APS
The Power To Make It Happen
Cholla Steam Electric Station
P.O. Box 188/STA 4451 • Joseph City, Arizona 86032 - 0188
Phone: (520) 288-1418
Fax: (520) 288-1454

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

February 22, 2000

Mr. William Grimley
Emission Measurement Center (MD-19)
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Attn: Electric Utility Steam Generating Unit Mercury Test Program

Re: Arizona Public Service Company (APS) – Cholla Power Plant
Submittal of Mercury Emissions Test Program Report

Dear Mr. William Grimley,

The Arizona Public Service Company (APS), Cholla Power Plant (Cholla) is hereby submitting three original copies, one of which is an unbound copy, of the "Mercury Emissions Test Program Report" for speciated mercury emissions testing performed at the Cholla Generating Station, Units 2 and 3.

Should you have any questions concerning the mercury emissions test program report, please contact me at (520) 288-1418 or our contractor for this ICR test project, Kurt Parker at TRC Environmental Corporation at (303) 792-5555.

Sincerely,
John M. Roznovak
John M. Roznovak
Cholla Environmental Consultant

Cc: Kurt Parker, TRC Environmental Corporation, 11 Inverness Drive East, Englewood, Colorado 80112

Enclosures (3): "Final Report, Mercury Emissions Test Program, Coal Fired Boilers, Unit 2 and Unit 3, Cholla Generating Station, Joseph City, Arizona"

MERCURY EMISSIONS TEST PROGRAM
COAL FIRED BOILERS
UNIT 2 AND UNIT 3
CHOLLA GENERATING STATION
JOSEPH CITY, ARIZONA

Prepared for:

ARIZONA PUBLIC SERVICE COMPANY
CHOLLA GENERATING STATION
P.O. Box 188
Joseph City, Arizona

Prepared by:

TRC ENVIRONMENTAL CORPORATION
DENVER RESOURCE CENTRE
ENVIRONMENTAL MEASUREMENTS DIVISION
7761 Shaffer Parkway, Suite 100
Littleton, Colorado 80127

TRC Project No. 25938

February 9, 2000

Prepared by:

TRC ENVIRONMENTAL CORPORATION
DENVER RESOURCE CENTRE
ENVIRONMENTAL MEASUREMENTS DIVISION
7761 Shaffer Parkway, Suite 100
Littleton, Colorado 80127
303.792.5555

TRC Project No. 25938
February 9, 2000

DISCLAIMER

TABLE OF CONTENTS

Section Page No.

1.0 INTRODUCTION 1
1.1 Summary of Test Program 1
1.1.1 Problem Definition and Background 1
1.1.2 Facility Information 2
1.2 Project Organization 2
1.2.1 Purpose/Background 2
1.2.2 Roles and Responsibilities 2
1.2.2.1 APS Generating Company 2
1.2.2.2 TRC Environmental Corporation 2
1.2.2.2.1 TRC's Program Manager 3
1.2.2.2.2 TRC's QA Officer 4
1.2.2.2.3 TRC's Lab Coordinator 5
1.2.2.2.4 TRC's Field Team Leader Responsibilities 5
1.2.2.3 Analytical Laboratory. 5

2.0 FACILITY AND SAMPLING LOCATION DESCRIPTIONS 6
2.1 Process Description and Operation 6
2.2 Flue Gas Sampling Locations 7
2.2.1 Unit 2 7
2.2.1.1 Unit 2 Inlet Duct Sampling Location 8
2.2.1.2 Unit 2 Outlet Stack Sampling Location 10
2.2.3 Unit 3 11
2.2.1.1 Unit 3 Inlet Duct Sampling Location 11
2.2.1.2 Unit 3 Outlet Stack Sampling Location 15
2.3 Process Sampling Locations 15

3.0 SUMMARY AND DISCUSSION OF RESULTS 17
3.1 Objectives and Test Matrix 17
3.2 Field Test Changes and Problems 17
3.2.1 Field Test Changes 17
3.2.1.1 Inlet Duct Sampling Location 17
3.2.1.2 Change in Collection Location of Process Samples 17
3.2.2 Sampling Difficulties or Issues 17
3.2.2.1 Exhaust Stack Sampling Trains 17
3.2.2.2 Inlet Stack Sampling Trains 18
3.3 Presentation of Results 19
3.3.1 Total Mercury Inflow to the Process 19
3.3.2 Speciated and Total Mercury Emissions 20
3.3.2.1 Unit 2 20
3.3.2.2 Unit 3 20
3.3.3 Emission Control Device Removal Efficiency 20
3.3.3.1 Unit 2 20
3.3.3.2 Unit 3 20
3.3.4 Overall Process Removal Efficiency 20

TABLE OF CONTENTS
(continued)

Section Page No.

4.0 SAMPLING AND ANALYTICAL PROCEDURES 25
4.1 Overview 25
4.2 Pre Sampling Activities 25
4.2.1 Equipment Calibration 25
4.2.2 Glassware Preparation 25
4.3 Onsite Sampling Activities 26
4.3.1 EPA Methods 1 and 2 for Velocity Measurements and Cyclonic Flow 26
4.3.2 EPA Method 4 for Moisture 26
4.3.3 Ontario Hydro Mercury Speciation Train (EPA EMC Pre-003) 27
4.3.4 EPA Method 3B for O_2 and CO_2 31
4.3.5 Process Sampling 31
4.4 Process Monitoring 31
4.5 Analytical Procedures 32
4.5.1 Mercury - Ontario Hydro Train Fractions 32
4.5.2 Coal Analyses 33
4.6 Calculations 36
4.6.1 Flow Rate and Isokinetic 36
4.6.2 Calculation for Particle Bound, Oxidized, Elemental and Total Mercury Concentrations 39
4.6.2.1 Particle-Bound Mercury 39
4.6.2.2 Oxidized Mercury 41
4.6.2.3 Elemental Mercury 42
4.6.2.4 Total Mercury 42
4.6.3 Emission Rate of Mercury Species 42
4.6.4 Mercury Removal Efficiency 43
4.6.5 Total Mercury Introduced into the Combustion Unit 43

5.0 QUALITY ASSURANCE 44
5.1 Overview 44
5.2 Field Quality Control Summary 44
5.2.1 Calibration Procedures 44
5.2.2 Equipment Leak Checks 44
5.2.3 Cyclonic Flow Check 44
5.2.4 Field Blanks 44
5.3 Sampling Handling 45
5.3.1 Sample Traceability 45
5.3.2 Chain-of-Custody Documentation 45
5.3.2.1 Labeling 45
5.3.2.2 Field Logbook 45
5.3.2.3 Chain-of-Custody Forms 46

TABLE OF CONTENTS
(continued)

Section		Page No.
	5.3.3 Sample Shipping	46
5.4	Laboratory Quality Control Summary	46
	5.4.1 Mercury in Exhaust Gases	46
	5.4.1.1 Spike and Spike Duplicates	46
	5.4.1.2 Duplicate Analysis	47
	5.4.1.3 Blank Results	47
	5.4.1.4 Audit Sample Analysis	47
	5.4.2 Analysis of the Process Feed Samples	47

List of Tables

Table No.		Page No.
Table 2.1	Unit 2 Inlet Traverse Sampling Points	9
Table 2.2	Unit 2 Outlet Stack Traverse Sampling Points	11
Table 2.3	Unit 3 Inlet Traverse Sampling Points	13
Table 2.4	Unit 3 Outlet Stack Traverse Sampling Points	15
Table 3.1	Test Matrix	21
Table 3.2	Measurements Conducted at each Test Location	22
Table 3.3	Summary Table of Emissions Data and Removal Efficiencies Unit 2	23
Table 3.4	Summary Table of Emissions Data and Removal Efficiencies Unit 3	24
Table 5.1	Spike/Spike Duplicate Results	48
Table 5.2	Laboratory Duplicate Results	48
Table 5.3	Blank Results	49

List of Figures

Figure No.		Page No.
Figure 1.1	Program Organization - Mercury Emissions Sampling Program	3
Figure 2.1	General Schematic of Cholla Unit 2	8
Figure 2.2	Unit 2 Top View General Layout	9
Figure 2.3	Unit 2 Top View - Inlet	10
Figure 2.4	Unit 2 Side View - Inlet	10
Figure 2.5	Unit 2 Stack Liner Cross Section	11
Figure 2.6	General Schematic of Cholla Unit 3	12
Figure 2.7	Unit 3 Top View General Layout	13
Figure 2.8	Unit 3 Top View - Inlet	14
Figure 2.9	Unit 3 Stack Liner Cross Section	15
Figure 4.1	Schematic of EPA Pre003-Ontario Hydro-Speciated Mercury Sampling Train in the Method 5 Vertical Sampling Configuration	28
Figure 4.2	Schematic of EPA Pre003-Ontario Hydro-Speciated Mercury Sampling Train in the Method 5 Horizontal Sampling Configuration Sampling Configuration	28

TABLE OF CONTENTS
(continued)

Figure No. Page No.

Figure 4.3 Analytical Scheme for EPA Pre-003-Ontario HydroMercury Analysis 34
Figure 4.4 Coal Sample Analytical Scheme 35

Appendices

Appendix A Results and Calculation

Appendix A - Section 1 Emissions Summary
Appendix A - Section 2 Isokinetic Summary
Appendix A - Section 3 Process Mercury Inflow Calculations

Appendix B Raw Field Data and Calibration Data Sheets

Appendix B - Section 1 Raw Field Data Sheets
Appendix B - Section 2 Calibration Data Sheets
Appendix B - Section 3 Process Data Sheets

Appendix C Sampling Log and Chain-of-Custody Records

Appendix C - Section 1 Exhaust Gas Streams
Appendix C - Section 2 Process Streams

Appendix D Analytical Data Sheets

Appendix D - Section 1 Exhaust Gas Streams
Appendix D - Section 2 Process Streams

Appendix E Audit Data Sheets

Appendix F List of Participants

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. APS Generating Company (APS) received written notice that the Cholla Generating Station had been selected to participate in Part III.

TRC Environmental Corporation (TRC) of Denver, Colorado was retained by APS to conduct the mercury emissions test program on Unit 2 and Unit 3 at the Cholla Generating Station.

1.1.2 Facility Information

The Cholla Power Plant is one of Arizona Public Service Company (APS) largest Steam Electric generating facilities. The facility is located in Navajo County, approximately two miles east of Joseph City on Interstate 40, and approximately 200 miles northeast of Phoenix. Unit 2 and Unit 3 were selected to be evaluated in this

program. Unit 2 and Unit 3, with net accredited megawatt capacities of 245 and 260 megawatts, respectively, were completed in 1978 and 1980. Unit 2 is equipped with a mechanical dust collector and wet scrubber system for control of sulfur dioxide (SO_2) and particulate matter. Unit 3 has an electrostatic precipitator for particulate removal. Units 2 and 3 share a common stack and are regulated as a single source for SO_2. Because of this, Unit 3 flue gases are not scrubbed. When Unit 3 is operating and Unit 2 is out of service, a special, lower sulfur coal (0.3-0.4% by weight) is used to minimize emissions and assure compliance with the Arizona SO_2 emission limitation of 0.8 pounds per million BTU (lbs/mmBtu). Mercury emissions testing was conducted after the mechanical dust collector and before the inlet to the wet scrubber of Unit 2, the outlet stack of Unit 2, the inlet to the electrostatic precipitator of Unit 3, and the outlet stack of Unit 3 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 APS'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 APS Generating Company

Mr. Doug Lavarnway was the APS Program Coordinator. He provided the overall program coordination amongst the Plant Program Coordinator, the USEPA Emissions Measurement Center, and TRC Environmental Corporation. The APS 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. John Roznovak, Environmental Consultant for the Cholla Generating Station, served as the Plant Program Coordinator and directed the test program for the facility. Mr. Roznovak acted as the primary contact with TRC and designated the appropriate APS personnel to coordinate plant operations with the emission test program. Mr. Roznovak coordinated the unit operations, the coal sampling, and emissions tests during each test run.

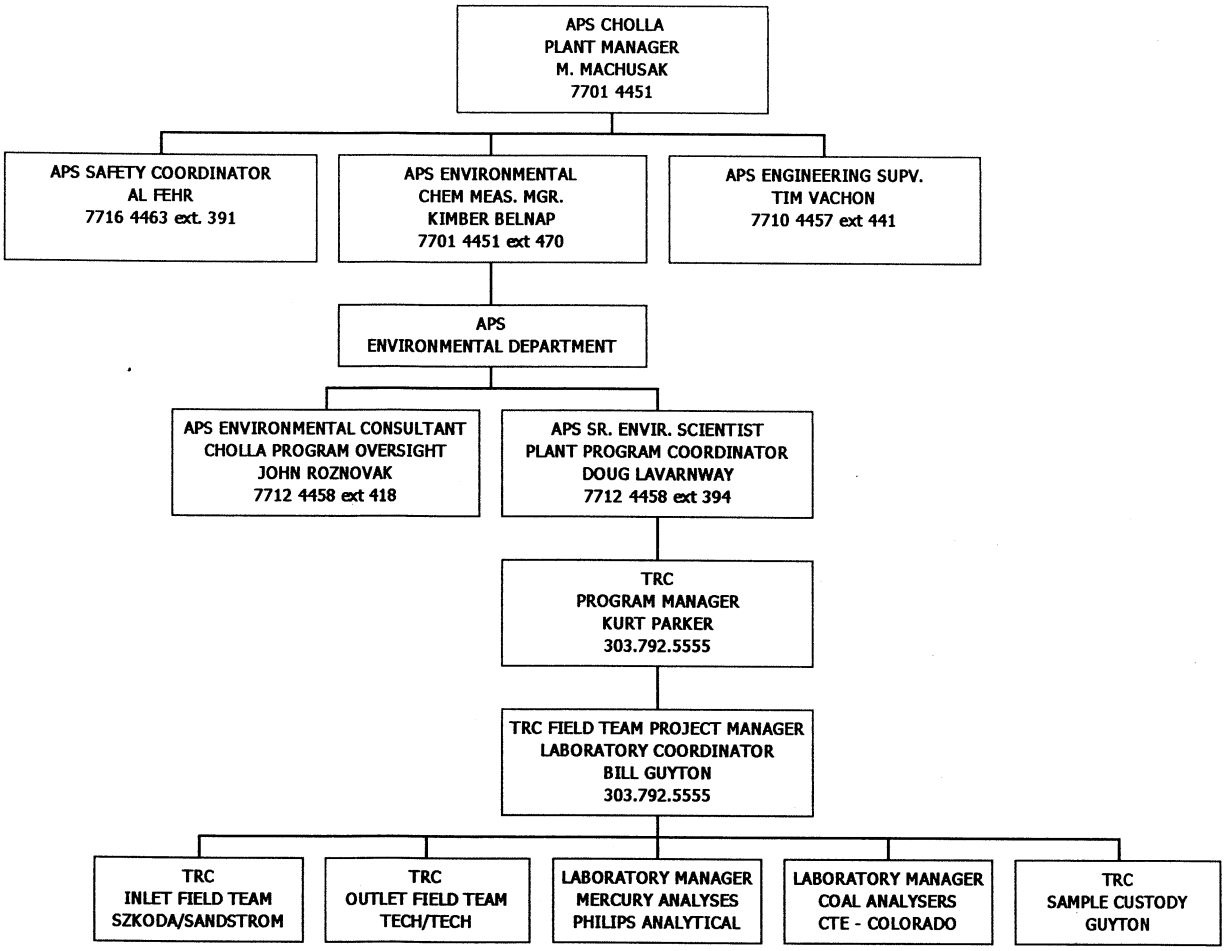
Additional Cholla personnel provided support in obtaining process data and coal samples. APS and TRC would like to recognize the contributions of the Cholla Unit 2 and Unit 3 operations and support personnel in the successful completion of this program.

1.2.2.2 TRC Environmental Corporation

TRC Environmental Corporation conducted the mercury emissions testing program for APS.

Figure 1.1
Program Organization - Mercury Emissions Sampling Program

TEST PROGRAM ORGANIZATION



1.2.2.2.1 TRC's Program Manager

Mr. Kurt Parker, of TRC's Air Measurements Department, served as TRC's program manager and the primary point of contact with APS for this project. TRC's field crew operated under the direct supervision of Mr. Parker. Mr. Parker coordinated the field crew's activities with the designated APS 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 APS 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 APS 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 Ms. Terry Pierce, 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. William Guyton, 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.
- Conducted the data analysis.
- Conducted the 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 APS 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.

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

The Cholla Power Plant is one of Arizona Public Service Company (APS) largest Steam Electric generating facilities. The facility is located in Navajo County, approximately two miles east of Joseph City on Interstate 40, and approximately 200 miles northeast of Phoenix. The plant elevation is 5,019 feet above sea level. Cholla presently consists of four coal-fired units. Unit 1 was completed in 1962 and has a net accredited megawatt capacity of 110 megawatts. Units 2 and 3 with net accredited megawatt capacities of 245 and 260 megawatts, respectively, were completed in 1978 and 1980. Unit 4 with a net accredited megawatt capacity of 380 megawatts was placed in commercial operation in 1981. Although Cholla Unit 5 was permitted and preliminary construction was commenced in 1980, construction was halted that same year.

Water for Cholla comes from a well field on the 13,748 acre plant site. These wells originally filled and continue to re-supply a 380 acre impoundment, Cholla Lake, adjacent to the plant. Condenser cooling for Units 1 and 2 is provided by Cholla Lake, while Units 3 and 4 have mechanical draft cooling towers and Unit 3 receives make-up water from the lake, while Unit 4 receives make-up water from the well field.

Unit 2 and Unit 3 were evaluated in this program. Unit 2 has four venturi flooded disc scrubbers/ absorbers for sulfur dioxide control and secondary particulate removal (one of the scrubber / absorber towers is rotated as a maintenance spare), a mechanical dust collector for primary particulate removal, and a T-fired furnace with close-coupled over-fired air (OFA) for reduced production of nitrogen oxides. Unit 3 has a hot side electrostatic precipitator (ESP) for particulate removal and a T-fired furnace with close-coupled OFA for reduced production of nitrogen oxides. Units 2 and 3 share a common stack and are regulated as a single source for SO_2. Unit 2 and 3 sulfur dioxide *emissions are "bubbled" and* averaged on a Megawatt weighted basis. Because of this, Unit 3 flue gases are not scrubbed. When Unit 3 is operating and Unit 2 is out of service, a special, lower sulfur coal (0.3-0.4% by weight) is used to minimize emissions and assure compliance with the Arizona SO_2 emission limitation of 0.8 pounds per million BTU (lbs/mmBtu).

Each Unit typically operates 24 hours per day, seven (7) days per week, 365 days per year, and 8760 hours per year. On occasion, the Units are cycled off line when *economics dictates that, for* the loads required at a particular season, load is served by lower cost generation. Each Unit periodically receives scheduled maintenance (overhauls) approximately every other year and unscheduled maintenance/repair when necessary. Overhauls last from two weeks to two months.

Cholla burns coal primarily from the McKinley Mine near Gallup, New Mexico. The coal is transported 115 miles to Cholla using unit trains. The coal is unloaded at the "coal handling" facility, which directs coal to either the Units or one of two coal piles. The old track feeders send coal to the Units or to the low sulfur coal pile where it can later be reclaimed, while the new track feeders send coal to the Units or main coal pile. The main coal pile contains approximately a 45 day supply of coal, while the low sulfur coal pile is maintained at an adequate supply level at all times.

The four Cholla Units typically burn approximately 3.7 million tons of coal annually, or about 100 rail car loads a day. The source of the Cholla plant fuel supply is the McKinley Mine near Gallup, New Mexico, which is operated by Pittsburgh and Midway, Inc. The coal is transported approximately 115 miles to the plant site by Burlington

Northern Santa Fe (BNSF) Railroad unit trains. BNSF has a main line right-of-way adjacent to the plant.

Coal unloaded at coal handling is released through the bottom of the unit trains to one of two large grates known as grizzlies. The coal collected below the grizzly at the old track feeders load to a coal conveying belt, which travels to coal crusher tower #1. At coal crusher #1, the coal can be directed either to the low sulfur coal pile or it can be crushed and directed to the Unit 1 silos or to coal crusher tower #2 where it can be conveyed to the silos for Units 2, 3, or 4. The coal that is stacked out to the low sulfur pile is not crushed prior to stacking it out.

Reclaim off of the low sulfur pile is pushed by a bulldozer into the grizzly at the old track feeders and thereby enters the coal handling system via crusher Tower #1 where it is crushed and then directed to the Unit 1 silos or via a reversible belt to crusher Tower #2 for transport to Units 2-4. The coal collected below the grizzly at the new track feeders load a coal conveying belt, which travels to coal crusher tower #2. The crusher tower reduces the size of the coal before transporting the coal to Unit 1 (via crusher tower 01) or to the transfer tower #2 which sends it to the main pile or sends the coal to Unit 2, Unit 3, and Unit 4 via the transition tower. Reclaim off of the bottom of the main pile goes to transfer tower #2 (via crusher tower #2) and is transported to Units 1-4. The crusher/transfer towers coal conveyor belts feed the top of Unit coal silos. All Unit silos gravity feed coal to feeders that supply each pulverizer. The pulverizers grind the coal to the consistency of talcum powder before firing in the furnace.

All four (4) Units combust bituminous/sub-bituminous coal to heat *high purity* water to create super-heated steam, *which* is used as the thermodynamic medium, which drives the turbines/generators to produce electricity. Unit 1 uses natural gas as the warm up/stabilization fuel and Units 2, 3, and 4 use diesel fuel #2 as the warm-up/ stabilization fuel. All warm-up/ stabilization fuels are fired less than one percent of total unit operating time. Historical operating data indicates this to be approximately 0.7 percent of total heat input on Unit 1 and approximately 0.3 percent on Units 2, 3, and 4.

Unit 4 has a waste oil burning system which injects used oil into the furnace for energy recovery purposes and is co-fired with coal and is performed on a periodic basis. The total heat input from this activity is less than 0.1 percent of total heat input on Unit 4 on an annual basis.

2.2 FLUE GAS SAMPLING LOCATIONS

2.2.1 Unit 2

Unit 2 is supported by both sulfur dioxide and particulate removal equipment manufactured by Research Cottrell (1974). The system is composed of 4 wet venturi (3 in service during full load, 1 is a maintenance spare) scrubber modules and 4 absorber towers. This system removes 90% sulfur dioxide and 98.8% particulate matter. Figure 2.1 provides a general layout of the unit.

Scrubbing Liquor	**Lime**
Gas Flow rate (ACFM)	**413,000 per tower**
Liquor Flow Rate (GPM)	**5,300 lower/16,000 upper tower**
Pressure Drop Across Unit ("H_2O) – Min/Normal	**18**
Pressure Drop Across Unit ("H_2O) – Max/Normal	**24**
Inlet Air Temperature (°F) – Design	**277**
Outlet Air Temperature (°F) – Design	**159**

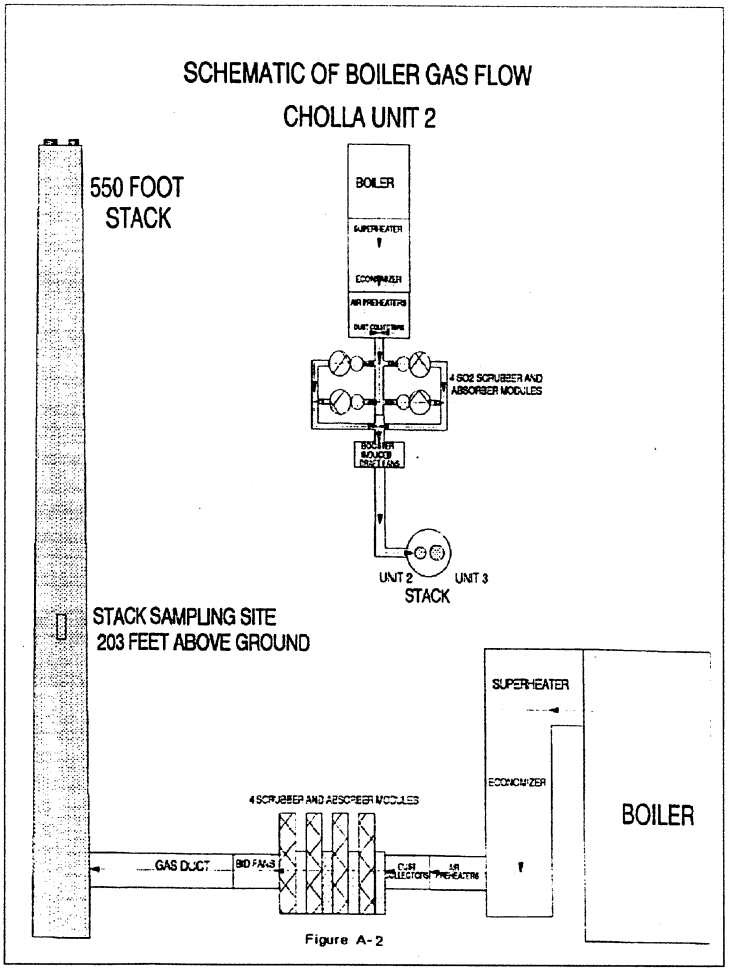


Figure 2.1 General Schematic of Cholla Unit 2

2.2.1.1 Inlet Duct Sampling Location

An overview of the unit flow is provided in Figure 2.2. The Unit 2 inlet duct work has extremely limited access for sampling. Based on duct layout, a sample location at the exhaust of the mechanical dust collector "B" side in the ducting just prior to the inlet to the scrubbers was selected. Four six-inch sample ports exist at this location. There are significant turns in the duct and flow disturbances were encountered. The sample location ductwork measures (external dimensions) 34' wide by 9'4" deep by 112' long from the air Preheater (APH) to the scrubber inlet. Location of ports are approximately 30' from an upstream disturbance and 20' from a downstream disturbance. Sampling was conducted in a vertical orientation. Internal dimensions of the inlet sampling duct are 34' wide but converge immediately by 8' 6" deep by 106' 6" long.

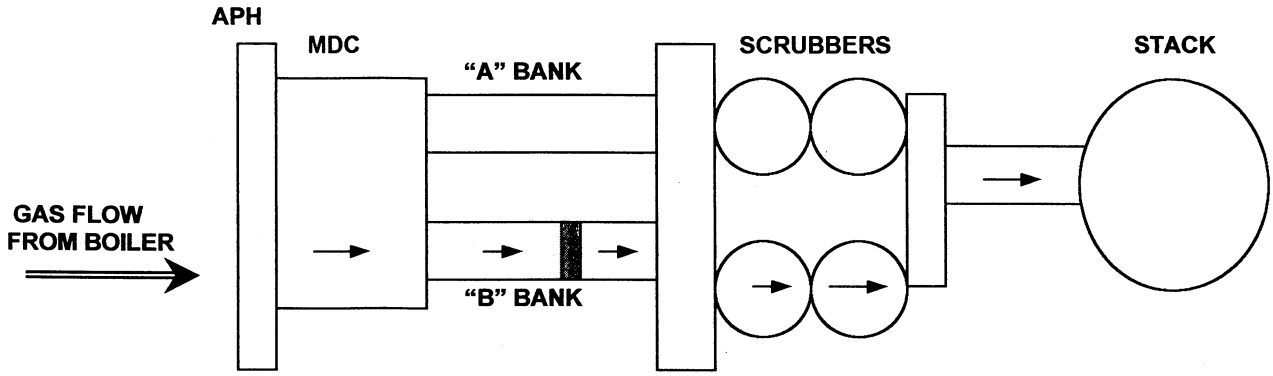


Figure 2.2 TOP VIEW of U2 General Layout

APH	Air Preheater
MDC	Mechanical Dust Collector
"A/B" BANK	Sides of Duct from MDC to Scrubber
SCRUBBERS	Scrubber/Absorbers
STACK	Exhaust Stack
▬	Sample Location - INLET

Thumbnail photos are provided below to better support the visualization of the location, configuration and limited upstream/downstream disturbances. Figure 2-3 is a general top view and Figure 2-4 is a general side view.

Table 2.1
UNIT 2 INLET TRAVERSE SAMPLING POINTS

Duct Dimensions	88.5" deep x 415" wide
Sample Port Length	18.5"
Number of Sample Ports	4
Total Number of Sample Points	24
Number of points per Traverse	6

Point	Distance from Port (in.)
1	25.88
2	40.63
3	55.38
4	70.13
5	84.88
6	99.63

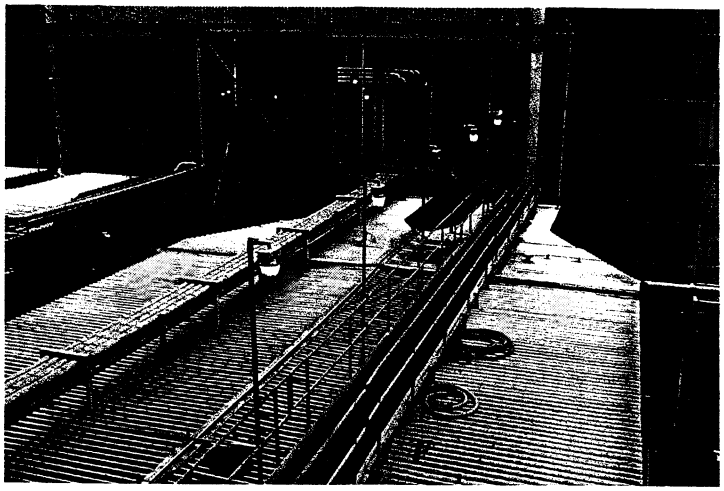


Figure 2.3 – Unit 2 TOP VIEW

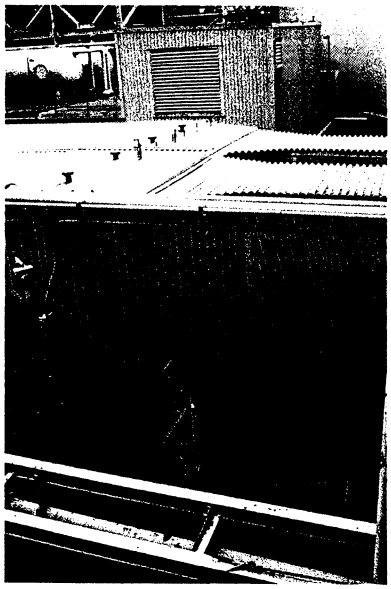


Figure 2.4 – Unit 2 SIDE VIEW

2.2.1.2 Outlet Stack Sampling Location

The exhaust stacks for Unit 2 and Unit 3 share a common outer liner (Figure 2.5). Both units discharge through the exhaust stack approximately 550 feet tall. The sampling location, for both Units is 203 feet above ground level with flue gas entering the stack at 60′ 9″ above ground level (AGL). An elevator services the stacks. Four 6-inch ports, located 90° apart on the same plane, are provided on both stacks. The specific dimensions for Unit 2 is provided in Table 2.2. The circular stack is 176 inches in diameter. The test ports are located 142.25 feet (9.7 stack diameters) downstream of the nearest flow disturbance and 347 feet (23.7 stack diameters) upstream of the stack exhaust to the atmosphere. There are four 6-inch sampling ports installed at 90° intervals at the sample location.

TRC conducted a 12 point traverse, 3 points per port, during each test run. Table 2-2 presents these traverse points.

Table 2.2
UNIT 2 OUTLET TRAVERSE SAMPLING POINTS

Stack Diameter (D)	176"
Distance Downstream	1,707"
Equivalent Downstream (D)	9.7
Distance Upstream	4,164"
Equivalent Upstream (D)	23.7
Method 1 Criteria Met	Yes
Number of Sample Ports	4
Sample Port Length	6"
Total Number of Sample Points	12
Number of points per Traverse	3

Point	Distance from Port (in.)
1	13.75
2	31.68
3	58.13

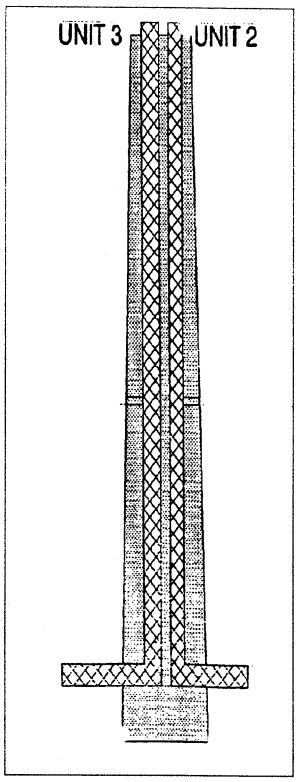


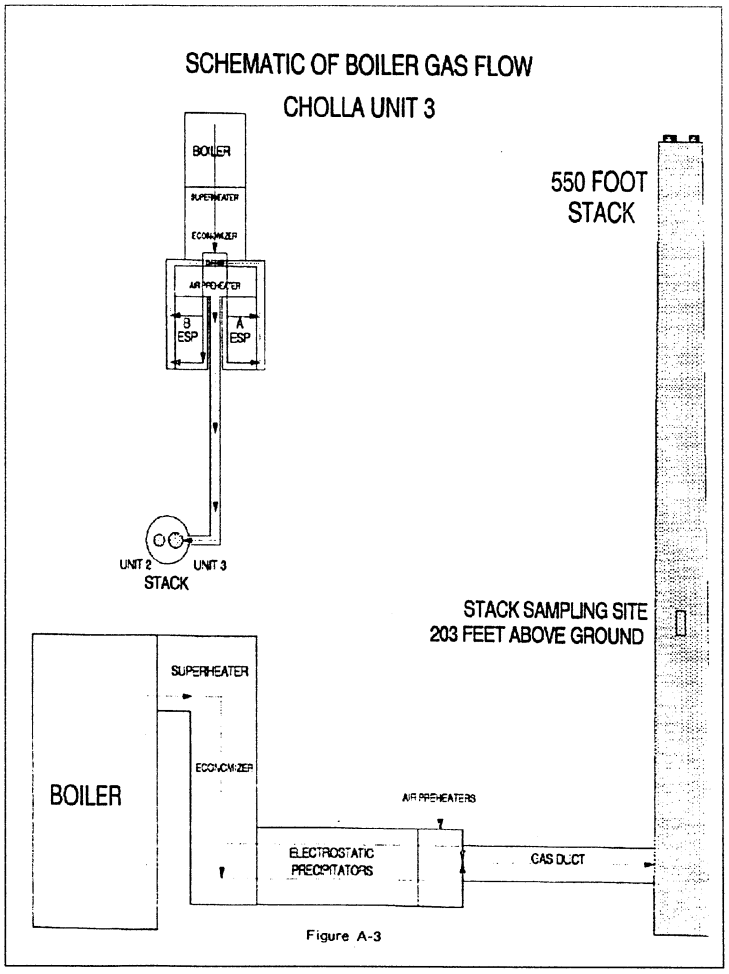
Figure 2.5
Stack Liner Cross-section

2.2.2 Unit 3

Unit 3 flue gases are not scrubbed. When Unit 3 is operating and Unit 2 is out of service, a special, lower sulfur coal (0.3-0.4% by weight) is used to minimize emissions and assure compliance with the Arizona SO_2 emission limitation of 0.8 pounds per million BTU (lbs/mmBtu). Unit 3 particulate control is provided by an Universal Oil ESP having ninety-nine percent removal efficiency. Efficiency of 99.8% is based on 925K ACFM gas flow at 650° F per side and 10% of electrical bus sections out of service. Figure 2.6 provides a general layout of the unit.

Inlet Air Temperature (°F) – Min/Normal	500
Outlet Air Temperature (°F) – Max/Normal	750
Gas Velocity through ESP (FPS)	4.39
Voltage and Current Ratings for each TR	
Field 1-4	1000ma & 45 KV
Field 5-10	1200ma & 45 KV

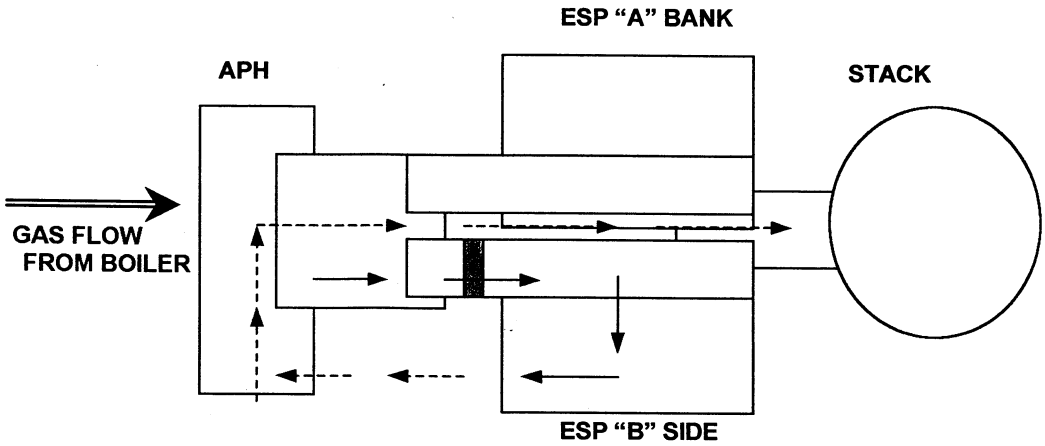
Figure 2.6 General Schematic of Cholla Unit 3



2.2.2.1 Inlet Duct Sampling Location

An overview of the Unit flow is provided in Figure 2.7. The Unit 3 inlet duct sampling location is located just before the ESP "B" side having four six-inch sample ports in a duct measuring (outside dimensions) 16' wide by 27' deep x 78' long. The location of ports is approximately 10' from an upstream disturbance and 30' from a downstream disturbance (but starts to converge within 10 feet of the inlet to the ESP). As with the Unit 2 duct, sampling was conducted in a vertical orientation. The gas path flows through the air Preheater, past the sample location to the top banks of the ESP, underneath to the lower banks of the ESP. The gas then exits at the bottom of the ESP, turns at approximately 180 degrees underneath the ESP banks and passes underneath the APH again. The gas then combines prior to entering the stack.

Figure 2.7 TOP VIEW of U3 General Layout



APH	Air Preheater
ESP	Electrostatic Precipitator
"A/B" BANK	Sides of Duct from into ESP (at top) Both "A" and "B" sides exit at bottom
STACK	Exhaust Stack
▬	Sample Location - INLET

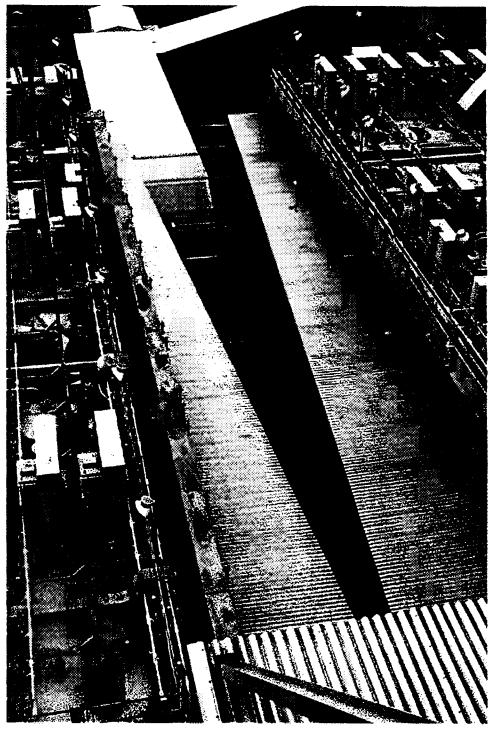
A thumbnail photo is provided below to better support the visualization of the location, configuration and limited taper as the gas stream enters the inlet to the precipitator (ESP). Figure 2.8 is a general top view of the inlet sample location.

Table 2.3
UNIT 3 INLET TRAVERSE SAMPLING POINTS

Duct Dimensions	27' deep x 9'6" wide
Sample Port Length	19.0"
Number of Sample Ports	4
Total Number of Sample Points	64
Total Number of Sample Points Used	24
Number of points per Traverse	6

Point	Distance from Port (in.)
1	29.13
2	49.38
3	69.63
4	89.88
5	110.13
6	130.34

Figure 2.8
U3 Top View (just prior to Right hand turn into ESP)



2.2.2.2 Outlet Stack Sampling Location

The exhaust stacks for Unit 2 and Unit 3 share a common outer liner (Figure 2.9). Both units discharge through the exhaust stack approximately 550 feet tall. The sampling location, for both Units is 203 feet above ground level with flue gas entering the stack at 60' 9" above ground level (AGL). An elevator services the stacks. Four 6-inch ports, located 90° apart on the same plane, are provided on both stacks. The specific dimensions for Unit 3 are provided in Table 2.4. The circular stack is 210 inches in diameter. The test ports are located 142.25 feet (8.1 stack diameters) downstream of the nearest flow disturbance and 347 feet (19.8 stack diameters) upstream of the stack exhaust to the atmosphere. There are four 6-inch sampling ports installed at 90° intervals at the sample location.

TRC conducted a 12 point traverse, 3 points per port, during each test run. Table 2.4 presents these traverse points.

Table 2.4
UNIT 3 OUTLET TRAVERSE SAMPLING POINTS

Stack Diameter (D)	210"
Distance Downstream	1,707"
Equivalent Downstream (D)	8.1
Distance Upstream	4,164"
Equivalent Upstream (D)	19.8
Method 1 Criteria Met	Yes
Number of Sample Ports	4
Sample Port Length	6"
Total Number of Sample Points	12
Number of points per Traverse	3

Point	Distance from Port (in.)
1	15.24
2	36.66
3	68.16

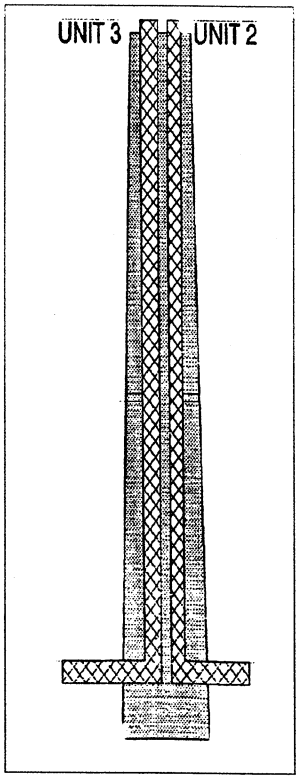


Figure 2.9
Stack Liner Cross-section

2.3 PROCESS SAMPLING LOCATIONS

The coal sampling location for both Unit 2 and Unit 3 were the same. The sample ports are located just after the bowl mill final crushing (pulverizing) and just prior to injection into the boiler. Each coal pulverizer has one sampling port called a diffuser gate, which is located after the pulverizer and right before the four pipes

that send finely crushed coal to each respective burner. This sample location provides as-fired coal samples, with a residence time of less than ten seconds before combustion. This virtually eliminated any lag time associated with the coal quality at the sample point and that "as-fired" during the test period. The coal at this point is the consistency of fine talcum powder.

This sample point was in lieu of the traditional sample locations for coal sampling upstream of the final crushing at the silo where lag time must be accounted for to compare the coal quality at the sample point with the "as-fired conditions." Five mills service each Unit boiler with four mills active at all times to support full load conditions.

SECTION 3.0
SUMMARY AND DISCUSSION OF RESULTS

3.1 OBJECTIVES AND TEST MATRIX

The objectives of the test program 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**

3.2 FIELD TEST CHANGES AND PROBLEMS

3.2.1 Field Test Changes

3.2.1.1 Inlet Sample Train Operation

Due to the high negative static pressure encountered at the MDC/ESP inlet, 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 Change in Collection Location of Process Samples

The SSTP called for collection of process samples from the coal belt feeders. Due to limited access to the belt feeders, it was not possible to collect coal samples from them. The facility had previously installed coal sampling ports at exit of the pulverizers at both Unit 2 and Unit 3. The coal sampling was moved to this location. This sample location provides as-fired coal samples, with a residence time of less than ten seconds before combustion. This modification is considered to have improved upon the quality of the coal sampling.

3.2.2 Sampling Difficulties or Issues

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.

3.2.2.1 Exhaust Stack Sampling Trains

The following problems/difficulties were encountered during conduct of the sampling at the outlet stacks:

- ✓ Unit 2 Run 2, between the third and fourth test ports the glass nozzle was accidentally bumped against the stack and broken. The broken nozzle and pieces were rinsed and the solution recovered.

A new nozzle with a slightly different diameter was then installed and a leak check performed, prior to resuming the sampling in the fourth port. The isokinetic rate calculation was adjusted to account for the sample volume and stack flow rate measured during the use of each nozzle.

- ✓ For Unit 3 Run 1, the KCl sample fraction was cracked during shipment to the laboratory with minimal sample lost. No corrections were made to the final results.

- ✓ For Unit 3 Run 3, the KCl sample fraction was broken during shipment to the laboratory. The average value found for Runs 1 and 4 were used for the final calculations.

3.2.2.2 Inlet Sampling Trains

Logistics at the inlet duct to both units were the cause of several minor problems with regard to sample train operation and port changes. The highly negative static pressure, which exists at the location and its impact, has been discussed previously in Section 3.1. The high inlet temperature for Unit 3 caused logistical difficulties in conducting the sampling traverses. The following problems/difficulties were encountered during operation of the inlet sample trains:

- ✓ For both units, the sample filter was replaced during the run when the isokinetic rate could not be met. This occurred several times during the test program, but is considered part of the normal operation of the test method at uncontrolled sampling locations. Each time a sample filter was replaced, a leak check was performed before and after the replacement. All post sampling leak checks for each filter were found within acceptable limits (<=0.02 cfm) and sampling was not initiated with any filter until the leak rate was found within acceptable limits.

- ✓ At Unit 3, the thermocouple for the probe temperature was found to be giving a false reading. It was determined that the thermocouple was most likely damaged by being exposed to the high duct temperature. To compensate for this, the probe was kept insulated as much as possible and full heat (maximum current) was applied to the probe for the duration of each test run. Applying the constant heat to the probe in conjunction with the high temperature of the flue gas (~680 °F or more) ensured that the probe temperature was maintained at a minimum to the prescribed temperature (320 °F ±27°F). In addition, there was no difficulty in keeping the filter box at or above the prescribe temperature of (320 °F ±27°F).

- ✓ For Unit 3, Run 1 the pitot lines were found to have touched the probe and melted shut. The pitot lines were replaced and verified to be leak free. The measured differential pressures were then checked for the first two points and updated. The correct differential pressures were found to be higher than used for the isokinetic sample rate calculation for these two points, resulting in a sample rate below the optimum rate. The isokinetic rate calculated for the entire run was found to be well within the method limits (103.1% compared to a limit of 100% ±10%).

- ✓ Also for Unit 3 Run 1, the orsat bag was contaminated/compromised during analysis. The absorbing solution was inadvertently introduced into the sample bag. The found results were voided and the average results from runs 2 & 3 were used for the flow rate calculations.

- ✓ For Unit 3, Run 2 the sample train connecting glassware was found disturbed partway through the

test run. Subsequently a leak check was performed which documented a high leak rate through the sample train. The test run was voided for both the inlet and outlet sample locations. A third and fourth test run were then completed.

- ✓ For Unit 2, Run 2 the glass nozzle was accidentally bumped against the sample port during a port change and broken. The broken nozzle and pieces were rinsed and the solution recovered. A new nozzle of the same diameter was then installed and a leak check performed, prior to resuming the sampling in the fourth port.

- ✓ For Unit 2, Run 3 the sample train solutions were found partially "backed up" during sample recovery at the on-site laboratory. Upon investigation, it was verified that the solutions and sample train were in tact and in the proper impingers. The sample train was recovered normally with the addition of a separate sample bottle for the solution from impinger 3. The amount of solutions transferred to the proceeding solutions was minimal. Due to the limited ability of the facility to support additional testing, it was decided that conducting another sample run was not feasible. The results of the speciated mercury analysis for this sample found all of the results to be within the range of the test Runs 1 and 2.

- ✓ For Unit 2 Run 2, the KCl sample fraction was broken during shipment to the laboratory. The average value found for Runs 1 and 3 were used for the final calculations.

- ✓ For Unit 2 Run 3, the HNO_3 sample fraction was broken during shipment to the laboratory. The average value found for Runs 1 and 3 were used for the final calculations.

3.3 PRESENTATION OF RESULTS

The objectives of the program, presented in section 3.1, center upon the determination of Hg emissions at the inlet and outlet of the Unit 2 and Unit 3 emission control devices.

Presented in Tables 3.3 and 3.4 are the results required to fulfill the objectives identified for this test program. The following sections discuss the results pertinent to each of the objectives 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 coal utilized in the operation of each unit during the specific test periods. Results for Unit 2 and Unit 3 are presented for each run and are based upon the concentration of mercury measured and the feed rate of coal into the process.

Tables 3.3 and 3.4 also present the concentration of mercury measured in the process materials and the calculated feed rate (mg/hr) of mercury into the process. 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

Although measurable quantities were reported by the laboratory for impingers 5 thru 7, the level of elemental

mercury in the 4th impinger (HNO_3/H_2O_2) was below the MDL for some of the sample trains. The detection limit for these samples is small in comparison to that found in the $KMnO_4/H_2SO_4$ sample fraction. Therefore the overall results for elemental mercury for these samples were reported using the values found for the $KMnO_4/H_2SO_4$ sample fraction.

3.3.2.1 Unit 2

Concentrations and emission rates for mercury are presented in Table 3.3. Results are presented on a speciated and total basis in terms of ug/dscm and mg/hr. Emission rates expressed in terms of lbs/hr and lbs/MMBtu.

3.3.2.2 Unit 3

Concentrations and emission rates for mercury are presented in Table 3.4. Results are presented on a speciated and total basis in terms of ug/dscm and mg/hr. Emission rates expressed in terms of Lb/hr and lb/MMBtu.

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 combined exhaust stack and the unit's MDC/ESP inlet sample locations. The Total feed rate of mercury into each Unit, as determined from the process sampling, was also required to calculate the final results. Data from the fourth test run at the inlet was not utilized in the calculation of control device efficiency.

3.3.3.1 Unit 2

The wet scrubber control device demonstrated a high removal efficiency for the particulate bound fraction, averaging 73.2% for the test program. RE for oxidized mercury (Hg^{2+}) was determined to be 85.2% and that of elemental (Hg^0) averaged –37.2%. The overall RE for mercury averaged 6.0%. Results are in Table 3.3.

3.3.3.2 Unit 3

The ESP control device demonstrated a high removal efficiency for the particulate bound fraction, averaging 96.7% for the test program. RE for oxidized mercury (Hg^{2+}) was determined to be –25.3% and that of elemental (Hg^0) averaged –79.3%. The overall RE for mercury averaged 4.8%. Results are presented in Table 3.4.

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 control device exhaust. The overall process RE for mercury averaged 22.8% for Unit 2 64.5% for Unit 3.

Table 3-1. APS CHOLLA GENERATING STATION TEST MATRIX

Sampling Location	Sample/Type Pollutant	Sampling Method	Sampling Organization	No. of Runs	Sample Time (min)	Analytical Method	Analytical Laboratory
UNIT 2 - INLET MDC Exhaust after air preheaters	Mercury speciated	Ontario Hydro (includes EPA RM1, RM2 & RM4	TRC	3	120	Ontario/Hydro & SW846, 7470A, CVAA	Philips Analytical Services, Canada
	O_2/CO_2	RM3B (Bag)	TRC	3	120	3B Orsat	TRC
UNIT 2 - OUTLET after scrubbers and absorbers @ Exhaust Stack	Mercury Speciated	Ontario Hydro (includes EPA RM1, RM2 & RM4	TRC	3	120	Ontario/Hydro & SW846, 7470A, CVAA	Philips analytical Services, Canada
	O_2/CO_2	RM3B (Bag)	TRC	3	120	3B Orsat	TRC
Coal Sampling BOTH UNITS	Sample Hg, S chlorine HHV proximate Total Moisture	ASTM D 2234-97a	APS	3	120	ASTM D2013-86 D3684-94,D4239-97 D2361-95 D5865-98 D5142-90 D3302-97	CTE Colorado
UNIT 3 – INLET Economizer Exhaust before "B" side ESP	Mercury speciated	Ontario Hydro (includes EPA RM1, RM2 & RM4	TRC	3	120	Ontario/Hydro & SW846, 7470A, CVAA	Philips Analytical Services, Canada
	O_2/CO_2	RM3B (Bag)	TRC	3	120	3B Orsat	TRC
UNIT 3 – OUTLET After ESP's @ Exhaust Stack	Mercury speciated	Ontario Hydro (includes EPA RM1, RM2 & RM4	TRC	3	120	Ontario/Hydro & SW846, 7470A, CVAA	Philips Analytical Services, Canada
	O_2/CO_2	RM3B (Bag)	TRC	3	120	3B Orsat	TRC

Table 3-2
MEASUREMENTS CONDUCTED AT EACH TEST LOCATION

UNIT 2 – INLET (After Dust Collector)	U2- Exhaust Stack (@ 203' level)	UNIT 3 – Inlet before "B" side ESP	U3 - Exhaust Stack (@ 203' level)
EPA-EMC - Pre-003 Speciated Mercury Ontario Hydro	EPA-EMC - Pre-003 Speciated Mercury Ontario Hydro	EPA-EMC - Pre-003 Speciated Mercury Ontario Hydro	EPA-EMC - Pre-003 Speciated Mercury Ontario Hydro
O_2/CO_2 (RM3B)	O_2/CO_2 (RM3B)	O_2/CO_2 (RM3B)	O_2/CO_2 (RM3B)
Sampling Location Traverse Points (RM-1)	Sampling Location Traverse Points (RM-1)	Sampling Location Traverse Points (RM-1)	Sampling Location Traverse Points (RM-1)
Velocity (RM-2)	Velocity (RM-2)	Velocity (RM-2)	Velocity (RM-2)
Moisture (RM-4)	Moisture (RM-4)	Moisture (RM-4)	Moisture (RM-4)

Table 3.3 SUMMARY TABLE OF EMISSIONS DATA AND REMOVAL EFFICIENCIES - UNIT 2

Method/ Component	Units	Unit 2 - Inlet				Unit 2 - Outlet Stack				Scrubber (I/O) Mercury Removal Efficiency, %				Process Samples				Process Feed (P_F/O) Mercury Removal Efficiency, %			
		Run 1	Run 2	Run 3	AVG	Run 1	Run 2	Run 3	AVG	Run 1	Run 2	Run 3	AVG	Run 1	Run 2	Run 3	AVG	Run 1	Run 2	Run 3	AVG
MERCURY																					
Particle Bound Mercury	mg/dscm	3.78E-04	1.06E-03	3.87E-04	6.10E-04	1.33E-04	1.58E-04	9.33E-05	1.28E-04	64.88%	85.17%	75.90%	75.32%	-	-	-	-	-	-	-	-
	mg/hr	3.57E+02	8.67E+02	3.55E+02	5.26E+02	1.31E+02	1.54E+02	9.24E+01	1.26E+02	63.31%	82.18%	73.94%	73.15%	-	-	-	-	-	-	-	-
Oxidized Mercury	mg/dscm	8.83E-04	8.92E-04	1.97E-03	1.25E-03	1.77E-04	1.24E-04	1.23E-04	1.41E-04	79.98%	86.06%	93.76%	86.60%	-	-	-	-	-	-	-	-
	mg/hr	8.34E+02	7.27E+02	1.80E+03	1.12E+03	1.74E+02	1.22E+02	1.22E+02	1.39E+02	79.09%	83.25%	93.25%	85.20%	-	-	-	-	-	-	-	-
Elemental Mercury	mg/dscm	4.24E-03	2.50E-03	2.86E-03	3.20E-03	3.34E-03	3.92E-03	3.73E-03	0.004	21.30%	-56.64%	-30.70%	-22.02%	-	-	-	-	-	-	-	-
	mg/hr	4.01E+03	2.04E+03	2.62E+03	2.89E+03	3.29E+03	3.84E+03	3.70E+03	3609.613	17.78%	-88.15%	-41.29%	-37.22%	-	-	-	-	-	-	-	-
Total Mercury	mg/dscm	5.23E-03	3.57E-03	4.45E-03	4.41E-03	3.65E-03	4.20E-03	3.95E-03	0.004	30.21%	-17.84%	11.24%	7.87%	-	-	-	-	-	-	-	-
	mg/hr	4.94E+03	3.63E+03	4.08E+03	4.22E+03	3.60E+03	4.11E+03	3.91E+03	3874.731	27.10%	-13.23%	4.05%	5.97%	-	-	-	-	-	-	-	-
COAL SAMPLE																					
Total Mercury Concentration	mg/G	-	-	-	-	-	-	-	-	-	-	-	-	4.50E-05	4.00E-05	3.50E-05	4.00E-05	-	-	-	-
Feed Rate, as Fired	KG/hr	-	-	-	-	-	-	-	-	-	-	-	-	1.33E+05	1.32E+05	1.35E+05	1.33E+05	-	-	-	-
Sulfur	WT%	-	-	-	-	-	-	-	-	-	-	-	-	0.495	0.51	0.525	0.51	-	-	-	-
Chlorine	mg/G	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	0	-	-	-	-
HHV, dry basis	Btu/lb	-	-	-	-	-	-	-	-	-	-	-	-	11222.5	10955	11134.5	11104	-	-	-	-
Moisture	WT%	-	-	-	-	-	-	-	-	-	-	-	-	5.68	6.13	5.76	5.856667	-	-	-	-
Hg Feed Rate	mg/hr	-	-	-	-	-	-	-	-	-	-	-	-	5.63E+03	4.97E+03	4.47E+03	5.02E+03	36.02%	17.17%	12.46%	22.81%

Table 3.4 SUMMARY TABLE OF EMISSIONS DATA AND REMOVAL EFFICIENCIES - UNIT 3

Method/ Component	Units	Unit 3 - Inlet				Unit 3 - Outlet Stack				ESP (I/O) Mercury Removal Efficiency, %				Process Samples				Process Feed (P_F/O) Mercury Removal Efficiency, %			
		Run 1	Run 3	Run 4	AVG	Run 1	Run 3	Run 4	AVG	Run 1	Run 3	Run 4	AVG	Run 1	Run 3	Run 4	AVG	Run 1	Run 3	Run 4	AVG
MERCURY																					
Particle Bound Mercury	mg/dscm	6.53E-05	4.77E-04	4.26E-04	3.23E-04	1.43E-05	1.06E-05	1.30E-05	1.27E-05	78.05%	97.73%	96.95%	90.91%	-	-	-	-	-	-	-	-
	mg/hr	4.25E+02	4.46E+02	3.99E+02	4.23E+02	1.58E+01	1.17E+01	1.40E+01	1.38E+01	96.29%	97.37%	96.49%	96.71%	-	-	-	-	-	-	-	-
Oxidized Mercury	Mg/dscm	3.53E-04	3.00E-04	4.11E-04	3.55E-04	4.19E-04	1.06E-05	3.30E-04	2.53E-04	-18.67%	96.46%	19.64%	32.48%	-	-	-	-	-	-	-	-
	mg/hr	3.34E+02	2.80E+02	3.84E+02	3.33E+02	4.62E+02	4.07E+02	3.56E+02	4.08E+02	-38.14%	-45.10%	7.37%	-25.29%	-	-	-	-	-	-	-	-
Elemental Mercury	mg/dscm	1.84E-03	4.38E-04	5.89E-04	9.67E-04	1.54E-03	8.64E-04	1.06E-03	0.001	16.51%	-97.20%	-83.74%	-54.81%	-	-	-	-	-	-	-	-
	mg/hr	1.74E+03	4.10E+02	5.51E+02	9.02E+02	1.70E+03	9.38E+02	1.17E+03	1.27E+03	2.73%	-128.94%	-111.79%	-79.33%	-	-	-	-	-	-	-	-
Total Mercury	mg/dscm	1.91E-03	1.21E-03	1.43E-03	1.52E-03	1.97E-03	8.75E-04	1.43E-03	0.001	-3.35%	27.97%	0.05%	8.22%	-	-	-	-	-	-	-	-
	mg/hr	2.50E+03	1.14E+03	1.33E+03	1.66E+03	2.17E+03	9.50E+02	1.54E+03	1.55E+03	13.21%	16.38%	-15.21%	4.79%	-	-	-	-	-	-	-	-
COAL SAMPLE																					
Total Mercury Concentration	mg/G	-	-	-	-	-	-	-	-	-	-	-	-	4.00E-05	4.00E-05	3.00E-05	3.67E-05	-	-	-	-
Feed Rate, as Fired	KG/hr	-	-	-	-	-	-	-	-	-	-	-	-	1.26E+05	1.31E+05	1.31E+05	1.29E+05	-	-	-	-
Sulfur	WT%	-	-	-	-	-	-	-	-	-	-	-	-	0.43	0.42	0.42	0.42	-	-	-	-
Chlorine	mg/G	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	-	-	-	-
HHV, dry basis	Btu/lb	-	-	-	-	-	-	-	-	-	-	-	-	11863	12172	12135	12056.67	-	-	-	-
Moisture	WT%	-	-	-	-	-	-	-	-	-	-	-	-	7.49	7.74	7.45	7.56	-	-	-	-
Hg Feed Rate	mg/hr	-	-	-	-	-	-	-	-	-	-	-	-	4.66E+03	4.83E+03	3.64E+03	4.38E+03	53.38%	80.34%	57.77%	64.51%

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 used in this program:

EPA EMC Pre-003	**Draft Standard Test Method for Elemental, Oxidized, Particle-Bound AND Total Mercury in Flue Gas Generated From Coal-Fired Stationary Sources (Ontario Hydro Method) 10/21/99 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

Pre-sampling activities included equipment calibration, pre-cleaning of the sample train glassware, and other miscellaneous tasks. Each of these activities are described or referenced in the following subsections. Other pre-sampling 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

Refer to 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 pre-cleaning to avoid contamination of the sample from the collection container or devices.

The Ontario Hydro sampling train glassware was pre-cleaned with an alconox 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 or plastic film.

4.3 ONSITE SAMPLING ACTIVITIES

Onsite sampling activities included equipment set up and conducting testing of the inlet duct and outlet stack for both Unit 2 and 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 outlet 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. Flow conditions were acceptable at the outlet locations.

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 Unit 2 and Unit 3 inlet and outlet via EMC Pre-003 "*Draft Standard Test Method for Elemental, Oxidized, Particle-Bound, and Total Mercury Emissions in 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 October 21, 1999.

The OHM 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. The inlet probe at both units was oriented in a vertical position and sampling train was oriented in a horizontal position as shown in Figure 4.1. For the outlet sample locations the probe and sampling train were both oriented in a horizontal position as shown in Figure 4.2.

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 ± 27°F or at 248°F ± 25°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. All stack and train operating parameters were recorded at each sampling point.

Figure 4.1
Method EPA EMC - Ontario Hydro-Speciated Mercury Sampling Train - Vertical

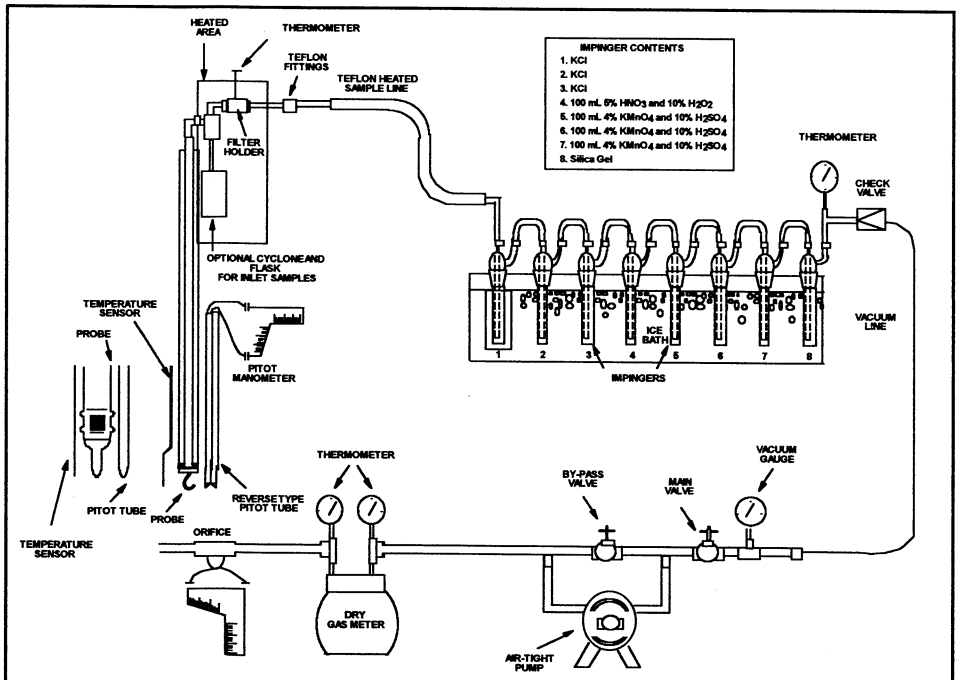
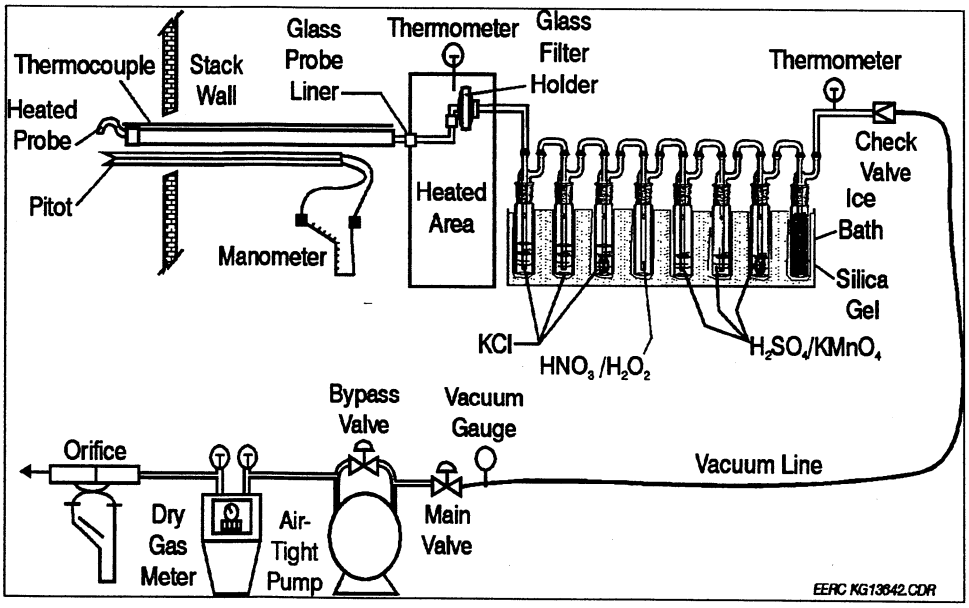


Figure 4-2. Schematic of EPA PRE003-Ontario Hydro-Speciated Mercury-Sampling Train in the Method 5 Verticle Sampling Configuration

Figure 4.2
Method EPA EMC - Ontario Hydro-Speciated Mercury Sampling Train - Horizontal



The sampling duration at each location was 120 minutes. 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 (Sample Filter)** - Disassembled the filter housing and transferred the filter to its original petri dish. Sealed the petri dish with Teflon^R tape and labeled it with the appropriate sample information. Any filter fibers adhering to the support gasket were transferred to the petri dish.
- ✓ **Container No. 2 (All rinses in Front of the Sample Filter** - 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^R-lined cap. The container was sealed, weighed, and labeled.
- ✓ **Container No. 3 (Impingers 1 through 3, KCl Impinger and Rinses)** - 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 HNO_3 into a glass amber container with a Teflon lined cap. 5% $KMNO_4$ solution was added very slowly to each impinger and gently mixed. 5% $KMNO_4$ solution was added in this fashion until a purple color remained for 15 minutes. The solutions were then poured into the container. The impingers and connecting glassware were rinsed with 10% HNO_3. Although unlikely, if deposits remained on the impinger surfaces, they were removed by doing another 10% HNO_3 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% $KMnO_4$ 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 HNO_3 and added this rinse to Container 3. The container was sealed, weighed, and labeled.
- ✓ **Container No. 4 (Impinger 4, HNO_3-H_2O_2 Impinger contents and Rinses)** - The contents of the fourth impinger were weighed and transferred to a glass amber container with a Teflon^R-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, weighed, and labeled.
- ✓ **Container No. 5 (Impingers 5 through 7, H_2SO_4/$KMnO_4$ 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 H_2SO_4-$KMnO_4$ impingers into

a vented amber glass sample, Container 5. Rinsed the impingers and connecting glassware with a 0.1 N HNO_3 a minimum of two times. A third rinse was then completed to remove any brown stains from the surface of the impingers. This rinse consists of 0.1N HNO_3 and several drops of 10% hydroxylamine solution. 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 H_2SO_4-$KMnO_4$ solution until a pink or slightly purple color was obtained. Performed a final 0.1 N HNO_3 rinse of the impingers and connecting glassware followed by a water rinse. The 0.1 N HNO_3 rinse was added to Container 5, and the water rinse was discarded. The container was sealed, weighed, and labeled.

- ✓ **Container No. 6 (Impinger 8, Silica Gel Impinger Contents)** The silica gel impinger was weighed to obtain a final weight.

- ✓ **Solution Blanks (Containers 7 thru11)** - Solution blanks were taken each time new reagents were prepared.

- ✓ **Container 7 - (0.1 N HNO_3 Blank)** - Placed 50 mL of the 0.1 N HNO_3 solution used in the sample recovery process into a properly labeled container. Sealed the container.

- ✓ **Container 8 (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 9 (5% HNO_3 - 10% v/v H_2O_2 Blank)** - Placed 50 mL of the HNO_3-H_2O_2 solution used as the nitric acid impinger reagent into a properly labeled container. Sealed the container.

- ✓ **Container 10 (H_2SO_4 - $KMnO_4$ Blank)** - Placed 50 mL of the H_2SO_4 - $KMnO_4$ 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 11 (10% Hydroxylamine Sulfate Blank)** - Placed 100 mL of hydroxylamine sulfate solution into a properly labeled sample container. Sealed the container.

- ✓ **Container 12 (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. 2 - Front-Half 0.1N HNO_3 Rinse
- ✓ Container No. 3 - Impingers 1, 2 & 3 KCl Impinger Catch & Rinse
- ✓ Container No. 4 - Impinger 4 - 0.1N HNO_3 Impinger Catch & Rinse
- ✓ Container No. 5 - Impingers 5 - 7 - $KMnO_4$ Impinger Catch & Rinse

4.3.4 EPA Method 3B for O_2 and CO_2

The O_2 and CO_2 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 Excess Air*". Three or more passes were made until three results were within 0.2% (absolute) of each other.

4.3.5 Process Sampling

The coal sampling procedure followed during speciated mercury testing was ASTM D 2234-97a, with the following method exceptions made due to sampling location and the design of the coal pulverizers. Each coal pulverizer has one sampling port called a diffuser gate, which is located after the pulverizer and right before the four pipes that send finely crushed coal to each respective burner. This sample location provides as-fired coal samples, with a residence time of less than ten seconds before combustion. The coal at this point is the consistency of fine talcum powder. The ASTM method calls for larger size coal samples, but this is not possible at these sample locations on Unit 2 and Unit 3.

At the beginning of a speciated mercury test run, each of the four operating pulverizers is sampled with a cone sampler. There is a total of five pulverizers, however, one is a maintenance spare, and is not needed for full load operation. Sample bags are filled from each diffuser gate, then closed for compositing and rifling in the on-site coal lab after the completion of a test run. The sampling was representative of the coal fired during a test run, but not fully continuous at each location, as each diffuser location would have produced an un-manageable amount of coal (estimated at 100 pounds of coal per diffuser gate). Furthermore, the sampler must move back and forth between each pulverizer because the cone sampler must be inserted into the gate to obtain a coal sample.

Sampling was completed by the end of each respective test run. The sample bags were taken to the on-site coal lab where two, five-pound bags of coal sample were recovered for lab analysis. Each final bag is double heat-sealed and has the Unit number, date, time of the beginning of test run, test run number, Hg test project, and the name or initials of the sampler. ASTM Method D 3684-94, Total Mercury in Coal, will be used by the lab performing the mercury analysis on the coal, along with chlorine, ultimate and proximate analysis.

4.4 PROCESS MONITORING

The facility operations data acquisition system (DAS) was utilized to record all operations data at approximately one minute intervals. The data was averaged over the entire run period. Coal feed was totaled over each test run as well.

Unit 2 scrubber parameters were monitored and recorded in the Unit 2 scrubber control room or Citech data system. ESP control values for Unit 3 were recorded manually by environmental Citech during the test program. Operations data collected by the facility is incorporated in Appendix C. The following process data was obtained.

Coal feeders	feed rate K lb/hr and totalizer
Lime slurry	feed rate K lb/hr for each absorber
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
Wind Box (furnace) pressure	in H_2O
Air heater temperature	in/out F
# of mills in operation	#
# of burners in operation	#
Combustion air flow	K lb/hr
Furnace	O_2
Unit 2 - Scrubber	
Gas Flow Rate (per tower)	ACFM
Liquor Flow Rate	GPM
Pressure Drop Across Unit	"H_2O
Liquid Pressure Drop Across Unit	"H_2O
Inlet/Outlet Air Temperature	°F
Unit 3 Electrostatic Precipitator	
Pressure Drop	"H_2O
Voltage and Current rating	kva (raw values only)
	MA (raw values only)
Transformer/Rectifier	IN/OUT of Service
U2 – SO_2 CEMs (inlet/Outlet)	ppm or #/MMBTU
U3 – SO_2 CEMs (Outlet)	ppm or #/MMBTU

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 4-2.

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 4-3.

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 Oxy Bomb Combustion /Atomic Absorption Method.
- ✓ ASTM D4208 -88 Standard Test Method for Chlorine in Coal by the Oxy 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).

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	**ug/g, (ppm)**
Chlorine	**ug/g, (ppm)**
Sulfur	**wt%, (lb/lb)**
ash	**wt%, (lb/lb)**
moisture	**wt%, (lb/lb)**
gross heating value	**Btu/lb**

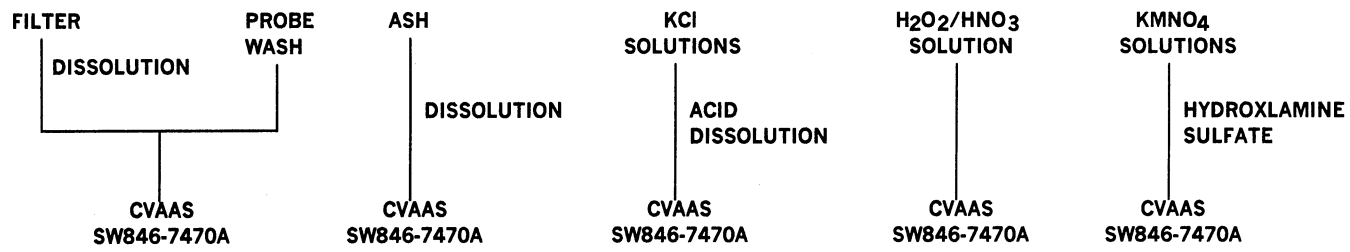


Figure 4-3. Analytical Scheme for EPA-Pre-003-Ontario Hydro Sampling Train Mercury Analysis

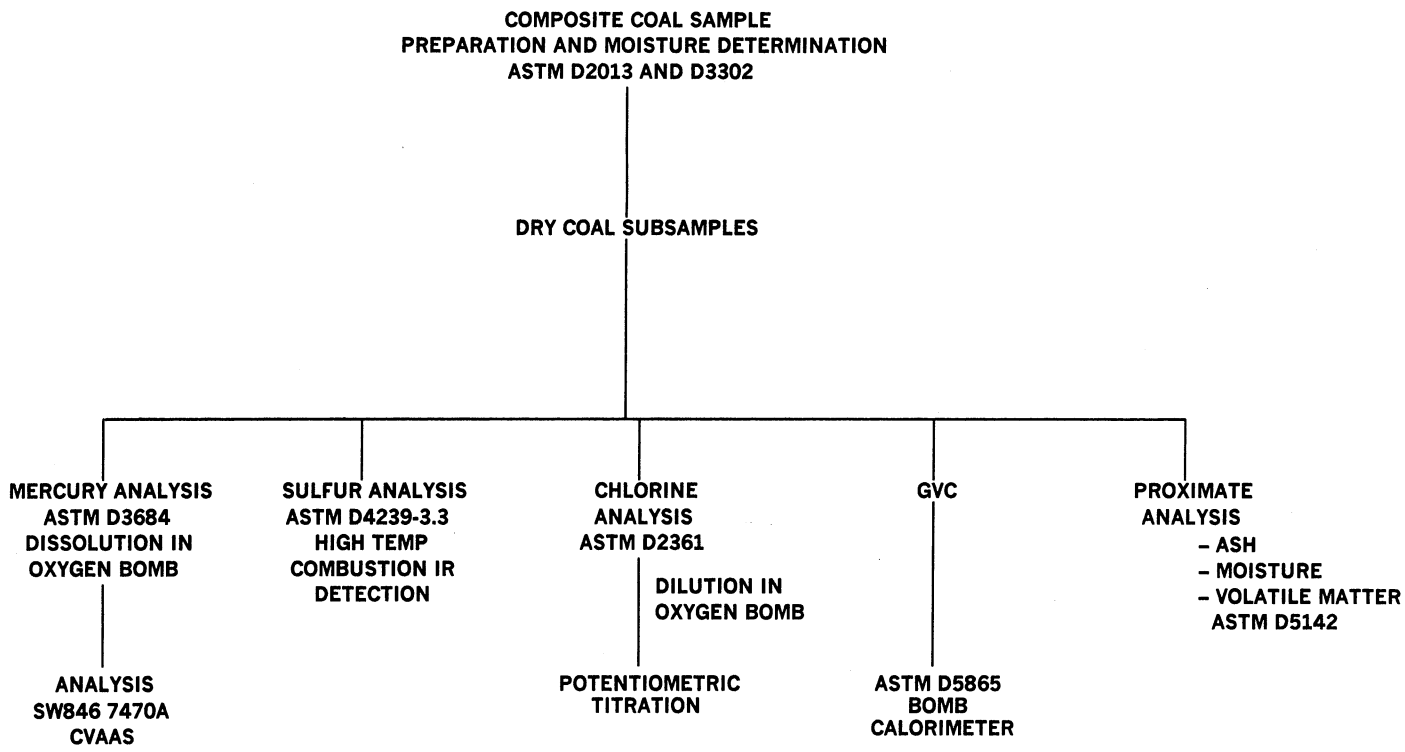


Figure 4-4. Coal Sample Analytical Scheme

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), 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	=	T	Dry Gas Meter, ft^3	=	VM
Pitot ΔP, in. H_2O	=	ΔP	Orifice ΔH, in. H_2O	=	PM
Dry Gas Temp In, °F	=	TMI	Dry Gas Temp Out, °F	=	TMO
Static Pressure, in. H_2O	=	PST	Stack Temp, °F	=	TS

1. DN = Nozzle Diameter, inches _____ in.

2. PB = Barometric Pressure, inches Hg _____ in.Hg

3. TT = Net Sampling Time, minutes _____ min.

4. VM = VM final - VM initial = Sample Gas Volume, ft^3 _____ ft^3

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] = _____ ft^3

5. Average Dry Gas Temperature at meter, °F

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

6. Average Orifice Pressure Drop, inches Hg

$$PM = \frac{\text{Average } \Delta H\text{, in. } H_2O}{13.6}$$ _____ in. Hg

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

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

Y = dry gas meter calibration factor

Y = _____ _____ ft^3

8. Total Water Collected

VW = gm H_2O silica gel + gm impinger H_2O _____ gm

Note: If ml H_2O is measured - (ml * 0.9982 gm/ml = ____ gm)

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

VW gas = 0.04715 * VW _____ scf

10. Percent moisture in stack gas

$$\% M = \frac{100 * VW\ gas}{VMSTD + VW\ gas}$$ _____ %

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

$$\% M = \frac{VP}{PS} * 100$$ _____ %

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

$$PST = \frac{PST\ "\ H_2O}{13.6}$$ _____ in. Hg

PS = PB ± Average PST _____ in. Hg

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} _____ in. Hg

$$VP = SVP - 0.00367*(PS)*(TS_{dry} - TS_{wet})*[\ 1+(\ TS_{wet} - 32)\ /\ 1571\ ]$$ _____ in. Hg

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 * 0.44) + (% O_2 * 0.32) + [(% CO + % N_2) * 0.28] _____ mole dry

12a. % Excess Air

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

13. Molecular Weight of wet stack gas
MW = (MWD * MD) + 18 * (1 - MD) _____ lb/lb mole wet

14. AS = Stack Area, square inches

Circular = 3.141579 * R^2 _____ sq. in.

Rectangular = Length * Width _____ sq. in.

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

$$PST = \frac{PST\ "H_2O}{13.6}$$ _____ in. Hg

PS = PB ± Average PST _____ in. Hg

16. TS_{avg} = Average Stack Temperature _____ °F

17. SDE_{avg} = SQRT(ΔP)$_{avg}$ * SQRT (TS_{avg} + 460)

18. Stack gas velocity at stack conditions, afpm

$$Vs = Kp\ Cp \sqrt{dp} \sqrt{\frac{Tsavg}{(PsMs)}}$$

where;

VS =
Kp = Pitot tube coefficient

Cp = Pitot tube constant _____ afpm

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

$$Q_a = \frac{VS * 60 * A_S}{144}$$ _____ acfm

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

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

21. Percent Isokinetics

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

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:

$$Hg_{ASH}\ (\mu g/g) = (\ IR\ ) * (\ DF\ ) \qquad \text{[Eq. 8]}$$

where:

IR = instrument reading, µg/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:

$$Hg_{PR}\ (\mu g) = (\ IR\ ) * (\ V_1\ ) \qquad \text{[Eq. 9]}$$

where:

IR = instrument reading, µg/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:

$$Hg_{FB}\ (\mu gs) = (\ IR\ ) * (\ V_2\ ) \qquad \text{[Eq. 10]}$$

where:

IR = instrument reading, µg/L
V_2 = total volume of sample filter blank digest, L.

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

$$Hg_{PARTICULATE}\ (mg) = (\ Hg_{ASH}\ )*(\ W_{ASH}\ ) - Hg_{FB} + Hg_{PR} \qquad \text{[Eq. 11]}$$

where:

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

The concentration of particle-bound mercury (µg/dscm) in the gas stream is determined using Equation 12:

$$Hg_{TP}\ (\mu gs/dscm) = Hg_{PARTICULATE} / V_{m(std)} \qquad \text{[Eq. 12]}$$

where:

$V_{m(std)}$ is the 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 µg/L in the KCl impinger solutions using Equation 13:

$$HG_{KCL}\ (\mu gs/L) = (\ IR\ ) * (\ DF\ ) \qquad \text{[Eq. 13]}$$

where:

IR = instrument reading, µg/L

$$DF = \frac{\text{dilution factor} = V_D + V(H_2SO_4) + V(HNO_3) + V(KMnO_4) + V(K_2S_2O_8) + V(NH_2OH)}{V_D}$$

V_D = total digested volume, 10 mL
$V(H_2SO_4)$ = volume of added concentrated H_2SO_4, 0.5 mL
$V(HNO_3)$ = volume of added concentrated HNO_3, 0.5 mL
$V(KMnO_4)$ = volume of added 5% w/v $KMnO_4$, 1.5 mL
$V(K_2,S_2,O_8)$ = volume of added 5% w/v $K_2S_2O_4$, 0.75 mL
$V(NH_2OH)$ = 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:

$$HG_O\ (\mu g) = (\ Hg_{KCL}\ ) * (\ V_3\ ) - (\ Hg_{OB}\ ) * (\ V_3\ ) \qquad \text{[Eq. 14]}$$

where:

Hg_{KCl} = Mercury concentration measured in KCl aliquot, µg/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, µg/L

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

$$Hg^{2+}\ (\mu g/dscm) = Hg_O\ /\ V_{m(std)} \qquad \text{[Eq. 15]}$$

where:

$V_{m(std)}$ is the total volume of dry gas sampled at standard conditions, dscm

4.6.2.3 Elemental Mercury

4.6.2.3.1 HNO_3-H_2O_2 Solution (Impinger 4)

Calculate the concentration of mercury in µg/L in the HNO_3-H_2O_2 impinger solution using Equation 16:

$$Hg_{H2O2}\ (\mu g/L) = (\ IR\ ) * (\ DF\ ) \qquad \text{[Eq. 16]}$$

where:

IR = instrument reading, µg/L
DF = dilution factor = $\dfrac{V_D + V(HCl) + V(KMnO_4) + V(K_2S_2O_8) + V(NH_2OH)}{V_D}$

V_D = total digested volume, 5 mL
$V(HCl)$ = volume of added concentration HCl, 0.25 mL
$V(KMnO_4)$ = volume of added saturated $KMnO_4$, mL (volume need to turn sample to a purple color)
$V(K_2S_2O_8)$ = volume of added 5% w/v $K_2S_2O_4$, 0.75 mL (if used)
$V(NH_2OH)$ = volume of added 10% w/v hydroxylamine sulfate, 1.0 mL

The amount of mercury in the HNO_3-H_2O_2 solution blank is calculated in the same way.

4.6.2.3.2 H_2SO_4-$KMnO_4$ Solution (Impingers 5-7)

Calculate the concentration of mercury in µg/L in the H_2SO_4-$KMnO_4$ impinger solutions using Equation 17:

$$\text{Mercury } (\mu g/L) = IR \qquad \text{[Eq. 17]}$$

where:

IR = instrument reading, µg/L

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 H_2SO_4-$KMnO_4$ 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 H_2SO_4-$KMnO_4$ impingers plus the mercury in the HNO_3-H_2O_2 impingers minus the solution blanks as shown in Equation 18:

$$Hg_E\ (\mu g) = (Hg_{H2O2})*(V_4) - (Hg_{EB1})*(V_4) + (Hg_{KMNO4})*(V_5) - (H_{EB2})*(V_5) \qquad \text{[Eq. 18]}$$

where:

Hg_{H2O2}	=	mercury concentration measured in HNO_3-H_2O_2 aliquot, µg/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, µg/L
HB_{KMNO4}	=	Mercury concentration measured in H_2SO_4-$KMnO_4$ aliquot µg/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, µg/L

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

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

where:

$V_{m(std)}$ is the 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:

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

4.6.3 Emission Rate of Mercury Species

The following equation is used for each species.

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

$$\text{g/hr} = \frac{\text{lb}}{\text{hour}} \times \frac{453.59\ \text{g}}{\text{lb}}$$

4.6.4 Mercury Removal Efficiency of Pollution Control System for each Species

%RE = [(total inlet g/hr) – (outlet g/hr)] / (total inlet g/hr) * 100

4.6.5 Total Mercury Introduced into the Combustion Unit

From coal analysis:

G/hr = (ug/g in FEED) * (FEEDRATE lbs/hr) * 1000 lbs/Klb * 453.59 g/lb * 1g/10^6 ugs

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 Generator Test Program Arizona Public Service Company Cholla Generating Station "*, May 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 erated 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 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.2.

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 was verified in accordance with Section 2.4 of EPA Method 1 during preliminary traverses conducted at each outlet sampling location.

5.2.4 Field Blanks

Field blanks were taken as outlined in the method, recovered, sealed, weighed, and labeled.

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 it's 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.

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).

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 and accompanied every sample or group of individually identified samples. Each person who had custody signed the COC form.

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 that 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.

The following subsections detail the Laboratory QC measures performed on the samples that 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 detected in either the reagent blanks however, background levels of 0.19 ug was found with the Unit 2 filters and 0.027 ug for Unit 3 (inlet).

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 by the National Institute for Standards and Technology (NIST). The audit sample was prepared and analyzed with percent recovery of 99%. The recovery of the audit sample analysis was well within acceptance limits of 90 - 110% recovery. The result of the audit sample analysis can be found in the analytical data package located in Appendix D.

5.4.2 Analysis of the Process Feed Samples

The process samples were analyzed for the parameters;

- Coal - mercury, sulfur, chlorine, and higher heating value, moisture, and ash content

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 Sample Results

Component	Blank Spike 1		Blank Spike 2		Matrix Spike 1		Matrix Duplicate Spike 1		Matrix Spike 2		Matrix Duplicate Spike 2	
	µg	% Rec.	µg	% Rec.	µg	% Rec.	µg	% Rec.	µg	% Rec.	µg	% Rec.
Filter	0.11	110	0.10	100	0.13	100	0.12	96	2.4	97	2.4	93
KCl	0.29	97	0.30	100	1.8	100	1.8	100	2.0	100	1.9	99
$KmnO_4$	0.30	100	0.30	100	5.1	87	5.1	90	10	85	10	84
H_2O_2	0.10	100	0.10	100	2.6	100	2.5	100	3.1	110	3.0	100

Table 5-2
Duplicate Sample Results

Component	Unit 3 Outlet Run 1		Unit 2 Inlet Run 1	
	Original µg	Duplicate µg	Original µg	Duplicate % Rec.
Filter	0.027	0.026	0.59	0.57
KCl	0.79	0.80	0.95	0.96
$KmnO_4$	2.9	2.8	6.2	6.1
H_2O_2	<0.25	<0.25	0.43	0.44

Table 5-3
Blank Sample Results

Component	Method Blank µg	Field Blank µg
Filter	<0.010	0.19
KCl	<0.030	<0.033
$KmnO_4$	<0.030	<0.050
H_2O_2	<0.010	<0.25

APPENDIX A
RESULTS AND CALCULATIONS