel-, and control device-specific mercury emission factors.

#### *Test Matrix*

The test matrix is presented in Table 3-1, and actual test times are shown in Table 3-2. Table 3-1 includes a list of test methods used. In addition to speciated mercury, the flue gas measurements included moisture, stack gas flow, and O<sub>2</sub>/CO<sub>2</sub>.

### 3.2 Field Test Changes and Problems

#### *Change of Analytical Method and Laboratory for Mercury in Coal*

The test plan called for coal mercury analysis to be performed by Philip Analytical, using EPA SW 846. However, the results for two of the three samples were not detected less than 0.04 ppm, and the third sample was measured at 0.04 ppm.

In an effort to achieve lower detection limits and more precisely quantify mercury in the coal, splits of the samples were analyzed by Frontier Geosciences. The samples were digested by cold aqua regia (modified EPA 7371) and analyzed by cold vapor atomic fluorescence (modified EPA 1631). These methods provided detectable levels of mercury in the coal for all three samples, and are used as the reported mercury values.

**Table 3-1. Test Matrix for Mercury ICR Tests at Navajo 3**

Sampling Location	No. of Runs	Species Measured	Sampling Method	Sample Run Time	Analytical Method	Analytical Laboratory
Outlet	3	Speciated Hg	Ontario Hydro	120 min	Ontario Hydro	Philip Services
Outlet	3	Moisture	EPA 4	Concurrent	Gravimetric, compared with saturation value	FERCo
Outlet	3	Gas Flow	EPA 1/2	Concurrent	Pitot Traverse	FERCo
Outlet	3	O <sub>2</sub>	Batch Sample	Concurrent	Portable O <sub>2</sub>	FERCo
Outlet	3	CO <sub>2</sub>	N/A	Concurrent	Stoichiometric calculation	FERCo
Inlet	3	Speciated Hg	Ontario Hydro	120 min	Ontario Hydro	Philip Services
Inlet	3	Moisture	EPA 4	Concurrent	Gravimetric	FERCo
Inlet	3	Gas Flow	EPA 1/2	Concurrent	Pitot Traverse	FERCo
Inlet	3	O <sub>2</sub>	Batch Sample	Concurrent	Portable O <sub>2</sub>	FERCo
Inlet	3	CO <sub>2</sub>	N/A	Concurrent	Stoichiometric calculation	FERCo
Coal Feeders	3	Cl in coal	Modified ASTM D2234	1 grab sample per coal feeder per run	EPA SW 846: 5050/9056 (Cl)	Philip
Coal Feeders	3	HHV, Ash, S, Moisture	Modified ASTM D2234	1 grab sample per mill per run	ASTM D514290	CTE
Coal Feeders	3	Hg in coal	Modified ASTM D2234	1 grab sample per mill per run	Modified EPA 7371/1631	Frontier Geosciences

**Table 3-2. Navajo 3 Sampling Times**

	Run 1	Run 2	Run 3
Date, 1999	25-Oct	26-Oct	26-Oct
<b>Inlet Tests</b>			
Start time	1507	0755	1137
Stop time	1726	1015	1353
Total sample time, min	120	120	120
<b>Outlet Tests</b>			
Start time	1500	0755	1130
Stop time	1727	1015	1350
Total sample time, min	120	120	120
<b>Notes:</b>			
1. Gas flow, moisture, O <sub>2</sub> were concurrent with mercury tests.			
2. Coal samples were collected during the first and last hour of each run.			

### 3.3 Presentation of Results

The test results are presented in the following tables and figure:

- Table 3-3. Sample gas conditions.
- Table 3-4. Mercury concentration and speciation results.
- Table 3-5. Mercury removal across scrubber by species.
- Figure 3-1. Mercury speciation across scrubber.

Results are calculated as  $\mu\text{g}/\text{scm}$  (at a reference temperature of 68°F), and normalized for dilution by converting to a  $\text{lb}/10^{12}$  Btu basis. This method allows direct comparison of inlet and stack results without incorporating uncertainties involved in gas flow measurement.

Major observations that can be made from the results are:

1. Mercury is primarily in the elemental phase at both the inlet (73% of total mercury) and at the stack (99.2% of total mercury). Oxidized mercury was 27% of the total at the inlet and not detected at the stack. There was no measurable particulate mercury at the inlet, and low levels of particulate mercury (0.8% of total mercury) at the stack. However, as described in Section 5.2, the presence of particulate mercury at the stack is attributed to sample contamination in the laboratory.

**Table 3-3. Navajo Unit 3 Sample Gas Conditions**

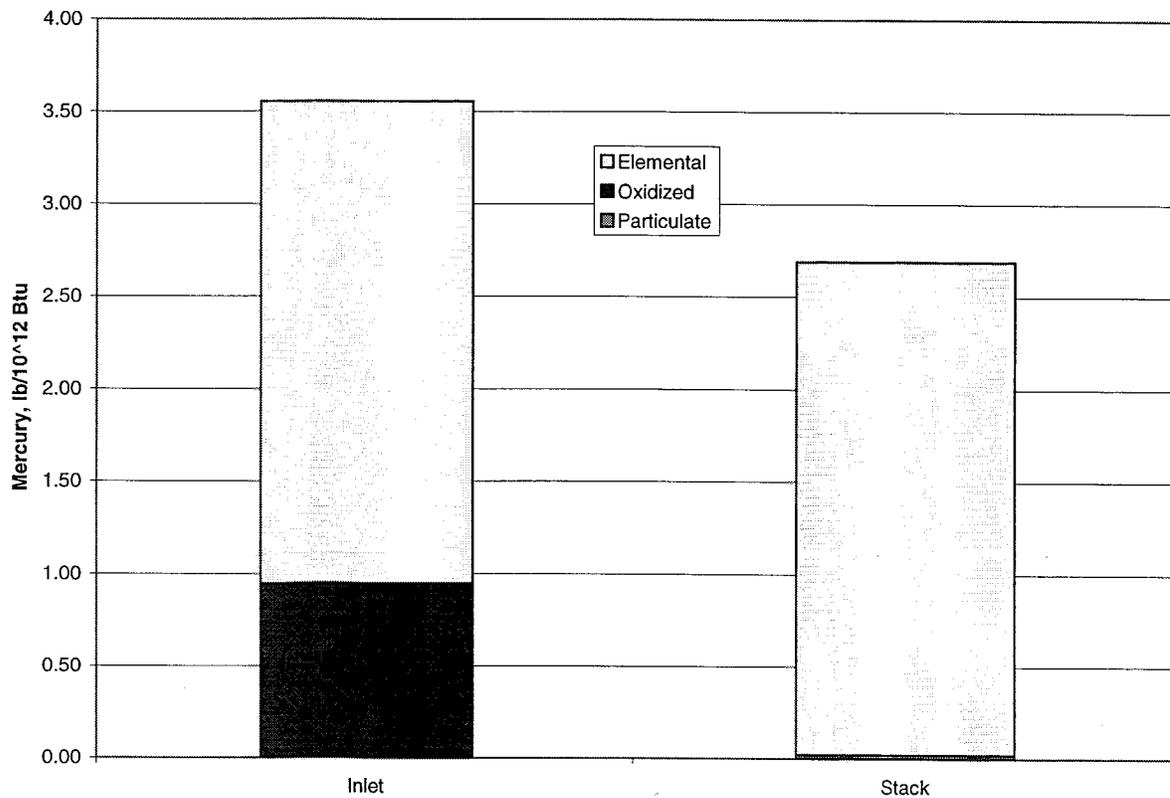
	<b>Run 1</b>	<b>Run 2</b>	<b>Run 3</b>	<b>Average</b>
<b>Test Date</b>	25-Oct	26-Oct	26-Oct	
<b>Module B Inlet Gas Properties</b>				
Temperature, F	314	305	313	310
Gas flow, dscfm (dilution corrected from stack)	1,798,401	1,768,608	1,811,563	1,792,752
Comparison gas flows:				
Pitot traverse x 2	1,809,007	1,788,113	1,833,776	1,810,299
Calculated from fuel input and O <sub>2</sub>	1,811,264	1,760,805	1,803,632	1,791,733
O <sub>2</sub> , %	6.23	5.88	6.00	6.04
CO <sub>2</sub> , %	10.09	10.30	10.12	10.17
H <sub>2</sub> O, %	8.89	8.53	8.76	8.73
<b>Stack</b>				
Temperature, F	120	120	121	121
Gas flow, dscfm from pitot traverse	1,765,899	1,761,571	1,793,508	1,773,659
Comparison gas flows:				
CEMS	1,724,891	1,755,362	1,752,589	1,744,281
Calculated from fuel input and O <sub>2</sub>	1,778,530	1,753,799	1,785,655	1,772,650
O <sub>2</sub> , %	5.96	5.82	5.85	5.88
CO <sub>2</sub> , %	10.28	10.34	10.22	10.28
H <sub>2</sub> O, % from sample train	14.42	14.57	15.07	14.69
H <sub>2</sub> O, % at saturation	13.80	13.80	14.10	13.90

**Table 3-4. Navajo Unit 3 Mercury Speciation Results**

	Run 1	Run 2	Run 3	Average
<b>Test Date</b>	25-Oct	26-Oct	26-Oct	
<b>Inlet Mercury Speciation</b>				
Particulate mercury				
ug/dscm	ND<0.05	ND<0.05	ND<0.04	ND<0.05
lb/10 <sup>12</sup> Btu	ND<0.04	ND<0.04	ND<0.04	ND<0.04
% of total Hg	0%	0%	0%	0%
Oxidized mercury				
ug/dscm	2.39	0.38	0.52	1.10
lb/10 <sup>12</sup> Btu	2.08	0.32	0.45	0.95
% of total Hg	45%	10%	15%	27%
Elemental mercury				
ug/dscm	2.91	3.30	2.92	3.04
lb/10 <sup>12</sup> Btu	2.52	2.80	2.50	2.61
% of total Hg	55%	90%	85%	73%
Total mercury				
ug/dscm	5.30	3.68	3.45	4.14
lb/10 <sup>12</sup> Btu	4.60	3.12	2.95	3.56
<b>Stack Mercury Speciation</b>				
Particulate mercury				
ug/dscm	0.045	0.019	0.011	0.025
lb/10 <sup>12</sup> Btu	0.039	0.016	0.009	0.021
% of total Hg	1.5%	0.6%	0.3%	0.8%
Oxidized mercury				
ug/dscm	ND<0.06	ND<0.06	ND<0.06	ND<0.06
lb/10 <sup>12</sup> Btu	ND<0.05	ND<0.05	ND<0.05	ND<0.05
% of total Hg	0%	0%	0%	0%
Elemental mercury				
ug/dscm	3.07	3.20	3.17	3.15
lb/10 <sup>12</sup> Btu	2.62	2.70	2.68	2.67
% of total Hg	98.5%	99.4%	99.7%	99.2%
Total mercury				
ug/dscm	3.12	3.22	3.18	3.17
lb/10 <sup>12</sup> Btu	2.66	2.72	2.69	2.69
<b>Coal Analysis</b>				
Mercury, ppm dry	0.040	0.024	0.027	0.030
Mercury, lb/10 <sup>12</sup> Btu	3.1	1.9	2.1	2.4
Chlorine, ppm dry	200	200	ND<100	150
Moisture, %	11.53	12.13	12.35	12.0
Sulfur, % dry	0.53	0.57	0.56	0.55
Ash, % dry	7.8	7.74	7.11	7.55
HHV, Btu/lb as fired	11,299	11,159	11,263	11,240
Coal flow, lb/hr as fired	690,300	695,700	700,400	695,467
<b>Total Mercury Mass Rates</b>				
lb/hr input in coal	0.024	0.015	0.017	0.019
lb/hr at scrubber inlet	0.036	0.024	0.023	0.028
lb/hr at stack	0.021	0.021	0.021	0.021

**Table 3-5. Navajo Unit 3 Mercury Removal Efficiency**

	<b>Run 1</b>	<b>Run 2</b>	<b>Run 3</b>	<b>Average</b>
Date, 1999	25-Oct	26-Oct	26-Oct	
<b>Total mercury</b>				
Inlet, lb/10 <sup>12</sup> Btu	4.60	3.12	2.95	3.56
Stack, lb/10 <sup>12</sup> Btu	2.66	2.72	2.69	2.69
Removal efficiency, %	42%	13%	9%	24%
<b>Particulate mercury</b>				
Inlet, lb/10 <sup>12</sup> Btu	ND<0.04	ND<0.04	ND<0.04	ND<0.04
Stack, lb/10 <sup>12</sup> Btu	0.04	0.02	0.01	0.02
Removal efficiency, %	N/A	N/A	N/A	N/A
<b>Oxidized mercury</b>				
Inlet, lb/10 <sup>12</sup> Btu	2.08	0.32	0.45	0.95
Stack, lb/10 <sup>12</sup> Btu	ND<0.05	ND<0.05	ND<0.05	ND<0.05
Removal efficiency, %	>98%	>84%	>89%	>95%
<b>Elemental mercury</b>				
Inlet, lb/10 <sup>12</sup> Btu	2.52	2.80	2.50	2.61
Stack, lb/10 <sup>12</sup> Btu	2.62	2.70	2.68	2.67
Removal efficiency, %	-4%	3%	-7%	-2%



**Figure 3-1. Mercury Speciation Across Navajo Unit 3 Scrubber**

2. Mercury levels in the coal averaged 2.4 lb/10<sup>12</sup> Btu, or 0.030 ppm. This concentration is 32% lower than the 3.5 lb/10<sup>12</sup> Btu measured at the inlet.
3. Oxidized mercury was removed to below detectable levels across the scrubber.
4. Elemental mercury was almost equal at the inlet and the stack.



# 4

## SAMPLING AND ANALYTICAL PROCEDURES

---

### 4.1 Test Methods

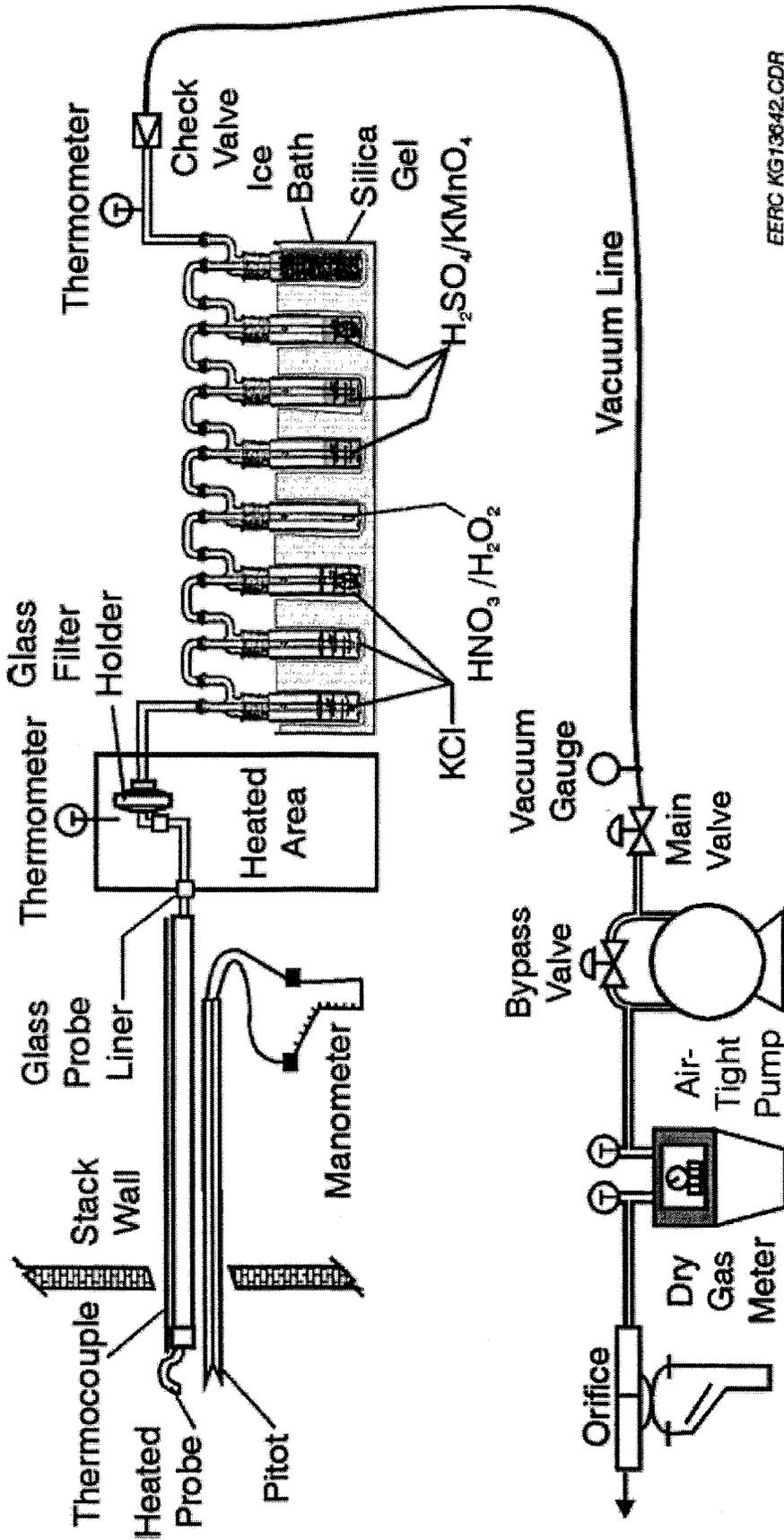
This section contains a summary of the sampling and analytical procedures used to conduct the mercury speciation required in EPA's ICR titled, "Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)" dated April 8, 1999. The full text of the method was presented as Appendix A of the Test Plan.

Subsequent to submittal of the Test Plan, additional drafts of the Ontario Hydro Method were published. Wherever possible, the new features of these drafts were incorporated into the program.

Speciated mercury samples were collected in three test runs at the inlet and outlet of the control device. The inlet and outlet sampling were concurrent. A field blank was collected at each test location on October 19. The field blank consisted of assembling a sample train, transporting it to the sample location, conducting a leak check, letting the train sit for two to three hours, and then recovering the train as if it were a sample.

EPA methods to determine flue gas flow rate were used. EPA Reference Method 5 and 17 requirements for isokinetic sampling were followed. Each impinger was weighed before and after sampling to determine flue gas moisture content.

Figure 4-1 presents a schematic of the mercury speciation sample train, Table 4-1 presents a list of sample train components for the Method 17 configuration, and Table 4-2 presents a list of sample train components for the Method 5 configuration. The sampling train was set up with in-stack filtration (EPA Method 17 configuration) for the inlet location and external heated filtration (EPA Method 5 configuration) for the stack location.



EERC KG13642.CDR

Figure 4-1. Schematic of the Mercury Speciation Sample Train (Method 5 option as used at the stack is shown; Method 17 in-stack filtration was used for the Inlet on Navajo 3)

**Table 4-1. Sample Train Components - Method 17 Configuration**

Component	Details
Nozzle	Glass.
Filter	Quartz thimble, in glass thimble holder.
Probe	Teflon, heated to minimum 120 C.
Connector line	Heated teflon line used to connect from probe to impingers. Heated to minimum 120 C.
Impingers 1, 2	1 mol/l KCl solution; modified Smith Greenburg (SG) impinger.
Impinger 3	1 mol/l KCl solution; standard Smith Greenburg impinger.
Impinger 4	5% nitric acid/10% hydrogen peroxide; modified SG impinger.
Impingers 5, 6	4% potassium permanganate/10% sulfuric acid; modified SG impinger.
Impinger 7	4% potassium permanganate/10% sulfuric acid; standard SG impinger.
Impinger 8	Silica gel; modified Smith Greenburg Impinger

**Table 4-2. Sample Train Components - Method 5 Configuration**

Component	Details
Nozzle	Glass
Probe	Glass, heated to minimum 120 C.
Filter	Quartz, in glass holder, heated to minimum 120 C.
Filter support	Teflon.
Connector line	Heated teflon line used to connect from filter outlet to impingers. Heated to minimum 120 C.
Impingers 1, 2	1 mol/l KCl solution; modified Smith Greenburg (SG) impinger.
Impinger 3	1 mol/l KCl solution; standard Smith Greenburg impinger.
Impinger 4	5% nitric acid/10% hydrogen peroxide; modified SG impinger.
Impingers 5, 6	4% potassium permanganate/10% sulfuric acid; modified SG impinger.
Impinger 7	4% potassium permanganate/10% sulfuric acid; standard SG impinger.
Impinger 8	Silica gel; modified Smith Greenburg Impinger

Sample was withdrawn from the flue gas stream isokinetically through the filtration system, which was followed by a series of impingers in an ice bath. Particulate-bound mercury was collected on the front half and filter; oxidized mercury was collected in impingers containing 1 N potassium chloride solution; and elemental mercury was collected in one impinger containing a 5% nitric acid and 10% peroxide solution, and in three impingers containing a solution of 10% sulfuric acid and 4% potassium permanganate. An impinger containing silica gel collected any remaining moisture.

The filter media was quartz fiber filters. At both the inlet and outlet quartz thimbles in a glass holders were used. At the inlet the probe included a heated teflon line; at the stack a heated glass probe was used. An additional heated teflon line was used to transport the flue gas from the end of the probe to the inlet of the first impinger. Both the probe and the line were heated to maintain a minimum gas temperature of 248°F.

A two hour sampling time was used at the inlet and stack, with a target sample volume of 1 to 2.5 standard cubic meters.

### ***Sample Recovery***

Figure 4-2 is a schematic of the sample recovery procedure for the impinger train. The samples were recovered into precleaned glass bottles with vented teflon lined lids for shipment to the laboratory. The following sample fractions were recovered (specific rinse solutions are contained in the method):

1. The sample filter;
2. The front half rinse (includes all surfaces upstream of the filter)
3. Impinger 1 through 3 (KCl impingers) and rinses;
4. Impinger 4 (HNO<sub>3</sub>/H<sub>2</sub>O<sub>2</sub> impinger) and rinses;
5. Impingers 5 through 7 (KMnO<sub>4</sub>/H<sub>2</sub>SO<sub>4</sub> impingers) and rinses;
6. Impinger 8 (silica gel impinger). Note this sample is weighed for moisture determination and is not included in the mercury analysis.

### ***Sample Digestion and Analysis***

The sample fractions were digested and analyzed as specified in the method and summarized below:

#### **Ash Sample (Containers 1 and 2)**

If the particulate catch is greater than 1 gram (as would be the case at most particulate control device inlet locations), an aliquot of the particulate collected on the filter is digested by microwave digestion.

### KCl Impingers (Container 3)

The impingers are digested using  $\text{H}_2\text{SO}_4$ ,  $\text{HNO}_3$ , and  $\text{KMnO}_4$  solutions as specified in the method.

### $\text{KNO}_3\text{-H}_2\text{O}_2$ Impinger (Container 4)

The impinger solution is digested using  $\text{HCl}$  and  $\text{KMnO}_4$  solutions as specified in the method.

### $\text{H}_2\text{SO}_4\text{-KMnO}_4$ Impingers (Container 5)

The impinger solution is digested using hydroxylamine sulfate as specified in the method.

### Analysis

Each digested fraction is analyzed in duplicate for total mercury by cold vapor atomic absorption (CVAAS). CVAAS is a method based on the absorption of radiation at 253.7 nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrometer. Absorbency is measured as a function of mercury concentration. A soda-lime trap and a magnesium perchlorate trap must be used to precondition the gas before it enters the absorption cell.

1. Rinse filter holder and connector with 0.1 N HNO<sub>3</sub>.
2. Add H<sub>2</sub>SO<sub>4</sub>/KMnO<sub>4</sub> to each impinger bottle until purple color remains.
3. Rinse with 0.1 N HNO<sub>3</sub>.
4. Rinse with 8N HCl if brown residue remains.
5. Final rinse with 0.1 N HNO<sub>3</sub>.

**Rinse Bottles Sparingly with**

- 0.1N HNO<sub>3</sub>
- 8N HCl
- 0.1N HNO<sub>3</sub>

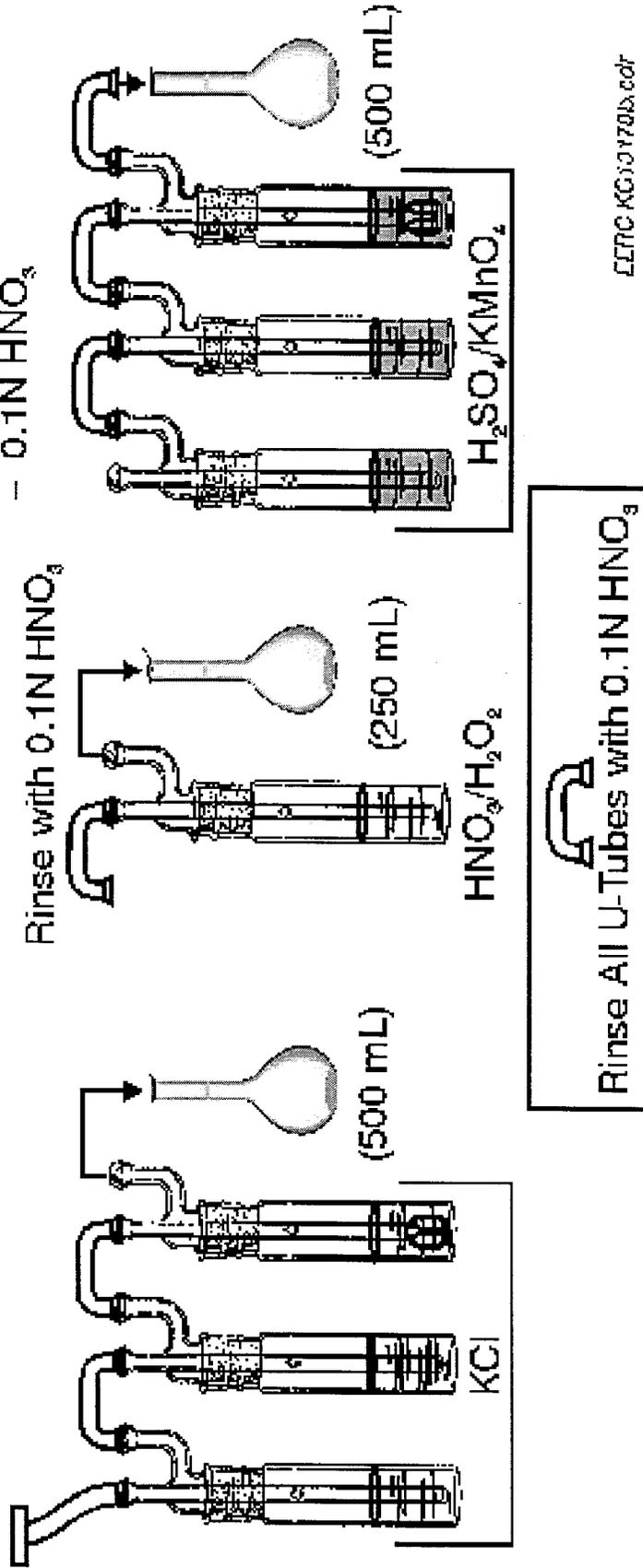


Figure 4-2. Sample Recovery Scheme for the Mercury Sampling Train

## **Handling of Non Detects**

This section addresses how data was handled in cases where no mercury was detected in an analytical fraction.

*A single analytical fraction representing a subset of a mercury species is not detected.* When more than one sample component is analyzed to determine a mercury species and one fraction is not detected, it is counted as zero. This occurred on all samples for elemental mercury, which is the sum of the mercury collected in the HNO<sub>3</sub>/H<sub>2</sub>O<sub>2</sub> impinger and the H<sub>2</sub>SO<sub>4</sub>/KMnO<sub>4</sub> impingers. For example, on Test 3-Stack the H<sub>2</sub>O<sub>2</sub> fraction was ND<0.25 µg and the KMnO<sub>4</sub> fraction was 5.7 µg. Elemental mercury was reported as 5.7 µg.

*No mercury is detected for a species on all three test runs.* When all three test runs show no detectable levels of mercury for a mercury species, that mercury species is reported as not detected at less than highest detection limit. For example, the results for the three inlet particulate mercury runs were all ND<0.04 lb/10<sup>12</sup> Btu. The average is reported as ND<0.04 lb/10<sup>12</sup> Btu.

In summing up individual species to determine total mercury, a value of zero is used for non-detected species. For example, the average inlet mercury values (in lb/10<sup>12</sup> Btu) were ND<0.04 for particulate mercury, 0.95 for oxidized mercury, and 2.61 for elemental mercury. Total mercury is reported as 0.95 + 2.61, or 3.56.

In calculating the percentage of mercury in each two species, a value of zero is used for the non-detected species. For the example listed in the preceding paragraph, the results are reported as 0% particulate mercury, 24% oxidized mercury, and 76% elemental mercury.

## **Auxiliary Flue Gas Measurements**

Auxiliary flue gas measurements performed were flue gas flow rate per EPA Methods 1 and 2 (pitot traverse), O<sub>2</sub> by portable O<sub>2</sub> analyzer (as described below), and H<sub>2</sub>O by EPA Method 4 (condensation/gravimetric analysis). These measurements were collected as integral parts of all mercury speciation test runs at both the inlet and stack locations.

### **Stack Moisture**

Measured moisture values at the stack were compared with saturation moistures for each test, and found to be 0.4 to 1.0% higher. This excess is possibly due to collection of liquid water droplets. In accordance with EPA guidelines, saturation moisture was used for calculation of gas density, isokinetic sample rates, and standard duct gas flow rates.

### **Inlet Flow Determination**

There are typically be higher uncertainties in gas flow measurements at the inlet location relative to the stack location since the inlet location does not meet Method 1. To report total inlet gas

flows and to calculate mercury levels in terms of lb/hr at the inlet, the stack flow, corrected for dilution using O<sub>2</sub> measurements, was used to calculate total inlet gas flow values. The inlet pitot traverses, multiplied by a factor of two because one of two ducts was sampled, are presented for comparison purposes.

### Stack Flow Determination

Stack flow was measured by the pitot traverse conducted as part of the mercury test.

### Comparative Flow Rate Calculations

As a QA indicator, additional flow rate determinations were done. At both locations, exhaust gas flow was calculated based on boiler fuel input and oxygen (F<sub>d</sub>) F factors. The plant CEMS stack flow rate is also presented.

### Alternate Methodology for O<sub>2</sub>/CO<sub>2</sub> Determination

As an alternate to conventional Orsat analysis, the following procedure was used for determination of O<sub>2</sub> and CO<sub>2</sub> content.

O<sub>2</sub> determination. O<sub>2</sub> was measured by a portable O<sub>2</sub> analyzer using an electrochemical cell. The gas sample for the portable analyzer was drawn through a tube inserted in the exit gas of the sample gas meter. This provides direct analysis of the gas sampled for the mercury test. Care was taken that the O<sub>2</sub> sample tube was not inserted so far that it interfered with the meter orifice pressure differential reading. Calibration procedures for the portable analyzer included:

1. At the beginning of the test day, the instrument was calibrated on ambient air. As-found readings were then taken using zero gas and an EPA Protocol 1 mid scale O<sub>2</sub> calibration gas (40 to 60% of the span used to collect readings). If these as found readings were within 2% of span, the data was acceptable. If the readings were outside of these ranges, the O<sub>2</sub> cell was replaced, the instrument was repaired, or an alternate instrument was used.
2. During testing, the calibration of the instrument was checked on ambient air every three or four sample points. If the as-read value on air had drifted more than 0.2% O<sub>2</sub> (0.8% of scale), the instrument was recalibrated.
3. At the end of the test day, the calibration error step described in Step 1 above was repeated.

CO<sub>2</sub> determination. CO<sub>2</sub> is used only for molecular weight determination. At the stack, CO<sub>2</sub> readings were taken from the plant CEMS.

At the inlet, the CO<sub>2</sub> was calculated by stoichiometric calculations, using standard F factors.

### ***Determination of Scrubber Efficiency***

#### Scrubber Efficiency Determination

Scrubber removal efficiency was calculated according to Equation 1 below:

$$(1) \quad E = 1 - C_{\text{out}}/C_{\text{in}}$$

Where,

E = Scrubber removal efficiency

$C_{\text{out}}$  = Measured concentration at scrubber outlet

$C_{\text{in}}$  = Measured concentration at scrubber inlet

It is important that the inlet and outlet values be corrected for air leakage to provide results on a consistent basis. For this program, the correction was achieved by calculating mercury concentration in units of lb/10<sup>12</sup> Btu.

#### **4.2 Process Data**

Process data was collected on computer logs set up by station personnel. Data collected included key boiler, scrubber, and ESP operating parameters, and all CEMS data.

Prior to and during each test, unit operation was assessed by station personnel to assure that operating conditions were within project target ranges.



# 5

## INTERNAL QA/QC ACTIVITIES

---

### 5.1 QA/QC Problems

There were no sampling related QA/QC problems. All  $\text{KMnO}_4$  impingers were purple at the conclusion of each test.

### 5.2 QA Audits and Data Quality Objectives

QA audit samples were analyzed as specified in the Ontario Hydro Method and listed in Table 5-1. Data quality objectives are listed in Table 5-2. Table 5-3 presents audit results and compares data quality results with data quality objectives. Table 5-4 presents individual mercury fraction mass measurements, along with field blank results.

All data quality objectives were met, with the following exceptions:

1. The range of results for inlet oxidized mercury exceeded the target of +/- 35% from the mean. The results of the three runs were 2.1, 0.32, 0.45  $\text{lb}/10^{12}$  Btu. Unit operation and coal supply were steady for all three runs. All analyses were repeated by both Philip and EERC, and similar results were obtained. Thus the discrepancy is due to either some unknown variable in process operation, or to sample contamination prior to analysis. The Run 1 result may well be an outlier, but because the cause of the discrepancy cannot be determined the Run 1 oxidized mercury result has not been discarded.
2. The range of results for stack particulate mercury exceeded the target of +/- 35% from the mean. The results from the three runs were 0.045, 0.019, and 0.011  $\text{lb}/10^{12}$  Btu. Exceeding the relative deviation target is not considered significant since this level of data scatter is small on an absolute basis and particulate mercury represented only 0.4% of total mercury at the stack.
3. Detected levels of mercury were seen in the reagent and field blanks for the stack particulate fraction. Because these levels were higher than those seen in the sample an investigation was conducted.

A detailed review revealed the source of the mercury to be a contaminated auto-pipette used in sample preparation. When reagent was added to each sample the level of contamination decreased as the pipette cleaned itself. Thus, the mercury levels were successively lower in the order in which samples were prepared.

**Table 5-1. Audit Samples for Ontario Hydro Mercury Speciation**

<b>Audit Sample</b>	<b>Acceptance Criteria and Frequency</b>	<b>Reference</b>
Known reagent spike	Every 10 samples.	Ontario Hydro Section 13.4.1
Certified reference ash	One per program.	Ontario Hydro Section 13.4.1

**Table 5-2. Data Quality Objectives for Flue Gas Mercury Analyses**

<b>Measure</b>	<b>Objective</b>	<b>Approach</b>
Accuracy	$\leq 10\%$ of sample value or $\leq 10x$ instrument detection limit	Reagent blanks-analyze one blank per batch of each reagent
Accuracy	Field blank $\leq 30\%$ of sample value, or no greater than reagent blank; whichever is higher	Collect and analyze one field blank at inlet and one at outlet; criteria evaluated for each mercury species
Accuracy	$\pm 10\%$ of nominal value	One known reagent spike every ten samples
Precision, lab analysis	$\leq 10\%$ RPD	All laboratory samples analyzed in duplicate, every 10th sample analyzed in triplicate
Completeness	$\geq 95\%$	Failed or incomplete tests to be repeated, if possible and practical

The conclusion to be drawn is that the particulate mercury measured at the stack is most likely the result of sample contamination.

- The filter method blank was  $0.067 \mu\text{g}$ , compared to  $\text{ND} < 0.08 \mu\text{g}$  for all of the test filters. This is due to the reagent contamination noted above, and is not considered to be significant.

### 5.3 Comparison Analyses

As an independent Quality Assurance check on the data, splits of the KCl and  $\text{KMnO}_4$  samples were analyzed by the University of North Dakota Energy and Environmental Research Center (EERC). These results, shown in Table 5-5, indicate excellent agreement between the laboratories.

**Table 5-3. Results Evaluation and Verification Checklist**

<b>Measure</b>	<b>Objective</b>	<b>Result</b>
<i>Unit Operation</i>		
Unit operating conditions	No unusual conditions	Steady, normal operation
Air pollution control device operation	No unusual conditions	Steady, normal operation
<i>Sample Train Information</i>		
Trains leak checked before/after each test	<0.02 cfm	All tests passed
Pitot probes leak checked	Zero leakage	All tests passed
Probe, line, and filter temperature maintained	Minimum 120 C	All tests passed
Sample rate isokinetics	90-110%	95-101% at inlet 97-100% at stack
Sample volume	1-2.5 std cubic meters	1.7-1.8 m <sup>3</sup> at inlet 1.7-1.8 m <sup>3</sup> at stack
Post-test color of permanganate impingers	Purple	All tests passed
<i>Results/lab QA</i>		
Flow rate for triplicate runs	All runs w/in 10% of mean (adjusted for load)	All flows w/in 2% of mean at inlet and stack
Stack temperature for triplicate runs	All runs w/in 5% of mean	W/in 1% at inlet and stack
Total mercury for triplicate runs	All runs w/in 35% of mean	W/in 29% at inlet W/in 2% at stack
Particulate mercury	All runs w/in 35% of mean	Not detected at inlet One run 56% below mean and one run 80% above mean at stack.
Oxidized mercury	All runs w/in 35% of mean	One run 119% above mean, one run 71% below mean, and one run 52% below mean at inlet. Not detected at stack.
Elemental mercury	All runs w/in 35% of mean	W/in 7% at inlet W/in 2% at stack
Sample and blank spikes	w/in 10% of value	All tests passed
Field blanks	<30% of measured values	See Table 5-4
Method/reagent blank	<10% of sample	Exceeded on filter samples

**Table 5-4. Navajo 3 Sample Fraction Mercury Measurements**

	Run 1	Run 2	Run 3	Average	Field blank	Field blank/ sample, %	Method blank
<b>Inlet, µg/sample</b>							
Filter/probe wash (particulate Hg)	ND<0.080	ND<0.080	ND<0.080	ND<0.080	ND<0.080	ND	0.067
KCl fraction (oxidized Hg)	3.95	0.63	0.93	1.8	ND<0.10	ND	ND<0.030
H <sub>2</sub> O <sub>2</sub> fraction (elemental Hg)	ND<0.25	ND<0.25	ND<0.25	ND<0.25	ND<0.25	ND	ND<0.010
KMnO <sub>4</sub> fraction (elemental Hg)	4.8	5.5	5.2	5.2	0.12	2%	ND<0.030
<b>Stack, µg/sample</b>							
Filter/probe wash (particulate Hg)	0.078	0.034	0.019	0.044	0.094	215%	0.067
KCl fraction (oxidized Hg)	ND<0.10	ND<0.10	ND<0.10	ND<0.10	ND<0.10	ND	ND<0.030
H <sub>2</sub> O <sub>2</sub> fraction (elemental Hg)	ND<0.25	ND<0.25	ND<0.25	ND<0.25	ND<0.25	ND	ND<0.010
KMnO <sub>4</sub> fraction (elemental Hg)	5.3	5.6	5.7	5.5	ND<0.05	ND	ND<0.030

**Table 5-5. Results of Independent QA Analyses of Navajo 3 Samples**

Run No.	1	2	3	Average
Date, 1999	25-Oct	26-Oct	26-Oct	
<i>Inlet laboratory mercury results, µg/sample</i>				
KCl fraction by Philip	4.0	0.6	0.9	1.8
KCl fraction by EERC	4.4	0.7	1.0	2.0
KMnO <sub>4</sub> fraction by Philip	4.8	5.5	5.2	5.2
KMnO <sub>4</sub> fraction by EERC	4.5	5.2	4.8	4.9
<i>Stack laboratory mercury results, µg/sample</i>				
KCl fraction by Philip	ND<0.10	ND<0.10	ND<0.10	ND<0.10
KCl fraction by EERC	0.10	0.07	0.08	0.08
KMnO <sub>4</sub> fraction by Philip	5.3	5.6	5.7	5.5
KMnO <sub>4</sub> fraction by EERC	5.1	5.7	5.5	5.4
<i>Total mercury mass rates</i>				
Inlet lb/hr by Philip	0.036	0.024	0.023	0.028
Inlet lb/hr by EERC	0.036	0.023	0.022	0.027
Stack lb/hr by Philip	0.021	0.021	0.021	0.021
Stack lb/hr by EERC	0.020	0.022	0.021	0.021