



January 28, 2000

U.S. Environmental Protection Agency
Emission Measurement Center
Interstate 40 and Page Road
4930 Old Page Road
Room Number E-108
Durham, NC 27709

Attention: Mr. William Grimley
Electric Utility Steam Generating Unit Mercury Test Program

Subject: Mercury Emissions Test Program of the Pulverized Coal Fired Boilers Units 1 and 3 at the Brayton Point
Generating Station, Somerset, Massachusetts
(TRC Reference No. 26064)

Dear Mr. Grimley,

On behalf of PG&E Generating Company, TRC Environmental Corporation submitted three (3) copies of a final report entitled, "*Mercury Emissions Test Program of the Pulverized Coal Fired Boilers Units 1 and 3 at the Brayton Point Generating Station, Somerset, Massachusetts*", dated December 1999.

Following the submittal of the final report it was discovered that the outlet sampling location descriptions for Unit 1 and Unit 3 were not correct. The descriptions presented in section 2.2.2.1 and 2.2.2.2 as well as the corresponding figures (2-5 and 2-6) did not list the proper upstream and down stream dimensions for the locations. Please find enclosed three copies of revised sections 2.2.2.1 and 2.2.2.2 and figures 2-5 and 2-6 to replace the text and figures provided with the reports submitted on December 23, 1999. This revision requires the exchanging of pages 2-8, 2-9 and 2-10.

In addition a transcription error was found in Table 3-3 on page 3-9 of the final report. The error resulted in the presentation of an incorrect mercury (Hg) emission rate (mg/hr) for the analyses of the as-fired coal samples. All other values reported in Table 3-3 are correct. Please find enclosed three copies of a revised Table 3-3 to replace the table provided with the reports submitted on December 23, 1999.

Should you have any questions regarding this change, please do not hesitate to call me at (978) 656-3550.

Sincerely,
TRC Environmental Corporation

Michael P. Martin
Project Manager

enclosures

cc: Mr. A. Rayner Kenison, PG&E Generating Company
Mr. Ken Small, PG&E Generating Company
Ms. Valarie Gill, PG&E Generating Company

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TRC Project No. 26046-0030-00003

December 1999

FINAL REPORT

**Mercury Emissions Test Program of the
Pulverized Coal Fired Boilers Units 1 and 3
at the Brayton Point Generating Station
Somerset, Massachusetts**

Prepared for

PG&E Generating Company
Brayton Point Generating Station
Brayton Point Road
Somerset, Massachusetts

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TABLE OF CONTENTS

<i>Section</i>	<i>Page</i>
1.0 INTRODUCTION	1-1
1.1 Summary of Test Program	1-1
1.1.1 Problem Definition and Background	1-1
1.1.2 Facility Information	1-2
1.2 Project Organization	1-3
1.2.1 Purpose/Background	1-3
1.2.2 Roles and Responsibilities	1-3
1.2.2.1 PG&E Generating Company	1-3
1.2.2.2 TRC Environmental Corporation	1-5
1.2.2.3 Analytical Laboratory	1-8
2.0 FACILITY AND SAMPLING LOCATION DESCRIPTIONS	2-1
2.1 Process Description and Operation	2-1
2.1.1 Electrostatic Precipitation System	2-1
2.1.2 Operating Schedule	2-1
2.2 Flue Gas Sampling Locations	2-3
2.2.1 ESP Inlet Locations	2-3
2.2.1.1 Unit 1	2-3
2.2.1.2 Unit 3	2-6
2.2.2 ESP Exhaust Stack Sampling Locations	2-8
2.2.2.1 Unit 1	2-8
2.2.2.2 Unit 3	2-8
2.3 Process Sampling Locations	2-11
2.3.1 Coal Samples	2-11
3.0 SUMMARY AND DISCUSSION OF RESULTS	3-1
3.1 Objectives and Test Matrix	3-1
3.2 Field Test Changes and Problems	3-1
3.2.1 Field Test Changes	3-1
3.2.1.1 Inlet Sample Train Operation (Unit 1 and Unit 3)	3-1
3.2.1.2 Exhaust Stack Sample Train Operation (Unit 1)	3-2
3.2.2 Problems	3-2
3.2.2.1 Exhaust Stack Sampling Trains (Unit 1 and Unit 3)	3-2
3.2.2.2 Inlet Sampling Trains (Unit 1 and Unit 3)	3-2
3.3 Presentation of Results	3-4
3.3.1 Total Mercury Inflow to the Process	3-4
3.3.2 Speciated and Total Mercury Emissions (Inlet and Outlet of Control Device)	3-5
3.3.3 Emission Control Device Removal Efficiency	3-5
3.3.3.1 Unit 1	3-5

TABLE OF CONTENTS (continued)

<i>Section</i>	<i>Page</i>
3.3.3.2 Unit 3	3-5
3.3.4 Overall Process Removal Efficiency	3-6
4.0 SAMPLING AND ANALYTICAL PROCEDURES	4-1
4.1 Overview	4-1
4.2 Presampling Activities	4-2
4.2.1 Equipment Calibration	4-2
4.2.2 Glassware Preparation	4-2
4.3 Onsite Sampling Activities	4-2
4.3.1 EPA Methods 1 and 2 for Velocity Measurements and Cyclonic Flow ..	4-2
4.3.2 EPA Method 4 for Moisture	4-3
4.3.3 Ontario Hydro Mercury Speciation Train (EPA EMC Pre-003)	4-4
4.3.4 EPA Method 3B for O ₂ and CO ₂	4-11
4.3.5 Process Sampling	4-11
4.3.5.1 Coal Sampling	4-11
4.4 Process Monitoring	4-11
4.5 Analytical Procedures	4-12
4.5.1 Mercury - Ontario Hydro Train Fractions	4-12
4.5.2 Coal Analyses	4-14
4.6 Calculations	4-16
4.6.1 Flowrates and Isokinetics	4-16
4.6.1.1 Determination of Time Weighted Nozzle Diameter ..	4-19
4.6.2 Calculation for Particle Bound, Oxidized, Elemental and Total Mercury Concentrations	4-20
4.6.2.1 Particle-Bound Mercury	4-20
4.6.2.2 Oxidized Mercury	4-22
4.6.2.3 Elemental Mercury	4-23
4.6.2.4 Total Mercury	4-25
4.6.3 Emission Rate of Mercury Species	4-25
4.6.4 Mercury Removal Efficiency of Pollution Control System for each Species	4-26
4.6.5 Coal Analyses	4-26
4.6.6 Total Mercury Introduced into the Combustion Unit	4-26
5.0 QUALITY ASSURANCE	5-1
5.1 Overview	5-1
5.2 Field Quality Control Summary	5-1
5.2.1 Calibration Procedures	5-1
5.2.2 Equipment Leak Checks	5-2
5.2.3 Cyclonic Flow Check	5-2

TABLE OF CONTENTS (continued)

<i>Section</i>		<i>Page</i>
	5.2.4 Field Blanks	5-2
5.3	Sampling Handling	5-3
	5.3.1 Sample Traceability	5-3
	5.3.2 Chain-of-Custody Documentation	5-4
	5.3.2.1 Labeling	5-4
	5.3.2.2 Field Logbook	5-4
	5.3.2.3 Chain-of-Custody Forms	5-4
	5.3.3 Sample Shipping	5-5
5.4	Laboratory Quality Control Summary	5-5
	5.4.1 Mercury in Exhaust Gases	5-6
	5.4.1.1 Spike and Spike Duplicates	5-6
	5.4.1.2 Duplicate Analysis	5-6
	5.4.1.3 Blank Results	5-6
	5.4.1.4 Audit Sample Analysis	5-7
	5.4.2 Analysis of the Process Feed Samples	5-7

Appendices

A	Results and Calculation
A.1	Unit 1
A.1.1	Emissions Summary
A.1.2	Isokinetic Summary
A.1.3	Process Mercury Inflow Calculations
A.2	Unit 3
A.2.1	Emissions Summary
A.2.2	Isokinetic Summary
A.2.3	Process Mercury Inflow Calculations
B	Raw Field Data and Calibration Data Sheets
B.1	Unit 1
B.1.1	Raw Field Data Sheets
B.1.2	Calibration Data Sheets
B.2	Unit 3
B.2.1	Raw Field Data Sheets
B.2.2	Calibration Data Sheets
C	Sampling Log and Chain-of-Custody Records
C.1	Unit 1
C.1.1	Exhaust Gas Streams
C.1.2	Process Streams

TABLE OF CONTENTS (continued)

Appendices (continued)

C.2	Unit 3	
	C.2.1	Exhaust Gas Streams
	C.2.2	Process Streams
D	Analytical Data Sheets	
	D.1	Unit 1
		D.1.1 Exhaust Gas Streams
		D.1.2 Process Streams
	D.2	Unit 1
		D.2.1 Exhaust Gas Streams
		D.2.2 Process Streams
E	Audit Data Sheets	
F	List of Participants	
	F.1	Unit 1
	F.2	Unit 3
G	Additional Information	
	G.1	Unit 1
	G.2	Unit 3

TABLES

<i>Number</i>		<i>Page</i>
2-1	Unit 1 ESP Inlet Traverse Sampling Points	2-3
2-2	Unit 3 ESP Inlet Traverse Sampling Points	2-6
2-3	Unit 1 Exhaust Stack Traverse Sampling Points	2-8
2-4	Unit 3 Exhaust Stack Traverse Sampling Points	2-11
3-1	PG&E Gen Brayton Point Generating Station Test Matrix for Units 1 and 3	3-7
3-2	Measurements Conducted at each Test Location, Runs 1, 2 and 3 for Units 1 and 3 ..	3-8
3-3	Summary Table of Emissions Data and Removal Efficiencies - Unit 1	3-9
3-4	Summary Table of Emissions Data and Removal Efficiencies - Unit 3	3-10
3-5	Summary Table of Emissions Data - Unit 1	3-11
3-6	Summary Table of Emissions Data - Unit 3	3-12
3-7	Distribution of Speciated Mercury Emissions - Unit 1	3-13
3-8	Distribution of Speciated Mercury Emissions - Unit 3	3-14
5-1	Spike/Spike Duplicate Results	5-8
5-2	Laboratory Duplicate Results	5-9
5-3	Blank Results	5-10

TABLE OF CONTENTS (continued)

FIGURES

<i>Number</i>		<i>Page</i>
1-1	Program Organization - Mercury Emissions Sampling Program	1-4
2-1	Process Air Flow Schematic	2-2
2-2	Unit 1 Gas Exhaust Circuit	2-4
2-3	Unit 1 Inlet Sampling Locations	2-5
2-4	Unit 3 Gas Exhaust Circuit	2-7
2-5	Unit 3 Inlet Sampling Location	2-9
2-6	Stack Sampling Location Units 1 & 3	2-10
2-7	Coal Sampling Location	2-12
4-1	Schematic of EPA Pre003-Ontario Hydro-Speciatiated Mercury Sampling Train in the Method 5 Horizontal Sampling Configuration	4-6
4-2	Schematic of EPA Pre003-Ontario Hydro-Speciatiated Mercury Sampling Train in the Method 5 Vertical Sampling Configuration	4-7
4-3	Analytical Scheme for EPA Pre-003-Ontario Hydro Sampling Train Mercury Analysis	4-13
4-4	Coal Sample Analytical Scheme	4-15

SECTION 1.0 INTRODUCTION

1.1 SUMMARY OF TEST PROGRAM

1.1.1 Problem Definition and Background

The United States Environmental Protection Agency (USEPA), in its "Study of Hazardous Air pollutant emissions from Electric Utility Steam Generating Units – Final Report to Congress", stated that mercury is the Hazardous Air Pollutant (HAP) of greatest potential concern from coal-fired utility steam generators and that additional research and monitoring are merited. The USEPA also listed a number of research needs related to mercury emissions (e.g., how much is emitted from various types of units; how much is divalent vs. elemental mercury; and how do factors such as control device, fuel type, and plant configuration affect emissions and speciation). After reviewing the report, the Administrator concluded that obtaining additional information was appropriate and necessary for subsequent regulatory decisions. Specifically, the data will provide the USEPA with updated information on the total amount of mercury emitted from electric utility steam generating units and on the speciation and controllability of such mercury.

The USEPA, under its authority of Section 114 of the Clean Air Act (CAA), is requiring all coal-fired electric utility steam generating units to provide certain information under an Information Collection Request (ICR) that will allow the Agency to calculate the annual mercury emissions from each such unit and subsequently determine whether it is appropriate and necessary to regulate the mercury emissions from electric utility steam generating units. Section 112(n)(1)(A) of the CAA allows the Administrator to regulate the electric utility steam generating units if it is found that such regulation is appropriate and necessary after the results of the ICR are reviewed.

The ICR was approved on November 13, 1998 by the Office of Management and Budget and consists of three parts. In Part I, all units were required to submit background information on the coal fired, and unit descriptions, including operations and control devices. In Part II, all units

were required to sample the coal fired over each month at least three times, for the 1999 calendar year and analyze the samples for mercury, chlorine, gross heating value and proximate analysis. For participation in Part III, speciated mercury emission testing, the agency statistically selected units based on coal type, control device, and operations. Emissions testing was conducted utilizing the most current revision of the DRAFT Ontario Hydro Mercury Sampling Method. This method is a modification of USEPA Method 29 in 40 CFR 60 Appendix A.

The units selected for Part III were notified in writing by the USEPA. Units not selected were eligible to participate in Part III on a voluntary basis. PG&E Generating Company (PG&E Gen) elected to participate in Part III on a voluntary basis at the Brayton Point Generating Station. The purpose of PG&E Gen's voluntary participation was two fold:

- to contribute to improved accuracy and completeness of the EPA's mercury ICR results; and
- to develop specific emissions data for several of PG&E Gen's coal fired electric utility steam generating units.

TRC Environmental Corporation (TRC) of Lowell, Massachusetts was retained by PG&E Gen to conduct the mercury emissions test program on Units 1 and 3 at the Brayton Point Generating Station.

1.1.2 Facility Information

The facility is located in Somerset, Massachusetts and is designated by ORIS/Facility ID 01619, with Unit IDs 1 and 3.

Particulate matter (PM) emissions from Units 1 and 3 are controlled by electrostatic precipitator (ESP) systems. Mercury emissions testing was conducted at each inlet to the ESP and each ESP's exhaust stack to determine speciated mercury emissions prior to and following emission control.

1.2 PROJECT ORGANIZATION

1.2.1 Purpose/Background

The purpose of the project organization was to provide a clear understanding of the role that each party would play in the study and to provide lines of authority and reporting.

1.2.2 Roles and Responsibilities

Figure 1-1 presents PG&E Gen's organization chart for this program showing the individuals responsible for each element of the overall program and the primary lines of communication.

1.2.2.1 *PG&E Generating Company*

Mr. A. Rayner Kenison was the PG&E Gen Program Coordinator. He provided the overall program coordination amongst the Plant Program Coordinator, the USEPA Emissions Measurement Center, and TRC Environmental Corporation. The PG&E Gen Program Coordinator reviewed the Quality Assurance Program Plan (QAPP), the Site Specific Test Plan (SSTP), each test report, and submitted the final versions to the USEPA Emissions Measurement Center.

Mr. Ken Small, Environmental Manager for the Brayton Point Generating Station, served as the Plant Program Coordinator and directed the test program for the facility. Mr. Small acted as the primary contact with TRC and designated the appropriate PG&E Gen personnel to coordinate plant operations with the emission test program. The PG&E Gen Plant Program Coordinator coordinated the unit operations, the coal sampling, and emissions tests during each test run. Additional Brayton Point personnel provided support in overcoming sampling logistics and obtaining process data and coal samples. PG&E Gen and TRC would like to recognize the contributions of the Brayton Point Unit 1 and 3 operations and support personnel in the successful completion of this program.

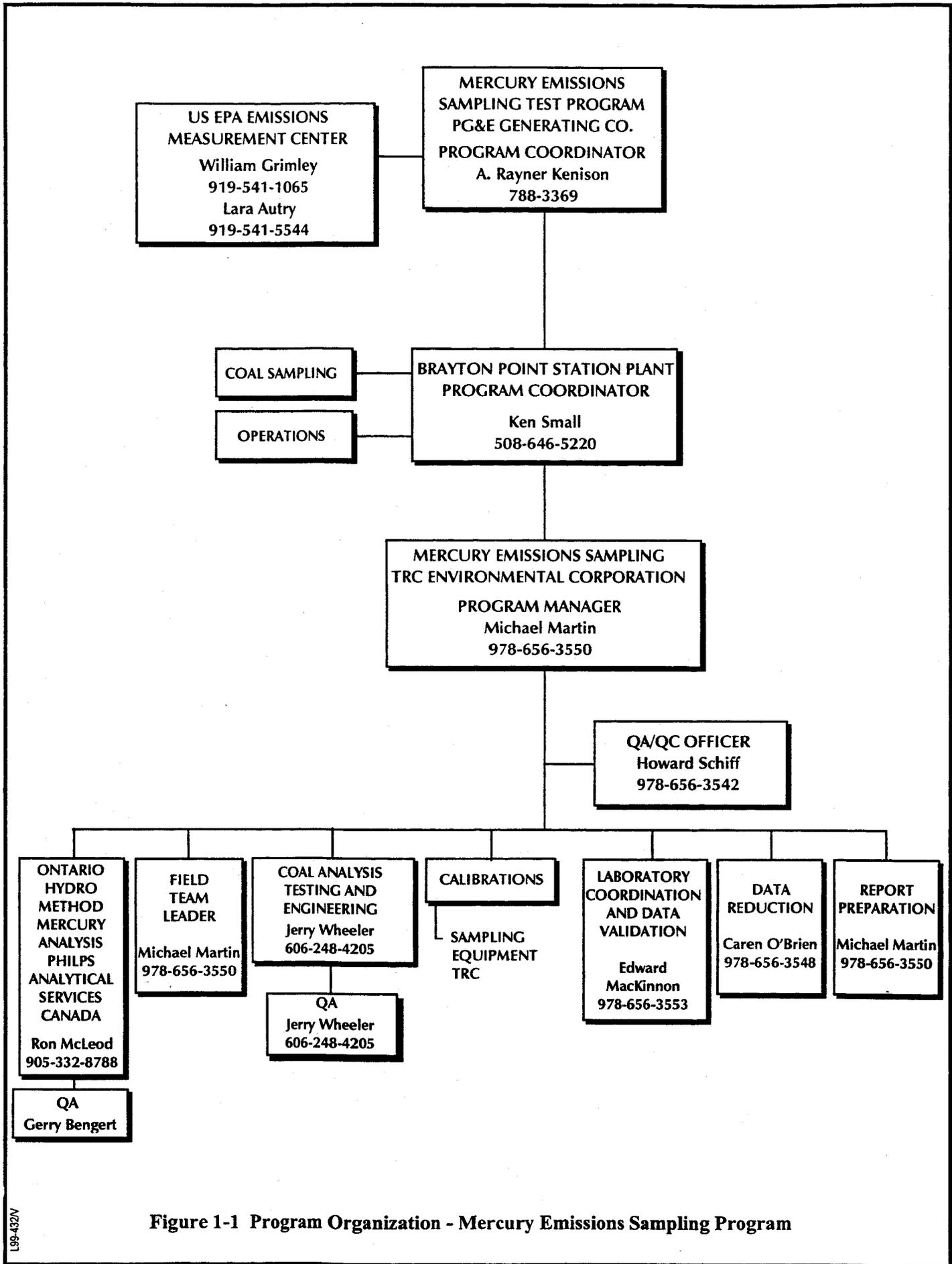


Figure 1-1 Program Organization - Mercury Emissions Sampling Program

1.2.2.2 TRC Environmental Corporation

TRC Environmental Corporation conducted the mercury emissions testing program for PG&E Gen.

1.2.2.2.1 TRC's Program Manager

Mr. Michael Martin, of TRC's Air Measurements Department, served as TRC's program manager and the primary point of contact with PG&E Gen for this project. TRC's field crew operated under the direct supervision of Mr. Martin. Mr. Martin coordinated the field crew's activities with the designated PG&E Gen personnel to complete the program on schedule and in accordance with the EPA approved Site Specific Test Plan (SSTP).

The Program Manager had the full responsibility and authority from both a technical and administrative standpoint for the successful conduct of this work. He was the principal point of contact with the PG&E Gen Program Coordinator for all matters relating to contract performance and technical progress.

Working with TRC's Laboratory Coordinator, TRC's Program Manger managed the assignment of analytical work to the analytical laboratories. Ultimately, TRC's Program Manager was responsible for assuring that all tasks were completed on schedule and within budget, while maintaining the quality objectives of the program. To do so, TRC's Program Manager carried out the following functions:

- Administered program activities within the TRC team (s).
- Coordinated activities within the TRC team(s).
- Attended program meetings.
- Conducted pretest site specific surveys.
- Effected corrective actions which included quality, budget and schedule maintenance measures.

- Interacted with the sampling teams to ensure proper performance of the test procedures.
- Communicated directly with the PG&E Gen Program Manager.
- Prepared or reviewed Site Specific Test Plans
- Reviewed the QAPP.
- Prepared or reviewed the site specific test reports.
- Reviewed the data validation and reduction.

In summary, TRC's Program Manager ensured that the program was effectively staffed, managed, coordinated and satisfactorily completed.

1.2.2.2.2 TRC's QA Officer

Program Quality Assurance / Quality Control was under the direction of Mr. Howard F. Schiff, Program QA Officer. He was responsible for ensuring that all program deliverables adhered to the highest quality principles. He reported programmatically to the Program Manager, but he derived his authority from the TRC Air Measurements Manager.

TRC's QA Officer initiated or followed up on corrective actions and aided in the preparation of the section of the site specific final report summarizing QA/QC activities, problems identified and corrective actions taken.

TRC's QA Officer carried out the following functions:

- Implemented all QA procedures.
- Prepared or reviewed the QAPP.
- Reviewed and approved each Site Specific Test Plan (SSTP) prior to submittal.
- Ensured that all required equipment calibrations were conducted prior and subsequent to each field test.
- Provided written summaries of Program QC activities for submission to the Program Manager.

- Advised technical staff of appropriate QC measures and corrective actions, prepared QC procedure write-up, as needed.
- Assisted in data analysis.
- Reviewed Site Specific Final Test Reports.

1.2.2.2.3 TRC's Laboratory Coordinator

Laboratory coordination and data validation were under the direction of Mr. Edward MacKinnon, who carried out the following functions:

- Acted as the laboratory coordinator between the sampling team(s) and the analytical laboratories.
- Communicated the specific analytical QC requirements to the laboratories.
- Supervised the schedule and budget for the laboratories.
- Received, validated, and distributed the laboratory data.
- Assisted in data analysis.
- Assisted in report preparation.

1.2.2.2.4 Field Team Leader's Responsibilities

The Field Team Leader coordinated the activities of the sampling team. The Field Team Leader was responsible for the following functions:

- Supervised the source sampling train operators.
- Coordinated the sampling program with the Plant Program Coordinators.
- Assisted the train operators in trouble-shooting and maintaining the sampling trains.
- Collected all sampling train data sheets, determined isokinetic ratios, determined acceptability of train leak checks and ensured that each train was operated in accordance with the EPA sampling protocol.

- Oversaw the recovery, packing and shipping of the samples to the respective analytical laboratory.
- Informed the TRC and PG&E Gen Program and Plant Program Coordinators on which sampling runs met all validating criteria and if not, determined if additional sampling runs were to be conducted.

1.2.2.3 Analytical Laboratory

The contracted analytical laboratories (Phillips Analytical Services (Phillips) and Commercial Testing and Engineering) were responsible for sample analysis and assisting with data reporting. The contracted laboratories were responsible for conducting the analyses in accordance with the methods and procedures specified in the SSTP and the QAPP. Specifically, Phillips analyzed the Ontario Hydro Mercury train samples and Commercial Testing and Engineering analyzed the as-fired coal samples and the flue gas desulfurization media samples.

The Laboratory Managers were responsible to ensure that the QAPP was followed. In summary, the Laboratory Managers performed the following duties:

- Ensured that laboratory services were available to support the sample analysis.
- Ensured that the Program Quality Assurance Program Plan was followed.
- Ensured that the laboratory QA/QC procedures were implemented.

SECTION 2.0 FACILITY AND SAMPLING LOCATION DESCRIPTIONS

2.1 PROCESS DESCRIPTION AND OPERATION

There are four separate boiler units at the facility. Units 1 and 3 were the only boiler units participating in this study.

Unit 1 is a 250 MW pulverized coal fired steam generator. Unit 3 is a 630 MW pulverized coal fired steam generator. Each unit is equipped with an ESP system to reduce particulate emissions. Low NO_x burners with over-fire air are used for NO_x emission reduction. Oil ignitors are used for boiler warmup, coal burner ignition, and coal flame stabilization. An air flow schematic of the process is presented in Figure 2-1.

The facility is equipped with a continuous emission monitoring system (CEMS). The CEMS measures and reports opacity, CO₂, SO₂, NO_x and CO levels in the exhaust gas.

2.1.1 Electrostatic Precipitation System

Units 1 and 3 are each equipped with an ESP system for the control of particulate emissions. The flue gases flow from the economizer outlet through the air pre-heater to the precipitator and then to the exhaust stack for each boiler.

2.1.2 Operating Schedule

During the test program, the Units 1 and 3 were operating at a "steady-state" load condition throughout each test run. The steady-state load represented the maximum capacity (+/- 5%) of the source being tested, 250 MW and 650 MW, respectively.

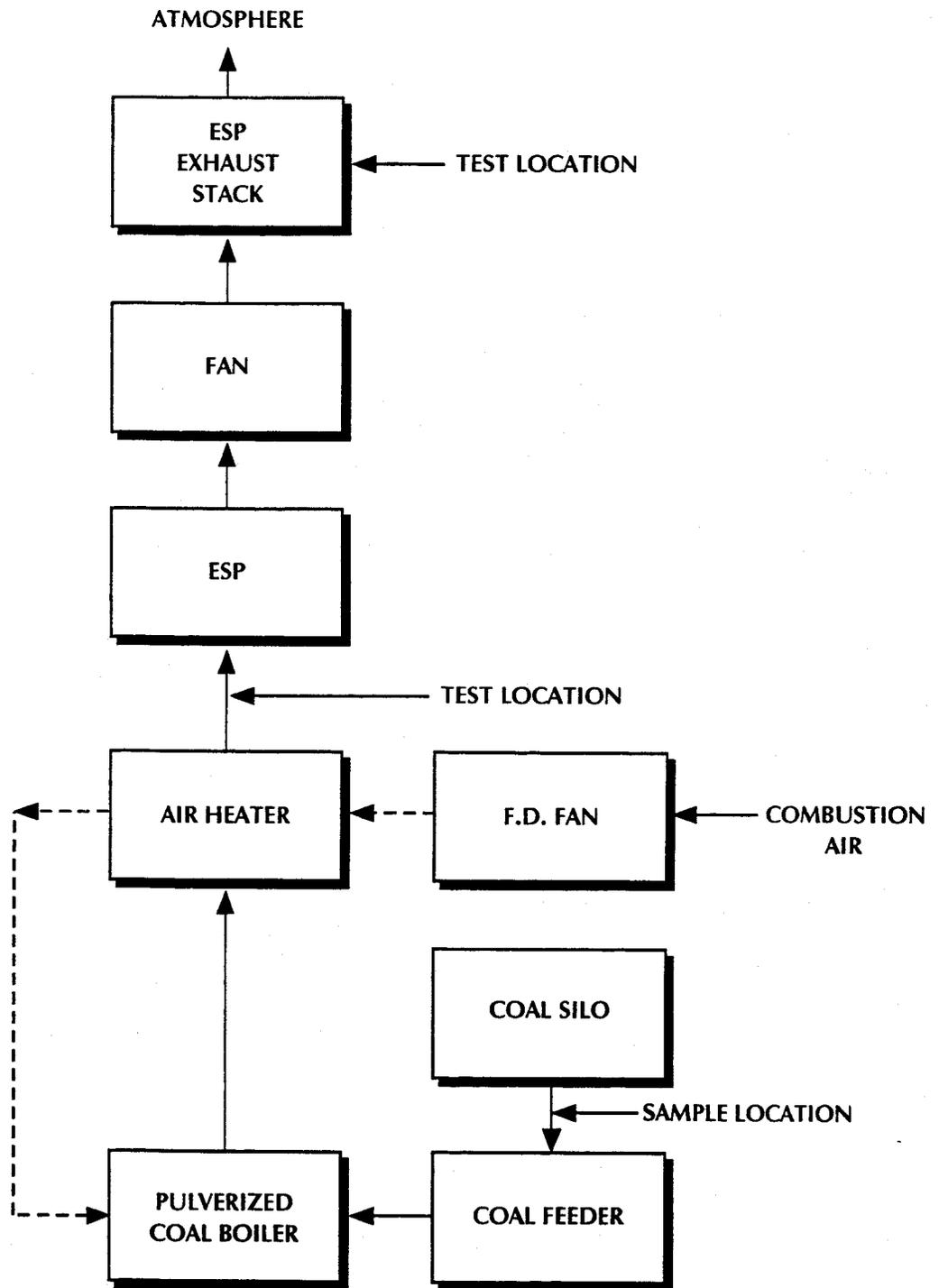


Figure 2-1. Process Air Flow Schematic

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2.2 FLUE GAS SAMPLING LOCATIONS

The sampling was conducted at the ESP inlets and in the ESP exhaust stacks for both Unit 1 and Unit 3. A plan view of the ESP Systems is shown in Figure 2-2.

2.2.1 ESP Inlet Locations

2.2.1.1 Unit 1

As shown in Figure 2-3, there are two air pre-heaters, designated east and west. There are eight 4-inch ID sample ports located on top of each air pre-heater exhaust. The duct work is 252 inches by 72 inches with an equivalent diameter of 112 inches. The ports are located less than 2.0 equivalent diameters downstream and less than 0.5 equivalent diameters upstream of the nearest flow disturbances which does not meet the minimum distance requirements of EPA Method 1. There is no other point of access prior to the ESP which could meet the Method 1 minimum distance requirements, therefore the existing sample ports were utilized during the test program.

Two sampling ports on the west inlet were not accessible due to an overhead obstruction. As a result, the west inlet was sampled at 24 points (6 × 4). All eight ports were accessible at the east inlet. TRC conducted a 32 point traverse at the east inlet location (8 × 4 grid). The sampling point locations for the east and west inlets are presented in Table 2-1.

TABLE 2-1. UNIT 1 ESP INLET TRAVERSE SAMPLING POINTS

Point	Distance from Wall (in.)
1	9
2	27
3	45
4	63

Precipitators Units 1, 2, and 3

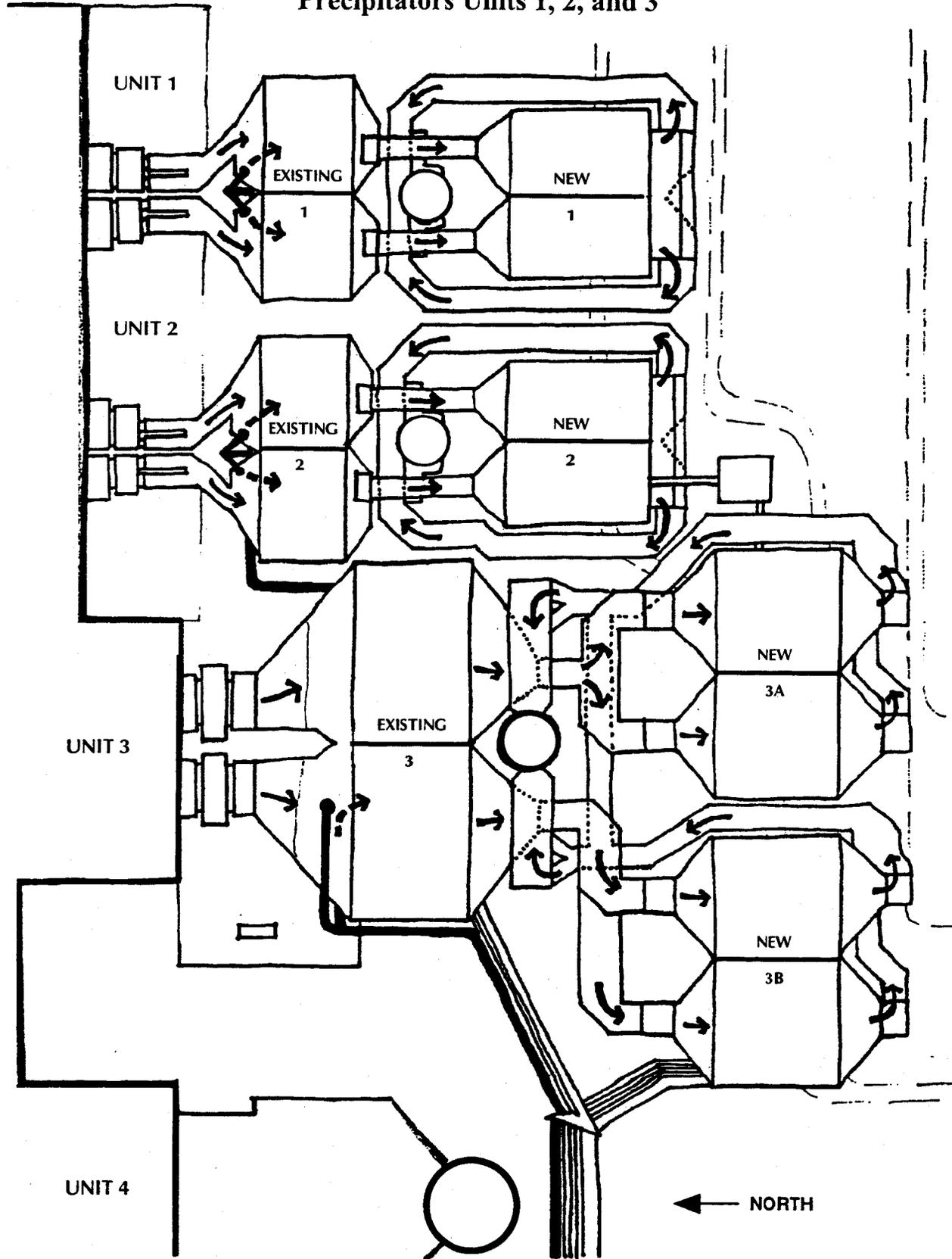


Figure 2-2. Unit 1 and 3 Plan View of ESP Systems

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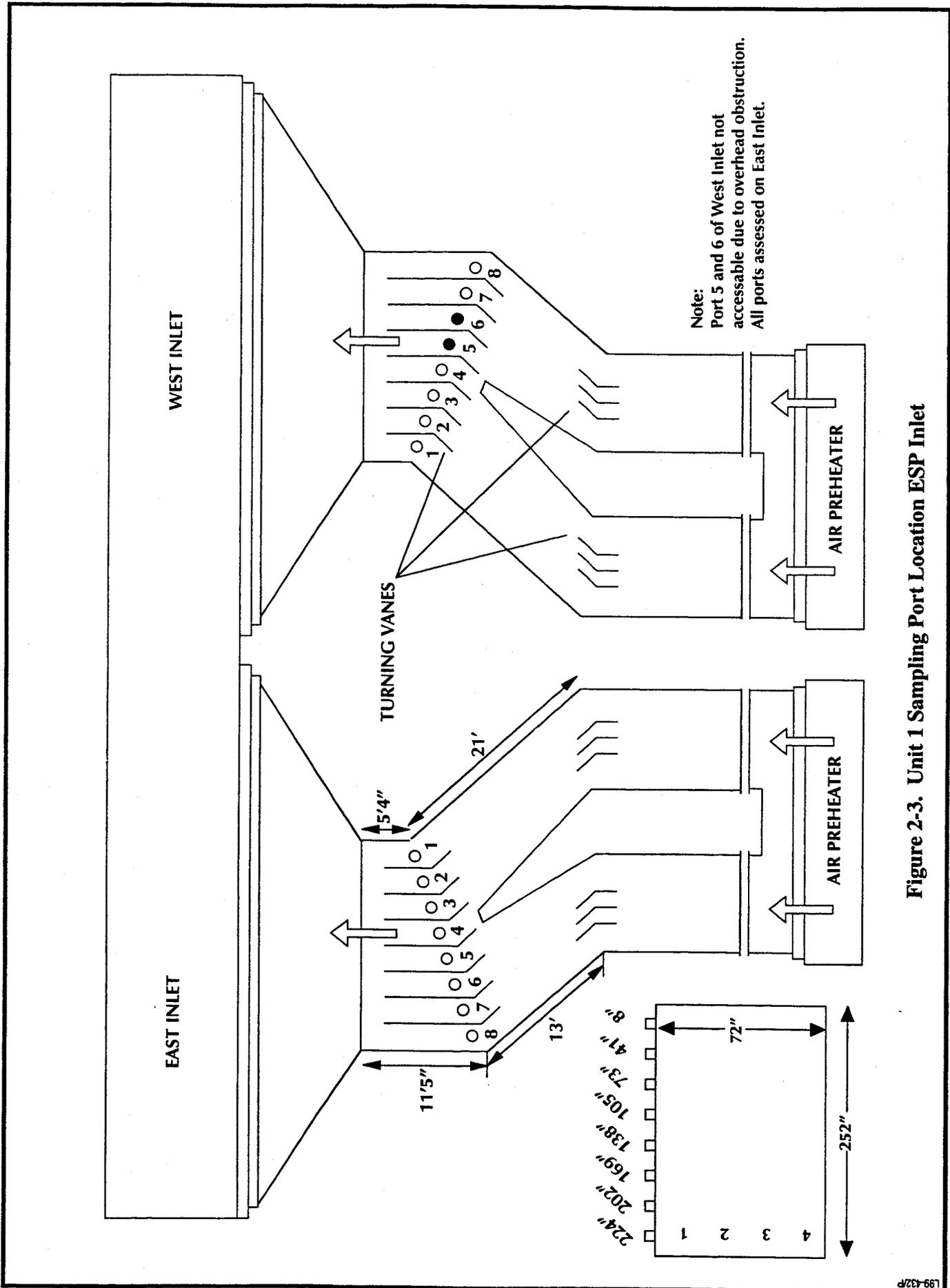


Figure 2-3. Unit 1 Sampling Port Location ESP Inlet

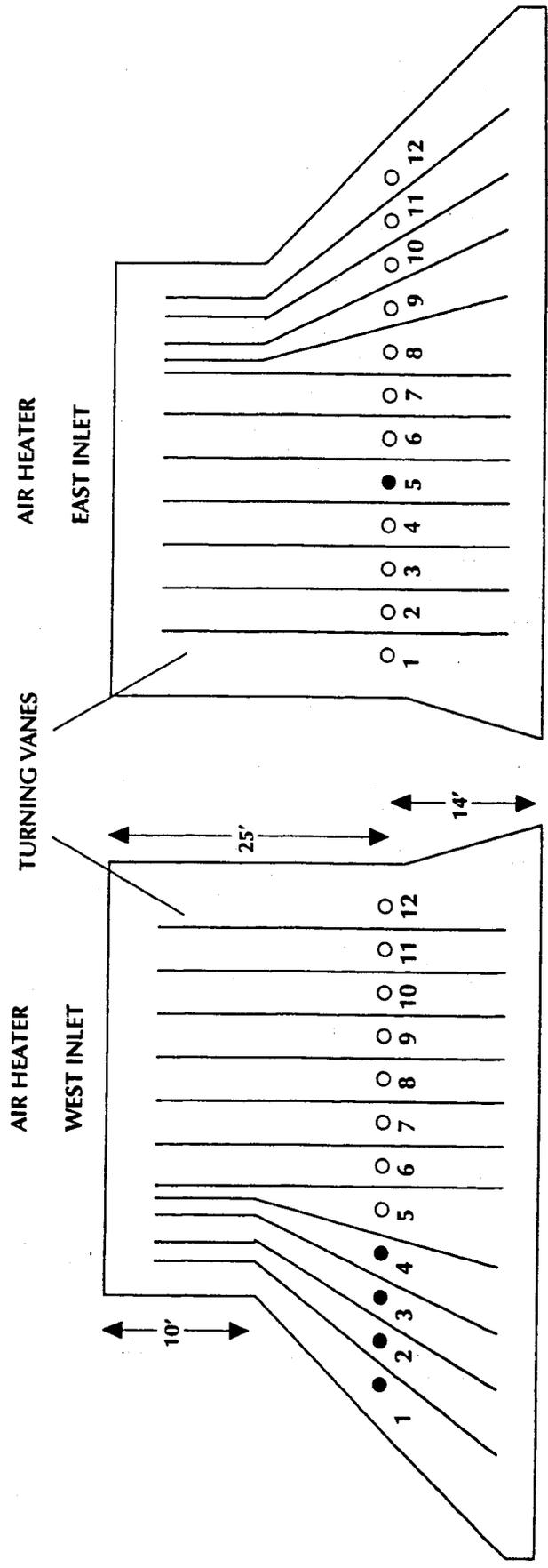
2.2.1.2 Unit 3

As shown in Figure 2-4, there are two air pre-heaters, designated east and west. There are twelve 4-inch ID sample ports located on top of each air pre-heater exhaust. The duct work is 720 inches by 90 inches with an equivalent diameter of 160 inches. The ports are located less than 2.0 equivalent diameters downstream and less than 0.5 equivalent diameters upstream of the nearest flow disturbances which does not meet the minimum distance requirements of EPA Method 1. There is no other point of access prior to the ESP which could meet the Method 1 minimum distance requirements, therefore the existing sample ports were utilized during the test program.

TRC conducted a 44 point traverse at the east inlet location (11 × 4 grid). Port 5 on the east inlet was not accessible because of an internal obstruction. Ports 1 thru 4 of the west inlet exhibited velocity profiles indicative of reverse air flow. Low velocity pressures and yaw angles of greater than 90° were observed during preliminary velocity traverses. As a result, these four ports were not utilized during the test program for Unit 3. TRC conducted a 32 point traverse using the eight remaining ports of the west inlet. The sampling point locations for the east and west inlets are presented in Table 2-2.

TABLE 2-2. UNIT 3 ESP INLET TRAVERSE SAMPLING POINTS

Point	Distance from Wall (in.)
1	11.25
2	33.75
3	56.25
4	78.75



Note:
 Ports 1-4 of West Inlet not sampled. Port 5 on East Inlet not sampled due to internal obstruction.

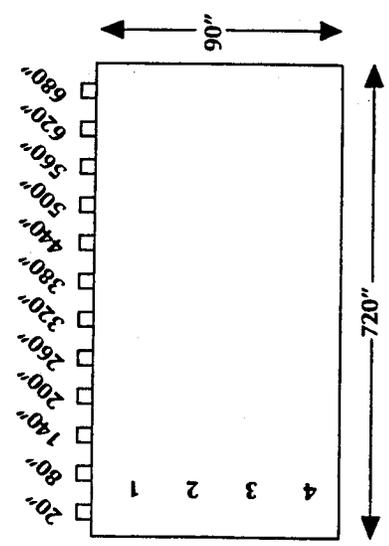


Figure 2-4. Unit 3 ESP Sampling Port Locations

2.2.2 ESP Exhaust Stack Sampling Locations

2.2.2.1 Unit 1

Unit 1 and the associated ESP system discharge to an exhaust stack that is approximately 351 feet tall. The sampling location is 170 feet above grade with a permanent test platform. At this elevation, Figure 2-5, the test platform is serviced by an elevator. The exhaust stack has an inside diameter of 16.313 feet (195.76 inches). Four 6-inch ports, located 90° apart on the same plane, are present on the stack. These ports are located 140 feet (8.6 stack diameters) downstream of the stack entrance and 180 feet (11 stack diameters) below the stack exhaust.

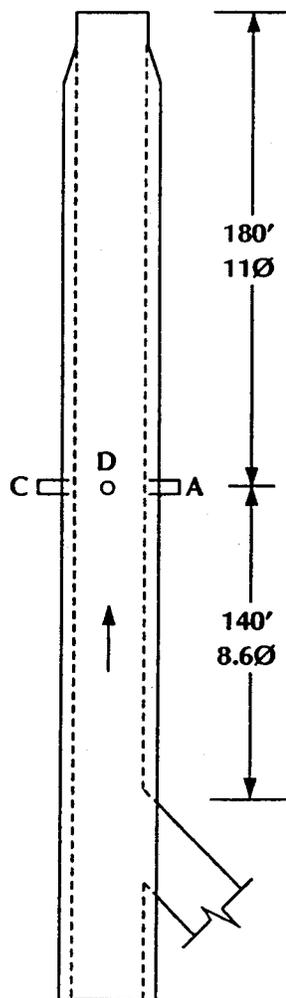
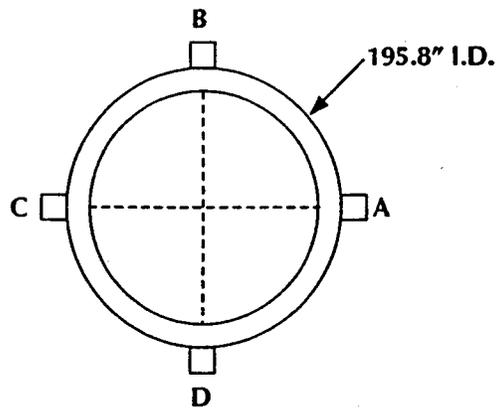
In accordance with EPA Method 1, TRC conducted a 16-point traverse (8-points on each diameter, 4 points per port) during each test run. Table 2-3 presents these traverse points.

TABLE 2-3. UNIT 1 EXHAUST STACK TRAVERSE SAMPLING POINTS

Point	Percent of Stack Diameter	Distance From Wall (in.)
1	3.2	6.27
2	10.5	20.56
3	19.4	37.99
4	32.3	63.24

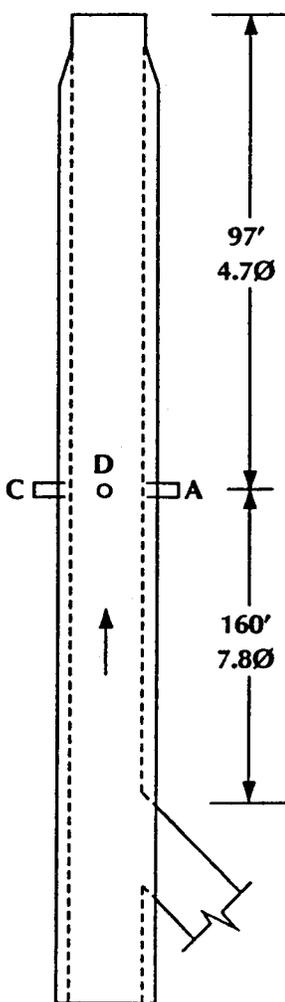
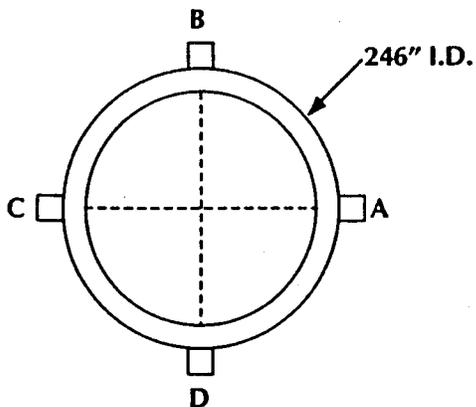
2.2.2.2 Unit 3

Unit 3 and the associated ESP system discharge to an exhaust stack approximately 51 feet tall. The sampling location is 270 feet above grade with a permanent test platform. At this elevation, as shown in Figure 2-6, the test platform is serviced by an elevator. The exhaust stack has an inside diameter of 20.5 feet (246 inches). Four 6-inch ports, located 90° apart on the same plane, are present on the stack. These ports are located 160 feet (7.8 stack diameters) downstream of the nearest disturbance and 97 feet (4.7 stack diameters) below the stack exhaust.



Not to Scale

Figure 2-5. Unit 1 Stack Sampling Location



Not to Scale

Figure 2-6. Unit 3 Stack Sampling Location

LD-134/S

In accordance with EPA Method 1, TRC conducted a 16-point traverse (8-points on each diameter, 4 points per port) during each test run. Table 2-4 presents these traverse points.

TABLE 2-4. UNIT 3 EXHAUST STACK TRAVERSE SAMPLING POINTS

Point	Percent of Stack Diameter	Distance From Wall (in.)
1	3.2	7.87
2	10.5	25.83
3	19.4	47.72
4	32.3	79.45

2.3 PROCESS SAMPLING LOCATIONS

During each sample run, "as-fired" coal samples were obtained at the following locations.

2.3.1 Coal Samples

An "as-fired" composite coal sample was obtained from both units during each of the sample runs. The samples for Unit 1 were obtained from the sample port in the inlet ducts of each of the four belt feeders and the samples for Unit 3 were obtained from the sample ports in the inlet ducts of each of the five belt feeders (as shown in Figure 2-7).

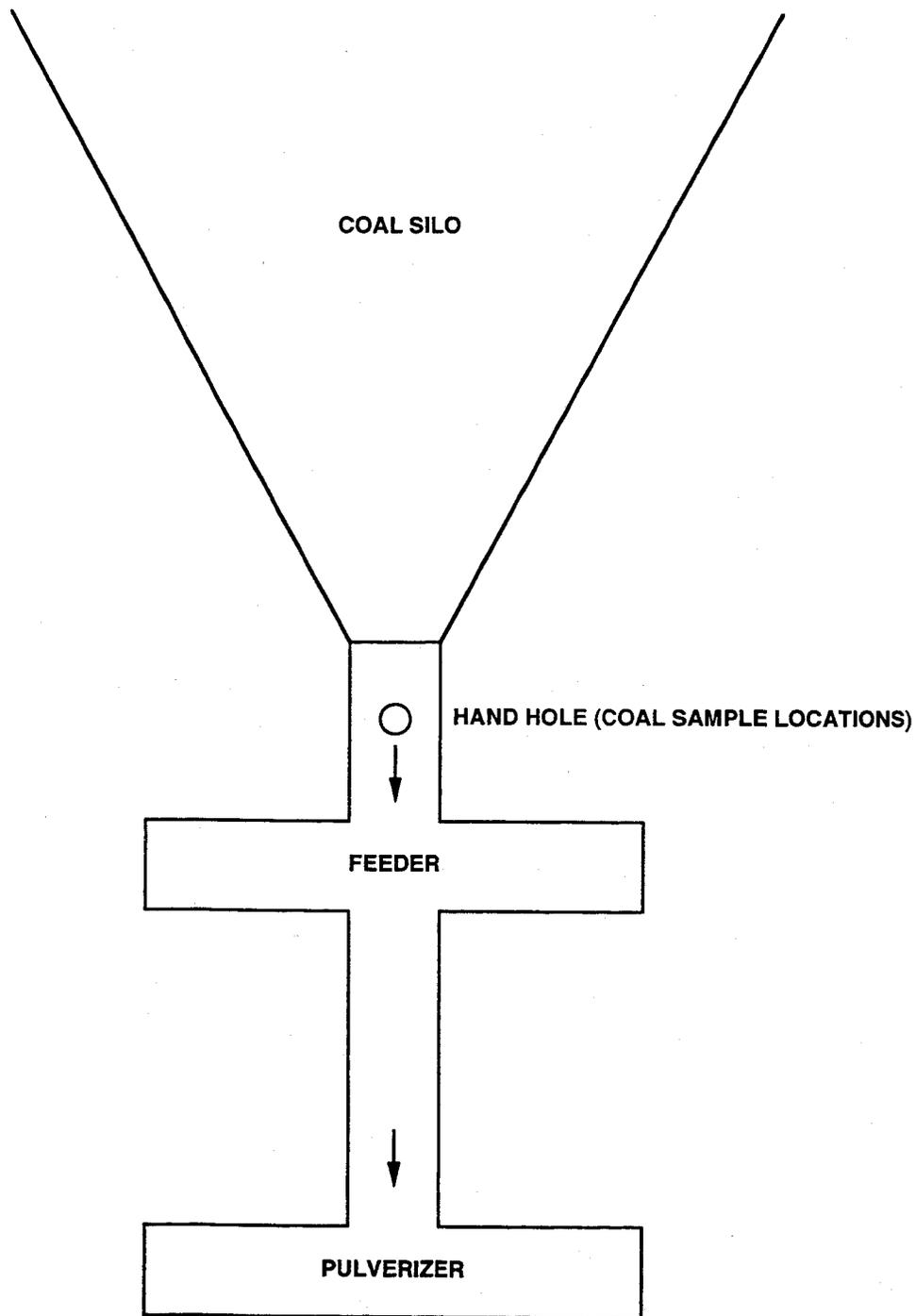


Figure 2-7. Coal Sample Location

SECTION 3.0 SUMMARY AND DISCUSSION OF RESULTS

3.1 OBJECTIVES AND TEST MATRIX

The objectives of the Unit 1 and Unit 3 test programs were as follows:

- measure the total inflow of mercury to the process;
- measure the concentration and emission rate of mercury on a speciated basis at the inlet and outlet of the facility pollution control equipment;
- determine the removal efficiency (RE) of the control equipment on a speciated and total basis; and
- calculate an overall RE based upon the total inflow of mercury to the system.

Table 3-1 presents the sampling and analytical matrix for the two units. Table 3-2 shows the measurements made at each test location.

3.2 FIELD TEST CHANGES AND PROBLEMS

3.2.1 Field Test Changes

3.2.1.1 *Inlet Sample Train Operation (Unit 1 and Unit 3)*

Due to the high negative static pressure encountered at the ESP inlets (Unit 1 and Unit 3), the sample trains were started prior to insertion into the stack for each sample port traverse and were not shut down upon completion of a port traverse until after the nozzle had exited the sample port. This was necessary to avoid a back flush of the sample train and also to prevent the loss of any particulate matter during port changes. At the start of a sample port, the initial dry gas meter reading was taken as the nozzle of the sample train cleared the sample port sleeve and entered the gas stream. The final reading for a port was taken as the nozzle exited the gas stream and entered the sample port sleeve. Taking the volume readings in this manner discounted the volume of air which passed through the train prior to entering or after exiting the stack.

3.2.1.2 *Exhaust Stack Sample Train Operation (Unit 1)*

A heated teflon sample line was used between the sample probe and filter housing in order to facilitate port changes at the exhaust stack for Unit 1. The sample line was maintained at stack temperature ± 27 degrees and was recovered in the same manner as the sample probe at the end of each test run.

3.2.2 **Problems**

This section documents problems that were encountered in the completion of the sampling program and the actions taken to overcome and/or correct the problems. None of the problems or actions taken are considered to have had a significant or negative impact upon the results reported.

3.2.2.1 *Exhaust Stack Sampling Trains (Unit 1 and Unit 3)*

No problems were encountered at the exhaust stack sampling location for either unit.

3.2.2.2 *Inlet Sampling Trains (Unit 1 and Unit 3)*

Logistics at the ESP inlets were the cause of several problems with regard to sample train operation and port changes. The highly negative static pressure which exists at the locations and its impact have been discussed previously in Section 3.1. The high static also contributed to several of the problems encountered.

3.2.2.2.1 *Unit 1*

The problems encountered at the ESP inlet for Unit 1 were as follows:

- During preliminary velocity traverses, it was discovered that port 5 and 6 of the west ESP inlet duct could not be traversed with the OHM sampling train. A catwalk and a cable tray above the ports blocked access. The configuration of the sample location also required that the probe be separated from the rest of the train in order to move between ports 4 and 7. The train was leaked checked both, prior to removal and following re-connection of the sample probe.
- Approximately halfway through Run 1 at the west ESP inlet, there was breakthrough of particulate matter into the KCl impingers of the OHM sampling train. The train operator noticed particulate entering the impinger train approximately 84 minutes into the test. An inspection of the train showed that the glass fiber filter had separated from the teflon support, allowing particulate to pass around the filter. Particulate matter was evident in impingers 1, 2, and 3 of the sample train. Impinger 4 did not have any particulate matter present. The test run was invalidated and an additional test run (No. 4) was conducted at all three sample locations.
- Following completion of Run 2 at the west ESP inlet, it was noticed that a small amount of particulate matter had passed around the edge of the glass fiber filter and into the KCl impingers of the OHM sampling train. It could not be determined when the filter seal had been compromised. Particulate matter was evident in impingers 1, 2, and 3 of the sample train. Impinger 4 did not have any particulate matter present. An additional test run (No. 5) was conducted at all three sample locations. The samples from run 2 were analyzed. Data from run 2 is presented in the summary Tables 3-3, 3-5, and 3-7 for comparison only, and has not been included in the reported averages.
- Volumetric flow rates measured at the ESP inlet to Unit 1 averaged 17% higher than the flow rates measured at the exhaust stack sampling location. Given that the inlet locations could not meet the minimum criteria for location of the sample ports, the flow rates measured at the exhaust stack are considered to better reflect unit operation. Emission rates of mercury reported for the ESP inlet were calculated using the concentrations measured at the inlet locations and the corresponding volumetric flow rate measured at the ESP exhaust stack. Emission rates calculated using the measured inlet flow rates are provided in Appendix A.

3.2.2.2.2 *Unit 3*

The problems encountered at the ESP inlet for Unit 3 were as follows:

- During preliminary velocity traverses of the west ESP inlet duct, it was determined that ports 1, 2, 3, and 4 exhibited velocity profiles indicative of reverse air flow. Low velocity pressure and yaw angles of greater than 90° were observed during the preliminary velocity traverses. As a result, these 4 ports were not utilized during the test program for Unit 3.

- During preliminary velocity traverses, it was discovered that port 5 of the east ESP inlet was obstructed by a turning vane and could not be traversed with the OHM sampling train. As a result, this port was not utilized during the test program for Unit 3.
- During Run 1, there was a loss of power at the inlet location. Sample trains were back-flushed by the high negative static when the power to the sample pumps was lost. Adverse weather (wind driven rain) contributed to the loss of power as ground fault protected circuits were in use. Further testing was postponed until the following day. The sample trains from Run 1 were invalidated and discarded. An additional test run (No. 4) was conducted at three sample locations.
- During Run 2, The nozzle for the east inlet train was broken while changing between ports 7 and 8. A leak check from the probe union was valid. A second nozzle was utilized to complete the run. It was determined that given the total mass of particulate collected by the sampling train, the potential loss of particulate matter from the breakage of the nozzle was insignificant. Sample train isokenetics were calculated based upon the time period and sample volume collected for each nozzle. Section 4.6 presents the calculations utilized.
- Volumetric flow rates measured at the ESP inlet to Unit 3 averaged 16% higher than the flow rates measured at the exhaust stack sampling location. Given that the inlet locations could not meet the minimum criteria for location of the sample ports, the flow rates measured at the exhaust stack are considered to better reflect unit operation. Emission rates of mercury reported for the ESP inlet were calculated using the concentrations measured at the inlet locations and the corresponding volumetric flow rate measured at the ESP exhaust stack. Emission rates calculated using the measured inlet flow rates are provided in Appendix A.

3.3 PRESENTATION OF RESULTS

Presented in the following sections are the results required to fulfill the objectives identified for this test program. Each section discusses the results pertinent to an objective in greater detail.

3.3.1 Total Mercury Inflow to the Process

The total mercury inflow to the process was determined through sampling and analysis of the fuel. Results are presented for each run and are based upon the concentration of mercury measured and the feed rate of material into the process.

Tables 3-3 and 3-4 present the concentration of mercury measured in the process materials and the calculated feed rate (mg/hr) of mercury into Unit 1 and Unit 3 respectively. The sulfur and chlorine content of the fuel as well as the as fired HHV are also presented.

3.3.2 Speciated and Total Mercury Emissions (Inlet and Outlet of Control Device)

Concentrations and emission rates for mercury are presented in Tables 3-3 and 3-4 for Unit 1 and Unit 3 respectively. Results are presented on a speciated and total basis in terms of ug/dscm and mg/hr. Similarly, emission rates expressed in terms of lbs/hr and lbs/MMBtu are presented in Tables 3-5 and 3-6. Tables 3-7 and 3-8 present the distribution of speciated mercury for Unit 1 and Unit 3 as a percentage of the total emission rate (mg/hr). Averages reported for Unit 1 do not include results for Run 2 as discussed in Section 3.2.2.2.1. Results for individual test runs are presented in Appendix A.

In the case where mercury concentrations were below the Method Detection Limit (MDL) for a particular sample fraction, concentrations and emission rates were reported as "less than" (<) values. Although measurable quantities of elemental mercury were reported for the sample fractions containing impingers 5 through 7 (KMnO₄/H₂SO₄), the level of elemental mercury in the 4th impinger (HNO₃/H₂O₂) was below the MDL for all sample trains. Therefore the overall results for elemental mercury were reported as less than values.

3.3.3 Emission Control Device Removal Efficiency

The removal efficiency (RE) of the emission control equipment for speciated and total mercury was evaluated as part of the test program. RE calculations are based upon the emission rate measured for each of the speciated components at the ESP exhaust stack and the ESP inlet sample locations.

3.3.3.1 *Unit 1*

As would be expected, the control device for Unit 1 demonstrated a higher efficiency for the particulate bound fraction when compared to that achieved for the other two fractions measured. Particle bound mercury RE averaged 66.79% for the test program. RE for oxidized mercury (Hg^{2+}) was determined to be 6.58% and that of elemental (Hg^0) averaged 15.75%. The overall RE for mercury averaged 29.10%.

3.3.3.2 *Unit 3*

Similar to Unit 1, the control device for Unit 3 demonstrated a higher efficiency for the particulate bound fraction, averaging 76.46% for the test program. RE for oxidized mercury (Hg^{2+}) was determined to be 16.93%. The ESP system demonstrated no effective removal of elemental mercury (Hg^0). The overall RE for mercury averaged 31.92%.

3.3.4 Overall Process Removal Efficiency

The RE of the process for total mercury was evaluated as part of the test program. RE calculations are based upon the inflow of mercury to the system, based upon process monitoring, and the total mercury emission rate measured at the ESP exhaust stack. As shown in Table 3-3, the overall process RE for mercury averaged 15.01% for Unit 1. As shown in Table 3-4, the overall process RE for mercury averaged 33.27% for Unit 3.

TABLE 3-1. PG&E GEN BRAYTON POINT GENERATING STATION TEST MATRIX FOR UNITS 1 AND 3

Sampling Location	Sample/Type Pollutant	Sampling Method	Sampling Organization	No. of Trains at Location	No. of Runs Per Train	Sample Run Time (min)	Analytical Method	Analytical Laboratory
East Inlet to the ESP	Mercury speciated	Ontario Hydro (includes EPA M1, 2 & 4),	TRC	1	3	120	Ontario/Hydro & SW846, 7047A, CVAA	Philips Analytical Services
	O ₂ /CO ₂	M3B (Bag)	TRC	1	3	120	3B Orsat	TRC
West Inlet to the ESP	Mercury speciated	Ontario Hydro (includes EPA M1, 2 & 4),	TRC	1	3	120	Ontario/Hydro & SW846, 7047A, CVAA	Philips Analytical Services
	O ₂ /CO ₂	M3B (Bag)	TRC	1	3	120	3B Orsat	TRC
Exhaust Stack	Mercury Speciated	Ontario Hydro (includes EPA M1, 2 & 4)	TRC	1	3	120	Ontario/Hydro & SW846, 7470A, CVAA	Philips Analytical Services
	O ₂ /CO ₂	M3B (Bag)	TRC	1	3	120	3B Orsat	TRC
Coal Sampling	Sample	ASTM D2234-97a	PG&E Gen	-	3	120	ASTM 2013-86	Commercial Testing & Engineering
	Mercury Sulfur Chlorine GCV proximate moisture						D3684-94 D4234-92 D4208-88 D5865-98 D5142-90 D3302-97	

**TABLE 3-2. MEASUREMENTS CONDUCTED AT EACH TEST LOCATION
FOR UNITS 1 AND 3**

ESP Inlet East and West	ESP Exhaust Stack	Process
EPA-EMC - Pre-003 Speciated Mercury - Ontario Hydro	EPA-EMC - Pre-003 Speciated Mercury - Ontario Hydro	Coal Feed Sample
O ₂ /CO ₂ (M3B)	O ₂ /CO ₂ (M3B)	
Sampling Location & Traverse Points (M-1)	Sampling Location & Traverse Points (M-1)	
Velocity (M-2)	Velocity (M-2)	
Moisture (M-4)	Moisture (M-4)	

TABLE 3-3. SUMMARY TABLE OF EMISSIONS DATA AND REMOVAL EFFICIENCIES - UNIT 1

Method/ Component	Units	ESP Inlet ²					Outlet Stack					Inlet/Outlet Removal Efficiency					
		2	3	4	5	Avg ¹	2	3	4	5	Avg ¹	2	3	4	5	Avg ¹	
Ontario Hydro / Hg																	
Particle Bound	µg/dscm	2.22	1.60	2.06	1.69	1.78	0.0053				0.58	0.58					
	mg/hr	2,444	1,656	2,121	1,764	1,847	5.72				600	606					
Oxidized, Hg ²⁺	µg/dscm	3.61	2.66	2.91	0.04	2.76	4.19				2.46	2.56					
	mg/hr	3,793	2,735	2,965	2,862	2,854	4,486				2,530	2,656					
Elemental, Hg ⁰	µg/dscm	<0.35	<0.51	<0.39	<0.41	<0.44	<0.44				<0.38	<0.37					
	mg/hr	<379	<530	<412	<440	<461	<470				<394	<382					
Total, Hg	µg/dscm	<6.18	<4.77	<5.36	<4.82	<4.98	<4.64				<3.43	<3.51					
	mg/hr	<6,616	<4,921	<5,498	<5,066	<5,162	<4,962				<3,524	<3,645					

Method/Component	Units	Process Samples					Overall Process Removal Efficiency										
		2	3	4	5	Avg ¹	2	3	4	5	Avg ¹						
Coal Samples																	
Hg	µg/g	8.00E-02	5.00E-02	6.00E-02	5.00E-02	5.00E-02					24.78%	1.89%					
Hg Rate	mg/hr	6,597	4,082	4,817	4,069	4,323											
Sulfur	Wt %	0.83	0.73	0.76	0.76	0.75											
Chlorine	%	0.03	0.07	0.07	0.09	0.08											
HHV	Btu/lb	13,684	13,756	13,754	13,723	13,744											
Total Hg Feed Rate	mg/hr	6,597	4,082	4,817	4,069	4,323											

¹ - Reported Averages not inclusive of Run 2 data

² - Inlet emission rate mg/hr calculated based upon outlet volumetric flow rate

TABLE 3-4. SUMMARY TABLE OF EMISSIONS DATA AND REMOVAL EFFICIENCIES - UNIT 3

Method/ Component	Units	ESP Inlet ¹				Outlet Stack				Inlet/Outlet Removal Efficiency			
		2	3	4	Avg	2	3	4	Avg	2	3	4	Avg
<i>Ontario Hydro / Hg</i>													
Particle Bound	$\mu\text{g/dscm}$	2.25	1.40	1.10	1.58	0.54	0.62	<0.019	0.39				
	mg/hr	6,112	3,363	2,800	4,092	1,373	1,564	<47	994	77.54%	53.51%	98.33%	76.46%
Oxidized, Hg ²⁺	$\mu\text{g/dscm}$	2.63	2.40	2.56	2.53	2.19	1.59	2.48	2.09				
	mg/hr	6,399	6,118	6,419	6,312	5,589	4,007	6,185	5,263	12.65%	34.51%	3.64%	16.93%
Elemental, Hg ⁰	$\mu\text{g/dscm}$	<0.51	<0.52	<2.52	<1.18	<0.64	<0.48	<2.46	<1.19				
	mg/hr	<1302	<1,373	<6,315	<2,997	<1,618	<1,212	<6,138	<2,992	-24.31%	11.75%	2.80%	-3.25%
Total, Hg	$\mu\text{g/dscm}$	<5.39	<4.31	<6.18	<5.30	<3.37	<2.69	<4.96	<3.67				
	mg/hr	<13,812	<10,854	<15,534	<13,400	<8,850	<6,782	<12,370	<9,244	37.88%	37.52%	20.36%	31.92%

Method/Component	Units	Process Samples				Overall Process Removal Efficiency			
		2	3	4	Avg	2	3	4	Avg
<i>Coal Samples</i>									
Hg	$\mu\text{g/g}$	1.0E-01	7.0E-02	7.0E-02	8.0E-02	50.61%	42.39%	6.79%	33.27%
Hg Rate	mg/hr	17,373	11,773	13,272	14,139				
Sulfur	Wt %	0.69	0.74	0.75	0.73				
Chlorine	%	0.09	0.11	0.09	0.10				
HHV	Btu/lb	12,714	12,703	13,037	12,818				
Total Hg Feed Rate	mg/hr	17,373	11,773	13,272	14,139				

¹ - Inlet emission rate mg/hr calculated based upon outlet volumetric flow rate

TABLE 3-5. SUMMARY TABLE OF EMISSIONS DATA - UNIT 1

Method/Component	Units	ESP Inlet ²					Outlet Stack								
		2	3	4	5	Avg ¹	2	3	4	5	Avg ¹				
<i>Ontario Hydro / Hg</i>															
Particle Bound	lb/hr	5.32E-03	3.60E-03	4.62E-03	3.84E-03	4.02E-03	1.24E-05	1.32E-03	1.31E-03	1.33E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03
	lb/MMBtu	4.36E-06	2.87E-06	3.73E-06	3.07E-06	3.22E-06	5.13E-09	5.64E-07	5.40E-07	5.48E-07	5.64E-07	5.40E-07	5.48E-07	5.45E-07	5.45E-07
Oxidized, Hg ²⁺	lb/hr	8.25E-03	5.95E-03	6.45E-03	6.23E-03	6.21E-03	9.76E-03	6.37E-03	5.50E-03	5.24E-03	6.37E-03	5.50E-03	5.24E-03	5.78E-03	5.78E-03
	lb/MMBtu	6.89E-06	4.77E-06	5.25E-06	4.98E-06	5.00E-06	4.02E-06	2.74E-06	2.27E-06	2.15E-06	2.74E-06	2.27E-06	2.15E-06	2.39E-06	2.39E-06
Elemental, Hg ⁰	lb/hr	<8.25E-04	<1.15E-03	<8.97E-04	<9.57E-04	<1.00E-03	<1.02E-03	<8.01E-04	<8.58E-04	<8.38E-04	<8.01E-04	<8.58E-04	<8.38E-04	<8.32E-04	<8.32E-04
	lb/MMBtu	<6.79E-07	<9.12E-07	<7.12E-07	<7.69E-07	<7.97E-07	<4.22E-07	<3.32E-07	<3.55E-07	<3.44E-07	<3.32E-07	<3.55E-07	<3.44E-07	<3.44E-07	<3.44E-07
Total, Hg	lb/hr	<1.44E-02	<1.07E-02	<1.20E-02	<1.10E-02	<1.12E-02	<1.08E-02	<8.71E-04	<7.67E-03	<7.41E-03	<8.71E-04	<7.67E-03	<7.41E-03	<7.93E-03	<7.93E-03
	lb/MMBtu	<1.19E-05	<8.55E-06	<9.70E-06	<8.82E-06	<9.02E-06	<4.45E-06	<3.61E-06	<3.17E-06	<3.05E-06	<3.61E-06	<3.17E-06	<3.05E-06	<3.28E-06	<3.28E-06

¹ - Reported Averages not inclusive of Run 2 data

² - Inlet emission rate lb/hr calculated based upon outlet volumetric flow rate

TABLE 3-6. SUMMARY TABLE OF EMISSIONS DATA - UNIT 3

Method/Component	Units	ESP Inlet ¹				Outlet Stack							
		2	3	4	Avg	2	3	4	Avg				
<i>Ontario Hydro / Hg</i>													
Particle Bound	lb/hr	1.33E-02	7.32E-03	6.09E-03	8.90E-03	2.99E-03	3.40E-03	<1.02E-04	2.16E-03				
	lb/MMBtu	4.58E-06	2.61E-06	2.00E-06	3.07E-06	5.59E-07	6.88E-07	<1.86E-08	4.22E-07				
Oxidized, Hg ²⁺	lb/hr	1.39E-02	1.33E-02	1.40E-02	1.37E-02	1.22E-02	8.72E-03	1.35E-05	1.14E-02				
	lb/MMBtu	5.20E-06	4.48E-06	4.65E-06	4.78E-06	2.28E-06	1.76E-06	2.45E-06	2.16E-06				
Elemental, Hg ⁰	lb/hr	<2.83E-03	<2.99E-03	<1.37E-03	<6.52E-03	<3.52E-03	<2.64E-03	<1.34E-02	<6.50E-03				
	lb/MMBtu	<1.02E-06	<9.69E-07	<4.57E-06	<2.19E-06	<6.59E-07	<5.33E-07	<2.43E-06	<1.21E-06				
Total, Hg	lb/hr	<3.01E-02	<2.36E-02	<3.38E-02	<2.92E-02	<1.87E-02	<1.48E-02	<2.69E-02	<2.01E-02				
	lb/MMBtu	<1.08E-05	<8.06E-06	<1.12E-05	<1.00E-05	<3.49E-06	<2.99E-06	<4.91E-06	<3.80E-06				

¹ - Inlet emission rate lb/hr calculated based upon outlet volumetric flow rate

TABLE 3-8. DISTRIBUTION OF SPECIATED MERCURY EMISSIONS - UNIT 3

Method/ Component	Units	ESP Inlet ¹				ESP Exhaust Stack				Inlet/Outlet Removal Efficiency				
		2	3	4	Avg ¹	2	3	4	Avg ¹	2	3	4	Avg ¹	
<i>Ontario Hydro / Hg</i>														
Particle Bound	mg/hr	6,112	3,363	2,800	4,092	1,373	1,564	<47	994					
	% of Total	44%	31%	18%	31%	16%	23%	0%	13%	77.54%	53.51%	98.33%		76.46%
Oxidized, Hg ²⁺	mg/hr	6,399	6,118	6,419	6,312	5,589	4,007	6,185	5,260					
	% of Total	46%	56%	41%	48%	65%	59%	50%	58%	12.65%	34.51%	3.64%		16.93%
Elemental, Hg ⁰	mg/hr	<1302	<1,373	<6,315	<2,997	<1,618	<1,212	<6,138	<2,989					
	% of Total	9%	13%	41%	21%	19%	18%	50%	29%	-24.31%	11.75%	2.80%		-3.25%
Total, Hg	mg/hr	<13,812	<10,854	<15,534	<13,400	<8,850	<6,782	<12,370	<9,244	37.88%	37.52%	20.36%		31.92%

¹ - Inlet emission rate mg/hr calculated based upon outlet volumetric flow rate

SECTION 4.0 SAMPLING AND ANALYTICAL PROCEDURES

4.1 OVERVIEW

This section describes the procedures that TRC followed during the field sampling program. Throughout the program TRC followed 40 CFR, Part 60, Appendix A Methods and USEPA Preliminary Approved Sampling Protocols.

The remainder of this section is divided into several subsections: Field Program Description; Presampling Activities, Onsite Sampling Activities, Process Monitoring, Analytical Procedures, and Calculations.

The following test methods were utilized:

- EPA EMC Pre-003 Draft Standard Test Method for Elemental, Oxidized, Particle Bound Mercury Emissions in Flue Gas Generated From Coal-Fired Stationary Sources (Ontario Hydro Method) 7/7/99 revision.
- EPA Method 1 Sample Velocity Traverse for Stationary Sources
- EPA Method 2 Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S pitot tube)
- EPA Method 3B Gas Analysis for the Determination of Emission Rate Correction Factor or Excess Air
- EPA Method 4 Determination of Moisture Content in Stack Gases
- ASTM D2234-97a Standard Practice For the Collection of Representative Samples of Coal

4.2 PRESAMPLING ACTIVITIES

Presampling activities included equipment calibration, precleaning of the sample train glassware, and other miscellaneous tasks. Each of these activities are described or referenced in the following subsections. Other presampling activities included team meetings, equipment packing, and finalization of all details leading up to the coordinated initiation of the sampling program.

4.2.1 Equipment Calibration

See Section 5.0, Quality Assurance and Quality Control, of this Final Report.

4.2.2 Glassware Preparation

The sample train glassware and sample containers required specialized precleaning to avoid contamination of the sample from the collection container or devices.

The Ontario Hydro sampling train glassware was precleaned with analconox soap and water wash. The glassware was rinsed with tap water, followed by three additional rinses with deionized water. The glassware was then soaked in a 10 percent nitric acid solution for 4 hours, rinsed three times with deionized water, and a final rinse with acetone. The glassware was then air dried and sealed with parafilm.

4.3 ONSITE SAMPLING ACTIVITIES

Onsite sampling activities included equipment set up and conducting simultaneous testing of the ESP inlets and the exhaust stacks for Unit 1 and subsequently for Unit 3.

4.3.1 EPA Methods 1 and 2 for Velocity Measurements and Cyclonic Flow

Velocity traverses were conducted at all sampling locations with an S-type pitot assembly in

accordance with 40 CFR Part 60, Appendix A, Method 1 "*Sample and Velocity Traverses for Stationary Sources*" and Method 2 "*Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)*". An S-type pitot tube with an attached inclined manometer was used to measure the gas velocities. An attached Type-K thermocouple with a remote digital display was used to determine the flue gas temperature. During the test program, velocity measurements were conducted during each test run at each sampling location. The required number of velocity measurement points for each sampling location was determined following EPA Method 1.

Cyclonic flow checks were conducted at each sampling location prior to sampling in accordance with Section 2.4 of EPA Method 1. This procedure is referred to as the nulling technique. An S-type pitot tube connected to an inclined manometer was used in this method. The pitot tube was positioned at each traverse point so that the face openings of the pitot tube were perpendicular to the stack cross-sectional plane. This position is called the "0° reference". The velocity pressure (ΔP) measurement was noted. If the ΔP reading was zero, the cyclonic angle was recorded as 0°. If the ΔP reading was not zero, the pitot tube was rotated clockwise or counter clockwise until the ΔP reading became zero. This angle was then measured with a leveled protractor and reported to the nearest degree. After this null technique was applied at each traverse point, the average of the cyclonic angles was calculated. If this average was less than 20°, the flow condition in the source was acceptable to test.

4.3.2 EPA Method 4 for Moisture

Moisture was determined for each test run according to EPA Reference Method 4, "*Determination of Moisture Content in Stack Gases*," as an integral part of the Ontario Hydro Method. The principle of this method is to remove the moisture from the sample stream and determine the moisture either volumetrically or gravimetrically.

Prior to the test program, a preliminary Method 4 was conducted at each sampling location to determine moisture and allow for the calculation of isokinetic sampling ratios. This sampling train used a glass lined probe with a thermocouple and S-type pitot tube attached to the probe for the

measurement of gas temperature and velocity. The sample gas passed through a series of four ice-cooled impingers kept below 68°F to enable condensation of entrained moisture. The first two impingers contained 100 mL of deionized water. The third impinger was empty and the fourth impinger contained a preweighed amount of silica gel. The impingers were followed by a dry gas meter, pump, and calibrated orifice meter. All impingers were weighed prior to the setup of the train.

Leak checks of the entire Method 4 sampling trains were performed before and after each sampling run. All leak checks and leakage rates were documented on the relevant field test data sheet. The acceptance criterion for the Method 4 train was a leak rate of ≤ 0.02 cfm at the highest vacuum obtained during the run.

Following the completion of the preliminary test run, the Method 4 train was transported to a recovery area onsite. The sample recovery sequence was as follows:

- Removed the sampling train to the recovery area;
- Noted the condition of the train (i.e., impinger contents color, silica gel color, etc.); and
- The final weight of all impingers were obtained.

4.3.3 Ontario Hydro Mercury Speciation Train (EPA EMC Pre-003)

Speciated mercury (Hg) was determined at the ESP inlets and the ESP exhaust stack for Units 1 and 3 via EMC Pre-003 "*Draft Standard Test Method for Elemental, Oxidized, Particle Bound, and Total Mercury Emissions in the Flue Gas Generated From Coal Fired Stationary Sources (Ontario Hydro Method)*". The description of the sampling and analytical methodology in this section is based on the draft method released July 7, 1999.

The exhaust stack sampling train consisted of a heated stainless steel, glass-lined probe with a glass button-hook nozzle. A thermocouple and S-type pitot tube were attached to the probe for

the measurement of gas temperature and velocity. At the stack sampling location, the probe and sampling train were oriented in a horizontal position as shown in Figure 4-1.

The ESP inlet sampling locations required that the probe be in a vertical sampling configuration and that a cyclone and flask be placed in front of the filter holder as shown in Figure 4-2. The probe was attached to the hot box as shown in the diagram and the exit of the filter holder was connected to the impinger train by a heated teflon sample line. The connections to the heated line consisted of teflon fittings and a glass socket joint.

The sample gas passed through the probe assembly to a heated tared glass fiber filter, on a Teflon filter support, contained in a borosilicate filter holder. The probe and the gases exiting the filter holder were maintained at either the stack temperature $\pm 21^\circ\text{F}$ or at $248^\circ\text{F} \pm 25^\circ\text{F}$ whichever was greater. Downstream of the heated filter, the sample gas passed through a series of eight ice bath cooled impingers, kept below 68°F to enable condensation of entrained moisture and the gaseous mercury species. The first, second and third impingers each contained 100 mL of a 1N KCl solution. The fourth impinger contained 100 mL of a 5% HNO_3 /10% H_2O_2 solution. The fifth, sixth, and seventh impingers each contained 100 mL of a 4% KMnO_4 /10% H_2SO_4 solution. The eighth impinger contained 200 - 400 gms of silica gel. All filled impingers were weighed prior to placing the impingers in the train. The impingers were followed by a leak free pump, dry gas meter and calibrated orifice meter.

The first, second, fourth, sixth, and eighth impingers were of the Modified Greenburg design. The third, fifth and seventh impingers were standard Greenburg Smith impingers. No silicone grease was used in the train.

Sampling was isokinetic ($\pm 10\%$) with a sample volume of between 35.31 and 88.25 dscf (1-2.5 dscm) collected. All stack and train operating parameters were recorded at each sampling point.

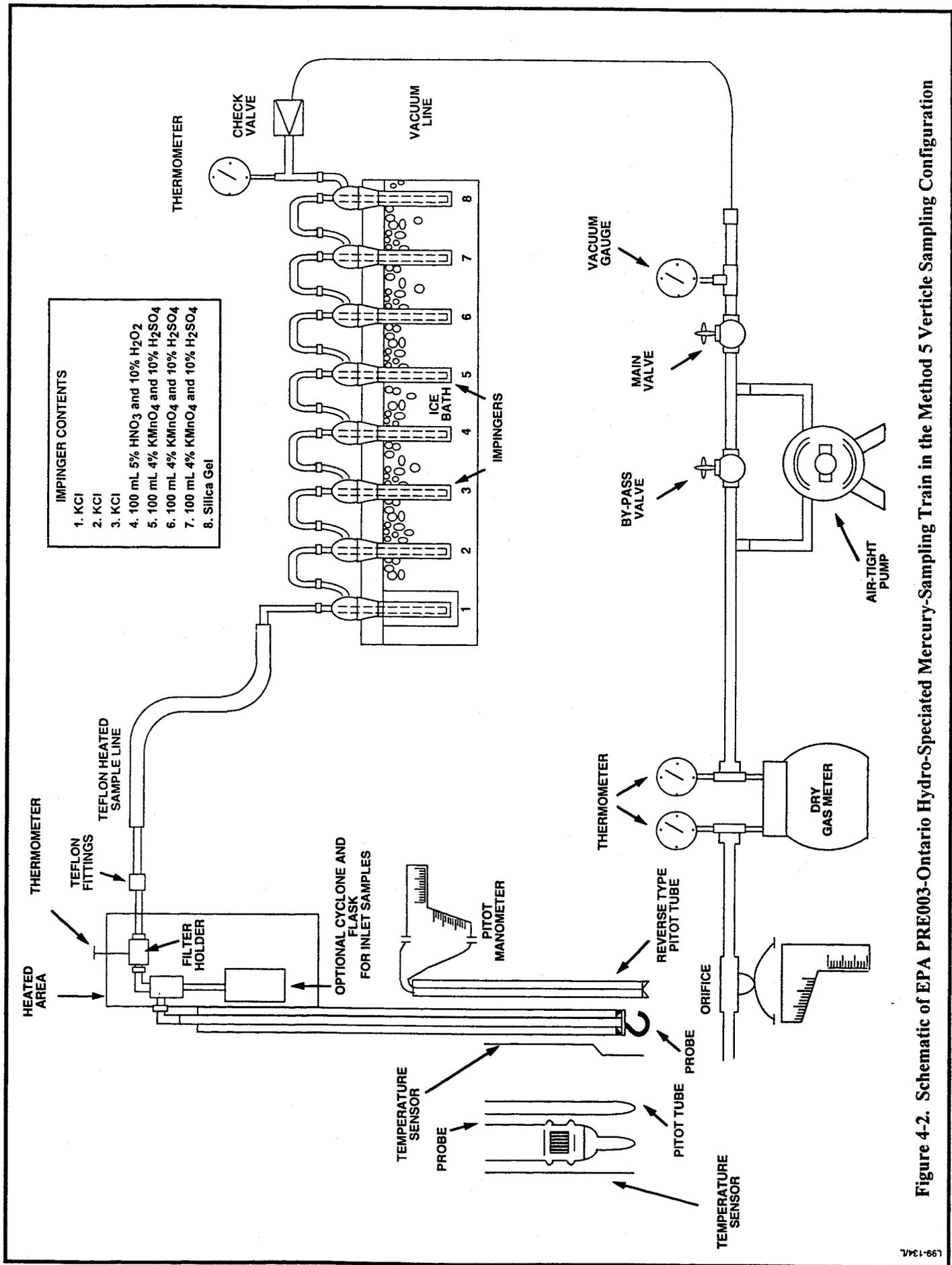


Figure 4-2. Schematic of EPA PRE003-Ontario Hydro-Speciated Mercury-Sampling Train in the Method 5 Verticle Sampling Configuration

The sampling duration for each unit was as follows:

Unit 1:

- At the west inlet location, the sampling duration at each point was 6.5 minutes, for a total of 156 minutes for the 24-point traverse.
- At the east inlet location, the sampling duration at each point was five minutes, for a total of 160 minutes for the 32-point traverse
- At the stack location, the sampling duration at each point was 10 minutes, for a total of 160 minutes for the 16-point traverse.

Unit 3:

- At the west inlet location, the sampling duration at each point was five minutes, for a total of 160 minutes for the 32-point traverse.
- At the east inlet location, the sampling duration at each point was 3.5 minutes for a total of 154 minutes for the 44-point traverse.
- At the stack location the sampling duration at each point was 10 minutes for a total of 160 minutes for a 16-point traverse.

Leak checks of the entire Ontario Hydro sampling trains were performed before and after each sampling run. All leak checks and leakage rates were documented on the relevant field test data sheets. The acceptance criterion was a post run leak rate of ≤ 0.02 cfm at the highest vacuum obtained during the test run. The pre run leak check criterion was ≤ 0.02 cfm at 15 in Hg.

Following the completion of each test run, the Ontario Hydro train was transported to a recovery area onsite. The sample recovery sequence was as follows:

- All openings on the probe, inlet to cyclone/or filter holder and impingers were sealed with teflon tape.
- The sampling train was removed to the recovery area.
- The condition of the train was noted (i.e., filter, impinger contents color, silica gel color, etc.).

- Container No. 1 - Disassembled the filter housing and transferred the filter to its original glass petri dish. Sealed the petri dish with Teflon[®] tape and labeled it with the appropriate sample information. Any filter fibers adhering to the support gasket were transferred to the petri dish.
- Container 1B - The ash collected in the cyclone/flask from the inlet trains was transferred to a 250 mL amber wide mouth bottle. The bottle was sealed with teflon tape and labels.
- Container No. 2 - The front half of the train, nozzle, probe, and front-half filter housing, cyclone and flask were brush-rinsed with 100 mL of 0.1N nitric acid into an amber glass container with a Teflon[®]-lined cap. The container was sealed and labeled.
- Container No. 3 - The contents of the first three KCl impingers were weighed. The filter support, backhalf of the filter holder and connecting glassware were rinsed with 0.1 N HNO₃ into a glass amber container with a Teflon lined cap. The 5% KMnO₄ solution was added to each impinger until a purple color remained. The solutions were then poured into the container. The impingers and connecting glassware were rinsed with 10% HNO₃. Although unlikely, if deposits remained on the impinger surfaces, they were removed by doing another 10% HNO₃ rinse that had a very small amount (several drops) of 10% hydroxylamine sulfate solution added to each of the KCl impingers. These rinses were added to Container 3. If the solution in Container 3 became clear, a small amount of the 5% KMnO₄ solution was added until a pink or slightly purple color was obtained. Checked again after 90 minutes to ensure that the purple color remained. Performed a final rinse of the impingers and connecting glassware with 0.1 N HNO₃ and added this rinse to Container 3. The container was sealed and labeled.
- Container No. 4 - The contents of the fourth impinger were weighed and transferred to a glass amber container with a Teflon[®]-lined cap. The impinger and U-tubes were rinsed twice with three 25 mL portions of 0.1N nitric acid into a sample container. The container was sealed and labeled.
- Container No. 5 (Impingers 5 through 7, H₂SO₄/KMnO₄ Impinger Contents and Rinses) - Dried the exterior surfaces of Impingers 5, 6, and 7. Then weighed and recorded the weight of each impinger (to the nearest 0.5 g). Poured all of the liquid from the three H₂SO₄-KMnO₄ impingers into a glass sample, Container 5. Rinsed the impingers and connecting glassware with a 0.1 N HNO₃. If deposits remained on the impinger surfaces, after the two rinses, removed them by doing a third rinse with 0.1 N HNO₃ and several drops hydroxylamine sulfate. On a drop by drop basis added more hydroxylamine sulfate until the deposits were removed. Added these rinses to Container 5. If the solution in Container 5 became clear, added small amounts of H₂SO₄-KMnO₄ solution until a pink or slightly purple color was obtained. Performed a final 0.1 N HNO₃ rinse of the impingers and connecting glassware followed by a water rinse. The 0.1 N HNO₃ rinse was added to Container 5, and the water rinse was discarded. The container was sealed and labeled.

- The silica gel impinger was weighed to obtain a final weight.
- Solution Blanks (Containers 6 thru 10) - Solution blanks were taken each time new reagents were prepared.
- Container 6 - (0.1 N HNO₃ Blank) - Placed 50 mL of the 0.1 N HNO₃ solution used in the sample recovery process into a properly labeled container. Sealed the container.
- Container 7 (1 N KCl Blank) - Placed 50 mL of the 1 N KCl solution used as the impinger solution into a properly labeled container. Sealed the container.
- Container 8 (5% HNO₃ - 10% v/v H₂O₂ Blank) - Placed 50 mL of the HNO₃-H₂O₂ solution used as the nitric acid impinger reagent into a properly labeled container. Sealed the container.
- Container 9 (H₂SO₄ - KMnO₄ Blank) - Placed 50 mL of the H₂SO₄ - KMnO₄ solution used as the impinger solution in the sample recovery process into a properly labeled container. Refer to Note 4 in Section 13.2.10.5 of this method.
- Container 10 (10% Hydroxylamine Sulfate Blank) - Placed 100 mL of hydroxylamine sulfate solution into a properly labeled sample container. Sealed the container.
- Container 11 (Sample Filter Blank) - Once during each field test, placed into a properly labeled petri dish three unused blank filters from the same lot as the sampling filters. Sealed the petri dish.
- All containers were checked to ensure proper sealing, proper labeling, and that all liquid levels were marked. All samples were logged onto a chain-of-custody record.

The Ontario Hydro train produced the following samples:

- Container No. 1 - Filter
- Container No. 1B - Ash (Inlet only)
- Container No. 2 - Front-Half 0.1N HNO₃ Rinse
- Container No. 3 - Impingers 1, 2 & 3 KCl Impinger Catch & Rinse
- Container No. 4 - Impinger 4 - 0.1N HNO₃ Impinger Catch & Rinse
- Container No. 5 - Impingers 5 - 7 - KMnO₄ Impinger Catch & Rinse

4.3.4 EPA Method 3B for O₂ and CO₂

The O₂ and CO₂ concentrations in the integrated bag sample were analyzed onsite within four hours of the completion of the run with an Orsat analyzer as per EPA Method 3B, "*Gas Analysis for the Determination of Emission Rate Correction Factor or Excess Air*". Three or more passes were made until three results were within 0.2% (absolute) of each other.

4.3.5 Process Sampling

4.3.5.1 Coal Sampling

An integrated composite sample of the "as-fired" coal was obtained during each sampling run according to ASTM D-2234-97.

The subsamples were obtained from each of the four coal silos every 30 minutes. A concentric slotted tube sampler (grain thief) was inserted into the port, the outer tube was twisted to the open position and the coal filled the slots. The outer tube was twisted closed and the sample was removed. The collected sample was placed in a five gallon plastic bucket and covered. Each subsample consisted of three grab samples from two of the three sampling ports. A subsample was obtained from each silo every 30 minutes. At the end of the run, the composite samples from all silos were combined by riffing into one composite sample.

The composite sample was reduced at the analytical laboratory by riffing to an analytical and reserve sample at about 5 pounds each.

4.4 PROCESS MONITORING

The facility operations data acquisition system (DAS) was utilized to record all operations data at one minute intervals. The data was averaged over the entire run period. Coal feed was also totalized over the run.

Operations data collected by the facility is incorporated in Appendix G. The following process data was obtained.

Coal feeders	feed rate K lb/hr and totalizer reading for each feeder.
Electrical generation	KW
Main steam flow	K lb/hour
Main steam temp.	°F
Main steam pressure	PSIG
Reheater steamer flow	K lb/hr
Feed water flow	K lb/hr
Furnace draft	in H ₂ O
Wind box pressure	in H ₂ O
Air heater temperature	in °F, out °F
Gas recirculation rate	%
Mills in operation	Total #
Burners in operation	Total #
Combustion air flow	K lb/hr
Furnace and stack O ₂ /CO	%, ppm
ESP temp.	°F
ESP Δp	in H ₂ O
ESP operations data for each TR set	
	PV - Primary volts
	PA - Primary amps
	SV - Secondary volts
	SA - Secondary amps

4.5 ANALYTICAL PROCEDURES

4.5.1 Mercury - Ontario Hydro Train Fractions

The Ontario Hydro train sample fractions samples were prepared according to Pre-003 and were analyzed for mercury by following the procedures in SW-846 Method 7470A. A schematic of the analytical process is shown in Figure 4-3.

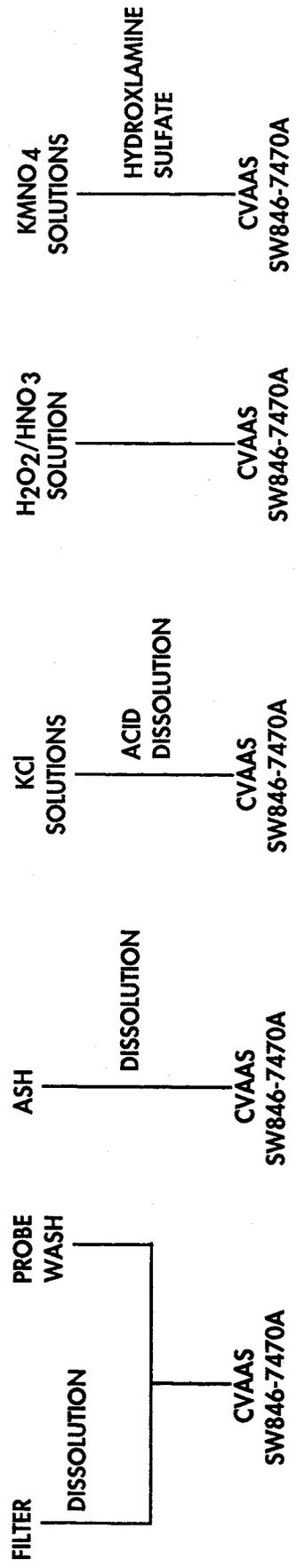


Figure 4-3. Analytical Scheme for Ontario-Hydrotrain Mercury Analysis

The sampling train components were recovered and digested in the separate fractions. Materials collected in the sampling train were digested with acid solutions to dissolve inorganics and to remove organic constituents that may create analytical interferences. Acid digestion was performed using conventional or microwave digestion techniques.

All acid digested sample train fractions were analyzed for mercury by cold vapor atomic absorption spectroscopy (CVAAS) (SW 846 7470A).

4.5.2 Coal Analyses

The samples were analyzed for sulfur, mercury, chlorine, total moisture, proximate analysis, and gross calorific value (GCV) by the methods delineated below. A schematic of the analytical process is shown in Figure 4-4.

Coal Sampling and Analysis

- ASTM D2234-97a Standard Practice for the Collection of Representative Samples of Coal.
- ASTM D2013-86 (1994) Standard method for Preparing Coal samples for Analysis.
- ASTM D3684-94 Standard Test Method for Total Mercury in Coal by the Oxygen Bomb Combustion /Atomic Absorption Method.
- ASTM D4208 -88 Standard Test Method for Chlorine in Coal by the Oxygen Bomb Combustion/Ion Selective Electrode Method.
- ASTM D3302-97a Standard Test Method for Total Moisture in Coal.
- ASTM D5142-90 Standard Test Method for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures.
- ASTM D 4239-97 Standard Test Methods for Sulfur in the Analysis Sample of Coal and Coke Using High Temperature Tube Furnace Combustion Methods.
- ASTM D 5865-98 Standard Test Method for Gross Calorific Value Of Coal and Coke
- EPA SW846 7470A Mercury in Liquid Waste (Manual Cold Vapor Technique).
- EPA SW846 7471A Mercury in Solid or Semi-Solid Waste (Manual Cold Vapor Technique).

COMPOSITE COAL SAMPLE
 PREPARATION AND MOISTURE DETERMINATION
 ASTM D2013 AND D3302

DRY COAL SUBSAMPLES

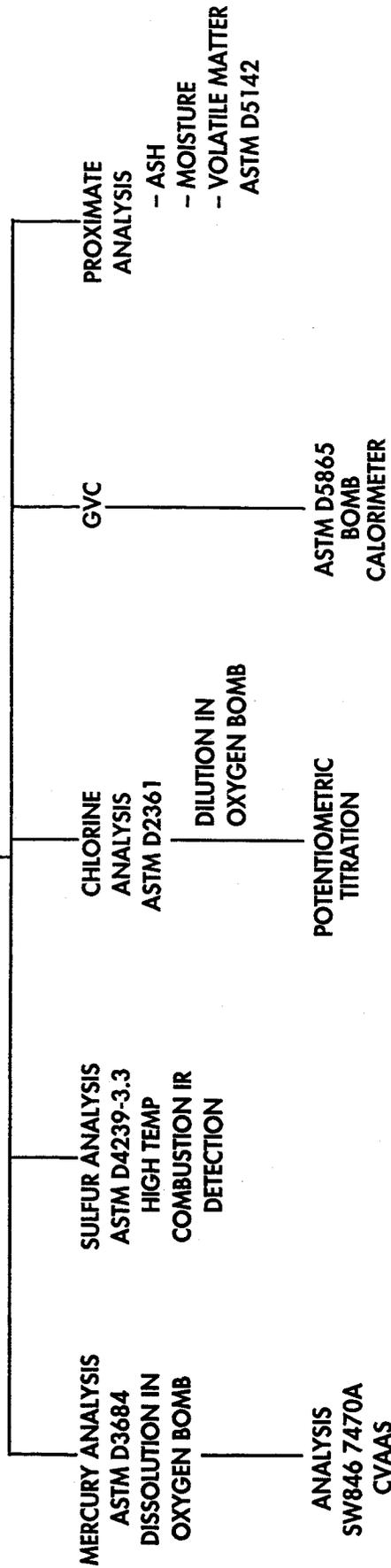


Figure 4-4. Coal Sample Analytical Scheme

4.6 CALCULATIONS

4.6.1 Flowrates and Isokinetics

The sequential calculations for the determination of gas velocity at stack conditions (afpm), gas volumetric flow rate at stack conditions (acfm), and gas volumetric flow rate at standard conditions (dscfm), and isokinetics found in 40 CFR 60 Appendix A Methods 1-5 are presented below.

Calculations for Stack Volume and Isokinetic Ratio

Time =	TT	T
Dry Gas Meter, ft ³ =	VM	
Pitot ΔP , in. H ₂ O =	ΔP	
Orifice ΔH , in. H ₂ O =	PM	
Dry Gas Temp In, °F =	TMI	
Dry Gas Temp Out, °F =	TMO	
Stack Static Pressure, in. H ₂ O =	PST	
Stack Temp, °F =	TS	

1. DN = Nozzle Diameter, inches

2. PB = Barometric Pressure, inches Hg

3. TT = Net Sampling Time, minutes

4. VM = VM final - VM initial = Sample Gas Volume, ft³

4A. VML = Use only if any final or intermediate leak check rate is over 0.02 cfm

LI = Leak rate after any given sampling period, cfm

TLI = Total time of sample period in which leak occurred, minutes

VML = VM - [(L1 - 0.02) TLI + (L2 - 0.02) TL2 + (L3 - 0.02) TL3 + (L4 - 0.02) TL4] =

5. Average Dry Gas Temperature at meter, °F

$$TM = \frac{\text{Average TMI} + \text{Average TMO}}{2}$$

6. Average Orifice Pressure Drop, inches Hg

$$PM = \frac{\text{Average } \Delta H, \text{ in. H}_2\text{O}}{13.6}$$

7. Volume of dry gas sampled at standard conditions, dscf^a

$$VMSTD = \frac{528 \times (Y) \times (VM) \times (PB + PM)}{29.92 \times (TM + 460)}$$

Y = dry gas meter calibration factor

8. Total Water Collected

$$VW = \text{gm H}_2\text{O silica gel} + \text{gm impinger H}_2\text{O}$$

Note: If ml H₂O is measured - (ml × 0.9982 gm/ml = ____ gm)

9. Volume of water vapor at standard conditions, scf^b

$$VW_{\text{gas}} = 0.04715 \times VW$$

10. Percent moisture in stack gas

$$\% M = \frac{100 \times VW_{\text{gas}}}{VMSTD + VW_{\text{gas}}}$$

10a. Percent moisture in stack gas - saturation (wet bulb/dry bulb method)

$$\% M = \frac{VP}{PS} \times 100$$

PS = Stack Pressure, absolute, inches Hg = PB ± Avg PST

PST = Stack static pressure

$$PST = \frac{\text{PST in. H}_2\text{O}}{13.6}$$

PS = PB ± Average PST

TS_{dry} = Stack Temperature, dry

TS_{wet} = Stack Temperature, wet

Note: When TS_{dry} = TS_{wet}, the gas stream is saturated

SVP = water saturation vapor pressure at TS_{wet}

$$VP = SVP - \left[0.00367 \times (PS) \times (TS_{dry} - TS_{wet}) \times \left(1 + \left(\frac{TS_{wet} - 32}{1571} \right) \right) \right]$$

11. Mole Fraction of dry gas (dimensionless)

$$MD = \frac{100 - \%M}{100}$$

Note: The proper %M must be used in this calculation. The % vapor moisture can never be greater than the saturation value at given stack temperature. If 10 is greater than 10a, this is an indication of water droplets in the gas stream.

If $10 < 10a$ - use 10 %M in calculation

If $10 > 10a$ - use 10a %M in calculation

12. Molecular weight of dry stack gas

$$MWD = (\% CO_2 \times 0.44) + (\% O_2 \times 0.32) + [(\% CO + \% N_2) \times 0.28]$$

- 12a. % Excess Air

$$\%EA = \frac{[(\% O_2) - 0.5 \times (\% CO)] \times 100}{[(0.264) \times (\% N_2)] - (\% O_2) + 0.5 \times (\% CO)}$$

13. Molecular Weight of wet stack gas

$$MW = (MWD \times MD) + 18 \times (1 - MD)$$

14. AS = Stack Area, square inches

$$\text{Circular} = \left(\frac{\text{stack diameter}}{2} \right)^2 \pi$$

$$\text{Rectangular} = \text{Length} \times \text{Width}$$

15. PS = Stack Pressure, absolute, inches Hg = PB ± Avg PST

PST = Stack static pressure

$$PST = \frac{PST \text{ in. H}_2\text{O}}{13.6}$$

$$PS = PB \pm \text{Average PST}$$

16. TS_{avg} = Average Stack Temperature

$$17. \quad SDE_{avg} = \left(\sqrt{\Delta P} \right)_{avg} \times \sqrt{TS_{avg} + 460}$$

18. Stack gas velocity at stack conditions, afpm

$$VS = 5130^c \times C_p \times SDE_{avg} \times \left[\frac{1}{PS \times MW} \right]^{1/2}$$

C_p = pitot tube coefficient

19. Stack gas volumetric flow rate at stack conditions, acfm

$$Q_a = \frac{VS \times AS}{144}$$

20. Stack gas volumetric flow rate at standard conditions, dscfm^e

$$Q_s = \frac{Q_a \times 528 \times MD \times PS}{(29.92) \times (TS_{avg} + 460)}$$

21. Percent Isokinetics

$$\%ISO = \frac{1039^f \times (TS_{avg} + 460) \times VMSTD}{VS \times TT \times PS \times MD \times (DN)^2}$$

^a = Dry standard cubic feet at 68°F (528°R) and 29.92 in. Hg

^b = Standard conditions at 68°F (528°R) and 29.92 in.Hg

$$^c = 5130 = \frac{\text{ft}}{85.5 \text{ sec}} \left[\frac{(\text{lb/lb-mole}) \times (\text{in. Hg})}{(^{\circ}\text{R}) \times (\text{in. H}_2\text{O})} \right] \times 60 \text{ sec/min}$$

^d = Actual cubic feet per minute

^e = Dry standard cubic feet per minute at 68°F (528°R) and 29.92 in.Hg

$$^f = 1039 = \frac{29.92 \text{ in. Hg}}{528^{\circ}\text{R}} \times \frac{144 \text{ in.}^2}{\text{ft}^2} \times \frac{4}{\pi} \times 100$$

4.6.1.1 *Determination of Time Weighted Nozzle Diameter (Use of Multiple Nozzles)*

The following equation was utilized to determine the time weighted average nozzle diameter:

$$DN_{TW} = \left(\frac{DN_1 \times TimeDN_1}{TotalTime} \right) + \left(\frac{DN_2 \times TimeDN_2}{TotalTime} \right)$$

The time weighted nozzle diameter was then utilized in the subsequent determination of the sample train isokenetic ratio.

4.6.2 Calculation for Particle Bound, Oxidized, Elemental and Total Mercury Concentrations

The calculations for mercury species (i.e., as collected by the Ontario Hydro Sampling Train) are presented below. These are excerpted from Method Pre-003.

4.6.2.1 Particle-Bound Mercury

4.6.2.1.1 Case 1: Amount of Ash on the Filter is Greater Than 0.5 g

Calculate the concentration of mercury in ug/g in the ash sample (Hg_{ash}) using Equation 8:

$$Hg_{ash}, \mu g / g = (IR)(DF) \quad [Eq. 8]$$

where:

IR = instrument reading, $\mu g/L$

DF = dilution factor = (total digested volume, L)/(mass of ash digested, g)

Calculate the amount of mercury in the probe rinse (Hg_{pr} , Container 2) in μg using Equation 9:

$$Hg_{pr}, \mu g = (IR)(V_1) \quad [Eq. 9]$$

where:

IR = instrument reading, $\mu\text{g/L}$

V_1 = total volume of probe rinse sample from which sample aliquot was taken, L.

Calculate the amount of mercury on the sample filter blank (Hg_{fb}) in the same way using Equation 10:

$$\text{Hg}_{fb}, \mu\text{g} = (\text{IR})(V_2) \quad [\text{Eq. 10}]$$

where:

IR = instrument reading, $\mu\text{g/L}$

V_2 = total volume of sample filter blank digest, L.

The total amount of particle-bound mercury (Hg_{ip}) then is determined using Equation 11:

$$\text{Hg}(\text{particle}), \text{mg} = (\text{Hg}_{ash})(W_{ash}) - \text{Hg}_{fb} + \text{Hg}_{pr} \quad [\text{Eq. 11}]$$

where:

W_{ash} = the total ash weight on filter, g

The concentration of particle-bound mercury ($\mu\text{g/dscm}$) in the gas stream is then determined using Equation 12:

$$\text{Hg}^{tp}, \mu\text{g/dscm} = \text{Hg}(\text{particle}) / V_{m(\text{std})} \quad [\text{Eq. 12}]$$

where:

$V_{m(\text{std})}$ = total volume of dry gas sampled at standard (normal) conditions, dscm

4.6.2.1.2 Case 2: Amount of Ash on the Filter is Less than 0.5 g

The calculation is the same as in Case 1 except the entire sample (ash and filter) is digested; therefore, DF in Equation 8 is defined only by the total digested volume. Equations 9-11 remain the same.

4.6.2.2 Oxidized Mercury

4.6.2.2.1 KCl Solution (Impingers 1-3)

Calculate the concentration of mercury in $\mu\text{g/L}$ in the KCl impinger solutions using Equation 13:

$$\text{Hg}_{\text{KCl}}, \mu\text{g/L} = (\text{IR})(\text{DF}) \quad [\text{Eq. 13}]$$

where:

IR = instrument reading, $\mu\text{g/L}$

DF = $\frac{\text{dilution factor} = V_D + V(\text{H}_2\text{SO}_4) + V(\text{HNO}_3) + V(\text{KMnO}_4) + V(\text{K}_2\text{S}_2\text{O}_8) + V(\text{NH}_2\text{OH})}{V_D}$

V_D = total digested volume, 10 mL

$V(\text{H}_2\text{SO}_4)$ = volume of added concentrated H_2SO_4 , 0.5 mL

$V(\text{HNO}_3)$ = volume of added concentrated HNO_3 , 0.5 mL

$V(\text{KMnO}_4)$ = volume of added 5% w/v KMnO_4 , 1.5 mL

$V(\text{K}_2\text{S}_2\text{O}_8)$ = volume of added 5% w/v $\text{K}_2\text{S}_2\text{O}_8$, 0.75 mL

$V(\text{NH}_2\text{OH})$ = volume of added 10% w/v hydroxylamine sulfate, 1.0 mL

The amount of mercury in the KCl solution blank is calculated in the same way.

4.6.2.2.2 Total Oxidized Mercury (Hgo)

Total Oxidized Mercury (Hgo) is defined by method as the mercury measured in the KCl sample

minus the mercury measured in the KCl solution blanks as shown in Equation 14:

$$Hg_o, \mu g = (Hg_{KCl})(V_3) - (Hg_{Ob})(V_3) \quad [Eq. 14]$$

where:

Hg_{KCl} = Mercury concentration measured in KCl aliquot, $\mu g/L$

V_3 = Total volume of aqueous KCl from which sample aliquot was taken, L

Hg_{Ob} = Mercury concentration measured in KCl solution blank aliquot, $\mu g/L$

The concentration of Hg^{2+} ($\mu g/dscm$) in the gas stream is then determined using Equation 15:

$$Hg^{2+}, \mu g / dscm = Hg_o / V_{m(std)} \quad [Eq. 15]$$

where:

$V_{m(std)}$ = Total volume of dry gas sampled at standard conditions, dscm

4.6.2.3 *Elemental Mercury*

4.6.2.3.1 *HNO₃-H₂O₂ Solution (Impinger 4)*

Calculate the concentration of mercury in $\mu g/L$ in the HNO₃-H₂O₂ impinger solution using Equation 16:

$$Hg_{H_2O_2}, \mu g / L = (IR)(DF) \quad [Eq. 16]$$

where:

IR = instrument reading, $\mu g/L$

DF = dilution factor = $\frac{V_D + V(HCl) + V(KMnO_4) + V(K_2S_2O_8) + V(NH_2OH)}{V_D}$

V_D	=	total digested volume, 5 mL
$V(\text{HCl})$	=	volume of added concentration HCl, 0.25 mL
$V(\text{KMnO}_4)$	=	volume of added saturated KMnO_4 , mL (volume needed to turn sample to a purple color)
$V(\text{K}_2\text{S}_2\text{O}_8)$	=	volume of added 5% w/v $\text{K}_2\text{S}_2\text{O}_8$, 0.75 mL (if used)
$V(\text{NH}_2\text{OH})$	=	volume of added 10% w/v hydroxylamine sulfate, 1.0 mL

The amount of mercury in the $\text{HNO}_3\text{-H}_2\text{O}_2$ solution blank is calculated in the same way.

4.6.2.3.2 $\text{H}_2\text{SO}_4\text{-KMnO}_4$ Solution (Impingers 5-7)

Calculate the concentration of mercury in $\mu\text{g/L}$ in the $\text{H}_2\text{SO}_4\text{-KMnO}_4$ impinger solutions using Equation 17:

$$\text{Mercury, } \mu\text{g} / \text{L} = \text{IR} \quad [\text{Eq. 17}]$$

where:

IR = instrument reading, $\mu\text{g/L}$

Note 7 - There is no dilution factor since no addition is made to the solution after the aliquot is taken for analysis.

The concentration of mercury in the $\text{H}_2\text{SO}_4\text{-KMnO}_4$ solution blank is calculated in the same way.

4.6.2.3.3 Total Elemental Mercury (Hg_E)

Total Elemental Mercury (Hg_E) is defined by method as the mercury measured in the $\text{H}_2\text{SO}_4\text{-KMnO}_4$ impingers plus the mercury in the $\text{HNO}_3\text{-H}_2\text{O}_2$ impingers minus the solution blanks as shown in Equation 18:

$$Hg_E, \mu g = (Hg_{H2O2})(V_4) - (Hg_{Eb1})(V_4) + (Hg_{KMnO4})(V_5) - (Hg_{Eb2})(V_5) \quad [Eq. 18]$$

where:

Hg_{H2O2} = Mercury concentration measured in HNO_3 - H_2O_2 aliquot, $\mu g/L$

V_4 = Total volume of aqueous HNO_3 - H_2O_2 from which sample aliquot was taken, L

Hg_{Eb1} = Mercury concentration measured in HNO_3 - H_2O_2 solution blank aliquot, $\mu g/L$

Hg_{KMnO4} = Mercury concentration measured in H_2SO_4 - $KMnO_4$ aliquot $\mu g/L$

V_5 = Total volume of aqueous H_2SO_4 - $KMnO_4$ from which sample aliquot was taken, L

Hg_{Eb2} = Mercury concentration measured in H_2SO_4 - $KMnO_4$ solution blank aliquot, $\mu g/L$

The concentration of Hg^0 ($\mu g/dscm$) in the gas stream is then determined using Equation 19:

$$Hg^0, \mu g/dscm = Hg_E / V_{m(std)} \quad [Eq. 19]$$

where:

$V_{m(std)}$ = Total volume of dry gas sampled at standard conditions, dscm

4.6.2.4 Total Mercury

Total mercury is defined by the method as the sum of the particulate bound mercury, oxidized mercury, and elemental mercury as shown in Equation 20:

$$Hg(\text{total}), \mu g/dscm = Hg^{tp} + Hg^{2+} + Hg^0 \quad [Eq. 20]$$

4.6.3 Emission Rate of Mercury Species

The following equation is used for each species.

$$\text{lb/hr} = \frac{\mu\text{g/dscf mercury species} \times Q_s \text{ dscfm} \times 60 \text{ min/hour}}{453.59 \times 10^6 \mu\text{g/lb}}$$

$$\text{mg/hr} = \frac{\text{lb}}{\text{hour}} \times \frac{453,590 \text{ mg}}{\text{lb}}$$

4.6.4 Mercury Removal Efficiency of Pollution Control System for each Species

$$RE = \frac{[(\text{total inlet mg/hr}) - (\text{outlet mg/hr})] \times 100}{\text{total inlet mg/hr}} = \%$$

4.6.5 Coal Analyses

The calculations for the concentration of pollutant in coal are given in each ASTM standard method. Pollutant concentrations were reported by the laboratory as follows:

Mercury	$\mu\text{g/g}$, (ppm)
Chlorine	$\mu\text{g/g}$, (ppm)
Sulfur	wt%, (lb/lb)
ash	wt%, (lb/lb)
moisture	wt%, (lb/lb)
gross heating value	Btu/lb

4.6.6 Total Mercury Introduced into the Combustion Unit

Mercury From Process Streams:

$$\frac{\text{mg}}{\text{hr}} = (\mu\text{g} / \text{g in feed}) \times \left(\frac{1000 \text{ lbs}}{\text{Klb}} \right) \times \left(\frac{453,590 \text{ mg}}{\text{lb}} \right) \times \left(\frac{1 \text{ mg}}{10^3 \mu\text{g}} \right)$$

$$\frac{lb}{hr} = \frac{mg}{hr} \times \frac{1}{453,590lb}$$

Total mercury to pollution control system:

$$\text{mg/hr total} = \text{mg/hr coal}$$

SECTION 5.0 QUALITY ASSURANCE

5.1 OVERVIEW

Quality Assurance/Quality Control (QA/QC) protocols followed during this program were based on the procedures of the methods employed, as well as any additional measures outlined in the Quality Assurance Program Plan entitled; "*Quality Assurance Program Plan Mercury Emissions From Electric Utility Coal Fired Steam Generators Test Program US Generating Company*", September 1999. Results of the QA/QC activities employed during this program are provided in this section.

As part of TRC's ongoing quality control for data reduction and reporting, all calculations are done using standardized EPA equations. TRC routinely reduces field data on a daily basis using a personal computer with software containing validated EPA equations. Isokinetics were determined at the end of each test day. Data such as those shown in the attached appendices were generated each day, with the exception of pollutant concentrations and emission rates, which were obtained after sample analyses were completed.

5.2 FIELD QUALITY CONTROL SUMMARY

5.2.1 Calibration Procedures

Calibration of the field sampling equipment was performed by TRC prior to the field sampling effort. Copies of the calibration sheets were submitted to the field team leader to take onsite and for inclusion in the project file. Calibrations were performed as described in the EPA publications "*Quality Assurance Handbook for Air Pollution Measurement systems; Volume III - Stationary Source Specific Methods*," (EPA-600/4-77-027b) and EPA 40 CFR Part 60, Appendix A. Equipment that was calibrated included the sample metering system, nozzles, barometers, thermocouples and pitot tubes. Pitot specific coefficients were determined for all pitots utilized

during the test program by wind tunnel calibration in accordance with EPA Method 2 criteria. All calibrations were available for review during the test program. Copies of the equipment calibration forms can be found in Appendix B.

5.2.2 Equipment Leak Checks

Prior to sampling, each sampling train was leak checked according to the procedures outlined in EPA Reference Method 5. During the course of a test run, a leak check was conducted before and after every test or if replacement of a component became necessary. Final leak checks were performed to ensure that no leaks developed in the train during the course of the test run. All leakage rates were recorded on the isokinetic sampling data sheets presented in the appendices. Leak check results for all sampling trains met method acceptance criteria.

5.2.3 Cyclonic Flow Check

The absence of cyclonic flow within the exhaust stacks was verified during preliminary traverses conducted prior to sampling, in accordance with Section 2.4 of EPA Method 1. Cyclonic flow was not found.

Inlet sampling locations for Unit 1 and Unit 3 did not meet EPA criteria with regard to average cyclonic flow angles. However, these locations provided the only access for sampling upstream of the ESPs for each unit. Therefore, these locations were utilized for sample collection.

Emission rates for the inlet locations were calculated utilizing the outlet volumetric flowrate as discussed in Sections 3.2.2.2.1 and 3.2.2.2.2.

5.2.4 Field Blanks

Field blanks for both the inlet and outlet locations were taken during the setup day prior to the first test run. The field blanks were taken to each location, leak checked, and allowed to stay at the sampling location for the same time duration as a test run. At the completion of the time

period, the blank trains were leak checked and brought down to the mobile laboratory for recovery. The glassware used for the field blanks was then recycled for Test Run 2 inlet and outlet samples.

5.3 SAMPLE HANDLING

This section presents the sample handling, sample traceability, chain-of-custody (COC) procedures, sample transport and field documentation that TRC followed for the test program.

5.3.1 Sample Traceability

The purpose of sample traceability procedures was to document the identity of the sample and its handling from its first existence as a sample until analysis and data reduction were completed. Custody records traced a sample from its collection through all transfers of custody until it was transferred to the analytical laboratory. Internal laboratory records then documented the custody of the sample through its final disposition.

Sample integrity was maintained throughout all sampling and analysis programs. In accordance with SW-846, a sample was considered to be under a person's custody if the sample was:

- In that person's physical possession.
- In view of that person after acquiring possession.
- Secured by that person so that no one could tamper with the sample.
- Secured by that person in an area which was restricted to authorized personnel.

These criteria were used to define the meaning of "custody" and to ensure the integrity of the test program samples from collection to data reporting. Restricted access to the samples was an integral part of the COC procedure.

5.3.3 Sample Shipping

Samples were packaged and shipped according to U.S. Department of Transportation, International Air Transportation Authority, and EPA regulations. Samples were delivered to the laboratory so that the requested analyses were performed within the specified allowable holding time. Samples were accompanied by the COC form. The COC form listed the variables to be analyzed by the laboratory and the total number and type of samples shipped for analysis. Authorized laboratory personnel acknowledged receipt of shipment by signing and dating the COC form.

5.4 LABORATORY QUALITY CONTROL SUMMARY

As a routine QA/QC procedure, the laboratory analyzed blank and spike samples. The blank samples included laboratory reagents (method blanks), field blanks, and reagent blanks. Method blanks are used to measure any contaminants which may be introduced to the sample during sample handling in the laboratory. Field blanks are used to measure any contaminants which may be introduced to the samples from the sampling equipment and sampling technique.

Reagent blanks help measure any sample contamination which may have occurred in the reagents used to prepare and recover the sampling trains. The spike samples consisted of matrix spikes, matrix spike duplicates (MS/MSD) and blank spikes. The matrix and blank spikes were used to check the performance and the recovery efficiency of the various analytical methods used in this work.

The precision of analyses was measured by performing spikes and spike duplicates with the analytes of interest. The difference between duplicate analyses (MS/MSD) was used to estimate the precision of the analyses and the recovery of the spike samples was used to estimate the bias (accuracy) of the analysis.

Samples were held within sight of the samplers or sample custodian, or were kept in sealed and secured containers at all times. Sealed containers were used to ship the samples to the laboratory.

5.3.2 Chain-of-Custody Documentation

5.3.2.1 Labeling

Sample identification labels were used by TRC to ensure that the required information was entered in the field. Sample labels were affixed to each appropriate process sample container for process samples at the time of collection. Exhaust gas sample labels were affixed to the appropriate container at the time of sample recovery. All samples collected during the test were labeled following the designated code system as stated in the Site Specific Test Plan (SSTP). Each sample label was preprinted prior to the test.

5.3.2.2 Field Logbook

A permanently-bound field logbook was maintained by TRC's Field Team Leader. Information pertinent to the sampling was recorded in a sampling log. All entries were made in indelible ink and all corrections followed error correction protocol of one line through the error, initial of the person performing the correction and the date of the correction. Sampling personnel also recorded all information on the appropriate sampling forms.

5.3.2.3 Chain-of-Custody Forms

To establish the documentation necessary to trace sample possession from the time of collection, a COC form was filled out (in four parts) and accompanied every sample or group of individually identified samples. Each person who had custody signed the COC form.

The following subsections detail the Laboratory QC measures performed on the samples which were collected during this program.

5.4.1 Mercury in Exhaust Gases

Exhaust gases were sampled for mercury utilizing the Draft Ontario-Hydro Speciated Mercury sample train. The analysis of the samples for mercury determination was accomplished using cold-vapor atomic absorption spectroscopy. Instrument calibration and calibration verification was performed in accordance with the above mentioned method.

5.4.1.1 *Spike and Spike Duplicates*

The results of matrix spikes and matrix spike duplicates and a laboratory blank spike and blank spike duplicate prepared and analyzed along with the samples are presented in Table 5-1. The results presented in the table indicate that the analytical system was in control for the analysis of the samples.

5.4.1.2 *Duplicate Analysis*

The results of the duplicate analysis of a prepared sample from both the inlet and outlet locations are presented in Table 5-2. The duplicate results indicate that precision of the instrument was within method criteria.

5.4.1.3 *Blank Results*

Table 5-3 presents the results of the mercury analysis of the reagent and field blanks. As can be seen in Table 5-3, no mercury contamination was present in either the reagent or field blanks.

5.4.1.4 *Audit Sample Analysis*

As required by the Ontario-Hydro method, an audit sample was analyzed along with the samples. The audit sample was obtained from the National Institute for Standards and Technology (NIST). The audit sample recovery was 99% . The recovery of the audit sample analysis was well within acceptance limits of 90 - 110% recovery. The results of the audit sample analysis can be found in the analytical data package located in Appendix E.

5.4.2 *Analysis of the Process Feed Samples*

The process feed sample, coal, was analyzed for mercury, sulfur, chlorine, and higher heating value.

The quality control data submitted with the analytical results indicate that the analytical process was within method specifications and the results should be considered valid.

TABLE 5-1. SPIKE/SPIKE DUPLICATE RESULTS

Boiler #1

Component	Sample ID(s)	Spike Conc. (ug)	Sample Conc. (ug)	Measured Conc.		Percent Rec.			RPD	Limit
				MS (ug)	MSD (ug)	MS	MSD	MSD		
Fly Ash (mg/Kg)	Inlet a Run 2	1.0	0.39	1.5	N/S	110%		75-125%		20%
Front Half	Inlet b Run 3	1.0	1.2	2.2	2.2	97%	97%	75-125%	0.00%	20%
KCl	Inlet a Run 4	6	6	12	11	96%	95%	75-125%	0.87%	20%
KMnO4	Inlet b Run 2	0.6	0.31	0.9	0.9	91%	103%	75-125%	7.73%	20%
HNO3/H2O2	Inlet a Run 2	2.6	0	2.5	2.6	100%	100%	75-125%	0.39%	20%

Blank Spike

Component	Sample ID(s)	Spike Conc. (ug)	Sample Conc. (ug)	Measured Conc.		Percent Rec.			RPD	Limit
				MS (ug)	MSD (ug)	MS	MSD	MSD		
Fly Ash (mg/Kg)		0.1	0	0.10	0.09	95%	94%	75-125%	1.06%	20%
Front Half		0.3	0	0.32	0.29	109%	97%	75-125%	11.73%	20%
KCl		0.3	0	0.30	0.31	100%	100%	75-125%	0.33%	20%
KMnO4		0.1	0	0.050	0.046	100%	92%	75-125%	8.33%	20%

Boiler #3

Component	Sample ID(s)	Spike Conc. (ug)	Sample Conc. (ug)	Measured Conc.		Percent Rec.			RPD	Limit
				MS (ug)	MSD (ug)	MS	MSD	MSD		
Front Half	Outlet Run 4	0.5	0	0.55	0.54	102%	100%	75-125%	1.83%	20%
KCl	Outlet Run 4	6	6.6	13	13	99%	98%	75-125%	0.77%	20%
KMnO4	Outlet Run 4	7	6.3	13	13	97%	97%	75-125%	0.00%	20%
HNO3/H2O2	Outlet Run 4	3	0	3	3	110%	114%	75-125%	3.94%	20%
KMnO4	Inlet E Run 2	0.6	0.83	1.4	1.4	91%	90%	75-125%	0.59%	20%
HNO3/H2O2	Inlet E Run 2	2.6	0	2.7	2.8	107%	110%	75-125%	2.17%	20%

Blank Spike

Component	Sample ID(s)	Spike Conc. (ug)	Sample Conc. (ug)	Measured Conc.		Percent Rec.			RPD	Limit
				MS (ug)	MSD (ug)	MS	MSD	MSD		
Fly Ash (mg/Kg)		0.1	0	0.10	0.10	100%	100%	75-125%	0.00%	20%
Front Half		0.3	0	0.32	0.32	110%	110%	75-125%	0.00%	20%
KCl		0.3	0	0.30	0.30	100%	100%	75-125%	0.00%	20%
KMnO4		0.1	0	0.100	0.110	100%	110%	75-125%	9.52%	20%

TABLE 5-2 LABORATORY DUPLICATE RESULTS

Boiler #1

Field Sample ID.:	Inlet a Run 2	Reporting Limit	Inlet a Run 2	Reporting Limit	RPD	RPD Limit
Component	(mg/Kg)	(mg/Kg)	(mg/Kg)	(mg/Kg)		
Fly Ash	0.39	0.04	0.41	0.04	5.00%	25%
Field Sample ID.:	Inlet b Run 3	Reporting Limit	Inlet b Run 3	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
Front Half	1.2	0.01	1.2	0.01	0.00%	25%
Field Sample ID.:	Inlet a Run 4	Reporting Limit	Inlet a Run 4	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
KCl	6.2	0.03	6	0.03	3.28%	25%
Field Sample ID.:	Inlet b Run 2	Reporting Limit	Inlet b Run 2	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
KMnO4	0.6	0.03	0.33	0.03	58.1%	25%
Field Sample ID.:	Inlet a Run 2	Reporting Limit	Inlet a Run 2	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
HNO3/H2O2	<0.25	0.01	<0.25	0.01	0.0%	25%
Field Sample ID.:	Inlet a Run 5	Reporting Limit	Inlet a Run 5	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
KMnO4	0.4	0.03	0.94	0.03	80.6%	25%

Boiler #3

Field Sample ID.:	Outlet Run 4	Reporting Limit	Outlet Run 4	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
Front Half	<0.05	0.01	<0.05	0.01	0.0%	25%
Field Sample ID.:	Outlet Run 4	Reporting Limit	Outlet Run 4	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
KCl	6.6	0.03	6.5	0.03	1.53%	25%
Field Sample ID.:	Outlet Run 4	Reporting Limit	Outlet Run 4	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
KMnO4	6.3	0.03	6.3	0.03	0.0%	25%
Field Sample ID.:	Outlet Run 4	Reporting Limit	Outlet Run 4	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
HNO3/H2O2	<0.25	0.01	<0.25	0.01	0.0%	25%
Field Sample ID.:	Inlet E Run 2	Reporting Limit	Inlet E Run 2	Reporting Limit	RPD	RPD Limit
Component	(ug)	(ug)	(ug)	(ug)		
KMnO4	0.84	0.03	0.82	0.03	2.4%	25%

TABLE 5-3 BLANK RESULTS

Boiler # 1

Field Sample ID.:	Reagent Blank	Inlet	Outlet
Component	(ug)	Field Blank	Field Blank
		(ug)	(ug)
Front Half	<0.01	<0.01	<0.01
KCl	<0.03	<0.03	<0.03
KMnO4	<0.03	<0.03	<0.03
HNO3/H2O2	<0.25	<0.25	<0.25

Boiler # 3

Field Sample ID.:	Reagent Blank	Inlet	Outlet	Reagent Blank
Component	(ug)	Field Blank	Field Blank	Run 4
		(ug)	(ug)	(ug)
Front Half	<0.01	<0.01	<0.01	<0.01
KCl	<0.03	<0.03	<0.03	<0.03
KMnO4	<0.03	<0.03	<0.03	<0.03
HNO3/H2O2	<0.25	<0.25	<0.25	<0.25