

Note: This is a reference cited in AP 42, *Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources*. AP42 is located on the EPA web site at [www.epa.gov/ttn/chief/ap42/](http://www.epa.gov/ttn/chief/ap42/)

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02\_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

United States  
Environmental Protection  
Agency

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

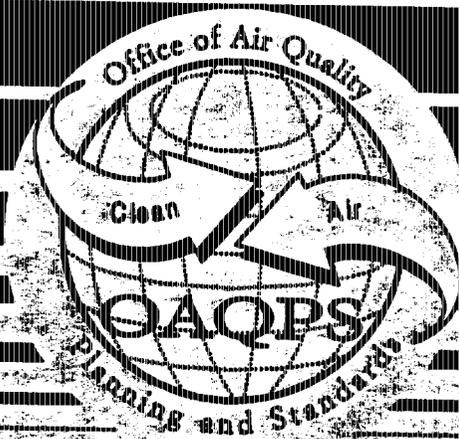
EMB Report 90-MW1-6  
Volume I  
February 1991

Air



# Medical Waste Incineration Emission Test Report

## Jordan Hospital Plymouth, Massachusetts



DCN: 90-275-026-25-07

MEDICAL WASTE INCINERATION  
EMISSION TEST REPORT

VOLUME I

Jordan Hospital  
Plymouth, Massachusetts

EMB Project No. 88-MWI-06  
Work Assignment 1.25  
Contract No. 68-D-90054

Prepared for:

Dennis Holzschuh  
Work Assignment Manager  
Emission Measurement Branch, MD-14  
U.S. Environmental Protection Agency  
Research Triangle Park, North Carolina 27711

Prepared by:

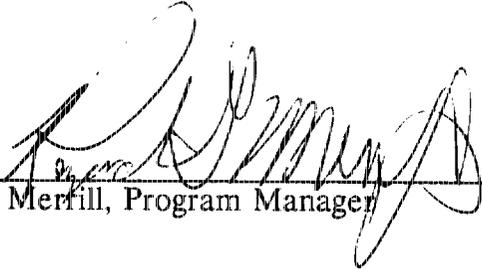
Radian Corporation  
3200 Nelson Highway/Chapel Hill Road  
Post Office Box 13000  
Research Triangle Park, North Carolina 27709

February, 1992

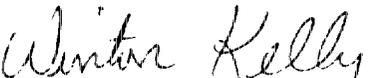
## RADIAN REPORT CERTIFICATION

This report has been reviewed by the following Radian personnel and is a true representation of the results obtained from the sampling program conducted at the Jordan Hospital Medical Waste Incinerator in Plymouth, Massachusetts. The testing was conducted from March 5 to March 9, 1991. The sampling and analytical methods were performed in accordance with EPA reference procedures or EPA approved modifications to those procedures.

### APPROVAL:

  
\_\_\_\_\_  
Ray Merrill, Program Manager

2/24/92  
Date

  
\_\_\_\_\_  
Winton Kelly, Project Director

2/24/92  
Date

## CONTENTS

<u>Section</u>	<u>Page</u>
List of Figures . . . . .	vi
List of Tables . . . . .	viii

### Volume I

1.0 INTRODUCTION . . . . .	1-1
1.1 Test Objectives . . . . .	1-1
1.2 Site Description . . . . .	1-2
1.3 Air Emissions Control System . . . . .	1-6
1.4 Emissions Measurement Program . . . . .	1-8
1.5 Quality Assurance/Quality Control (QA/QC) . . . . .	1-13
1.6 Description of Report Contents . . . . .	1-13
2.0 SUMMARY OF RESULTS . . . . .	2-1
2.1 Emissions Test Log . . . . .	2-1
2.2 CDD/CDF Results . . . . .	2-1
2.3 Toxic Metals Results . . . . .	2-30
2.4 Particulate Matter/Visible Emissions . . . . .	2-56
2.5 Halogen Gas Emissions . . . . .	2-60
2.6 Hydrogen Chloride CEM Results . . . . .	2-70
2.7 CEM Results . . . . .	2-70
2.8 Ash Loss-on-Ignition and Carbon Content Results . . . . .	2-76
2.9 Microbial Survivability Results . . . . .	2-76
2.10 Particle Size Distribution Results . . . . .	2-88
2.11 CDD/CDF Emission Values Incorporating the Toluene Recovery Results . . . . .	2-92
3.0 PROCESS DESCRIPTION AND SUMMARY OF PROCESS OPERATION DURING TESTING AT JORDAN HOSPITAL . . . . .	3-1
3.1 Introduction . . . . .	3-1
3.2 Process Description . . . . .	3-1
3.3 Pretest Activities . . . . .	3-6
3.4 Process Conditions During Testing . . . . .	3-8
4.0 SAMPLE LOCATIONS . . . . .	4-1
5.0 SAMPLING AND ANALYTICAL PROCEDURES BY ANALYTE . . . . .	5-1
5.1 CDD/CDF Emissions Testing Method . . . . .	5-1
5.2 Particulate Matter and Metals Emissions Testing Method . . . . .	5-23
5.3 Microbial Survivability Testing . . . . .	5-35
5.4 HCl/HBr/HF Emissions Testing by EPA Method 26 . . . . .	5-51
5.5 EPA Methods 1-4 . . . . .	5-55

CONTENTS, continued

<u>Section</u>		<u>Page</u>
5.6	Continuous Emissions Monitoring (CEM) Methods .....	5-56
5.7	Visible Emissions .....	5-66
5.8	Process Sampling Procedure .....	5-66
5.9	Particle Size Distribution Sampling Methods .....	5-67
6.0	QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC) .....	6-1
6.1	QA/QC Definitions and Objectives .....	6-2
6.2	Manual Flue Gas Sampling and Recovery Parameters .....	6-3
6.3	QC Procedures for Ash and Pipe Sampling .....	6-22
6.4	Analytical Quality Assurance .....	6-23
6.5	CEM Quality Assurances .....	6-37
6.6	PSD Quality Assurance .....	6-40
6.7	Data Variability .....	6-40
7.0	REFERENCES .....	7-1

Volume II

APPENDICES

A EMISSIONS TESTING FIELD DATA SHEETS

- A.1 CDD/CDF Run Sheets
- A.2 PM/Metals Run Sheets
- A.3 Microbial Run Sheets
- A.4 HCl/HBr/HF Run Sheets
- A.5 Opacity Data
- A.6 Miscellaneous Field Data

B PROCESS DATA SHEETS

- B.1 Ash and Pipe Recovery Sheets
- B.2 Field Data Sheets

Volume III

APPENDICES

C SAMPLE PARAMETER CALCULATION SHEETS

- C.1 CDD/CDF
- C.2 PM/Metals
- C.3 Microbial
- C.4 HCl/HBr/HF

## CONTENTS, continued

- D CEM DATA
  - D.1 CEM Plots
  - D.2 CEM Tables
  - D.3 CEM QA/QC
  - D.4 CEM Linearity Checks
  - D.5 CEM Cooldown Data
  - D.6 CEM Cooldown Plots
  
- E ANALYTICAL DATA
  - E.1 CDD/CDF
  - E.2 PM/Metals and PSD
  - E.3 Microbial
  - E.4 HCl/HBr/HF
  - E.5 Sample Identification Log
  
- F MICROBIAL SURVIVABILITY DATA REDUCTION
  
- G CALIBRATION DATA SHEETS
  
- H SAMPLE EQUATIONS
  
- I PARTICIPANTS
  
- J VISIBLE EMISSIONS DATA AND AVERAGES
  
- K SAMPLING AND ANALYTICAL PROTOCOLS
  - K.1 EPA Proposed Method 23 - Determination of CDDs and CDFs from Stationary Sources
  - K.2 Methodology for the Determination of Metals Emissions in Exhaust Gases from Incineration Processes
  - K.3 Microbial Survivability Test for Medical Waste Incinerator Emissions
  - K.4 Microbial Survivability Test for Medical Waste Incinerator Ash
  - K.5 Determination of HCl Emissions from Stationary Sources

## FIGURES

		<u>Page</u>
1-1	Jordan Hospital Incinerator .....	1-3
1-2	Inlet Sample Locations .....	1-7
2-1	Location of Microbe Spikes in Incinerator .....	2-87
2-2	Particle Size Distribution Run 2 Results With and Without Condensable PM .....	2-93
2-3	Particle Size Distribution Run 3 Results With and Without Condensable PM .....	2-94
3-1	Temperature Profile for Run 1 .....	3-11
3-2	Temperature Profile for Run 2 .....	3-12
3-3	Temperature Profile for Run 3 .....	3-13
3-4	Temperature Profile for Run 4 .....	3-14
3-5	Temperature Profile for Run 5 .....	3-15
3-6	Temperature Profile for Run 6 .....	3-16
3-7	Spore Placement Diagram .....	3-17
4-1	Inlet Sample Locations .....	4-2
4-2	Stack Gas Sample Locations .....	4-3
4-3	Traverse Point Layout (Stack Location) .....	4-4
4-4	Inlet Flue Gas Sample Location .....	4-5
4-5	Traverse Point Layout for Microbial Survivability .....	4-7
4-6	Traverse Point Layout for CDD/CDF and Metals (Inlet Location) .....	4-8
5-1	CDD/CDF Sampling Train Configuration .....	5-4
5-2	Impinger Configuration for CDD/CDF Sampling .....	5-9
5-3	CDD/CDF Field Recovery Scheme .....	5-16
5-4	Extraction and Analysis Schematic for CDD/CDF Samples .....	5-19
5-5	Schematic of Multiple Metals Sampling Train .....	5-24
5-6	Impinger Configuration for PM/Metals Sampling .....	5-25
5-7	Metals Sample Recovery Scheme .....	5-29
5-8	Metals Sample Preparation and Analysis Scheme .....	5-33
5-9	Indicator Spore Spiking Scheme for Combustion Gas Destruction Efficiency Testing .....	5-37
5-10	Sampling Train for Determination of Indicator Spore Emissions .....	5-39
5-11	Sample Recovery Scheme for Microbial Viability Testing .....	5-42
5-12	Modified (Mesh) Ash Quality Assembly and Pipe Ash Quality Assembly ...	5-44
5-13	Sample Preparation and Analysis Scheme for Microbial Testing of Ash Samples .....	5-46
5-14	Analysis Scheme for Pipe Sample Microbial Viability Testing .....	5-47
5-15	Sample and Analysis Scheme for Microbial Testing .....	5-49
5-16	HCl Sample Train Configuration .....	5-52

FIGURES, continued

	<u>Page</u>
5-17 HCl/HBr/HF Sample Recovery Scheme .....	5-54
5-18 Schematic of CEM System .....	5-57
5-19 Anderson MK III In-Stack Impactor with Particle Pre-Separator Sampling Train .....	5-68

## TABLES

		<u>Page</u>
1-1	Jordan Hospital MWI Test Matrix .....	1-9
2-1	Emissions Test Log .....	2-2
2-2	Summary of CDD/CDF Tests Showing Average Daily Flue Gas and Incinerator Bottom Ash Mass Rates and Scrubber Water Concentrations ...	2-5
2-3	CDD/CDF Average Flue Gas Concentrations for Burn and Burndown Conditions .....	2-6
2-4	CDD/CDF Average Flue Gas Concentrations Corrected to 7% O <sub>2</sub> for Burn and Burndown Conditions .....	2-9
2-5	CDD/CDF Stack Emissions and Outlet to Inlet Emissions Ratios for Burn and Burndown Conditions .....	2-10
2-6	CDD/CDF Average Flue Gas Toxic Equivalencies Corrected to 7% O <sub>2</sub> for Burn and Burndown Conditions .....	2-11
2-7	CDD/CDF Emissions Averaged Over Each Test Day .....	2-12
2-8	CDD/CDF Flue Gas Concentrations at the Inlet and Outlet Sample Location During the Burn Condition .....	2-13
2-9	CDD/CDF Flue Gas Concentrations Corrected to 7% O <sub>2</sub> at the Inlet and Outlet Sample Location During the Burn Condition .....	2-15
2-10	CDD/CDF Gas Toxic Equivalencies Corrected to 7% O <sub>2</sub> for the Burn Condition .....	2-16
2-11	CDD/CDF Stack Emissions for the Burn Condition .....	2-17
2-12	CDD/CDF Flue Gas Concentrations at the Inlet and Outlet Sample Location During the Burndown Condition .....	2-18
2-13	CDD/CDF Flue Gas Concentrations Corrected to 7% O <sub>2</sub> at the Inlet and Outlet Sample Location During the Burndown Condition .....	2-19
2-14	CDD/CDF Flue Gas Toxic Equivalencies Corrected to 7% O <sub>2</sub> for the Burndown Condition .....	2-20
2-15	CDD/CDF Stack Emissions for the Burndown Condition .....	2-22
2-16	CDD/CDF Emissions Sampling and Flue Gas Parameters at Inlet .....	2-23
2-17	CDD/CDF Emissions Sampling and Flue Gas Parameters at Outlet .....	2-24
2-18	CDD/CDF Concentrations in Ash .....	2-25
2-19	CDD/CDF Toxic Equivalencies in Ash .....	2-27
2-20	CDD/CDF Daily Discharge Rate in the Ash Stream .....	2-28
2-21	CDD/CDF Concentrations in Absorber Make-up Water and Discharge Water .....	2-29
2-22	CDD/CDF Toxic Equivalencies in Absorber Make-up Water and Discharge Water .....	2-31
2-23	Summary of Toxic Metals Flue Gas Emission Rates and Metals in Ash .....	2-33
2-24	Average Metals Emission Rates and Removal Efficiencies for Burn and Burndown Conditions .....	2-35
2-25	Daily Average Toxic Metals Flue Gas Mass Rates and Removal Efficiencies .....	2-37

TABLES, continued

	<u>Page</u>
2-26 Metals Concentrations, Emission Rates, and Removal Efficiencies for Run 1 (Burn Condition) . . . . .	2-38
2-27 Metals Concentrations, Emission Rates, and Removal Efficiencies for Run 2 (Burndown Condition) . . . . .	2-39
2-28 Metals Concentrations, Emission Rates, and Removal Efficiencies for Run 3 (Burn Condition) . . . . .	2-40
2-29 Metals Concentrations, Emission Rates, and Removal Efficiencies for Run 4 (Burndown Condition) . . . . .	2-41
2-30 Metals Concentrations, Emission Rates, and Removal Efficiencies for Run 5 (Burn Condition) . . . . .	2-42
2-31 Metals Concentrations, Emission Rates, and Removal Efficiencies for Run 6 (Burndown Condition) . . . . .	2-43
2-32 Ratio of Metals to Particulate Matter for Burn Condition . . . . .	2-44
2-33 Ratio of Metals to Particulate Matter for Burndown Condition . . . . .	2-46
2-34 Comparison of Outlet to Inlet Metals/PM Ratios for Burn and Burndown Conditions . . . . .	2-47
2-35 Metals Amounts in Inlet Flue Gas Samples by Sample Fraction . . . . .	2-48
2-36 Metals Amounts in Outlet Flue Gas Samples by Sample Fraction . . . . .	2-49
2-37 Metals/PM Emissions Sampling and Flue Gas Parameters at Inlet . . . . .	2-51
2-38 Metals/PM Emissions Sampling and Flue Gas Parameters at Outlet . . . . .	2-52
2-39 Metals in Ash Concentrations . . . . .	2-53
2-40 Metals Daily Discharge Rates in the Ash Stream . . . . .	2-54
2-41 Metals and Solids in Absorber Make-up and Discharge Water . . . . .	2-55
2-42 Average Particulate Matter Concentrations, Emission Rates, and Removal Efficiency . . . . .	2-57
2-43 Particulate Matter Concentrations and Emissions for Burn Condition . . . . .	2-58
2-44 Particulate Matter Concentrations and Emissions for Burndown Condition . . . . .	2-59
2-45 Percent Opacity Observations Summary . . . . .	2-61
2-46 Hydrogen Chloride Removal Efficiency . . . . .	2-62
2-47 Summary of HCl Results at the Inlet . . . . .	2-64
2-48 Summary of HCl Results at the Outlet . . . . .	2-65
2-49 Summary of HF Results at the Inlet . . . . .	2-66
2-50 Summary of HF Results at the Outlet . . . . .	2-67
2-51 Summary of HBr Results at the Inlet . . . . .	2-68
2-52 Summary of HBr Results at the Outlet . . . . .	2-69
2-53 Comparison of Manual and CEM HCl Results at the Inlet Sample Location . . . . .	2-71
2-54 Continuous Emissions Monitoring Test Averages . . . . .	2-73
2-55 Continuous Emissions Monitoring Test Averages Corrected to 7% O <sub>2</sub> . . . . .	2-74
2-56 Continuous Emissions Monitoring Averages for the Cooldown Period . . . . .	2-75

TABLES, continued

	<u>Page</u>
2-57	Summary of Ash Carbon Content, LOI, and Moisture Results . . . . . 2-77
2-58	Summary of Incinerator Feed Amounts and Ash Generation Per Run . . . . . 2-80
2-59	Overall Microbial Survivability . . . . . 2-82
2-60	Viable Spore Emissions . . . . . 2-83
2-61	Indicator Spore Emissions Sampling and Flue Gas Parameters . . . . . 2-85
2-62	Viable Spores in Ash . . . . . 2-86
2-63	Viable Spores in Pipes . . . . . 2-89
2-64	Particle Size Distribution Run 2 Results . . . . . 2-91
2-65	Particle Size Distribution Run 3 Results . . . . . 2-95
2-66	CDD/CDF Flue Gas Concentrations Corrected to 7% O <sub>2</sub> During the Burn Condition (Runs 1, 3, 5) Incorporating the Toluene Recovery Results . . . . . 2-96
2-67	CDD/CDF Flue Gas Toxic Equivalencies Corrected to 7% O <sub>2</sub> During the Burn Condition (Runs 1, 3, 5) Incorporation the Toluene Recovery Results . . . . . 2-97
2-68	CDD/CDF Flue Gas Concentrations Corrected to 7% O <sub>2</sub> During the Recovery Results Burndown Condition (Runs 2, 4, 6) Incorporating the Toluene Recovery Results . . . . . 2-98
2-69	CDD/CDF Flue Gas Toxic Equivalencies Corrected to 7% O <sub>2</sub> During the Burndown Condition (Runs 2, 4, 6) Incorporating the Toluene Recovery Results . . . . . 2-99
3-1	Process Data Summary for Emissions Testing at Jordan Hospital . . . . . 3-10
5-1	Test Methods used for the Jordan Hospital MWI . . . . . 5-2
5-2	Sampling Times, Minimum Sampling Volumes, and Detection Limits . . . . . 5-3
5-3	CDD/CDF Glassware Cleaning Procedure . . . . . 5-6
5-4	CDD/CDF Sampling Checklist . . . . . 5-12
5-5	CDD/CDF Sample Fractions Shipped to Analytical Laboratory . . . . . 5-17
5-6	CDD/CDF Congeners Analyzed . . . . . 5-18
5-7	CDD/CDF Blanks Collected . . . . . 5-21
5-8	Approximate Detection Limits for Metals of Interest Using EMB Draft Method . . . . . 5-32
5-9	Indicator Spore Testing QA/QC Checks . . . . . 5-50
5-10	CEM Operating Ranges and Calibration Gases . . . . . 5-63
6-1	Summary of Precision, Accuracy, and Completeness Objectives . . . . . 6-4
6-2	Leak Check Results for CDD/CDF Emissions Tests . . . . . 6-5
6-3	Isokinetic Sampling Rates for CDD/CDF, Metals, and Microorganisms Test Runs . . . . . 6-7
6-4	Dry Gas Meter Post-Test Calibration Results . . . . . 6-8
6-5	CDD/CDF Field Blank Results . . . . . 6-9

TABLES, continued

	<u>Page</u>
6-6 CDD/CDF Toluene Rinse Full Screen Analytical Results Compared to MM5 Analytical Results for Condition 1 .....	6-11
6-7 CDD/CDF Toluene Rinse Full Screen Analytical Results Compared to MM5 Analytical Results for Condition 2 .....	6-12
6-8 CDD/CDF Toluene Rinse Full Screen Analytical Results Compared to MM5 Analytical Results for Condition 3 .....	6-13
6-9 CDD/CDF Toluene Rinse Confirmation Analytical Results Compared to MM5 Analytical Results for All Conditions .....	6-14
6-10 CDD/CDF Toluene Field Blank Results .....	6-15
6-11 Leak Check Results for Toxic Metals .....	6-16
6-12 Metals Field Blank Results Compared to Average Amounts Collected During the Test Runs .....	6-17
6-13 Leak Check Results for Microbial Survivability in Emissions Sampling Runs .....	6-18
6-14 Halogen Laboratory Proof Blank Results Compared to Run Results .....	6-20
6-15 Method Blank and Field Blank Results for the MM5 and Toluene Flue Gas Samples .....	6-21
6-16 Standards Recovery Results for CDD/CDF Analyses; Test Run Samples ...	6-26
6-17 Standards Recovery Results for CDD/CDF Analyses; Blank Samples .....	6-27
6-18 Standards Recovery Results for the CDD/CDF Toluene Analyses; Test Run Samples .....	6-28
6-19 Standards Recovery Results for the CDD/CDF Toluene Analyses; Blank Samples .....	6-29
6-20 Standards Recovery Results for the CDD/CDF Ash Analyses .....	6-30
6-21 Metals Ash and Flue Gas Method Blank Results .....	6-31
6-22 Metals Method Blank Spike Results .....	6-32
6-23 Halogen Method Blank, XAD Proof Blank, Reagent Blank, and Matrix Spike Recovery .....	6-34
6-24 Wet Spore Spike Solution Confirmation Analysis .....	6-35
6-25 Dry Spore Spike Material Confirmation Analysis .....	6-36
6-26 CEM Internal QA/QC Checks .....	6-38
6-27 Coefficients of Variation for the CDD/CDF Flue Gas Concentrations .....	6-42
6-28 Coefficients of Variation of the Flue Gas Metals Concentrations at the Inlet .....	6-43
6-29 Coefficients of Variation of the Flue Gas Metals Concentrations at the Outlet .....	6-44
6-30 Coefficients of Variation for Halogen Flue Gas Concentrations .....	6-45
6-31 Coefficients of Variation of CEM Gas Concentrations .....	6-47

## 1. INTRODUCTION

The United States Environmental Protection Agency (EPA) has determined that medical waste incinerator (MWI) emissions may reasonably be anticipated to contribute to the endangerment of public health and welfare. As a consequence, new source performance standards (NSPS) for new MWIs and emission guidelines for existing MWI's are being developed under Sections 111(b), 111(d), and 129 of the Clean Air Act, as amended November 1990.

The Office of Air Quality Planning and Standards (OAQPS), through its Industrial Studies Branch (ISB) and Emissions Measurement Branch (EMB), is responsible for reviewing the existing air emissions data base and gathering additional data where necessary. As a result of this review, several MWI emission tests are being conducted to support the regulatory development program.

The emissions that are being studied for standards development are the criteria pollutants--particulate matter (PM), sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), and total hydrocarbons (THC); as well as other acid gases, such as hydrogen chloride (HCl); chlorinated organics, including dioxins and furans; trace metals; and pathogens.

### 1.1 TEST OBJECTIVES

The purpose of the testing program at the Jordan Hospital facility in Plymouth, Massachusetts, was to obtain uncontrolled and controlled emission data from a controlled, batch-fed MWI. These data are used in the regulatory development program for MWIs. In addition, certain data will be used by Jordan Hospital to show compliance with applicable Massachusetts regulations. The specific objectives were:

- Determine what levels of CO, PM, SO<sub>2</sub>, NO<sub>x</sub>, HCl, metals, THC and polychlorinated dibenzo-p-dioxins (CDD) and polychlorinated dibenzofurans (CDF) were emitted from the combustor when burning medical wastes;
- Determine the levels of PM, acid gases, metals, and CDD/CDF emissions associated with a fabric filter/packed bed absorber control technology;

- Calculate the control efficiencies for PM, acid gases, metals, and CDD/CDF;
- Determine the microbial survivability based on a surrogate indicator organism that was spiked into the incinerator feed during each test run.
- Determine the degree of combustion of the feed wastes based on percent carbon and loss on ignition (LOI) of the bottom ash and fly ash collected in the fabric filter;
- Determine if there are differences in the uncontrolled and controlled emissions between the two distinct operating modes of the batch cycle (burn and burndown) based on analysis of continuous emission monitors (CEMs) data; and
- Determine the relationship, if any, between visible emissions and other emissions, such as PM.

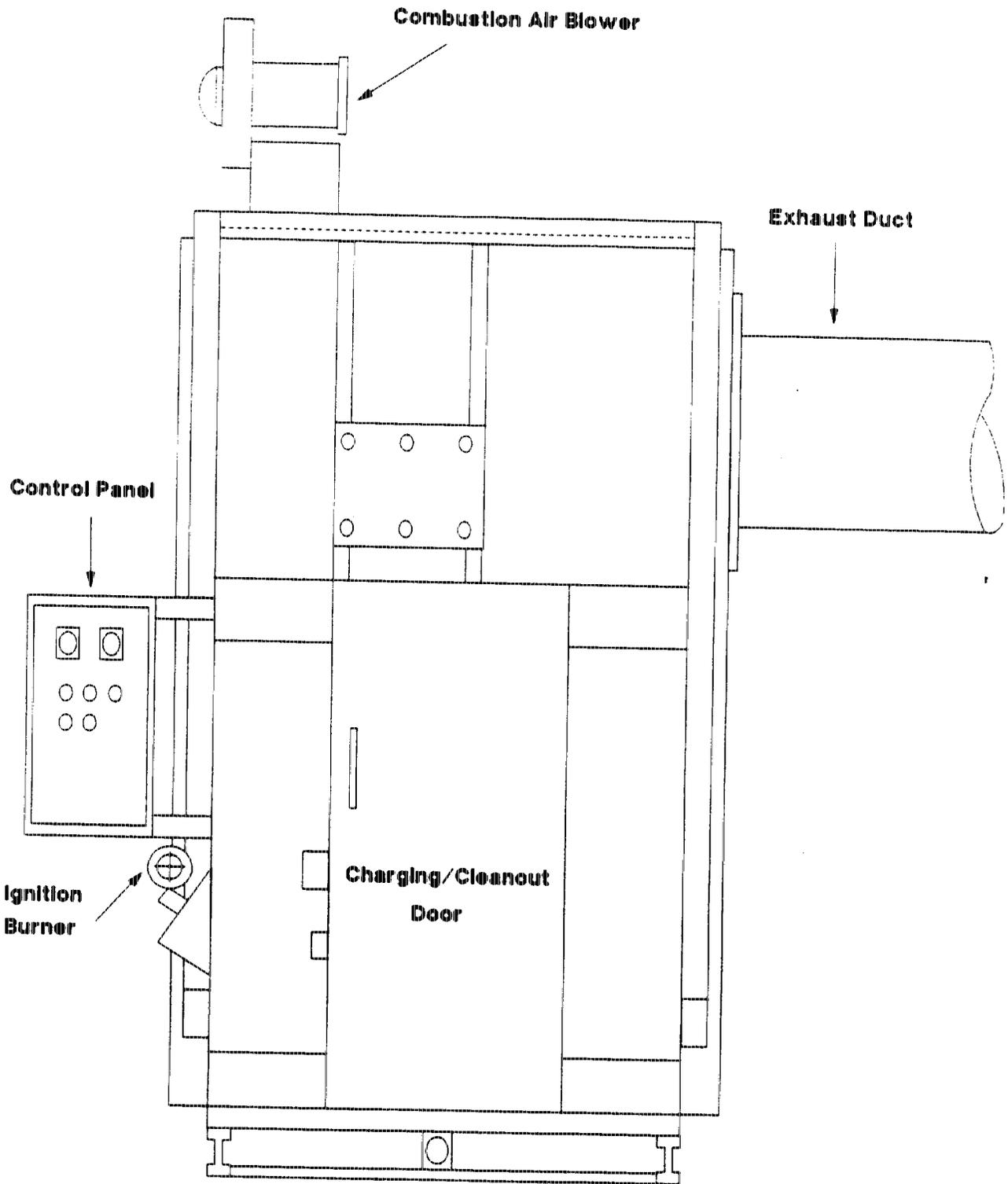
The measurements described above were repeated in triplicate at the design operating condition while the incinerator was burning red bag and pathological hospital wastes. The test conditions were near the design burning rate of a nominal 750 lbs per batch of Type 0-4 mixed waste with a secondary chamber temperature setpoint of 1800°F.

Key process operating variables including flue gas oxygen (O<sub>2</sub>), carbon dioxide (CO<sub>2</sub>), primary and secondary chamber temperatures, air flows, and the total amount of waste charged were monitored and recorded to document the operating conditions during each test.

The test program included an internal quality control program. The goal of the quality assurance/quality control (QA/QC) activities was to ensure that the results were of known precision and accuracy, and that they were complete, representative and comparable.

## 1.2 SITE DESCRIPTION

Jordan Hospital is located in Plymouth, Massachusetts. The MWI at this facility is a batch-burn Simonds Model 2151B. It has a rated volume of 215 cubic feet in the primary combustion chamber, which corresponds to a nominal 750 lb/batch of Type 0-4 waste. A front view of the incinerator is shown in Figure 1-1. One natural gas-fired burner in the primary chamber is used to light the waste after a preset temperature



**Figure 1-1. Jordan Hospital Incinerator  
(Air Pollution Control System Not Shown)**

condition is met in the secondary chamber. The primary chamber temperature is controlled by modulating the combustion air according to timers and the primary chamber temperature. The primary chamber temperature varies between ambient and > 1500°F during a typical 24 hour operating cycle. For approximately 16 hours, the temperature is below 1000°F and for approximately 8 hours, the temperature is above 1000°F. The unit is charged manually by opening a large refractory-lined charging door at the front of the primary chamber. The unit is designed for approximately 22 hours of operation each day, and ashes must be periodically removed manually when the unit is cool.

The secondary chamber on this unit is calculated to have a gas retention time of about two seconds. A gas-fired auxiliary burner in the secondary chamber is activated automatically when the temperature falls below a preset level, normally 1800°F. Set point and actual temperatures in each chamber are displayed on a dial in the control panel.

The unit has air pollution control devices, namely a fabric filter for particulate removal and a packed bed absorber (scrubber) for acid gas removal. The hot gas from the incinerator is drawn by means of a fan through the hot side of a heat exchanger where it is cooled to below 400°F. The gas then passes through the fabric filter to remove particulates. Passing through the fan and damper system (which is used to maintain uniform pressure in the incinerator) the gas is then passed through a packed bed wet scrubber. The cooled gas is then directed through the cold side of the heat exchanger where it extracts heat from the hot flue gas and then passes to the stack.

There is no full time operator for this facility per se. The hospital housekeeping staff is currently responsible for charging the incinerator with waste and seeing that the incinerator is started. Once the incinerator is started, the operator is free to leave and go about other duties, checking in occasionally to monitor key parameters to make sure that the unit is operating properly.

The typical hours of supervised operation are from 7:00 a.m. to 3:00 p.m. During this time or what is called the "Burn" operational mode, the primary chamber is supplied with low-fire (low flow) air and the secondary chamber modulates between high-fire (high flow) and low-fire conditions to maintain the set point temperatures. After

approximately 7 hours at this condition the unit moves into what is called the "burndown" operation with the primary chamber cycling between high-fire and low-fire air according to primary chamber temperature. After about 5½ hours of burndown operation, the secondary chamber burner shuts off. However, the air flow is maintained in both chambers during a burn out or cool down period which lasts about 10½ hours.

The incinerator is typically fired three times per week (about every other day) and the ash is removed once per week after it is allowed to cool.

Waste materials are collected by the hospital housekeeping staff. Waste is collected from all patient contact areas, including patient rooms, examination rooms, operating and recovery rooms, and laboratories. Included in the waste stream are waste drugs and chemicals; patient contact items such as disposable garments and dressings; lab wastes; disposable surgical tools; sharps; diagnostic devices; and human tissue. Only red bag and sharps containers are fed into the incinerator. Pathological waste is estimated at from 5 to 10 percent of the total waste weight.

Non-red bag wastes such as cafeteria and office wastes are collected by the housekeeping staff and placed in standard 30-gallon plastic trash bags, and deposited in a dumpster. Red bags are transported via plastic bin-type carts from the collection area to the incinerator area. The hospital incinerator operator hand feeds and stacks the bags in the incinerator prior to ignition.

The combustion process utilized to incinerate wastes in this type of incinerator is known as controlled or "starved" air incineration. The unit is designed with two separate chambers (a primary chamber and a secondary chamber) in which controlled amounts of combustion air and combustible material are admitted. The lower chamber, known as the primary air ignition chamber, is operated at below stoichiometric (or air starved conditions). A gas-fired pilot burner is only used to ignite the waste material. Limited amounts of underfire air are admitted through ports in the lower chamber so that combustion of the fixed carbon matter can be sustained.

The volatile matter is vaporized in the lower chamber and passes into the secondary combustion chamber. A second gas-fired burner is used to ignite the combustible gases and maintain secondary chamber temperatures within a specified temperature range. The upper burner modulates between a low-fire and high-fire

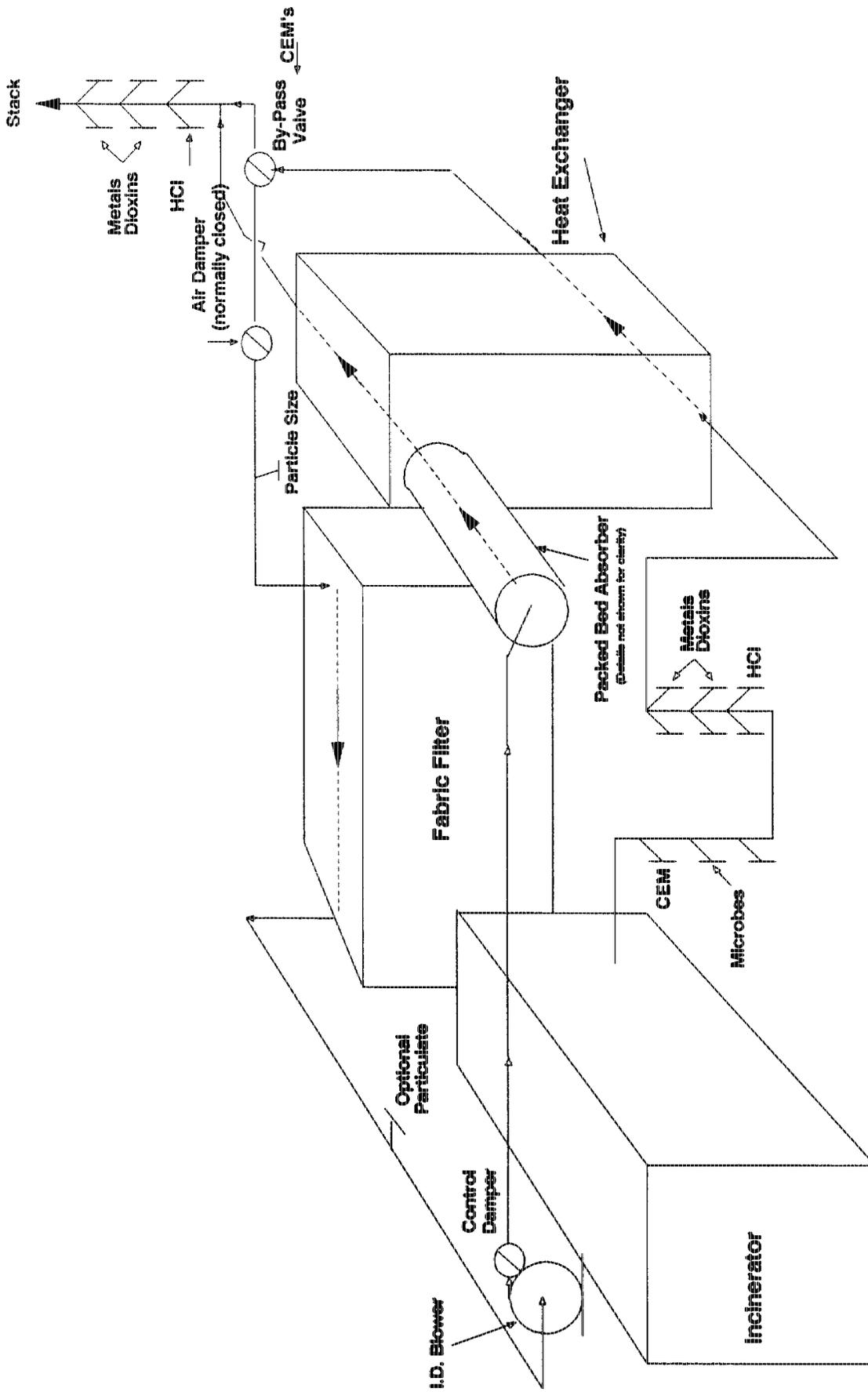
condition to maintain upper chamber temperatures. In the secondary chamber, excess air is supplied to achieve more complete combustion of the volatile matter and entrained solids by providing an adequate oxygen supply and turbulent mixing.

### 1.3 AIR EMISSIONS CONTROL SYSTEM

Jordan Hospital's MWI is equipped with an air emissions control system. The system is shown schematically in Figure 1-2. A more detailed description of each of the system components and its function is given below:

- Cooling Device. A heat exchanger is used to accomplish the cooling from the secondary temperature of about 1600 to 1800°F to the fabric filter temperature of 365-400°F. Jordan's system consists of a tube and shell air-to-air heat exchanger. The 1600-1800°F gases exit the incinerator and enter the heat exchanger. Cooling of the gases is performed by the 130°F air exiting the packed bed absorber passing over the tube bundle in which the incinerator flue gas is flowing. In addition to the heat exchanger there is also a water injection system upstream at fabric filter in the heat exchanger ductwork as well as an air damper system upstream of the fabric filter for additional cooling capabilities.
  
- Fabric Filter. At 365 to 400°F, the exhaust gases go into a fabric filter. This contains thirty-six P-84 bags to retain useability at 450°F, with a 500°F maximum temperature and a 350°F operating temperature. The P-84 bags are a woven synthetic material with a polyamide coating which has been felted to smooth the bag surface. The fabric filter is made of 316 L stainless steel. The fabric filter has a compressed air pulse cleaning system, to remove PM. The cleaning system is made up of seven pulse jet solenoids that operate at 30-second intervals to clean the bags and maintain a differential pressure of less than 6 inches water column (in. w.c.).
  
- Blower. After the fabric filter is the main blower, which provides the air movement for:
  - the two combustion chambers, serving as an induced draft fan;
  - the packed bed absorber and the fabric filter;
  - the ductwork;
  - heat exchanger; and,
  - the stack.

There are dampers at fan and inlet to fabric filter. The damper at the fan is used for draft adjustments to maintain uniform incinerator pressure while exhausting the flue gases. The fabric filter damper is used for rapid cooling of flue gases entering the fabric filter.



**Figure 1-2. Generalized Schematic Showing Incinerator, Air Pollution Control Devices, and Sampling Locations; Jordan Hospital (1991)**

- Packed Bed Absorber. The gases leave the blower and enter a packed bed absorber which is made of fiberglass. The absorber consists of three sections made up of a Kimre woven polypropylene packed bed. The absorber is cylindrical, and mounts horizontally above the floor. The two front beds have a manifold which houses four nozzles each that spray water onto and against the bed at a total flow of 60-80 gpm (8-10 gpm at each nozzle).

The liquid for the packed bed scrubber is held in the polypropylene tanks directly below the scrubber. There are three cascaded tanks with absorber liquor flowing into the left tank and then directed into a central tank where caustic (50% NaOH) is added. The liquor goes from the central tank to the third tank where make-up water is added and pH is monitored. The pH is maintained at 6.5 - 9.5. From the third tank, the absorber liquor is directed to the system pump and to the manifold of nozzle feed lines. There is a manual bleed, located on the left return tank, (3 - 5 gpm) to control the buildup of salts in the system. The tanks are maintained at an appropriate level as determined by hydraulic conditions.

- By-Pass Damper. A damper to bypass the air pollution control system and vent directly out the stack is located at the heat exchanger outlet. This damper is provided so that in the event of a breakdown, the absorber, the fabric filter, and the rest of the air pollution control system are not destroyed by excessive temperatures. The bypass damper is open during the pre-heat cycle when the emissions system is not in operation and is also interlocked to open upon failure of the ID fan, or upon excessively high temperature at the fabric filter or absorber inlet when the air pollution control system is in operation.
- Controls. The entire system is controlled by a programmable controller and separate process controllers. This control is integrated into the incinerator controls so that interlocks, operating controls, and dump controls are handled in a coordinated fashion.

#### 1.4 EMISSIONS MEASUREMENT PROGRAM

This section provides an overview of the emissions measurement program conducted at Jordan Hospital. Included in this section are summaries of the test matrix, sampling locations, sampling methods, and laboratory analysis.

##### 1.4.1 Test Matrix

The sampling and analytical matrix for this test program is presented in Table 1-1. Sampling locations are shown in Figure 1-2. Both manual emissions tests and CEMs were employed for the Jordan Hospital MWI test program. Flue gas was sampled at both the inlet and outlet to the air pollution control system (APC system). In addition to

TABLE 1-1. JORDAN HOSPITAL MWI TEST MATRIX

Sample Location	Number of Runs	Sample Type	Sample Method	Sample Duration	Analysis Method	Laboratory
Inlet, Stack	3	Particulates/Metals (Pb, Cr, Cd, Be, Hg, Ni, As, Sb, Ag, Ba, Tl)	EPA Method 5/Combined Metals Train	4 hours	Gravimetric Atomic Adsorption/ICAP	Radian
Inlet, Stack	3	CDD/CDF	EPA Method 23 and GC/MS Method 8290	4 hours	Mass Spectrometry and High Resolution MS for CDD/CDF	Triangle Labs, Inc.
Inlet, Stack	27 <sup>a</sup>	HCl/HBr/HF	EPA Method 26	1 hour <sup>a</sup>	Ion Chromatography	Radian
Inlet	18 <sup>b</sup>	Indicator Spores	Draft EPA Method	2 hours <sup>b</sup>	Microbial Draft Method	RTI
Inlet, Stack	3 <sup>c</sup>	SO <sub>2</sub>	EPA Method 6C	Continuous <sup>c</sup>	UV Analyzer CEM	Radian
Inlet, Stack	3 <sup>c</sup>	O <sub>2</sub> /CO <sub>2</sub>	EPA Method 3A	Continuous <sup>c</sup>	Zirconium Oxide Cell/NDIR CEN	Radian
Inlet, Stack	3 <sup>c</sup>	NO <sub>x</sub>	EPA Method 7E	Continuous <sup>c</sup>	Chemiluminescence CEM	Radian
Inlet, Stack	3 <sup>c</sup>	CO	EPA Method 10	Continuous <sup>c</sup>	NDIR CEM	Radian
Inlet, Stack	3 <sup>c</sup>	THC	EPA Method 25A	Continuous <sup>c</sup>	FID CEM	Radian
Inlet, Stack	3 <sup>c</sup>	HCl	CEM	Continuous <sup>c</sup>	NDIR CEM	Radian
Inlet, Stack	3 <sup>d</sup>	Opacity <sub>2</sub>	EPA Method 9	daylight hours <sup>d</sup>	Visual	Radian
Incinerator	3	Incinerator Ash	Representative Composite Sample	1/day	LOI, Carbon, Metals	Radian
	3		Representative Composite Sample	1/day	CDD/CDF	Triangle Labs, Inc.
	3		Representative Composite Sample	1/day	Microbial Draft Method	RTI
Incinerator	27	Indicator Spore Pipes	Manual	1/day	Microbial Draft Method	RTI
Absorber	1	Make Up Water	Grab	1/day	CDD/CDF, Metals	Triangle Labs, Radian
Absorber	1	Discharge Water	Grab	1/day	CDD/CDF, Metals	Triangle Labs, Radian

<sup>a</sup>One-hour runs per test day.

<sup>b</sup>Two hour runs per test day.

<sup>c</sup>Continuous during test periods and throughout burndown cycle. (Approximately 20 hr/day.)

<sup>d</sup>Concurrent with particulate/metals run during daylight hours.

flue gas sampling, incinerator bottom ash and ash quality pipe samples were taken as well as absorber make-up and discharge water. Each of these tests are briefly described in Sections 1.4.3 and 1.4.4.

#### 1.4.2 Sampling Locations

Flue gas samples were collected at the exhaust stack using three sets of ports and at the APC inlet using six sets of ports.

Sampling at the exhaust stack was conducted as shown in Figure 4-2. The lower set of ports was used for the CEM, HCl/CEM, and manual HCl tests. The center set of ports was used for CDD/CDF testing. The upper set of ports was used for PM/metals testing.

Figure 4-4 shows sampling locations at the APC inlet piping. The first port on the down-flow section of piping was used for CEMs. The lower two ports were used for microbial testing. The lower port on the up-flow section was used for manual HCl testing. The middle port accommodated CDD/CDF testing and the uppermost port was used for PM/metals testing.

Incinerator ash was sampled each day following operation. Ash was completely removed from the incinerator manually and screened through ½" mesh. The ash was then placed in bulk ash containers and mixed to provide a nearly uniform mass of which representative grab samples were taken. Fly ash sampling from the baghouse was also conducted but not enough material was acquired to conduct a full set of analyses on.

Absorber water samples were also taken. Grab samples were taken from a water supply tap (make-up water) and the absorber discharge line (discharge water).

#### 1.4.3 Sampling Methods

Total PM emissions along with a series of 11 toxic metals [lead (Pb), chromium (Cr), cadmium (Cd), mercury (Hg), nickel (Ni), arsenic (As), beryllium (Be), antimony (Sb), barium (Ba), silver (Ag), and thallium (Tl)], were determined using a single sample train. Particulate loading on the filter and front half (nozzle/probe, filter holder) rinse was determined gravimetrically. Metals analyses were then completed on the filter front half rinses and back half impinger catches using atomic absorption (AA) and inductively coupled argon plasma spectroscopy (ICAP) techniques. Flue gas samples for CDD/CDF were collected using EPA Method 23. Flue gas was extracted isokinetically and

CDD/CDF was collected on the filter, on a chilled adsorbent trap, and in the impingers. The analysis was completed using High Resolution Gas Chromatography (HRGC) coupled with High Resolution Mass Spectrometry (HRMS) detection.

Hydrogen chloride, hydrogen bromide (HBr), and hydrogen fluoride (HF) concentrations in the stack gas were determined using EPA Method 26. Gas was extracted from the stack and passed through an acidified collection solution which stabilized the respective halogen ions (Cl<sup>-</sup>, Br<sup>-</sup>, F<sup>-</sup>). The quantity of ions collected was then determined using ion chromatography (IC) analyses.

Two types of Microbial Survivability testing were completed. These tests were intended to evaluate the effectiveness of the MWI in destroying microbial elements in the waste. The first was aimed at determining microbial survivality in the combustion gases (emissions) and bottom ash. Indicator spores in solution (wet-spores) were loaded onto material commonly found in the medical waste stream and then charged into the incinerator to determine the ability of the indicator organisms to survive in the combustion gases and the incinerator bottom ash. The second microbial survivability test utilized freeze dried indicator spores (dry-spores) encased in insulated double pipe containers (pipe-samples) which were spiked to the MWI. Flue gas testing for spore emissions was conducted simultaneously with the other emissions testing were also loaded into the incinerator. The next day following the daily burn cycle, ash samples and pipe samples were recovered and subsequently analyzed for spore viability. Direct ash sampling and pipe sampling were conducted daily when the ash was removed manually from the incinerator. Flue gas samples were collected isokinetically and passed through a circulating phosphate buffer solution. Following the test, the buffer solution samples were analyzed for viable spores using microbiological identification, culturing, and quantification techniques outlined in the EPA draft method "Microbial Survivability Test for Medical Waste Incinerator Emissions." Ash samples and pipe samples were analyzed as outlined in the EPA draft method "Microbial Survivability Test for Medical Waste Incinerator Ash."

Visual opacity measurements were also taken continuously during the particulate test periods. A certified observer documented incinerator stack gas opacity by following EPA Method 9 protocol.

Gaseous emissions (NO<sub>x</sub>, CO, SO<sub>2</sub>, THC, and HCl) were measured using CEMs continuously during the day. The diluent gases (O<sub>2</sub>, CO<sub>2</sub>) were measured using CEMs at all times when tests were being performed so that the emission results could be normalized to a reference O<sub>2</sub> or CO<sub>2</sub> basis. The O<sub>2</sub> and CO<sub>2</sub> results were also used in the calculation of flue gas molecular weight for stack gas flow rate calculations.

Ash was sampled manually and mixed to provide a representative composite sample. Samples were taken for analysis as follows: loss-on-ignition (LOI), carbon, toxic metals, dioxins, and microbial analysis. An archive sample was also saved for each test condition. Indicator spore pipes were charged daily (prior to the start of incineration) into the incinerator and recovered manually for microbial analysis. Detailed descriptions of the sampling and analytical procedures are provided in Section 5.

#### 1.4.4 Laboratory Analyses

All manual flue gas tests were sent out for extensive laboratory analyses. Samples from CDD/CDF emission tests were analyzed for tetra-octa CDD/CDF isomers by Triangle Laboratories, Inc (Triangle). Ash samples were also analyzed by Triangle for these analytes. Analytical procedures followed EPA Method 23 protocols (Analytical Method 8290X). This technique incorporates HRGC/HRMS analytical procedures.

Samples from particulate matter/metals emission tests were analyzed by Radian's Perimeter Park (PPK) laboratory. Analytical procedures were completed using ICAPS, Graphite Furnace Atomic Absorption Spectroscopy (GFAAS), and Cold Vapor Atomic Absorption Spectroscopy (CVAAS). Incinerator ash was also analyzed for metals content using these techniques. Particulate matter was analyzed using gravimetric techniques following EPA Method 5 guidelines. Samples from halogen emission tests were analyzed by Radian's PPK laboratory. Quantities of chloride, bromide, and fluoride ions in the impinger solutions were determined using IC techniques.

Microbial survivability samples from the emissions tests and the ash and pipe tests were analyzed for viable spores of Bacillus stearothermophilus (B. stearothermophilus) by Research Triangle Institute (RTI). Impinger samples (emissions), ash, and pipe samples were cultured and enumerated using analytical techniques recently developed specific for this test method. This protocol is given in the EPA draft methods "Microbial

Survivability Test for Medical Waste Incinerator Emissions" and "Microbial Survivability Test for Medical Waste Incinerator Ash.

The incinerator ash was analyzed by McCoy Labs for volatile matter (LOI) by Standard Methods of Water and Wastes, Method 209G, and for carbon content by ASTM Method D 3178-84.

#### 1.5 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

All flue gas testing procedures followed comprehensive QA/QC procedures as outlined in the Jordan Hospital MWI test plan and EPA reference methods. A full description of the resulting QA parameters is given in Section 6.

Post-test leak check criteria were met for the majority of outlet manual sampling trains. The inlet sampling trains did not meet all of the leak checks and sample volumes needed to be leak corrected. The corrections resulted in minimal changes in sample volume (1-6%) and would therefore did not significantly change the emission values. The allowable isokinetic QC range of  $\pm 10$  percent of 100 percent was met for 21 of the 30 emission test runs. The exceedances mostly fell within 20 percent of 100 percent and were not expected to affect the overall quality of the data. All post-test dry gas meter calibration checks were within 5 percent of the full calibration factor. Field blanks (FB) results showed very little CDD/CDF contamination. The halogen FB showed virtually no contamination. Final toluene rinses of the CDD/CDF samples showed only small amounts of residual CDD/CDF isomers remaining after the methylene chloride rinse.

From an analytical QA perspective, all analyses were completed under a strict QA/QC regimen. Outlet CDD/CDF flue gas and CDD/CDF ash samples had to be diluted because of analytical saturation problems. Matrix spike values for all metals except silver were within the acceptable range.

#### 1.6 DESCRIPTION OF REPORT CONTENTS

Section 1 of this report provides an introduction to the medical waste testing program conducted at Jordan Hospital in Plymouth, Massachusetts. This section includes the test objective, a brief site description, an overview of the emissions measurement program, a brief overview of the QA/QC program, and this description of the report contents.

Section 2 gives a summary of the test results. Included in the contents of this section are the emissions test log, CDD/CDF results, toxic metals results, PM/visible emissions results, halogen results, CEM results, ash LOI and carbon results, and microbial survivability results.

Section 3 details the process and operation of the Jordan incinerator and gives process results. Included in the process results are the waste feed amounts and incinerator chamber temperatures.

Section 4 provides a detailed description and drawings of the sample locations.

Section 5 presents detailed descriptions of sampling and analytical procedures. The descriptions that are covered in this section are the CDD/CDF testing method, the PM and toxic metals testing method, microbial survivability testing methods, the manual halogen emissions testing method, EPA Methods 1 through 4, CEM methods, the visible emissions method, particle size distribution tests, and process sampling procedures.

Section 6 provides details of the QA/QC procedures used on this program and the QC results. Included in this section is a summary of QA/QC objectives, QC procedures for the manual flue gas sampling methods, QC procedures for the ash and pipe (microbial) sampling, analytical QC procedures and QA parameters, and CEM QC procedure and QA parameters.

Appendices containing the actual field data sheets and computer data listings are contained in a separate volume.

## 2. SUMMARY OF RESULTS

This section provides results of the test program conducted at the Jordan Hospital MWI from March 5 to March 9, 1991. Included in this section are results of manual flue gas tests conducted for CDD/CDF, toxic metals, PM, visible emissions, halogens, and microbial survivability. This section also contains the results of continuous emissions monitoring for O<sub>2</sub>, CO<sub>2</sub>, CO, NO<sub>x</sub>, SO<sub>2</sub>, THC, and HCl gases as well as particle size distribution (PSD) results. Results from analyses of ash and scrubber water are also included.

### 2.1 EMISSIONS TEST LOG

Six test runs were conducted during 3 test days. Flue gas sample locations were at the inlet and outlet (stack) to the air pollution control devices (APCD). Two test runs were conducted on each day with the first corresponding to the incinerator burn condition and the second to the burndown condition. The CEM instruments monitored gas concentrations during burn, burndown, and cooldown periods of each test day. Table 2-1 presents the emissions test log. This table shows the test date, run number and condition, test type, run times, and port change times for all the flue gas testing conducted during this program.

### 2.2 CDD/CDF RESULTS

#### 2.2.1 Overview

Simultaneous CDD/CDF test runs were conducted at the inlet and outlet of the Jordan Hospital MWI APCD. Two runs were conducted each day. The first run, conducted during the burn cycle, typically lasted seven hours. Testing was initiated approximately 0-5 minutes before the incinerator reached the initial secondary chamber burn temperature set point. Following the burn cycle, a second test run was conducted to determine emissions during burndown. These test runs were started within 5 minutes of burndown initiation except for Day 2 (Run 4). For this run, the inlet run was started 45 minutes after the burn period was initiated.

Testing protocol followed EPA Method 23 which requires a final sample recovery rinse with toluene to be analyzed separately from the rest of the sample. Because these

TABLE 2-1. EMISSIONS TEST LOG;  
JORDAN HOSPITAL (1991)

DATE	RUN NO./ CONDITION	TEST TYPE *	INLET		OUTLET	
			RUN TIME	PORT CHANGES	RUN TIME	PORT CHANGES
3/05/91	1/Burn	PM/TM	09:50-16:49	13:26-14:10	09:47-16:49	13:07-13:10
3/05/91	1/Burn	CDD/CDF	09:44-16:49	13:20-14:09	09:45-16:49	13:06-13:15
3/05/91	1A/Burn	HCl	09:56-11:26		09:45-11:15	
3/05/91	1B/Burn	HCl	12:43-13:43		11:25-12:55	
3/05/91	1C/Burn	HCl	14:21-15:51		14:21-15:51	
3/05/91	1D/Burn	HCl	16:20-16:49		16:21-16:49	
3/05/91	1/Burn	Spore	09:38-16:18			
3/05/91	1/Burn	PSD	11:28-11:58			
	Burn Period		09:47-16:49			
3/05/91	2/Burndown	PM/TM	17:35-22:10	20:23-20:48	16:49-22:13	20:09-20:12
3/05/91	2/Burndown	CDD/CDF	17:35-22:10	20:23-20:48	16:49-22:13	20:09-20:14
3/05/91	2A/Burndown	HCl	17:45-19:15		17:45-19:15	
3/05/91	2B/Burndown	HCl	19:23-20:53		19:24-20:54	
3/05/91	2/Burndown	Spore	16:45-22:05			
	Burndown Period		16:49-22:11			
3/07/91	3/Burn	PM/TM	09:32-16:30	13:08-13:22	09:32-16:30	12:52-13:01
3/07/91	3/Burn	CDD/CDF	09:30-16:30	13:06-13:22	09:32-16:30	13:01-13:04
3/07/91	3A/Burn	HCl	09:31-11:01		09:32-11:02	
3/07/91	3B/Burn	HCl	11:12-12:42		11:13-12:43	
3/07/91	3C/Burn	HCl	12:53-14:23		12:58-14:28	
3/07/91	3D/Burn	HCl	14:35-16:05		14:35-16:05	
3/07/91	3/Burn	Spore	09:31-16:11			
	Burn Period		09:30-16:38			
3/07/91	4/Burndown	PM/TM	16:35-21:57	19:23-19:34	16:34-22:00	19:54-20:15
3/07/91	4/Burndown	CDD/CDF	16:34-21:58	19:22-19:34	16:33-21:59	19:53-20:15
3/07/91	4A/Burndown	HCl	16:59-18:29		17:00-18:30	
3/07/91	4B/Burndown	HCl	18:42-20:12		18:42-20:12	
3/07/91	4C/Burndown	HCl	20:20-21:57		20:20-21:50	
3/07/91	4/Burndown	Spore	16:30-22:59			
3/07/91	4/Burndown	PSD	15:02-17:42			
	Burndown Period		16:38-21:58			

TABLE 2-1. EMISSIONS TEST LOG (continued);  
JORDAN HOSPITAL (1991)

DATE	RUN NO./ CONDITION	TEST TYPE *	INLET		OUTLET	
			RUN TIME	PORT CHANGES	RUN TIME	PORT CHANGES
3/09/91	5/Burn	PM/TM	09:25-16:30	13:01-13:08	09:27-16:32	12:47-12:53
3/09/91	5/Burn	CDD/CDF	09:25-16:29	13:01-13:08	09:27-16:32	12:47-12:52
3/09/91	5A/Burn	HCl	09:43-11:13		09:37-11:07	
3/09/91	5B/Burn	HCl	11:33-13:03		11:33-13:03	
3/09/91	5C/Burn	HCl	13:19-14:49		13:19-14:49	
3/09/91	5D/Burn	HCl	15:08-16:29		15:08-16:32	
3/09/91	5/Burn	Spore	09:26-16:06			
	Burn Period		09:25-16:25			
3/09/91	6/Burndown	PM/TM	16:31-21:44	19:19-19:27	16:44-21:46	20:04-20:11
3/09/91	6/Burndown	CDD/CDF	16:29-21:44	19:17-19:27	16:42-21:46	20:02-20:10
3/09/91	6A/Burndown	HCl	17:03-18:33		17:08-18:38	
3/09/91	6B/Burndown	HCl	18:48-20:18		18:48-20:18	
3/09/91	6C/Burndown	HCl	20:26-21:44		20:26-21:46	
3/09/91	6/Burndown	Spore	16:28-21:46			
3/09/91	6/Burndown	PSD	11:14-13:46			
	Burndown Period		16:25-21:44			

\* HCl = manual HCl/HBr/HF tests

PM/TM = Particulate Matter/Toxic Metals tests

CDD/CDF = Tetra - Octa polychlorinated dibenzo-p-dioxins/dibenzo furans tests

Spore = Indicator Spore Microbial Survivability tests

PSD = Particle Size Distribution tests

data were not incorporated into the final emission results, they will be presented with the sampling QA parameters in Section 6.2.1. A brief summary of the gas phase CDD/CDF concentrations incorporating both the pooled Modified Method 5 results with the toluene rinse results is given in Section 2.11.

As well as flue gas samples, daily incinerator bottom ash and scrubber water samples were also taken. Each ash sample was also analyzed for tetra through octa CDD/CDF isomers. Results are given as quantitated values, non-detected values, or estimated maximum possible concentrations (EMPCs). The EMPC values are flagged by parentheses. These values were only incorporated into the emission calculations for isomers where the EMPC flags were noted in the analytical results summary sheet. (See Appendix E.1 for analytical results). The CDD/CDF isomers categorized as "other" did not normally include EMPC values.

Table 2-2 presents a summary of the CDD/CDF emissions, CDD/CDF ash concentrations, mass of CDD/CDF isomers discharged in the ash stream, and scrubber water concentrations. Flue gas emission rates were found to be much higher at the outlet than at the inlet. Inlet averages ranged from 0.24  $\mu\text{g/hr}$  for 2378 TCDD to 73.4  $\mu\text{g/hr}$  for Octa-CDF. Outlet values ranged from 0.64  $\mu\text{g/hr}$  for 123789 HxCDF to 937  $\mu\text{g/hr}$  for Other TCDF. All CDD/CDF congeners were detected in both the ash and scrubber water samples. Average rates of removal of CDD/CDF isomers in the ash stream ranged from 24  $\mu\text{g/day}$  for 2378 TCDF to 16,500  $\mu\text{g/day}$  for Other TCDF. Scrubber water concentrations ranged from 0.12 to 137 parts per trillion by weight (ppt. wt).

The following sections report CDD/CDF average emissions test results in Section 2.2.2, results from each run in Section 2.2.3, sample parameters are shown in Section 2.2.4, incinerator ash CDD/CDF concentrations in Section 2.2.5, and scrubber water CDD/CDF concentrations in Section 2.2.6. All field data and analytical data are shown in Appendices A.1 and E.1, respectively.

## 2.2.2 CDD/CDF Emission Results

Tables 2-3 through 2-6 present the average CDD/CDF emission parameters for the test program. Daily emission averages calculated by averaging the burn and burndown runs on a time weighted basis are shown in Table 2-7. Emission tests analyses

TABLE 2-2. SUMMARY OF CDD/CDF TESTS SHOWING AVERAGE DAILY FLUE GAS AND INCINERATOR BOTTOM ASH MASS RATES AND SCRUBBER WATER CONCENTRATIONS; JORDAN HOSPITAL (1991)

CONGENER	AVERAGE DAILY EMISSION RATES <sup>a</sup>		AVERAGE BOTTOM ASH PARAMETERS		AVERAGE SCRUBBER DISCHARGE WATER CONC.
	Inlet (ug/hr)	Outlet (ug/hr)	CONC. (ppb.wt)	DISCHARGE (mg/day)	(ppt.wt) <sup>c</sup>
<b>DIOXINS</b>					
2378 TCDD	0.240	1.316	0.700	0.024	0.123
Other TCDD	3.110	534.503	111.580	4.027	28.643
12378 PCDD	1.510	7.936	5.500	0.191	1.873
Other PCDD	7.185	486.266	140.867	4.959	114.127
123478 HxCDD	2.151	5.185	5.633	0.202	3.030
123678 HxCDD	1.403	7.961	7.867	0.279	5.067
123789 HxCDD	4.840	13.613	15.100	0.537	8.500
Other HxCDD	12.628	255.961	141.433	5.106	126.170
1234678-HpCDD	17.247	17.767	48.633	1.750	37.367
Other Hepta-CDD	0.025	29.915	56.667	2.057	136.833
Octa-CDD	59.809	6.537	50.433	1.751	28.967
<b>Total CDD <sup>b</sup></b>	<b>97.0</b>	<b>1367.0</b>	<b>584.4</b>	<b>20.9</b>	<b>490.7</b>
<b>FURANS</b>					
2378 TCDF	1.647	13.103	11.167	0.385	12.300
Other TCDF	49.924	936.526	476.167	16.503	29.033
12378 PCDF	4.590	17.851	10.100	0.342	2.570
23478 PCDF	4.883	34.317	21.967	0.742	8.633
Other PCDF	55.359	498.020	222.933	7.613	87.097
123478 HxCDF	20.163	59.564	78.533	2.755	28.600
123678 HxCDF	9.812	17.491	19.000	0.660	7.567
234678 HxCDF	10.535	24.864	30.367	1.066	16.567
123789 HxCDF	1.538	0.637	0.510	0.018	0.543
Other HxCDF	48.961	145.208	115.257	4.044	57.257
1234678-HpCDF	32.477	26.461	59.267	2.078	31.867
1234789-HpCDF	7.117	2.031	3.700	0.129	4.233
Other Hepta-CDF	24.220	15.127	27.867	0.977	28.533
Octa-CDF	73.359	3.184	20.800	0.703	13.867
<b>TOTAL CDF <sup>b</sup></b>	<b>343.8</b>	<b>1794.4</b>	<b>1097.6</b>	<b>38.0</b>	<b>328.7</b>
<b>TOTAL CDD+CDF <sup>b</sup></b>	<b>440.9</b>	<b>3161.3</b>	<b>1682.0</b>	<b>58.9</b>	<b>819.4</b>

<sup>a</sup> Flue gas mass rates were averaged from incinerator burn test run averages (duration ~ 7 hrs) and incinerator burndown test run averages (~5.5 hrs).

<sup>b</sup> Values represent the average of the totals (not the sum of the averages)

<sup>c</sup> Scrubber discharge water had an approximate flow rate of 3-5 gpm.

TABLE 2-3. CDD/CDF AVERAGE FLUE GAS CONCENTRATIONS  
FOR BURN (RUNS 1, 3, & 5) AND BURNDOWN  
(RUNS 2, 4, & 6) CONDITIONS; JORDAN HOSPITAL (1991)

CONGENER	BURN CONDITION GAS CONCENTRATION (ng/dscm) <sup>a</sup>		BURNDOWN CONDITION GAS CONCENTRATION (ng/dscm)	
	IN	OUT	IN	OUT
	DIOXINS			
2378 TCDD	0.041	0.746	0.464	0.283
Other TCDD	0.498	324.705	6.372	92.540
12378 PCDD	0.128	3.921	3.002	2.419
Other PCDD	0.485	255.393	16.034	135.257
123478 HxCDD	0.220	2.683	3.887	1.416
123678 HxCDD	0.185	4.114	3.140	2.227
123789 HxCDD	0.596	7.010	8.021	3.817
Other HxCDD	1.521	133.057	27.481	70.661
1234678-HpCDD	1.064	9.206	40.356	4.835
Other Hepta-CDD	0.114	15.562	0	8.005
Octa-CDD	3.567	3.494	122.711	1.677
<b>Total CDD</b>	<b>6.40</b>	<b>759.89</b>	<b>226.50</b>	<b>323.14</b>
FURANS				
2378 TCDF	0.155	7.201	3.763	3.134
Other TCDF	4.448	554.843	111.651	175.632
12378 PCDF	0.143	9.286	11.286	4.844
23478 PCDF	0.450	17.739	11.254	9.225
Other PCDF	3.344	262.462	131.792	129.937
123478 HxCDF	0.923	30.214	48.540	17.438
123678 HxCDF	0.309	8.852	24.064	5.130
234678 HxCDF	0.700	12.673	24.686	7.080
123789 HxCDF	0.060	0.295	3.075	0.218
Other HxCDF	1.476	74.125	120.080	41.768
1234678-HpCDF	1.240	13.703	78.940	7.348
1234789-HpCDF	0.418	1.083	17.078	0.527
Other Hepta-CDF	0.829	7.817	59.143	4.234
Octa-CDF	2.818	1.708	178.420	0.828
<b>TOTAL CDF</b>	<b>17.1</b>	<b>1002.0</b>	<b>822.7</b>	<b>407.3</b>
<b>TOTAL CDD+CDF</b>	<b>23.5</b>	<b>1761.9</b>	<b>1049.2</b>	<b>730.5</b>

<sup>a</sup> Standard conditions are defined as 1 atm and 68 °F.

were targeted for the tetra through octa 2378 substituted CDD/CDF isomers. Results are presented for each isomer as well as for each tetra-octa homologue total (Total CDD, Total CDF).

Average CDD/CDF inlet and outlet gas concentrations for the burn and burndown test conditions are presented in Table 2-3. Stack gas concentrations of all target CDD/CDF congeners were detected during each test condition throughout the program at both the inlet and outlet. In comparing gas concentrations at the inlet to those found at the outlet, higher concentrations for the majority of congeners were observed at the outlet (stack). With low inlet particulate loading and high inlet temperatures (~1100°F or 600°C), this phenomenon is not surprising. Dioxins and furans are theorized to form through several chemical mechanisms. One mechanism proposes that CDD/CDF forms from heavy organics and a chlorine donor (2). The optimum temperature window for this reaction ranges from 500 to 600°F. At temperatures above 750°F, this reaction is slowed considerably (2). The additional amounts of CDD/CDF species found at the outlet may have formed downstream of the inlet sample location where lower temperatures occurred. Additionally, the PM inlet loading was relatively low during these tests (Averages = 0.007 and 0.05 g/dscm at burn and burndown, respectively), and the absence of this available surface area for catalytic reactions involving organics may also help explain the low inlet CDD/CDF concentrations.

Average inlet CDD/CDF congener concentrations ranged from 0.041 ng/dscm for 2378 TCDD during the burn condition to 178 ng/dscm for octa-CDF during burndown conditions. Inlet CDD + CDF loading was higher during the burndown condition with Total CDD + CDF concentrations at 1,049 ng/dscm versus 23.5 ng/dscm during the burn condition.

Outlet burndown concentrations on the other hand, were generally lower than during the burn conditions. Total CDD + CDF values were 730 and 1,762 ng/dscm for burndown and burn tests, respectively. A possible explanation may be that with the higher inlet PM loading during the burndown condition, the inlet CDD/CDF isomers associated with the PM were removed more effectively by the fabric filter.

Average CDD/CDF concentrations corrected to 7 percent oxygen are presented in Table 2-4. Corrected concentrations were approximately 4 times higher than the uncorrected values at the outlet and 1.2 to 1.4 times higher at the inlet. Average oxygen concentrations at the outlet and inlet were 17.5 and 9.6% by volume/dry, respectively.

Average CDD/CDF emission rates for each condition are shown in Table 2-5. Average inlet mass rates of 2378 TCDD for the burn and burndown condition were 0.05 and 0.44  $\mu\text{g/hr}$ , respectively. Outlet 2378 TCDD values were 1.8 and 0.67  $\mu\text{g/hr}$  for burn and burndown, respectively. In order to present added perspective into the comparison of outlet and inlet CDD/CDF mass rates, an outlet to inlet mass rate ratio is also shown. Average ratios for the burn condition range from 10 for OCDF to 28,900 for Other HxCDD. Burndown values are somewhat lower. The outlet to inlet ratios for Total CDD + CDF for the burn and burndown conditions are 1,235 and 122, respectively. These values highlight the relatively lower outlet mass rates which occurred during the burndown versus burn condition.

Table 2-6 presents average corrected CDD/CDF gas concentrations in 2378 TCDD Toxic Equivalents. The concentration of each congener corrected to 7 percent  $\text{O}_2$  was multiplied by its respective Toxic Equivalency Factor (TEF) to determine 2378 Toxic Equivalents. The TEF's used in this report are the international TEF (I-TEF) developed by the North Atlantic Treaty Organization Committee of the Challenges of Modern Society (NATO/CCMS)(1). The average outlet 2378 Toxic Equivalent Concentrations for Total CDD + CDF for the burn and burndown were 75.4, and 44.1  $\text{ng/dscm}$  at 7 percent  $\text{O}_2$ , respectively.

Table 2-7 presents burn and burndown mass emission rates averaged on a daily basis using time weighing averaging techniques. Typically, the incinerator burn lasted for 7 hours and the burndown lasted for 5.5 hours. Day 2 inlet and outlet values were the highest of the three test days. Daily Total CDD + CDF emission rates at the outlet were 2,744, 4,499, and 2,241  $\mu\text{g/hr}$  for Days 1-3, respectively.

### 2.2.3 CDD/CDF Flue Gas Results for Each Run

Tables 2-8 through 2-11 present CDD/CDF flue gas results for the burn condition test runs (Runs 1, 3, & 5). Table 2-8 presents uncorrected flue gas concentrations at the inlet and outlet. Only one of these runs detected 2378 TCDD at

TABLE 2-4. CDD/CDF AVERAGE FLUE GAS CONCENTRATIONS  
CORRECTED TO 7% O<sub>2</sub> FOR BURN (RUNS 1, 3, & 5)  
AND BURNDOWN (RUNS 2, 4, & 6) CONDITIONS;  
JORDAN HOSPITAL (1991)

CONGENER	BURN CONDITION CONCENTRATION (ng/dscm @ 7% O <sub>2</sub> ) a		BURNDOWN CONDITION CONCENTRATION (ng/dscm @ 7% O <sub>2</sub> )	
	IN	OUT	IN	OUT
<b>DIOXINS</b>				
2378 TCDD	0.059	2.885	0.533	1.191
Other TCDD	0.704	1263.921	7.763	389.280
12378 PCDD	0.184	15.112	3.465	10.161
Other PCDD	0.677	993.744	19.293	567.949
123478 HxCDD	0.315	10.300	4.530	5.927
123678 HxCDD	0.262	15.863	3.724	9.311
123789 HxCDD	0.854	26.973	9.435	15.954
Other HxCDD	2.159	512.775	32.747	295.232
1234678-HpCDD	1.508	35.279	47.054	20.140
Other Hepta-CDD	0.140	59.641	0	33.435
Octa-CDD	5.081	13.427	141.181	6.991
<b>Total CDD</b>	<b>9.08</b>	<b>2949.9</b>	<b>263.9</b>	<b>1355.6</b>
<b>FURANS</b>				
2378 TCDF	0.214	27.919	4.385	13.203
Other TCDF	6.285	2156.605	132.588	739.513
12378 PCDF	0.202	35.803	12.894	20.343
23478 PCDF	0.632	68.068	13.053	38.652
Other PCDF	4.736	1008.992	151.850	544.506
123478 HxCDF	1.298	116.853	55.892	73.057
123678 HxCDF	0.435	34.186	27.542	21.494
234678 HxCDF	0.985	48.825	28.679	29.689
123789 HxCDF	0.085	1.131	3.553	0.912
Other HxCDF	2.086	286.731	137.513	175.254
1234678-HpCDF	1.746	52.705	90.615	30.687
1234789-HpCDF	0.593	4.159	19.657	2.194
Other Hepta-CDF	1.176	30.075	67.748	17.683
Octa-CDF	3.998	6.590	204.653	3.446
<b>TOTAL PCDF</b>	<b>24.2</b>	<b>3878.6</b>	<b>949.4</b>	<b>1710.6</b>
<b>TOTAL PCDD+PCDF</b>	<b>33.3</b>	<b>6828.6</b>	<b>1213.4</b>	<b>3066.2</b>

a Standard conditions are defined as 1 atm and 68 °F.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

TABLE 2-5. CDD/CDF STACK EMISSIONS AND OUTLET TO INLET EMISSIONS RATIOS FOR BURN (RUNS 1,3,5) AND BURNDOWN (RUNS 2,4,6) CONDITIONS; JORDAN HOSPITAL (1991)

CONGENER	BURN CONDITION			BURNDOWN CONDITION		
	EMISSIONS		OUTLET/INLET	EMISSIONS		OUTLET/INLET
	INLET (ug/hr)	OUTLET (ug/hr)	RATIO (Runs 1,3,5) <sup>a</sup>	INLET (ug/hr)	OUTLET (ug/hr)	RATIO (Runs 2,4,6) <sup>a</sup>
<b>DIOXINS</b>						
2378 TCDD	0.05	1.80	110	0.44	0.67	6.25
Other TCDD	0.60	772.15	7,625	6.45	221.12	2,868.8
12378 PCDD	0.15	9.54	294	2.81	5.80	147.8
Other PCDD	0.58	611.20	3,973	15.95	320.58	1,464.5
123478 HxCDD	0.26	6.55	153	3.69	3.38	47.9
123678 HxCDD	0.22	9.97	241	3.06	5.29	72.5
123789 HxCDD	0.72	17.03	472	7.72	9.08	194.3
Other HxCDD	1.83	322.47	28,886	26.94	167.76	6,678.2
1234678-HpCDD	1.28	22.55	140	38.35	11.41	34.3
Other Hepta-CDD	0.00	38.12	NA	0.00	19.01	NA
Octa-CDD	4.29	8.49	81	114.40	3.95	3.1
<b>Total CDD</b>	<b>7.68</b>	<b>1820</b>	<b>2962 <sup>a</sup></b>	<b>215</b>	<b>768</b>	<b>420 <sup>a</sup></b>
<b>FURANS</b>						
2378 TCDF	0.19	17.33	232	3.58	7.49	51.3
Other TCDF	5.34	1328.31	1,751	108.98	417.16	245.9
12378 PCDF	0.17	22.57	629	10.41	11.57	112.0
23478 PCDF	0.54	43.50	405	10.62	22.10	87.2
Other PCDF	4.02	639.86	4,937	123.12	309.55	307.3
123478 HxCDF	1.11	73.06	391	45.31	41.66	75.8
123678 HxCDF	0.37	21.44	319	22.26	12.25	67.2
234678 HxCDF	0.84	30.80	217	23.34	16.98	49.9
123789 HxCDF	0.07	0.72	32	2.88	0.52	11.6
Other HxCDF	1.77	179.25	2,454	111.19	100.04	101.7
1234678-HpCDF	1.49	33.22	121	73.36	17.50	15.5
1234789-HpCDF	0.50	2.62	22	15.95	1.24	1.4
Other Hepta-CDF	0.99	18.94	151	54.85	10.07	3.8
Octa-CDF	3.38	4.12	10	165.66	1.94	0.45
<b>TOTAL CDF</b>	<b>20.56</b>	<b>2416</b>	<b>885 <sup>a</sup></b>	<b>771</b>	<b>970</b>	<b>78.9 <sup>a</sup></b>
<b>TOTAL CDD+CDF</b>	<b>28.24</b>	<b>4236</b>	<b>1235 <sup>a</sup></b>	<b>986</b>	<b>1738</b>	<b>122.1 <sup>a</sup></b>

<sup>a</sup> Calculated from the average of the individual test run ratios as shown on Tables 2-11 and 2-15.

TABLE 2-6. CDD/CDF AVERAGE FLUE GAS TOXIC EQUIVALENCIES CORRECTED TO 7% O<sub>2</sub> FOR BURN (RUNS 1, 3, & 5) AND BURNDOWN (RUNS 2, 4, & 6) CONDITIONS; JORDAN HOSPITAL (1991)

CONGENER	TOXIC EQUIVALENCY FACTOR <sup>a</sup>	BURN CONDITION TOXIC EQUIVALENCIES (ng/dscm @ 7% O <sub>2</sub> ) <sup>b</sup>		BURNDOWN CONDITION TOXIC EQUIVALENCIES (ng/dscm @ 7% O <sub>2</sub> )	
		IN	OUT	IN	OUT
		<b>DIOXINS</b>			
2378 TCDD	1.00000	0.059	2.885	0.533	1.191
Other TCDD	0.00000	0.000	0.000	0.000	0.000
12378 PCDD	0.50000	0.092	7.556	1.732	5.081
Other PCDD	0.00000	0.000	0.000	0.000	0.000
123478 HxCDD	0.10000	0.032	1.030	0.453	0.593
123678 HxCDD	0.10000	0.026	1.586	0.372	0.931
123789 HxCDD	0.10000	0.085	2.697	0.943	1.595
Other HxCDD	0.00000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.01000	0.015	0.353	0.471	0.201
Other Hepta-CDD	0.00000	0.000	0.000	0.000	0.000
Octa-CDD	0.00100	0.005	0.013	0.141	0.007
<b>Total CDD</b>		<b>0.125</b>	<b>16.121</b>	<b>3.603</b>	<b>9.599</b>
<b>FURANS</b>					
2378 TCDF	0.10000	0.021	2.792	0.438	1.320
Other TCDF	0.00000	0.000	0.000	0.000	0.000
12378 PCDF	0.05000	0.010	1.790	0.645	1.017
23478 PCDF	0.50000	0.316	34.034	6.527	19.326
Other PCDF	0.00000	0.000	0.000	0.000	0.000
123478 HxCDF	0.10000	0.130	11.685	5.589	7.306
123678 HxCDF	0.10000	0.043	3.419	2.754	2.149
234678 HxCDF	0.10000	0.098	4.882	2.868	2.969
123789 HxCDF	0.10000	0.009	0.113	0.355	0.091
Other HxCDF	0.00000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.01000	0.017	0.527	0.906	0.307
1234789-HpCDF	0.01000	0.006	0.041	0.197	0.022
Other Hepta-CDF	0.00000	0.000	0.000	0.000	0.000
Octa-CDF	0.00100	0.004	0.007	0.205	0.003
<b>TOTAL CDF</b>		<b>0.647</b>	<b>59.291</b>	<b>20.365</b>	<b>34.511</b>
<b>TOTAL CDD+CDF</b>		<b>0.772</b>	<b>75.412</b>	<b>23.968</b>	<b>44.110</b>

<sup>a</sup> North Atlantic Treaty Organization, Committee on the Challenges of Modern Society. Pilot Study on International Information Exchange on Dioxins and Related Compounds: International Toxicity Equivalency Factor (I-TEF) Methods of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Report No. 176, August 1988.

<sup>b</sup> Standard conditions are defined as 1 atm and 68°F.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

TABLE 2-7. CDD/CDF EMISSIONS AVERAGED OVER EACH TEST DAY;  
JORDAN HOSPITAL (1991)

CONGENER	DAY 1 (RUNS 1 & 2)		DAY 2 (RUNS 3 & 4)		DAY 3 (RUNS 5 & 6)	
	Inlet (ug/hr)	Outlet (ug/hr)	Inlet (ug/hr)	Outlet (ug/hr)	Inlet (ug/hr)	Outlet (ug/hr)
<b>DIOXINS</b>						
2378 TCDD	(0.064)	1.121	(0.156)	1.906	0.499	0.922
Other TCDD	0.053	471.472	4.504	648.288	4.774	483.748
12378 PCDD	[0.029]	6.789	0.890	12.871	2.131	4.147
Other PCDD	(0.109)	470.229	9.374	663.518	12.072	325.052
123478 HxCDD	[0.043]	3.700	1.700	8.506	2.602	3.348
123678 HxCDD	0.020	6.109	1.410	12.533	2.781	5.240
123789 HxCDD	[0.036]	9.932	4.590	21.776	5.090	9.130
Other HxCDD	0.153	191.522	13.426	401.833	24.306	174.528
1234678-HpCDD	0.110	11.851	11.566	30.664	40.064	10.787
Other Hepta-CDD	0.000	20.692	0.074	51.356	0.000	17.698
Octa-CDD	0.312	4.378	46.470	10.265	132.643	4.969
<b>Total CDD</b>	<b>0.775</b>	<b>1197.793</b>	<b>63.372</b>	<b>1863.517</b>	<b>226.961</b>	<b>1039.568</b>
<b>FURANS</b>						
2378 TCDF	0.063	12.188	1.078	18.700	3.799	8.420
Other TCDF	0.737	867.766	51.160	1254.464	97.873	687.347
12378 PCDF	(0.034)	15.112	1.125	28.469	12.611	9.972
23478 PCDF	0.093	26.177	2.709	60.423	11.846	16.351
Other PCDF	0.523	379.780	23.153	810.764	142.402	303.518
123478 HxCDF	0.207	50.956	8.304	93.655	51.977	34.080
123678 HxCDF	0.070	14.560	2.781	27.595	26.587	10.317
234678 HxCDF	0.143	19.901	6.262	40.393	25.201	14.297
123789 HxCDF	[0.026]	0.474	0.960	1.108	2.115	0.328
Other HxCDF	0.347	126.954	14.396	227.011	132.138	81.657
1234678-HpCDF	0.299	18.140	11.247	41.591	85.886	19.651
1234789-HpCDF	0.270	1.247	2.854	3.099	18.227	1.746
Other Hepta-CDF	0.433	10.465	7.240	23.565	64.989	11.352
Octa-CDF	0.651	2.242	24.180	4.760	195.247	2.551
<b>TOTAL CDF</b>	<b>3.718</b>	<b>1545.961</b>	<b>156.900</b>	<b>2635.596</b>	<b>870.898</b>	<b>1201.589</b>
<b>TOTAL CDD+CDF</b>	<b>4.493</b>	<b>2743.754</b>	<b>220.272</b>	<b>4499.113</b>	<b>1097.859</b>	<b>2241.157</b>

[ ] = Minimum Detection Limit

( ) = Estimated Maximum Possible Concentration.

TABLE 2-8. CDD/CDF FLUE GAS CONCENTRATIONS AT THE INLET AND OUTLET  
 SAMPLE LOCATION DURING THE BURN CONDITON (RUNS 1,3,5);  
 JORDAN HOSPITAL (1991)

CONGENER	INLET CONCENTRATION (ng/dscm, as measured) a				OUTLET CONCENTRATION (ng/dscm, as measured)			
	RUN 1	RUN 3	RUN 5	AVERAGE	RUN 1	RUN 3	RUN 5	AVERAGE
<b>DIOXINS</b>								
2378 TCDD	[0.019]	[0.010]	(0.041)	0.041	0.63	1.02	(0.592)	0.75
Other TCDD	0.057	0.062	1.375	0.498	291.35	352.70	330.06	324.71
12378 PCDD	[0.033]	[0.021]	0.128	0.128	3.28	6.08	2.40	3.92
Other PCDD	(0.104)	0.103	1.247	0.485	252.44	323.18	190.56	255.39
123478 HxCDD	[0.047]	[0.026]	0.220	0.220	1.85	4.08	2.12	2.68
123678 HxCDD	[0.033]	0.026	0.344	0.185	3.21	5.87	3.27	4.11
123789 HxCDD	[0.043]	[0.021]	0.596	0.596	5.10	10.20	5.74	7.01
Other HxCDD	(0.218)	0.005	4.340	1.521	100.92	188.69	109.56	133.06
1234678-HpCDD	0.100	(0.114)	2.979	1.064	6.28	14.81	6.53	9.21
Other Hepta-CDD	0.000	0.000	0.000	0.000	10.71	25.08	10.90	15.56
Octa-CDD	0.214	[0.052]	6.920	3.567	2.35	4.99	3.15	3.49
<b>Total CDD</b>	<b>0.692</b>	<b>0.319</b>	<b>18.189</b>	<b>6.397</b>	<b>678.11</b>	<b>936.69</b>	<b>664.88</b>	<b>759.89</b>
<b>FURANS</b>								
2378 TCDF	0.052	0.052	0.362	0.155	6.64	9.76	5.20	7.20
Other TCDF	0.612	0.444	12.287	4.448	523.89	693.90	446.73	554.84
12378 PCDF	(0.024)	0.026	0.380	0.143	7.77	14.15	5.94	9.29
23478 PCDF	0.081	0.077	1.192	0.450	13.59	29.73	9.90	17.74
Other PCDF	0.536	0.067	9.427	3.344	196.20	403.91	187.27	262.46
123478 HxCDF	0.180	0.114	2.475	0.923	26.72	43.27	20.65	30.21
123678 HxCDF	0.062	0.041	0.825	0.309	7.48	12.81	6.26	8.85
234678 HxCDF	(0.133)	0.088	1.879	0.700	10.10	19.00	8.92	12.67
123789 HxCDF	[0.028]	[0.015]	0.060	0.060	0.21	0.49	(0.186)	0.30
Other HxCDF	0.280	0.036	4.111	1.476	66.18	106.55	49.64	74.13
1234678-HpCDF	(0.214)	0.160	3.346	1.240	9.27	19.00	12.83	13.70
1234789-HpCDF	[0.043]	0.057	0.779	0.418	(0.649)	1.45	1.15	1.08
Other Hepta-CDF	0.066	0.083	2.337	0.829	5.32	10.78	7.35	7.82
Octa-CDF	0.142	0.382	7.929	2.818	1.26	2.24	1.62	1.71
<b>TOTAL CDF</b>	<b>2.383</b>	<b>1.626</b>	<b>47.388</b>	<b>17.132</b>	<b>875.29</b>	<b>1367.06</b>	<b>763.66</b>	<b>1002.00</b>
<b>TOTAL CDD+CDF</b>	<b>3.08</b>	<b>1.94</b>	<b>65.58</b>	<b>23.53</b>	<b>1553.40</b>	<b>2303.74</b>	<b>1428.54</b>	<b>1761.89</b>

a Standard conditions are defined as 1 atm and 68 °F.

[ ] = Minimum Detection Limit

( ) = Estimated Maximum Possible Concentration.

the inlet. All three runs detected 2378 TCDD at the outlet. Run 3 results showed substantially higher dioxins and furans at the inlet with the Total CDD + CDF at 65.6 ng/dscm versus 3.08 and 1.94 for Runs 1 and 2, respectively. Outlet concentrations of Total CDD + CDF were more comparable between the three runs at 1,553, 2,304, and 1,429 ng/dscm for Runs 1, 2, and 3, respectively.

Table 2-9 presents the burn condition flue gas concentrations corrected to 7 percent oxygen. Results show the same trends as discussed with the uncorrected values.

Table 2-10 presents 2378 TCDD Toxic Equivalency Concentrations of the flue gas for the burn condition. Total CDD + CDF Toxic Equivalencies for the inlet range from 0.093 ng/dscm at 7 percent O<sub>2</sub> for Run 3 to 2.12 ng/dscm at 7 percent O<sub>2</sub> for Run 5. Outlet values ranged from 48.2 for Run 5 to 112 ng/dscm at 7 percent O<sub>2</sub> for Run 3.

Table 2-11 presents the flue gas CDD/CDF mass rates for the burn condition test runs. Inlet and outlet mass rates are presented for Runs 1, 3, and 5. Outlet to inlet mass rate ratios are also presented.

Tables 2-12 through 2-15 present CDD/CDF flue gas emissions test results for the test runs conducted during burndown condition. These included test runs 2, 4, and 6. Inlet and outlet flue gas CDD/CDF concentrations are presented in Table 2-12. Inlet Total CDD + CDF values were 4.29, 457, and 2,687 ng/dscm for Runs 2, 4, and 6, respectively. Outlet values for the three runs were more comparable at 740, 993, and 458 ng/dscm.

Table 2-13 presents the oxygen-corrected flue gas CDD/CDF concentrations for the burndown condition. Trends follow the same pattern as the uncorrected values with inlet Total CDD + CDF concentrations ranging from a low of 4.97 ng/dscm at 7 percent O<sub>2</sub> for Run 2 to 3,036 ng/dscm at 7 percent O<sub>2</sub> for Run 6. Outlet values were 3,320, 4,061, and 1,818 ng/dscm at 7 percent O<sub>2</sub> for Runs 2, 4, and 6, respectively.

Table 2-14 presents the 2378 TCDD toxic equivalent flue gas concentrations. Total CDD + CDF Toxic Equivalencies for the inlet were 0.15, 11.5 and 60.2 ng/dscm at 7 percent O<sub>2</sub> for Runs 2, 4, and 6, respectively. Outlet values were 43.8, 68.0, and 20.4 ng/dscm at 7 percent O<sub>2</sub>.

TABLE 2-9. CDD/CDF FLUE GAS CONCENTRATIONS CORRECTED TO 7% O<sub>2</sub>  
AT THE INLET AND OUTLET SAMPLE LOCATION DURING THE  
BURN CONDITION (RUNS 1,3,5); JORDAN HOSPITAL (1991)

CONGENER	INLET CONCENTRATION (ng/dscm, adjusted to 7 percent O <sub>2</sub> ) a				OUTLET CONCENTRATION (ng/dscm, adjusted to 7 percent O <sub>2</sub> )			
	RUN 1	RUN 3	RUN 5	AVERAGE b	RUN 1	RUN 3	RUN 5	AVERAGE
<b>DIOXINS</b>								
2378 TCDD	[0.022]	[0.012]	(0.059)	0.059	2.65	3.72	(2.286)	2.89
Other TCDD	0.065	0.076	1.970	0.704	1227.22	1290.14	1274.40	1263.92
12378 PCDD	[0.038]	[0.026]	0.184	0.184	13.83	22.23	9.28	15.11
Other PCDD	(0.119)	0.127	1.786	0.677	1063.32	1182.16	735.75	993.74
123478 HxCDD	[0.054]	[0.032]	0.315	0.315	7.80	14.93	8.17	10.30
123678 HxCDD	[0.038]	0.032	0.493	0.262	13.50	21.47	12.61	15.86
123789 HxCDD	[0.049]	[0.026]	0.854	0.854	21.46	37.30	22.15	26.97
Other HxCDD	(0.250)	0.006	6.219	2.159	425.07	690.22	423.04	512.77
1234678-HpCDD	0.114	(0.140)	4.269	1.508	26.45	54.16	25.23	35.28
Other Hepta-CDD	0.000	0.000	0.000	0.140	45.10	91.74	42.09	59.64
Octa-CDD	0.245	[0.064]	9.917	5.081	9.89	18.24	12.16	13.43
<b>Total CDD</b>	<b>0.794</b>	<b>0.381</b>	<b>26.066</b>	<b>9.080</b>	<b>2856.28</b>	<b>3426.31</b>	<b>2567.17</b>	<b>2949.92</b>
<b>FURANS</b>								
2378 TCDF	0.060	0.064	0.519	0.214	27.97	35.72	20.06	27.92
Other TCDF	0.703	0.546	17.607	6.285	2206.70	2538.23	1724.89	2156.61
12378 PCDF	(0.028)	0.032	0.545	0.202	32.72	51.75	22.94	35.80
23478 PCDF	0.093	0.095	1.708	0.632	57.23	108.74	38.23	68.07
Other PCDF	0.616	0.083	13.509	4.736	826.43	1477.47	723.08	1008.99
123478 HxCDF	0.207	0.140	3.546	1.298	112.54	158.29	79.73	116.85
123678 HxCDF	0.071	0.051	1.182	0.435	31.51	46.87	24.18	34.19
234678 HxCDF	(0.153)	0.108	2.693	0.985	42.52	69.51	34.44	48.82
123789 HxCDF	[0.032]	[0.018]	0.085	0.085	0.88	1.79	(0.718)	1.13
Other HxCDF	0.322	0.044	5.891	2.086	278.77	389.74	191.68	286.73
1234678-HpCDF	(0.246)	0.197	4.794	1.746	39.07	69.51	49.54	52.71
1234789-HpCDF	[0.049]	0.070	1.116	0.593	(2.734)	5.30	4.44	4.16
Other Hepta-CDF	0.076	0.102	3.349	1.176	22.43	39.44	28.36	30.08
Octa-CDF	0.164	0.470	11.361	3.998	5.31	8.19	6.27	6.59
<b>TOTAL CDF</b>	<b>2.739</b>	<b>2.000</b>	<b>67.906</b>	<b>24.215</b>	<b>3687</b>	<b>5001</b>	<b>2949</b>	<b>3879</b>
<b>TOTAL CDD+CDF</b>	<b>3.533</b>	<b>2.382</b>	<b>93.97</b>	<b>33.295</b>	<b>6543</b>	<b>8427</b>	<b>5516</b>	<b>6829</b>

a Standard conditions are defined as 1 atm and 68 °F.

[ ] = Minimum Detection Limit

( ) = Estimated Maximum Possible Concentration

b Detection limits are considered zeros for calculating averages.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

TABLE 2-10. CDD/CDF FLUE GAS TOXIC EQUIVALENCIES CORRECTED TO 7% O2 FOR THE BURN CONDITION (RUNS 1, 3, & 5); JORDAN HOSPITAL (1991)

CONGENER	2378-TCDD TOXIC EQUIV. FACTOR <sup>a</sup>	INLET 2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2) <sup>b</sup>				OUTLET 2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
		RUN 1	RUN 3	RUN 5	AVERAGE <sup>c</sup>	RUN 1	RUN 3	RUN 5	AVERAGE
<b>DIOXINS</b>									
2378 TCDD	1.00000	[0.022]	[0.012]	(0.059)	0.059	2.65	3.72	(2.286)	2.89
Other TCDD	0.00000	0.000	0.000	0.000	0	0.00	0.00	0.00	0
12378 PCDD	0.50000	[0.019]	[0.013]	0.092	0.092	6.91	11.11	4.64	7.56
Other PCDD	0.00000	(0.000)	0.000	0.000	0	0.00	0.00	0.00	0
123478 HxCDD	0.10000	[0.005]	[0.003]	0.032	0.032	0.78	1.49	0.82	1.03
123678 HxCDD	0.10000	[0.004]	0.003	0.049	0.026	1.35	2.15	1.26	1.59
123789 HxCDD	0.10000	[0.005]	[0.003]	0.085	0.085	2.15	3.73	2.22	2.70
Other HxCDD	0.00000	(0.000)	0.000	0.000	0	0.00	0.00	0.00	0
1234678-HpCDD	0.01000	0.001	(0.001)	0.043	0.015	0.26	0.54	0.25	0.35
Other Hepta-CDD	0.00000	0.000	(0.000)	0.000	0	0.00	0.00	0.00	0
Octa-CDD	0.00100	0.000	[0.000]	0.010	0.005	0.01	0.02	0.01	0.01
<b>Total CDD</b>		<b>0.001</b>	<b>0.004</b>	<b>0.370</b>	<b>0.125</b>	<b>14.12</b>	<b>22.76</b>	<b>11.48</b>	<b>16.12</b>
<b>FURANS</b>									
2378 TCDF	0.10000	0.006	0.006	0.052	0.021	2.80	3.57	2.01	2.79
Other TCDF	0.00000	0.000	0.000	0.000	0	0.00	0.00	0.00	0
12378 PCDF	0.05000	(0.001)	0.002	0.027	0.010	1.64	2.59	1.15	1.79
23478 PCDF	0.50000	0.046	0.048	0.854	0.316	28.62	54.37	19.12	34.03
Other PCDF	0.00000	0.000	0.000	0.000	0	0.00	0.00	0.00	0
123478 HxCDF	0.10000	0.021	0.014	0.355	0.130	11.25	15.83	7.97	11.69
123678 HxCDF	0.10000	0.007	0.005	0.118	0.043	3.15	4.69	2.42	3.42
234678 HxCDF	0.10000	(0.015)	0.011	0.269	0.098	4.25	6.95	3.44	4.88
123789 HxCDF	0.10000	[0.003]	[0.002]	0.009	0.009	0.09	0.18	(0.072)	0.11
Other HxCDF	0.00000	0.000	0.000	0.000	0	0.00	0.00	0.00	0
1234678-HpCDF	0.01000	(0.002)	0.002	0.048	0.017	0.39	0.70	0.50	0.53
1234789-HpCDF	0.01000	[0.000]	0.001	0.011	0.006	(0.027)	0.05	0.04	0.04
Other Hepta-CDF	0.00000	0.000	0.000	0.000	0	0.00	0.00	0.00	0
Octa-CDF	0.00100	0.000	0.000	0.011	0.004	0.01	0.01	0.01	0.01
<b>TOTAL CDF</b>		<b>0.098</b>	<b>0.089</b>	<b>1.754</b>	<b>0.647</b>	<b>52.22</b>	<b>88.93</b>	<b>36.72</b>	<b>59.29</b>
<b>TOTAL CDD+CDF</b>		<b>0.100</b>	<b>0.093</b>	<b>2.124</b>	<b>0.772</b>	<b>66.33</b>	<b>111.69</b>	<b>48.21</b>	<b>75.41</b>

<sup>a</sup> North Atlantic Treaty Organization, Committee on the Challenges of Modern Society. Pilot Study on International Information Exchange on Dioxins and Related Compounds: International Toxicity Equivalency Factor (I-TEF) Methods of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Report No. 176, August 1988.

<sup>b</sup> Standard conditions are defined as 1 atm and 68 °F.

[ ] = Minimum Detection Limit.

( ) = Estimated maximum Possible Concentration

<sup>c</sup> Detection limits are considered zeros for calculating averages.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

TABLE 2-11. CDD/CDF STACK EMISSIONS AND OUTLET/INLET EMISSIONS RATIOS FOR THE BURN CONDITION (RUNS 1,3,5); JORDAN HOSPITAL (1991)

CONGENER	RUN 1 EMISSIONS			RUN 3 EMISSIONS			RUN 5 EMISSIONS			BURN AVG EMISSIONS		
	INLET (ug/hr)	OUTLET (ug/hr)	OUT/IN RATIO	INLET (ug/hr)	OUTLET (ug/hr)	OUT/IN RATIO	INLET (ug/hr)	OUTLET (ug/hr)	OUT/IN RATIO	INLET (ug/hr)	OUTLET (ug/hr)	OUT/IN RATIO
DIOXINS												
2378 TCDD	[0.023]	1.34	58.47	[0.011]	2.69	244.42	(0.049)	(1.365)	27.86	0.05	1.80	110.2
Other TCDD	0.07	622.16	9051.36	0.07	933.35	13363.33	1.65	760.94	460.36	0.60	772.15	7625.0
12378 PCDD	[0.040]	7.01	175.23	[0.024]	16.08	670.08	0.15	5.54	35.92	0.15	9.54	293.7
Other PCDD	(0.126)	539.07	4278.30	0.12	855.23	7346.91	1.50	439.31	293.14	0.58	611.20	3972.8
123478 HxCDD	[0.057]	3.95	69.35	[0.029]	10.80	372.56	0.26	4.88	18.44	0.26	6.55	153.5
123678 HxCDD	[0.040]	6.85	171.16	0.03	15.53	533.79	0.41	7.53	18.23	0.22	9.97	241.1
123789 HxCDD	[0.052]	10.88	272.02	[0.024]	26.99	1124.41	0.72	13.23	18.47	0.72	17.03	471.6
Other HxCDD	(0.263)	215.50	819.38	0.01	499.34	85791.65	5.22	252.59	48.41	1.83	322.47	28886.5
1234678-HpCDD	0.12	13.41	111.46	(0.129)	39.18	303.75	3.58	15.06	4.21	1.28	22.55	139.8
Other Hepta-CDD	0.00	22.86	NA	0.00	66.37	NA	0.00	25.13	NA	0.00	38.12	NA
Octa-CDD	0.26	5.01	19.45	[0.059]	13.19	223.63	8.32	7.26	0.87	4.29	8.49	81.3
<b>Total CDD</b>	<b>0.84</b>	<b>1448.0</b>	<b>1810</b>	<b>0.35</b>	<b>2479</b>	<b>7082</b>	<b>21.87</b>	<b>1533</b>	<b>70.10</b>	<b>7.68</b>	<b>1,820</b>	<b>2961.6</b>
FURANS												
2378 TCDF	0.06	14.18	225.08	0.06	25.84	443.97	0.44	11.98	27.52	0.19	17.33	232.2
Other TCDF	0.74	1118.72	1514.00	0.50	1836.28	3668.53	14.77	1029.92	69.72	5.34	1328.31	1750.7
12378 PCDF	(0.029)	16.59	571.93	0.03	37.44	1286.58	0.46	13.70	29.95	0.17	22.57	629.5
23478 PCDF	0.10	29.02	297.97	0.09	78.67	901.06	1.43	22.83	15.94	0.54	43.50	405.0
Other PCDF	0.65	418.97	647.29	0.08	1068.88	14126.53	11.33	431.74	38.09	4.02	639.86	4937.3
123478 HxCDF	0.22	57.05	262.11	0.13	114.52	894.32	2.98	47.61	16.00	1.11	73.06	390.8
123678 HxCDF	0.07	15.97	214.53	0.05	33.91	728.19	0.99	14.44	14.56	0.37	21.44	319.1
234678 HxCDF	(0.161)	21.56	133.90	0.10	50.29	508.23	2.26	20.56	9.10	0.84	30.80	217.1
123789 HxCDF	[0.034]	0.45	13.18	[0.017]	1.29	76.15	0.07	(0.429)	5.99	0.07	0.72	31.8
Other HxCDF	0.34	141.33	418.18	0.04	281.96	6920.48	4.94	114.45	23.16	1.77	179.25	2453.9
1234678-HpCDF	(0.258)	19.81	76.77	0.18	50.29	278.71	4.02	29.58	7.35	1.49	33.22	120.9
1234789-HpCDF	[0.052]	(1.386)	2.62	0.06	3.83	59.88	0.94	2.65	2.83	0.50	2.62	21.8
Other Hepta-CDF	0.08	11.37	141.78	0.09	28.53	306.35	2.81	16.94	6.03	0.99	18.94	151.4
Octa-CDF	0.17	2.69	15.65	0.43	5.92	13.76	9.53	3.75	0.39	3.38	4.12	9.9
<b>TOTAL CDF</b>	<b>2.88</b>	<b>1869</b>	<b>650</b>	<b>1.83</b>	<b>3618</b>	<b>1973</b>	<b>57.0</b>	<b>1761</b>	<b>30.9</b>	<b>20.56</b>	<b>2,416</b>	<b>884.6</b>
<b>TOTAL CDD+CDF</b>	<b>3.71</b>	<b>3317</b>	<b>894</b>	<b>2.20</b>	<b>6096</b>	<b>2771</b>	<b>78.8</b>	<b>3293</b>	<b>41.8</b>	<b>28.24</b>	<b>4,236</b>	<b>1235.5</b>

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Concentration.

TABLE 2-12. CDD/CDF FLUE GAS CONCENTRATIONS AT THE INLET AND OUTLET SAMPLE LOCATION DURING THE BURNDOWN CONDITION (RUNS 2, 4, & 6); JORDAN HOSPITAL (1991)

CONGENER	INLET CONCENTRATION (ng/dscm, as measured) <sup>a</sup>				OUTLET CONCENTRATION (ng/dscm, as measured)			
	RUN 2	RUN 4	RUN 6	AVERAGE	RUN 2	RUN 4	RUN 6	AVERAGE
<b>DIOXINS</b>								
2378 TCDD	(0.050)	(0.139)	1.20	0.46	0.31	(0.361)	0.18	0.28
Other TCDD	0.02	9.31	9.78	6.37	101.82	112.26	63.54	92.54
12378 PCDD	[0.012]	0.79	5.21	3.00	2.42	3.61	1.24	2.42
Other PCDD	(0.068)	7.41	28.63	16.03	141.23	171.15	93.39	135.26
123478 HxCDD	[0.019]	1.52	6.26	3.89	1.25	2.28	0.71	1.42
123678 HxCDD	0.02	2.90	6.50	3.14	1.91	3.58	1.19	2.23
123789 HxCDD	[0.012]	4.09	11.95	8.02	3.23	6.23	2.00	3.82
Other HxCDD	0.01	27.99	54.45	27.48	59.50	114.11	38.37	70.66
1234678-HpCDD	0.07	23.96	97.03	40.36	3.65	8.10	2.76	4.83
Other Hepta-CDD	0.00	0.00	0.00	0.00	6.63	13.15	4.23	8.00
Octa-CDD	0.30	41.45	326.38	122.71	1.32	2.67	1.05	1.68
<b>Total CDD</b>	<b>0.54</b>	<b>131.56</b>	<b>547.39</b>	<b>226.50</b>	<b>323.26</b>	<b>437.50</b>	<b>208.65</b>	<b>323.14</b>
<b>FURANS</b>								
2378 TCDF	0.05	2.18	9.06	3.76	3.56	3.85	2.00	3.13
Other TCDF	0.57	106.07	228.31	111.65	200.26	200.24	126.39	175.63
12378 PCDF	(0.031)	2.31	31.52	11.29	4.90	6.92	2.71	4.84
23478 PCDF	0.07	5.54	28.15	11.25	8.35	15.14	4.18	9.22
Other PCDF	0.28	48.18	346.91	131.79	122.05	195.72	72.04	129.94
123478 HxCDF	0.15	17.16	128.31	48.54	15.97	27.64	8.70	17.44
123678 HxCDF	0.05	5.74	66.40	24.06	4.72	8.05	2.62	5.13
234678 HxCDF	0.09	12.94	61.03	24.69	6.59	11.42	3.23	7.08
123789 HxCDF	[0.012]	0.86	5.29	3.08	0.19	0.36	0.10	0.22
Other HxCDF	0.28	29.97	329.99	120.08	40.18	64.54	20.58	41.77
1234678-HpCDF	0.27	23.23	213.31	78.94	5.93	12.60	3.52	7.35
1234789-HpCDF	0.21	5.87	45.15	17.08	0.40	0.89	(0.295)	0.53
Other Hepta-CDF	0.70	14.98	161.75	59.14	3.45	7.12	2.14	4.23
Octa-CDF	1.00	49.90	484.36	178.42	0.61	1.35	0.52	0.83
<b>TOTAL CDF</b>	<b>3.75</b>	<b>324.95</b>	<b>2139.53</b>	<b>822.75</b>	<b>417.15</b>	<b>555.84</b>	<b>249.03</b>	<b>407.34</b>
<b>TOTAL CDD+CDF</b>	<b>4.29</b>	<b>456.51</b>	<b>2686.93</b>	<b>1049.24</b>	<b>740.41</b>	<b>993.34</b>	<b>457.69</b>	<b>730.48</b>

<sup>a</sup> Standard conditions are defined as 1 atm and 68 °F.

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Concentration.

TABLE 2-13. CDD/CDF FLUE GAS CONCENTRATIONS CORRECTED TO 7% O<sub>2</sub> AT THE INLET AND OUTLET SAMPLE LOCATION DURING THE BURNDOWN CONDITION (RUNS 2, 4, & 6); JORDAN HOSPITAL (1991)

CONGENER	INLET CONCENTRATION (ng/dscm, adjusted to 7 percent O <sub>2</sub> ) <sup>a</sup>				OUTLET CONCENTRATION (ng/dscm, adjusted to 7 percent O <sub>2</sub> )			
	RUN 2	RUN 4	RUN 6	AVERAGE	RUN 2	RUN 4	RUN 6	AVERAGE
<b>DIOXINS</b>								
2378 TCDD	(0.058)	(0.182)	1.36	0.53	1.38	(1.476)	0.72	1.19
Other TCDD	0.03	12.20	11.06	7.76	456.56	458.94	252.34	389.28
12378 PCDD	[0.014]	1.04	5.89	3.46	10.83	14.74	4.91	10.16
Other PCDD	(0.079)	25.45	32.35	19.29	633.24	699.72	370.89	567.95
123478 HxCDD	[0.022]	1.99	7.07	4.53	5.61	9.34	2.83	5.93
123678 HxCDD	0.02	3.81	7.34	3.72	8.57	14.64	4.72	9.31
123789 HxCDD	[0.014]	5.37	13.50	9.43	14.48	25.45	7.93	15.95
Other HxCDD	0.01	36.70	61.53	32.75	266.79	466.51	152.40	295.23
1234678-HpCDD	0.09	31.42	109.66	47.05	16.35	33.12	10.95	20.14
Other Hepta-CDD	0.00	0.00	0.00	0.00	29.74	53.76	16.81	33.44
Octa-CDD	0.35	54.36	368.84	141.18	5.91	10.91	4.15	6.99
<b>Total CDD</b>	<b>0.63</b>	<b>172.51</b>	<b>618.60</b>	<b>263.91</b>	<b>1449.45</b>	<b>1788.60</b>	<b>828.66</b>	<b>1355.57</b>
<b>FURANS</b>								
2378 TCDF	0.06	2.86	10.24	4.38	15.95	15.72	7.93	13.20
Other TCDF	0.66	139.10	258.01	132.59	897.96	818.63	501.95	739.51
12378 PCDF	(0.036)	3.03	35.62	12.89	21.96	28.30	10.76	20.34
23478 PCDF	0.08	7.27	31.81	13.05	37.42	61.91	16.62	38.65
Other PCDF	0.32	63.19	392.04	151.85	547.26	800.15	286.10	544.51
123478 HxCDF	0.17	22.50	145.00	55.89	71.60	113.02	34.56	73.06
123678 HxCDF	0.06	7.53	75.04	27.54	21.17	32.92	10.39	21.49
234678 HxCDF	0.11	16.96	68.96	28.68	29.54	46.68	12.84	29.69
123789 HxCDF	[0.014]	1.13	5.98	3.55	0.85	1.47	0.42	0.91
Other HxCDF	0.32	39.30	372.92	137.51	180.16	263.87	81.73	175.25
1234678-HpCDF	0.32	30.47	241.06	90.61	26.59	51.50	13.97	30.69
1234789-HpCDF	0.25	7.70	51.02	19.66	1.77	3.64	(1.172)	2.19
Other Hepta-CDF	0.81	19.65	182.79	67.75	15.46	29.09	8.50	17.68
Octa-CDF	1.15	65.44	547.37	204.65	2.76	5.50	2.08	3.45
<b>TOTAL CDF</b>	<b>4.35</b>	<b>426.11</b>	<b>2417.85</b>	<b>949.44</b>	<b>1870.46</b>	<b>2272.41</b>	<b>989.02</b>	<b>1710.63</b>
<b>TOTAL CDD+CDF</b>	<b>4.97</b>	<b>598.63</b>	<b>3036.45</b>	<b>1213.35</b>	<b>3319.92</b>	<b>4061.02</b>	<b>1817.68</b>	<b>3066.20</b>

<sup>a</sup> Standard conditions are defined as 1 atm and 68 °F.

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Concentration.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

TABLE 2-14. CDD/CDF FLUE GAS TOXIC EQUIVALENCIES CORRECTED TO 7% O<sub>2</sub> FOR THE BURNDOWN CONDITION (RUNS 2, 4, & 6); JORDAN HOSPITAL (1991)

CONGENER	2378-TCDD TOXIC EQUIV. FACTOR <sup>a</sup>	INLET 2378 TOXIC EQUIVALENCIE (ng/dscm, adjusted to 7 percent O <sub>2</sub> ) <sup>b</sup>				OUTLET 2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O <sub>2</sub> )			
		RUN 2	RUN 4	RUN 6	AVERAGE	RUN 2	RUN 4	RUN 6	AVERAGE
<b>DIOXINS</b>									
2378 TCDD	1.00000	(0.058)	(0.182)	1.359	0.533	1.379	(1.476)	0.718	1.191
Other TCDD	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDD	0.50000	[0.007]	0.519	2.945	1.732	5.416	7.371	2.455	5.081
Other PCDD	0.00000	(0.000)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.10000	[0.002]	0.199	0.707	0.453	0.561	0.934	0.283	0.593
123678 HxCDD	0.10000	0.002	0.381	0.734	0.372	0.857	1.464	0.472	0.931
123789 HxCDD	0.10000	[0.001]	0.537	1.350	0.943	1.448	2.545	0.793	1.595
Other HxCDD	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.01000	0.001	0.314	1.097	0.471	0.163	0.331	0.110	0.201
Other Hepta-CDD	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDD	0.00100	0.000	0.054	0.369	0.141	0.006	0.011	0.004	0.007
<b>Total CDD</b>		<b>0.061</b>	<b>2.186</b>	<b>8.561</b>	<b>3.603</b>	<b>9.830</b>	<b>14.132</b>	<b>4.835</b>	<b>9.599</b>
<b>FURANS</b>									
2378 TCDF	0.10000	0.006	0.286	1.024	0.438	1.595	1.572	0.793	1.320
Other TCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDF	0.05000	(0.002)	0.151	1.781	0.645	1.098	1.415	0.538	1.017
23478 PCDF	0.50000	0.040	3.635	15.905	6.527	18.712	30.957	8.309	19.326
Other PCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	0.10000	0.017	2.250	14.500	5.589	7.160	11.302	3.456	7.306
123678 HxCDF	0.10000	0.006	0.753	7.504	2.754	2.117	3.292	1.039	2.149
234678 HxCDF	0.10000	0.011	1.696	6.896	2.868	2.954	4.668	1.284	2.969
123789 HxCDF	0.10000	[0.001]	0.113	0.598	0.355	0.085	0.147	0.042	0.091
Other HxCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.01000	0.003	0.305	2.411	0.906	0.266	0.515	0.140	0.307
1234789-HpCDF	0.01000	0.002	0.077	0.510	0.197	0.018	0.036	(0.012)	0.022
Other Hepta-CDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDF	0.00100	0.001	0.065	0.547	0.205	0.003	0.006	0.002	0.003
<b>TOTAL CDF</b>		<b>0.088</b>	<b>9.332</b>	<b>51.676</b>	<b>20.365</b>	<b>34.007</b>	<b>53.910</b>	<b>15.615</b>	<b>34.511</b>
<b>TOTAL CDD+CDF</b>		<b>0.149</b>	<b>11.519</b>	<b>60.237</b>	<b>23.968</b>	<b>43.838</b>	<b>68.042</b>	<b>20.449</b>	<b>44.110</b>

<sup>a</sup> North Atlantic Treaty Organization, Committee on the Challenges of Modern Society. Pilot Study on International Information Exchange on Dioxins and Related Compounds: International Toxicity Equivalency Factor (I-TEF) Methods of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Report No. 176, August 1988.

<sup>b</sup> Standard conditions are defined as 1 atm and 68°F.

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Concentration.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

Table 2-15 presents the mass emission rates for the test runs during burndown condition. Outlet to inlet ratios of mass rate are also presented. The most noticeable observation is that almost all of the inlet CDD/CDF species during Run 6 had mass rates higher than the associated outlet values. This may be correlated to the relatively higher inlet PM loading that occurred during Run 6. Only during this run were filters and/or impinger solutions noticeably discolored by "soot" type deposits. The Run 6 inlet Total CDD + CDF mass rate was 2,440  $\mu\text{g/hr}$  compared to 859  $\mu\text{g/hr}$  at the outlet.

#### 2.2.4 CDD/CDF Flue Gas Sample Parameters

The flue gas sample parameters for Runs 1, 3, and 5 are shown in Table 2-16. Values such as sampling rate, meter volume, stack gas temperature, gas  $\text{O}_2/\text{CO}_2/\text{H}_2\text{O}$  concentrations, stack gas flow rates, and isokinetics are shown. Values for the burndown condition (Runs 2, 4, and 6) are shown in Table 2-17. Five out of twelve CDD/CDF test runs did not meet the isokinetic criterion of being within 10 percent of 100. This is further discussed in Section 6.

#### 2.2.5 CDD/CDF Ash Results

Incinerator bottom ash was completely removed from the incinerator on the afternoon following each of the three test days. Fabric filter fly ash sampling was attempted however not enough material was available to complete the analyses and therefore any reference to ash in this report is referring to incinerator bottom ash. After collection, the ash was passed through a one-half inch mesh sieve to remove large pieces of glass, metal, or other large objects. The sifted ash was stored in a pre-cleaned stainless steel drum and allowed to cool. Daily composite ash samples were then taken using a 4 foot sample thief. An approximately 1 liter bottle was filled with ash and sent to the laboratory for CDD/CDF analyses.

Ash samples were analyzed for the same CDD/CDF isomers that the flue gas samples were analyzed for. Ash CDD/CDF concentrations for each test day as well as a pre-test sample are presented in Table 2-18. Concentrations are given in units of parts-per-billion by weight (ppb.wt).

All CDD/CDF congeners were detected in the test run samples as well as the pre-test sample. Pre-test incinerator operation had a slightly shorter burndown cycle (approximately 4 hours). Concentrations of 2378 TCDD in the test run samples ranged

TABLE 2-15. CDD/PCDF STACK EMISSIONS AND OUTLET/INLET EMISSIONS RATIOS FOR THE BURNDOWN CONDITION (RUNS 2,4,6); JORDAN HOSPITAL (1991)

CONGENER	RUN 2 EMISSIONS			RUN 4 EMISSIONS			RUN 6 EMISSIONS			BURNDOWN AVG EMISSIONS		
	INLET (ug/hr)	OUTLET (ug/hr)	OUT/IN RATIO	INLET (ug/hr)	OUTLET (ug/hr)	OUT/IN RATIO	INLET (ug/hr)	OUTLET (ug/hr)	OUT/IN RATIO	INLET (ug/hr)	OUTLET (ug/hr)	OUT/IN RATIO
DIOXINS												
2378 TCDD	(0.064)	0.83	12.93	(0.156)	(0.859)	5.51	1.09	0.34	0.31	0.44	0.39	6.25
Other TCDD	0.03	274.0	8567.17	10.4	267.0	25.59	8.9	122.4	13.77	6.45	221.12	2868.84
12378 PCDD	[0.015]	6.5	433.40	0.9	8.6	9.66	4.7	2.3	0.49	2.81	5.80	147.85
Other PCDD	(0.087)	380.0	4367.96	21.8	407.1	18.71	26.0	174.6	6.72	15.95	320.58	1464.46
123478 HxCDD	[0.024]	3.4	140.36	1.7	5.4	3.19	5.7	1.3	0.23	3.69	3.38	47.93
123678 HxCDD	0.02	5.1	214.36	3.3	8.5	2.62	5.9	2.2	0.38	3.06	5.29	72.45
123789 HxCDD	[0.015]	8.7	579.18	4.6	14.8	3.23	10.8	3.7	0.34	7.72	9.08	194.25
Other HxCDD	0.01	160.1	20024.55	31.4	271.4	8.65	49.4	71.7	1.45	26.94	167.76	6678.22
1234678-HpCDD	0.10	9.8	102.25	26.9	19.3	0.72	88.1	5.2	0.06	38.35	11.41	34.34
Other Hepta-CDD	0.00	17.8	NA	0.0	31.3	NA	0.0	7.9	NA	0.00	19.01	NA
Octa-CDD	0.38	3.5	9.24	46.5	6.3	0.14	296.3	2.0	0.01	114.40	3.95	3.13
<b>Total CDD</b>	<b>0.7</b>	<b>869.8</b>	<b>1252.14</b>	<b>147.5</b>	<b>1040.6</b>	<b>7.06</b>	<b>497.0</b>	<b>393.7</b>	<b>0.79</b>	<b>215.06</b>	<b>768.05</b>	<b>420.00</b>
FURANS												
2378 TCDF	0.06	9.6	149.69	2.4	9.1	3.75	8.2	3.7	0.45	3.58	7.49	51.30
Other TCDF	0.74	538.9	732.60	118.9	476.3	4.01	207.3	236.3	1.14	108.98	417.16	245.91
12378 PCDF	(0.040)	13.2	329.48	2.6	16.5	6.36	28.6	5.1	0.18	10.41	11.57	112.01
23478 PCDF	0.09	22.5	255.36	6.2	36.0	5.80	25.6	7.8	0.31	10.62	22.10	87.15
Other PCDF	0.36	328.4	912.81	54.0	465.5	8.62	315.0	134.7	0.43	123.12	309.55	307.29
123478 HxCDF	0.19	43.0	223.91	19.2	65.8	3.42	116.5	16.3	0.14	45.31	41.66	75.82
123678 HxCDF	0.06	12.7	198.66	6.4	19.2	2.98	60.3	4.9	0.08	22.26	12.25	67.24
234678 HxCDF	0.12	17.7	147.84	14.5	27.2	1.87	55.4	6.0	0.11	23.34	16.98	49.94
123789 HxCDF	[0.015]	0.5	33.88	1.0	0.9	0.89	4.8	0.2	0.04	2.88	0.52	11.61
Other HxCDF	0.36	108.1	300.50	33.6	153.5	4.57	299.6	38.5	0.13	111.19	100.04	101.73
1234678-HpCDF	0.35	16.0	45.36	26.0	30.0	1.15	193.7	6.6	0.03	73.36	17.50	15.51
1234789-HpCDF	0.27	1.1	3.91	6.6	2.1	0.32	41.0	(0.552)	0.01	15.95	1.06	1.42
Other Hepta-CDF	0.90	9.3	10.36	16.8	16.9	1.01	146.9	4.0	0.03	54.85	10.07	3.80
Octa-CDF	1.28	1.7	1.29	55.9	3.2	0.06	439.8	1.0	0.00	165.66	1.94	0.45
<b>TOTAL CDF</b>	<b>4.82</b>	<b>1122.5</b>	<b>232.82</b>	<b>364.3</b>	<b>1322.1</b>	<b>3.63</b>	<b>1942.5</b>	<b>465.6</b>	<b>0.24</b>	<b>770.5</b>	<b>970.1</b>	<b>78.90</b>
<b>TOTAL CDD+CDF</b>	<b>5.52</b>	<b>1992.3</b>	<b>361.20</b>	<b>511.8</b>	<b>2362.7</b>	<b>4.62</b>	<b>2439.5</b>	<b>859.3</b>	<b>0.35</b>	<b>985.6</b>	<b>1738.1</b>	<b>122.06</b>

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Concentration.

TABLE 2-16. CDD/CDF EMISSIONS SAMPLING AND FLUE GAS PARAMETERS  
AT INLET; JORDAN HOSPITAL (1991)

RUN NUMBER DATE	BURN CONDITION			
	Run 1 03/05/91	Run 3 03/07/91	Run 5 03/09/91	AVERAGE
Total Sampling Time (min.)	370	404	423	NA
Average Sampling Rate (dscfm)	0.20	0.17	0.18	0.18
Metered Volume (dscf)	74.41	68.4	77.03	73.28
Metered Volume (dscm)	2.107	1.937	2.182	2.075
Average Stack Temperature (°F)	1170	1220	1122	1170
O2 Concentration (%V)	8.8	9.6	11.2	9.9
CO2 Concentration (%V)	7.5	5.9	5.1	6.2
Stack Gas Moisture (%V)	9.58	8.33	6.94	8.3
Volumetric Flow Rate (dscfm)	710	663	708	694
Volumetric Flow Rate (dscmm)	20.12	18.79	20.04	19.65
Percent Isokinetic	117	106	107	NA
RUN NUMBER DATE	BURNDOWN CONDITION			
	Run 2 03/05/91	Run 4 03/07/91	Run 6 03/09/91	AVERAGE
Total Sampling Time (min.)	248	311	305	NA
Average Sampling Rate (dscfm)	0.23	0.17	0.14	0.18
Metered Volume (dscf)	56.75	53.5	44.04	51.43
Metered Volume (dscm)	1.607	1.515	1.247	1.456
Average Stack Temperature (°F)	1096	1173	1223	1164
O2 Concentration (%V)	8.9	10.3	8.6	9.3
CO2 Concentration (%V)	8.9	6.3	7.7	7.6
Stack Gas Moisture (%V)	8.33	6.36	6.57	7.1
Volumetric Flow Rate (dscfm)	756	660	534	650.00
Volumetric Flow Rate (dscmm)	21.4	18.7	15.1	18.40
Percent Isokinetic	130	109	112	NA

NA = Not Applicable.

TABLE 2-17. CDD/CDF EMISSIONS SAMPLING AND FLUE GAS PARAMETERS  
AT OUTLET; JORDAN HOSPITAL (1991)

RUN NUMBER DATE	BURN CONDITION			
	Run 1 03/05/91	Run 3 03/07/91	Run 5 03/09/91	AVERAGE
Total Sampling Time (min.)	415	404	415	NA
Average Sampling Rate (dscfm)	0.45	0.46	0.50	0.47
Metered Volume (dscf)	184.93	187.66	208.61	193.73
Metered Volume (dscm)	5.24	5.315	5.908	5.488
Average Stack Temperature (°F)	174	186	171	177
O2 Concentration (%V)	17.6	17.1	17.3	17.3
CO2 Concentration (%V)	1.8	2.2	2.2	2.1
Stack Gas Moisture (%V)	27.37	7.84	12.63	15.9
Volumetric Flow Rate (dscfm)	1257	1557	1357	1390
Volumetric Flow Rate (dscmm)	35.59	44.11	38.42	39.37
Percent Isokinetic	112	94	115	NA
RUN NUMBER DATE	BURNDOWN CONDITION			
	Run 2 03/05/91	Run 4 03/07/91	Run 6 03/09/91	AVERAGE
Total Sampling Time (min.)	324	306	296	NA
Average Sampling Rate (dscfm)	0.50	0.48	0.25	0.41
Metered Volume (dscf)	160.77	146.89	74.26	127.31
Metered Volume (dscm)	4.553	4.16	2.103	3.605
Average Stack Temperature (°F)	183	186	172	180
O2 Concentration (%V)	17.8	17.5	17.4	17.6
CO2 Concentration (%V)	1.9	2.1	2.4	2.1
Stack Gas Moisture (%V)	14.63	14.6	15.74	15.0
Volumetric Flow Rate (dscfm)	1584	1400	1100	1361
Volumetric Flow Rate (dscmm)	44.85	39.64	31.16	38.55
Percent Isokinetic	98	99	103	NA

NA = Not Applicable.

TABLE 2-18. CDD/CDF CONCENTRATIONS IN INCINERATOR BOTTOM ASH;  
JORDAN HOSPITAL (1991)

SAMPLE ID: DATE: RUN No.s CONGENER	PRE-TEST ASH 03/01 (ppb.wt)	ASH COLLECTED DURING TEST PROGRAM			
		03/05 1 & 2 (ppb.wt)	03/07 3 & 4 (ppb.wt)	03/09 5 & 6 (ppb.wt)	AVERAGE (ppb.wt)
2378 TCDD	0.450	0.960	(0.650)	(0.490)	0.700
Other TCDD	64.150	136.040	147.000	51.700	111.580
12378 PCDD	3.000	6.900	5.700	3.900	5.500
Other PCDD	65.100	169.100	162.300	91.200	140.867
123478 HxCDD	2.700	7.100	7.000	(2.800)	5.633
123678 HxCDD	3.700	9.800	9.400	4.400	7.867
123789 HxCDD	7.400	18.700	18.300	8.300	15.100
Other HxCDD	67.000	156.400	191.300	76.600	141.433
1234678-HpCDD	22.400	53.200	64.900	27.800	48.633
Other Hepta-CDD	30.000	57.800	80.100	32.100	56.667
Octa-CDD	30.900	55.300	55.000	41.000	50.433
<b>Total CDD</b>	<b>296.800</b>	<b>671.300</b>	<b>741.650</b>	<b>340.290</b>	<b>584.413</b>
<b>FURANS</b>					
2378 TCDF	7.000	15.000	10.800	7.700	11.167
Other TCDF	178.000	609.000	488.200	331.300	476.167
12378 PCDF	5.000	13.300	8.800	8.200	10.100
23478 PCDF	11.100	30.700	18.100	17.100	21.967
Other PCDF	123.900	267.000	212.100	189.700	222.933
123478 HxCDF	42.200	103.000	86.100	46.500	78.533
123678 HxCDF	10.900	23.400	20.100	13.500	19.000
234678 HxCDF	16.400	37.000	34.300	19.800	30.367
123789 HxCDF	0.240	0.640	0.600	0.290	0.510
Other HxCDF	68.260	135.960	130.900	78.910	115.257
1234678-HpCDF	29.300	73.100	66.100	38.600	59.267
1234789-HpCDF	1.400	4.300	4.000	2.800	3.700
Other Hepta-CDF	14.400	31.600	31.900	20.100	27.867
Octa-CDF	10.900	21.200	19.500	21.700	20.800
<b>TOTAL CDF</b>	<b>519.000</b>	<b>1365.200</b>	<b>1131.500</b>	<b>796.200</b>	<b>1097.633</b>
<b>TOTAL CDD+CDF</b>	<b>815.800</b>	<b>2036.500</b>	<b>1873.150</b>	<b>1136.490</b>	<b>1682.047</b>

( ) = Estimated Maximum Possible Concentration.

from 0.49 to 0.96 ppb.wt. Test Day 1 had the highest Total CDD + CDF concentrations at 2,036 ppb.wt as compared to 1,873 and 1,136 ppb.wt for Days 2 and 3, respectively. The daily ash results do not appear to vary as much as the flue gas values. The highest values for each respective species appear to be within a factor of 2 of the lowest value. Further discussion on data variability can be found in Section 6.

Table 2-19 presents the 2378 TCDD Toxic Equivalencies for the Jordan incinerator ash. Total CDD + CDF values for Days 1, 2, and 3 were 43.3, 33.1, and 22.5 ppb.wt 2378 TCDD toxic equivalents, respectively.

Table 2-20 presents the mass of CDD/CDF isomers discharged in the ash stream. Ash removed weights for the 3 Test Days were 70.34, 94.82, and 60.35 lbs for Days 1 through 3, respectively. Average 2378 TCDD discharged in the ash stream was 0.024 mg/day. The highest average value for an individual isomer or "other" designated isomers was 16.5 mg/day for Other TCDF compounds.

#### 2.2.6 CDD/CDF Concentrations in Absorber Water

The liquor used in the packed bed absorber drains into a three tank, cascaded system. Overall flow rates were not measured during this test program however manufacturer's specifications state liquor flow to be 8-10 gpm through each of eight nozzles (64 - 80 gpm). Liquor drains from the scrubber into the first holding tank. There is a 3-5 gpm blow-down (discharge) off this first holding tank which is drained into a floor drain in the incinerator room. The liquor remaining in the first tank flows into the second tank where the pH is buffered with 50% caustic (NaOH) to maintain the acid removing capacity. Absorber discharge liquor (water) samples were collected from the No. 1 tank blow-down line. Absorber make-up water was sampled during each test day. However, only one sample was analyzed with the results assumed to represent all test days. Absorber discharge water samples were taken on each test day by collecting a grab sample from the drain pipe located underneath as floor drain. All three absorber water discharge samples were analyzed. Results are given in units of parts per trillion by weight (ppt.wt).

Table 2-21 presents the results for the CDD/CDF absorber water analyses. The make-up water showed positive detections of more than half the target CDD/CDF

TABLE 2-19. CDD/CDF ASH TOXIC EQUIVALENCIES;  
JORDAN HOSPITAL (1991)

SAMPLE ID: DATE: RUN No. CONGENER	TOXIC EQUIV. FACTOR a	PRE-TEST ASH	ASH COLLECTED DURING TEST PROGRAM			
		03/01	03/05	03/07	03/09	AVERAGE
		1 & 2 TEF - (ppb.wt)	1 & 2 TEF - (ppb.wt)	3 & 4 TEF - (ppb.wt)	5 & 6 TEF - (ppb.wt)	TEF - (ppb.wt)
2378 TCDD	1.00000	0.450	0.960	(0.6500)	(0.4900)	0.700
Other TCDD	0.00000	0.000	0.000	0.000	0.000	0.000
12378 PCDD	0.50000	1.500	3.450	2.850	1.950	2.750
Other PCDD	0.00000	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.10000	0.270	0.710	0.700	(0.2800)	0.563
123678 HxCDD	0.10000	0.370	0.980	0.940	0.440	0.787
123789 HxCDD	0.10000	0.740	1.870	1.830	0.830	1.510
Other HxCDD	0.00000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.01000	0.224	0.532	0.649	0.278	0.486
Other Hepta-CDD	0.00000	0.000	0.000	0.000	0.000	0.000
Octa-CDD	0.00100	0.031	0.055	0.055	0.041	0.050
<b>Total CDD</b>		<b>3.585</b>	<b>8.557</b>	<b>7.674</b>	<b>4.309</b>	<b>6.847</b>
<b>FURANS</b>						
2378 TCDF	0.10000	0.700	1.500	1.080	0.770	1.117
Other TCDF	0.00000	0.000	0.000	0.000	0.000	0.000
12378 PCDF	0.05000	0.250	0.665	0.440	0.410	0.505
23478 PCDF	0.50000	5.550	15.350	9.050	8.550	10.983
Other PCDF	0.00000	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	0.10000	4.220	10.300	8.610	4.650	7.853
123678 HxCDF	0.10000	1.090	2.340	2.010	1.350	1.900
234678 HxCDF	0.10000	1.640	3.700	3.430	1.980	3.037
123789 HxCDF	0.10000	0.024	0.064	0.060	0.029	0.051
Other HxCDF	0.00000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.01000	0.293	0.731	0.661	0.386	0.593
1234789-HpCDF	0.01000	0.014	0.043	0.040	0.028	0.037
Other Hepta-CDF	0.00000	0.000	0.000	0.000	0.000	0.000
Octa-CDF	0.00100	0.011	0.021	0.020	0.022	0.021
<b>TOTAL CDF</b>		<b>13.792</b>	<b>34.714</b>	<b>25.401</b>	<b>18.175</b>	<b>26.096</b>
<b>TOTAL CDD+CDF</b>		<b>17.377</b>	<b>43.271</b>	<b>33.075</b>	<b>22.484</b>	<b>32.943</b>

a North Atlantic Treaty Organization, Committee on Challenges of Modern Society. Pilot Study on International Information Exchange on Dioxins and Related Compounds: International Toxicity Equivalency Factor (I-TEF) Methods of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Report No. 176, August 1988.

( ) = Estimated Maximum Possible Concentration.

TABLE 2-20. CDD/CDF DAILY DISCHARGE RATE IN THE ASH STREAM;  
JORDAN HOSPITAL (1991)

DATE: RUN No. CONGENER	MASS REMOVED IN ASH			
	03/05 1 & 2 (mg/day)	03/07 3 & 4 (mg/day)	03/09 5 & 6 (mg/day)	AVERAGE (mg/day)
2378 TCDD	0.031	(0.028)	(0.013)	0.024
Other TCDD	4.340	6.326	1.415	4.027
12378 PCDD	0.220	0.245	0.107	0.191
Other PCDD	5.395	6.984	2.497	4.959
123478 HxCDD	0.227	0.301	(0.077)	0.202
123678 HxCDD	0.313	0.405	0.120	0.279
123789 HxCDD	0.597	0.787	0.227	0.537
Other HxCDD	4.990	8.232	2.097	5.106
1234678-HpCDD	1.697	2.793	0.761	1.750
Other Hepta-CDD	1.844	3.447	0.879	2.057
Octa-CDD	1.764	2.367	1.122	1.751
<b>Total CDD</b>	<b>21.418</b>	<b>31.915</b>	<b>9.315</b>	<b>20.883</b>
<b>FURANS</b>				
2378 TCDF	0.479	0.465	0.211	0.385
Other TCDF	19.430	21.008	9.069	16.503
12378 PCDF	0.424	0.379	0.224	0.342
23478 PCDF	0.979	0.779	0.468	0.742
Other PCDF	8.519	9.127	5.193	7.613
123478 HxCDF	3.286	3.705	1.273	2.755
123678 HxCDF	0.747	0.865	0.370	0.660
234678 HxCDF	1.181	1.476	0.542	1.066
123789 HxCDF	0.020	0.026	0.008	0.018
Other HxCDF	4.338	5.633	2.160	4.044
1234678-HpCDF	2.332	2.844	1.057	2.078
1234789-HpCDF	0.137	0.172	0.077	0.129
Other Hepta-CDF	1.008	1.373	0.550	0.977
Octa-CDF	0.676	0.839	0.594	0.703
<b>TOTAL CDF</b>	<b>43.557</b>	<b>48.691</b>	<b>21.795</b>	<b>38.015</b>
<b>TOTAL CDD+CDF</b>	<b>64.976</b>	<b>80.606</b>	<b>31.110</b>	<b>58.897</b>

( ) = Estimated Maximum Possible Concentration.

TABLE 2-21. CDD/CDF CONCENTRATIONS IN ABSORBER MAKE-UP WATER AND DISCHARGE WATER; JORDAN HOSPITAL (1991)

SAMPLE ID: DATE: RUN No. CONGENER	MAKE UP 03/05 1 & 2 (ppt. wt)	DISCHARGE			
		03/05 1 & 2 (ppt. wt)	03/07 3 & 4 (ppt. wt)	03/09 5 & 6 (ppt. wt)	AVERAGE (ppt. wt)
2378 TCDD	(0.003)	0.050	0.290	0.030	0.123
Other TCDD	0.007	10.050	69.310	6.570	28.643
12378 PCDD	0.001	0.380	4.900	0.340	1.873
Other PCDD	0.005	26.620	293.100	22.660	114.127
123478 HxCDD	[0.005]	0.700	7.800	0.590	3.030
123678 HxCDD	[0.003]	1.400	12.600	1.200	5.067
123789 HxCDD	[0.005]	1.900	22.000	1.600	8.500
Other HxCDD	0.020	28.800	327.600	22.110	126.170
1234678-HpCDD	0.020	12.500	93.400	6.200	37.367
Other Hepta-CDD	0.020	28.900	369.600	12.000	136.833
Octa-CDD	0.260	12.100	69.700	5.100	28.967
<b>Total CDD</b>	<b>0.336</b>	<b>123.400</b>	<b>1270.300</b>	<b>78.400</b>	<b>490.700</b>
<b>FURANS</b>					
2378 TCDF	0.040	4.300	28.800	3.800	12.300
Other TCDF	0.040	10.900	68.000	8.200	29.033
12378 PCDF	[0.003]	0.700	6.300	0.710	2.570
23478 PCDF	[0.003]	2.000	22.200	1.700	8.633
Other PCDF	[0.003]	20.900	221.500	18.890	87.097
123478 HxCDF	0.002	6.700	71.700	7.400	28.600
123678 HxCDF	[0.003]	1.900	18.600	2.200	7.567
234678 HxCDF	0.004	3.700	41.900	4.100	16.567
123789 HxCDF	[0.003]	0.140	(1.300)	0.190	0.543
Other HxCDF	0.003	14.560	142.800	14.410	57.257
1234678-HpCDF	0.004	9.600	80.000	6.000	31.867
1234789-HpCDF	[0.005]	1.400	10.200	1.100	4.233
Other Hepta-CDF	0.001	9.000	71.800	4.800	28.533
Octa-CDF	0.010	6.600	31.200	3.800	13.867
<b>TOTAL CDF</b>	<b>0.104</b>	<b>92.400</b>	<b>816.300</b>	<b>77.300</b>	<b>328.667</b>
<b>TOTAL CDD+CDF</b>	<b>0.440</b>	<b>215.800</b>	<b>2086.600</b>	<b>155.700</b>	<b>819.367</b>

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Concentration.

isomers. Concentrations of 2378 TCDD in the make-up water were 0.003 ppt.wt. The Total CDD + CDF concentration was 0.44 ppt.wt.

Absorber discharge water CDD/CDF concentrations were higher than the make-up water. Concentrations of 2378 TCDD for Days 1, 2, and 3 were 0.05, 0.29 and 0.03 ppt.wt, respectively. The Total CDD + CDF values were 216, 2,087, and 156 ppt.wt, respectively. Day 2 (03/07/91) concentrations for all isomers were approximately 5 to 10 times higher than either Day 1 or Day 3 values.

Table 2-22 shows the absorber water CDD/CDF concentrations as 2378 TCDD toxic equivalents. The Total CDD + CDF 2378 TCDD toxic equivalents for Days 1, 2, and 3 were 3.60, 35.6, and 3.34 ppt.wt, respectively. The make-up water 2378 TCDD toxic equivalents for Total CDD + CDF was determined to be 0.009 ppt.wt.

The flow rates of absorber make-up water and discharge water were not measured during this test program. However, manufacturing specifications state that discharge water flow rates to be 3-5 gpm. Based on a 5 gpm flow, approximate mass rates for CDD/CDF congeners can be estimated. At the average 2378 TCDD concentration of 0.123 ppt. wt, the corresponding mass rate at 5 gpm would be 0.314  $\mu\text{g/hr}$ . Total CDD + CDF mass rates calculated in this fashion using the average value of 819 ppt. wt at 5 gpm would be 930  $\mu\text{g/hr}$ .

## 2.3 TOXIC METALS RESULTS

### 2.3.1 Overview

A single sampling train was used to determine emission rates of a series of 11 metals Sb, As, Ba, Be, Cd, Pb, Hg, Ni, Ag, and Tl, and PM. Three sampling runs were performed under each of the two test conditions (burn and burndown) in order to ensure representative test results. Sampling locations, methods, and QA/QC procedures and results are discussed in Sections 4, 5, and 6, respectively. The average metals emission rates and removal efficiencies are summarized in Section 2.3.2. The results for each individual run are presented in Section 2.3.4. Concentrations at dry, standard conditions, concentrations adjusted to 7 percent O<sub>2</sub>, and emission rates are shown. The metals to PM ratios are presented in Section 2.3.5, flue gas metals by sample fraction in Section 2.3.6, and metals concentration in ash in Section 2.3.2.

TABLE 2-22. CDD/CDF TOXIC EQUIVALENCIES OF ABSORBER  
MAKE-UP WATER AND DISCHARGE WATER;  
JORDAN HOSPITAL (1991)

SAMPLE ID: DATE: RUN No. CONGENER	TOXIC EQUIV. FACTOR <sup>a</sup>	MAKE UP	DISCHARGE WATER			
		03/05 1 & 2 TEF - (ppt.wt)	03/05 1 & 2 TEF - (ppt.wt)	03/07 3 & 4 TEF - (ppt.wt)	03/09 5 & 6 TEF - (ppt.wt)	AVERAGE TEF - (ppt.wt)
2378 TCDD	1.00000	(0.0030)	0.050	0.290	0.030	0.123
Other TCDD	0.00000	0.000	0.000	0.000	0.000	0.000
12378 PCDD	0.50000	0.001	0.190	2.450	0.170	0.937
Other PCDD	0.00000	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.10000	[0.0005]	0.070	0.780	0.059	0.303
123678 HxCDD	0.10000	[0.0003]	0.140	1.260	0.120	0.507
123789 HxCDD	0.10000	[0.0005]	0.190	2.200	0.160	0.850
Other HxCDD	0.00000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.01000	0.000	0.125	0.934	0.062	0.374
Other Hepta-CDD	0.00000	0.000	0.000	0.000	0.000	0.000
Octa-CDD	0.00100	0.000	0.012	0.070	0.005	0.029
<b>Total CDD</b>		<b>0.004</b>	<b>0.777</b>	<b>7.984</b>	<b>0.606</b>	<b>3.122</b>
<b>FURANS</b>						
2378 TCDF	0.10000	0.004	0.430	2.880	0.380	1.230
Other TCDF	0.00000	0.000	0.000	0.000	0.000	0.000
12378 PCDF	0.05000	[0.0002]	0.035	0.315	0.036	0.129
23478 PCDF	0.50000	[0.0015]	1.000	11.100	0.850	4.317
Other PCDF	0.00000	[0.0000]	0.000	0.000	0.000	0.000
123478 HxCDF	0.10000	0.000	0.670	7.170	0.740	2.860
123678 HxCDF	0.10000	[0.0003]	0.190	1.860	0.220	0.757
234678 HxCDF	0.10000	0.000	0.370	4.190	0.410	1.657
123789 HxCDF	0.10000	[0.0003]	0.014	(0.1300)	0.019	0.054
Other HxCDF	0.00000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.01000	0.000	0.096	0.800	0.060	0.319
1234789-HpCDF	0.01000	[0.0001]	0.014	0.102	0.011	0.042
Other Hepta-CDF	0.00000	0.000	0.000	0.000	0.000	0.000
Octa-CDF	0.00100	0.000	0.007	0.031	0.004	0.014
<b>TOTAL CDF</b>		<b>0.005</b>	<b>2.826</b>	<b>28.578</b>	<b>2.729</b>	<b>11.378</b>
<b>TOTAL CDD+CDF</b>		<b>0.009</b>	<b>3.603</b>	<b>36.562</b>	<b>3.335</b>	<b>14.500</b>

a North Atlantic Treaty Organization, Committee on Challenges of Modern Society. Pilot Study on International Information Exchange on Dioxins and Related Compounds: International Toxicity Equivalency Factor (I-TEF) Methods of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Rerpot No. 176, August 1988.

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Concentration.

A summary of the Jordan Hospital toxic metals results is presented in Table 2-23. Inlet mass rates ranged from not detected for Be and Tl, to 4.8 grams/hr (g/hr) during the burndown period for Pb. Outlet emissions ranged from not detected for Be and Tl to 0.57 g/hr for Pb. The associated removal efficiencies were all above 70 percent for the burndown and generally above 50 percent for the burn period. Average metals discharge amounts in the ash stream are presented on a daily basis (includes burn and burndown periods). Mercury, Ag, and Tl were not detected. Other values of metals in ash ranged from 0.073 g/day for Be to 31.4 g/day for Pb. Further details on flue gas and ash toxic metals results are given in the following sections.

### 2.3.2 Metals Data Reduction

The values reported in the following toxic metals results include respective detection limits for metals which were not detected in the samples. Since the samples were analyzed in three separate fractions (see Section 5 for details), guidelines for mathematically handling detection limits were required. The guidelines used for this report are:

- If a metal was detected in one or more fractions of the sample train but not in all fractions, only the detected values were used to determine total sample mass (non detects = zero).
- If a metal was not detected in any fractions of a sample train, the lowest detection limit reported for an individual fraction was used as the overall sample detection limit.

For the purpose of calculating average results:

- If a metal was detected in one or more of the test runs but not in all, only those runs for which a detected result was obtained were used in calculating the average. (Runs where the metal was not detected were not included for averaging.)
- If the metal was not detected in any of the three runs, then the average results were reported as not detected at the average detection limit.

TABLE 2-23. SUMMARY OF TOXIC METALS FLUE GAS EMISSION RATES AND IN METALS IN ASH  
 JORDAN HOSPITAL (1991)

METAL	AVERAGE BURN EMISSIONS			AVERAGE BURNDOWN EMISSIONS			REMOVAL EFFICIENCY <sup>a</sup> (%)	AVERAGE CONC. IN ASH (mg/kg)	AVERAGE DISCHARGE IN ASH (grams/day) <sup>*</sup>
	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY <sup>a</sup> (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY <sup>a</sup> (%)			
Antimony	0.019	0.004	76.1	0.087	0.003	92.6	518	18.06	
Arsenic	0.001	[0.0002]	>80	0.004	[0.0002]	>90.1	5.37	0.23	
Barium	0.010	0.002	68.6	0.059	0.004	89.7	3835	135.32	
Beryllium	[0.0001]	[0.00005]	NA	[0.0001]	[0.00006]	NA	2.12	0.073	
Cadmium	0.033	0.002	92.8	0.172	0.002	98.6	46.4	1.57	
Chromium	0.015	0.004	77.2	0.021	0.003	84.3	685	22.44	
Lead	0.798	0.009	98.8	4.791	0.038	99.2	901	31.38	
Mercury	1.297	0.263	78.7	2.520	0.572	70.3	[9.80]	[0.334]	
Nickel	0.007	0.010	-165.4	0.011	0.002	81.4	86.8	2.8	
Silver	0.002	0.003	54.0	0.003	0.001	NA	[1.20]	[0.04]	
Thallium	[0.001]	[0.0005]	NA	[0.001]	[0.001]	NA	[1.50]	[0.05]	

\* Both a burn and burndown run were conducted each day. Typical durations of the burn periods were 7 hours and burndown periods were 5.5 hours.

[ ] = Minimum Detection Limit.

<sup>a</sup> Average removal efficiency calculated from individual run values shown in Table 2-24.

This approach assumes that it is most likely that an element would be found in the train fraction with the lowest detection limit; therefore, the minimum detection limit for the entire train is based on the lowest fraction detection limit.

The ash samples were analyzed for the same series of metals as were the emissions test samples. These results will be reported in Section 2.3.7.

### 2.3.3 Metals Emissions

Table 2-24 presents the metals emissions results for each test condition. Two incinerator operating conditions were tested. The first was the initial ~7 hour burn period of the batch load of approximately 750 lbs of Type 0 to 4 waste (see Section 3 for an explanation of waste type) with a secondary chamber temperature setpoint of 1800°F. The second condition or "burndown" occupied the next ~5½ hours following the burn condition. The primary chamber operated on low-fire air during the burn test condition, and on high-fire air and low fire (depending on primary chamber, temperature) during the burndown test condition. The emission test results include a mass rate for each metal at the inlet and outlet, and the associated removal efficiencies.

During the burn condition, Hg had the highest average mass rate at the inlet, with 1.297 g/hr, followed by Pb with 0.798 g/hr. Beryllium and Tl were not detected in any of the runs at the inlet or outlet during the burn condition. Mercury was the most prevalent element collected for the three runs at the outlet during the burn condition with an average emission rate of 0.263 g/hr. Sample results for Ni during the burn condition showed negative removal efficiencies for two of the three runs. The Run 1 value resulted from similar inlet and outlet mass rates of Ni at 0.003 and 0.004 g/hr, respectively. Run 3 showed a substantially higher mass rate of Ni at the outlet of 0.019 g/hr versus 0.003 g/hr at the inlet. All other metals showed positive removal efficiencies for this run. Analytical QA showed good Ni standards recovery and no contamination in the blank samples was found. Further explanation is beyond the scope of this data report.

During the burndown condition, Pb had the highest average mass rate for the inlet runs with 4.791 g/hr, followed by Hg at 2.520 g/hr. As with the burn condition, Be and Tl were not collected in detectable amounts for any of the runs at the inlet and outlet during the burndown condition. Mercury was the most prevalent element

TABLE 2-24. AVERAGE METALS EMISSION RATES AND REMOVAL EFFICIENCIES FOR BURN AND BURNDOWN CONDITIONS; JORDAN HOSPITAL (1991)

CONDITION	BURN						BURNDOWN								
	RUN 1		RUN 3		RUN 5		RUN 4		RUN 6		AVERAGE				
LOCATION	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)
Antimony	0.023	0.004	82.5	0.016	0.004	77.3	0.017	0.005	68.4	0.019	0.004	76.1	0.019	0.004	76.1
Arsenic	0.001	[0.0002]	> 80	[0.0002]	[0.0002]	NA	[0.001]	[0.0002]	NA	0.001	[0.0002]	> 80	0.001	[0.0002]	> 80
Barium	0.007	0.002	62.3	0.018	0.002	89.1	0.004	0.002	54.4	0.010	0.002	68.6	0.010	0.002	68.6
Beryllium	[0.0001]	[0.00005]	NA												
Cadmium	0.059	0.004	93.8	0.023	0.002	92.1	0.017	0.001	92.5	0.033	0.002	92.8	0.033	0.002	92.8
Chromium	0.019	0.005	72.9	0.013	0.003	78.0	0.014	0.003	80.8	0.015	0.004	77.2	0.015	0.004	77.2
Lead	0.966	0.007	99.3	0.642	0.011	98.2	0.787	0.008	98.9	0.798	0.009	98.8	0.798	0.009	98.8
Mercury	0.710	0.241	66.1	2.897	0.514	82.3	0.283	0.035	87.8	1.297	0.263	78.7	1.297	0.263	78.7
Nickel	0.003	0.004	-28.9	0.003	0.019	-517.5	0.016	0.008	50.3	0.007	0.010	-165.4	0.007	0.010	-165.4
Silver	[0.0005]	0.007	NA	0.003	0.001	54.0	0.002	[0.0003]	> 85	0.002	0.003	54.0	0.002	0.003	54.0
Thallium	[0.001]	[0.0005]	NA												
CONDITION	BURN						BURNDOWN								
LOCATION	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)
Antimony	0.053	0.004	92.1	0.089	0.006	93.0	0.118	[0.001]	> 99.2	0.087	0.003	92.6	0.087	0.003	92.6
Arsenic	0.003	[0.0002]	> 93.3	0.001	[0.0002]	> 80	0.007	[0.0002]	> 97.1	0.004	[0.0002]	> 90.1	0.004	[0.0002]	> 90.1
Barium	0.015	0.003	80.1	0.103	0.003	97.0	0.058	0.005	92.0	0.059	0.004	89.7	0.059	0.004	89.7
Beryllium	[0.0001]	[0.00005]	NA	[0.0001]	[0.00006]	NA	[0.0001]	[0.00007]	NA	[0.0001]	[0.00006]	NA	[0.0001]	[0.00006]	NA
Cadmium	0.168	0.002	98.9	0.179	0.002	98.9	0.170	0.003	98.1	0.172	0.002	98.6	0.172	0.002	98.6
Chromium	0.031	0.002	94.3	0.016	0.004	76.9	0.017	0.003	81.7	0.021	0.003	84.3	0.021	0.003	84.3
Lead	5.75	0.039	99.3	3.57	0.022	99.4	5.06	0.051	99.0	4.791	0.038	99.2	4.791	0.038	99.2
Mercury	0.725	0.285	60.7	6.12	1.22	80.1	0.716	0.214	70.1	2.520	0.572	70.3	2.520	0.572	70.3
Nickel	0.011	0.001	91.7	0.008	0.002	79.9	0.015	0.004	72.7	0.011	0.002	81.4	0.011	0.002	81.4
Silver	0.002	0.004	-95.2	[0.001]	[0.0003]	NA	0.006	[0.0004]	> 93.3	0.003	0.001	NA	0.003	0.001	NA
Thallium	[0.001]	[0.001]	NA												

Note: Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples. Detection limits are not included in the averages unless otherwise indicated.

NA = Not applicable

[] = Minimum Detection Limit.

collected for the three outlet runs during the burndown condition with an average emission rate of 0.572 g/hr, with Pb having the next highest emission rate at 0.038 g/hr. As with Ni, results for Ag also showed a negative removal efficiency for Run 2, with a mass rate of 0.002 g/hr at the inlet and 0.004 g/hr at the outlet. Sample results for the other metals showed positive removal efficiencies for Run 2, and therefore, sampling error or analytical error is probably not the cause of these values. Other reasons which could cause this value can not be given at this time.

Of the metals for which an average removal efficiency could be calculated, the removal efficiencies for the burndown condition were generally higher than those for the burn condition. Barium had an average removal efficiency of 68.6 percent during the burn condition and an average of 89.7 percent during the burndown condition. Lead has an average removal efficiency of 98.8 percent during the burn condition and 99.2 percent for the burndown condition.

Flue gas mass rates of metals are presented as daily averages in Table 2-25. Emission rates from the burn and burndown runs from each day were averaged on a time weighted basis using the total minutes of burn and burndown incinerator operation. (These durations were almost identical to the respective run sample times.)

#### 2.3.4 Metals Flue Gas Concentrations

Metals concentrations, mass rates, and removal efficiencies are presented for each run in Tables 2-26 through 2-31. Also shown for each run are the location, date, time, O<sub>2</sub> concentration, and flow rate. Flue gas concentrations are given in terms of  $\mu\text{g}/\text{dscm}$ , and  $\mu\text{g}/\text{dscm}$  corrected to 7 percent O<sub>2</sub>. Oxygen concentrations were calculated from CEM data as shown in Section 2.7.

#### 2.3.5 Flue Gas Metals to PM Ratios

A summary of the ratio of metals to PM for the burn condition is presented in Table 2-32. Metals to PM ratios are given in units of milligrams of metal to grams of PM collected by the sampling train. The inlet values range from 0.090 mg arsenic per gram of PM during Run 1 to 362 mg Hg per gram of PM during Run 3. Lead had the highest inlet ratios for Runs 1 and 5, with 77.8 and 113 mg metal/g PM, respectively.

TABLE 2-25. DAILY AVERAGE TOXIC METALS FLUE GAS MASS RATES AND REMOVAL EFFICIENCIES;  
JORDAN HOSPITAL (1991)

CONDITION RUN NO. LOCATION	DAY 1 AVERAGE			DAY 2 AVERAGE			DAY 3 AVERAGE		
	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)	INLET (g/hr)	OUTLET (g/hr)	REMOVAL EFFICIENCY (%)
Antimony	0.0361	0.0041	86.65	0.0471	0.0047	84.02	0.0606	0.0030	81.70
Arsenic	0.0018	[0.0002]	85.76	0.002	[0.0002]	>80.00	0.007	[0.0002]	>97.1
Barium	0.0105	0.0027	70.00	0.0544	0.0025	92.48	0.0274	0.0030	70.63
Beryllium	[0.0001]	[0.00005]	NA	[0.0001]	[0.00005]	NA	[0.0001]	[0.00006]	NA
Cadmium	0.1063	0.0029	96.01	0.0898	0.0019	95.01	0.0827	0.0021	94.92
Chromium	0.0240	0.0037	82.16	0.0142	0.0032	77.53	0.0156	0.0029	81.19
Lead	3.0363	0.0208	99.30	1.8941	0.0160	98.71	2.6294	0.0268	98.94
Mercury	0.7163	0.2598	63.76	4.2754	0.8152	81.36	0.4699	0.1118	80.16
Nickel	0.0068	0.0028	23.30	0.0052	0.0115	-261.93	0.0153	0.0062	59.97
Silver	0.002	0.0060	-95.20	0.003	0.001	54.00	0.0037	[0.0004]	>88.6
Thallium	[0.0001]	[0.00005]	NA	[0.0001]	[0.00005]	NA	[0.0001]	[0.00005]	NA

NOTE: Emission rate averages were calculated using the the individual test run values and weighting them by the respective incinerator burn and burn-down durations.

TABLE 2-26. METALS CONCENTRATIONS, EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 1 (BURN CONDITION)  
JORDAN HOSPITAL (1991)

LOCATION	INLET	OUTLET	REMOVAL EFFICIENCY (%)
DATE TIME	03/05/91 09:50-16:49	03/05/91 09:47-16:49	
O2 CONCENTRATION (% V)	8.80	17.6	
FLOW RATE (dscmm)	25.8	38.7	
Antimony (ug/dscm)	15.0	1.75	82.5
(ug/dscm @7% O2)	17.3	7.37	
(g/hr)	0.023	0.004	
Arsenic (ug/dscm)	0.718	[0.084]	> 80
(ug/dscm @7% O2)	0.825	[0.354]	
(g/hr)	0.001	[0.0002]	
Barium (ug/dscm)	4.52	1.04	65.3
(ug/dscm @7% O2)	5.20	4.40	
(g/hr)	0.007	0.002	
Beryllium (ug/dscm)	[0.052]	[0.021]	NA
(ug/dscm @7% O2)	[0.060]	[0.088]	
(g/hr)	[0.0001]	[0.00005]	
Cadmium (ug/dscm)	38.3	1.58	93.8
(ug/dscm @7% O2)	43.9	6.64	
(g/hr)	0.059	0.004	
Chromium (ug/dscm)	12.2	2.20	72.9
(ug/dscm @7% O2)	14.0	9.26	
(g/hr)	0.019	0.005	
Lead (ug/dscm)	625	2.82	99.3
(ug/dscm @7% O2)	718	11.9	
(g/hr)	0.966	0.007	
Mercury (ug/dscm)	459	104	66.1
(ug/dscm @7% O2)	527	436	
(g/hr)	0.710	0.241	
Nickel (ug/dscm)	2.11	1.81	-28.9
(ug/dscm @7% O2)	2.43	7.63	
(g/hr)	0.003	0.004	
Silver (ug/dscm)	[0.313]	3.14	NA
(ug/dscm @7% O2)	[0.360]	13.2	
(g/hr)	[0.0005]	0.007	
Thallium (ug/dscm)	[0.523]	[0.210]	NA
(ug/dscm @7% O2)	[0.601]	[0.885]	
(g/hr)	[0.001]	[0.0005]	

Note: Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples. Detection limits are not included in the averages unless otherwise indicated.

NA = Not applicable

TABLE 2-27. METALS CONCENTRATIONS, EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 2 (BURNDOWN CONDITION)  
JORDAN HOSPITAL (1991)

LOCATION	INLET	OUTLET	REMOVAL EFFICIENCY (%)
DATE	03/05/91	03/05/91	
TIME	17:35-22:10	16:49-22:13	
O2 CONCENTRATION (% V)	8.90	17.8	
FLOW RATE (dscmm)	21.4	40.6	
Antimony (ug/dscm)	41.2	1.70	92.1
(ug/dscm @7% O2)	47.7	7.64	
(g/hr)	0.053	0.004	
Arsenic (ug/dscm)	2.08	[0.098]	> 93.3
(ug/dscm @7% O2)	2.40	[0.439]	
(g/hr)	0.003	[0.0002]	
Barium (ug/dscm)	11.7	1.03	80.1
(ug/dscm @7% O2)	13.6	4.62	
(g/hr)	0.015	0.003	
Beryllium (ug/dscm)	[0.085]	[0.024]	NA
(ug/dscm @7% O2)	[0.098]	[0.108]	
(g/hr)	[0.0001]	[0.00005]	
Cadmium (ug/dscm)	131	0.761	98.9
(ug/dscm @7% O2)	152	3.41	
(g/hr)	0.168	0.002	
Chromium (ug/dscm)	24.0	0.719	94.3
(ug/dscm @7% O2)	27.7	3.22	
(g/hr)	0.031	0.002	
Lead (ug/dscm)	4478	16.2	99.3
(ug/dscm @7% O2)	5187	72.5	
(g/hr)	5.75	0.039	
Mercury (ug/dscm)	564	117	60.7
(ug/dscm @7% O2)	654	525	
(g/hr)	0.725	0.285	
Nickel (ug/dscm)	8.90	0.387	91.7
(ug/dscm @7% O2)	10.3	1.74	
(g/hr)	0.011	0.001	
Silver (ug/dscm)	1.72	1.77	-95.2
(ug/dscm @7% O2)	1.99	7.94	
(g/hr)	0.002	0.004	
Thallium (ug/dscm)	[0.852]	[0.244]	NA
(ug/dscm @7% O2)	[0.987]	[1.094]	
(g/hr)	[0.001]	[0.001]	

Note: Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples. Detection limits are not included in the averages unless otherwise indicated.

NA = Not applicable

TABLE 2-28. METALS CONCENTRATIONS, EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 3 (BURN CONDITION)  
JORDAN HOSPITAL (1991)

LOCATION	INLET	OUTLET	REMOVAL EFFICIENCY (%)
DATE TIME	03/07/91 09:32-16:30	03/07/91 09:32-16:30	
O2 CONCENTRATION (% V)	9.60	17.1	
FLOW RATE (dscmm)	20.7	34.9	
Antimony (ug/dscm)	12.5	1.68	77.3
(ug/dscm @7% O2)	15.3	6.15	
(g/hr)	0.016	0.004	
Arsenic (ug/dscm)	[0.196]	[0.090]	NA
(ug/dscm @7% O2)	[0.241]	[0.329]	
(g/hr)	[0.0002]	[0.0002]	
Barium (ug/dscm)	14.6	0.946	89.1
(ug/dscm @7% O2)	18.0	3.46	
(g/hr)	0.018	0.002	
Beryllium (ug/dscm)	[0.049]	[0.022]	NA
(ug/dscm @7% O2)	[0.060]	[0.080]	
(g/hr)	[0.0001]	[0.00005]	
Cadmium (ug/dscm)	18.5	0.870	92.1
(ug/dscm @7% O2)	22.8	3.18	
(g/hr)	0.023	0.002	
Chromium (ug/dscm)	10.2	1.33	78.0
(ug/dscm @7% O2)	12.5	4.87	
(g/hr)	0.013	0.003	
Lead (ug/dscm)	516	5.38	98.2
(ug/dscm @7% O2)	634	19.7	
(g/hr)	0.642	0.011	
Mercury (ug/dscm)	2327	245	82.3
(ug/dscm @7% O2)	2862	898	
(g/hr)	2.897	0.514	
Nickel (ug/dscm)	2.46	9.03	-517.5
(ug/dscm @7% O2)	3.02	33.0	
(g/hr)	0.003	0.019	
Silver (ug/dscm)	2.34	0.640	54.0
(ug/dscm @7% O2)	2.88	2.34	
(g/hr)	0.003	0.001	
Thallium (ug/dscm)	[0.490]	[0.224]	NA
(ug/dscm @7% O2)	[0.603]	[0.819]	
(g/hr)	[0.001]	[0.0005]	

Note: Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples. Detection limits are not included in the averages unless otherwise indicated.

NA = Not applicable

TABLE 2-29. METALS CONCENTRATIONS, EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 4 (BURNDOWN CONDITION)

JORDAN HOSPITAL (1991)

LOCATION	INLET	OUTLET	REMOVAL EFFICIENCY (%)
DATE TIME	03/07/91 16:35-21:57	03/07/91 16:34-22:00	
O2 CONCENTRATION (% V)	10.30	17.5	
FLOW RATE (dscmm)	15.5	32.7	
Antimony (ug/dscm)	96.0	3.21	93.0
(ug/dscm @7% O2)	126	13.1	
(g/hr)	0.089	0.006	
Arsenic (ug/dscm)	1.38	[0.127]	> 80
(ug/dscm @7% O2)	1.81	[0.519]	
(g/hr)	0.001	[0.0002]	
Barium (ug/dscm)	110	1.59	97.0
(ug/dscm @7% O2)	145	6.51	
(g/hr)	0.103	0.003	
Beryllium (ug/dscm)	[0.119]	[0.032]	NA
(ug/dscm @7% O2)	[0.156]	[0.131]	
(g/hr)	[0.0001]	[0.00006]	
Cadmium (ug/dscm)	192	0.990	98.9
(ug/dscm @7% O2)	252	4.05	
(g/hr)	0.179	0.002	
Chromium (ug/dscm)	17.4	1.91	76.9
(ug/dscm @7% O2)	22.9	7.81	
(g/hr)	0.016	0.004	
Lead (ug/dscm)	3834	11.4	99.4
(ug/dscm @7% O2)	5028	46.5	
(g/hr)	3.57	0.022	
Mercury (ug/dscm)	6574	622	80.1
(ug/dscm @7% O2)	8620	2541	
(g/hr)	6.12	1.22	
Nickel (ug/dscm)	8.33	0.821	79.9
(ug/dscm @7% O2)	10.9	3.36	
(g/hr)	0.008	0.002	
Silver (ug/dscm)	[0.713]	[0.190]	NA
(ug/dscm @7% O2)	[0.935]	[0.777]	
(g/hr)	[0.001]	[0.0003]	
Thallium (ug/dscm)	[1.186]	[0.318]	NA
(ug/dscm @7% O2)	[1.555]	[1.300]	
(g/hr)	[0.001]	[0.001]	

Note: Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples. Detection limits are not included in the averages unless otherwise indicated.

NA = Not applicable

TABLE 2-30. METALS CONCENTRATIONS, EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 5 (BURN CONDITION)

JORDAN HOSPITAL (1991)

LOCATION	INLET	OUTLET	REMOVAL EFFICIENCY (%)
DATE TIME	03/09/91 09:25-16:30	03/09/91 09:25-16:30	
O2 CONCENTRATION (%V)	11.2	17.3	
FLOW RATE (dscmm)	17.7	37.8	
Antimony (ug/dscm)	16.0	2.37	68.4
(ug/dscm @7% O2)	23.0	9.15	
(g/hr)	0.017	0.005	
Arsenic (ug/dscm)	[0.557]	[0.084]	NA
(ug/dscm @7% O2)	[0.798]	[0.324]	
(g/hr)	[0.001]	[0.0002]	
Barium (ug/dscm)	3.63	0.776	54.4
(ug/dscm @7% O2)	5.20	3.00	
(g/hr)	0.004	0.002	
Beryllium (ug/dscm)	[0.060]	[0.021]	NA
(ug/dscm @7% O2)	[0.086]	[0.081]	
(g/hr)	[0.0001]	[0.00005]	
Cadmium (ug/dscm)	15.6	0.547	92.5
(ug/dscm @7% O2)	22.3	2.11	
(g/hr)	0.017	0.001	
Chromium (ug/dscm)	13.6	1.22	80.8
(ug/dscm @7% O2)	19.4	4.71	
(g/hr)	0.014	0.003	
Lead (ug/dscm)	742	3.73	98.9
(ug/dscm @7% O2)	1063	14.4	
(g/hr)	0.787	0.008	
Mercury (ug/dscm)	267	15.2	87.8
(ug/dscm @7% O2)	383	58.9	
(g/hr)	0.283	0.035	
Nickel (ug/dscm)	14.7	3.42	50.3
(ug/dscm @7% O2)	21.1	13.2	
(g/hr)	0.016	0.008	
Silver (ug/dscm)	2.28	[0.126]	> 85
(ug/dscm @7% O2)	3.27	[0.487]	
(g/hr)	0.002	[0.0003]	
Thallium (ug/dscm)	[0.602]	[0.211]	NA
(ug/dscm @7% O2)	[0.863]	[0.815]	
(g/hr)	[0.001]	[0.0005]	

Note: Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples. Detection limits are not included in the averages unless otherwise indicated.

NA = Not applicable

TABLE 2-31. METALS CONCENTRATIONS, EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 6 (BURNDOWN CONDITION)  
JORDAN HOSPITAL (1991)

LOCATION	INLET	OUTLET	REMOVAL EFFICIENCY (%)
DATE	03/09/91	03/09/91	
TIME	16:31-21:44	16:44-21:46	
O2 CONCENTRATION (%V)	8.60	17.4	
FLOW RATE (dscmm)	14.8	29.1	
Antimony (ug/dscm)	133	[0.637]	> 99.2
(ug/dscm @7% O2)	150	[2.530]	
(g/hr)	0.118	[0.001]	
Arsenic (ug/dscm)	8.24	[0.170]	> 97.1
(ug/dscm @7% O2)	9.31	[0.675]	
(g/hr)	0.007	[0.0002]	
Barium (ug/dscm)	65.6	2.66	92.0
(ug/dscm @7% O2)	74.1	10.6	
(g/hr)	0.058	0.005	
Beryllium (ug/dscm)	[0.114]	[0.042]	NA
(ug/dscm @7% O2)	[0.129]	[0.167]	
(g/hr)	[0.0001]	[0.00007]	
Cadmium (ug/dscm)	191	1.80	98.1
(ug/dscm @7% O2)	216	7.15	
(g/hr)	0.170	0.003	
Chromium (ug/dscm)	19.4	1.81	81.7
(ug/dscm @7% O2)	21.9	7.20	
(g/hr)	0.017	0.003	
Lead (ug/dscm)	5674	29.1	99.0
(ug/dscm @7% O2)	6412	116	
(g/hr)	5.06	0.051	
Mercury (ug/dscm)	803	122	70.1
(ug/dscm @7% O2)	908	486	
(g/hr)	0.716	0.214	
Nickel (ug/dscm)	16.7	2.33	72.7
(ug/dscm @7% O2)	18.9	9.26	
(g/hr)	0.015	0.004	
Silver (ug/dscm)	6.54	[0.255]	> 93.3
(ug/dscm @7% O2)	7.40	[1.013]	
(g/hr)	0.006	[0.0004]	
Thallium (ug/dscm)	[1.145]	[0.425]	NA
(ug/dscm @7% O2)	[1.294]	[1.688]	
(g/hr)	[0.001]	[0.001]	

Note: Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples. Detection limits are not included in the averages unless otherwise indicated.

NA = Not applicable

TABLE 2-32. RATIO OF METALS TO PARTICULATE MATTER FOR BURN CONDITION  
 JORDAN HOSPITAL (1991)

LOCATION	INLET					OUTLET				
	Run 1	Run 3	Run 5	Average	Run 1	Run 3	Run 5	Average		
Antimony	1.874	1.942	2.447	2.053	NA	1.631	1.795	2.490		
Arsenic	0.090	ND	ND	0.035	ND	ND	ND	ND		
Barium	0.564	2.274	0.555	1.134	NA	0.919	0.588	1.183		
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND		
Cadmium	4.769	2.888	2.378	3.486	NA	0.845	0.415	1.284		
Chromium	1.519	1.588	2.072	1.693	NA	1.293	0.925	2.038		
Lead	77.899	80.283	113.307	88.369	NA	5.223	2.830	5.069		
Mercury	57.228	362.366	40.791	154.948	NA	238.178	11.554	152.216		
Nickel	0.263	0.383	2.247	0.845	NA	8.760	2.594	5.983		
Silver	ND	0.364	0.349	0.217	NA	0.621	ND	1.632		
Thallium	ND	ND	ND	ND	ND	ND	ND	ND		

a ND = Metal not detected in the flue gas.

b NA = Not applicable, particulate matter was not detected in this sample.

Outlet values range from 0.415 mg Cd per gram of PM during Run 5 to 238 mg Hg per gram of PM during Run 3. There was no measurable amount of PM collected during Run 1 and ratios for that run were not calculated.

Table 2-33 presents a summary of the ratio by weight of metals to PM for the burndown condition. Inlet values range from 0.036 mg As per gram of PM to 174 mg Hg per gram of PM. Lead had the highest ratios for Runs 2 and 6 with 138 and 67 mg per gram of PM, respectively. Values at the outlet range from 0.824 mg Ni per gram of PM to 624 mg Hg per gram of PM. Mercury had the highest ratios for all three runs at the outlet.

A comparison of the metals to PM ratios at the outlet to those at the inlet is given in Table 2-34. The values were calculated by dividing the outlet metal to PM ratio by the inlet metal to PM ratio. A number close to 1 would indicate no relative change in the proportion of metals in the flue gas particulate across the APCD. A number less than 1, or high inlet metal to PM versus low outlet metal to PM, indicates higher removal of the metals in the gas stream than its associated PM. Values greater than 1 indicate less removal of the metals species compared to its associated PM. There can also be other interpretations of the data as well.

There appears to be a distinct difference between the burn and burndown outlet to inlet ratios. The average burn outlet to inlet values are mostly less than 1, whereas the burndown values with the exception of Pb, are all greater than 1. This difference may reflect the higher inlet PM loading during burndown coupled with high removal efficiency of non-metal containing PM.

#### 2.3.6 Flue Gas Metals by Sample Fraction and Flue Gas Sample Parameters

Table 2-35 presents the metals amounts in the inlet flue gas samples by sample fraction for the burn and burndown conditions. The highest proportion of Hg was consistently collected in the nitric acid/hydrogen peroxide impingers (Impingers 1-3). All of the other metals, except Ni in Run 5 and Sb in Run 6, were collected in the highest proportions in the front half (filter, nozzle/probe rinse).

The metals amounts in the outlet flue gas samples are presented in Table 2-36 by sample fraction. As at the inlet, the highest proportion of Hg was consistently collected in the nitric acid/hydrogen peroxide impingers. All of the other metals were collected in

TABLE 2-33. RATIO OF METALS TO PARTICULATE MATTER FOR BURNDOWN CONDITION  
 JORDAN HOSPITAL (1991)

LOCATION	METALS/PARTICULATE RATIO (mg metal per gram of particulate)							
	INLET			OUTLET				
RUN NUMBER	Run 2	Run 4	Run 6	Average	Run 2	Run 4	Run 6	Average
Antimony	1.266	2.536	1.575	1.711	4.401	3.224	ND	1.739
Arsenic	0.064	0.036	0.098	0.075	ND	ND	ND	ND
Barium	0.361	2.916	0.779	1.152	2.662	1.598	1.249	1.587
Beryllium	a	ND	ND	ND	ND	ND	ND	ND
Cadmium	4.023	5.078	2.266	3.364	1.964	0.994	0.845	1.072
Chromium	0.736	0.460	0.230	0.415	1.856	1.916	0.851	1.353
Lead	137.631	101.232	67.418	93.522	41.731	11.426	13.656	17.431
Mercury	17.347	173.570	9.544	48.681	301.964	623.821	57.380	278.264
Nickel	0.273	0.220	0.199	0.223	1.000	0.824	1.094	0.992
Silver	0.053	ND	0.078	0.054	4.569	ND	ND	0.731
Thallium	ND	ND	ND	ND	NA	ND	ND	ND

a ND = Metal not detected in the flue gas.

TABLE 2-34. COMPARISON OF OUTLET TO INLET METALS/PM RATIOS FOR BURN AND BURN DOWN CONDITIONS  
JORDAN HOSPITAL (1991)

METAL	(OUTLET METALS/PM)/(INLET METALS /PM)			(OUTLET METALS/PM)/(INLET METALS /PM)			AVERAGE BURNDOWN	
	RUN 1	RUN 3	RUN 5	AVERAGE BURN	RUN 2	RUN 4		RUN 6
Antimony	NA <sup>a</sup>	0.84	0.73	0.79	3.48	1.27	ND	2.37
Arsenic	NA	b ND	ND	ND	ND	ND	ND	ND
Barium	NA	0.40	1.06	0.73	7.38	0.55	1.60	3.18
Beryllium	NA	ND	ND	ND	ND	ND	ND	ND
Cadmium	NA	0.29	0.17	0.23	0.49	0.20	0.37	0.35
Chromium	NA	0.81	0.45	0.63	2.52	4.16	3.69	3.46
Lead	NA	0.07	0.02	0.05	0.30	0.11	0.20	0.21
Mercury	NA	0.66	0.28	0.47	17.41	3.59	6.01	9.00
Nickel	NA	22.88	1.15	12.02	3.66	3.75	5.50	4.30
Silver	NA	1.70	ND	0.85	86.39	ND	ND	86.39
Thallium	NA	ND	ND	ND	ND	ND	ND	ND

<sup>a</sup> The amount of PM collected during Run 1 was not measurable.

<sup>b</sup> ND = metal not detected in the sample.

TABLE 2-35. METALS AMOUNTS IN INLET FLUE GAS SAMPLES BY SAMPLE FRACTION  
JORDAN HOSPITAL (1991)

BURN									
METAL	RUN 1 (total ug)			RUN 3 (total ug)			RUN 5 (total ug)		
	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6 a	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6
Antimony	19.9	11.7		22.9	5.09		20.6	8.15	
Arsenic	1.51	b [0.438]		[1.000]	[0.440]		[1.000]	[2.000]	
Barium	8.95	0.559		32.4	0.374		5.85	0.667	
Beryllium	[0.250]	[0.110]		[0.250]	[0.110]		[0.250]	[0.108]	
Cadmium	80.0	0.406		41.2	0.418		27.0	0.936	
Chromium	22.2	3.41		21.5	1.38		17.5	6.85	
Lead	1312	1.38		1156	0.876		1330	1.36	
Mercury	11.4	947	6.47	8.48	5208	5.21	[2.450]	478	1.3
Nickel	3.98	0.460		4.88	0.638		7.6	18.8	
Silver	[1.500]	[0.658]		5.25	[0.660]		4.10	[0.645]	
Thallium	[1.250]	[1.100]		[1.250]	[1.100]		[1.250]	[1.080]	
BURNDOWN									
METAL	RUN 2 (total ug)			RUN 4 (total ug)			RUN 6 (total ug)		
	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6
Antimony	48.5	3.67		75.5	14.4		58.5	67.7	
Arsenic	2.63	[0.433]		1.29	[0.445]		6.95	0.892	
Barium	14.4	0.466		103	0.367		61.9	0.534	
Beryllium	[0.250]	[0.108]		[0.250]	[0.111]		[0.250]	[0.109]	
Cadmium	164	1.831		180.0	[0.222]		181	0.556	
Chromium	28.8	1.55		14.0	2.32		17.1	1.36	
Lead	5672	1.15		3588	0.663		5400	1.52	
Mercury	[2.450]	713	2.03	2.50	6148	2.57	9.65	755	[0.650]
Nickel	9.98	1.29		6.90	0.900		15.6	0.338	
Silver	2.18	[0.650]		[1.500]	[0.667]		6.23	[0.654]	
Thallium	[1.250]	[1.080]		[1.250]	[1.110]		[1.250]	[1.090]	

a Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples.

b Impingers 4, 5, 6 analyzed for mercury content only.

TABLE 2-36. METALS AMOUNTS IN OUTLET FLUE GAS SAMPLES BY SAMPLE FRACTION  
JORDAN HOSPITAL (1991)

BURN									
METAL	RUN 1 (total ug)			RUN 3 (total ug)			RUN 5 (total ug)		
	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6 a	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6
Antimony	8.75	b [1.580]		7.88	[1.570]		11.9	[1.590]	
Arsenic	[1.000]	[0.420]		[1.000]	[0.420]		[1.000]	[0.423]	
Barium	4.70	0.515		4.08	0.357		3.9	[0.106]	
Beryllium	[0.250]	[0.105]		[0.250]	[0.105]		[0.250]	[0.106]	
Cadmium	3.93	3.952		4.08	[0.210]		2.75	[0.211]	
Chromium	10.1	0.883		5.45	0.797		6.13	[0.634]	
Lead	13.0	1.11		24.6	0.626		18.2	0.560	
Mercury	3.70	465	48.7	3.10	1061	86.3	[2.450]	57.8	18.8
Nickel	8.38	0.673		38.0	4.31		17.2	[0.317]	
Silver	15.7	[.631]		3.00	[0.630]		[1.500]	[0.634]	
Thallium	[1.250]	[1.050]		[1.250]	[1.050]		[1.250]	[1.060]	
BURNDOWN									
METAL	RUN 2 (total ug)			RUN 4 (total ug)			RUN 6 (total ug)		
	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6	FRONT HALF	IMPINGERS 1,2,3	IMPINGER 4,5,6
Antimony	7.35	[1.580]		10.8	[1.600]		[3.750]	[1.620]	
Arsenic	[1.000]	[0.422]		[1.000]	[0.426]		[1.000]	[0.433]	
Barium	4.15	0.295		5.15	0.203		6.48	0.292	
Beryllium	[0.250]	[0.105]		[0.250]	[0.107]		[0.250]	[0.108]	
Cadmium	3.28	[0.211]		3.33	[0.213]		4.58	[0.216]	
Chromium	2.00	1.10		4.78	1.64		3.55	1.06	
Lead	68.5	1.19		37.5	0.777		73.3	0.717	
Mercury	[2.450]	499	5.28	[2.450]	2061	28.8	[2.450]	298	13.0
Nickel	[0.750]	1.67		2.43	0.331		5.93	[0.325]	
Silver	7.63	[0.632]		[1.500]	[0.640]		[1.500]	[0.649]	
Thallium	[1.250]	[1.050]		[1.250]	[1.070]		[1.250]	[1.080]	

a Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples.

b Impingers 4, 5, 6 analyzed for mercury content only.

the highest proportions in the front half fraction, except for Cd in Run 1 (3.95  $\mu\text{g}$  in the back half versus 3.93  $\mu\text{g}$  in the front half). Laboratory analytical results for each sample fraction are presented in detail in Appendix E.2.

Sampling and flue gas parameters for the PM/metals runs at the inlet are shown in Table 2-37, and Table 2-38 presents the parameters for the runs at the outlet. Total sampling times, sample volumes, and isokinetic results for each sampling run are presented. Three out of the twelve metals runs did not meet the isokinetic criterion of being within 10 percent of 100 percent. This is further discussed in Section 6. Appendix C.2 contains a complete listing of these and additional sampling and flue gas parameters for each run. The field data sheets are contained in Appendix A.2.

### 2.3.7 Metals in Ash and Absorber Water

A sample of the incinerator bottom ash was collected the following afternoon after each test day. The test day 1 sample includes flue gas Runs 1 and 2, test day 2 includes Runs 3 and 4, and test day 3 includes Runs 5 and 6. Each sample represented the ash generated for both the burn and burndown conditions. The metals of interest were the same as those sampled for in the flue gas. Concentrations of the metals in the ash in units of mg/kg were determined by extracting the metals from 1 gram of ash in 100 ml of extraction fluid. The analyses were then completed as discussed in Section 5.

The metals in ash results are shown in Table 2-39. Chromium was the most prevalent metal in the ash from Day 1 with 1,087 mg/kg. Later days showed Cr values much lower at 394 and 573 mg/kg for Day 2 and 3, respectively. Barium showed the highest concentration of metals in the ash from Days 2 and 3, with 5,694 and 5,394 mg/kg, respectively. Silver was detected in the pretest ash sample, but not in the run samples. Thallium and Hg were not detected in any of the ash samples. Analytical results of the ash analyses are contained in Appendix E.2.

Table 2-40 shows the mass of each metal removed from the incinerator in the ash stream.

Table 2-41 presents the metals concentrations in the absorber water. Water solids concentrations is also included.

TABLE 2-37. METALS/PM EMISSIONS SAMPLING AND FLUE GAS  
PARAMETERS AT INLET; JORDAN HOSPITAL (1991)

RUN NUMBER DATE	BURN CONDITION			AVERAGE
	Run 1 03/05/91	Run 3 03/07/91	Run 5 03/09/91	
Total Sampling Time (min.)	375	403	418	NA
Average Sampling Rate (dscfm)	0.20	0.20	0.15	0.18
Metered Volume (dscf)	74.21	79.22	63.4	72.28
Metered Volume (dscm)	2.102	2.244	1.795	2.047
Average Stack Temperature (F)	1171	1195	1183	1183
O2 Concentration (%V)	8.8	9.6	11.2	9.9
CO2 Concentration (%V)	7.5	5.9	5.1	6.2
Stack Gas Moisture (%V)	9.0	10.8	9.6	9.8
Volumetric Flow Rate (dscfm)	910	733	625	756
Volumetric Flow Rate (dscmm)	25.77	20.75	17.69	21.40
Percent Isokinetic	90.9	111	101	NA
RUN NUMBER DATE	BURNDOWN CONDITION			AVERAGE
	Run 2 03/05/91	Run 4 03/07/91	Run 6 03/09/91	
Total Sampling Time (min.)	250	311	305	NA
Average Sampling Rate (dscfm)	0.18	0.11	0.11	0.13
Metered Volume (dscf)	44.74	33.07	33.63	37.15
Metered Volume (dscm)	1.267	0.936	0.952	1.052
Average Stack Temperature (F)	1108	1130	1228	1155
O2 Concentration (%V)	8.9	10.3	8.6	9.3
CO2 Concentration (%V)	8.9	6.3	7.7	7.6
Stack Gas Moisture (%V)	8.0	10.2	6.5	8.3
Volumetric Flow Rate (dscfm)	756	548	524	609
Volumetric Flow Rate (dscmm)	21.40	15.52	14.85	17.26
Percent Isokinetic	99.0	81.1	87.1	NA

NA = Not applicable.

TABLE 2-38. METALS/PM EMISSIONS SAMPLING AND FLUE GAS  
PARAMETERS AT OUTLET; JORDAN HOSPITAL (1991)

RUN NUMBER DATE	BURN CONDITION			
	Run 1 03/05/91	Run 3 03/07/91	Run 5 03/09/91	AVERAGE
Total Sampling Time (min.)	415	404	419	NA
Average Sampling Rate (dscfm)	0.43	0.41	0.42	0.42
Metered Volume (dscf)	176.47	165.54	177.41	173.14
Metered Volume (dscm)	4.998	4.688	5.024	4.903
Average Stack Temperature (F)	181	192	176	183
O2 Concentration (%V)	17.6	17.1	17.3	17.3
CO2 Concentration (%V)	1.8	2.2	2.2	2.1
Stack Gas Moisture (%V)	15.8	16.2	13.2	15.0
Volumetric Flow Rate (dscfm)	1368	1232	1333	1311
Volumetric Flow Rate (dscmm)	38.74	34.90	37.75	37.13
Percent Isokinetic	96.4	103	100	NA
RUN NUMBER DATE	BURNDOWN CONDITION			
	Run 2 03/05/91	Run 4 03/07/91	Run 6 03/09/91	AVERAGE
Total Sampling Time (min.)	321	305	295	NA
Average Sampling Rate (dscfm)	0.47	0.39	0.3	0.39
Metered Volume (dscf)	152.22	118.72	89.84	120.26
Metered Volume (dscm)	1.311	3.362	2.544	2.406
Average Stack Temperature (F)	187	193	180	186
O2 Concentration (%V)	17.8	17.5	17.4	17.6
CO2 Concentration (%V)	1.9	2.1	2.4	2.1
Stack Gas Moisture (%V)	13.92	14.65	11.95	13.5
Volumetric Flow Rate (dscfm)	1434	1153	1028	1205
Volumetric Flow Rate (dscmm)	40.60	32.66	29.12	34.13
Percent Isokinetic	103	105	93.3	NA

NA = Not applicable

TABLE 2-39. METALS IN ASH CONCENTRATIONS;  
JORDAN HOSPITAL (1991)

Sample	Pretest Ash (mg/kg)	Day 1 (mg/kg)	Day 2 (mg/kg)	Day 3 (mg/kg)	Average Days 1,2,3 (mg/kg)
Antimony	638	290	660	604	518
Arsenic	10.8	[4.46]	5.37	[4.00]	5.37
Barium	927	416	5694	5394	3835
Beryllium	0.37	1.14	2.46	2.76	2.12
Cadmium	11.9	64.8	39.4	35	46.4
Chromium	123	1087	394	573	685
Lead	867	678	1093	931	901
Mercury	[9.80]	[9.80]	[9.80]	[9.80]	[9.80]
Nickel	29.7	96	53.4	111	86.8
Silver	2.28	[1.20]	[1.20]	[1.20]	[1.20]
Thallium	[1.50]	[1.50]	[1.50]	[1.50]	[1.50]

NOTES:

-Values enclosed in brackets represent minimum detection limits  
for samples not detected in the samples.

-Day 1 = Runs 1,2; Day 2 = Runs 3,4; Day 3 = Runs 5,6.

TABLE 2-40. METALS DAILY DISCHARGE RATES IN THE ASH STREAM;  
JORDAN HOSPITAL (1991)

Sample	Day 1 (grams/day)	Day 2 (grams/day)	Day 3 (grams/day)	AVERAGE (grams/day)
Antimony	9.25	28.40	16.53	18.06
Arsenic	[0.14]	0.23	[0.11]	0.23
Barium	13.27	245.02	147.66	135.32
Beryllium	0.04	0.11	0.08	0.07
Cadmium	2.07	1.70	0.96	1.57
Chromium	34.68	16.95	15.69	22.44
Lead	21.63	47.03	25.49	31.38
Mercury	[0.313]	[0.422]	[0.268]	[0.334]
Nickel	3.06	2.30	3.04	2.80
Silver	[0.038]	[0.052]	[0.033]	[0.041]
Thallium	[0.048]	[0.065]	[0.041]	[0.051]
LBS ASH	70.34	94.87	60.35	75.20

Note: Values enclosed in brackets represent the minimum detection limits  
for compounds not detected in samples.

NA = Not applicable

TABLE 2.41. METALS AND SOLIDS IN ABSORBER MAKE-UP AND DISCHARGE WATER;  
JORDAN HOSPITAL (1991)

Sample Test Day Date	Make-up Water			Discharge Water				
	Pre-test 03/03/91 (ug/l) a	Day 1 03/05/91 (ug/l)	Day 2 03/07/91 (ug/l)	Day 3 03/09/91 (ug/l)	Pre-test 03/03/91 (ug/l)	Day 1 03/05/91 (ug/l)	Day 2 03/07/91 (ug/l)	Day 3 03/09/91 (ug/l)
Antimony	[7.50] b	[7.50]	[7.50]	[7.50]	[7.50]	[7.50]	[7.50]	[7.50]
Arsenic	[2.00]	[2.00]	[2.00]	[2.00]	[2.00]	[2.00]	[2.00]	[2.00]
Barium	1.75	1.95	2.00	3.05	5.20	5.30	3.70	3.25
Beryllium	[0.50]	[0.50]	[0.50]	[0.50]	[0.50]	[0.50]	[0.50]	[0.50]
Cadmium	[12.0]	[12.0]	[12.0]	[12.0]	[12.0]	18.4	[12.0]	[12.0]
Chromium	[3.00]	[3.00]	[3.00]	[3.00]	[3.00]	3.80	3.50	[3.00]
Lead	[1.50]	2.62	[1.50]	5.40	36.3	86.5	59.0	15.4
Mercury	[1.96]	[1.96]	[1.96]	[1.96]	251	636	286	65.8
Nickel	[1.50]	[1.50]	[1.50]	[1.50]	[1.50]	[1.50]	3.20	[1.50]
Silver	[3.00]	[3.00]	[3.00]	[3.00]	[3.00]	[3.00]	[3.00]	[3.00]
Thallium	[2.50]	[2.50]	[2.50]	[2.50]	[2.50]	[2.50]	[2.50]	[2.50]
Solids (mg/l)	ND c	ND	49.0	29.0	ND	1656	459	36.0

a Concentrations are in ug of metal per liter of water

b Values enclosed in brackets represent minimum detection limits for metals not detected in the samples

c ND = non detects

## 2.4 PARTICULATE MATTER/VISIBLE EMISSIONS

### 2.4.1 Particulate Matter Results

Particulate matter emissions were determined from the same sampling train as used for metals determinations. Before metals analysis, PM collected on the filter and in the front half acetone rinse (probe, nozzle, filter holder) was analyzed gravimetrically as discussed in Section 5.

The average PM stack gas concentrations and mass rates for the inlet runs and outlet runs, for both the burn and burndown conditions, are presented in Table 2-42. Uncorrected concentrations and concentrations adjusted to 7 percent O<sub>2</sub> are shown. Removal efficiencies, based on the mass rates at the inlet and outlet, for both test conditions, are also shown. The average concentration and average mass rate at the inlet were higher for the burndown condition than for the burn condition (0.052 g/dscm and 0.051 kg/hr versus 0.007 g/dscm and 0.0091 kg/hr). The average concentration and emission rate at the outlet did not vary as much for the two test conditions (0.0012 g/dscm and 0.0022 kg/hr for burndown condition, 0.00078 g/dscm and 0.0017 kg/hr for burn condition). The removal efficiency for the burndown condition was 95.7 percent compared to a removal efficiency of 64.8 percent for the burn condition.

Particulate matter concentrations, emission rates, and removal efficiencies for the individual runs during the burn condition are summarized in Table 2-43. There was no measurable amount of PM collected at the outlet during Run 1. Run 5 showed the highest PM concentration and emission rate at the outlet with 0.0013 g/dscm and 0.0030 kg/hr, respectively. Removal efficiencies ranged from 56.9 percent for Run 5 to 72.7 percent for Run 3.

Table 2-44 shows the PM concentrations, emission rates, and removal efficiencies for the runs during the burn condition. Run 2 has the lowest concentration and emission rate at the outlet with 0.00039 g/dscm and 0.0009 kg/hr, respectively. Run 6 outlet had the highest concentration and emission rate at 0.0021 g/dscm and 0.0037 kg/hr, respectively.

A brief summary of the sampling and flue gas parameters for the PM runs was given in Tables 2-37 and 2-38. Appendix C.2 presents a detailed listing of the

TABLE 2-42. AVERAGE PARTICULATE MATTER CONCENTRATIONS,  
EMISSION RATES AND REMOVAL EFFICIENCIES;  
JORDAN HOSPITAL (1991)

TEST CONDITIONS	BURN		BURNDOWN	
	INLET AVERAGE	OUTLET AVERAGE	INLET AVERAGE	OUTLET AVERAGE
CONCENTRATIONS		REMOVAL EFF. (%) <sup>a</sup>		REMOVAL EFF. (%)
grains/dscf	0.0031	0.00034	0.023	0.00051
grains/dscf @ 7% O <sub>2</sub>	0.0039	0.0013	0.027	0.0021
grams/dscm	0.0070	0.00078	0.052	0.0012
grams/dscm @ 7% O <sub>2</sub>	0.0088	0.0030	0.061	0.0048
EMISSION RATES				
(lb/hr)	0.020	0.0038	0.112	0.0049
(kg/hr)	0.0091	0.0017	0.051	0.0022
		64.8		95.7

<sup>a</sup> = Average removal efficiency calculated from individual test run values,  
which are based on PM emissions rates (see Tables 2-43 & 2-44)

TABLE 2-43. PARTICULATE MATTER CONCENTRATIONS AND EMISSIONS FOR BURN CONDITION;  
JORDAN HOSPITAL (1991)

DATE	LOCATION	RUN NUMBER	TIME	FLUE GAS CONCENTRATION			FLUE GAS EMISSION RATE		REMOVAL EFFICIENCY (%)	
				(grains/dscf) @ 7% O <sub>2</sub>	(grains/dscf) @ 7% O <sub>2</sub>	(grams/dscm) @ 7% O <sub>2</sub>	(lb/hr)	(kg/hr)		
03/05/91	INLET	1	09:50-16:49	0.0035	0.0040	0.0080	0.0092	0.027	0.012	
03/07/91	INLET	3	09:32-16:30	0.0028	0.0035	0.0064	0.0079	0.018	0.0080	
03/09/91	INLET	5	09:25-16:30	0.0029	0.0041	0.0065	0.0094	0.015	0.0069	
			AVERAGES	0.0031	0.0039	0.0070	0.0088	0.020	0.0091	
03/05/91	OUTLET	1	09:47-16:49	NA	NA	NA	NA	NA	NA	NA
03/07/91	OUTLET	3	09:32-16:30	0.00045	0.0016	0.0010	0.0038	0.0048	0.0022	72.7
03/09/91	OUTLET	5	09:25-16:30	0.00058	0.0022	0.0013	0.0051	0.0066	0.0030	56.9
			AVERAGES	0.00052	0.0019	0.0012	0.0044	0.0057	0.0026	64.8

NA = Not applicable, particulate matter was not detected in this sample.

a = Removal efficiency is based on inlet and outlet emission rates.  $\{(1 - \text{out}/\text{in}) * 100\}$

TABLE 2-44. PARTICULATE MATTER CONCENTRATIONS AND EMISSIONS FOR BURNDOWN CONDITION;  
JORDAN HOSPITAL (1991)

DATE	LOCATION	RUN NUMBER	TIME	FLUE GAS CONCENTRATION			FLUE GAS EMISSION RATE		REMOVAL EFFICIENCY (%)	
				(grains/dscf @ 7% O <sub>2</sub> )	(grains/dscf @ 7% O <sub>2</sub> )	(grams/dscm @ 7% O <sub>2</sub> )	(lb/hr)	(kg/hr)		
03/05/91	INLET	2	17:35-22:10	0.014	0.016	0.033	0.038	0.092	0.042	
03/07/91	INLET	4	16:35-21:57	0.017	0.022	0.038	0.050	0.078	0.035	
03/09/91	INLET	6	16:31-21:44	0.037	0.042	0.084	0.095	0.165	0.075	
			AVERAGES	0.023	0.027	0.052	0.061	0.112	0.051	
03/05/91	OUTLET	2	16:49-22:13	0.00017	0.00076	0.00039	0.0017	0.0021	0.00090	97.7
03/07/91	OUTLET	4	16:34-22:00	0.00044	0.0018	0.0010	0.0041	0.0043	0.0020	94.5
03/09/91	OUTLET	6	16:44-21:46	0.00093	0.0037	0.0021	0.0085	0.0082	0.0037	95.0
			AVERAGES	0.00051	0.0021	0.0012	0.0048	0.0049	0.0022	95.7

\* = Removal efficiency is based on inlet and outlet emission rates.  $\{(1 - \text{out}/\text{in}) * 100\}$

parameters for each sampling run. Appendix E.2 shows the gravimetric PM analytical results.

#### 2.4.2 Visible Emissions

The opacity of emissions from the stack were determined visually by a qualified observer following EPA Method 9 protocol. Sets of observations were recorded typically for 1 hour durations, separated by 10 to 15 minute intervals for observer breaks. Data was recorded for 6 hours on Day 1, 5 hours on Day 2, and 6 hours on Day 3. Observations were curtailed each day at approximately 1700 hours due to darkness and were therefore only taken during a partial period of the burndown test duration.

Observations were recorded at 15-second intervals to the nearest 5 percent opacity. Rolling 6 minute averages of the 15-second field observations were calculated by taking the average of each 15-second observation and the 23 previous readings. Table 2-45 presents a summary of the highest 15-second observation and highest 6 minute average for each observation set. The highest 6 minute average recorded on Day 1 and Day 2 was 1 percent, while the Day 3 high was 4 percent.

### 2.5 HALOGEN GAS EMISSIONS

Hydrogen chloride, HF, and HBr gas concentrations were manually sampled at the inlet and at the stack, following EPA Method 26 procedures. In this method, flue gas was extracted from the sample location and passed through acidified water. The HCl solubilizes and forms chloride (Cl<sup>-</sup>) ions in acidified water. Ion chromatography was used to detect the Cl<sup>-</sup>, bromide (Br<sup>-</sup>), and fluoride (F<sup>-</sup>) ions present in the sample. Testing was conducted on three test days at the operating conditions described previously.

#### 2.5.1 Halogen Gas Emissions Results

Table 2-46 presents a summary of HCl inlet and outlet concentrations and emission rates and presents the HCl removal efficiency for the absorber system. Twenty runs were completed, 12 runs during the burn cycle and 8 runs during the burndown cycle. The removal efficiency for Run 1B could not be calculated because the inlet and outlet sampling was not conducted at the same time. One sample for Run 5B was recovered improperly and, therefore, a HCl removal efficiency could not be calculated. The HCl removal efficiencies ranged from 45.9 percent to 97.5 percent.

TABLE 2-45. PERCENT OPACITY OBSERVATIONS SUMMARY;  
JORDAN HOSPITAL (1991)

Test Day	Observation Set	Time	Condition <sup>a</sup>	Highest 15 second Observation (% Opacity)	Highest 6 minute Average (% Opacity)
Day 1 (03/05/91)	M9-01	0942-1042	Burn	0	0
	M9-02	1056-1156	Burn	0	0
	M9-03	1214-1314	Burn	0	0
	M9-04	1354-1438	Burn	0	0
	M9-05	1448-1548	Burn	5	1
	M9-06	1600-1700	Burn	5	1
	M9-07	1705-1720	Burndown	5	1
Day 2 (03/07/91)	M9-08	0931-1008	Burn	0	0
	M9-09	1056-1156	Burn	5	1
	M9-10	1211-1311	Burn	5	1
	M9-11	1348-1448	Burn	0	0
	M9-12	1453-1603	Burn	0	0
	M9-13	1614-1714	Burndown	5	1
Day 3 (03/09/91)	M9-14	0920-1020	Burn	10	2
	M9-15	1031-1131	Burn	10	3
	M9-16	1207-1307	Burn	10	3
	M9-17	1318-1418	Burn	10	4
	M9-18	1444-1544	Burn	10	3
	M9-20	1603-1703	Burndown	10	3

<sup>a</sup> Opacity readings could only be taken during the first part of the burndown condition due to darkness.

Table 2-46. HYDROGEN CHLORIDE REMOVAL EFFICIENCY;  
JORDAN HOSPITAL (1991)

HCl RUN NO.	DATE	CONDITION	INLET			OUTLET			REMOVAL EFFICIENCY (%)
			SAMPLING TIME	GAS CONC. (ppmv)	EMISSION RATE (lb/hr)	SAMPLING TIME	GAS CONC. (ppmv)	EMISSION RATE (lb/hr)	
1	3/5/91	BURN	09:56-11:26	39.9	0.184	09:45-11:15	2.717	0.020	89.0
1B	3/5/91	BURN	12:43-13:43	43.4	0.200	11:25-12:55	3.425	0.026	NA
1C	3/5/91	BURN	14:21-15:51	122.6	0.566	14:21-15:51	3.798	0.028	95.0
1D	3/5/91	BURN	16:20-16:49	99.6	0.428	16:20-16:49	5.724	0.049	88.5
AVG				76.3	0.345		3.916	0.031	90.8
2A	3/5/91	BURNDOWN	17:45-19:55	403.0	1.731	17:45-19:55	31.540	0.270	84.4
2B	3/5/91	BURNDOWN	19:23-20:53	30.8	0.132	19:24-20:54	5.238	0.045	66.0
AVG				216.9	0.932		18.389	0.158	75.2
3A	3/7/91	BURN	09:31-11:01	18.3	0.073	09:32-11:02	2.531	0.020	72.4
3B	3/7/91	BURN	11:12-12:42	50.4	0.200	11:13-12:43	4.064	0.032	83.9
3C	3/7/91	BURN	12:53-14:23	155.8	0.618	12:58-14:28	14.323	0.114	81.6
3D	3/7/91	BURN	14:35-16:05	117.5	0.466	14:35-16:05	6.416	0.051	89.1
AVG				85.5	0.339		6.833	0.054	81.8
4A	3/7/91	BURNDOWN	16:59-18:29	216.0	0.743	17:00-18:30	26.642	0.193	74.0
4B	3/7/91	BURNDOWN	18:42-20:12	198.4	0.682	18:42-20:12	32.653	0.237	65.3
4C	3/7/91	BURNDOWN	20:20-21:57	178.0	0.612	20:20-21:50	25.380	0.184	69.9
AVG				197.5	0.679		28.225	0.205	69.7
5A	3/9/91	BURN	09:43-11:13	21.0	0.079	09:37-11:07	5.591	0.043	45.9
5B	3/9/91	BURN	11:33-13:03	9.4	0.036	11:33-13:03	NC	NC	NC
5C	3/9/91	BURN	13:19-14:49	92.9	0.352	13:19-14:49	3.204	0.029	91.7
5D	3/9/91	BURN	15:08-16:28	133.8	0.507	15:08-16:32	4.092	0.031	93.8
AVG				64.3	0.243		4.296	0.033	82.6
6A	3/9/91	BURNDOWN	17:03-18:33	272.1	0.818	17:08-18:38	9.998	0.060	92.6
6B	3/9/91	BURNDOWN	18:48-20:18	262.3	0.789	18:48-20:18	6.894	0.042	94.7
6C	3/9/91	BURNDOWN	20:26-21:44	378.9	1.140	20:26-21:46	4.726	0.029	97.5
AVG				304.4	0.916		7.206	0.044	94.9

NA = NOT APPLICABLE (Tests were not conducted at the same time)

NC = Sample was not recovered properly.

NOTE: An average of the flow rates determined by the PM/ Metals and CDD/CDF sampling trains was used for HCl emission rate calculations. Efficiencies calculated using emission rates as follows;  $(1 - \text{In/Out}) * 100$

Table 2-47 provides a summary of the HCl results at the inlet. Concentrations are reported in mg/dscm and parts per million by volume/dry (ppmv), both at measured conditions and corrected to a 7 percent O<sub>2</sub> basis.

Average values for the burn periods were similar, ranging from 87 to 158 ppmv at 7 percent O<sub>2</sub>. Likewise, average HCl values for the burndown periods were similar, ranging from 236 to 367 ppmv at 7 percent O<sub>2</sub>.

Table 2-48 shows the HCl results at the outlet (stack) for the same test periods shown in the previous table. The average HCl during a test period at the outlet varied from a low of 12 ppmv at 7 percent O<sub>2</sub> during a burn period to 111 ppmv at 7 percent O<sub>2</sub> during a burndown period.

Data from Tables 2-47 and 2-48 were used to generate the HCl removal efficiencies in Table 2-46.

Table 2-49 summarizes the HF results at the inlet. Measurable quantities of HF were found in only 1 out of 20 runs (Run 14 during Day 3 burndown period). A concentration of approximately 3 ppmv at 7 percent O<sub>2</sub> was calculated for this run. All other values shown in brackets represent minimum detection limits for HF.

Table 2-50 presents the HF results at the outlet. As shown, no measurable quantities of HF were found in any of the test runs. All the values shown in the brackets represent minimum detection limits.

Table 2-51 provides the HBr results at the inlet for all runs conducted at the Jordan Hospital MWI. Measurable quantities of HBr were found in only 1 out of 20 test runs. A concentration of 0.05 ppmv at 7 percent O<sub>2</sub> was detected for Run 9 (during the burn period on Day 2). The calculated values for this run are shown in parenthesis to signify that these values are less than five times the detection limit in the analytical laboratory.

A summary of the HBr results is presented in Table 2-52. Very small amounts were detected in 2 out of 20 runs (Run 8 and Run 9 during the burn period on Day 2). Even though these values are above five times the detection limit, they are under 1 ppmv at 7 percent O<sub>2</sub> and are, therefore, insignificant. All other values shown in brackets represent detection limits.

TABLE 2-47. SUMMARY OF HCI RESULTS AT THE INLET;  
JORDAN HOSPITAL (1991)

HCI TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATES	
	(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	(g/hr)	(lb/hr)
1A	60.5	65.2	39.9	43.0	83.5	0.184
1B	65.7	75.5	43.4	49.8	90.8	0.200
1C	185.9	228.6	122.6	150.8	256.7	0.566
1D	150.9	189.0	99.6	124.7	194.0	0.428
<b>AVERAGE</b>	<b>115.7</b>	<b>139.6</b>	<b>76.3</b>	<b>92.1</b>	<b>156.3</b>	<b>0.345</b>
2A	610.9	653.2	403.0	430.9	785.4	1.731
2B	46.6	61.1	30.8	40.3	59.9	0.132
<b>AVERAGE</b>	<b>328.8</b>	<b>357.2</b>	<b>216.9</b>	<b>235.6</b>	<b>422.7</b>	<b>0.932</b>
3A	27.8	32.5	18.3	21.4	33.0	0.073
3B	76.5	90.1	50.4	59.4	90.8	0.200
3C	236.2	285.6	155.8	188.4	280.4	0.618
3D	178.2	223.1	117.5	147.2	211.4	0.466
<b>AVERAGE</b>	<b>194.4</b>	<b>238.9</b>	<b>128.2</b>	<b>157.6</b>	<b>230.7</b>	<b>0.509</b>
4A	327.6	367.2	216.1	242.2	336.8	0.743
4B	300.8	394.5	198.4	260.2	309.4	0.682
4C	269.8	364.1	178.0	240.2	277.5	0.612
<b>AVERAGE</b>	<b>299.4</b>	<b>375.3</b>	<b>197.5</b>	<b>247.5</b>	<b>307.9</b>	<b>0.679</b>
5A	31.81	68.025	20.982	44.870	36.054	0.0795
5B	14.2	18.5	9.4	12.2	16.1	0.036
5C	140.9	179.6	92.9	118.5	159.7	0.352
5D	202.9	261.1	133.8	172.3	230.0	0.507
<b>AVERAGE</b>	<b>97.3</b>	<b>131.5</b>	<b>64.2</b>	<b>86.7</b>	<b>110.3</b>	<b>0.243</b>
6A	412.5	374.7	272.1	247.2	371.2	0.818
6B	397.7	536.7	262.3	354.0	357.9	0.789
6C	574.5	760.5	378.9	501.7	517.1	1.140
<b>AVERAGE</b>	<b>461.5</b>	<b>557.3</b>	<b>304.4</b>	<b>367.6</b>	<b>415.4</b>	<b>0.916</b>

TABLE 2-48. SUMMARY OF HCl RESULTS AT THE OUTLET (STACK);  
JORDAN HOSPITAL (1991)

HCl TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATES	
	(mg/dscm)	(mg/dscm @7% O <sub>2</sub> )	(ppmv)	(ppmv @7% O <sub>2</sub> )	(g/hr)	(lb/hr)
1A	4.12	15.47	2.72	10.21	9.19	0.020
1B	5.19	20.62	3.43	13.60	11.58	0.026
1C	5.76	26.68	3.80	17.60	12.84	0.028
1D	8.68	38.91	5.72	25.66	22.25	0.049
<b>AVERAGE</b>	<b>5.94</b>	<b>25.42</b>	<b>3.92</b>	<b>16.77</b>	<b>13.96</b>	<b>0.031</b>
2A	47.82	207.70	31.54	137.00	122.59	0.270
2B	7.94	38.07	5.24	25.11	20.36	0.045
<b>AVERAGE</b>	<b>27.88</b>	<b>122.88</b>	<b>18.39</b>	<b>81.05</b>	<b>71.48</b>	<b>0.158</b>
3A	3.84	12.12	2.53	7.99	9.10	0.020
3B	6.16	21.96	4.06	14.49	14.61	0.032
3C	21.71	86.24	14.32	56.88	51.48	0.114
3D	9.73	38.63	6.42	25.48	23.06	0.051
<b>AVERAGE</b>	<b>10.36</b>	<b>39.74</b>	<b>6.83</b>	<b>26.21</b>	<b>24.56</b>	<b>0.054</b>
4A	40.39	160.41	26.64	105.81	87.61	0.193
4B	49.50	208.52	32.65	137.54	107.38	0.237
4C	38.48	137.14	25.38	90.46	83.46	0.184
<b>AVERAGE</b>	<b>42.79</b>	<b>168.69</b>	<b>28.22</b>	<b>111.27</b>	<b>92.82</b>	<b>0.205</b>
5A	8.48	22.36	5.59	14.75	19.37	0.043
5B	NC	NC	NC	NC	NC	NC
5C	4.86	13.70	3.20	9.03	11.10	0.024
5D	6.20	17.49	4.09	11.54	14.18	0.031
<b>AVERAGE</b>	<b>6.51</b>	<b>17.85</b>	<b>4.30</b>	<b>11.77</b>	<b>14.88</b>	<b>0.033</b>
6A	15.16	39.53	10.00	26.07	27.43	0.060
6B	10.45	26.75	6.89	17.65	18.91	0.042
6C	7.16	18.97	4.73	12.51	12.97	0.029
<b>AVERAGE</b>	<b>10.92</b>	<b>28.42</b>	<b>7.21</b>	<b>18.74</b>	<b>19.77</b>	<b>0.044</b>

NC = Analysis not completed due to improper sample recovery.

TABLE 2-49. SUMMARY OF HF RESULTS AT THE INLET;  
JORDAN HOSPITAL (1991)

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE	
	(mg/dscm)	(mg/dscm @7% O <sub>2</sub> )	(ppmv)	(ppmv @7% O <sub>2</sub> )	(g/hr)	(lb/hr)
1A	[0.4448]	[0.4788]	[0.5348]	[0.5758]	[0.6138]	[0.0018]
1B	[0.6348]	[0.7288]	[0.7628]	[0.8758]	[0.8768]	[0.0028]
1C	[0.4368]	[0.5368]	[0.5248]	[0.6458]	[0.6028]	[0.0018]
AVERAGE	[0.505]	[0.581]	[0.607]	[0.698]	[0.697]	[0.001]
2A	[1.1489]	[1.43 <sup>o</sup> 9]	[1.3809]	[1.7289]	[1.4769]	[0.0039]
2B	[0.4339]	[0.4639]	[0.5219]	[0.5579]	[0.5579]	[0.0019]
2C	[0.4098]	[0.5368]	[0.4928]	[0.6458]	[0.5268]	[0.0018]
AVERAGE	[0.6642]	[0.8132]	[0.7985]	[0.9775]	[0.8539]	[0.0025]
3A	[0.4408]	[0.5148]	[0.5298]	[0.6188]	[0.5228]	[0.0018]
3B	[0.4328]	[0.5098]	[0.5198]	[0.6118]	[0.5138]	[0.0018]
3C	[0.4680]	[0.5660]	[0.5630]	[0.6800]	[0.5550]	[0.0010]
3D	[0.4419]	[0.5529]	[0.5309]	[0.6649]	[0.5239]	[0.0019]
AVERAGE	[0.445]	[0.535]	[0.535]	[0.643]	[0.528]	[0.001]
4A	[0.5119]	[0.5739]	[0.6149]	[0.6889]	[0.5269]	[0.0019]
4B	[0.4520]	[0.5930]	[0.5430]	[0.7120]	[0.4650]	[0.0010]
4C	[0.3990]	[0.5380]	[0.4800]	[0.6480]	[0.4100]	[0.0010]
AVERAGE	[0.454]	[0.568]	[0.546]	[0.683]	[0.467]	[0.001]
5A	1.165	2.491	1.400	2.995	1.320	0.003
5B	[0.4430]	[0.5750]	[0.5330]	[0.6920]	[0.5020]	[0.0010]
5C	[0.4430]	[0.5650]	[0.5330]	[0.6800]	[0.5020]	[0.0010]
5D	[0.4680]	[0.6020]	[0.5630]	[0.7250]	[0.5300]	[0.0010]
AVERAGE	1.165	2.491	1.400	2.995	1.320	0.003
6A	[0.4169]	[0.3789]	[0.5009]	[0.4549]	[0.3749]	[0.0019]
6B	[0.4312]	[0.5822]	[0.5182]	[0.6992]	[0.3882]	[0.0012]
6C	[0.4792]	[0.6342]	[0.5762]	[0.7632]	[0.4312]	[0.0012]
AVERAGE	[0.442]	[0.531]	[0.531]	[0.639]	[0.398]	[0.001]

[ ] = Minimum detection limit.

TABLE 2-50. SUMMARY OF HF RESULTS AT THE OUTLET;  
JORDAN HOSPITAL (1991)

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE	
	(mg/dscm)	(mg/dscm @7% O <sub>2</sub> )	(ppmv)	(ppmv @7% O <sub>2</sub> )	(g/hr)	(lb/hr)
1A	[0.2579]	[0.9659]	[0.3099]	[1.1619]	[0.5739]	[0.0019]
1B	[0.2438]	[0.9658]	[0.2928]	[1.1608]	[0.5428]	[0.0018]
1C	[0.2218]	[1.0248]	[0.2668]	[1.2328]	[0.4938]	[0.0018]
<b>AVERAGE</b>	<b>[0.240]</b>	<b>[0.985]</b>	<b>[0.289]</b>	<b>[1.184]</b>	<b>[0.536]</b>	<b>[0.001]</b>
2A	[0.7188]	[3.2198]	[0.8638]	[3.8708]	[1.8418]	[0.0048]
2B	[0.2216]	[0.9606]	[0.2666]	[1.1556]	[0.5676]	[0.0016]
2C	[0.2216]	[0.9606]	[0.2666]	[1.1556]	[0.5676]	[0.0016]
<b>AVERAGE</b>	<b>[0.3873]</b>	<b>[1.7137]</b>	<b>[0.4657]</b>	<b>[2.0607]</b>	<b>[0.9923]</b>	<b>[0.0027]</b>
3A	[0.2198]	[0.6928]	[0.2638]	[0.8318]	[0.5198]	[0.0018]
3B	[0.2198]	[0.7818]	[0.2638]	[0.9378]	[0.5198]	[0.0018]
3C	[0.2199]	[0.8709]	[0.2639]	[1.0449]	[0.5199]	[0.0019]
3D	[0.2258]	[0.8948]	[0.2708]	[1.0728]	[0.5348]	[0.0018]
<b>AVERAGE</b>	<b>[0.221]</b>	<b>[0.809]</b>	<b>[0.265]</b>	<b>[0.971]</b>	<b>[0.523]</b>	<b>[0.001]</b>
4A	[0.2048]	[0.8108]	[0.2458]	[0.9738]	[0.4428]	[0.0018]
4B	[0.2699]	[1.1339]	[0.3239]	[1.3619]	[0.5839]	[0.0019]
4C	[0.2008]	[0.7138]	[0.2408]	[0.8558]	[0.4348]	[0.0018]
<b>AVERAGE</b>	<b>[0.224]</b>	<b>[0.885]</b>	<b>[0.269]</b>	<b>[1.063]</b>	<b>[0.486]</b>	<b>[0.001]</b>
5A	[0.2401]	[0.6331]	[0.2891]	[0.7621]	[0.5481]	[0.0011]
5B	[0.2138]	[0.5188]	[0.2568]	[0.6228]	[0.4878]	[0.0018]
5C	[0.2188]	[0.6158]	[0.2628]	[0.7398]	[0.4988]	[0.0018]
5D	[0.2391]	[0.6741]	[0.2871]	[0.8091]	[0.5461]	[0.0011]
<b>AVERAGE</b>	<b>[0.228]</b>	<b>[0.610]</b>	<b>[0.274]</b>	<b>[0.733]</b>	<b>[0.520]</b>	<b>[0.001]</b>
6A	[0.2239]	[0.5829]	[0.2689]	[0.6999]	[0.4049]	[0.0019]
6B	[0.2228]	[0.5688]	[0.2678]	[0.6838]	[0.4028]	[0.0018]
6C	[0.2428]	[0.6418]	[0.2918]	[0.7708]	[0.4388]	[0.0018]
<b>AVERAGE</b>	<b>[0.229]</b>	<b>[0.597]</b>	<b>[0.275]</b>	<b>[0.717]</b>	<b>[0.415]</b>	<b>[0.001]</b>

[ ] = Minimum detection limit.

TABLE 2-51. SUMMARY OF HBr RESULTS AT THE INLET;  
JORDAN HOSPITAL (1991)

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE	
	(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	(g/hr)	(lb/hr)
1A	[0.1306]	[0.1406]	[0.0396]	[0.0426]	[0.1806]	[0.0006]
1B	[0.1867]	[0.2147]	[0.0557]	[0.0637]	[0.2577]	[0.0017]
1C	[0.1286]	[0.1576]	[0.0386]	[0.0476]	[0.1776]	[0.0006]
AVERAGE	[0.148]	[0.170]	[0.044]	[0.051]	[0.205]	[0.000]
2A	[0.3367]	[0.4217]	[0.1007]	[0.1257]	[0.4327]	[0.0017]
2B	[0.1277]	[0.1367]	[0.0387]	[0.0417]	[0.1637]	[0.0007]
2C	[0.1207]	[0.1577]	[0.0367]	[0.0477]	[0.1547]	[0.0007]
AVERAGE	[0.1950]	[0.2387]	[0.0587]	[0.0717]	[0.2504]	[0.0010]
3A	[0.1296]	[0.1516]	[0.0386]	[0.0446]	[0.1536]	[0.0006]
3B	[0.1266]	[0.1486]	[0.0376]	[0.0446]	[0.1506]	[0.0006]
3C	(0.1569)	(0.1899)	(0.0469)	(0.0569)	(0.1859)	(0.0009)
3D	[0.1297]	[0.1627]	[0.0387]	[0.0487]	[0.1537]	[0.0007]
AVERAGE	0.156	0.189	0.046	0.056	0.185	0.001
4A	[0.1507]	[0.1687]	[0.0457]	[0.0507]	[0.1547]	[0.0007]
4B	[0.1297]	[0.1697]	[0.0387]	[0.0507]	[0.1337]	[0.0007]
4C	[0.1147]	[0.1547]	[0.0347]	[0.0467]	[0.1177]	[0.0007]
AVERAGE	[0.131]	[0.164]	[0.039]	[0.049]	[0.135]	[0.000]
5A	[0.1257]	[0.2677]	[0.0377]	[0.0797]	[0.1427]	[0.0007]
5B	[0.1277]	[0.1657]	[0.0387]	[0.0497]	[0.1447]	[0.0007]
5C	[0.1267]	[0.1617]	[0.0377]	[0.0477]	[0.1437]	[0.0007]
5D	[0.1346]	[0.1726]	[0.0406]	[0.0516]	[0.1526]	[0.0006]
AVERAGE	[0.128]	[0.191]	[0.038]	[0.057]	[0.145]	[0.000]
6A	[0.1227]	[0.1117]	[0.0367]	[0.0337]	[0.1107]	[0.0007]
6B	[0.1237]	[0.1667]	[0.0377]	[0.0507]	[0.1117]	[0.0007]
6C	[0.1376]	[0.1816]	[0.0416]	[0.0546]	[0.1236]	[0.0006]
AVERAGE	[0.127]	[0.153]	[0.038]	[0.046]	[0.115]	[0.000]

[ ] = Minimum detection limit.

( ) = Estimated maximum possible concentration.

TABLE 2-52. SUMMARY OF HBr RESULTS AT THE OUTLET;  
JORDAN HOSPITAL (1991)

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE	
	(mg/dscm)	(mg/dscm @7% O <sub>2</sub> )	(ppmv)	(ppmv @7% O <sub>2</sub> )	(g/hr)	(lb/hr)
1A	[0.0757]	[0.2827]	[0.0227]	[0.0837]	[0.1677]	[0.0007]
1B	[0.0716]	[0.2826]	[0.0216]	[0.0836]	[0.1586]	[0.0006]
1C	[0.0656]	[0.3016]	[0.0196]	[0.0886]	[0.1456]	[0.0006]
AVERAGE	[0.070]	[0.288]	[0.021]	[0.085]	[0.157]	[0.000]
2A	[0.2106]	[0.9426]	[0.0626]	[0.2786]	[0.5386]	[0.0016]
2B	[0.0656]	[0.2826]	[0.0196]	[0.0836]	[0.1676]	[0.0006]
2C	[0.0656]	[0.3126]	[0.0196]	[0.0916]	[0.1676]	[0.0006]
AVERAGE	[0.1139]	[0.5126]	[0.0339]	[0.1513]	[0.2913]	[0.0009]
3A	[0.0646]	[0.2026]	[0.0196]	[0.0606]	[0.1526]	[0.0006]
3B	0.910	3.244	0.271	0.964	2.158	0.005
3C	1.036	4.114	0.308	1.223	2.457	0.005
3D	[0.0666]	[0.2626]	[0.0206]	[0.0796]	[0.1566]	[0.0006]
AVERAGE	0.973	3.679	0.289	1.094	2.307	0.005
4A	[0.0606]	[0.2386]	[0.0186]	[0.0716]	[0.1306]	[0.0006]
4B	[0.0797]	[0.3337]	[0.0237]	[0.0977]	[0.1717]	[0.0007]
4C	[0.0596]	[0.2106]	[0.0186]	[0.0646]	[0.1286]	[0.0006]
AVERAGE	[0.066]	[0.260]	[0.020]	[0.077]	[0.143]	[0.000]
5A	[0.0697]	[0.1827]	[0.0217]	[0.0557]	[0.1587]	[0.0007]
5B	[0.0626]	[0.1516]	[0.0186]	[0.0446]	[0.1426]	[0.0006]
5C	[0.0646]	[0.1806]	[0.0196]	[0.0546]	[0.1466]	[0.0006]
5D	[0.0687]	[0.1927]	[0.0207]	[0.0567]	[0.1557]	[0.0007]
AVERAGE	[0.066]	[0.176]	[0.020]	[0.052]	[0.150]	[0.000]
6A	[0.0657]	[0.1707]	[0.0197]	[0.0507]	[0.1187]	[0.0007]
6B	[0.0656]	[0.1666]	[0.0196]	[0.0496]	[0.1186]	[0.0006]
6C	[0.0716]	[0.1886]	[0.0216]	[0.0566]	[0.1286]	[0.0006]
AVERAGE	[0.067]	[0.175]	[0.020]	[0.052]	[0.121]	[0.000]

[ ] = Minimum detection limit.

Since no significant quantities of HF and HBr were detected, no removal efficiencies were calculated.

## 2.6 HYDROGEN CHLORIDE CEM RESULTS

Simultaneous flue gas determinations of HCl flue gas concentration was made by both the manual method (EPA Method 26) as well as by a CEM analyzer.

Measurements were made at both the inlet and outlet. The analyzers were TECO Model 15 instruments employing dilution probe extractive techniques.

Because of the dilution probe system, the HCl CEMs had to be calibrated after the incinerator had reached its steady state operating temperature. Post-test calibrations could not be performed after the burndown run because flue gas temperatures would decrease so quickly. However, QC gas challenges were made on the system and are documented in Appendix D.

The inlet results comparison is made in Table 2-53. Averages are presented for the time interval corresponding to the manual test runs. These runs were typically 1 hour to 1½ hours in duration. All of the CEM averages appear to be substantially higher than the manual values.

The outlet HCl CEM flue gas concentrations could not be determined using the HCl CEM analyzer because the concentrations were too low to resolve using the dilution probe extractive system. An undiluted sample stream could not have been used either as HCl gas would have been removed along with the moisture during conditioning procedures.

## 2.7 CEM RESULTS

Continuous emissions monitoring was conducted at the inlet and outlet to the APCD during all three test runs. The CEMs were operated from the beginning of the test run until the morning of the following day. Monitoring was performed using an extractive sample system and instrument methods to measure NO<sub>x</sub>, CO, SO<sub>2</sub>, THC, and HCl concentrations. The diluent gases (O<sub>2</sub>, CO<sub>2</sub>) were measured using CEMs at all times so that the emission results could be normalized to a reference 7 percent O<sub>2</sub>. Concentrations of NO<sub>x</sub>, SO<sub>2</sub>, CO, CO<sub>2</sub>, and O<sub>2</sub> were measured on a dry basis with the sample stream conditioned as shown in Figure 5-16. The THC concentrations were also monitored on a wet basis, by allowing the sample stream to bypass the conditioners. All

TABLE 2-53. COMPARISON OF MANUAL AND CEM HCl RESULTS  
 AT THE INLET SAMPLE LOCATION;  
 JORDAN HOSPITAL (1991)

TEST RUN NUMBER	MANUAL HCl RESULTS		CEM HCl RESULTS	
	(ppmV)	(ppmV @7% O <sub>2</sub> )	(ppmV)	(ppmV @7% O <sub>2</sub> )
1A	39.9	43.0	249.2	266.7
1B	43.4	49.8	350.4	411.0
1C	122.6	150.8	330.2	427.4
1D	99.6	124.7	371.6	485.2
AVERAGE	76.3	92.1	325.4	397.6
2A	403.0	430.9	NC	NC
2B	30.8	40.3	NC	NC
AVERAGE	216.9	235.6	NA	NA
3A	18.3	21.4	NC	NC
3B	50.4	59.4	229.8	269.6
3C	155.8	188.4	215.8	270.8
3D	117.5	147.2	197.1	254.8
AVERAGE	128.2	157.6	214.2	265.1
4A	216.1	242.2	825.1	1174.8
4B	198.4	260.2	252.4	346.6
4C	178.0	240.2	201.5	282.6
AVERAGE	197.5	247.5	426.3	601.3
5A	21.0	44.9	NC	NC
5B	9.4	12.2	272.0	300.9
5C	92.9	118.5	305.3	401.1
5D	133.8	172.3	404.5	544.1
AVERAGE	64.2	86.7	327.3	415.4
6A	272.1	247.2	NC	NC
6B	262.3	354.0	534.9	686.0
6C	378.9	501.7	482.6	665.5
AVERAGE	304.4	367.6	508.7	675.8

NC= Run not completed.

ND = Not Determined.

CEM data were recorded as 30-second averages over each sampling interval, copies of which are included in Appendix D.

Two additional CEM analyzers were used during this program to monitor HCl concentrations at the inlet and outlet to the APCD. These systems used separate gas extractive systems employing dilution probe techniques. The resulting concentrations were calculated on a ppm by volume, wet basis.

The 30-second CEM values were averaged over the sampling interval for each test run. The run averages summarized in Tables 2-54 and 2-55 present actual and corrected values, respectively. Actual concentrations are presented as they were measured ( $\text{NO}_x$ ,  $\text{SO}_2$ ,  $\text{CO}$ ,  $\text{CO}_2$ , and  $\text{O}_2$ -dry; THC and HCl-wet). Each 30-second CEM reading was corrected to 7 percent  $\text{O}_2$  based on the corresponding  $\text{O}_2$  value. Averages of the corrected values were then calculated. For HCl and THC, the corrected values are still on a wet basis. Overall averages are presented for each CEM parameter under each of the six test runs.

Of the two HCl CEM analyzers, only the inlet unit produced valid data. Both systems used a dilution probe extracting system which on the outlet sample location, rendered the HCl concentration too low to be detected by the analyzer. Valid inlet and outlet HCl testing was also performed by the manual EPA reference method 26 with results reported in Section 2.5 and 2.6.

All CEM analyzers were left operative while the unit was cooling down. This period (cool-down) occurred for approximately ~10 hours from 22:00 hours to 09:00 hours the next day. The average CEM gas concentrations for the cooldown periods are shown in Table 2-56. Cooldown CEM data and time plots are shown in Appendices D.5 and D.6. Because stack temperatures were substantially cooler than during the test phase, the HCl CEM data can not be used for calculating accurate emission averages for the cooldown period. This is because the dilution ratio of the HCl dilution probes are proportional to the stack temperature and any deviations from the temperature exhibited during calibration procedures (i.e. burn temperature) would cause inaccuracies in the data.

TABLE 2-54. CONTINUOUS EMISSIONS MONITORING TEST AVERAGES AS MEASURED;  
JORDAN HOSPITAL (1991)

TIME	INLET SO <sub>2</sub> (ppmV/dry)	OUTLET SO <sub>2</sub>	INLET O <sub>2</sub> (ppmV/dry)	OUTLET O <sub>2</sub>	INLET CO <sub>2</sub> (ppmV/dry)	OUTLET CO <sub>2</sub>	INLET NO <sub>x</sub> (ppmV/dry)	OUTLET NO <sub>x</sub>	INLET CO (ppmV/dry)	OUTLET CO	INLET HCl (ppmV/wet) <sup>a</sup>	OUTLET HCl	INLET THC (ppmV/wet)	OUTLET THC
RUN 1 BURN AVG	6.16	0.71	8.80	17.63	7.51	1.78	76.74	7.03	323.00	NA	12.11	0.85		
RUN 2 BURNDOWN AVG	33.29	3.50	8.85	17.77	8.88	1.86	108.85	6.16	266.40	NA	5.58	0.84		
RUN 3 BURN AVG	8.84	0.35	9.56	17.06	5.91	2.20	65.28	8.87	211.02	NA	NA	NA		
RUN 4 BURNDOWN AVG	23.05	1.11	10.32	17.46	6.30	2.11	75.43	0.09	452.24	NA	NA	NA		
RUN 5 BURN AVG	4.60	0.53	11.18	17.26	5.13	2.16	60.41	1.72	422.47	NA	5.94	NA		
RUN 6 BURNDOWN AVG	41.30	5.27	8.61	17.41	7.75	2.38	103.41	53.46	485.98	NA	8.58	NA		

<sup>a</sup> HCl concentrations were determined by manual methods as well. A comparison of CEM vs. manual results is presented in Section 2.6.  
NA = Not available; THC instrument was not operating during that time interval.

The outlet HCl instrument showed poor resolution in the lower concentration ranges.

TABLE 2-55. CONTINUOUS EMISSIONS MONITORING TEST AVERAGES CORRECTED TO 7 PERCENT OXYGEN;  
 JORDAN HOSPITAL (1991)

TIME	INLET SO <sub>2</sub> (ppmV/dry)	OUTLET SO <sub>2</sub>	INLET O <sub>2</sub> (ppm V/dry)	OUTLET O <sub>2</sub>	INLET CO <sub>2</sub> (ppm V/dry)	OUTLET CO <sub>2</sub>	INLET NO <sub>x</sub> (ppm V/dry)	OUTLET NO <sub>x</sub>	INLET CO (ppm V/dr	OUTLET CO	INLET HCl (ppm V/wet) <sup>a</sup>	OUTLET HCl	INLET THC (ppm V/wet)	OUTLET THC
RUN 1 BURN AVG	7.41	3.08	8.80	17.63	NA	NA	89.71	7.79	387.36	NA	16.32	3.71		
RUN 2 BURNDOWN AVG	33.92	14.95	8.85	17.77	NA	NA	120.43	7.23	73.71	NA	6.44	3.83		
RUN 3 BURN AVG	11.23	1.24	9.56	17.06	NA	NA	81.43	7.28	288.54	NA	NA	NA		
RUN 4 BURNDOWN AVG	29.63	4.49	10.32	17.46	NA	NA	97.32	0.27	778.28	NA	NA	NA		
RUN 5 BURN AVG	6.75	2.05	11.18	17.26	NA	NA	86.21	2.19	302.14	NA	8.77	NA		
RUN 6 BURNDOWN AVG	36.33	18.27	8.61	17.41	NA	NA	109.15	36.21	375.73	NA	10.45	NA		

<sup>a</sup> HCl concentrations were determined by manual methods as well. A comparison of CEM vs. manual results is presented in Section 2.6.

NA = Not available; THC instrument was not operating during that time interval.

CO<sub>2</sub> is not presented on a corrected basis.

The outlet HCl instrument showed poor resolution in the lower concentration ranges.

TABLE 2-56. CONTINUOUS EMISSIONS MONITORING AVERAGES FOR THE COOL-DOWN PERIOD;  
JORDAN HOSPITAL (1991)

TIME	INLET SO <sub>2</sub> (ppm V/dry)	OUTLET SO <sub>2</sub> (ppm V/dry)	INLET O <sub>2</sub> (ppm V/dry)	OUTLET O <sub>2</sub> (ppm V/dry)	INLET CO <sub>2</sub> (ppm V/dry)	OUTLET CO <sub>2</sub> (ppm V/dry)	INLET NO <sub>x</sub> (ppm V/dry)	OUTLET NO <sub>x</sub> (ppm V/dry)	INLET CO (ppm V/dry)	OUTLET CO (ppm V/dry)	INLET HCl (ppm V/wet) †	OUTLET HCl (ppm V/wet) †	INLET THC (ppm V/wet)	OUTLET THC (ppm V/wet)
DAY 1 (post Runs 1&2) (3/5-3/6; 22:12-08:32)	35.6	1.5	19.4	20.3	0.9	0.02	21.1		259.2		NA	NA	72.5	0.8
DAY 2 (post Runs 3&4) (3/7-3/8; 21:59-08:14)	21.00	0.40	20.00	20.40	0.60	0.20	6.90		165.00		NA	NA	NA	NA
DAY 3 (post Runs 5&6) (3/9-3/10; 21:45-08:00)	9.50	1.20	20.60	20.70	0.40	0.20	6.90		172.60		NA	NA	40.90	NA

All cool-down CEM data and plots are shown in Appendix D.

NA = Not available; THC instrument was not operating during that time interval.

Both HCl instruments were not calibrated for the low stack temperatures exhibited during the Cool-down period. The outlet HCl instrument showed poor resolution in the lower concentration ranges.

## 2.8 ASH LOSS-ON-IGNITION AND CARBON CONTENT RESULTS

This section presents results of laboratory analyses of ash samples collected. During the testing, ash was removed manually from the incinerator each morning following a test day, screened through 1/2-inch mesh, weighed, and placed in clean 55-gallon metal cans. After the ash was allowed to cool, samples were taken manually and composited to obtain as representative a sample as possible. Portions were taken from the composite sample for the various analyses, including one sample which was analyzed for moisture content, LOI, and carbon content.

Samples were collected for three replicate test days at rated operating conditions (total of three runs).

Table 2-57 presents a summary of the ash analysis results. The moisture content of the samples ranged from 0.86 percent for Test Day 2 to 20.33 percent for Test Day 1. The ash moisture content for Test Day 1 was exceptionally high due to the fact that a water spray was used to quench the ash prior to removal. The average moisture values for the two test days, excluding Test Day 1 was 3.02 percent.

Loss-on-ignition results varied from 17.15 percent for Test Day 3 to 24.21 percent for Test Day 1. The average LOI for all 3 test days was 19.5 percent.

Carbon content in the ash samples varied from 5.61 percent for Test Day 3 to 9.34 percent for Test Day 1. The average value for Test Days 2 and 3 was 6.21 percent. The test Day 1 value was not used in calculating the average carbon content because of the water used to cool the ash may have biased that day's value.

## 2.9 MICROBIAL SURVIVABILITY RESULTS

This section provides the background and test matrix for microbial survivability testing and presents the test results for microbial survivability in emissions, in ash and in ash quality pipes.

### 2.9.1 Background and Test Matrix

One of the objectives of this test program was to further develop testing methods to determine microbial survivability in incinerator processes. As part of the MWI test program at Jordan Hospital, testing was conducted to determine microbial survivability based on a surrogate indicator organism that was spiked into the incinerator feed during each test run. The surrogate indicator organism used was a type of soil spore known as

TABLE 2-57. SUMMARY OF ASH CARBON CONTENT, LOI, AND MOISTURE RESULTS  
 JORDAN HOSPITAL (1991)

CONDITION <sup>a</sup>	TEST DATE	TEST DAY NUMBER	SAMPLE DATE	MOISTURE <sup>b</sup> (%)	L.O.I. <sup>c</sup> (%)	TOTAL LOSS <sup>d</sup> (%)	CARBON <sup>b</sup> (%)
Pretest	Pretest	Pretest	03/01/91	0.96	18.48	19.26	7.48
Rated	03/05/91	1	03/06/91	20.33 <sup>e</sup>	24.21	39.61 <sup>e</sup>	9.34 <sup>e</sup>
Rated	03/07/91	2	03/08/91	0.86	17.34	18.05	6.81
Rated	03/09/91	3	03/09/91	5.18	17.15	21.44	5.61
AVERAGE:				3.02 (5)	19.56	19.75 <sup>e</sup>	6.21 <sup>e</sup>

<sup>a</sup> Rated conditions of 750 lbs of waste per batch.

<sup>b</sup> As received basis.

<sup>c</sup> L.O.I. reported on a dry basis.

<sup>d</sup> Total Loss is the sum of moisture and L.O.I. values.

<sup>e</sup> Water spray was used to cool ash prior to removal. These values are not used for moisture total loss and carbon averages.

Bacillus stearothermophilus. This organism was chosen because it survives at high temperatures and it is easy to culture and identify. Also, it is non-pathogenic and is not commonly found in medical waste streams.

Two types of testing were performed. The first test method was aimed at determining microbial survivability in the combustion gases (emissions) and the bottom ash. For these tests, a known quantity of B. stearothermophilus in solution (wet spores) was absorbed onto materials commonly found in the medical waste stream (i.e., gauze, paper, bandages, etc.), placed in plastic trash bags, and charged to the MWI along with the medical waste. Emissions testing was conducted at the incinerator exit upstream of the air pollution control system using the protocol described in the EPA draft method "Microbial Survivability Test for Medical Waste Incinerator Emissions" (Appendix K). This testing was performed concurrently with other emissions testing (PM/Metals, CDD/CDF, halogens, and CEMs) during the burn and burndown periods. Ash samples were taken daily each morning following a test when the incinerator was cleaned manually. The ash was sampled and analyzed as described in the EPA Draft Method "Microbial Survivability Test for Medical Waste Incinerator Ash" (Appendix K).

The second Microbial Survivability test method utilized freeze-dried spores (dry spores) encapsulated in metal pipes which were insulated and contained in two designs of outer containers. These tests were used to aid in the assessment of microbial survivability in the ash. Two types of outer containers were used for comparison to each other. One type used a large (6 inch by 2 inch diameter) metal pipe capped at both ends and filled with vermiculite insulation. Another type utilized high temperature ceramic insulation contained by wire mesh.

Complete details of the microbial spiking, recovery and analysis procedures are given in Section 5.3.

Two emissions test runs were performed at the rated incinerator operating conditions (burn and burn down) each day for three test days. Each test day the incinerator was spiked with the wet spore stock as well as the dry spore samples. Liquid spores were poured into mock garbage bags containing absorbent materials and placed in eight locations as shown in Figure 2-1. Each of the eight bags also contained a wire mesh package containing freeze-dried spores encased in the small metal tubes. Nine

metal pipes containing freeze-dried spores encased in the metal tubes were placed on the floor of the incinerator as shown prior to charging the incinerator with waste. Eight liquid spore bags were spiked in the same manner for Test Day 2. Nine metal pipes were placed on the floor in the same locations as in Test Day 1. No mesh packages were charged for this test. Prior to Test Day 3, eight liquid spore bags and nine metal pipes were placed in the same locations as in both previous tests. Each of the eight bags also contained a wire mesh package. Nine additional wire mesh packages containing dry spores were placed on the incinerator floor next to each metal pipe.

Table 2-58 summarizes the spore spiking times and quantities as well as waste feed and total ash quantities.

### 2.9.2 Overall Microbial Survivability

By comparing the number of wet spores spiked to the incinerator with the number of viable spores exiting in both the stack gas and incinerator ash, an overall microbial survivability value can be determined as follows:

$$MS = \left( \frac{S_e + A_e}{S_s} \right) \times 100$$

MS	=	spore microbial survivability (wet)
$S_e$	=	Number of viable spores detected exiting the stack
$A_e$	=	Number of viable spores detected in the incinerator ash
$S_s$	=	Number of viable spores spiked in the waste feed

This is an adaptation of the destruction efficiency (DE) calculation presented in the reference test protocol which calculates DE based only on stack emissions and a separate DE based on spores in ash. By combining the two DE estimates a more complete estimate of Microbial Survivability (1 - DE) is obtained. The total number of spores in the ash was calculated by multiplying the number of spores found in 1 gram of ash by the total weight of ash removed from the incinerator per day. The values presented in this section were taken from a "quantitative summary" performed on the raw analytical data by the analytical laboratory. These results are included in the analytical results shown in Appendix E.3, and calculations are shown in Appendix F.

TABLE 2-58. SUMMARY OF INCINERATOR FEED AMOUNTS AND ASH GENERATION PER RUN;  
JORDAN HOSPITAL (1991)

RUN NUMBER	TEST DAY	DATE	DESIGN LOAD RATE (lbs)	TIMES	WET SPORE SPIKE AMOUNTS (total spores)	DRY SPORE SPIKE AMOUNTS (total spores)	TOTAL WASTE FEED (lbs)	TOTAL ASH WEIGHT (lbs) c
1,2	1	03/05/91	750	08:45	1.71E+12	1.7E+8 d	719.07	70.34
3,4	2	03/07/91	750	08:30	1.71E+12	9.0E+7 e	702.21	94.87
5,6	3	03/09/91	750	08:25	1.58E+12	2.6E+8 f	729.38	60.35

a Two indicator spore emissions test runs were conducted every day. One during the Burn and one during the Burndown.

b Wet spores were added in eight ~250 ml aliquots spread over separate waste bags.

c Total ash weight includes relatively large pieces of material (glass, metal, etc.)

d Eight mesh containers were placed in each of the eight wet spike bags. Nine pipes were placed on the floor.

e Nine pipes were placed on the floor.

f Eight mesh containers were placed in each of eight wet spore spike bags. Nine pipes and nine mesh containers were placed on the floor.

Table 2-59 presents the overall survivability of the indicator spores. Several stack gas samples had viable spore colonies on the culture plate. However, because there was only quantitative consistency shown in one of these samples (Run 3) and the fact that the field blank showed some positive detects, the other samples were assigned relatively high less than values ( $<1000$ ,  $<10,000$  spores/analysis). Spores were found in most of the ash samples, including the background ash sample. As with the flue gas samples, two test day samples were assigned less than values (Days 1 and 3). These numbers were based on the consistency of detected values as well as a method recovery efficiency factor. The Day 2 sample showed some spores present on the plate. Incorporating both the flue gas and ash results, the associated Microbial Survivalities were  $<0.06$ ,  $0.0005$  and  $<1.76$  percent for Days 1, 2, and 3, respectively. Flue gas microbial survivability and ash microbial survivability are further discussed in the following sections. All microbial survivability calculations are shown in Appendix F.

### 2.9.3 Microbial Survivability in Emissions

Microbial Survivability in emissions tests were conducted to quantify the number of viable spores exiting the stack during the test run. The formulas used for calculating the number of viable spores existing in the stack,  $S_e$ , is calculated as shown in Appendix F, and in the EPA draft method in Appendix K.

Each test day for viable spore emissions was actually made up of 2 runs; one during the burn period and one during the burndown period. An approximate 1.5 liter sample of impinger collection solution was generated for each run. These run samples were recovered in a disinfected mobile laboratory, sealed, and sent to the analytical laboratory.

For each run performed, 6 aliquots were prepared for analysis: three 10 ml and three 100 ml aliquots. The filter plates were examined and colonies counted after a 48-hour period. For 2 test runs samples and the field blank sample, additional aliquots were counted on 2 serial dilutions (1:10) on 1 ml of the original impinger solution. All of these results were used to determine the final test run values.

Table 2-60 presents the Microbial Survivability in Emissions test results. There were several test runs where viable spores were found on the culture plate. Runs 1-3

TABLE 2-59. OVERALL MICROBIAL SURVIVABILITY;  
JORDAN HOSPITAL (1991)

RUN NUMBER	TEST DAY	DATE	CONDITION	NUMBER OF INDICATOR SPORES SPIKED TO THE INCINERATOR (total spores)	NUMBER INDICATOR SPORES EXITING THE STACK (total spores)	NUMBER OF INDICATOR SPORES IN ASH (total spores)	MICROBIAL SURVIVABILITY (%) <sup>a</sup>	MICROBIAL LOG REDUCTION <sup>b</sup>
1	1	03/05/91	BURN		< 1.03E+08			
2	1	03/05/91	BURNDOWN		< 8.37E+08			
	TOTAL			1.71E+12	< 9.40E+08	< 4.62E+05	< 5.52E-02	> 3.2
3	2	03/07/91	BURN		1.05E+05			
4	2	03/07/91	BURNDOWN		< 1.18E+05			
	TOTAL			1.71E+12	1.05E+05	(0.56 to 7.70)E+06 <sup>c</sup>	4.63E-04	5.3
5	3	03/09/91	BURN		< 1.02E+05			
6	3	03/09/91	BURNDOWN		< 1.52E+05			
	TOTAL			1.58E+12	< 2.54E+05	< 2.78E+10	< 1.76	> 1.8

<sup>a</sup> MS = (stack spores + ash spores)/(spiked spores) \* 100

<sup>b</sup> MLR = log(spiked spores) - log(stack spores + ash spores)

<sup>c</sup> This range of numbers was based on the value presented in the quantitative analytical summary shown in Appendix E.3 (See Table 2-62).  
NOTE: All MS and MLR calculations are shown in Appendix F.

TABLE 2-60. VIABLE SPORE EMISSIONS;  
JORDAN HOSPITAL (1991)

RUN NUMBER	CONDITION	NUMBER OF INDICATOR SPORES IN ALIQUOT (100 ml)	NUMBER OF INDICATOR SPORES IN SAMPLE	CONCENTRATION OF INDICATOR SPORES IN FLUE GAS (#/dscm)	NUMBER OF INDICATOR SPORES EXITING STACK DURING TEST PERIOD
1	BURN	< 1,000	< 31,227	< 15,723	< 1.03E+08
2	BURNDOWN	< 10,000	< 295,523	< 207,968	< 8.37E+08
3	BURN	1	35	18	1.05E+05
4	BURNDOWN	< 1	26	< 29	< 1.18E+05
5	BURN	< 1	30	< 16	< 1.02E+05
6	BURNDOWN	< 1	34	< 39	< 1.52E+05

NOTE: Values taken from averages of repetitive analytical runs as presented in the analytical quantitative summary in Appendix E.3  
All calculations are shown in Appendix F.

samples were determined to have <1000, <10,000, and 1 spore per 100 ml aliquot of impinger solution. The values were then factored by the total impinger solution volume, meter volume, stack gas flow rate and test duration to calculate total spores emitted per test run.

The Microbial Survivability sampling and flue gas parameters are shown in Table 2-61.

#### 2.9.4 Microbial Survivability in Ash

Incinerator ash was completely removed from the incinerator every day and stored in a pre-cleaned, disinfected stainless steel drum. Composite ash samples were pulled from the drum using a sample thief and then mixed and deposited into clean, amber glass sample bottles. The composite samples were then submitted to the laboratory for culturing and enumeration of B. stearoothermophilus.

The microbial survivability in ash results for the Jordan MWI tests are presented in Table 2-62. Three one gram ash aliquots were taken from each sample and extracted in 100 mls of phosphate butter solution. Three one ml aliquots were taken from each 100 ml aliquot and separately filtered, cultured, and counted. Three serial dilutions were prepared on the test day 3 sample and also triple plated. B. stearoothermophilus colonies were found in several of the cultures. After reviewing counts from replicate analyses and incorporating a standard recovery efficiency value, the final sample values were determined. Test days 1 and 3 were assigned less than values of <145 and <1,014,493 spores/gram, respectively. The Test day 2 sample was assigned a value of  $96 \pm 83$  spores/gram. A quantitative summary of the analytical data used to compile this data is shown in Appendix E.3.

#### 2.9.5 Microbial Survivability in Pipes

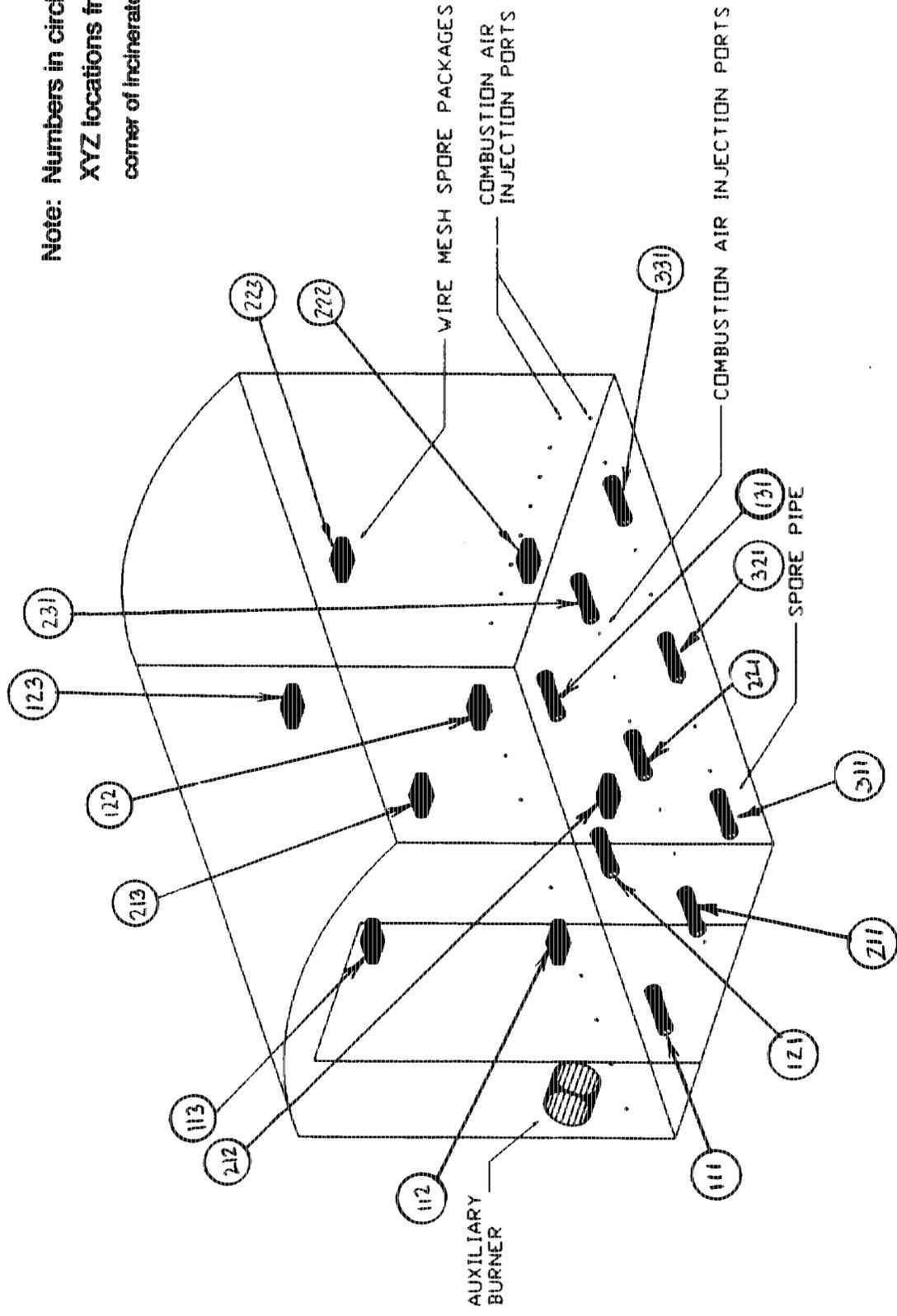
Pipe and wire mesh samples which were loaded with days indicator spores were placed into the incinerator during each test day. The approximate location of the samples in the incinerator is shown in Figure 2-1. The pipes were recovered the following morning during ash removal. After allowing the samples to cool, the inner containers were removed from the outer containers and sent to the laboratory for analysis. The entire contents of the inner pipe were rinsed, filtered, and cultured.

TABLE 2-61 INDICATOR SPORE EMISSIONS SAMPLING AND FLUE GAS PARAMETERS;  
JORDAN HOSPITAL (1991)

RUN NUMBER:	RUN 1 (BURN)	RUN 2 (BURNDOWN)
Total Sampling Time (min.)	400	320
Average Stack Temperature (°F)	1638	1592
Carbon Dioxide Concentration (% V)	7.50	8.90
Oxygen Concentration (% V)	8.80	8.90
Average Sampling Rate (dscfm)	0.18	0.16
Standard Metered Volume, Vm(std) (dscm)	1.986	1.421
Stack Moisture (% V)	9.31	8.18
Volumetric Flow Rate (dscfm)	576	444
Volumetric Flow Rate (dscmm)	16.3	12.6
Percent Isokinetic	101.4	118.8
RUN NUMBER:	RUN 3 (BURN)	RUN 4 (BURNDOWN)
Total Sampling Time (min.)	400	330
Average Stack Temperature (°F)	1613	1614
Carbon Dioxide Concentration (% V)	5.90	6.30
Oxygen Concentration (% V)	9.60	6.30
Average Sampling Rate (dscfm)	0.17	0.09
Standard Metered Volume, Vm(std) (dscm)	1.870	0.869
Stack Moisture (% V)	9.57	8.28
Volumetric Flow Rate (dscfm)	513	435
Volumetric Flow Rate (dscmm)	14.5	12.3
Percent Isokinetic	107.2	92.5
RUN NUMBER:	RUN 5 (BURN)	RUN 6 (BURNDOWN)
Total Sampling Time (min.)	400	320
Average Stack Temperature (°F)	1644	1649
Carbon Dioxide Concentration (% V)	5.10	7.75
Oxygen Concentration (% V)	11.20	8.61
Average Sampling Rate (dscfm)	0.16	0.10
Standard Metered Volume, Vm(std) (dscm)	1.866	0.870
Stack Moisture (% V)	8.26	6.50
Volumetric Flow Rate (dscfm)	562	431
Volumetric Flow Rate (dscmm)	15.9	12.2
Percent Isokinetic	102.6	96.5

TABLE 2-62. VIABLE SPORES IN ASH;  
 JORDAN HOSPITAL (1991)

TEST DAY	RUN NUMBER	CONCENTRATION OF INDICATOR SPORES IN ASH (spores/g ash)	NUMBER OF INDICATOR SPORES EXITING INCINERATOR IN ASH (total spores)
0	Pre-Test	16 +/- 48	NA
1	1,2	< 145	< 4.62E+06
2	3,4	96 +/- 83	4.13E+06
3	5,6	< 1,014,493	< 2.78E+10



**Note: Numbers in circles indicate XYZ locations from front left corner of incinerator.**

**FIGURE 2-1. Location of Microbe Spikes in Incinerator  
JORDAN HOSPITAL (1991)**

The number of viable spores found in the pipes is presented in Table 2-63. In comparing the number of indicator spores found in the pipe and mesh samples to the quantity of dry spores loaded into each sample, the survivability is very low. Three out of 17 samples from day 1 had viable spores found. Two out of 9 Day 2 samples and 4 out of 26 Day 3 samples had several spores found. Only a small amount of spores were found in those samples (highest value was 8 spores).

## 2.10 PARTICLE SIZE DISTRIBUTION RESULTS

Three PSD test runs were conducted during the Jordan Hospital MWI test program. An in-stack eight stage MK III cascade impactor sampling device was used (See Section 5.9 for PSD Method). The PSD sampling location was downstream of the test exchanger, immediately upstream of the fabric filter. Condensable PM was also determined by placing an ambient temperature back-up filter downstream of the impactor and recovering the aqueous impinger fraction and solvent impinger rinse. Following a test, the impactor was inspected to determine if there was adequate particle loading on each of the filter stages. A properly loaded impactor has distinct particulate "piles" under each stage's acceleration jets (holes). An underloaded impactor is evidenced by clean, undisturbed filters while an over-loaded impactor has particulate piles which overlap and appear to have "broken-up" (evidence of PM re-entrainment). An assessment of the quality of particulate loading was made by the recovery technician with observations noted on the PSD field data sheets (See Appendix A.6). Of those three PSD runs, the first one did not meet recovery QC objectives and, therefore, was not included in these results. The test results for PSD Runs 2 and 3 will be reported in the following section.

Figures in this section show the log-normal plots of the PSD runs. The log of Particle cut size ( $D_{p50}$ ) at each impactor stage is plotted against mass fraction of particulate less than that  $D_{p50}$ , on a probability (normal) scale. Linear regression analyses were conducted and the correlation coefficients ( $R^2$ ) are shown on each figure.

Table 2-64 reports the Run 2 PSD results. Test 2 was conducted during the last hour of burn and the first hour of burndown on March 7, 1991 (Test Day 2). The size distribution results are given for total PM, including the condensable fraction, as well as

TABLE 2-63. VIABLE SPORES IN PIPES;  
JORDAN HOSPITAL (1991)

TEST DAY	SPIKE DATE	NUMBER OF SPORES	LOCATION (XYZ) <sup>a</sup>	SAMPLE TYPE
1	03/05/91	0	111	PIPE
1	03/05/91	8	211	PIPE
1	03/05/91	0	311	PIPE
1	03/05/91	0	121	PIPE
1	03/05/91	0	221	PIPE
1	03/05/91	0	321	PIPE
1	03/05/91	0	131	PIPE
1	03/05/91	3	331	PIPE
1	03/05/91	0	231	PIPE
1	03/05/91	0	213	MESH
1	03/05/91	0	112	MESH
1	03/05/91	0	113	MESH
1	03/05/91	0	223	MESH
1	03/05/91	1	123	MESH
1	03/05/91	0	212	MESH
1	03/05/91	0	222	MESH
1	03/05/91	0	122	MESH
2	03/07/91	0	111	PIPE
2	03/07/91	0	211	PIPE
2	03/07/91	0	311	PIPE
2	03/07/91	0	121	PIPE
2	03/07/91	0	221	PIPE
2	03/07/91	0	321	PIPE
2	03/07/91	0	131	PIPE
2	03/07/91	1	231	PIPE
2	03/07/91	1	331	PIPE

<sup>a</sup> See Figure 2-1

NOTE: All pipe and mesh sample containers were spiked with  $9.0E+07$  to  $2.6E+08$  freeze-dried spores at approximately 08:30 am (See Table 2-58) and recovered the following day.

TABLE 2-63. VIABLE SPORES IN PIPES (continued);  
JORDAN HOSPITAL (1991)

TEST DAY	SPIKE DATE	NUMBER OF SPORES	LOCATION (XYZ) <sup>a</sup>	SAMPLE TYPE
3	03/09/91	0	311	PIPE
3	03/09/91	0	213	MESH
3	03/09/91	0	231	MESH
3	03/09/91	0	321	PIPE
3	03/09/91	0	331	MESH
3	03/09/91	0	112	MESH
3	03/09/91	0	123	MESH
3	03/09/91	0	111	MESH
3	03/09/91	0	111	PIPE
3	03/09/91	0	112	MESH
3	03/09/91	1	113	MESH
3	03/09/91	0	121	MESH
3	03/09/91	0	121	PIPE
3	03/09/91	0	122	MESH
3	03/09/91	0	131	MESH
3	03/09/91	0	131	PIPE
3	03/09/91	0	211	MESH
3	03/09/91	1	211	PIPE
3	03/09/91	0	212	MESH
3	03/09/91	0	221	MESH
3	03/09/91	0	221	PIPE
3	03/09/91	0	222	MESH
3	03/09/91	0	223	MESH
3	03/09/91	2	231	PIPE
3	03/09/91	NF <sup>b</sup>	311	MESH
3	03/09/91	1	321	MESH
3	03/09/91	0	331	PIPE
BLANK	03/07/91	>274	NA <sup>c</sup>	AMBIENT
BLANK	03/07/91	1	NA <sup>c</sup>	BLANK
BLANK	03/07/91	>274	NA <sup>c</sup>	DRYSTOCK

<sup>a</sup> See Figure 2-1

NOTE: All pipe and mesh sample containers were spiked with  $9.0E+07$  to  $2.6E+08$  freeze-dried spores at approximately 08:30 am (See Table 2-58) and recovered the following day.

<sup>b</sup> NA - Not Charged Into Incinerator.

<sup>c</sup> NF - Not Found in Ash After Test.

TABLE 2-64. PARTICLE SIZE DISTRIBUTION RUN 2 RESULTS ;  
JORDAN HOSPITAL (1991)

DATE:	03/07/91	Net Weight	Mass Fraction	Mass Fract. Less Than	Interval Geometric Midpoint	dM/dlog DP	CONC
STAGE	Dp50 (microns)	(grams)			(microns)	(gr/dscf)	(gr/dscf)
INCLUDING CONDENSABLE PM							
Preim & 1	11.93	0.005986	0.1404	0.8596 *	24.42	2.472E-03	0.001538
2	7.82	0.000285	0.0067	0.8529	9.66	3.992E-04	0.000073
3	5.10	0.000155	0.0036	0.8493	6.31	2.148E-04	0.000040
4	3.60	0.000105	0.0025	0.8468	4.29	1.786E-04	0.000027
5	2.13	0.000225	0.0053	0.8416	2.77	2.539E-04	0.000058
6	1.21	0.000525	0.0123	0.8292	1.61	5.485E-04	0.000135
7	0.74	0.001020	0.0239	0.8053	0.95	1.228E-03	0.000262
8	0.47	0.002270	0.0532	0.7521	0.59	2.906E-03	0.000583
BCK-UP		0.032068	0.7521	0.0000 *	0.05	4.184E-03	0.008241
TOTAL		0.042639	1.0000				0.010958
NOT INCLUDING CONDENSABLE PM							
Preim & 1	11.93	0.005986	0.2246	0.7754 *	24.42	2.472E-03	0.001538
2	7.82	0.000285	0.0107	0.7647	9.66	3.992E-04	0.000073
3	5.10	0.000155	0.0058	0.7589	6.31	2.148E-04	0.000040
4	3.60	0.000105	0.0039	0.7549	4.29	1.786E-04	0.000027
5	2.13	0.000225	0.0084	0.7465	2.77	2.539E-04	0.000058
6	1.21	0.000525	0.0197	0.7268	1.61	5.485E-04	0.000135
7	0.74	0.001020	0.0383	0.6885	0.95	1.228E-03	0.000262
8	0.47	0.002270	0.0852	0.6034	0.59	2.906E-03	0.000583
BCK-UP		0.016080	0.6034	0.0000 *	0.05	2.098E-03	0.004132
TOTAL		0.026651	1.0000				0.006849
* these values assume top end and bottom end dp50s of 50 and .005 um.							
<b>FLUE GAS AND SAMPLING PARAMETERS</b>							
Sampling Time	15:02-17:42 (150 MIN)						
Test Condition	BURN and BURNDOWN						
Average Stack Temperature (°F)	393						
Average Sampling Rate (dscfm)	0.40						
Standard Metered Volume, Vm(std) (dscf)	60.05						
Standard Metered Volume, Vm(std) (dscm)	1.701						
Stack Moisture (%V)	12.2						
Percent Isokinetic	117.9						

for PM not including the condensable fraction. The results are presented graphically in Figure 2-2. Approximately 80 percent of the total PM was less than 1  $\mu\text{m}$ .

Table 2-65 reports the results from PSD Run 3. This test run was conducted during the burn conditions on March 9, 1991 (Test Day 3). The Run 3 PSD results are presented graphically in Figure 2-3. Slightly larger particle sizes were found in this run as approximately 80 percent of the particles were less than 10  $\mu\text{m}$ .

#### 2.11 CDD/CDF EMISSION VALUES INCORPORATING THE TOLUENE RECOVERY RESULTS

In accordance with EPA Method 23, a final toluene rinse was completed on the CDD/CDF sampling train after the methylene chloride ( $\text{MeCl}_2$ ) rinse procedure. This was done to determine how well the  $\text{MeCl}_2$  was collecting all of the CDD/CDF material. As prescribed in the method, these values were to be used only as a QA indicator and were not to be incorporated into the emission values. Therefore, a full presentation of the data is given in Section 6. However, to gain perspective into how these values effected the gas phase CDD/CDF concentrations, stack gas CDD/CDF concentrations incorporating the toluene recovery amounts are given in Tables 2-66 through 2-69. Tables 2-66 and 2-67 present results for the burn condition and 2-68 and 2-69 show the burndown results. Concentrations are given corrected to 7 percent  $\text{O}_2$  as well as in 2378 TCDD Toxic Equivalents. Results for each test run as well as the overall condition averages are given. These values can be directly compared to the non-toluene CDD/CDF gas concentrations shown in Tables 2-9 and 2-10 for the burn condition and Tables 2-13 and 2-14 for the burndown condition.

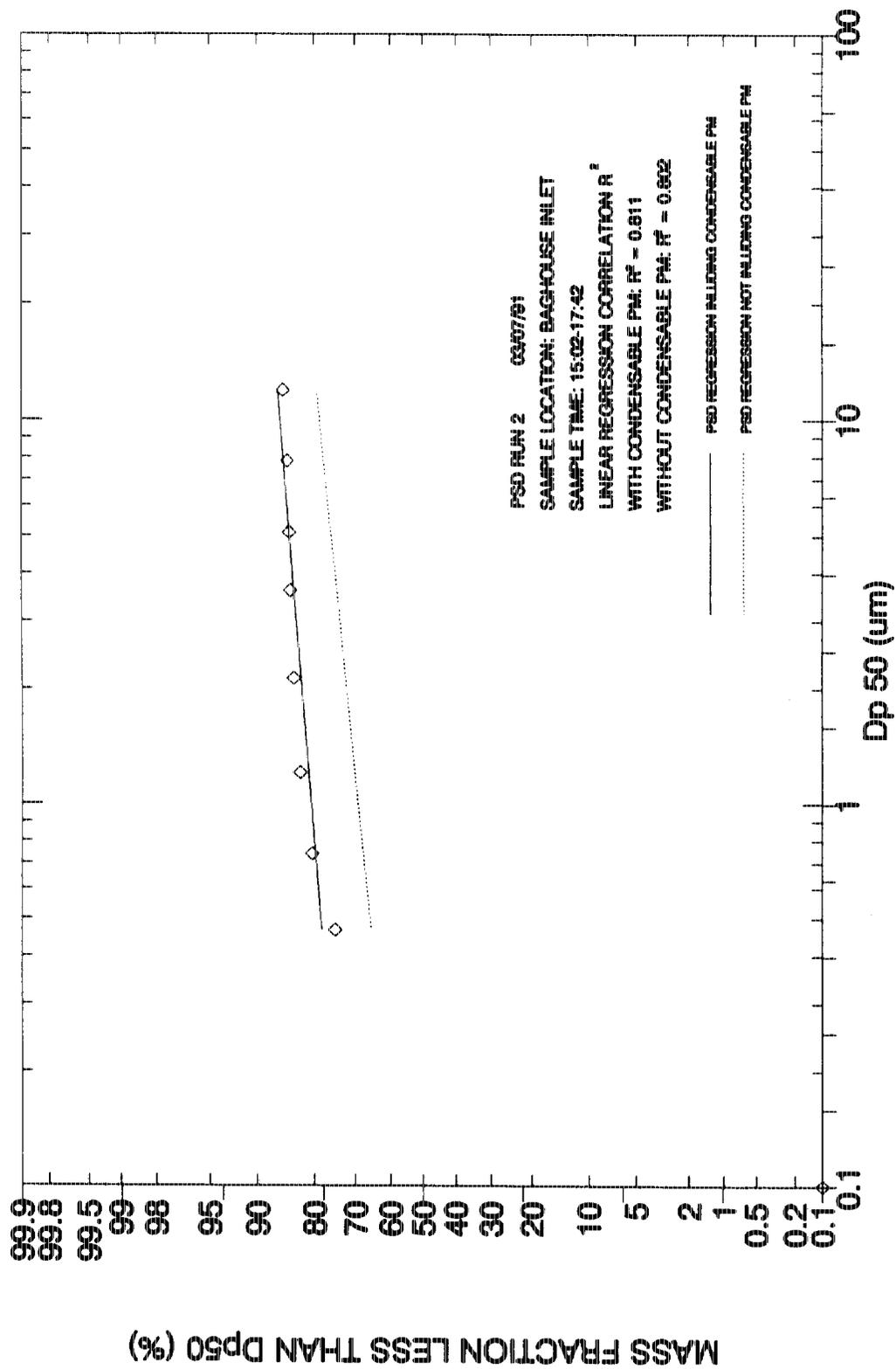


FIGURE 2-2. PARTICLE SIZE DISTRIBUTION RUN 2 RESULTS WITH AND WITHOUT CONDENSABLE PM;  
 JORDAN HOSPITAL (1991)

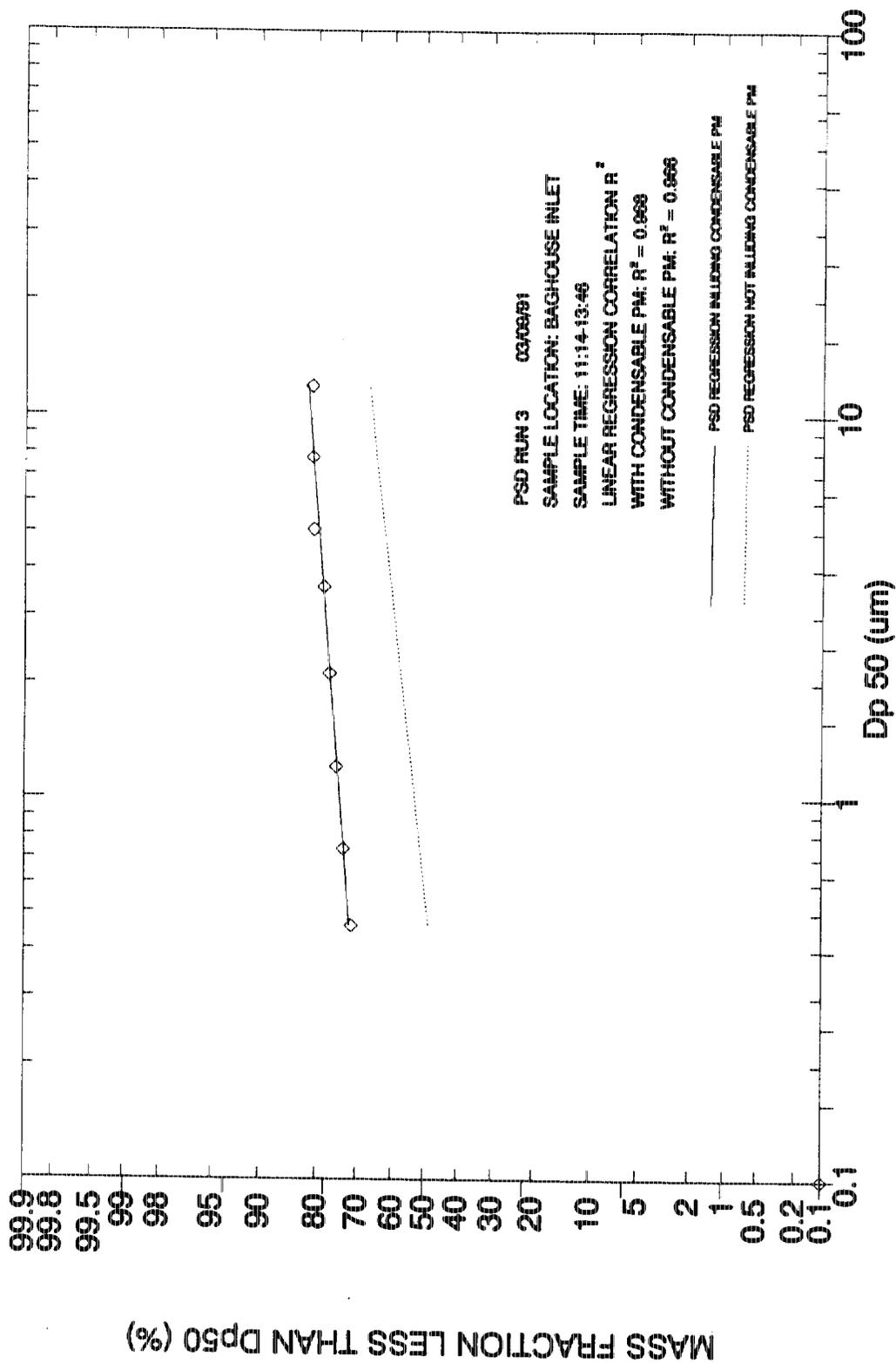


FIGURE 2-3. PARTICLE SIZE DISTRIBUTION RUN 3 RESULTS WITH AND WITHOUT CONDENSABLE PM;  
 JORDAN HOSPITAL (1991)

TABLE 2-65. PARTICLE SIZE DISTRIBUTION RUN 3 RESULTS  
JORDAN HOSPITAL (1991)

DATE:	03/09/91	Net Weight	Mass	Mass Fract.	Interval	dM/dlog DP	CONC
STAGE	Dp50 (microns)	(grams)	Fraction	Less Than	Geometric Midpoint (microns)	(gr/dscf)	(gr/dscf)
INCLUDING CONDENSABLE PM							
Preim & 1	11.88	0.004352	0.1929	0.8071	24.37	1.687E-03	0.001053
2	7.79	0.000045	0.0020	0.8051	9.62	5.934E-05	0.000011
3	5.08	0.000035	0.0016	0.8035	6.29	4.567E-05	0.000008
4	3.59	0.000505	0.0224	0.7812	4.27	8.086E-04	0.000122
5	2.12	0.000320	0.0142	0.7670	2.76	3.399E-04	0.000077
6	1.20	0.000385	0.0171	0.7499	1.60	3.785E-04	0.000093
7	0.74	0.000415	0.0184	0.7315	0.94	4.699E-04	0.000100
8	0.46	0.000505	0.0224	0.7091	0.58	6.063E-04	0.000122
BCK-UP		0.015997	0.7091	-0.0000	0.05	1.968E-03	0.003871
TOTAL		0.022559	1.0000				0.005459
NOT INCLUDING CONDENSABLE PM							
Preim & 1	11.88	0.004352	0.3515	0.6485 *	24.37	1.687E-03	0.001053
2	7.79	0.000045	0.0036	0.6449	9.62	5.934E-05	0.000011
3	5.08	0.000035	0.0028	0.6421	6.29	4.567E-05	0.000008
4	3.59	0.000505	0.0408	0.6013	4.27	8.086E-04	0.000122
5	2.12	0.000320	0.0258	0.5754	2.76	3.399E-04	0.000077
6	1.20	0.000385	0.0311	0.5443	1.60	3.785E-04	0.000093
7	0.74	0.000415	0.0335	0.5108	0.94	4.699E-04	0.000100
8	0.46	0.000505	0.0408	0.4700	0.58	6.063E-04	0.000122
BCK-UP		0.005820	0.4700	0.0000 *	0.05	7.161E-04	0.001408
TOTAL		0.012382	1.0000				0.002996
* these values assume top end and bottom end dp50s of 50 and .005 um.							
<b>FLUE GAS AND SAMPLING PARAMETERS</b>							
Sampling Time	11:14-13:46 (152 min)						
Test Condition	BURN						
Average Stack Temperature (°F)	370						
Average Sampling Rate (dscfm)	0.42						
Standard Metered Volume, Vm(std) (dscf)	63.71						
Standard Metered Volume, Vm(std) (dscm)	1.804						
Stack Moisture (% V)	11.2						
Percent Isokinetic	116						

TABLE 2-66. CDD/CDF FLUE GAS CONCENTRATIONS CORRECTED TO 7% O<sub>2</sub> DURING THE BURN CONDITION (RUNS 1,3,5) INCORPORATING THE TOLUENE RECOVERY RESULTS; JORDAN HOSPITAL (1991)

CONGENER	INLET CONCENTRATION (ng/dscm, adjusted to 7 percent O <sub>2</sub> ) <sup>a</sup>				OUTLET CONCENTRATION (ng/dscm, adjusted to 7 percent O <sub>2</sub> )			
	RUN 1	RUN 3	RUN 5	AVERAGE <sup>b</sup>	RUN 1	RUN 3	RUN 5	AVERAGE
<b>DIOXINS</b>								
2378 TCDD	[0.024]	[0.016]	(0.059)	0.059	2.653	3.716	(2.286)	2.885
Other TCDD	0.065	0.076	1.974	0.705	1227.233	1290.582	1274.416	1264.077
12378 PCDD	[0.041]	[0.031]	0.184	0.184	13.826	22.239	9.280	15.115
Other PCDD	(0.134)	0.158	1.796	0.696	1063.332	1182.453	735.760	993.848
123478 HxCDD	[0.059]	[0.038]	0.315	0.315	7.797	14.947	8.169	10.304
123678 HxCDD	[0.041]	0.032	0.493	0.262	13.505	21.494	12.613	15.871
123789 HxCDD	[0.053]	[0.031]	0.854	0.854	21.463	37.326	22.155	26.981
Other HxCDD	(0.250)	0.006	6.227	2.161	425.100	690.549	423.083	512.911
1234678-HpCDD	0.114	(0.140)	4.274	1.510	26.446	54.285	25.235	35.322
Other Hepta-CDD	0.000	0.000	0.005	0.005	45.095	91.956	42.088	59.713
Octa-CDD	0.269	0.022	9.932	3.408	9.887	18.325	12.180	13.464
<b>Total CDD</b>	<b>0.83</b>	<b>0.43</b>	<b>26.11</b>	<b>9.13</b>	<b>2856.34</b>	<b>3427.87</b>	<b>2567.27</b>	<b>2950.49</b>
<b>FURANS</b>								
2378 TCDF	0.060	0.064	0.520	0.214	27.976	35.733	20.064	27.924
Other TCDF	0.703	0.546	17.628	6.293	2206.742	2539.129	1724.914	2156.928
12378 PCDF	(0.028)	0.032	0.545	0.202	32.716	51.774	22.939	35.810
23478 PCDF	0.093	0.095	1.708	0.632	57.233	108.774	38.234	68.081
Other PCDF	0.616	0.083	13.519	4.739	826.446	1477.965	723.092	1009.168
123478 HxCDF	0.207	0.140	3.546	1.298	112.538	158.400	79.741	116.893
123678 HxCDF	0.071	0.051	1.182	0.435	31.511	46.902	24.183	34.198
234678 HxCDF	0.155	0.108	2.699	0.987	42.523	69.621	34.448	48.864
123789 HxCDF	[0.036]	[0.026]	0.085	0.085	0.884	1.789	(0.718)	1.131
Other HxCDF	0.322	0.044	5.896	2.087	391.326	548.373	191.696	377.132
1234678-HpCDF	(0.246)	0.197	4.799	1.747	39.067	69.616	49.547	52.743
1234789-HpCDF	[0.049]	0.070	1.116	0.593	(2.734)	5.311	4.444	4.163
Other Hepta-CDF	0.076	0.102	3.350	1.176	19.694	39.449	28.366	29.170
Octa-CDF	0.164	0.470	11.361	3.998	5.305	8.223	6.274	6.601
<b>TOTAL CDF</b>	<b>2.74</b>	<b>2.00</b>	<b>67.96</b>	<b>24.23</b>	<b>3796.69</b>	<b>5161.06</b>	<b>2948.66</b>	<b>3968.80</b>
<b>TOTAL CDD+CDF</b>	<b>3.57</b>	<b>2.43</b>	<b>94.07</b>	<b>33.36</b>	<b>6653.03</b>	<b>8588.93</b>	<b>5515.92</b>	<b>6919.30</b>

<sup>a</sup> Standard conditions are defined as 1 atm and 68 °F.

[ ] = Minimum Detection Limit

( ) = Estimated Maximum Possible Concentration

<sup>b</sup> Detection limits are considered zeros for calculating averages.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

TABLE 2-67. CDD/CDF FLUE GAS TOXIC EQUIVALENCIES CORRECTED TO 7% O<sub>2</sub> FOR THE BURN CONDITION (RUNS 1, 3, & 5) INCORPORATING THE TOLUENE RECOVERY RESULTS; JORDAN HOSPITAL (1991)

CONGENER	2378-TCDD TOXIC EQUIV. FACTOR <sup>a</sup>	INLET 2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O <sub>2</sub> ) <sup>b</sup>				OUTLET 2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O <sub>2</sub> )			
		RUN 1	RUN 3	RUN 5	AVERAGE	RUN 1	RUN 3	RUN 5	AVERAGE
<b>DIOXINS</b>									
2378 TCDD	1.00000	[0.024]	[0.016]	(0.059)	0.059	2.653	3.716	(2.286)	2.885
Other TCDD	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDD	0.50000	[0.021]	[0.016]	0.092	0.092	6.913	11.120	4.640	7.558
Other PCDD	0.00000	(0.000)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.10000	[0.006]	[0.004]	0.032	0.032	0.780	1.495	0.817	1.030
123678 HxCDD	0.10000	[0.004]	0.003	0.049	0.026	1.350	2.149	1.261	1.587
123789 HxCDD	0.10000	[0.005]	[0.003]	0.085	0.085	2.146	3.733	2.215	2.698
Other HxCDD	0.00000	(0.000)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.01000	0.001	(0.001)	0.043	0.015	0.264	0.543	0.252	0.353
Other Hepta-CDD	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDD	0.00100	0.000	0.000	0.010	0.003	0.010	0.018	0.012	0.013
<b>Total CDD</b>		<b>0.001</b>	<b>0.004</b>	<b>0.370</b>	<b>0.125</b>	<b>14.12</b>	<b>22.77</b>	<b>11.48</b>	<b>16.12</b>
<b>FURANS</b>									
2378 TCDF	0.10000	0.006	0.006	0.052	0.021	2.798	3.573	2.006	2.792
Other TCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDF	0.05000	(0.001)	0.002	0.027	0.010	1.636	2.589	1.147	1.790
23478 PCDF	0.50000	0.046	0.048	0.854	0.316	28.617	54.387	19.117	34.040
Other PCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	0.10000	0.021	0.014	0.355	0.130	11.254	15.840	7.974	11.689
123678 HxCDF	0.10000	0.007	0.005	0.118	0.043	3.151	4.690	2.418	3.420
234678 HxCDF	0.10000	0.016	0.011	0.270	0.099	4.252	6.962	3.445	4.886
123789 HxCDF	0.10000	[0.004]	[0.003]	0.009	0.009	0.088	0.179	(0.072)	0.113
Other HxCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.01000	(0.002)	0.002	0.048	0.017	0.391	0.696	0.495	0.527
1234789-HpCDF	0.01000	[0.000]	0.001	0.011	0.006	(0.027)	0.053	0.044	0.042
Other Hepta-CDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDF	0.00100	0.000	0.000	0.011	0.004	0.005	0.008	0.006	0.007
<b>TOTAL CDF</b>		<b>0.099</b>	<b>0.089</b>	<b>1.75</b>	<b>0.65</b>	<b>52.22</b>	<b>88.98</b>	<b>36.73</b>	<b>59.31</b>
<b>TOTAL CDD+CDF</b>		<b>0.100</b>	<b>0.093</b>	<b>2.12</b>	<b>0.77</b>	<b>66.34</b>	<b>111.75</b>	<b>48.21</b>	<b>75.43</b>

<sup>a</sup> North Atlantic Treaty Organization, Committee on the Challenges of Modern Society. Pilot Study on International Information Exchange on Dioxins and Related Compounds: International Toxicity Equivalency Factor (I-TEF) Methods of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Report No. 176, August 1988.

<sup>b</sup> Standard conditions are defined as 1 atm and 68 °F.

[ ] = Minimum Detection Limit.

( ) = Estimated maximum Possible Concentration

Detection limits are considered zeros for calculating averages.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

TABLE 2-68. CDD/CDF FLUE GAS CONCENTRATIONS CORRECTED TO 7% O<sub>2</sub> DURING THE BURNDOWN CONDITION (RUNS 2, 4, & 6); INCORPORATING THE TOLUENE RECOVERY RESULTS; JORDAN HOSPITAL (1991)

CONGENER	INLET CONCENTRATION (ng/dscm, adjusted to 7 percent O <sub>2</sub> ) <sup>a</sup>				OUTLET CONCENTRATION (ng/dscm, adjusted to 7 percent O <sub>2</sub> )			
	RUN 2	RUN 4	RUN 6	AVERAGE	RUN 2	RUN 4	RUN 6	AVERAGE
<b>DIOXINS</b>								
2378 TCDD	(0.058)	(0.182)	1.367	0.536	1.379	(1.476)	0.718	1.191
Other TCDD	0.029	12.204	11.078	7.770	456.572	457.644	259.906	391.374
12378 PCDD	[0.019]	1.039	5.923	3.481	10.833	14.762	4.910	10.168
Other PCDD	(0.079)	25.613	32.415	19.369	633.250	699.846	370.951	568.016
123478 HxCDD	[0.027]	1.991	7.123	4.557	5.613	9.359	2.833	5.935
123678 HxCDD	0.022	3.808	7.395	3.742	8.568	14.700	4.736	9.335
123789 HxCDD	[0.019]	5.366	13.632	9.499	14.477	25.519	7.941	15.979
Other HxCDD	0.007	36.709	61.980	32.899	266.806	467.397	152.417	295.540
1234678-HpCDD	0.086	31.437	111.014	47.513	16.348	33.386	10.993	20.242
Other Hepta-CDD	0.000	0.000	1.441	0.720	29.741	54.261	16.866	33.623
Octa-CDD	0.356	54.414	375.265	143.345	5.909	11.092	4.235	7.079
<b>Total CDD</b>	<b>0.637</b>	<b>172.76</b>	<b>628.63</b>	<b>267.34</b>	<b>1449.50</b>	<b>1789.44</b>	<b>836.50</b>	<b>1358.48</b>
<b>FURANS</b>								
2378 TCDF	0.058	2.858	10.282	4.399	15.963	15.837	7.957	13.252
Other TCDF	0.663	139.114	258.871	132.883	897.956	818.814	501.966	739.579
12378 PCDF	(0.036)	3.029	35.793	12.953	21.961	28.337	10.764	20.354
23478 PCDF	0.079	7.271	31.954	13.101	37.423	61.991	16.628	38.681
Other PCDF	0.324	63.192	393.556	152.358	547.263	801.045	286.146	544.818
123478 HxCDF	0.173	22.512	146.041	56.242	71.596	113.281	34.590	73.156
123678 HxCDF	0.058	7.533	75.567	27.719	21.174	33.009	10.397	21.527
234678 HxCDF	0.112	16.973	69.579	28.888	29.545	46.848	12.874	29.755
123789 HxCDF	[0.019]	1.125	6.039	3.582	0.847	1.474	0.415	0.912
Other HxCDF	0.324	61.809	521.227	194.453	180.162	264.390	81.751	175.435
1234678-HpCDF	0.317	30.575	243.461	91.451	26.590	51.698	14.003	30.764
1234789-HpCDF	0.245	7.703	51.658	19.869	1.773	3.655	(1.172)	2.200
Other Hepta-CDF	0.807	19.651	184.680	68.379	15.462	29.119	8.498	17.693
Octa-CDF	1.153	65.467	554.891	207.170	2.757	5.587	2.077	3.474
<b>TOTAL CDF</b>	<b>4.35</b>	<b>448.81</b>	<b>2583.60</b>	<b>1012.25</b>	<b>1870.47</b>	<b>2275.08</b>	<b>989.24</b>	<b>1711.60</b>
<b>TOTAL CDD+CDF</b>	<b>4.99</b>	<b>621.58</b>	<b>3212.23</b>	<b>1279.60</b>	<b>3319.97</b>	<b>4064.53</b>	<b>1825.75</b>	<b>3070.08</b>

<sup>a</sup> Standard conditions are defined as 1 atm and 68 °F.

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Concentration.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

TABLE 2-69. CDD/CDF FLUE GAS TOXIC EQUIVALENCIES CORRECTED TO 7% O<sub>2</sub> FOR THE BURNDOWN CONDITION (RUNS 2, 4, & 6) INCORPORATING THE TOLUENE RECOVERY RESULTS; JORDAN HOSPITAL (1991)

CONGENER	2378-TCDD TOXIC EQUIV. FACTOR <sup>a</sup>	INLET 2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O <sub>2</sub> ) <sup>b</sup>				OUTLET 2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O <sub>2</sub> )			
		RUN 2	RUN 4	RUN 6	AVERAGE	RUN 2	RUN 4	RUN 6	AVERAGE
<b>DIOXINS</b>									
2378 TCDD	1.00000	(0.058)	(0.182)	1.367	0.536	1.379	(1.476)	0.718	1.191
Other TCDD	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDD	0.50000	[0.010]	0.519	2.961	1.740	5.416	7.381	2.455	5.084
Other PCDD	0.00000	(0.000)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.10000	[0.003]	0.199	0.712	0.456	0.561	0.936	0.283	0.594
123678 HxCDD	0.10000	0.002	0.381	0.740	0.374	0.857	1.470	0.474	0.933
123789 HxCDD	0.10000	[0.002]	0.537	1.363	0.950	1.448	2.552	0.794	1.598
Other HxCDD	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.01000	0.001	0.314	1.110	0.475	0.163	0.334	0.110	0.202
Other Hepta-CDD	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDD	0.00100	0.000	0.054	0.375	0.143	0.006	0.011	0.004	0.007
<b>Total CDD</b>		<b>0.061</b>	<b>2.187</b>	<b>8.629</b>	<b>3.626</b>	<b>9.830</b>	<b>14.160</b>	<b>4.838</b>	<b>9.609</b>
<b>FURANS</b>									
2378 TCDF	0.10000	0.006	0.286	1.028	0.440	1.596	1.584	0.796	1.325
Other TCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDF	0.05000	(0.002)	0.151	1.790	0.648	1.098	1.417	0.538	1.018
23478 PCDF	0.50000	0.040	3.635	15.977	6.551	18.712	30.996	8.314	19.340
Other PCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	0.10000	0.017	2.251	14.604	5.624	7.160	11.328	3.459	7.316
123678 HxCDF	0.10000	0.006	0.753	7.557	2.772	2.117	3.301	1.040	2.153
234678 HxCDF	0.10000	0.011	1.697	6.958	2.889	2.954	4.685	1.287	2.976
123789 HxCDF	0.10000	[0.002]	0.113	0.604	0.358	0.085	0.147	0.042	0.091
Other HxCDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.01000	0.003	0.306	2.435	0.915	0.266	0.517	0.140	0.308
1234789-HpCDF	0.01000	0.002	0.077	0.517	0.199	0.018	0.037	(0.012)	0.022
Other Hepta-CDF	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDF	0.00100	0.001	0.065	0.555	0.207	0.003	0.006	0.002	0.003
<b>TOTAL CDF</b>		<b>0.088</b>	<b>9.335</b>	<b>52.02</b>	<b>20.48</b>	<b>34.01</b>	<b>54.02</b>	<b>15.63</b>	<b>34.55</b>
<b>TOTAL CDD+CDF</b>		<b>0.150</b>	<b>11.522</b>	<b>60.65</b>	<b>24.11</b>	<b>43.84</b>	<b>68.18</b>	<b>20.47</b>	<b>44.16</b>

<sup>a</sup> North Atlantic Treaty Organization, Committee on the Challenges of Modern Society. Pilot Study on International Information Exchange on Dioxins and Related Compounds: International Toxicity Equivalency Factor (I-TEF) Methods of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Report No. 176, August 1988.

<sup>b</sup> Standard conditions are defined as 1 atm and 68°F.

[ ] = Minimum Detection Limit.

NOTE: Inlet oxygen measurements were made upstream of the CDD/CDF sample port and may have been lower than the actual value encountered at the sample location.

The associated inlet CDD/CDF oxygen corrected values may be biased slightly low as well.

### 3. PROCESS DESCRIPTION AND SUMMARY OF PROCESS OPERATION DURING TESTING AT JORDAN HOSPITAL

#### 3.1 INTRODUCTION

Jordan Hospital is a 162-bed hospital located in Plymouth, Massachusetts. The medical waste incinerator (MWI) at this facility is a batch-burn Simonds Model 2151B. The MWI system at Jordan Hospital also has a heat exchanger for flue gas cooling, a baghouse for particulate matter (PM) removal, and a packed-bed scrubber for acid gas removal that was designed and installed by B. G. Wickburg Company. The hot gas from the incinerator is drawn by means of the main blower through a heat exchanger, where it is cooled below 204°C (400°F) before passing through the baghouse. After moving through the main blower and the automatic controlled damper system, which is used to maintain a uniform draft in the primary chamber, the gas passes through the packed-bed wet scrubber, the cold side of the heat exchanger, and then out the stack.

The following sections describe the MWI system as tested and the process operations during the pretest and actual testing. Section 3.2 describes the incinerator, the heat exchanger, the baghouse, the main blower, and the packed-bed scrubber; provides a description of the hospital waste management practices; and describes the typical daily operation of the system by the operators. Section 3.3 discusses the pretest activities deemed necessary to ensure the success of the test program. Finally, Section 3.4 describes the process conditions encountered during testing.

#### 3.2 PROCESS DESCRIPTION

##### 3.2.1 Incinerator

The Simonds Model 2151B is a dual-chamber, controlled-air, batch-burn MWI. The rectangular primary chamber has a volume of 6.1 cubic meters (m<sup>3</sup>) (215 cubic feet [ft<sup>3</sup>]) and operates in a starved-air mode. The combustion air is injected into the primary chamber through 28 air injection ports distributed evenly around the side and back walls 15 centimeters (cm) (6 inches [in]) above the hearth and another 8 air injection ports evenly spaced from front to back in a straight line down the center of the hearth. The waste is charged to the primary chamber one time for each complete incineration cycle. The primary chamber is fully loaded to within 15 cm (6 in) of the top while also leaving a 15 cm (6 in) clearance channel between the primary chamber burner

and the waste bed. The combustion air modulates between either high or low flow according to preset timers and the temperature in the primary chamber. One natural gas-fired burner in the primary chamber ignites the waste charge once a preset temperature has been reached in the secondary chamber. The primary chamber burner operates for a small amount of time (typically 60 seconds) according to a preset timer.

The secondary chamber has a volume of 2.60 m<sup>3</sup> (91.7 ft<sup>3</sup>) and is operated in an excess-air mode. The calculated secondary chamber residence time, according to the permit application form, is 1.16 seconds at 871°C (1600°F). The combustion air for the secondary chamber, which is supplied by the same blower that provides the primary chamber combustion air, is controlled by a manually set valve and remains constant throughout the entire incineration cycle. One natural gas-fired burner in the secondary chamber ignites and shuts off according to a preset timer and, while burning, modulates between either high or low fire according to the secondary chamber temperature.

Seven timers, TD1 through TD7, and two thermocouples control the various processes for incinerating a batch charge of medical waste in this unit. The following is a brief description of a typical incineration cycle for this facility.

After the waste has been loaded and the charge door secured, the incinerator is manually started. When the incinerator is turned on, TD7 (purge timer) starts. This timer starts the combustion air blower, and the primary chamber combustion air goes to high flow to purge any combustible gases from the unit. When TD7 times out (typically 45 seconds), the combustion air blower stops and the secondary chamber burner ignites and modulates to high fire since the secondary chamber temperature is below the high secondary chamber temperature set-point of 1010°C (1850°F). This is the beginning of the preheat cycle. Once the secondary chamber temperature reaches the low secondary chamber temperature set-point of 871°C (1600°F), TD5 (primary ignition timer) starts, the primary chamber burner fires, the combustion air blower starts, and the primary chamber combustion air modulates to low flow. This is the beginning of the burn cycle. When TD5 times out (typically 60 seconds), the primary chamber burner turns off and TD6 (pathological on timer) starts. The TD6 timer is used to ignite the primary chamber burner if the pathological waste switch is in the on position and to time the actual burn cycle no matter what position the pathological switch is in. (The

pathological switch was in the off position for the three test runs performed at Jordan Hospital). When TD6 times out (typically 6.5 hours), TD3 (carburetor extend timer) and TD4 (pathological duration timer) start. The TD4 timer is used to set the amount of time that the primary chamber burner stays on if the pathological switch is in the on position. If the pathological switch is in the off position, TD4 still times, but the primary chamber burner does not fire. When TD3 times out (typically 30 minutes), the primary chamber combustion air changes to the high flow setting if the primary chamber temperature is still below the high primary chamber temperature set-point of 677°C (1250°F), TD2 (carburetor off timer) starts, and the burndown cycle begins.

During the burndown cycle, the primary chamber combustion air modulates between either high or low flow, depending on whether the primary chamber temperature is below or above the high primary chamber temperature set-point. The secondary chamber burner modulates between either high or low fire, depending on whether the secondary chamber temperature is below or above the high secondary chamber temperature set-point. When TD2 times out (typically 5.3 hours), the secondary chamber burner turns off, and TD1 (shutdown timer) starts. This is the beginning of the cooldown cycle.

During the cooldown cycle, all burners are turned off, the combustion air blower remains on, and the primary chamber combustion air modulates between either high or low flow, depending on the primary chamber temperature. When TD1 times out (typically 10.25 hours), the combustion air blower turns off and all timers are reset for the next burn.

### 3.2.2 Heat Exchanger

A shell and tube air-to-air heat exchanger is used to cool the flue gases leaving the secondary chamber before they enter the baghouse. These gases are at a temperature of about 871°C (1600°F) to 982°C (1800°F) and are cooled to 185°C (365°F) to 204°C (400°F) by the 54°C (130°F) flue gases exiting the wet scrubber. The flue gases from the packed-bed scrubber are warmed to about 149°C (300°F) and then passed out the stack. If the heat exchanger exit temperature climbs above the temperature set-point of 182°C (360°F), a water spray is started in order to drop the flue gas temperature.

### 3.2.3 Baghouse

A pulse-jet, single-chamber horizontal baghouse with 36 P-84 bags is used to remove PM from the flue gases. The outer shell of the baghouse is made of 316L stainless steel. The baghouse is designed to operate at 177°C (350°F) with a maximum temperature excursion to 260°C (500°F). Six rows of six bags each collect PM on the outside of each bag. The compressed-air pulse cleaning system is composed of a row of six tubes, each controlled by a diaphragm, self-piloted valve, to blow the dust off the bags and into a bottom chute, and another valve and control solenoid to blow the dust down the bottom chute towards the cleanout door. The system was programmed so that the pulse jet solenoids operated at 30-second intervals once the baghouse pressure drop exceeded 0.5 kilopascals (kpa) (2 inches of water column [in w.c.]). The total cleaning time for the baghouse should have been 3.5 minutes; however, the system was mistakenly programmed for a total of eight solenoids and a total cleaning time of 4 minutes. The cleaning system should maintain a differential pressure of less than 1.5 kpa (6 in. w.c.) across the baghouse. Also, in order to protect the baghouse against high temperatures, a temperature-controlled air damper is used. If the baghouse inlet temperature exceeds the temperature set-point of 204°C (400°F), the baghouse air damper opens, allowing ambient air in to cool the flue gases. If the baghouse inlet temperature remains above the set-point temperature for more than 2 minutes, the bypass valve opens, the main blower turns off, and the flue gases go directly to the stack.

### 3.2.4 Main Blower

A centrifugal blower is used to provide the air movement as an induced draft fan for the two combustion chambers, the hot side of the heat exchanger, and the baghouse and as a forced draft fan for the wet scrubber, the cold side of the heat exchanger, and the stack. An automatic controlled damper at the outlet of the fan is used to maintain a uniform draft in the primary chamber. The blower was designed for a capacity of 42.5 dry standard cubic meters per minute (dscmm) (1,500 dry standard cubic feet per minute [dscfm]) at 2.7 kpa (11 in w.c.) and a speed of 1,200 revolutions per minute (rpm).

### 3.2.5 Packed-Bed Scrubber

A horizontal packed-bed crossflow scrubber is used to remove acid gases. The scrubber shell is made of fiberglass and consists of two removal sections and one demister section with each section being 71 cm (28 in) in diameter and comprised of kimre woven polypropylene packing. The two removal sections are each 15 cm (6 in) thick and the demister section is 10 cm (4 in) thick. At the entrance to the scrubber, a water spray is used to cool the flue gases by evaporation. The amount of water spray is adjustable with a manual valve. The temperature of the flue gas is monitored just after the water spray before entering the first removal section. If this temperature is above the scrubber inlet temperature set-point of 80°C (176°F) for more than 2 minutes, the bypass valve opens, the main blower turns off, and the flue gases go directly to the stack. The two front removal beds have a manifold that houses four nozzles that spray a liquid solution onto and against the bed at a rate of approximately 208 liters per minute (ℓ/min) (55 gallons per minute [gal/min]). B.G. Wickburg claims that the design liquid-to-gas contact time is adequate for the liquid to remove the hydrochloric acid (HCl) to a level in excess of 97.5 percent, or below 20 parts per million (ppm). The liquid solution is held in three polypropylene tanks directly below the scrubber and consists of a mixture of salts, caustic soda, and water maintained at a design pH of 6.5 to 9.5. The pH is controlled by the injection of caustic soda into the end tank which is controlled according to a pH sensor located in the middle tank. All these tanks are connected by overflow pipes. According to the representative from B.G. Wickburg, three tanks were used instead of one due to space limitations. This solution is pumped by the main pump throughout the system. A manual bleed to the sewer to the left of the return tank of up to 11 ℓ/min (3 gal/min) controls the buildup of salts in the system. The tanks are maintained at an appropriate level as determined by hydraulic conditions.

### 3.2.6 Waste Management Practices

The waste materials are collected by the hospital housekeeping staff. The red bag, or infectious, waste is collected from all patient contact areas including patient rooms, examination rooms, operating and recovery rooms, and laboratories. This red bag waste is composed of drugs and chemicals; patient contact items such as disposable garments, dressings, and disposable surgical tools; sharps; diagnostic devices; and human

tissue. Pathological waste is estimated to be from 5 to 10 percent of the total waste weight. Only red bag wastes and sharps containers are fed into the incinerator.

The non-red bag wastes such as cafeteria and office wastes are placed in standard 30-gallon plastic trash bags and placed in a dumpster.

### 3.2.7 Typical Daily Operation

The hospital maintenance staff is responsible for operating the MWI. The typical hours of supervised operation are from 7:00 to 15:00 and consist of charging the incinerator in the morning (approximately 20 minutes), starting the incinerator, and occasionally monitoring key parameters to make sure the unit is operating properly. The time required for the entire burn, which includes the preheat cycle, the burn cycle, the burndown cycle, and the cooldown cycle, is approximately 24 hours. At the end of the burn, the primary and secondary chamber temperatures are approximately 288°C (550°F). At these temperatures, the charge door can be opened, but the MWI is too hot for the ash to be removed or another waste charge to be added. Typically the incinerator is fired three times a week (about every other day) with the ash being removed only once a week. The ash is then put into red bags, placed into boxes, and shipped to a medical waste disposal facility.

## 3.3 PRETEST ACTIVITIES

A pretest was conducted on March 1, 1991, to determine the operational readiness of the incinerator and the ability of the incinerator to operate successfully at the desired conditions of feed rate and temperature. The test conditions were the design burning rate of a nominal 340 kilograms (kg) (750 pounds [lb]) per batch of mixed Type 0-4 waste with a secondary chamber temperature set-point of 982°C (1800°F).

For the pretest on March 1, 1991, 318.4 kg (702 lb) of waste were loaded into the primary chamber, and the unit was started at 13:30. At 14:37, the secondary chamber had reached the low secondary chamber set-point temperature of 871°C (1600°F), and the primary chamber burner fired for 60 seconds. At 14:38, the primary chamber burner turned off and TD6 started, which was the beginning of the burn cycle. At 21:10, 6 hours and 32 minutes later, TD6 timed out and TD4 started. At 21:36, TD4 timed out and TD2 started. This was the end of the burn cycle, which lasted 6 hours and 58 minutes, and the beginning of the burndown cycle. At this time, the primary chamber air

changed to the high flow rate because the primary chamber temperature was below the low primary chamber set-point of 621°C (1150°F). At 02:04 on March 2, 1991, TD2 timed out, TD1 started, and the secondary chamber burner turned off. This was the end of the burndown cycle, which lasted 4 hours and 28 minutes, and the beginning of the cooldown cycle. During the cooldown cycle, both the primary and secondary chamber burners were off, and the combustion air remained on in both chambers. The primary chamber combustion air, however, was still controlled between high and low flow based on the temperature in that chamber. At 12:20, the cooldown cycle was completed, and the unit shut down.

During the preheat cycle, while the secondary chamber temperature was below 871°C (1600°F), the main blower was not operating and there was no draft in the primary chamber. The heat and flames from the secondary chamber ignited some of the waste in the primary chamber, however, which caused considerable smoking from around the charge door seals and the primary chamber burner.

During the burn cycle, the temperature in the primary chamber increased slowly from 121°C (250°F) to 566°C (1050°F). The temperature in the secondary chamber increased from 871°C (1600°F) to 982°C (1800°F) and was maintained at that temperature by the secondary chamber burner's switching between high and low fire.

At the beginning of the burndown cycle (21:36), the primary chamber combustion air switched to the high flow rate and the primary chamber temperature began to increase more rapidly. At 22:21, the primary chamber temperature reached 621°C (1150°F), and the primary combustion air switched back to the low flow rate. The primary chamber temperature then continued to increase slowly until reaching 704°C (1300°F) at 02:04, which was the end of the burndown cycle. Also at the beginning of the burndown cycle, the secondary chamber temperature increased until 22:00, when it peaked at about 1093°C (2000°F). The secondary chamber temperature then decreased until 22:26, when it reached 982°C (1800°F), and then cycled between 982°C (1800°F) and 1010°C (1850°F) as the secondary chamber burner cycled between high and low fire.

At 02:04, the beginning of the cooldown cycle, the secondary chamber burner turned off and the secondary chamber temperature began to decrease. At the same time, the primary chamber temperature started to increase. At 03:15 the primary

chamber temperature reached 927°C (1700°F) and started to decline. Both chamber temperatures continued to decrease until 12:20, when the cooldown cycle was over and the unit shut down.

Nils Anderson of Resource Technology Corporation, the company that installed the MWI, recommended an increase in both the time and temperature of the burndown cycle during the actual test program. This recommendation was made because of the rapid increase in the primary chamber temperature during the pretest when the unit changed from the burn cycle to the burndown cycle and when the unit changed from the burndown to the cooldown cycle.

The primary chamber low temperature set-point was changed from 621°C (1150°F) to 677°C (1250°F), and the burndown time was changed from 4 hours 28 minutes to 5 hours 20 minutes. The settings were maintained for the entire test period and were also the recommended operational settings for the hospital to use after the testing program was completed.

#### 3.4 PROCESS CONDITIONS DURING TESTING

The primary purpose of this source test was to characterize uncontrolled and controlled emissions from a batch-fed MWI operating at design conditions with emissions controlled by a fabric filter/packed-bed scrubber. The measurements were repeated in triplicate at the design conditions while the incinerator burned red bag hospital waste.

The incinerator and air pollution control system seemed to operate properly during all three test runs with the exception of the smoking problem from around the door seals. This seemed to be a problem with the main blower and the draft control system's being able to maintain a negative draft in the primary chamber. Also, this problem seemed to be aggravated by the air leakage due to the modifications made to the secondary chamber exhaust section for testing purposes and through the test ports around the test probes during the actual sampling period.

The incinerator and air pollution control system operating parameters monitored during each test run were the charge weight, the primary and secondary chamber temperatures, the incinerator draft, the baghouse inlet temperature, the baghouse pressure drop, the scrubber temperature, the scrubber pH, the scrubber pressure drop, the flameport temperature, the temperatures at various positions within the primary

chamber, the ash weights, the opacity, and the actual times for the various incinerator operating cycles. A data logger was used to record all the above parameters except for the charge weight, the ash weight, the scrubber pH, the baghouse pressure drop, and the opacity, which were manually recorded. Averages for the recorded operating parameters are presented in Table 3-1, and the data sheets documenting the recorded parameters are presented in Appendix B. Figures 3-1 through 3-6 show the data-logged temperature profiles for each run. A summary of each test run is given below.

#### 3.4.1 Test Run 1: March 5, 1991

The loading of the waste into the incinerator for Run 1 began at 08:00 on March 4, 1991. Nine indicator spore pipes with thermocouples placed inside were positioned on the floor of the primary chamber. Also, eight wire mesh indicator spore packages with thermocouples were placed inside the separate indicator spore bags and located within the waste bed (see Figure 3-7). The loading procedure was completed at 12:00, with 326 kg (719 lb) of waste having been loaded into the primary chamber. At this time it was discovered that the automatic data loggers were not operating, and the test was postponed until March 5, 1991. Dry ice was loaded into the primary chamber in order to cool the indicator spores until the test could begin.

The loading process, which normally takes only 20 minutes, took approximately 4 hours due to the careful placement of the thermocouples within the waste so that a three-dimensional temperature profile of the burning waste bed could be obtained. Due to the increased loading time and the increased cooldown time necessary to facilitate the careful placement of the waste bags, Mr. Bill Maxwell of EPA decided to perform this three-dimensional temperature profile test only once. The remaining two tests had the nine thermocouples within the spore pipes on the floor of the incinerator, but no thermocouples were placed within the wire mesh packages.

At 08:33 on March 5, 1991, the automatic data logging system had been repaired, and the MWI was started. The primary chamber low temperature set-point was 371°C (700°F), the primary chamber high temperature set-point was 677°C (1250°F), the secondary chamber low temperature set-point was 871°C (1600°F), the secondary chamber high temperature set-point was 1010°C (1850°F), the baghouse cleaning cycle

Table 3-1. Process Data Summary for Emissions Testing at Jordan Hospital

Test Run No.	Test Date	Target Conditions			Daily Operation			Actual Test Conditions (a)					
		Charge Rate (lb/batch)	Secondary Chamber Temp (F)	Total Waste Charged (lb/batch)	Ash (% of Waste Charged)	Avg Primary Chamber Temp (F)	Avg Sec. Chamber Temp (F)	Inlet		Outlet		Avg. gas Res. time in Sec. Chamb (b) (sec)	
1	3/05/91	750	1800	719.1	9.8	653	1788	2758	1171	2025	178		1.45
2	3/05/91		1800			1196	1866	2434	1102	2150	185	1.52	
3	3/07/91	750	1800	702.2	13.5	600	1789	2439	1208	1942	189	1.67	
4	3/07/91		1800			1205	1846	2010	1152	1838	190	1.91	
5	3/09/91	750	1800	729.4	8.3	640	1799	2214	1153	1853	174	1.77	
6	3/09/91		1800			1197	1922	1806	1226	1489	176	2.16	

(a) Includes port changes and times for all trains; not just the method 5 trains.

(b) Residence time is based on the secondary chamber volume of 2.60 m<sup>3</sup> (91.7 ft<sup>3</sup>) and is calculated as follows for Run 1:

$$\text{Res. time, sec} = \frac{(91.7 \text{ ft}^3)(60 \text{ s/min})(1171 + 460 \text{ R})}{(2758 \text{ acfm})(1788 + 460 \text{ R})}$$

# TEMPERATURE PROFILE FOR JORDAN HOSPITAL

RUN 1 BURN (3 - 05 - 91)

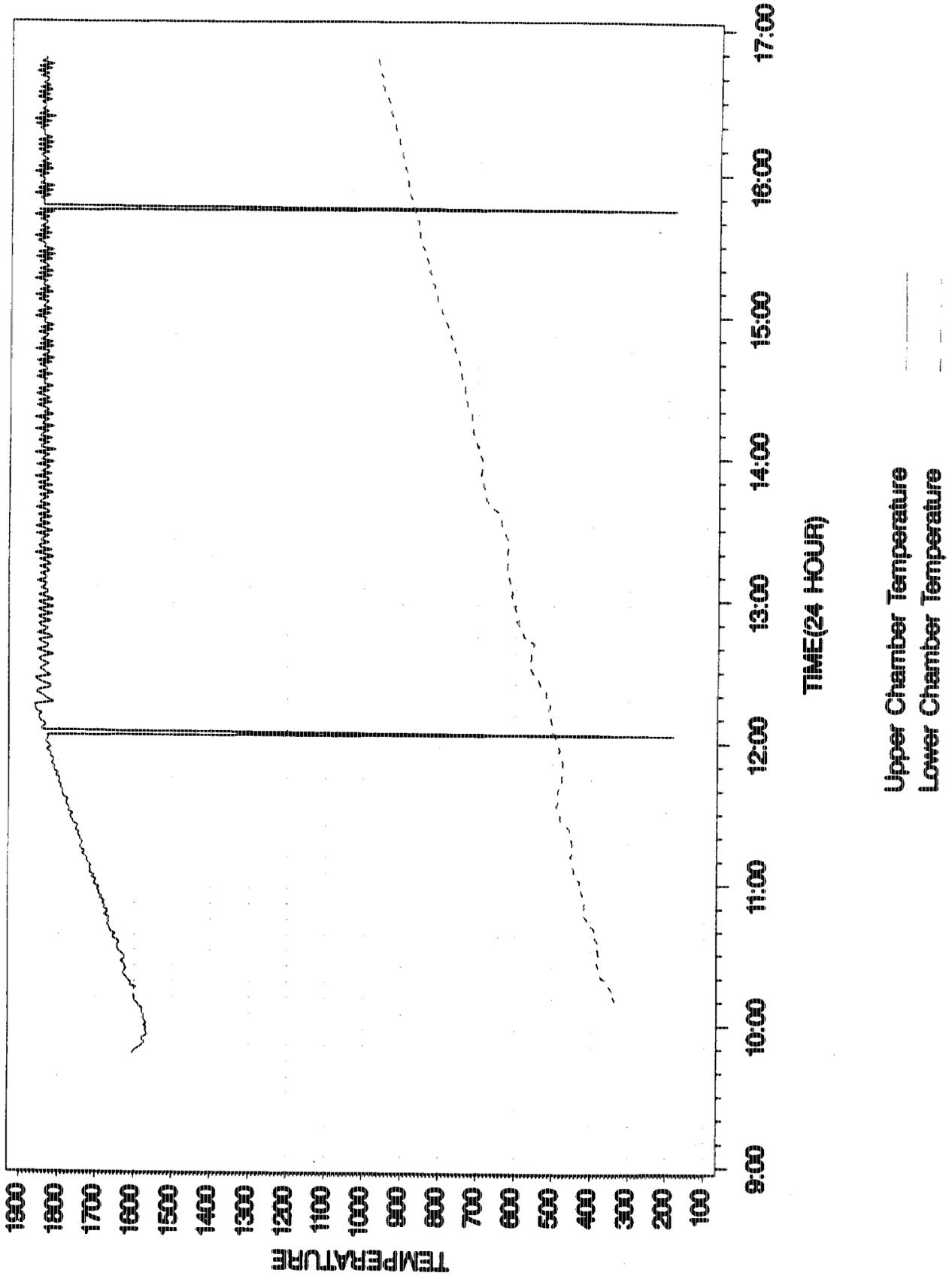
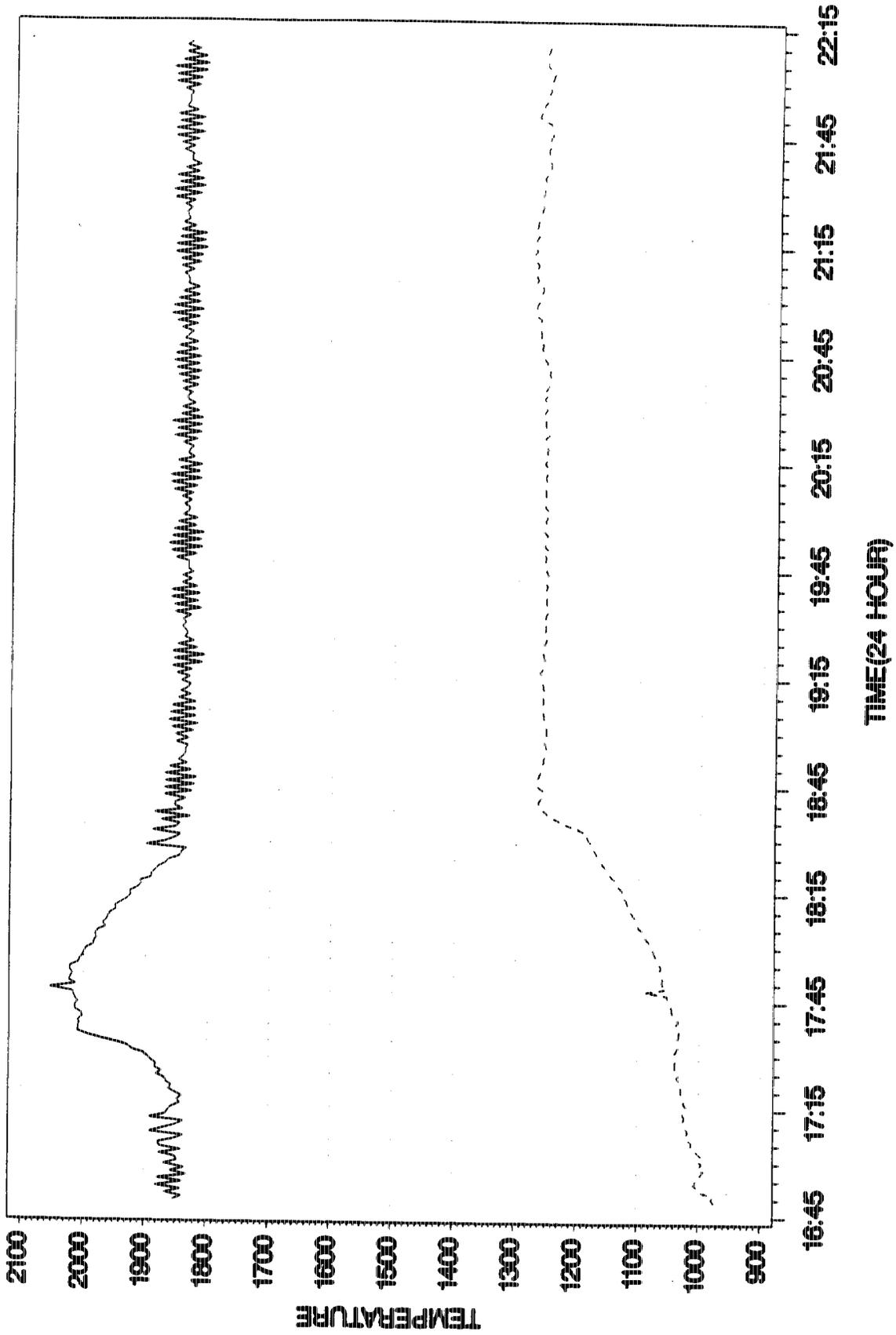


Figure 3 - 1. Temperature Profile for Run 1

# TEMPERATURE PROFILE FOR JORDAN HOSPITAL

RUN 2 BURNDOWN (3-05-91)



Upper Chamber Temperature  
Lower Chamber Temperature

Figure 3 -- 2. Temperature Profile for Run 2

# TEMPERATURE PROFILE FOR JORDAN HOSPITAL

RUN 3 BURN (3-07-91)

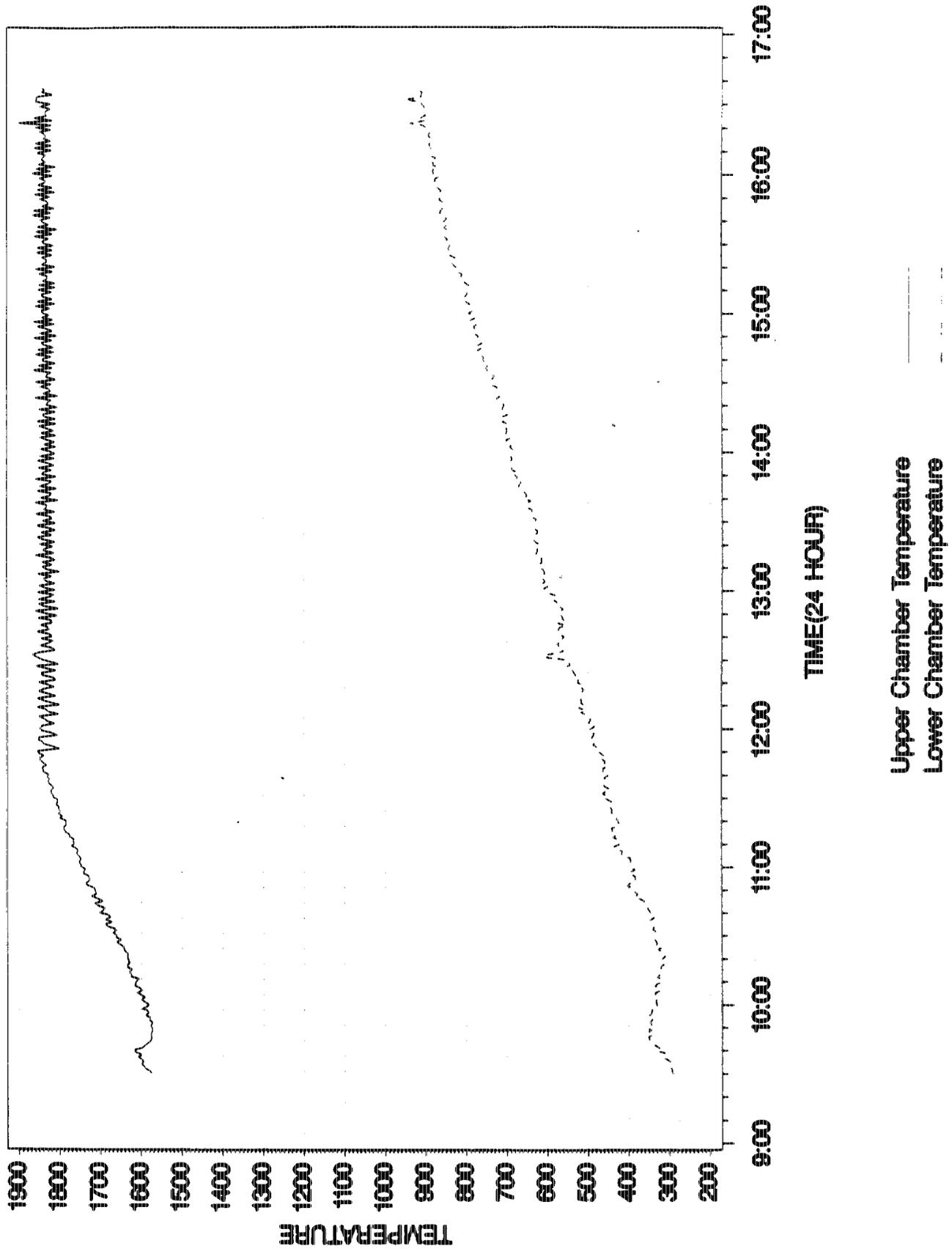
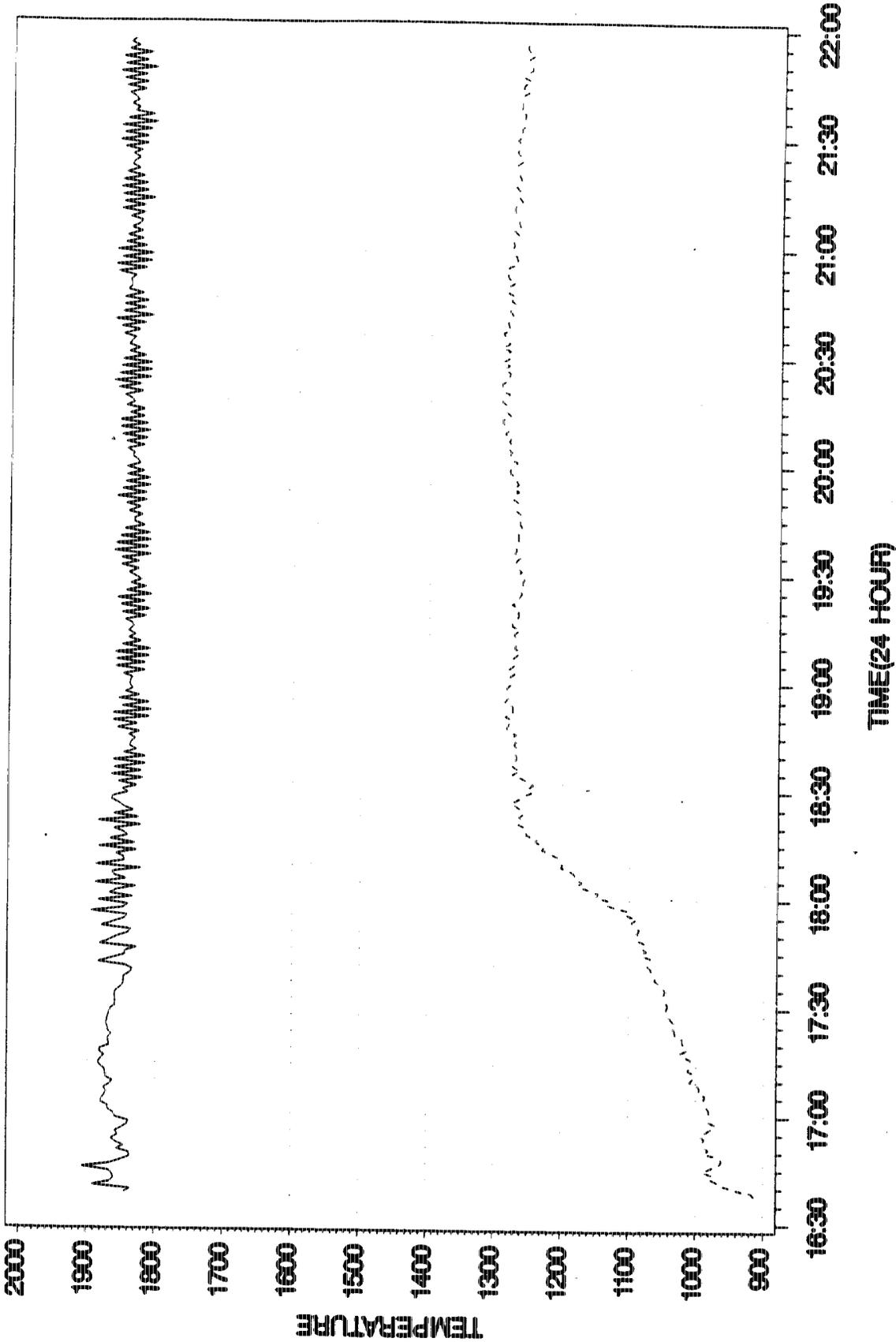


Figure 3-3 Temperature Profile for Run 3

# TEMPERATURE PROFILE FOR JORDAN HOSPITAL

RUN 4 BURNDOWN (3-07-91)

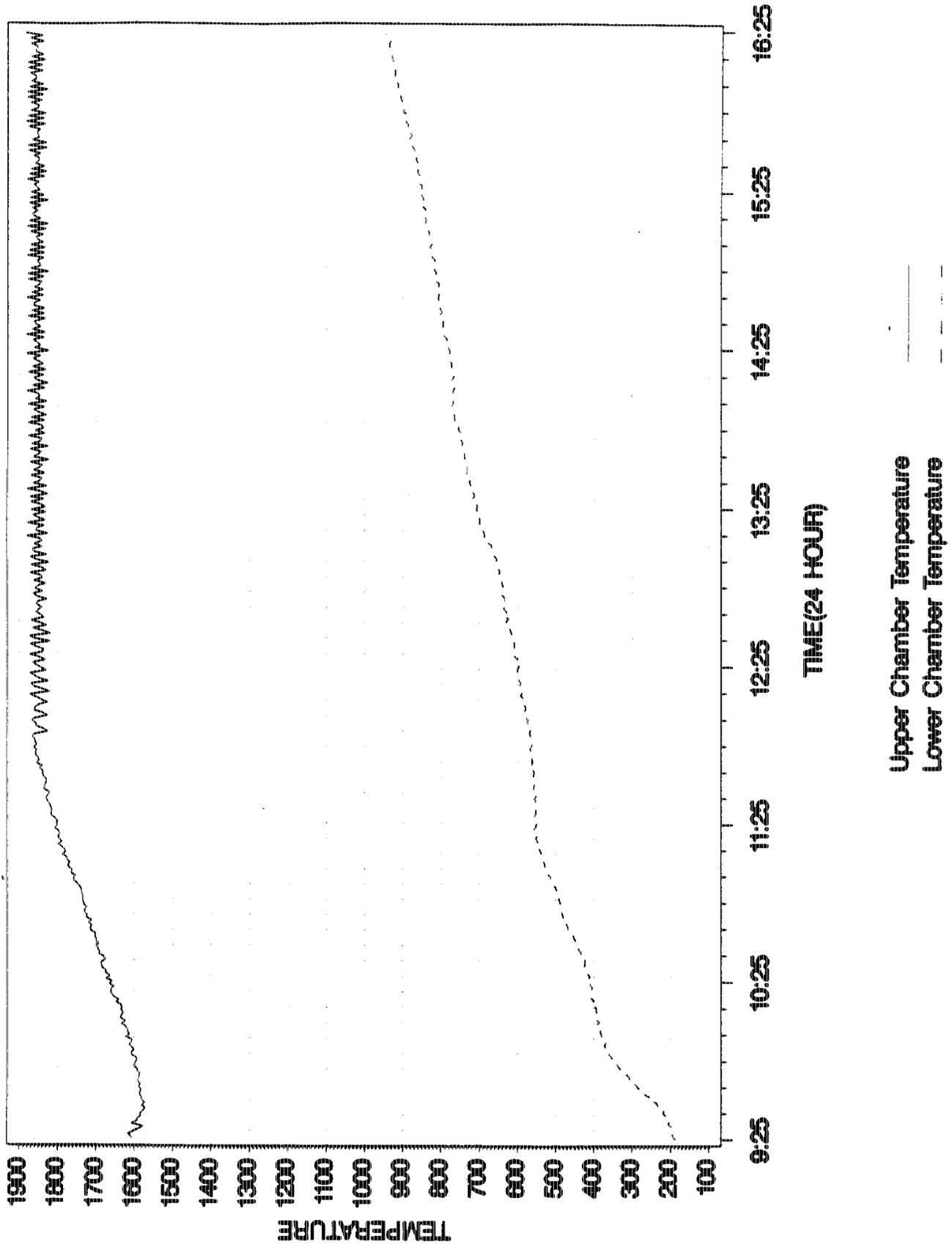


Upper Chamber Temperature  
Lower Chamber Temperature

Figure 3 - 4. Temperature Profile for Run 4

# TEMPERATURE PROFILE FOR JORDAN HOSPITAL

RUN 5 BURN (3 - 08 - 91)



Upper Chamber Temperature  
Lower Chamber Temperature

Figure 3 - 5 Temperature Profile for Run 5

# TEMPERATURE PROFILE FOR JORDAN HOSPITAL

## RUN 6 BURNDOWN (3-08-91)

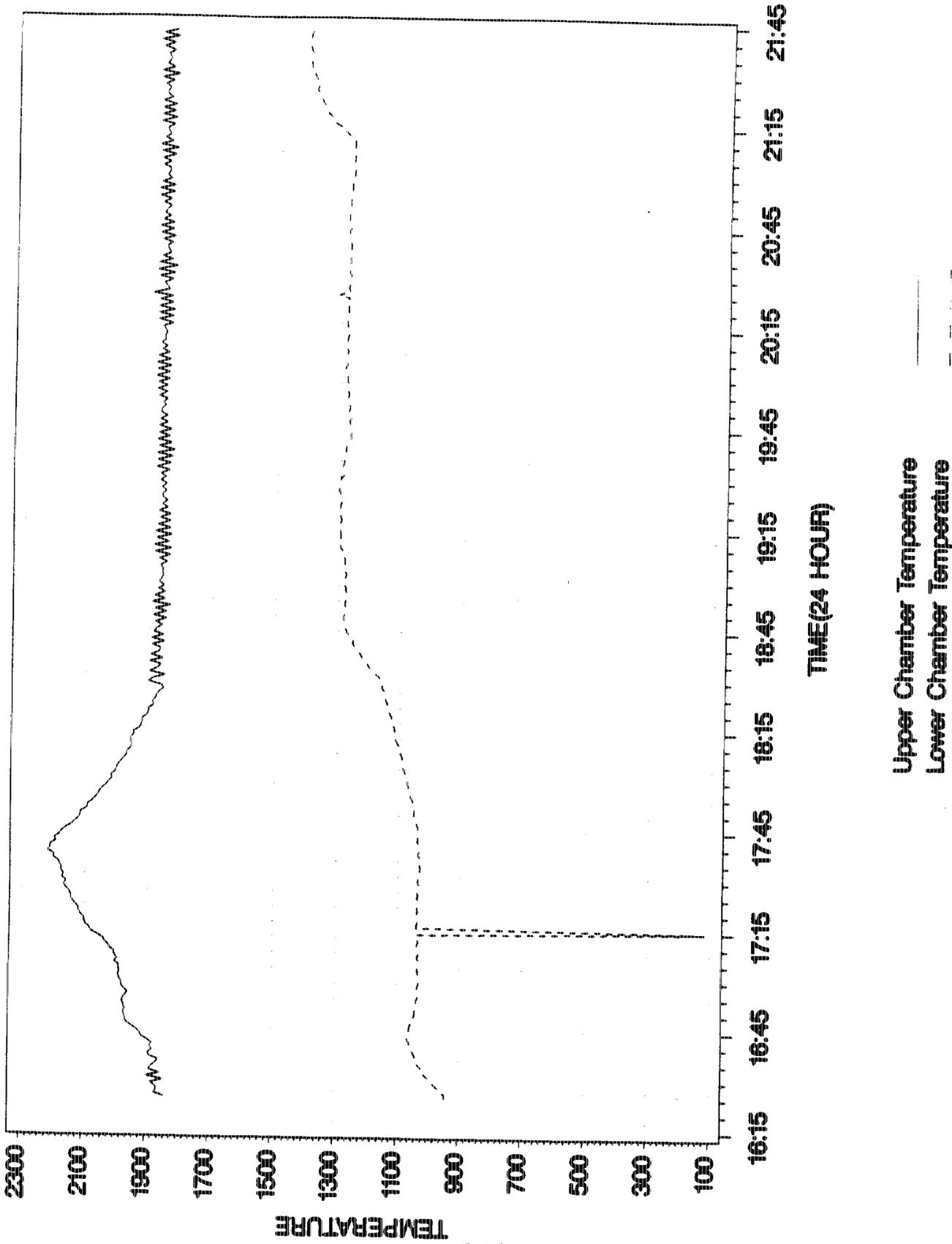
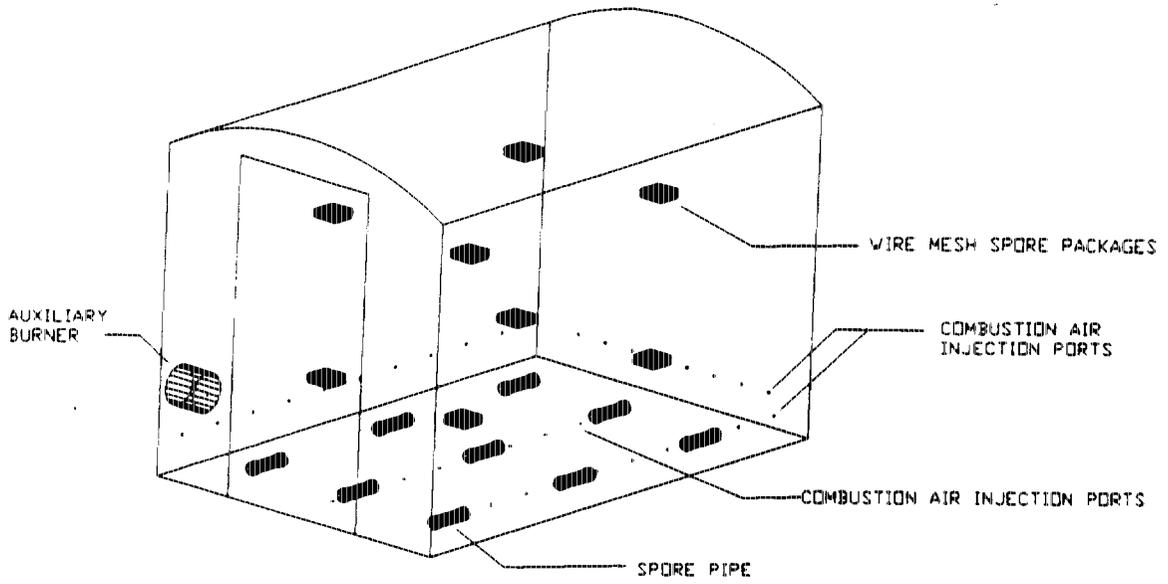
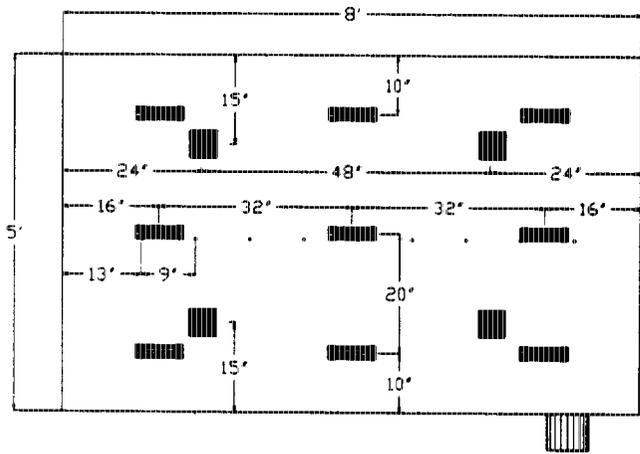


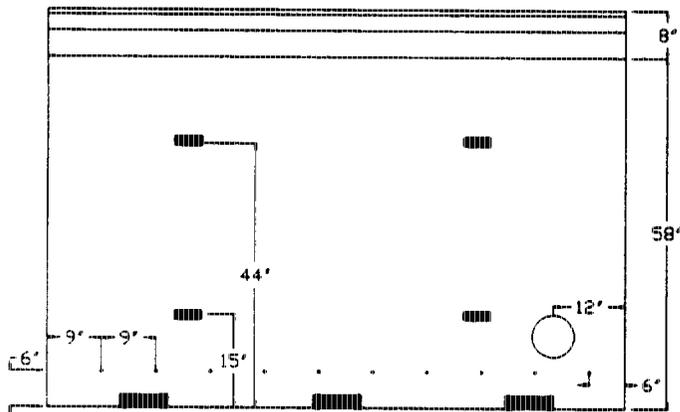
Figure 3-6 Temperature Profile for Run 6



ISOMETRIC VIEW



PLAN VIEW



SIDE VIEW

Figure 3-7. Spore Placement Diagram  
3-17

was 30 seconds, the baghouse inlet temperature set-point was 204°C (400°F), the heat exchanger exit temperature set-point was 185°C (365°F), the scrubber temperature set-point was 80°C (176°F), and the timer set-points were as follows: TD1 = 10, TD2 = 5.5, TD3 = 2.0, TD4 = 3.5, TD5 = 3.75, TD6 = 6.5, and TD7 = 2.5.

A considerable amount of smoke came from around the charge door seals and the primary chamber burner while the secondary chamber temperature was below 871°C (1600°F) during the preheat cycle.

At 09:46, the secondary chamber temperature reached 873°C (1603°F) and TD5 started. The TD5 timer timed out 60 seconds later, and the primary burner did not light. Therefore, the timer was reset by unplugging and replugging it. At this time, the primary burner fired and burned for 60 seconds until TD5 timed out again. This was the beginning of the burn cycle and the burn cycle testing.

At approximately 12:20, the secondary chamber temperature reached 1010°C (1850°F), and the secondary chamber burner changed to low fire. The secondary chamber temperature then began to cycle between 982°C (1800°F) and 1010°C (1850°F) as the secondary chamber burner cycled between high and low fire. Also at this time, the primary chamber draft cycled between -0.07 and +0.12 kpa (-0.3 and +0.5 in. w.c.). When the primary chamber draft changed to positive, smoke leaked from around the charge door and the primary chamber burner. Apparently, when the secondary chamber burner changed to high fire, the main blower could not remove all the flue gases until the control damper had opened sufficiently. Once the control system recognized the positive pressure in the primary chamber, the damper opened, the primary chamber draft increased, and the smoking stopped. Also, if ports were left open, or the port area around the probes was not sealed tightly, the smoking was much worse. The smoking problem also occurred during the pretest, when no testing was being performed, but seemed to be in smaller amounts. Increased diligence was exercised in keeping the test ports sealed during the remainder of the test program.

At 16:49, the burn cycle ended and the burndown cycle began. At this time, the primary chamber air flow, which up until this point had been in low flow, changed to high flow, and the smoking from the doors and primary burner increased. Apparently, when the primary chamber blower is on high flow and the secondary chamber burner is

on high fire, the main blower cannot remove all the flue gases and maintain a negative draft in the primary chamber even when the control damper is at the full open setting. This smoking problem then cycled on and off as the secondary chamber cycled between high and low fire until 18:45, when the primary chamber temperature climbed above 677°C (1250°F) and the primary chamber combustion air changed to low flow. At this time, the ID fan and control damper were able to maintain a slightly negative draft and control the smoking problem fairly well.

At 22:11, the burndown cycle ended and the cooldown cycle began. At 08:30 on March 6, 1991, the cooldown cycle ended and the unit shut down. The incinerator door was opened at 08:35, and the main blower was turned on to help cool the incinerator more quickly. A white to gray ash covered the hearth to a depth of 5 to 10 cm (2 to 4 in) with one small clump of smoldering material. The burnout appeared to be very good.

At 15:20, the ash cleanout began. A small amount of water was sprayed onto the ash bed to minimize the dust. The total weight of the ash removed was 31.91 kg (70.34 lb).

Once the incinerator had been cleaned, nine indicator spore pipes with thermocouples were placed on the hearth in preparation for Run 2.

#### 3.4.2 Test Run 2: March 7, 1991

The loading of the waste into the incinerator for Run 2 began at 07:30 on March 7, 1991, and 318.5 kg (702.21 lb) of waste were loaded. Nine indicator spore pipes with thermocouples were on the floor of the incinerator. The eight wire mesh indicator spore packages, however, were inadvertently left out of the spore bags during the loading procedure. See Figure 3-7 for the location of the pipes.

At 08:27, the incinerator was started and the preheat cycle began. All the setpoints were the same as those for Run 1 except that TD5 was increased from 3.75 to 7.5. This was due to the primary chamber burner not igniting before TD5 had timed out in Run 1.

During the preheat cycle, before the burn cycle began, there was smoke coming from around the door seals and the primary chamber burner. At 09:36, the secondary

chamber temperature reached 872°C (1602°F), TD5 started, the primary chamber burner fired for 120 seconds, and the burn cycle began.

At approximately 11:45, the secondary chamber temperature reached 1010°C (1850°F) and the secondary chamber burner changed to low fire. As the secondary burner began to cycle between low and high fire, the smoking around the door seals and the primary burner became much worse. The incinerator draft was cycling between -0.07 and +0.01 kpa (-0.3 and +0.05 in. w.c.) as the control damper cycled with the secondary chamber burner, trying to maintain a draft in the primary chamber. At 12:50, Ms. Maureen Pellegrini from B. G. Wickburg Company, Inc., changed the full open position of the control damper. The damper was opened as much as possible for the full open setting. The impact of this change on the primary chamber draft was minimal, and the smoking continued to cycle with the secondary chamber burner. At 16:38, the burn cycle ended and the burndown cycle began. The primary chamber combustion air changed to high flow, and the smoking problem increased. The smoking problem continued until approximately 18:20, when the primary chamber temperature reached 677°C (1250°F) and the primary chamber combustion air changed to low flow.

While the smoking problem around the door seals and through the primary chamber burner occurred during the pretest, the amount of smoke released was much greater when the manual test trains were operating, and especially during port changes when the ports had to be open for a short time. It was decided that some effort to compensate for the decrease in draft from the testing procedures was necessary because the amount of smoke being released was substantial and was causing problems not only in the incinerator room but throughout the hospital. Ms. Pellegrini had already changed the control damper full open position to its maximum setting, but it was a small change in damper position and the effect on the smoking problem was minimal. Ms. Pellegrini then suggested a slight increase in the ID fan speed in order to increase the ID fan capacity. It was agreed to try this for the next test on March 9, 1991.

At 21:58, the burndown cycle ended and the cooldown cycle began. At 08:14 on March 8, 1991, the cooldown cycle ended and the unit shut down.

The incinerator was opened at 08:20, and the main blower was turned on to cool the incinerator for ash removal. The hearth was covered with a light-gray ash with some

dark black spots to a depth of 5 to 10 cm (2 to 4 in). There were no visible smoldering clumps, and the burnout appeared to be very good.

At 13:50 the ash cleanout began. A small amount of water was sprayed onto the ash bed to minimize the dust. The total weight of the ash removed was 43.03 kg (94.87 lb).

Once the incinerator had been cleaned, nine indicator spore pipes with thermocouples were placed on the hearth in preparation for Run 3.

At 15:00, the main blower pulleys were changed in order to increase the fan speed from 1,740 to 1,839 rpm. According to Ms. Pellegrini, this adjustment should increase the fan capacity by approximately 5 percent.

#### 3.4.3 Test Run 3: March 9, 1991

The loading of the waste into the incinerator for Run 3 began at 07:30 on March 9, 1991. The eight wire mesh indicator spore packages that were inadvertently left out of Run 2 plus one more were placed beside the nine indicator spore pipes on the incinerator hearth, and 330.7 kg (729.38 lb) of waste were then loaded into the incinerator. Also, eight wire mesh indicator spore packages were placed inside the separate indicator spore bags and located within the waste bed. See Figure 3-7 for placement of the pipes and mesh packages.

At 08:18, the incinerator was started and the preheat cycle began. All the setpoints were the same as those for Run 2.

At 09:26, the secondary chamber temperature reached 872°C (1602°F) and TD5 started, but the primary chamber burner did not fire during the entire 120-second cycle. The timer was reset, the burner fired, and the burn cycle began.

At 10:04, the main blower shut down and the bypass valve opened, sending the flue gases directly to the stack. This bypass happened because the scrubber inlet temperature exceeded the scrubber inlet temperature set-point of 80°C (176°F) for more than 2 minutes. Within about one minute, the gases cooled, the bypass valve closed, and the flue gases were again being passed through the baghouse and scrubber by the main blower. At this point, the scrubber inlet water flow rate was increased so that a scrubber inlet temperature of approximately 49°C (120°F) would be maintained. When the main

blower capacity had been increased by increasing the blower rpm, the scrubber cooling water flow had not been increased.

The primary chamber draft increased with the increase in the main blower rpm. However, the smoking problem continued, though it appeared to be in smaller amounts.

At 12:04, the secondary chamber temperature reached 1010°C (1850°F) and the secondary chamber burner changed to low fire. The secondary chamber temperature then alternated between 982°C (1800°F) and 1010°C (1850°F) as the secondary chamber burner cycled between low and high fire.

At 16:25, the burn cycle ended and the burndown cycle began. The secondary chamber temperature continued increasing until it finally peaked at 1193°C (2180°F) at 17:41 and then started to decline. By 18:45, the secondary chamber temperature had dropped below 1010°C (1850°F), and the secondary chamber burner was again cycling between low and high fire.

At 21:44, the burndown cycle was over and the cooldown cycle began. At 07:59 on March 10, 1991, the cooldown cycle ended and the unit shut down.

The incinerator was opened at 07:59, and the main blower was turned on to cool the incinerator for ash removal. The hearth was covered with a light-gray ash mixed with more black spots than were present in the ash from the other two runs. The ash depth varied between 5 to 10 cm (2 to 4 in). No smoldering clumps were visible. The total weight of the ash removed was 27.37 kg (60.35 lb).

#### 4. SAMPLING LOCATIONS

The sampling locations used during the emission testing program at the Jordan Hospital MWI are described in this section. Flue gas samples were collected at the inlet to the APCD and at the exhaust stack.

An unlined steel stack extension was fabricated and temporarily installed at the top of the existing stack. The existing stack is also a 21 inches inside diameter (ID) steel stack housed in a brick shell. The existing stack has ample straight run for meeting Method 1 sample point requirements; however, only a single set of ports was in place and the extension had to be installed. The existing stack was 40 feet high. The general configuration of the stack/extension placement is shown in Figure 4-1.

The extension was 21 in. ID and 16 feet high. Three sets of test ports were provided as shown in Figure 4-2. The lower set of ports were used for the CEM, HCl/CEM, and manual HCl tests. The upper two sets of ports were used for both CDD/CDF and PM/Metals testing. The two upper sets of ports were aligned with each other in the vertical plane, while the lowest set was offset by 45° to prevent flow disturbances. The test ports were located in an ideal location according to EPA Method 1. There were at least two stack diameters of undisturbed flow downstream of the ports, and greater than eight diameters of undisturbed flow upstream of the ports. (NOTE: CDD/CDF and metals sampling probes are not treated as upstream disturbances for the upper set of ports.)

The number of traverse points required for the CDD/CDF and PM/Metals testing is eight. Four points on each of two diameters were used as shown in Figure 4-3.

The sampling location at the inlet to the air pollution control system is shown in Figure 4-4. Four manual flue gas sampling trains were employed at the inlet as well as both the main CEM and HCl/CEM extractive systems. The manual trains consisted of microbial, CDD/CDF, PM/Metals, and the midjet HCl trains. Immediately after the gas exited the incineration chamber, it was directed downward in a 4.75 x 19.25 inch refractory-lined duct. Eight inches below the gas entrance to this duct, two sample probes were located for inlet CEMS (O<sub>2</sub>, CO<sub>2</sub>, CO, NO<sub>x</sub>, SO<sub>2</sub>, and THC), and inlet HCl CEM. Estimated temperature at this locations probably ranged from 1500 to 2000°F.

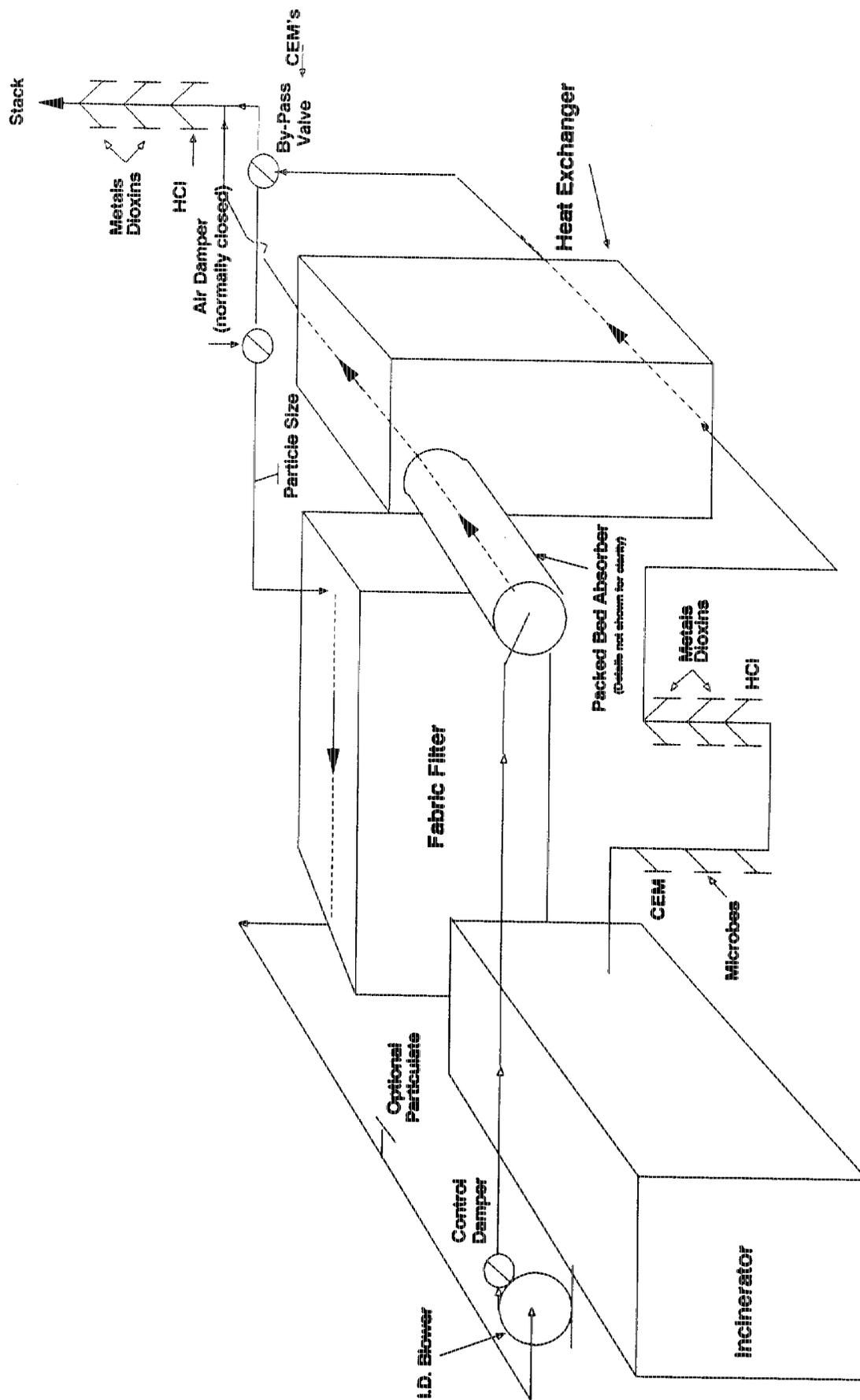
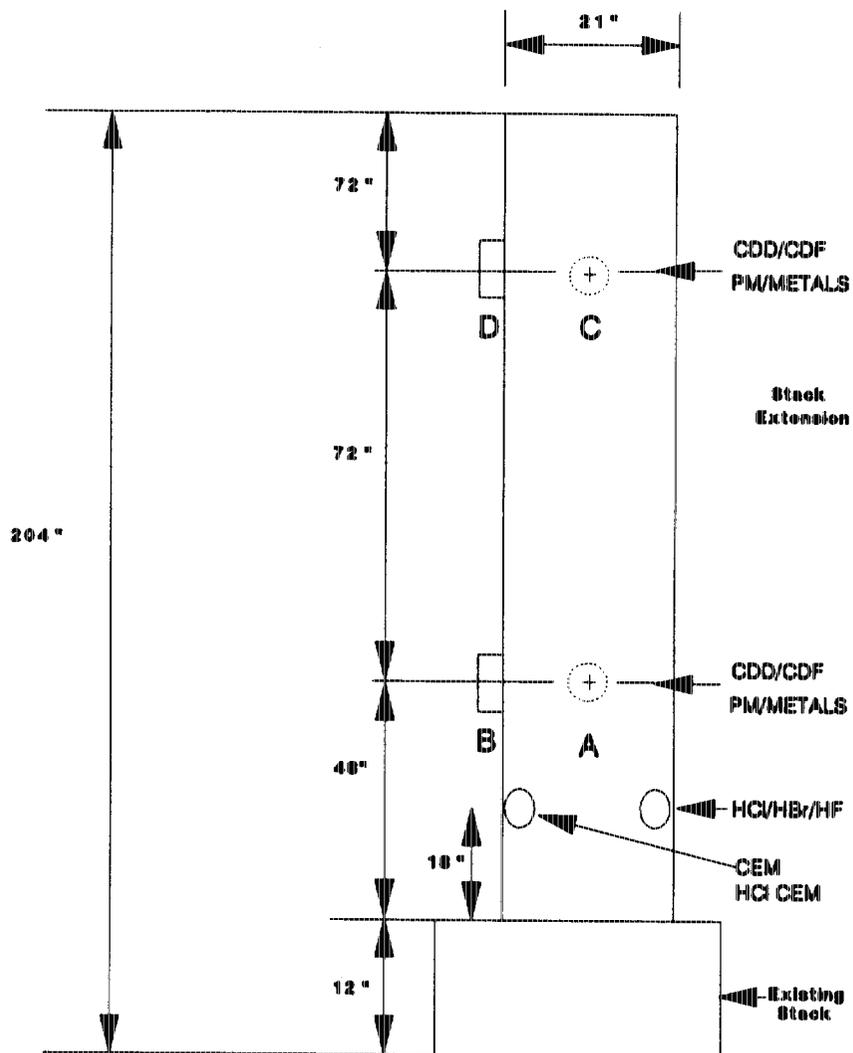
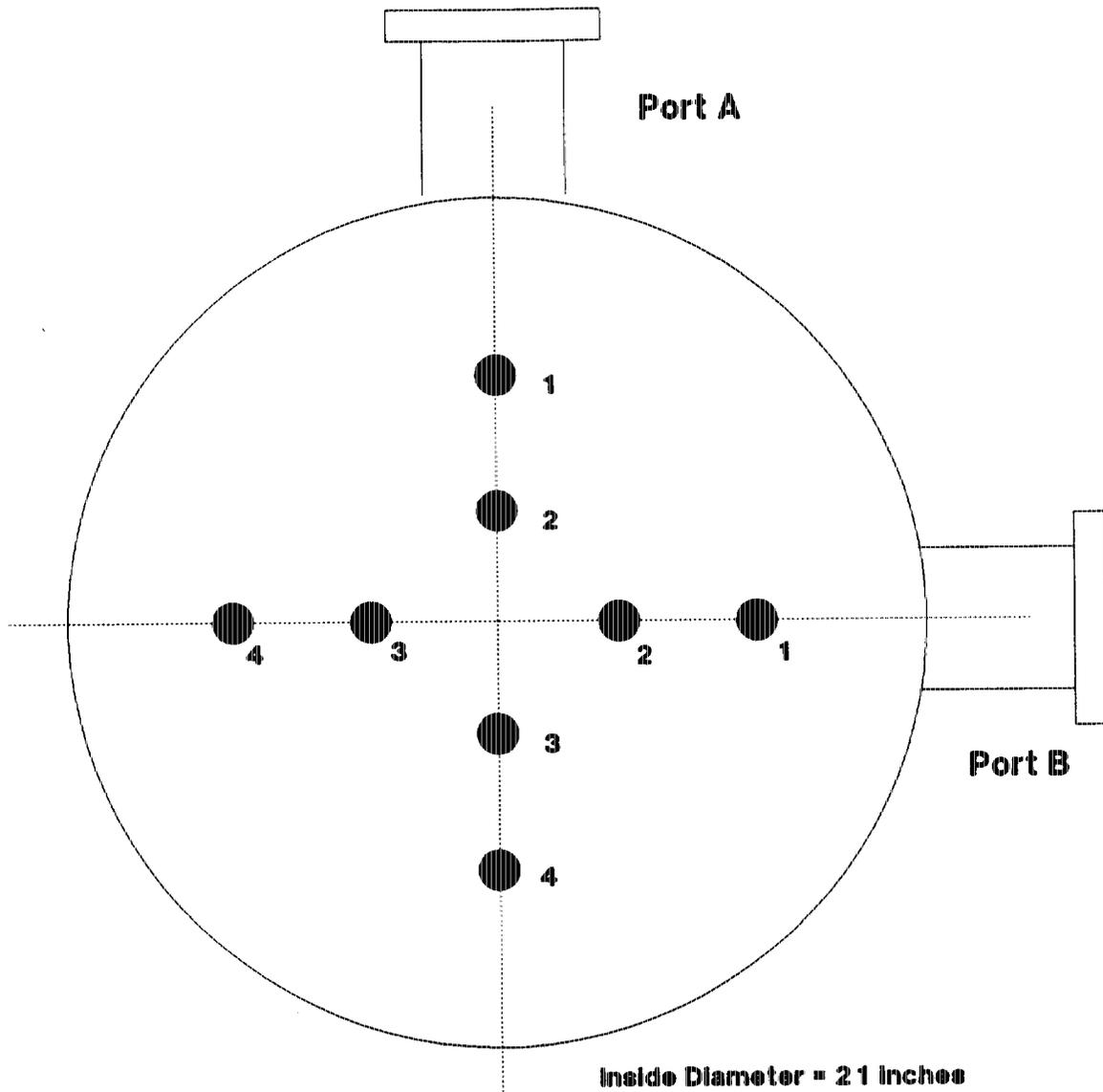


Figure 4-1. Generalized Schematic Showing Incinerator, Air Pollution Control Devices, and Sampling Locations; Jordan Hospital (1991)

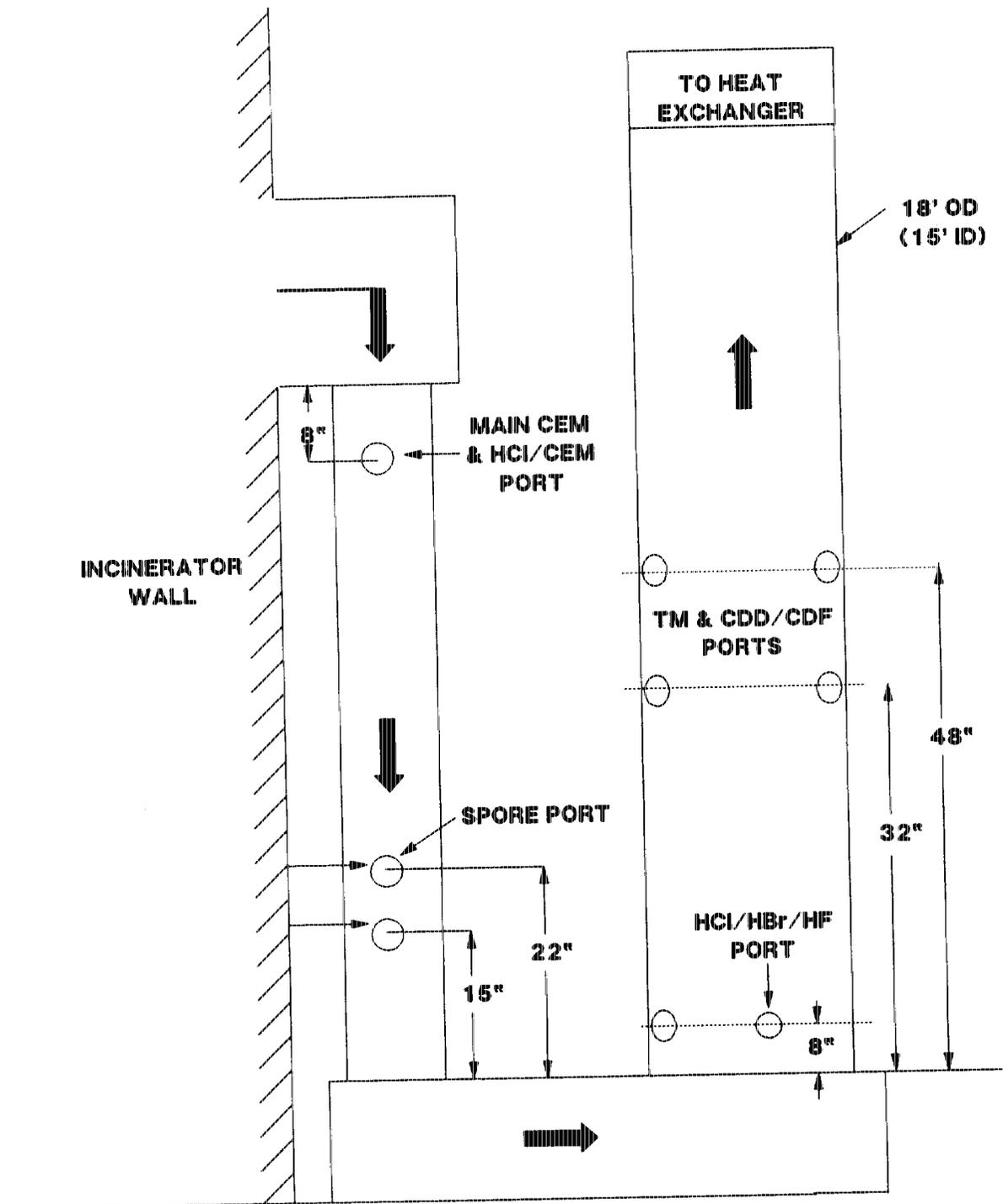


**Figure 4-2. Stack Gas Sample Locations  
Jordan Hospital (1991)**



Point	Percent of Diameter	Inches from Inside Wall
1	6.7	1.4
2	25.0	5.25
3	75.0	15.75
4	93.3	19.6

**Figure 4-3. Traverse Point Layout (Stack Location)  
Jordan Hospital (1991)**



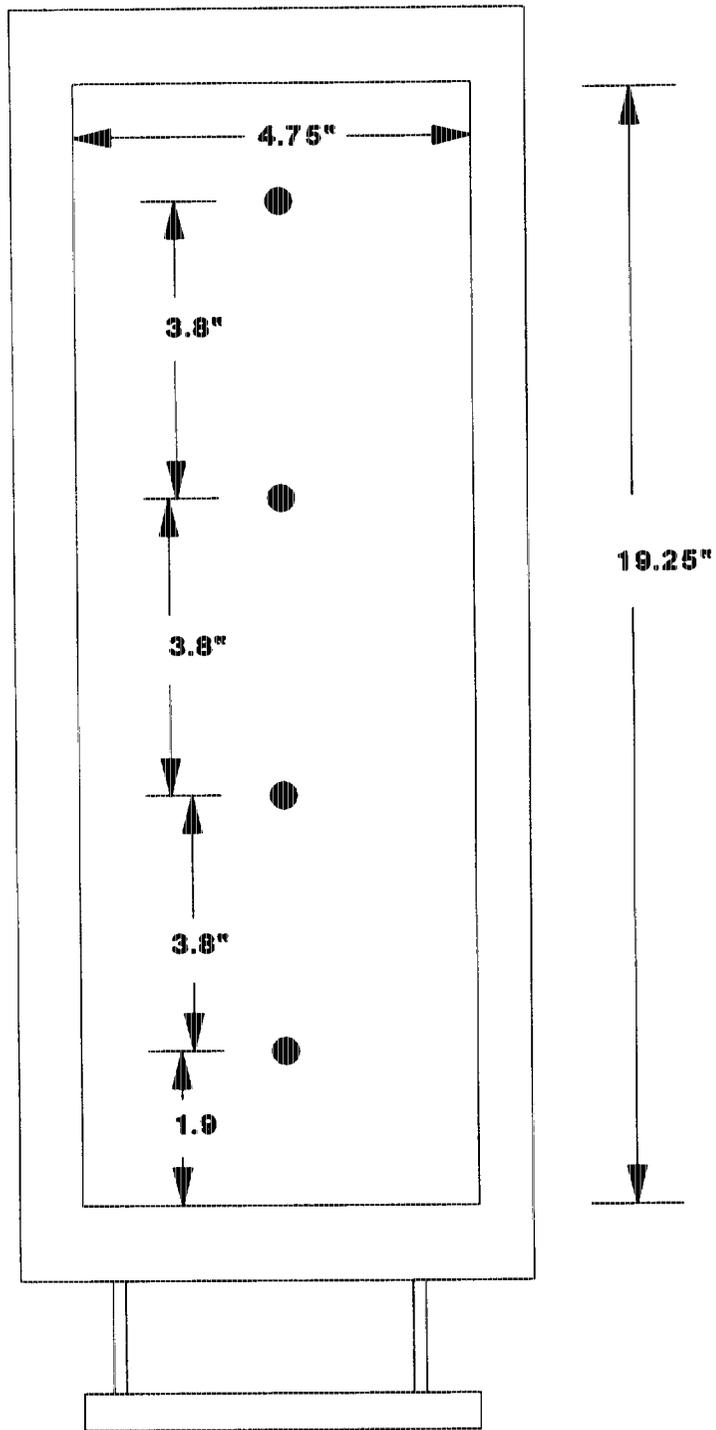
**Figure 4-4. Inlet Flue Gas Sample Location; Jordan Hospital (1991)**

The microbial train accessed flow gases through a single port in a 4.75 x 19.25 inch ID duct, with an equivalent diameter of 7.6 inches. This location was approximately 5 equivalent diameters downstream and 2.9 diameters upstream from the closest flow disturbances. A 1 x 4 sampling matrix was used as shown in Figure 4-5.

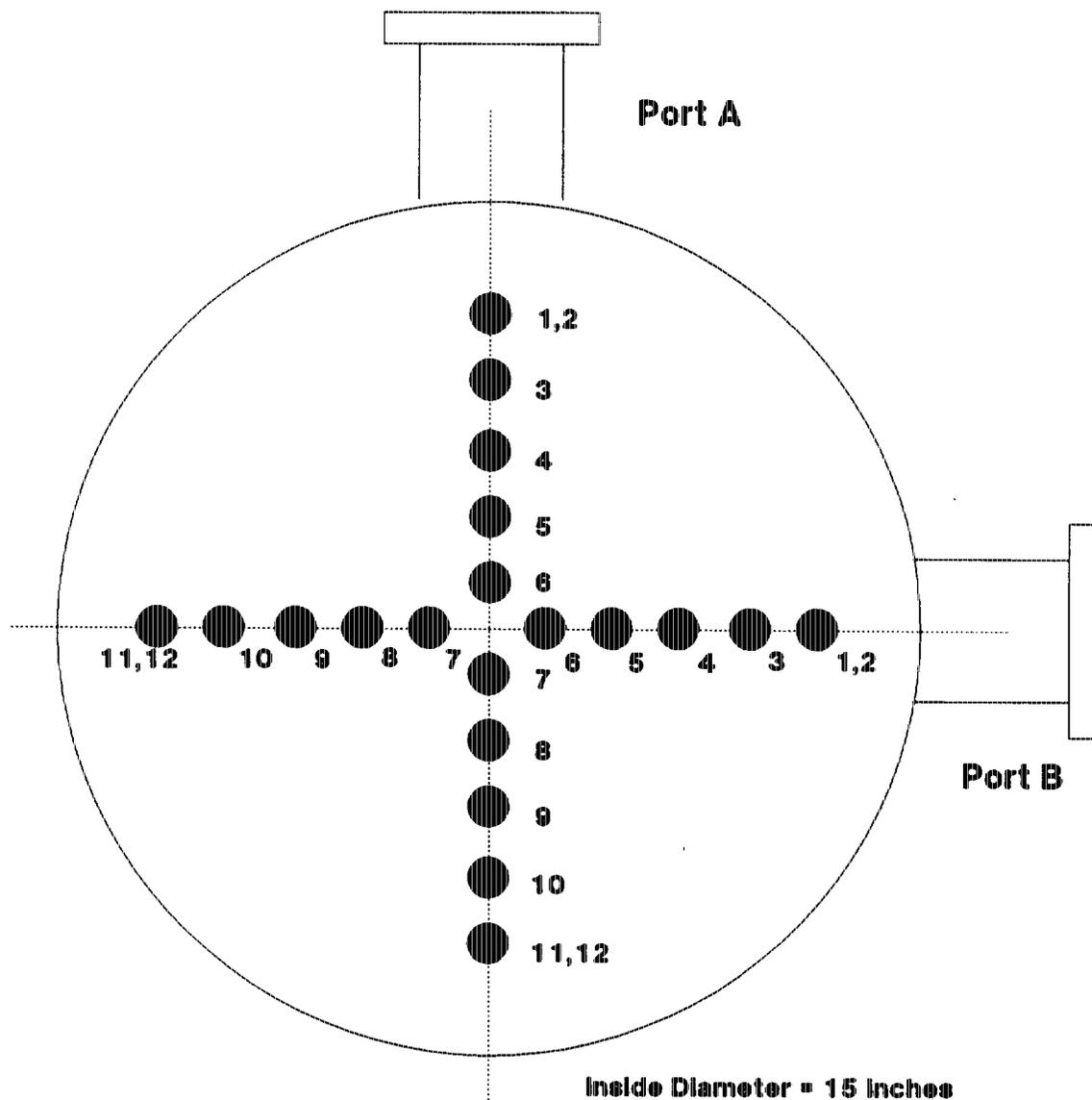
The inlet manual HCl/HBr/HF tests were conducted in a port downstream of the microbial port located in the 15-inch ID cylindrical duct. These tests were not isokinetic and hence, Method 1 sample location criteria did not apply.

The inlet CDD/CDF sample train and the PM/Metals train accessed flue gas through ports in a refractory-lined 15 inch ID duct. There were two sets of two sampling ports established for isokinetic sampling. The lower set was 2.1 duct diameters downstream and approximately 2 diameters upstream from the closest flow disturbance. The upper set was 3.2 duct diameters downstream and approximately 1.5 duct diameters upstream from the closest flow disturbance. Both CDD/CDF and PM/Metals inlet tests were conducted simultaneously through one set of ports (same level). Traverse points were used for CDD/CDF and PM/Metals tests as shown in Figure 4-6. Twenty points were actually used as Points 1 and 2 were combined and Points 11 and 12 were combined, because they were located within 1 inch of the duct wall.

Ash, scrubber make-up water, and scrubber blowdown water were also sampled during this test program. Ash was removed from the incinerator bed the day (afternoon) following a test series (burn run and burndown run). Ash was placed in a large (55 gallon) stainless steel drum where it was later composited into 1 liter samples using a sample thief. Scrubber make-up water samples were collected from a hose tap located inside the incinerator room. Scrubber blowdown water was collected from a scrubber liquor discharge line.



**Figure 4-5 Traverse Point Layout for Flue Gas Microbial Survivability (Inlet Location)**



Inside Diameter = 15 Inches

Point	Percent of Diameter	Inches from Inside Wall
1	2.1	1.0
2	6.7	1.0
3	11.8	1.8
4	17.7	2.7
5	25.0	3.75
6	35.8	5.4
7	64.4	9.7
8	75.0	11.25
9	82.3	12.3
10	86.2	12.9
11	93.3	14.0
12	97.9	14.0

Figure 4-6. Traverse Point Layout for CDD/CDF and Metals (Inlet Location)

## 5. SAMPLING AND ANALYTICAL PROCEDURES BY ANALYTE

The sampling and analytical procedures used for the Jordan Hospital MWI test program were the most recent revisions of the published EPA methods. Where published methods were not available, state-of-the-art sampling and analytical methods were used. In this section, descriptions of each sampling and analytical method by analyte were provided.

A summary of the sampling methods that were used is included in Table 5-1. Sampling times, minimum sampling volumes, and detection limits are summarized for the manual sampling methods in Table 5-2.

### 5.1 CDD/CDF EMISSIONS TESTING METHOD

The sampling and analytical method for determining flue gas emissions of CDD/CDF was EPA Proposed Method 23. This methodology is a combination of the American Society of Mechanical Engineers (ASME) 1984 draft protocol and the EPA Method 8290. The analytical method was designated as Method 8290X by Triangle Laboratories, Inc., Research Triangle Park, North Carolina, who performed the analyses. (Because of proprietary reasons, Triangle Laboratories has requested that a copy of their standard operating procedures not be included in this test report.)

#### 5.1.1 CDD/CDF Sampling Equipment

The CDD/CDF sampling method used the sampling train shown in Figure 5-1. Basically, the sampling system is similar to a Method 5 train with the exception of the following:

- Used all components (quartz probe/nozzle liner, all other glassware, filters) which were pre-cleaned using solvent rinses and extraction techniques; and
- Used a condensing coil and XAD-II<sup>®</sup> resin absorption module located between the filter and impinger train.

All sampling equipment specifications are detailed in the reference method shown in Appendix K.

TABLE 5-1. TEST METHODS USED FOR THE JORDAN HOSPITAL MWI

Analyte	Method
CDD/CDF	EPA Proposed Method 23 with GC/MS Method 8290
Particulates	EPA/EMSL Multimetals Train
Lead	
Mercury	
Arsenic	
Nickel	
Cadmium	
Chromium	
Beryllium	
Antimony	
Barium	
Silver	
Thallium	
SO <sub>2</sub>	EPA Instrument Methods 6C
O <sub>2</sub> /CO <sub>2</sub>	3A
CO	10
NO <sub>x</sub>	7E
THC	25A/18
HCl	NDIR CEM Analyzer
HCl	EPA Draft Method 26
HBr	EPA Draft Method 26
HF	EPA Draft Method 26
Microorganisms in Emissions	EPA Draft Method "Microbial Survivability Tests for MWI Emissions"
Microorganisms in Pipe Test and Direct Ash Test	EPA Draft Method "Microbial Survivability Tests for MWI Ash"
Opacity	EPA Method 9
Loss On Ignition	Standard Methods of Water & Wastes 209G
Carbon	ASTM D 3178-84

TABLE 5-2. SAMPLING TIMES, MINIMUM SAMPLING VOLUMES AND DETECTION LIMITS FOR THE JORDAN HOSPITAL MWI TESTS

Sampling Train	Sampling Time (hours)	Minimum Sample Volume (dscf)	Analyte	Detection Limit	
				Flue Gas	Analytical
CDD/CDF	4 <sup>a</sup>	120	CDD/CDF	0.3 ng/dscm	0.01 ng
PM/Metals	4 <sup>a</sup>	120	PM	0.006 gr/dscf	50-100 mg <sup>e</sup>
			As	0.3 g/dscm	0.002 g/ml
			Cd	0.6 g/dscm	0.006 g/ml
			Cr	1.6 g/dscm	0.015 g/ml
			Pb	0.2 g/dscm	0.002 g/ml
			Hg	25 g/dscm	0.25 g/ml
			Ni	1.6 g/dscm	0.015 g/ml
			Be	0.3 g/dscm	0.0003 g/ml
			Ba	0.2 g/dscm	0.002 g/ml
			Sb	3.3 g/dscm	0.032 g/ml
			Ag	0.71 g/dscm	0.007 g/ml
Tl	4.2 g/dscm	0.040 g/ml			
HCl/HBr/HF	1.0	120 liters <sup>b</sup>	Cl <sup>-</sup>	28 g/dscm	0.11 g/ml
			Br <sup>-</sup>	32 g/dscm	0.127 g/ml
			F <sup>-</sup>	100 g/dscm	0.40 <sup>c</sup> g/ml
Microorganisms	3.2	30	Indicator spores <sup>d</sup>	30 viable spores <sup>c</sup> dscm	1 viable spores aliquot

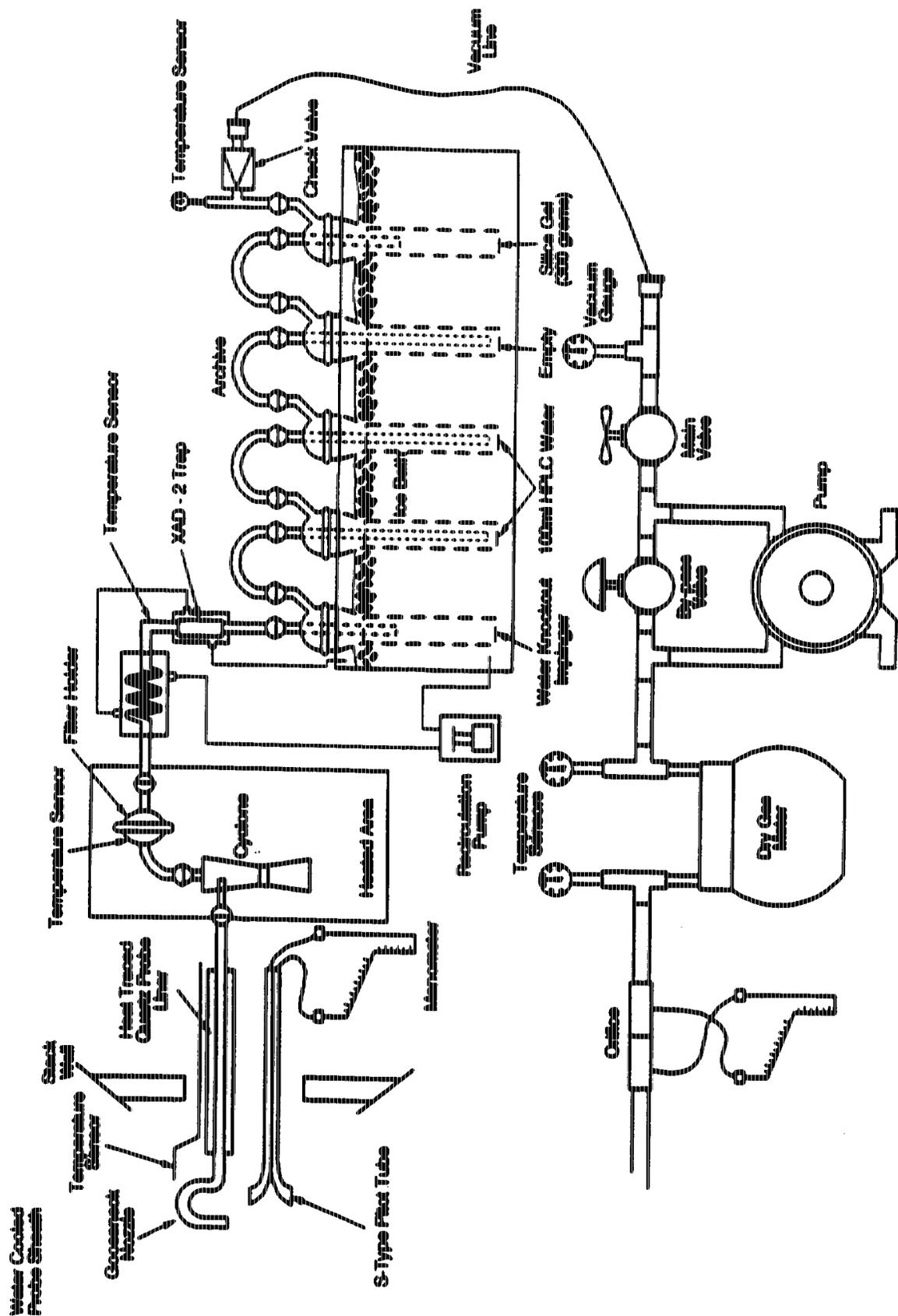
<sup>a</sup> An average sampling rate of 0.5 ft<sup>3</sup>/min was used to calculate sampling time.

<sup>b</sup> An average sampling rate of 2 liters/min was used to calculate the sample volume.

<sup>c</sup> Detection limit based on 100 ml aliquot. Method is still under development. Actual limit may vary.

<sup>d</sup> The indicator spore will be *Bacillus stearothermophilus*. (only 1 l)

<sup>e</sup> Based on average detection limits for tetra-octa CDD/CDF congeners.



6000000

Figure 5-1. CDD/CDF Sampling Train Configuration

### 5.1.2 CDD/CDF Equipment Preparation

In addition to the standard EPA Method 5 requirements, the CDD/CDF sampling method included several unique preparation steps which ensured that the sampling train components were not contaminated with organics that may interfere with analysis. The glassware, glass fiber filters, and absorbing resin were cleaned and the filters and resin were checked for residuals before they were packed.

5.1.2.1 Glassware Preparation. Glassware was cleaned as shown in Table 5-3. Glassware was washed in soapy water, rinsed with distilled water, baked, and then rinsed with acetone followed by methylene chloride. Clean glassware was allowed to dry under a hood loosely covered with foil to prevent laboratory contamination. Once the glassware was dried, the air-exposed ends were sealed with methylene chloride-rinsed aluminum foil. All the glass components of the sampling train (including the glass nozzles) plus any sample bottles, flasks, petri dishes, graduated cylinders, and pipets that were used during sampling and recovery were cleaned according to this procedure. Non-glass components (such as the Teflon®-coated filter screens and seals, tweezers, Teflon® squeeze bottles, nylon probe brushes, and nylon nozzle brushes) were cleaned following the same procedure except that no baking was performed.

This cleaning procedure deviates from the EPA proposed method; however, past experience has shown that the use of chromic acid solution may cause analytical interferences with the compounds of interest.

5.1.2.2 XAD-II® Resin and Filters Preparation. The XAD-II® absorbing resin and glass fiber filters were pre-cleaned by separate procedures according to the specified method. Only pesticide-grade solvents and HPLC-grade water were used to prepare for organic sampling and to recover these samples. The lot number, manufacturer, and grade of each reagent used was recorded in the laboratory notebook.

To prepare the filters, a batch of 50 was placed in a soxhlet pre-cleaned by extraction with toluene. The soxhlet was charged with fresh toluene and refluxed for 16 hours. After the extraction, the toluene was analyzed as described in Sections 5.2 and 5.3 of the reference method for the presence of Tetrachloro Dibenzo-p-Dioxins (TCDD) or Tetrachloro Dibenzofurans (TCDF). If these analytes were found, the filters were

TABLE 5-3. CDD/CDF GLASSWARE CLEANING PROCEDURE  
(Train Components, Sample Containers and  
Laboratory Glassware)

---

NOTE: USE VITON® GLOVES AND ADEQUATE VENTILATION WHEN  
RINSING WITH SOLVENTS

1. Soak all glassware in hot soapy water (Alconox®).
2. Tap water rinse to remove soap.
3. Distilled/deionized H<sub>2</sub>O rinse (X3).<sup>a</sup>
4. Bake at 450°F for 2 hours.<sup>b</sup>
5. Acetone rinse (X3), (pesticide grade).
6. Methylene chloride (X3), (pesticide grade)
7. Cap glassware with clean glass plugs or methylene chloride rinsed aluminum foil.
8. Mark cleaned glassware with color-coded identification sticker.
9. Glassware is rinsed immediately before using with acetone and methylene chloride (laboratory proof).

---

<sup>a</sup> (X3) = three times.

<sup>b</sup> Step (4) has been added to the cleanup procedure to replace the dichromate soak specified in the reference method. Radian has demonstrated in the past that it sufficiently removes organic artifacts. It is not used for probe liners and non-glass components of the train that cannot withstand 450°F (i.e., teflon-coated filter screen and seals, tweezers, teflon squeeze bottles, nylon probe and nozzle brushes).

re-extracted until no TCDD or TCDF was detected. The filters were then dried completely under a clean nitrogen ( $N_2$ ) stream. Each filter was individually checked for holes, tears, creases, or discoloration, and if found, was discarded. Acceptable filters were stored in a pre-cleaned petri dish, labeled by date of inspection, and sealed with Teflon® tape.

To prepare the absorbing resin, the XAD-II® resin was cleaned in the following sequential order:

- Rinse with HPLC-grade water, discard water;
- Soak in HPLC-grade water overnight, discard water;
- Extract in soxhlet with HPLC-grade water for 8 hours, discard water;
- Extract with methanol for 22 hours, discard solvent;
- Extract with methylene chloride for 22 hours, discard solvent;
- Extract with methylene chloride for 22 hours, retain an aliquot of solvent for gas chromatography analysis of TCDDs and TCDFs; and
- Dry resin under a clean  $N_2$  stream.

Once the resin was completely dry, it was checked for the presence of methylene chloride, TCDDs, and TCDFs as described in Section 3.1.2.3.1 of the reference method. If TCDDs or TCDFs were found, the resin was re-extracted. If methylene chloride was found, the resin was dried until the excess solvent was removed. The absorbent was to be used within four weeks of cleaning.

The cleaned XAD-II® resin was spiked with five CDD/CDF internal standards. Due to the special handling considerations required for the CDD/CDF internal standards, the spiking was performed by Triangle Laboratories. For convenience and to minimize contamination, Triangle Laboratories also performed the resin and filter cleanup procedures and loaded the resin into the glass traps.

5.1.2.3 CDD/CDF Method 5 Equipment Preparation. The remaining preparation included calibration and leak checking of all sampling train equipment. This included: meterboxes, thermocouples, nozzles, pitot tubes, and umbilicals. Referenced calibration procedures were followed when available. The results were properly

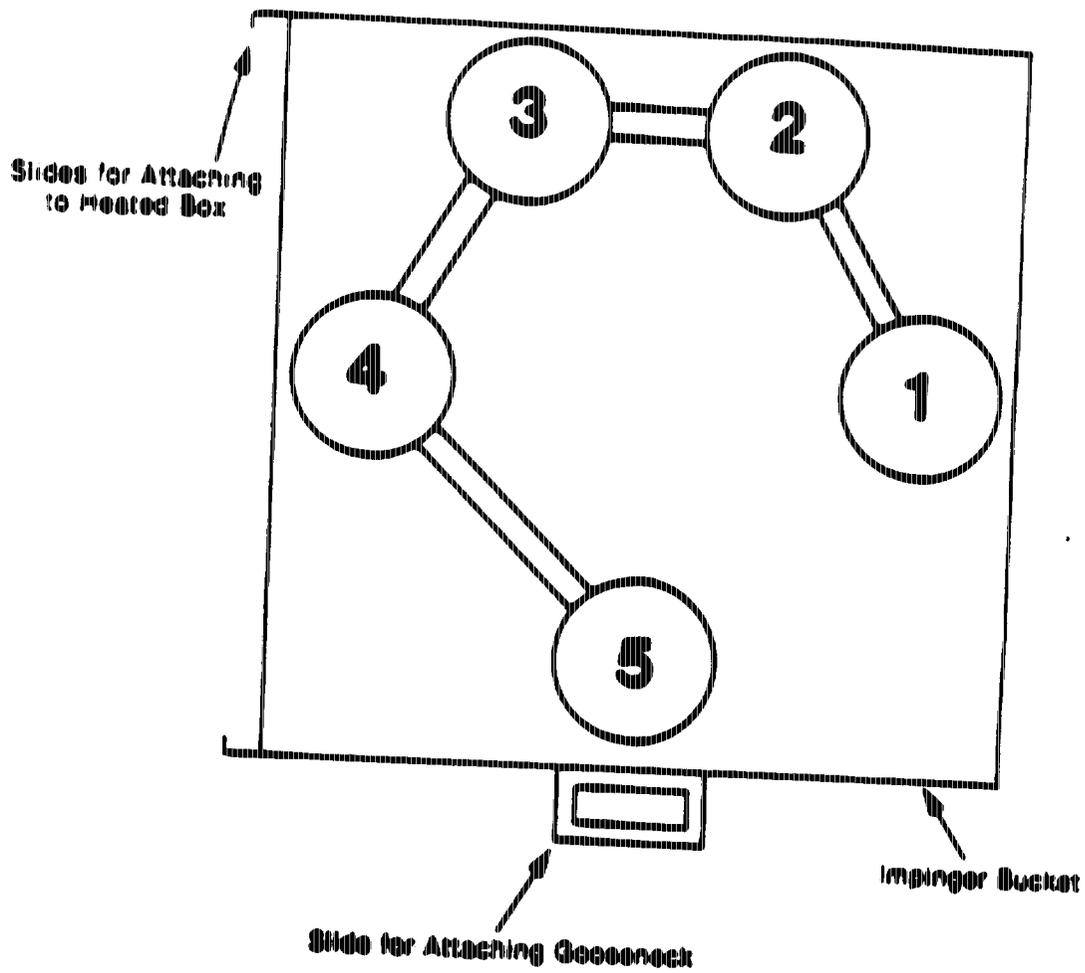
documented in a laboratory notebook or project file and retained. If a referenced calibration technique for a particular piece of apparatus was not available, then a state-of-the-art technique was used. A discussion of the techniques used to calibrate this equipment is presented in Section 7.2.7.

### 5.1.3 CDD/CDF Sampling Operations

5.1.3.1 Preliminary Measurements. Prior to sampling, preliminary measurements were required to ensure isokinetic sampling. These included determining the traverse point locations, performing a preliminary velocity traverse, cyclonic flow check, and moisture determination. These measurements were used to calculate a "K factor." The K factor was used to determine an isokinetic sampling rate from stack gas flow readings taken during sampling.

Measurements were then made of the duct inside diameter, port nozzle length, and the distances to the nearest upstream and downstream flow disturbances. These measurements were then used to determine sampling point locations by following EPA Reference Method 1 guidelines. The distances were then marked on the sampling probe using an indelible marker.

5.1.3.2 Assembling the Train. Assembling the CDD/CDF sampling train components was completed in the recovery trailer and final train assembly was performed at the stack location. First, the empty, clean impingers were assembled and laid out in the proper order in the recovery trailer. Each ground glass joint was carefully inspected for hairline cracks. The first impinger was a knockout impinger which has a short tip. The purpose of this impinger was to collect condensate which forms in the coil and XAD-II<sup>®</sup> resin trap. The next two impingers were modified tip impingers which each contain 100 ml of HPLC-grade water. The fourth impinger was empty, and the fifth impinger contains 200 to 300 grams of blue indicating silica gel. After the impingers were loaded, each impinger was weighed, and the initial weight and contents of each impinger were recorded on a recovery data sheet. The impingers were connected together using clean glass U-tube connectors and arranged in the impinger bucket as shown in Figure 5-2. The height of all the impingers was approximately the same to obtain a leak free seal. The open ends of the train were sealed with methylene chloride-rinsed aluminum foil or clean ground glass caps.



**Figure 8-2. Impinger Configuration for CDD/CDF Sampling**

The second step was to load the filter into the filter holder in the recovery trailer. The filter holder was then capped off and placed with the resin trap and condenser coil (capped) into the impinger bucket. A supply of pre-cleaned foil and socket joints was also placed in the bucket in a clean plastic bag for the convenience of the samplers. To avoid contamination of the sample, sealing greases were not used. The train components were transferred to the sampling location and assembled as previously shown in Figure 5-1.

5.1.3.3 Sampling Procedures. After the train was assembled, the heaters were turned on for the probe liner and heated filter box and the sorbent module/condensor coil recirculating pump was turned on. When the system reaches the appropriate temperatures, the sampling train was ready for pre-test leakchecking. The temperature of the sorbent module resin must not exceed 50°C (120°F) at any time and during testing it must not exceed 20°C (68°F). The filter skin temperature was maintained at 120 ± 14°F (248 ± 25°F). The probe temperature was maintained above 100°C (212°F).

The sampling trains were leak checked at the start and finish of sampling. (Method 5/23 protocol only requires post-test leakchecks and recommends pre-test leakchecks.) Radian protocol also incorporated leak checks before and after every port change. An acceptable pre-test leak rate was less than 0.02 acfm (ft<sup>3</sup>/min) at approximately 15 inches of mercury (in. Hg). If during testing, a piece of glassware needs to be emptied or replaced, a leak check was performed before the glassware piece was removed, and after the train was re-assembled.

To leak check the assembled train, the nozzle end was capped off and a vacuum of 15 in. Hg was pulled in the system. When the system was evacuated, the volume of gas flowing through the system was timed for 60 seconds. After the leak rate was determined, the cap was slowly removed from the nozzle end until the vacuum drops off, and then the pump was turned off. If the leak rate requirement was not met, the train was systematically checked by first capping the train at the filter, at the first impinger, etc., until the leak was located and corrected.

After a successful pre-test leak check had been conducted, all train components were at their specified temperatures, initial data were recorded [dry gas meter (DGM) reading], the test can be initiated. Sampling train data were recorded periodically on

standard data forms. A checklist for CDD/CDF sampling is included in Table 5-4. A sampling operation that was unique to CDD/CDF sampling was that the gas temperature entering the resin trap must be below 20°C (68°F). The gas was cooled by a water jacket condenser through which ice water was circulated.

The leak rates and sampling start and stop times were recorded on the sampling task log. Also, any other events that occur during sampling were recorded on the task log, such as sorbent module heat excursions, pitot cleaning, thermocouple malfunctions, heater malfunctions, or any other unusual occurrences.

If the probe liner breaks while the DGM was not running (i.e., during port changes or after the run was completed), the probe liner was replaced, the run was completed, and sample recovery done on both the broken sections of the glass liner and the replacement liner. If the break occurred while the DGM was running and the exact time of the break was noted, the test was stopped so that the probe liner could be replaced. The run was then completed and sample recovery done on all liner sections. If the recovered sample appeared unusual, the sample was discarded and an additional run was performed later. If the recovered sample appeared normal, the run was tentatively acceptable.

At the conclusion of the test run, the sample pump (or flow) was turned off, the probe was removed from the duct, a final DGM reading was taken, and a post-test leak check was completed. The procedure was identical to the pre-test procedure; however, the vacuum should be at least one inch Hg higher than the highest vacuum attained during sampling. An acceptable leak rate was less than 4 percent of the average sample rate or 0.02 acfm (whichever was lower). If a final leak rate does not meet the acceptable criterion, the test run may still be accepted upon approval of the test administrator. If so, the measured leak rate was reduced by subtracting the allowable leak rate from it and then multiplied for the period of time in which the leak occurred. This "leaked volume" was then subtracted from the measured gas volume in order to determine the final gas sample volume.

TABLE 5-4. CDD/CDF SAMPLING CHECKLIST

---

Before test starts:

1. Check impinger set to verify the correct order, orientation, and number of impingers. Verify probe markings, and remark if necessary.
  2. Check that you have all the correct pieces of glassware. Have a spare probe liner, probe sheath, meter box, and filter ready to go at location.
  3. Check for data sheets and barometric pressure.
  4. Bag sampling equipment for CO<sub>2</sub>/O<sub>2</sub> needs to be ready except when using CEMs for CO<sub>2</sub>/O<sub>2</sub> determinations.
  5. Examine meter box - level it, zero the manometers, and confirm that the pump is operational.
  6. Verify the filter is loaded correctly and as tight as possible; place filter in line with the train and leak check at 15 inches Hg.
  7. Add probe to train.
  8. Check thermocouples - make sure they are reading correctly.
  9. Conduct pitot leak check, recheck manometer zero.
  10. Do final leak check; record leak rate and vacuum on sampling log.
  11. Turn on variacs and check to see that the heat is increasing.
  12. Check that cooling water is flowing and on. Add ice to impinger buckets.
  13. Check isokinetic K-factor - make sure it is correct. (Refer to previous results to confirm assumptions. Two people should calculate this independently to double check it.)
-

TABLE 5-4. CDD/CDF SAMPLING CHECKLIST, continued

---

During Test:

1. Notify crew chief of any sampling problems ASAP. Train operator should fill in sampling log and document any abnormalities.
2. Perform simultaneous/concurrent testing with other locations (if applicable). Maintain filter temperature between 248°F ±25°F. Keep temperature as steady as possible. Maintain the resin trap and impinger temperatures below 68°F. Maintain probe temperature above 212°F.
3. Leak check between ports and record on data sheet. Leak check if the test is stopped to change silica gel, to decant condensate, or to change filters.
4. Record sampling times, rate, and location for the fixed gas bag sampling (CO, CO<sub>2</sub>, O<sub>2</sub>), if applicable.
5. Blow back pitot tubes periodically if expecting moisture entrapment.
6. Change filter if vacuum suddenly increases or exceeds 15 inches Hg.
7. Check impinger solutions every 1/2 hour; if the knockout impinger is approaching full, stop test and empty it into a pre-weighed bottle and replace it in the train.
8. Check impinger silica gel every 1/2 hour; if indicator color begins to fade, request a prefilled, preweighed impinger from the recovery trailer.
9. Check the ice in the impinger bucket frequently. If the stack gas temperatures are high, the ice will melt at the bottom rapidly. Maintain condensor coil and silica gel impinger gas temperatures below 68°F.

After test is completed:

1. Record final meter reading.
  2. Do final leak check of sampling train at maximum vacuum during test.
  3. Do final pitot leak check.
-

TABLE 5-4. CDD/CDF SAMPLING CHECKLIST, continued

- 
4. Check completeness of data sheet. Verify that impinger bucket identification is recorded on the data sheets. Note any abnormal conditions.
  5. Leak check function (level, zero, etc.) of pitot tubes and inspect for tip damage.
  6. Disassemble train, cap sections, and take each section and all data sheets down to recovery trailer.
  7. Probe recovery (use 950 ml bottles)
    - a) Bring probes into recovery trailer (or other enclosed area).
    - b) Wipe the exterior of the probe to remove any loose material that could contaminate the sample.
    - c) Carefully remove the nozzle/probe liner and cap it off with prerinsed aluminum foil.
    - d) For acetone rinses (all trains)
      - Attach precleaned cyclone flask to probe to catch rinses
      - Wet all sides of probe interior with acetone
      - While holding the probe in an inclined position, put precleaned probe brush down into probe and brush it in and out
      - Rinse the brush, while in the probe, with acetone
      - Do this at least 3 times until all the particulate has been recovered.
      - Recover acetone into a preweighed, prelabeled sample container
    - e) Follow the procedure outlined in (d) using methylene chloride. Recover the solvent into the same acetone recovery bottle.
    - f) Follow the procedure outlined in (d) using toluene. Recover this solvent into a separate preweighed prelabelled sample container.
  8. Cap both ends of nozzle/probe liner for the next day, and store in dry safe place.
  9. Make sure data sheets are completely filled out, legible, and give them to the Crew Chief.
-

#### 5.1.4 CDD/CDF Sample Recovery

To facilitate transfer from the sampling location to the recovery trailer, the sampling train was disassembled into the following sections: the probe liner, filter holder, filter to condenser glassware, condenser sorbent module, and the impingers in their bucket. Each of these sections was capped with methylene chloride-rinsed aluminum foil or ground glass caps before removal to the recovery trailer. Once in the trailer, field recovery followed the scheme shown in Figure 5-3. The samples were recovered and stored in cleaned amber glass bottles to prevent light degradation.

The solvents used for train recovery were all pesticide grade. The use of the highest grade reagents for train recovery was essential to prevent the introduction of chemical impurities which interfere with the quantitative analytical determinations.

Field recovery results in the sample components listed in Table 5-5. The sorbent module was stored in a cooler on ice at all times. The samples were shipped to the analytical laboratory by truck accompanied by written information designating target analyses.

#### 5.1.5 CDD/CDF Analytical Procedures

The analytical procedure used to obtain CDD/CDF concentrations from a single flue gas sample were by HRGC and HRMS (resolution from 8000-10000 m/e). The target CDD/CDF congeners are listed in Table 5-6. The analyses were performed by Triangle Laboratories, Inc., by Method 8290X.

The flue gas samples were analyzed in two fractions according to the scheme in Figure 5-4. One fraction was the total train methylene chloride and acetone rinses, filter(s), and sorbent module; the other fraction was comprised of the toluene rinse of applicable portions of the sampling train. For the CDD/CDF analysis, isotopically-labeled surrogate compounds and internal standards were added to the samples before the extraction process was initiated. The internal standards and surrogates that were used are described in detail in EPA Method 23.

Data from the mass spectrometer were recorded and stored on a computer file as well as printed on paper. Results such as amount detected, detection limit, retention time, and internal standard and surrogate standard recoveries were calculated by



TABLE 5-5. CDD/CDF SAMPLE FRACTIONS SHIPPED  
TO ANALYTICAL LABORATORY

Container/ Component	Code	Fraction
1	F	Filter(s)
2	PR <sup>a</sup>	Acetone and methylene chloride rinses of nozzle/probe, cyclone, front half/back half filter holder, filter support, connecting glassware, condensor
3	PRT <sup>b</sup> CRT <sup>b</sup>	Toluene rinse of nozzle/probe, cyclone, front half/back half filter holder, filter support, connecting line and condensor
4	SM	XAD-II® resin trap (sorbent module)

<sup>a</sup> Rinses include acetone and methylene chloride recovered into the same sample bottle.

<sup>b</sup> Rinses of toluene recovered into separate sample bottle (sometimes toluene probe rinse (PRT) and coil rinse (CRT) are recovered separately).

TABLE 5-6. CDD/CDF CONGENERS ANALYZED

---

DIOXINS:

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 PeCDD)  
Total pentachlorinated dibenzo-p-dioxins (PeCDD)  
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:

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 PeCDF)  
2,3,4,7,8 pentachlorodibenzofuran (2,3,4,7,8 PeCDF)  
Total pentachlorinated dibenzofurans (PeCDF)  
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)  
2,3,4,6,7,8 hexachlorodibenzofuran (2,3,4,6,7,8 HxCDF)  
1,2,3,7,8,9 hexachlorodibenzofuran (1,2,3,7,8,9 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)

---

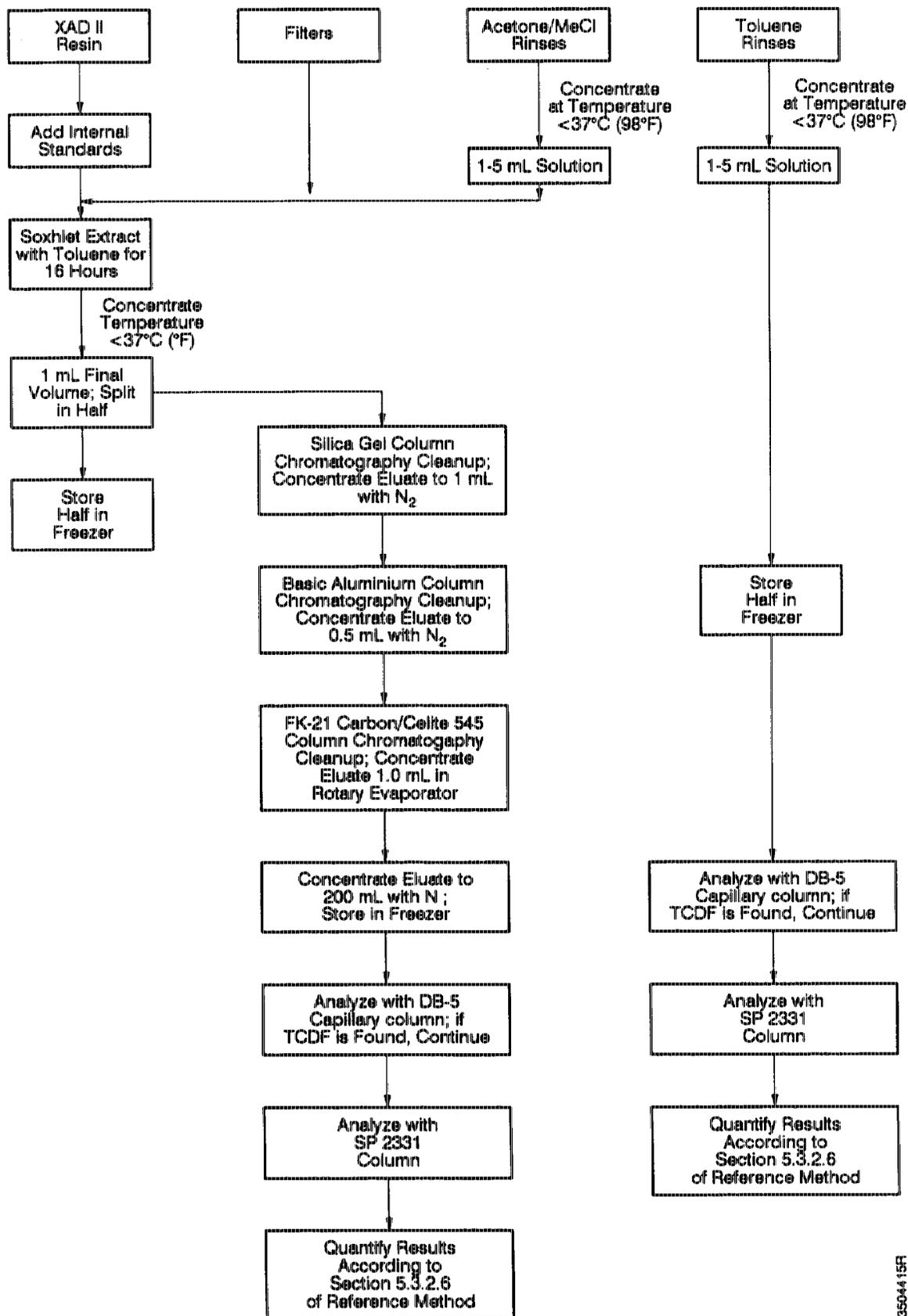


Figure 5-4. Extraction and Analysis Schematic for CDD/CDF Samples

computer. The chromatograms were retained by the analytical laboratory and also included in the analytical report delivered to Radian Corporation.

5.1.5.1 Preparation of Samples for Extraction. Upon receiving the sample shipment, the samples were checked against the Chain-of-Custody forms and then assigned an analytical laboratory sample number. Each sample component was reweighed to determine if leakage occurred during travel. Color, appearance, and other particulars of the samples were noted. Samples were extracted within 21 days of collection.

5.1.5.2 Calibration of GC/MS System. A five-point calibration of the GC/MS system was performed to demonstrate instrument linearity over the concentration range of interest. Relative response factors were calculated for each congener or compound of interest. The response factors were verified on a daily basis using a continuing calibration standard consisting of a mid-level mixed isomer standard. The instrument performance was acceptable only if the measured response factors for the labeled and unlabeled compounds and the ion-abundance ratios were within the allowable limits specified in the method (52200, 52201 FR 891220).

#### 5.1.6 CDD/CDF Analytical Quality Control

All quality control procedures specified in the test method were followed. Blanks were used to determine analytical contamination, calibration standards were used for instrument calibration and linearity checks, internal standards were used to determine isomer recoveries and adjust response factors for matrix effects, surrogate standards were used to measure the collection efficiency of the sampling methodology, and an alternate standard was used as a column efficiency check.

5.1.6.1 CDD/CDF Quality Control Blanks. Three different types of sample blanks were collected for CDD/CDF analysis. The type of blanks that were required are shown in Table 5-7.

Reagent blanks of 1000 ml of each reagent used at the test site were saved for potential analysis. Each reagent blank was of the same lot as was used during the sampling program. Each lot number and reagent grade was recorded on the field blank label and in the laboratory notebook.

TABLE 5-7. CDD/CDF BLANKS COLLECTED

Blank	Collection	Analysis
Field Blanks	One run collected and analyzed for each sampling location.	Analyze with flue gas samples.
Glassware Proof Blank	Each train to be used (2) will be loaded and quantitatively recovered prior to sampling	Archive for potential analysis
Method Blank	At least one for each analytical batch	Analyze with each analytical batch of flue gas samples
Reagent Blanks	One 1000 ml sample for each reagent and lot.	Archive for potential analysis.

A glassware blank (proof blank) was recovered from each set of sample train glassware that was used to collect the organic samples. The precleaned glassware, which consists of a probe liner, filter holder, condensor coil, and impinger set, was loaded as if for sampling and then quantitatively recovered exactly as the samples were. Analysis of the generated fractions was used to check the effectiveness of the glassware cleaning procedure only if sample analysis indicates a potential contamination problem.

A field blank was collected from a set of CDD/CDF glassware that had been used to collect at least one sample and had been recovered. The train was re-loaded and left at a sampling location during a test run. The train was then recovered. The purpose of the field blank was to measure the level of contamination that occurs from handling, loading, recovering, and transporting the sampling train. The field blanks were analyzed with the flue gas samples. The field blanks showed no problems with contamination.

To verify the flue gas sample was quantitatively recovered, toluene rinses were also analyzed separately from the other fractions.

In addition to the three types of blanks that were required for the sampling program, the analytical laboratory analyzed a method blank with each set of flue gas samples. This consisted of prepping and analyzing reagent water by the exact procedure used for the samples analysis. The purpose of this was to verify that there was no laboratory contamination of the field samples.

5.1.6.2 Quality Control Standards and Duplicates. Recoveries of the internal standards must be between 40 to 130 percent for the tetra- through hexachlorinated compounds and between 25 to 130 percent for the hepta- and octachlorinated homologues. If these requirements were not met, the data was acceptable if the signal to noise ratio was greater than or equal to ten. If these requirements were met, the results for the native (sampled) species were adjusted according to the internal standard recoveries.

Surrogate standard recoveries must be between 70 to 130 percent. If the recoveries of all standards were less than 70 percent, the project director was notified immediately to determine if the surrogate results can be used to adjust the results of the native species.

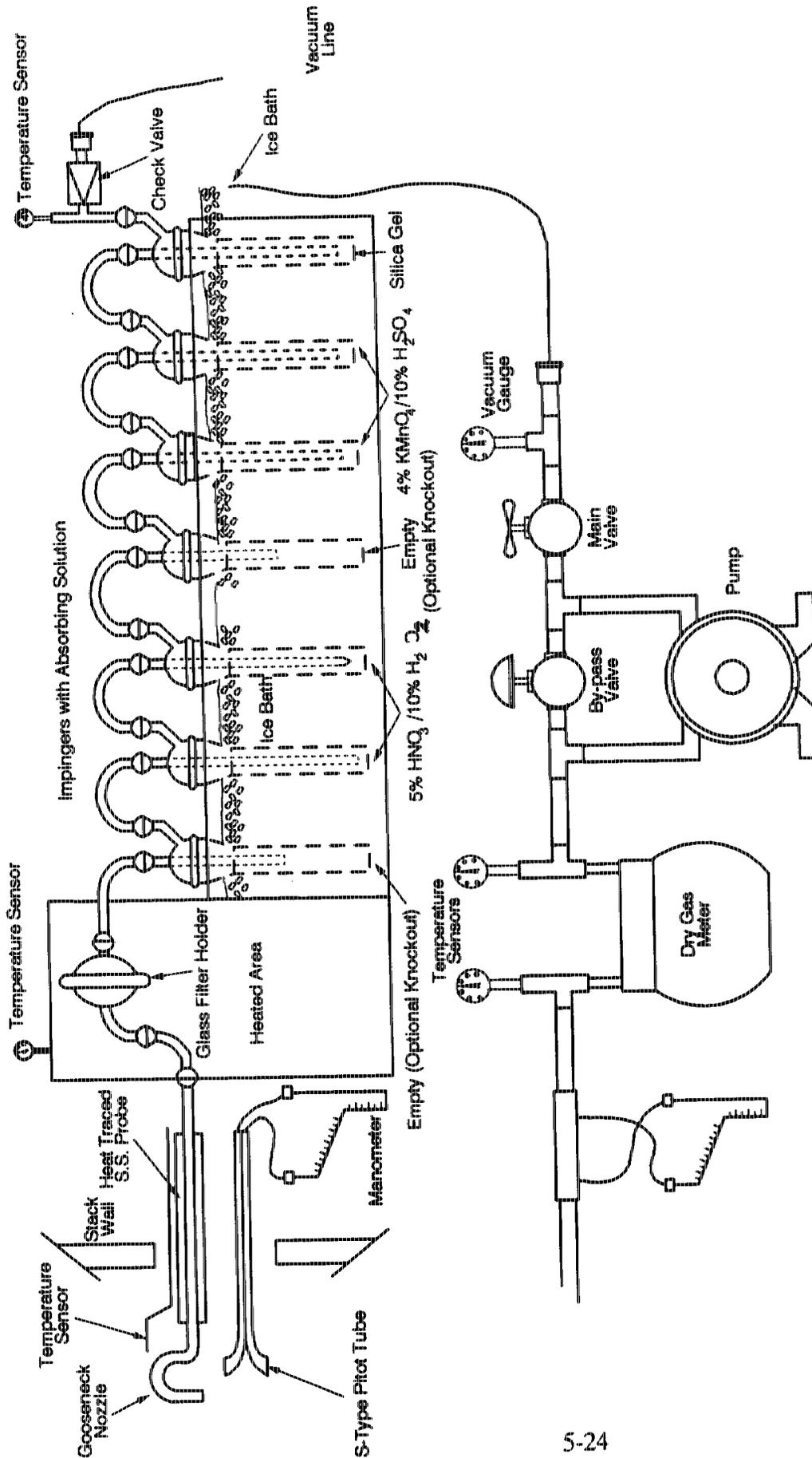
Duplicate analysis was performed for every ten samples. The purpose of this was to evaluate the precision of the combined sample preparation and analytical methodology.

## 5.2 PARTICULATE MATTER AND METALS EMISSIONS TESTING METHOD

Sampling for PM and metals was performed according to an EPA Emission Measurement Branch (EMB) draft protocol entitled "Methodology for the Determination of Metals Emissions in Exhaust Gases from Incineration Processes." The protocol was presented in Appendix K. This method was applicable for the determination of particulates and Pb, Ni, zinc (Zn), phosphorus (P), Cr, copper (Cu), manganese (Mn), selenium (Se), Be, Tl, Ag, Sb, Ba, Cd, As, and Hg emissions from various types of incinerators. Analyses of the Jordan Hospital MWI test samples were performed for As, Cd, Cr, Hg, Ni, Pb, Sb, Ag, Ba, Be, and Tl.

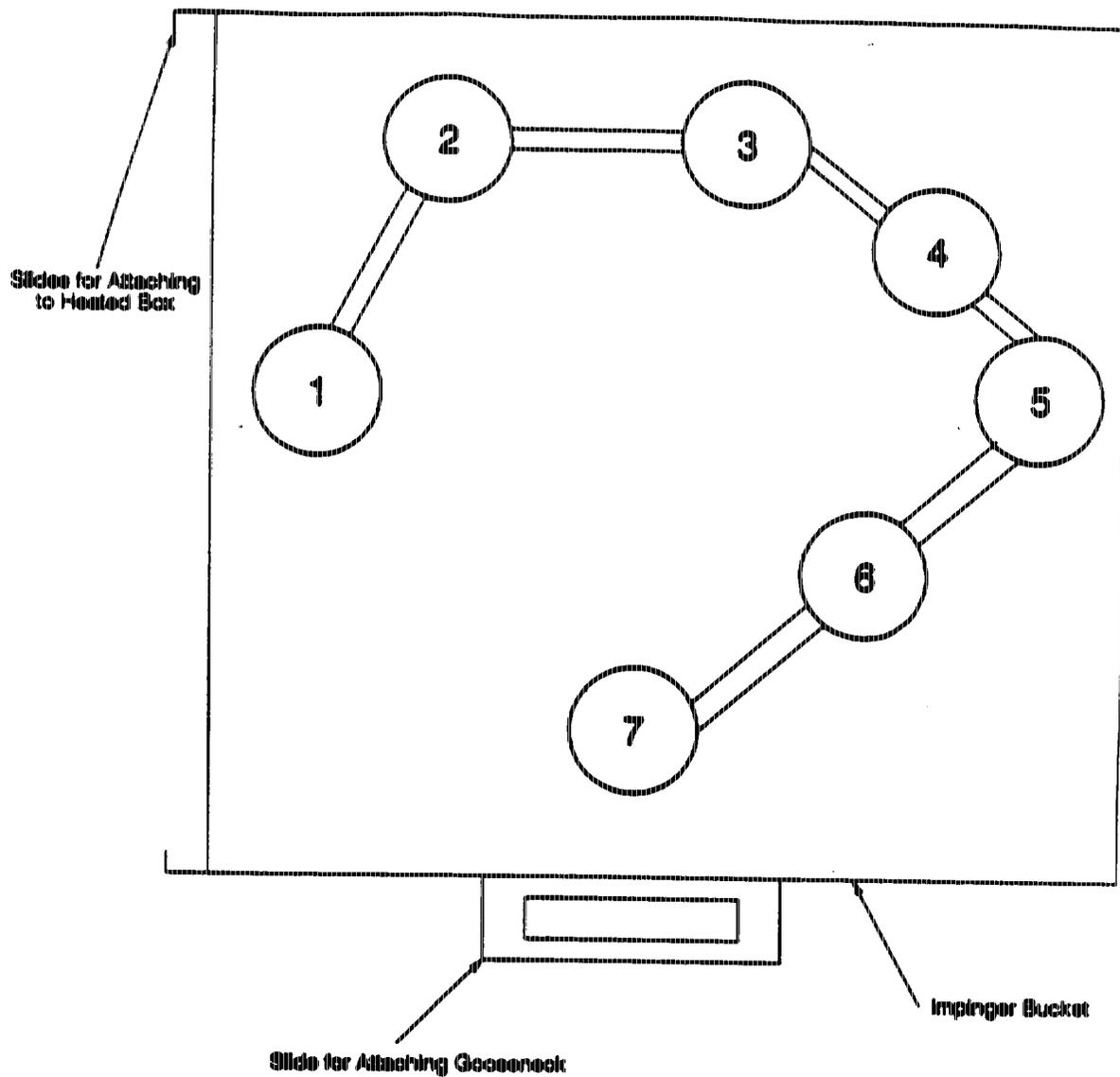
The PM emissions were also determined from this sampling train. Particulate concentrations were based on the weight gain of the filter and the front half acetone rinses (probe, nozzle, and filter holder). After the gravimetric analyses had been completed, the sample fractions were then analyzed for the target metals as discussed in Section 5.2.5. 5.2.1 PM/Metals Sampling Equipment

The methodology used the sampling train shown in Figure 5-5. The 5-impinger train consisted of a quartz nozzle/probe liner followed by a heated filter assembly with a Teflon® filter support, a series of impingers, and the usual EPA Method 5 meterbox and vacuum pump. The sample was not exposed to any metal surfaces in this train. The contents of the sequential impingers were: two impingers with a 5 percent HNO<sub>3</sub>/10 percent H<sub>2</sub>O<sub>2</sub> solution, two impingers with a 4 percent KMnO<sub>4</sub>/10 percent sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) solution, and an impinger containing silica gel. An optional empty knockout impinger was added. The second impinger containing HNO<sub>3</sub>/H<sub>2</sub>O<sub>2</sub> was of the Greenburg-Smith design; the other impingers had straight tubes. The impingers were connected together with clean glass U-tube connectors and were arranged in an impinger bucket as shown in Figure 5-6. Sampling train components were recovered and analyzed in separate front and back half fractions according to the described method.



3804709R

Figure 5-5. Schematic of Multiple Metals Sampling Train



**Figure 5-6. Impinger Configuration for PM/Metals Sampling (optional knock out impinger not shown)**

## 5.2.2 PM/Metals Sampling Equipment Preparation

5.2.2.1 Glassware Preparation. Glassware was washed in hot soapy water, rinsed with tap water (3X), and then rinsed with deionized distilled water (3X). The glassware was then subjected to the following series of soaks and rinses:

- Soak in a 10 percent  $\text{HNO}_3$  solution for a minimum of 4 hours;
- Rinse with deionized distilled water rinse (3X); and
- Rinse with acetone rinse.

The cleaned glassware was allowed to air dry in a contamination-free environment. The ends were then covered with parafilm. All glass components of the sampling train plus any sample bottles, pipets, Erlenmeyer flasks, petri dishes, graduated cylinders, and other laboratory glassware used during sample preparation, recovery, and analysis were cleaned according to this procedure.

5.2.2.2 Reagent Preparation. The sample train filters were Pallflex Tissuequartz 2500QAS filters. The acids and  $\text{H}_2\text{O}_2$  peroxide were Baker "Intra-analyzed" grade or equivalent. The peroxide was purchased specifically for this test site and was kept cold until it was opened.

The reagent water was Baker "Analyzed HPLC" grade or equivalent. The lot number, manufacturer, and grade of each reagent that was used was recorded in the laboratory notebook.

The  $\text{HNO}_3/\text{H}_2\text{O}_2$  absorbing solution and the acidic  $\text{KMnO}_4$  absorbing solution was prepared fresh daily according to Sections 4.2.1 and 4.2.2 of the reference method. The analyst wore both safety glasses and protective gloves when the reagents were mixed and handled. Each reagent had its own designated transfer and dilution glassware. This glassware was marked for identification with a felt tip glass marking pen and used only for the reagent for which it was designated.

The acidic  $\text{KMnO}_4$  solution was prepared by the following procedure.

- Quantitatively remove 400 ml from a 4 liter bottle of Baker "Analyzed HPLC" water so that 3.6 liters remained in the bottle. This bottle was labeled 4.4 percent  $\text{KMnO}_4$  in water.

- Quantitatively add 160 g of potassium permanganate crystals to the bottle; a Teflon® stirring bar and stirring plate were used to stir as thoroughly as possible. This reagent was stored on the counter in a plastic tub at all times.
- Each morning the acidic reagent was needed, 900 ml of  $\text{KMnO}_4$  solution was decanted into a 1000 ml volumetric flask. Carefully added 100 ml of concentrated  $\text{H}_2\text{SO}_4$  and mixed. This reagent was volatile and must be mixed cautiously. The flask cap was held on the flask, mixed once, vent quickly. Mixing was completed slowly until the mixture was homogenous. The solution was allowed to cool and brought to a final volume to 1000 ml with  $\text{H}_2\text{O}$ .
- The reagent was filtered through Wattman 541 filter paper into another volumetric flask or 2 liter amber bottle. This bottle was labeled 4 percent acidic  $\text{KMnO}_4$  absorbing solution. The top was vented and the reagent was stored in a plastic tub at all times.

5.2.2.3 Equipment Preparation. The remaining preparation included calibration and leak checking of all train equipment as specified in EPA Method 5. This equipment included the probe nozzles, pitot tubes, metering system, probe heater, temperature gauges, leakcheck metering system, and barometer. A laboratory field notebook was maintained to record these calibration values.

### 5.2.3 PM/Metals Sampling Operations

The sampling operations used for PM/Metals testing were virtually the same as those for the CDD/CDF tests as discussed in Section 5.1.2. The only differences were that there was no condensor coil so coil temperatures were not recorded and glass caps, Teflon® tape, or parafilm was used to seal off the sample train components rather than foil. Detailed instructions for assembling the metals sampling train were found beginning on page 14 of the reference method.

### 5.2.4 PM/Metals Sample Recovery

The recovery procedures were begun as soon as the probe was removed from the stack and the post-test leakcheck was completed.

To facilitate transfer from the sampling location to the recovery trailer, the sampling train was disassembled into three sections: the nozzle/probe liner, filter holder, and impingers in their bucket. Each of these sections was capped with Teflon® tape or parafilm before removal to the recovery trailer.

Once in the trailers, the sampling train was recovered as separate front and back half fractions. A diagram illustrating front half and back half sample recovery procedures is shown in Figure 5-7. No equipment with exposed metal surfaces was used in the sample recovery procedures. The weight gain in each of the impingers was recorded to determine the moisture content in the flue gas. Following weighing of the impingers, the front half of the train was recovered, which included the filter and all sample-exposed surfaces forward of the filter. The probe liner was rinsed with acetone by tilting and rotating the probe while squirting acetone into its upper end so that all inside surfaces were wetted. The acetone was quantitatively collected into the appropriate bottle.

This rinse was followed by additional brush/rinse procedures using a non-metallic brush; the probe was held in an inclined position and acetone was squirted into the upper end as the brush was pushed through with a twisting action. All of the acetone and particulate was caught in the sample container. This procedure was repeated until no visible particulate remains and finished with a final acetone rinse of the probe and brush. The front half of the filter was also rinsed with acetone until all visible particulate was removed. After all front half acetone washes were collected, the cap was tightened, the liquid level marked, and the bottle weighed to determine the acetone rinse volume. The method specifies a total of 100 ml of acetone may be used for rinsing these components. However, Radian feels that a thorough rinse requires more reagent. An acetone reagent blank of approximately the same volume as the acetone rinses was analyzed with the samples.

The nozzle/probe liner, and front half of the filter holder was rinsed three times with 0.1N HNO<sub>3</sub> and placed into a separate amber bottle. The bottle was capped tightly, the weight of the combined rinse recorded, and the liquid level marked. The filter was placed in a clean, well-marked glass petri dish and sealed with Teflon® tape.

Prior to recovering the back half impingers, the contents were weighed for moisture control determinations. Any unusual appearance of the filter or impinger contents were noted. Pictures were taken to further document any abnormality.

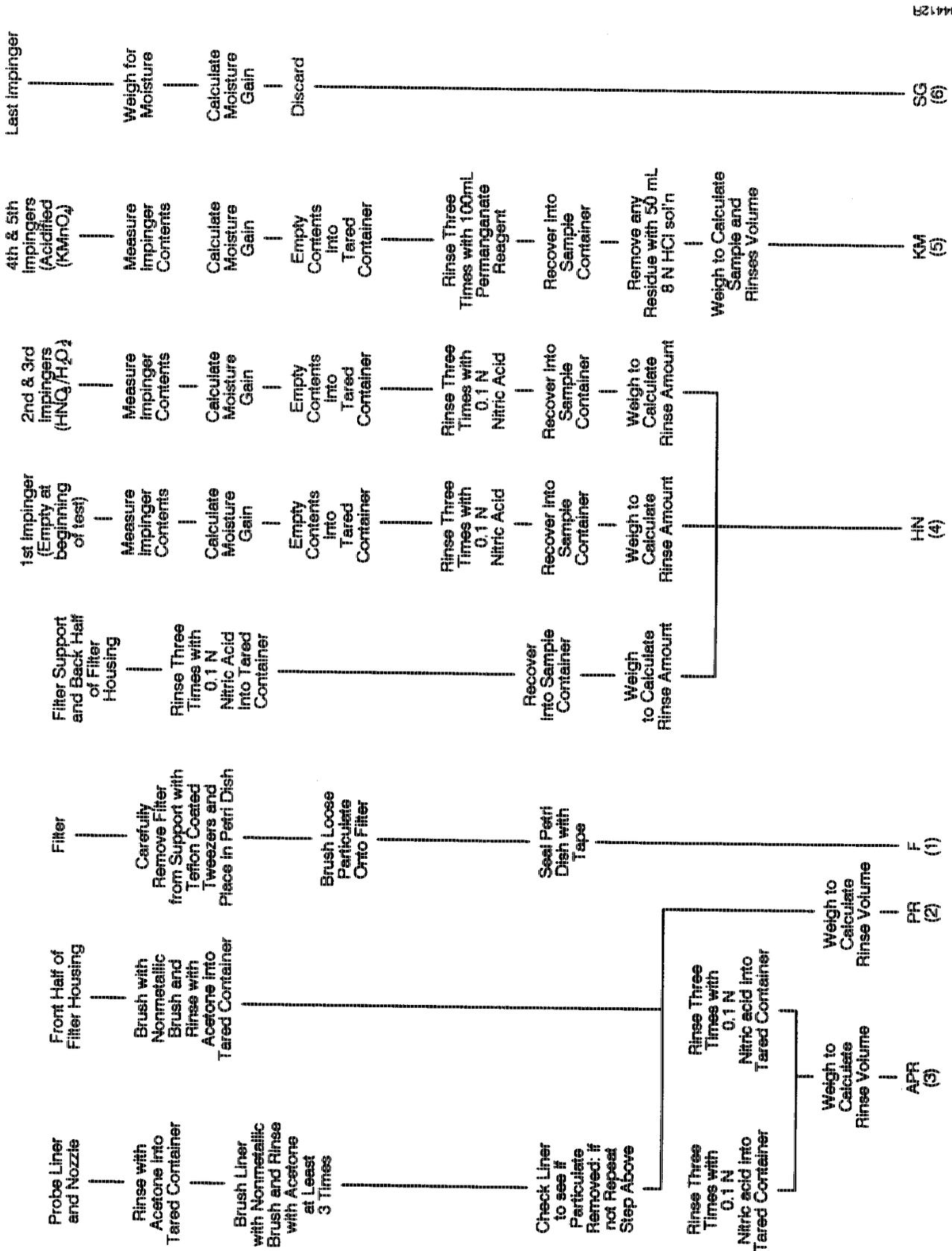


Figure 5-7. Metals Sample Recovery Scheme

The contents in the knockout impinger were recovered into a preweighed, pre-labeled bottle with the contents from the  $\text{HNO}_3/\text{H}_2\text{O}_2$  impingers. These impingers and connecting glassware were rinsed thoroughly with 0.1N  $\text{HNO}_3$ , the rinse was captured in the impinger contents bottle, and a final weight was taken. Again, the method specifies a total of 100 ml of 0.1N  $\text{HNO}_3$  be used to rinse these components. A  $\text{HNO}_3$  reagent blank of approximately the same volume as the rinse volume was analyzed with the samples.

The impingers that contain the acidified  $\text{KMnO}_4$  solution were poured together into a preweighed, pre-labeled bottle. The impingers and connecting glassware were rinsed with at least 100 ml of the acidified  $\text{KMnO}_4$  solution (from the same batch used for sampling) a minimum of three times. Rinses were added to the sample recovery bottle. A final 50 ml 8N hydrochloric acid ( $\text{HCl}$ ) rinse was conducted and placed into the sample recovery bottle. A final weight was recorded and the liquid level was marked on the bottle. The bottle cap was loosely tightened to allow venting.

After final weighing, the silica gel from the train was saved in a bag for regeneration after the job has been completed. The ground glass fittings on the silica gel impinger were wiped off after sample recovery to assure a leak tight fit for the next test.

A reagent blank was recovered in the field for each of the following reagents:

- Acetone blank - 100 ml sample size;
- 0.1N  $\text{HNO}_3$  blank - 1000 ml sample size;
- 5 percent  $\text{HNO}_3$ /10 percent  $\text{H}_2\text{O}_2$  blank - 200 ml sample size;
- Acidified  $\text{KMnO}_4$  blank - 1000 ml sample size; this blank should have a vented cap;
- 8N  $\text{HCl}$  blank - 50 ml sample size;
- Dilution water; and
- Filter blank - one each.

Each reagent blank was of the same lot as was used during the sampling program. Each lot number and reagent grade was recorded on the field blank label.

The liquid level of each sample container was marked on the bottle in order to determine if any sample loss occurred during shipment.

Approximate detection limits for the various metals of interest are summarized in Table 5-8.

#### 5.2.5 Particulate Analysis

The same general gravimetric procedure described in Method 5, Section 4.3 was followed. Both filters and precleaned beakers were weighed to a constant weight before use in the field. The same balance used for taring was used for weighing the samples.

The acetone rinses were evaporated under a clear hood at 20°C (68°F) in a tared beaker temperature silica gel. The filter was also desiccated under the same conditions to a constant weight. Weight gain was reported to the nearest 0.1 mg. Each replicate weighing agreed to within 0.5 mg or 1 percent of total weight less tare weight, whichever was greater, between two consecutive weighings, and were at least 6 hours apart.

#### 5.2.6 Metals Analytical Procedures

A diagram illustrating the sample preparation and analytical procedure for the target metals is shown in Figure 5-8.

The front half fractions basically were digested with concentrated HNO<sub>3</sub> and hydrofluoric (HF) acid in either a microwave pressure vessel or a Parr® bomb. The microwave digestion took place over a period of approximately 10 to 12 minutes in intervals of 1 to 2 minutes at 600 watts; the Parr® bomb digestion was for 6 hours at 140°C (285°F). Both the digested filter and the digested probe rinses were combined to yield the front half sample fraction. The fraction was diluted to a specified volume with water and divided for analysis by applicable instrumentation.

The absorbing solutions from the HNO<sub>3</sub>/H<sub>2</sub>O<sub>2</sub> impingers were combined. An aliquot was removed for the analysis of mercury by CVAAS and the remainder was acidified and reduced to near dryness. The sample was then digested in either a microwave or by conventional digestion, with 50 percent HNO<sub>3</sub> and 3 percent H<sub>2</sub>O<sub>2</sub>. After the fraction had cooled, it was filtered and diluted to a specified volume with water.

TABLE 5.8 APPROXIMATE DETECTION LIMITS FOR METALS OF INTEREST USING EMB DRAFT METHOD

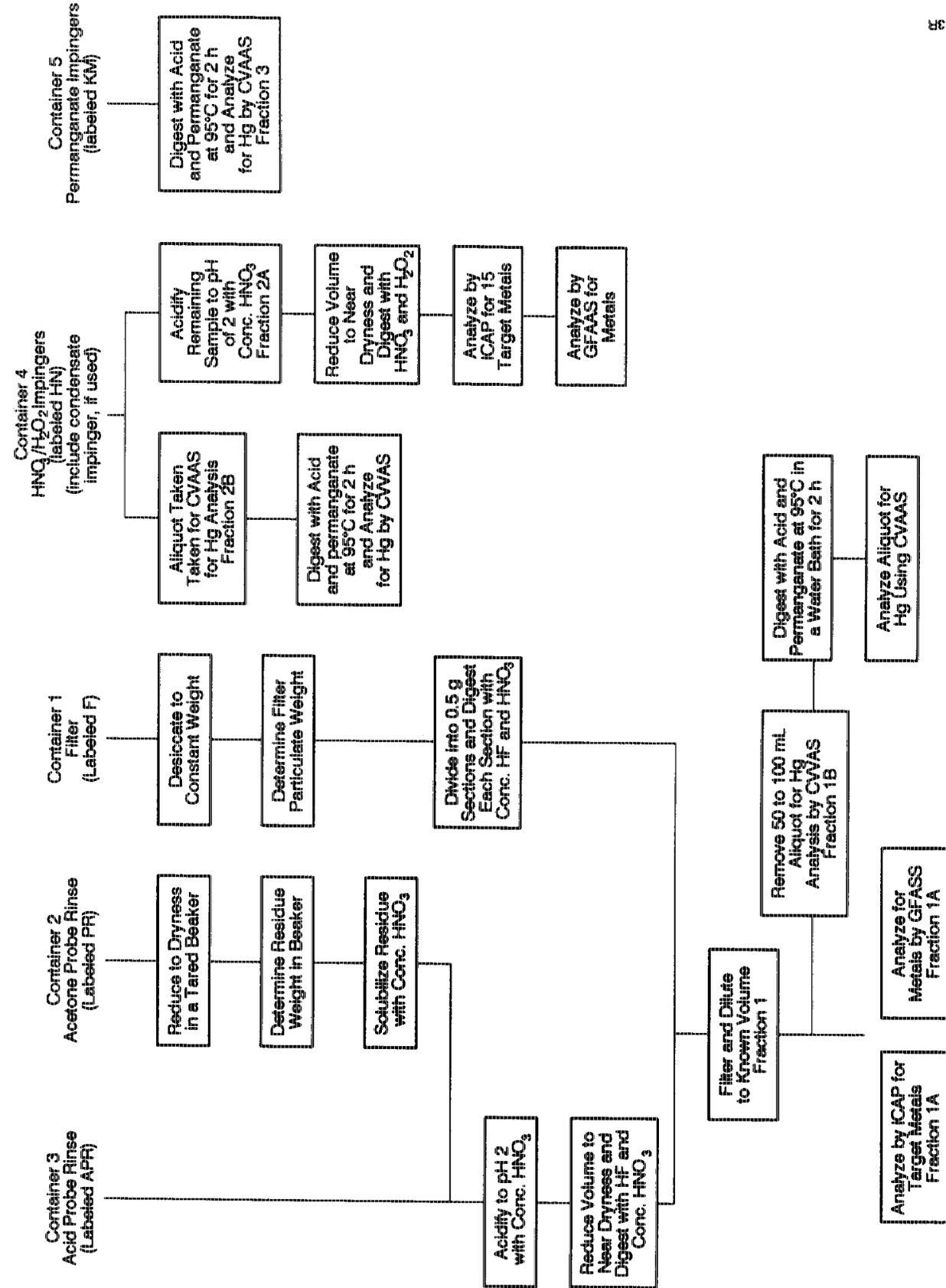
Metal	Method <sup>a</sup>	Analytical Detection Limits ( $\mu\text{g}/\text{ml}$ )	Instack Method Detection Limits <sup>b</sup>	
			Front Half (300 ml sample size) ( $\mu\text{g}/\text{m}^3$ )	Back Half (150 ml sample size) ( $\mu\text{g}/\text{m}^3$ )
Chromium	ICAP	0.007	1.7	0.8
Cadmium	ICAP	0.004	1.0	0.5
Arsenic <sup>d</sup>	GFAAS	0.001	0.3	0.1
Lead <sup>d</sup>	GFAAS	0.001	0.2	0.1
Mercury	CVAAS	0.0002	0.05	0.03 <sup>c</sup>
Nickel	ICAP	0.015	3.6	1.8
Barium	ICAP	0.002	0.5	0.3
Beryllium	ICAP	0.0003	0.07	0.04
Silver	ICAP	0.007	1.7	0.9
Antimony	ICAP	0.032	7.7	3.8
Thallium	ICAP	0.040	9.6	4.8

<sup>a</sup> ICAP = Inductively Coupled Argon Plasma  
 GFAAS = Graphite Furnace Atomic Absorption Spectroscopy  
 CVAAS = Cold Vapor Atomic Absorption Spectroscopy

<sup>b</sup> These detection limits are based on a stack gas sample volume of 1.25 m<sup>3</sup>. If 5 m<sup>3</sup> are collected, the instack method detection limits are 1/4 of the values indicated.

<sup>c</sup> The detection limit for mercury is the same in the HNO<sub>3</sub>/H<sub>2</sub>O<sub>2</sub> fraction as it is in the KMnO<sub>4</sub> fraction.

<sup>d</sup> If Fe and Al are present, samples will be diluted which may raise analytical detection limits.



35044 13R

Figure 5-8. Metals Sample Preparation and Analysis Scheme

Each sample fraction was analyzed by ICAPS using EPA Method 200.7. All target metals except mercury, iron, and aluminum, were quantified. If iron and aluminum were present, the samples were diluted to reduce their interferences on arsenic and lead. If arsenic or lead levels were less than 2 ppm, GFAAS was used to analyze for these elements by EPA Methods 7060 and 7421. Matrix modifiers such as specific buffering agents may be added to these aliquots to react with and tie up interfering agents. The total volume of the absorbing solutions and rinses for the various fractions were measured and recorded in the field notebook.

To prepare for mercury analysis by CVAAS, an aliquot from the  $\text{KMnO}_4$  impingers,  $\text{HNO}_3/\text{H}_2\text{O}_2$  impingers, filter digestion, and front half rinses were digested with acidic reagents at  $95^\circ\text{C}$  in capped BOD bottles for approximately 3 hours. Hydroxylamine hydrochloride solution and stannous chloride was added immediately before analysis. Cold vapor AAS analysis for mercury followed the procedure outlined in EPA Method 7470 or in Standard Methods for Water and Wastewater Analysis, Method 303F.

#### 5.2.7 Quality Control for Metals Analytical Procedures

All quality control procedures specified in the test method were followed. All field reagent blanks were processed, digested, and analyzed as specified in the test method. To ensure optimum sensitivity in measurements, the concentrations of target metals in the solutions were at least 10 times the analytical detection limits.

5.2.7.1 ICAP Standards and Quality Control Samples. The quality control procedures included running two standards for instrument checks (or frequency of 10 percent), two calibration blank runs (or frequency of 10 percent), one interference check sample at the beginning of the analysis (must be within 10 percent or analyze by standard addition), one quality control sample to check the accuracy of the calibration standards (must be within 10 percent of calibration), one duplicate analysis and one standard addition for every 10 samples (must be within 5 percent of average or repeat all analysis).

Standards less than  $1\ \mu\text{g}/\text{ml}$  of a metal were prepared daily; those with concentrations greater than this were made weekly or bi-monthly.

5.2.7.2 Graphite Furnace Standards and Quality Control Samples. Standards used for GFAAS analysis were matrix matched with the samples analyzed and the matrix modifiers that were added. Standards less than 1  $\mu\text{g}/\text{ml}$  of a metal were prepared daily; those with concentrations greater than this were made weekly or bi-monthly. A minimum of five standards make the standard curve. Quality control samples were prepared from a separate 10  $\mu\text{g}/\text{ml}$  standard by diluting it into the range of the samples.

All samples were analyzed in duplicate. A matrix spike on one front half sample and one back half sample for each 10 field samples was analyzed. If recoveries of less than 75 percent or greater than 120 percent were obtained for the matrix spike, each sample was analyzed by the method of additions. One quality control sample was analyzed to check the accuracy of the calibration standards. The results must be within 10 percent or the calibration repeated.

5.2.7.3 Mercury Standards and Quality Control. An intermediate mercury standard was prepared weekly; working standards were prepared daily. The calibration curve was made with at least six points. Quality Control samples were prepared from a separate 10  $\mu\text{g}/\text{ml}$  standard by diluting it into the range of the samples.

A quality control sample had to agree within 10 percent of the calibration, or the calibration will be repeated. A matrix spike on one of every 10 samples from the  $\text{HNO}_3/\text{H}_2\text{O}_2$  back half sample fraction must be within 20 percent or the samples were analyzed by the method of standard addition.

### 5.3 MICROBIAL SURVIVABILITY TESTING

The Jordan Hospital MWI was loaded with waste containing surrogate indicator organisms which measured the ability of native microbes to survive the incineration process. This ability of the surrogate indicator organisms to survive directly reflected microbial destruction efficiency for a given incinerator. Several test methods were being employed to measure microbial survivability. The first test method was aimed at determining microbial survivability in the combustion gases and the ash. This method involved inoculating a known quantity of spores in solution onto materials normally found in the medical waste stream (i.e., gowns, petri dishes, gauze, etc.). Direct ash sampling and flue gas testing were conducted in order to determine the destruction

efficiency. Test procedures follow guidelines set forth by the EPA draft methods located in Appendix K.

The second test method utilizes spiked spore samples encased in insulated metal containers charged into the incinerator with the waste stream. These tests were aimed at comparing this method with the direct ash sampling method and should provide a general assessment of microbial survivability and destruction efficiency. Two types of insulated outer containers were used for comparison to each other. One type utilizes large (6 inch by 2 inch diameter) metal pipes filled with vermiculite insulation and capped at both ends. Another type utilizes a 1/2-inch thick blanket of high temperature ceramic insulation rolled and contained by a wire mesh wrap. Both outer containers hold a smaller 3/8 inch diameter stainless steel tube capped at both ends. The smaller tube contains a known quantity (approximately  $1 \times 10^7$  spores) of freeze dried spores. Following the test, the viability of the indicator spores in each sample was checked to assess the destruction efficiency based on the number of spores that remain in the ash. Testing procedures used here follow an EPA draft method entitled "Microbial Survivability Test for Medical Waste Incinerator Ash." The following sections detail both spiking procedures (emissions/ash and pipe) as well as the spore flue gas sampling and analytical techniques.

### 5.3.1 Spiking Procedure for Emissions and Ash Microbial Loading

In order to conduct emissions and ash testing for microbe survivability, a series of waste materials inoculated with indicator spores were charged into the incinerator. A known quantity of B. stearothermophilus wet spores were inoculated onto or in materials normally found in the medical waste stream such as gowns, petri dishes, test tubes, gauze, towels, etc. The waste was loaded into the incinerator with the batch of wastes charged prior to the emission tests conducted at the incinerator outlet. Direct ash samples were collected after the incineration cycle has been completed and the ash has cooled sufficiently.

5.3.1.1 Equipment. A "wet spore" culture solution was prepared by the University of Alabama. The culture inoculum was divided between the three sampling days as shown in Figure 5-9. The spore solution was prepared as a frozen slurry in 1-liter

# FERMENTATION

## Batch 1

Run 1, Run 2 (Test Day 1)	Run 3, Run 4 (Test Day 2)	Run 5, Run 6 (Test Day 3)
Fraction a	a	a
Fraction b	b	b
Fraction c	c	c
Fraction d	d	d
Fraction e	e	e
Fraction f	f	f
Fraction g	g	g
Fraction h	h	h

**Notes:** Each Fraction is loaded into the incinerator as near as possible to the centroid of each of eight equal sub-volumes of the total incinerator volume prior to each batch run.

A minimum of  $1 \times 10^{12}$  are spiked on each test day.

**Figure 5-9. Indicator Spore Spiking Scheme for  
Combustion Gas Destruction Efficiency Testing  
Jordan Hospital (1991)**

amounts. Inoculation quantities were approximately 500 mls. The culture inoculum was added directly to various materials using sterile gloves and the prepackaged containers.

5.3.1.2 Spiking Preparation and Procedure. The spiked waste sample was prepared so that a minimum of  $1 \times 10^{12}$  spores were charged into the incinerator per test day (the exact quantity was recorded). The total charge each day was separated into eight nearly equal batches. The eight batches of spores were inoculated in eight mock garbage bags and placed into the incinerator prior to each day's startup. Two sampling runs were performed per test day, however, since Jordan was a batch-fed unit, more spores could not be inoculated after the unit has started.

### 5.3.2 Indicator Spore Flue Gas Sampling

Flue gas was extracted from the incinerator stack during the burn and burndown periods to determine spore emissions. The testing procedure followed the previously mentioned, draft EPA method. Flue gas samples were collected isokinetically in a buffered solution in impingers (no filter). The recovered samples were divided into different volume aliquots. These samples were cultured and colonies were identified using gram stains to establish cellular morphology, and possibly other biochemical tests as needed. The colonies were then enumerated. The following sections describe the flue gas sampling techniques used.

5.3.2.1 Equipment. A schematic of the spore sampling train is shown in Figure 5-10. Flue gas samples were extracted isokinetically through a quartz nozzle/probe system housed in a water-cooled sheath. A smaller tube was located inside the sampling probe to deliver a buffered solution at the nozzle end of the probe. This allowed the gas sample stream to be immediately buffered, preventing acid condensate from killing viable spores. From the probe, the sample stream was delivered to a series of chilled impingers. The first two contained 200 ml and 100 ml, respectively, of phosphate-buffered solution to collect indicator spores. The third impinger served as a knock-out (empty) and the fourth contained silica gel. In between the third and fourth impinger, a small amount of quartz wool was placed to collect PM. This material was rinsed into the impinger catch during recovery operations. The remainder of the sampling train was identical to a Method 5 system. (Meter box containing pump, meter, velocity and sampling pressure manometers, etc.)

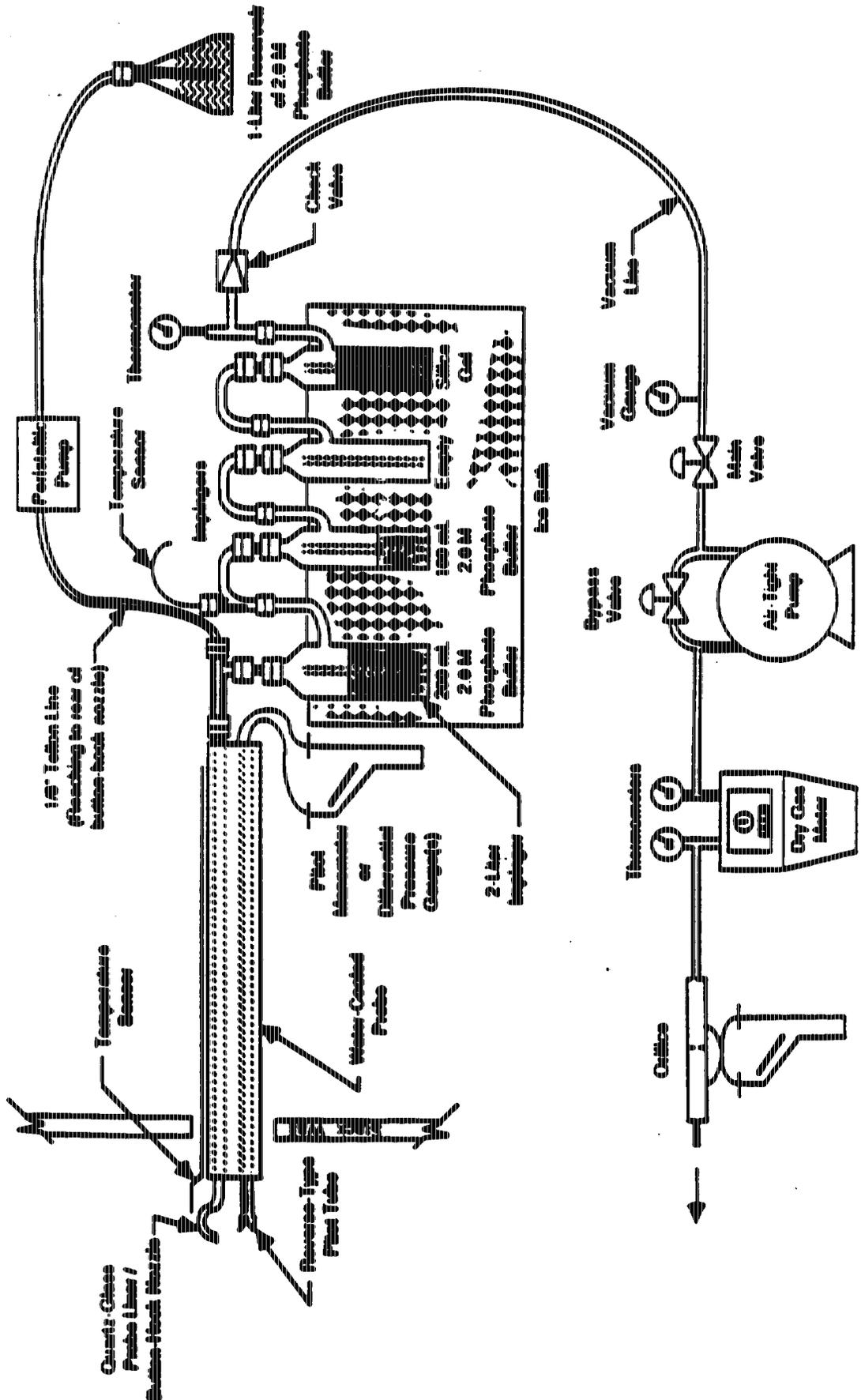


Figure 5-10. Sampling Train for Determination of Indicator Spore Emissions

A Peristaltic pump was used to deliver the buffer solution to the probe tip. The pump was capable of accurately metering a 10 to 20 ml/minute flow rate.

5.3.2.2 Sampling Preparation. All equipment used for sampling and sample recovery, which come into contact with the sample, was H<sub>2</sub>O<sub>2</sub>/alcohol disinfected and washed before each run. The nozzle/probe liner, impingers, impinger connections, and the nozzle/probe brush were first washed using the same procedure as discussed in Section 5.3.4.2. Following washing, all components were disinfected with H<sub>2</sub>O<sub>2</sub>/alcohol. After completing this procedure, all components were sealed with Parafilm® to prevent contamination. Additional sample containers, recovery items, and analytical equipment were sterilized by autoclaving or another equivalent method. Some of the items which require sterilization were wash bottles, two liter glass sample storage bottles, incubation tubes, petri dishes, filter units, reagent water (sterile deionized), and buffering reagent.

The train was assembled by first antiseptically adding the buffer solution to the first two impingers. Silica gel was added to the fourth impinger and the impinger train was connected to the meter box via an umbilical line. A pre-test leakcheck on the impinger train was completed at approximately 15 in. Hg. Leakage rates in excess of 4 percent of the average sampling rate or 0.02 cfm, whichever was less, were unacceptable.

5.3.2.3 Flue Gas Sampling. Before inserting the probe into the stack, the nozzle cap was removed and alignment of the nozzle and pitot tube were checked. The probe cooling water flow was started and adjusted. The buffering system pump was then started making sure that the probe was slightly inclined so that the buffer solution drained into the first impinger. The probe was inserted into the duct and located at the first sampling traverse point. Isokinetic sampling commenced in accordance with Method 5 guidelines. All sampling parameters ( $\Delta P$ , gas meter readings, stack temperature, meter temperatures, meter  $\Delta H$ , meter vacuum, first impinger temperature, and silica gel impinger temperature) were periodically monitored, adjusted, and recorded throughout the test run.

Two different trains were used. When the first traverse was completed, the second traverse was immediately started with the second train.

After completion of the test run, the probe was removed from the stack and the flow of buffering solution turned off. The final meter reading was recorded and the sample train was leak checked. Post-test leakchecks were completed at a vacuum equal to or greater than the maximum vacuum reached during the sampling run. Acceptable post-test leakcheck criterion was the same as was previously mentioned for the pre-test leakchecks.

5.3.2.4 Sample Recovery. Sample recovery procedures are summarized in Figure 5-11. After the probe has cooled, the probe cooling water was turned off. The nozzle tip was inspected for port scrapings or any external matter near the tip and removed if found. The probe was disconnected from the impinger train. The probe and probe buffer delivery tube, were rinsed and brushed with sterile buffer solution. All rinses were collected in a sterile sample bottle.

The impingers were weighed and the contents were antiseptically transferred to the sample bottle containing the nozzle/probe rinsings. The pH of the sample was adjusted if necessary to between 6.0 and 7.5 with 1.0 N NaOH. The level of liquid in the sample bottle was marked to determine later if leakage occurred during transport. The bottle was then packed in ice so that sample temperatures were maintained at or below 4°C (39°F), for shipment to the laboratory.

### 5.3.3 Direct Ash Sampling for Indicator Spores

Direct ash sampling provided an indication of the ability of the indicator organism to survive the incinerator process under various conditions. An outline of the proposed ash sampling protocol was found in Appendix K. Ash samples were recovered from the ash when it has cooled sufficiently. Ash samples were taken using a sampling thief, composited and placed in clean sample jars. During each sampling run, two samples were taken. One was transported to the laboratory for analysis and the second sample was used to determine the pH of the material and the archived as a backup sample. Laboratory samples were tested in accordance with proposed Draft Method found in Appendix K.

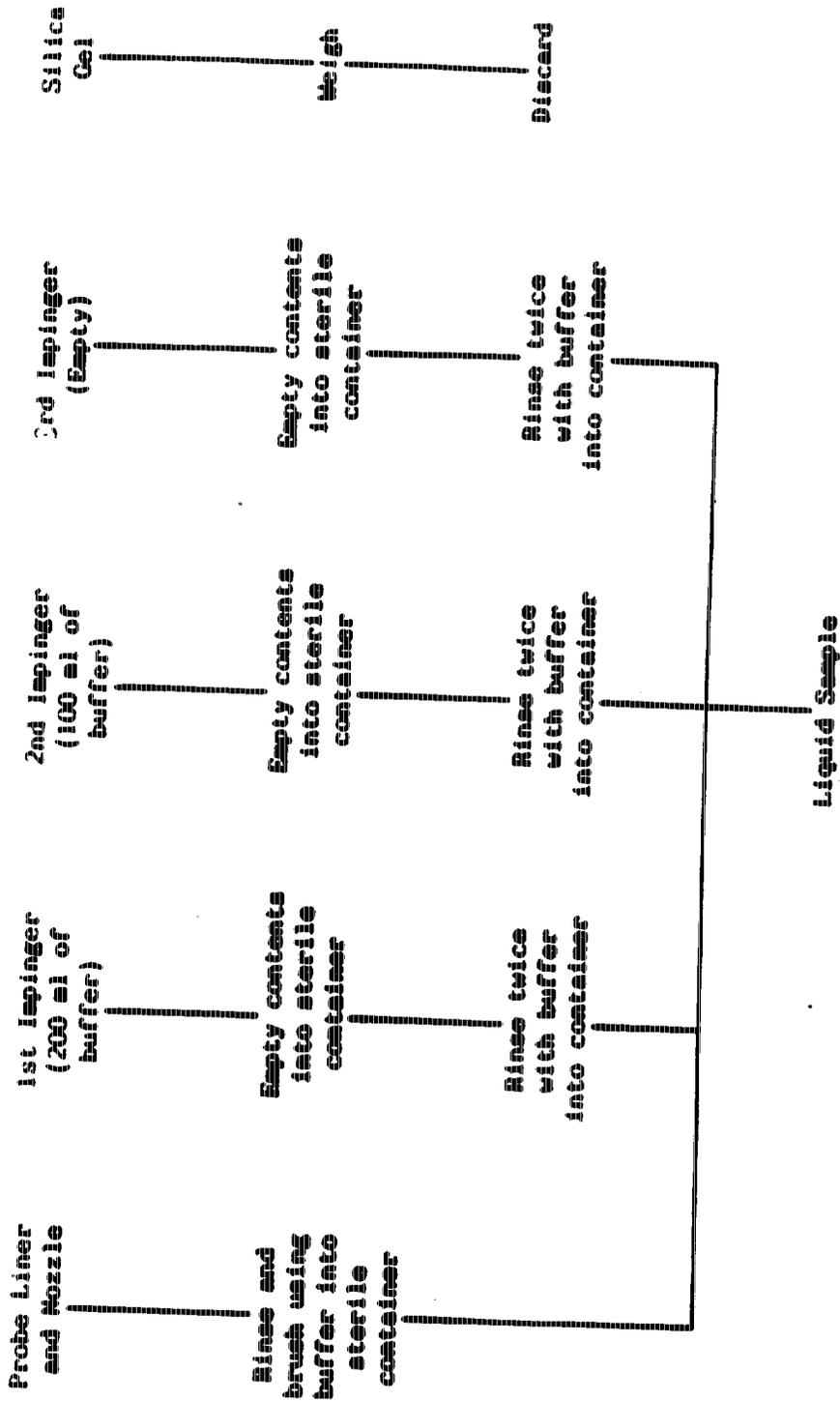


Figure 5-11. Sample Recovery Scheme for Microbial Viability Testing

5.3.3.1 Equipment. Ash samples were taken using a disinfected sample thief and placed in sample containers for transport to the laboratory. These samples were stored on ice. The pH of the ash was determined by adding a known amount of deionized water to a weighed aliquot of ash and measuring the pH by specific ion electrode.

#### 5.3.4 Pipe Spiking Procedures

The waste was charged into the incinerator with known quantities of Bacillus stearothermophilus (B. stearothermophilus) contained in both kinds of insulated pipes. Samples were cultured according to the Draft Method found in Appendix K. Colonies of B. stearothermophilus were then gram stained to ensure correct cellular morphology and further identified using biochemical tests as needed. Enumeration of B. stearothermophilus was then completed.

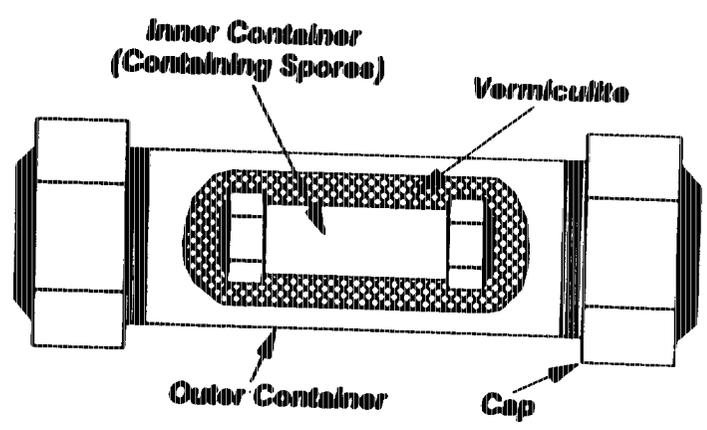
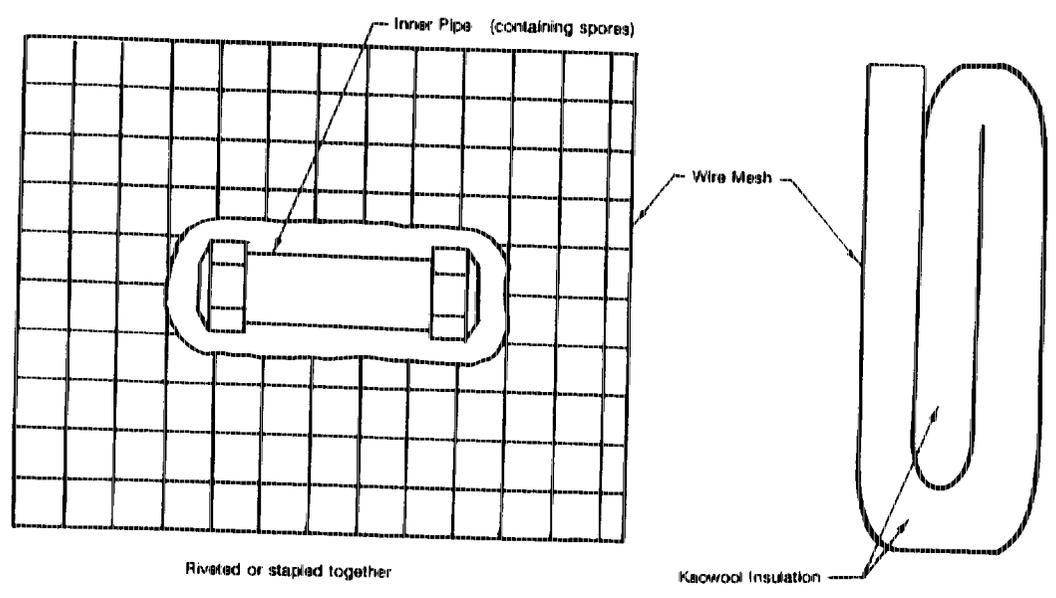
5.3.4.1 Spiking Equipment. A diagram of the pipe sample assemblies used for the pipe test is shown in Figure 5-12. The indicator organisms were freeze-dried spores (lyophilized) that were prepared by American Type Culture Collection in Rockville, Maryland. A small amount of lyophilized material equalling approximately  $1 \times 10^7$  spores was prepared and packaged in the inner metal containers.

The inner metal container consisted of a short piece (2-4 inch) of 3/8 stainless steel tubing capped on both ends with Swagelock™ caps. This inner container was then placed in the outer container which was either a 2 inch diameter steel pipe nipple about 6 inches long, or the insulated mesh wrap. Each outer container was identified with a unique identification number for tracking location. Enough vermiculite or other thermal insulation surrounded the inner container to maintain its position in the center and to protect it from thermal shock.

5.3.4.2 Spiking Preparation. The inner container and caps were cleaned and disinfected before use. This procedure consisted of soaking the containers for at least one hour in 1.0 N HNO<sub>3</sub>, washing with laboratory detergent, rinsing 3 times with tap water, 3 times with sterilized deionized water, and finally, rinsing with 90 percent isopropyl alcohol.

The spiked sample was prepared by placing a known amount of spores (targeted at  $1 \times 10^7$ ) inside the inner container and then sealed using the end caps. The inner

5-8



**FIGURE 5-12. Modified (Mesh) Ash Quality Assembly and Pipe Ash Quality Assembly  
JORDAN HOSPITAL (1991)**

container was placed in the outer container with enough vermiculite or ceramic insulation to position it in the center.

5.3.4.3 Spiking Procedure. The Jordan Hospital MWI was a batch-fed intermittent incinerator that operates essentially around the clock on the days that it was fired. The typical hours of operating were from 7:00 a.m. to 7:00 a.m. the following day. During this time, the unit operates in three distinct modes. The burn period was the first mode, which generally lasts 5½ to 6 hours. The second mode was the burndown period which was almost 7 to 8 hours in duration. The cooldown period was the final mode, which lasts from 10 to 12 hours.

Nine metal pipes were loaded onto the incinerator floor and covered with wastes prior to the start of operating. The locations of the pipes are shown in Figure 2-1. Eight mesh containers were placed in the wet spore spike bags and located nearly evenly throughout the volume of the incinerator as shown.

5.3.4.4 Sample Recovery. The pipes were recovered from the incinerator following a cool down period the morning following the test run. When the ash cleanout door was opened, the location of the samples on the floor was recorded to the extent possible. The samples were recovered and the hot ashes removed from the combustion chamber. Excess debris was removed from the outer container. The inner pipe was then recovered and identified and placed in labeled baggies. The pipe samples were maintained at or below 4°C (39°F) in an ice cooler with care to protect them from contamination from melting ice or cross-contamination from other samples or spike materials.

### 5.3.5 Microbial Analysis

The quantity of viable spores were determined from the pipe samples, flue gas samples, and the direct ash samples. Sample preparation for the three sample types is discussed below.

5.3.5.1 Pipe Sample and Ash Analytical Preparation Procedure. The sample preparation and analysis scheme for the pipe and ash samples were presented in Figures 5-13 and 5-14. The analysis was performed within 96 hours after sample recovery. The contents of the inner container of the pipe and the direct ash samples were transferred to separate sterile incubation tubes. The inside of the sample

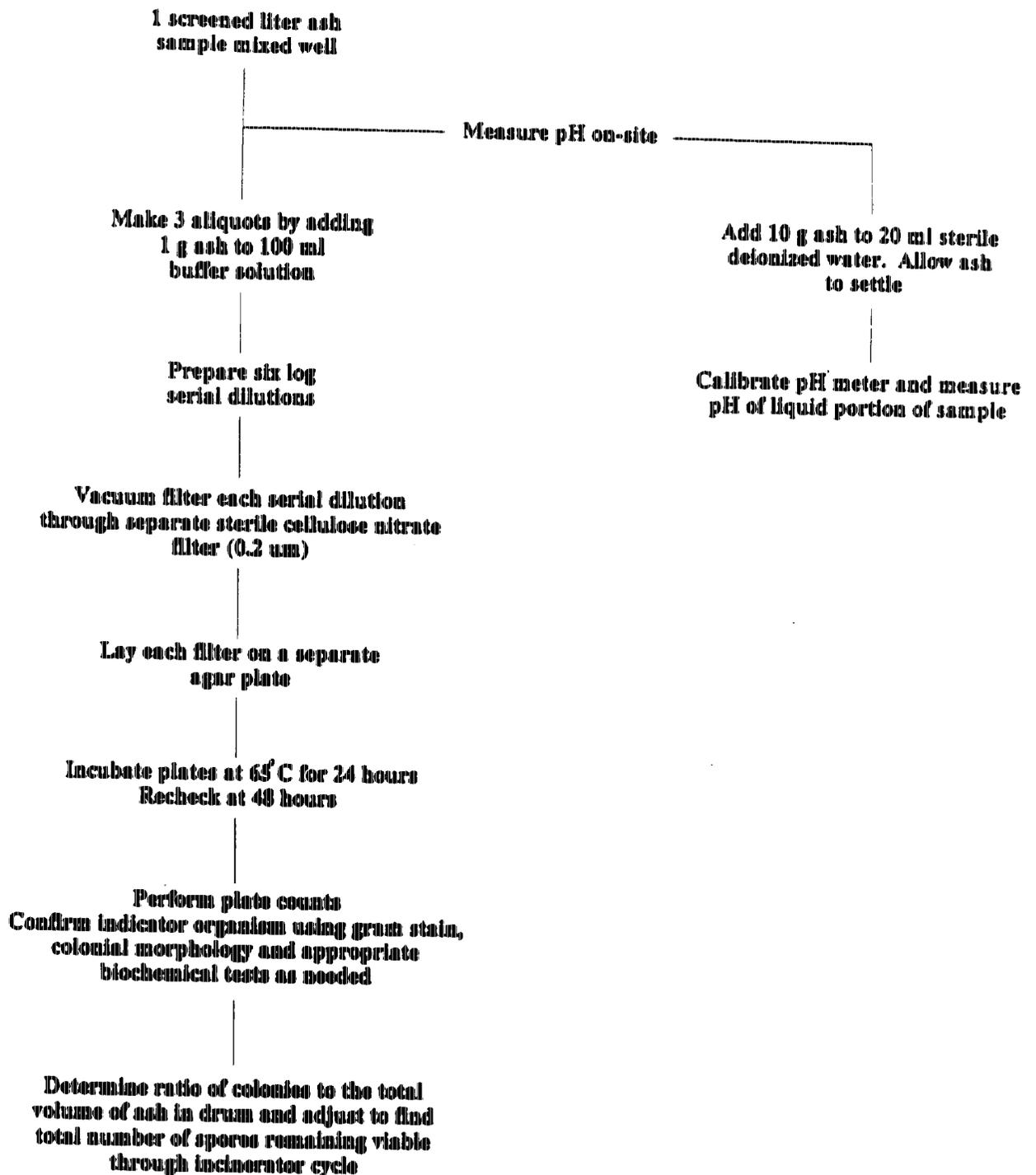


Figure 5-13. Sample and Analysis Scheme for Microbial Testing of Ash Samples

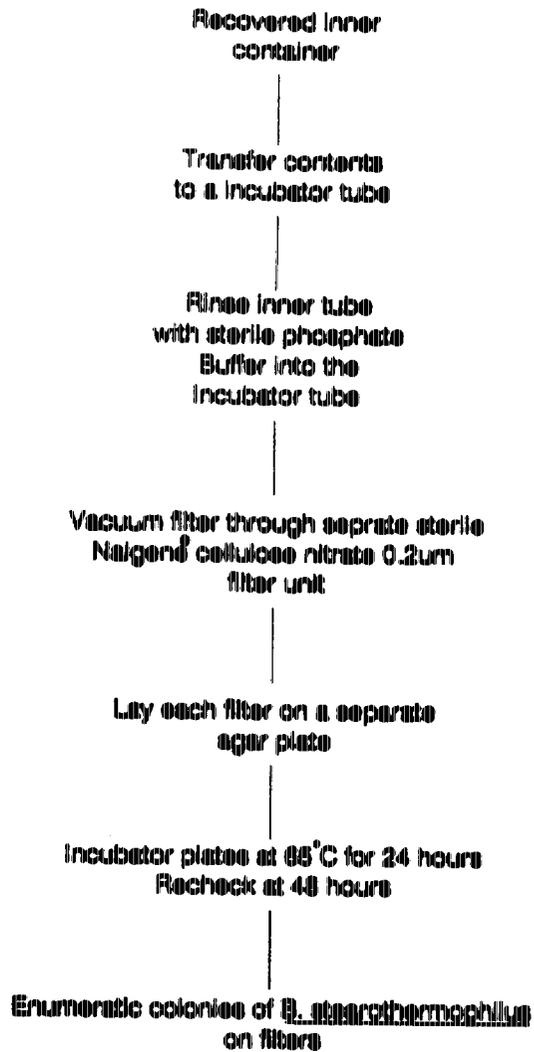


Figure 5-14. Analysis Scheme for Pipe Sample Microbial Viability Tests

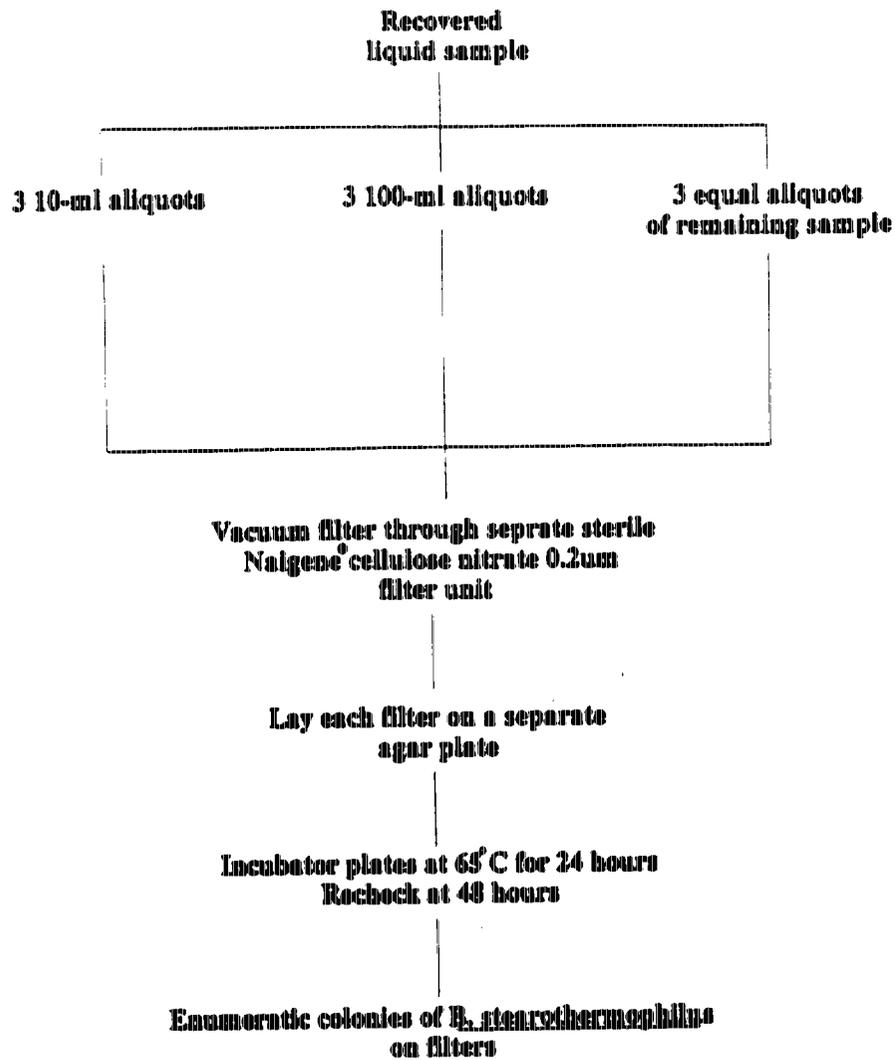
containers were rinsed with sterile phosphate buffer solution into the respective incubation tube. Any glassware used for this transfer procedure was rinsed with sterile deionized water into the respective incubation tubes. The direct ash samples were mixed and aseptically added to 100 mls of sterile deionized water before further processing.

5.3.5.2 Flue Gas Sample Analytical Preparation Procedure. The sample preparation and analysis scheme is presented in Figure 5-15. The level of each sample was checked to determine if leakage during shipment occurred. Each sample contains approximately 1.5 to 2.0 liters of sample. The sample was then aliquoted and prepared as shown in Figure 5-15. Three 10 ml aliquots, three 100 ml aliquots, and three equal volume of the remaining solution was prepared. The aliquots were placed in sterile incubation tubes, one set was processed without heat-treatment, the other with heat-treatment. Each aliquot was then filtered and placed onto agar plates as discussed in the following sections.

5.3.5.3 Colonial Enumeration and Identification Procedure. Agar plates were prepared by pouring the molten trypticase soy agar into a sufficient number of petri dishes for both sample and field blanks. The media was then allowed to harden. Each sample was then filtered through a separate vacuum filter unit employing a sterile cellulose nitrate filter (0.2  $\mu\text{m}$ ). The incubation tube was rinsed with sterile deionized water and poured through the filter as well. Each filter was removed from the filtering unit using sterile forceps and placed face up on an agar plate. The plates were incubated in an air convection incubator at 65°C (49°F) for 18 to 24 hours prior to colonial examination. The plates were removed from the incubator and colonies of B. stearoothermophilus were quantified. A variety of tests including a gram stain and biochemicals may be used to confirm that the colonies were B. stearoothermophilus.

5.3.5.4 Indicator Spore Analytical Quality Control. The QA/QC procedures followed during spore enumeration and verification procedures (analysis) are documented in Table 5-9. An aliquot from one batch of the wet spore spiking slurry was sent to RTI to verify the manufacturer's count.

Field blanks from a flue gas (impinger) sample as well as a non-charged pipe sample, were analyzed to check for contamination during preparation or recovery procedures. Duplicates were analyzed for impinger samples from two test runs.



**Figure 5-15. Sample Preparation and Analysis Scheme for Microbial Testing**

TABLE 5-9. INDICATOR SPORE TESTING QA/QC CHECKS

Sample Type	Number	QA/QC Check
Wet Spores	1	Verify manufacturer's wet spore count by sending an aliquot from one slurry to RTI for count.
Field Blank - Impinger Sample	1	Prepare train through leakcheck, run buffer solution for 2 hours, collect 1 field blank sample
Field Blank - Pipe Sample	2	Fully prepare pipe sample without placing spore charge inside to check for handling contamination
Duplicates - Impinger Sample	2	Complete duplicate analyses on 2 impinger samples from 2 test runs
Field Duplicates - Pipe Samples	3	Load duplicate pipe samples on 3 separate occasions into incinerator and analyze
Pre-Test Ash Blank	1	Collect ash samples using the test procedures prior to any spiking of indicator spores

A blank ash sample was collected prior to the test program to check for the presence of indicator spores in the background ash prior to any spiking.

#### 5.4 HYDROGEN CHLORIDE/HYDROGEN BROMIDE/HYDROGEN FLUORIDE EMISSIONS TESTING BY EPA METHOD 26

Hydrogen chloride, HBr, and HF sampling was accomplished using a single sampling train. The procedure followed the EPA Method 26 draft protocol entitled "The Determination of HCl Emissions from Municipal and Hazardous Waste Incinerators." In this method, an integrated gas sample was extracted from the stack and passed through acidified water. In acidified water, HCl solubilizes and forms  $\text{Cl}^-$  ions. Ion chromatography was used to detect the  $\text{Cl}^-$  ions present in the sample. For this test program, the presence of  $\text{Br}^-$  and  $\text{F}^-$  ions were also be detected by IC. The method is included in Appendix K.

##### 5.4.1 HCl/HBr/HF Sampling Equipment

A diagram of the HCl/HBr/HF sampling train is shown in Figure 5-16. The sampling train consisted of a quartz probe with a pallflex Teflon/glass filter to remove PM, and a series of chilled midget impingers and a DGM system. A small amount of quartz glass wool was placed in the front half of the filter holder to help remove excessive PM found in this gas stream. Because the high temperatures of the stack and the shortness of the sampling probe the sample gas in the probe was kept above the acid dewpoint, the probe was not heated. The train consisted of two impingers containing 0.1 N sulfuric acid ( $\text{H}_2\text{SO}_4$ ) to collect HCl, HBr, and HF; two impingers containing 0.1 N NaOH to capture any pollutants present in the flue gas that might cause DGM damage; and finally one silica gel impinger.

##### 5.4.2 HCl/HBr/HF Sampling Preparation

5.4.2.1 Equipment Preparation. Sampling preparation included calibration and leak checking of all train equipment. This included meterboxes, thermocouples, and umbilicals. Referenced calibration procedures were followed when available, and the results properly documented and retained. If a referenced calibration technique for a particular piece of apparatus was not available, then a state-of-the-art technique was used.

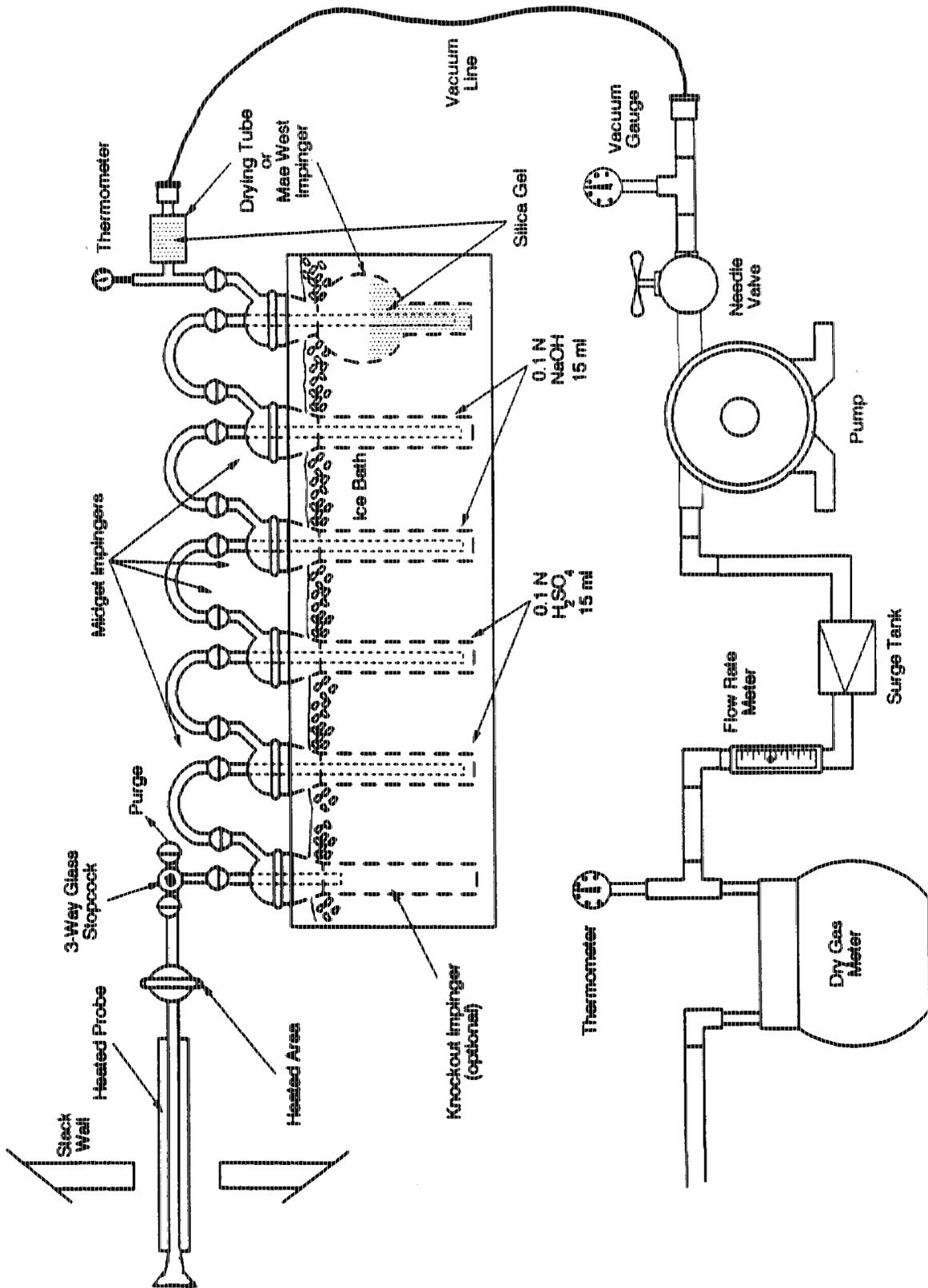


Figure 5-16. HCl Sample Train Configuration

5.4.2.2 Assembling the Train. Assembly of the sampling train was done both in the recovery trailer and at the stack location. First, the empty clean impingers were assembled and laid out in the proper order. The optimal knockout impinger was not used for testing at this facility. The first two impingers contained 15 to 20 ml 0.1 N  $H_2SO_4$  each, followed by two impingers filled with 15 to 20 ml each of 0.1 N NaOH, and finally an impinger containing 20 to 30 grams of silica gel. When the impingers were loaded, they were wrapped with Teflon® tape to secure the two sections of the impinger. The impingers were connected together using U-tube connectors and arranged in the impinger bucket. The height of all the impingers was approximately the same to easily obtain a leak-free seal. The open ends of the train were sealed with aluminum foil.

#### 5.4.3 HCl/HBr/HF Sampling Operations

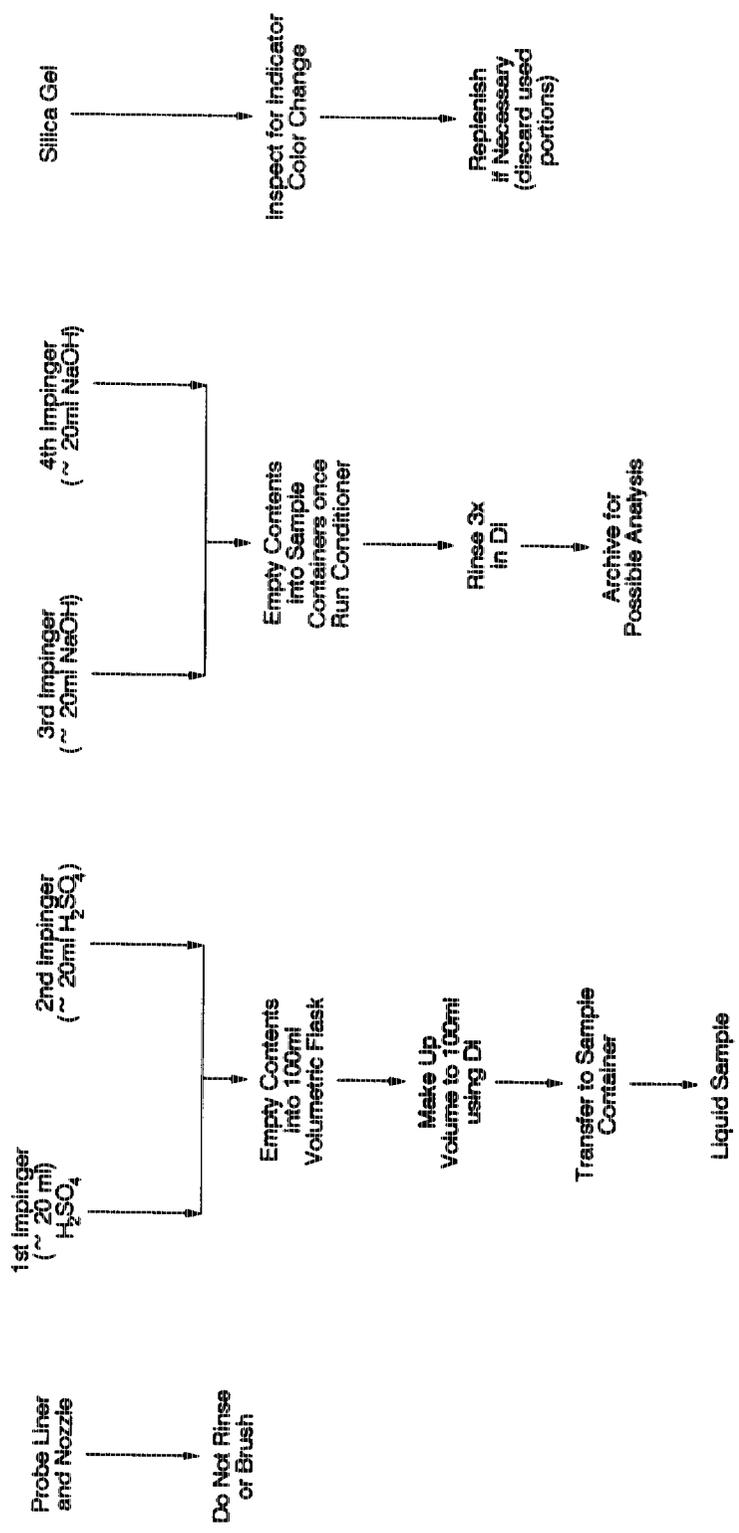
Prior to sampling, the HCl/HBr/HF train was leakchecked as required by Method 26 protocol. The leak checking procedure was the same as that discussed in Section 5.1. The leak rate, sampling start and stop times, and any other events were recorded on the sampling task log. Upon completion of a sampling run, the leakcheck procedure was repeated. Sampling train data were recorded every five minutes, and include readings of the DGM, DGM temperature, flow rate meter, and vacuum gauge.

#### 5.4.4 HCl/HBr/HF Sample Recovery

The impingers were disconnected from the probe and filter and moved to the recovery trailer. Once in the trailer, the contents of the two acidified impingers were quantitatively recovered with deionized distilled water and placed into a clean sample bottle. The sample bottle was sealed, mixed and labeled, and the fluid level marked. The contents of the second set of impingers (containing the 0.1 N NaOH) were discarded for every triplicate series except for one. These were archived for possible future analyses. The sample recovery scheme is shown in Figure 5-17.

#### 5.4.5 HCl/HBr/HF Analytical Procedures

Before analysis, the samples were checked against the chain-of-custody forms and then given an analytical laboratory sample number. Then, each sample was examined to determine if any leakage occurred and any color or other particulars of the samples were noted.



3804510R

Figure 5-17. HCl/HBr/HF Sample Recovery Scheme

The IC conditions were described by the type of analytical column and whether suppressed or nonsuppressed IC was used. Prior to sample analysis, a stable baseline was established and water samples were injected until no Cl<sup>-</sup>, Br<sup>-</sup>, or F<sup>-</sup> appears in the chromatogram. Then, the IC was calibrated using standards spanning the appropriate concentration range, starting with the lowest concentration standard. Next, a QC check sample was injected in duplicate, followed by a water blank and the field samples. The calibration standards were re-injected at the end of the analysis to allow compensation for any drift in the instrument response during analysis of the field samples. The Cl<sup>-</sup>, Br<sup>-</sup>, and F<sup>-</sup> sample concentrations were calculated from either the respective ion peak area or peak height and the calibration curve.

#### 5.4.6 HCl/HBr/HF Analytical Quality Control

The IC was calibrated with a minimum of three concentrations, not including zero. A correlation coefficient of greater than or equal to 0.995 was achieved to have an acceptable calibration. At least 10 percent of the total number of samples were analyzed in duplicate. Ion concentrations in the duplicates must agree to within  $\pm 20$  percent.

### 5.5 EPA METHODS 1-4

#### 5.5.1 Traverse Point Location By EPA Method 1

The number and location of sampling traverse points necessary for isokinetic and flow sampling was dictated by EPA Method 1 protocol. These parameters were based upon how much duct distance separates the sampling ports from the closest downstream and upstream flow disturbances. The minimum number of traverse points for a circular duct less than 24 inches was 4 (8 total sample points). Several sets of perpendicular sampling ports were established in the incinerator outlet. Traverse point locations were determined for each port depending on the distances to duct disturbances (see Section 4).

#### 5.5.2 Volumetric Flow Rate Determination by EPA Method 2

Volumetric flow rate was measured according to EPA Method 2. A Type K thermocouple and S-type pitot tube were used to measure flue gas temperature and velocity, respectively. All of the isokinetically sampled methods that were used incorporate Method 2 (CDD/CDF, PM/Metals, Microorganisms).

5.5.2.1 Sampling and Equipment Preparation. For EPA Method 2, the pitot tubes were calibrated before use following the directions in the method. Also, the pitots were leak checked before and after each run.

5.5.2.2 Sampling Operations. The parameters that were measured include the pressure drop across the pitots, stack temperature, and stack static and ambient pressure. These parameters were measured at each traverse point, as applicable. A computer program was used to calculate the average velocity during the sampling period.

### 5.5.3 O<sub>2</sub> and CO<sub>2</sub> Concentrations by EPA Method 3A

The O<sub>2</sub> and CO<sub>2</sub> concentrations were determined by CEMs following EPA Method 3A. Flue gas was extracted from the duct and delivered to the CEM system through heated Teflon® tubing. The sample stream was then conditioned (particulate and moisture removed) and was directed to the analyzers. The O<sub>2</sub> and CO<sub>2</sub> concentrations were, therefore, determined on a dry basis. Average concentrations were calculated to coincide with each respective time period of interest. More information on the CEM system will be given in Section 5.6.

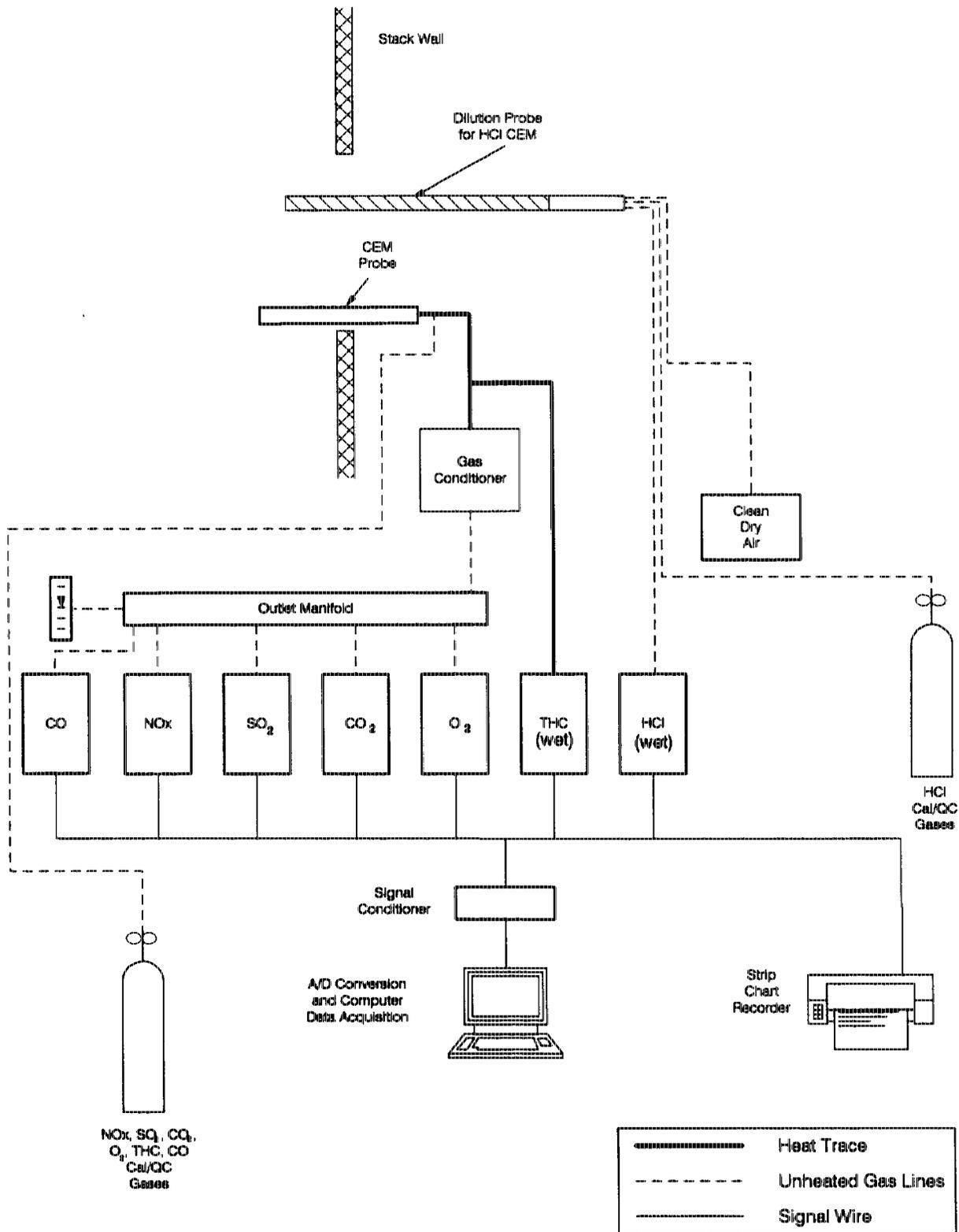
### 5.5.4 Average Moisture Determination by EPA Method 4

The average flue gas moisture content was determined according to EPA Method 4. Before sampling, the initial weight of the impingers was recorded. When sampling was completed, the final weights of the impingers were recorded, and the weight gain was calculated. The weight gain and the volume of gas sampled were used to calculate the average moisture content (percent) of the flue gas. The calculations were performed by computer. Method 4 was incorporated in the techniques used for all of the manual sampling methods that were used during the test.

## 5.6 CONTINUOUS EMISSIONS MONITORING (CEM) METHODS

EPA Methods 3A, 7E, 6C, and 10 were continuous monitoring methods for measuring CO<sub>2</sub>, O<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, and CO concentrations. Total hydrocarbons were analyzed by EPA Method 25A. Flue gas HCl concentrations were also monitored using CEM procedures using state-of-the-art equipment and procedures. A diagram of the CEM system is shown in Figure 5-18.

Two extractive systems were used to obtain flue gas samples for the CEM systems. One system was for HCl monitoring and the other system was for all other CEMs. For



**Figure 5-18. Schematic of CEM System (only 1 of 2 systems shown; separate inlet & outlet system)**

the main CEM extraction system, samples were withdrawn continuously at a single point from the incinerator outlet duct and transferred to the CEM trailer through heat-traced Teflon® line. The flue gas was conditioned (temperature lowered and moisture removed) before the flue gas stream was split using a manifold to the various analyzers. Hydrocarbon measurements were made on a wet basis; therefore, its sample stream bypasses the gas conditioner.

#### 5.6.1 CEM Sampling Equipment

5.6.1.1 Sample Probes. The main CEM probe consisted of a black iron pipe mounted to a Swagelok® reducing union which was attached directly to the heat trace tubing. The probe was placed approximately at a point of average velocity in the stack determined by a prior velocity traverse.

5.6.1.2 Heated Lines. Heated sample lines were used to transfer the flue gas samples to the instrument trailer for O<sub>2</sub>, CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, CO, and THC analyses. These lines were heated in order to prevent condensation. Condensate could clog sample lines or provide a medium for the flue gas sample to react and change composition.

All heat trace lines contained three 3/8 inch Teflon® tubes. One tube carried the sample, one tube was used for calibration and QC gases, and the other was available as a backup. These gases were then directed up to the sampling probe and through the entire sampling/conditioning system.

5.6.1.3 Gas Conditioning. Exemplar PEL 3 and PEL 4-Special gas conditioners were used to reduce the moisture content of the flue gas. The Exemplar systems use thermoelectric cooling plates to lower the temperature of the gas and condense any moisture in the sample. Condensate was immediately removed from the sample path by a dried sample slipstream that blows across the plates, greatly reducing the potential for sample bias. Additionally, the systems operated under positive pressure eliminating the possibility of a leak. The gas conditioner was located in the CEM trailer.

5.6.1.4 HCl CEM Sample System. The HCl flue gas concentrations were monitored using a CEM analyzer as well as by manual test runs. The HCl CEM sampling system used a GMD Model 797 dilution probe. This probe could not be used at the expected flue gas temperature ranges (approximately 1600-1900°F). Therefore, a slip-stream of flue gas was extracted from the stack and allowed to cool to approximately

400 to 500°F as it passed through a length of smaller pipe (i.e., 1 inch ID). The dilution probe was placed in a sampling well in the slipstream pipe for HCl CEM gas extraction. A thermocouple was located adjacent to the probe to monitor gas temperatures (see Figure 5-16). A nominal dilution ratio of 200:1 was used.

## 5.6.2 CEM Principles of Operation

5.6.2.1 SO<sub>2</sub> Analysis. The Western 721A SO<sub>2</sub> analyzer was essentially a continuous spectrophotometer in the ultraviolet (UV) range. The SO<sub>2</sub> selectively absorbs UV light at a wavelength of 202.5 nm. To take advantage of this property of SO<sub>2</sub>, the analyzer emits UV light at 202.5 nm and measures the absorbance (A) of the radiation through the sample cell by the decrease in intensity. Beer's law,  $A = abc$ , was used to convert the absorbance into SO<sub>2</sub> concentration (A = absorbance, a = absorbitivity, b = path length, c = concentration). The SO<sub>2</sub> measurements were performed using EPA Method 6C.

5.6.2.2 NO<sub>x</sub> Analysis. The principle of operation of this instrument was a chemiluminescent reaction in which ozone (O<sub>3</sub>) reacts with nitric oxide (NO) to form oxygen (O<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>). During this reaction, a photon was emitted which was detected by a photomultiplier tube. The instrument was capable of analyzing total oxides of nitrogen (NO + NO<sub>2</sub>) by thermally converting NO<sub>2</sub> to NO in a separate reaction chamber prior to the photomultiplier tube, if desired. The NO<sub>x</sub> measurements were performed using EPA Method 7E.

5.6.2.3 O<sub>2</sub> Analysis. Oxygen analysis was completed using one of the instruments discussed below.

The Thermo WDG III measured O<sub>2</sub> using an electrochemical cell. Porous platinum electrodes were attached to the inside and outside of the cell which provided the instrument voltage response. Zirconium oxide contained in the cell conducted electrons when it was hot due to the mobility of O<sub>2</sub> ions in its crystal structure. A difference in O<sub>2</sub> concentration between the sample side of the cell and the reference (outside) side of the cell produced a voltage. This response voltage was proportional to the logarithm of the O<sub>2</sub> concentration ratio. A linearizer circuit board was used to make the response linear. Reference gas was ambient air at 20.9 percent O<sub>2</sub> by volume.

The Beckman 755 O<sub>2</sub> analyzer used electron paramagnetic resonance to detect O<sub>2</sub> molecules. Unlike most substances, O<sub>2</sub> had a triplet electron ground state which left one electron unpaired, making it a paramagnetic molecule. This electron may have had one of two spin quantum states ( $m_s = \pm 1/2$ ). By applying an alternating electromagnetic field of the proper frequency, the Beckman 755 O<sub>2</sub> analyzer induced resonance between the two spin quantum states. In effect, the O<sub>2</sub> analyzer measured the electromagnetic energy absorbed by O<sub>2</sub> molecules at the resonant frequency. Oxygen measurements were performed using EPA Method 3A.

5.6.2.4 CO<sub>2</sub> Analysis. Non-dispersive infrared (NDIR) CO<sub>2</sub> analyzers emitted a specific wavelength of infrared (IR) radiation through the sample cell which was selectively absorbed by CO<sub>2</sub> molecules. The intensity of radiation which reached the end of the sample cell was compared to the intensity of radiation through a CO<sub>2</sub>-free reference cell. A reference cell was used to determine background absorbance which was subtracted from the sample absorbance. The detector used two chambers filled with CO<sub>2</sub> which were connected by a deflective metallic diaphragm. One side received radiation from the sample cell and the other side received radiation from the reference cell. Since more radiation was absorbed in the sample cell than in the reference cell, less radiation reached the sample side of the detector. This caused a deflection of the diaphragm due to increased heat from radiation absorption on the reference side. Deflection of the diaphragm created an electrical potential which was proportional to absorbance. Absorbance was directly proportional to CO<sub>2</sub> concentration in the gas. Carbon dioxide measurements were performed using EPA Method 3A.

5.6.2.5 CO Analysis. Either a TECO Model 48 or a Model 48H analyzer was used to monitor CO emissions. Both TECO analyzers measured CO using the same principle of operation as CO<sub>2</sub> analysis. The instruments were identical except that a different wavelength of infrared radiation was used; 5 nm was selective for CO. Carbon monoxide measurements were performed using EPA Method 10.

5.6.2.6 Total Hydrocarbon Analysis. Either a Beckman Model 400, 402 or 404 was used to monitor Total Hydrocarbon (THC) emissions. By allowing the THC sample stream to bypass the gas conditioners, concentrations were determined on a wet basis. All analyses employ Flame Ionization Detectors (FID). As the flue gas entered the

detector the hydrocarbons were combusted in a hydrogen flame. The ions and electrons formed in the flame entered an electrode gap, decrease the gas resistance, and permitted a current flow in an external circuit. The resulting current was proportional to the instantaneous concentration of the total hydrocarbons. This method was not selective between species. EPA Method 25A applied to the continuous measurement of total gaseous organic concentrations of primarily alkanes, alkenes, and/or arenes (aromatic hydrocarbons). The results were reported on a methane basis and methane was used as the calibration gas.

5.6.2.7 HCl CEM Analysis. HCl flue gas concentrations were continuously monitored using an NDIR/GFC instrument manufactured by Thermo Electron Corporation (TECO). Detection of HCl was achieved by alternately passing an infrared (IR) beam between reference HCl gas and reference HCl free gas contained in the filter wheel. The "chopped" beam passed through the sample cell to the detector. The difference in IR beam strength caused by the absorption of the IR beam was proportional to the HCl concentration.

### 5.6.3 CEM Calibration

All the CEM instruments were calibrated once during the test program (and linearized, if necessary) using a minimum of three certified calibration gases (zero and two upscale points). Radian performed the multipoint calibrations with four general categories of certified gases: zero gas (generally N<sub>2</sub>), a low scale gas concentration, a midrange concentration, and a high scale concentration (span gas). The criterion for acceptable linearity was a correlation coefficient (R<sup>2</sup>) of greater than or equal to 0.998, where the independent variable was cylinder gas concentration and the dependent variable was instrument response. If an instrument did not meet these requirements, it was linearized by adjusting potentiometers on the linearity card within the instrument or by other adjustments, if necessary.

The CEM analyzers were calibrated before and after each test run (test day) on a two point basis: zero gas (generally N<sub>2</sub>), and a high-range span gas. These calibrations were used to calculate response factors used for sample gas concentration determinations. Instrument drift as a percent of span was also determined using these calibrating for each test run.

After each initial calibration, midrange gases for all instruments were analyzed, with no adjustment permitted, as a quality control (QC) check. If the QC midrange gas concentration observed were within  $\pm 2$  percent of full scale, the calibration was accepted and the operator began sampling. If the QC check did not fulfill this requirement, another calibration was performed and linearization may be performed if deemed necessary. Calibration procedures were further detailed in the daily operating procedure (Section 5.6.5).

Table 5-10 lists the concentration of all calibration and QC gases to be used on this test program.

#### 5.6.4 Data Acquisition

The data acquisition system used for the Jordan Hospital MWI test program consisted of an Omega signal conditioner, a Tecmar A/D converter and a COMPAQ 286 computer. All instrument outputs were connected in parallel to stripchart recorders and the Omega signal conditioner. The stripchart recorders were a back-up system to the computer data acquisition system data. The signal conditioner adjusts the voltage response range from the output range of the instrument (typically 0-100 mV or 0-10 mV) to 0-5 volts. The A/D converter then digitizes the analog inputs for use by the computer. A Radian computer program was used to translate the digitized voltages into relevant concentrations in engineering units (ppmV, %V, etc.). The computer program had several modes of operation: calibration, data acquisition, data reduction, data view, data edit, and data import. The import function was used to combine other data files for comparison and correlation. On-line color graphics and data manipulation were included in the data acquisition portion of the program so that the operator and on-site engineers may monitor trends in the process.

#### 5.6.5 Daily Operating Procedure

The following is a detailed standard operating procedure for calibrating and operating the CEMS:

1. Turn on COMPAQ computer and EPSON printer, put printer on-line, and load the CEM.EXE program. Be sure that the CEM instruments have been on for at least 20 hours.
2. Synchronize watch with sample location leaders.

TABLE 5-10. CEM OPERATING RANGES AND CALIBRATION GASES

Analyte	Gas Concentration
<u>CO<sub>2</sub></u>	
Instrument	Beckman 865
Range	0-20%
Span Gas Value	18%
Zero Gas	N <sub>2</sub>
Midrange QC Gas Value	10%
Low Range QC Gas Value	5%
<u>CO - dry</u>	
Instrument	TECO 48H
Range	0-50,000 ppm
Span Gas Value	1000, 9000 or 19,000 ppm <sup>a</sup>
Zero Gas	N <sub>2</sub>
Midrange QC Gas Value	1000 or 9000 ppm
Low Range QC Gas Value	2100 ppm
<u>CO - wet</u>	
Instrument	TECO 48
Range	0-100, 0-200, 0-5000 ppm
Span Gas Value	1000, 180 or 90 ppm <sup>a</sup>
Zero Gas	N <sub>2</sub>
Midrange QC Gas Value	180 ppm
Low Range QC Gas Value	90 ppm
<u>O<sub>2</sub></u>	
Instrument	Thermox WDG III
Range	0-25%
Span Gas Value	20%
Zero Gas	0.2% O <sub>2</sub>
Midrange QC Gas Value	10%
Low Range QC Gas Value	5%

TABLE 5-10. CEM OPERATING RANGES AND CALIBRATION GASES, continued

Analyte	Gas Concentration
<u>SO<sub>2</sub></u>	
Instrument	Western 721A
Range	0-500 or 0-5000 ppm
Span Gas Value	200 or 50 ppm
Zero Gas	N <sub>2</sub>
Midrange QC Gas	100 ppm
Low Range QC Gas	30 ppm
<u>NO<sub>x</sub></u>	
Instrument	TECO 10AR
Range	0-250 ppm
Span Gas Value	200 ppm
Zero Gas	N <sub>2</sub>
Midrange QC Gas Value	100 ppm
Low Range QC Gas Value	50 ppm
<u>THC</u>	
Instrument	Beckman 402
Range	0-10, 0-50, 0-100 ppm
Span Gas Value	100 ppm as methane
Zero Gas	N <sub>2</sub>
Midrange QC Gas Value	45 ppm as methane
Low Range QC Gas Value	25 ppm as methane
<u>HCl</u>	
Instrument	TECO Model 15
Range	0-2000 ppm
Span Gas Value	1800 ppm
Zero Gas	N <sub>2</sub>
Midrange QC Gas Value	900 ppm
Low Range QC Gas Value	100 ppm

<sup>a</sup> Several sets of calibration/QC gases were acquired in order to closely approximate stack gas concentrations.

3. Turn on strip chart recorders (SCR) and make appropriate notes on charts and in logbook (write down all procedures and observations in logbook and on SCRs as the day progresses).
4. Turn on the gas conditioners and blow back compressor. Blow back the system.
5. Open all calibration gas cylinders so that they may be introduced to the instruments via control panel valves.
6. Perform daily pre-test leak check on CEMs by introducing ultra high purity nitrogen to the system. Zero all instruments except the Thermox O<sub>2</sub> analyzers. Make adjustments to the zero potentiometers as required to zero the instruments. Be sure to check and maintain all flows throughout calibration and operation.
7. Record the zero values in the computer calibration routine.
8. Introduce 0.2 percent O<sub>2</sub> to set the low scale response for the Thermox O<sub>2</sub> analyzers and repeat Step 7 for these instruments.
9. Introduce the mixed span gases for O<sub>2</sub>, CO<sub>2</sub>, and CO. Make adjustments as required to these instruments.
10. Enter these values in the computer calibration routine.
11. Introduce the NO<sub>x</sub> span gas.
12. Make adjustments to the NO<sub>x</sub> instruments as required and enter the value into the computer calibration routine.
13. Introduce the SO<sub>2</sub> span gas for the SO<sub>2</sub> analyzer, repeat Step 12 for the SO<sub>2</sub> analyzer. (Note that all calibration gases were passed through the entire sampling system.)
14. Switch the Western SO<sub>2</sub> analyzer range to 0-500 ppm introduce the span gas for this range and repeat Step 12 for this instrument.
15. Introduce the HCl span gas to the HCl dilution probe/CEM analyzer. Repeat Step 12 for this system.
16. Check the calibration table on the computer, and make a hardcopy. Put the computer in the standby mode.

17. Introduce QC gases to instruments in the same sequence as the calibration gases. Record three minutes of data for each, once the responses have stabilized. If the QC gas response is not within  $\pm 2$  percent of the instrument range the operator should recalibrate the instrument, or perform other corrective actions.
18. Begin sampling routine, with the computer on stand by.
19. Start the data acquisition system when signaled by radio that system is in stack.
20. Carefully check all flows and pressures during the operation of the instruments and watch for apparent problems in any of the instruments, such as unusual readings or unreasonable fluctuations. Check the gas conditioning system periodically and drain the traps.
21. Stop the data acquisition system at the end of the test when signaled.
22. Perform final leakcheck of system.
23. Perform the final calibration (Repeat steps 6-17) except make no adjustments to the system.
24. Check for drift on each channel.

#### 5.7 VISIBLE EMISSIONS

The opacity of emissions were determined visually by a qualified observer following EPA Method 9. The observer was certified within 6 months before the test, as required by the method. Opacity observations were recorded to the nearest 5 percent at 15-second intervals. Twenty-four observations were recorded and averaged per each data set. Observation continued throughout the 4-hour test run each day.

#### 5.8 PROCESS SAMPLING PROCEDURE

Incinerator ash was composited each test day into a cleaned, 55 gallon plastic drum after initial cooling in 30 gallon cans that were used by the facility. After testing was completed for that day, approximately 1 gallon of ash was taken from the composited sample using a sample thief. This composite was then quartered. The quarters were sent to respective laboratories for analyses of LOI/carbon, metals, and CDD/CDF. The fourth quarter was archived or used as needed.

## 5.9 PARTICLE SIZE DISTRIBUTION SAMPLING METHODS

Results from the PSD tests characterized particulate mass into ranges separated by the PSD sampler's 50 percent effective cut points ( $D_{p50}$ ) for each stage. The  $D_{p50}$  represents the aerodynamic diameter of a particle that had been collected by that respective PSD stage with 50 percent collection efficiency.

Particle size distribution measurements were obtained with Anderson Mark III in-stack cascade impactor employing a pre-separator. A schematic of the sampling train is shown in Figure 5-19. The impactor consisted of eight stages plus a final filter. Each stage had a number of concentric round jets offset on each succeeding stage such that the one plate served both as jet and impaction surface. The Anderson MK III was operated in the range from 0.3 to 0.7 acfm and the flue gas was sampled isokinetically ( $100 \pm 20$  percent) with a recommended weight gain of 50 mg.

The impactor was prepared by loading the substrates into the impactor and recorded the identification number and tare weight. The stage order was checked for correctness as the stages were assembled. The impinger train was prepared according to EPA Method 5. Then, the impactor and preseparator/nozzle were attached to the probe and the probe attached to the impinger train. Once assembled, the sampling train was leak checked at 15 in. Hg. The leakrate had to be below 0.02 cfm.

Prior to sampling, a preliminary velocity tranverse was conducted to determine a point of average velocity. The nozzle was then selected to ensure both isokinetic sampling as well as to give the desired particle separation. The impactor was preheated to approximately stack temperature prior to placing it inside the duct. Sampling was then conducted at a single point of average velocity at a fixed sampling rate. The sampling rate was not adjusted during the run.

After sampling was completed, the impactor was cooled and each stage was carefully recovered. Particles from the nozzle, pre-separator, and rinse were added to the first stage catch. Each substrate was examined for particle bounce, overloading, and re-entrainment. The substrates were weighted to a constant weight as detailed in Section 5.2.

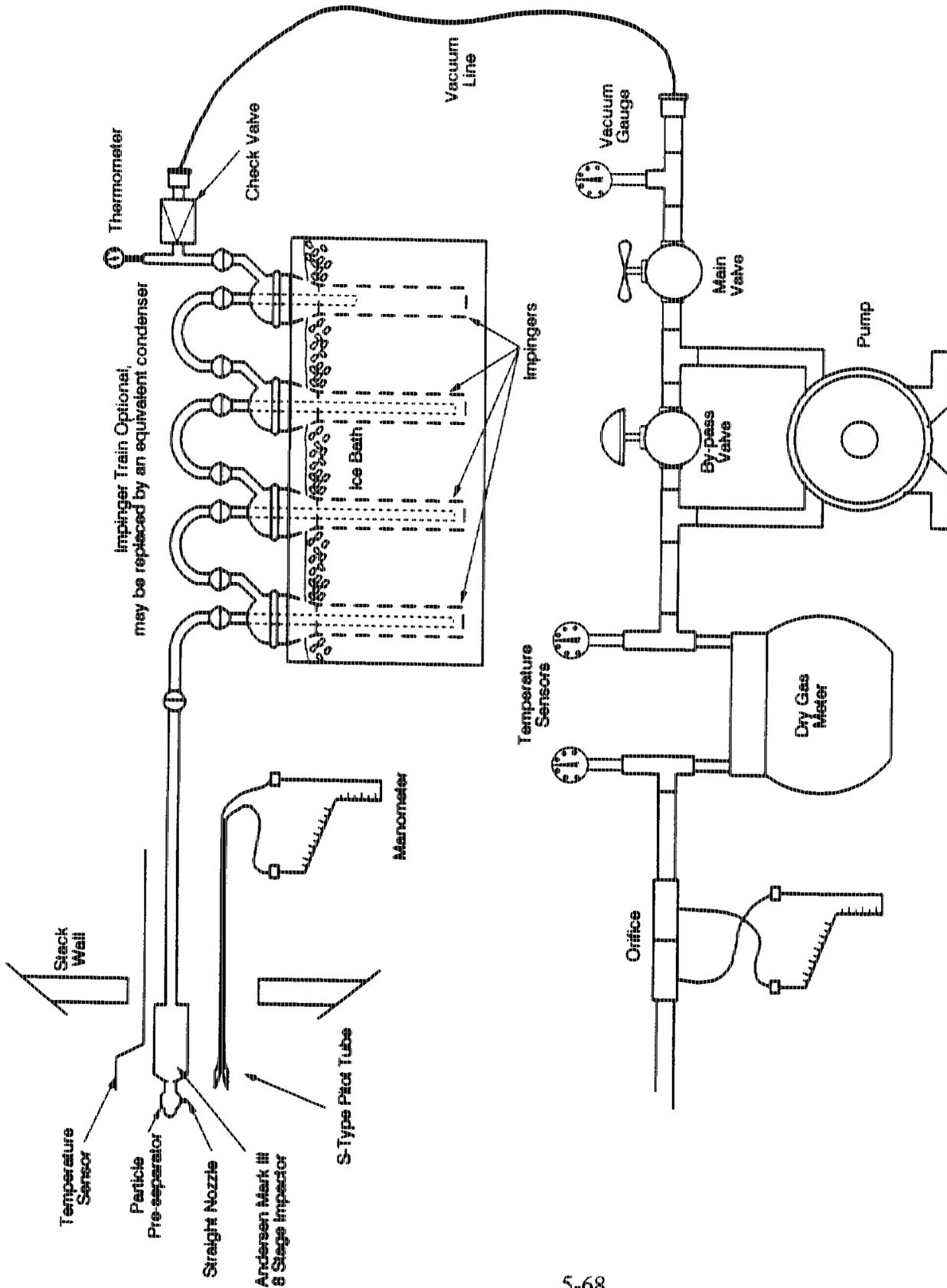


Figure 5-19. Anderson MK III In-Stack Impactor with Particle Pre-Separator Sampling Train

## 6. QUALITY ASSURANCE/QUALITY CONTROL

Specific Quality Assurance/Quality Control (QA/QC) procedures were strictly adhered to during this test program to ensure the production of useful and valid data throughout the course of the project. A detailed presentation of QC procedures for all manual flue gas sampling, process sample collection, and CEM operations can be found in the Jordan Test Plan. This section will report the test program QA parameters so that the degree of data quality may be ascertained.

In summary, a high degree of data quality was maintained throughout the project. Manual flue gas sampling at the inlet was conducted at low sample rates because of unexpected low flue gas flow rates. Therefore, sample rates were also correspondingly low at approximately 0.1 to 0.2 cfm. This resulted in several of the inlet CDD/CDF and PM/metals test runs not meeting the post-test leak rate criterion of less than four percent of the sample flow. These sample runs were leak corrected resulting in a decreased sample volume of 0.1 to 6.8 percent of the total volume. Several outlet CDD/CDF runs were also leak corrected resulting in decreased sample volumes of 0.3 to 0.9 percent. These procedures are discussed further in Section 6.2. All post-test calibration checks of the dry gas meters were within acceptable limits. Manual isokinetic sampling trains at the inlet and outlet met the isokinetic criterion of  $\pm 10$  percent of 100 for the majority of test runs. Dioxin inlet and outlet field blanks showed very little detection of the target CDD/CDF compounds. Comparisons of the amount of CDD/CDF congeners collected in the toluene rinse versus the amount in the methylene chloride/pooled MM5 sample fraction showed only a small amount of residual CDD/CDF was present in the toluene rinses. The majority of standards recoveries for the CDD/CDF analyses were within acceptable limits. Metals blank results showed virtually no contamination. Method spike values for the metals analyzed were all within acceptable limits except for silver. Silver had method spike recoveries of less than 5 percent. Gravimetric analyses of the 6 inlet and 6 outlet PM samples showed positive weight gains for both the filter and rinse fractions for all runs except the Run 1 outlet filter. A non-detect assignment was made to this run PM sample catch. The manual halogen gas tests met acceptable reagent blank levels and method spike results. The

CEM results showed good calibration drift values and QC gas responses. Excessive drift (approximately 10 percent) was found on the inlet CO<sub>2</sub> and THC monitors on Day 1 and on the SO<sub>2</sub> monitor on Day 3. This data was drift corrected. All monitors operated very smoothly except for the HCl and THC instruments. Outlet HCl concentrations were so low, that the dilution sample system did not allow for their resolution on the monitor. The inlet HCl CEM operated satisfactorily. However, this data did not match up well with the Method 26 data (see Section 2.6). The THC analyzers only performed acceptably for a portion of the test program. Microbial survivability test samples were also analyzed. Flue gas, ash, and pipe samples showed good replicate analytical results. One of the three PSD runs was not analyzed because of underloading. Runs 2 and 3 appeared to be adequately loaded and were reported.

Section 6.1 presents the QA/QC definitions and data quality objectives. Section 6.2 presents manual flue gas sampling and recovery QA parameters. Section 6.3 discusses the QC procedures for ash and pipe sampling and Section 6.4 presents method-specific analytical QA parameters. Section 6.5 discusses the CEM QA parameters. Section 6.6 presents a QA discussion on the PSD tests. Section 6.7 presents a discussion on data variability.

## 6.1 QA/QC DEFINITIONS AND OBJECTIVES

The overall QA/QC objective is to ensure precision, accuracy, completeness, comparability, and representativeness for each major measurement parameter called for in this test program. For this test program, quality control and quality assurance can be defined as follows:

- Quality Control: The overall system of activities whose purpose is to provide a quality product or service. QC procedures are routinely followed to ensure high data quality.
- Quality Assurance: A system of activities whose purpose is to provide assurance that the overall quality control is being done effectively. Assessments can be made from QA parameters on what degree of data quality was achieved.
- Data Quality: The characteristics of a product (measurement data) that bear on its ability to satisfy a given purpose. These characteristics are defined as follows:

- 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 and in this report will be expressed as the relative standard deviation or coefficient of variation.
- Accuracy - The degree of agreement of a measurement (or an average of measurements of the same thing), X, with an accepted reference or true value, T, can be expressed as the difference between two values, X-T, the ratio X/T, or the difference as a percentage of the reference or true value, 100 (X-T)/T.
- 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 prescribed test conditions.
- Comparability - A measure of the confidence with which one data set can be compared with another.
- Representativeness - The degree to which data accurately and precisely represent a characteristic of a population, variations of a parameter at a sampling point, or an environmental condition.

A summary of the estimated precision, accuracy, and completeness objectives is presented in Table 6-1.

## 6.2 MANUAL FLUE GAS SAMPLING AND RECOVERY PARAMETERS

The following section will report method-specific sampling QA parameters so that insight can be gained at the quality of emissions test data produced from manual tests during the test program.

### 6.2.1 CDD/CDF Sampling Quality Assurance

Table 6-2 lists both the pre-test and post-test leak checks completed on the CDD/CDF sampling trains. The acceptance criterion is that all post-test leak checks must be less than 0.02 cfm or 4 percent of the average sampling rate (whichever is less). Flue gas flow rates were roughly 1000 cfm which was substantially lower than the 2500 cfm expected. One piece quart nozzles/probe liners had been fabricated and did not allow for a wide selection of nozzle sizes. The largest nozzles present only allowed isokinetic sampling at 0.1 to 0.2 cfm. Because this flow rate was so low, the 4 percent of sample flow rate leak check criterion was also low. The criterion was not met on five of the six inlet CDD/CDF test runs. Outlet CDD/CDF sample trains did not pass leak

TABLE 6-1. SUMMARY OF PRECISION, ACCURACY, AND COMPLETENESS OBJECTIVES<sup>a</sup>

Parameter	Precision (RSD)	Accuracy <sup>b</sup> (%)	Completeness <sup>c</sup> (%)
Dioxins/Furans Emissions	±40 <sup>d</sup>	±50	100
Metals Emissions	±15 <sup>d</sup>	±30	100
Particulate Matter Emissions	±12	±10	100
HCl/HBr/HF Concentrations	±10 <sup>d</sup>	±15	95
Indicator Spore Emissions	ND	ND	100
CEM Concentrations	±20	±15	95
Velocity/Volumetric Flow Rate	±6	±10	95
Fixed Gases/Molecular Weight	±0.3%V	±0.5%V	100
Flue Gas Moisture	±20	±10	95
Flue Gas Temperature	±2°F	±5°F	100

RSD = Relative Standard Deviation. Uses worst case assumption that variation amongst run results is not due to process variation.

ND = Not Determined at this time.

<sup>a</sup> Precision and accuracy estimated based on results of EPA collaborative tests. All values stated represent worst case values. All values are absolute percentages unless otherwise indicated.

<sup>b</sup> Relative error (%) derived from audit analyses, where:

$$\text{Percent Relative Error} = \frac{\text{Measured Value} - \text{Actual Value}}{\text{Actual Value}} \times 100$$

<sup>c</sup> Minimum valid data as a percentage of total tests conducted.

<sup>d</sup> Analytical phase only. Percent difference for duplicate analyses, where:

$$\text{Percent Relative Error} = \frac{\text{First Value} - \text{Second Value}}{0.5 (\text{First} + \text{Second Values})} \times 100$$

<sup>e</sup> Minimum requirements of EPA Method 6C, based on percent of full scale.

<sup>f</sup> No measureable bias has been detected in the available literature.

TABLE 6-2. LEAK CHECK RESULTS FOR CDD/CDF SAMPLE TRAINS  
JORDAN HOSPITAL (1991)

DATE	RUN NUMBER	MAXIMUM VACUUM	PORT	AVG. SAMPLE RATE (scfm)	4% SAMPLE RATE (scfm) <sup>a</sup>	MEASURED LEAK RATE	INCHES FOR LEAK CHECK	LEAK CORRECTED (Y OR N)
03/05/91	1 INLET	2	A	.186	.007	.001	15	N
		2	B	.222	.009	.020	12	Y
03/05/91	1 OUTLET	4	A	.2138	.009	.014	17	N
		4	B	.4724	.019	.014	10	N
03/05/91	2 INLET	2	A	.2314	.009	.010	15	Y
		2	B	.2414	.010	.019	19	Y
03/05/91	2 OUTLET	3	A	.4913	.020	NR	10	N
		3	B	.5164	.021	.024	NR	Y
03/07/91	3 INLET	2.5	A	NR <sup>b</sup>	NR	NR	15	N
		2	B	NR	NR	NR	NR	N
03/07/91	3 OUTLET	7	A	.4582	.018	.020	10	Y
		8	B	.4811	.019	.025	13	Y
03/07/91	4 INLET	1	A	.1952	.008	.008	12	Y
		1	B	.1422	.006	.004	10	N
03/07/91	4 OUTLET	8	A	.4760	.019	.012	12	N
		10	B	.4368	.019	.006	11	N
03/09/91	5 INLET	1	A	.1969	.008	.009	15	Y
		1	B	.1632	.007	.009	12	Y
03/09/91	5 OUTLET	4	A	.5109	.020	.008	10	N
		4	B	.4582	.018	.008	NR	N
03/09/91	6 INLET	1	A	.1139	.005	.008	12	Y
		2	B	.1704	.007	.006	10	N
03/09/91	6 OUTLET	4	A	.2465	.010	.004	10	N
		4	B	.2322	.009	.016	10	Y

<sup>a</sup> Because these rates are lower than 0.02 cfm, these values are the acceptable criterion.

<sup>b</sup> NR = Not recorded.

check for three of the six test runs. The majority of leak rates were lower than 0.02 cfm and therefore the amount of sample volume corrections were minimal.

Table 6-3 presents the isokinetic sampling rates for CDD/CDF, PM/Metals, and Microbial Survivability sampling trains. The acceptance criterion is that the average sampling rate must be within 10 percent of 100 percent isokinetic. Isokinetic rates were outside of the 10 percent criterion for three of the six inlet test runs. Two out of six outlet test runs were outside of the 10 percent criterion. Because the majority of particle sizes were less than 1  $\mu$ m and 10  $\mu$ m (see PSD Run 2 and Run 3 results - Section 2), non-isokinetic samples would not cause significant errors. This is due to the fact that as the particles get smaller, they behave more like a gas and isokinetic sampling becomes less important.

All dry gas meters are fully calibrated every six months against an EPA approved intermediate standard. The full calibration factor or meter Y is used to correct actual metered sample to true sample volume. To verify the full calibration, a post-test calibration is performed. The full and post-test calibration coefficients must be within 5 percent to meet Radian's internal QA/QC acceptance criterion. As can be seen from Table 6-4, the post-test calibration factor for all meter boxes used for CDD/CDF, PM/metals, microorganisms, and halogens were well within the 5 percent criterion of the full calibration factor.

Field blanks were collected at both the inlet and outlet to verify the absence of any sample contamination. The CDD/CDF sampling train was fully prepared, taken to the sample location, leak checked, and then recovered. Table 6-5 compares the CDD/CDF analytical results for the MM5 field blanks versus average MM5 catches for the test runs (toluene field blank results are presented in the following section). No 2378 TCDD was detected in either the inlet or outlet MM5 field blank. A small amount of 2378 TCDF was found in the outlet FB but only at levels ranging from 0.02 to 0.07 percent of average test run catches. Confirmation analysis reported a much lower 2378 TCDF value than the full screen at 0.005 ng versus 0.07 ng. Other CDD/CDF congeners were detected in the MM5 field blank but at much lower amounts than in any of the test runs. Because the amount of contamination was so low, no field blank

TABLE 6-3. ISOKINETIC SAMPLING RATES FOR CDD/CDF, METAL, AND MICROORGANISM TEST RUNS; JORDAN HOSPITAL (1991)

DATE	RUN NUMBER	CDD/CDF ISOKINETIC SAMPLE RATE (%)	TOXIC METALS ISOKINETIC SAMPLE RATE (%)	MICROORGANISMS ISOKINETIC SAMPLE RATE (%)
03/05/91	1 INLET	116	90.9	101
03/05/91	1 OUTLET	112	96.4	
03/05/91	2 INLET	130	99	111
03/05/91	2 OUTLET	98.2	103	
03/07/91	3 INLET	106	111	107
03/07/91	3 OUTLET	94	103	
03/07/91	4 INLET	109	81.1	92.5
03/07/91	4 OUTLET	98.9	105	
03/09/91	5 INLET	107	101	103
03/09/91	5 OUTLET	115	100	
03/09/91	6 INLET	112	87.1	96.5
03/09/91	6 OUTLET	103	93.3	

TABLE 6-4. DRY GAS METER POST-TEST CALIBRATION RESULTS;  
JORDAN HOSPITAL (1991)

METER BOX ID	SAMPLE TRAINS	FULL CALIBRATION FACTOR	POST-TEST CALIBRATION FACTOR	POST-TEST DEVIATION (%) <sup>a</sup>
SAC-03	CDD/CDF-IN METALS-IN	1.0012	0.9925	-0.87
SAC-02	CDD/CDF-IN METALS-IN	1.0017	0.9918	-0.99
SAC-01	CDD/CDF-IN	0.9960	0.9884	-0.76
Box-3	METALS-IN	0.99910	NR	NA
N-30	METALS-OUT	0.9926	0.9885	-0.41
N-31	CDD/CDF-OUT	1.0080	0.9851	-2.3
N-32	METALS-OUT	1.0000	0.9940	-0.60
SAC-05	CDD/CDF-OUT	1.0011	0.9978	-0.33
15	SPORE-IN	0.9913	NR	NA
V-02729	HALOGENS-OUT	0.9919	0.9870	-0.49
V-5	HALOGENS-IN	1.0104	1.0146	0.42

a  $(\text{Post-Test}) - (\text{Full}) \times 100$   
(Full)

NR = Not Recorded NA = Not Applicable

TABLE 6-5. CDD/CDF FIELD BLANK RESULTS COMPARED  
TO AVERAGE RUN RESULTS; JORDAN HOSPITAL (1991)

LOCATION	INLET			OUTLET		
	MMS FIELD BLANK (total ng)	MMS BURN AVG (total ng)	MMS BURNDOWN AVG (total ng)	MMS FIELD BLANK (total ng)	MMS BURN AVG (total ng)	MMS BURNDOWN AVG (total pp)
CONGENER						
<b>FULL SCREEN ANALYSES</b>						
2378-TCDD	[0.030]	0.09	0.60	[0.005]	4.07	1.09
TOTAL TCDD	[0.030]	1.08	9.28	0.11	1786.7	355.3
12378-PeCDD	[0.040]	0.30	3.85	[0.010]	21.2	9.53
TOTAL PeCDD	[0.040]	1.14	24.30	0.28	1410.0	526.7
123478-HxCDD	[0.050]	0.50	5.05	[0.010]	14.6	5.57
123678-HxCDD	0.03	0.40	4.18	0.01	22.4	8.70
123789-HxCDD	[0.040]	1.30	10.6	0.02	38.3	14.93
TOTAL HxCDD	0.03	4.17	51.3	0.16	801.7	304.6
1234678-HpCDD	(0.160)	2.31	52.5	0.06	50.1	18.7
TOTAL HpCDD	(0.160)	2.31	52.5	0.12	134.7	50.0
Octa-CDD	0.43	7.78	156.8	0.13	19.1	6.43
2378-TCDF	[0.020]	2.56	20.6	0.07	499.0	130.3
TOTAL TCDF	[0.020]	9.60	132.4	0.16	2546.7	571.7
12378-PeCDF	[0.030]	0.31	14.3	(0.010)	50.3	18.9
23478-PeCDF	[0.030]	0.97	14.5	0.02	95.9	36.6
TOTAL PeCDF	[0.030]	8.54	197.5	0.13	1573.3	562.7
123478-HxCDF	0.06	2.00	62.1	0.05	164.0	68.7
123678-HxCDF	0.03	0.67	30.5	0.01	48.1	20.2
234678-HxCDF	0.05	1.52	32.0	0.04	68.9	28.1
123789-HxCDF	[0.040]	0.10	3.95	[0.010]	1.60	0.860
TOTAL HxCDF	0.13	7.35	279.6	0.13	684.3	282.7
1234678-HpCDF	0.15	2.69	100.5	0.05	75.1	28.9
1234789-HpCDF	0.07	0.91	21.8	[0.010]	5.97	2.04
TOTAL HpCDF	0.29	4.94	197.6	0.06	122.8	47.4
Octa-CDF	(0.530)	6.11	227.1	(0.020)	9.37	3.17
<b>CONFIRMATION ANALYSES</b>						
2378-TCDD		0.23	1.73	(0.005)		3.00
2378-TCDF		0.33	4.89	0.01		4.20
TOTAL TCDD		1.80	14.3	0.05		138.0
TOTAL TCDF		9.99	153.7	0.09		270.0

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Detection Limit.

corrections were made on the emissions results. Analytical blank results are further discussed in Section 6.4.1.

6.2.1.1 CDD/CDF Toluene Recovery Results. As a newly developed step in EPA CDD/CDF sample recovery protocol, a final toluene rinse was completed on the sample train glassware. Following the test, the nozzle/probe, filter housing, and condenser coil were recovered using methylene chloride. This sample fraction was analyzed along with the filter and XAD trap to determine total CDD/CDF collected in the sample. A final toluene rinse of all the above components was completed and analyzed separately as a part of EPA Method 23 QA protocol. The following discussion and tables present those results.

Tables 6-6 through 6-9 compare the toluene recovery amounts of CDD/CDF congeners to the respective MM5 amounts from full screen analyses (all units in picograms). Table 6-6 and 6-7 report inlet results and 6-8 and 6-9 report outlet results. The ratio of the toluene catch to the MM5 expressed as a percentage ( $T/M \times 100$ ), is also given. The results reveal only a relatively small amount of CDD/CDF isomers present in the toluene samples. For the inlet samples, average T/M ratios range from 0 to 2.9 percent (Other PCDD). Outlet average values range from 0 to 2.7 percent (Octa CDF).

The confirmation toluene analytical results are compared to the confirmation MM5 values in Tables 6-10 and 6-11. The T/M ratios presented here are also very low. T/M values ranged from 0 to 1.03 percent.

The toluene field blanks analytical results are compared to the toluene test run analytical results in Table 6-12. The inlet field blank did not detect any isomers except Total PCDD and Total PCDF. The outlet toluene field blank detected a number of CDD/CDF isomers but only at a fraction of the test run amounts.

#### 6.2.2 PM/Metals Sampling Quality Assurance

Table 6-13 presents the leak check results for the PM/Metals. As was stated earlier, because the inlet sample flow rates were so low, the 4 percent of sample flow leak rate criterion was also low. All six PM/metals inlet test runs did not meet the leak check criterion and were leak corrected. Corrections only decreased the sample volume by a small percentage. All outlet tests passed post-test leak checks.

TABLE 6-6. CDD/CDF TOLUENE RINSE FULL SCREEN ANALYTICAL RESULTS COMPARED TO MMS ANALYTICAL RESULTS FOR INLET, BURN CONDITION SAMPLES- JORDAN HOSPITAL (1991)

CONGENER	RUN 1			RUN 3			RUN 5			AVERAGE		
	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)
DIOXINS												
2378 TCDD	[40.00]	[3.700]	NA	[20.00]	[5.500]	NA	[90.00]	[4.200]	NA	[50.000]	[4.467]	NA
Other TCDD	120	[3.700]	0.00	120	[5.500]	0.00	3000	5.70	0.19	1080	5.70	0.528
12378 PCDD	[70.00]	[5.700]	NA	[40.00]	[8.100]	NA	280	[5.900]	0.00	280	[6.567]	0.00
Other PCDD	(220.0)	(27.10)	12.32	200	(49.00)	24.5	2720	(15.00)	0.551	1046	30.4	2.901
123478 HxCDD	[100.0]	[7.200]	NA	[50.00]	[10.80]	NA	480	[7.400]	0.00	480	[8.467]	0.00
123678 HxCDD	[70.00]	[4.800]	NA	50	[7.100]	0.00	750	[4.900]	0.00	400	[5.600]	0.00
123789 HxCDD	[90.00]	[6.100]	NA	[40.00]	[9.100]	NA	1300	[6.300]	0.00	1300	[7.167]	0.00
Other HxCDD	(460.0)	[5.800]	0.00	10.0	[8.800]	0.00	9470	(12.00)	0.127	3313	12	0.362
1234678-HpCDD	210	[10.10]	0.00	(220.0)	[17.00]	0.00	6500	(8.700)	0.134	2310	8.70	0.377
Other HpCDD	0.00	[10.10]	NA	(220.0)	[17.00]	0.00	0.00	7.90	NA	220	7.90	3.591
Octa-CDD	450	43.6	9.689	[100.0]	34.1	NA	15100	23.5	0.156	7775	33.7	0.434
<b>Total CDD</b>	<b>1460</b>	<b>70.7</b>	<b>4.84</b>	<b>820</b>	<b>83.1</b>	<b>10.13</b>	<b>35600</b>	<b>72.8</b>	<b>0.184</b>	<b>12960</b>	<b>75.5</b>	<b>0.541</b>
FURANS												
2378 TCDF	110	[2.700]	0.00	100	[4.100]	0.00	790	1.80	0.228	333	1.8	0.540
Other TCDF	1290	[2.700]	0.00	860	[4.100]	0.00	26810	32.5	0.121	9653	32.5	0.337
12378 PCDF	50	[3.000]	0.00	50	[5.600]	0.00	830	[3.800]	0.00	310	[4.133]	0.00
23478 PCDF	170	[2.800]	0.00	150	[5.300]	0.00	2600	[3.600]	0.00	973	[3.900]	0.00
Other PCDF	1080	[2.900]	0.00	130	[5.500]	0.00	20570	14.5	0.070	7260	14.5	0.200
123478 HxCDF	380	[5.400]	0.00	220	[8.600]	0.00	5400	[6.100]	0.00	2000	[6.700]	0.00
123678 HxCDF	130	[4.100]	0.00	80	[6.600]	0.00	1800	[4.700]	0.00	670	[5.133]	0.00
234678 HxCDF	280	4.30	1.536	170	[8.500]	0.00	4100	(9.300)	0.227	1517	6.8	0.448
123789 HxCDF	60	[5.900]	0.00	30	[9.500]	0.00	130	[6.800]	0.00	73.3	[7.400]	0.00
Other HxCDF	250	-0.10	-0.04	40	[8.100]	0.00	8970	(16.90)	0.188	3087	8.4	0.272
1234678-HpCDF	450	[4.300]	0.00	310	[7.400]	0.00	7300	7.40	0.101	2687	7.4	0.275
1234789-HpCDF	90	[7.000]	0.00	110	[12.10]	0.00	1700	[8.400]	0.00	633	[9.167]	0.00
Other HpCDF	-400	[5.300]	0.00	160	[9.200]	0.00	5100	1.70	0.033	1620	1.7	0.105
Octa-CDF	300	[13.90]	0.00	740	[22.70]	0.00	17300	[16.70]	0.00	6113	[17.767]	0.00
<b>Total CDF</b>	<b>4240</b>	<b>4.20</b>	<b>0.999</b>	<b>3150</b>	<b>0.0</b>	<b>0.00</b>	<b>103400</b>	<b>84.1</b>	<b>0.081</b>	<b>36930</b>	<b>44.15</b>	<b>0.120</b>
<b>Total CDD+CDF</b>	<b>5700</b>	<b>74.9</b>	<b>1.314</b>	<b>3970</b>	<b>83.1</b>	<b>2.093</b>	<b>143000</b>	<b>156.9</b>	<b>0.110</b>	<b>50890</b>	<b>104.967</b>	<b>0.206</b>

[ ] = minimum detection limit (not used in the averages or summations)

( ) = estimated maximum possible concentration (included in averages and summations)

TABLE 6-7. CDD/CDF TOLUENE RINSE FULL SCREEN ANALYTICAL RESULTS COMPARED TO MMS ANALYTICAL RESULTS FOR INLET, BURNDOWN CONDITION SAMPLES- JORDAN HOSPITAL (1991)

CONGENER	RUN 2			RUN 4			RUN 6			AVERAGE		
	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)
DIOXINS												
2378 TCDD	(80.00)	[4.400]	0.00	(210.0)	[2.500]	0.00	1500	8.20	0.547	597	8.20	1.37
Other TCDD	40	(4.400)	11.0	14100	[2.500]	0.00	12200	23.7	0.194	8780	14.1	0.160
12378 PCDD	(20.00)	[6.000]	0.00	1200	[4.200]	0.00	6500	(35.50)	0.546	2573	35.5	1.380
Other PCDD	(110.0)	[6.000]	0.00	29400	(191.0)	0.650	35700	104	0.291	21737	147	0.679
123478 HxCDD	(30.00)	[6.900]	0.00	2300	[5.800]	0.00	7800	60.0	0.769	3377	60.0	1.777
123678 HxCDD	30	[4.500]	0.00	4400	[3.900]	0.00	8100	60.4	0.746	4177	60.4	1.446
123789 HxCDD	(20.00)	[5.800]	0.00	6200	[4.900]	0.00	14900	142	0.953	7040	142	2.017
Other HxCDD	10	[5.600]	0.00	42400	(10.50)	0.025	67900	493	0.725	36770	251	0.684
1234678-HpCDD	120	[10.80]	0.00	36300	19.9	0.055	121000	1500	1.240	52473	760	1.448
Other HpCDD	0.00	[10.80]	NA	0.00	0.00	NA	0.00	1590	NA	NA	1590	NA
Octa-CDD	480	(14.10)	2.90	62800	(65.30)	0.104	407000	7090	1.742	156760	2389	1.524
<b>Total CDD</b>	<b>940</b>	<b>18.5</b>	<b>1.97</b>	<b>199310</b>	<b>256.7</b>	<b>0.144</b>	<b>687600</b>	<b>11106</b>	<b>1.627</b>	<b>294783</b>	<b>3814</b>	<b>1.293</b>
FURANS												
2378 TCDF	300	[2.600]	0.00	28100	2.00	0.007	33300	46.3	0.139	20567	24.2	0.117
Other TCDF	800	[2.600]	0.00	82900	21.8	0.026	251700	954	0.379	111800	488	0.436
12378 PCDF	(50.00)	[4.700]	0.00	3500	[2.800]	0.00	39300	196	0.499	14283	196	1.372
23478 PCDF	110	[4.400]	0.00	8400	[2.600]	0.00	35100	160	0.456	14537	160	1.101
Other PCDF	450	[4.500]	0.00	73000	7.20	0.010	432600	1674	0.387	168683	840	0.498
123478 HxCDF	240	[5.700]	0.00	26000	8.90	0.034	160000	1150	0.719	62080	579	0.933
123678 HxCDF	80	[4.400]	0.00	8700	(3.300)	0.038	82800	585	0.707	30527	294	0.964
234678 HxCDF	150	5.50	3.67	19600	8.90	0.045	76100	678	0.891	31950	230	0.722
123789 HxCDF	[20.00]	[6.300]	NA	1300	[5.300]	0.00	6600	63.9	0.968	3950	63.9	1.618
Other HxCDF	450	-0.20	-0.04	45400	3.60	0.008	411500	2503	0.608	152450	835	0.548
1234678-HpCDF	440	[4.800]	0.00	35200	(12.40)	0.035	266000	2650	0.996	100547	1331	1.324
1234789-HpCDF	340	[7.800]	0.00	8900	[6.800]	0.00	56300	703	1.249	21847	703	3.218
Other HpCDF	1120	[6.000]	0.00	22700	(15.40)	0.068	201700	2087	1.035	75173	1051	1.398
Octa-CDF	1600	[14.80]	0.00	75600	(35.50)	0.047	604000	8300	1.374	227067	4168	1.835
<b>Total CDF</b>	<b>6130</b>	<b>5.30</b>	<b>0.086</b>	<b>499300</b>	<b>119</b>	<b>0.027</b>	<b>2657000</b>	<b>21750</b>	<b>0.819</b>	<b>1034143</b>	<b>7291</b>	<b>0.705</b>
<b>Total CDD-CDF</b>	<b>7070</b>	<b>21.8</b>	<b>0.337</b>	<b>638610</b>	<b>405.7</b>	<b>0.064</b>	<b>3339600</b>	<b>32856</b>	<b>0.984</b>	<b>1328427</b>	<b>11095</b>	<b>0.835</b>

[ ] = minimum detection limit (not used in the averages or summations)

( ) = estimated maximum possible concentration (included in averages and summations)

TABLE 6-8. CDD/PCDF TOLUENE RINSE FULL SCREEN ANALYTICAL RESULTS COMPARED TO MMS ANALYTICAL RESULTS FOR OUTLET, BURN CONDITION SAMPLES- JORDAN HOSPITAL (1991)

CONGENER	RUN 1			RUN 3			RUN 5			AVERAGE		
	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)
DIOXINS												
2378 TCDD	3300	[5.000]	0.00	5400	[5.100]	0.00	(3500)	[3.800]	0.00	4067	[4.633]	0.0
Other TCDD	1526700	(13.20)	0.001	1874600	643	0.034	1950000	21.8	0.001	1783767	226	0.013
12378 PCDD	17200	[9.600]	0.00	32300	(13.90)	0.043	14200	[7.000]	0.00	21233	13.9	0.065
Other PCDD	1322800	15.3	0.001	1717700	444	0.026	1125800	7.5	0.001	1388767	156	0.011
123478 HxCDD	9700	[15.00]	0.00	21700	(17.70)	0.082	12500	[11.00]	0.00	14633	17.7	0.121
123678 HxCDD	16800	[9.900]	0.00	31200	31.9	0.102	19300	[7.300]	0.00	22433	31.9	0.142
123789 HxCDD	26700	[12.70]	0.00	54200	36.2	0.067	33900	[9.300]	0.00	38267	36.2	0.095
Other HxCDD	528800	36.8	0.007	1002900	482.9	0.048	647300	71.4	0.011	726333	197	0.027
1234678-HpCDD	32900	[29.70]	0.00	78700	178	0.226	38600	12.4	0.032	50067	95.2	0.190
Other HpCDD	56100	[29.70]	0.00	133300	314	0.236	64400	0.00	0.00	84600	314	0.371
Octa-CDD	12300	[56.30]	0.00	26500	127	0.479	18600	37.1	0.199	19133	82.1	0.429
<b>Total CDD</b>	<b>3553300</b>	<b>65.3</b>	<b>0.002</b>	<b>6978500</b>	<b>2255</b>	<b>0.046</b>	<b>5925100</b>	<b>150</b>	<b>0.004</b>	<b>4153900</b>	<b>535</b>	<b>0.020</b>
FURANS												
2378 TCDF	504000	2.40	0.0005	541000	20.4	0.004	452000	[2.200]	0.00	499000	11.4	0.002
Other TCDF	2006000	50.4	0.003	2259000	1309	0.058	1878000	41.1	0.002	2047667	467	0.023
12378 PCDF	40700	[6.500]	0.00	75200	(28.80)	0.038	35100	[3.600]	0.00	50333	28.8	0.057
23478 PCDF	71200	[6.100]	0.00	158000	51.5	0.033	58500	(2.600)	0.004	95900	27.1	0.028
Other PCDF	1028100	23.1	0.002	2146800	745	0.035	1106400	26.4	0.002	1427100	265	0.019
123478 HxCDF	140000	[11.20]	0.00	230000	159	0.069	122000	13.7	0.011	164000	86.4	0.053
123678 HxCDF	39200	[8.600]	0.00	68100	48.9	0.072	37000	(3.800)	0.010	48100	26.4	0.055
234678 HxCDF	52900	[11.10]	0.00	101000	161	0.159	52700	10.5	0.020	68867	85.8	0.125
123789 HxCDF	1100	[12.40]	0.00	2600	[10.40]	0.00	(1100)	[6.900]	0.00	1600	[9.900]	0.00
Other HxCDF	346800	(20.40)	0.006	566300	339	0.050	293300	19.2	0.007	402133	126	0.031
1234678-HpCDF	48600	[11.00]	0.00	101000	154	0.152	75800	13.4	0.018	75133	83.7	0.111
1234789-HpCDF	(3400.)	[17.90]	0.00	7700	(16.90)	0.219	6800	[8.400]	0.00	5967	16.9	0.283
Other HpCDF	27900	[13.60]	0.00	57300	37	0.065	43400	3.20	0.007	42867	20.1	0.047
Octa-CDF	6600	[44.30]	0.00	11900	(48.20)	0.405	9600	[15.90]	0.00	9367	48.2	0.515
<b>Total CDF</b>	<b>4316500</b>	<b>96.3</b>	<b>0.002</b>	<b>6325900</b>	<b>3119</b>	<b>0.049</b>	<b>4171700</b>	<b>134</b>	<b>0.003</b>	<b>4938033</b>	<b>1116</b>	<b>0.023</b>
<b>Total CDD+CDF</b>	<b>7869800</b>	<b>161.6</b>	<b>0.002</b>	<b>11304400</b>	<b>5405</b>	<b>0.045</b>	<b>8099800</b>	<b>284</b>	<b>0.004</b>	<b>9091333</b>	<b>1951</b>	<b>0.021</b>

[ ] = minimum detection limit (not used in the averages or summations)

( ) = estimated maximum possible concentration (included in averages and summations)

TABLE 6-9. CDD/CDF TOLUENE RINSE FULL SCREEN ANALYTICAL RESULTS COMPARED TO MMS ANALYTICAL RESULTS FOR OUTLET, BURNDOWN CONDITION SAMPLES- JORDAN HOSPITAL (1991)

CONGENER	RUN 2			RUN 4			RUN 6			AVERAGE		
	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)
DIOXINS												
2378 TCDD	1400	[5.900]	0.00	(1500)	[6.000]	0.00	380	[3.300]	0.00	1093	[5.067]	0.00
Other TCDD	463600	11.5	0.002	467000	177	0.038	133620	8.80	0.007	354740	65.8	0.019
12378 PCDD	11000	[10.00]	0.000	15000	21.4	0.143	2600	[5.200]	0.00	9533	21.4	0.224
Other PCDD	643000	12.5	0.002	712000	131	0.018	196400	30.8	0.016	517133	58.0	0.011
123478 HxCDD	5700	[14.60]	0.00	9500	23.3	0.245	1500	[6.400]	0.00	5567	23.3	0.419
123678 HxCDD	8700	[9.700]	0.00	14900	58.1	0.390	2500	(7.800)	0.312	8700	33.0	0.379
123789 HxCDD	14700	[12.40]	0.00	25900	66.8	0.258	4200	5.10	0.121	14933	36.0	0.241
Other HxCDD	270900	(19.80)	0.007	474700	902	0.190	80700	17.5	0.022	275433	313	0.114
1234678-HpCDD	16600	[30.30]	0.00	33700	272	0.807	5800	20.9	0.360	18700	146	0.783
Other HpCDD	30200	[30.30]	0.00	54700	513	0.938	8900	30.9	0.347	31267	272	0.870
Octa-CDD	6000	[68.60]	0.00	11100	(187.0)	1.685	2200	42.4	1.927	6433	115	1.783
<b>Total CDD</b>	<b>1471800</b>	<b>43.8</b>	<b>0.003</b>	<b>1820000</b>	<b>2351</b>	<b>0.129</b>	<b>438800</b>	<b>164</b>	<b>0.037</b>	<b>1245333</b>	<b>853</b>	<b>0.069</b>
FURANS												
2378 TCDF	179000	(9.200)	0.005	171000	115	0.067	40800	13.4	0.033	130267	45.9	0.035
Other TCDF	579000	(9.200)	0.002	571000	187	0.033	174200	7.40	0.004	441400	67.9	0.015
12378 PCDF	22300	[7.200]	0.00	28800	(34.30)	0.119	5700	[4.000]	0.00	18933	34.3	0.181
23478 PCDF	38000	[6.800]	0.00	63000	79.2	0.126	8800	5.10	0.058	36600	42.2	0.115
Other PCDF	555700	[7.000]	0.00	814200	941	0.116	151500	23.8	0.016	507133	482	0.095
123478 HxCDF	72700	[10.90]	0.00	115000	270	0.235	18300	16.7	0.091	68667	143	0.209
123678 HxCDF	21500	[8.400]	0.00	33500	88.5	0.264	5500	(5.800)	0.105	20167	47.2	0.234
234678 HxCDF	30000	[10.80]	0.00	47500	170	0.358	6800	17.1	0.251	28100	93.6	0.333
123789 HxCDF	860	[12.10]	0.00	1500	[13.00]	0.0	220	[5.900]	0.00	860	[10.333]	0.00
Other HxCDF	182940	[10.40]	0.00	268500	532	0.198	43280	15.8	0.037	164907	274	0.166
1234678-HpCDF	27000	[10.80]	0.00	52400	205	0.391	7400	15.3	0.207	28933	110	0.381
1234789-HpCDF	1800	[17.60]	0.00	3700	(19.30)	0.522	(620.0)	[6.900]	0.00	2040	19.3	0.946
Other HpCDF	15700	[13.40]	0.00	29600	49.0	0.166	4500	3.60	0.08	16600	26.3	0.158
Octa-CDF	2800	[54.00]	0.00	5600	85.2	1.521	1100	[14.40]	0.00	3167	85.2	2.691
<b>Total CDF</b>	<b>1729300</b>	<b>19.4</b>	<b>0.001</b>	<b>2205300</b>	<b>2775</b>	<b>0.126</b>	<b>468700</b>	<b>124</b>	<b>0.076</b>	<b>1467733</b>	<b>972</b>	<b>0.066</b>
<b>Total CDD+CDF</b>	<b>3201100</b>	<b>62.2</b>	<b>0.002</b>	<b>4025300</b>	<b>5126</b>	<b>0.127</b>	<b>907520</b>	<b>288</b>	<b>0.032</b>	<b>2711507</b>	<b>1825</b>	<b>0.067</b>

[ ] = minimum detection limit (not used in the averages or summations)

( ) = estimated maximum possible concentration (included in averages and summations)

TABLE 6-10. CDD/TCDF TOLUENE RINSE CONFIRMATION ANALYTICAL RESULTS  
 COMPARED TO MMS ANALYTICAL RESULTS FOR THE INLET  
 SAMPLE LOCATION; JORDAN HOSPITAL (1991)

CONGENER	RUN 1 INLET			RUN 3 INLET			RUN 5 INLET			INLET BURN AVERAGE		
	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)
DIOXINS												
2378 TCDD	(80.00)	NC	NA	(100.0)	NC	NA	520	[1.00]	NA	233	[1.00]	NA
Other TCDD	120.0	NC	NA	190.0	NC	NA	4,580	14.6	0.319	1,630	14.6	0.896
FURANS												
2378 TCDF	110.0	NC	NA	100.0	NC	NA	790	1.8	0.228	333	1.8	0.540
Other TCDF	1290.0	NC	NA	860.0	NC	NA	26,810	32.5	0.121	9,653	32.5	0.337
CONGENER	RUN 2 INLET			RUN 4 INLET			RUN 6 INLET			INLET BURNDOWN AVERAGE		
	MMS (pg)	TOLUENE (pg)	OL/MMS (%)	MMS (pg)	TOLUENE (pg)	OL/MMS (%)	MMS (pg)	TOLUENE (pg)	OL/MMS (%)	MMS (pg)	TOLUENE (pg)	TOL/MMS (%)
DIOXINS												
2378 TCDD	(100.0)	NC	NA	2,400	[1.500]	NA	2,700	18.4	0.681	1,733	18.4	1.062
Other TCDD	60.0	NC	NA	19,500	8,500	0.044	8,600	89.6	1.042	9,387	49.1	0.523
FURANS												
2378 TCDF	80.0	NC	NA	3,300	2.0	0.061	20,900	46.3	0.222	8,093	24.2	0.298
Other TCDF	920.0	NC	NA	160,700	21.8	0.014	275,100	953.7	0.347	145,573	487.8	0.335

[ ] = minimum detection limit. (not used in the averages or summations)  
 ( ) = estimated maximum possible concentration (included in averages and summations)  
 NA = not applicable  
 NC = No confirmation analysis conducted



TABLE 6-12. CDD/CDF TOLUENE FIELD BLANK RESULTS  
JORDAN HOSPITAL (1991)

LOCATION CONDITION	INLET			OUTLET		
	FIELD BLANK (total pg)	BURN AVG (total pg)	BURNDOWN AVG (total pg)	FIELD BLANK (total pg)	BURN AVG (total pg)	BURNDOWN AVG (total pg)
<b>CONGENER</b>						
<b>FULL SCREEN ANALYSIS</b>						
<b>DIOXINS</b>						
2378-TCDD	[5.700]	[4.500]	8.20	[6.100]	[4.600]	[5.000]
TOTAL TCDD	[5.700]	5.70	18.15	[6.100]	226	65.8
12378-PeCDD	[10.000]	[6.600]	(35.5)	[21.500]	(13.900)	21.4
TOTAL PeCDD	(138)	(30.4)	147.5	136	155.6	65.1
123478-HxCDD	[12.300]	[8.500]	60	[28.400]	(17.700)	23.3
123678-HxCDD	[8.200]	[5.600]	60.4	[18.800]	31.9	32.95
123789-HxCDD	[10.500]	[7.200]	142	[24.100]	36.2	35.95
TOTAL HxCDD	[10.000]	(12.0)	382	136	220	364
1234678-HpCDD	[20.500]	(8.700)	760	29.9	95.2	146.45
TOTAL HpCDD	[20.500]	7.90	1555	76	252.2	418.4
Octa-CDD	22.3	33.7	2389	70.3	82.05	114.7
<b>FURANS</b>						
2378-TCDF	[3.500]	9.80	68.3	5.40	85.6	45.9
TOTAL TCDF	[3.500]	9.80	512	5.40	435.9	111
12378-PeCDF	[6.400]	[4.200]	196	[6.200]	(28.8)	(34.300)
23478-PeCDF	[6.000]	[3.900]	160	[5.900]	27.05	42.15
TOTAL PeCDF	(5.700)	14.5	1019	8.90	282	524.45
123478-HxCDF	[10.200]	[6.700]	579	15.2	86.35	143.35
123678-HxCDF	[7.800]	[5.100]	294	4.30	26.35	47.15
234678-HxCDF	[10.100]	6.8	231	15.5	85.75	93.55
123789-HxCDF	[11.300]	[7.400]	63.9	[12.100]	[9.900]	[10.300]
TOTAL HxCDF	[9.700]	10.55	1669	62.1	257	554.8
1234678-HpCDF	[9.000]	7.40	1331	21.0	83.7	110.15
1234789-HpCDF	[14.600]	[9.200]	703	[17.500]	(16.9)	(19.300)
TOTAL HpCDF	[11.100]	9.10	2728	26.0	103.8	136.45
Octa-CDF	[30.800]	[17.800]	4168	[49.400]	(48.200)	85.2
<b>CONFIRMATION ANALYSES</b>						
2378-TCDD		[1.000]	18.4		22.5	[10.500]
2378-TCDF		1.80	24.15		11.4	4.633
TOTAL TCDD		14.6	58.25		266	133
TOTAL TCDF		34.3	512		475	195

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Detection Limit.

TABLE 6-13. LEAK CHECK RESULTS FOR TOXIC METALS  
JORDAN HOSPITAL (1991)

DATE	RUN NUMBER	MAXIMUM VACCUUM	PORT	AVG. SAMPLE RATE (ccfm)	4% SAMPLE RATE (ccfm) =	MEASURED LEAK RATE	INCHES FOR LEAK CHECK	LEAK CORRECTED (Y OR N)
03/05/91	1 INLET	1	A	0.201	0.008	0.002	6	N
	1	1	B	0.220	0.009	0.04	5	Y
03/05/91	1 OUTLET	3	A	0.414	0.017	NR <sup>b</sup>	NR	N
	4	4	B	0.418	0.017	0.016	8	N
03/05/91	2 INLET	1	A	0.1657	0.007	0.009	10	Y
	1	1	B	0.206	0.008	0.01	10	Y
03/05/91	2 OUTLET	3.5	A	0.480	0.019	NR	NR	N
	3	3	B	0.437	0.018	0.014	8	N
03/07/91	3 INLET	1	A	0.187	0.007	0.012	15	Y
	1	1	B	0.226	0.009	0.009	12	N
03/07/91	3 OUTLET	4	A	0.409	0.016	0.006	10	N
	4	4	B	0.422	0.017	0.016	10	N
03/07/91	4 INLET	1	A	0.118	0.005	0.01	14	Y
	1	1	B	0.110	0.004	0.012	2	Y
03/07/91	4 OUTLET	1	A	0.391	0.016	NR	NR	N
	1	1	B	0.343	0.014	0.002	5	N
03/09/91	5 INLET	1	A	0.182	0.007	0.012	14	Y
	1	1	B	0.127	0.005	0.012	20	Y
03/09/91	5 OUTLET	4	A	0.457	0.018	0.01	8	N
	3	3	B	0.372	0.015	0.01	9	N
03/09/91	6 INLET	1	A	0.114	0.005	0.018	12	Y
	1	1	B	0.115	0.005	0.014		Y
03/09/91	6 OUTLET	1	A	0.306	0.012	NR	NR	N
	1	1	B	0.266	0.011	0.012	8	N

<sup>a</sup> Because these rates are lower than 0.02 cfm, these values are the acceptable criterion.

<sup>b</sup> NR = Not recorded.

The isokinetic sampling rates for the PM/Metals trains are listed in Table 6-3. All isokinetic values were within 10 percent of 100 percent except three inlet runs.

The post-test dry gas meter calibration checks for boxes used for PM/Metals sampling are shown in Table 6-4. The results are well within the 5 percent acceptance criterion.

#### 6.2.3 Microbial Survivability in Emissions Quality Assurance

Table 6-14 presents the leak check results for the Microbial Survivability in emissions test runs. Several leak checks did not meet the leak rate criterion, however the exceedances were so minimal that no leak correcting has been done.

Microbial emission testing isokinetic results are presented in Table 6-3. Five out of six test runs met the isokinetic criterion of  $\pm 10$  percent of 100 percent.

The microbial emissions field blank results are shown in Appendix E.3. The average count was determined to be 20 spores per 100 ml aliquot.

No post-test calibration was performed on meter box 15 which was used for the microorganism in emissions tests.

#### 6.2.4 Halogen Flue Gas Sampling Quality Assurance

Halogen flue gas concentration tests did not use an isokinetic sampling method. A constant flow of flue gas was extracted from the stack through a heated 3 foot quartz probe. The sample stream was bubbled through a series of impinger collection solutions and sent to the laboratory for analysis of  $\text{Cl}^-$ ,  $\text{F}^-$ , and  $\text{Br}^-$ . A slight modification to the method (EPA Method 26) was incorporated into the test scheme by placing a small amount of quartz wool into the upstream side of the HCl filter housing.

Leak checks were completed before and after each halogen test run. They were conducted by establishing approximately 10 inches of vacuum on the train, plugging the end of the probe, turning off the flow, and checking for any detectable vacuum loss over a 30-second period. If a leak was observed in the system, the run was invalidated. (There was no quantitation of leak rate.) All halogen test results had sample trains which met the post-test leak check criterion.

Halogen field blank results are shown in Table 6-15. A value of 3.06 total mg of  $\text{Cl}^-$  was detected in the field blank. No  $\text{Br}^-$  or  $\text{F}^-$  was detected in the field blank.

TABLE 6-14. LEAK CHECK RESULTS FOR MICROORGANISMS IN FLUE GAS TESTING  
JORDAN HOSPITAL (1991)

DATE	RUN NUMBER	MAXIMUM VACCUUM	AVG. SAMPLE RATE (scfm)	4% SAMPLE RATE (scfm) <sup>a</sup>	MEASURED LEAK RATE	INCHES FOR LEAK CHECK	LEAK CORRECTED (Y OR N)
03/05/91	1 INLET	3.5	0.18	0.007	0.010	14.0	N
03/05/91	2 INLET	0.0	0.16	0.006	0.006	12.0	N
03/07/91	3 INLET	0.0	0.17	0.007	0.016	10.0	N
03/07/91	4 INLET	2.2	0.09	0.004	0.012	14.0	N
03/09/91	5 INLET	0.0	0.16	0.006	0.002	0.0	N
03/09/91	6 INLET	3.0	0.10	0.004	0.008	3.0	N

<sup>a</sup> Because these rates are lower than 0.02 cfm, these values are the acceptable criterion.

<sup>b</sup> NR = Not recorded.

TABLE 6-15. HALOGEN FIELD BLANK, REAGENT BLANK, AND  
METHOD BLANK RESULTS; JORDAN HOSPITAL (1991) <sup>a</sup>

ANALYTE	INLET FIELD BLANK (total mg)	H <sub>2</sub> SO <sub>4</sub> REAGENT BLANK (total mg)	NaOH REAGENT BLANK (total mg)	METHOD BLANK 1 (total mg)	METHOD BLANK 2 (total mg)
Cl	3.06	[0.110]	0.131	[0.0103]	[0.0103]
F	[0.040]	[0.040]	[0.0414]	[0.0362]	[0.0362]
Br	[0.0127]	[0.0127]	[0.0131]	[0.0115]	[0.0115]

<sup>a</sup> Values are reported as the respective anions.

[ ] = Minimum Detection Limit

### 6.3 QC PROCEDURES FOR ASH AND PIPE SAMPLING

As stated in Section 5.3, the incinerator waste charges were spiked with B. stearothermophilus in both wet and dry forms. Solutions of B. stearothermophilus (wet spores) were spiked to the incinerator to coincide with simultaneous emissions testing and daily ash sampling. Assessments of B. stearothermophilus survivability could then be made. A pre-aliquoted stock solution of wet spores of approximately 500 ml was deposited onto paper waste material and placed in a new, clean plastic garbage bags for each spike. This package was then added to the normal waste loads at precise spiking times. Freeze-dried quantities of B. stearothermophilus (dry spores) were placed in sealed pipes (See Figure 5-12) to determine the viability of "thermally shaded" microbial matter. Two pipes (one large and one small) were placed into the charging bin three times daily.

For both wet and dry spore spiking procedures, only pre-cleaned/disinfected materials were used for handling, application, and transport. The wet spore aliquots were divided and sealed at the manufacturer. This prevented any losses of material during shipment or upon application. (The empty solution container was also placed in the spiked waste charge.) The spiked charge was tied closed and deposited upright into the incinerator. Personnel handling the spiking material used disposable plastic gloves to prevent any cross-contamination.

The inner containers for the pipe samples were acid washed and alcohol disinfected. These were then placed in clean baggies awaiting the dry spore charge. The dry spore was loaded into the pipe container on the same day as it was spiked. The dry spore material was received from the manufacturer in seal, glass vials. This allowed for easy and complete transfer of all the spore material to the inner container.

In conjunction with the wet spore/microbial survivability tests, incinerator ash was collected before each test day (from the previous test run). The ash was also analyzed for metals, CDD/CDF, carbon, loss on ignition, moisture content, as well as indicator spores. All of the ash was completely removed from the incinerator bed every morning, passed through a 1-inch mesh stainless steel sieve and placed in a large 55-gallon drum. Using a sample "thief", four approximately 500 gram samples were taken and placed in

pre-cleaned, amber glass bottles. All material used for sampling, sample compositing, and sample aliquoting was cleaned to prevent any sample contamination.

During the ash removal process, the pipe samples were also recovered. The outer containers were allowed to cool and then opened. The inner container was removed and placed in a clean, dry Ziplock baggie, labeled and kept in a clean environment prior to shipment to the laboratory. Further Microbial QA information is presented in Section 6.4.4.

## 6.4 ANALYTICAL QUALITY ASSURANCE

The following section reports QA parameters for the CDD/CDF, Metals, Halogen, and Microbial Survivability analytical results.

### 6.4.1 CDD/CDF Analytical Quality Assurance

6.4.1.1 Flue Gas (MM5) Analytical Procedure. There were two samples generated for each flue gas (MM5) test run. One sample consisted of the pooled MM5 sample which received both the full screen and confirmation analyses. The second sample was the post-recovery, toluene rinse, which also received a full screen and confirmation analysis. The full screen analyses were conducted using a DB-5 GC column which allows for the separation of each class of chlorination (i.e., tetras, penta, etc.) and fully resolves 2378 TCDD from the other TCDD isomers. The confirmation analysis, performed on a DB-225 GC column, is needed to fully resolve the 2378 TCDF from the other TCDF isomers. The 2378 TCDD and total TCDD isomers are also reported on the confirmation analysis. The final results for 2378 TCDF and other TCDF emission parameters were taken from the confirmation analysis. All other CDD/CDF results were taken from the full screen analysis unless directed otherwise by the analytical "case narratives" which are shown in Appendix E-1.

A component of the CDD/CDF analytical laboratory's QA/QC program is adding isotopically labeled standards to each sample during various stages of analysis to determine recovery efficiencies and to aid in the quantitation of "native" CDD/CDF species. Four different type standards are added. Surrogate standards are usually spiked on the XAD absorbent trap prior to the sampling session. (Toluene surrogates are added to the sample prior to extraction.) Recovery of these compounds allows for the evaluation of overall sample collection efficiency and analytical matrix effects. Internal

standards are spiked after the sampling session but prior to extraction. Alternate standards are also spiked at this stage. Recovery percentage of internal standards are used in quantifying the flue gas native CDD/CDF isomers. Recovery of alternate standards allows for extraction/fractionation efficiencies to be determined. Finally, recovery standards are added after fractionation, just prior to the HRGC/HRMS analysis. Internal standards recovery are determined relative to recovery standards recovery. Recovery standards recovery efficiencies are not typically reported with the analytical results.

Poor recovery percentage of the various standards can reveal poor data quality. In some cases, if an analysis with a poor recovery is also accompanied by a suitable QA/QC "flag", the sample result can be validated. A full discussion of the analytical QA/QC program can not be presented in this summary report, but can be found in Triangle's CDD/CDF Data User Manual.

6.4.1.2 CDD/CDF MM5 Analytical Protocol Changes. Based on previous Hospital MWI test programs, high levels of organics were expected to be found in the inlet CDD/CDF MM5 samples. The inlet XAD-2 modules were spiked 10-20 times the normal surrogate standard levels (100 ng). Outlet XAD-2 modules were spiked with 4 ng. Even though much lower levels of CDD/CDF isomers were detected at the inlet, the high spike did not appear to create any analytical difficulties. Modified analytical protocols were also developed for samples with saturated responses. One percent of the MM5 extracts were used for resolving these saturated samples instead of the typical 50 percent. All ash and outlet MM5 samples showed saturation and were analyzed a second time using these dilution techniques. This resulted in a diluted fraction which did not saturate the MS detector.

6.4.1.3 CDD/CDF MM5 Blank Results. Both method blanks and field blanks were analyzed for CDD/CDF isomers. A MM5 method blank was analyzed for each batch of samples. All water samples showed no CDD/CDF isomers detected. Small quantities of several isomers were detected in the method blanks for the inlet MM5, outlet MM5, toluene rinses, and the ash samples. Levels were all less than one third the "theoretical method quantitation limit" and were, therefore, within analytical QA guidelines.

6.4.1.4 CDD/CDF Standard Recoveries. Tables 6-16 and 6-17, and Tables 6-18 and 6-19 present the standard recovery values for the MM5 flue gas and toluene flue gas samples, respectively. Both full screen (FS) and confirmation (C) values are presented. Confirmation analyses were only completed when positive detections of 2378 TCDD or 2378 TCDF were found in the full screen (DB-5) analysis. The analytical acceptance criterion for internal standard recoveries is 40 percent to 130 percent for tetra- through hexa-chlorinated compounds, while the range is 25 percent to 130 percent for hepta- and octa-chlorinated compounds. Recoveries outside of these limits may still be acceptable if other identification criteria are met.

Internal standard recoveries for MM5 Runs FS and C at both the inlet and outlet all met the acceptable criteria. One internal standard recovery for HpCDD 678, MM5-outlet Run 5 and outside the control limit at 163 percent. This high value was not flagged for any other QA exceedances. All toluene internal standards recoveries were within the acceptance criteria except for the field blank-outlet, HxCDD 678 isomer with a recovery of 39.1 percent. This is not expected to impact the quality of the outlet CDD/CDF data.

All CDD/CDF data was inspected and released as valid by the Triangle Laboratory QA officer.

Table 6-20 present the recovery standards for the ash samples. All recoveries were within acceptable limits, except for the pre-test ash 2378 TCDF internal standard recovery at 175 percent. This is not expected to impact the quality of the data. Further information on standards recoveries can be found in Appendix E.1.

#### 6.4.2 Metals Analytical Quality Assurance

The analytical methods used for the flue gas samples, the ash samples, and the metals samples are fully discussed in Section 5. The following paragraph will briefly report to metals analytical QA parameters.

Table 6-21 present the method blank metals results for both the ash and flue gas samples. No metals were detected in the ash blank. Barium, Cr, and Hg were detected in the flue gas method blank at low levels.

Table 6-22 presents the method spike results for the metals analyses. All spiked recoveries were within the QA allowance of  $\pm 20$  percent of 100 percent except for Sb

TABLE 6-16. STANDARDS RECOVERIES FOR THE CDD/CDF MODIFIED METHOD 5 INLET ANALYSES  
 JORDAN HOSPITAL (1991)

SAMPLE ID	MMS-RUN 1	MMS-RUN 2	MMS-RUN 3	MMS-RUN 4	MMS-RUN 5	MMS-RUN 6	MMS FIELD BLANK
<b>FULL SCREEN ANALYSES</b>							
<b>SURROGATE STANDARDS RECOVERY (%)</b>							
37Cl-TCDD	85.6	88.1	82.7	76.9	88.7	92.0	92.7
13C12-PeCDF 234	83.1	86.2	99.6	79.8	94.0	77.3	98.3
13C12-HxCDF 478	84.9	84.1	88.4	89.6	98.0	96.5	99.0
13C12-HxCDD 478	97.8	88.6	103.0	88.2	103.0	94.9	80.8
13C12-HpCDF 789	88.2	106.0	90.7	86.3	91.7	81.7	110.0
<b>ALTERNATE STANDARDS RECOVERY</b>							
13C12-HxCDF 789	109.0	117.0	112.0	109.0	107.0	107.0	108.0
13C12-HxCDF 234	105.0	114.0	110.0	108.0	104.0	108.0	105.0
<b>INTERNAL STANDARDS RECOVERY</b>							
13C12-2378-TCDF	69.4	63.7	77.5	73.8	80.5	77.6	69.3
13C12-2378-TCDD	87.8	78.6	95.4	88.1	94.1	94.1	81.5
13C12-PeCDF 123	94.0	106.0	104.0	119.0	96.1	109.0	102.0
13C12-PeCDD 123	103.0	122.0	114.0	118.0	105.0	118.0	120.0
13C12-HxCDF 678	125.0	147.0	136.0	122.0	121.0	122.0	119.0
13C12-HxCDD 678	102.0	136.0	116.0	117.0	107.0	109.0	137.0
13C12-HpCDF 678	101.0	107.0	103.0	109.0	96.8	118.0	97.9
13C12-HpCDD 678	97.3	115.0	94.9	100.0	85.8	101.0	103.0
13C12-OCDD	69.8	87.4	67.2	78.9	63.5	77.9	75.0
<b>CONFIRMATION DATA</b>							
<b>SURROGATE STANDARD RECOVERY (%)</b>							
37Cl-TCDD	88.5	92.1	94.6	88.1	92.2	87.0	
<b>INTERNAL STANDARDS RECOVERY (%)</b>							
13C12-2378-TCDF	96.3	84.4	105	95.9	102	82.3	
13C12-2378-TCDD	104	93.2	113	98.8	99.8	96.9	

TABLE 6-17. STANDARDS RECOVERIES FOR THE CDD/CDF MODIFIED METHOD 5 OUTLET ANALYSES  
 JORDAN HOSPITAL (1991)

SAMPLE ID	MMS RUN 1	MMS RUN 2	MMS RUN 3	MMS RUN 4	MMS RUN 5	MMS RUN 6	MMS FIELD BLANK
<b>FULL SCREEN ANALYSES</b>							
<b>SURROGATE STANDARDS RECOVERY (%)</b>							
37Cl-TCDD	129.0	114.0	142.0	109.0	126.0	99.9	108.0
13C12-PeCDF 234	98.4	90.2	130.0	123.0	95.8	84.5	105.0
13C12-HxCDF 478	122.0	114.0	120.0	129.0	107.0	112.0	107.0
13C12-HxCDD 478	113.0	110.0	122.0	119.0	128.0	106.0	105.0
13C12-HpCDF 789	94.3	107.0	101.0	112.0	103.0	89.0	96.5
<b>ALTERNATE STANDARDS RECOVERY</b>							
13C12-HxCDF 789	95.1	33.0	95.2	87.0	107.0	83.7	84.4
13C12-HxCDF 234	92.3	33.9	98.5	84.2	112.0	81.1	83.0
<b>INTERNAL STANDARDS RECOVERY</b>							
13C12-2378-TCDF	97.0	27.9	98.6	98.9	136.0	81.6	81.0
13C12-2378-TCDD	73.3	31.4	86.4	94.0	107.0	73.2	79.7
13C12-PeCDF 123	79.6	43.1	95.5	105.0	118.0	90.7	93.7
13C12-PeCDD 123	62.7	37.4	104.0	110.0	105.0	67.0	80.7
13C12-HxCDF 678	94.6	33.6	83.7	82.7	124.0	89.1	86.4
13C12-HxCDD 678	88.6	41.5	88.3	91.9	110.0	89.2	101.0
13C12-HpCDF 678	92.5	35.7	84.6	81.9	97.4	72.0	80.9
13C12-HpCDD 678	83.8	44.8	90.3	107.0	163.0	76.7	90.6
13C12-OCDD	50.9	43.4	82.4	107.0	87.8	51.1	67.1
<b>CONFIRMATION DATA</b>							
<b>SURROGATE STANDARD RECOVERY (%)</b>							
37Cl-TCDD	93.2	92.4	86.3	97.4	91.4	91.0	
<b>INTERNAL STANDARDS RECOVERY (%)</b>							
13C12-2378-TCDF	93.4	36.6	84.9	111	116	85.0	
13C12-2378-TCDD	91.4	37.3	98.8	116	118	85.7	

TABLE 6-18. STANDARDS RECOVERIES FOR CDD/CDF TOLUENE RINSE INLET ANALYSES  
 JORDAN HOSPITAL (1991)

SAMPLE ID	TOL-RUN 1	TOL-RUN 2	TOL-RUN 3	TOL-RUN 4	TOL-RUN 5	TOL-RUN 6	TOL FIELD BLANK
<b>FULL SCREEN ANALYSES</b>							
<b>SURROGATE STANDARDS RECOVERY (%)</b>							
37Cl-TCDD	55.5	58.0	58.9	45.8	58.2	60.5	57.7
13C12-PeCDF 234	66.3	63.0	72.5	47.0	66.1	71.0	60.2
13C12-HxCDF 478	72.0	73.2	70.5	64.0	69.2	76.0	68.6
13C12-HxCDD 478	69.9	77.0	71.4	65.1	72.9	77.8	73.4
13C12-HpCDF 789	61.5	64.0	60.2	49.8	60.0	67.6	56.7
<b>ALTERNATE STANDARDS RECOVERY</b>							
13C12-HxCDF 789	67.2	71.0	68.3	56.7	64.4	70.8	64.3
13C12-HxCDF 234	72.3	72.0	68.5	60.1	66.7	77.7	67.2
<b>INTERNAL STANDARDS RECOVERY</b>							
13C12-2378-TCDF	55.8	63.2	50.9	42.9	58.7	51.1	62.0
13C12-2378-TCDD	61.0	58.1	58.7	50.8	58.5	60.4	59.7
13C12-PeCDF 123	94.0	66.8	70.1	56.7	79.7	73.3	65.2
13C12-PeCDD 123	92.8	97.7	91.7	72.0	96.2	79.9	78.3
13C12-HxCDF 678	70.6	69.2	68.9	66.3	68.0	68.7	65.6
13C12-HxCDD 678	87.7	95.4	91.4	90.0	93.7	74.5	89.9
13C12-HpCDF 678	74.0	68.5	66.5	63.5	67.4	72.9	62.2
13C12-HpCDD 678	73.7	71.9	68.7	62.4	70.1	70.5	64.2
13C12-OCDD	56.1	54.8	53.6	42.3	51.1	54.9	44.6
<b>CONFIRMATION DATA</b>							
<b>SURROGATE STANDARD RECOVERY (%)</b>							
37Cl-TCDD				44.5	55.1	58.7	
<b>INTERNAL STANDARDS RECOVERY (%)</b>							
13C12-2378-TCDF				52.2	61.8	82.2	
13C12-2378-TCDD				54.8	62.4	65.7	

TABLE 6-19. STANDARDS RECOVERIES FOR CDD/CDF TOLUENE RINSE OUTLET ANALYSES  
JORDAN HOSPITAL (1991)

SAMPLE ID	TOL-RUN 1	TOL-RUN 2	TOL-RUN 3	TOL-RUN 4	TOL-RUN 5	TOL-RUN 6	TOL FIELD BLANK
<b>FULL SCREEN ANALYSES</b>							
<b>SURROGATE STANDARDS RECOVERY (%)</b>							
37Cl-TCDD	58.1	60.8	58.9	56.4	56.4	52.1	58.9
13C12-PeCDF 234	52.2	56.3	59.5	73.0	73.0	55.4	66.3
13C12-HxCDF 478	92.7	109.0	75.3	70.0	70.0	67.8	73.6
13C12-HxCDD 478	80.4	94.1	87.8	72.9	72.9	87.4	72.9
13C12-HpCDF 789	64.3	67.8	59.6	63.1	63.1	56.2	45.5
<b>ALTERNATE STANDARDS RECOVERY</b>							
13C12-HxCDF 789	75.6	80.5	67.6	68.2	68.2	56.4	60.4
13C12-HxCDF 234	81.3	100.0	117.0	70.3	70.3	84.7	65.7
<b>INTERNAL STANDARDS RECOVERY</b>							
13C12-2378-TCDF	55.5	59.9	59.4	48.3	48.3	57.5	42.4
13C12-2378-TCDD	67.3	65.9	69.2	61.3	61.3	51.9	53.0
13C12-PeCDF 123	63.6	66.5	63.6	80.3	80.3	51.9	64.2
13C12-PeCDD 123	81.2	89.9	94.9	77.4	77.4	74.5	34.8
13C12-HxCDF 678	90.9	101.0	72.9	67.8	67.8	59.0	61.2
13C12-HxCDD 678	113.0	126.0	103.0	64.3	64.3	80.7	39.1
13C12-HpCDF 678	77.5	85.6	68.9	68.6	68.6	61.6	51.8
13C12-HpCDD 678	67.7	72.0	65.7	69.8	69.8	61.5	46.6
13C12-OCDD	47.4	42.2	48.3	55.1	55.1	44.9	27.9
<b>CONFIRMATION DATA</b>							
<b>SURROGATE STANDARD RECOVERY (%)</b>							
37Cl-TCDD	55.3	47.7	58.5	45.2	99.2	42.4	
<b>INTERNAL STANDARDS RECOVERY (%)</b>							
13C12-2378-TCDF	60.1	60.4	67.7	58.8	115	59.4	
13C12-2378-TCDD	66.3	53.5	70.3	54.4	119	44.4	

TABLE 6-20. STANDARDS RECOVERY RESULTS FOR CDD/CDF ASH AND SCRUBBER WATER ANALYSES  
JORDAN HOSPITAL (1991)

SAMPLE ID	PRE-TEST			ASH			SCRUBBER WATER			MAKE-UP WATER (03/05/91)
	DAY 1	DAY 2	DAY 3	DAY 1	DAY 2	DAY 3	DAY 1	DAY 2	DAY 3	
<u>FULL SCREEN ANALYSIS</u>										
SURROGATE STANDARDS RECOVERY (%)										
37Cl-TCDD	71.8	91.9	70.1	72.6	88.0	77.0	72.6	88.0	77.0	68.1
13C12-PeCDF 234	66.8	92.5	42.3	76.0	123.0	95.2	76.0	123.0	95.2	59.1
13C12-HxCDF 478	121.0	142.0	115.0	135	96.6	126	135	96.6	126	75.4
13C12-HxCDD 478	97.6	94.2	76.7	121	96.4	107	121	96.4	107	74.1
13C12-HpCDF 789	60.1	112.0	118.0	86.7	77.7	90.0	86.7	77.7	90.0	65.7
ALTERNATE STANDARDS RECOVERY										
13C12-HxCDF 789	88.7	106.0	98.8	85.2	83.9	91.5	85.2	83.9	91.5	45.2
13C12-HxCDF 234	97.4	109.0	109.0	90.4	85.6	95.2	90.4	85.6	95.2	73.8
INTERNAL STANDARDS RECOVERY										
13C12-2378-TCDF	175.0	105.0	77.2	85.1	125.0	77.5	85.1	125.0	77.5	60.6
13C12-2378-TCDD	92.0	84.1	73.5	72.6	79.6	76.6	72.6	79.6	76.6	59.3
13C12-PeCDF 123	176.0	115.0	88.2	71.7	87.5	92.7	71.7	87.5	92.7	45.9
13C12-PeCDD 123	72.9	77.6	78.2	64.5	74.2	87.9	64.5	74.2	87.9	67.7
13C12-HxCDF 678	119.0	81.6	78.1	115	75.4	88.0	115	75.4	88.0	70.9
13C12-HxCDD 678	88.6	81.5	77.1	120	82.5	96.7	120	82.5	96.7	69.0
13C12-HpCDF 678	182.0	93.6	78.7	99.0	72.0	103	99.0	72.0	103	66.6
13C12-HpCDD 678	123.0	94.5	80.9	93.6	73.0	101	93.6	73.0	101	67.3
13C12-OCDD	78.7	74.4	62.8	29.8	54.3	30.9	29.8	54.3	30.9	47.3
<u>CONFIRMATION DATA</u>										
SURROGATE STANDARD RECOVERY (%)										
37Cl-TCDD	92.9	85.3	72.4	66.3	104	88.3	66.3	104	88.3	65.5
INTERNAL STANDARDS RECOVERY (%)										
13C12-2378-TCDF	109	89.6	82.3	75.0	107	87.5	75.0	107	87.5	87.6
13C12-2378-TCDD	87.7	75.4	69.8	73.7	95.2	87.8	73.7	95.2	87.8	75.3

TABLE 6-21. METALS ASH AND FLUE GAS METHOD  
BLANK RESULTS; JORDAN HOSPITAL (1991)

METAL	ASH METHOD BLANK (mg/kg)	FLUE GAS METHOD BLANK		
		FRONT HALF (total ug)	IMPINGERS 1,2,3 (total ug)	IMPINGERS 4,5,6 <sup>a</sup> (total ug)
Antimony	[1.50]	[3.00]	[1.61]	
Arsenic	[4.00]	[0.800]	[0.130]	
Barium	[0.100]	(0.580)	[0.108]	
Beryllium	[0.100]	[0.200]	[0.108]	
Cadmium	[0.200]	[0.400]	[0.215]	
Chromium	[0.600]	(1.58)	[0.646]	
Lead	[0.30]	[0.600]	[0.323]	
Mercury	[9.80]	(2.00)	2.77	[0.647]
Nickel	[0.300]	[0.600]	[0.323]	
Silver	[0.600]	[1.20]	[0.646]	
Thallium	[1.50]	[1.00]	[1.08]	

<sup>a</sup> Impingers 4, 5 and 6 sample fractions analyzed for Mercury content only.

[ ] = Minimum Detection Limit.

( ) = Estimated Maximum Possible Detection Limit.

TABLE 6-22. METALS METHOD SPIKE RESULTS  
JORDAN HOSPITAL (1991)

METAL	METHOD SPIKE (% rec.)			METHOD SPIKE DUPLICATE (% rec.)		
	FRONT HALF	IMPINGERS 1,2,3	IMPINGERS 4,5,6	FRONT HALF	IMPINGERS 1,2,3	IMPINGERS 4,5,6
Antimony	72.4	68.6		71.8	57.8	
Arsenic	106	93.0		103	90.0	
Barium	98.2	97.0		95.3	101	
Beryllium	101	103		98.6	108	
Cadmium	101	106		99.3	109	
Chromium	104	104		102	107	
Lead	100	102		98.2	105	
Mercury	105	102	106	106	102	102
Nickel	104	106		101	109	
Silver	102	3.08		86.8	4.30	
Thallium	108	104		104	100	

and Ag. Silver especially had low recoveries at 3.08 and 4.3 percent for the back half analyses. Silver was detected in very low amounts throughout the test program. No matrix corrections were applied.

#### 6.4.3 Halogen Analytical Quality Assessment

The analysis for Cl<sup>-</sup>, F<sup>-</sup>, and Br<sup>-</sup> incorporate stringent QA/QC guidelines. Table 6-23 presents the method blank results for the IC analysis. None of the target halogen ions were detected in any of the method blanks, or the reagent blank. The field blank revealed very low amounts of HCl but only represented a small amount of the run amounts.

The matrix spike recoveries are also shown in Table 6-23. Results for all 3 ions were within the 20 percent criteria.

#### 6.4.4 Microbial Survivability Quality Assurance

The stock wet spore solution, that were used for spiking the incinerator was analyzed. These results are listed in Table 6-24. One pre-aliquoted wet spore bag and a 10 ml vial filled with the spore slurry were submitted for confirmation analysis. The confirmation counts of  $7.2 \times 10^8$  and  $1.4 \times 10^{10}$  spores/ml were higher than the manufacturer's respective count of  $6.0 \times 10^8$  and  $8.5 \times 10^8$  spores/ml for the two samples, respectively. Because the final analyses were also completed by the same laboratory conducting confirmation analyses, the confirmation results were used to calculate Overall Microbial Survivability.

A dry spore sample was also sent in for QA analysis. These results are shown in Table 6-25. The sample was sent to the laboratory as it was received from the manufacturer (in a glass vial). The confirmation count of  $6.0 \times 10^7$  exceeded the manufacturer's count of  $1.0 \times 10^7$ .

A pipe which was loaded with spores and not charged to the incinerator (ambient pipe) was also submitted for analysis (see Appendix E.3). The results were  $6.0 \times 10^7$  spores.

TABLE 6-23. MATRIX SPIKE AND MATRIX SPIKE DUPLICATES  
 RECOVERY VALUES  
 JORDAN HOSPITAL (1991)

ANALYTE	RUN 3		RUN 1		RUN 10	
	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)
Cl	102.00	100.00	106.00	105.00	105.00	105.00
F	91.20	90.40	103.00	103.00	106.00	106.00
Br	95.80	93.20	115.00	115.00	109.00	109.00

TABLE 6-24. WET SPORE SPIKE SOLUTION CONFIRMATION ANALYSIS  
 JORDAN HOSPITAL (1991)

SAMPLE ID	MANUFACTURER'S COUNT (spores/ml)	CONFIRMATION AVERAGE (viable spores/ml)	CONFIRMATION COUNT STANDARD DEVIATION (viable spores/ml)
Spike Aliquot Spore Susp. -1	6.0E+08	7.2E+08	3.2E+07
Spike Aliquot Spore Susp. -2	8.5E+08	1.4E+10	2.1E+08

NOTE: All values were taken from the average of the 1 ml, 48 hour counts.

Spike Aliquot Spore Susp. -1 was labelled 3.00E+11 spores/bag at 500 ml/bag.

Spike Aliquot Spore Susp. -2 was labelled 4.27E+11 spores/bag at 500 ml/bag.

**TABLE 6-25. DRY SPORE SPIKE SOLUTION CONFIRMATION ANALYSIS  
JORDAN HOSPITAL (1991)**

SAMPLE ID	MANUFACTURER'S COUNT (spores/vial)	CONFIRMATION AVERAGE (viable spores/vial)	CONFIRMATION COUNT STANDARD DEVIATION (viable spores/vial)
Dry Spore Stock	1.00+07	6.0E+07	6.7E+06

NOTE: All values were taken from the average of the 1 ml, 17 hour counts.

## 6.5 CEM QUALITY ASSURANCES

Flue gas was analyzed for carbon monoxide (CO), oxygen (O<sub>2</sub>), carbon dioxide (CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and total hydrocarbons (THC), using EPA Methods 10, 3A, 6C, 7E, and 25A, respectively. An additional CEM analyzer was also employed for real time HCl gas concentrations.

### 6.5.1 CEM Data Overview

CEM sampling system and instruments were operated performing daily QA/QC procedures. These included QC gas challenges, sample systems blow back, probe maintenance, filter replacement, conditioner inspection and maintenance, calibration drift checks and others. The aim was to ensure a quality data product. Details of the CEM QC procedures are fully outlined in this test program's test plan.

Table 6-26 presents the CEM internal QA/QC checks along with their respective acceptance criteria which were conducted at the Jordan MWI tests.

### 6.5.2 Calibration Drift Checks

All CEM analyzers were calibrated daily with a zero gas (generally nitrogen), and a high-range span gas. Calibrations were performed prior to and at the completion of each test run. By comparing the post-test calibration to the pre-test calibration, the calibration drift was determined (zero drift and span drift). Post-test calibrations could not be completed for the HCl CEM test runs. This was because HCl calibrations had to be completed at stack gas temperatures and the incinerator would go into a "burndown" mode (lower temperature) before the post-test calibration could be performed.

Daily drift requirements between calibrations for both zero and span was  $\pm 3$  percent of full scale as required by EPA Methods 6C and 3A. Although Method 10 for CO allows  $\pm 10$  percent of full scale drift, the CO drift requirements were  $\pm 3$  percent for this test program, to ensure the quality of data produced.

The zero and span calibration drift results for each CEM analyzer on each test day are listed in Appendix D. Day 1 (March 5, 1991) showed excessive calibration drifts on the inlet CO<sub>2</sub> and the inlet THC. With span drifts of 8.79 and -50.7 percent for the above two analyzers, drift corrections were employed. The Day 1 inlet SO<sub>2</sub> CEM analyzer showed high drift as well at 8.8 percent, however, no corrections were made

TABLE 6-26. CEM INTERNAL QA/QC CHECKS

Check	Frequency	Criteria
Initial Leak Check	Once/Site	< 4% of Total flow while under vacuum
Daily Leak Checks	Before Each Test Run	< 0.5% O <sub>2</sub> with 0.2% O <sub>2</sub> gas
Calibration Drift	Daily	< ±3% Span zero and upscale gas (can use ±10 ppm limit for HCl if less restrictive)
Multipoint Linearity Check (Calibration Error)	Every 3 <sup>rd</sup> Day 3 point for O <sub>2</sub> , CO <sub>2</sub> , NO <sub>x</sub> , SO <sub>2</sub> , HCl 4 point for CO, THC	r = 0.998
Sample System Bias	Every 3 <sup>rd</sup> Day Zero and Span	< 5% Span
Response Time	Once/Site	85% of time for stable SO <sub>2</sub> measurements
NO <sub>x</sub> Convertor	Once/Site	> 90% conversion efficiency
Stratification Test	Once/Site	Within 10% of average

because response to the final QC gases was slightly low (within 5 percent of the certified concentrations).

Day 2 CEM responses showed no excessive calibration drift. All Day 3 instruments were within the 3 percent calibration drift criterion except the inlet CO<sub>2</sub> and -9.19 percent and the inlet NO<sub>x</sub> at 10.59 percent. The inlet CO<sub>2</sub> values were not drift corrected because responses from both the initial and final QC gases were almost identical indicating very little drift. The inlet NO<sub>x</sub> values were drift corrected.

#### 6.5.3 Daily QC Gas Challenges

After initial calibration, mid-range QC 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 difference between the measured response and the certified concentration was within  $\pm 2$  percent of full scale of the analyzer full range.

The results of the daily QC gas challenges all shown in Appendix D. Several QC gas responses exceeded the QC criterion. However, other QC challenges were made for these instruments with acceptable results.

#### 6.5.4 Multipoint Linearity Check

During the test program, the multipoint linearity was determined for each CEM analyzer. This is important because flue gas concentrations are determined from a two point linear regression analysis (zero calibration and span calibration gas). Multipoint calibrations are performed with either three or four certified gases depending on the instrument: a zero gas, a low scale gas concentration, a mid-range concentration, and a high scale concentration (span gas). The QC criterion for acceptable linearity will be a correlation coefficient (r) of greater than or equal to .998, where the independent variable is the cylinder gas concentration and the dependent variable is the instrument response.

The results of the CEM linearity checks are listed in Appendix d. All linearity checks met the acceptance criteria.

#### 6.5.5 Sample Bias

All calibrations and linearity checks were performed through the entire sampling system. Therefore, any system bias which may have existed was compensated for in the calibrations.

#### 6.6 PSD QUALITY ASSURANCE

The most important QC procedure performed on a PSD test is inspecting the quality of particulate loadings on every impactor stage. Assessments can then be made on the validity of the test run. All PSD test runs were inspected during the Jordan Hospital MWI test program and observations were noted on the field data sheets (see Appendix A.6). Only those runs with discrete "particulate piles", showing no evidence of overloading, were accepted. The PSD Run 1 was underloaded, and was not accepted as valid test run. Runs 2 and 3 were validated by the recovery technician and the results are reported in Section 2.9.

All PSD sample trains were carefully configured and a pre-test leak check was completed on the system. In order to prevent sample particulate matter from being disturbed, post-test leak checks could not be completed on a PSD sample train. All pre-test PSD leak checks met the acceptable criterion of less than 0.02 cfm at 0 inches Hg vacuum.

#### 6.7 DATA VARIABILITY

##### 6.7.1 Overview

Coefficients of Variation (CV) were calculated for all the final stack gas pollutant concentrations. The CV or relative standard deviation (RSD) is calculated by dividing the standard deviation by the mean and expressed as a percentage. CVs from several distinct groups of data can be combined into a "Pooled CV". The pooled CV is calculated as follows:

$$CV = \frac{S}{M} \times 100$$

where:

CV = Coefficient of variation

S = Standard deviation (calculated using LOTUS 123™ which uses n and not n-1 where n = number of data points.)

M = mean

$$CV_p = \sqrt{\frac{\sum (CV_i)^2 n_i}{\sum n_i}}$$

$CV_p$  = pooled coefficient of Variation

$CV_i$  = Coefficient of variation for a simple sample set i.

$n_i$  = Number of data points in that sample set.

The CV values expressed in the following tables are not intended to represent sampling/analytical precision. They are more a reflection of the variability of the data as a whole, including process caused emission variability.

#### 6.7.2 CDD/CDF Data Variation

Table 6-27 presents the CVs for the CDD/CDF flue gas concentrations. Values are listed for each congener for each triplicate run as well as a pooled CV for the entire six runs. Pooled CVs are also compiled for all of the congeners at each location and for the entire test program (overall). The overall pooled CVs for the CDD/CDF flue gas concentrations was 106 and 103 percent for the burn and burndown conditions at the inlet. The pooled CVs for the outlet for the two conditions were 33.3 and 42.1 percent.

Table 6-28 and 6-29 presents CVs for the metal flue gas concentrations. The overall pooled CV for the metals flue gas concentrations was 49.5 percent for the outlet and 55.6 percent for the inlet sample location.

The halogen gas test CVs are listed in Table 6-30. Values were calculated for each run as each run consisted of multiple "sub-runs" (Run 1 Burn = Halogen Runs 1 through 4). Only HCl CV values were calculated. The overall pooled CVs for the HCl gas concentrations was 57.5 percent at the inlet and 46.5 at the outlet.

TABLE 6-27. COEFFICIENTS OF VARIATIONS FOR THE CDD/CDF FLUE  
GAS CONCENTRATIONS  
JORDAN HOSPITAL (1991)

CONGENER	INLET			OUTLET		
	RUNS 1,3,5	RUNS 2,4,6	POOLED CV (%)	RUNS 1,3,5	RUNS 2,4,6	POOLED CV (%)
<b>DIOXINS</b>						
2378 TCDD	47.1	112.9	86.5	25.7	26.7	26.2
Other TCDD	124.5	70.5	101.2	7.8	22.6	16.9
12378 PCDD	47.3	76.4	63.5	39.9	40.0	40.0
Other PCDD	111.2	74.2	94.5	21.2	23.7	22.5
123478 HxCDD	47.1	68.5	58.8	37.1	46.0	41.8
123678 HxCDD	84.6	84.4	84.5	30.2	45.0	38.3
123789 HxCDD	47.1	61.8	55.0	32.4	46.5	40.1
Other HxCDD	131.2	80.9	109.0	29.7	45.2	38.2
1234678-HpCDD	127.2	102.2	115.4	43.0	48.3	45.8
Other HpCDD	47.1		47.1	43.2	47.1	45.2
Octa-CDD	135.1	118.2	126.9	31.6	42.3	37.3
<b>FURANS</b>						
2378 TCDF	94.1	102.2	98.3	26.5	25.9	26.2
Other TCDF	124.6	83.3	106.0	18.6	19.8	19.2
12378 PCDF	116.9	127.0	122.0	37.9	35.5	36.7
23478 PCDF	116.6	108.0	112.4	48.5	49.0	48.8
Other PCDF	128.8	116.4	122.7	38.1	39.1	38.6
123478 HxCDF	118.9	117.1	118.0	31.6	44.7	38.8
123678 HxCDF	117.9	124.8	121.4	32.1	43.6	38.3
234678 HxCDF	119.1	106.2	112.9	35.5	47.4	41.9
123789 HxCDF	46.8	75.4	62.8	46.6	48.9	47.8
Other HxCDF	126.5	124.0	125.2	32.2	43.1	38.0
1234678-HpCDF	120.1	120.9	120.5	29.3	52.2	42.4
1234789-HpCDF	84.9	117.0	102.2	30.5	49.3	41.0
Other HpCDF	128.7	123.1	125.9	28.8	49.7	40.6
Octa-CDF	128.3	121.8	125.1	23.7	44.5	35.6
Pooled CV	106.0	102.9		33.3	42.1	

TABLE 6-28. COEFFICIENTS OF VARIATION OF THE  
FLUE GAS METALS CONCENTRATIONS AT THE INLET  
JORDAN HOSPITAL (1991)

CONDITION RUN	BURN 1,3,5 CV (%)	BURNDOWN 2,4,6 CV (%)	POOLED CV (%)
Antimony	10.3	41.8	30.4
Arsenic	NC	79.1	79.1
Barium	65.6	64.5	65.0
Beryllium	NC	NC	NC
Cadmium	41.7	16.7	31.8
Chromium	11.5	13.5	12.5
Lead	14.7	16.4	15.6
Mercury	91.3	105	98.4
Nickel	91.1	33.9	68.8
Silver	1.2	58.4	41.3
Thallium	NC	NC	NC
<b>Pooled CV</b>	<b>54.9</b>	<b>56.1</b>	
<b>Overall Pooled CV</b>	<b>55.6</b>		

NC = Not Calculated

TABLE 6-29. COEFFICIENTS OF VARIATION OF THE  
FLUE GAS METALS CONCENTRATIONS AT THE OUTLET  
JORDAN HOSPITAL (1991)

CONDITION RUN	BURN 1,3,5 CV (%)	BURNDOWN 2,4,6 CV (%)	POOLED CV (%)
Antimony	16.0	30.7	23.0
Arsenic	NC	NC	NC
Barium	12.0	38.4	28.4
Beryllium	NC	NC	NC
Cadmium	43.1	37.7	40.5
Chromium	27.6	36.5	32.3
Lead	26.6	39.6	33.7
Mercury	78.1	82.5	80.3
Nickel	65.0	70.6	67.9
Silver	66.2	NC	66.2
Thallium	NC	NC	NC
<b>Pooled CV</b>	<b>47.0</b>	<b>52.3</b>	
<b>Overall Pooled CV</b>	<b>49.5</b>		

NC = Not Calculated

TABLE 6-30. COEFFICIENTS OF VARIATION FOR  
 HALOGEN (HCI) FLUE GAS CONCENTRATIONS  
 JORDAN HOSPITAL (1990)

TEST RUN NUMBER	INLET CV (%)	OUTLET CV (%)
Average 1-4	46.74	28.44
Average 4-6	85.82	71.51
Average 7-10	63.26	66.44
Average 11-13	7.87	11.24
Average 14-17	79.88	47.64
Average 18-20	17.36	30.03
<b>Total Pooled Halogen</b>	<b>57.49</b>	<b>46.52</b>

Table 6-31 presents the CV values for the CEM 30 second averages. It should be noted in comparing these numbers to the manual test CVs, that the CEM data reflect real time, almost instantaneous changes in concentrations. The manual tests are all integrated tests which by sampling over an extended period of time, result in a "smoothed" average concentration for that time period. The overall pooled CVs for the CEM data was 288 percent at the inlet sampling location and 144 percent at the outlet.

TABLE 6-31. COEFFICIENTS OF VARIATION OF CEM GAS CONCENTRATIONS  
JORDAN HOSPITAL (1991)

RUN NUMBER	DATE	COEFFICIENTS OF VARIATION - INLET (percent)										THC	POOLED CV BY RUN
		O2	CO2	CO	NOX	SO2	HCl	THC	POOLED CV BY RUN				
1	03/05/91	18.37	11.13	333.21	10.99	44.58	26.28	48.44	129.1				
2	03/05/91	30.11	32.34	66.68	50.83	98.05	17.79	64.51	57.4				
3	03/07/91	22.27	18.29	891.57	18.69	55.31	30.53	365.2					
4	03/07/91	29.31	32.86	590.44	56.49	97.86	73.12	118.26	233.8				
5	03/09/91	20.19	24.35	1364.26	29.30	97.71	15.57	4.39	517.3				
6	03/09/91	36.72	34.79	404.22	44.97	183.03	45.16	80.26	173.2				
Pooled Compound		26.9	27.0	739.8	39.0	105.9	39.9	67.0					
Inlet CEM Overall Pooled		288.19											
		COEFFICIENTS OF VARIATION - OUTLET (percent)											
1	03/05/91	2.71	14.57			77.08		4.10	39.3				
2	03/05/91	2.99	24.25			82.86		7.66	43.4				
3	03/07/91	5.12	21.15			191.43		398.29	221.2				
4	03/07/91	3.77	22.07			117.09		443.63	229.7				
5	03/09/91	3.91	16.53			104.94			61.4				
6	03/09/91	4.62	27.82			149.09			87.6				
Pooled Compound		3.9	21.5			126.8							
Outlet CEM Overall Pooled		143.78											

## 7. REFERENCES

1. North Atlantic Treaty Organization, Committee on the Challenges of Modern Society. Pilot Study on International Information Exchange on Dioxins and Related Compounds: International Toxicity Equivalency Factor (I-TEF) Methods of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Report No. 176, August 1988.
2. Radian Corporation, Municipal Waste Combustors - Background Information for Proposed Guidelines for Existing Facilities, EPA 450/3-89-27e, August 1989.