



Municipal Waste Combustion Multipollutant Study

Characterization Emission Test Report

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

CHARACTERIZATION 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
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This report has been reviewed by the Emission Standards Division of the Office of Air Quality Planning and Standards, EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Copies of this report are available through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

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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.

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

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 SO₂ emissions has been implemented. Additionally, the lime feed now operates at a higher rate than during the test program. Because of these actions, SO₂ emissions are believed to have decreased from the values reported here.

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

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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 III of the Clean Air Act and for existing MWC under Section III(d) of the Act. The Federal Register notice follows 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 several more 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_2), 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) Studies¹, additional data were 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 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 principal objectives of the parametric test program were:

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

The parametric test program was conducted in two phases: the characterization test program and the performance test program. The overall objective of the characterization test program, which took place in June 1987 at the Marion County facility, was to evaluate the performance of the combustor and the emissions control system over the range of operation allowed by the facility's air quality permit. The results of the characterization test program are the subject of this report.

The specific objectives of the characterization phase of the test program were to:

1. Determine values for the baseline combustion parameters (combustion efficiency, CO, CO₂, O₂, SO₂, NO_x, THC, HCl, and combustor temperature profile) when the steam load, excess air, and air distribution are set at normal or design conditions.

2. Determine the baseline performance of the flue gas cleaning system for SO_2/HCl removal when the temperature and reagent ratio (stoichiometric ratio) are set at normal or design conditions.
3. Determine the effect of load, excess air and air distribution on CO emissions at baseline emission control system operating conditions.
4. Determine SO_2/HCl removal efficiency and reagent ratios for off-design temperatures in the emission control system during baseline combustor operating conditions.

The evaluation was conducted primarily with continuous emission monitors (CEMs) and plant instrumentation. During each of the process conditions, 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 these three locations throughout the test program. Entropy Environmentalists, Inc., conducted continuous measurements of HCl at the three locations.²

In addition to the measurements described in the previous paragraph, CDD/CDF sampling at the inlet and outlet to the control devices was conducted during the startup and shutdown test conditions. These results are reported in a separate document.³ Baseline CDD/CDF emissions data were collected by EPA during previous emissions tests conducted at the facility in September 1986⁴ and February 1987.⁵

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 characterization test program. The combustor is a reciprocating grate, mass-burning type with a waterwall boiler that produces superheated steam.

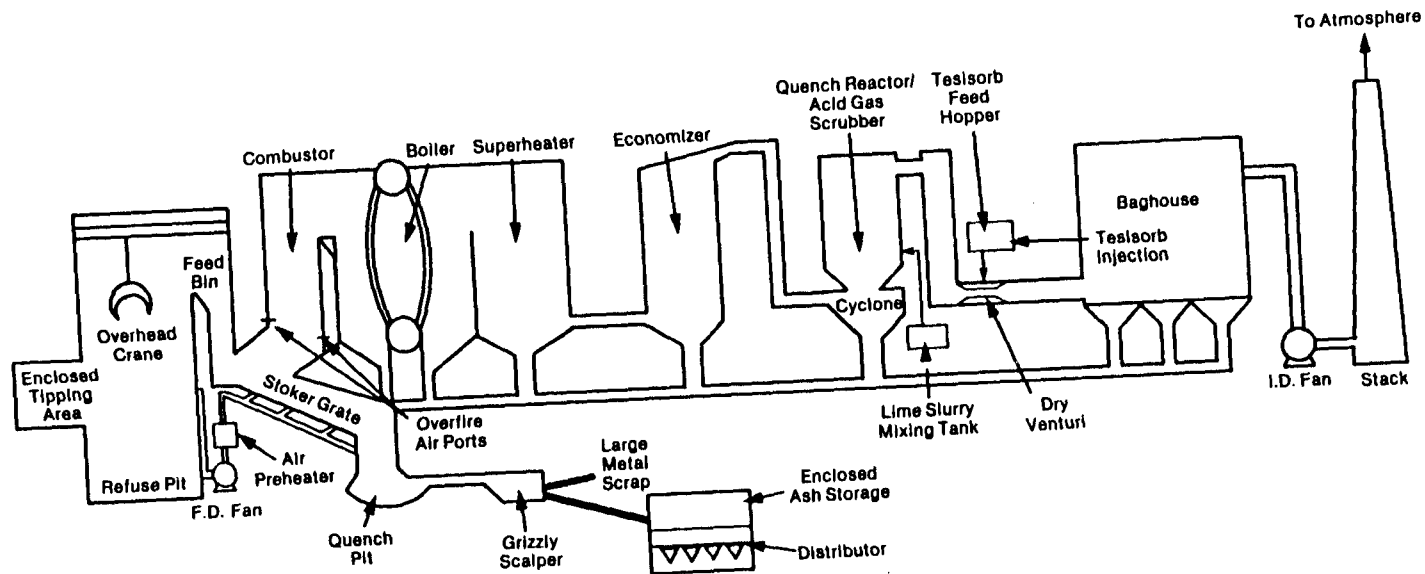


Figure 1-1. Marion County Process Line

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 receiving pit. A manually operated overhead crane transfers the refuse from the receiving pit to the incinerator charging chute. An inclined grate and ash discharge system designed by Martin GmbH is used at the Marion County facility.

1.3 CHARACTERIZATION TEST PROGRAM

1.3.1 Sampling Matrix

The Characterization Test Program was performed from June 2 through June 16, 1987. Table 1-1 presents the overall characterization test matrix that was planned and performed by EPA in conjunction with Ogden Martin. The first two test runs established baseline emissions. Combustor and control device operating conditions were varied during the next 12 test runs.

During the test program, several procedures 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 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 proved appropriate for the various combustor ash collection points.
2. An empty modified tip impinger was inserted as the first impinger in the HCl train. Evaluations of the collection efficiency of the HCl sampling train and effect of the midpoint gas conditioning system were also added to the test program. These modifications and problems with the on-site specific ion electrode analyses more than tripled the number of analyses performed.

TABLE 1-1. MARION COUNTY CHARACTERIZATION TEST SAMPLING MATRIX

Sample	1 Base- line	2 Base- line	3(a)	3(b)	4	5	6(a)	6(b)	7	8	9	10	11(a)	11(b)
<u>Process Operating Conditions</u> ^a														
<u>Combustors</u>														
Load (lb/hr steam)	N	N	N	N	N	N	L	L	L	L	L	N	N	N
Excess Air	N	N	L	H	N	N	N	H	L	N	N	N	N	N
Overfire/Underfire Air Distribution	N	N	N	N	L	H	N	N	N	L	H	N	N	N
<u>Control Device</u>														
Spray Dryer Outlet Temperature (°F)	N	N	N	N	N	N	N	N	N	N	N	L	H	H
<u>Continuous Monitoring</u> ^b														
O ₂ (CEM)	Radian	}	_____→											
CO (CEM)	Radian													
CO ₂ (CEM)	Radian													
SO ₂ (CEM)	Radian													
NO _x (CEM)	Radian													
THC (CEM)	Radian	}	_____→											
HCl (CEM)	Entropy													
<u>Manual Sampling</u> ^c														
O ₂ (Orsat)	Radian	}	_____→											
CO ₂ (Orsat)	Radian													
HCl (manual)	Radian													
Pre-and Post-Test Velocity Traverse	Radian													
<u>Ash Samples</u>														
Superheater	Radian	}	_____→											
Economizer	Radian													
Cyclone	Radian													
Baghouse	Radian													
<u>Emission Control Reagents</u>														
Lime Slurry	Radian									Radian				
Tesisorb	Radian									Radian				
<u>Process Monitoring (Control Room)</u>														
Plant Strip Chart Recorders	Radian	_____→												
Manual Recorded	EPA/MRI	_____→												
Refuse feed rate	Marion Operator	_____→												

^a N = normal

L = low

H = high

T = Test condition to be determined on-site.

^b Conducted simultaneously at the inlet, midpoint and breeching. NO_x, THC, CO were measured at the inlet and outlet only.^c Conducted at the inlet, midpoint and breeching. The velocity traverses were conducted at the inlet, midpoint and outlet stack. For Runs 1 and 2, the outlet stack velocity traverses were conducted by Ogden Martin due to space limitations on the platform.

3. The approach to the stratification testing at the breeching was modified to include a reference measurement and both SO_2 and NO_x were used as the flue gas indicators.
4. The test conditions for Runs 7b, 12 and 13 were to be determined on-site. However, additional test conditions were not identified and these runs were deleted. Shutdown and startup testing became Runs 12 and 13, respectively.

The target and actual values of the combustion and control device parameters that were varied during the characterization test program are summarized in Table 1-2. Where applicable, the values are an average of all tests at that condition.

The sampling intervals and samples collected for the Characterization Test Program are summarized in Table 1-3. In general, each run was conducted over a 3-hour period. Problems that occurred during each test run are also noted.

1.3.2 Sampling and Analytical Procedures

Sampling at the control device inlet, midpoint and outlet were performed simultaneously following similar protocols. A summary of the sampling and analytical procedures used is presented in Table 1-4. The target CDD/CDF congeners for the ash analyses are listed in Table 1-5.

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 (ODEQ), and for ensuring that the process and control

TABLE 1-2. TARGET AND ACTUAL VALUES OF COMBUSTION AND CONTROL DEVICE
PARAMETERS VARIED DURING THE CHARACTERIZATION TEST PROGRAM

	Excess Air		Steam Load (lb/hr)		Overfire Air Distribution (% of total air)		Inlet Temperature to Fabric Filter (^o F)	
	Target	Actual	Target	Actual	Target	Actual	Target	Actual
Normal (baseline)	70% (8.5% O ₂ wet)	74.7 7.4	66,400	67,100	25	NT	285-300	300
High	110% (9.5% O ₂ wet)	99.5 8.7	-- ^b	-- ^b	30	NT	360	330, 360 ^c
Low	44% (6.5% O ₂ wet)	36.2 4.6	50,550	50,550	0	NT	260	262

^aExcess air is calculated based on conditions at the inlet sampling location.

^bA high steam load test condition was not tested.

^cRun 11A = 330^oF, Run 11B = 360^oF. During Run 11A, the average fabric filter inlet temperature was 330^oF, although the target temperature was 360^oF. During Run 11B, the target temperature of 360^oF was achieved. Therefore, the two averages are reported separately.

NT = Not available at this time.

TABLE 1-3. SUMMARY OF THE SAMPLING INTERVALS FOR CHARACTERIZATION TEST PROGRAM AT THE MARION COUNTY MWC
(24-Hour Clock Basis)

Date	Run	Manual Sampling			CEMS ^a	Ash				Lime Slurry or Tesisorb	Comments
		Inlet	Midpoint	Outlet		Baghouse	Cyclone	Super- heater	Economizer		
06/04/87	1	1300-1600	1300-1600	1300-1600	1300-1600	1400, 1550	1330,1430,1530	NS	NS	NS	Outlet HCl manual results invalidated. SO ₂ spikes occurred.
06/05/87	2	1100-1400	1100-1400	1100-1400	1100-1400	1200,1257,1402	1130,1230,1330	NS	NS	LS-1152 TS-1152	SO ₂ spikes occurred.
06/06/87	3a	1000-1300	1000-1300	1000-1300	1000-1300	1100,1205,1305	1030-1300	NS	1105,1120,1205	NS	Inlet HCl manual results invalidated. CO spikes occurred due to a blockage on the feed table.
06/06/87	3b	1430-1521	1430-1730	1430-1730	1430-1730	1530,1640,1730	1500,1600,1700	NS	Sample collected, but log sheet lost. Sample times unknown.	NS	Difficulty in maintaining high excess air conditions. Furnace draft was unsteady and went positive at times.
06/08/87	4	1300-1600	1300-1600	1300-1600	1300-1600	1400,1500,1600	1330,1430,1530	1437,1455	1520,1550	NS	Some wet fuel was burned.
06/09/87	5	1000-1300	1000-1300	1000-1300	1000-1300	1100,1200,1300	1030,1130,1230	1030-1325	1031-1325	NS	No problems occurred.
06/10/87	6a	1000-1300	1000-1300	1000-1300	1000-1300	1100,1200,1300	1030-1300	1030-1311	1029-1310	NS	Plugging of the slaker strainer caused erratic lime slurry feedrates.

TABLE 1-3. SUMMARY OF THE SAMPLING INTERVALS FOR CHARACTERIZATION TEST PROGRAM AT THE MARION COUNTY MWC (Continued)
(24-hour Clock Basis)

Date	Run	Manual Sampling			CEMS ^a	Ash				Lime Slurry or Tesisorb	Comments
		Inlet	Midpoint	Outlet		Baghouse	Cyclone	Super- heater	Economizer		
06/10/87	6b	1500-1734	1500-1734	1500-1734	1500-1734	1600, 1700	1530,1630,1730	1529-1730	1530-1729	NS	Quench pit seal broke causing CO spike. Testing aborted 1/2 hour early due to baghouse bypassing.
06/11/87	7	1400-1700	1400-1700	1400-1700	1400-1700	1500,1600,1700	1430-1700	1430-1701	1431-1700	NS	Difficulty in maintaining quench reactor outlet temperature and negative furnace draft due to low flue gas flowrates.
06/12/87	8	1000-1300	1000-1300	1000-1300	1000-1300	1100,1200,1300	1030-1300	1030-1301	1030-1302	NS	No problems occurred.
06/15/87	9	1430-1800	1430-1800	1430-1800	1430-1800	1530,1630,1730	1300,1400,1500	1459-1759	1500-1800	LS-1605 TS-1600	Plant O ₂ data is suspect due to calibration problems.
06/15/87	10	1230-1600	1230-1600	1230-1600	1230-1600	1330,1430,1530	1300,1400,1500	1200-1559	1259-1600	NS	Inlet HCl manual results invalidated.
06/16/87	11a	1000-1300	1000-1300	1000-1300	1000-1300	1130,1230,1300	1030,1130,1230	1029-1258	1030-1259	NS	No problems occurred.
06/16/87	11b	1430-1730	1430-1730	1430-1730	1430-1730	1530 ^b ,1630,1730	1500,1600,1700	1459-1730	1459-1729	NS	No problems occurred.

^a All locations were sampled simultaneously.

^b Collected 35 gallon baghouse-ash sample for Ted Brna.

NS = sample not collected.

LS = lime slurry.

TS = Tesisorb.

lmo/037

TABLE 1-4. SUMMARY OF SAMPLING AND ANALYTICAL PROCEDURES

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)
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)
Baghouse Ash, Cyclone Ash, Economizer Ash, and Superheater Ash	Composited Grab Sample	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)
Moisture	EPA Method 4	--
Volumetric Flow Rate	EPA Methods 1 and 2	--
Fixed gases (O ₂ , CO ₂ , N ₂)	EPA Method 3	Orsat

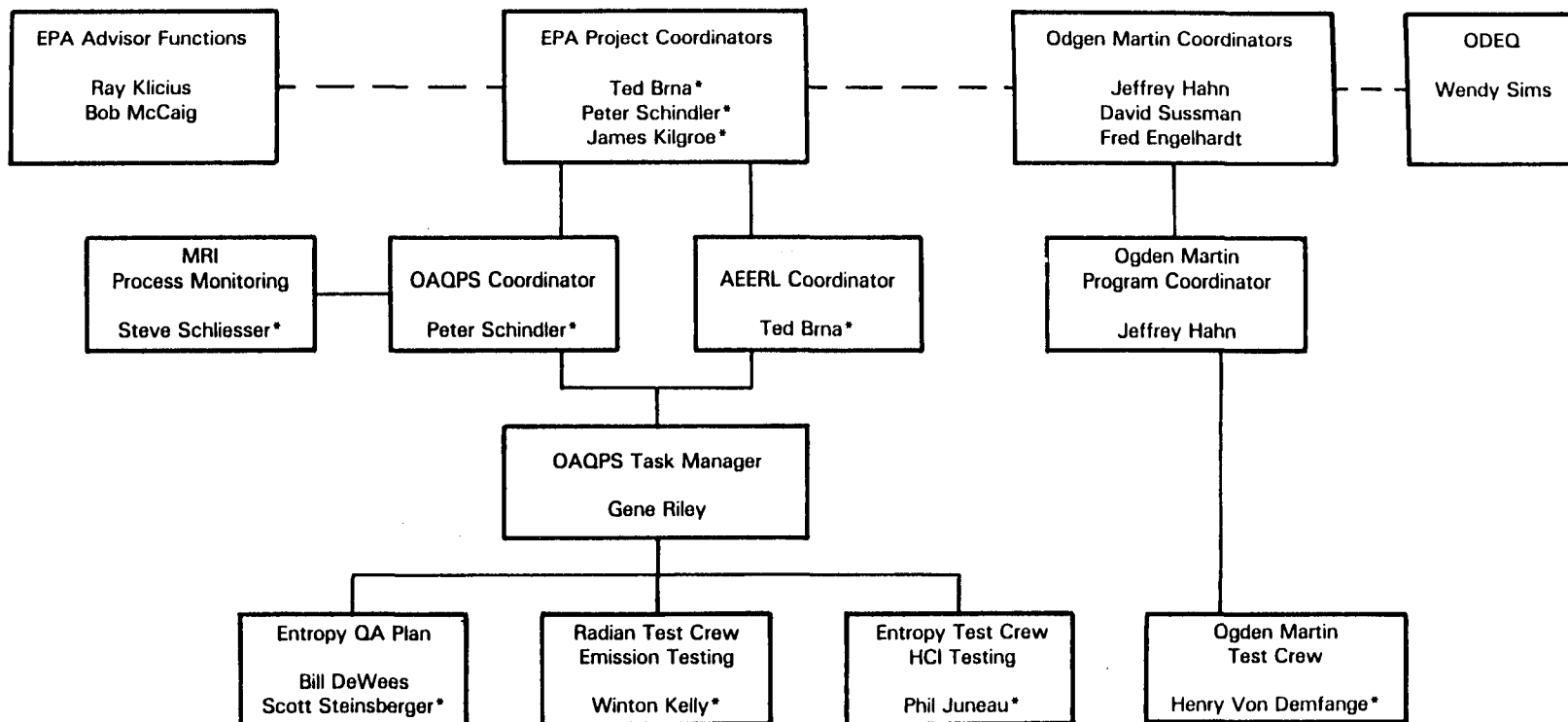
TABLE 1-5. CDD/CDF CONGENERS ANALYZED FOR
THE MARION COUNTY TEST PROGRAM

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-dioxin (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 Environmental Quality
 MRI - Midwest Research Institute
 * - On-Site

Figure 1-2. Marion County Characterization Test Program
Line of Communication

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. Data comparability was achieved by using standard units of measure as specified in the methods.

In addition to Radian's internal QC program, an independent performance and systems audit was conducted by Entropy Environmentalists, Inc., and is reported separately.⁶ The independent audit was conducted during 2 days prior to the start of the test program, during 1 day at the middle of the test program and during 1 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 and Recommendations
Section 4.0	Description of Process Operation
Section 5.0	Sampling Locations
Section 6.0	Sampling and Analytical Procedures
Section 7.0	Internal Quality Assurance/Quality Control
Section 8.0	References
Section 9.0	Metric-to-English Conversion Table

The supporting data and calculations for the results presented in Volume I are included in Volumes II to VI. Volume II contains a summary of the test results, which includes 1-minute plots of selected variables. Volume III includes the printouts of 1-minute averages for the CEM parameters and the Method 5 results for the manual HCl sampling train. Volume IV includes copies of all the field data sheets. The analytical reports and test logs are included in Appendix V. Appendix VI includes the 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 characterization test program conducted at the Marion County Solid Waste-to-Energy Facility are presented in this section. The baseline, combustor variation and control device variation results are summarized in Tables 2-1 and 2-2. These tables include the results of the greatest interest. The results represent an average value of a parameter over a sampling period. The HCl reduction efficiency based on CEM data across the total emission control system (cyclone, quench reactor, and fabric filter) ranged from 75.8 to 98.4 percent. Controlled HCl emissions ranged from 11.5 to 214 ppmv, dry, normalized to 12 percent CO₂. Control system removal efficiencies for SO₂ ranged from zero to 92.5 percent with controlled SO₂ emissions ranging from 9.9 to 484 ppmv, dry, normalized to 12 percent CO₂. The NO_x emissions ranged from 184 to 310 ppmv, dry, normalized to 12 percent CO₂ and NO_x removal was not observed across the control system. Non-condensable THC emissions ranged from 0.6 to 2.4 ppmv, as propane, dry, normalized to 12 percent CO₂ and also were not reduced by the control system. The CO emissions ranged from 2.2 to 17 ppmv, dry normalized to 12 percent CO₂. Excess air ranged from 36.2 to 144 percent.

Additional results and discussion are provided in the following sections. Baseline results are presented first in Section 2.1. Then, the results of the combustor evaluation and off-design temperature control system evaluation are presented in Sections 2.2 and 2.3, respectively. The results are presented in each subsection according to the following scheme: acid gases that include HCl and SO₂; temperature profile of the system; combustion parameters that include steam load, excess air, and combustion efficiency; fixed gases that include CO, CO₂ and O₂; additional pollutants that include NO_x and THC; and CDD/CDF concentrations in the superheater, economizer, cyclone and baghouse ash. The supporting data and example calculations for the results presented 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

lmo/036

TABLE 2-1. SUMMARY OF BASELINE AND COMBUSTOR VARIATION RESULTS FOR THE MARION COUNTY MWC

TEST CONDITION	1 BASELINE	2 BASELINE	3A LOW LOAD LOW AIR	3B HIGH AIR	4 LOW O/F	5 HIGH O/F	6A LOW LOAD	6B LOW LOAD HIGH AIR	7 LOW LOAD LOW AIR	8 LOW LOAD LOW O/F	9 LOW LOAD HIGH O/F
HCl REDUCTION EFFICIENCY (%) ^a											
QUENCH REACTOR	64.4	70.2	61.6	73.9	76.1	84.8	72.1	84.8	67.2	67.2	70.0
TOTAL SYSTEM	85.9	94.9	90.2	92.5	98.4	93.7	91.2	95.6	90.2	93.0	96.9
SO ₂ REDUCTION EFFICIENCY (%)											
QUENCH REACTOR	17.5	55.9	26.0	23.1	74.5	41.7	39.1	55.7	29.8	24.7	77.3
TOTAL SYSTEM	25.3	69.2	57.6	49.7	92.5	62.4	52.4	80.7	53.0	58.2	87.1
STOICHIOMETRIC RATIO	1.08	1.33	1.26	1.07	2.22	1.14	1.40	2.24	1.62	2.50	2.36
HCl EMISSIONS (ppmv at 12 % CO ₂) ^{a,b}											
INLET	646.2	631.0	495.6	703.8	647.8	728.8	693.1	624.8	652.8	568.2	641.7
MIDPOINT	224.7	183.3	176.6	160.4	161.5	110.2	225.0	92.5	224.7	185.9	203.5
OUTLET	83.7	35.0	49.9	47.7	11.5	45.5	69.6	27.4	67.2	39.5	19.7
SO ₂ EMISSIONS (ppmv at 12 % CO ₂) ^b											
INLET	558.9	298.9	428.4	522.7	120.2	425.0	339.6	275.2	281.1	210.1	167.5
MIDPOINT	449.7	128.4	294.5	351.2	31.9	246.6	240.5	118.8	206.8	157.6	40.3
OUTLET	383.1	99.5	185.5	236.9	9.9	157.8	184.6	52.5	139.2	87.5	21.3
NO _x EMISSIONS (ppmv at 12 % CO ₂) ^{b,c}	305.1	285.4	199.5	310.2	221.4	274.2	256.4	233.3	190.6	183.6	276.1
THC EMISSIONS (ppmv at 12 % CO ₂) ^{b,d}	0.9	0.6	0.7	0.6	0.6	NR ^e	1.9	1.5	NR ^e	1.6	1.5
CO EMISSIONS (ppmv at 12 % CO ₂) ^b	11.5	11.2	5.1	17.0	13.2	7.9	2.0	16.9	2.2	6.9	10.7
EXCESS AIR (%) ^f	73.3	71.1	36.2	99.5	70.1	68.9	70.1	144.1	57.9	85.8	90.8
STEAM LOAD (lb/hr)	67180	67240	63990	63940	65460	68970	51230	47960	51590	49900	52090
TEMPERATURES (deg. F) ^g											
MIDDLE OF COMBUSTOR, FIRST PASS	1666	1708	1895	1572	1731	1808	1767	1490	1885	1733	1639
TOP OF COMBUSTOR, FIRST PASS	1665	1688	1771	1561	1694	1734	1675	1417	1766	1668	1578
QUENCH REACTOR OUTLET	300	300	300	299	301	299	302	300	288	298	299
STACK OPACITY (%)	0	0	2.9	1.1	1.1	1.0	3.7	10.9	1.0	1.0	1.2
TOTAL CDD/CDF ASH RESULTS (ng/g)											
SUPERHEATER	NS ^e	NS ^e	NS ^e	NS ^e	3.70	NA ^e	16.4	3.77	NA ^e	NA ^e	NA ^e
ECONOMIZER	NS	NS	NA	1.47	46.5	NA	5.68	1.75	NA	NA	NA
CYCLONE	NA	NA	NA	2.76	2.60	NA	2.34	1.54	NA	NA	NA
BAGHOUSE	NA	NA	NA	12.2	12.9	NA	13.1	13.4	NA	NA	NA

^aHCl reduction efficiencies and concentrations are based on CEM data.^bAll flue gas emissions are reported on a dry basis.^cNO_x data are reported for the inlet only, since emissions were not affected by the control device.^dTHC results are reported for the outlet for Runs 1-4 and for the inlet for Runs 6A, 6B, 8, and 9. The data were invalidated due to instrument malfunctions for both the inlet and outlet instruments for Runs 5 and 7.^eNA = Sample was collected but not analyzed. NR = Data set invalidated due to instrument malfunction. NS = Sample was not collected.^fPercent excess air is based on inlet CEM data.^gCombustor temperatures were measured using uncalibrated thermocouples. Accuracy of reported temperatures is uncertain.

TABLE 2-2. SUMMARY OF BASELINE AND CONTROL DEVICE VARIATION RESULTS FOR THE MARION COUNTY MWC

TEST CONDITION:	1 BASELINE	2 BASELINE	10 LOW TEMP	11A HIGH TEMP	11B HIGH TEMP
HCL REDUCTION EFFICIENCY (%) ^a					
QUENCH REACTOR	64.4	70.2	78.8	57.6	61.7
TOTAL SYSTEM	85.9	94.9	97.6	78.9	75.8
SO2 REDUCTION EFFICIENCY (%)					
QUENCH REACTOR	17.5	55.9	18.2	-14.6 ^c	-37.9 ^c
TOTAL SYSTEM	25.3	69.2	72.9	0.9	-18.3 ^c
STOICHIOMETRIC RATIO	1.08	1.33	1.14	1.06	1.59
HCL EMISSIONS (ppmV at 12 % CO2) ^{a,b}					
INLET	646.2	631.0	814.4	718.2	750.0
MIDPOINT	224.7	183.3	180.0	295.4	313.1
OUTLET	83.7	35.0	20.4	157.7	213.8
SO2 EMISSIONS (ppmV at 12 % CO2) ^b					
INLET	558.9	298.9	382.6	470.2	118.0
MIDPOINT	449.7	128.4	325.8	522.5	177.5
OUTLET	383.1	99.5	108.0	484.4	164.5
NOx EMISSIONS (ppmV at 12 % CO2) ^{b,d}	305.1	285.4	265.2	247.0	261.9
THC EMISSIONS (ppmV at 12 % CO2) ^{b,e}	0.9	0.6	2.3	2.4	1.7
CO EMISSIONS (ppmV at 12 % CO2) ^b	11.5	11.2	10.8	8.9	14.5
EXCESS AIR (%) ^f	73.3	71.1	79.7	72.1	77.5
STEAM LOAD (lb/hr)	67180	67240	67120	67770	66100
TEMPERATURES (deg. F) ^g					
MIDDLE OF COMBUSTOR	1666	1708	1784	1827	1745
TOP OF COMBUSTOR, FIRST PASS	1665	1688	1618	1775	1719
QUENCH REACTOR OUTLET	300	300	262	330	360
STACK OPACITY (%)	0	0	1.1	1.0	1.0
TOTAL CDD/CDF ASH RESULTS (ng/g)					
SUPERHEATER	NS ^h	NS	NA	NA	3.71
ECONOMIZER	NS	NS	NA	NA	7.69
CYCLONE	NA	NA	NA	NA	2.14
BAGHOUSE	NA	NA	5.11	6.69	10.2

^a HCl reduction efficiencies and concentrations are based on CEM data.

^b All flue gas emissions are reported on a dry basis.

^c Considering the accuracy of the instruments (calibrated at a large span but measuring low concentrations), the results are considered equivalent. The data indicate that no real removal of SO2 occurred. The apparent negative removal efficiencies can be considered equivalent to zero.

^d NOx data are reported for the inlet only, since emissions were not affected by the control device.

^e THC results are for the outlet for Runs 1-2 and the inlet for Runs 10-11B.

^f Excess air based on inlet CEM data.

^g Combustor temperatures were measured using uncalibrated thermocouples. Accuracy of reported temperatures is uncertain.

^h NA = Sample was collected but not analyzed. NS = Sample was not collected.

concentrations that were measured. For the reader's ease, a Metric-to-English conversion table is included in Section 9.0.

2.1 BASELINE EMISSIONS

2.1.1 Baseline Acid Gas Emissions

The primary acid gases of interest for the characterization test program were HCl and SO₂. Baseline acid gas concentrations and control efficiencies are presented in Table 2-3.

Baseline uncontrolled SO₂ concentrations were measured during Runs 1 and 2, as well as Runs 10, 11A and 11B. The average uncontrolled SO₂ concentration for baseline operation was 366 ppmV, dry, normalized to 12 percent CO₂ with a relative standard deviation of 46 percent. The uncontrolled SO₂ concentrations ranged from 118 to 559 ppmV, dry, normalized to 12 percent CO₂. The significant variations in uncontrolled SO₂ emissions are a result of changes in fuel composition, since combustor conditions were equivalent for these runs.

Baseline SO₂ concentrations after the quench reactor were 450 ppmV, dry normalized to 12 percent CO₂ for Run 1 and 128 ppmV, dry, normalized to 12 percent CO₂. The average SO₂ concentration after the quench reactor was 289 ppmV, dry, normalized to 12 percent CO₂.

Baseline controlled SO₂ concentrations ranged from 383 ppmV, dry normalized to 12 percent CO₂ for Run 1 to 99.5 ppmV, dry, normalized to 12 percent CO₂ for Run 2. The average controlled SO₂ concentration was 241 ppmV dry normalized to 12 percent CO₂.

Baseline removal efficiency for SO₂ across the control device system was 25.3 percent during Run 1 and 69.2 percent during Run 2. The average baseline removal efficiency across the control device was 47.2 percent. The quench reactor removal efficiency for Run 1 was 17.5 percent and 55.9 percent for Run 2. The average baseline quench reactor removal efficiency was 36.7 percent. The fabric filter reduced the SO₂ mass flowrate an additional 9.4 percent during Run 1 and 30.1 percent during Run 2.

TABLE 2-3. SUMMARY OF BASELINE ACID GASES AND CONTROL EFFICIENCIES

TEST CONDITION	1 BASE- LINE	2 BASE- LINE	10 LOW QR OUT T.	11A HIGH QR OUT T.	11B HIGH QR OUT T.	BASELINE AVERAGE	OVERALL AVERAGE	PERCENT RSD
INLET SO ₂ , ppmv, dry	484	274	328	415	108	379	322	44.8
INLET SO ₂ , lb/hr	147	87.4	99.9	125	35.5	117	99	42.8
INLET HCl, ppmv, dry ^a	480	519	699	646	695	500	608	16.8
INLET HCl, lb/hr ^a	83.0	94.3	60.5	111	130	88.7	95.7	27.6
STOICHIOMETRIC RATIO	1.08	1.33	1.14	1.06	1.59	1.21	NA	NA
INLET SO ₂ , ppmv @12% CO ₂	559	299	383	470	118	429	366	46
MIDPOINT SO ₂ , ppmv @12% CO ₂	450	128	326	523	178	289	NA	NA
OUTLET SO ₂ , ppmv @12% CO ₂	383	99.5	108	484	165	241	NA	NA
INLET HCl, MANUAL, ppmv @12% CO ₂	462	502	NR	745	767	482	619	26
MIDPOINT HCl, MANUAL, ppmv @12% CO ₂	177	222	229	408	545	200	NA	NA
OUTLET HCl, MANUAL, ppmv @12% CO ₂	NR	37.6	23.4	172	228	18.8	NA	NA
INLET HCl, CEM, ppmv @12% CO ₂	646	631	814	718	750	639	712	11
MIDPOINT HCl, CEM, ppmv @12% CO ₂	225	183	180	295	313	204	NA	NA
OUTLET HCl, CEM, ppmv @12% CO ₂	83.7	35.0	20.4	158	214	59.3	NA	NA
<u>QUENCH REACTOR EFFICIENCY</u>								
PERCENT SO ₂ REDUCTION	17.5	55.9	18.2	-14.6 ^b	-37.9 ^b	36.7	NA	NA
PERCENT HCl REDUCTION, CEM	64.4	70.2	78.8	57.6	61.7	67.3	NA	NA
PERCENT HCl REDUCTION, MANUAL	60.7	54.5	NR	43.6	34.8	57.6	NA	NA
<u>FABRIC FILTER EFFICIENCY</u>								
PERCENT SO ₂ REDUCTION	9.4	30.1	66.8	13.5	14.2	19.7	NA	NA
PERCENT HCl REDUCTION, CEM	60.4	82.8	88.6	50.2	36.8	71.6	NA	NA
PERCENT HCl REDUCTION, MANUAL	NR	84.7	89.8	60.6	61.3	42.4	NA	NA
<u>OVERALL SYSTEM EFFICIENCY</u>								
PERCENT SO ₂ REDUCTION	25.3	69.2	72.9	0.9	-18.3 ^b	47.2	NA	NA
PERCENT HCl REDUCTION, CEM	85.9	94.9	97.6	78.9	75.8	90.4	NA	NA
PERCENT HCl REDUCTION, MANUAL	NR	93.1	NR	77.8	74.8	46.5	NA	NA

Note: All values are reported on a dry basis.

NA = Not applicable.

NR = Not reported due to invalidation.

^a Average of CEM and manual results.

^b Instrument inaccuracies because of measuring low concentrations while calibrated with a large span and differences between individual analyzers are responsible for the differences in SO₂ concentration at the three locations. These values should be considered equivalent and indicate that no significant removal of SO₂ took place during these runs.

Baseline uncontrolled HCl concentrations were also measured during Runs 1, 2, 10, 11A and 11B. The average uncontrolled HCl concentration for baseline operation was 712 ppmV, dry, normalized to 12 percent CO₂ based on CEM data and 619 ppmV, dry, normalized to 12 percent CO₂ based on the manual method data. The manual method uncontrolled value for Run 10 was invalidated because of a low moisture value and is not included in the average.

Baseline HCl concentrations after the quench reactor ranged from 225 to 183 ppmV, dry, normalized to 12 percent CO₂ for Runs 1 and 2, respectively, based on CEM data. The average HCl concentration after the quench reactor was 204 ppmV, dry, normalized to 12 percent CO₂.

The average controlled HCl concentration for baseline conditions was 59.3 ppmV, dry normalized to 12 percent CO₂ based on CEM data. The HCl concentration ranged from 83.7 to 35.0 ppmV, dry, normalized to 12 percent CO₂ for Runs 1 and 2, respectively.

Average baseline control device HCl removal efficiencies were 90.4 percent for the continuous monitoring testing and 93.1 percent (Run 2 only) for the manual methods tests. Quench reactor HCl removal efficiency averaged 67.3 percent by CEM measurement and 57.6 percent by manual measurement. Fabric filter HCl removal efficiency baseline averages were 71.6 percent by CEM and 84.7 percent for manual method Test 2.

The average stoichiometric ratio for the baseline conditions was 1.21. The stoichiometric ratio for Run 1 was 1.08 due to the high SO₂ concentrations and 1.33 for Run 2, which had lower SO₂ concentrations. Stoichiometric ratio is the molar ratio of the actual calcium supplied by the quench reactor to the theoretical calcium required to react with the inlet SO₂ and HCl.

2.1.2 Temperature Profile for Baseline Conditions

The temperature of the flue gas was monitored at eleven points in the MWC system beginning with the combustion air and ending at the breeching to the

outlet stack. The thermocouples used to measure the furnace temperature were uncalibrated, making the accuracy of the reported values uncertain. The points are shown in Figure 2-1. The results for the baseline conditions are summarized in Table 2-4. In addition to Runs 1 and 2, Runs 10, 11A and 11B are considered baseline for temperatures through the quench reactor inlet. An average baseline value and standard deviation were calculated for each location. The standard deviation at each location was less than five percent of the average indicating that conditions were similar during the baseline tests.

The combustion air was preheated to an average temperature of 236°F. The temperature achieved at the middle of the first pass of the combustor was 1746°F. At the economizer outlet the temperature was reduced to 423°F. The quench reactor reduced the temperature to an average of 300°F.

2.1.3 Combustion Parameters and Combustion Efficiency

The primary indicators of combustion conditions are discussed in this section and include steam load, excess air, combustion efficiency, CO concentration and volumetric flowrate. Additional parameters are reported in Appendix A. The results for the combustor baseline test conditions are summarized in Table 2-5. In addition to Runs 1 and 2, Runs 10, 11A and 11B are included as combustor baseline test runs.

During the baseline test runs, the average steam flowrate was 67082 lb/hr and the relative standard deviation was 0.9 percent. The target steam load was 66,400 lb/hr. The average excess air during baseline testing was 74.7 percent with a relative standard deviation of 5 percent. The target excess air level was 70 percent. Excess air was measured at the combustor outlet (control device inlet).

Combustion efficiency was calculated based on the ratio of moles of CO to moles of CO and CO₂ measured at the combustor outlet. During the baseline test runs, the combustion efficiency ranged from 99.88 to 99.93 percent with an average of 99.9 percent. The CO concentration ranged from 13.3 to 7.9 ppmv, dry, respectively.

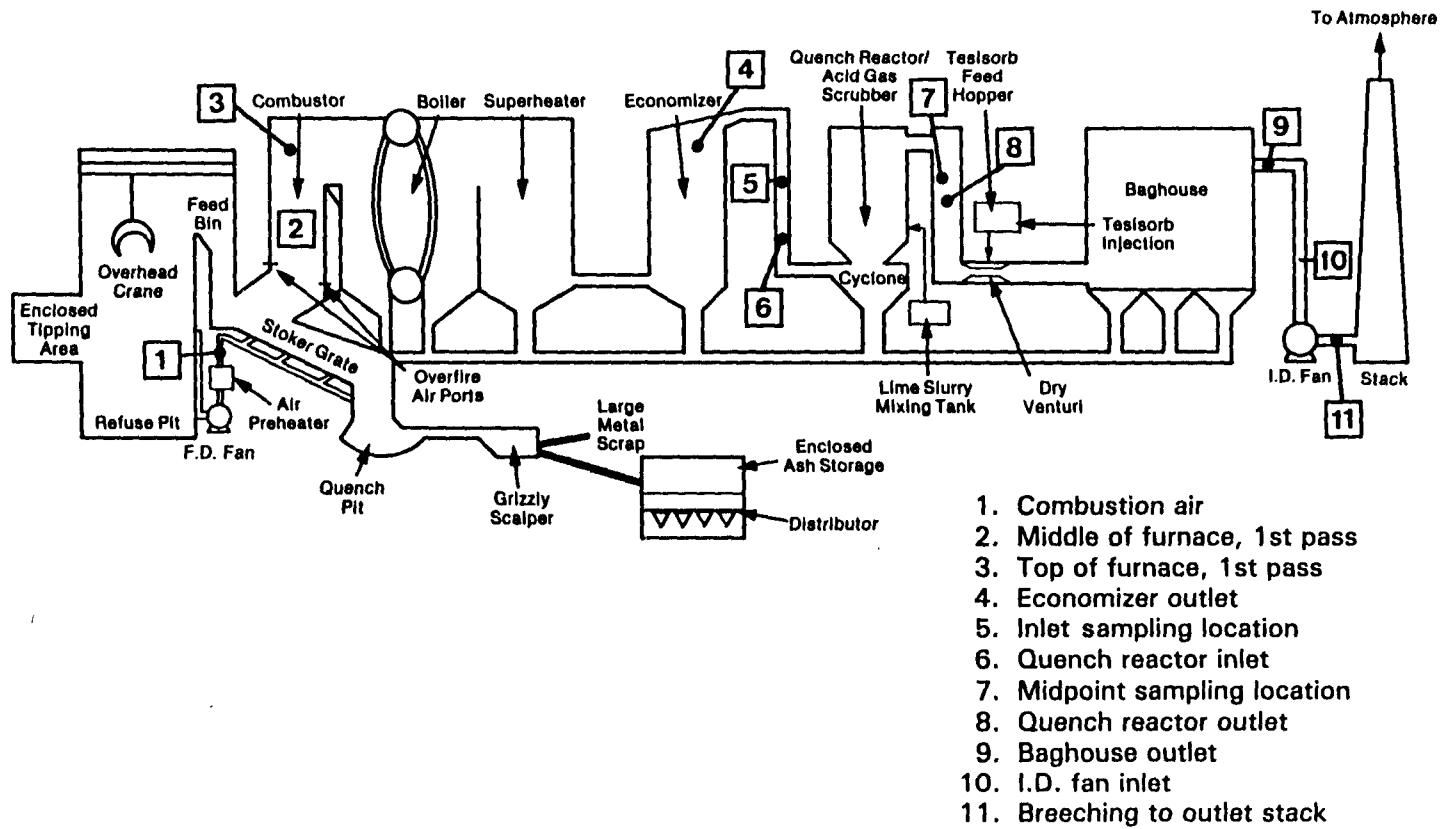


Figure 2-1. Location of Temperature Indicators for the Marion County MWC

TABLE 2-4. BASELINE TEMPERATURE PROFILE FOR THE MARION COUNTY MWC

LOCATION CODE	1 COMBUSTOR BASELINE	2 COMBUSTOR BASELINE	10 COMBUSTOR BASELINE	11A COMBUSTOR BASELINE	11B COMBUSTOR BASELINE	BASELINE AVERAGE	STANDARD DEVIATION (%)
TEMPERATURES (deg. F)							
1 COMBUSTION AIR	245	241	230	232	230	236	2.9
2 MIDDLE OF FURNACE, FIRST PASS	1666	1708	1784	1827	1745	1746	3.6
3 TOP OF FURNACE, FIRST PASS	1665	1688	1618	1775	1719	1693	3.5
4 ECONOMIZER FLUE GAS OUTLET	417	409	424	422	445	423	3.2
5 INLET SAMPLING LOCATION	420	434	441	433	465	439	3.8
6 QUENCH REACTOR INLET	432	430	436	434	461	439	2.9
7 MIDPOINT SAMPLING LOCATION	298	296	281 ^a	310 ^a	362 ^a	297 ^b	0.7 ^c
8 QUENCH REACTOR OUTLET	300	300	262	330	360	300	0.0
9 BAGHOUSE OUTLET	280	280	252	302	334	280	0.0
10 ID FAN INLET	285	283	254	305	334	284	0.7
11 BREECHING TO OUTLET STACK	291	277	260	303	352	284	4.9

^a

RUN 10 WAS A CONTROL DEVICE VARIATION RUN WITH A LOW QUENCH REACTOR TEMPERATURE.
 RUNS 11A AND 11B WERE CONTROL DEVICE VARIATION RUNS WITH A HIGH QUENCH REACTOR TEMPERATURE.
 RUNS 10, 11A AND 11B ARE CONSIDERED BASELINE FOR THE COMBUSTOR TEMPERATURES.

^b

ONLY RUNS 1 AND 2 ARE USED TO CALCULATE THE COMBUSTOR BASELINE AVERAGE BELOW THIS POINT.

^c

DIFFERENCE IS CALCULATED BASED ON RUNS 1 AND 2 ONLY.
 DIFFERENCE = [RUN 1 - RUN 2]/[(0.5)*(RUN 1 + RUN 2)]* 100%

TABLE 2-5. BASELINE COMBUSTION PARAMETERS FOR THE MARION COUNTY MWC

COMBUSTION PARAMETER	1 COMBUSTOR BASELINE	2 COMBUSTOR BASELINE	10 COMBUSTOR BASELINE	11A COMBUSTOR BASELINE	11B COMBUSTOR BASELINE	BASLINE AVERAGE	STANDARD DEVIATION (%)
STEAM FLOW (lb/hr)	67180	67240	67120	67770	66100	67082	0.9
EXCESS AIR (PERCENT) ^a	73.3	71.1	79.7	72.1	77.5	74.7	4.9
CO CONCENTRATION (ppmv, DRY) ^a	10.0	10.3	9.3	7.9	13.3	10.2	19.5
CO2 CONCENTRATION (% by vol, DRY) ^a	10.4	11.0	10.3	10.6	11	10.7	3.1
O2 CONCENTRATION (% by vol, DRY) ^a	9.0	8.8	9.4	8.9	9.2	9.1	2.7
COMBUSTION EFFICIENCY (%) ^{a,b}	99.90	99.91	99.91	99.93	99.88	99.90	0.02
VOLUMETRIC FLOWRATE (ACFM) ^c	57150	60920	59100	57430	65620	60044	3463

^a Measured at the inlet sampling location based on CEM data.

^b Combustion efficiency = moles of CO/[moles of CO + moles of CO2]*100%

^c Measured at the inlet sampling location.

Volumetric flowrate as measured at the combustor inlet was an average of 60,044 acfm. The flowrate ranged from 57,150 to 65,620 acfm with relative standard deviation of 6 percent.

2.1.4 Fixed Gases (CO, CO₂, O₂)

Fixed gas concentrations at baseline are presented in Table 2-6. During baseline conditions (Runs 1 and 2) carbon dioxide concentration in the boiler outlet (control device inlet) flue gas averaged 10.1 percent by volume, dry, by EPA Method 3 (Orsat analysis) and 10.7 percent by volume, dry, by CEM instrument analysis for a pooled average of 10.4 percent by volume, dry. Oxygen analyses yielded an average concentration of 9.2 percent by volume, dry, by Orsat and 8.9 percent by volume, dry, by CEM, with a pooled average of 9.1 percent by volume, dry. Control device evaluation test runs can also be considered as baseline test conditions for the boiler outlet since no furnace parameters were abnormal. A pooled result incorporating ORSAT and CEM values for Runs 1, 2, 10, 11A and 11B yielded an average of 9.1 percent by volume O₂, dry, (RSD = 2.7 percent) and 10.4 percent by volume CO₂, dry, (RSD = 4.0 percent). The relative standard deviations for these pooled averages are excellent and indicate consistency in the process operation and the sample analyses.

Carbon monoxide concentrations at the boiler outlet during baseline test conditions were 10.0 ppmv, dry, (Run 1) and 10.3 ppmv, dry, (Run 2) for an average baseline concentration of 10.2 ppmv, dry. The average baseline boiler outlet CO concentration including the control device evaluation runs was 10.2 ppmv, dry, with a standard deviation of 1.98 (RSD = 19.5 percent). Although there was some variability in carbon monoxide concentration, the CO levels were consistently below 20 ppmV, dry basis.

2.1.5 Additional Pollutants of Interest (NO_x and THC)

Baseline concentrations for NO_x and THC are presented in Table 2-7. Baseline uncontrolled NO_x concentrations were 305 ppm normalized to 12 percent CO₂ for Run 1 and 285 ppm normalized to 12 percent CO₂ for Run 2. This gives an average NO_x baseline concentration of 295 ppm normalized to 12 percent CO₂.

TABLE 2-6. BASELINE FIXED GASES CONCENTRATIONS (CO, CO₂, O₂)

TEST CONDITION	1 BASELINE	2 BASELINE	10 LOW QR OUT T.	11A HIGH QR OUT T.	11B HIGH QR OUT T.	BASELINE AVERAGE	OVERALL AVERAGE	PERCENT RSD
<u>INLET ORSAT</u>								
O ₂ , %v, DRY	9.0	9.4	8.8	9.0	9.4	9.2	9.1	2.9
CO ₂ , %v, DRY	10.0	10.1	10.2	10.2	9.7	10.1	10.0	2.1
PERCENT EXCESS AIR	72.7	78.4	69.9	73.7	78.6	75.6	74.7	5.1
Fo ^a	1.19	1.15	1.19	1.17	1.19	1.17	1.18	1.52
<u>INLET CEM</u>								
O ₂ , %v, DRY	9.0	8.8	9.4	8.9	9.2	8.9	9.1	2.7
CO ₂ , %v, DRY	10.4	11.0	10.3	10.6	11.0	10.7	10.7	3.1
CO, ppmv, DRY	10.0	10.3	9.3	7.9	13.3	10.2	10.2	19.5
PERCENT EXCESS AIR	73.3	71.1	79.7	72.1	77.5	72.2	74.7	4.9
Fo ^a	1.14	1.10	1.12	1.13	1.06	1.12	1.11	2.83
<u>INLET AVERAGE^b</u>								
O ₂ , %v, DRY	9.0	9.1	9.1	9.0	9.3	9.1	9.1	2.7 ^c
CO ₂ , %v, DRY	10.2	10.6	10.3	10.4	10.4	10.4	10.4	4.0 ^c
PERCENT EXCESS AIR	73.0	74.8	75.8	72.9	78.1	73.9	74.7	4.7 ^c
Fo ^a	1.17	1.13	1.16	1.15	1.13	1.15	1.14	3.8 ^c

^aFo = (20.9 - %O₂ dry)/(%CO₂, dry).

^bAverage of Orsat and CEM values.

^cRelative standard deviation based on all data points (CEM and Orsat).

TABLE 2-7. NO_x AND THC EMISSIONS FOR BASELINE CONDITIONS

TEST CONDITION:	1	2	10	11A	11B			
	BASE-	BASE-	LOW QR	HIGH QR	HIGH QR	BASELINE	OVERALL	PERCENT
	LINE	LINE	OUT T.	OUT T.	OUT T.	AVERAGE	AVERAGE	RSD
INLET								
NO _x , ppmv, DRY	264	262	228	218	240	263	242	8.4
NO _x , ppmv @12% CO ₂	305	285	265	247	262	295	273	8.3
NO _x , lb/hr	57.7	59.9	49.7	47.3	56.5	59	54	10.0
OUTLET								
NO _x , ppmv, DRY	204	205	194	165	196	205	193	8.5
NO _x , ppmv @12% CO ₂	306	304	287	250	302	305	290	8.1
NO _x , lb/hr	63.0	59.2	51.8	46.1	55.2	61	55	11.9
INLET								
THC, ppmv as propane, DRY	NR	0.7	2.0	2.1	1.6	0.7	1.6	39.9
THC, ppmv as propane @12% CO ₂	NR	0.8	2.3	2.4	1.7	0.8	1.8	41.6
THC, lb/hr as propane	NR	0.2	0.4	0.4	0.4	0.2	0.3	37.9
OUTLET								
THC, ppmv as propane, DRY	0.6	0.4	NR	NR	NR	0.5	NA	NA
THC, ppmv as propane @12% CO ₂	0.9	0.6	NR	NR	NR	0.7	NA	NA
THC, lb/hr as propane	0.2	0.1	NR	NR	NR	0.1	NA	NA

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

NA = Not applicable.

Controlled baseline NO_x concentrations were 306 ppm normalized to 12 percent CO₂ and 304 ppm normalized to 12 percent CO₂ for Run 1 and Run 2, respectively. The average control device outlet NO_x concentrations was 305 ppm normalized to 12 percent CO₂. Outlet mass flowrates for Runs 1 and 2 were 63.0 lb/hr and 59.2 lb/hr, respectively.

The consistency of normalized NO_x concentrations from inlet to outlet indicates that the control device did not reduce the concentrations of nitrogen oxides significantly. Observed differences between inlet and outlet NO_x concentrations are within expected instrument variability.

Baseline total non-condensable hydrocarbon emissions for the Marion County Solid Waste-to-Energy Facility were less than 1 ppm as propane, which is a concentration close to the instrument's detection limit. The outlet concentrations of the THC were 0.9 ppmV for Run 1 and 0.6 ppmV for Run 2. The inlet THC monitor detected an average of 0.8 ppm (dry) for Run 2. (All values are normalized to 12 percent CO₂.) The control device does not appear to affect the normalized concentration of THC.

2.1.6 CDD/CDF Concentrations in Ash

Baseline CDD/CDF concentrations in superheater, economizer, cyclone and baghouse ashes are shown in Table 2-8. The total CDD, total CDF, and total 2378-TCDD toxic equivalent concentrations are given for the four ash sampling locations. The baseline superheater ash and economizer ash results are from Run 11B samples. Baseline results for the cyclone ash and baghouse ash are averages from previous studies in February 1987⁷ and September 1986⁸ at the Marion County MWC. There are no simultaneously collected baseline results for the four ash sampling locations because there were difficulties with the sampling technique for the economizer ash and superheater ash when the system was at baseline conditions (Runs 1 and 2). During Run 11B, only the combustor was at baseline conditions, so only the superheater ash and economizer ash were indicative of baseline. In the previous studies at the Marion County MWC, the system was at baseline, but economizer ash and superheater ash samples were not collected.

TABLE 2-8. CDD AND CDF CONCENTRATIONS AND 2378-TCDD TOXIC EQUIVALENCIES FOR ASH FROM BASELINE CONDITIONS AT MARION COUNTY MWC

Ash Type	Run 11B	Method Study ^a Average	Emission Test ^b Average	Baseline ^c Average
TOTAL CDD CONCENTRATION (ng/g)				
Superheater Ash	0.400	NC ^d	NC	0.400
Economizer Ash	0.710	NC	NC	0.710
Cyclone Ash	NB ^e	1.65	3.58	2.81
Baghouse Ash	NB	4.63	4.56	4.59
TOTAL CDF CONCENTRATION (ng/g)				
Superheater Ash	3.31	NC	NC	3.31
Economizer Ash	6.98	NC	NC	6.98
Cyclone Ash	NB	2.88	1.22	1.88
Baghouse Ash	NB	11.4	3.38	6.58
2378-TCDD TOXIC EQUIVALENT CONCENTRATION (ng/g)				
Superheater Ash	0.030	NC	NC	0.030
Economizer Ash	0.085	NC	NC	0.085
Cyclone Ash	NB	0.060	0.082	0.074
Baghouse Ash	NB	0.159	0.141	0.148

^a Average ash concentration from Runs 1 and 5 of February 1987 Method Study at Marion County MWC.

^b Average ash concentration from Runs 1-3 of September 1986 Emission Test at Marion County MWC.

^c Baseline average is Run 11B results for superheater ash and economizer ash and average of Method Study and Emission Test results for cyclone ash and baghouse ash

^d NC = Not collected. Sample not collected during this test.

^e NB = Not baseline. Quench reactor outlet temperature was varied in Run 11B, so ash collected at the cyclone and baghouse was not from baseline conditions.

The baseline total CDD average concentration ranged from 0.40 ng/g for the superheater ash to 4.59 ng/g for the baghouse ash. The baseline total CDF average concentration ranged from 3.31 ng/g for superheater ash to 6.98 ng/g for economizer ash. The baseline 2378-TCDD toxic equivalency concentration ranged from 0.03 ng/g for the superheater ash to 0.15 ng/g for the baghouse ash.

The concentrations of the individual CDD/CDF species are presented in Table 2-9. The baseline concentrations for the superheater ash and economizer ash are from Run 11B. The concentrations include the confirmation results for 2378-TCDF and, if less interference occurred, for 2378-TCDD. The concentrations for the cyclone ash and baghouse ash are averages of the Emission Test and Method Study results. The results for each run of the Emission Test and Method Study are given in References 7 and 8, respectively.

In Figure 2-2, the homologue distributions for CDD, and CDF at baseline conditions are shown. This is based on Run 11B distributions for economizer ash and superheater and an average distribution from the previous studies for the superheater ash and cyclone ash. The distribution does not appear to change significantly across the different sampling locations.

2.2 COMBUSTOR VARIATIONS

2.2.1 Temperature Profile During Combustor Variations

The temperature profile results for the combustor variation conditions are presented in Table 2-10. The difference from the baseline average for each of the combustor variation conditions is presented in Table 2-11 and graphically in Figures 2-3 and 2-4. Figure 2-3 presents the differences for all the low load conditions and Figure 2-4 presents the difference for the air distribution and excess air conditions.

The temperatures monitored varied less than 20 percent from baseline. Low load, high excess air (Run 6B) and low load, low excess air (Run 7) showed the most change in the temperature profile.

TABLE 2-9. CDD AND CDF CONCENTRATIONS FOR ASH AT BASELINE
CONDITIONS AT MARION COUNTY MWC

Isomer	CDD/CDF CONCENTRATION (ng/g) ^a			
	Ash Type			
	Superheater	Economizer ^b	Cyclone	Baghouse
DIOXINS				
Mono-CDD	(0.001) ^c	(0.003)	(0.001)	(0.001)
Di-CDD	[0.009]	(0.003)	0.014	0.025
Tri-CDD	[0.054]	0.030	0.056	0.142
2378 TCDD	0.008	0.013	0.014	0.020
Other TCDD	0.049	0.099	0.164	0.270
12378 PCDD	[0.006]	0.023	0.040	0.055
Other PCDD	0.017	0.100	0.388	0.550
123478 HxCDD	[0.003]	0.011	0.026	0.052
123678 HxCDD	[0.004]	[0.009]	0.084	0.099
123789 HxCDD	[0.011]	0.016	0.076	0.090
Other HxCDD	0.025	0.052	0.764	1.10
1234678 HpCDD	0.061	0.081	0.383	0.622
Other HpCDD	0.049	0.080	0.341	0.605
Octa-CDD	0.191	0.208	0.456	0.959
Total CDD	0.400	0.710	2.81	4.59
FURANS				
Mono-CDF	(0.001)	(0.003)	0.004	0.010
Di-CDF	[0.240]	[0.475]	(0.444)	0.276
Tri-CDF	1.04	1.91	0.712	2.59
2378 TCDF	0.070	0.220	0.160	0.516
Other TCDF	0.952	2.16	0.378	1.42
12378 PCDF	0.066	0.144	0.032	0.086
23478 PCDF	0.052	0.153	0.070	0.189
Other PCDF	0.309	0.856	0.202	0.700
123478 HxCDF	0.063	0.178	0.042	0.094
123678 HxCDF	0.040	0.075	0.020	0.048
234678 HxCDF	0.045	0.099	0.041	0.157
123789 HxCDF	0.004	[0.007]	0.002	(0.048)
Other HxCDF	0.159	0.375	0.089	0.192
1234678 HpCDF	0.112	0.356	0.065	0.148
1234789 HpCDF	0.041	0.037	0.002	0.024
Other HpCDF	0.099	0.189	0.017	0.046
Octa-CDF	0.259	0.225	0.044	0.083
Total CDF	3.31	6.98	1.88	6.58
Total CDD/CDF	3.71	7.69	4.69	11.2

^a Superheater ash and economizer ash results are from Run 11B. Cyclone ash and baghouse ash results are average of results from Emission Test and Method Study runs at Marion County MWC.

^b Concentration for the economizer ash is the average of duplicate analyses.

^c Not detected. Detection limit given in parentheses; estimated maximum possible concentration (EMPC) given in brackets. Values of detection limits or EMPCs are not included in totals.

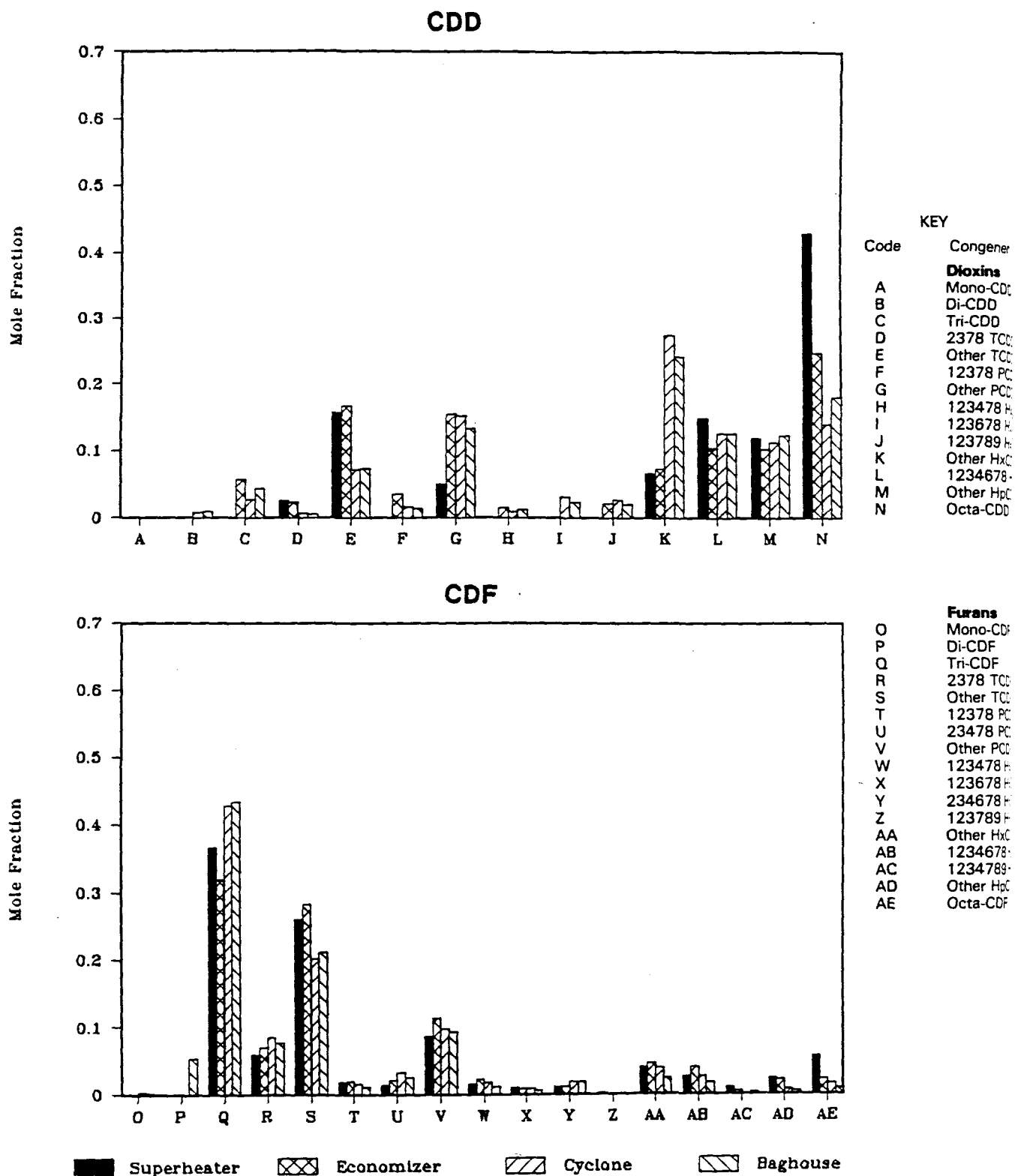


Figure 2-2. Baseline Congener Distribution for Ash

TABLE 2-10. COMBUSTOR VARIATION TEMPERATURE PROFILE FOR THE MARION COUNTY MWC

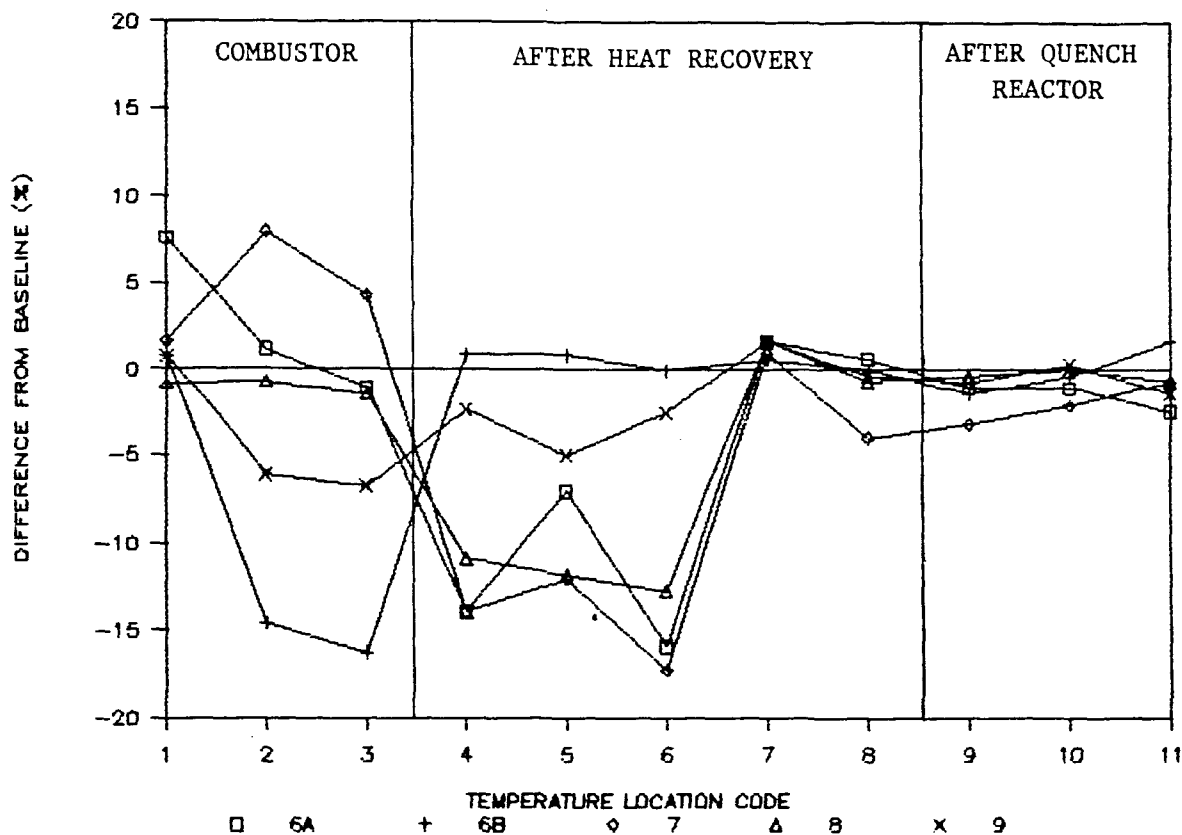
		3A	3B	4	5	6A	6B	7	8	9
LOCATION		LOW AIR	HIGH	LOW OF	HIGH OF	LOW	LOW LOAD	LOW LOAD	LOW LOAD	LOW LOAD
CODE			EXCESS AIR	AIR	AIR	LOAD	HIGH AIR	LOW AIR	LOW OF	HIGH OF
=====										
TEMPERATURES (deg. F)										
1	COMBUSTION AIR	240	245	235	239	254	238	240	234	238
2	MIDDLE OF FURNACE, FIRST PASS	1895	1572	1731	1808	1767	1490	1885	1733	1639
3	TOP OF FURNACE, FIRST PASS	1771	1561	1694	1734	1675	1417	1766	1668	1578
4	ECONOMIZER FLUE GAS OUTLET	366	432	416	416	364	427	364	377	413
5	INLET SAMPLING LOCATION	381	452	430	428	408	443	386	387	417
6	QUENCH REACTOR INLET	374	440	430	433	369	439	363	383	428
7	MIDPOINT SAMPLING LOCATION	301	296	300	298	302	299	300	302	302
8	QUENCH REACTOR OUTLET	300	299	301	299	302	300	288	298	299
9	BAGHOUSE OUTLET	279	280	278	279	277	276	271	279	278
10	ID FAN INLET	283	285	283	282	281	283	278	284	285
11	BREECHING TO OUTLET STACK	279	279	280	280	277	289	282	282	280
=====										
LOW AIR = Low excess air										
HIGH OF = High overfire air distribution										

TABLE 2-11. DIFFERENCE FROM BASELINE FOR COMBUSTOR EVALUATION FOR THE MARION COUNTY MWC

LOCATION CODE	3A	3B	4	5	6A	6B	7	8	9
	LOW AIR	HIGH EXCESS AIR	LOW OF AIR	HIGH OF AIR	LOW LOAD	LOW LOAD HIGH AIR	LOW LOAD LOW AIR	LOW LOAD LOW OF	LOW LOAD HIGH OF
=====									
TEMPERATURE SENSOR LOCATIONS									
1 COMBUSTION AIR	2	4	0	1	8	1	2	-1	1
2 MIDDLE OF FURNACE, FIRST PASS	9	-10	-1	4	1	-15	8	-1	-6
3 TOP OF FURNACE, FIRST PASS	5	-8	0	2	-1	-16	4	-1	-7
4 ECONOMIZER FLUE GAS OUTLET	-14	2	-2	-2	-14	1	-14	-11	-2
5 INLET SAMPLING LOCATION	-13	3	-2	-2	-7	1	-12	-12	-5
6 QUENCH REACTOR INLET	-15	0	-2	-1	-16	0	-17	-13	-2
7 MIDPOINT SAMPLING LOCATION	1	0	1	0	2	1	1	2	2
8 QUENCH REACTOR OUTLET	0	0	0	0	1	0	-4	-1	0
9 BAGHOUSE OUTLET	0	0	-1	0	-1	-1	-3	0	-1
10 ID FAN INLET	0	0	0	-1	-1	0	-2	0	0
11 BREECHING TO OUTLET STACK	-2	-2	-1	-1	-2	2	-1	-1	-1

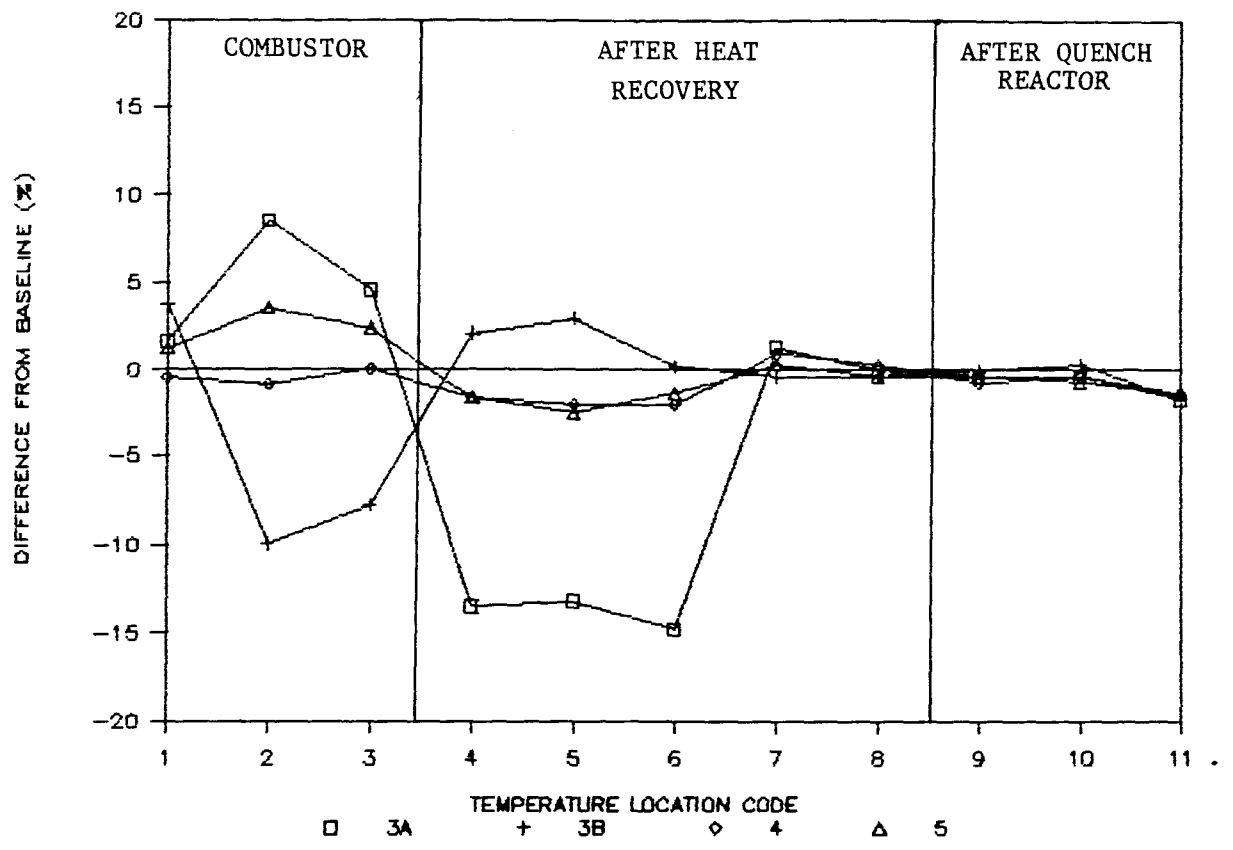
=====

Difference (percent) = (Run value - baseline)/baseline * 100%. The baseline average is used.



1. Combustion air
2. Middle of furnace, 1st pass
3. Top of furnace, 1st pass
4. Economizer outlet
5. Inlet Sampling location
6. Quench reactor inlet
7. Midpoint sampling location
8. Quench reactor outlet
9. Baghouse outlet
10. I.D. fan inlet
11. Breeching to outlet stack

Figure 2-3. Temperature Profile for Low Load Combustor Evaluation Conditions



1. Combustion air
2. Middle of furnace, 1st pass
3. Top of furnace, 1st pass
4. Economizer outlet
5. Inlet Sampling location
6. Quench reactor inlet
7. Midpoint sampling location
8. Quench reactor outlet
9. Baghouse outlet
10. I.D. fan inlet
11. Breeching to outlet stack

Figure 2-4. Temperature Profile for Air Distribution and Excess Air Combustor Evaluation Conditions

2.2.2 Combustion Parameters during Combustor Variations

The results for the primary indicators of combustion conditions during the combustor variations are summarized in Table 2-12. The difference from baseline expressed as a percent for each parameter is summarized in Table 2-13. Steam load was within 5 percent of baseline for Runs 3A, 3B, 4 and 5 and was reduced to approximately 75 percent for Runs 6A, 6B, 7, 8 and 9. The variation in the steam load is shown graphically in Figure 2-5.

Excess air ranged from a low of 36.2 percent during Run 3A (low excess air) to a high of 144 percent during Run 6B (low load, high excess air). The variation in excess air is shown graphically in Figure 2-6.

Combustion efficiency varied from 99.86 to 99.98 percent. Correspondingly, the CO concentration ranged from 12.6 to 1.7 ppmv dry. The CO values reported are averages for each test run. The variations during each test run are discussed in Section 2.2.3.

To aid in the evaluation of the temperature profile, the variation in the volumetric flowrate is shown graphically in Figure 2-7. The volumetric flowrate of the flue gas was lowest during Run 7 (low load, low excess air) and highest during Run 3B (high excess air). The volumetric flowrate did not change more than 30 percent from baseline.

2.2.3 Fixed Gases (CO, CO₂, O₂)

Results of the fixed gases are presented on a dry basis in Table 2-14. The average values discussed in this section are the averages of the CEM and Orsat results. Over the course of the combustor variations, average oxygen levels ranged from 6.0 percent by volume to 12.4 percent by volume and the average carbon dioxide levels ranged from 7.4 percent by volume to 12.9 percent by volume. The highest oxygen concentrations were observed during the high excess air test conditions 6B (low load, high excess air) and 3B (high excess air). Oxygen content during these runs averaged 12.4 percent by volume

TABLE 2-12. COMBUSTION PARAMETERS DURING THE COMBUSTOR EVALUATION

COMBUSTION PARAMETER	3A LOW AIR	3B HIGH EXCESS AIR	4 LOW O/F AIR	5 HIGH O/F AIR	6A LOW LOAD	6B LOW LOAD HIGH AIR	7 LOW LOAD LOW AIR	8 LOW LOAD LOW O/F	9 LOW LOAD HIGH O/F
STEAM FLOW (lb/hr)	63990	63940	65460	68970	51230	47960	51590	49900	52090
EXCESS AIR (PERCENT) ^a	36.2	99.5	70.1	68.9	70.1	144.1	57.9	85.8	90.8
CO CONCENTRATION (ppmv, DRY) ^a	5.6	12.6	11.3	6.9	1.7	10.3	2.1	5.6	8.5
CO ₂ CONCENTRATION (% by vol, DRY) ^a	13.1	8.9	10.3	10.5	10.3	7.3	11.6	9.8	9.5
O ₂ CONCENTRATION (% by vol, DRY) ^a	5.7	10.6	8.8	8.7	8.8	12.5	7.8	9.8	10.1
COMBUSTION EFFICIENCY (%) ^{a,b}	99.96	99.86	99.89	99.93	99.98	99.86	99.98	99.94	99.91
VOLUMETRIC FLOWRATE (ACFM) ^c	46980	67270	60600	58590	52310	59640	42280	42350	49360

^a Measured at the inlet sampling location based on CEM data.

^b Combustion efficiency = moles of CO/[moles of CO + moles of CO₂]*100%

^c Measured at the inlet sampling location.

TABLE 2-13. DIFFERENCE FROM BASELINE FOR COMBUSTION PARAMETERS DURING THE COMBUSTOR EVALUATION

COMBUSTION PARAMETER	3A LOW AIR	3B HIGH EXCESS AIR	4 LOW O/F AIR	5 HIGH O/F AIR	6A LOW LOAD	6B LOW LOAD HIGH AIR	7 LOW LOAD LOW AIR	8 LOW LOAD LOW O/F	9 LOW LOAD HIGH O/F
STEAM FLOW (lb/hr)	95	95	98	103	76	71	77	74	78
EXCESS AIR (PERCENT)	-52	33	-6	-8	-6	93	-23	15	21
CO CONCENTRATION (ppmv, DRY)	-45	24	11	-32	-83	1	-79	-45	-16
CO2 CONCENTRATION (% by vol, DRY)	23	-17	-3	-2	-3	-32	9	-8	-11
O2 CONCENTRATION (% by vol, DRY)	-37	17	-3	-4	-3	38	-14	8	11
COMBUSTION EFFICIENCY (%)	0	0	0	0	0	0	0	0	0
VOLUMETRIC FLOWRATE (ACFM)	-22	12	1	-2	-13	-1	-30	-29	-18
Difference (percent) = (Run value - baseline)/baseline * 100%. The baseline average is used.									

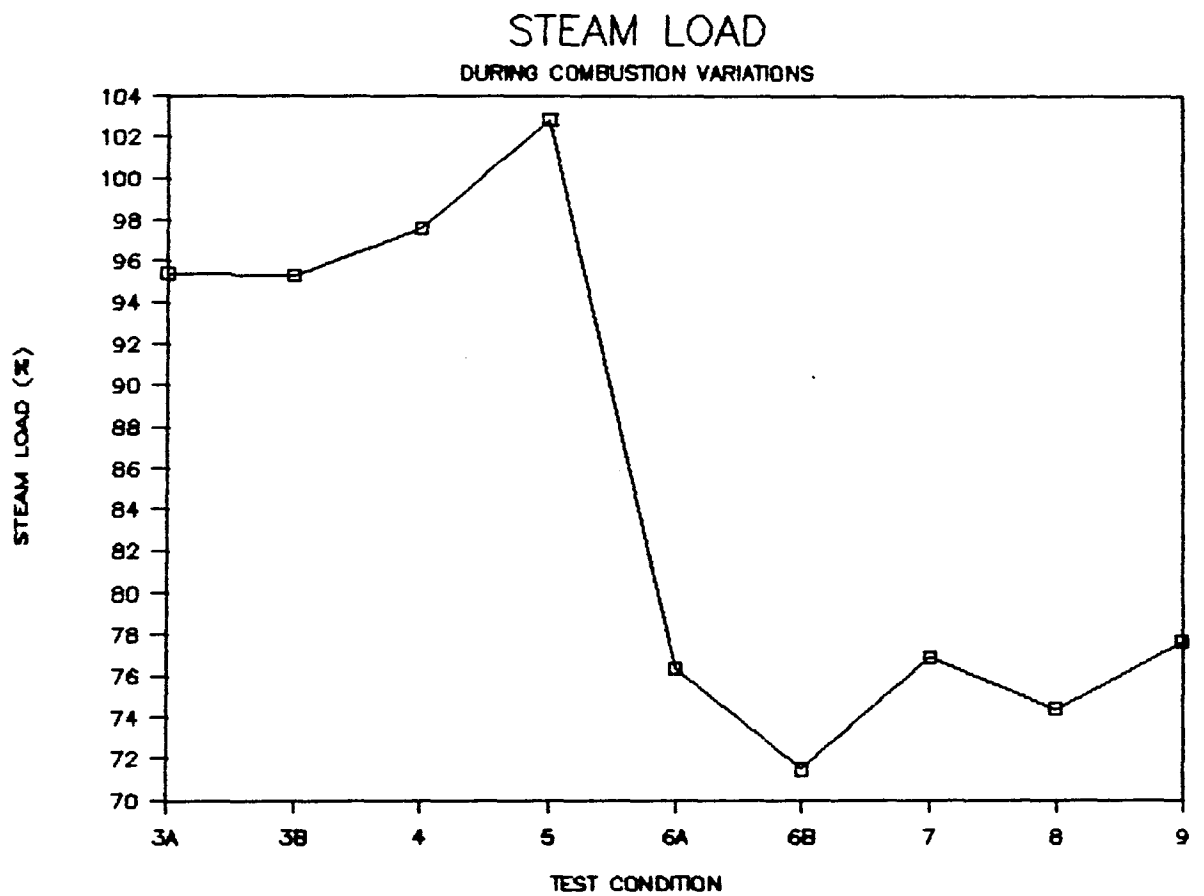


Figure 2-5. Variation of Steam Loading During the Combustor Evaluation

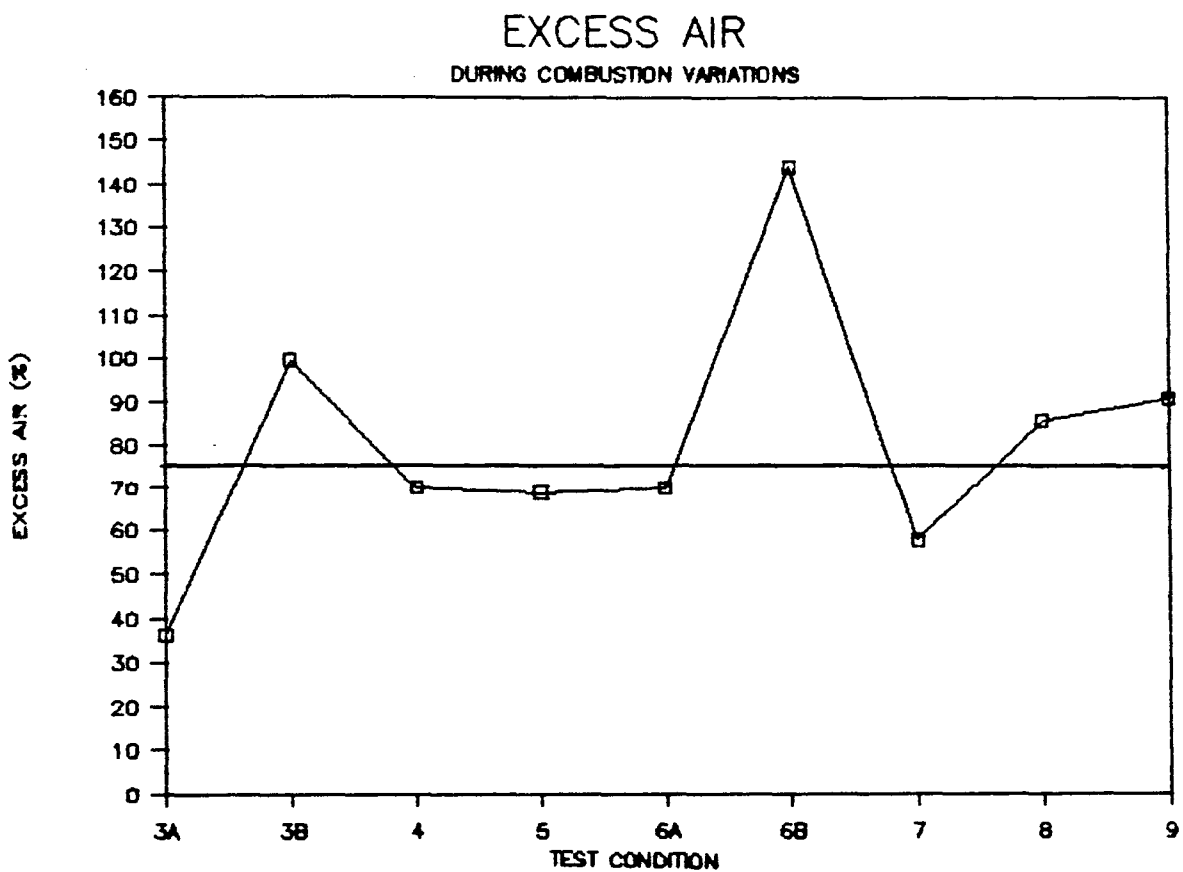


Figure 2-6. Variation of Excess Air During the Combustor Evaluation

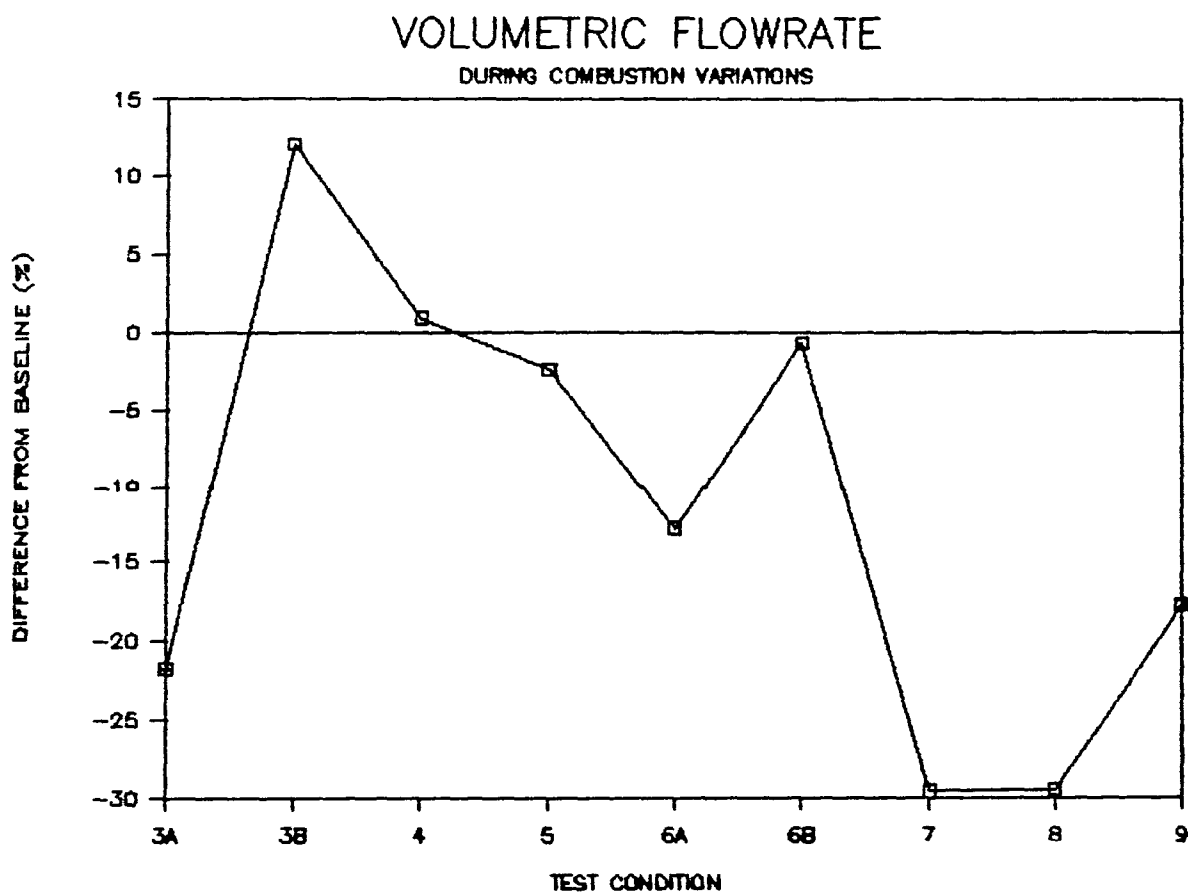


Figure 2-7. Variation of Volumetric Flowrate During the Combustor Evaluation

TABLE 2-14. FIXED GASES (CO, CO₂, O₂) AT COMBUSTOR EVALUATION TEST CONDITIONS

TEST CONDITION	1 BASE- LINE	2 BASE- LINE	3A LOW XS AIR	3B HIGH XS AIR	4 LOW O/F AIR	5 HIGH O/F AIR	6A LOW LOAD	6B LOW LOAD HI XS AIR	7 LOW LOAD Lo XS AIR	8 LOW LOAD LOW O/F	9 LOW LOAD HIGH O/F
<u>INLET ORSAT</u>											
O ₂ , %v, DRY	9.0	9.4	6.2	10.9	8.9	8.9	9.1	12.2	7.8	9.7	10.0
CO ₂ , %v, DRY	10.0	10.1	12.6	8.9	9.7	10.0	10.7	7.5	11.6	9.5	9.4
PERCENT EXCESS AIR	72.7	78.4	40.2	106	70.6	71.1	75.4	136	57.9	84.0	88.7
Fo ^a	1.19	1.15	1.17	1.13	1.24	1.20	1.10	1.16	1.13	1.17	1.16
<u>INLET CEM</u>											
O ₂ , %v, DRY	9.0	8.8	5.7	10.6	8.8	8.7	8.8	12.5	7.8	9.8	10.1
CO ₂ , %v, DRY	10.4	11.0	13.1	8.9	10.3	10.5	10.3	7.3	11.6	9.8	9.5
CO, ppmv, DRY	10.0	10.3	5.6	12.6	11.3	6.9	1.7	10.3	2.1	5.6	8.5
PERCENT EXCESS AIR	73.3	71.1	36.2	99.5	70.1	68.9	70.1	144	57.9	85.8	90.8
Fo ^a	1.14	1.10	1.16	1.16	1.17	1.16	1.17	1.15	1.13	1.13	1.14
<u>INLET AVERAGE^b</u>											
O ₂ , %v, DRY	9.0	9.1	6.0	10.8	8.9	8.8	9.0	12.4	7.8	9.8	10.1
CO ₂ , %v, DRY	10.2	10.6	12.9	8.9	10.0	10.3	10.5	7.4	11.6	9.7	9.5
CO, ppmv, DRY adjusted to 12 percent CO ₂	11.8	11.7	5.2	17.0	13.6	8.0	1.9	16.7	2.2	6.9	10.7
PERCENT EXCESS AIR	73.0	74.8	38.2	103	70.4	70.0	72.8	140	57.9	84.9	89.8
Fo ^a	1.17	1.13	1.17	1.15	1.21	1.18	1.14	1.16	1.13	1.15	1.15

^aFo = (20.9 - % O₂, dry) / (% CO₂, dry)^bAverage of inlet CEM and Orsat values.

for Run 6B and 10.8 percent by volume for Run 3B. Carbon dioxide concentration was lowest during these runs with an average CO₂ concentration for Run 6B of 7.4 percent by volume and an average CO₂ concentration for Run 3B of 8.9 percent by volume. This is primarily due to dilution from excess air. Excess air was 140 percent and 103 percent for Run 6B and 3B, respectively.

Test conditions 3A and 7 had the lowest oxygen concentrations and the highest CO₂ concentrations. These were both low excess air test conditions in which the excess air was 38.2 percent for Run 3A and 57.9 percent for Run 7.

Carbon monoxide concentrations at the boiler outlet were low across the spectrum of combustor variations made at the Marion County MWC. CO concentration (corrected to 12 percent CO₂) was lowest during Run 6A (low load) at 1.9 ppmv. The highest CO concentration observed was during Run 3B (low excess air), at 17.0 ppmv. Comparison of combustor temperatures with CO levels reveals that the five test conditions (6A, 7, 3A, 8, 5) exhibiting the lowest CO concentrations (corrected to 12 percent CO₂) corresponded to the five highest middle furnace temperatures. These temperatures ranged from 1733°F (Run 8) to 1895°F (Run 3A). All other mid-furnace temperatures ranged from 1490°F (Run 6B) to 1731°F (Run 4).

Figure 2-8 compares plots of CO, O₂ and CO₂ concentration at the boiler outlet with combustion air flow/steam load plots for Runs 2-9. Run 2 was chosen as a more representative baseline than Run 1 due to more stable process conditions and more consistent analyses. CO was particularly erratic during Run 3B (high excess air) and Run 4 (low overfire/underfire air distribution) and was also erratic during Run 2 (baseline), Run 6B (low load, high excess air) and Run 8 (low load, low overfire/underfire air distribution).

High CO spikes were observed near the end of Run 3A (low excess air) and at the middle and end of Run 6B (low load, high excess air). In Run 6B the CO spikes are attributed to a quench pit seal that broke during the test. Run 3A maintained steady low CO emissions through most of the test. The CO spikes in

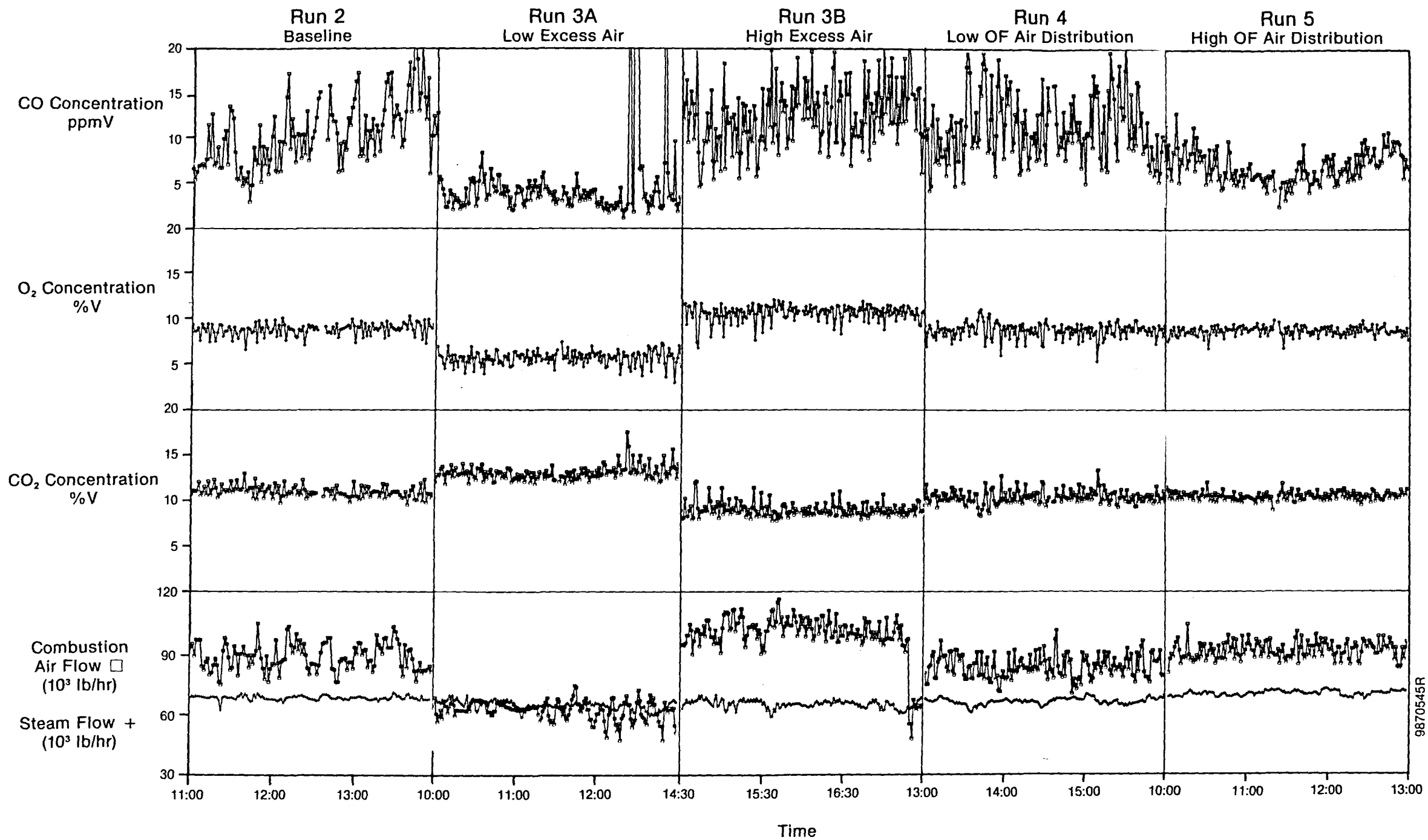


Figure 2-8. Fixed Gas Concentration Histories during the Combustion Evaluation

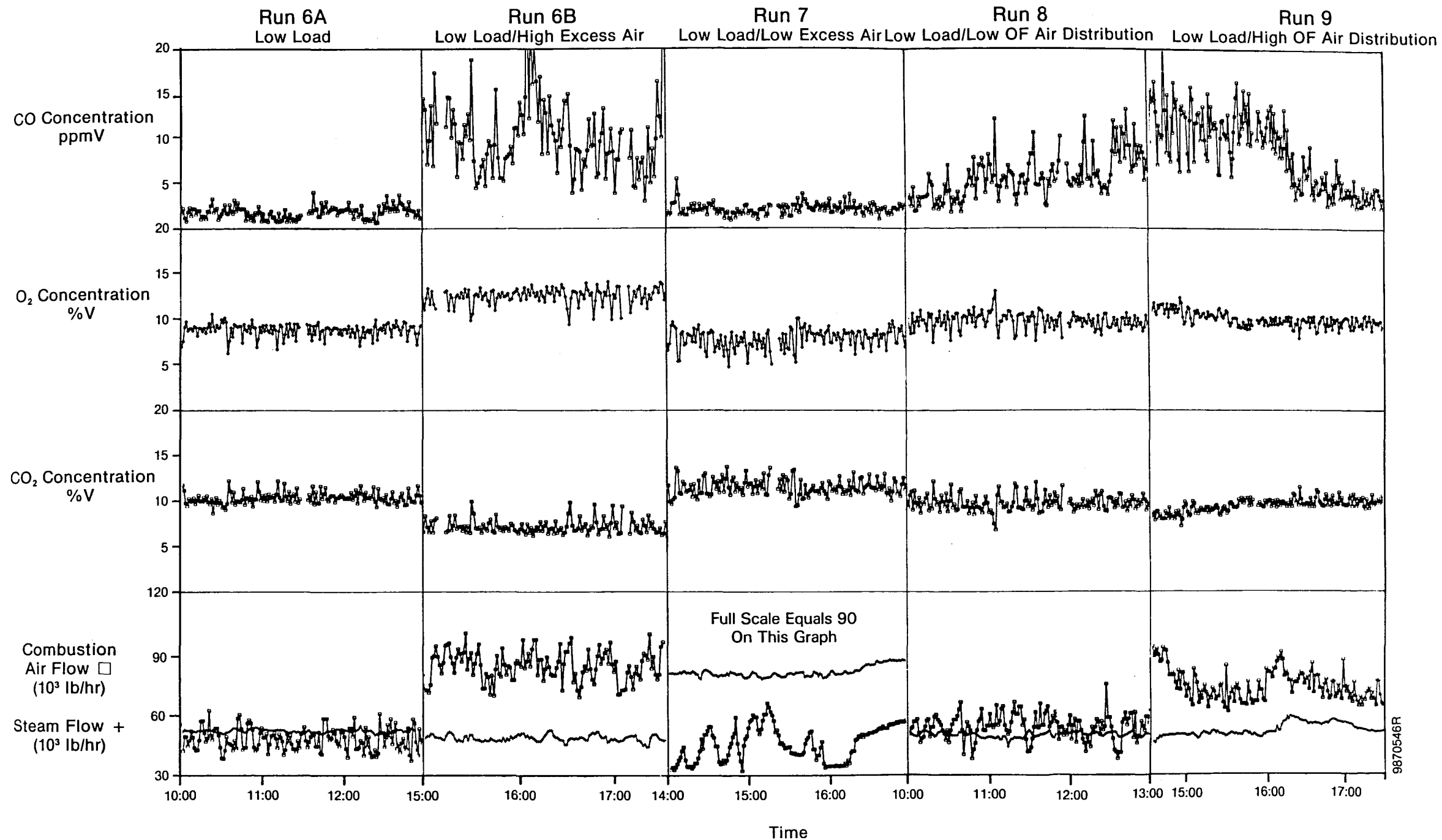


Figure 2-8. Fixed Gas Concentration Histories during the Combustion Evaluation
(continued)

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3A were caused by a blockage on the feed table. The CO spikes exhibited in Run 3A were also more pronounced than in Run 6B; typical CO concentrations during Run 3A were approximately 4.5 ppmv but the peaks reached as high as 95 ppmv, whereas during Run 6B there was a great deal of fluctuation. During the period of CO perturbation in Run 3A, oxygen concentration also showed some unusually low troughs and CO₂ exhibited several high peaks. Combustion air became more erratic during the Run 3A CO peaks and was generally lower than for the rest of the run. Steam load also seemed to be more unstable and decreased slightly during this period.

Oxygen and carbon dioxide levels varied from run to run due to the different air distributions. Generally, these concentrations were relatively stable, varying only one or two percent by volume. The greatest consistent fluctuations were seen in Test conditions 3B, 4, 6B, 8 and 7. With the exception of Run 7, these tests also exhibited erratic CO concentrations. The fluctuations in O₂ and CO₂ during Run 7 were caused by erratic ID fan behavior due to the low gas flowrates.

2.2.4 Additional Pollutants of Interest (NO_x and THC)

NO_x and THC concentrations during the combustor variations are presented in Table 2-15. During the combustor variations testing, NO_x mass flowrates decreased with lower load conditions. The average control device inlet NO_x for the low load conditions (Runs 6A, 6B, 7, 8, 9) was 35.0 lb/hr (RSD = 20.4 percent). During normal load conditions (Runs 1, 2, 3A, 3B, 4, 5) NO_x mass flowrates averaged 51.8 lb/hr (RSD = 16.0 percent), while the baseline conditions (Runs 1 & 2) averaged 58.8 lb/hr.

Non-condensable THC emissions during all of the test conditions were close to instrument detection limits. THC emissions for all runs were on the order of magnitude of a tenth of a pound per hour as propane. The combustor variations did not seem to affect the rate of hydrocarbon emissions at these levels.

TABLE 2-15. NO_x AND THC EMISSIONS FOR THE COMBUSTOR EVALUATION CONDITIONS

TEST CONDITION:	1 BASE- LINE	2 BASE- LINE	3A LOW XS AIR	3B HIGH XS AIR	4 LOW O/F AIR	5 HIGH O/F AIR	6A LOW LOAD Hi XS	6B LOW LOAD AIR	7 LOW LOAD Lo XS	8 LOW LOAD AIR	9 LOW LOAD LOW O/F HIGH O/F
INLET											
NO _x , ppmv, DRY	264	262	218	230	190	240	220	142	184	150	219
NO _x , ppmv @12% CO ₂	305	285	200	310	221	274	256	233	191	184	276
NO _x , lb/hr	57.7	59.9	40.4	56.1	43.3	53.6	44.6	32.3	30.8	25.7	42.0
OUTLET											
NO _x , ppmv, DRY	204	205	165	188	149	187	170	126	148	112	170
NO _x , ppmv @12% CO ₂	306	304	195	304	239	274	243	270	202	177	283
NO _x , lb/hr	63.0	59.2	38.6	61.1	42.4	54.2	37.0	37.8	30.9	24.9	43.5
INLET											
THC, ppmv as propane, DRY	NR	0.7	NR	NR	0.5	NR	1.6	0.9	NR	1.3	1.2
THC, ppmv as propane @12% CO ₂	NR	0.8	NR	NR	0.6	NR	1.9	1.5	NR	1.6	1.5
THC, lb/hr as propane	NR	0.2	NR	NR	0.1	NR	0.3	0.2	NR	0.2	0.2
OUTLET											
THC, ppmv as propane, DRY	0.6	0.4	0.6	0.4	0.4	0.4	NR	NR	NR	NR	NR
THC, ppmv as propane @12% CO ₂	0.9	0.6	0.7	0.6	0.6	0.0	0.0	0.0	NR	NR	NR
THC, lb/hr as propane	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	NR	NR	NR

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

2.2.5 Acid Gas Emissions

Acid gas concentrations during the combustor evaluation are presented in Tables 2-16 and 2-17. The average uncontrolled mass flowrates during low load conditions for SO₂ and HCl were 55.0 lb/hr SO₂ with a relative standard deviation of 34.0 percent and 73.6 lb/hr HCl with a relative standard deviation of 19.2 percent. (HCl average is based on combined CEM and manual method results.) During normal load conditions uncontrolled SO₂ mass flowrates averaged 105.9 lb/hr with a relative standard deviation of 38.6 percent while CEM and manual HCl tests gave an average uncontrolled HCl mass flowrate of 89.0 lb/hr with a standard deviation of 13.6 percent.

The control efficiencies and stoichiometric ratios during the combustor evaluation conditions are presented in Table 2-17. Combined SO₂ and HCl stoichiometric ratios (molar ratio of calcium supplied by the quench reactor to the theoretical calcium to react with inlet SO₂ and HCl) ranged from 1.07 to 2.50. The HCl control efficiencies for the overall control system ranged from 85.9 to 98.4 percent. SO₂ removal efficiency ranged from 25.3 percent to 92.5 percent.

2.2.6 CDD/CDF Concentration in the Ash

In Table 2-18, the CDD/CDF concentration and 2378-TCDD toxic equivalencies are presented for ash under combustor evaluation conditions. Ash samples were taken at the superheater, economizer, cyclone, and baghouse. The average results for ash at baseline conditions are also shown in Table 2-18 for comparison.

Total CDD concentrations during combustor variations were significantly different from baseline in at least one run for the superheater ash, economizer ash, and cyclone ash. The baghouse ash CDD concentrations were not significantly different than the baseline results for all the runs. The economizer ash was significantly higher at 37 ng/g of total CDD than baseline at 0.71 ng/g for Run 4. The superheater ash CDD concentrations were significantly higher than baseline in Runs 4 and 6A. In the cyclone ash, the CDD results for Runs 4, 6A and 6B were significantly lower than baseline.

TABLE 2-16. SUMMARY OF ACID GAS CONCENTRATIONS DURING THE COMBUSTOR EVALUATION

TEST CONDITION:	1 BASE- LINE	2 BASE- LINE	3A LOW XS AIR	3B HIGH XS AIR	4 LOW O/F AIR	5 HIGH O/F AIR	6A LOW LOAD H1 XS AIR	6B LOW LOAD Lo XS AIR	7 LOW LOAD LOW O/F	8 LOW LOAD HIGH O/F	9 LOW LOAD HIGH O/F
INLET SO ₂ , ppmv @12% CO ₂	559	299	428	523	120	425	340	275	281	210	168
MIDPOINT SO ₂ , ppmv @12% CO ₂	448	128	295	351	31.9	247	241	119	207	158	40.3
OUTLET SO ₂ , ppmv @12% CO ₂	383	99.5	186	237	9.9	158	185	52.5	139	87.5	21.3
INLET HCl, MANUAL, ppmv @12% CO ₂	462	502	385	NR	420	598	652	475	648	530	539
MIDPOINT HCl, MANUAL, ppmv @12% CO ₂	177	222	229	208	189	325	484	294	413	266	280
OUTLET HCl, MANUAL, ppmv @12% CO ₂	NR	37.6	53.8	65.4	13.1	66.3	72.7	49.3	80.9	50.5	30.2
INLET HCl, CEM, ppmv @12% CO ₂	646	631	496	704	648	729	693	625	653	568	642
MIDPOINT HCl, CEM, ppmv @12% CO ₂	225	183	177	160	162	110	225	92.5	225	186	204
OUTLET HCl, CEM, ppmv @12% CO ₂	83.7	35.0	49.9	47.7	11.5	45.5	69.6	27.4	67.2	39.5	19.7

Note: All values reported are normalized to 12% CO₂.

NR = Not reported due to invalidation.

TABLE 2-17. CONTROL DEVICE REMOVAL EFFICIENCIES DURING THE COMBUSTION EVALUATION

TEST CONDITION:	1 BASE- LINE	2 BASE- LINE	3A LOW XS AIR	3B HIGH XS AIR	4 LOW O/F AIR	5 HIGH O/F AIR	6A LOW LOAD	6B LOW LOAD H1 XS AIR	7 LOW LOAD Lo XS AIR	8 LOW LOAD LOW O/F	9 LOW LOAD HIGH O/F
INLET SO ₂ , ppmv, dry	484	274	468	388	103	372	292	167	272	172	133
INLET SO ₂ , lb/hr	147	87.4	121	132	32.8	116	82.3	53.1	63.2	41.0	35.4
INLET HCl, ppmV, dry ^a	480	519	481	522	458	581	577	335	629	448	467
INLET HCl, lb/hr ^a	83.0	94.3	70.6	101	82.8	103	92.7	60.4	83.1	60.9	71.1
STOICHIOMETRIC RATIO	1.08	1.33	1.26	1.07	2.22	1.14	1.40	2.24	1.62	2.50	2.36
<u>QUENCH REACTOR EFFICIENCY</u>											
PERCENT SO ₂ REDUCTION	17.5	55.9	26.0	23.1	74.5	41.7	39.1	55.7	29.8	24.7	77.3
PERCENT HCl REDUCTION, CEM	64.4	70.2	61.6	73.9	76.1	84.8	72.1	84.8	67.2	67.2	70.0
PERCENT HCl REDUCTION, MANUAL	60.7	54.5	35.8	NR	56.8	45.4	36.2	36.5	39.1	49.7	50.8
<u>FABRIC FILTER EFFICIENCY</u>											
PERCENT SO ₂ REDUCTION	9.4	30.1	42.8	34.6	70.7	35.6	21.9	56.5	33.1	44.4	43.4
PERCENT HCl REDUCTION, CEM	60.4	82.8	74.4	71.2	93.3	58.4	68.6	70.8	70.3	78.7	89.7
PERCENT HCl REDUCTION, MANUAL	NR	84.7	78.7	69.6	93.4	79.5	84.7	83.5	80.6	81.0	88.5
<u>OVERALL SYSTEM EFFICIENCY</u>											
PERCENT SO ₂ REDUCTION	25.3	69.2	57.6	49.7	92.5	62.4	52.5	80.7	53.0	58.2	87.1
PERCENT HCl REDUCTION, CEM	85.9	94.9	90.2	92.5	98.4	93.7	91.2	95.6	90.2	93.0	96.9
PERCENT HCl REDUCTION, MANUAL	NR	93.1	86.3	NR	97.2	88.8	90.2	89.5	88.2	90.4	94.3

NR = Not reported due to invalidation.

^a Average of CEM and manual results.

TABLE 2-18. CDD AND CDF CONCENTRATIONS AND 2378-TCDD TOXIC EQUIVALENCIES FOR
ASH FROM COMBUSTOR EVALUATION CONDITIONS AT MARION COUNTY MWC

Ash Type	Run 3B High EA	Run 4 Low OF Air	Run 6A Low Load	Run 6B Low Load High EA	Baseline Average
TOTAL CDD CONCENTRATION (ng/g)					
Superheater Ash	NC	1.78	6.91	0.926	0.400
Economizer Ash	0.277	37.1	0.634	0.520	0.710
Cyclone Ash	1.11	0.522	0.625	0.681	2.81
Baghouse Ash	1.74	1.84	2.18	2.33	4.59
TOTAL CDF CONCENTRATION (ng/g)					
Superheater Ash	NC	1.92	9.46	2.84	3.31
Economizer Ash	1.19	9.34	5.04	1.23	6.98
Cyclone Ash	1.65	2.08	1.71	0.863	1.88
Baghouse Ash	10.5	11.1	10.9	11.1	6.58
2378-TCDD TOXIC EQUIVALENT CONCENTRATION (ng/g)					
Superheater Ash	NC	0.022	0.176	0.036	0.030
Economizer Ash	0.015	0.589	0.047	0.009	0.085
Cyclone Ash	0.024	0.029	0.031	0.017	0.074
Baghouse Ash	0.119	0.141	0.113	0.115	0.148

EA = Excess air.

OF Air = Overfire air distribution.

NC = Not collected. Sample not collected during this run.

There were few significant variations from baseline for total CDF concentrations. Only in the economizer ash samples for Runs 3B and 6B did the concentrations significantly differ from baseline. These results were both lower than baseline. The 2378-TCDD toxic equivalent concentrations for the four types of ash were usually lower than the baseline results. Only for the economizer ash of Run 4 and the superheater ash of Run 6A was the toxic equivalency higher than baseline. For both ash samples, the toxic equivalency was approximately six times the baseline value. The baghouse ash results were similar to baseline results for all the runs, but were consistently lower.

The concentrations of the specific CDD/CDF congeners in the ash are shown in Tables 2-19 to 2-22. Each table shows the results for all the samples taken at a single sampling location. Congener distributions are presented graphically in Figures 2-9 and 2-10. Baseline congener distributions are distinguished by entirely shaded areas in Figures 2-9 and 2-10. Tables of the distributions are presented in Appendix A.1.2. Most of the CDD and CDF homologue distributions are fairly similar to baseline. For the economizer ash, the CDD homologue distributions for Runs 4, 5B and 6B are different from baseline. In Run 4 there is a greater fraction of lower chlorinated homologues than baseline. For Runs 3B and 6B, there are greater fractions of higher chlorinated homologues. The differences for Runs 3B and 6B may be from low homologue concentrations, however, with many congeners not detected.

2.3 EFFECT OF OFF-DESIGN TEMPERATURES IN THE EMISSION CONTROL SYSTEM

2.3.1 Acid Gas Emissions during Control Device Variations

During the control device evaluation portion of the characterization tests, the quench reactor outlet temperature was varied. The lime slurry feed rate is controlled based on the flue gas temperature at the quench reactor outlet. The quench reactor has two purposes: to reduce the temperature of the flue gas before entering the baghouse and to reduce HCl and SO₂ emissions. The stoichiometric ratio (molar ratio of calcium supplied by the quench reactor to the theoretical calcium to react with the inlet SO₂ and HCl) and quench reactor outlet temperature cannot be independently controlled.

TABLE 2-19. CDD AND CDF RESULTS FOR SUPERHEATER ASH AT COMBUSTOR EVALUATION CONDITIONS

TEST CONDITIONS	3B	4	Run Number		Baseline
			6A	6B	
Combustor					
Load (lb/hr steam)	Normal	Normal	Low	Low	Normal
Excess Air	High	Normal	Normal	High	Normal
Overfire Air					
Distribution	Normal	Low	Normal	Normal	Normal
Control Device					
Quench Reactor Outlet					
Temperature	Normal	Normal	Normal	Normal	----
CDD/CDF CONCENTRATION (ng/g)					
Isomer	3B	4	Run Number		Baseline ^a
			6A	6B	
DIOXINS					
Mono-CDD		(0.003) ^b	(0.001)	(0.001)	(0.001)
Di-CDD		[0.012]	[0.023]	[0.022]	[0.009]
Tri-CDD		0.056	0.318	0.091	[0.054]
2378 TCDD		[0.006]	0.021	0.011	0.008
Other TCDD		0.174	0.810	0.161	0.049
12378 PCDD		0.011	0.118	[0.025]	[0.006]
Other PCDD		0.330	1.14	0.155	0.017
123478 HxCDD		0.010	0.108	0.014	[0.003]
123678 HxCDD		[0.019]	0.162	0.019	[0.004]
123789 HxCDD		0.033	0.273	0.041	[0.011]
Other HxCDD		0.537	1.30	0.098	0.025
1234678 HpCDD		0.138	0.765	0.083	0.061
Other HpCDD		0.190	0.820	0.093	0.049
Octa-CDD	N	0.300	1.07	0.160	0.191
Total CDD	O T	1.78	6.91	0.926	0.400
FURANS					
	C				
Mono-CDF	O	(0.001)	(0.001)	(0.001)	(0.001)
Di-CDF	L	[0.056]	0.091	0.028	[0.240]
Tri-CDF	L	0.334	1.78	0.535	1.04
2378 TCDF	E	0.040	0.120	0.040	0.070
Other TCDF	C	0.685	2.54	0.719	0.952
12378 PCDF	T	[0.046]	0.146	0.051	0.066
23478 PCDF	E	0.044	0.199	0.064	0.052
Other PCDF	D	0.312	1.56	0.548	0.309
123478 HxCDF		0.077	0.458	0.136	0.063
123678 HxCDF		0.030	0.198	0.061	0.040
234678 HxCDF		0.026	0.137	0.044	0.045
123789 HxCDF		(0.003)	(0.003)	[0.012]	0.004
Other HxCDF		0.129	0.914	0.245	0.159
1234678 HpCDF		0.108	0.833	0.228	0.112
1234789 HpCDF		0.011	0.046	[0.014]	0.041
Other HpCDF		0.053	0.234	0.076	0.099
Octa-CDF		0.075	0.201	0.068	0.259
Total CDF		1.92	9.46	2.84	3.31
Total CDD/CDF		3.70	16.4	3.77	3.71

^aBaseline is Run 11B results.^bNot detected. Detection limit given in parentheses; estimated maximum possible concentration (EMPC) given in brackets.

TABLE 2-20. CDD AND CDF RESULTS FOR ECONOMIZER ASH AT COMBUSTOR EVALUATION CONDITIONS

TEST CONDITIONS	Run Number				Baseline
	3B	4	6A	6B	
Combustor					
Load (lb/hr steam)	Normal	Normal	Low	Low	Normal
Excess Air	High	Normal	Normal	High	Normal
Overfire Air					
Distribution	Normal	Low	Normal	Normal	Normal
Control Device					
Quench Reactor Outlet Temperature	Normal	Normal	Normal	Normal	----

CDD/CDF CONCENTRATION (ng/g)					
Isomer	Run Number				Baseline ^a
	3B	4	6A	6B	
DIOXINS					
Mono-CDD	(0.003) ^b	(0.003)	(0.003)	(0.003)	(0.003)
Di-CDD	(0.003)	1.15	[0.017]	(0.003)	(0.003)
Tri-CDD	[0.023]	6.36	[0.075]	(0.003)	0.030
2378 TCDD	[0.037]	0.260	0.014	[0.003]	0.013
Other TCDD	0.024	8.16	0.087	0.015	0.099
12378 PCDD	0.006	0.198	[0.017]	0.005	0.023
Other PCDD	0.000	7.78	0.043	0.000	0.100
123478 HxCDD	(0.003)	0.179	[0.011]	[0.003]	0.011
123678 HxCDD	(0.003)	0.278	[0.010]	[0.005]	[0.009]
123789 HxCDD	(0.005)	0.731	[0.029]	0.016	0.016
Other HxCDD	[0.052]	5.75	0.070	0.027	0.052
1234678 HpCDD	0.025	1.40	0.089	0.085	0.081
Other HpCDD	0.021	2.21	0.082	0.068	0.080
Octa-CDD	0.201	2.66	0.249	0.304	0.208
Total CDD	0.277	37.1	0.634	0.520	0.710
FURANS					
Mono-CDF	(0.003)	[0.050]	[0.012]	(0.001)	(0.003)
Di-CDF	(0.008)	[0.605]	0.135	(0.005)	[0.475]
Tri-CDF	0.495	1.50	1.64	0.104	1.91
2378 TCDF	0.090	0.160	0.100	[0.04]	0.220
Other TCDF	0.403	2.51	1.72	0.257	2.16
12378 PCDF	[0.021]	0.106	0.095	0.017	0.144
23478 PCDF	0.018	0.185	0.081	0.027	0.153
Other PCDF	0.101	1.44	0.561	0.123	0.856
123478 HxCDF	0.025	0.359	0.110	0.054	0.178
123678 HxCDF	0.011	0.120	0.052	0.023	0.075
234678 HxCDF	(0.003)	0.242	0.042	0.039	0.099
123789 HxCDF	(0.003)	0.095	[0.007]	(0.003)	[0.007]
Other HxCDF	0.005	0.579	0.194	0.056	0.375
1234678 HpCDF	0.040	0.705	0.150	0.122	0.356
1234789 HpCDF	(0.003)	0.099	[0.015]	0.033	0.037
Other HpCDF	0.004	0.452	0.067	0.090	0.189
Octa-CDF	[0.023]	0.791	0.090	0.285	0.225
Total CDF	1.19	9.34	5.04	1.23	6.98
Total CDD/CDF	1.47	46.5	5.68	1.75	7.69

^aConcentration of baseline ash is the average of duplicate analyses for Run 11B.^bNot detected. Detection limit given in parentheses; estimated maximum possible concentration (EMPC) given in brackets.

TABLE 2-21. CDD AND CDF RESULTS FOR CYCLONE ASH AT COMBUSTOR EVALUATION CONDITIONS

TEST CONDITIONS	3B	4	Run Number		Baseline
			6A	6B	
Combustor					
Load (lb/hr steam)	Normal	Normal	Low	Low	Normal
Excess Air	High	Normal	Normal	High	Normal
Overfire Air					
Distribution	Normal	Low	Normal	Normal	Normal
Control Device					
Quench Reactor Outlet					
Temperature	Normal	Normal	Normal	Normal	Normal
CDD/CDF CONCENTRATION (ng/g)					
Isomer	3B	4	Run Number		Baseline ^a
			6A	6B	
DIOXINS					
Mono-CDD	(0.001) ^b	(0.001)	(0.001)	(0.001)	(0.001)
Di-CDD	[0.002]	(0.001)	(0.001)	(0.003)	0.014
Tri-CDD	[0.043]	[0.050]	0.012	0.011	0.056
2378 TCDD	0.012	[0.010]	0.008	0.005	0.014
Other TCDD	0.126	0.064	0.031	0.024	0.164
12378 PCDD	[0.021]	0.011	0.011	0.007	0.040
Other PCDD	0.217	0.077	0.103	0.088	0.388
123478 HxCDD	0.012	0.006	0.007	0.007	0.026
123678 HxCDD	0.036	[0.018]	0.021	0.021	0.084
123789 HxCDD	0.046	0.021	0.026	0.027	0.076
Other HxCDD	0.154	0.084	0.096	0.095	0.764
1234678 HpCDD	0.168	0.086	0.097	0.122	0.383
Other HpCDD	0.139	0.066	0.080	0.089	0.341
Octa-CDD	0.201	0.107	0.133	0.185	0.456
Total CDD	1.11	0.522	0.625	0.681	2.81
FURANS					
Mono-CDF	(0.001)	(0.001)	[0.001]	(0.001)	0.004
Di-CDF	[0.025]	[0.036]	(0.003)	[0.007]	(0.444)
Tri-CDF	0.331	0.645	0.486	0.225	0.712
2378 TCDF	[0.06]	0.100	0.060	0.020	0.160
Other TCDF	0.639	0.798	0.623	0.241	0.378
12378 PCDF	[0.042]	0.051	0.030	0.020	0.032
23478 PCDF	0.037	0.038	0.035	[0.023]	0.070
Other PCDF	0.273	0.229	0.216	0.129	0.202
123478 HxCDF	0.064	0.044	0.048	0.041	0.042
123678 HxCDF	0.035	0.022	0.021	0.020	0.020
234678 HxCDF	0.026	0.015	0.017	[0.015]	0.041
123789 HxCDF	(0.001)	(0.001)	(0.001)	(0.001)	0.002
Other HxCDF	0.104	0.066	0.071	0.056	0.089
1234678 HpCDF	0.102	0.057	0.090	0.083	0.065
1234789 HpCDF	[0.004]	[0.003]	[0.003]	[0.004]	0.002
Other HpCDF	0.020	0.015	0.015	0.010	0.017
Octa-CDF	0.021	[0.013]	[0.015]	0.018	0.044
Total CDF	1.65	2.08	1.71	0.863	1.88
Total CDD/CDF	2.76	2.60	2.34	1.54	4.69

^a Baseline is average of Emission Test and Method Study results.^b Not detected. Detection limit given in parentheses; estimated maximum possible concentration (EMPC) given in brackets.

TABLE 2-22. CDD AND CDF RESULTS FOR BAGHOUSE ASH AT COMBUSTOR EVALUATION CONDITIONS

TEST CONDITIONS	3B	4	Run Number		Baseline
			6A	6B	
Combustor					
Load (lb/hr steam)	Normal	Normal	Low	Low	Normal
Excess Air	High	Normal	Normal	High	Normal
Overfire Air					
Distribution	Normal	Low	Normal	Normal	Normal
Control Device					
Quench Reactor Outlet					
Temperature	Normal	Normal	Normal	Normal	Normal
CDD/CDF CONCENTRATION (ng/g)					
Isomer	3B ^a	4	Run Number		Baseline ^b
			6A	6B	
DIOXINS					
Mono-CDD	(0.005) ^c	(0.001)	(0.001)	[0.103]	(0.001)
Di-CDD	[0.059]	[0.056]	[0.081]	0.035	0.025
Tri-CDD	0.142	[0.244]	0.203	0.203	0.142
2378 TCDD	0.028	0.035	0.029	(0.003)	0.020
Other TCDD	0.268	0.330	0.282	0.282	0.270
12378 PCDD	0.037	0.042	0.036	0.040	0.055
Other PCDD	0.227	0.311	0.302	0.261	0.550
123478 HxCDD	0.011	0.022	0.022	0.024	0.052
123678 HxCDD	0.045	0.054	0.047	0.046	0.099
123789 HxCDD	0.073	0.082	0.070	0.074	0.090
Other HxCDD	0.201	0.165	0.384	0.364	1.10
1234678 HpCDD	0.227	0.255	0.256	0.290	0.622
Other HpCDD	0.196	0.201	0.215	0.278	0.605
Octa-CDD	0.288	0.347	0.333	0.437	0.959
Total CDD	1.74	1.84	2.18	2.33	4.59
FURANS					
Mono-CDF	[0.026]	[0.006]	0.014	0.019	0.010
Di-CDF	0.037	0.104	0.021	2.330	0.276
Tri-CDF	3.30	3.60	4.47	4.25	2.59
2378 TCDF	0.200	0.280	0.230	0.520	0.516
Other TCDF	4.16	4.33	3.76	2.27	1.42
12378 PCDF	0.186	0.197	0.118	0.172	0.086
23478 PCDF	0.151	0.160	0.123	0.145	0.189
Other PCDF	1.41	1.47	1.21	0.786	0.700
123478 HxCDF	0.214	0.168	0.148	0.156	0.094
123678 HxCDF	0.099	0.096	0.077	0.076	0.048
234678 HxCDF	0.038	0.066	0.060	[0.066]	0.157
123789 HxCDF	(0.010)	(0.003)	0.010	(0.003)	(0.048)
Other HxCDF	0.398	0.392	0.332	0.064	0.192
1234678 HpCDF	0.273	0.164	0.188	0.236	0.148
1234789 HpCDF	0.005	0.013	0.014	[0.018]	0.024
Other HpCDF	0.030	0.017	0.050	0.078	0.046
Octa-CDF	[0.134]	0.034	0.044	[0.064]	0.083
Total CDF	10.5	11.1	10.9	11.1	6.58
Total CDD/CDF	12.2	12.9	13.1	13.4	11.2

^aConcentration for Run 3B ash is the average of duplicate analyses.^bBaseline is average of Emission Test and Method Study results.^cNot detected. Detection limit given in parentheses; estimated maximum possible concentration (EMPC) given in brackets.

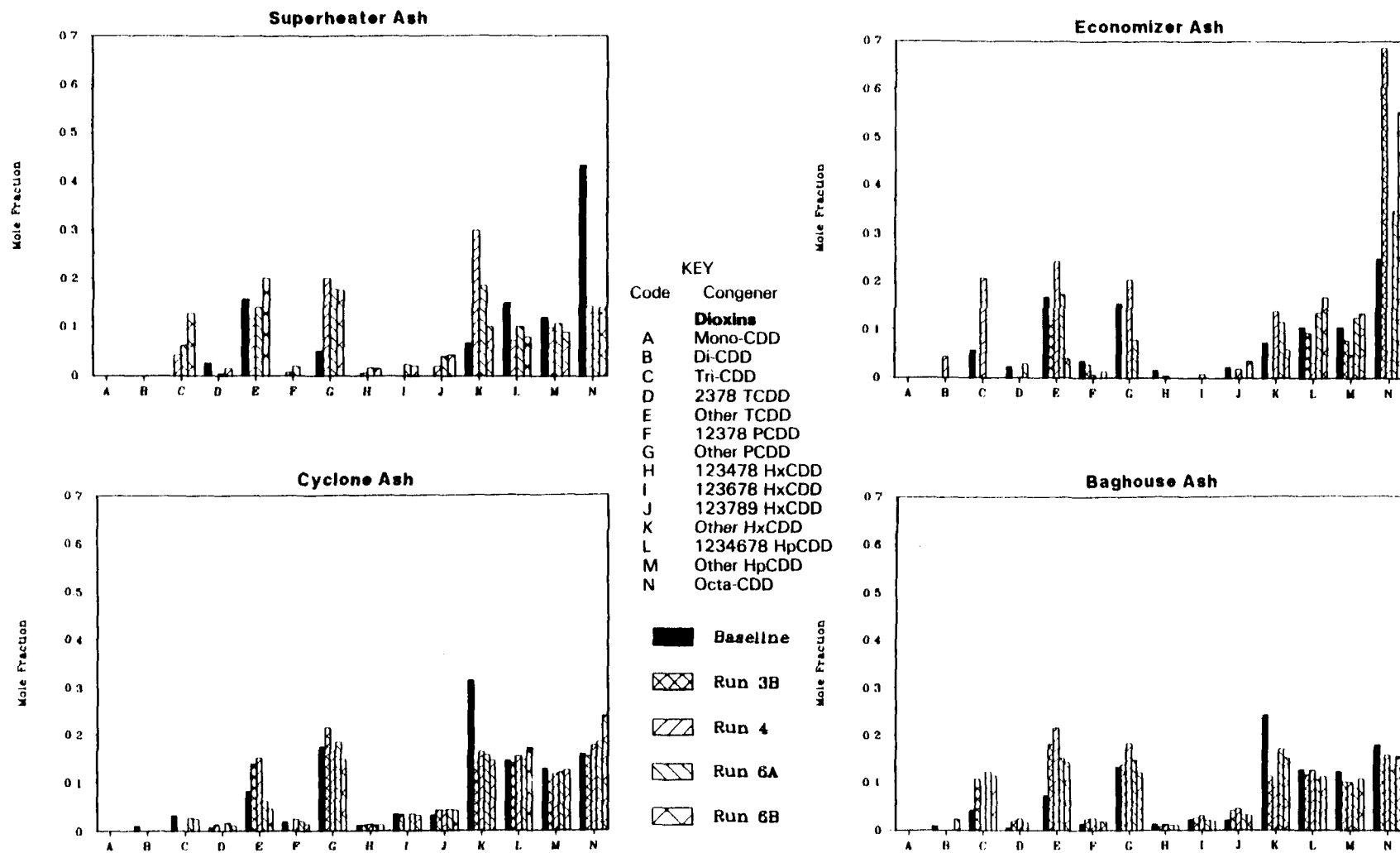


Figure 2-9. Ash CDD Congener Distributions

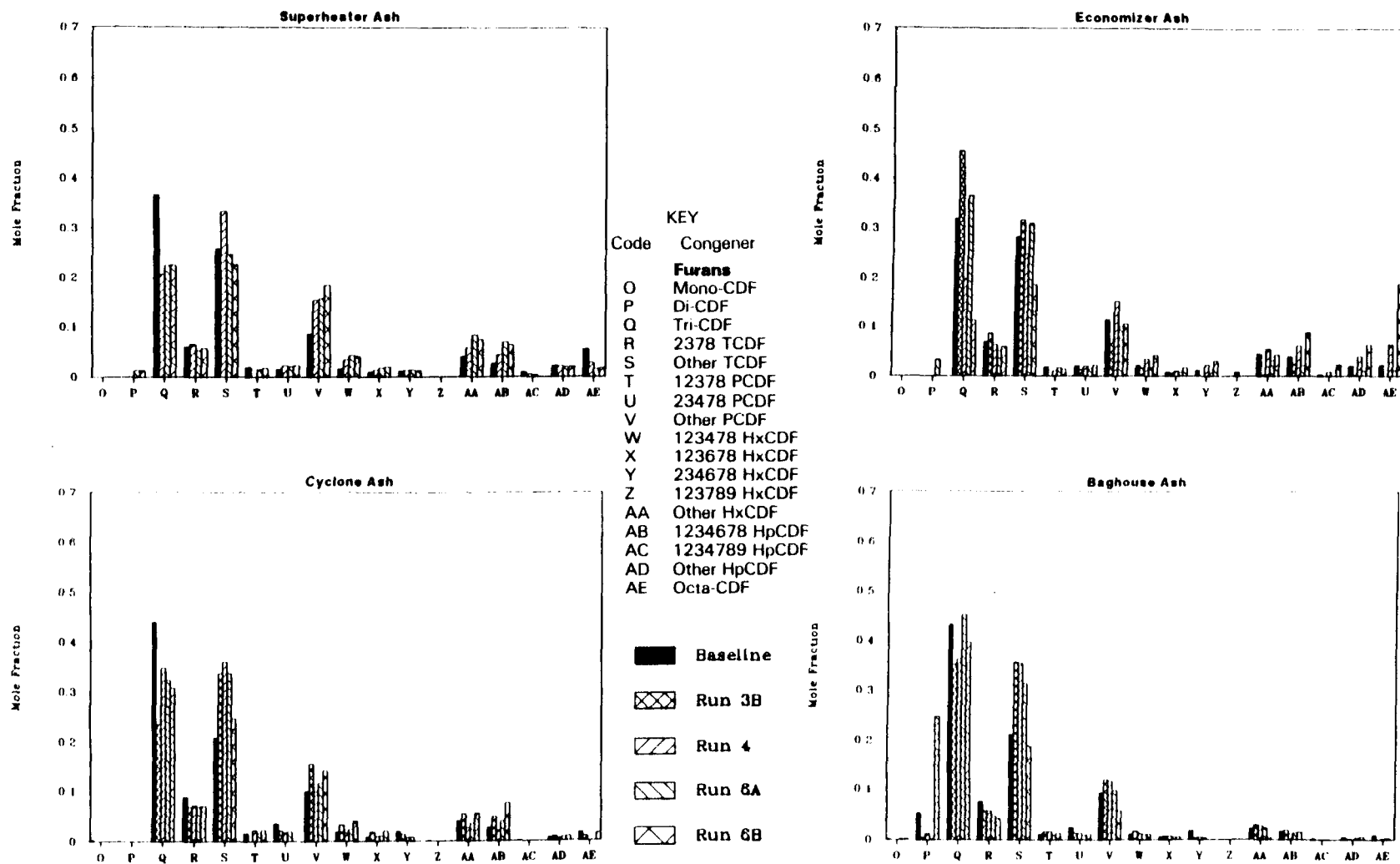


Figure 2-10. Ash CDF Congener Distributions

During baseline conditions (Runs 1 and 2) the quench reactor outlet temperature was 300°F. Test condition 10 had a lower than design quench reactor outlet temperature of 262°F, which corresponds to an increased rate of lime slurry injection. Runs 11A and 11B had increased quench reactor outlet temperatures of 330°F and 360°F respectively. These higher temperatures are due to decreased lime slurry injection, with Run 11B having the lowest rate.

Two parameters which may affect acid gas removal efficiency are: inlet acid gas concentration and the injection rate of lime. These two variables may be combined to form the stoichiometric ratio (molar ratio of supplied calcium to acid gas) which is a major influence on acid gas reduction efficiency. HCl and SO₂ concentrations during the control device evaluations are presented in Table 2-23. The acid gas stoichiometric ratios and control efficiencies are also summarized in Table 2-23. The stoichiometric ratios for Runs 10, 11A, and 11B were 1.14, 1.06, and 1.59 respectively.

Figure 2-11 compares HCl and SO₂ inlet gas concentration to reduction efficiencies. Only data from Run 2 are used to show baseline because inlet SO₂ concentrations for Run 1 are atypically high, causing a lower stoichiometric ratio than normally used. These plots indicate that as acid gas concentration increases, efficiency decreases. Peaks in SO₂ and HCl correspond to lows in the respective efficiency plots. SO₂ concentration seems to more dramatically affect efficiency than HCl; however, SO₂ concentration varies more than HCl. These plots also indicate that the control device removes HCl more effectively than SO₂. Efficiency increased for both HCl and SO₂ during Run 10. HCl and SO₂ reduction efficiencies were decreased during Runs 11A and 11B.

2.3.2 Temperature Profile during Control Device Variations

The temperature profile results for off-design temperatures in the control system are presented in Table 2-24. Also included in Table 2-24 is the difference from the baseline average, which is shown graphically in Figure 2-12.

TABLE 2-23. ACID GAS BEHAVIOR FOR THE CONTROL DEVICE EVALUATION TESTING

TEST CONDITION	1 BASE- LINE	2 BASE- LINE	10 LOW QR OUT T.	11A HIGH QR OUT T.	11B HIGH QR OUT T.
INLET SO ₂ , ppmv, dry	484	274	328	415	108
INLET SO ₂ , lb/hr	147	87.4	99.9	125	35.5
INLET HCl, ppmv, dry ^a	480	519	699	646	695
INLET HCl, lb/hr ^a	83.0	94.3	60.5	111	130
STOICHIOMETRIC RATIO	1.08	1.33	1.14	1.06	1.59
INLET SO ₂ , ppmv @12% CO ₂	559	299	383	470	118
MIDPOINT SO ₂ , ppmv @12% CO ₂	450	128	326	523	178
OUTLET SO ₂ , ppmv @12% CO ₂	383	99.5	108	484	165
INLET HCl, MANUAL, ppmv @12% CO ₂	462	502	NR	745	767
MIDPOINT HCl, MANUAL, ppmv @12% CO ₂	177	222	229	408	545
OUTLET HCl, MANUAL, ppmv @12% CO ₂	NR	37.6	23.4	172	228
INLET HCl, CEM, ppmv @12% CO ₂	646	631	814	718	750
MIDPOINT HCl, CEM, ppmv @12% CO ₂	225	183	180	295	313
OUTLET HCl, CEM, ppmv @12% CO ₂	83.7	35.0	20.4	158	214
<u>QUENCH REACTOR EFFICIENCY</u>					
PERCENT SO ₂ REDUCTION	17.5	55.9	18.2	-14.6 ^b	-37.9 ^b
PERCENT HCl REDUCTION, CEM	64.4	70.2	78.8	57.6	61.7
PERCENT HCl REDUCTION, MANUAL	60.7	54.5	NR	43.6	34.8
<u>FABRIC FILTER EFFICIENCY</u>					
PERCENT SO ₂ REDUCTION	9.4	30.1	66.8	13.5	14.2
PERCENT HCl REDUCTION, CEM	60.4	82.8	88.6	50.2	36.8
PERCENT HCl REDUCTION, MANUAL	NR	84.7	89.8	60.6	61.3
<u>OVERALL SYSTEM EFFICIENCY</u>					
PERCENT SO ₂ REDUCTION	25.3	69.2	72.9	0.9	-18.3 ^b
PERCENT HCl REDUCTION, CEM	85.9	94.9	97.6	78.9	75.8
PERCENT HCl REDUCTION, MANUAL	NR	93.1	NR	77.8	74.8

Note: All values are reported on a dry basis.

NR = Not reported due to invalidation.

^a Average of CEM and manual results.

^b Instrument inaccuracies because of measuring low concentrations while calibrated with a large span and differences between individual analyzers are responsible for the differences in SO₂ concentration at the three locations. These values should be considered equivalent and indicate that no significant removal of SO₂ took place during these runs.

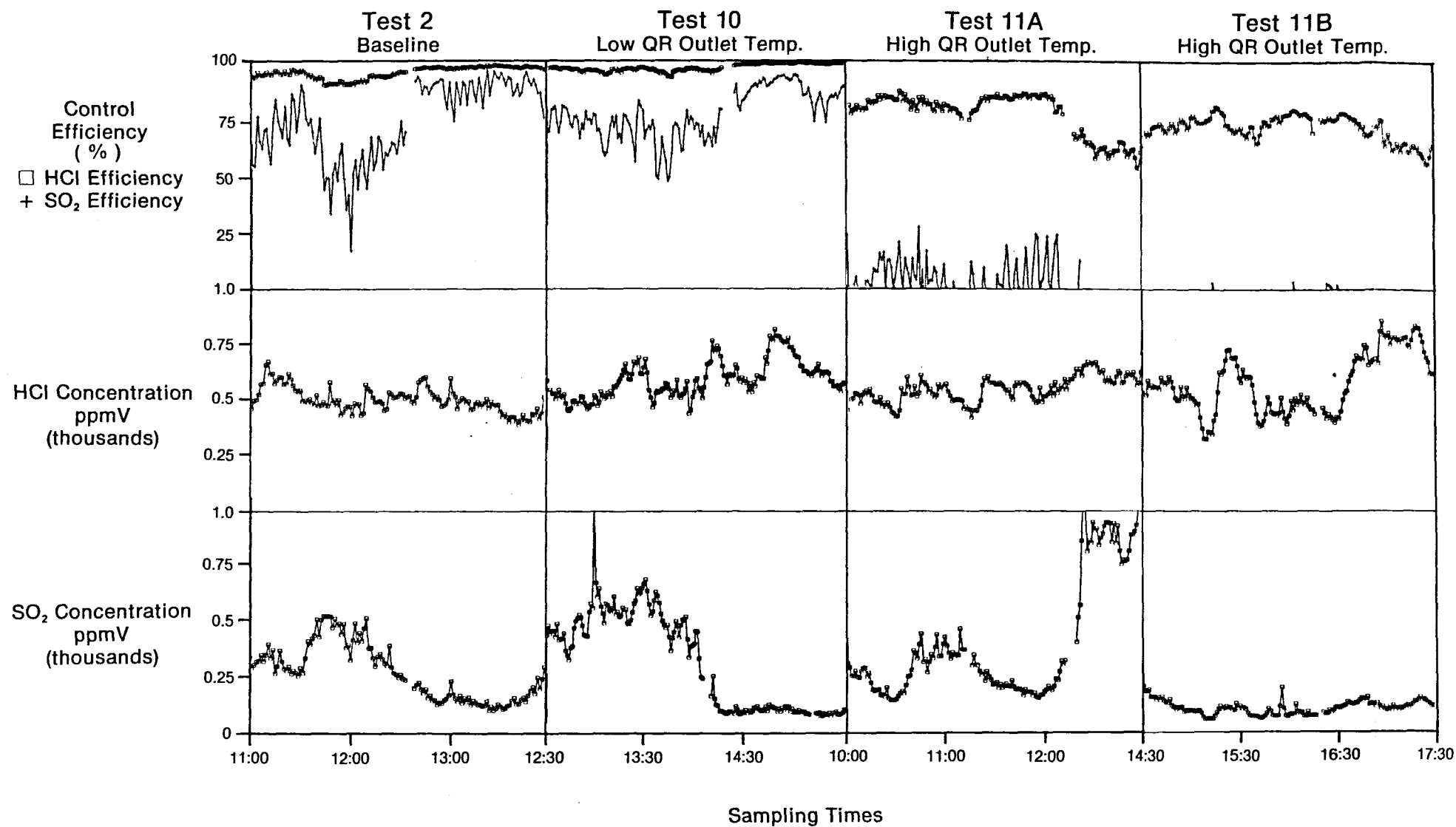


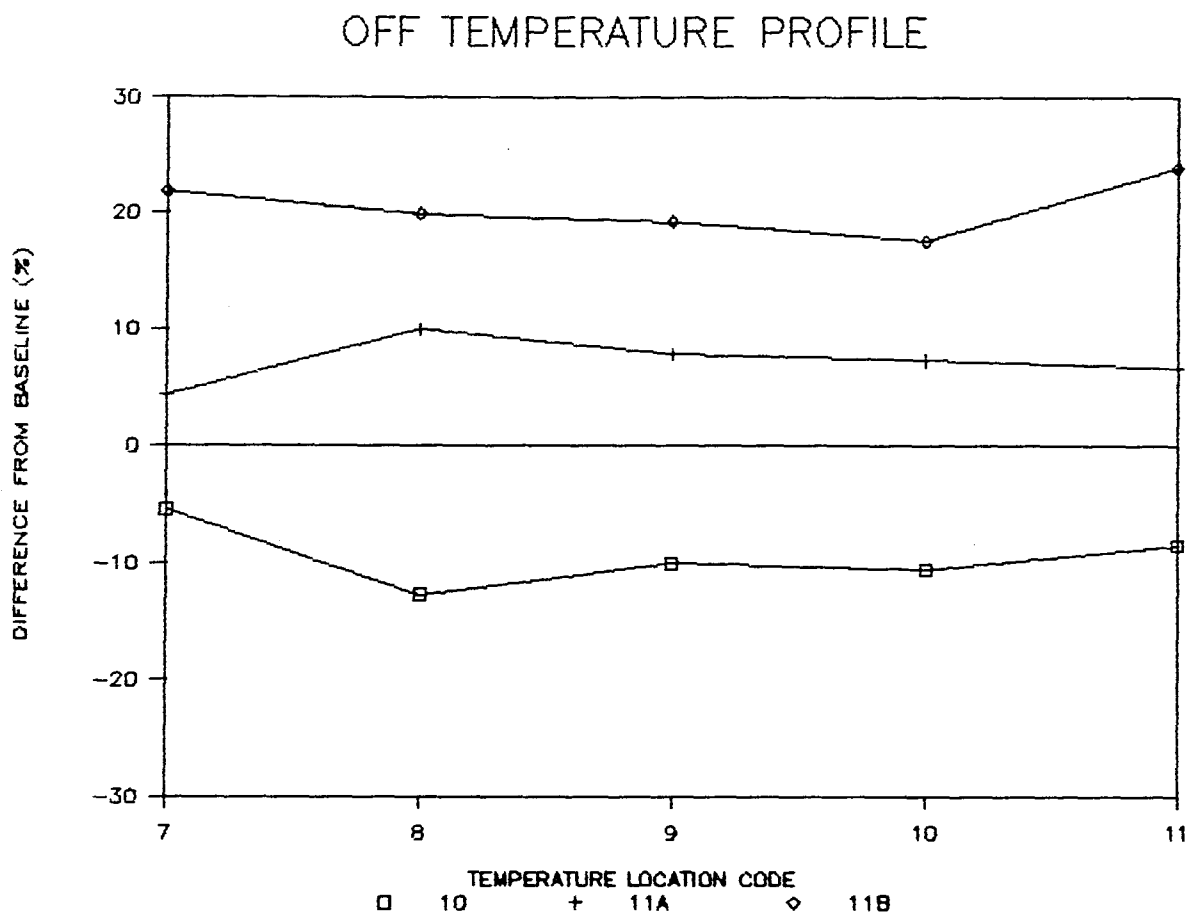
Figure 2-11. Effect of Acid Gas Concentration on Control Efficiency

9870547R

TABLE 2-24. TEMPERATURE PROFILE AND DIFFERENCE FROM BASELINE

=====				=====			
LOCATION		10	11A	11B	10	11A	11B
CODE		LOW QUENCH	HIGH QUENCH	HIGH QUENCH	LOW QUENCH	HIGH QUENCH	HIGH QUENCH
		TEMPERATURE	TEMPERATURE	TEMPERATURE	TEMPERATURE	TEMPERATURE	TEMPERATURE
=====				=====			
TEMPERATURES, deg. F:							
7	MIDPOINT SAMPLING LOCATION	281	310	362	-5	4	22
8	QUENCH REACTOR OUTLET	262	330	360	-13	10	20
9	BAGHOUSE OUTLET	252	302	334	-10	8	19
10	ID FAN INLET	254	305	334	-11	7	18
11	BREECHING TO OUTLET STACK	260	303	352	-8	7	24
=====				=====			

Difference (percent) = (run value - baseline)/baseline * 100%.



- 7. Midpoint sampling location
- 8. Quench reactor outlet
- 9. Baghouse outlet
- 10. I.D. fan inlet
- 11. Breeching to outlet stack

Figure 2-12. Temperature Profile for After the Quench Reactor for Control Device Evaluation Conditions

During the low temperature condition (Run 10), the quench reactor outlet temperature was 13 percent below baseline. The moderately high temperature condition (Run 11A) was 10 percent above baseline and the high temperature condition (Run 11B) was 20 percent above baseline.

2.3.3 Fixed Gases (CO, CO₂, O₂) and Additional Pollutants of Interest (NO_x and THC)

During the control device evaluation runs (10, 11A, and 11B) no furnace or combustion parameters were altered. Since the control device does not significantly affect CO, O₂, CO₂, NO_x or THC levels in the flue gas, other than by leakage, the control device evaluation runs may be considered baseline runs for fixed gas emissions at the boiler outlet. Therefore CO₂, O₂ and CO concentrations for these tests are discussed in Section 2.1.4 and NO_x and THC are discussed in Section 2.1.5 as baseline conditions.

2.3.4 CDD/CDF Concentrations in Ash during Control Device Variations

In Table 2-25, the CDD/CDF concentrations and 2378-TCDD toxic equivalencies are presented for the ash under control device evaluation conditions. Ash samples were taken at the baghouse for Runs 10, 11A, and 11B, and at the cyclone for Run 11B. The ash samples from the superheater and economizer were not analyzed, since these would not be affected by off-design temperatures in the emission control system. The results for ash at baseline conditions are shown also in Table 2-25.

The total CDD concentrations were 0.90 ng/g for Run 11B cyclone ash and ranged from 1.22 ng/g for Run 11A baghouse ash to 1.9 ng/g for Run 11B baghouse ash. The total CDF concentrations were 1.24 ng/g for Run 11B cyclone ash and ranged from 3.80 ng/g for Run 10 baghouse ash to 8.33 ng/g for Run 11B baghouse ash. The total CDF concentrations were not significantly different from baseline for any of the test conditions or sampling locations. The total CDD concentrations were significantly lower than baseline for all samples except for Run 11B baghouse ash. Similar to the total CDD concentrations, the

TABLE 2-25. CDD AND CDF CONCENTRATIONS AND 2378-TCDD TOXIC EQUIVALENCIES FOR
ASH FROM CONTROL DEVICE EVALUATION CONDITIONS AT MARION COUNTY MWC

Ash Type	Run 10 Low QR Outlet Temp.	Run 11A High QR Outlet Temp.	Run 11B High QR Outlet Temp.	Baseline Average
TOTAL CDD CONCENTRATION (ng/g)				
Cyclone Ash	NA	NA	0.903	2.81
Baghouse Ash	1.30	1.22	1.90	4.59
TOTAL CDF CONCENTRATION (ng/g)				
Cyclone Ash	NA	NA	1.24	1.88
Baghouse Ash	3.80	5.47	8.33	6.58
2378-TCDD TOXIC EQUIVALENT CONCENTRATION (ng/g)				
Cyclone Ash	NA	NA	0.015	0.074
Baghouse Ash	0.019	0.036	0.077	0.148

QR = Quench reactor.

NA = Not analyzed. These samples were collected but not analyzed.

2378-TCDD toxic equivalencies were significantly lower than baseline for all samples except Run 11B baghouse ash. This sample yielded a toxic equivalency lower than the baseline, although it was not significantly different. The 2378-TCDD equivalencies were all below 0.10 ng/g.

The concentrations of the specific CDD/CDF congeners in the ash are shown in Tables 2-26 and 2-27. Each table shows the results for all the samples taken at a single sampling location. Congener distributions are presented in Figure 2-13. Tables of the distributions are in Appendix A. In Figure 2-13, the baseline congener distributions are distinguished by entirely shaded areas. All the distributions appear very similar to baseline.

TABLE 2-26. CDD AND CDF RESULTS FOR CYCLONE ASH AT CONTROL DEVICE EVALUATION CONDITIONS

TEST CONDITIONS	Run Number	
	11B	Baseline
Combustor		
Load (lb/hr steam)	Normal	Normal
Excess Air	Normal	Normal
Overfire Air		
Distribution	Normal	Normal
Control Device		
Quench Reactor Outlet		
Temperature	High	Normal

CDD/CDF CONCENTRATION (ng/g)		
Isomer	Run Number	
	11B	Baseline ^a
DIOXINS		
Mono-CDD	(0.001) ^b	(0.001)
Di-CDD	(0.003)	0.014
Tri-CDD	[0.020]	0.056
2378 TCDD	0.005	0.014
Other TCDD	0.055	0.164
12378 PCDD	[0.012]	0.040
Other PCDD	0.124	0.388
123478 HxCDD	0.013	0.026
123678 HxCDD	0.032	0.084
123789 HxCDD	0.030	0.076
Other HxCDD	0.142	0.764
1234678 HpCDD	0.168	0.383
Other HpCDD	0.164	0.341
Octa-CDD	0.170	0.456
Total CDD	0.903	2.81
FURANS		
Mono-CDF	[0.022]	0.004
Di-CDF	[0.138]	(0.444)
Tri-CDF	0.413	0.712
2378 TCDF	[0.04]	0.160
Other TCDF	0.430	0.378
12378 PCDF	0.022	0.032
23478 PCDF	0.026	0.070
Other PCDF	0.168	0.202
123478 HxCDF	0.041	0.042
123678 HxCDF	0.019	0.020
234678 HxCDF	[0.011]	0.041
123789 HxCDF	(0.001)	0.002
Other HxCDF	0.049	0.089
1234678 HpCDF	0.061	0.065
1234789 HpCDF	(0.003)	0.002
Other HpCDF	0.007	0.017
Octa-CDF	[0.009]	0.044
Total CDF	1.24	1.88
Total CDD/CDF	2.14	4.69

^aBaseline is average of Emission Test and Method Study results.^bNot detected. Detection limit given in parentheses; estimated maximum possible concentration (EMPC) given in brackets.

TABLE 2-27. CDD AND CDF RESULTS FOR BAGHOUSE ASH AT CONTROL DEVICE EVALUATION CONDITIONS

TEST CONDITIONS	Run Number			
	10	11A	11B	Baseline
Combustor				
Load (lb/hr steam)	Normal	Normal	Normal	Normal
Excess Air	Normal	Normal	Normal	Normal
Overfire Air				
Distribution	Normal	Normal	Normal	Normal
Control Device				
Quench Reactor Outlet Temperature	Low	High	High	Normal

CDD/CDF CONCENTRATION (ng/g)				
Isomer	Run Number			Baseline ^a
	10	11A	11B	

DIOXINS				
Mono-CDD	[0.025] ^b	(0.003)	(0.003)	(0.001)
Di-CDD	[0.022]	[0.029]	[0.054]	0.025
Tri-CDD	0.106	0.024	0.194	0.142
2378 TCDD	(0.001)	0.008	0.018	0.020
Other TCDD	0.126	0.158	0.200	0.270
12378 PCDD	0.013	0.017	[0.025]	0.055
Other PCDD	0.117	0.151	0.262	0.550
123478 HxCDD	0.012	[0.013]	[0.017]	0.052
123678 HxCDD	0.030	0.030	0.040	0.099
123789 HxCDD	0.038	0.032	0.060	0.090
Other HxCDD	0.262	0.129	0.182	1.10
1234678 HpCDD	0.189	0.200	0.282	0.622
Other HpCDD	0.149	0.170	0.243	0.605
Octa-CDD	0.260	0.299	0.422	0.959
Total CDD	1.30	1.22	1.90	4.59

FURANS				
Mono-CDF	(0.001)	(0.003)	0.017	0.010
Di-CDF	0.033	[0.574]	[0.950]	0.276
Tri-CDF	1.80	2.50	3.54	2.59
2378 TCDF	[0.11]	[0.11]	0.260	0.516
Other TCDF	1.26	1.99	2.99	1.42
12378 PCDF	[0.044]	0.047	0.102	0.086
23478 PCDF	0.047	0.056	0.099	0.189
Other PCDF	0.407	0.494	0.881	0.700
123478 HxCDF	0.053	0.064	0.088	0.094
123678 HxCDF	0.022	0.028	0.046	0.048
234678 HxCDF	[0.021]	0.027	0.036	0.157
123789 HxCDF	(0.003)	(0.003)	(0.003)	(0.048)
Other HxCDF	0.102	0.138	0.154	0.192
1234678 HpCDF	0.071	0.085	0.103	0.148
1234789 HpCDF	(0.003)	(0.003)	[0.006]	0.024
Other HpCDF	0.015	0.021	0.020	0.046
Octa-CDF	[0.013]	0.023	[0.018]	0.083
Total CDF	3.80	5.47	8.33	6.58

Total CDD/CDF	5.11	6.69	10.2	11.2
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^aBaseline is the average of Emission Test and Method Study results.

^bNot detected. Detection limit given in parentheses; estimated maximum possible concentration (EMPC) given in brackets.

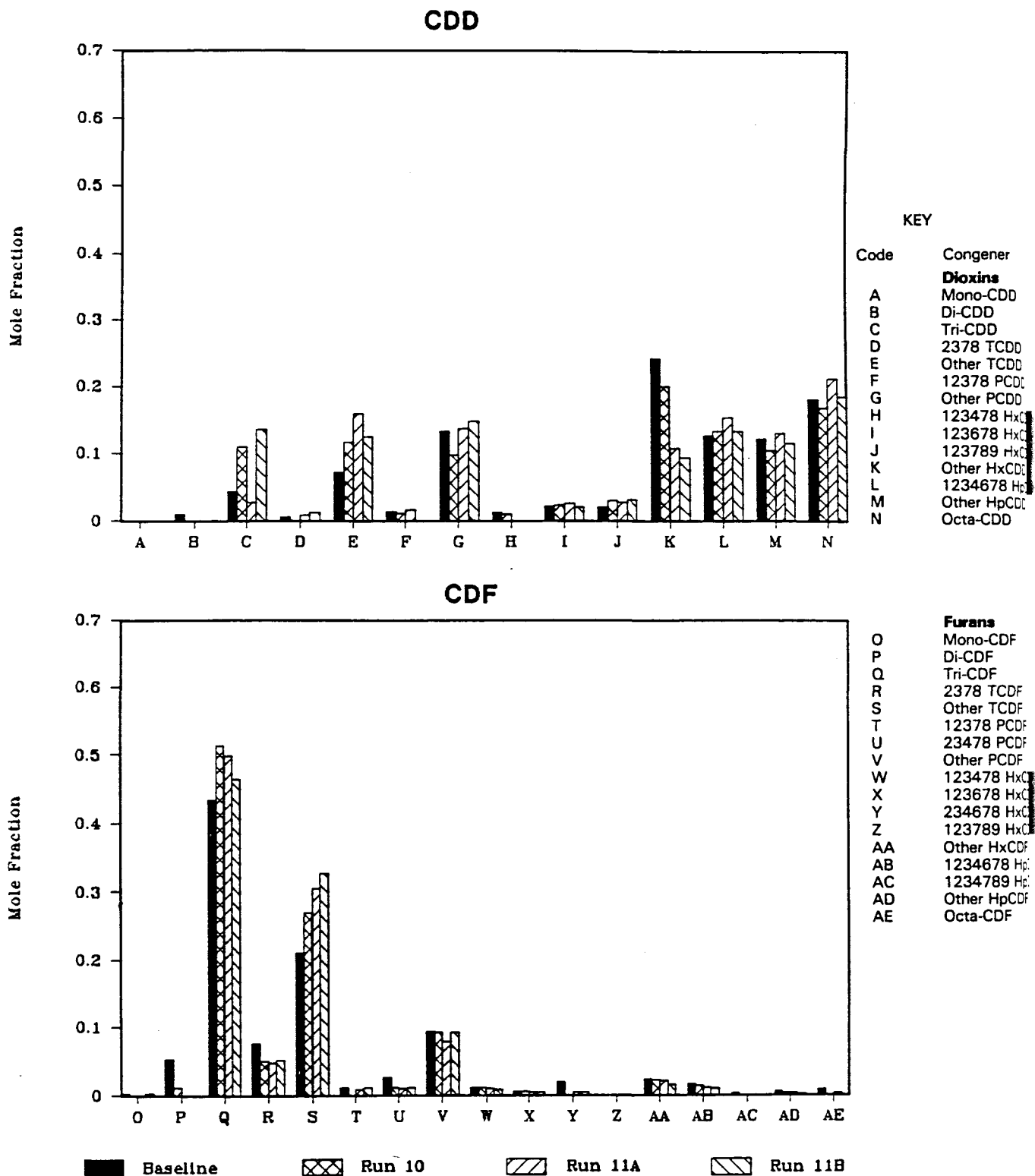


Figure 2-13. CDD/CDF Congener Distributions for Baghouse Ash During the Control Device Evaluation

3.0 CONCLUSIONS

The specific objectives of the characterization phase of the test program, as discussed in Section 1.1, were achieved. Combustion parameters and acid gas removal efficiencies were characterized for baseline operation.

The effects of load, excess air, and overfire air distribution were determined to be minimal. CO emissions from baseline to worst case conditions ranged from 11 ppmV, dry, normalized to 12 percent CO₂ to 17 ppmV, dry, normalized to 12 percent CO₂.

SO₂ and HCl removal efficiencies for the quench reactor/fabric filter (QR/FF) emission control system were determined to be a function of quench reactor outlet temperature and stoichiometric ratio. The effect of quench reactor outlet temperature and stoichiometric ratio were not determined separately due to the configuration of the quench reactor system. The HCl removal efficiencies during the control device evaluation ranged from 97.6 percent at the lowest temperature condition (262°F) to 75.8 percent at the highest temperature condition (360°F).

Removal efficiencies for SO₂ during the control device evaluation ranged from zero at the highest temperature condition (360°F) to 72.9 percent at the lowest temperature condition (262°F). However, SO₂ removal efficiencies were highly variable due to the variability of the uncontrolled combustor emissions. Also, SO₂ was less effectively removed than HCl by the QR/FF control system.

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 4980 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 (O₂) controller that controls the feeder and the grate speed, and a steam load controller that controls the underfire air dampers. When the O₂ level is above a given set point, waste feeding begins, and when the O₂ level is low, feeding stops. As the feed rate increases, steam flow increases and the underfire air dampers gradually close, reducing the flow of O₂. As the O₂ 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 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 flowrates vary between 1636 m³/min (57,750 acfm) at 199°C (390°F) and 1885 m³/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 m³/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 stoichiometric ratio cannot be changed independently of the quench reactor outlet temperature, but rather is dependent on both the temperature and inlet acid gas concentration.

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 five 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. PM and Oregon DEQ condensible emissions are required to be controlled to a level of 69 mg/dscm (0.03 gr/dscf) at 12 percent CO₂.

4.2 TESTING GOALS

The purpose of this characterization test was to evaluate the operation and performance of the MWC system in order to determine:

1. The normal operating envelope of the combustor and resulting quench reactor/fabric filter (QR/FF) performance over this operating envelope.
2. The variation in performance of the QR/FF in the control of acid gases at different control device operating temperatures.
3. The performance of the QR/FF in the control of organic emissions (CDD/CDF) during combustor shutdown and startup conditions.

Each of these goals was met in a separate phase of the testing program. During the combustor evaluation phase, the QR/FF control device was operated at baseline conditions while combustor parameters were varied. During the control device evaluation phase, the combustor was operated at baseline conditions while quench reactor operating temperatures were varied. The process shutdown and startup composed a separate evaluation outside the characterization testing.

The results of the characterization testing will be used to determine which of the combustor and control device operating conditions require additional evaluation in a performance test. While the characterization test consisted of only flue gas CEM measurements, manual HCl sampling, and ash sampling, performance testing will include CDD/CDF, metals, or other flue gas measurements in addition to CEMs, and a more extensive ash sampling program. The characterization testing is intended to provide EPA with clues concerning which operating conditions could potentially result in episodes of higher air pollution emissions, and to what extent the QR/FF controls these emissions.

4.3 TESTING MATRIX

4.3.1 Combustor Evaluation

Three primary combustor operating variables were selected for evaluation. These variables were:

1. Steam load,
2. Excess air, and
3. Overfire air distribution

A matrix of combustor evaluation test conditions is presented in Table 4-1. Baseline conditions were evaluated during the first two days (Runs 1 and 2). After establishing baseline conditions, five test conditions were evaluated. The conditions were low excess air (Run 3A), high excess air (Run 3B), low overfire air distribution (Run 4), high overfire air distribution (Run 5), and low steam load (Run 6A). The low steam load operating condition was maintained for Run 6B through Run 9 and the excess air and overfire air distribution were varied again. The resulting operating conditions were, in addition to low steam load for each test, low excess air (Run 7), high excess air (Run 6B), low overfire air distribution (Run 8), and high overfire air distribution (Run 9). It should be noted that during each of the runs (1-9), the quench reactor/fabric filter was operating at baseline conditions with a quench reactor outlet temperature set point of 300°F. With one exception, which will be discussed later, the 300°F temperature was generally maintained within $\pm 5^{\circ}\text{F}$ throughout the test runs.

Baseline operating conditions were established in meetings with the facility owner/operator prior to the testing. For each of the three primary combustor variables baseline conditions were reported to be:

Steam load - 66,400 lb/hr
Excess air - 70 percent
Overfire air - 25 percent of total air

TABLE 4-1. COMBUSTOR EVALUATION TEST MATRIX

Run # ^a	Description	Steam Load	Excess Air	OF ^b Air Distribution
1	Baseline	N ^c	N	N
2	Baseline	N	N	N
3A	Low EA ^d	N	L ^e	N
3B	High EA	N	H ^f	N
4	Low OF distribution	N	N	L
5	High OF distribution	N	N	H
6A	Low load	L	N	N
6B	Low load/high EA	L	H	N
7	Low load/low EA	L	L	N
8	Low load/low OF air	L	N	L
9	Low load/high OF air	L	N	H

^aRuns 3A and 3B and Runs 6A and 6B were labelled to distinguish separate runs performed on one given test day.

^bOF = Overfire air distribution

^cN = normal

^dEA = Excess Air

^eL = low

^fH = high

Target values for the combustor variables during characterization testing were established also. The low steam load target was established at 75 percent of normal, or approximately 50,550 lb/hr. The low and high excess air target values were 44 percent and 110 percent, respectively. The low and high overfire air distribution target values were approximately 0 and 30 percent, respectively. With the exception of low steam load conditions, the target amount of variation from baseline for each of the primary combustor operating parameters was established for specific test runs by evaluating flame patterns in the fire box and determining the resulting operating conditions.

Steam load (lb/hr), total combustion air flow (10^3 lb/hr) and percent O_2 at the boiler outlet were monitored directly from readouts in the control room. The overfire air flowrate is monitored indirectly by a pressure setting (in. WC) in each of the supply headers prior to being injected into the furnace. There are three rows of overfire air nozzles (front, upper rear, and lower rear).

A list of the process parameters which were recorded during each of the test runs is provided in Table 4-2. These were generally recorded at 15-minute intervals with the exception of lime slurry specific gravity, which was a field measurement reported by plant personnel every hour. Strip charts were copied for those process parameters which were recorded in the control room. Table 4-3 details the range in primary operating variables that was measured during each of the Phase I runs.

4.3.2 Control Device Evaluation

The primary control device variable under evaluation was the quench reactor (spray dryer) outlet temperature. Studies by Environment Canada indicate that the performance of acid gas control equipment in the removal of organic and acid gas emissions can be highly temperature dependent. One Environment Canada study involved temperature variations with a humidification/dry injection system that provided conclusive results on the removal of these pollutants.⁹ The characterization program attempted to

TABLE 4-2. PROCESS OPERATING PARAMETERS RECORDED
DURING MARION COUNTY TESTING

Parameters	Units
Refuse feed rate (Crane weight scale)	lb
Steam flow	lb/hr
Steam pressure	psig
Steam temperature	°F
Combustion air flow	10 ³ lb/hr
Combustion air temperature	°F
Overfire air nozzle pressure	in W.C.
- Front	
- Upper rear	
- Lower rear	
O ₂ concentration (boiler exit)	% vol. (wet)
Temperatures	°F
- Middle of furnace 1st pass	
- Top of furnace 1st pass	
- Economizer outlet	
- Quench Reactor inlet	
- Quench reactor outlet	
- I.D. fan inlet	
- Baghouse outlet	
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.

TABLE 4-3. TESTED OPERATING RANGE OF PRIMARY OPERATING VARIABLES

Run #	Steam Load (lb/hr)	Excess Air ^a (percent)	Flue Gas Flow Rate (acfm) ^a	Overfire Air (in. WC)		
				Front	Upper Rear	Lower Rear
1	67180	72.7	57150	15.2	6.0	15.5
2	67240	78.4	60920	15.3	4.9	15.6
3A	63990	40.2	46980	7.0	0.6	3.7
3B	63940	106.0	67270	17.8	9.8	17.5
4	65460	70.6	60600	4.5	0.4	0.9
5	68970	71.7	58590	19.3	10.6	17.5
6A	51230	75.4	52310	7.1	0.6	4.8
6B	47960	135.6	59640	13.0	6.6	11.4
7	51590	57.9	42280	4.6	0	1.2
8	49900	84.0	42350	1.7	0.2	0.4
9	52090	88.7	49360	10.2	11.0	12.8

^a Measured at economizer outlet.

verify the effect of temperature on control of organic and acid gas emissions by a commercial scale quench reactor and fabric filter. However, the operating temperature of the Marion County QR/FF could not be varied independently at a given stoichiometric ratio as was done in the Environment Canada study. The flow of lime slurry to the Marion County quench reactor is adjusted based on the flue gas operating temperature measured at the quench reactor outlet. As the flow of lime slurry is adjusted, the stoichiometric ratio varies, since the lime content per unit mass of slurry is constant. The baseline operating temperature was 300°F. The low operating temperature target (Run 10) was 260°F, and the higher operating temperature targets (Runs 11A and 11B) were 330°F and 360°F, respectively. To the extent possible, normal steady-state combustion conditions were maintained at full steam load during each of these runs.

The following sections describe the process operations that were experienced during each of the runs in the characterization testing at Marion County, with an attempt to highlight any process upsets or unusual operating conditions that took place.

Run 1 - Baseline

Process operations were very stable during the test run. There was an observed SO₂ spike reported from the CEM instrument trailer that did not correspond to any specific process variation (such as increased operating temperature). Observations of the pit led to speculation that the source of sulfur may have been the large quantities of gypsum sheet rock from demolition wastes received that day.

Run 2 - Baseline

Process operations were very stable with no upsets.

Run 3A - Low excess air

Excess air was dropped to a target value of 5 percent oxygen on a wet basis at the economizer outlet. Steam flow was maintained at design levels and the overfire air distribution was adjusted in an attempt to maintain the baseline value of 25 percent total air. Between 1200 and 1230 there was a blockage on the feed table which caused a secondary fire and unsteady air conditions. As a result, several CO spikes were reported from the instrument trailer. Operating at low excess air values resulted in increased furnace operating temperatures. There was a delay in starting the test because of excessive fuel bed thickness. This was caused when the ash discharge seal broke resulting in increased O_2 values which caused the controller to increase the feeder speed.

Run 3B - High excess air

After making adjustments to primary operating variables to establish the high excess air operating conditions, the furnace temperatures dropped as expected. There was some difficulty maintaining the high excess air (O_2) operating conditions early after the transition, and design steam loads had a tendency to slip about 5-10 percent. The furnace draft was very unsteady, and the furnace pressure went positive often during the testing period.

Run 4 - Low overfire air distribution

With the exception of 5" W.C. pressure on the front wall nozzles, the overfire air flows were near zero. The 5" W.C. was necessary in order to protect the nozzles from flames (provide cooling). Two drops in temperature without corresponding drops in steam load or O_2 indicated wet fuel.

Run 5 - High overfire air distribution

Relatively stable operating conditions were experienced throughout the test. No problems or major process excursions were observed.

Run 6A - Low load

The run was completed without combustion upsets. Erratic lime slurry flows were experienced due to frequent plugging of the slaker strainer.

Run 6B - Low load, high excess air

The quench pit seal was broken resulting in a spike in CO concentration. Instrument air was lost twice, resulting in baghouse bypass. The test was aborted one half hour early when this problem could not be resolved.

Run 7 - Low load, low excess air

The extremely low air flows associated with this operating condition caused the I.D. fan to have difficulty in regulating itself. The furnace draft was positive during several episodes, further reducing flue gas flowrates. The quench reactor did not adjust slurry injection rates and the quench reactor outlet temperature plummeted from the design target of 300°F to 232°F. This can be observed in the process data, and it resulted in an increased removal of HCl and SO₂ during the episode. Chunks of lime approximately 1 inch in diameter dropped down into the cyclone ash. The problem was resolved by slightly increasing gas flowrates and steam load and maintaining negative draft on the I.D. fan.

Run 8 - Low load/low overfire air

An electrical fault temporarily caused the fuel feeding to stop and the feeder went to maximum stroke. It was corrected and did not affect testing.

Run 9 - Low load/high overfire air

The plant had problems with the daily O₂ calibration during testing. Because of disagreement with Radian CEMs, the plant O₂ data are considered suspect. No process upsets were experienced.

Run 10 - Low QR temperature

No process problems occurred.

Runs 11A/11B - High QR temperature

No process problems occurred.

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.

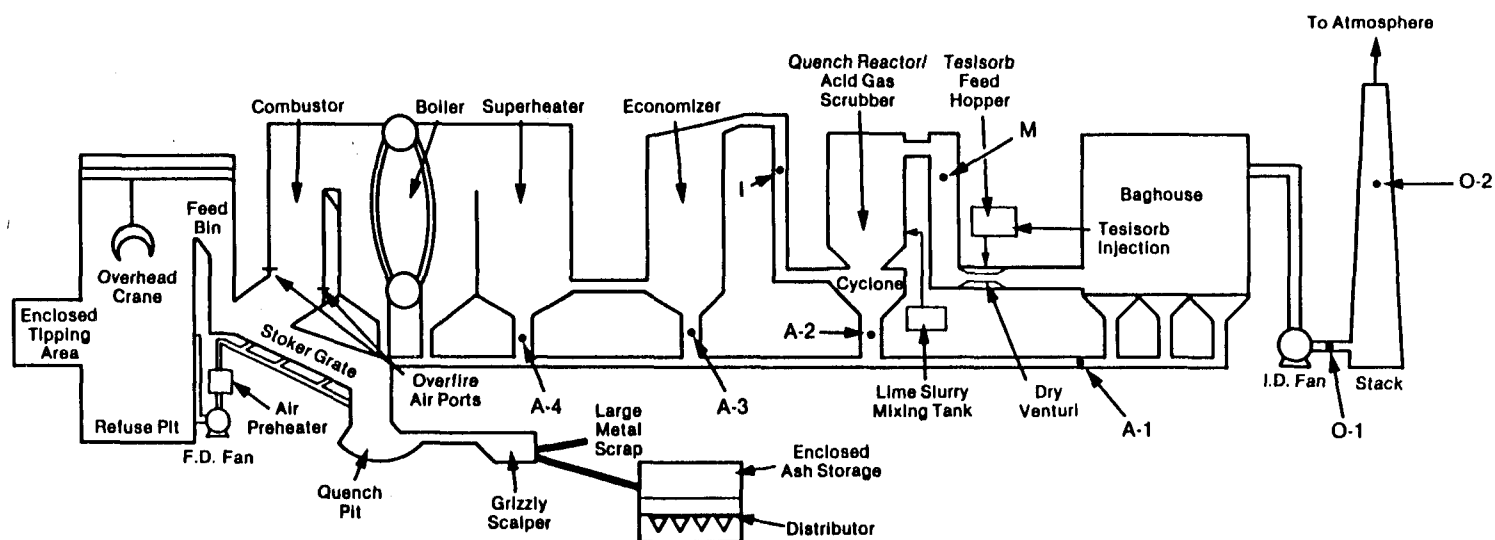
5.1 FLUE GAS

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 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 6-inch ID 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 8-inch-long nipples and are accessible from the same platform.

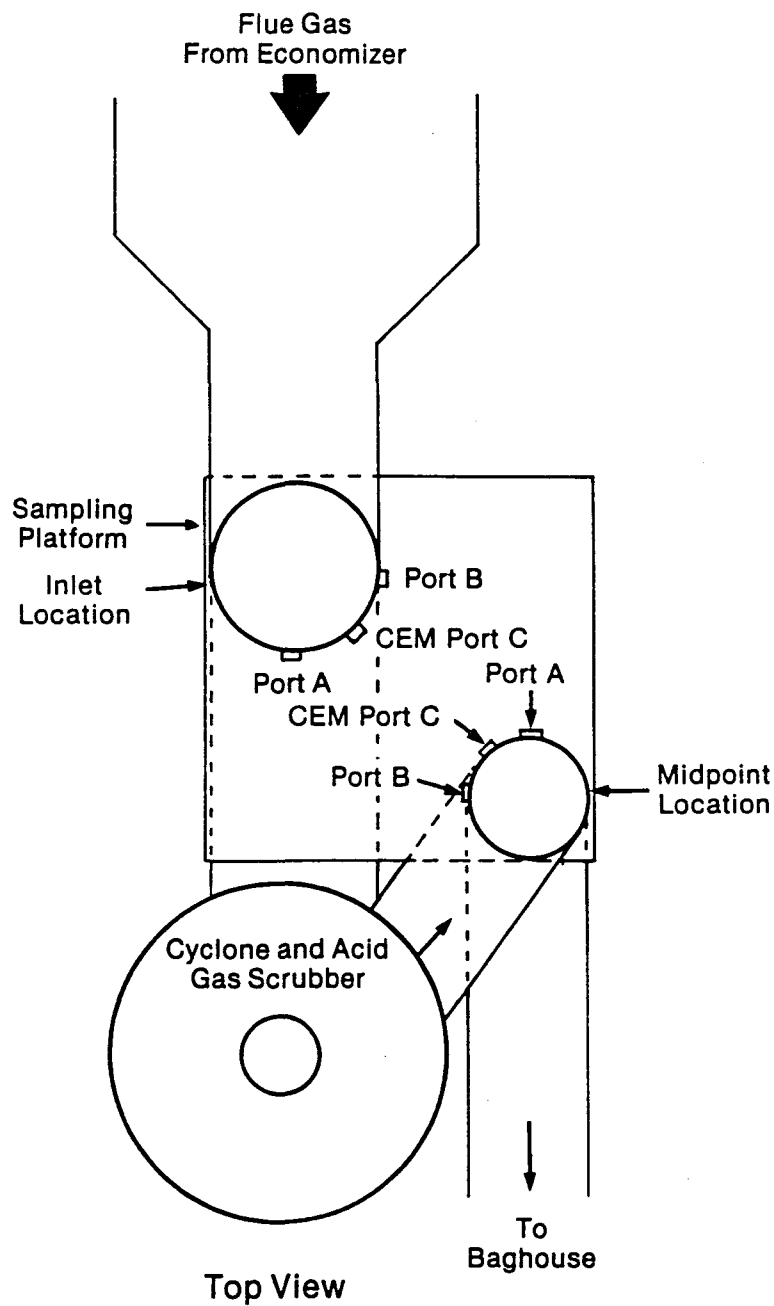
EPA Method 1 was used to select the number and location of the traverse points for Ports A and B. The ports are located approximately 4 equivalent duct diameters (28'6") downstream of a 90° bend in the duct and approximately 1.9 equivalent duct diameters (13'1") upstream of a 90° bend in the duct. Following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



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

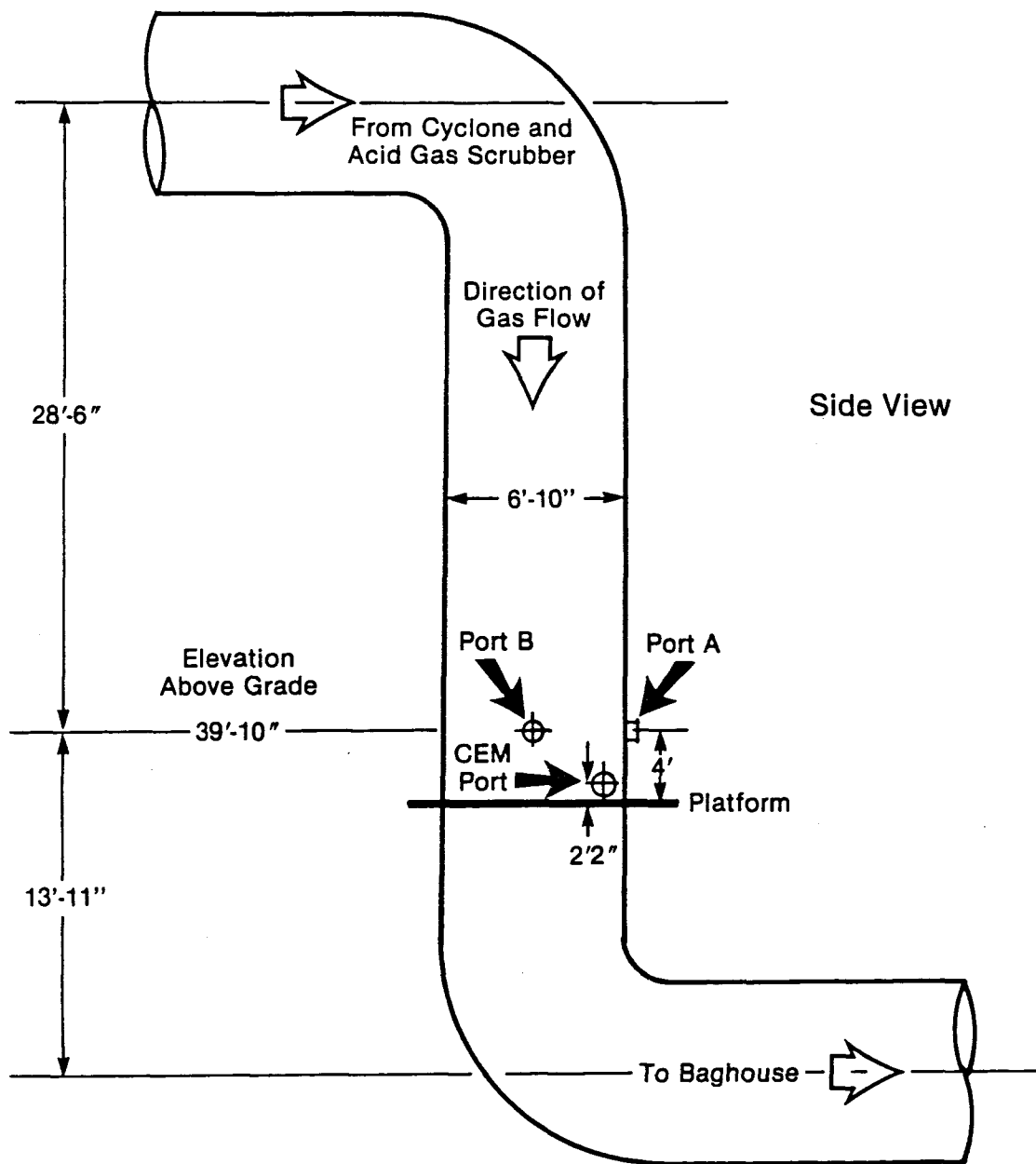
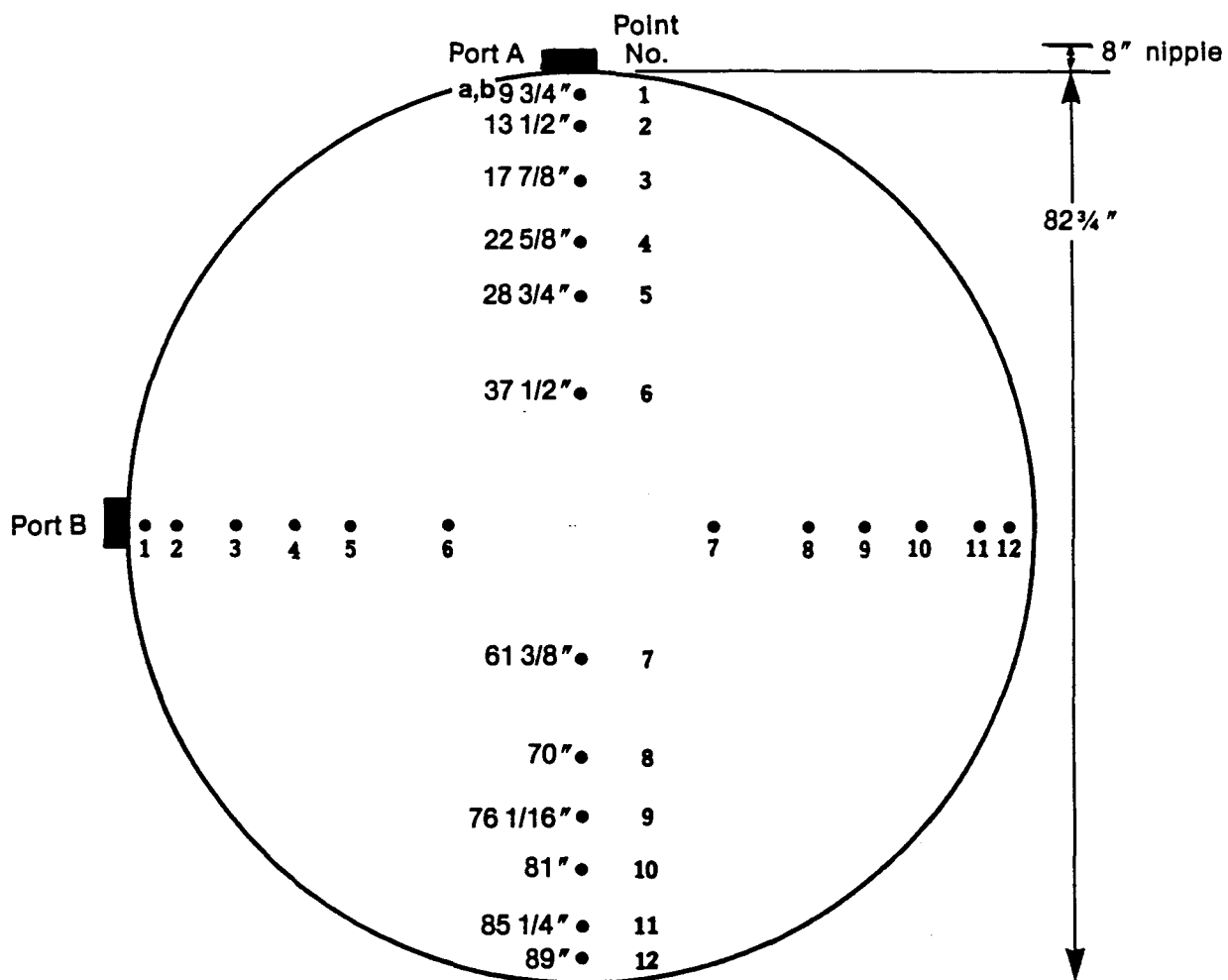


Figure 5-3. Side View of Boiler Outlet Sampling Location at Marion County MWC



^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.

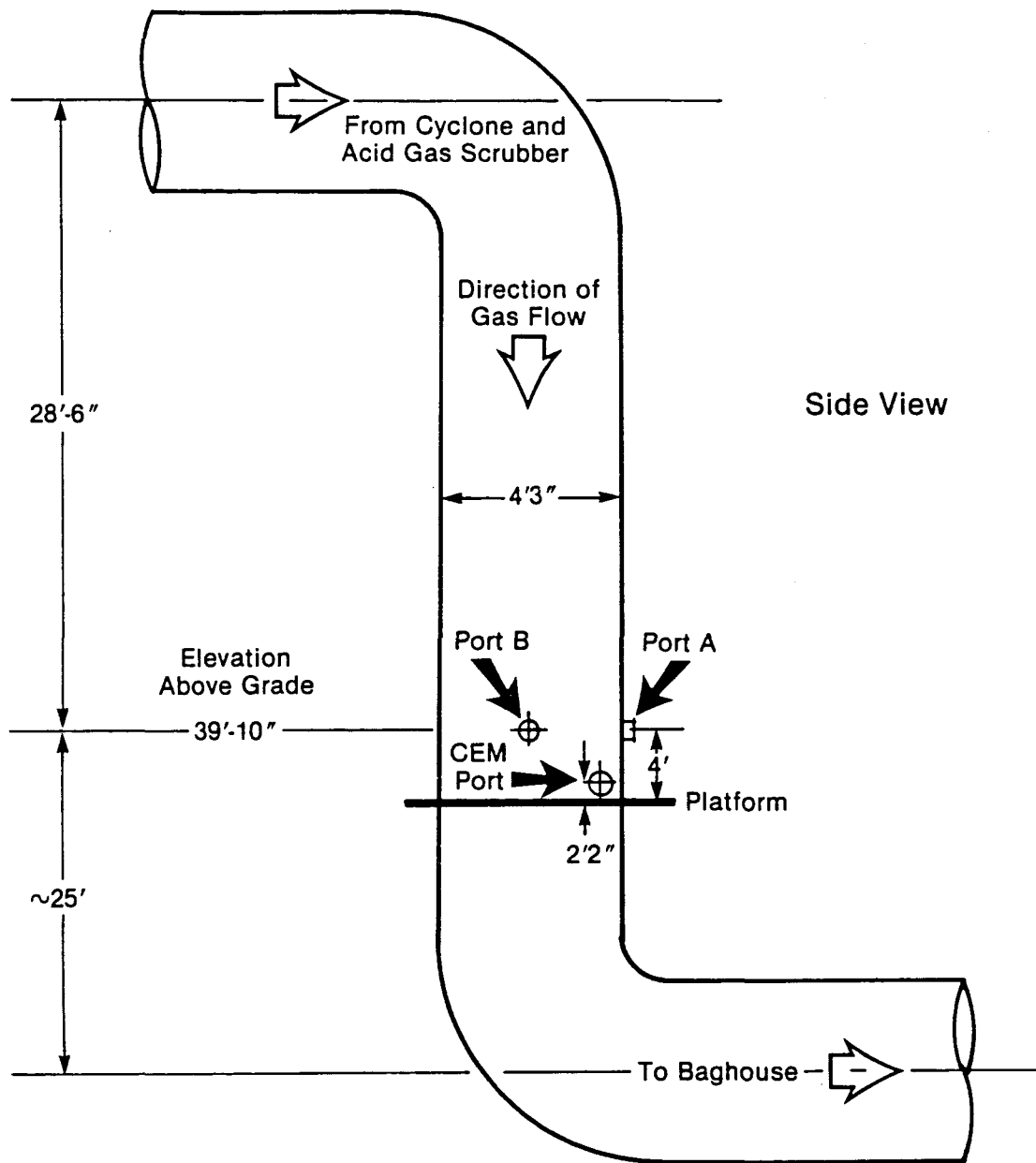
The average volumetric flowrate through the duct was 29,400 dry standard cubic feet per minute (dscfm) at an average temperature of 423°F. The velocity head reading from the pitot tubes ranged from 0.07 to 0.2 in. H₂O in previous tests, which is in the low range for the manometers that are standard equipment 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 H₂O.

5.1.2 Midpoint Sampling Location

The parameters that were measured at the midpoint sampling location include volumetric flowrate, moisture, HCl, SO₂, O₂, and CO₂. 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.

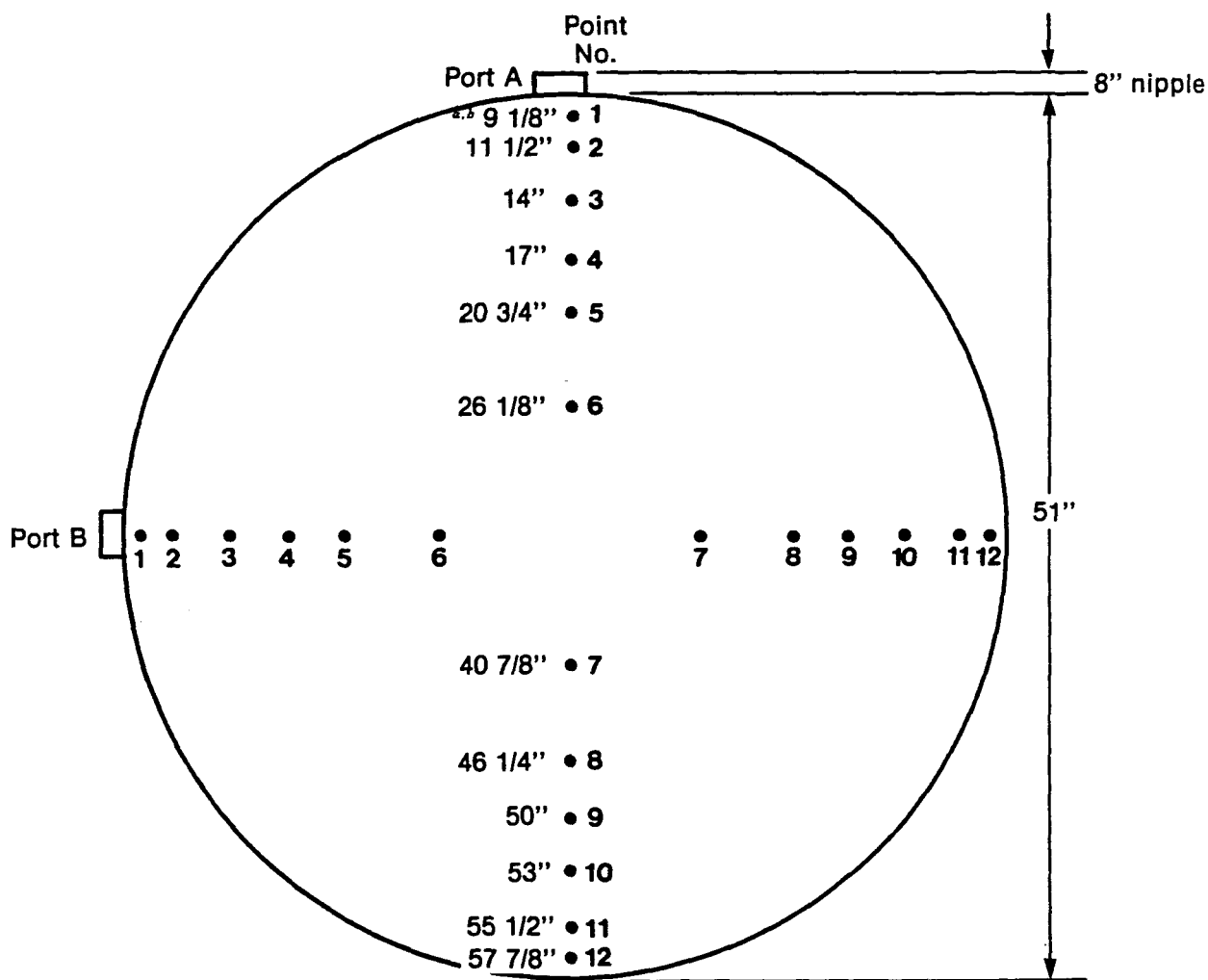
The midpoint sampling locations has three six-inch I.D. ports located in a circular duct 51" in diameter. Two of the ports (Ports A and B) are located in the same place, 90° apart. The third port (Port C) is located about two feet downstream on a different axis. All the ports have 8-inch-long nipples. 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 (28'6") downstream of a 90° 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



*Measurement from the outside of the nipple for probe marking

*Traverse points are located as specified in EPA Method 1

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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.

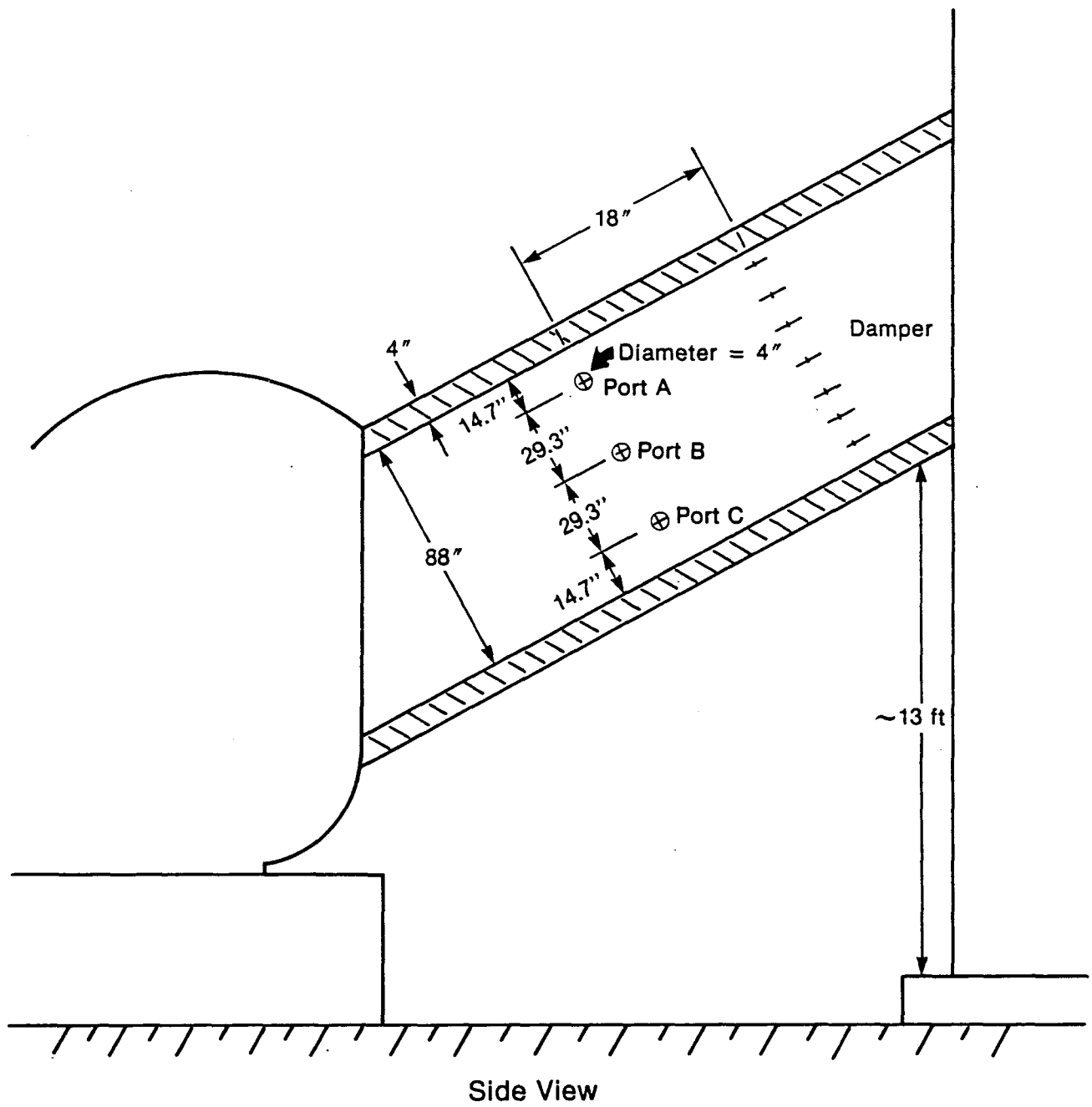
The average volumetric flowrate of the duct was 34,800 dscfm at an average temperature of 303°F . Static pressure draft at this point in the system averaged negative 4.9 inches of water.

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.

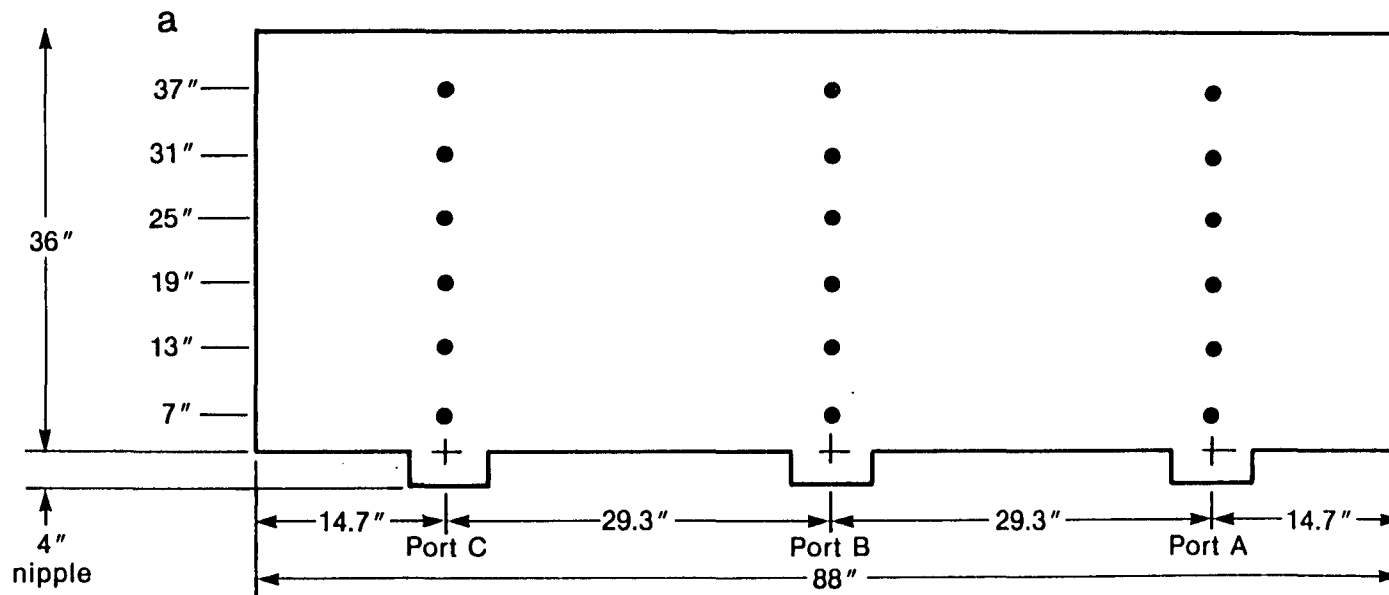
The breeching sampling location has three four-inch ID ports located in a rectangular duct 7 ft. 4 in. high by 3 ft. deep. All of the ports have 4-inch-long nipples. The ports were accessed by temporary scaffolding.

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 flowcheck conducted according to EPA Method 1, indicated that the average degree of rotation was 2° . EPA Method 1 specifies that the average degree of rotation should be equal to or less than 10° .



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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

The average volumetric flowrate of the duct was 37,400 dscfm at an average temperature of 287°F. Static pressure at this point was 0.35 inches WC for Runs 1 to 6B, 8.0 inches WC for Runs 6 to 10 and 0.50 inches WC for Runs 11A and 11B.

5.1.4 Outlet Stack Sampling Location

The parameter that was measured at the outlet stack sampling location was volumetric flowrate. A top view and 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 4-inch ID ports located in a circular duct 48" 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 4-inch-long nipples.

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° as specified by EPA Method 1. A stratification check was not performed at this location since only velocity traverses were collected.

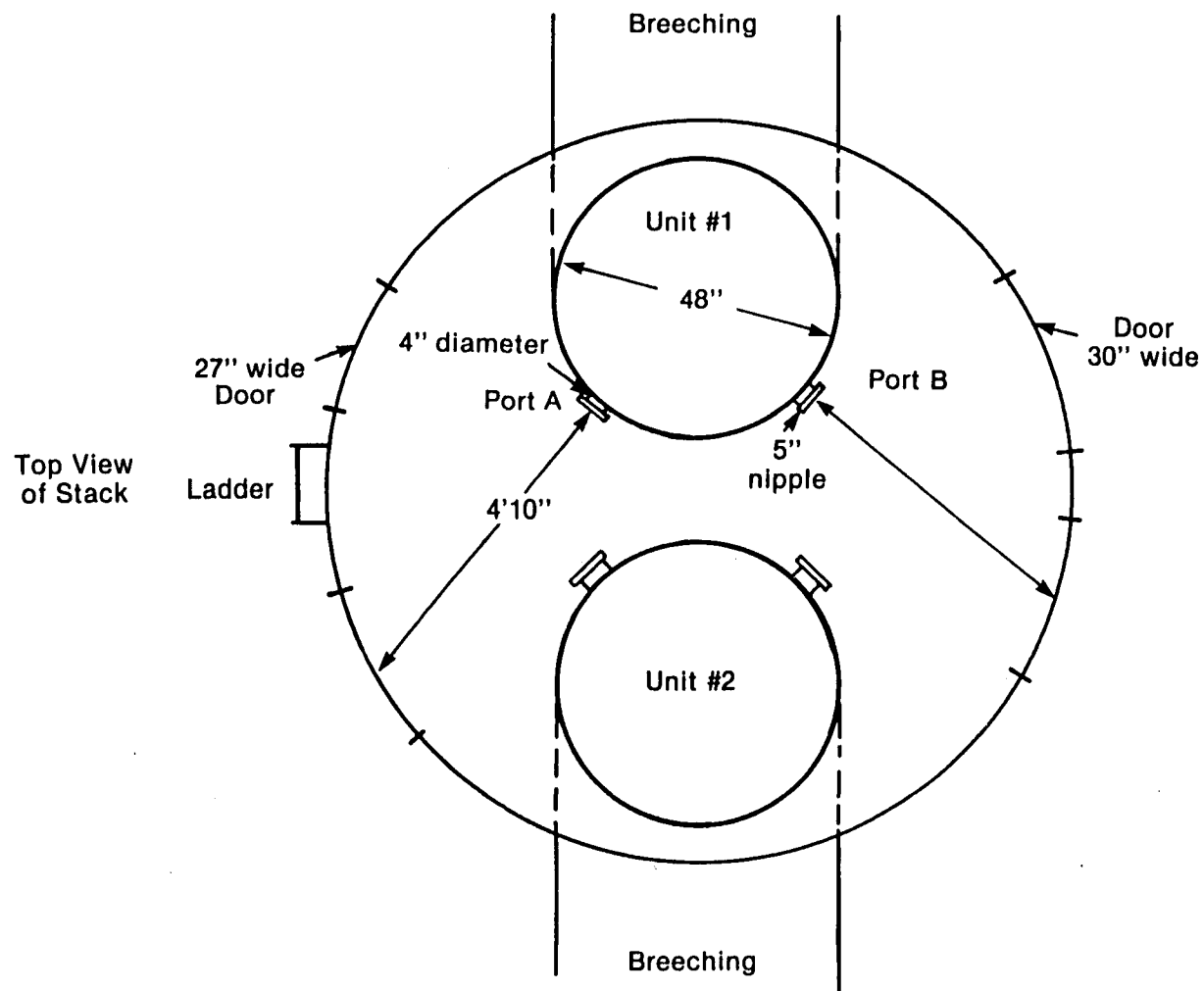


Figure 5-9. Outlet Stack Sampling Location at Marion County MWC

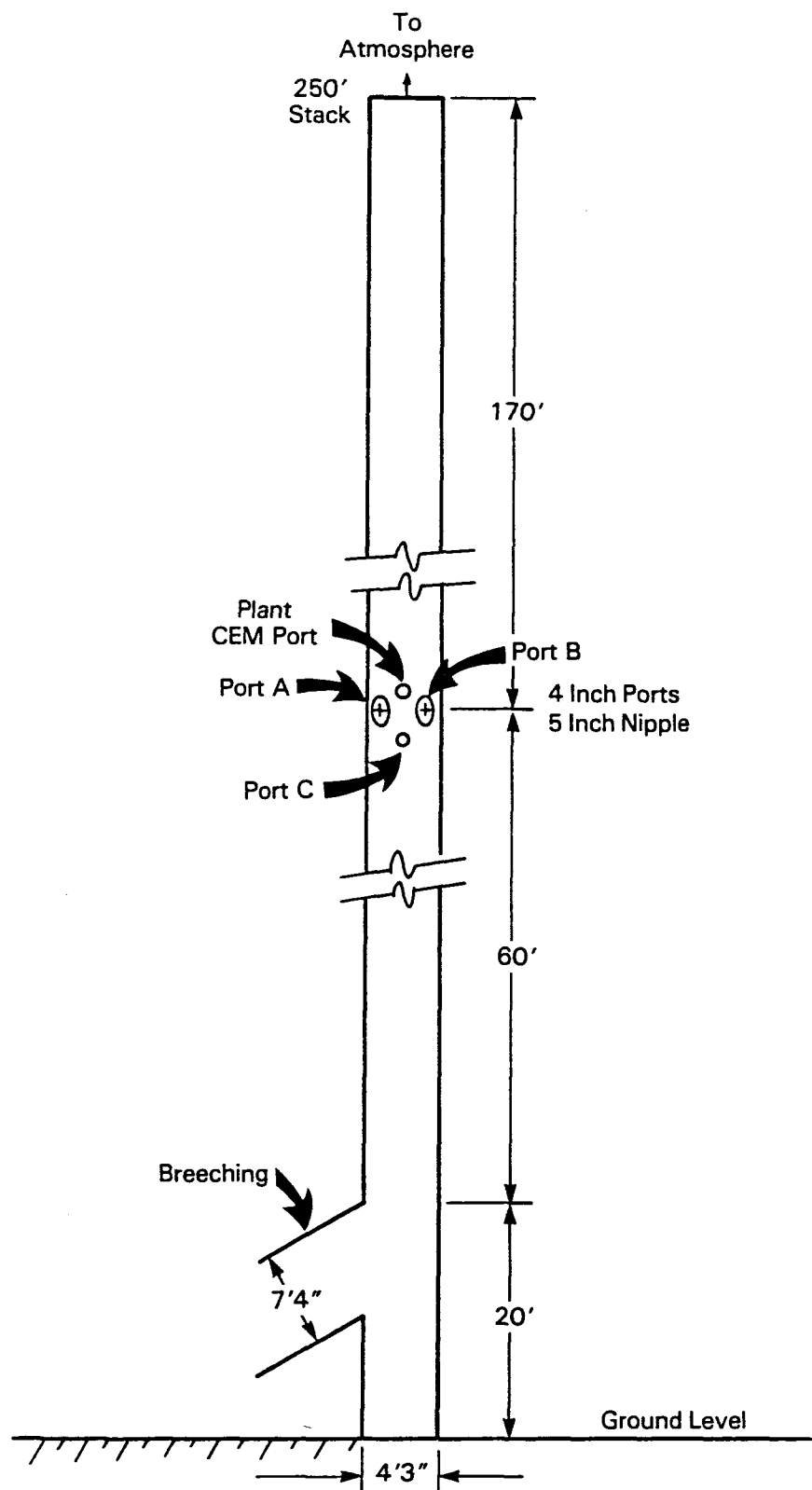
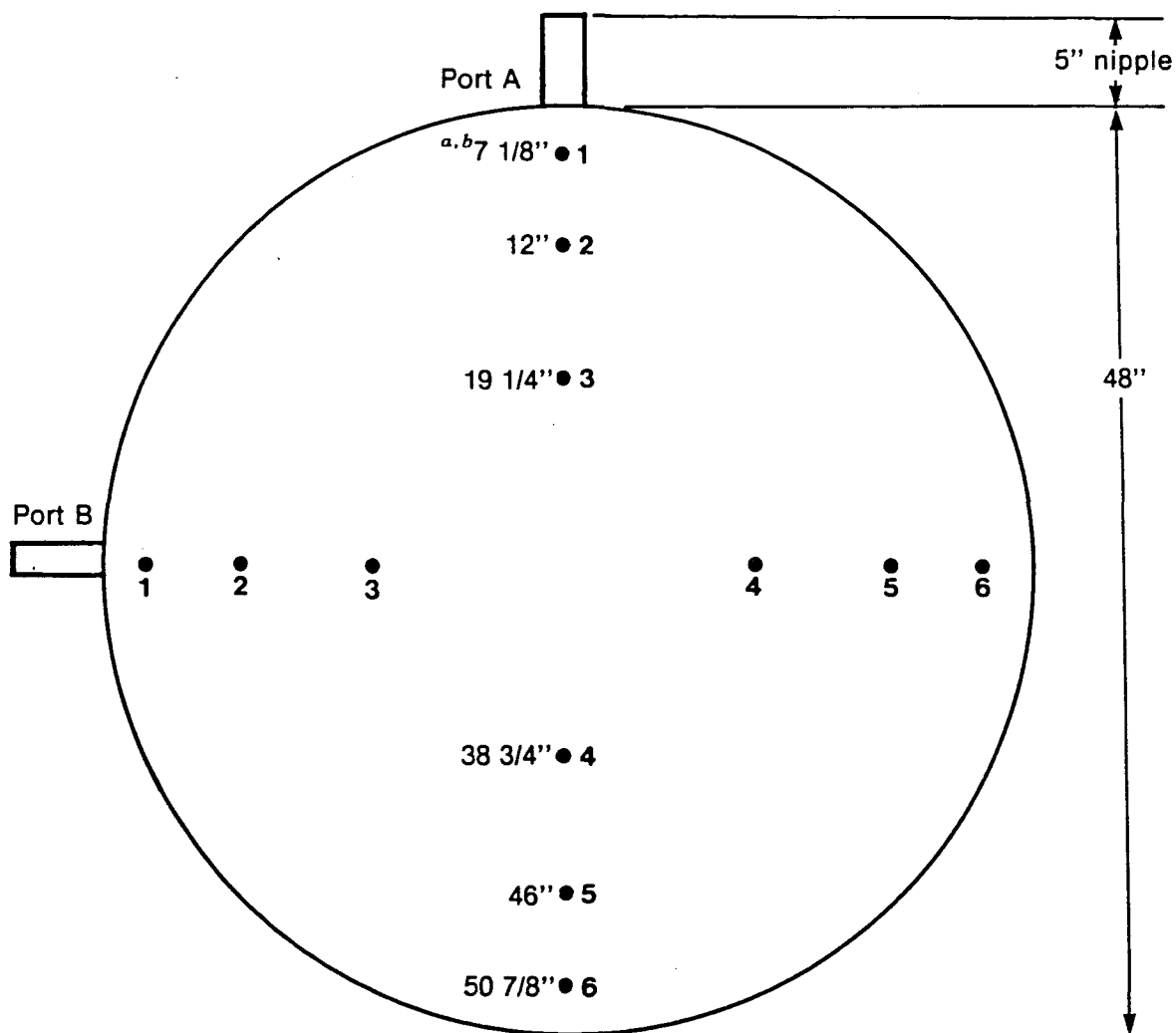


Figure 5-10. Side View of Outlet Stack Sampling Location at Marion County MWC



^aMeasurement from the outside of the nipple for probe marking

^bTraverse 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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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. The trier was withdrawn periodically to empty the ash.¹⁰ The side and top views of the superheater ash sampling location and sampling apparatus are shown in Figures 5-12 and 5-13, respectively.

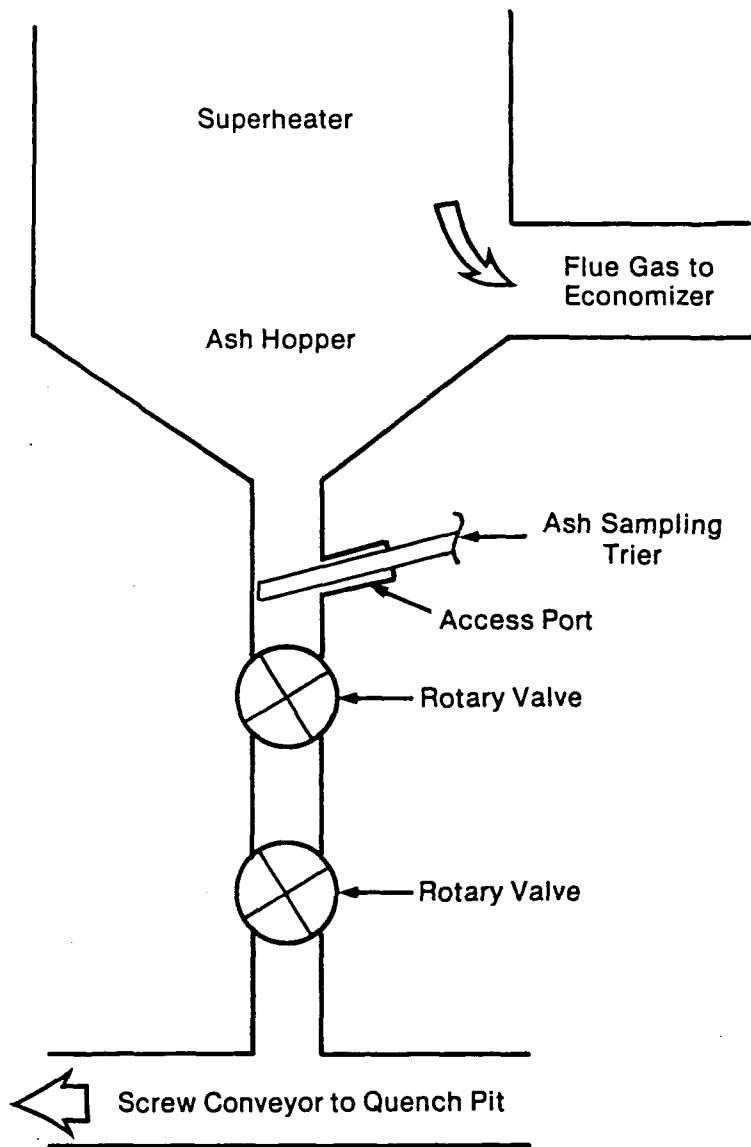
5.2.2 Economizer Ash Sampling Location

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.



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

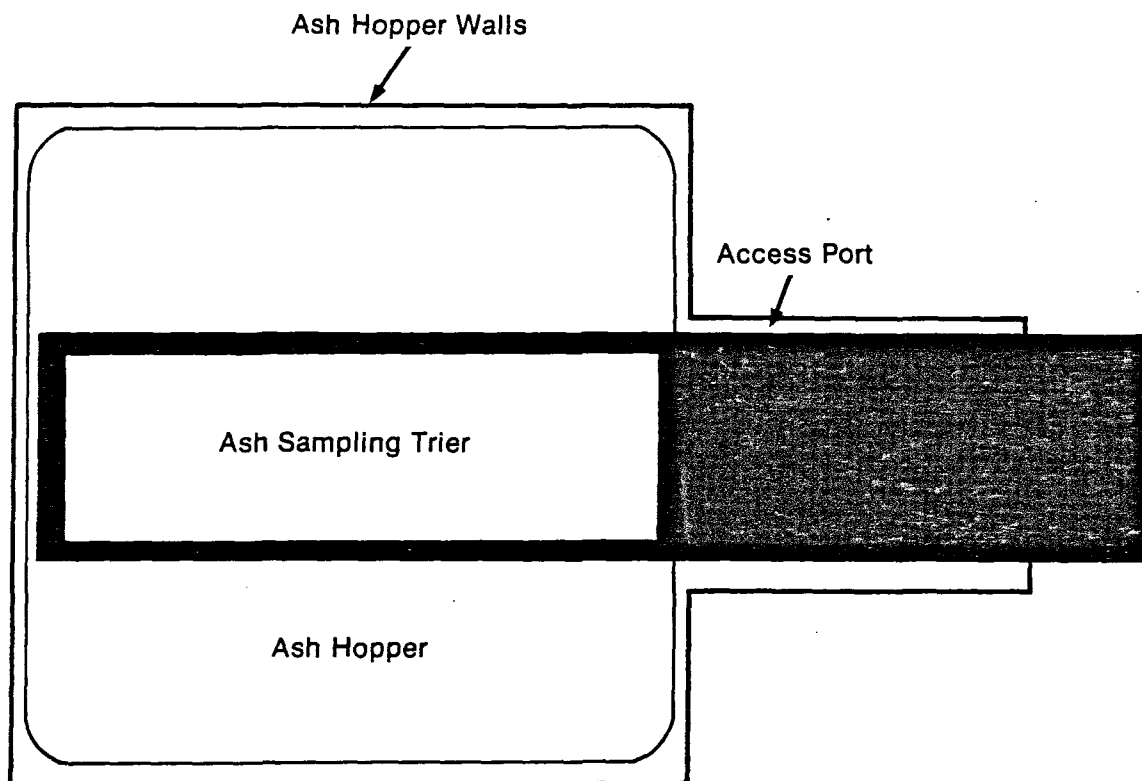
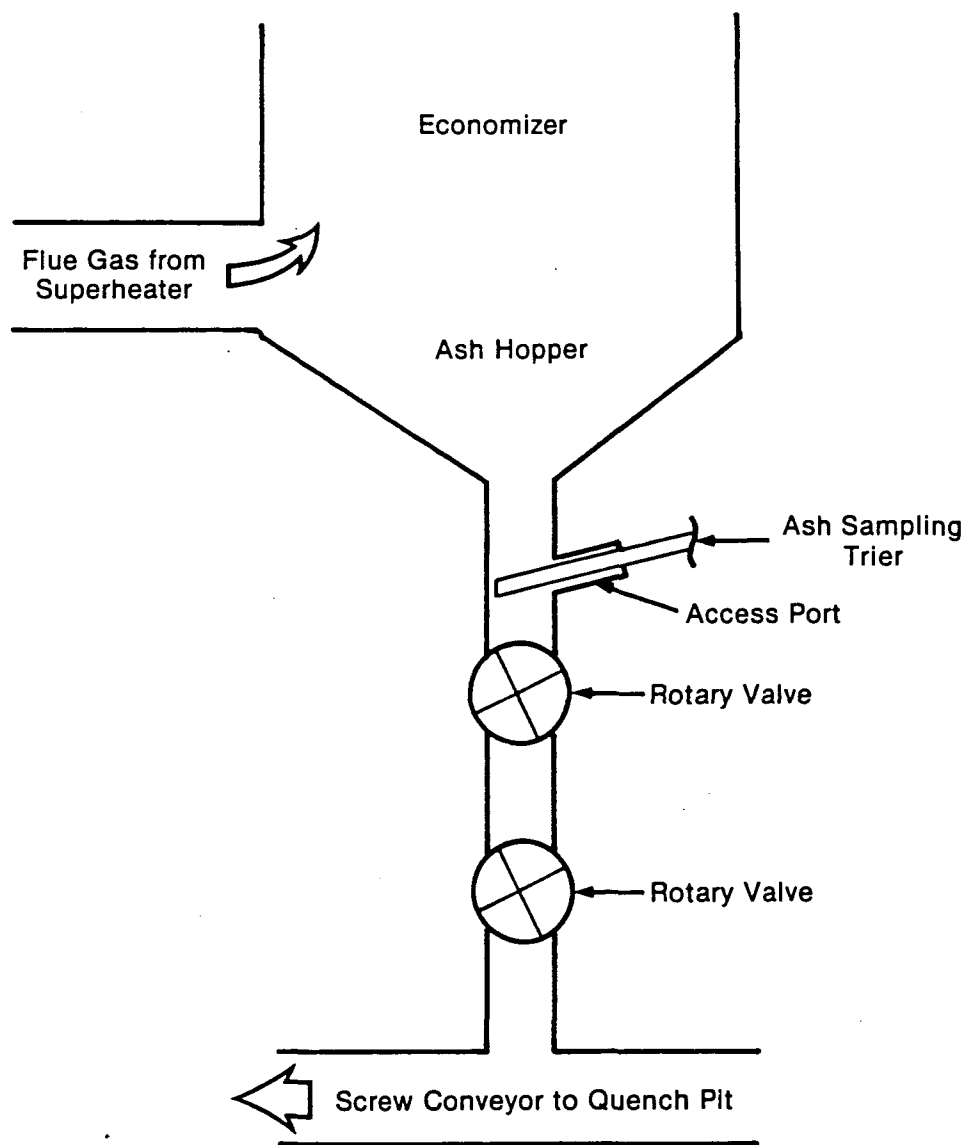


Figure 5-13. Top View of Superheater Ash Sampling Location
at Marion County MWC



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

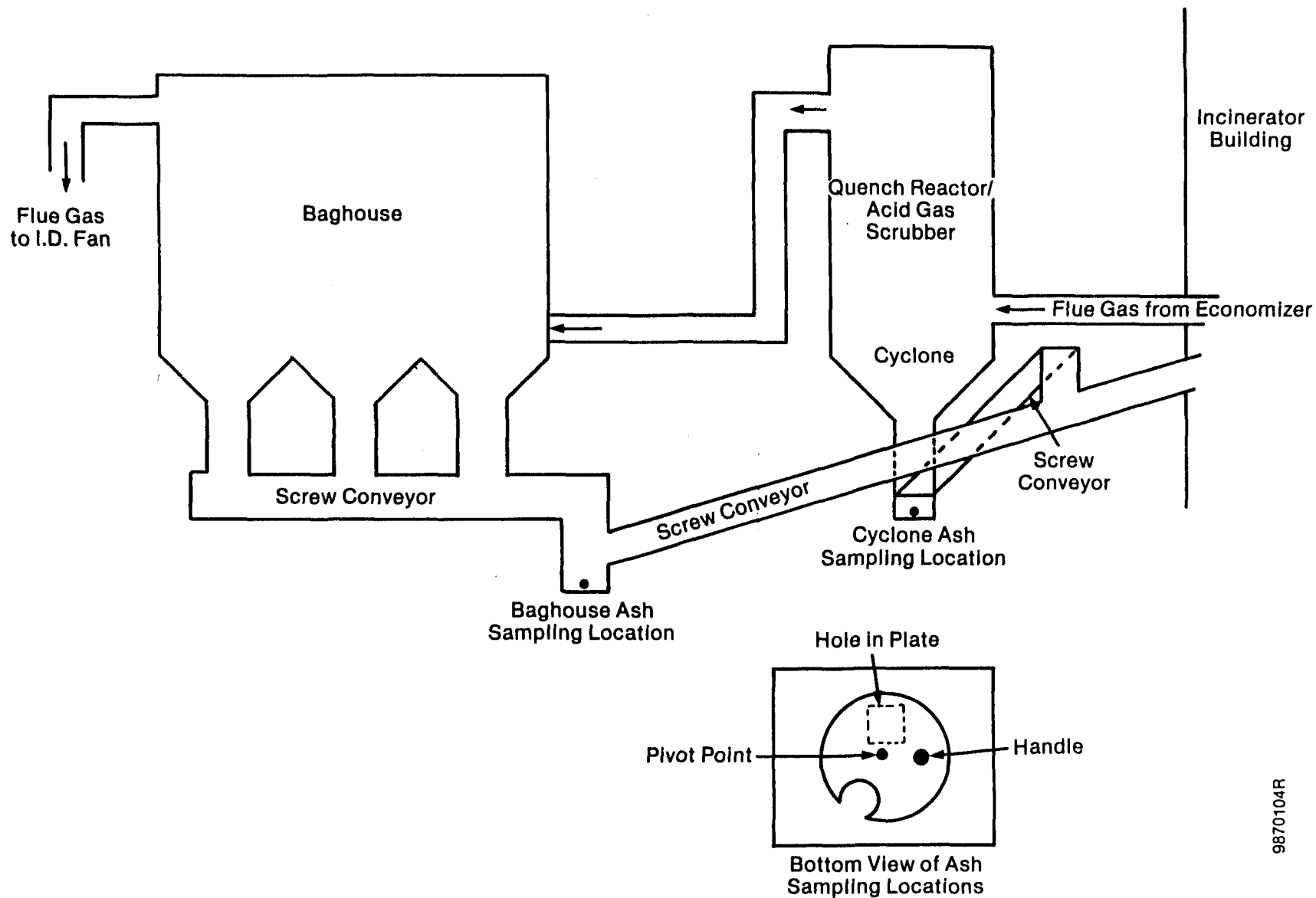


Figure 5-15. Baghouse Ash and Cyclone Ash Sampling Locations at Marion County MWC

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.

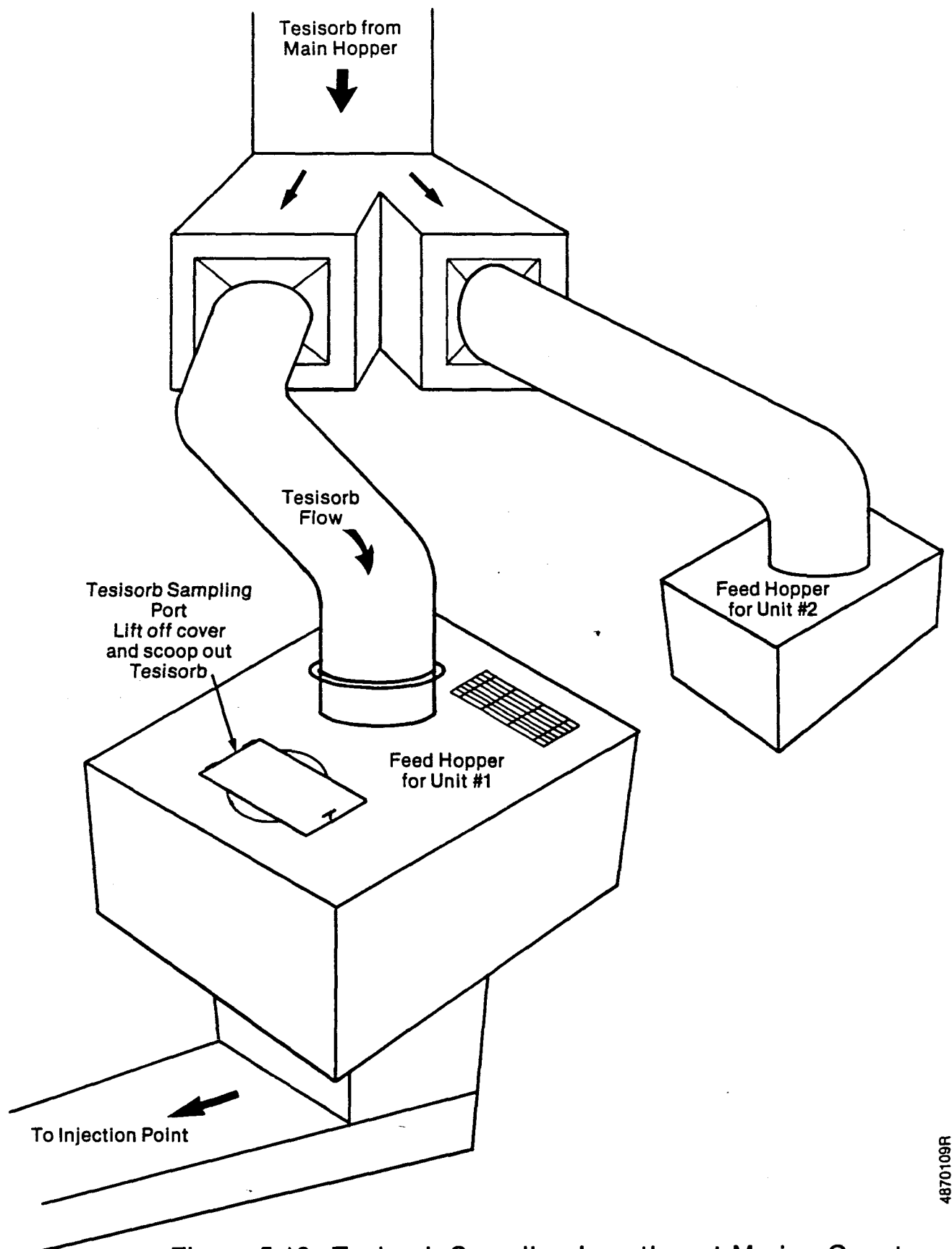


Figure 5-16. Tesisorb Sampling Location at Marion County

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.¹¹

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.

CEMs 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 CO₂, O₂, and SO₂ at each location. CO, NO_x and THC were monitored at the inlet and outlet only. HCl concentrations were also monitored continuously by Entropy Environmentalists, Inc., at the inlet, midpoint and outlet but 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 11 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:

1. Reactions between the injected lime and acid gases (primarily HCl and SO₂) 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.
2. 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.
3. 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.
4. 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 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

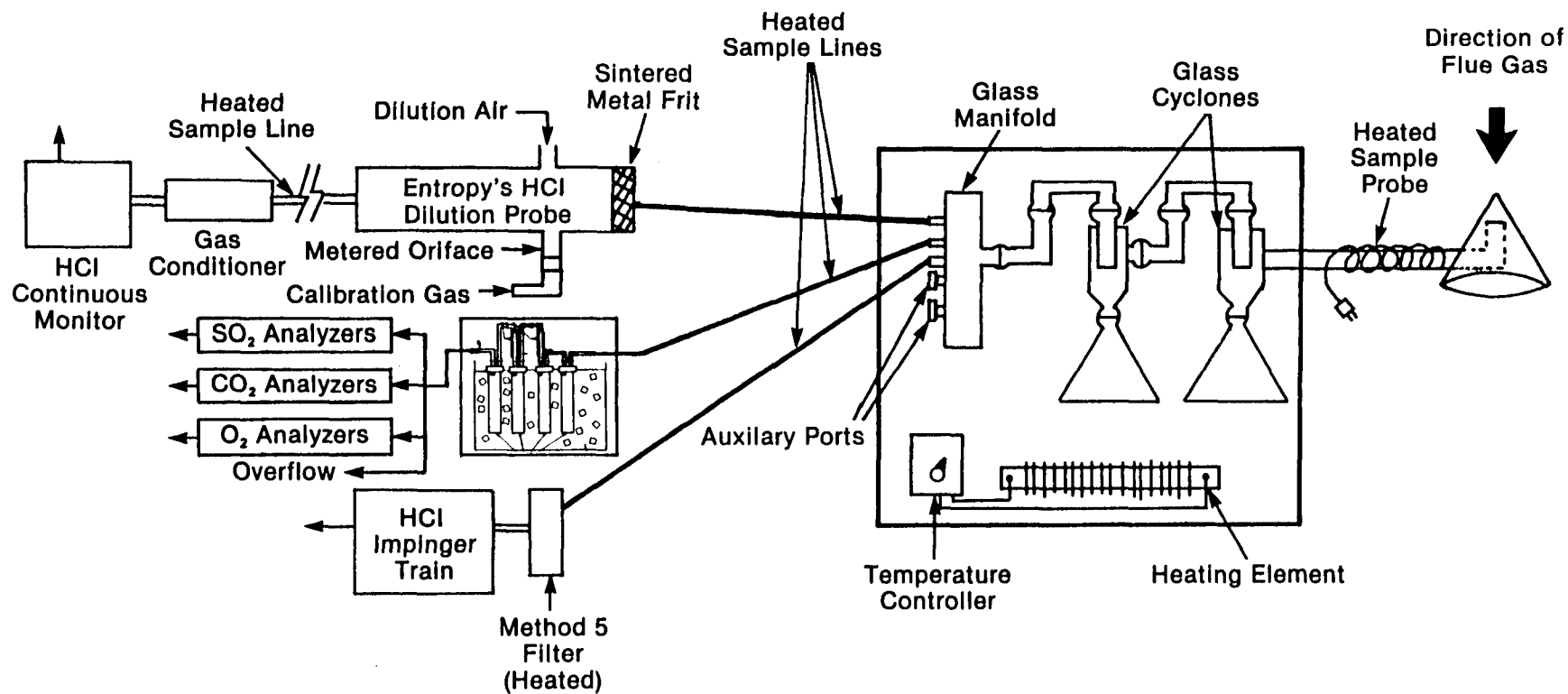


Figure 6-1. CEM Sampling and Analysis Scheme for the Midpoint Sampling Location for the Marion County MWC

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:

1. 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.
2. 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.
3. 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 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, during the initial attempts the SO_2 concentrations varied significantly with feed causing too much variation at each traverse point. The indicator was then switched to NO_x .

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

GEM data were reported as approximately 1-minute averages. The Radian data acquisition system used for this test program scanned each channel 1700 times per minute and then stored a 1700-scan average in memory. Depending on the available space in memory, storing the data took a variable amount of time varying by a few seconds. Thus, the 1700-scan averages were stored approximately every minute, rather than exactly on a minute interval.

The 1-minute averages were averaged every hour to generate three to four hourly averages per test run. Each hour interval was 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.

During the transition period between test conditions, monitoring was continued. Therefore, the GEM analyzers were calibrated at the beginning and end of each test day rather than for each test condition.

6.2 MANUAL METHODS

6.2.1 HCl Determination

HCl sampling was based on EPA Reference Method 5 with modifications that allowed collection of HCl in the back half of the sampling train. Further development of this 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 11.

6.2.1.1 Manual HCl Sampling. The following program-specific changes were required for manual HCl sampling at all locations for the characterization 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.
5. A glasswool plug was placed in the glass probe liner for the outlet train. No filter was used.
6. For the inlet train, a filter was used with no glasswool in the probe liner.
7. The front half of the sampling trains was not recovered. The glassware was rinsed with distilled water to remove particulate and the rinses discarded.
8. Buttonhook nozzles were not used.
9. Sampling was conducted for 3 hours.
10. The pitots at the inlet location were blown back every 15 minutes due to the high particulate loading.

6.2.1.2 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 specific ion electrode (SIE) on-site. The analyzed aliquots were saved and later reanalyzed by ion chromatography (IC) in the laboratory. The samples were evaluated for matrix interference by the method of additions using SIE.

6.2.2 Volumetric Flowrate Determination

The volumetric flowrate of flue gas was measured according to EPA Method 2. The flowrate was determined at the inlet, midpoint, and outlet sampling locations both prior to and at the completion of each test run.

6.2.3 Moisture Determination

The average flue gas moisture content was determined according to EPA Method 4. This is discussed in more detail in Section 4.2.5 of Reference 11.

6.2.4 Fixed Gases Determination

The molecular weight and CO₂ and O₂ 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.

6.2.5 SO₂ Determination

Manual sampling and analyses for SO₂ 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.

6.2.6 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. This collected 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.

The analytical methods for determining CDD and CDF are described in Section 5.5.1 of Reference 12. Both screening and confirmation analyses were performed. The confirmation results for 2378-TCDF were used for each sample. The confirmation results for 2378-TCDD were used only if less interference was present. This was determined by comparing the screening and confirmation results and selecting the lower value.

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.¹³

7.1 QUALITY ASSURANCE OVERVIEW OF THE MARION COUNTY TEST PROGRAM

The Marion County Characterization test program was organized such that the quality assurance function allowed complete independence in program review. Radian's Quality Assurance Officer reports 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 focussed heavily upon controlling measurement data within established acceptance criteria.

Internal QA conducted by Radian personnel centered around 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 which provides a documented history of each sample and provides assurance 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, and 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 (QA) played a key role in the Marion County Test Program. Entropy Environmentalist, 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:

- o Precision - 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.

- o 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.
- o 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.
- o Comparability - A measure of the confidence with which one data set can be compared with another.
- o 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 criterion shown in Table 7-1. In fact, the day-to-day precision, expressed as the percent coefficient of variation (Standard deviation/mean), was less than 3 percent for all analyzers except SO₂ 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 percent.

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 criterion 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 ^b	±40%	±28%	±50%	NA ^c	90%	100%
CDF ^b	±40%	±22%	±50%	NA ^c	90%	100%
Continuous Emission Monitors ^{d,e}						
<u>Inlet:</u>						
O ₂	±10%	0.65%	±10%	2.3%	90%	100%
CO ₂	±10%	2.56%	±10%	6.6%	90%	100%
CO ²	±10%	1.10%	±10%	3.07%	90%	100%
THC	±10%	2.44%	±10%	4.6%	90%	100%
NO	±10%	1.98%	±10%	2.7%	90%	100%
SO ₂ ^x	±10%	1.81%	±10%	2.1%	90%	100%
High Range SO ₂	±10%	0.64%	±10%	NC ^e	90%	100%
<u>Midpoint:</u>						
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%
<u>Outlet:</u>						
CO ₂	±10%	1.98%	±10%	2.3% ^k	90%	100%
SO ₂	±10%	0.88%	±10%	4.3%	90%	100%
NO ₂	±10%	1.39%	±10%	4.5%	90%	100%
THC ^x	±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	±6%	NC	±10%	1.4% ^j	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	2.53%	NE	2.7%	90%	93%

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

^bThe values for precision represent the mean absolute differences for two identical analyses of the same sample for the same isomers.

^cThe 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.

^dPrecision of the CEMs is expressed as the % coefficient of variation (CV) determined from daily analyses of a QC standard, where

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

^eThe accuracy of the CEMs is expressed as the absolute relative error as determined from independent audit standards.

^fND = Not determined for this parameter.

^gNC = No performance audit or QC analyses performed for this parameter.

^hRelative accuracy expressed as the mean absolute relative error from ASTM thermometer.

ⁱPrecision (%CV) and accuracy (absolute relative error) based on analysis of chloride QA audit sample.

^jAccuracy expressed as mean % absolute relative error from an EPA critical orifice.

^kThe accuracy of the outlet SO₂ monitor is based on the revised quench factor equation discussed in Section 7.3.8.

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

Criteria	Control Limit	Corrective Action
<u>Manual Sampling</u>		
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 $\pm 5\%$ 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	$1.00 \pm 1\%$	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
<u>CEM Measurements</u>		
Linearity Multipoint Calibration (four points)	$R \leq 0.9950$	Adjust instrument, recalibrate
Daily Drift (zero and span)	a) $\pm 5\%$ b) 75% of data $\leq 20\%$ c) $> 20\%$ d) 2 days with drift greater than 10 percent	Data not adjusted Adjust data assuming linear drift over testing period. Reject data 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 (continued)</u>		
Sampling System Bias	$\pm 5\%$ 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	$\pm 7\%$ of manual result	Repeat interference check to verify. If verified, clean sample lines and check calibration
Line Leakcheck	$> 0.5\% \text{ O}_2$	Locate and repair leak, recheck
Manifold Leakcheck	$> 0.5\% \text{ O}_2$	Locate and repair leak, recheck
<u>CDD/CDF Analytical Results</u>		
Internal Standard Recoveries	$100 \pm 50\%$	Re-extract and re-analyze if below 20% or greater than 180%
Surrogate Recoveries	$100 \pm 50\%$	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
<u>CDD/CDF Analytical Results (continued)</u>		
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 $\leq 50\%$	Check data manipulations
<u>HCl Analytical Results (specific ion electrode method)</u>		
Duplicate	Percent Difference $\leq 10\%$	Reanalyze
Internal Audit Sample	Relative Error $\pm 10\%$ of audit sample	Analyze by ion chromatography
Audit Blank		Analyze by ion chromatography
Interference Check by Method of Additions	$\pm 10\%$ of true value	Analyze by ion chromatography
Linearity of Calibration Curve	$R \geq 0.995$	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. 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 Ash CDD/CDF Sampling and Analysis

Quality control for the ash sampling included procedures for contamination control as well as measurement integrity. Equal size increments were collected at regularly scheduled intervals. Only sample containers and tools that had been thoroughly and properly cleaned were used for sample collection. Immediately after any compositing, all samples were properly transferred to appropriate storage containers.

For the CDD/CDF ash 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 ¹³C-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 ash samples were spiked with known amounts of internal standards and surrogates prior to extraction. The internal standards were added during the soxhlet extraction step. 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 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 economizer and cyclone ash were all within the acceptable range. Recoveries for superheater ash were all within the QC criterion except for the recovery of $^{13}\text{C}_{12}$ -OCDD which ranged from 30 to 48 percent. Good recoveries of the other internal standards indicate that the lower recoveries reported for $^{13}\text{C}_{12}$ -OCDD are not systematic analytical laboratory errors and are probably caused by a sample matrix effect on the column cleanup and possibly retention on carbonaceous ash.

Surrogate recoveries are summarized in Table 7-4. All ash surrogate recoveries were well within the QC criterion of ± 50 percent, ranging from 76 to 135 percent.

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

TABLE 7-3. INTERNAL STANDARDS RECOVERY RESULTS FOR
MARION COUNTY CDD/CDF ASH ANALYSES

Sample	Recovery (%)				
	$^{2378-13}\text{C}_{12}\text{-TCDD}$	$^{13}\text{C}_{12}\text{-PCDD}$	$^{13}\text{C}_{12}\text{-HxCDD}$	$^{13}\text{C}_{12}\text{-HpCDD}$	$^{13}\text{C}_{12}\text{-OCDD}$
<u>Superheater Ash</u>					
Run 4	100	89	79	68	48
Run 6A	76	76	74	51	29
Run 6B	87	82	77	60	42
Run 11B	91	88	83	63	45
<u>Economizer Ash</u>					
Run 3B	96	92	78	72	61
Run 4	97	95	79	75	62
Run 6A	87	78	65	59	47
Run 6B	97	96	79	74	65
Run 11B	90	83	73	63	48
Run 11B (Duplicate)	102	96	79	67	49
<u>Cyclone Ash</u>					
Run 3B	88	91	85	67	55
Run 4	84	86	85	71	52
Run 6A	88	94	91	73	60
Run 6B	79	82	78	63	52
Run 11B	80	84	81	60	46

TABLE 7-3. INTERNAL STANDARDS RECOVERY RESULTS FOR
MARION COUNTY CDD/CDF ASH ANALYSES

(Continued)

Sample	Recovery (%)				
	$^{2378-13}\text{C}_{12}\text{-TCDD}$	$^{13}\text{C}_{12}\text{-PCDD}$	$^{13}\text{C}_{12}\text{-HxCDD}$	$^{13}\text{C}_{12}\text{-HpCDD}$	$^{13}\text{C}_{12}\text{-OCDD}$
<u>Baghouse Ash</u>					
Run 3B	93	87	92	92	79
Run 3B (Dup.)	97	97	86	89	76
Run 4	92	94	80	83	70
Run 6A	99	103	88	83	64
Run 6B	78	73	71	60	59
Run 10	95	90	78	70	58
Run 11A	96	92	84	71	53
Run 11B	102	91	83	80	72

TABLE 7-4. SURROGATE RECOVERIES FOR MARION COUNTY
ASH CDD/CDF ANALYSES

Sample	Recovery (%)		
	$^{13}\text{C}_{12}$ -TCDF	^{37}Cl -TCDD	$^{13}\text{C}_{12}$ -HxCDF
<u>Superheater Ash</u>			
Run 4	99	100	99
Run 6A	92	98	94
Run 6B	98	95	94
Run 11B	92	95	96
<u>Economizer Ash</u>			
Run 3B	99	102	96
Run 4	95	103	97
Run 6A	102	99	99
Run 6B	97	103	95
Run 11B	90	99	97
Run 11B (Dup.)	97	101	103
<u>Cyclone Ash</u>			
Run 3B	91	76	95
Run 4	82	97	91
Run 6A	92	96	93
Run 6B	89	95	93
Run 11B	95	94	93
<u>Baghouse Ash</u>			
Run 3B	135	105	113
Run 3B (Dup.)	122	96	111
Run 4	122	94	107
Run 6A	124	98	103
Run 6B	88	82	85
Run 10	123	94	100
Run 11A	95	96	104
Run 11B	95	97	99

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

Analyte	Duplicates ^{a,b}							
	Baghouse Ash (3B)				Economizer Ash (11B)			
	Result #1	Result #2	Average	Absolute Percent Difference	Result #1	Result #2	Average	Absolute Percent Difference
<u>Dioxins</u>								
Mono-CDD	(0.005)	(0.003)	-- ^c	--	(0.003)	(0.003)	--	--
Di-CDD	(0.010)	[0.059]	--	--	(0.003)	(0.003)	--	--
Tri-CDD	0.088	0.196	0.142	76.1	0.021	0.038	0.030	56.7
2378-TCDD	0.026	0.030	0.028	14.3	0.013	0.013	0.013	0.00
Other TCDD	0.148	0.389	0.269	89.6	0.083	0.114	0.099	31.3
12378 PCDD	0.036	0.038	0.037	5.40	0.020	0.025	0.023	21.7
Other PCDD	0.177	0.276	0.227	43.6	0.080	0.121	0.101	40.6
123478 HxCDD	[0.030]	0.022	--	--	0.010	0.011	0.011	9.10
123678 HxCDD	0.041	0.048	0.045	15.6	[0.009]	[0.009]	--	--
123789 HxCDD	0.076	0.070	0.073	8.22	0.031	[0.035]	--	--
Other HxCDD	0.174	0.228	0.201	26.9	0.050	0.053	0.052	5.77
1234678 HpCDD	0.212	0.242	0.227	13.2	0.069	0.093	0.081	29.6
Other HpCDD	0.187	0.205	0.196	9.18	0.070	0.090	0.080	25.0
Octa-CDD	0.247	0.328	0.288	28.1	0.188	0.227	0.208	18.8
Average				31.9				23.5

^aAll results reported in ppb. 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

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

^cDash indicates not applicable.

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

Analyte	Duplicates ^{a,b}							
	Baghouse Ash (3B)				Economizer Ash (11B)			
	Result #1	Result #2	Average	Absolute Percent Difference	Result #1	Result #2	Average	Absolute Percent Difference
<u>Furans</u>								
Mono-CDF	(0.005)	[0.026]	-- ^c	--	(0.001)	(0.003)	--	--
Di-CDF	(0.015)	0.074	--	--	[0.351]	[0.475]	--	--
Tri-CDF	2.949	3.652	3.301	21.3	1.596	2.224	1.910	32.9
2378 TCDF	2.400	2.000	2.200	18.2	1.900	2.100	2.000	10.0
Other TCDF	3.385	4.108	3.746	19.3	1.777	2.036	1.907	13.6
12378 PCDF	0.167	0.204	0.186	19.9	0.134	0.153	0.144	13.2
23478 PCDF	0.152	0.150	0.151	1.32	0.140	0.166	0.153	16.9
Other PCDF	1.149	1.666	1.408	36.7	0.794	0.918	0.856	14.5
123478 HxCDF	0.240	0.187	0.214	24.8	0.158	0.198	0.178	22.5
123678 HxCDF	0.088	0.109	0.099	21.2	0.063	0.086	0.075	30.7
234678 HxCDF	[0.059]	0.075	--	--	0.093	0.105	0.099	12.1
123789 HxCDF	(0.010)	(0.003)	--	--	[0.007]	(0.003)	--	--
Other HxCDF	0.392	0.403	0.398	2.76	0.325	0.425	0.375	26.7
1234678 HpCDF	0.351	0.195	0.273	57.1	0.317	0.395	0.356	21.9
1234789 HpCDF	(0.008)	0.009	--	--	0.030	0.043	0.037	35.1
Other HpCDF	0.039	0.021	0.030	60.0	0.158	0.220	0.189	32.8
Octa-CDF	[0.134]	[0.035]	--	--	0.195	0.254	0.225	26.2
Average				23.6				21.0

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

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

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

^c Dash indicates not applicable.

The reproducibility or precision of the sample preparation and analytical methodology was well within the QC criterion for nearly every isomer. The average differences for the duplicate analyses were 28 percent and 22 percent for CDDs and CDFs, respectively.

7.3.1.3 Sample Blanks. Analytical method blanks were analyzed as part of the QC program. These results are presented in Table 7-6. Insignificant quantities of the target analytes were found in two of the method blanks. Only OCDD, at a concentration of 0.006 ppb, was found in method blank #2. Trace amounts of 2378-TCDF, 123478-HxCDF, and 1234678-HpCDF were found in method blank #3. These concentrations were very close to the method detection limit or in the noise range (10 times the detection limit), and therefore, are not considered significant.

7.3.2 HCl Flue Gas Sampling and Analysis Quality Control

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. Sampling quality control followed standard Method 5 procedures. The specific ion electrode (SIE) detection method was used for on-site measurement of free chloride ions in aqueous solutions.

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.

TABLE 7-6. ANALYTICAL METHOD BLANK RESULTS FOR
MARION COUNTY CDD/CDF ASH ANALYSES^{a, b}

Analyte	Method Blank 1	Method Blank 2	Method Blank 3
Total MCDD	ND (0.003)	ND (0.001)	ND (0.003)
Total DCDD	ND [0.007]	ND [0.006]	ND (0.003)
Total TriCDD	ND (0.005)	ND (0.005)	ND (0.008)
2378-TCDD	ND (0.003)	ND (0.003)	ND (0.003)
Total TCDD	ND [0.004]	ND [0.003]	ND (0.003)
12378-PCDD	ND (0.003)	ND (0.003)	ND (0.003)
Total PCDD	ND (0.003)	ND (0.003)	ND (0.003)
123478-HxCDD	ND (0.003)	ND (0.003)	ND (0.003)
123678-HxCDD	ND (0.003)	ND (0.003)	ND (0.003)
123789-HxCDD	ND (0.003)	ND (0.003)	ND (0.003)
Total HxCDD	ND [0.011]	ND [0.007]	ND (0.003)
1234678-HpCDD	ND (0.003)	ND (0.003)	ND (0.003)
Total HpCDD	ND (0.003)	ND (0.003)	ND (0.003)
OCDD	ND (0.005)	0.006	ND (0.005)
Total MCDF	ND (0.003)	ND (0.001)	ND (0.003)
Total DCDF	ND (0.005)	ND (0.003)	ND (0.005)
Total TriCDF	ND (0.005)	ND (0.003)	ND (0.005)
2378-TCDF	ND (0.003)	ND (0.003)	0.005
Total TCDF	ND (0.003)	ND (0.003)	0.005
12378-PCDF	ND (0.003)	ND (0.003)	ND (0.003)
23478-PCDF	ND (0.003)	ND (0.003)	ND (0.003)
Total-PCDF	ND (0.003)	ND (0.003)	ND (0.003)
123478-HxCDF	ND (0.003)	ND (0.003)	0.009
123678-HxCDF	ND (0.003)	ND (0.001)	ND (0.003)
234678-HxCDF	ND (0.003)	ND (0.003)	ND (0.003)
123789-HxCDF	ND (0.003)	ND (0.003)	ND (0.003)
Total HxCDF	ND (0.003)	ND (0.003)	0.010
1234678-HpCDF	ND (0.003)	ND (0.003)	0.025
1234789-HpCDF	ND (0.003)	ND (0.003)	ND (0.003)
Total HpCDF	ND (0.003)	ND (0.003)	0.028
OCDF	ND (0.005)	ND (0.003)	ND (0.005)

^aND= not detected at the method detection limit shown in parentheses.
Estimated maximum possible concentration reported in brackets.

^bMethod detection limit and/or measured concentrations reported in ppb.

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 chromatography. These results were used to support the SIE data and can be found in Appendix H.2.2.

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.

Reagent 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 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.

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 DI 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.

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-HC11N1-I1A	3000	3900 ^c	-23.1
MAR0604-HC11N1-I2A	800	720 ^c	11.1
MAR-0604-HC1-MID1-I1A	1000	1300 ^c	-23.1
MAR-0604-HC1-MID1-I2A	Offscale	230 ^c	--
MAR-0604-HC1-OUT1-I1A	250	260 ^c	-3.8
MAR-0604-HC1-OUT1-I2A	15.0	24.0 ^c	-37.5
MAR-0605-HC1-IN2-I1A	4400	4200	4.8
MAR-0605-HC1-IN2-I2A	720	700	2.9
MAR-0605-HC1-MID-2-I1A	1200	1200	0.0
MAR-0605-HC1-MID-2-I2A	52.0	56.0	-7.1
MAR-0605-HC1-OUT-2-I1A	220.0	220.0	0.0
MAR-0605-HC1-OUT-2-I2A	10.0	10.5	-4.8
MAR-0608-HC1-IN-4-I1A	3300	2800	17.9 ^e
MAR-0608-HC1-IN-4-I2A	525	430	22.1 ^e
MAR-0608-HC1-MID-4-I1A	1040	860	20.9 ^e
MAR-0608-HC1-MID-4-I2A	Offscale	16.0	--
MAR-0608-HC1-OUT-4-I1A	54.0	63.0	-14.3 ^e
MAR-0608-HC1-OUT-4-I2A	2.0	1.90	5.3
QA5	105.0	100.0	5.0

^aA 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.

^bRelative percent difference calculated as $[(A - B)/B] \times 100$, 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.

^cThese 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.

^dThe 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).

^eThese values are considered to be outside the QC criteria, but samples were not reanalyzed during this time period.

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 (spray dryer 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. Two Thermo Electron Corporation (TECO) Model 40 SO_2 analyzers were used to monitor the midpoint and fabric filter outlet locations. The midpoint TECO 40 SO_2 analyzer was used for the inlet location for Runs 10, 11A, and 11B. 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 a photon. 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 inlet location for Runs 1-9. For Runs 10, 11A, and 11B the Western SO_2 analyzer was used for the midpoint location. The Western instrument is essentially a continuous spectrophotometer in the ultraviolet range. SO_2 selectively absorbs ultraviolet (UV) light at a wavelength of 202.5 nm and 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 both Beckman Model 865, non-dispersive infrared analyzers. Non-dispersive infrared analyzers emit a specific wavelength of infrared radiation through the sample cell which is selectively absorbed by CO_2 molecules. The CO instrument was offset at the outlet location to compensate for interferences caused by the presence of CO_2 in the flue gas since the CO levels in the flue gas were low (20-40 ppm). Since this offset was significant for the outlet analyzer, the CO data for this location were discarded.

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 Tables 7-8 through 7-11. Daily drift requirements for both zero and span were ± 5 percent for each run. For the 12 days of sampling with 15 analyzers (approximately 180 data points), the instrument drift was routinely 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 testing 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 was caused by the high lime/moisture content in the gas. Bias check results are presented in Table 7-12. The QC criteria was sampling system bias ± 5 percent of span. The bias for CO_2 and SO_2 analyzers changed 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 7-13. The 95 percent 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 one or three hour averaging intervals. The response times for obtaining 95 percent 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.

TABLE 7-8. SUMMARY OF CEM DRIFT CHECKS FOR MARION COUNTY, INLET^{a,b,c}

Date	Test Condition	O ₂ Drift (%V)	CO ₂ Drift (%V)	CO Drift (ppm)	SO ₂ Drift (ppm)	NO _x Drift (ppm)	THC Drift (ppm)
6-04-87	1	-0.129	9.281 ^d	0.098	1.916	-1.130	11.891 ^d
6-05-87	2	-0.575	2.931	0.108	-2.326	-2.847	6.021 ^d
6-06-87	3A,3B	-0.124	0.883	1.133	0.589	-1.947	-0.288
6-08-87	4	0.562	0.051	1.388	-0.045	0.551	16.158 ^d
6-09-87	5	0.680	2.205	2.253	2.237	1.814	31.854 ^e
6-10-87	6A,6B	0.534	9.255 ^d	1.764	-0.542	-1.676	3.188
6-11-87	7	-0.255	16.945 ^d	0.853	2.007	-2.747	2.077
6-12-87	8,9	0.158	10.931 ^d	1.074	3.529	-4.831	1.977
6-15-87	10	1.775	4.359	1.341	-2.713	-0.696	1.643
6-16-87	11A,11B	1.347	-2.496	0.848	3.274	2.050	2.963
6-21-87	12	-0.026	8.982 ^d	-0.187	-0.829	0.700	2.641
6-22-87	13	-0.810	-0.152	-0.060	2.473	-0.669	10.873 ^d

^aDrifts expressed as [(Final Response Factor - Initial Response Factor)/Initial Factor] x 100.

^bQC criterion is percent drift within ± 5 percent.

^cThe instrument spans were as follows: 0-25%V for O₂, 0-20%V for CO₂, 0-100 ppm for CO, 0-500 ppm for SO₂, runs 1-9, 0-1000 ppm for SO₂, runs 10-13, 0-1000 ppm for NO_x, and 0-100 ppm for THC runs 1-5, 12, 13 and 0-10 ppm for runs 6-11.

^dExceeds 5% QC criteria.

^eExceeds 20% rejection criteria. Drift correction applied and data retained conditionally.

TABLE 7-9. SUMMARY OF CEM DRIFT CHECKS FOR MARION COUNTY, MIDPOINT ^{a,b,c}

Date	Test Condition	O ₂ Drift (%V)	CO ₂ Drift (%V)	SO ₂ Drift (ppm)
6-04-87	1	0.239	6.880	8.118 ^d
6-05-87	2	0.266	4.203 ^d	22.772 ^e
6-06-87	3A,3B	-0.287	15.297 ^d	8.850 ^d
6-08-87	4	0.298	0.409	12.403 ^d
6-09-87	5	1.297	-2.236	16.115 ^d
6-10-87	6A,6B	2.927	4.062	3.075
6-11-87	7	1.495	8.421 ^d	2.924
6-12-87	8,9	1.408	13.740 ^d	8.608 ^d
6-15-87	10	1.252	-0.460	2.144
6-16-87	11A,11B	1.413	-5.252 ^d	0.255
6-21-87	12	0.074	3.506	0.853
6-22-87	13	0.353	2.600	NR

^aDrifts expressed as [(Final Response Factor - Initial Response Factor)/Initial Factor] x 100.

^bQC criterion is percent drift within ± 5 .

^cInstrument spans were 0-25%V for O₂, 0-25% V for CO₂, and 0-500 ppm for SO₂.

^dExceeds 5% QC criteria.

^eExceeds 20% rejection criteria. Drift correction applied and data retained conditionally.

NR - not reported for this parameter on this day.

TABLE 7-10. SUMMARY OF CEM DRIFT CHECKS FOR MARION COUNTY, OUTLET^{a,b,c}

Date	Test Condition	O ₂ Drift (%V)	CO ₂ Drift (%V)	SO ₂ Drift (ppm)	CO Drift (ppm)	THC Drift (ppm)	NO _x Drift (ppm)
6-04-87	1	0.972	-0.566	-0.570	0.910	0.797	12.653 ^d
6-05-87	2	0.067	0.372	-0.185	-0.145	-0.750	8.305 ^d
6-06-87	3A,3B	0.147	9.473 ^d	1.161	0.786	0.298	5.877
6-08-87	4	-1.128	-9.837 ^d	-2.466	-0.112	0.015	2.466
6-09-87	5	-1.447	0.108	4.320	0.231	0.786	6.609 ^d
6-10-87	6A,6B	-1.011	1.491	-1.339	1.075	NR	9.874 ^d
6-11-87	7	-1.037	0.062	-0.641	1.355	NR	15.807 ^d
6-12-87	8,9	-0.909	0.596	4.186	1.008	NR	24.983 ^e
6-15-87	10	1.120	-0.411	-1.628	0.290	NR	9.658 ^d
6-16-87	11A,11B	-1.164	0.392	0.915	-0.036	NR	18.786 ^d
6-21-87	12	-1.352	0.551	0.949	0.995	0.329	9.190 ^d
6-22-87	13	-3.147	5.020 ^d	-1.829	0.729	1.379	6.614 ^d

^aDrifts expressed as [(Final Response Factor - Initial Response Factor)/Initial Factor] x 100.

^bQC criterion is percent drift within ± 5 .

^cThe instrument spans were 0-25% V for O₂, 0-20% V for CO₂, 0-500 ppm for SO₂, 0-500 ppm for CO, and 0-1000 ppm for NO_x, and 0-10 ppm for THC.

^dExceeds 5% QC criteria.

^eExceeds 20% rejection criteria. Drift correction applied and data retained conditionally.

NR = not reported.

TABLE 7-11. SUMMARY OF CEM HIGH RANGE SO_2 DRIFT
CHECKS FOR MARION COUNTY^{a,b}

Date	Test Condition	Location	Percent Drift	Instrument Range
6-04-87	1	Inlet	4.498	0-5000 ppm
6-05-87	2	Inlet	1.362	0-5000 ppm
6-06-87	3A,3B	Inlet	3.716	0-5000 ppm
6-08-87	4	Inlet	-0.136	0-5000 ppm
6-09-87	5	Inlet	0.317	0-5000 ppm
6-10-87	6A,6B	Inlet	1.910	0-5000 ppm
6-11-87	7	Inlet	1.504	0-5000 ppm
6-12-87	8,9	Inlet	3.352	0-5000 ppm
6-15-87	10	Inlet	4.667	0-5000 ppm
6-16-87	11A,11B	Midpoint	1.409	0-5000 ppm

^aDrifts expressed as $[(\text{Final Response Factor} - \text{Initial Response Factor}) / \text{Initial Factor}] \times 100$.

^bQC criterion is percent drift within ± 5 .

TABLE 7-12. CEM SYSTEM BIAS TEST FOR MARION COUNTY SO₂ AND CO₂ ANALYZERS

Date	Sampling System	Analyte (Units)	Range	Concentrations			System Bias	Percent of Span ^{a, 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

^aPercent of span calculated as: Percent of span = (system bias/span) x 100

^bQC criteria is sampling system bias within $\pm 5\%$ of span.

TABLE 7-13. RESPONSE TIMES (95%) FOR MARION COUNTY MIDRANGE CEM QC GASES^a

Instrument	Location					
	Inlet		Midpoint		Outlet	
	Response Time (Minutes)	Gas Concentration	Response Time (Minutes)	Gas Concentration	Response Time (Minutes)	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

^aQC criteria is response time of less than one minute.

^bThese response times were determined using high-range calibration gases.

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

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 7-14. These results indicate that the day-to-day precision of the instruments was well within the QC criteria of ± 10 percent coefficient of variation (CV). The percentage CV was less than 6 percent for all analyzers. The calibration of the CEMs was also shown to be consistent with mean percent difference 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 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 . CO_2 and O_2 were checked using Manual EPA Method 3. CO , THC , and NO_x were not checked. These results are presented in Tables 7-15 through 7-19. 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. For the inlet location, only the absolute difference between the Orsat and CEM value for Run 11B slightly exceeded 1 percent; it was 1.3 percent. At the midpoint, only 3 values exceeded the QC criteria; 1.8 (Run 6A, O_2), 1.9 (Run 6A, CO_2) and 1.5 (Run 11A, CO_2). At the outlet, 3 values exceeded the QC criteria; 1.2 (Run 6A, O_2), 1.8 (Run 5, CO_2), and 1.1 (Run 11A, CO_2). These exceedences are most likely due to a leak in the CEM sampling system.

TABLE 7-14. DAILY QUALITY CONTROL CHECKS FOR THE MARION COUNTY CEMS^a

Number of Points	Parameter	Certified Concentration	Mean Measured Concentration	Mean Percent Difference ^c	Percent Coefficient of Variation
<u>Inlet</u>					
1	O ₂ %V	5.02	4.8	-(4.38) ^b	-- ^d
10	O ₂ %V	10.02	9.78	-2.40	0.62
11	CO ppmV	39.8	39.0	-2.01	1.10
1	CO ₂ %V	4.00	4.00	(0.00)	--
10	CO ₂ %V	7.99	8.26	3.38	2.56
9	SO ₂ ppmV	214.9	224.3	4.37	1.77
2	SO ₂ ppmV	442.6	442.6	0.00	--
10	NO _x ppmV	380.3	378.4	-.50	1.73
5	THC ppmC	42.7	42.6	-.23	1.56
6	THC ppmC	4.3	4.5	4.65	3.32
6	SO ₂ ppmV	1911.3	1981.5	3.67	1.46
3	SO ₂ ppmV	839.4	772.8	-7.93	0.33
2	SO ₂ ppmV	412.3	395.6	-4.05	0.14
<u>Midpoint</u>					
1	O ₂ %V	5.02	5.2	(3.59)	--
10	O ₂ %V	10.2	10.1	0.99	1.48
1	CO ₂ %V	4.00	4.10	(2.50)	--
10	CO ₂ %V	7.99	8.14	1.88	1.76
7	SO ₂ ppmV	214.9	209.3	-2.61	2.19
4	SO ₂ ppmV	214.2	217.7	1.63	5.54
<u>Outlet</u>					
1	CO ₂ %V	4.00	3.6	-(10.00)	--
10	CO ₂ %V	7.99	8.2	2.63	1.98
11	SO ₂ ppmV	214.9	221.7	3.16	0.88
9	NO _x ppmV	380.3	375.3	-1.31	1.39
2	NO _x ppmV	380.4	372.6	-2.05	0.00
5	THC ppmC	4.30	4.5	4.65	7.20
1	CO ₂ %V	4.00	3.6	-(10.00)	--
1	CO ppmV	81.0	81.4	0.49	--
10	CO ppmV	202.0	200.9	-.55	0.32

^aMean Percent difference determined from the data included in Appendix H and calculated as:

$$\frac{[\text{Measured Concentration} - \text{Certified Concentration}]}{\text{Certified Concentration}} \times 100$$

^bPercent difference in parentheses is based on a single measurement.

^cQC criteria was percent coefficient of variation and mean percent difference within 10 percent.

^dDash indicates %CV not applicable.

TABLE 7-15. COMPARISON OF MEASURED METHOD 3 AND CEM O₂^{a,b}
AND CO₂ RESULTS FOR MARION COUNTY, INLET

Test Condition	O ₂		Absolute Difference	CO ₂		Absolute Difference
	Method 3	CEM		Method 3	CEM	
1	9.0	9.0	0.0	10.0	10.4	-0.4
2	9.4	8.8	0.6	10.1	11.0	-0.9
3A	6.2	5.7	0.5	12.6	13.1	-0.5
3B	10.9	10.6	0.3	8.9	8.9	0.0
4	8.9	8.8	0.1	9.7	10.3	-0.6
5	8.9	8.7	0.2	10.0	10.5	-0.5
6A	9.1	8.8	0.3	10.7	10.3	0.4
6B	12.2	12.5	-0.3	7.5	7.3	0.2
7	7.8	7.8	0.0	11.6	11.6	0.0
8	9.7	9.8	-0.1	9.5	9.8	-0.3
9	10.0	10.1	-0.1	9.4	9.5	-0.1
10	8.8	9.4	-0.6	10.2	10.3	-0.1
11A	9.0	8.9	0.1	10.2	10.6	-0.4
11B	9.4	9.2	0.2	9.7	11.0	-1.3

^aAll values expressed in percent, calculated as [Method 3 value - CEM value].

^bQC criteria is absolute difference between Orsat and CEM value within 1 percent.

TABLE 7-16. COMPARISON OF MEASURED METHOD 3 AND CEM O₂ AND CO₂ RESULTS FOR MARION COUNTY, MIDPOINT ^{a,b}

Test Condition	O ₂		Absolute Difference	CO ₂		Absolute Difference
	Method 3	CEM		Method 3	CEM	
1	10.8	10.9	-0.1	8.7	8.6	0.1
2	10.8	10.7	0.1	8.5	9.0	-0.5
3A	9.1	8.5	0.6	10.3	11.1	-0.8
3B	11.9	11.9	0.0	7.6	8.5	-0.9
4	10.6	9.9	0.7	8.8	8.8	0.0
5	10.8	10.2	0.6	8.8	8.9	-0.1
6A	8.9	10.7	-1.8	10.7	8.8	1.9
6B	13.8	13.5	0.3	6.2	6.2	0.0
7	10.2	9.9	0.3	9.3	9.4	-0.1
8	11.7	11.4	0.3	7.9	8.2	-0.3
9	12.0	11.4	0.6	7.5	7.9	-0.4
10	10.6	10.6	0.0	8.7	8.8	-0.1
11A	12.6	10.9	1.7	7.3	8.8	-1.5
11B	11.2	11.0	0.2	8.4	8.6	-0.2

^aAll values expressed in percent and calculated as [Method 3 value - CEM value].

^bQC criteria is absolute difference between Orsat and CEM value within 1 percent.

TABLE 7-17. COMPARISON OF MEASURED METHOD 3 AND CEM O₂ AND CO₂ RESULTS FOR MARION COUNTY, OUTLET^{2a,b}

Test Condition	O ₂		Absolute Difference	CO ₂		Absolute Difference
	Method 3	CEM		Method 3	CEM	
1	11.9	11.7	0.2	7.8	8.0	-0.2
2	12.0	11.9	0.1	7.8	8.1	-0.3
3A	9.6	10.1	-0.5	9.8	10.2	-0.4
3B	13.4	13.2	0.2	6.4	7.4	-1.0
4	11.5	12.2	-0.7	7.9	7.5	0.4
5	12.8	12.0	0.8	6.4	8.2	-1.8
6A	10.6	11.8	-1.2	8.5	8.4	0.1
6B	14.1	15.0	-0.9	5.7	5.6	0.1
7	11.1	11.3	-0.2	8.7	8.8	-0.1
8	12.4	12.8	-0.4	7.4	7.6	-0.2
9	12.4	13.1	-0.7	7.2	7.2	0.0
10	11.8	11.7	0.1	7.6	8.1	-0.5
11A	12.8	11.9	0.9	6.8	7.9	-1.1
11B	12.2	12.0	0.2	7.4	7.8	-0.4

^aAll values expressed in percent and calculated as [Method 3 value - CEM value].

^bQC criteria is absolute difference between Orsat and CEM value within 1 percent.

TABLE 7-18. COMPARISON OF EPA METHOD 6 AND CEM SO₂ 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
Relative Accuracy ^d			-14.1%			+ 2.5%			+8.3%

^aTwo 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.

^bThe relative percent difference was calculated as:

$$[(\text{CEM value} - \text{Method 6 value}) / \text{Method 6 value}] \times 100.$$

^cA reasonable QC criteria was relative difference within ± 20 percent.

^dRelative Accuracy calculated according to Appendix F, Relative Accuracy Audit Procedure, 40CFR Part 60.

TABLE 7-19. COMPARISON OF HCl MANUAL RESULT (SIE) AND CEM RESULT FOR MARION COUNTY^{a, b}

Test Condition	Inlet			Midpoint			Outlet		
	CEM (ppm)	SIE (ppm)	Relative Percent Difference	CEM (ppm)	SIE (ppm)	Relative Percent Difference	CEM (ppm)	SIE (ppm)	Relative Percent Difference
1	560	400	40.0	161	127	27.1	55.8	--- ^c	---
2	579	460	25.7	138	168	-18.1	23.6	25.4	-7.10
3A	541	420	28.7	163	212	-23.0	42.4	45.7	7.30
3B	522	---	---	114	148	-23.0	29.4	40.3	-27.0
4	556	361	54.2	118	139	-14.6	7.2	8.2	-12.5
5	638	524	21.8	81.7	241	-66.1	31.1	45.3	-31.4
6A	595	559	6.40	165	355	-53.5	48.7	50.9	-4.40
6B	380	289	31.4	47.8	152	-68.6	12.8	23.0	-44.3
7	631	626	0.82	176	324	-45.7	49.3	59.3	-16.9
8	464	433	7.26	127	182	-30.0	25.0	32.0	-22.0
9	508	427	19.1	134	185	-27.4	11.8	18.1	-34.7
10	699	---	---	132	168	-21.5	13.8	15.8	-12.8
11A	634	635	-0.15	217	299	-27.5	104	113	-8.47
11B	688	703	-2.23	224	391	-42.5	139	148	-6.23
Average			19.8			34.9			17.6

^aRelative percent difference calculated as [(CEM value - SIE value)/SIE value] x 100.

^bThere 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.

^cDashes indicate run was invalidated. For more discussion, see Section 2 of this report.

For the EPA Method 6 and CEM SO₂ comparison, the relative differences between the two values averaged -14.1, 3.63, and 9.3 percent, respectively, for the inlet, midpoint, and outlet location. These differences were all within the QC criterion for all locations.

As seen from Table 7-19, when comparing the manual versus CEM HCl results, the average relative percent differences, based on the HCl manual result determined from SIE, were 20, 35, and 18, for the inlet, midpoint, and outlet, respectively. However, since there is currently no HCl CEM or manual reference method and there is no QC criteria for the absolute relative differences, these values are reported for informational purposes only. The high positive differences (CEM values generally lower than manual results) observed for the midpoint location are most likely due to a reaction of HCl in the CEM sampling system (interface). The differences for the inlet and outlet locations were variable, and averaged 19.8 and 17.6 percent, respectively. An extra dry impinger was added to the HCl sampling train which resulted in greater liquid contact and improved relative accuracy.

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 7-20 summarizes the leakchecks for the HCl trains, which were all within the QC criteria of 0.02 cfm.

7.3.5 Validation of Fixed Gases Results

The validity of Orsat and CEM O₂ and CO₂ analysis results was confirmed based on a combustion stoichiometry method. Normally, the ultimate CO₂ concentrations were calculated based on an ultimate analysis of the fuel. However, since ultimate analyses were not performed on the refuse

TABLE 7-20. LEAKCHECK SUMMARY FOR THE MARION COUNTY
HCl SAMPLING TRAINS

Date	Test Condition	Sampling ^a Location	Leak Check	Leak Rate ^{b,c} (ft ³ /min)	Pressure (in. H ₂ O)
6-04-87	1	Inlet	Initial	0.016	10
			Final	0.005	4
	1	Midpoint	Initial	0.015	15
			Final	0.007	3
	1	Outlet	Initial	0.010	10
			Final	0.020	--
6-05-87	2	Inlet	Initial	0.009	15
			Final	0.006	8
	2	Midpoint	Initial	0.013	13
			Final	0.015	4
	2	Outlet	Initial	0.010	10
			Final	0.012	7
6-06-87	3A	Inlet	Initial	0.005	25
			Final	0.003	10
	3A	Midpoint	Initial	0.014	15
			Final	0.005	5
	3A	Outlet	Initial	0.009	8
			Final	0.004	8
	3B	Inlet	Initial	0.008	12
			Final	0.013	20
	3B	Midpoint	Initial	0.008	16
			Final	0.003	5
	3B	Outlet	Initial	0.012	8
			Final	0.010	5

^aLocations sampled are relative positions in the air pollution control system.

^bLeak rates are expressed in actual cubic feet of gas over a two minute period.

^cQC criteria is ≤ 0.02 acfm or 4 percent of sampling rate, whichever is less.

--Dash indicates leakrate was less than or equal to 0.02 acfm, but not recorded.

TABLE 7-20. LEAKCHECK SUMMARY FOR THE MARION COUNTY
HCl SAMPLING TRAINS (Continued)

Date	Test Condition	Sampling Location ^a	Leak Check	Leak Rate ^{b,c} (ft ³ /min)	Pressure (in. H ₂ O)
6-08-87	4	Inlet	Initial	0.007	15
			Final	0.008	10
	4	Midpoint	Initial	0.010	12
			Final	0.003	5
	4	Outlet	Initial	0.012	6
			Final	0.005	4
6-09-87	5	Inlet	Initial	0.012	14
			Final	0.002	5
	5	Midpoint	Initial	0.008	12
			Final	0.008	5
	5	Outlet	Initial	0.007	6
			Final	0.007	5
6-10-87	6A	Inlet	Initial	0.007	15
			Final	0.006	5
	6A	Midpoint	Initial	0.009	10
			Final	0.003	4
	6A	Outlet	Initial	0.012	8
			Final	0.003	4
	6B	Inlet	Initial	0.014	14
			Final	0.009	5
	6B	Midpoint	Initial	0.003	10
			Final	0.002	5
	6B	Outlet	Initial	0.012	5
			Final	0.007	4
6-11-87	7	Inlet	Initial	0.010	15
			Final	0.005	6
	7	Midpoint	Initial	0.005	10
			Final	0.003	5
	7	Outlet	Initial	0.005	5
			Final	0.017	4

^aLocations sampled are relative positions in the air pollution control system.

^bLeak rates are expressed in actual cubic feet of gas over a two minute period.

^cQC criteria is ≤ 0.02 acfm or 4 percent of sampling rate, whichever is less.

--Dash indicates leakrate was less than or equal to 0.02 acfm, but not recorded.

TABLE 7-20. LEAKCHECK SUMMARY FOR THE MARION COUNTY
HCl SAMPLING TRAINS (Continued)

Date	Test Condition	Sampling Location ^a	Leak Check	Leak Rate ^{b,c} (ft ³ /min)	Pressure (in. H ₂ O)
6-12-87	8	Inlet	Initial	0.005	15
			Final	0.012	15
	8	Midpoint	Initial	0.004	10
			Final	0.001	12
	8	Outlet	Initial	0.005	5
			Final	0.010	4
	9	Inlet	Initial	0.011	18
			Final	0.020	4
	9	Midpoint	Initial	0.011	10
			Final	0.006	4
	9	Outlet	Initial	0.005	6
			Final	0.007	5
6-15-87	10	Inlet	Initial	0.012	15
			Final	0.004	5
	10	Midpoint	Initial	0.008	15
			Final	0.001	5
	10	Outlet	Initial	0.012	5
			Final	0.010	4
6-16-87	11A	Inlet	Initial	0.008	15
			Final	0.006	6
	11A	Midpoint	Initial	0.006	5
			Final	0.005	7
	11A	Outlet	Initial	0.012	15
			Final	0.013	4
	11B	Inlet	Initial	0.008	15
			Final	0.010	4
	11B	Midpoint	Initial	0.008	15
			Final	0.003	9
	11B	Outlet	Initial	0.007	6
			Final	0.007	4

^aLocations sampled are relative positions in the air pollution control system.

^bLeak rates are expressed in actual cubic feet of gas over a two minute period.

^cQC criteria is ≤ 0.02 acfm or 4 percent of sampling rate, whichever is less.

--Dash indicates leakrate was less than or equal to 0.02 acfm, but not recorded.

from this site an average based on the individual analyses was used. This approach assumes that the majority of the analyses are correct and intends to identify individual poor analyses. Plots of O_2 versus CO_2 were made for both CEM and Orsat analyses at the inlet, midpoint, and outlet. An F_o was calculated for each point using the equation:

$$F_o = (20.9 - \%O_2, \text{ dry})/(\% CO_2, \text{ dry})$$

Manipulation of this equation yields a straight line with slope equal to F_o . The intercepts of this line are 20.9 percent for the O_2 axis and ultimate CO_2 for the CO_2 axis. The ultimate CO_2 is the theoretical CO_2 concentration at zero percent excess air. ($CO_2, \text{ ult.} = \frac{20.9}{F_o}$).

An average F_o and ultimate CO_2 was calculated for each type of CO_2/O_2 analysis for each location. Plots of the lines determined from these parameters are shown in Figures 7-1 through 7-6. In each case, all of the points adhered well to the lines indicating precision in the measurements. It should be noted, however, that leaks are not detected by this method since the points would only move along the given lines due to a leak. This method ensures the integrity of the analysis, not the sampling. Comparison of CEM and Orsat plots will, however, give some insight into sampling integrity. These plots generally compare well. Test 6A at the CEM midpoint may have had some leakage judging from the position of the point on the line compared to the Orsat analysis, although the evidence is not conclusive. A degree of accuracy (bias) may be determined by comparing the ultimate CO_2 analysis for each point. With the exception of the CEM outlet system, all ultimate CO_2 values were near 18 percent CO_2 . The CEM outlet ultimate CO_2 was slightly less than 19 percent.

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-sized impingers. Quality control for the SO_2 analysis included duplicate titrations and analysis of a blank. These results are presented in Table 7-21.

VALIDATION OF FIXED GAS ANALYSIS

INLET CEM OXYGEN AND CARBON DIOXIDE

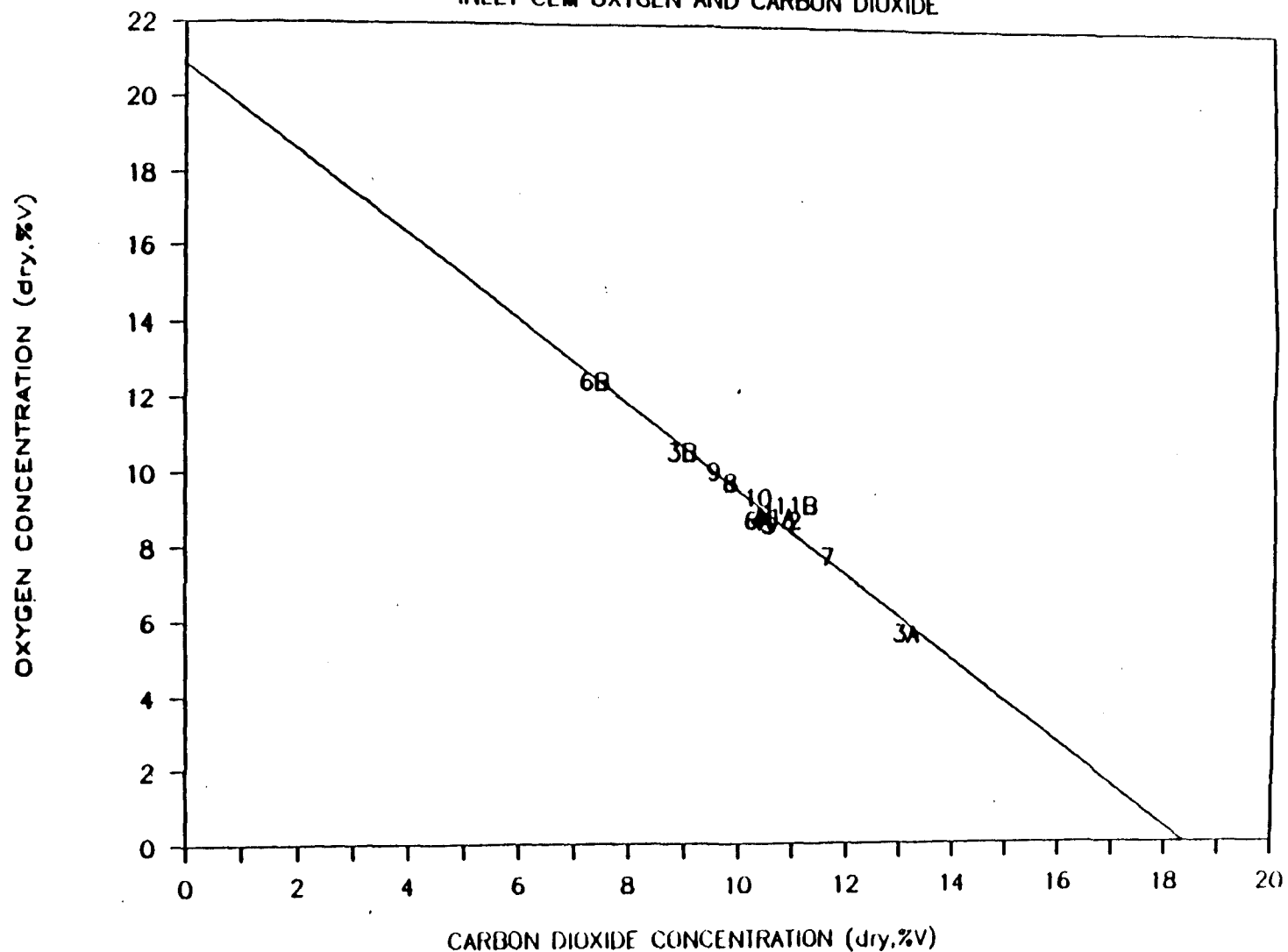


Figure 7-1. Validation of fixed gas analysis for the inlet CEM results

VALIDATION OF FIXED GAS ANALYSIS

INLET ORSAT OXYGEN AND CARBON DIOXIDE

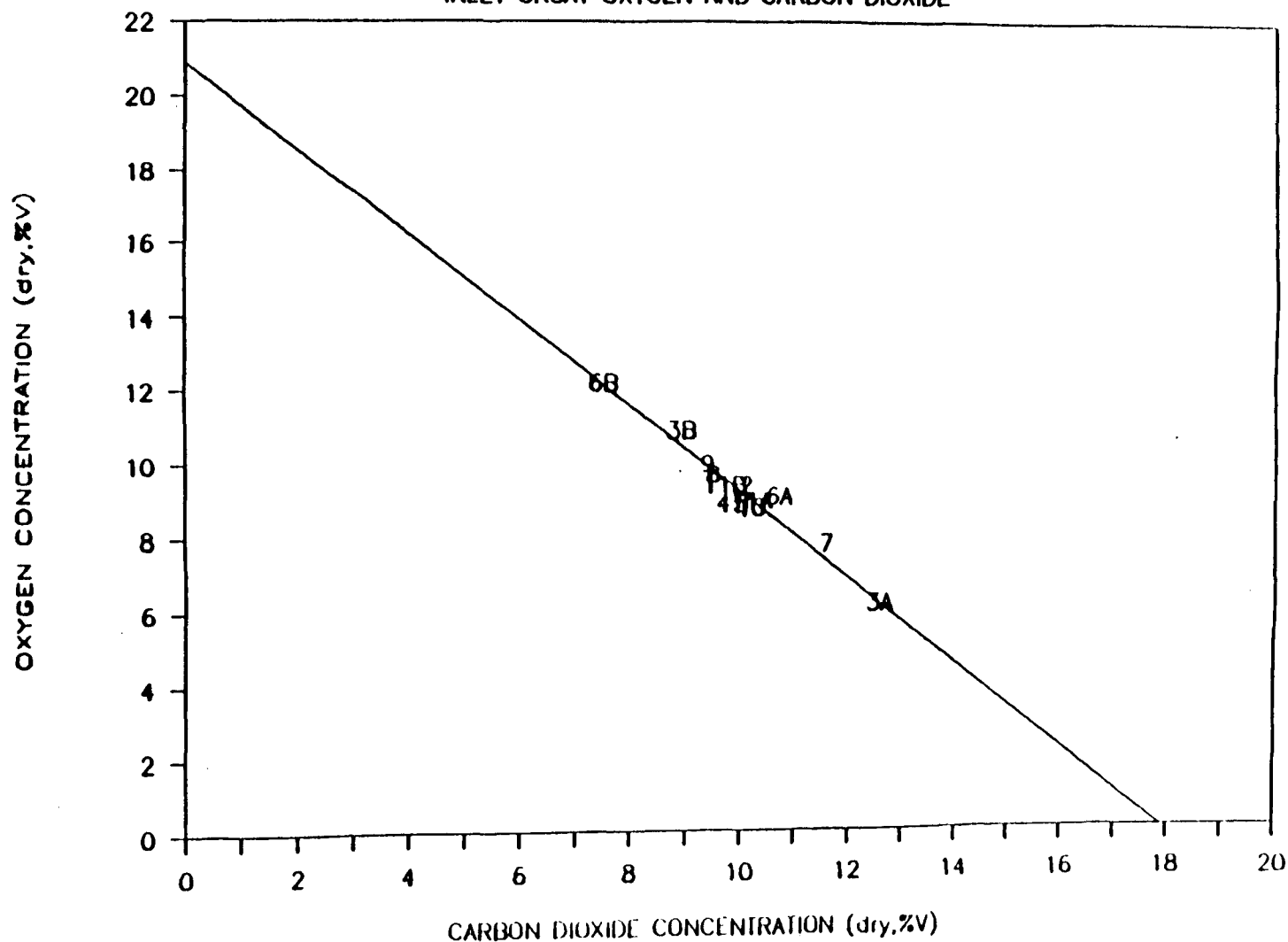


Figure 7-2. Validation of fixed gas analysis for the inlet Orsat results

VALIDATION OF FIXED GAS ANALYSIS

MIDPOINT CEM OXYGEN AND CARBON DIOXIDE

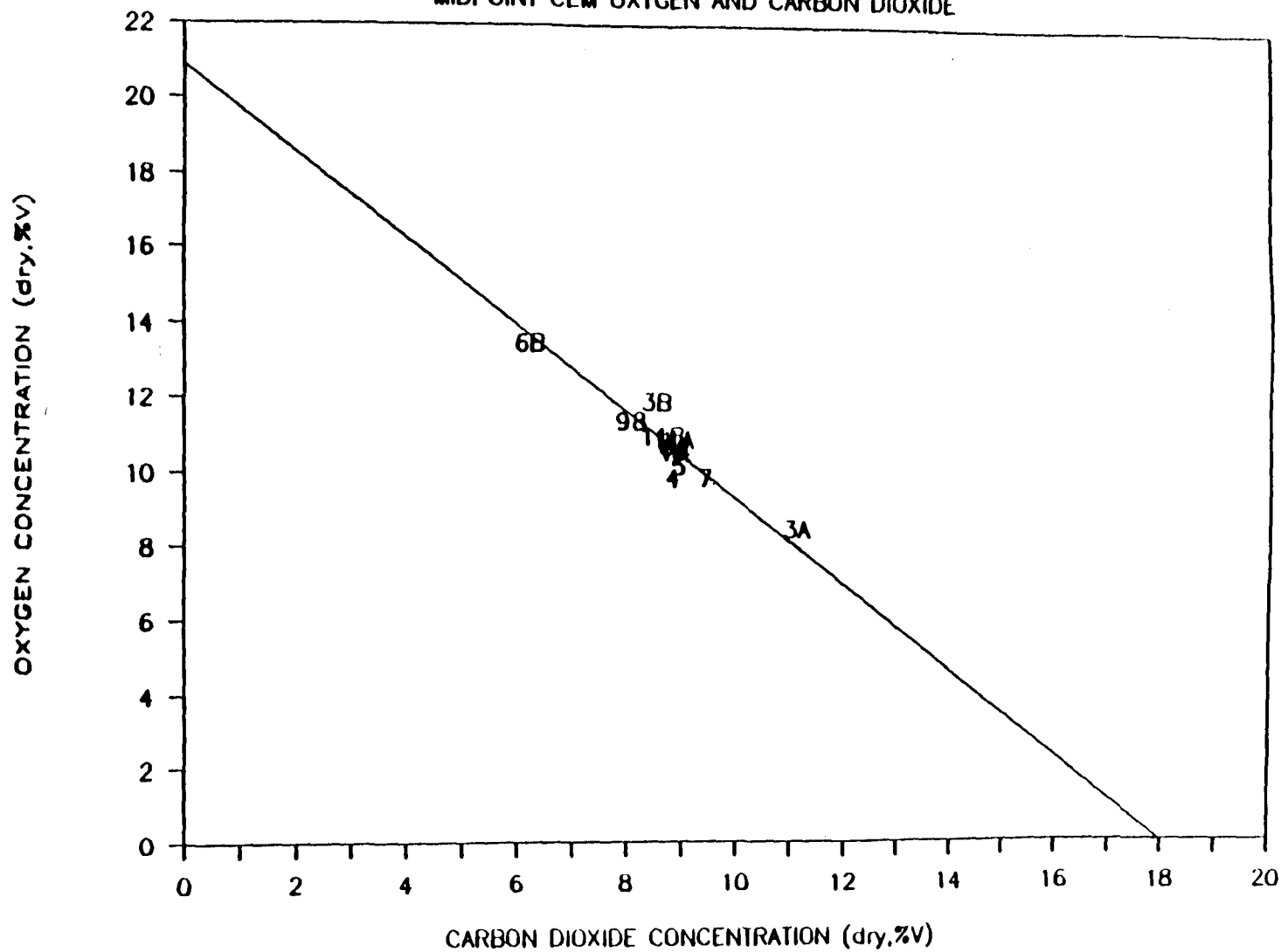


Figure 7-3. Validation of fixed gas analysis for the midpoint CEM results

VALIDATION OF FIXED GAS ANALYSIS

MIDPT. ORSAT OXYGEN AND CARBON DIOXIDE

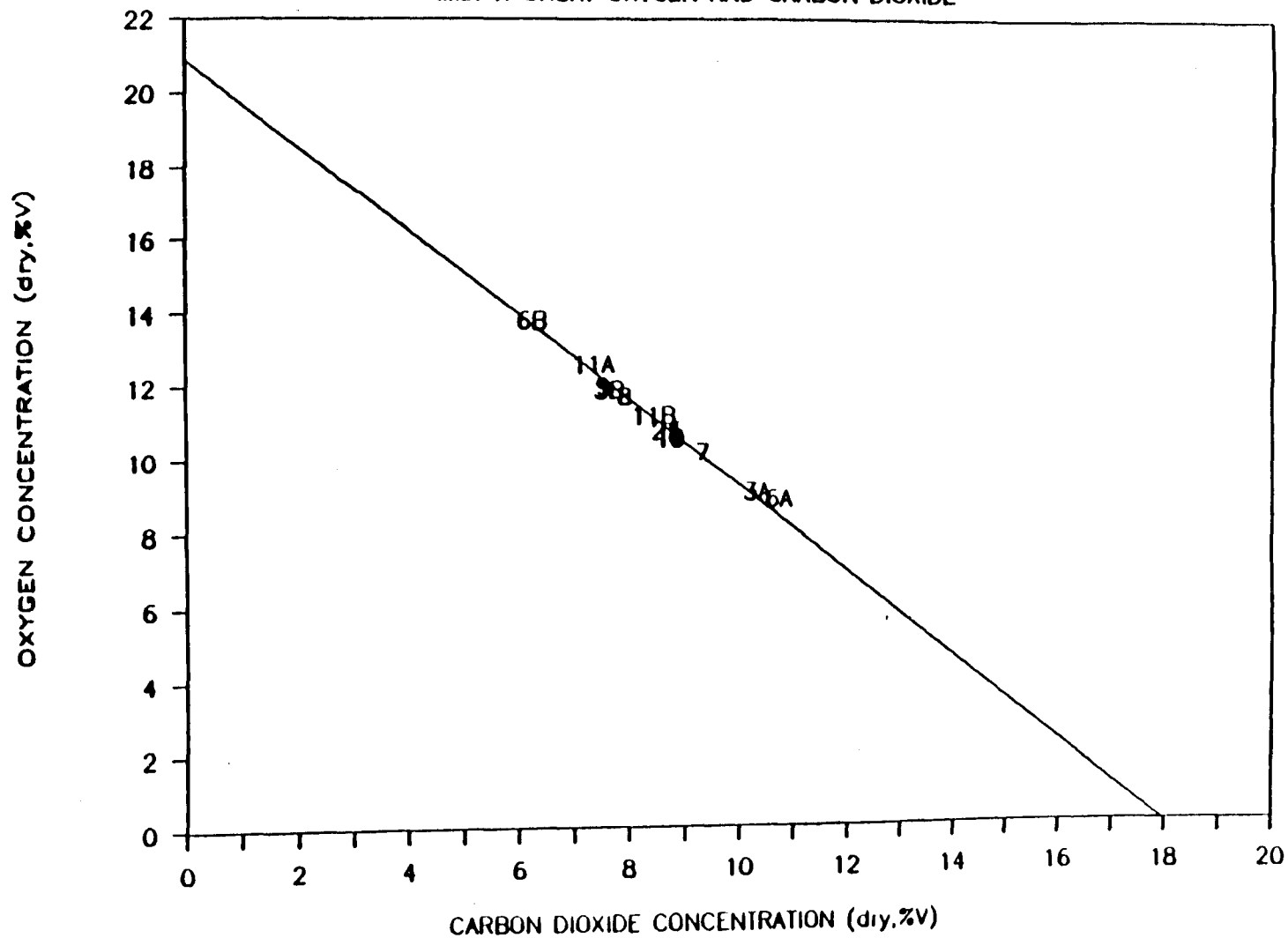


Figure 7-4. Validation of fixed gas analysis for the midpoint Orsat results

VALIDATION OF FIXED GAS ANALYSIS

OUTLET CEM OXYGEN AND CARBON DIOXIDE

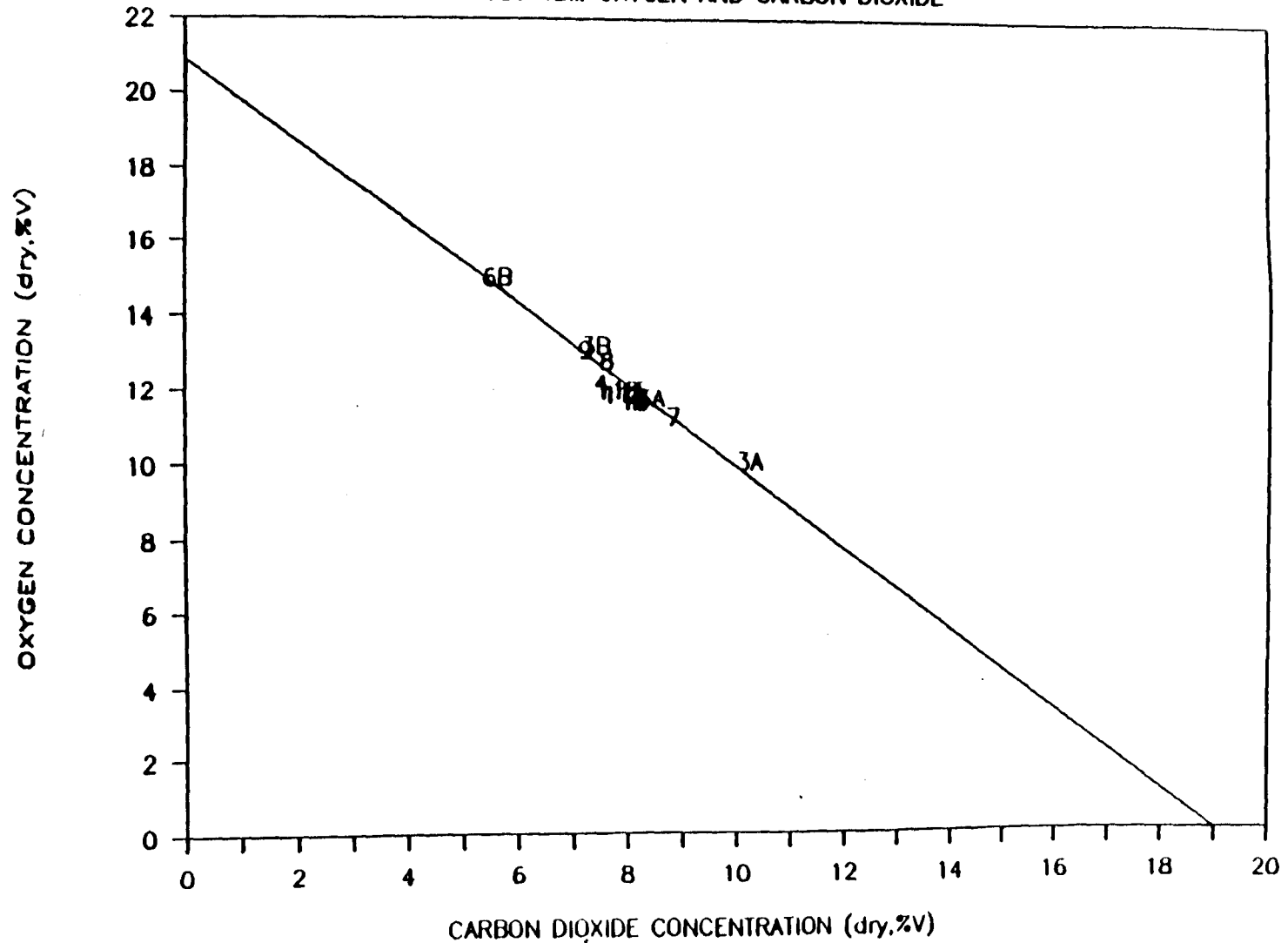


Figure 7-5. Validation of fixed gas analysis for the outlet CEM results

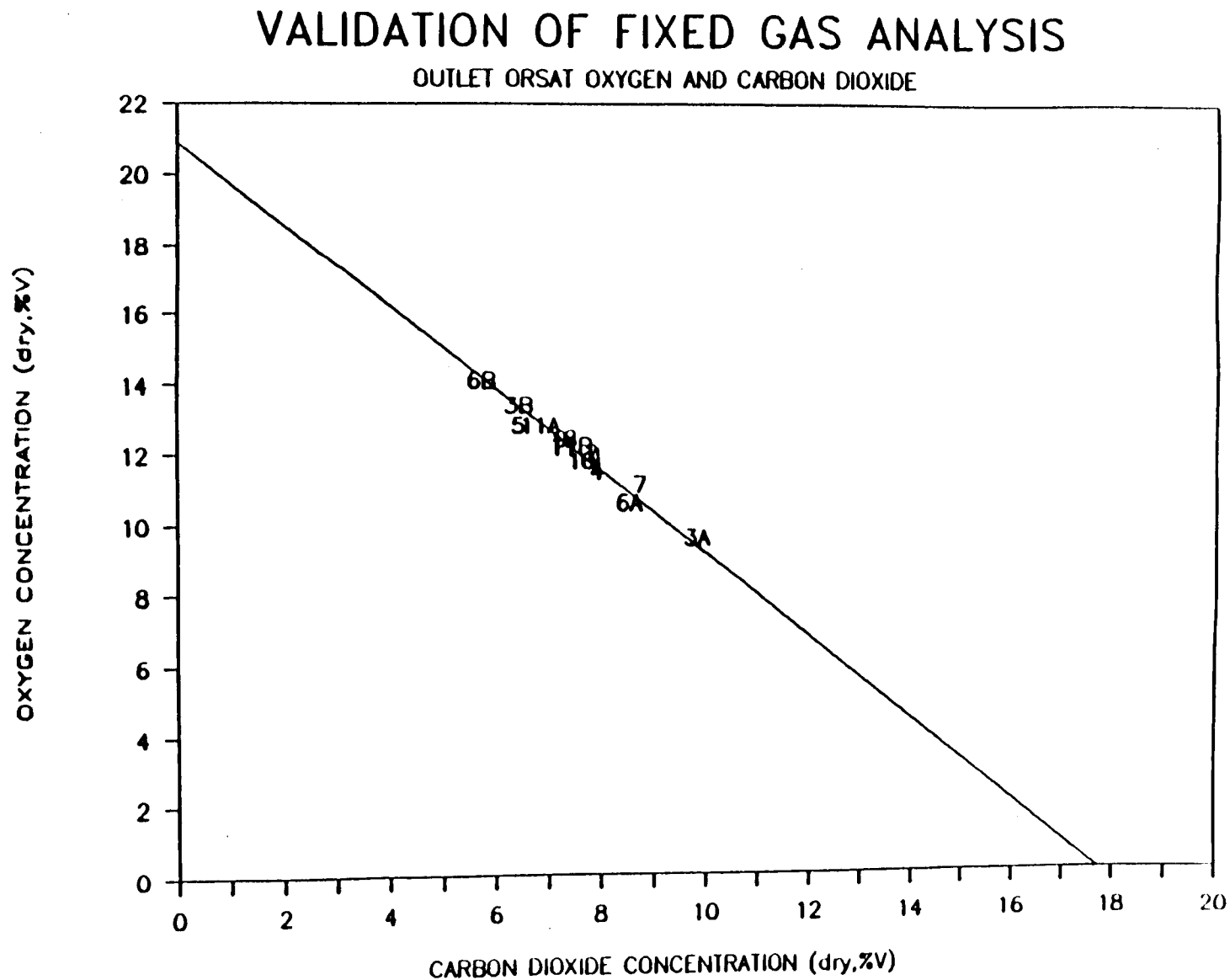


Figure 7-6. Validation of fixed gas analysis for the outlet Orsat results

TABLE 7-21. DUPLICATE RESULTS FOR MARION COUNTY
METHOD 6 SO₂ 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

^aAll values reported in milliliters of barium perchlorate titrant.

^bAnalytical method detection limit was 1.3 parts per million (ppm) or 1.3 ug/ml.

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

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 percent, respectively).

During analysis of the Method 6 SO₂ 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).

7.3.7 CEM Stratification Check

Stratification checks were initially performed with SO₂ but the significant variability in the SO₂ concentrations with time for a given point required that a less variable parameter such as NO_x and a reference point 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 7-22, 7-23, and 7-24, for the inlet, midpoint, and outlet sampling locations. As 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 percent acceptance criteria.

7.3.8 Sulfur Dioxide (SO₂) Quenching Study

External performance audits were conducted on Radian's CEMs on June 2, 3, 4, and 24. The performance evaluation audit of the SO₂ CEMs revealed a potential problem with the outlet SO₂ analyzer, which showed a high bias of

TABLE 7-22. CEM STRATIFICATION CHECK FOR THE MARION
COUNTY INLET SAMPLING LOCATION

Traverse Point	NO _x Concentration (ppmV)		Relative Percent Difference ^{a,b}
	Fixed Reference Probe	Traverse Probe	
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

^aRelative percent differences calculated as:

$$[(\text{Traverse Probe} - \text{Fixed Reference Probe}) / \text{Fixed Reference Probe}] \times 100.$$

^bQC criteria was relative percent difference within ± 10 percent.

TABLE 7-23. CEM STRATIFICATION CHECK FOR THE MARION
COUNTY MIDPOINT SAMPLING LOCATION

Traverse Point	NO _x Concentration (ppmV)		Relative Percent Difference ^{a,b}
	Fixed Reference Probe	Traverse Probe	
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

^aRelative percent differences calculated as:

$$[(\text{Traverse Probe} - \text{Fixed Reference Probe}) / \text{Fixed Reference Probe}] \times 100.$$

^bQC criteria was relative percent difference within ± 10 percent.

TABLE 7-24. CEM STRATIFICATION CHECK FOR THE MARION
COUNTY OUTLET SAMPLING LOCATION

Traverse Point	NO _x Concentration (ppmV)		Relative Percent Difference ^{a,b}
	Fixed Reference Probe	Traverse Probe	
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

^aRelative percent differences calculated as:

$$[(\text{Traverse Probe} - \text{Fixed Reference Probe}) / \text{Fixed Reference Probe}] \times 100.$$

^bQC criteria was relative percent difference within ± 10 percent.

12.3 percent and 15.8 percent when challenged with an SO₂/CO₂ audit gas mixture on June 2 and June 17. The analyzer appeared to be calibrated correctly when checked with SO₂ calibration gas. This type of analyzer requires a correction for the quenching caused by CO₂ and O₂. 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 CO₂ and O₂ were valid for the two TECO 40 SO₂ analyzers used at the Marion County characterization test. A detailed report of this study can be found in Appendix H.

Two TECO 40 SO₂ analyzers and one Western SO₂ analyzer were used for the Marion County testing. All of the SO₂ analyzers consistently passed internal QC checks and linearity checks using certified gases containing only SO₂ in nitrogen. However, as previously mentioned, the TECO 40 instruments exhibited poor accuracy in analyzing audit gases containing both SO₂ and CO₂. One of the TECO 40 instruments typically responded low, but within the required limits of ± 10 percent of the gas SO₂ 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 used to correct the data.

The SO₂ study on the two TECO 40 analyzers revealed that the TECO 40 #79 (used primarily for the outlet sampling location) required a revised quench factor, while the manufacturer's equation was deemed suitable for the TECO 40 #99 (used primarily for the midpoint sampling location). Table 7-25 reflects the average improved accuracy of 13 percent for concentrations determined using the revised quench equation. Using only the revised equation, only two samples in Table 7-25 did not meet the acceptance criteria (± 10 relative percent difference for audit gases and ± 20 relative percent for Method 6 SO₂ concentrations).

TABLE 7-25. COMPARISON OF MANUFACTURER'S AND DERIVED QUENCH
EQUATIONS FOR MARION COUNTY TECO 40 (#79) SO₂ 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)	Relative Percent Difference from the Reference Concentration ^c
6/2/87	Audit Gas Western Analyzer	219.0	251.0	-14.61	227.1	3.69
		228.7	251.0	-9.73	227.1	-0.73
6/17/87	Audit Gas Western Analyzer	219.0	253.7	-15.83	229.5	4.80
		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: $[(\text{Equation \#1 or \#2}) - (\text{SO}_2 \text{ Reference Concentration}) / \text{SO}_2 \text{ Reference Concentration}] \times 100$.

8.0 REFERENCES

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12. Reference 4.
13. Reference 6.

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
$^{\circ}\text{F}$	=	$(^{\circ}\text{C} \times 9/5) + 32^{\circ}\text{F}$
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