United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

EMB Report No. 87-MIN-04A
Volume I
September 1988

Air

EPA

Municipal Waste Combustion Multipollutant Study

Shutdown/Startup Emission Test Report

Marion County
Solid Waste-to-Energy Facility
Ogden Martin Systems of Marion, Inc.
Brooks, Oregon

DCN No. 88-222-124-12-08 EMB Report No. 87-MIN-4A

SHUTDOWN/STARTUP TEST PROGRAM
EMISSION TEST REPORT

MARION COUNTY
SOLID WASTE-TO-ENERGY FACILITY, INC.
OGDEN MARTIN SYSTEMS OF MARION
BROOKS, OREGON

VOLUME I: SUMMARY OF RESULTS

ESED Project No. 86/19
EPA Contract No. 68-02-4338
Work Assignment 17

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September 1988

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FOREWORD

The data contained in this report represent the operating conditions of the facility at the time of the test program. Since the completion of the test program, however, a program of screening the waste received at the facility and removing materials which resulted in high SO_2 emissions has been implemented. Additionally, the lime feed now operates at a higher rate than during the test program. Because of these actions, SO_2 emissions are believed to have decreased from the values reported here.

Acknowledgements

The work reported herein was performed by personnel from Radian Corporation, Midwest Research Insitute (MRI), Entropy Environmentalists, Inc., Ogden Projects, Inc., and the U. S. Environmental Protection Agency (EPA).

Radian's Task Director, Winton Kelly, directed the field sampling and analytical effort and was responsible for summarizing the test and analytical data presented in this report. Sample analyses were performed by Radian Corporation in Research Triangle Park, North Carolina, and by Triangle Laboratories, Inc., Research Triangle Park, North Carolina. Entropy Environmentalists, Inc. conducted the continuous HCl monitoring.

Mr. Peter Schindler, Office of Air Quality Planning and Standards, Industrial Studies Branch, EPA, served as Project Lead Engineer and was responsible for coordinating the process operations monitoring in conjunction with Dr. Ted Brna and Mr. Jim Kilgroe, who served as the Air and Energy Engineering Research Laboratory (AEERL) Lead Engineers.

Mr. Clyde E. Riley, Office of Air Quality Planning and Standards, Emission Measurements Branch, EPA, served as Project Task Manager and was responsible for overall test program coordination.

The Office of Air Quality Planning and Standards, EPA, would like to thank the following individuals for their cooperation and assistance in the execution of the test program:

Ogden Martin Systems of Marion, Inc.
Mr. Fred Engelhardt, Facility Manager
Mr. Russel Johnston, Chief Engineer
Mr. Don Penrose, Maintenance Supervisor

Martin GmbH
Mr. Johannes Martin, Director of Engineering and Design
Mr. Joachim Horn, Process Engineer

Ogden Projects, Inc.
Mr. David Sussman, Vice President - Environmental Affairs
Mr. Jeffrey Hahn, Vice President - Environmental Engineering
Mr. Henry Von Demfange, Manager - Environmental Testing

The efforts of these individuals and members of their staff are greatly appreciated.

RADIAN REPORT CERTIFICATION

This report has been reviewed by the following Radian personnel and is a true representation of the results obtained from the sampling program at Marion County Solid Waste-to-Energy Facility, Inc., Ogden Martin Systems of Marion, Brooks, Oregon. The sampling and analytical methods were performed in accordance with procedures outlined in the "Field Test Plan for the Characterization Test Program" dated June 2, 1987. The sampling and analytical plan was reviewed and accepted by the EPA/EMB Task Manager, Clyde E. Riley.

APPROVALS

Project Director: Winton E. Kelly Date: 10/12/87
Winton E. Kelly

Program Manager: Date: 10/13/87
Robert M. Dykes

QA Officer: Donna J. Holder Date: 10/13/87
Donna J. Holder

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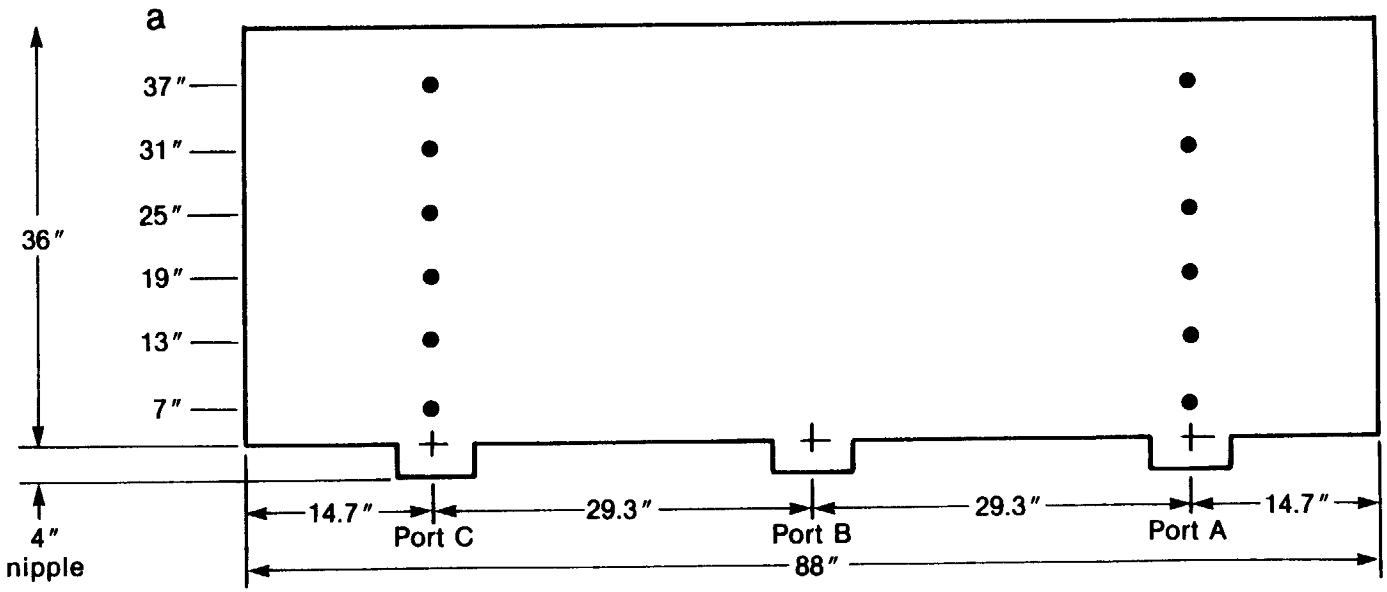

[a] Measurement from the outside of the nipple for probe marking

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Figure 5-8. Stratification Point Location for the Breeching Location at Marion County MWC

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1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) published an advance notice of proposed rulemaking in the Federal Register (52 FR 25399) which describes upcoming emission standards development for new municipal waste combustors (MWC) under Section 111 of the Clean Air Act and for existing MWC under Section 111(d) of the Act. The Federal Register notice concluded more than a year's work of development of the technical and health related documents which compose EPA's Report to Congress on MWC. The Report to Congress was a joint effort involving the Offices of Air Quality Planning and Standards (OAQPS), Solid Waste (OSW), and Research and Development (ORD).

The Emission Standards and Engineering Division (ESED) of OAQPS, through its Industrial Studies Branch (ISB) and Emissions Measurements Branch (EMB), is responsible for reviewing the existing air emission data base and gathering additional data where necessary. As a result of this review, several MWC emission tests were performed and are in the planning stages to support the current standards development work. Of particular importance is a more complete data base on emerging air pollution control technologies for MWC.

The emissions that are being studied by EPA are the criteria pollutants--particulate matter (PM), sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO) and total hydrocarbons (THC); other acid gases, such as hydrogen chloride (HCl); chlorinated organics including chlorinated dibenzo-p-dioxins (CDD) and chlorinated dibenzofurans (CDF); and specific metals including arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), nickel (Ni), lead (Pb) and beryllium (Be).

1.1 PURPOSE AND OBJECTIVES

A data gap was identified by ESED in the area of quench reactor/fabric filter (QR/FF) controlled emissions. Although QR/FF data were collected during studies at Quebec City in the National Incinerator Testing and Evaluation Program (NITEP) Studies,[1] additional data are required because the unit tested was a pilot scale unit and the testing did not evaluate the effect of combustion variation on control system performance. Thus, a multi-phase parametric test program was designed to supplement the QR/FF data base. The site selected for the parametric test program was the Marion County Solid Waste-to-Energy Facility in Brooks, Oregon. The parametric test program is being conducted in two phases: the characterization test program and the performance test program. The parametric test program has three principal objectives:

Characterization Testing:

- To evaluate the control efficiency of the QR/FF system over the normal operating range of the combustor.

Performance Testing:

- To evaluate the variation in QR/FF acid gas control as a function of control device operating temperature and lime stoichiometric ratio.
- To evaluate the control efficiency of the QR/FF system on organic emissions (CDD/CDF) during combustor shutdown and startup procedures.

The objectives of the characterization program were to characterize combustion parameters and acid gas removal efficiencies during baseline operations as well as during the range of the operation allowed by the facilities' air quality permit. The data generated during the characterization test program, which was conducted in June 1987, would be used to select the test matrix for the performance test program. The shutdown/startup testing was conducted on June 21-23 to coincide with a scheduled shutdown/startup of the facility. The results of the shutdown/startup testing are the subject of the this report. The results of the characterization test program are reported separately.[2] The performance test program is currently scheduled for Fall 1988 and may be performed at a different facility.

The shutdown/startup evaluation was conducted primarily with continuous emission monitors (CEMs) and plant instrumentation. Radian Corporation conducted continuous emission monitoring for SO_2, NO_x, O_2, CO, CO_2 and THC at the inlet to the control devices and at the outlet of the control devices. Also, SO_2, O_2 and CO_2 were continuously monitored at a midpoint between the quench reactor and the baghouse. Radian conducted simultaneous manual sampling for HCl at the inlet, midpoint and outlet locations and CDD/CDF sampling at the inlet and outlet locations. Entropy Environmentalists, Inc., conducted continuous measurements of HCl at the three locations.[3]

Baseline CDD/CDF emissions data were collected during previous emissions tests conducted at the facility by EPA in September 1986[4] and February 1987.[5] These results are used for comparison to the shutdown/startup CDD/CDF results.

1.2 BRIEF PROCESS DESCRIPTION

Figure 1-1 presents a process diagram of the two identical combustor systems at the Marion County facility. Unit No. 1 was tested during the shutdown/startup test program. The combustor is a reciprocating grate, mass-burn type with a waterwall boiler that produces superheated steam. The flue gas passes from the combustor into convection, superheater, and economizer sections before acid gas and particulate emissions are controlled by a quench reactor and fabric filter emissions control system.

The refuse is typical residential and commercial solid waste. No sorting or shredding is performed prior to incineration. The refuse is brought to the enclosed tipping area by truck and unloaded into the refuse pit. A manually operated overhead crane transfers the refuse from the refuse pit to the incinerator charging chute. An inclined grate and ash discharge system designed by Martin GmbH is used at the Marion County facility.

During shutdown, feeding of the refuse is discontinued and the chute seal door is closed to prevent backfires. Natural gas is used as a supplemental fuel as the refuse burns out on the grate. When the refuse is completely

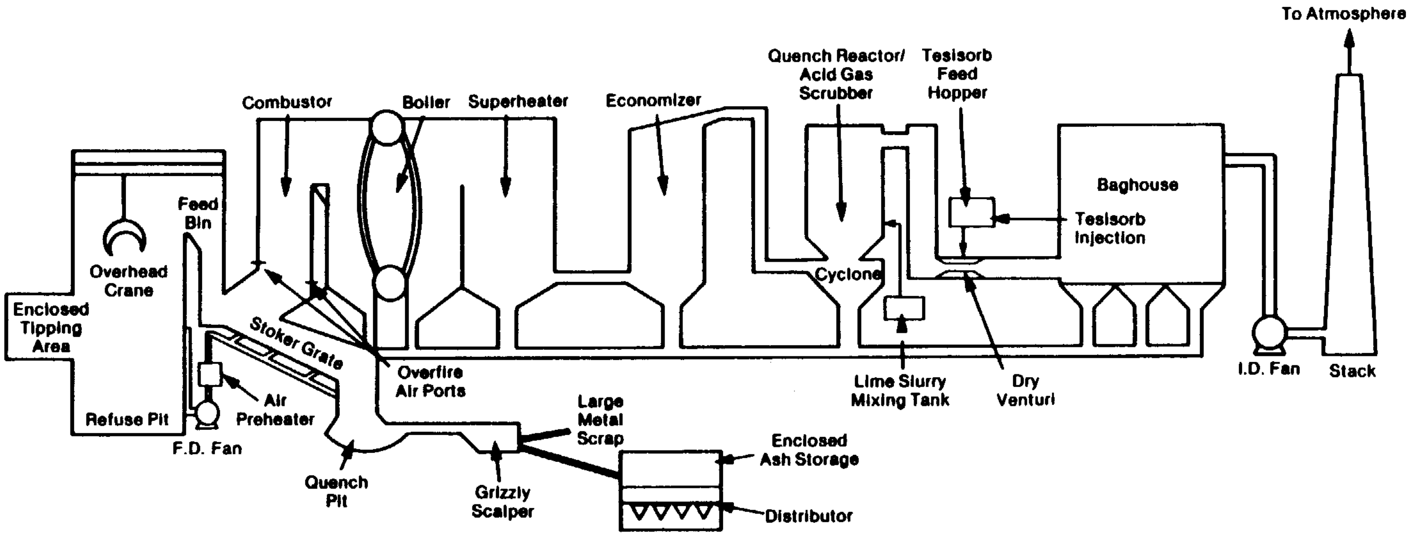


Figure 1-1. Marion County Process Line

burned out, the natural gas rate is reduced to slowly lower the combustor temperature until shutdown is complete.

During startup, natural gas is fired to preheat the system. At an inlet temperature of 285°F, the baghouse and Tesisorb® injection are put on-line and preheated for three hours. Then, the refuse feeding is begun and the rate increased in a ramped manner. Approximately 3 hours are required for the system to achieve steady state. Startup operations may be unpredictable since the operation is based more on temperature than time.

1.3 SHUTDOWN/STARTUP TEST PROGRAM

1.3.1 Sampling Matrix

The shutdown test was conducted on June 21, 1987, and the startup test was conducted on June 22/23, 1987. The shutdown/startup was scheduled by the plant for maintenance purposes. The overall test matrix that was developed and performed by EPA is summarized in Table 1-1. The test matrix included some site-specific considerations. At the outlet stack location, two CDD/CDF/HCl sampling trains were run simultaneously in order to lower the CDD/CDF minimum detection limits for the flue gas. At the inlet location during shutdown, one CDD/CDF/HCl train included a sootblowing interval and the other CDD/CDF/HCl train ran simultaneously once sootblowing was completed. At the inlet location during startup, two CDD/CDF/HCl trains and Method 3 (Orsat) samplers were run sequentially. The expected particulate loading at the inlet location during startup required that the two filters be used. Thus Train A was operated for the first half and Train B was operated for the second half of the startup period.

During the test program, several procedures as described in the test plan,[6] were modified and additional tasks were added based on initial results. They are discussed below:

1) Superheater ash was added to the list of process samples taken. For the superheater and economizer ash the collection technique was changed to inserting a tube across the hopper. The draft through

TABLE 1-1. SHUTDOWN/STARTUP TEST MATRIX FOR THE MARION COUNTY MWC

Parameters	Sampling Organization	Shutdown		Start-up	
Continuous Monitoring[a]					
O_2	Radian	11:57-15:18		23:25-03:24	
CO_2	↓				
CO					
SO_2					
HCl	Entropy				
NO_x	Radian				
THC	Radian				
Manual Sampling		Port A Train	Port B Train	Port A Train	Port B Train
CDD/CDF/HCl:					
Inlet	Radian	11:55-15:15[b]	12:25-15:15	23:25-01:25	01:25-03:25
Outlet		11:55-15:15	11:55-15:15	23:25-03:25	23:25-03:25
HCl: Midpoint		11:55-15:15		23:25-03:25	
O_2 and CO_2 by Orsat					
Inlet		11:55-14:30		23:25-01:25	01:25-03:25
Midpoint		11:55-15:15		23:25-03:25	
Outlet		11:55-15:15		23:25-03:25	
Ash Samples					
Superheater	Radian	11:55-15:15		23:25-03:25	
Economizer		11:55-15:15		23:25-03:25	
Cyclone		11:55-15:15		24:00-03:27	
Baghouse		15:15		00:22-03:26	
Emission Control Reagents					
Lime Slurry	Radian	NC		02:10	
Tesisorb	Radian	NC		01:04	
Process Monitoring	EPA/MRI/Plant	11:57-15:18		23:25-03:24	

[a] Conducted simultaneously at the inlet, midpoint and breeching. NO_x, THC and CO were measured at the inlet and outlet only.

[b] Included sootblowing.

NC = not collected.

the access hole was low enough so that the collected ash was not re-entrained when the sample was removed from the port. This technique is appropriate for the various combustor ash collection points.

2) An empty modified tip impinger was inserted as the first impinger in the midpoint HCl train.

1.3.2 Sampling and Analytical Procedures

Sampling at the control device inlet, midpoint and outlet was performed simultaneously following similar protocols. A summary of the sampling and analytical procedures used is presented in Table 1-2. The target CDD/CDF congeners for the flue gas analyses are listed in Table 1-3.

1.4 ORGANIZATION

In order to describe the many interests in the test program, a communication scheme is shown in Figure 1-2. Mr. Pete Schindler was the EPA/ISB lead engineer. He was assisted by Mr. Steve Schliesser of Midwest Research Institute. Dr. Ted Brna and Mr. James Kilgroe were the Air and Energy Engineering Research Laboratory (AEERL) lead engineers. Mr. Schindler, Mr. Schliesser, Mr. Kilgroe and Dr. Brna were responsible for coordinating the overall test program with the plant officials and the Oregon Department of Environmental Quality (DEQ), and for assuring that the process and control equipment operating conditions were suitable for testing. While on-site, any changes or problems were discussed between EPA, Oregon DEQ and Ogden Martin and agreed upon (with input from the test crew chiefs) before a change was made to the test program protocol.

1.5 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The test program was designed and executed with emphasis on completeness and data quality. A comprehensive internal quality assurance (QA) and quality control (QC) program was an integral part of Radian's test program. The goal of the QA/QC effort was to ensure that the data collected were of known precision and accuracy and that they were complete, representative and comparable.

TABLE 1-2. SUMMARY OF SAMPLING AND ANALYTICAL PROCEDURES USED FOR THE SHUTDOWN/STARTUP TEST PROGRAM AT THE MARION COUNTY MWC

Parameter	Sampling Method	Analytical Method
O_2 Inlet and Midpoint	EPA Method 3A	Thermox
O_2 Outlet	EPA Method 3A	Paramagnetic
CO Inlet and Outlet	EPA Method 10	Non-Dispersive Infrared (NDIR) Gas Filter Correlation
SO_2 Inlet	EPA Method 6C	Spectrophotometric (UV range)
SO_2 Midpoint and Outlet	EPA Method 6C	Pulsed Fluorescence
CO_2 Inlet, Midpoint and Outlet	EPA Method 3A	NDIR
NO_x Inlet and Outlet	EPA Method 7E	Chemiluminescent
THC Inlet and Outlet	EPA Method 25A	Flame Ionization Detector (FID)
CDD/CDF in the flue gas	EPA/ASME Protocol (December 1984 Draft)	High resolution GC/MS for CDD/CDF following EPA/ASME Protocol (Dec. 1984 draft)
Tesisorb and lime slurry	Grab sample	High resolution GC/MS for CDD/CDF following EPA/ASME Protocol (Dec. 1984 draft)
HCl	EPA Method 5 (Modified)	Specific Ion Electrode (SIE) and Ion Chromatography (IC)
Economizer ash, superheater ash, cyclone ash, baghouse ash	Composited grab sample	Archived for potential CDD/CDF analysis
Moisture	EPA Method 4	--
Volumetric Flowrate	EPA Methods 1 and 2	--
Fixed gases (O_2, CO_2, N_2)	EPA Method 3	Orsat

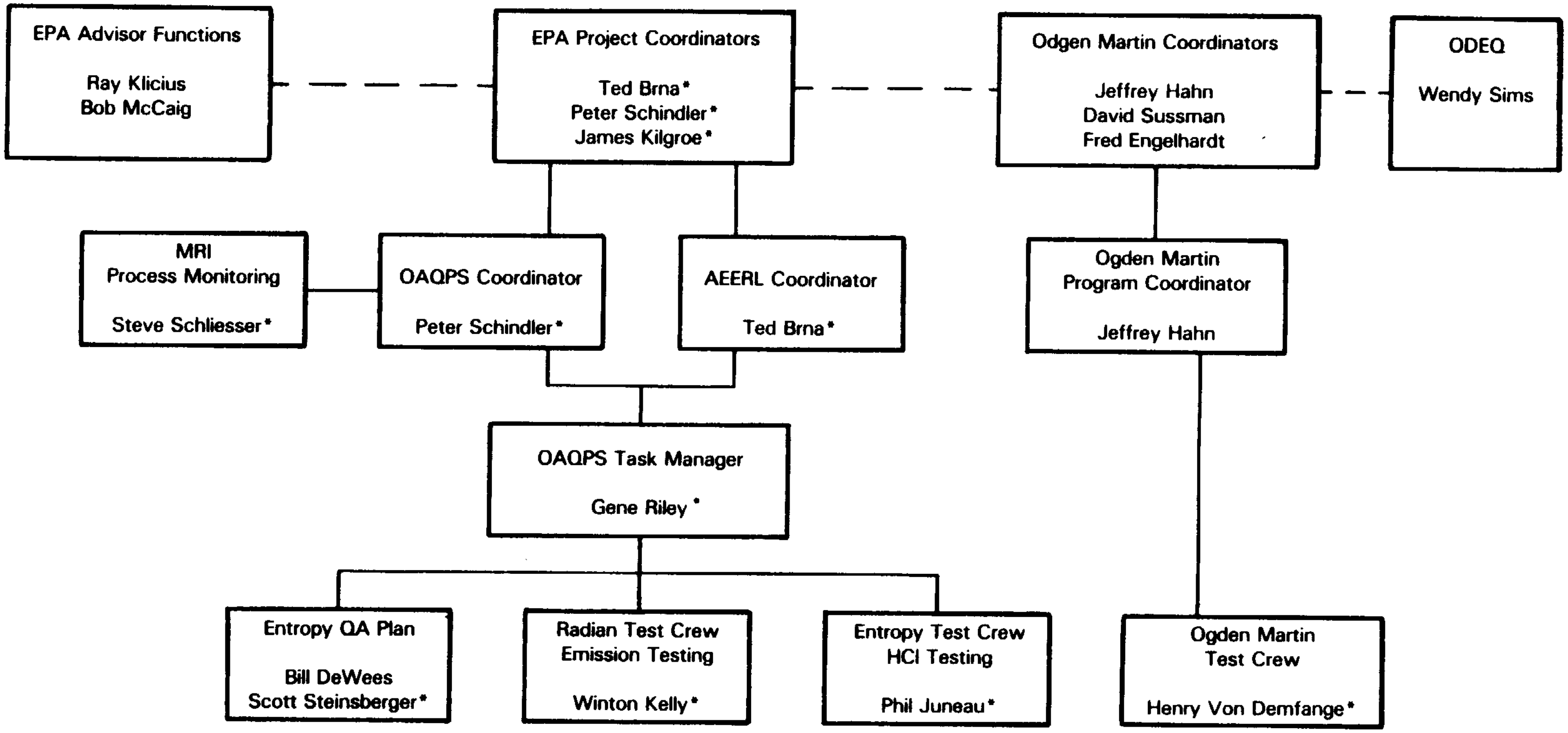
TABLE 1-3. CDD/CDF CONGENERS ANALYZED FOR THE SHUTDOWN/STARTUP TEST PROGRAM FOR THE MARION COUNTY MWC

DIOXINS

Monochloro dibenzo-p-dioxin (MCDD)
Total dichlorinated dibenzo-p-dioxins (DCDD)
Total Trichlorinated dibenzo-p-dioxins (TrCDD)
2,3,7,8 Tetrachlorodibenzo-p-dioxin (2,3,7,8 TCDD)
Total Tetrachlorinated dibenzo-p-dioxins (TCDD)
1,2,3,7,8 Pentachlorodibenzo-p-dioxin (1,2,3,7,8 PCDD)
Total Pentachlorinated dibenzo-p-dioxins (PCDD)
1,2,3,4,7,8 Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8 HxCDD)
1,2,3,6,7,8 Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8 HxCDD)
1,2,3,7,8,9 Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9 HxCDD)
Total Hexachlorinated dibenzo-p-dioxins (HxCDD)
1,2,3,4,6,7,8 Heptachlorodibenzo-p-dioxins (1,2,3,4,6,7,8 HpCDD)
Total Heptachlorinated dibenzo-p-dioxins (HpCDD)
Total Octachlorinated dibenzo-p-dioxins (OCDD)

FURANS

Monochloro dibenzofuran (MCDF)
Total dichlorinated dibenzofurans (DCDF)
Total Trichlorinated dibenzofurans (TrCDF)
2,3,7,8 Tetrachlorodibenzofurans (2,3,7,8 TCDF)
Total Tetrachlorinated dibenzofurans (TCDF)
1,2,3,7,8 Pentachlorodibenzofuran (1,2,3,7,8 PCDF)
2,3,4,7,8 Pentachlorodibenzofuran (2,3,4,7,8 PCDF)
Total Pentachlorinated dibenzofurans (PCDF)
1,2,3,4,7,8 Hexachlorodibenzofuran (1,2,3,4,7,8 HxCDF)
1,2,3,6,7,8 Hexachlorodibenzofuran (1,2,3,6,7,8 HxCDF)
1,2,3,7,8,9 Hexachlorodibenzofuran (1,2,3,7,8,9 HxCDF)
2,3,4,6,7,8 Hexachlorodibenzofuran (2,3,4,6,7,8 HxCDF)
Total Hexachlorinated dibenzofurans (HxCDF)
1,2,3,4,6,7,8 Heptachlorodibenzofuran (1,2,3,4,6,7,8 HpCDF)
1,2,3,4,7,8,9 Heptachlorodibenzofuran (1,2,3,4,7,8,9 HpCDF)
Total Heptachlorinated dibenzofurans (HpCDF)
Total Octachlorinated dibenzofurans (OCDF)



AEERL - Air and Energy Engineering Research Laboratory
OAQPS - Office of Air Quality Planning and Standards
ODEQ - Oregon Department of Enviromental Quality
MRI - Midwest Research Institute
* - On-Site

Figure 1-2. Marion County Shutdown/Startup Test Program Line of Communication

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In addition to Radian's internal QC program, an external performance and systems audit was conducted by Entropy Environmentalists, Inc., and is reported separately.[7] The independent audit was conducted during two days prior to the start of the test program, during one day at the middle of the test program and during one day at the conclusion of the test program, as well as periodically during the testing.

1.6 DESCRIPTION OF REPORT SECTIONS

The remaining sections of this volume are organized as follows:

Section 2.0	Summary of Results
Section 3.0	Conclusions
Section 4.0	Process Description and Operation
Section 5.0	Sample Point Locations
Section 6.0	Sampling and Analytical Procedures
Section 7.0	Internal Quality Assurance/Quality Control
Section 8.0	References
Section 9.0	English-to-Metric Conversion Table

The supporting data and calculations for the results presented in Volume I are included in Volumes II to III. Volume II contains a summary of the test results which includes one-minute plots of selected variables. Volume II also includes the printouts of one-minute adjusted averages for the CEM parameters and the Method 5 results for the manual sampling trains as well as copies of all the field data sheets and analytical reports. Volume III includes the test logs, process data sheets, QA/QC results, the summary of equipment used, sample calculations, sampling and analytical protocols, pertinent correspondence and project participants.

2.0 SUMMARY OF RESULTS

The results of the shutdown/startup test program are presented in this section. For comparison purposes, results during baseline operations are also presented. Baseline CDD/CDF concentrations in the flue gas for the Unit No. 1 combustor were measured during two previous test programs. The first was conducted in September 1986 and the second in February 1987. The combustor and control device data collected during these test programs as well as during the characterization test program indicated steady, well-controlled and consistent operation of the combustor over a ten-month period. Thus it is reasonable to compare baseline data collected at a different time to data collected during shutdown and startup operations.

The uncontrolled baseline CDD/CDF results are from testing performed by EPA in February 1987.[8] The controlled baseline results are from testing performed by Ogden Projects, Inc., in September 1987.[9] During the September 1987 testing, uncontrolled baseline CDD/CDF concentrations were measured, but the data are considered questionable due to extremely low internal standard recoveries. The purpose of the February test program was to collect additional uncontrolled CDD/CDF data. The February results varied insignificantly over the four-day period that traversed samples were collected. Also, the September results (only data from Run 2 were considered acceptable) were within the statistical range where 95 percent of the CDD/CDF results would be expected based on the February results. From the February testing, the average uncontrolled CDD concentration for Runs 1 through 4 was 31.2 ng/dscm, normalized to 12 percent CO_2 with a standard deviation of 5.2 and the average uncontrolled CDF concentration was 150 ng/dscm, normalized to 12 percent CO_2 with a standard deviation of 44.6. The results from Run 2 from the September test program were 26.5 ng/dscm, normalized to 12 percent CO_2, for CDDs and 44.3 ng/dscm, normalized to 12 percent CO_2 for CDFs. The February results for Runs 1 through 4 are included in Appendix N.

The controlled baseline CDD/CDF data obtained from Ogden Projects, Inc., were adjusted from standard conditions of 32°F, 1 atm to standard conditions of $68^{o}F$, 1 atm. The baseline CO, CO_2, O_2, SO_2, HCl, NO_x, THC, steam load and excess air results are averages of data collected during the characterization test program.[10]

A summary of the baseline, shutdown and startup results are presented in Table 2-1. This table includes the results of the greatest interest. Additional results are included in Appendix A.1. Steam load during shutdown was an average of 42,400 lb/hr and 56,000 lb/hr during startup. During baseline operation, steam load averaged 67,100 lb/hr. Excess air during shutdown averaged 139.5 percent and 77.9 percent during startup. Excess air averaged 74.7 percent during baseline operations. During shutdown and startup, CO averaged 6.9 and 8.0 ppmv, dry, respectively. CO averaged 10.2 ppmv, dry, during baseline operation.

Reduction of SO_2 across the control system was 74.5 percent during shutdown and 58.6 percent during startup. During baseline, SO_2 reduction was 69.2 percent. Reduction of HCl across the control system was 90.8 percent during shutdown and 90.2 percent during startup. The reduction efficiency for HCl was 90.4 percent during baseline operations.

During shutdown, the uncontrolled CDD/CDF concentration in the flue gas including sootblowing was 121 ng/dscm adjusted to 12 percent CO_2. Not including sootblowing, the uncontrolled CDD/CDF concentration was 62.1 ng/dscm adjusted to 12 percent CO_2. Controlled CDD/CDF concentrations in the flue gas were 6.00 and 0.943 ng/dscm adjusted to 12 percent CO_2 for Trains A and B, respectively.

During startup, the uncontrolled CDD/CDF concentration during the first half of startup was 790 ng/dscm, adjusted to 12 percent CO_2, and was 206 ng/dscm, adjusted to 12 percent CO_2, for the second half of startup. The controlled CDD/CDF concentration was 11.7 ng/dscm adjusted to 12 percent CO_2. The controlled result is an average for the entire startup test period of 3 hours.

TABLE 2-1. SUMMARY OF SHUTDOWN/STARTUP RESULTS FOR THE MARION COUNTY MWC

Parameter	Baseline		Shutdown				Startup			
	Uncontrolled	Controlled	Uncontrolled		Controlled		Uncontrolled		Controlled	
Steam Load (10^3 lb/hr)	67.1		42.4				56.0			
Excess Air (%)[a]	74.7		139.5				77.9			
CO (ppmv, dry)	10.2		6.9				8.0			
O_2 (% volume, dry)[b]	9.1		12.5				9.4			
CO_2 (% volume, dry)[b]	10.7		6.2				9.3			
SO_2 (ppmv, dry)[c]	365.7	241.3	262.1		79.6		215.6		95.1	
HCl (ppmv, dry)[c,d]	712.0	59.3	454.3		49.8		471.4		49.1	
NO_x (ppmv, dry)[c,e]	273		210.4		--		231.1		--	
THC (ppmv, dry)[c,e]	1.8		2.7		--		3.7		--	
SO_2 Reduction: Quench Reactor (%)	55.9[f]		24.8				29.3			
Total System (%)	69.2[f]		74.5				58.6			
HCl Reduction: Quench Reactor (%)[d]	67.3[f]		63.1[g]				66.8[g]			
Total System (%)[d]	90.4[f]		90.8				90.2			
CDD/CDF Results[h]			Train A[i]	Train B	Train A	Train B	Train A	Train B	Train A[j]	Train B
Volume of flue gas sampled (dscf)	144.6	NA	96.9	91.8	184.6	162.1	60.3	78.6		225.0
Flue gas flow rate (dscfm)	31900	36200	26600	29900	36900	34900	27600	35300		39800
Flue gas temperature (°F)	384	NA	383	374	285	285	388	448		280
Flue gas moisture (% by volume)	14.7	10.2	11.3	9.7	10.5	10.1	13.4	13.9		12.9
Isokinetics (%)	92-95	NA	99.5	98.6	100.2	102.2	99.7	101.6		103.6
Flue gas CDD/CDF Concentration[k] (ng/dscm at 12% CO_2)										
2378-TCDD	0.399	0.057	[0.235]	[0.131]	[0.027]	(0.009)	1.27	0.077		(0.002)
Total CDD	31.2	1.01	65.7	28.5	1.55	0.820	450	85.2		2.16
2378-TCDF	7.02	(0.062)	0.68	0.26	0.092	(0.002)	5.3	1.06		0.033
Total CDF	150	1.19	54.9	33.6	4.45	0.123	340	121		9.56
Total CDD & CDF	182	2.20	121	62.1	6.00	0.943	790	206		11.7
2378-TCDD Equivalents	1.96	0.063	0.666	0.282	0.015	0.0002	7.06	1.16		0.013

[a] Percent excess air is based on inlet CEM data.

[b] Measured at inlet sampling location.

[c] Normalized to 12% CO_2 using CEM data.

[d] HCl reduction efficiencies and concentrations are based on CEM data.

[e] NO_x and THC data are reported uncontrolled, since emissions were not affected by the control device.

[f] Based on Run 2 data from the Characterization Test Program.

[g] Based on manual HCl data.

[h] Standard conditions are 68°F and 1 atm.

[i] Included 1/2 hour of sootblowing.

[j] Results are not reported due to extremely low internal standard recoveries. The sample was re-extracted and the internal standard recoveries remained extremely low.

[k] CDD/CDF results were adjusted for internal standard recoveries and sample blanks. Results were normalized using Orsat data. Brackets indicate values reported as estimated maximum possible concentrations. Parentheses indicate values reported as minimum detection limits.

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Additional results and discussion are provided in the following sections. Flue gas CDD/CDF results are discussed in Section 2.1. A discussion of temperature profile and combustion efficiency during shutdown and startup is presented in Section 2.3. Acid gases (HCl and SO_2), fixed gases (CO, CO_2 and O_2) and additional pollutants of interest (NO_x and THC) are discussed in Sections 2.3, 2.4 and 2.5, respectively. Supporting data and example calculations are included in the appendices.

English and metric units are used to present the results. Typically, results of the sampling parameters (such as volumetric flowrate) are presented in English units and concentrations of pollutants are reported in metric units. Metric units are preferable for reporting the relatively low concentrations that were measured. The flue gas concentrations are presented on a dry basis. For the reader's ease, an English-to-Metric conversion table is included in Section 9.0.

2.1 CDD/CDF CONCENTRATIONS IN THE FLUE GAS

The CDD/CDF concentrations that were measured in the flue gas during shutdown and startup are presented in this section. The CDD/CDF concentrations in the flue gas during baseline operations are also presented for comparison. The uncontrolled baseline concentrations were measured by EPA in February 1987. The controlled baseline concentrations were measured by Ogden Projects, Inc., in September 1986.

A summary of the CDD/CDF concentrations, 2378-TCDD toxic equivalencies and control efficiencies is presented in Table 2-2. The toxic equivalencies that were calculated using the factors developed by EPA. During shutdown, the 2378-TCDD toxic equivalencies for the uncontrolled flue gas ranged from 0.282 ng/dscm without sootblowing to 0.666 ng/dscm with sootblowing. The controlled flue gas contained 0.008 ng/dscm as 2378-TCDD toxic equivalencies. During startup, the 2378-TCDD toxic equivalencies for the uncontrolled flue gas ranged from 7.06 ng/dscm during the first half to 1.16 ng/dscm during the second half. In the controlled flue gas, the 2378-TCDD toxic equivalency was 0.013 ng/dscm during startup.

TABLE 2-2. SUMMARY OF CDD/CDF RESULTS DURING THE SHUTDOWN/STARTUP TEST PROGRAM

	Uncontrolled					Controlled		
	Baseline	Shutdown		Startup		Baseline	Shutdown	Startup
		Without Soot-blowing	With Soot-blowing	First Half	Second Half			
Concentration (ng/dscm, normalized to 12%)								
Total CDD	31.2[a]	28.5	65.7[b]	450[c]	85.2[d]	1.01[e]	1.18[f]	2.16[g]
Total CDF	150.4[a]	33.6	54.9[b]	340[c]	121[d]	1.19[e]	2.29[f]	9.56[g]
2378-TCDD Toxic Equivalencies[h] (ng/dscm, normalized to 12% CO_2)	1.96	0.282	0.666[b]	7.06[c]	1.16[d]	0.063[e]	0.008[f]	0.013[g]
Reduction Efficiency of Total Control System (%)[i]	59-99		22-99		32-99			

[a] Results are the average of Runs 1, 2, 3, and 4 performed in February 1987. Data are included in Appendix N and additional details can be found in Reference 4.

[b] Includes an additional half-hour of sampling during two sequential sootblowing cycles from 1159 to 1224.

[c] Collected during first 1-1/2 hours of startup.

[d] Collected during second 1-1/2 hours of startup.

[e] Results from Reference 8. Testing performed by Ogden Projects, Inc., in September 1986. Averages of Runs 2 and 3. Run 1 had extremely low internal recoveries and the results are not reported.

[f] Average of two simultaneous sampling trains.

[g] Two simultaneous sampling trains were operated during startup. However, the Port A train internal recoveries were extremely low and are not reported. Results are for the Port B train which was traversed across one diameter only. The Port A train results are included in Appendix F.3.

[h] Toxic equivalencies calculated using factors developed by the U.S. EPA.

[i] Reduction efficiency is presented as a range based on the reduction efficiencies of the individual congeners. The baseline reduction efficiencies are based on Run 2 of the September 1986 Emissions Test Program.

The QR/FF reduction efficiency was calculated based on the individual congeners. During shutdown, the QR/FF reduction efficiencies ranged from 22 to 99 percent. During startup, the QR/FF reduction efficiencies ranged from 32 to 99 percent. The CDD/CDF concentrations and 2378-TCDD toxic equivalencies are discussed in more detail in Section 2.1.1. The reduction efficiencies across the control device system are presented in Section 2.1.2 and congener distributions are discussed in Section 2.1.3.

2.1.1 CDD/CDF Emissions and 2378-TCDD Toxic Equivalencies

The CDD/CDF concentrations in the flue gas measured during shutdown are presented in Table 2-3. Uncontrolled total CDD/CDF concentrations were measured at 121 ng/dscm, normalized to 12 percent CO_2, including sootblowing and 62.1 ng/dscm, normalized to 12 percent CO_2, after sootblowing was completed. The baseline average total CDD/CDF concentration was 182 ng/dscm, normalized to 12 percent CO_2.

During shutdown, the average controlled total CDD/CDF concentration was 3.47 ng/dscm, normalized to 12 percent CO_2. During baseline operations, the average total CDD/CDF concentration was 2.20 ng/dscm, normalized to 12 percent CO_2.

Overall, uncontrolled CDD/CDF concentrations were higher including sootblowing. However, the CDD/CDF concentrations measured during shutdown were not significantly different from those during baseline operation.

The CDD/CDF concentrations in the flue gas measured during startup are presented in Table 2-4. During the first half of startup, the uncontrolled total CDD/CDF concentration was 790 ng/dscm, normalized to 12 percent CO_2. During the second half of startup, the uncontrolled CDD/CDF concentration was 206 ng/dscm normalized to 12 percent CO_2. Controlled total CDD/CDF emissions were measured at 11.7 ng/dscm, normalized to 12 percent CO_2, for the complete startup period. Results for only one of the controlled emissions sampling trains are reported. Due to extremely low internal standards recoveries for

TABLE 2-3. FLUE GAS CDD/CDF RESULTS FOR SHUTDOWN TESTING FOR THE MARION COUNTY MWC

	CONCENTRATION (ng/dscm normalized to 12 % CO_2)							2378-TCDD TOXIC EQUIV FACTOR[f]	2378-TCDD TOXIC EQUIVALENCIES				
	UNCONTROLLED			CONTROLLED					UNCONTROLLED			CONTROLLED	
ISOMER	BASELINE[a]	WITH SOOT-BLOWING[b]	WITHOUT SOOT-BLOWING[c]	BASELINE[d]	TRAIN A[e]	TRAIN B[e]	AVERAGE[e] OF TRAIN A AND TRAIN B		BASELINE	WITH SOOT BLOWING	WITHOUT SOOT-BLOWING	BASELINE	AVERAGE OF TRAIN A AND TRAIN B
DIOXINS													
Mono-CDD	(0.009)	(0.167)	(0.167)	(0.001)	(0.293)	(0.102)	0.000	0.00000	0.000	0.000	0.000	0.000	0.000
Di-CDD	[2.71]	(0.321)	[0.763]	0.020	0.831	(0.142)	0.415	0.00000	0.000	0.000	0.000	0.000	0.000
Tri-CDD	3.77	2.06	1.37	0.017	[0.193]	[0.082]	0.000	0.00000	0.000	0.000	0.000	0.000	0.000
2378 TCDD	0.399	[0.235]	[0.131]	0.057	[0.027]	(0.009)	0.000	1.00000	0.399	0.000	0.000	0.057	0.000
Other TCDD	4.63	4.61	2.06	0.104	0.158	[0.045]	0.079	0.01000	0.046	0.046	0.021	0.001	0.001
12378 PCDD	0.512	0.540	0.233	0.004	[0.019]	(0.009)	0.000	0.50000	0.256	0.270	0.116	0.002	0.000
Other PCDD	4.22	6.35	2.71	0.042	0.201	[0.016]	0.101	0.00500	0.021	0.032	0.014	0.000	0.001
123478 HxCDD	0.363	0.772	[0.264]	(0.003)	(0.011)	(0.009)	0.000	0.04000	0.015	0.031	0.000	0.000	0.000
123678 HxCDD	0.509	1.76	[0.734]	(0.003)	(0.011)	(0.009)	0.000	0.04000	0.020	0.070	0.000	0.000	0.000
123789 HxCDD	0.829	[2.20]	0.980	(0.004)	(0.014)	(0.011)	0.000	0.04000	0.033	0.000	0.039	0.000	0.000
Other HxCDD	4.17	13.1	6.12	0.105	0.024	[0.091]	0.012	0.00040	0.002	0.005	0.002	0.000	0.000
1234678 HpCDD	2.95	10.2	4.58	0.111	0.187	0.115	0.151	0.00100	0.003	0.010	0.005	0.000	0.000
Other HpCDD	2.64	8.6	3.49	0.043	0.145	0.000	0.073	0.00001	0.000	0.000	0.000	0.000	0.000
Octa-CDD	6.19	17.7	6.98	0.507	[0.623]	0.705	0.353	0.00000	0.000	0.000	0.000	0.000	0.000
TOTAL CDD	31.2	65.7	28.5	1.01	1.55	0.820	1.18		0.795	0.465	0.197	0.060	0.001
FURANS													
Mono-CDF	0.086	0.465	[0.331]	(0.001)	1.18	(0.096)	0.588	0.00000	0.000	0.000	0.000	0.000	0.000
Di-CDF	11.9	1.51	2.52	(0.346)	(0.543)	(0.214)	0.000	0.00000	0.000	0.000	0.000	0.000	0.000
Tri-CDF	55.9	17.3	13.4	0.834	0.474	[0.079]	0.237	0.00000	0.000	0.000	0.000	0.000	0.000
2378 TCDF	7.02	0.68	0.26	(0.062)	0.092	(0.002)	0.046	0.10000	0.702	0.068	0.026	0.000	0.005
Other TCDF	37.7	16.3	8.83	0.292	2.43	0.033	1.23	0.00100	0.038	0.016	0.009	0.000	0.001
12378 PCDF	1.47	0.696	0.323	0.008	[0.076]	(0.006)	0.000	0.10000	0.147	0.070	0.032	0.001	0.000
23478 PCDF	2.02	[1.03]	[4.94]	0.011	[0.086]	(0.006)	0.000	0.10000	0.202	0.000	0.000	0.001	0.000
Other PCDF	14.9	6.19	3.40	0.019	0.204	[0.015]	0.102	0.00100	0.015	0.006	0.003	0.000	0.000
123478 HxCDF	2.44	1.90	0.898	(0.002)	0.068	(0.006)	0.034	0.01000	0.024	0.019	0.009	0.000	0.000
123678 HxCDF	1.31	0.953	0.438	(0.002)	[0.021]	(0.004)	0.000	0.01000	0.013	0.010	0.004	0.000	0.000
234678 HxCDF	1.14	0.974	[0.379]	(0.002)	(0.010)	(0.006)	0.000	0.01000	0.011	0.010	0.000	0.000	0.000
123789 HxCDF	0.262	(0.024)	(0.031)	(0.002)	(0.011)	(0.009)	0.000	0.01000	0.003	0.000	0.000	0.000	0.000
Other HxCDF	5.57	2.84	1.37	0.009	0.006	(0.006)	0.003	0.00010	0.001	0.000	0.000	0.000	0.000
1234678 HpCDF	4.04	2.88	1.24	(0.003)	[0.076]	0.064	0.032	0.00100	0.004	0.003	0.001	0.000	0.000
1234789 HpCDF	0.405	(0.037)	(0.041)	(0.004)	(0.011)	(0.009)	0.000	0.00100	0.000	0.000	0.000	0.000	0.000
Other HpCDF	1.67	1.24	0.35	(0.004)	[0.082]	0.026	0.013	0.00001	0.000	0.000	0.000	0.000	0.000
Octa-CDF	2.57	1.01	0.581	0.021	[0.014]	[0.061]	0.000	0.00000	0.000	0.000	0.000	0.000	0.000
TOTAL CDF	150	54.9	33.6	1.19	4.45	0.123	2.29		1.16	0.201	0.085	0.002	0.006
TOTAL CDD+CDF	182	121	62.1	2.20	6.00	0.943	3.47		1.96	0.666	0.282	0.063	0.008

[a] The uncontrolled baseline results are the average of Runs 1-4 collected by EPA in February 1987.

[b] Train A included two sootblowing cycles which lasted from 11:55 to 12:29. The sampling train was operated for 200 minutes. Minimum detection limits in the flue gas for the trains analyzed as front half/back half fractions are based on the higher detection limit for the front half or back half fraction.

[c] Train B was begun after sootblowing. Trains A and B were simultaneous.

[d] The controlled baseline results are the average of Runs 2 and 3 collected by Ogden Projects in September 1986. The results have been adjusted to standard conditions of 68 degrees F and 1 atm.

[e] Train A and Train B were traversed simultaneously in Ports A and B, respectively.

[f] Toxic equivalency factors developed by U.S. EPA.

NR = not reported

Values in parentheses are flue gas minimum detection limits and values in brackets are estimated maximum possible concentrations.

Standard conditions are 68 degrees F and 1 atm.

TABLE 2-4. FLUE GAS CDD/CDF RESULTS FOR STARTUP TESTING FOR THE MARION COUNTY MWC

	CONCENTRATION (ng/dscm normalized to 12 % CO2)					2378-TCDD TOXIC EQUIV FACTOR[b]	2378-TCDD TOXIC EQUIVALENCIES[d]				
	UNCONTROLLED			CONTROLLED			UNCONTROLLED			CONTROLLED	
		STARTUP						STARTUP			
ISOMER	BASELINE[a]	FIRST HALF	SECOND HALF	BASELINE[b]	STARTUP[c]		BASELINE	FIRST HALF	SECOND HALF	BASELINE	STARTUP
DIOXINS											
Mono-CDD	(0.009)	(0.260)	[0.194]	(0.001)	[0.100]	0.00000	0.000	0.000	0.000	0.000	0.000
Di-CDD	[2.71]	0.076	0.493	0.020	0.201	0.00000	0.000	0.000	0.000	0.000	0.000
Tri-CDD	3.77	2.00	2.80	0.017	0.435	0.00000	0.000	0.000	0.000	0.000	0.000
2378 TCDD	0.399	1.27	0.077	0.057	(0.002)	1.00000	0.399	1.27	0.077	0.057	0.000
Other TCDD	4.63	55.6	8.63	0.104	0.368	0.01000	0.046	0.556	0.086	0.001	0.004
12378 PCDD	0.512	3.16	0.189	0.004	[0.007]	0.50000	0.256	1.58	0.094	0.002	0.000
Other PCDD	4.22	86.2	12.3	0.042	0.092	0.00500	0.021	0.431	0.062	0.000	0.000
123478 HxCDD	0.363	3.99	0.907	(0.003)	[0.006]	0.04000	0.015	0.160	0.036	0.000	0.000
123678 HxCDD	0.509	10.5	2.10	(0.003)	0.018	0.04000	0.020	0.421	0.084	0.000	0.001
123789 HxCDD	0.829	4.43	2.78	(0.004)	0.007	0.04000	0.033	0.177	0.111	0.000	0.000
Other HxCDD	4.17	117	18.6	0.105	0.135	0.00040	0.002	0.047	0.007	0.000	0.000
1234678 HpCDD	2.95	53.8	11.0	0.111	0.128	0.00100	0.003	0.054	0.011	0.000	0.000
Other HpCDD	2.64	41.2	10.0	0.043	0.109	0.00001	0.000	0.000	0.000	0.000	0.000
Octa-CDD	6.19	70.9	15.2	0.507	0.671	0.00000	0.000	0.000	0.000	0.000	0.000
TOTAL CDD	31.2	450	85.2	1.01	2.16		0.795	4.70	0.569	0.060	0.005
FURANS											
Mono-CDF	0.086	4.56	[0.462]	(0.001)	0.229	0.00000	0.000	0.000	0.000	0.000	0.000
Di-CDF	11.9	1.98	4.18	(0.346)	2.33	0.00000	0.000	0.000	0.000	0.000	0.000
Tri-CDF	55.9	21.7	30.0	0.834	4.94	0.00000	0.000	0.000	0.000	0.000	0.000
2378 TCDF	7.02	5.3	1.06	(0.062)	0.033	0.10000	0.702	0.53	0.106	0.000	0.003
Other TCDF	37.7	162	40.2	0.292	1.60	0.00100	0.038	0.162	0.040	0.000	0.002
12378 PCDF	1.47	4.95	1.38	0.008	0.009	0.10000	0.147	0.495	0.138	0.001	0.001
23478 PCDF	2.02	8.86	2.05	0.011	0.019	0.10000	0.202	0.886	0.205	0.001	0.002
Other PCDF	14.9	67.0	16.8	0.019	0.100	0.00100	0.015	0.067	0.017	0.000	0.000
123478 HxCDF	2.44	7.55	3.81	(0.002)	0.013	0.01000	0.024	0.076	0.038	0.000	0.000
123678 HxCDF	1.31	7.35	1.81	(0.002)	[0.136]	0.01000	0.013	0.073	0.018	0.000	0.000
234678 HxCDF	1.14	6.00	2.05	(0.002)	[0.011]	0.01000	0.011	0.060	0.020	0.000	0.000
123789 HxCDF	0.262	[0.926]	0.155	(0.002)	[0.003]	0.01000	0.003	0.000	0.002	0.000	0.000
Other HxCDF	5.57	20.7	6.75	0.009	0.041	0.00010	0.001	0.002	0.001	0.000	0.000
1234678 HpCDF	4.04	11.9	6.14	(0.003)	0.048	0.00100	0.004	0.012	0.006	0.000	0.000
1234789 HpCDF	0.41	[1.77]	0.479	(0.004)	(0.003)	0.00100	0.000	0.000	0.000	0.000	0.000
Other HpCDF	1.67	6.6	2.45	(0.004)	0.063	0.00001	0.000	0.000	0.000	0.000	0.000
Octa-CDF	2.57	3.74	1.55	0.021	0.129	0.00000	0.000	0.000	0.000	0.000	0.000
TOTAL CDF	150	340	121	1.19	9.56		1.16	2.36	0.59	0.002	0.008
TOTAL CDD+CDF	182	790	206	2.20	11.7		1.96	7.06	1.16	0.063	0.013

[a] The uncontrolled baseline results are the average of Runs 1-4 collected by EPA in February 1987.

[b] The controlled baseline results are the average of Runs 2 and 3 collected by Ogden Projects in September 1986.

[c] Two trains were operated simultaneously in Port A and Port B. However, the internal standard recoveries for the Port A train were extremely low, and the results are not reported. The results reported are from the Port B train which was traversed only on one diameter of the duct. Results are the average of duplicate analyses.

[d] Toxic equivalency factors developed by U.S. EPA.

Values in parentheses are flue gas minimum detection limits and values in brackets are estimated maximum possible concentrations. Standard conditions are 68 degrees and 1 atm.

the Port A train sample, the Port A train results are considered questionable and are not reported.

During startup, uncontrolled CDD/CDF emissions were significantly higher during the first half of startup than during the second half of startup or baseline operations. Controlled CDD/CDF emissions were also higher than baseline, although not significantly.

2.1.2 CDD/CDF Reduction Across the Control System

The reduction efficiency of the control system (cyclone, quench reactor, and baghouse) during shutdown and startup is presented in Table 2-5. The reduction efficiency is calculated for each individual congener based on mass rates. Except for mono-CDF, the reduction efficiencies during shutdown were above 95 percent. During startup, the reduction efficiencies were above 83 percent except for di-CDD and di-CDF. Reduction efficiencies consistently in the 80 to 90 percent range indicate positive control of CDD/CDF by the QR/FF control system during shutdown and startup operating conditions.

2.1.3 CDD/CDF Congener Distributions

The CDD/CDF congener distributions are presented in Figure 2-1 for the uncontrolled flue gas and in Figure 2-2 for the controlled flue gas. Tabular results are presented in Tables 2-6 and 2-7. The uncontrolled flue gas from the shutdown and startup tests exhibited a similar distribution. For the CDD homologues, hexa-CDD, hepta-CDD, and octa-CDD comprised between 60 to 75 mole percent of the samples. The distributions for the controlled flue gas were quite variable. For the CDD homologues, di-CDD and octa-CDD were generally the most prevalent species. For the CDF homologues, the mono-CDF through the tetra-CDF generally comprised the largest portion of the samples.

2.2 PROCESS TEMPERATURE PROFILE AND COMBUSTION EFFICIENCY

The temperature profiles through the process during the startup and shutdown tests are presented in this section. Temperature profiles from four

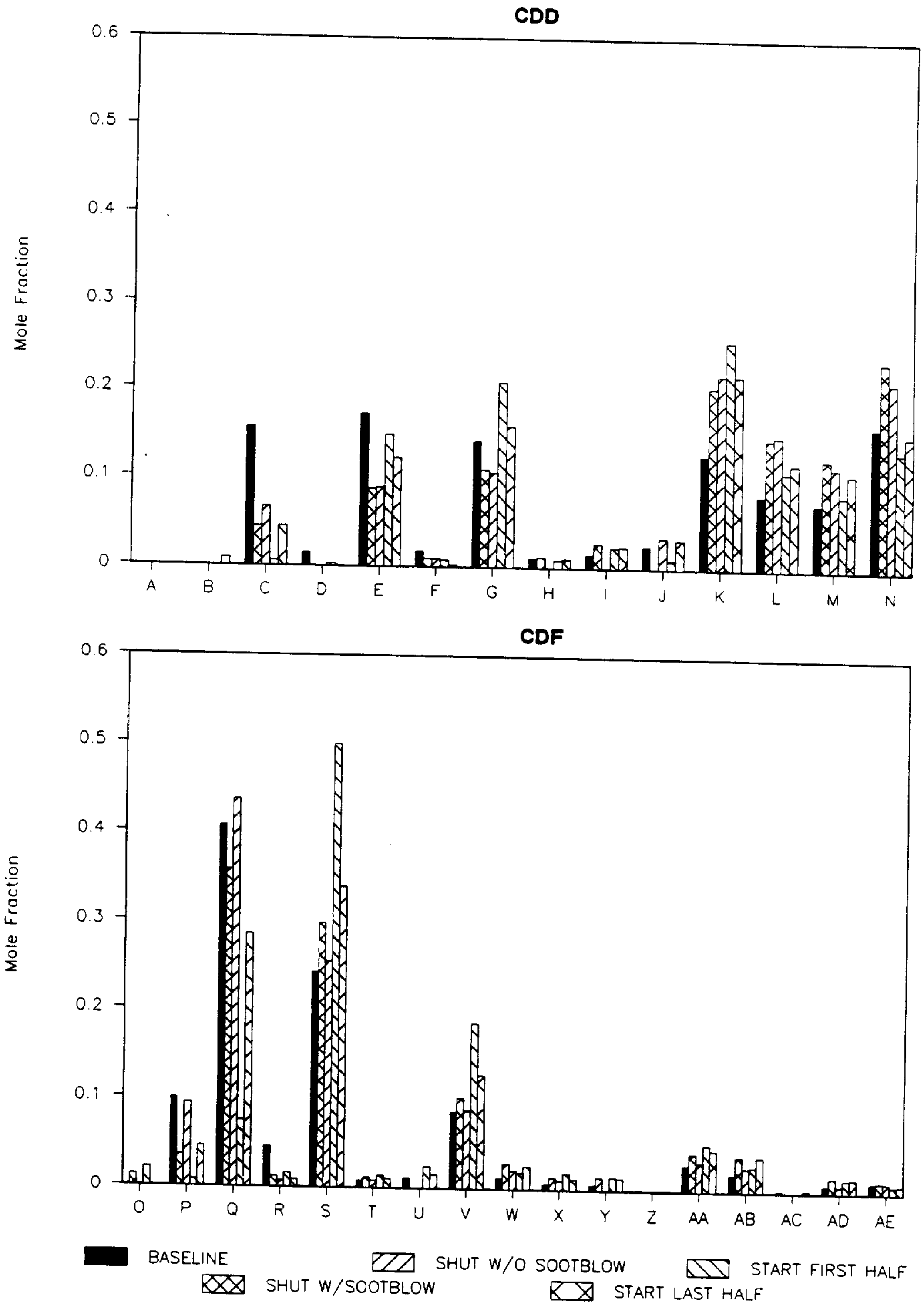
TABLE 2-5. CDD/CDF REDUCTION EFFICIENCIES DURING SHUTDOWN AND STARTUP FOR THE MARION COUNTY MWC

	Mass Flow Rate (g/hour)				Removal Efficiency[a] (percent)	
	Shutdown[b]		Startup[c]			
	Uncontrolled	Controlled	Uncontrolled	Controlled	Shutdown	Startup
DIOXINS						
Mono-CDD	0.0000	0.0000	0.0000	0.0000	--	--
Di-CDD	0.0000	0.0065	0.0128	0.0076	--	40.6
Tri-CDD	0.0520	0.0000	0.0973	0.0165	100.0	83.0
2378 TCDD	0.0000	0.0000	0.0215	0.0000	--	100.0
Other TCDD	0.116	0.0012	1.06	0.0140	98.9	98.7
12378 PCDD	0.0136	0.0000	0.0532	0.0000	100.0	100.0
Other PCDD	0.160	0.0016	1.62	0.0035	99.0	99.8
123478 HxCDD	0.0195	0.0000	0.0830	0.0000	100.0	100.0
123678 HxCDD	0.0445	0.0000	0.212	0.0007	100.0	99.7
123789 HxCDD	0.0000	0.0000	0.134	0.0002	--	99.8
Other HxCDD	0.330	0.0002	2.24	0.0051	99.9	99.8
1234678 HpCDD	0.258	0.0023	1.09	0.0049	99.1	99.6
Other HpCDD	0.217	0.0011	0.872	0.0041	99.5	99.5
Octa-CDD	0.448	0.0052	1.45	0.0255	98.8	98.2
TOTAL CDD	1.66	0.0182	8.96	0.0822	98.9	99.1
FURANS						
Mono-CDF	0.0118	0.0092	0.0703	0.0087	21.6	87.6
Di-CDF	0.0381	0.0000	0.130	0.0884	100.0	31.8
Tri-CDF	0.437	0.0037	1.04	0.188	99.1	82.0
2378 TCDF	0.0172	0.0007	0.106	0.0013	95.8	98.8
Other TCDF	0.412	0.0194	3.43	0.0609	95.3	98.2
12378 PCDF	0.0176	0.0000	0.109	0.0003	100.0	99.7
23478 PCDF	0.0000	0.0000	0.185	0.0007	--	99.6
Other PCDF	0.156	0.0016	1.43	0.0038	99.0	99.7
123478 HxCDF	0.0481	0.0005	0.207	0.0005	98.9	99.8
123678 HxCDF	0.0241	0.0000	0.156	0.0000	100.0	100.0
234678 HxCDF	0.0246	0.0000	0.141	0.0000	100.0	100.0
123789 HxCDF	0.0000	0.0000	0.0037	0.0000	--	100.0
Other HxCDF	0.0718	0.0000	0.479	0.0016	99.9	99.7
1234678 HpCDF	0.0729	0.0005	0.330	0.0018	99.3	99.4
1234789 HpCDF	0.0000	0.0000	0.0113	0.0000	--	100.0
Other HpCDF	0.0312	0.0002	0.160	0.0024	99.3	98.5
Octa-CDF	0.0254	0.0000	0.0943	0.0049	100.0	94.8
TOTAL CDF	1.39	0.0358	8.10	0.363	97.4	95.5
TOTAL CDD+CDF	3.05	0.0540	17.1	0.445	98.2	97.4

[a] Removal Efficiency (%) = (Uncontrolled - Controlled)/Uncontrolled*100

[b] Shutdown uncontrolled flow from train A with sootblowing. Controlled flow from average of both trains.

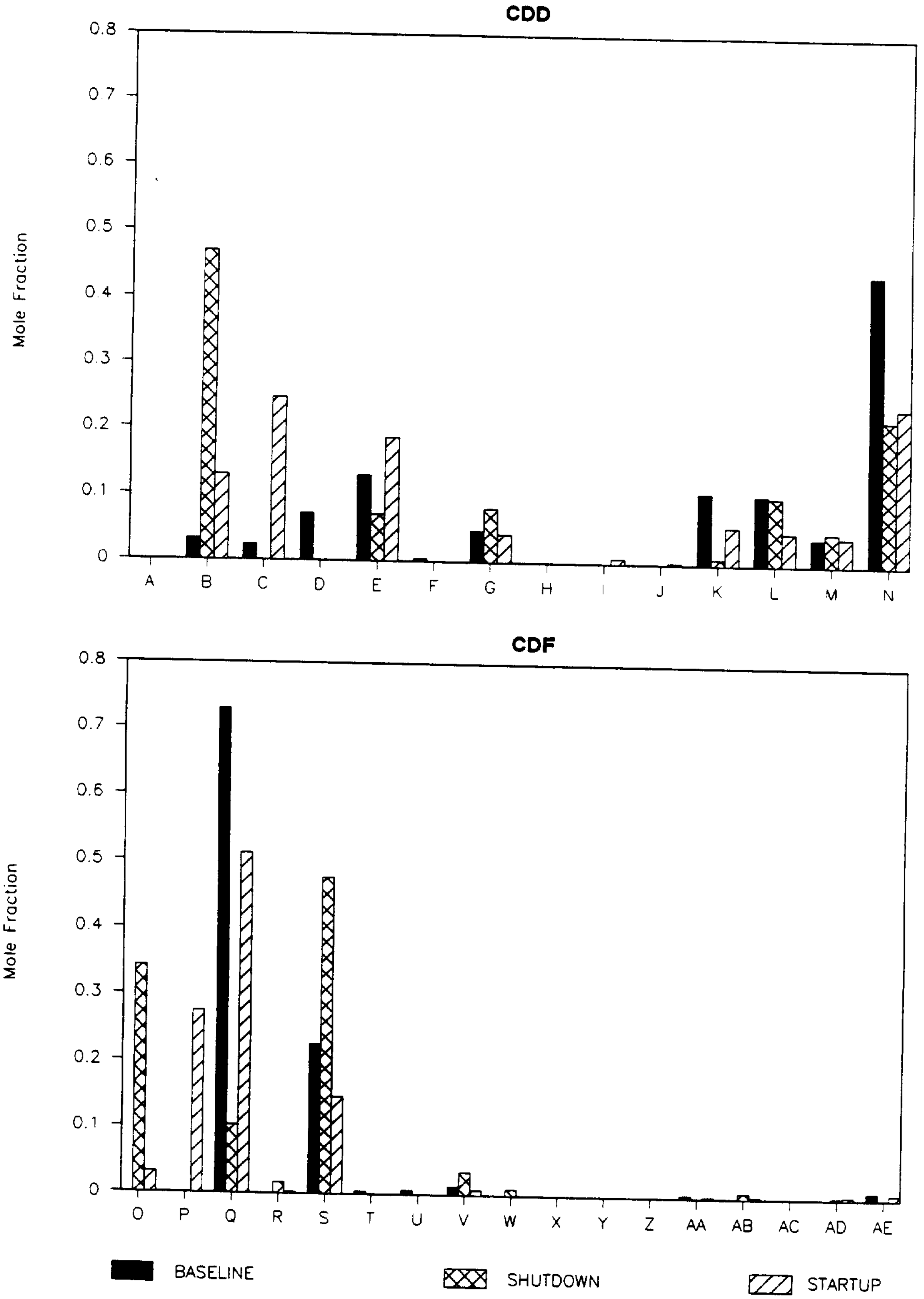
[c] Startup uncontrolled flow from average of both trains. Controlled flow from train B only.



KEY

Code	Congener
	Dioxins
A	Mono-CDD
B	Di-CDD
C	Tri-CDD
D	2378 TCDD
E	Other TCDD
F	12378 PCDD
G	Other PCDD
H	123478 HxCDD
I	123678 HxCDD
J	123789 HxCDD
K	Other HxCDD
L	1234678 HpCDD
M	Other HpCDD
N	Octa-CDD
	Furans
O	Mono-CDF
P	Di-CDF
Q	Tri-CDF
R	2378 TCDF
S	Other TCDF
T	12378 PCDF
U	23478 PCDF
V	Other PCDF
W	123478 HxCDF
X	123678 HxCDF
Y	234678 HxCDF
Z	123789 HxCDF
AA	Other HxCDF
AB	1234678 HpCDF
AC	1234789 HpCDF
AD	Other HpCDF
AE	Octa-CDF

Figure 2-1. CDD/CDF Congener Distributions for the Uncontrolled Flue Gas



KEY

Code	Congener
	Dioxins
A	Mono-CDD
B	Di-CDD
C	Tri-CDD
D	2378 TCDD
E	Other TCDD
F	12378 PCDD
G	Other PCDD
H	123478 HxCDD
I	123678 HxCDD
J	123789 HxCDD
K	Other HxCDD
L	1234678 HpCDD
M	Other HpCDD
N	Octa-CDD
	Furans
O	Mono-CDF
P	Di-CDF
Q	Tri-CDF
R	2378 TCDF
S	Other TCDF
T	12378 PCDF
U	23478 PCDF
V	Other PCDF
W	123478 HxCDF
X	123678 HxCDF
Y	234678 HxCDF
Z	123789 HxCDF
AA	Other HxCDF
AB	1234678 HpCDF
AC	1234789 HpCDF
AD	Other HpCDF
AE	Octa-CDF

Figure 2-2. CDD/CDF Congener Distributions for the Controlled Flue Gas

TABLE 2-6. CDD/CDF CONGENER DISTRIBUTIONS FOR UNCONTROLLED FLUE GAS AT MARION COUNTY MWC

ISOMER	MOLECULAR WEIGHT	MOLE FRACTIONS[a]				
			SHUTDOWN		STARTUP[e]	
		BASELINE[b]	WITH SOOT-BLOWING[c]	WITHOUT[d] SOOT-BLOWING	FIRST HALF	SECOND HALF
DIOXINS						
Mono-CDD	219	0.000	0.000	0.000	0.000	0.000
Di-CDD	253	0.000	0.000	0.000	0.000	0.009
Tri-CDD	288	0.157	0.044	0.066	0.006	0.045
2378 TCDD	322	0.015	0.000	0.000	0.003	0.001
Other TCDD	322	0.172	0.088	0.089	0.149	0.122
12378 PCDD	356	0.017	0.009	0.009	0.008	0.002
Other PCDD	356	0.142	0.109	0.106	0.209	0.158
123478 HxCDD	391	0.011	0.012	0.000	0.009	0.011
123678 HxCDD	391	0.016	0.028	0.000	0.023	0.025
123789 HxCDD	391	0.025	0.000	0.035	0.010	0.033
Other HxCDD	391	0.128	0.204	0.218	0.257	0.218
1234678 HpCDD	425	0.083	0.146	0.150	0.109	0.119
Other HpCDD	425	0.074	0.124	0.114	0.084	0.107
Octa-CDD	460	0.161	0.236	0.212	0.133	0.151
TOTAL CDD		1.000	1.000	1.000	1.000	1.000
FURANS						
Mono-CDF	203	0.001	0.013	0.000	0.021	0.000
Di-CDF	237	0.099	0.036	0.094	0.008	0.046
Tri-CDF	272	0.407	0.357	0.436	0.075	0.285
2378 TCDF	306	0.045	0.012	0.008	0.016	0.009
Other TCDF	306	0.243	0.299	0.255	0.499	0.339
12378 PCDF	340	0.009	0.011	0.008	0.014	0.010
23478 PCDF	340	0.012	0.000	0.000	0.025	0.016
Other PCDF	340	0.087	0.102	0.088	0.186	0.128
123478 HxCDF	375	0.013	0.029	0.021	0.019	0.026
123678 HxCDF	375	0.007	0.014	0.010	0.019	0.012
234678 HxCDF	375	0.006	0.015	0.000	0.015	0.014
123789 HxCDF	375	0.001	0.000	0.000	0.000	0.001
Other HxCDF	375	0.029	0.043	0.032	0.052	0.047
1234678 HpCDF	409	0.020	0.040	0.027	0.028	0.039
1234789 HpCDF	409	0.002	0.000	0.000	0.000	0.003
Other HpCDF	409	0.008	0.017	0.008	0.015	0.015
Octa-CDF	444	0.011	0.013	0.012	0.008	0.009
TOTAL CDF		1.000	1.000	1.000	1.000	1.000

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[a] Mole Fraction is the mole fraction based on the mono- through octa-homologues. CDD fractions are based on total CDD and CDF fractions are based on total CDF. Mole fractions are based on the total train results.

[b] The baseline results are the average of Runs 1-4 collected by EPA in February 1987.

[c] Sampling included two sootblowing cycles which lasted from 11:55 to 12:25.

[d] Sampling was begun after the sootblowing cycles were completed. Sampling was simultaneous following the sootblowing.

[e] The Port A sample was collected during the first half of the run and the Port B sample was collected during the second half.

TABLE 2-7. CDD/CDF CONGENER DISTRIBUTIONS FOR CONTROLLED FLUE GAS AT MARION COUNTY MWC

ISOMER	MOLECULAR WEIGHT	MOLE FRACTION[a]		
		BASELINE	SHUTDOWN[b]	STARTUP[c]
DIOXINS				
Mono-CDD	219	0.000	0.000	0.000
Di-CDD	253	0.032	0.470	0.129
Tri-CDD	288	0.024	0.000	0.247
2378 TCDD	322	0.071	0.000	0.000
Other TCDD	322	0.129	0.070	0.186
12378 PCDD	356	0.004	0.000	0.000
Other PCDD	356	0.047	0.081	0.042
123478 HxCDD	391	0.000	0.000	0.000
123678 HxCDD	391	0.000	0.000	0.008
123789 HxCDD	391	0.000	0.000	0.003
Other HxCDD	391	0.107	0.009	0.056
1234678 HpCDD	425	0.104	0.102	0.049
Other HpCDD	425	0.040	0.049	0.042
Octa-CDD	460	0.441	0.220	0.238
TOTAL CDD		1.000	1.000	1.000
FURANS				
Mono-CDF	203	0.000	0.343	0.032
Di-CDF	237	0.000	0.000	0.276
Tri-CDF	272	0.730	0.103	0.512
2378 TCDF	306	0.000	0.018	0.003
Other TCDF	306	0.227	0.476	0.147
12378 PCDF	340	0.006	0.000	0.001
23478 PCDF	340	0.008	0.000	0.002
Other PCDF	340	0.013	0.035	0.008
123478 HxCDF	375	0.000	0.011	0.001
123678 HxCDF	375	0.000	0.000	0.000
234678 HxCDF	375	0.000	0.000	0.000
123789 HxCDF	375	0.000	0.000	0.000
Other HxCDF	375	0.006	0.001	0.003
1234678 HpCDF	409	0.000	0.009	0.003
1234789 HpCDF	409	0.000	0.000	0.000
Other HpCDF	409	0.000	0.004	0.004
Octa-CDF	444	0.011	0.000	0.008
TOTAL CDF		1.000	1.000	1.000

[a] Mole Fraction is the mole fraction based on the mono- through octa-homologues. CDD fractions are based on total CDD and CDF fractions are based on total CDF. Mole fractions are based on the total train results.

[b] Results are based on the average concentrations from two sampling trains operated simultaneously.

[c] Results are from the port B train only. Because of low internal standard recoveries, the port A train results were not reported.

locations are used to characterize the process operation during the startup and shutdown tests. These monitoring locations are: 1) first pass middle of the combustor; 2) first pass top of the combustor; 3) economizer outlet; and 4) quench reactor outlet. The average temperatures for each test are summarized in Table 2-8. Also included is the average baseline temperature determined during the characterization test program. The average temperatures during the startup and shutdown tests did not vary significantly from baseline temperatures.

Thus, in order to observe the fluctuations of the temperatures with time during the test periods the temperature profiles were plotted for the combustion and control device. Temperature profiles during shutdown of the combustor and the control device are shown in Figures 2-3 and 2-4. Temperature profiles during startup are shown in Figures 2-5 and 2-6. The temperatures were recorded at five-minute intervals during the test periods. To aid in evaluating the temperature profiles, the significant operating events that occurred during shutdown and startup are presented in Tables 2-9 and 2-10, respectively. Some of the events are also indicated in the figures. It can be seen from these figures that the temperatures varied significantly over the startup and shutdown testing periods.

Another measure of the combustor performance is the combustion efficiency. The combustion efficiency was calculated based on the ratio of moles of CO to moles of CO and CO_2 measured at the combustor outlet. The combustion efficiency is plotted versus time in Figure 2-7 for the shutdown test and Figure 2-8 for the startup test. During the baseline test runs during the characterization test program, the combustion efficiency averaged 99.9 percent. During shutdown, the combustion efficiency ranged from 99.99 to 97.4 percent. During startup, the combustion efficiency ranged from 99.99 to 99.0 percent. The combustion efficiency is not presented for the shutdown test between 13:45 and 14:15 in Figure 2-7. During this time a malfunction of the CO monitor resulted in negative CO results, which gave a combustion efficiency greater than 100 percent.

TABLE 2-8. TEMPERATURE PROFILE FOR THE STARTUP AND SHUTDOWN TESTS AT MARION COUNTY, OR

Location	Average Temperature (°F)		
	Baseline[a]	Shutdown	Startup
Middle of the furnace, first pass	1,746	1,725	1,727
Top of the furnace, first pass	1,693	1,578	1,596
Economizer flue gas outlet	423	379	422
Quench reactor outlet	300	293	301

[a] Average of baseline operations data collected during the characterization test program.

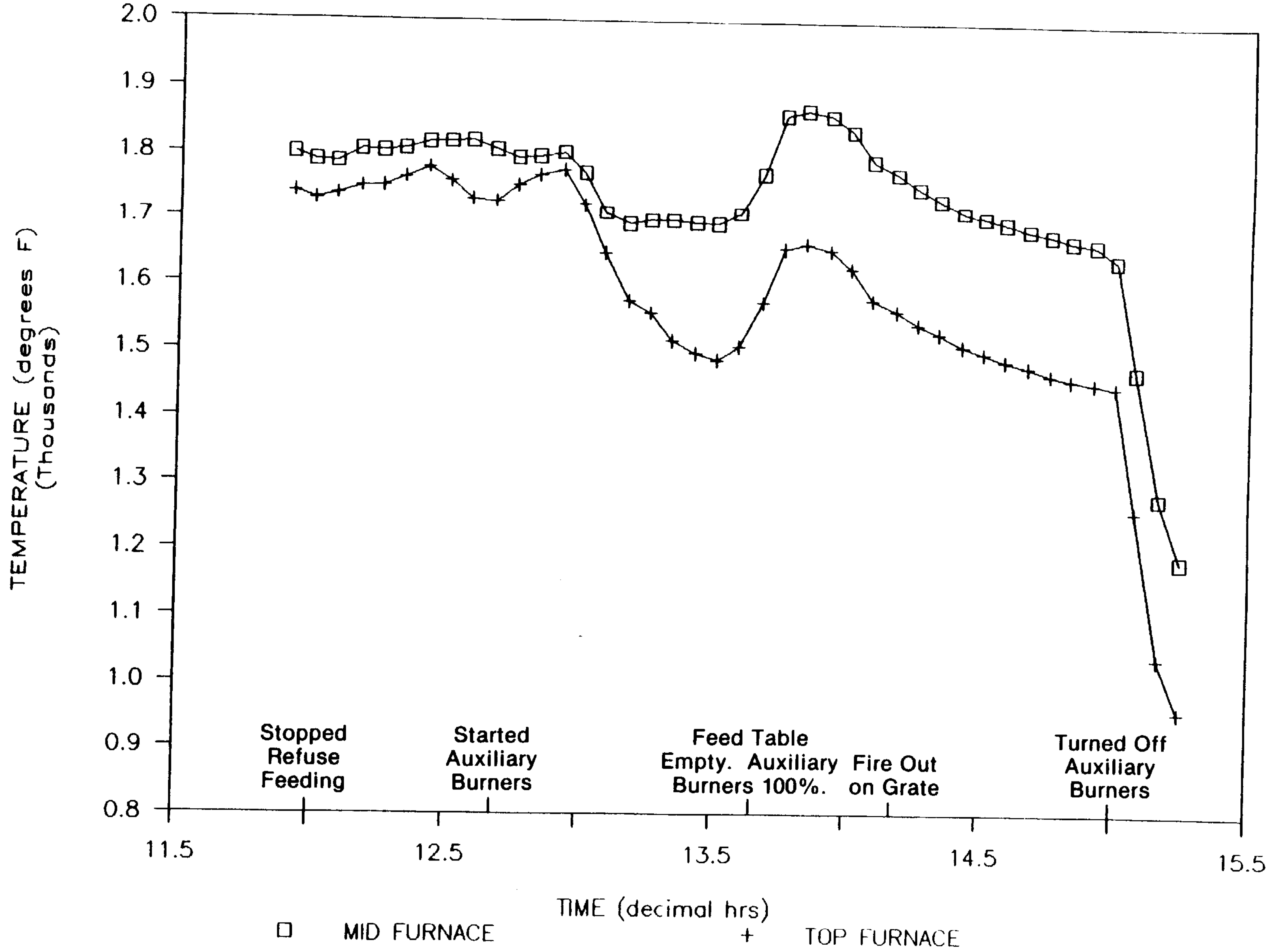


Figure 2-3. Combustor Temperature Profile During Shutdown

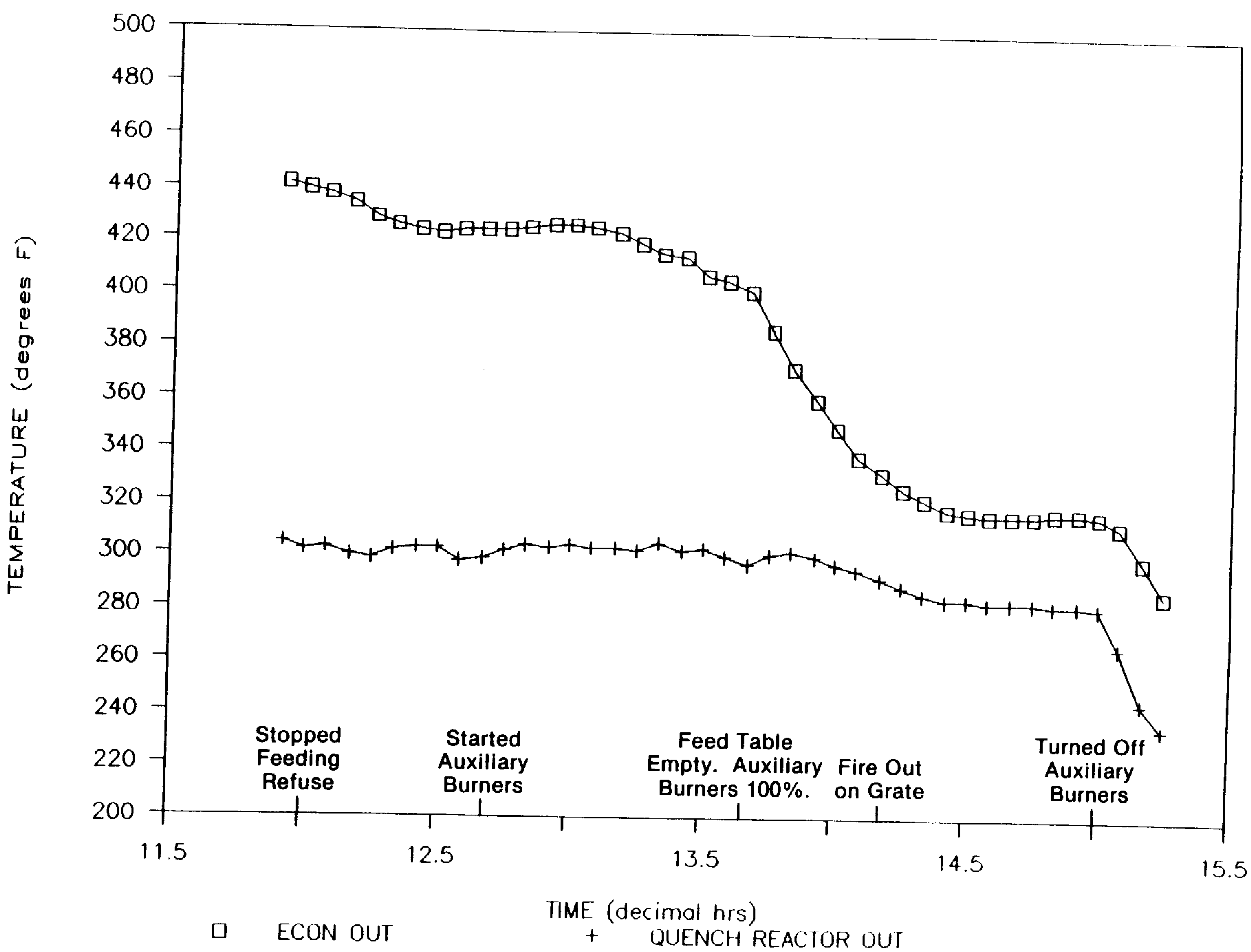


Figure 2-4. Control Device Temperature Profile During Shutdown

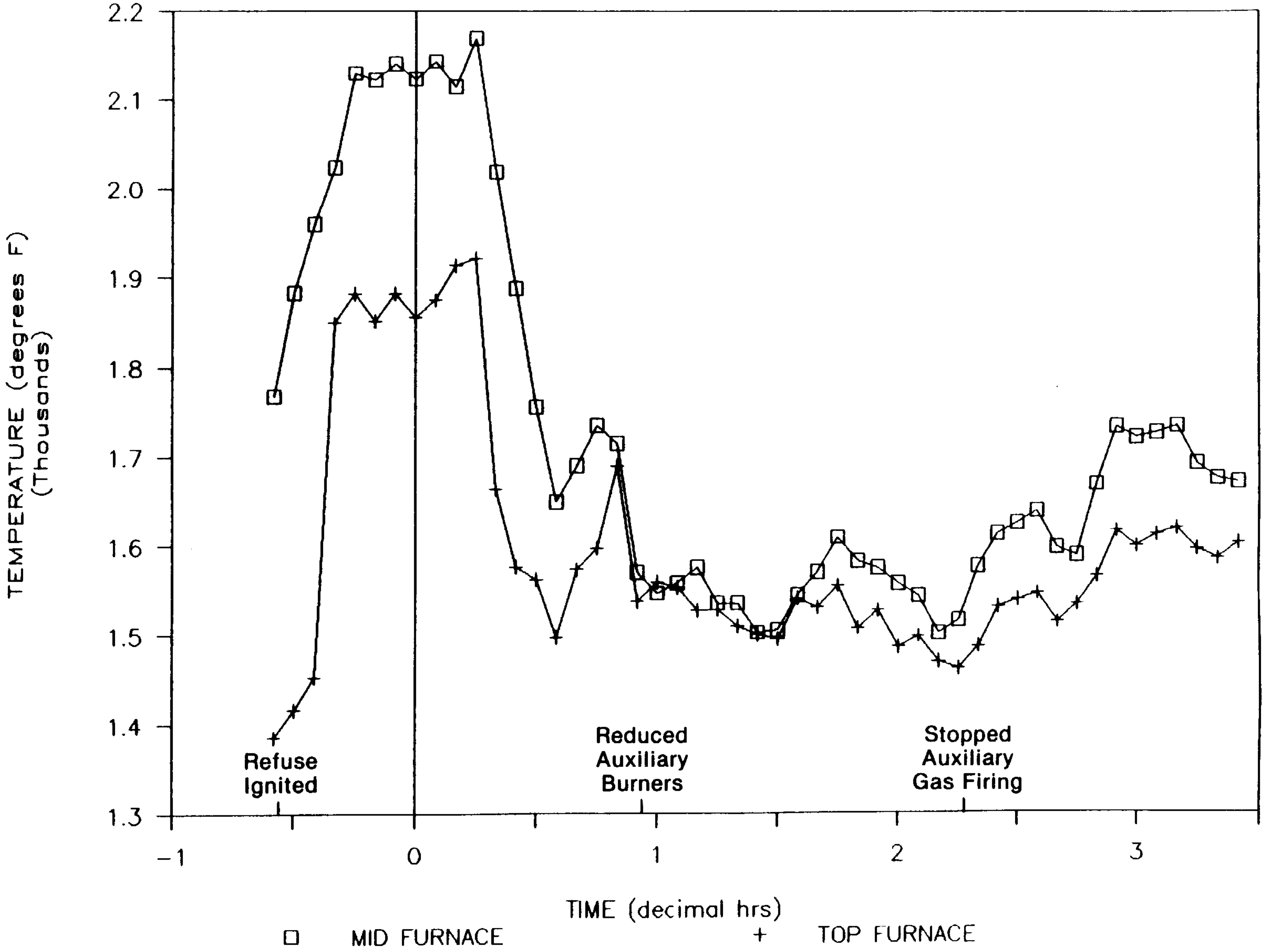


Figure 2-5. Combustor Temperature Profile During Startup

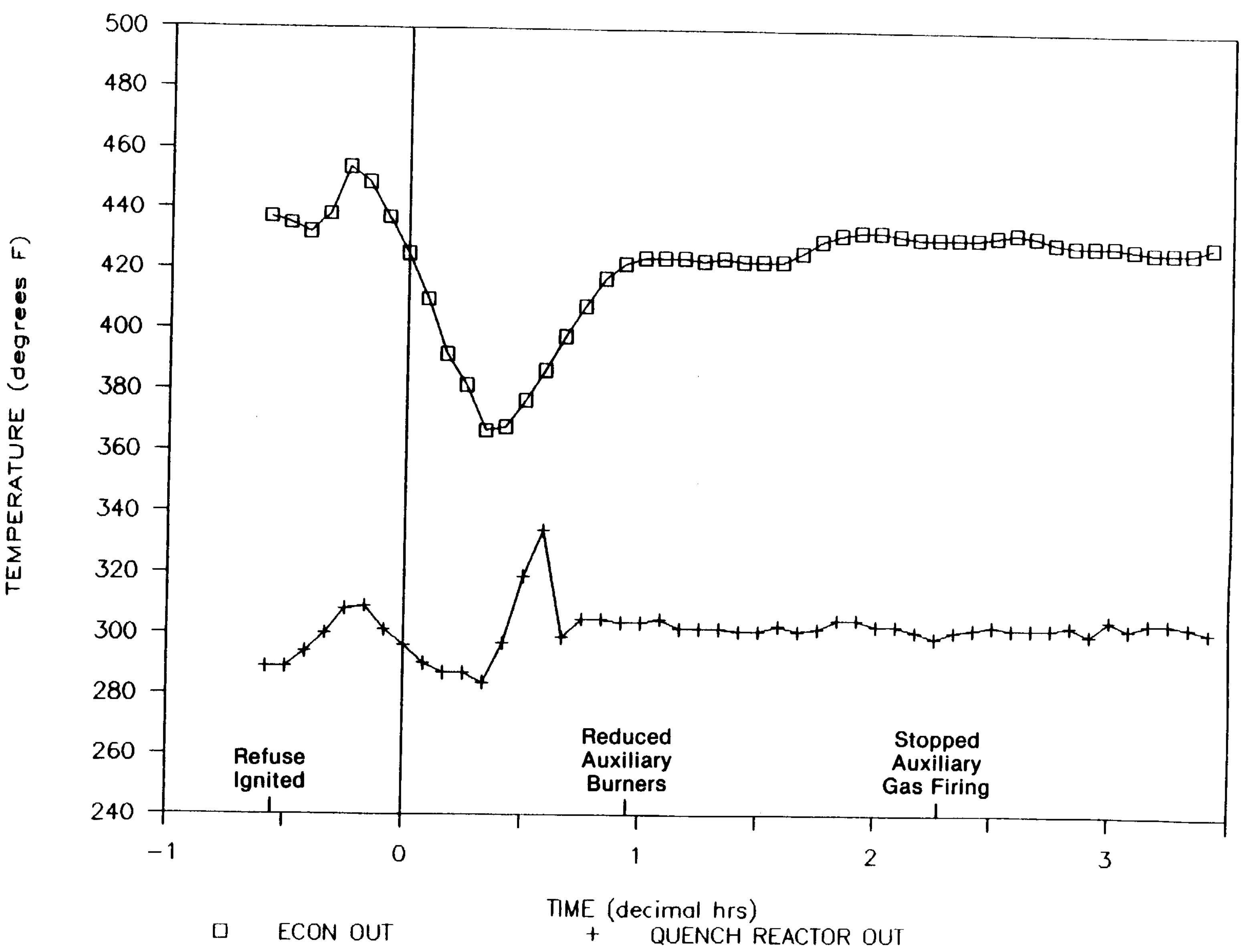


Figure 2-6. Control Device Temperature Profile During Startup

TABLE 2-9. SHUTDOWN EVENTS ON UNIT NO. 1, MARION COUNTY MWC

Time	Event
11:55	Started emission testing.
11:59	Began first sootblowing cycle.
12:00	Stopped refuse feeding.
12:12	End of first sootblowing cycle.
12:13	Began second sootblowing cycle.
12:14	Turned air heater off.
NR	Refuse feed chute low level indicator light on.
12:24	Completed second sootblowing cycle.
12:29	Started baghouse cleaning cycle. Fire out on grate.
~12:30	Closed feed chute hopper door.
12:40	Start auxiliary gas burners.
~13:00	Feed chute empty, reduced I.D. fan speed.
13:05	Reduced overfire air.
13:06	Change combustion control from O_2 to steam load.
13:23	Turned off steam turbine.
~13:40	Feed table empty.
13:40	Turned off overfire air fans.
13:43	Auxiliary burners 100%.
14:05	Reduced lime slurry injection flowrate (-1 nozzle).
14:25	Reduced lime slurry injection flowrate (-2 nozzles).
15:00	Reduced auxiliary burners.
15:02	Reduced lime slurry injection flowrate (-1 nozzle).
15:03	Turned off auxiliary burners.
15:04	Turned off F.D. fan.
15:13	Completed emission testing.

TABLE 2-10. STARTUP EVENTS ON UNIT NO. 1, MARION COUNTY MWC

June 22-23, 1987

Time	Event
16:10	Started I.D. fan at reduced level.
16:15	Started tesisorb injection.
19:00	Started lime system in silo.
19:01	Started auxiliary natural gas burners.
21:07	Increased auxiliary burner to 45%.
22:05	Started F.D. fan.
23:00	Began injecting lime slurry (3 nozzles).
23:20	Start feeding refuse. Started overfire air fan.
23:25	Refuse ignited. Started emissions testing. Increased F.D. and I.D. fans.
00:20	Baghouse compartment No. 6 cleaned.
00:40	Added two more nozzles to lime slurry injection.
00:54	Switched combustion control from furnace temperature to steam load.
00:55	Reduced auxiliary burner level. Turned on air heater.
02:15	Stopped auxiliary gas firing.
03:25	Completed emissions testing.

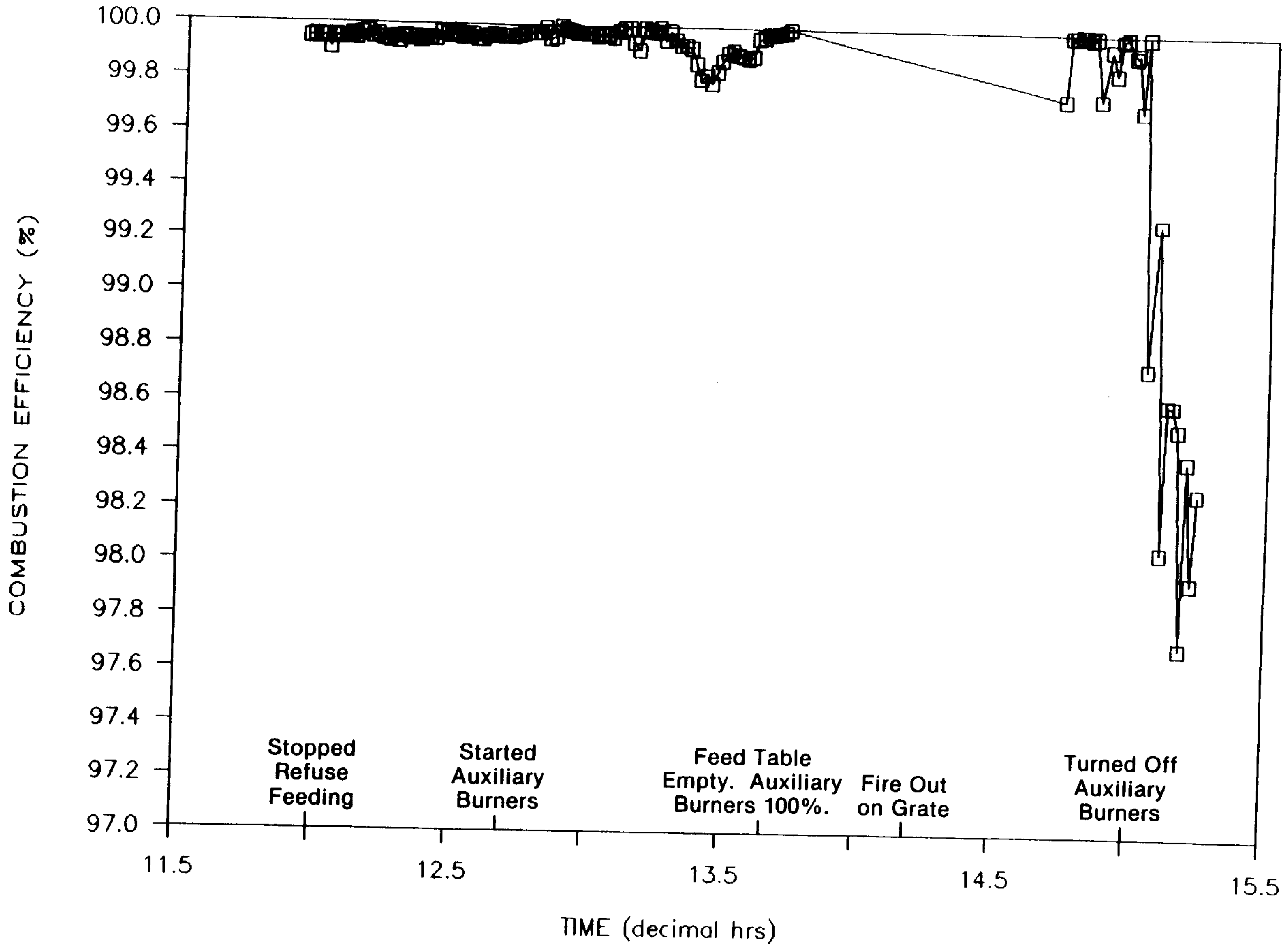


Figure 2-7. Combustion Efficiency During Shutdown

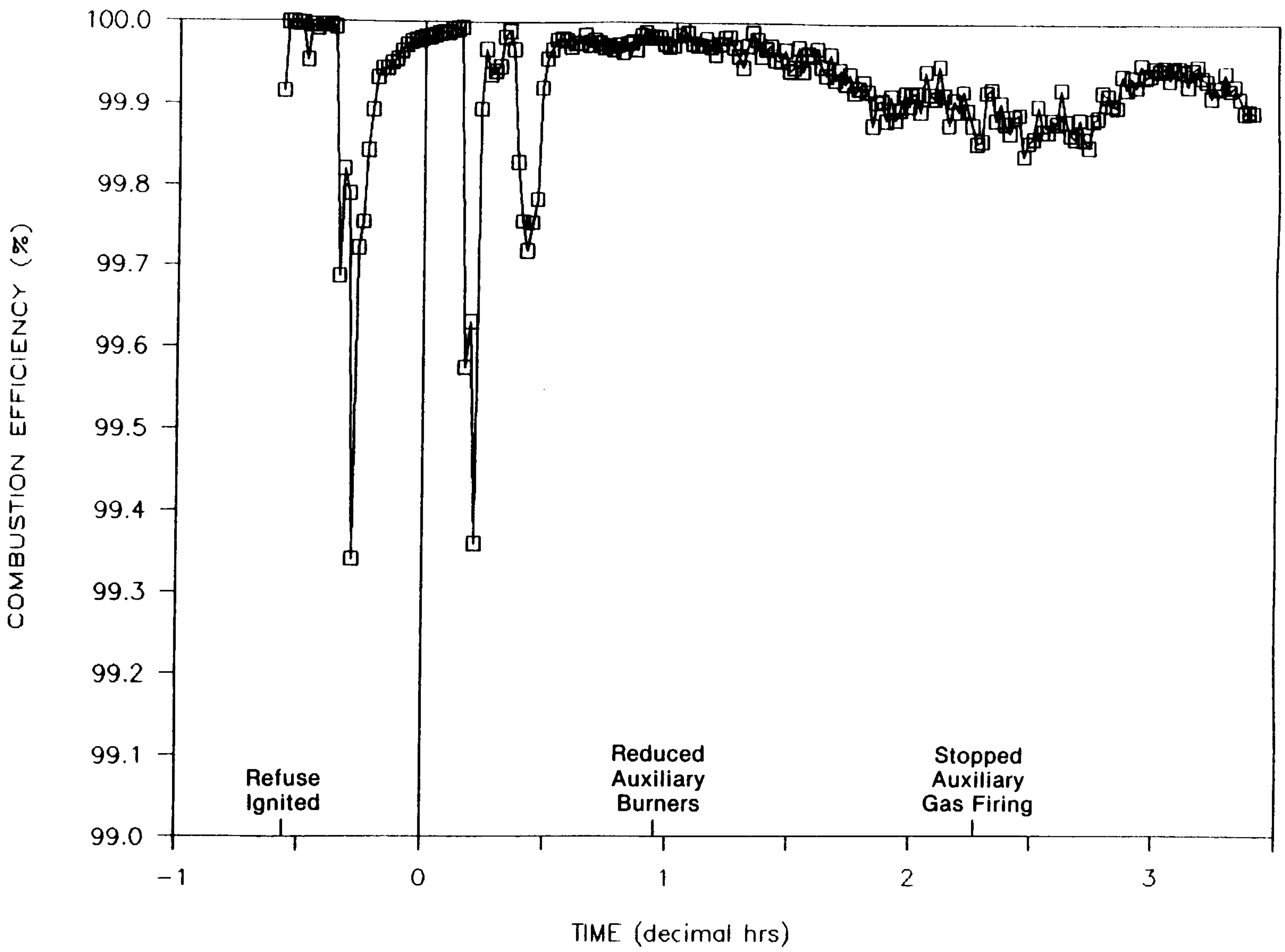


Figure 2-8. Combustion Efficiency During Startup

2.3 ACID GAS EMISSIONS

Acid gas emissions (HCl and SO_2) were measured during shutdown and startup conditions. SO_2 was measured by CEM at the inlet, midpoint, and outlet. HCl was measured by CEM at the inlet and outlet and by manual methods at the inlet, midpoint and outlet. All results presented in this section are on a dry basis.

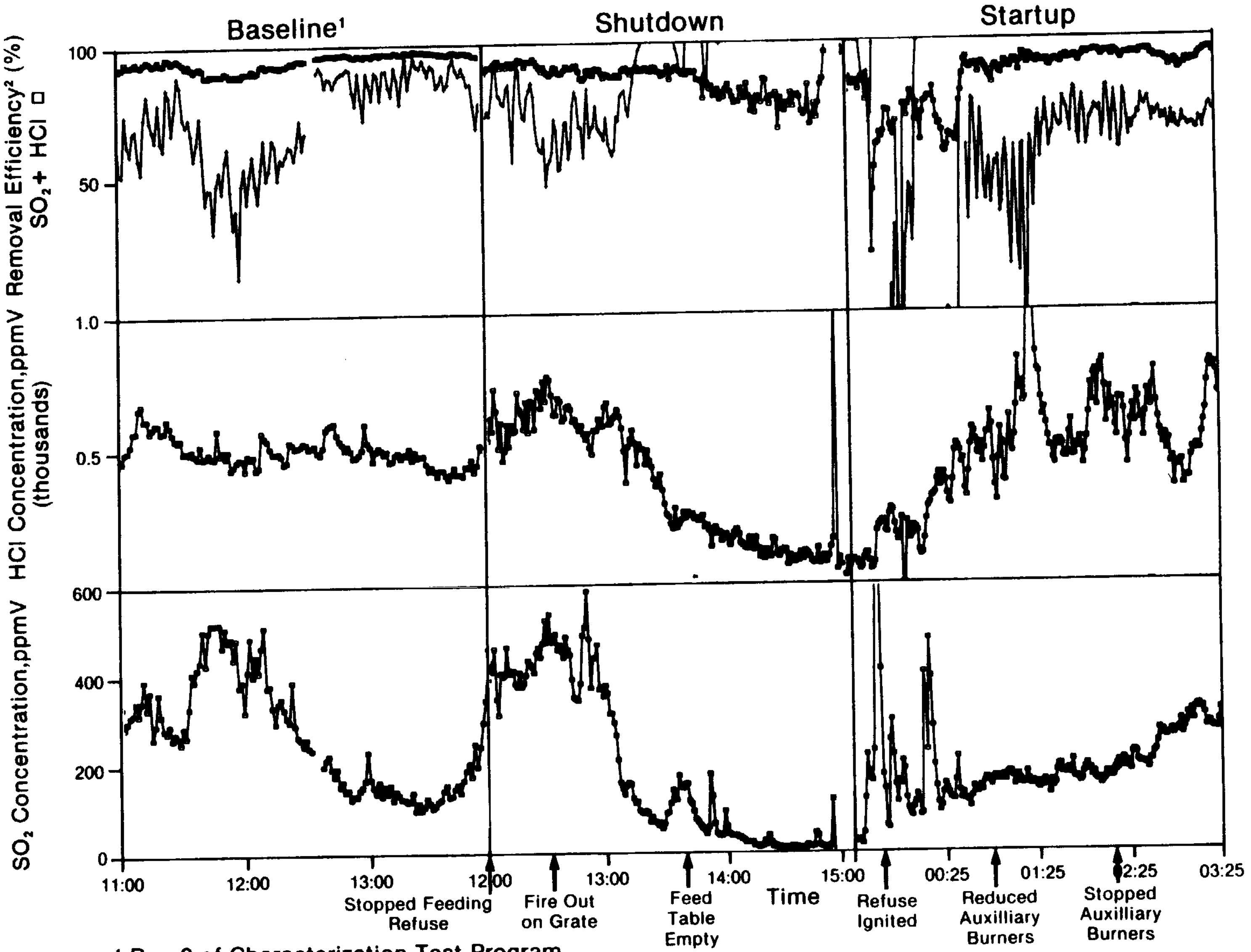
In Figure 2-9, plots of uncontrolled SO_2 and HCl concentrations and the control efficiency of each at one-minute intervals are shown for shutdown and startup. The average results are presented in Table 2-11.

During shutdown, uncontrolled HCl concentrations decreased from approximately 600 ppmv at 12 percent CO_2 to less than 100 ppmv at 12 percent CO_2. Uncontrolled SO_2 concentration decreased from approximately 500 ppmv at 12 percent CO_2 to less than 10 ppmv at 12 percent CO_2. The initial values of both SO_2 and HCl were similar to baseline values.

The average uncontrolled SO_2 concentration during shutdown was 262 ppmv at 12 percent CO_2. The average uncontrolled HCl concentration based on CEM data was 454 ppmv at 12 percent CO_2. Uncontrolled HCl concentrations from the two manual method sampling trains were 418 ppmv at 12 percent CO_2 with sootblowing and 314 ppmv at 12 percent CO_2 without sootblowing.

Although the normalized uncontrolled SO_2 concentrations from baseline and shutdown are similar, the mass flowrates are different. The average uncontrolled mass flowrate of SO_2 during shutdown was 40.5 pounds per hour (lb/hr), approximately half of the baseline rate of 87.4 lb/hr. This was also true for the HCl mass flowrates.

During the shutdown test, the normalized SO_2 concentrations did not decrease significantly from uncontrolled concentrations across the quench reactor (i.e., between the inlet and midpoint sampling locations). However, based on mass flowrates, SO_2 in the flue gas was reduced 24.8 percent across the quench reactor. Manual method HCl results showed a significant decrease in average concentrations across the quench reactor from 418 ppmv to



[1] Run 2 of Characterization Test Program

[2] One minute efficiencies are calculated from concentrations adjusted to 12% CO_2 since only the average flow rate for the test period is available

Figure 2-9. Removal Efficiency of the Total Control System and Uncontrolled Concentrations for HCl and SO_2 During Shutdown/Startup Testing at the Marion County MWC

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TABLE 2-11. ACID GAS RESULTS FOR SHUTDOWN AND STARTUP FOR THE MARION COUNTY MWC

TEST CONDITION:	BASELINE[a]	SHUTDOWN	STARTUP
INLET SO_2, ppmv, dry	274	135	167
INLET SO_2, lb/hr	87.4	40.5	58.9
INLET HCl, ppmv, dry[b]	519	212	379
INLET HCl, lb/hr[b]	94.3	35.1	72.6
REACTANT RATIO	1.33	1.04	1.16
INLET SO_2, ppmv @12% CO_2	299	262	216
MIDPOINT SO_2, ppmv @12% CO_2	128	235	169
OUTLET SO_2, ppmv @12% CO_2	99.5	79.6	95.1
INLET HCl, MANUAL, ppmv @12% CO_2	502	418[c] 314[d]	399[e] 612[f]
MIDPOINT HCl, MANUAL, ppmv @12% CO_2	222	173	191
OUTLET HCl, MANUAL, ppmv @12% CO_2	37.6	53.9[g] 54.7[g]	50.8[h] 49.6[h]
INLET HCl, CEM, ppmv @12% CO_2	631	454	471
MIDPOINT HCl, CEM, ppmv @12% CO_2	183	NA	NA
OUTLET HCl, CEM, ppmv @12% CO_2	35.0	49.8	49.1
QUENCH REACTOR EFFICIENCY			
PERCENT SO_2 REDUCTION	55.9	24.8	29.3
PERCENT HCl REDUCTION, CEM	70.2	NC	NC
PERCENT HCl REDUCTION, MANUAL	54.5	63.1[h]	66.8[j]
FABRIC FILTER EFFICIENCY			
PERCENT SO_2 REDUCTION	30.1	66.1	41.4
PERCENT HCl REDUCTION, CEM	82.8	NC	NC
PERCENT HCl REDUCTION, MANUAL	84.7	68.6	72.6
OVERALL SYSTEM EFFICIENCY			
PERCENT SO_2 REDUCTION	69.2	74.5	58.6
PERCENT HCl REDUCTION, CEM	94.9	90.8	90.2
PERCENT HCl REDUCTION, MANUAL	93.1	88.4[k]	90.9[l]

NOTE: All values are reported on a dry basis.
NA = Not reported because instrument was not operating during these runs.
NR = Not reported due to invalidation.
NC = Not calculated because CEM value was not reported.

[a] Baseline data are from Run 2 of the characterization test.

[b] Average of CEM and manual results.

[c] Sample taken over entire duration of test with sample train A. Included sootblowing during first half hour of run.

[d] Sampling started with sample train B after sootblowing was completed (1/2 hr.).

[e] Sample taken over first half of run with sample train A.

[f] Sample taken over second half of run with sample train B.

[g] Samples taken simultaneously with sample trains A and B during shutdown.

[h] Samples taken simultaneously with sample trains A and B during startup.

[i] Reduction efficiency based on results from inlet train A sample.

[j] Reduction efficiency based on average inlet concentration.

[k] Reduction efficiency based on inlet train A and outlet average results.

[l] Reduction efficiency based on inlet average and outlet average.

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173 ppmv (both at 12 percent CO_2). Using the uncontrolled HCl concentration with sootblowing to calculate the mass rate, HCl was reduced by 63.1 percent across the quench reactor.

The average controlled SO_2 concentration during shutdown was 79.6 ppmv at 12 percent CO_2. The average overall reduction in SO_2 across the control device was 74.5 percent based on mass flowrate. The removal efficiency was approximately 80 percent during the first hour of the run and then increased to 100 percent by the end of the shutdown test period. The apparent increase in control efficiency is due to the significant drop in the uncontrolled SO_2 concentration to levels less than 10 ppm. Considering the precision of the continuous monitoring instruments at these low concentrations, the uncontrolled and controlled SO_2 concentrations are equivalent.

During shutdown, the reduction in HCl across the total QR/FF control system was 90.8 percent based on mass flowrate from CEM data and 88.4 percent based on mass flowrate from manual data. During the shutdown test period, the efficiency based on normalized HCl concentration remained steady for most of the run at approximately 90 percent. The removal efficiency decreased slightly and became more variable in the latter part of the shutdown test.

The molar ratio of lime to acid gases was lower during shutdown than baseline, but did not significantly affect the acid gas removal efficiency. Based on the overall average flue gas HCl and SO_2 flowrates and the overall average dry lime feed rate, the reactant ratio was 1.04 during shutdown. The dry lime feed rate was calculated assuming equal distribution of lime from the totalizer to Units 1 and 2.

Over the duration of the startup test period, uncontrolled HCl emissions increased from zero to approximately 600 ppmv 12 percent CO_2. Over the same time period, SO_2 emissions increased from zero to 300 ppmv at 12 percent CO_2. The average uncontrolled SO_2 concentration was 216 ppmv at 12 percent CO_2 and the average uncontrolled HCl concentration was 471 ppmv at 12 percent CO_2 based on CEM measurements.

During startup, two sampling trains were used at the inlet. One train was used during the first two hours of the run and the other train was used to sample during the last two hours of the run. The average uncontrolled HCl concentration from the first half of the run was 399 ppmv at 12 percent CO_2. The average uncontrolled HCl concentration determined for the second half of the run was 612 ppmv at 12 percent CO_2. The average for the entire run was 506 ppmv at 12 percent CO_2.

Across the quench reactor, both HCl and SO_2 concentrations were reduced significantly. SO_2 reduction across the quench reactor was 29.3 percent based on mass flowrates. The average SO_2 concentration was 169 ppmv at 12 percent CO_2. The reduction in HCl across the quench reactor was 66.8 percent based on mass flowrates. The midpoint HCl concentration was 191 ppmv at 12 percent CO_2 by manual method measurements.

During startup, the average controlled SO_2 concentration was 95.1 ppmv at 12 percent CO_2. Based on the mass flowrate, the reduction in SO_2 across the system was 58.6 percent. The average controlled HCl concentration was 50.2 ppmv at 12 percent CO_2 from the average of the two manual sampling trains at the outlet. The percent reduction in HCl across the QR/FF control system was 90.2 percent and 90.9 percent based on mass flowrates determined from CEM and manual sampling results, respectively. The control efficiencies were erratic for both HCl and SO_2 during the first part of the startup period, but leveled out during the latter part of the test period.

The molar ratio of lime to acid gases during startup was lower than baseline or shutdown. Based on the overall flue gas HCl and SO_2 concentrations, and the overall average dry lime feed rate, the reactant ratio was 1.16.

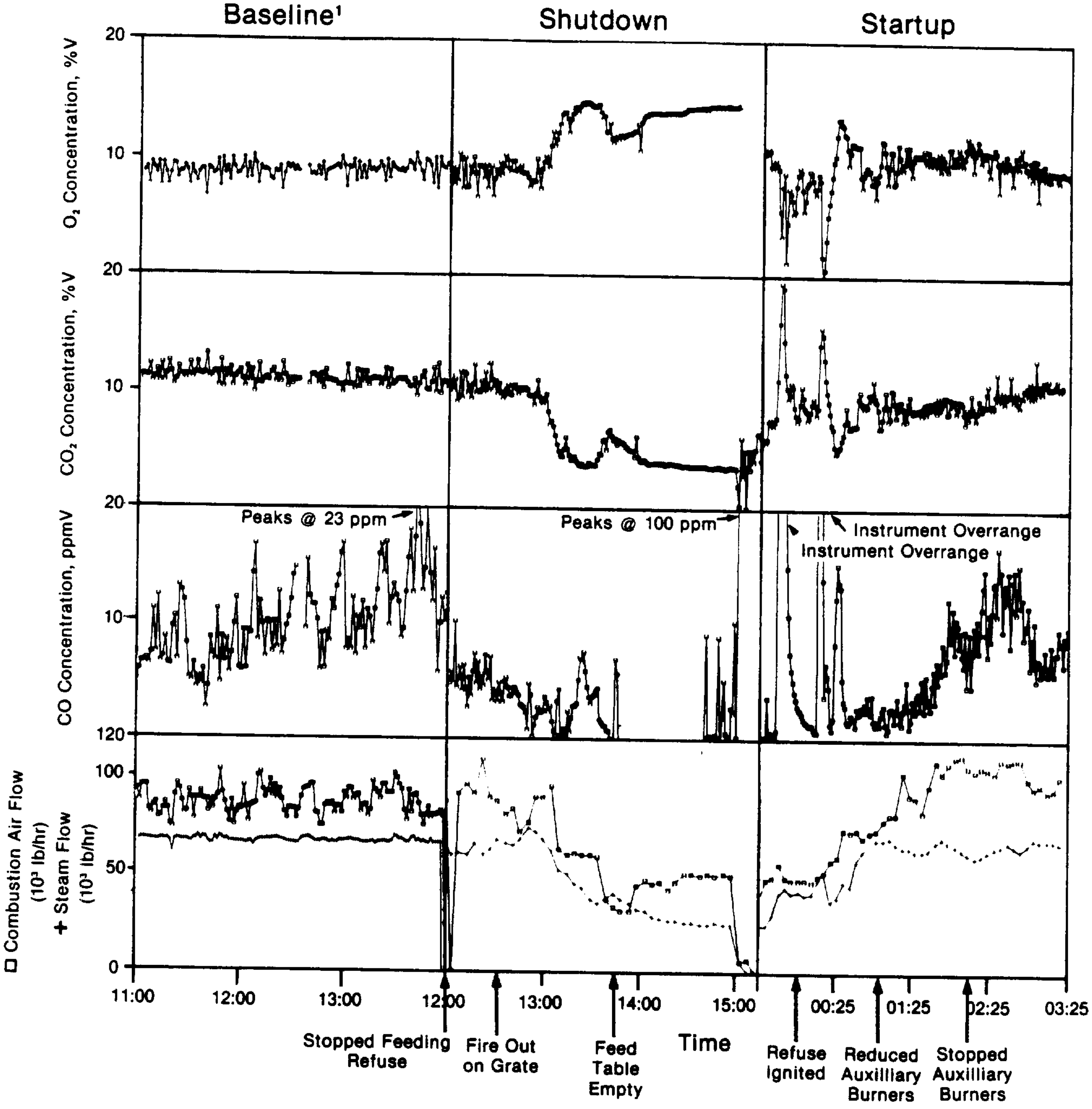
2.4 FIXED GASES (CO, CO_2 and O_2)

Oxygen (O_2), carbon dioxide (CO_2), and carbon monoxide (CO) were monitored by CEMs during shutdown and startup testing. Oxygen and carbon dioxide were also sampled manually by EPA Method 3 using Orsat analysis. Both O_2 and CO_2 were measured at the inlet, midpoint, and outlet; CO was measured at the inlet and outlet. Only the inlet results for the fixed gases are summarized since midpoint and outlet concentrations would be affected only by dilution. All the results are presented on a dry basis.

The fixed gases concentrations at the inlet are shown for baseline, shutdown, and startup conditions in Figure 2-10. Combustion air flow and steam flow are shown in Figure 2-10, also. The average results for the fixed gases are presented in Table 2-12. The results discussed here are the average of the CEM and manual (Orsat) data.

During shutdown, all the fixed gases exhibited transient behavior. Oxygen increased from near baseline, 9 percent by volume, to that of air (20.9 percent). The average oxygen concentration for the shutdown test was 12.1 percent by volume. Carbon dioxide decreased from baseline levels of about 10 percent by volume to approximately 4 percent by volume during the run. The average CO_2 concentration was 6.5 percent by volume. The high O_2 and low CO_2 are apparently a manifestation of higher excess air in the combustor. Excess air during the shutdown test period was 129 percent compared to an average of 73.2 percent for baseline. Carbon monoxide concentrations decreased from about 5 ppmv to near zero and increased to about 100 ppmv at the end of the shutdown test period. The average CO concentration was 6.9 ppmv during the shutdown test period.

During startup, the oxygen concentration averaged 9.6 percent by volume, which is not significantly different from baseline. The O_2 concentration was fairly steady through most of the run, although there was some erratic behavior during the first hour of the run. The O_2 concentration exhibited several troughs during this period, decreasing to both one and zero percent by volume at different times. The CO_2 concentration was fairly constant during most of the startup, although there were some peaks reaching 20 and 15 percent by volume. The average CO_2 concentration was 9.0 percent by volume.



[1] Run 2 of the Characterization Test Program

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Figure 2-10. Fixed Gases Concentration, Combustion Air Flow and Steam Load During the Shutdown/Startup Testing at the Marion County MWC

TABLE 2-12. FIXED GASES CONCENTRATIONS DURING SHUTDOWN AND STARTUP FOR THE MARION COUNTY MWC

TEST CONDITION:	BASELINE[a]	BASELINE[a]	SHUTDOWN	STARTUP[b]
CEM[c]				
O_2, %v, dry	9.0	8.8	12.5	9.4
CO_2, %v, dry	10.4	11.0	6.2	9.3
CO, ppmv, dry	10.0	10.3	6.9	8.0
PERCENT EXCESS AIR	73.3	71.1	140	77.9
Fo[d]	1.14	1.10	1.35	1.24
ORSAT[c]				
O2, %v, dry	9.0	9.4	11.7	9.8
CO2, %v, dry	10.0	10.1	6.7	8.7
PERCENT EXCESS AIR	72.7	78.4	119	83.0
Fo[d]	1.19	1.15	1.37	1.30
Average[e]				
O_2, %V, dry	9.0	9.1	12.1	9.6
CO_2, %V, dry	10.2	10.6	6.5	9.0
PERCENT EXCESS AIR	73.2	74.8	129	80.5
Fo[d]	1.17	1.13	1.36	1.27

[a] Baseline data are from Runs 1 and 2 of the characterization test program.

[b] Orsat results are the average of analyses at the two inlet ports.

[c] Monitored at the inlet sampling location. Does not include over-ranging intervals.

[d] Fo = $(20.9 - O_2\%)/(CO_2, \%)$

[e] Average of CEM and Orsat results.

The CO concentration was erratic throughout the startup test period. At the start of the run, there were several large CO peaks which over-ranged the CO instruments. Oxygen decreased to near zero due to two failures of the overfire air fan at 23:42 to 23:47 and 00:10 to 00:15. The CO concentration was estimated at over 5,000 ppm during these excursions based on engineering analysis of the strip chart recordings. After these excursions, the concentration decreased to about 2 ppmv and increased steadily to about 10 to 12 ppmv at the end of the run. The average CO concentration over the startup period was 8.0 ppmv. The CO and CO_2 peaks roughly corresponded with the troughs in O_2 concentration.

2.5 ADDITIONAL POLLUTANTS OF INTEREST (NO_x and THC)

The additional pollutants monitored during the testing were NO_x and THC. They were analyzed at the inlet and outlet. The NO_x and THC concentrations are presented in Table 2-13 for both shutdown and startup. The concentrations are also shown graphically in Figure 2-11. Since the NO_x and THC concentrations are not affected by the control device, except by dilution, only the inlet data are discussed here.

During shutdown, the average NO_x concentration was significantly lower than the average baseline value of 295 ppmv at 12 percent CO_2. The average NO_x concentration during shutdown was 210 ppmv at 12 percent CO_2. The mass flow of NO_x averaged 23.4 lb/hr, which is less than half of baseline. The NO_x concentration decreased from baseline levels and reached zero at the conclusion of the shutdown test period. The NO_x concentration remained steady at about 150 ppmv at 12 percent CO_2 during about half the run.

The THC concentration was very near baseline for most of the shutdown test period. At the end of the run, the concentration showed several high peaks. Although the peaks were accentuated by very low CO_2 values for normalization, there was a significant increase in THC concentration. The resulting THC peak concentrations were typically 20 to 30 ppmv and two peaks measured 97 and 400 ppmv at 12 percent CO_2. The THC concentrations were

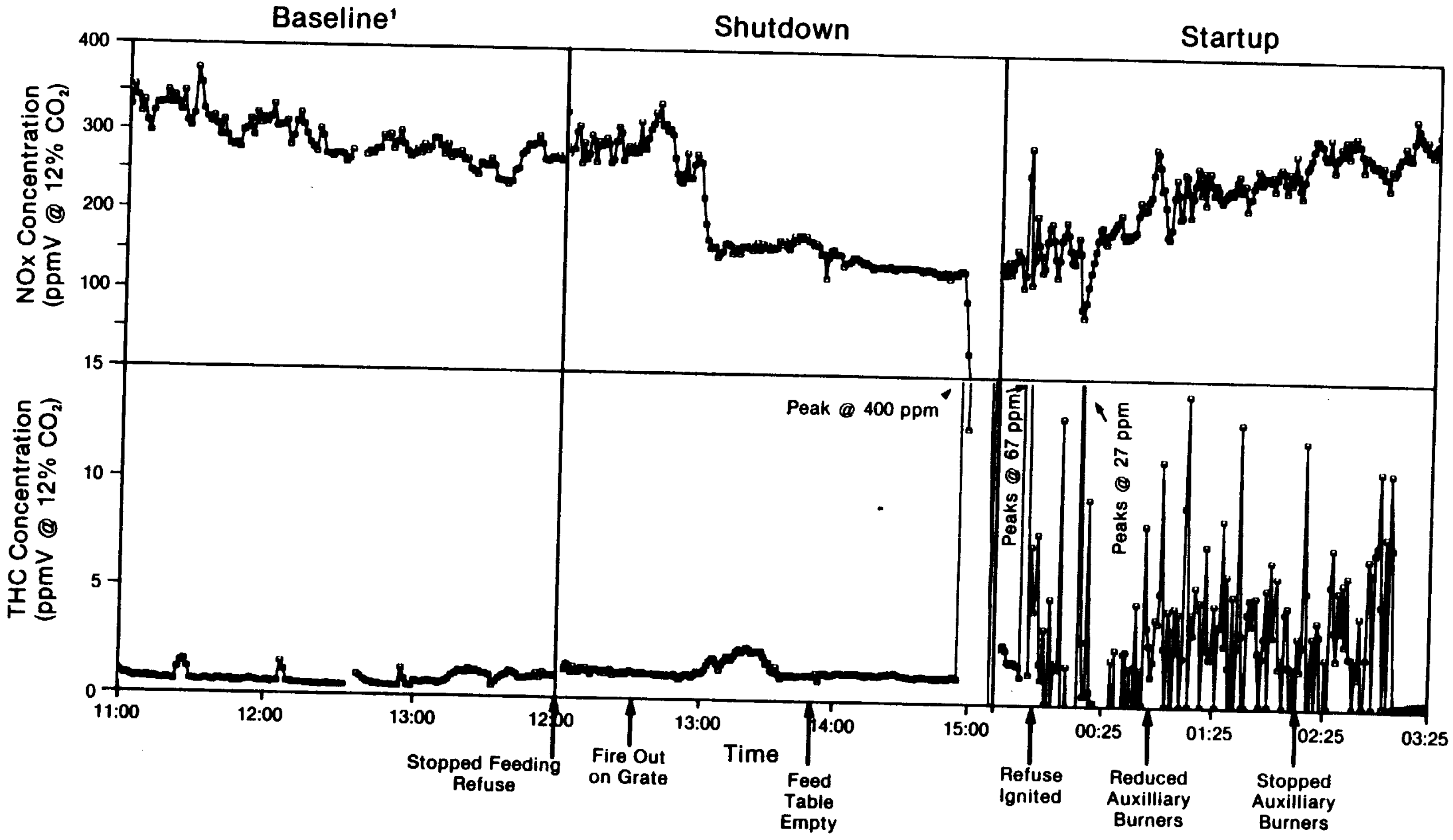
TABLE 2-13. NO_x AND THC CONCENTRATIONS DURING SHUTDOWN AND STARTUP FOR THE MARION COUNTY MWC

TEST CONDITION:	BASELINE	BASELINE	SHUTDOWN	STARTUP
NO_x, ppmv, dry	264	262	109	179
NOx, ppmv @12% CO2	305	285	210	231
NOx, lb/hr	57.7	59.9	23.4	45.3
THC, ppmv, dry	NR	0.7	1.4	2.9
THC, ppmv @12% CO_2	NR	0.8	2.7	3.7
THC, lb/hr	NR	0.2	0.3	0.7

[a] Baseline data are from Runs 1 and 2 of the characterization test program.

[b] Monitored at the inlet sampling location.

NR = Not reported due to invalidation or reading not taken.



[1] Run 2 of the Characterization Test Program

Figure 2-11. NOx and THC Concentrations During Shutdown/Startup Testing at the Marion County MWC

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typically 20 to 30 ppmv at 12 percent CO_2 during the shutdown test period. The mass flow averaged 0.3 lb/hr.

During the startup run, NO_x increased rapidly from zero and then steadily climbed to baseline levels. There were some erratic changes in concentration in the first hour of startup, but this diminished during the test period. The average NO_x concentration during startup was 231 ppmv at 12 percent CO_2. The average mass flow of NO_x was 45.3 lb/hr.

The THC concentration during startup was very different from baseline. For most of the test period, the THC concentration varied erratically from zero to approximately 8 ppmv at 12 percent CO_2. There were several peaks above this, also, with two peaks reaching 67 and 27 ppmv at 12 percent CO_2. During the last half hour of the run, the concentration stabilized near baseline values. The average THC concentration during startup was 3.7 ppmv at 12 percent CO_2, with a corresponding average mass flowrate of 0.7 lb/hr.

3.0 CONCLUSIONS

The CDD/CDF control efficiency of the quench reactor/fabric filter (QR/FF) emission control system during shutdown/startup operations was evaluated. The control efficiencies were calculated for each congener rather than on a total CDD/CDF basis. During shutdown, the control efficiencies for the CDD/CDF congeners were above 95 percent, except for mono-CDF. During startup, the control efficiencies for the CDD/CDF congeners were above 83 percent except for di-CDD and di-CDF. Reduction efficiencies consistently in the 80 to 90 percent range indicate positive control of CDD/CDF by the QR/FF control system.

The results indicated that uncontrolled CDD/CDF emissions increased during sootblowing. During shutdown operations, CDD/CDF emissions were not significantly different from baseline operations. However, the startup results did indicate a significant increase in CDD/CDF emissions during the first 1-1/2 hours of startup operations.

The quality assurance objectives for precision, accuracy and completeness were met.

4.0 PROCESS DESCRIPTION AND OPERATION

4.1 PROCESS DESCRIPTION

Ogden Martin operates two mass-burn waterwall combustors at the Marion County Solid Waste-to-Energy Facility. Each unit has a design capacity of 250 Mg/day (275 tpd) of municipal solid waste. The furnaces are equipped with Martin reverse-reciprocating stoker grate systems. The combustion chambers are refractory-lined to a level of 9 m (30 ft) above the stoker.

Refuse is trucked to the facility and dumped into an enclosed receiving pit. It is subsequently transferred to each combustor by overhead cranes. Then, the solid waste passes downward through the feed chute and is pushed onto the stoker grate by a hydraulically operated ram feeder.

4.1.1 Combustor Description

The combustor system is designed to operate at 90 percent excess air. During baseline testing conditions, the combustor operated at about 70 percent excess air. Underfire air is supplied via five air plenums and controlled by the pressure drop across the grate bars. Overfire combustion air, which is typically 25 to 30 percent of the total air, is injected through three rows of nozzles above the stoker at the front and rear walls of the combustor at design pressures exceeding 4,980 Pa (20 in. W.C.).

The combustion chamber is designed to sustain a flue gas temperature of 980°C (1800°F) for 2 seconds when solid waste is present on the stoker, including startup and shutdown. To ensure that these time and temperature specifications are maintained, each combustor is equipped with natural gas auxiliary burners with an individual capacity of 13 MW (45 million Btu/hr) located above the combustion chamber refractory lining.

The boiler system is a multi-pass design with a gas-tight membrane waterwall design. From the top of the combustion chamber, the flue gas flows downward through an open radiation pass before entering the evaporator tubes in the two-drum, boiler convection section. Superheater and economizer sections follow, each in its own pass. Each combustion unit generates a maximum continuous steam output of 30,000 kg/hr (66,400 lb/hr) at a pressure of 4520 kPa (655 psig) and a temperature of 370°C (700°F). The steam is delivered to a 13.1 megawatt (45 million Btu/hr) turbine generator. The electricity produced flows into the Portland General Electric Company (PGE) grid.

The Martin combustion system consists of an oxygen (O_2) controller which controls the feeder and the grate speed, and a steam load controller which controls the underfire air dampers. When the O_2 level is above a given set point, waste feeding begins, and when the O_2 level is low, feeding stops. As the feed rate increases, steam flow increases and the underfire air dampers gradually close, reducing the flow of O_2. As the O_2 level is lowered, the feeding rate slows. This system is self-modulating and is representative of state-of-the-art combustion controls.

Bottom ash and grate siftings are discharged into a water-quenched residue system. The ash disposal system consists of vibrating conveyors and belt conveyors, which transport the residue to an enclosed storage area where it is eventually trucked to a sanitary landfill for final disposal. Ash from the cyclone and fabric filter is collected separately and conveyed to the ash removal system to be handled and disposed of together with the bottom ash.

4.1.2 Emission Control System

The air pollution control system at the Marion County Solid Waste-to-Energy Facility consists of a a cyclone, quench reactor (spray dryer), a dry venturi, and a fabric filter (baghouse). The flue gases leave the economizer section at temperatures between 199°C to 270°C (390°F to 515°F) and enter the bottom of the quench reactor through a cyclonic inlet where removal of oversize particles takes place. Gas flow rates vary between 1636 m^3/min (57,750 acfm) at 199°C (390°F) and 1885 m^3/min (66,560 acfm) at 270°C (515°F). Slaked pebble lime slurry is injected through an array of five two-fluid nozzles near the bottom of the reactor vessel. The slurry water feed rate is approximately 0.05 to 0.07 m^3/min (12.8 to 18.2 gpm). The feed rate is varied to maintain the quench reactor outlet temperature within an operating range of 125-149°C (258-300°F). The stoichiometric ratio of lime to HCl is maintained at approximately 2 to 2.5 to ensure that upset peaks are sufficiently controlled. The system is designed so that the quench reactor outlet temperature and stoichiometric ratio are interdependent.

The lime concentration in the slurry is held nearly constant. Therefore, as the slurry feedrate increases so does the dry lime feedrate. Dry lime is fed by screw feeder to the slurry mixing tank every 5 minutes. The screw feeder is turned on until sufficient lime has been fed to the tank to yield the desired lime concentration in the slurry. The dry lime feed rate varies between 57 and 193 kg/hr (125-425 lb/hr).

After the lime slurry is mixed, it is screened to remove large solids, thereby maintaining a relatively stable specific gravity. The slurry is pumped to a distribution loop where a portion of it is distributed to the five nozzles and the remainder is recycled back to the slaker.

A low pressure drop dry venturi is located between the quench reactor and the baghouse. Tesisorb is injected into the venturi at a design rate of 24 kg/hr (53 lb/hr).

An Amerthem reverse air baghouse is installed downstream of the dry venturi for particulate matter (PM) collection. Each unit consists of six compartments with 120 bags in each. The fabric filter has a gross air-to-cloth ratio of 1.69:1 (net 2.31:1). The filter bags are made of a fiberglass material suitable for flue gas temperatures up to 268°C (515°F). The PM, lime, and Tesisorb cake on the fabric and must be cleaned off every 60 to 70 minutes. Unspent lime in the filter cake acts as an additional neutralization mechanism for acid gas collection. Particulate and Oregon DEQ condensible emissions are required to be controlled to a level of 69 mg/dscm (0.03 gr/dscf) at 12 percent CO_2.

4.2 PROCESS DATA RECORDED

The process data recorded during the shutdown/startup test program are presented in Table 4-1. The process data not discussed in Section 2 are summarized in Appendix A. Printouts of the recorded data included in Appendix D and the original data sheets and stripcharts are included in Appendix G.4.

4.3 Process Problems Encountered

4.3.1 Shutdown

The shutdown was longer than expected, lasting three hours rather than one. Two sequential boiler tube sootblowing cycles were included in the shutdown testing interval.

4.3.2 Startup

Startup began approximately six hours later than planned. The feedstroke setting for the ram feeder had been set to 52 inches during shutdown and had not been reset for startup (the normal length of the feedstroke is approximately eight inches). Also, initially overfire air was not available due to electrical malfunctions. These two problems contributed to two CO excursions of over 5,000 ppm that lasted about 5 minutes.

TABLE 4-1. PROCESS OPERATING PARAMETERS RECORDED DURING MARION COUNTY SHUTDOWN/STARTUP TEST PROGRAM

Parameters	Units
Refuse feed rate (Crane weight scale)	lb
Steam flow	lb/hr
Steam pressure	psig
Steam temperarture	°F
Combustion air flow	10^3 lb/hr
Combustion air temperature	°F
Overfire air nozzle pressure - Front - Upper rear - Lower rear	in W.C.
O_2 concentration (boiler exit)	% vol. (wet)
Temperatures - Middle of furnace 1st pass - Top of furnace 1st pass - Economizer outlet - Quench Reactor inlet - Quench reactor outlet - I.D. fan inlet - Baghouse outlet	°F
Quench reactor inlet pressure	in W.C.
Dry lime feed rate (Lime totalizer)	lb
Lime slurry specific gravity	
Dry venturi ΔP	in W.C.
Baghouse ΔP	in W.C.
Baghouse cleaning cycle	min
Stack opacity	%
Furnace draft	in W.C.

5.0 SAMPLE POINT LOCATIONS

The sampling locations are shown on the process line schematic in Figure 5-1. Each sampling location is discussed in the following sections.

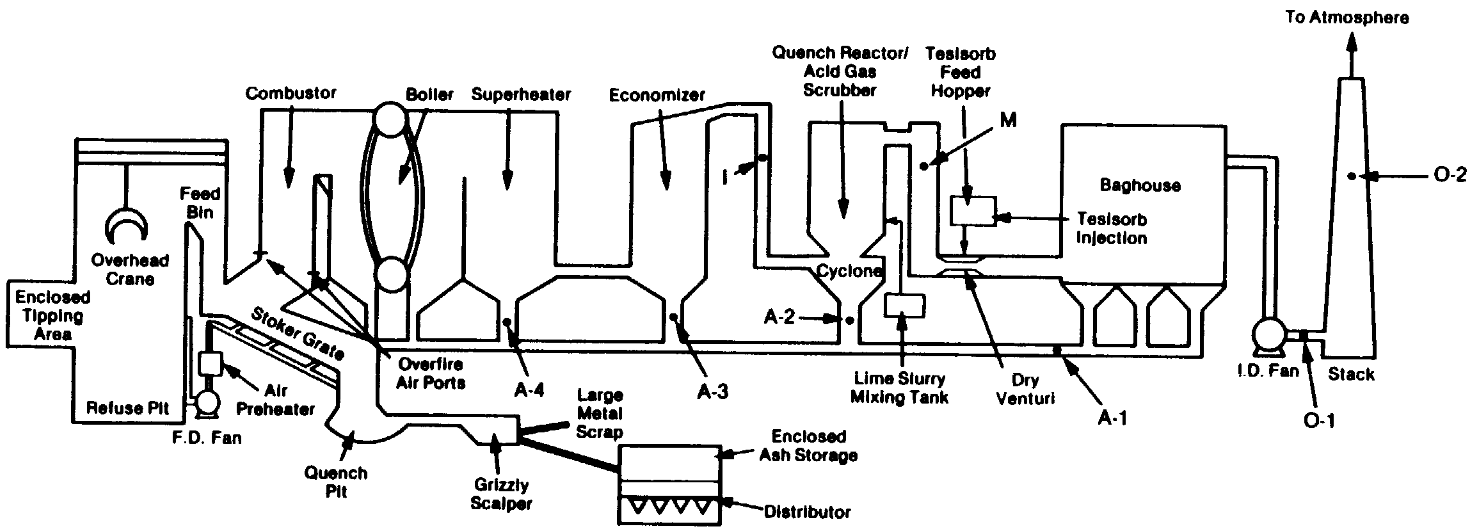
5.1 FLUE GAS

5.1.1 Boiler Outlet (Control Device Inlet) Sampling Location

The parameters that were measured at the boiler outlet (control device inlet) sampling location include CDD/CDF, volumetric flowrate, moisture, SO_2, HCl, O_2, CO, CO_2, NO_x and THC. A top view and side view of the boiler outlet sampling location are shown in Figures 5-2 and 5-3, respectively. The sampling location has three six-inch I.D. ports located in a circular duct 6 ft. 10 in. in diameter. Two of the ports (Ports A and B) are located in the same plane, 90° apart. These ports were used for the manual test methods. The third port (Port C) is located about two feet downstream on a different axis. This port was used to extract a fixed point sample for the continuous emission monitors (CEMs). All the ports have eight-inch-long nipples and are accessible from the same platform.

EPA Method 1 was used to select the number and location of the traverse points for Ports A and B. The ports are located approximately 4 equivalent duct diameters (28'6") downstream of a 90° bend in the duct and approximately 1.9 equivalent duct diameters (13'11") upstream of a 90° bend in the duct. Following EPA Method 1 procedures, a minimum of 24 traverse points were required. The traverse point location diagram is presented in Figure 5-4.

A cyclonic flow check of the location was conducted according to EPA Method 1 and the average degree of rotation was determined to be 5°. EPA Method 1 specifies that the average degree of rotation should be equal to or less than 10°. A stratification check was also conducted using NO_x as an indicator. The difference across the duct was less than 2.5 percent of the



I = Inlet location prior to the first control device
M = Midpoint location after quench reactor prior to the baghouse
O-1 = Outlet location in the breeching prior to the stack location
O-2 = Outlet location in the stack
A-1 = Baghouse ash
A-2 = Cyclone ash
A-3 = Economizer ash
A-4 = Superheater ash

Figure 5-1. Marion County MWC Process Line with Sampling Locations

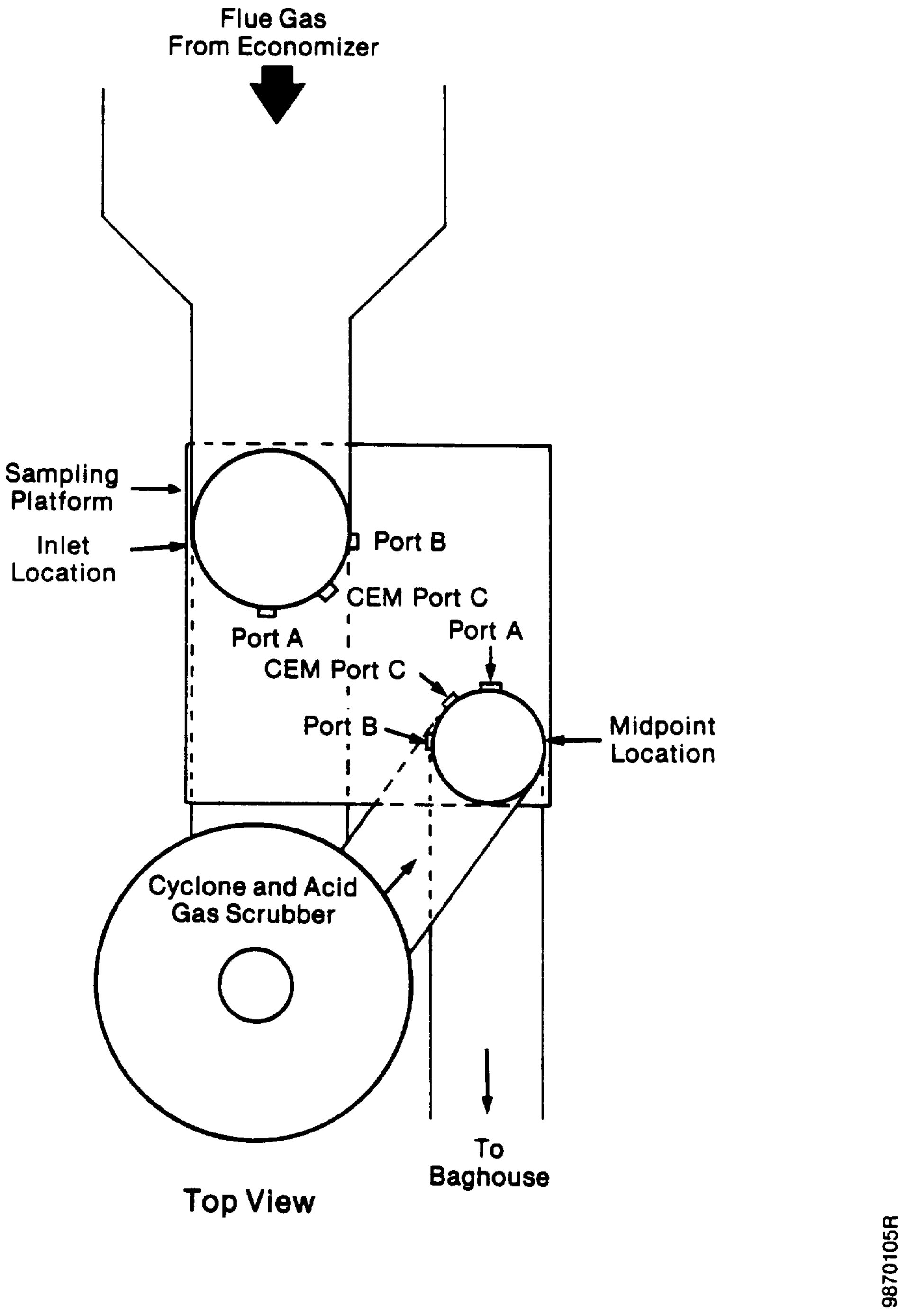


Figure 5-2. Top View of Boiler Outlet and Midpoint Sampling Locations at Marion County MWC

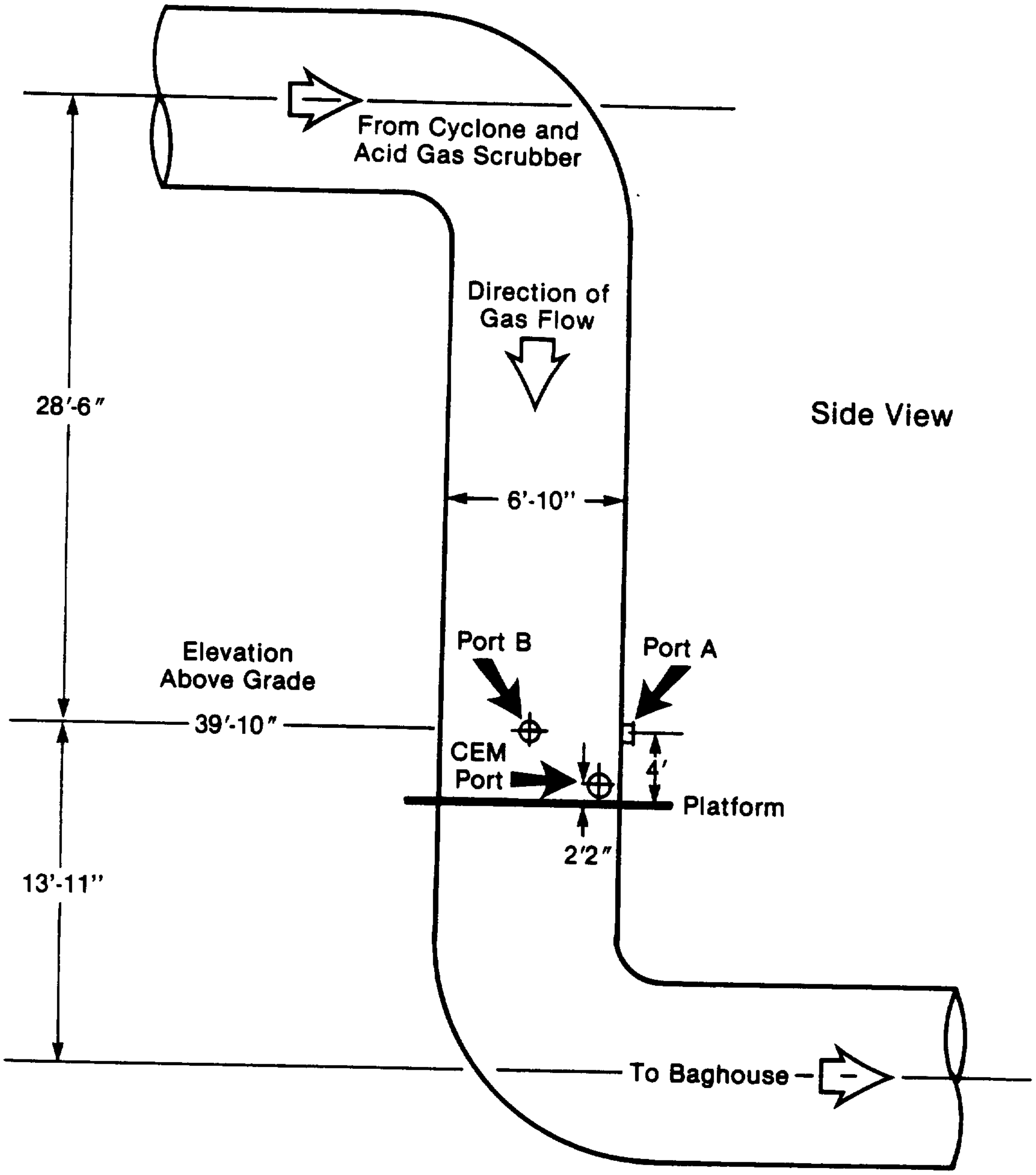


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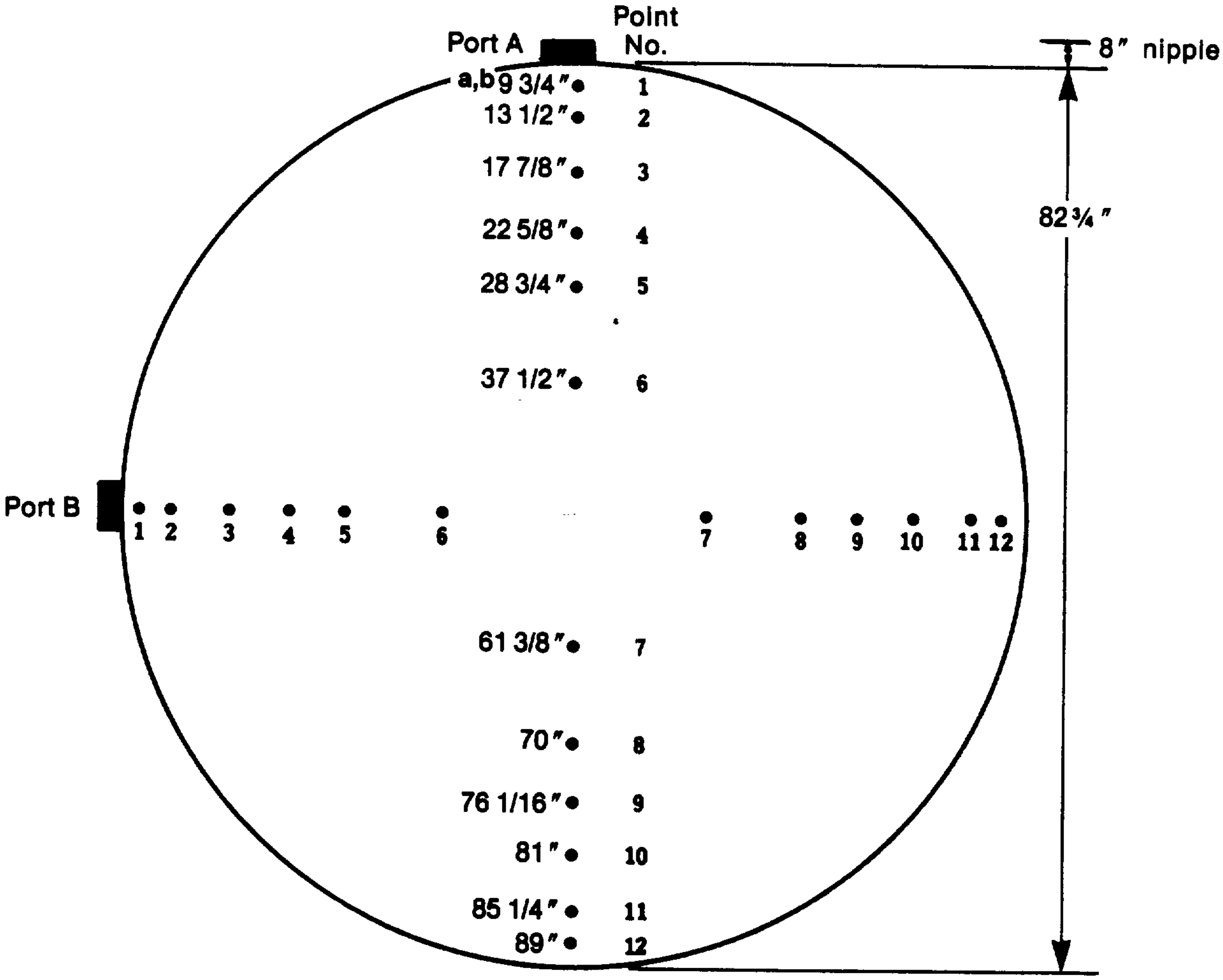
Figure 5-3. Side View of Boiler Outlet Sampling Location at Marion County MWC



[a] Measurement from the outside of the nipple for probe marking

[b] Traverse points are located as specified in EPA Method 1

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Figure 5-4. Traverse Point Location Diagram for Boiler Outlet Location at Marion County MWC reference point, indicating that stratification was not significant at this location.

The velocity head reading from the pitot tubes ranged from 0.07 to 0.2 in. H_2O in previous tests, which is in the low range for the manometers that are standard equipment in Radian meter boxes. Thus, an inclined manometer with a zero to one inch of water range was used. The velocity head reading remained in that range during this test program. Static pressure draft at this point in the system averaged negative 2.3 inches of H_2O.

5.1.2 Midpoint Sampling Location

The parameters that were measured at the midpoint sampling location include volumetric flowrate, moisture, HCl, SO_2, O_2, and CO_2. A top view of the midpoint sampling location was shown previously in Figure 5-2. A side view of the midpoint sampling location is shown in Figure 5-5.

The midpoint sampling locations has three six-inch I.D. ports located in a circular duct 51 inches in diameter. Two of the ports (Ports A and B) are located in the same plane, 90° apart. The third port (Port C) is located about two feet downstream on a different axis. All the ports have eight-inch-long nipples. Port C was used to extract the fixed point sample. Ports A and B were capped except during pre- and post-test velocity traverses.

EPA Method 1 was used to select the number and location of the traverse points for Ports A and B. The ports are located approximately 6 duct diameters (28 ft. 6 in.) downstream of a 90°F bend in the duct and approximately 5 equivalent duct diameters (25') upstream of 90° bend in the duct. Following EPA Method 1, a minimum of 12 traverse points were required for the velocity traverses. However, to coordinate sampling with the inlet, midpoint and outlet, 24 traverse points were used. The traverse point location diagram is presented in Figure 5-6.

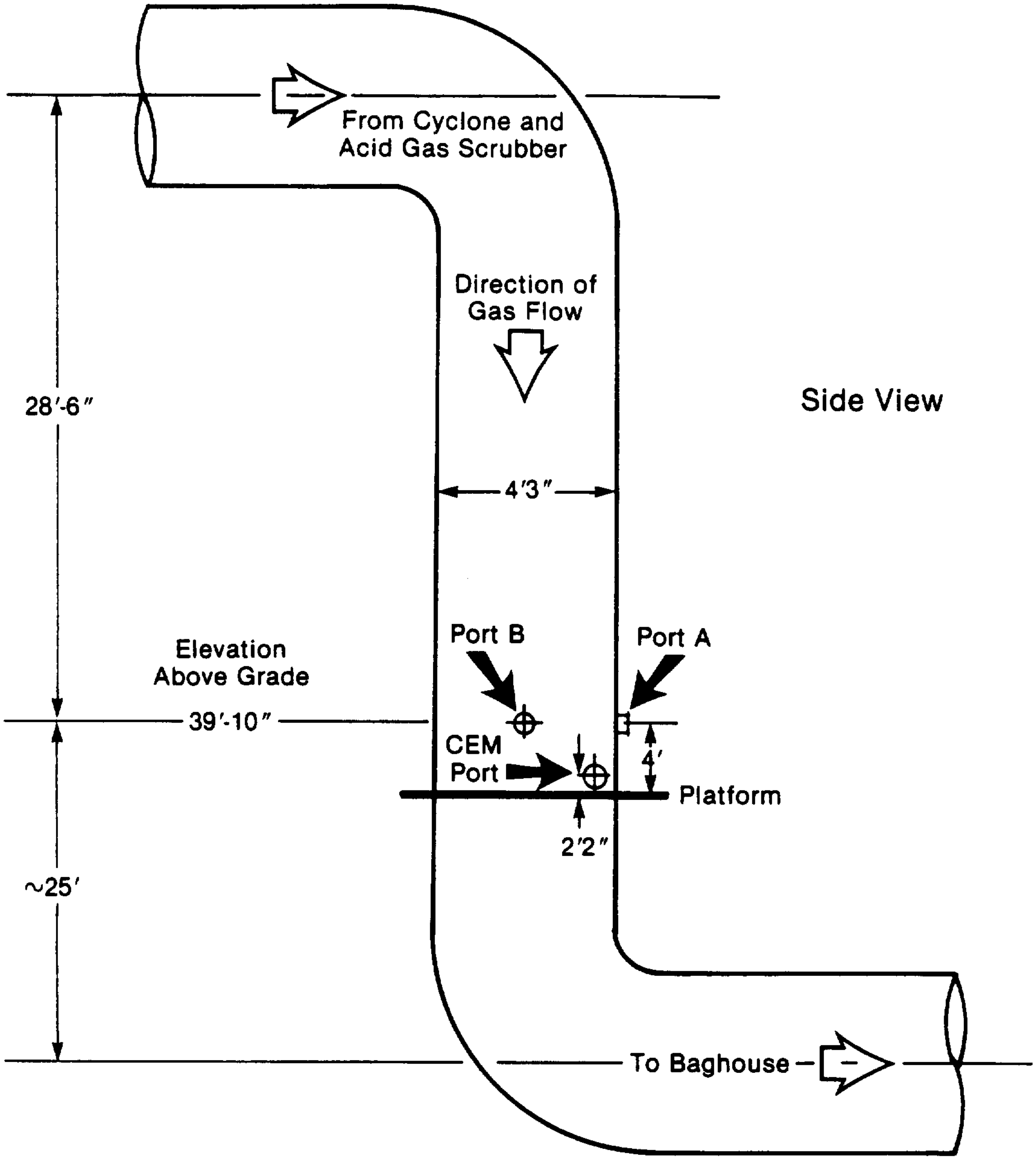

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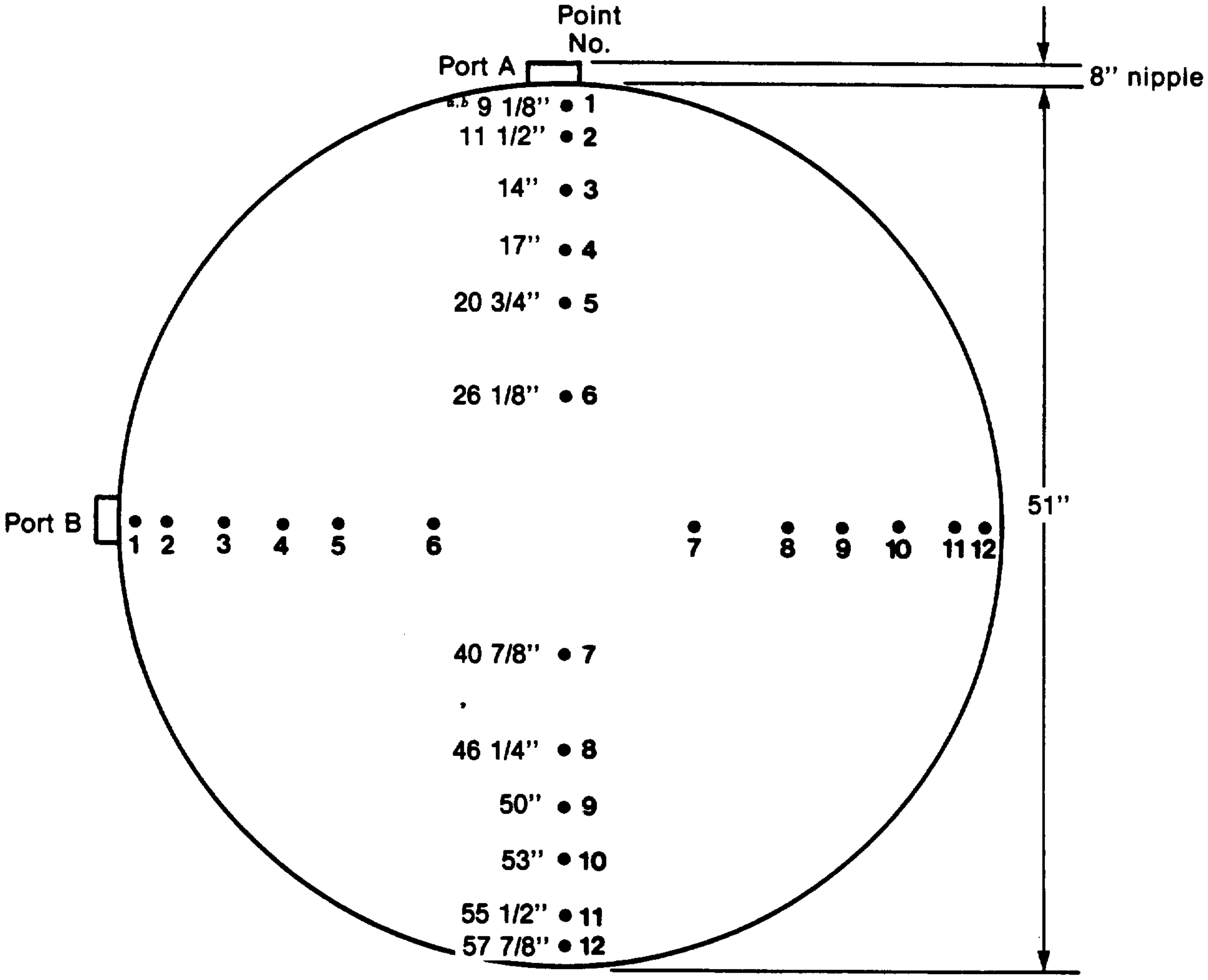
Figure 5-5. Side View of Midpoint Sampling Location at Marion County MWC



[a]Measurement from the outside of the nipple for probe marking

[b]Traverse points are located as specified in EPA Method 1

Figure 5-6. Velocity Traverse Point Location Diagram for the Midpoint Location at Marion County MWC

A cyclonic flow check of the location was conducted according to EPA Method 1 and the average degree of rotation was 5°. EPA Method 1 specifies that the average degree of rotation should be determined to be equal to or less than 10°. A stratification check was also conducted using NO_x as an indicator. The difference across the duct was less than 9 percent of the reference point, indicating that stratification was not significant at this location.

5.1.3 Breeching to the Outlet Stack

The parameters that were measured at the breeching to the outlet stack include SO_2, HCl, O_2, CO, CO_2, NO_x, and THC. A side view of the breeching to the outlet stack sampling location is shown in Figure 5-7.

The breeching sampling location has three four-inch I.D. ports located in a rectangular duct 7 ft. 4 in. high by 3 ft. deep. All of the ports have four-inch-long nipples. The ports were accessed by temporary scaffolding.

The ports are located approximately 18 inches upstream of dampers in the ducting and therefore the location does not qualify as an EPA Method 1 location. However, only fixed point gaseous samples were extracted from the breeching. A stratification check was performed using NO_x as an indicator using the point location diagram shown in Figure 5-8. Since the HCl probe was fixed permanently in Port B, the stratification check was performed using only Ports A and C. The difference across the duct was less than 2 percent of the reference point, indicating that stratification was not significant at this location. A cyclonic flow check conducted according to EPA Method 1, indicated that the average degree of rotation was 2°. EPA Methods 1 specifies that the average degree of rotation should be equal to or less than 10°.

5.1.4 Outlet Stack Sampling Location

The parameters that were measured at the outlet stack sampling location were CDD/CDF, HCl, moisture, O_2, CO_2 and volumetric flowrate. A top view and

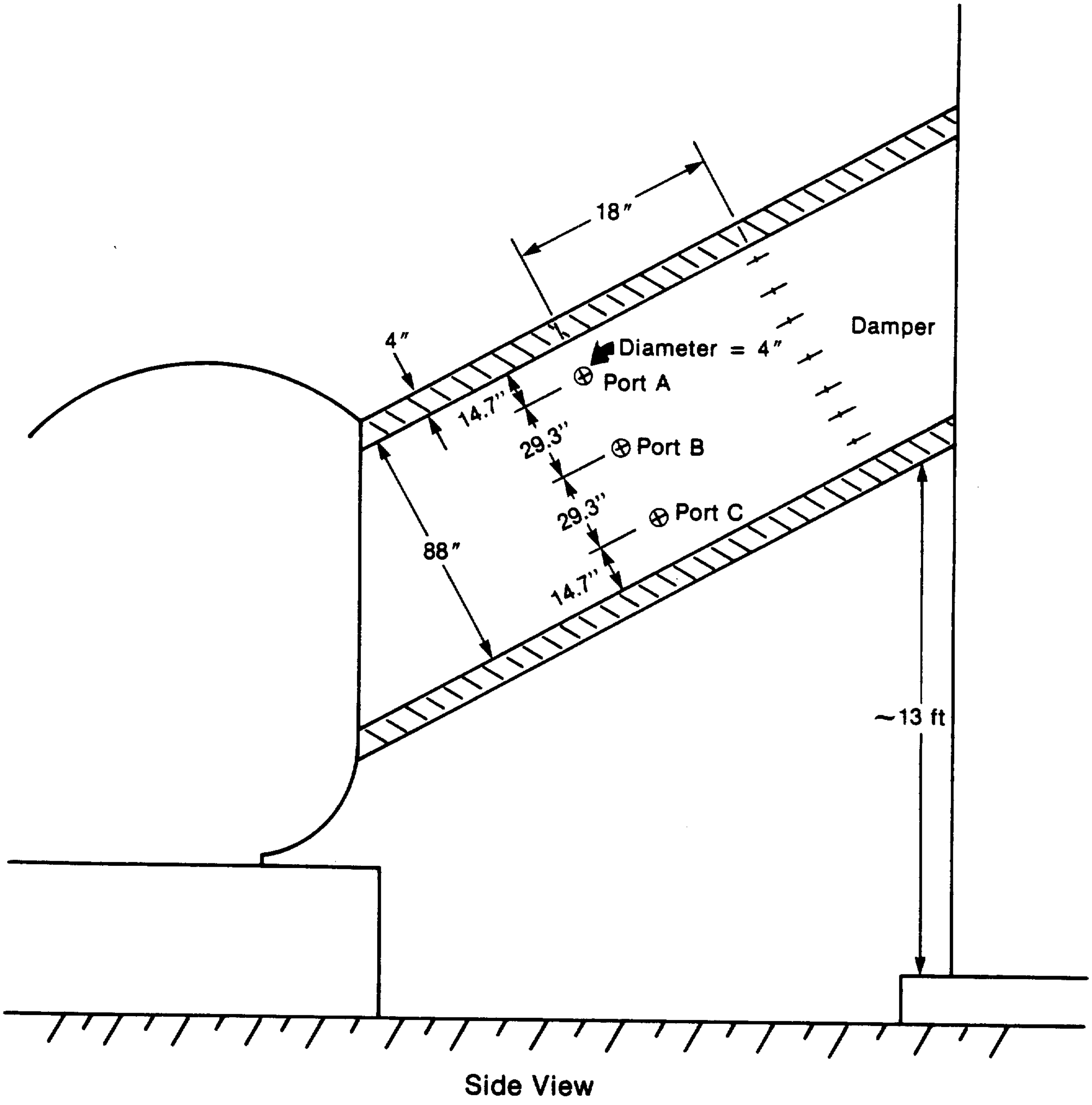
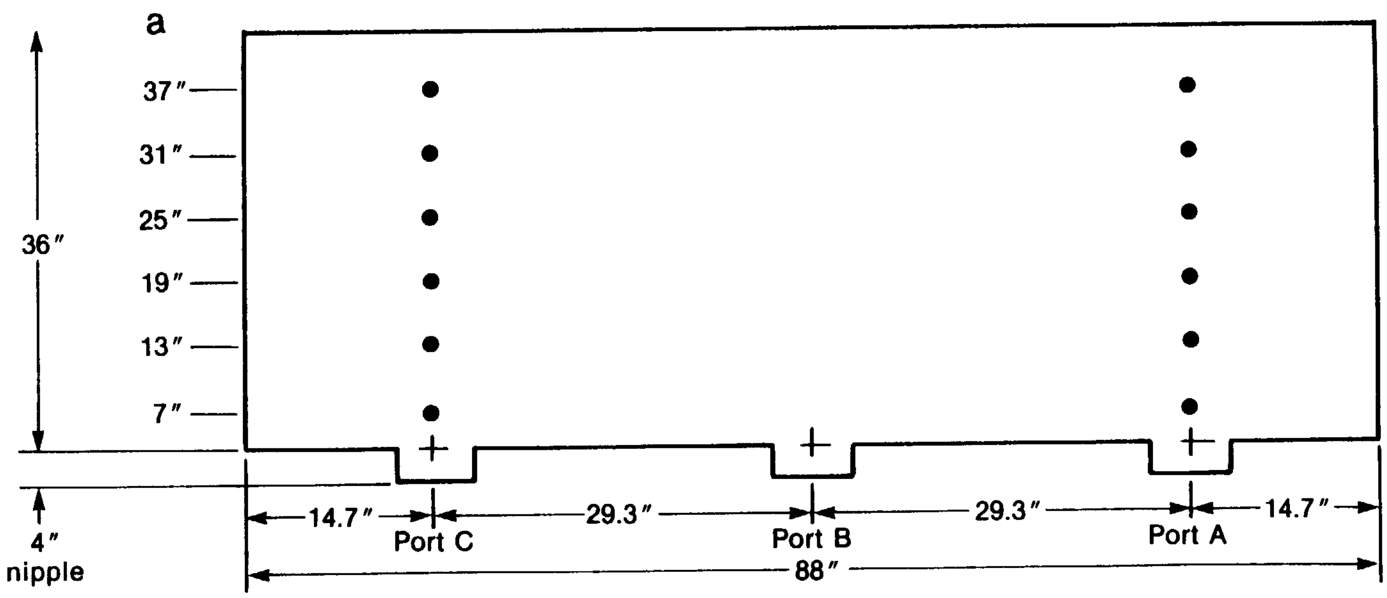


Figure 5-7. Breeching to the Stack Sampling Location at Marion County MWC



[a] Measurement from the outside of the nipple for probe marking

Figure 5-8. Stratification Point Location for the Breeching Location at Marion County MWC side view of the outlet stack sampling location are shown in Figures 5-9 and 5-10, respectively.

The outlet stack sampling location has three four-inch I.D. ports located in a circular duct 48" in diameter. Two of the ports (Ports A and B) are located in the same plane, 90^{o} apart. The third port is located about two feet upstream on a different axis for CEMs. All the ports have four-inch-long nipples. The plant CEM port is located downstream from Ports A and B.

Ports A and B were used, but Port C was capped since no fixed point sampling was conducted at this location. EPA Method 1 was used to select the number and location of the traverse points for Ports A and B. The ports are located approximately 13 equivalent duct diameters (60') downstream of the breeching and approximately 36 equivalent duct diameters (170') upstream of the top of the stack. Following EPA Method 1, a minimum of 12 traverse points were required. The traverse point location diagram is presented in Figure 5-11.

A cyclonic flow check was conducted and the average degree of rotation was confirmed to be less than 10^{o} as specified by EPA Method 1. A stratification check was not performed at this location since traversing samples were collected.

5.2 ASH AND PROCESS SAMPLES

5.2.1 Superheater Ash Sampling Location

The superheater ash was collected from the ash hopper before the ash dropped on the conveyor to the quench pit. At this point in the system, the draft is negative and a special sampling apparatus was required. A galvanized metal trier was inserted into the base of the hopper to collect the falling ash.[11] The trier was withdrawn periodically to empty the ash. The side and top views of the superheater ash sampling location and sampling apparatus are shown in Figures 5-12 and 5-13, respectively.

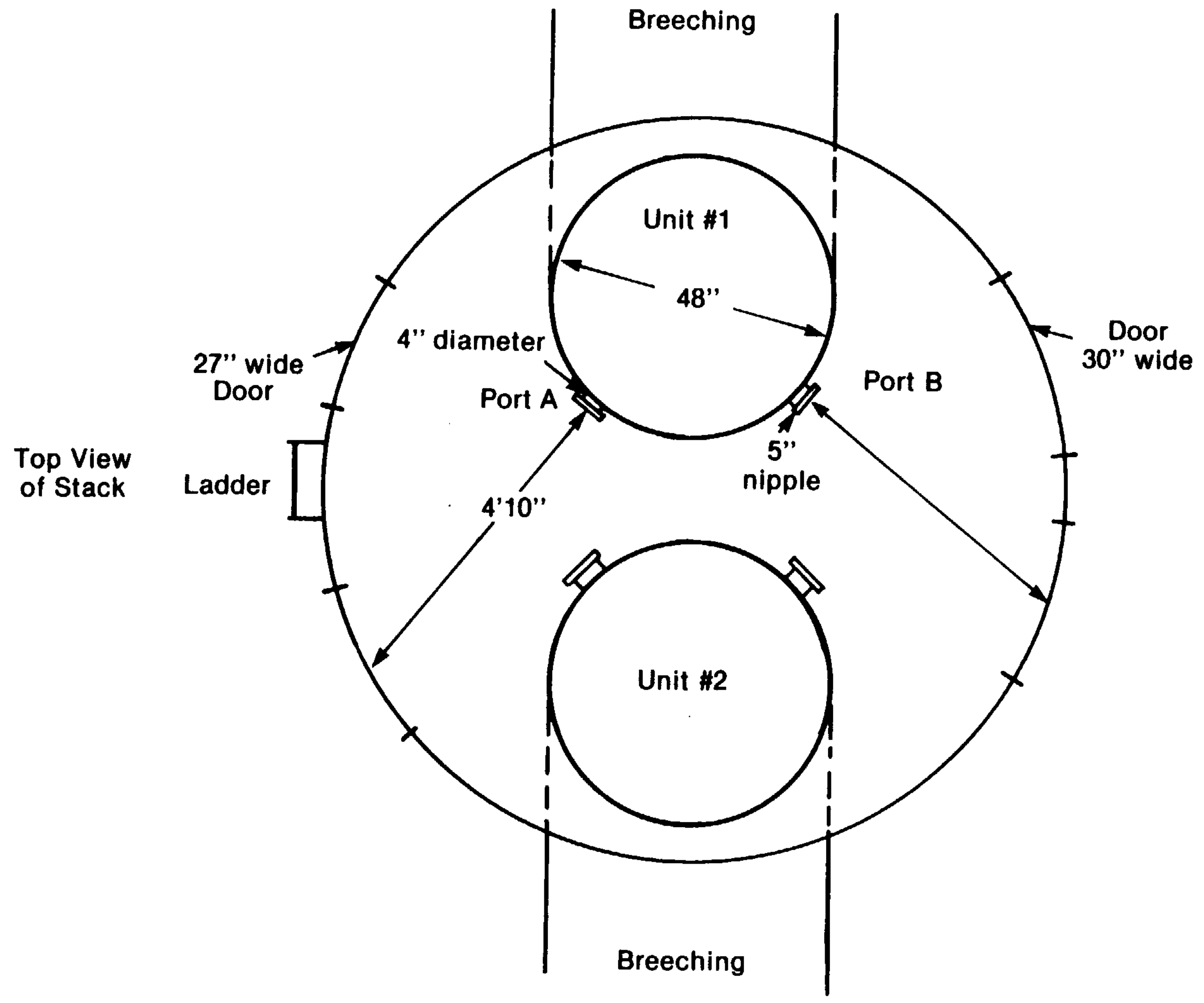


Figure 5-9. Outlet Stack Sampling Location at Marion County MWC

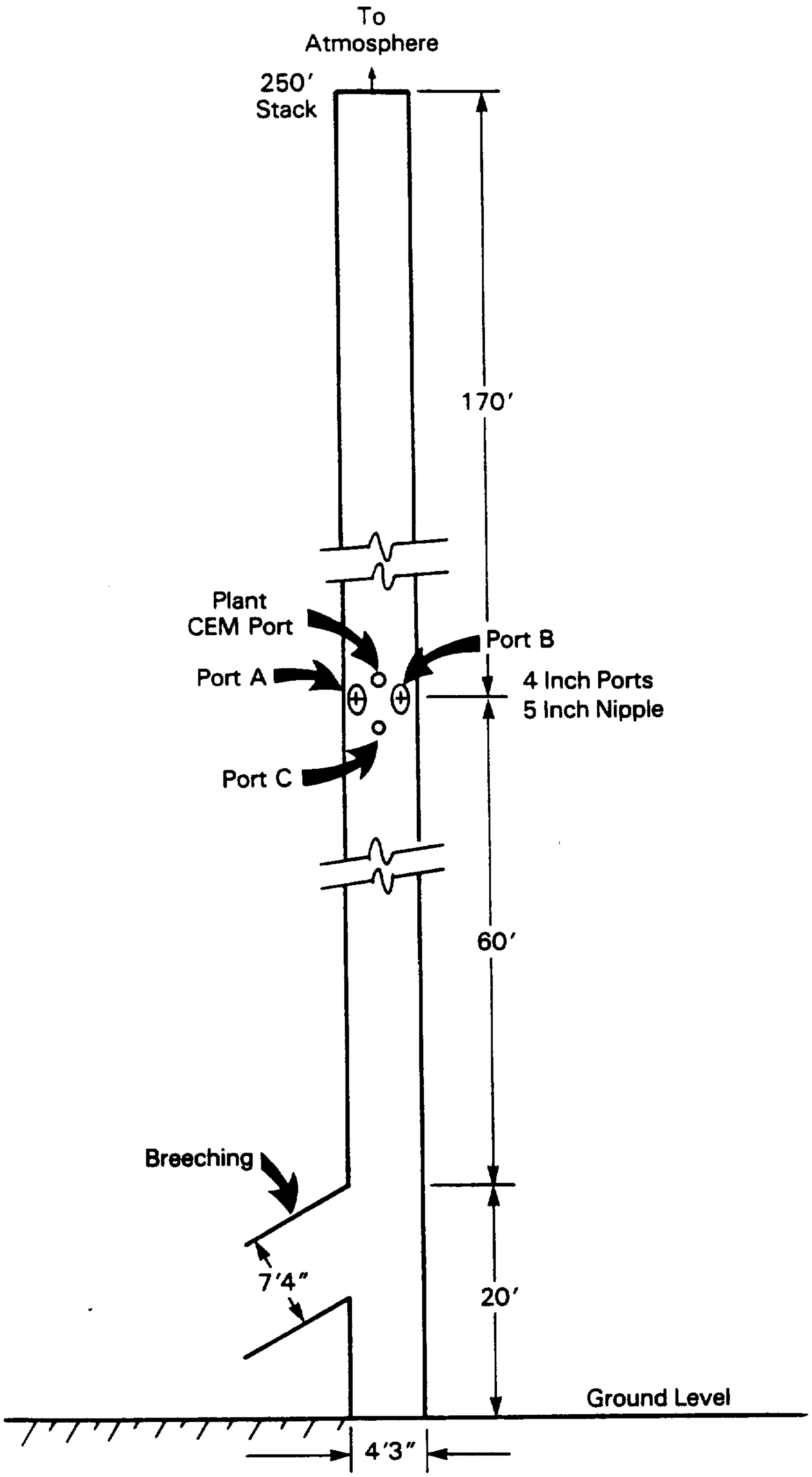


Figure 5-10. Side View of Outlet Stack Sampling Location at Marion County MWC

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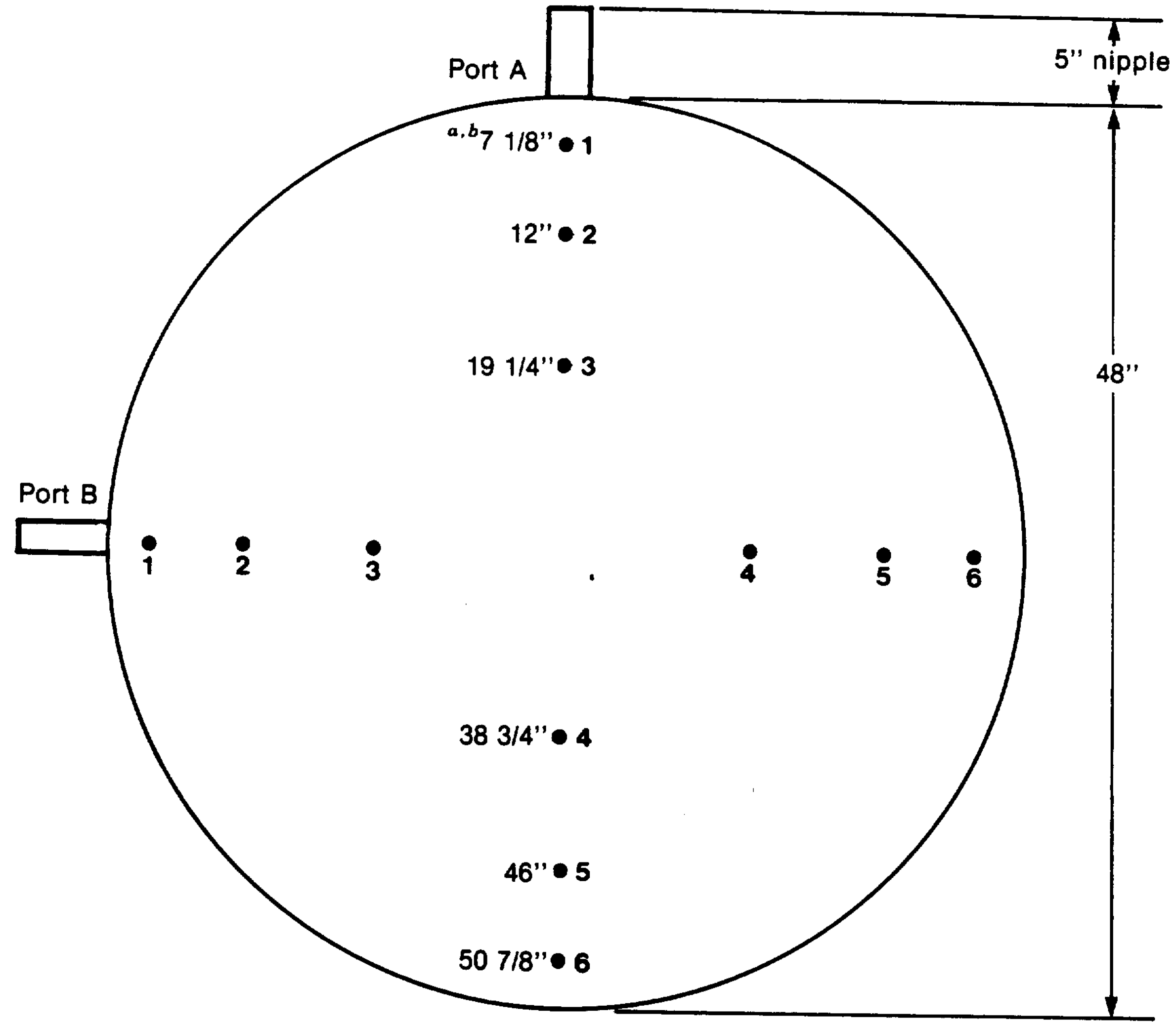

[a]Measurement from the outside of the nipple for probe marking

[b]Traverse points are located as specified in EPA Method 1

Figure 5-11. Velocity Traverse Point Location Diagram for the Outlet Stack Location at Marion County MWC

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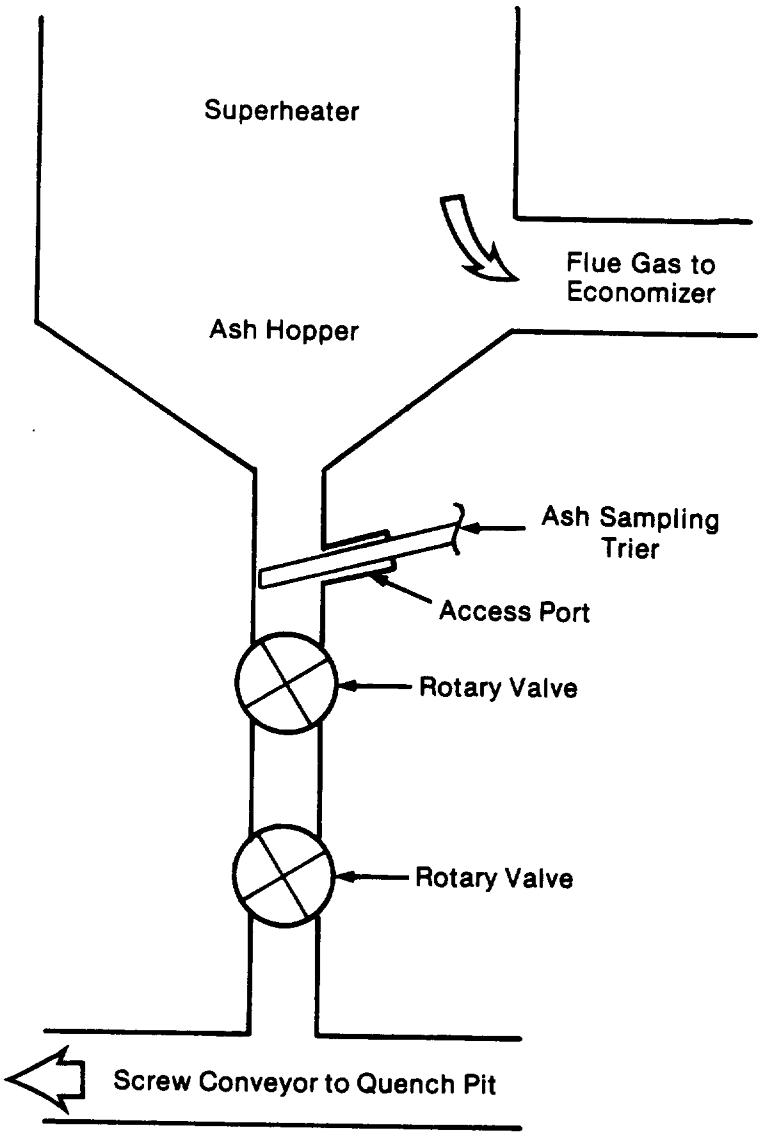

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Figure 5-12. Side View of Superheater Ash Sampling Location at Marion County MWC

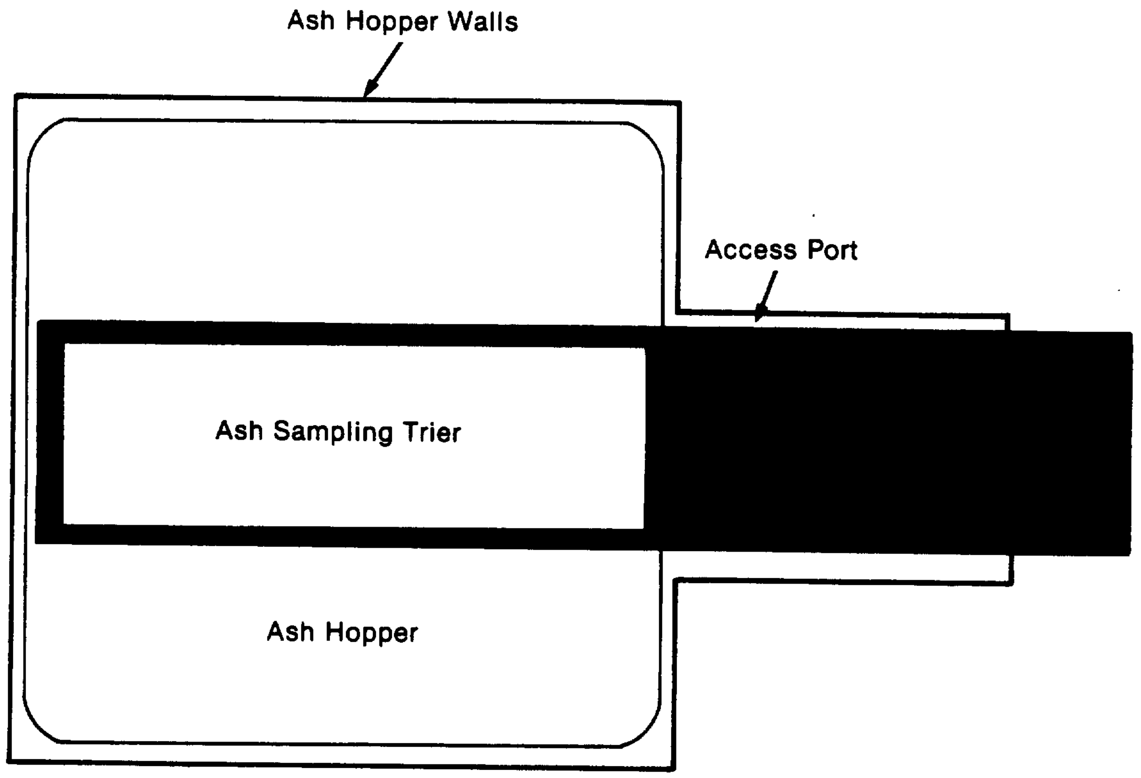

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Figure 5-13. Top View of Superheater Ash Sampling Location at Marion County MWC

5.2.2 Economizer Ash Sampling Location

The economizer ash sampling location was very similar to the superheater ash sampling location. The ash was collected from the ash hopper using the same type of sampling apparatus as used for the superheater ash. The side view of the economizer ash sampling device and location is shown in Figure 5-14 and the top view is the same as was shown in Figure 5-13.

5.2.3 Baghouse Ash and Cyclone Ash Sampling Locations

The sampling locations for the Unit No. 1 baghouse ash and cyclone ash are shown in Figure 5-15. The baghouse ash was collected from a screw conveyor at an intermediate transfer point before mixing with the cyclone ash. A hole was cut in an access plate and a sliding cover was bolted over the hole for easy access.

The cyclone ash was collected before mixing with the baghouse ash. A sliding cover was also made for the cyclone ash access plate.

5.2.4 Lime Slurry Sampling Location

The lime slurry samples were collected from the recycle hose on the lime slurry mixing tank. The mixing tank is accessible from the second floor of the area housing the lime slurry injection system.

5.2.5 Tesisorb Sampling Location

The Tesisorb samples were collected from the feed hopper to the injection system. A small plate was removed on the hopper to collect the samples. The sampling location is shown in Figure 5-16.

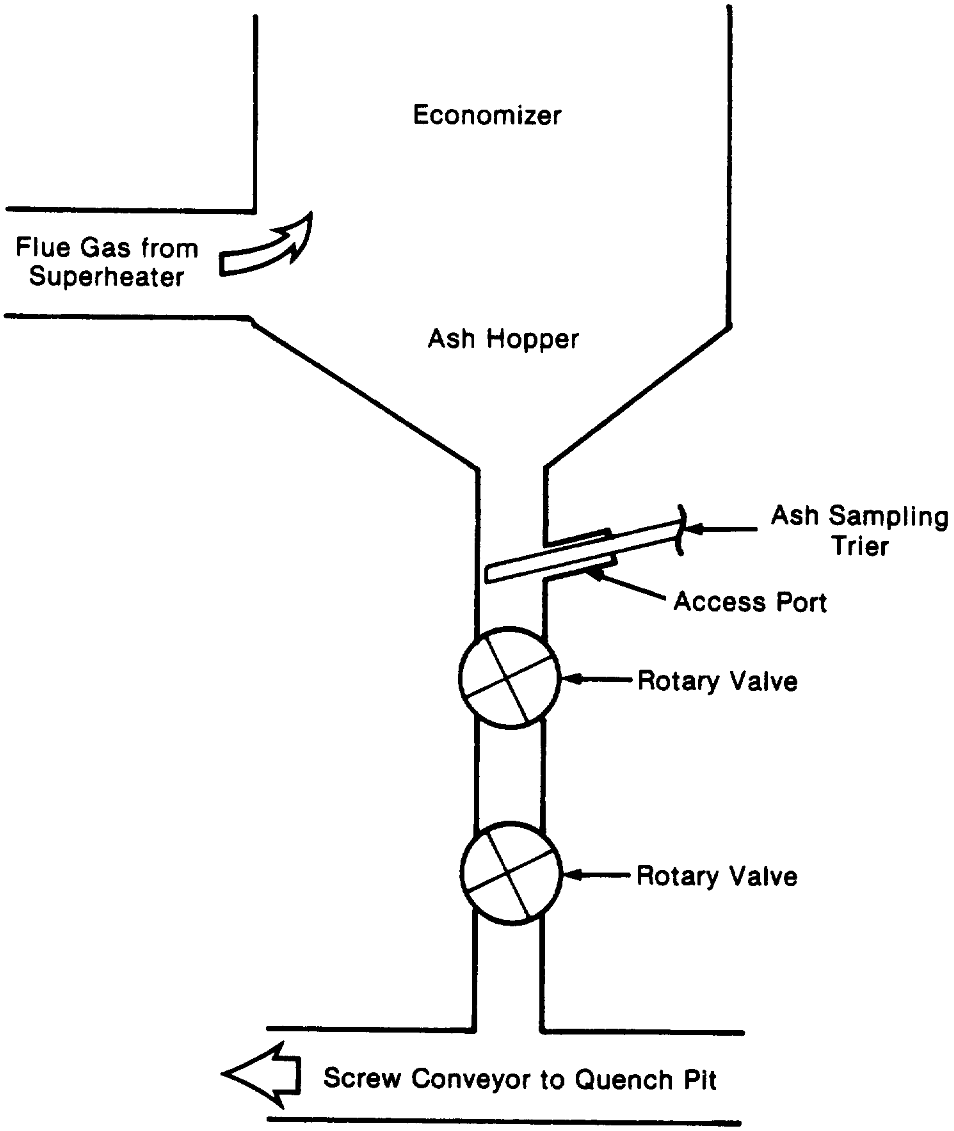

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Figure 5-14. Side View of Economizer Ash Sampling Location at Marion County MWC

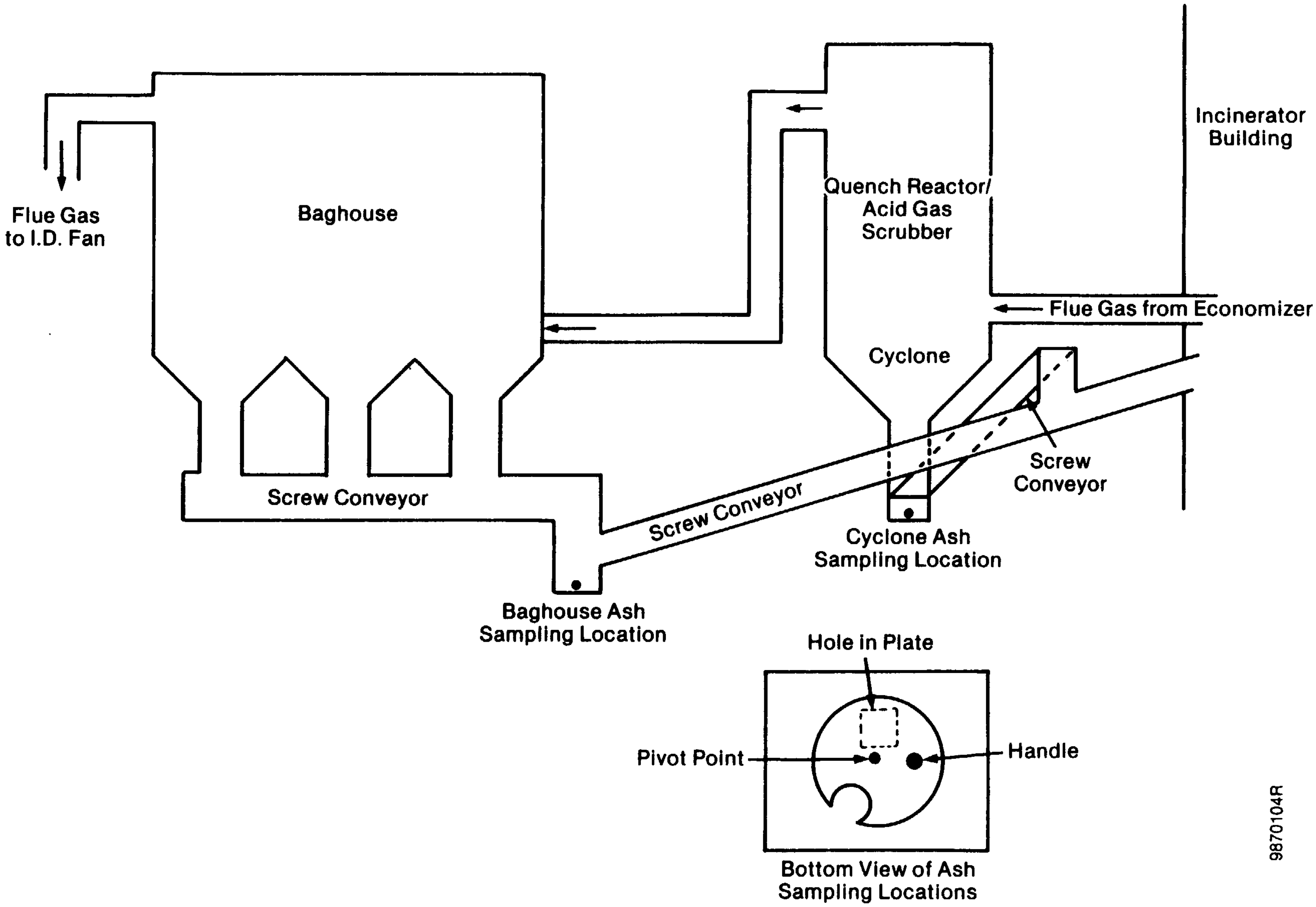

Figure 5-15. Baghouse Ash and Cyclone Ash Sampling Locations at Marion County MWC

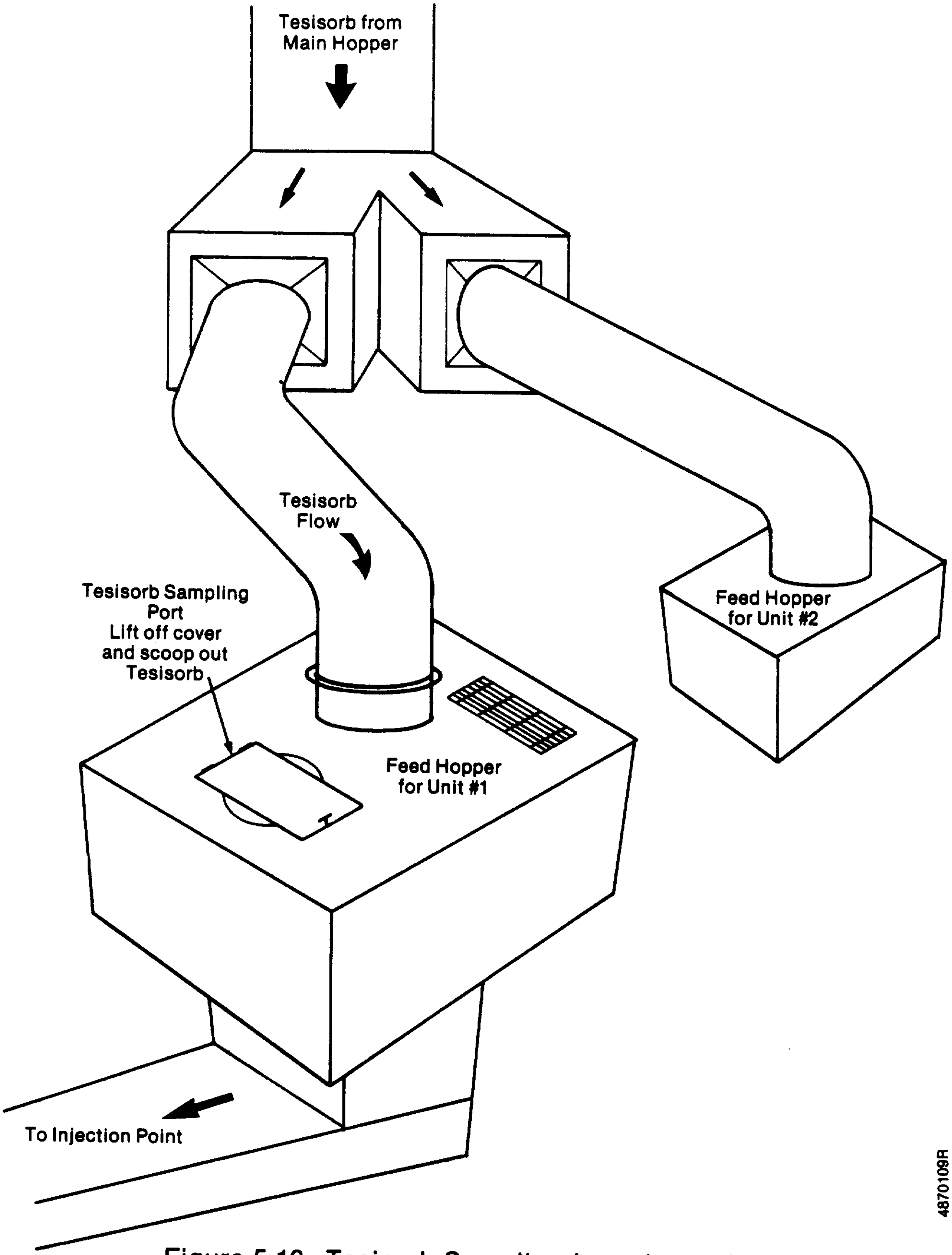

Figure 5-16. Tesisorb Sampling Location at Marion County

6.0 SAMPLING AND ANALYTICAL PROCEDURES

The sampling methods used for the Marion County Characterization Test were based on accepted EPA protocols. Modifications were made to suit the needs of the test program. The sampling methods and pertinent modifications are discussed below. Additional details of the sampling and analytical procedures are included in the test plan.[12]

6.1 CONTINUOUS EMISSION MONITORS (CEMs)

An extractive system was used to obtain flue gas samples for the CEM systems. The sample was withdrawn continuously at a single point from the stack and transferred to the CEM trailer through heat-traced teflon line. The flue gas was conditioned (temperature lowered and moisture and particulate removed) before the flue gas stream was split using a manifold to the various analyzers.

Continuous emission monitors were used to analyze flue gas from three locations: the control device inlet (boiler outlet), the midpoint location (quench reactor outlet) and the control device outlet (stack breeching). The flue gas was analyzed for CO_2, O_2, and SO_2 at each location. Several species, CO, NO_x, and THC, were monitored at the inlet and outlet only. Hydrogen chloride concentrations were also monitored continuously by Entropy Environmentalists, Inc., at the inlet, midpoint, and outlet, but their sampling methods are not discussed in this report.

The CEM equipment and sampling locations were standard systems, except that modifications were made to the midpoint sampling location. Stratification checks of the flue gas were also made. These site-specific modifications are discussed below. Refer to Sections 3.5 and 4.1 of Reference 12 for more details on the sampling methods.

6.1.1. Sampling at the Midpoint Location

The control device midpoint sampling location at the Marion County Solid Waste-to-Energy Facility is situated downstream from the quench reactor and prior to the Tesisorb injection system. Thus, flue gas extracted from the midpoint is unusual from a sampling point of view in several respects:

- Reactions between the injected lime and acid gases (primarily HCl and SO_2) in the flue gas occur in the zone between the quench reactor and the baghouse. Due to turbulent flow and changing acid gas concentrations, conditions at the midpoint are non-steady state with respect to the reactions of interest.
- Unreacted lime in the gas stream tends to adhere to the walls of the sample vessel and may react with acid gases in the sample, creating a bias.
- There is an increased moisture content in this area due to the injection of slaked lime. Condensate in the sample path could cause undesired reaction of acid gases.
- The use of a filter in the sample line is undesirable because acid gas scrubbing would occur if a lime filter cake built up in sample path.

In order to minimize these problems, a specially designed gas conditioning system was used. The midpoint sample probe, particulate reduction system, and moisture reduction system are shown in Figure 6-1. Particulate is reduced in the extracted sample at the stack in two ways. First, the sample probe intake is positioned away from the gas stream flow. Second, the extracted sample passes through two cyclones. Following these particulate reduction steps, the sample is divided by a manifold to the manual HCl sampling train, the continuous emissions monitors and to the Entropy HCl continuous monitor. The Radian continuous monitoring system then uses a system of upright condensers and knockout impingers in an ice bath to reduce moisture with minimal contact of the gas and condensate.

Overall, the system worked well. The residence time through the system was not significantly increased due to the sample conditioning set-up. Leak

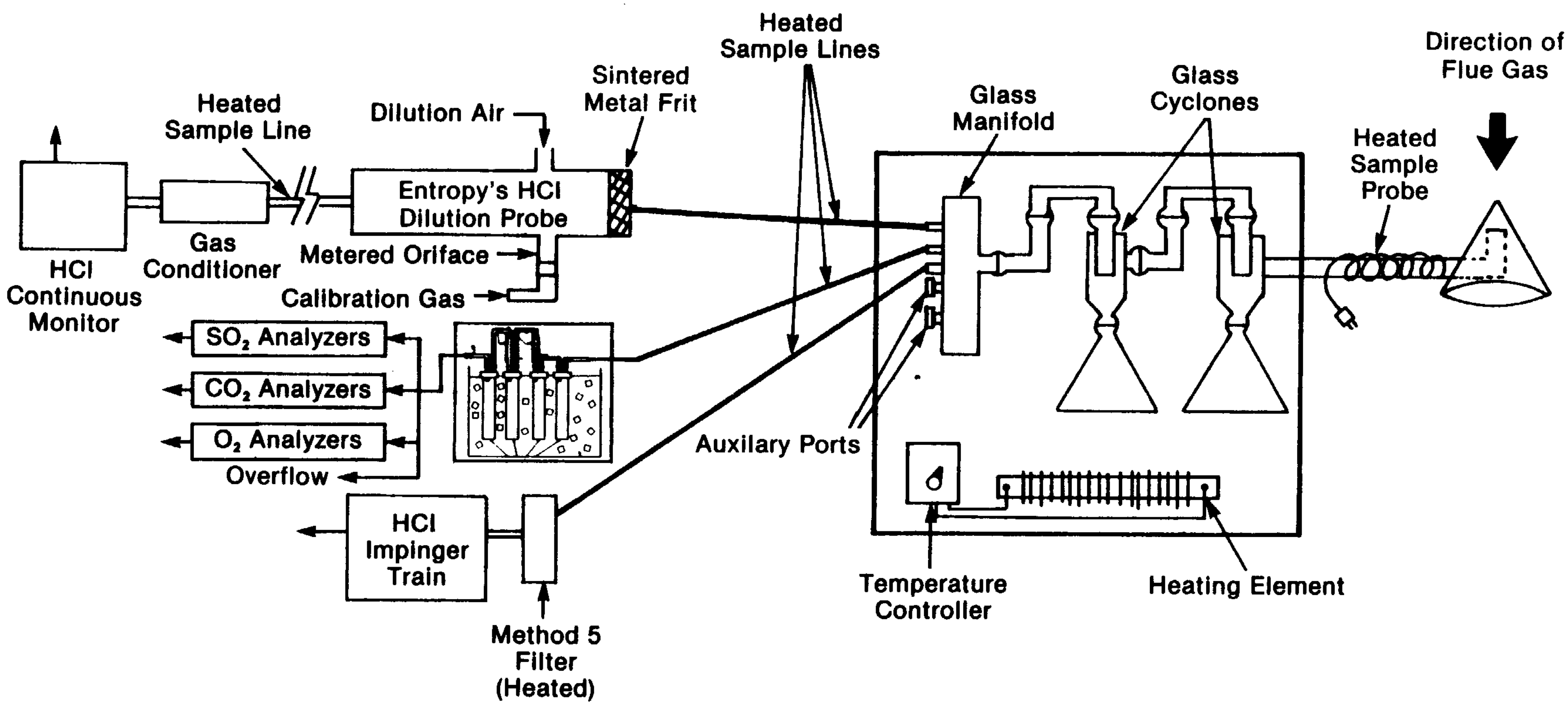

Figure 6-1. CEM Sampling and Analysis Scheme for the Midpoint Sampling Location for the Marion County MWC

problems were seldom encountered and were easy to correct when they occurred. Acid and fixed gas concentrations were in the expected ranges and compared logically to inlet and outlet concentrations. Oxygen concentration consistently increased from inlet to midpoint to outlet and pollutant gas concentrations consistently decreased. Also CEM SO_2 concentrations compared favorably with manual Method 6 runs during the interference tests. Orsat and CEM values for CO_2 and O_2 compared closely as well. The main problems encountered with the midpoint sampling system are listed below:

- SO_2 system bias checks at the midpoint show an average system bias for SO_2 of 16 percent. This bias was probably due to SO_2 reaction with adsorbed lime and/or leakage.
- Fine particulate which passed through the cyclones caused the pump for the continuous monitoring system to fail. The pumps were replaced and rebuilt between runs to ensure uninterrupted sampling.
- The manual method HCl train filter housing was installed backwards due to the configuration of the conditioning system. An evaluation of the bias for the manual method filter indicated that the negative bias was 22 percent.

For future sampling at the Marion County SWE facility, modifications to the midpoint sampling system should be considered. One suggestion would be to improve the initial particulate reduction system. Possibilities include: a smaller cyclone in series with the existing ones, an improved probe design, or perhaps even electrostatic methods. Additionally, frequent cleaning of the system would avoid undesirable buildup in the system. The manifold should also be modified to accommodate the filter for the HCl train.

6.1.2 Stratification Check

As an indication of stratification (incomplete mixing of the flue gas) the inlet, midpoint, and breeching sampling locations were traversed using the CEM probes. The test plan originally specified SO_2 as the indicator of stratification. However, because of problems evaluating the SO_2 concentration data, NO_x was also used as an indicator. Later evaluation of the data resolved the apparent problems encountered with SO_2 as the indicator.

Two probes were used during a stratification check. The first probe was located at a fixed point and was the reference probe. The second probe was traversed across the duct collecting approximately 5 minutes of data at each point. An average was calculated at each point for each probe. Relative differences between each probe at each point should be less than 10 percent.

6.1.3 Averaging Method

CEM data were reported as averages over 1 minute, 9 seconds. These averages were averaged every hour to generate three to four hourly averages per test run. Each hour interval was required to be 90 percent complete (54 of 60 readings) to be considered valid and acceptable.

In the event that an hour interval was determined to be unacceptable for a critical parameter (SO_2 and HCl at all locations, CO and O_2 at inlet) the test run was extended for additional hour intervals until a minimum of two acceptable intervals were collected. The CEM analyzers were calibrated at the beginning and end of each test.

6.2 MANUAL METHODS

6.2.1 CDD/CDF Determination

Sampling for CDD/CDF followed the December 1984 draft protocol for the determination of chlorinated organic compounds in stack emissions. The protocol was developed by the Environmental Standards workshop sponsored by the American Society of Mechanical Engineers (ASME) and EPA. The method is based on EPA Reference Method 5.

Modifications to the sampling protocol used were:

1) Inlet samples were analyzed as separate front half and back half fractions.

2) During shutdown, the inlet and outlet trains operated simultaneously. Each train traversed a single port only. At the inlet, the train with the sootblowing traversed Port A and the train without the sootblowing traversed Port B.

3) During startup, the inlet trains operated sequentially because of high particulate loading. The first train used traversed Port A and the second train traversed Port B. The outlet trains operated simultaneously and each train traversed one port only.

The modifications are described in Table 6-1, also. Additional details of the sampling and analytical protocol are described in Section 4.2.1 of Reference 12.

6.2.2 HCl Determination

HCl sampling was based on EPA Reference Method 5 with modifications which allowed collection of HCl in the back half of the Method 5 sampling train. Further development of the HCl method is currently underway. Thus, the method chosen was the current consensus of the sampling community. The method is described in Section 4.2.2 of Reference 12.

6.2.2.1 Manual HCl Sampling at the Inlet and Outlet. For the inlet and outlet location, a 25 ml aliquot of the combined impinger contents from the CDD/CDF sampling train was removed for on-site HCl analysis by specific ion electrode (SIE). The remaining impinger contents along with acetone and methylene chloride rinses were included in the CDD/CDF sample.

6.2.2.2 Manual HCl Sampling at the Midpoint. The following program-specific changes were required for manual HCl sampling at the midpoint location for the shutdown/startup test program:

1) The sampling rate was between 0.2 to 0.3 acfm.

2) Sampling was not isokinetic.

3) Sampling was fixed point.

4) Particulates were not quantified in the HCl trains.

TABLE 6-1. SAMPLING PROTOCOL MODIFICATIONS FOR FLUE GAS CDD/CDF DETERMINATION

	Inlet Location				Outlet Location			
Run	Train Designation	Port Traversed	Separate Front and Back Half Analysis	Simul-taneous Sampling	Train Designation	Port Traversed	Separate Front and Back Half Analysis	Simul-taneous Sampling
SHUTDOWN	A	A	Yes	Yes[a]	A	A	No	Yes
	B	B	Yes		B	B	No	
STARTUP	A	A	Yes	No[b]	A	A	No	Yes
	B	B	Yes		B	B	No	

[a] Train A operated for the entire run (11:55-15:15). Train B did not operate during the first 1/2 hour of the run (11:55-12:25) because of a sootblowing. During the remainder of the run (12:25-15:15), sampling was simultaneous.

[b] Train A operated during the first two hours (23:25-01:25) of the four-hour run. Train B operated during the last two hours of the run (01:25-03:25).

5) The front half fraction of the sampling trains was not recovered. The glassware was rinsed with distilled water to remove particulate and the rinses discarded.

6) Buttonhook nozzles were not used.

7) An empty knock-out impinger was inserted as the first impinger.

6.2.2.3 HCl Analysis. Both on-site and laboratory analyses of the HCl samples were performed for this test program. Aliquots of the samples were analyzed by SIE on-site. The analyzed aliquots were saved and later reanalyzed by ion chromatography (IC) in the laboratory due to suspected interferences in the SIE analyses. The results by IC are reported separately.[13] The samples were evaluated for matrix interference by the method of additions using SIE.

6.2.3 Volumetric Flowrate Determination

The volumetric flowrate of the flue gas was measured according to EPA Method 2. The flowrate was determined at the midpoint sampling location both prior to and at the completion of each test run. For the inlet and outlet locations, volumetric flowrate was measured simultaneously in the CDD/CDF/HCl sampling trains.

6.2.4 Moisture Determination

The average flue gas moisture content was determined according to EPA Method 4. This is discussed in more detailed in Section 4.2.5 of Reference 14.

6.2.5 Fixed Gases Determination

The molecular weight and CO_2 and O_2 content of the flue gas were determined according to EPA Method 3 using ORSAT values. This is discussed in more detail in Section 4.2.7 of Reference 11.

6.2.6 SO_2 Determination by EPA Method 6 (Manual)

Manual sampling and analyses for SO_2 in the flue gas followed EPA Method 6. The method was modified to use full-size impingers. This method is presented more fully in Section 4.2.8 of Reference 11.

6.2.7 Ash Sampling

The sampling methods for the baghouse ash and cyclone ash are described in Sections 3.4.5 and 4.2.3 of Reference 11. The sampling method for the economizer ash and superheater ash was modified from those methods because of negative draft at the sampling locations. The economizer ash and superheater ash were sampled by placing a galvanized metal trier trough in the ash hopper. Use of this method yielded a continuous-grab sample of the falling ash. The trier was emptied periodically and repositioned back in the hopper. Vacuum suction sampling methods were attempted earlier at these sampling locations but insufficient ash was collected. The collected grab samples were composited in the same manner as for the baghouse ash and cyclone ash.

7.0 INTERNAL QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Internal and external quality assurance and quality control procedures were strictly adhered to during this test program to ensure the production of useful and valid data throughout the course of the project. Internal QA/QC checks and procedures represent an integral part of the overall sampling scheme. The results of Radian's internal quality assurance/quality control program are presented in this section and in Appendix H. The results of the external QA performed by Entropy Environmentalists, Inc., are presented in a separate report.[15]

7.1 QUALITY ASSURANCE OVERVIEW OF THE MARION COUNTY TEST PROGRAM

The Marion County test program was organized such that the quality assurance function allowed complete independence in program review. Radian's Quality Assurance Officer reported directly to the Radian Program Manager for internal QA, and Entropy Environmentalists, Inc., reported directly to the EPA/EMB Task Manager for external QA. The primary QA/QC program objective was to provide data of known quality with respect to accuracy, precision, representativeness, and completeness. The QA/QC approach focused heavily upon controlling measurement data within established acceptance criteria.

Internal QA conducted by Radian personnel centered around the use of well-documented methodologies, which included detailed procedures for sampling and analysis, calibrations, labeling sample containers, preparation and cleaning of sample containers, sample preservation and storage, quality assurance, and quality control samples. In order to maximize comparability of measurement data, standard reference methods, including EPA and ASTM methods, were used whenever possible. A chain-of-custody system was established that provides a documented history of each sample and ensures that the integrity of the samples was maintained throughout the course of sample collection, handling, and analysis.

The various data reduction, validation, and reporting tasks were defined during initial project organization in order to meet the objectives of the program. Specific responsibilities were assigned to various members of the project team. In general, the Task Leaders were assigned primary responsibility for data reduction, validation, and reporting requirements for their respective tasks. The Lead Technical Coordinator provided overall review and coordination of the reporting efforts. Following initial data reduction, daily data summaries were prepared and submitted to the EPA Task Manager. These data summaries were used as input to the final report.

External quality assurance played a key role in the Marion County Test Program. Entropy Environmentalists, Inc., provided an independent assessment of the critical measurement systems by conducting performance evaluations using apparatus and/or standards that were different from those used to calibrate or collect the measurement data. The goal of the external audits was to evaluate the potential of the measurement systems to produce data of adequate quality to satisfy the objective of the test program. Upon completion of each performance audit, the auditor(s) discussed any specific weaknesses with the project team and made recommendations for corrective action. An audit report was subsequently prepared and distributed to the EPA/EMB Task Manager. The audit report outlines the audit approach and presents a summary of results and recommendations.[13]

7.2 QA/QC OBJECTIVES AND RESULTS

The overall quality assurance/quality control (QA/QC) objective was to ensure precision, accuracy, completeness, and representativeness for each parameter measured in this test program. These data characteristics are defined as follows:

- <u>Precision</u> - A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is best expressed in terms of the standard deviation (or the relative standard deviation). Various measures of precision exist depending upon the prescribed conditions.

- Accuracy - The degree of agreement of a measurement (or an average of measurements of the same thing), X, with an accepted or true value, T, usually expressed as the difference between two values, X-T, or the difference as percentage of the reference or true value, 100 (X-T)/T, and sometimes expresses as a ratio, X/T. Accuracy is a measure of the bias in a system.
- Completeness - A measure of the amount of valid data obtained from a measurement system compared with the amount that was expected to be obtained under the prescribed test conditions.
- Comparability - A measure of the confidence with which one data set can be compared with another.
- Representativeness - The degree to which data accurately and precisely represent a characteristic of population, variation of a parameter at a sampling point, or an environmental condition.

A summary of the estimated and achieved precision, accuracy, and completeness objectives is presented in Table 7-1. A more detailed discussion can be found throughout this section of the report.

In general, the precision and accuracy of the continuous emission monitors was well within the QC criteria shown in Table 7-1. In fact, the day-to-day precision, expressed as the percent coefficient of variation (i.e., Standard deviation/mean), was less than 3% for all analyzers except SO_2 midpoint and THC outlet. The accuracy of the CEMs was within the QC objective of ±10 percent for all monitors (0.9 - 5.8%). The accuracy of the chloride analyses was also acceptable with a mean absolute relative error of 2.7%.

Table 7-2 is a summary of the QC checks and corresponding acceptance criteria, control limits, and corrective actions that were followed during this program. The criteria are based on the methods, and the data used to calculate the achieved values can be found in the appendices of this report.

TABLE 7-1. SUMMARY OF ESTIMATED AND ACHIEVED PRECISION, ACCURACY, AND COMPLETENESS OBJECTIVES[a]

Parameter	Precision		Accuracy		Completeness	
	Estimated	Achieved	Estimated	Achieved	Estimated	Achieved
CDD	±40%	-8.6%[b]	±50%	NA[c]	90%	100%
CDF	±40%	+23.6%[b]	±50%	NA[c]	90%	100%
Continuous Emission Monitors[d,e]						
Inlet:						
O_2	±10%	0.65%	±10%	2.3%	90%	100%
CO_2	±10%	2.56%	±10%	6.6%	90%	100%
CO	±10%	1.10%	±10%	3.1%	90%	100%
THC	±10%	2.44%	±10%	4.6%	90%	100%
NO_x	±10%	1.98%	±10%	2.7%	90%	100%
SO_2	±10%	1.81%	±10%	2.1%	90%	100%
High Range SO_2	±10%	0.64%	±10%	NC[g]	90%	100%
Midpoint:						
O_2	±10%	1.48%	±10%	0.9%	90%	100%
CO_2	±10%	1.76%	±10%	5.8%	90%	100%
SO_2	±10%	3.86%	±10%	3.5%	90%	100%
Outlet:						
CO_2	±10%	1.98%	±10%	2.3%[k]	90%	100%
SO_2	±10%	0.88%	±10%	4.3%	90%	100%
NO_x	±10%	1.39%	±10%	4.5%	90%	100%
THC	±10%	7.20%	±10%	NC	90%	100%
CO	±10%	0.32%	±10%	5.3%	90%	100%
O_2	ND[f]	---		1.8%	90%	100%
Velocity/ Volumetric Flowrate[j]	±6%	NC	±10%	1.4%	90%	100%

TABLE 7-1. SUMMARY OF ESTIMATED AND ACHIEVED PRECISION, ACCURACY, AND COMPLETENESS OBJECTIVES[a] (continued)

Parameter	Precision		Accuracy		Completeness	
	Estimated	Achieved	Estimated	Achieved	Estimated	Achieved
Fixed Gases/ Molecular Weight[g]	±10%	NC	±20%	NC	90%	100%
Flue Gas Temperature[g,h]	±2°F	NC	±5°F	0.36%	90%	100%
HCl[i]	NE[l]	2.53%	NE	2.7%	90%	93%

[a] The reference for the estimated precision, accuracy, and completeness objectives is previous experience with these methods as well as EPA Methods 1-5 and the EPA/ASME protocol.

[b] The values for precision represent the mean percent differences for two identical analyses of the same sample for the same isomers.

[c] The accuracy of the CDD/CDF analyses was evaluated by EPA prepared performance audit samples. These results are not yet available. The accuracy objective was measured value to within ±50% of the true value for each isomer spiked.

[d] Precision of the CEMs is expressed as the % coefficient of variation (CV) determined from daily analyses of a QC standard, where

$$\% \text{ CV} = (\text{Standard deviation/Mean}) \times 100$$

[e] The accuracy of the CEMs is expressed as the relative percent error as determined from independent audit standards.

[f] ND = Not determined for this parameter.

[g] NC = No performance audit or QC analyses performed for this parameter.

[h] Relative accuracy expressed as the mean absolute relative error from an ASTM thermometer.

[i] Precision (%CV) and accuracy (absolute relative error) based on analysis of chloride QA audit sample.

[j] Accuracy expressed as mean % absolute relative error from an EPA critical orifice.

[k] The accuracy of the outlet SO_2 monitor is based on the revised quench factor equation discussed in Section 7.3.8.

[l] NE = Not evaluated.

TABLE 7-2. SUMMARY OF ACCEPTANCE CRITERIA, CONTROL LIMITS AND CORRECTIVE ACTION FOLLOWED FOR MARION COUNTY

Criteria	Control Limit	Corrective Action
Manual Sampling		
Final Leakrate (after each port)	≤ 0.02 acfm or 4 percent of sampling rate whichever is less	Adjust sample volume for port
Dry Gas Meter Calibration	Post average factor γ agree ± 5% of prefactor	Adjust sample volumes using the γ that gives smallest volume
Individual Correction Factors (γ)	Agree within 2% of average factor	Recalculate correction factor
Average Correction Factor	1.00 ± 1%	Adjust the dry gas meter and recalibrate
Intermediate Dry Gas Meter	Calibrated every six months against EPA standard	
Analytical Balance (top loader)	0.1 mg of NBS Class S Weights	Repair balance and recalibrate
CEM Measurements		
Linearity Multipoint Calibration (four points)	R ≤ 0.9950	Adjust instrument, recalibrate
Daily Drift (zero and span)	a) ± 5%	Data not adjusted
	b) 75% of data ≤ 20%	Adjust data assuming linear drift over testing period.
	c) > 20%	Reject data
	d) 2 days with drift greater than 10 percent	Perform Instrument maintenance

TABLE 7-2. SUMMARY OF ACCEPTANCE CRITERIA, CONTROL LIMITS AND CORRECTIVE ACTION FOLLOWED FOR MARION COUNTY (continued)

Criteria	Control Limit	Corrective Action
<u>CEM Measurements</u> (continued)		
Sampling System Bias	± 5% of span	Check heat tracing and/or clean sample line
Daily QC Check (mid-range)	± 10 percent of certified concentration.	Redo initial calibration.
Instrument Response time	less than one-minute	Increase sample flowrate or adjust instrument.
Interference Check (Relative Accuracy)	± 7% of manual result	Repeat interference check to verify. If verified, clean sample lines and check calibration.
Line Leakcheck	> 0.5% O_2	Locate and repair leak, recheck.
Manifold Leakcheck	> 0.5% O_2	Locate and repair leak, recheck.
<u>CDD/CDF Analytical Results</u>		
Internal Standard Recoveries	100 ± 50%	Re-extract and re-analyze if below 20% or greater than 180%.
Surrogate Recoveries	100 ± 50%	No action
Verification of Identification		
1) Ratio of M+ to M+2 or M+2 to M+4	Within 20% of theoretical value, except for tetrachloro which are taken within 13%	Re-evaluate peak identification

TABLE 7-2. SUMMARY OF ACCEPTANCE CRITERIA, CONTROL LIMITS AND CORRECTIVE ACTION FOLLOWED FOR MARION COUNTY (continued)

Criteria	Control Limit	Corrective Action
CDD/CDF Analytical Results (continued)		
2) Retention Time	Within 3 seconds of the corresponding or nearest 13C internal standard or surrogate standard (with reference to continuing calibration)	Re-evaluate peak identification
3) Signal-to-Noise Ratio	greater than 2.5	Reconsider peak identification
Duplicates	Percent Difference ≤ 50%	Check data manipulations
HCl Analytical Results (specific ion electrode method)		
Duplicate	Percent Difference ≤ 10%	Reanalyze
Internal Audit Sample	Relative Error ± 10% of audit sample	Analyze by ion chromatography
Audit Blank		Analyze by ion chromatography
Interference Check by Method of Additions	± 10% of true value	Analyze by ion chromatography
Linearity of Calibration Curve	R ≥ 0.995	Re-do calibration or use method of additions

7.3 QA/QC RESULTS

Sections 7.3.1 through 7.3.8 present the quality control (QC) procedures specific to each sampling and/or analytical method. Some of the QA/QC checks presented here were performed only once during the course of the test program either during the characterization or shutdown/startup testing. These sections contain only a brief summary of results. The raw sampling and analytical QA/QC data can be found in Appendix H.

7.3.1 Flue Gas CDD/CDF Sampling and Analysis

Quality control for the CDD/CDF sampling included several unique preparation steps which ensured that the sampling train components were not contaminated with organics that may have interfered with the analysis. The glassware, glass fiber filters, and XAD resins were all cleaned and checked for residuals before being packed. Sampling preparation also included calibration and leakchecking of all the train equipment. This included meterboxes, thermocouples, nozzles, pitot tubes, and umbilicals. Referenced calibration procedures were followed when available. Prior to sampling, certain preliminary measurements were made to ensure representative isokinetic sampling. These included marking the traverse points on the probe, a preliminary velocity traverse, a cyclonic flow check, and calculation of the K-factor.

Upon receiving the sample shipment, the samples were checked against the chain-of-custody and then assigned an analytical laboratory sample number. Each sample component was reweighed to determine if leakage occurred during travel and color or other particulars of the samples were noted. Samples were extracted within 14 days of collection.

For the CDD/CDF flue gas analyses, the positive identification criteria achieved for the characterization of polychlorinated dibenzodioxins and dibenzofurans can be found in the Analytical report in Appendix F.4 and are summarized below:

1. The integrated ion abundance ratio must be within 15 percent of the theoretical value,

2. The retention time for an analyses must be within 3 standard deviation intervals of the corresponding ^{13}C-labeled internal standard or surrogate standard,

3. The monitored ions for an analyte must maximize within 3 standard deviations intervals,

4. The signal-to-noise ratio (S/N) for all monitored ions must be greater than 2.5, and

5. The measured response factors (RFs) for both labeled and unlabeled compounds, obtained during a continuing calibration run must be within 20 percent for tetra- through heptachlorinated compounds and within 25 percent for octachlorinated compounds, of the mean values established during the initial calibration.

7.3.1.1 Internal Standard and Surrogate Recoveries. CDD/CDF flue gas samples were spiked with known amounts of internal standards and surrogates prior to extraction. The internal standards recoveries were used by Triangle Laboratories to adjust the results of the native species reported. The surrogate recoveries were not used to adjust results but were used to provide additional information on the sampling and extraction efficiency of the method.

The internal standard recoveries are summarized in Table 7-3. The QC objective as required by the ASME/EPA protocol is ±50 percent recovery for internal standards and surrogates. The internal standard recoveries for the inlet and outlet flue gas samples were all within the acceptable range except for the startup outlet Train A sample. This sample was extracted and analyzed twice and both times had low internal standard recoveries. The

TABLE 7-3. INTERNAL STANDARDS RECOVERY RESULTS FOR MARION COUNTY CDD/CDF FLUE GAS ANALYSESa

Sample	Recovery (%)				
	2378-$^{13}C_{12}$-TCDD	$^{13}C_{12}$-PCDD	$^{13}C_{12}$-HxCDD	$^{13}C_{12}$-HpCDD	$^{13}C_{12}$-OCDD
Inlet					
Shutdown FH(A)	99	116	87	87	70
Shutdown BH(A)	97	115	93	94	82
Shutdown FH(B)	97	101	77	87	80
Shutdown BH(B)	98	107	96	98	93
Startup FH(A)	89	114	79	83	71
Startup BH(A)	73	92	68	77	94
Startup FH(B)	97	114	92	98	88
Startup BH(B)	101	114	89	82	79
Outlet					
Shutdown CH(A)	87	107	84	75	81
Shutdown CH(B)	110	106	89	77	70
Startup CH(A)	3	2	3	2	1
Startup CH(A) Duplicate	3	2	3	2	1
Startup CH(B)	105	101	87	75	74
Startup CH(B) Duplicate	106	99	89	75	74

[a] FH - Front Half

BH - Back Half

CH - Combined Half

good recoveries of the other samples indicate that the poor recoveries for Startup A outlet were probably caused by the sample matrix.

The surrogate mixture of $^{13}C_{12}$-TCDF, ^{37}Cl-TCDD, and $^{13}C_{12}$ HxCDF was used for two different purposes in this program. This mixture was used as a field sampling spike for all XAD-2 resin trap fractions. A known quantity of each component was added to each resin trap prior to shipment to the field. The surrogate recovery results presented in Table 7-4 for all back half and combined train fractions represent the overall recovery of the surrogates and accounts for losses during sampling and analysis. The recovery of the field spikes was excellent, with recoveries ranging from 79 to 113 percent.

For the front half fractions of the sampling trains that were not spiked with the surrogate mixture prior to sampling, the surrogates were added at the same time as the internal standards. The surrogate recoveries were also excellent for these fractions, ranging from 88 to 109 percent.

7.3.1.2 Duplicate Analyses. Two of the Marion County flue gas samples were analyzed in duplicate and these results are presented in Table 7-5. The purpose of the duplicates was to evaluate the reproducibility (precision) of the sample preparation and analytical methodology. The QC criteria for analysis of field duplicates is agreement to within ±50 percent.

The reproducibility or precision of the sample preparation and analytical methodology was within the QC criterion for the majority of the isomers. The average percent differences for the duplicate analyses were -8.6% and 23.6% for CDDs and CDFs, respectively.

7.3.1.3 Sample Blanks. Three different blanks were analyzed for CDD/CDF; a laboratory proof blank, a field blank, and a laboratory method blank. A proof blank was obtained from a complete set of MM5 sample train glassware that had been cleaned according to the required procedure. The

TABLE 7-4. SURROGATE RECOVERIES FOR MARION COUNTY FLUE GAS CDD/CDF ANALYSES[a]

Sample	Recovery (%)		
	$^{13}C_{12}$-TCDF	^{37}Cl-TCDD	$^{13}C_{12}$-HxCDF
<u>Inlet</u>			
Shutdown(A) FH	92	98	99
Shutdown(A) BH	90	96	93
Shutdown(B) FH	95	102	103
Shutdown(B) BH	96	97	92
Startup(A) FH	94	102	109
Startup(A) BH	93	96	105
Startup(B) FH	88	96	100
Startup(B) BH	88	87	93
<u>Outlet</u>			
Shutdown(A) CH	81	79	82
Shutdown(B) CH	98	95	105
Startup(A) CH	113	108	93
Startup(A) CH Duplicate	99	105	86
Startup(B) CH	100	97	106
Startup(B) CH Duplicate	98	95	104

[a] FH - Front Half
BH - Back Half
CH - Combined Halves

TABLE 7-5. DUPLICATE RESULTS FOR MARION COUNTY CDD/CDF FLUE GAS ANALYSES

Analyte	Duplicates[a,b]							
	Startup(A), Outlet				Startup(B), Outlet			
	Result #1	Result #2	Average	Percent Difference	Result #1	Result #2	Average	Percent Difference
Dioxins								
Mono-CDD	(4.363)	10.092	--[c]	--	[0.247]	[0.358]	--	--
Di-CDD	3.164	[6.185]	--	--	0.750	0.688	0.719	8.6
Tri-CDD	10.036	9.392	9.714	6.6	1.853	1.265	1.559	37.7
2378-TCDD	(0.383)	(0.110)	--	--	(0.007)	(0.007)	--	--
Other TCDD	4.276	19.537	11.906	-128.2	1.551	1.086	1.319	35.3
12378 PCDD	(0.383)	(0.215)	--	--	[0.025]	(0.010)	-44	--
Other PCDD	8.868	6.476	7.672	31.2	0.381	0.279	0.330	30.9
123478 HxCDD	(0.293)	(0.270)	--	--	[0.022]	(0.010)	--	--
123678 HxCDD	(0.268)	[0.512]	--	--	0.072	0.060	0.066	18.2
123789 HxCDD	(0.320)	[0.528]	--	--	0.047	[0.051]	--	--
Other HxCDD	7.402	7.312	7.357	1.2	0.283	0.686	0.484	-83.2
Hepta-CDD	4.176	5.723	4.950	-31.3	0.859	0.838	0.849	2.5
Octa-CDD	[13.766]	32.017	--	--	2.462	2.347	2.404	4.8
Average				-24.1				6.85

TABLE 7-5. DUPLICATE RESULTS FOR MARION COUNTY CDD/CDF FLUE GAS ANALYSES (Continued)

Analyte	Duplicates[a,b]							
	Startup(A), Outlet				Startup(B), Outlet			
	Result #1	Result #2	Average	Percent Difference	Result #1	Result #2	Average	Percent Difference
Furans								
Mono-CDF	24.881	(0.088)	--	--	0.734	0.910	0.822	-21.4
Di-CDF	61.947	17.649	39.798	109.6	6.854	9.812	8.333	-4.1
Tri-CDF	140.917	84.012	112.5	50.6	16.674	18.754	17.714	-2.7
2378 TCDF	13.260	12.372	12.816	6.9	0.833	0.713	0.773	15.5
Other TCDF	51.399	49.285	50.342	4.2	5.187	4.999	5.093	3.7
12378 PCDF	(0.310)	[0.905]	--	--	0.037	0.025	0.031	38.7
23478 PCDF	[1.065]	[1.392]	--	--	0.061	0.075	0.068	-20.6
Other PCDF	8.994	10.151	9.573	-9.0	0.434	0.284	0.359	41.8
123478 HxCDF	(0.163)	1.088	--	--	[0.093]	0.090	--	--
123678 HxCDF	(0.220)	[0.255]	--	--	[0.038]	[0.027]	--	--
123789 HxCDF	(0.278)	[0.278]	--	--	(0.007)	[0.034]	--	--
Other HxCDF	1.411	0.064	0.737	100.7	0.180	0.116	0.148	43.2
Hepta-CDF	4.154	4.526	4.340	-8.6	0.410	0.383	0.397	6.8
Octa-CDF	(0.603)	(1.713)	--	--	0.509	0.415	0.462	20.3
Average				36.3				10.9

[a] All results reported in nanograms. ND = Not detected at the method detection limit shown in parentheses. The estimated maximum possible concentration is given in brackets.

[b] % Difference calculated as: % Diff = $[(X_1 - X_2)/\bar{X}] \times 100$, where

X_1 = result #1, X_2 = result #2, $\bar{X} = (X_1 + X_2)/2$

[c] Dash indicates not applicable.

pre-cleaned glassware, which consisted of a probe liner, filter holder, condenser coil, and impinger set, was loaded and then recovered by rinsing with acetone and methylene chloride three times each. The rinse was analyzed to check the effectiveness of the glassware cleaning procedure.

The field blank was collected from a set of CDD/CDF glassware that had been used to collect at least one sample and had been recovered. The train was re-loaded and left at the inlet sampling location during the test run. The train was then recovered. The purpose of the field blank was to measure the level of contamination that occurs from handling, loading, recovering, and transporting the sampling train.

The laboratory method blank was analyzed to verify that all of the reagents used in the process of sample preparation were free of contaminants. This blank used all of the reagents that the actual samples used and was concentrated to the same final volume as the field samples.

The results of the sample blanks are presented in Table 7-6. Small quantities of the HxCDD, Hepta-CDD, OCDD, TCDF, PCDF, HxCDF, and OCDF were found in the laboratory proof blank. The inlet field blank contained small amounts of HpCDD, OCDD, TriCDF, HxCDF, HpCDF, and OCDF. A trace quantity of OCDD was found in the laboratory method blank. The OCDD in the method blank was very close to the method detection limit or in the noise range (10 times the method detection limit) and is therefore considered insignificant. The concentrations of the isomers present in the laboratory proof and field blanks are relatively small in comparison to the minimum test run values at the inlet location, except for HpCDF and OCDF. Field blanks take into account the effects of residuals left from previous test and field exposure. The results of the inlet field blank cannot be used to represent an outlet field blank because the recovery part of the sample is different.

7.3.2 HCl Flue Gas Sampling and Analysis Quality Control

During the shutdown/startup testing, HCl was sampled by modifying the back half of the CDD/CDF sampling train to collect HCl in the impingers.

TABLE 7-6. SAMPLE BLANK RESULTS FOR MARION COUNTY CDD/CDF FLUE GAS ANALYSES[a,b]

Analyte	Laboratory Proof Blank	Analytical Method Blank	Field Blank
Total MCDD	ND (0.115)	ND (0.147)	ND (0.128)
Total DCDD	ND [0.163]	ND [0.114]	ND (0.177)
Total TriCDD	ND (0.010)	ND [0.952]	ND [0.054]
2378-TCDD	ND (0.010)	ND [0.027]	ND (0.010)
Total TCDD	ND [0.020]	ND [0.104]	ND [0.049]
12378-PCDD	ND (0.010)	ND (0.015)	ND (0.010)
Total PCDD	ND (0.010)	ND (0.015)	ND (0.010)
123478-HxCDD	ND (0.010)	ND (0.027)	ND (0.013)
123678-HxCDD	ND (0.010)	ND (0.027)	ND (0.010)
123789-HxCDD	ND [0.055]	ND (0.033)	ND (0.013)
Total HxCDD	0.139	ND [0.118]	ND [0.072]
1234678-HpCDD	0.485	ND (0.033)	0.244
Total HpCDD	0.878	ND (0.033)	0.431
OCDD	2.198	0.290	4.298
Total MCDF	ND (0.110)	ND (0.007)	ND (0.120)
Total DCDF	ND (0.242)	ND [0.054]	ND (0.268)
Total TriCDF	ND [0.069]	ND (0.013)	0.030
2378-TCDF	ND [0.077]	ND (0.015)	ND (0.007)
Total TCDF	0.034	ND (0.015)	ND (0.007)
12378-PCDF	ND (0.007)	ND (0.013)	ND (0.007)
23478-PCDF	ND (0.007)	ND (0.013)	ND (0.007)
Total-PCDF	0.075	ND (0.013)	ND (0.007)
123478-HxCDF	0.079	ND (0.018)	ND [0.035]
123678-HxCDF	ND [0.044]	ND (0.015)	ND (0.007)
234678-HxCDF	ND (0.053)	ND (0.022)	ND (0.010)
123789-HxCDF	ND (0.010)	ND (0.018)	ND (0.013)
Total HxCDF	0.200	ND (0.018)	0.144
1234678-HpCDF	0.294	ND [0.065]	0.565
1234789-HpCDF	ND (0.010)	ND (0.027)	ND (0.010)
Total HpCDF	0.321	ND [0.074]	2.075
OCDF	ND [0.221]	ND (0.037)	3.935

[a] ND= not detected at the method detection limit shown in parentheses. Estimated maximum possible concentration reported in brackets.

[b] Method detection limit and/or measured concentrations reported in nanograms.

The SIE detection method was used for on-site measurement of free chloride ions in aqueous solutions. Quality control analyses were performed prior to the startup/shutdown testing.

The on-site chloride analysis was audited externally daily with QA samples prepared by EPA/Cincinnati QC samples. Two concentration levels were prepared: 103 ug/ml and a 25.8 ug/ml samples. All of the audit results for 103 ug/ml QA samples were acceptable. The results for the 25.8 ug/ml audit samples were variable depending on the amount of dilution used to prepare the audit sample for analysis. With a five-fold dilution, the audit sample results were acceptable (true value within ±10 percent) for two out of three analysis.

Additional quality control included daily calibrations, analysis of blanks, and using the method of known additions to determine whether interferences were present in the sample matrix. The method of additions results are presented in Table 7-7. The QC criterion was agreement between the known addition measurement and direct reading measurement within ±10 percent. All 25 ml sample aliquots were saved for analysis by ion chromatograpy.

As seen from Table 7-7, several of the samples had relative percent differences outside the QC criterion of ±10 percent difference. In particular, the samples analyzed on 6-4-87 exceeded the ±10 percent. Also, the samples analyzed on 6-8-87 were, for the most part, outside the ±10 percent criteria. These samples are considered to be incorrect due to some type of erratic, electrode interference possibly due to a faulty electrode or temperature fluctuations in the room. After instrument adjustments were made, the 6-4-87 field samples were reanalyzed.

Blanks were also analyzed as part of the SIE quality control procedures. One HCl HPLC H_2O blank of water used in the Phase II Modified Method 5 trains was analyzed and showed less than 1 ppm chloride, or less than the method detection limit. One 0.1N NaOH blank of the sodium hydroxide used in the HCl

TABLE 7-7. RELATIVE PERCENT DIFFERENCES BETWEEN SIE DIRECT READING AND KNOWN ADDITION RESULTS FOR CHLORIDE CONCENTRATIONS

Sample ID	Concentration of HCL Obtained from Known Addition Measurement[a] (ppm)	Concentration of HCL Obtained from Direct Reading Measurement (ppm)	Relative % Difference Based On Direct Reading Measurement[b,d]
MAR0604-HCL1N1-I1A	3000	3900[c]	-23.1
MAR0604-HCL1N1-I2A	800	720[c]	11.1
MAR0604-HCL-MID1-I1A	1000	1300[c]	-23.1
MAR0604-HCL-MID1-I2A	Offscale	230[c]	---
MAR-0604-HCL-OUT1-I1A	250	260[c]	-3.8
MAR-0604-HCL-OUT1-I2A	15.0	24.0[c]	-37.5
MAR-0605-HCL-IN2-I1A	4400	4200	4.8
MAR-0605-HCL-IN2-I2A	720	700	2.9
MAR-0605-HCL-MID2-I1A	1200	1200	0.0
MAR-0605-HCL-MID2-I2A	52.0	56.0	-7.1
MAR-0605-HCL-OUT2-I1A	220.0	220.0	0.0
MAR-0605-HCL-OUT2-I2A	10.0	10.5	-4.8
MAR-0608-HCL-IN4-I1A	3300	2800	17.9[e]
MAR-0608-HCL-IN4-I2A	525	430	22.1[e]
MAR-0608-HCL-MID-4-I1A	1040	860	20.9[e]
MAR-0608-HCL-MID-4-12A	Offscale	16.0	---
MAR-0608-HCL-OUT-4-I1A	54.0	63.0	-14.3[e]
MAR-0608-HCL-OUT-4-I2A	2.0	1.90	5.3
QA5	105.0	100.0	5.0

---

[a] A difference between the two measurements (known addition and direct reading) greater than 10 percent was the QC criteria that was used to indicate the possibility of a complexing agent in the sample.

[b] Relative percent difference calculated as [(A - B)/B] x 100, where A is the concentration of chloride obtained from the known addition measurement and B is the concentration of chloride obtained from the direct reading measurement.

[c] These values were determined to be incorrect. Instrument adjustments were subsequently performed to eliminate any electrode interferences. All field samples that were analyzed during the same time period were reanalyzed following all instrument adjustments. The method of additions samples were not reanalyzed.

[d] The specific meter used during the analysis is designed to automatically determine method of additions concentrations. The instrument compensates for the change in concentration because of the standard addition and gives a reading for a new concentration which is compared directly to the concentration in the original sample (direct reading measurement).

[e] These values are considered to be outside the QC criteria, but samples were not reanalyzed during this time period.

train impingers was analyzed and was shown to contain 150 ppm of chloride. The high ionic strength due to the hydroxide solution may have increased the solution conductivity and resulted in high chloride concentration measurement. A field blank was also analyzed by SIE. The results showed 2.4 ppm of chloride which was insignificant in comparison to the field sample concentrations. The smallest concentration found in the samples was about 300 ppm of chloride. A laboratory proof blank was also collected but not analyzed by SIE. The NaOH used in the impinger solution of the MM5 back half was shown to cause high conductivity or interferences which results in false chloride readings.

An additional QC step was performed as part of the HCl analyses. Two cleaned MM5 sample bottles and two cleaned HCl sample bottles were analyzed for background contamination. 100 ml of deionized/distilled water was added to each sample bottle and then 1 ml of Ionic Strength Adjustor (ISA), sodium nitrate, was added. These solutions were then analyzed by SIE and all showed less than 1 ppm (0.43 ppm) of chloride.

7.3.3 Continuous Emission Monitor (CEM) Quality Control

CEMs were used to analyze flue gas from three locations: the control device inlet (boiler outlet), the midpoint location (quench reactor outlet) and the breeching to the stack. The flue gas was analyzed for CO_2, CO, O_2, SO_2, NO_x, and THC at the inlet and outlet, and CO_2, O_2, and SO_2 were monitored at the midpoint location. The limited availability of CEM instruments required that instruments based on different principles of operation be used to measure SO_2 at the three sampling locations.

A Thermo Electron Corporation (TECO) Model 40 SO_2 analyzer was used to monitor the inlet and midpoint outlet locations. The TECO works on the principle of pulsed fluorescence. A pulsed source of ultraviolet radiation electronically excites the SO_2 molecules in the sample cell. The excited molecules then decay back to their ground state by fluorescence, emitting photons. However, CO_2 and O_2 molecules also present in the sample will absorb the emitted photons causing the SO_2 concentration to be lower than the true value. The results can be adjusted using a quench factor, which is discussed in Section 7.3.8.

A Western Model 721A SO_2 analyzer was used at the outlet location. This instrument is essentially a continuous spectrophotometer in the ultraviolet range. Sulfur dioxide selectively absorbs ultraviolet (UV) light at a wavelength of 202.5 nm and the analyzer measures the absorbance (A) of the radiation through the sample cell by the decrease in intensity. This type of analyzer is not affected by CO_2 and O_2 concentrations.

The instruments used for CO were a TECO Model 48 operated at 0-100 ppm and a Beckman Model 865, non-dispersive infrared analyzer, operated at 0-500 ppm. Non-dispersive infrared analyzers emit a specific wavelength of infrared radiation through the sample cell which is selectively absorbed by CO_2 molecules. However, there is a small response to CO_2 at this wavelength. Because of the apparent CO response due to CO_2 and the very low measured results (20-40 ppm), the data collected at the outlet by the Beckman analyzers was not used. This was not unexpected. The purpose of the duplicate (Beckman) analyzer operated at a higher range was to provide a backup in case a high CO excursion occurred due to a process upset.

7.3.3.1 Daily Calibrations and Drift Checks. All CEM analyzers were calibrated daily with a zero gas (generally N_2), and a high-range span gas. Calibrations were performed in the morning prior to and at the completion of testing each day. Daily calibrations and drifts are summarized in Table 7-8. Daily drift requirements for both zero and span were ±5% for each run. The instrument drifts were generally within the 5 percent QC criteria. The only instrument showing consistently high drifts was the outlet NO_x analyzer. This drift was probably caused by some type of instrument malfunction. However, since the data are drift corrected, the CEM data quality is not affected.

7.3.3.2 System Bias Checks. During the course of the Marion County test program, bias checks of the CEM sampling systems were performed for the SO_2 and CO_2 analyzers. The checks were used to assess the potential measurement bias caused by the sampling lines and gas conditioning system. This check assesses the bias imparted to the sample by the sample lines and gas conditioning system. The high bias observed at the midpoint location

TABLE 7-8. SUMMARY OF CEM DRIFT CHECKS FOR MARION COUNTY SHUTDOWN/STARTUP [a,b]

Parameter	Percent Drift [a,b]					
	Run 12 (6-21-87)			Run 13 (6-22-87)		
	Inlet	Midpoint	Outlet	Inlet	Midpoint	Outlet
O_2 (0-25%V)	-0.026	0.074	-1.352	-0.810	0.353	-3.147
CO_2 (0-20%V)	8.982[c]	3.506	0.551	-0.152	2.600	5.020
CO (0-100 ppm, inlet) (0-500 ppm, outlet)	-0.187	NC[d]	0.995	-0.060	NC	0.729
SO_2 (0-1000 ppm, inlet) (0-500 ppm at Midpoint, outlet)	-0.829	0.853	9.949[c]	2.473	NC	-1.829
NO_x (0-1000 ppm)	0.699	NC	9.189[c]	-0.669	NC	6.614[c]
THC (0-100 ppm, inlet) (0-10%V, outlet)	2.641	NC	0.329	10.873[c]	NC	1.379

---

[a] Drifts expressed as [(Final Response Factor - Initial Response Factor)/ Initial Response Factor] x 100. Instrument range shown in parentheses.

[b] QC criterion is percent drift within ±5 percent.

[c] Exceeds 5% QC criteria. Drift correction applied.

[d] NC means data not collected for this location for these parameters.

was caused by the high lime/moisture content in the gas. Bias check results are presented in Table 7-9. The QC criterion was sampling system bias ±5 percent of span. The bias for CO and SO_2 analyzers ranged from 0.5 to -5.2 and was not considered enough to justify adjusting the data.

7.3.3.3 Response Times. Response times for the analyzers were determined as part of the CEM QC procedures. These results are presented in Table 7-10. The 95% response times for the fifteen analyzers ranged from 0.31 to 2.0 minutes. Since all results are reduced to 1-hour averages from the 1-minute data, the variation in response times is insignificant. Also, the response times are small compared to the 1- or 3- hour averaging intervals. The response times for obtaining 95% of the midrange QC gas concentration from zero concentration were approximately 0.80 minutes. Since the CEM/computer interface reads 1-minute averages during 3-hour tests, this lag will have an insignificant effect on the CEM data quality.

7.3.3.4 Daily QC Checks. After the morning calibrations, midrange gases for all instruments were analyzed, with no adjustment, as a quality control check of daily calibrations and to provide day-to-day precision estimates for each instrument. The calibration was considered acceptable if the quality control concentration was within ±10 percent of the certified concentration. If this QC check was unacceptable, another calibration was performed and linearization was performed if deemed necessary. The daily CEM QC checks are presented in Table 7-11. These results indicate that the day-to-day precision of the instruments was well within the QC criterion of ±10 percent coefficient of variation (CV). The percent CV was less than 5 percent for all analyzers. The calibration of the CEMs was also shown to be consistent with mean percent differences within 10 percent.

7.3.3.5 Multipoint Linearity Checks. All CEM instruments were calibrated on a multipoint basis each week on-site at the Marion County facility. Multipoint calibrations were performed with four certified gases: zero gas, a low scale gas concentration, a midrange concentration, and a high scale concentration (span gas). The QC criterion for acceptable linearity was a correlation coefficient (R^2) of greater than or equal to

TABLE 7-9. CEM SYSTEM BIAS TEST FOR MARION COUNTY SO_2 AND CO_2 ANALYZERS

Date	Sampling System	Analyte (Units)	Range	Concentrations			System Bias[a]	Percent of Span[b]
				Certified	Gas To Manifold	Gas To System		
6/02/87	Inlet	SO_2 (ppmV)	0-500	219	228	225.6	-2.4	-0.48
		SO_2 (ppmV)	0-500	13.1	12.5	13.3	0.8	0.16
		CO_2 (%V)	0-20	13.1	12.4	12.5	0.1	0.50
	Outlet	SO_2 (ppmV)	0-1000	219	225.9	213.2	-12.8	-1.28
		SO_2 (ppmV)	0-1000	13.1	15.6	16.8	1.2	0.12
		CO_2 (%V)	0-20	13.1	13.5	13.5	0.0	0.00
6/04/87	Midpoint	SO_2 (ppmV)	0-1000	219	222.7	171.1	-51.6	-5.16
		CO_2 (%V)	0-20	13.1	13.1	12.7	-0.4	-2.00
6/09/87	Inlet	SO_2 (ppmV)	0-5000	839.4	815.9	825.2	9.3	0.19
	Midpoint	SO_2 (ppmV)	0-1000	82.1	88.7	72.9	-15.8	-1.58
	Outlet	SO_2 (ppmV)	0-1000	82.1	88.7	82.9	-5.8	-0.58
6/17/87	Inlet	SO_2 (ppmV)	0-1000	219	219.1	192.9	-26.2	-2.62
	Outlet	SO_2 (ppmV)	0-1000	219	230.1	217.6	-12.5	-1.25

[a] QC criteria is sampling system bias within ±5% of span.

[b] Percent of span calculated as: Percent of span = (system bias/span) x 100

TABLE 7-10. RESPONSE TIMES (95%) FOR MARION COUNTY MIDRANGE CEM QC GASES

Instrument	Location					
	Inlet		Midpoint		Outlet	
	Response Time (Minutes)[a]	Gas Concentration	Response Time (Minutes)[a]	Gas Concentration	Response Time (Minutes)[a]	Gas Concentration
O_2	1.00	10.02%	0.88[b]	20.0%	2.00	20.0%
CO	1.15	202.0 ppmV	NA	NA	0.45	202.0 ppmV
CO_2	0.85	7.99%	0.67	7.99 ppmV	0.31	7.99%
SO_2	0.50	214.9 ppmV	1.10	214.9 ppmV	0.75	214.9 ppmV
NO_x	0.67	380.3 ppmV	NA	NA	0.50	380.3 ppmV
THC	0.46	4.30 ppmV	NA	NA	0.73	42.7 ppmV

[a] QC criteria is response time of less than one minute.

[b] These response times were determined using high-range calibration gases.

NA - Not applicable. These locations were not sampled for these parameters.

TABLE 7-11. DAILY QUALITY CONTROL CHECKS FOR THE MARION COUNTY CEMs[a]

Parameter	Certified Concentration	Mean Measured Concentration	Mean Percent Difference[b,c]	Percent Coefficient of Variation[d]
Inlet				
O_2 (%V)	10.02	9.75	-2.70	0.73
CO (ppmV)	3.98	39.1	1.76	0.36
CO_2 (%V)	7.99	8.80	10.1	3.21
SO_2 (ppmV)	214.9	226.4	5.33	4.66
NO_x (ppmV)	380.3	378.6	-0.45	0.75
THC (ppmC)	4.3	4.6	7.0	3.1
SO_2 (ppmV)	412.3	423.8	0.57	4.49
Midpoint				
O_2 (%V)	10.02	10.1	0.80	---
CO_2 (%V)	7.99	8.00	0.13	1.76
SO_2 (ppmV)	214.9	214.4	-0.24	1.25
Outlet				
O_2 (%V)	10.02	10.05	0.30	0.70
CO (ppmV)	202.0	201.5	0.25	0.14
CO_2 (ppmV)	7.99	8.15	2.01	0.87
SO_2 (ppmV)	214.9	232.2	8.03	1.86
NO_x (ppmV)	380.3	382.8	0.66	0.59
THC (ppmC)	4.30	4.65	8.14	1.52

---

[a] All values based on 2 measurements; 6-21-87 and 6-22-87, shutdown and startup, respectively.

[b] Percent difference calculated as [(measured concentration - certified concentration)/certified concentration] x 100.

[c] QC criteria was percent difference and percent coefficient of variation within ±10.

[d] Percent coefficient of variation calculated as (standard deviation/mean) x 100.

0.9950, where the independent variable was the cylinder gas concentration and the dependent variable was the instrument response. All CEM linearity checks were within the QC criteria of R^2 greater than 0.9950, indicating that linearity for all of the instruments was excellent.

7.3.3.6 Relative Accuracy. Interference checks were performed for CO_2, O_2, and SO_2 prior to shutdown/startup testing. The CO_2 and O_2 CEM were checked using Manual EPA Method 3. The CO, THC, and NO_x CEMs were not checked. These results are presented in Tables 7-12 and 7-13. For O_2 and CO_2, the QC criteria was absolute difference between Orsat and CEM value within 1 percent. For SO_2, the same criteria applies for the difference between the Method 6 and CEM results. The absolute differences between the O_2 and CO_2 CEM and Method 3 results were all within the QC criteria except for the outlet location for shutdown. These values were 1.1 percent for both O_2 and CO_2.

For the EPA Method 6 and CEM SO_2 comparison, the absolute differences between the two values averaged -14.1, 3.63, and 9.3%, respectively, for the inlet, midpoint, and outlet location. These differences were reasonable since Method 6 was not originally planned and the standards were not verified. Method 6 was performed only one time, for screening purposes.

As can be seen from Table 7-14, when comparing the manual and CEM HCl results, the CEM values were consistently lower than the manual values. The average relative difference was -5.73 percent.

7.3.4 Manual Sampling

HCl sampling was based on EPA Reference Method 5 with modifications which allowed the collection of HCl in the back half of the sampling train. Calibrations and/or inspections were made on all equipment prior to sampling. Sample train glassware and high-density polyethylene sample bottles were precleaned as previously described. All cleaned glassware was then sealed with glass plugs or parafilm to prevent contamination. Table 7-15 summarizes the leakchecks and isokinetics for the CDD/CDF/HCl trains, which were all within the QC criterion of 0.02 cfm.

TABLE 7-12. COMPARISON OF MEASURED METHOD 3 AND CEM O_2 AND CO_2 RESULTS FOR MARION COUNTY, INLET[a,b]

Test Condition	O_2			CO_2		
	Method 3	CEM	Difference	Method 3	CEM	Difference
<u>Inlet</u>						
Shutdown	11.7	12.5	-0.8	6.7	6.2	0.5
Startup	10.0	9.4	0.6	9.5	9.3	0.2
<u>Midpoint</u>						
Shutdown	13.9	14.1	-0.2	4.9	5.1	-0.2
Startup	11.7	12.2	-0.5	7.1	6.9	0.2
<u>Outlet</u>						
Shutdown	15.9	14.8	1.1	3.0	4.1	-1.1
Startup	12.1	12.8	-0.7	6.8	6.8	0.0

[a] All values expressed in units of percent, calculated as [Method 3 value - CEM value].

[b] QC criteria is a difference between Orsat (Method 3) and CEM value within 1 percent.

TABLE 7-13. COMPARISON OF EPA METHOD 6 AND CEM SO_2 RESULTS FOR MARION COUNTY [a,b]

Test Condition	Inlet			Midpoint			Outlet		
	Method 6 (ppmV)	CEM (ppmV)	Relative Difference (%)[c]	Method 6 (ppmV)	CEM (ppmV)	Relative Difference (%)[c]	Method 6 (ppmV)	CEM (ppmV)	Relative Difference (%)[c]
1	519.5	433.0	-16.7	325.8	351.6	7.91	115.7	121.8	5.27
2	274.8	225.9	-17.1	138.1	157.4	13.9	29.5	32.9	11.5
3	376.3	346.5	-7.91	250.4	223.2	-10.9	96.5	107.3	11.2

[a] Two minutes of the CEM sampling time were not included in the average concentration reported because the data acquisition system exceeded the full range (voltage) during this 2-minute period.

[b] The relative percent difference was calculated as [(CEM value - Method 6 value)/Method 6 value] x 100.

[c] A reasonable QC criterion was relative difference within ±20 percent.

TABLE 7-14. COMPARISON OF HCl MANUAL RESULT (SIE) AND CEM RESULT FOR MARION COUNTY SHUTDOWN/STARTUP TESTING

Test Condition	CEM (ppm)	SIE (ppm)	Relative Percent Difference[a,b]
<u>Inlet</u>			
Shutdown	d	d	--[e]
Startup	365.3	391.3[c]	-6.64
<u>Outlet</u>			
Shutdown	17.0	18.5	-8.11
Startup	27.8	28.5	-2.46

[a] Relative percent difference calculated as:
[(CEM value - SIE value)/SIE value] x 100.

[b] There is currently no CEM or manual reference method for HCl. Therefore, there is no QC criteria for the relative percent differences and both values are reported in this test report.

[c] Average of results from Train A (23:25 - 1:25) and Train B (1:25 - 3:25). CEMs were operated from 23:25 - 3:25.

[d] Since the manual trains for Ports A and B were not run simultaneously with HCL CEM monitors, the results are not compared. The port A train was operated from 11:55 to 15:15 and included soot blowing. The Port B train was operated from 12:25 - 15:15. The HCL CEMs were operated from 11:55 - 15:18.

[e] Dash indicates percent difference not applicable.

TABLE 7-15. LEAKCHECK AND ISOKINETICS SUMMARY FOR THE MARION COUNTY CDD/CDF/HCL SAMPLING TRAINS

Test Condition	Sampling Location[a]	Isokinetics (Percent)	Leak Check	Leak Rate[b,c]	Pressure (in. H_2O)
Shutdown(A)	Inlet	99.5	Initial	0.015	15
			Final	0.008	10
Shutdown(A)	Outlet	100.2	Initial	0.013	10
			Final	0.010	7
Shutdown(B)	Inlet	98.6	Initial	0.007	17
			Final	0.014	8
Shutdown(B)	Outlet	102.3	Initial	0.008	10
			Final	0.006	10
Startup(A)	Inlet	99.7	Initial	0.015	15
			Final	0.002	9
Startup(A)	Outlet	102.4	Initial	0.008	15
			Final	0.005	6
Startup(B)	Inlet	101.6	Initial	0.003	16
			Final	0.010	9
Startup(B)	Outlet	103.6	Initial	0.010	13
			Final	0.013	13

[a] Locations sampled are relative positions in the air pollution control system.

[b] Leak rates are expressed in actual cubic feet of gas over a two minute period.

[c] QC criteria is $\leq$0.02 acfm or 4 percent of sampling rate, whichever is less.

7.3.5 Validation of Fixed Gases Results

The validity of Orsat™ and CEM O_2 and CO_2 analysis results was not confirmed during the shutdown/startup testing. Normally, the ultimate CO_2 concentrations would be calculated based on an ultimate analysis of the fuel. However, the combustion stoichiometry method for validating the Orsat (Method 3) and CEM O_2 and CO_2 results could not be used. The validation method requires an ultimate analysis of the fuel. However, co-firing of natural gas with the municipal solid wastes took place during the shutdown/startup testing. Therefore, the fuel mixture and flowrates would be required to determine the ultimate fuel analyses. These process parameters are not available.

7.3.6 EPA Method 6 SO_2 Quality Control

Sampling and analysis for SO_2 followed EPA Method 6 except that the train was modified to use full-size impingers. Quality control for the SO_2 analysis included duplicate titrations and analysis of a blank, performed prior to the shutdown/startup testing. These results are presented in Table 7-16.

The fourteen duplicate titrations all agreed within the QC criteria (± 1 percent difference between duplicates) except for EPAQA9237, EPAQA7243, midpoint run 3, and outlet run 2, which were outside the QC criteria (1.68%, 1.70%, 2.53%, and 1.26%, respectively).

During analysis of the Method 6 SO_2 samples, an analytical sample blank was analyzed concurrent with the field samples. This blank consisted of the barium perchlorate titrant. The blank was analyzed with each batch of field samples. For all three analyses, the blank showed less than 0.05 milliliters of titrant required or nondetectable quantities of sulfur dioxide (analytical method detection limit was 1.3 ppm).

TABLE 7-16. DUPLICATE RESULTS FOR MARION COUNTY METHOD 6 SO_2 TITRATIONS[a,b]

Sample/ Run No.	Result #1	Result #2	Average	% Difference[c]
EPAQA9237	2.95	3.00	2.98	1.68
EPAQA4175	2.60	2.60	2.60	0.00
EPAQA8339	16.5	16.4	16.5	0.61
EPAQA2003	9.35	9.30	9.33	0.54
EPAQA7243	17.8	17.5	17.7	1.70
INLET 1	74.7	74.1	74.4	0.81
INLET 2	20.1	20.0	20.1	0.50
INLET 3	25.6	25.7	25.7	-0.39
MIDPOINT 1	37.9	38.2	38.1	-0.79
MIDPOINT 2	16.0	15.9	16.0	0.63
MIDPOINT 3	40.1	39.1	39.6	2.53
OUTLET 1	17.2	17.3	17.3	-0.58
OUTLET 2	4.00	3.95	3.98	1.26
OUTLET 3	14.1	14.0	14.1	0.71

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[a] All values reported in milliliters of barium perchlorate titrant.

[b] Analytical method detection limit was 1.3 parts per million (ppm) or 1.3 ug/ml.

[c] Percent difference calculated as $[(X1 - X_2)/\bar{X}] \times 100$, where X_1 = result #1, X_2 = result #2, $\bar{X} = (X_1 + X_2)/2$.

7.3.7 CEM Stratification Check

Stratification checks were initially performed with SO_2 but the significant variability in the SO_2 concentrations (no single reference point) with time for a given point required that a less variable parameter such as NO_x be used. QC checks for flue gas stratification in the CEM sampling duct were therefore performed on June 6, 1987 using NO_x. The NO_x concentration measured by a fixed reference probe (located at the CEM probe location) was compared to the NO_x concentration measured by traversing the duct with the sampling probe for approximately 5 minutes. These results are presented in Tables 7-17, 7-18, and 7-19, for the inlet, midpoint, and outlet sampling locations. As can be seen from the tables, the average relative percent differences between the fixed probe and the traverse readings were -0.48, -5.39, and 0.77 for the inlet, midpoint, and outlet, respectively, indicating that stratification was insignificant at the spray dryer inlet and the baghouse outlet. Stratification at the midpoint was higher but still within the 10% acceptance criteria. However, the apparent differences may have been due to the slower response time of the reference probe gas conditioning system.

7.3.8 Sulfur Dioxide (SO_2) Quenching Study

External performance audits were conducted on Radian's CEMs prior to the shutdown/startup testing on June 2, 3, 4, and 24. The performance evaluation audit of the SO_2 CEMs revealed a potential problem with the outlet SO_2 analyzer, which showed a high bias of 12.3% and 15.8% when challenged with an SO_2/CO_2 audit gas mixture on June 2 and 17. The analyzer appeared to be calibrated correctly when checked with SO_2 calibration gas. This type of analyzer requires a correction for the quenching caused by CO_2 and O_2. The uncorrected reading was very close to the audit cylinder value.

As a result, a study was initiated in-house to determine if the supplied manufacturer's quench correction factor equations used to correct for an interference caused by the presence of CO_2 and O_2 were valid for the

TABLE 7-17. CEM STRATIFICATION CHECK FOR THE MARION COUNTY INLET SAMPLING LOCATION

	NO_x Concentration (ppmV)		
Traverse Point	Fixed Reference Probe	Traverse Probe	Relative Percent Difference[a,b]
Co-located	228	229	0.44
A1	198	200	1.01
A3	219	220	0.45
A5	194	198	2.06
A7	188	193	0.03
A9	195	197	0.01
A11	258	252	-0.02
B2	225	225	0.00
B4	244	244	0.00
B6	224	223	-0.45
B8	213	216	1.4
B10	216	219	1.38
B12	238	238	0.00

[a] Relative percent differences calculated as:
[(Traverse Probe - Fixed Reference Probe)/Fixed Reference Probe] x 100.

[b] QC criteria was relative percent difference within ±10 percent.

TABLE 7-18. CEM STRATIFICATION CHECK FOR THE MARION COUNTY MIDPOINT SAMPLING LOCATION

	NO_x Concentration (ppmV)		
Traverse Point	Fixed Reference Probe	Traverse Probe	Relative Percent Difference[a,b]
Co-located	156	200	28.2
A1	200	201	0.50
A3	213	213	0.00
A5	221	226	2.26
A7	215	214	-0.46
A9	169	174	2.95
A11	174	177	1.72
B1	105	114	8.57
B3	109	117	7.33
B5	130	138	6.15
B7	150	157	4.66
B9	146	153	4.79
B11	143	148	3.49

[a] Relative percent differences calculated as:
[(Traverse Probe - Fixed Reference Probe)/Fixed Reference Probe] x 100.

[b] QC criteria was relative percent difference within ±10 percent.

TABLE 7-19. CEM STRATIFICATION CHECK FOR THE MARION COUNTY OUTLET SAMPLING LOCATION

Traverse Point	NO_x Concentration (ppmV) Fixed Reference Probe	NO_x Concentration (ppmV) Traverse Probe	Relative Percent Difference[a,b]
Co-located	165	164	-0.60
A1	163	162	-0.61
A2	163	161	-1.22
A3	162	160	-1.23
C1	152	152	-0.00
C2	163	162	-0.61
C3	171	169	-1.16

[a] Relative percent differences calculated as:
[(Traverse Probe - Fixed Reference Probe)/Fixed Reference Probe] x 100.

[b] QC criteria was relative percent difference within ±10 percent.

two TECO 40 SO_2 analyzers used in the Marion County characterization test. A detailed report of this study can be found in Appendix H.

Two TECO 40 SO_2 analyzers and one Western SO_2 analyzer were used for the Marion County testing. All of the SO_2 analyzers consistently passed internal QC checks and linearity checks using certified gases containing only SO_2 in nitrogen. However, as previously mentioned, the TECO 40 instruments exhibited poor accuracy in analyzing audit gases containing both SO_2 and CO_2. One of the TECO 40 instruments typically gave low responses, but within the required limits of ±10% of the gas SO_2 concentration. The other TECO 40 tended to respond high and slightly outside the QC limits. All analyzers were thoroughly checked out and no apparent malfunctions were found. Therefore, a post-test study was performed to determine whether revised quench factors could be suded to correct the data.

The SO_2 study on the two TECO 40 analyzers revealed that the TECO 40 #79 (used for the midpoint sampling location during the shutdown/startup program) required a revised quench factor, while the manufacturer's equation was deemed suitable for the TECO 40 #99 (used for the midpoint sampling location). Table 7-20 reflects the average improved accuracy of 13% for concentrations determined using the revised quench equation. Using only the revised equation, only two samples in Table 7-20 did not meet the acceptance criteria (±10 relative percent difference for audit gases and ±20 relative percent for Method 6 SO_2 concentrations) using the new equation.

As previously stated, the SO_2 study on the two TECO 40 analyzers revealed that the TECO 40 #79 analyzer required a revised quench factor, while the manufacturer's equation was deemed suitable for the TECO 40 #99. The manufacturer's quench factor equation is:

$$SO_2 \text{ (actual)} - SO_2 \text{ (observed)} \times [1 + 0.02139(O_2) + 0.0143(CO_2)]$$

The equation derived for the TECO 40 #79 is:

$$SO_2 \text{ (actual)} - SO_2 \text{ (observed)} \times [0.9054 + 0.0134(O_2) + 0.0129(CO_2)]$$

where

TABLE 7-20. COMPARISON OF MANUFACTURER'S AND DERIVED QUENCH EQUATIONS FOR MARION COUNTY TECO 40 (#79) SO_2 ANALYZER

Date	Sample	SO_2 Reference Concentration (ppmV)	Equation #1[a] SO_2 Concentration TECO #79 (ppmV)	Relative Percent Difference from the Reference Concentration[c]	Equation #2[b] SO_2 Concentration TECO #79 (ppmV) Concentration[c]	Relative Percent Difference from the Reference
6/2/87	Audit Gas	219.0	251.0	-14.61	227.1	3.69
	Western Analyzer	228.7	251.0	-9.73	227.1	-0.73
6/17/87	Audit Gas	219.0	253.7	-15.83	229.5	4.80
	Western Analyzer	235.9	253.7	-7.53	229.5	-2.71
6/18/87	Method 6, Run 1	115.7	135.1	-16.77	115.9	0.17
6/18/87	Method 6, Run 2	29.5	43.2	-46.3	38.2	29.4
6/18/87	Method 6, Run 3	96.5	144.1	-49.3	123.5	27.9

[a] Manufacturer's quench factor equation.

[b] Derived quench factor equation.

[c] Relative percent difference calculated as:

[(Equation #1 or #2) - (SO_2 Reference Concentration)/SO_2 Reference Equation] x 100.

SO_2 (actual) - the corrected SO_2 concentration in the sample, given oxygen and carbon dioxide concentration (ppmV).

SO_2 (observed) - the SO_2 concentration observed at the instrument (ppmV).

O_2 - the concentration of oxygen in the sample (%V)

CO_2 - the concentration of carbon dioxide in the sample (%V)

8.0 REFERENCES

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8. Reference 5.

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12. Reference 6.

13. Letter Report from Nancy Cole and Mike Vancil, Radian Corporation to Gene Riley, EMB Task Manager, U.S. Environmental Protection Agency. Marion County HCl Analyses. September 25, 1987.

14. Reference 6.

15. Reference 7.

9.0 METRIC-TO-ENGLISH CONVERSION TABLE

Metric		English
0.028317 dscm	=	1 dscf
0.028317 dscmm	=	1 dscfm
0.45359 kg/hr	=	1 lb/hr
1 ng/dscm	=	4.3699×10^{-10} grains/dscf
1 mg/dscm	=	4.3699×10^{-4} grains/dscf
^{o}F	=	(^{o}C x 9/5) + 32^{o}F
101325 Pa	=	1 atm
1 ng/kg	=	6.9998×10^{-9} grains/lb
1 ng/g	=	6.9998×10^{-6} grains/lb
1 mg/g	=	6.9998×10^{-3} grains/lb