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MEDICAL WASTE INCINERATION

EMISSION TEST REPORT

VOLUME 1

Central Carolina Hospital
Sanford, North Carolina

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1. INTRODUCTION

Under Section 11008 of the Medical Waste Tracking Act of 1988 (MWTA), the United States Environmental Protection Agency (EPA) must prepare a series of reports to Congress that provide information concerning the characterization of medical wastes, treatment and disposal technologies, and an assessment of the impact of medical waste on human health and the environment. The MWTA specifically requires that incineration methods be evaluated to determine their advantages and disadvantages, including their ability to render a medical waste non-infectious or less infectious, and unrecognizable.

The Office of Solid Waste (OSW) is responsible for implementation of the MWTA and for managing the various studies that are required to prepare the report to Congress. One of the basic needs in the evaluation of incineration as a treatment technology is a characterization of emissions and ash from existing MWI's. These data are required to assess the actual potential impacts on health and the environment from existing sources that do not have advanced combustion controls or air pollution control devices.

Therefore, OSW and the Office of Air Quality Planning and Standards (OAQPS) are working jointly to perform additional studies at typical existing medical waste incinerator (MWI) facilities. The emission test program described in this report is one of the studies.

The MWI facility at Central Carolina Hospital in Sanford, North Carolina, was selected for emissions testing because it is typical of many existing units in which pathological wastes are burned with a secondary chamber gas retention time of 0.3 to 0.4 seconds, and with no add-on emission control equipment (see Figure 1-1). Other factors in the selection were that the proximity to Research Triangle Park (RTP), North Carolina minimized travel expenditures and because the hospital administration had expressed an interest in cooperating with the EPA in the emission test program.

1.1 TEST OBJECTIVES

The objectives of the testing program at the Central Carolina Hospital MWI were:

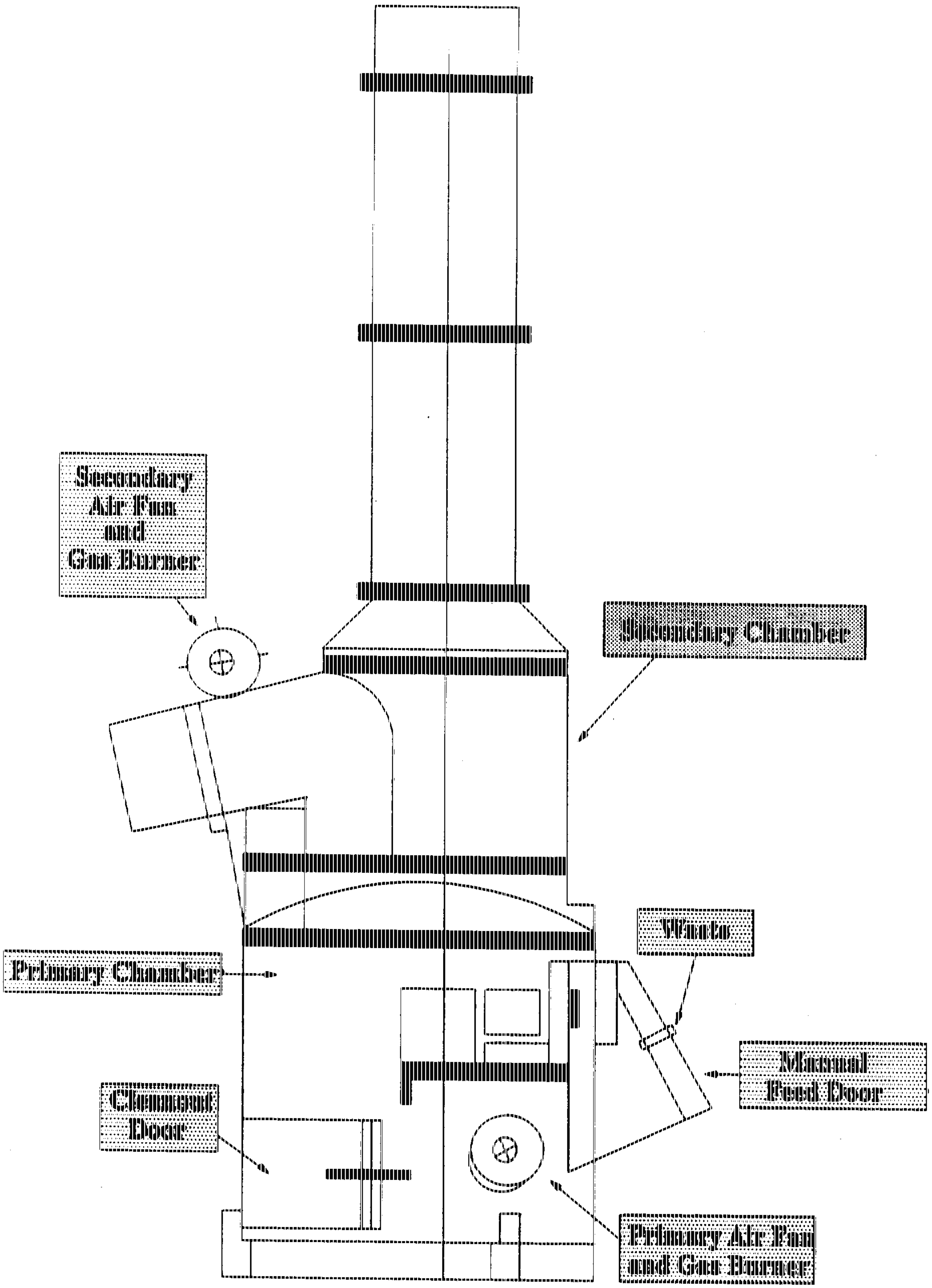

Figure 1-1. AMI Central Carolina Hospital Incinerator

- To obtain emission data from a facility that is not equipped with air pollution control devices and is typical of the existing population of medical waste incinerators.
- To collect data and evaluate the impact of incinerator operation variations on the emissions and ash as a factor in the overall effectiveness of incineration as a treatment method.

The measurements that were performed at this facility provided data to:

- Determine the mass emission rates of particulate matter (PM), selected metals, carbon monoxide (CO), total hydrocarbons (THC), sulfur dioxide (SO_2), nitrogen oxides (NO_x), hydrogen chloride (HCl), and polychlorinated dibenzo-p-dioxins (CDD) and polychlorinated dibenzofurans (CDF).
- Determine, if possible, the microorganism destruction efficiencies based on a surrogate indicator organism that is spiked into the incinerator feed during each test run.
- Determine the degree of combustion (burnout) of the wastes based on residual carbon, or loss on ignition (LOI), of the bottom ash that is collected for each test day.
- Determine the relationship, if any, between visible emissions and other emissions, such as PM.

The measurements described above were repeated at three operating conditions while the incinerator was burning hospital wastes (including red bag waste) to evaluate the effect of waste feed rate, charging frequency, and secondary chamber temperature on the emissions. These conditions were:

- Condition 1 - 100 percent pathological wastes at a charge rate of 100 pounds per hour (lb/hr) with a 15 minute charge cycle (25 lb/charge) and a secondary chamber temperature setpoint between 1800°F and 1900°F.
- Condition 2 - A mix of pathological and red bag waste typically burned at this facility (between 5 and 10 percent pathological waste) at a charge rate of 250 lb/hr (manufacturer's rating) with a 15 minute charge cycle and a 1600°F secondary chamber temperature setpoint.

- Condition 3 - 100 percent pathological wastes at a charge rate of 160 lb/hr with a 15 minute charge cycle (40 lb/charge) and a 1600°F secondary chamber temperature setpoint.

(These conditions were revised from those listed in the final test plan.)

Key process operating variables including flue gas oxygen (O_2), carbon dioxide (CO_2), primary and secondary chamber temperatures, and the amount and frequency of waste charging 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 are of known precision and accuracy, and that they are complete, representative and comparable.

1.2 BRIEF SITE DESCRIPTION

AMI Central Carolina Hospital is located in Sanford, North Carolina. The MWI at this facility is a Consumat Model C-75P. It has a rated capacity of 175 lb/hr of Type IV (pathological) waste. A plan view of the facility is shown in Figure 1-1. Two natural gas-fired auxiliary burners in the primary chamber are used to maintain a preset minimum combustion temperature. Primary chamber temperatures normally vary between 1200°F and 1600°F. The unit is charged manually by operating a large refractory-lined charging door that opens at the front of the primary chamber. It is designed for 8 to 12 hours of operation each day, and ashes must be removed manually after cooldown.

The secondary chamber on this unit is sized for a design gas retention time of about 0.3 to 0.4 seconds. A gas-fired auxiliary burner in the secondary chamber is activated automatically when the temperature falls below a preset level, normally 1600°F. Setpoint and actual temperatures in each chamber are displayed on a dial in the control panel. There is no add-on air pollution control device on this MWI. The stack is about 16 to 18 feet high and has no sampling ports. The unit is located outside, at the rear of the hospital.

There is a full time operator for the AMI Central Carolina Hospital MWI. The typical hours of operation are from 7:00 a.m. to 3:00 p.m. A burn down period of

5 hours on gas-firing is timed by the control panel. The gas is then extinguished and the incinerator is allowed to cool. The ash is typically removed from the incinerator from 7:00 a.m. to 8:00 a.m., and stored in 30 gallon metal cans. Two to five cans are filled each day.

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, dressings, disposable surgical tools and sharps and diagnostic devices; and human and animal tissue. Pathological waste is generally from 5 to 10 percent of the total waste weight.

Non-red bag wastes are collected by the housekeeping staff and placed in standard 30 gallon plastic trash bags, which are twist tied. The bags are transported via plastic bin type carts from the collection area to the incinerator area. Red bag wastes bags can be and are mixed with the other bags. The hospital incinerator operator hand feeds the bags through the incinerator feed door.

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 when operating on mixed medical waste (dry mode). Excess air conditions exist when the unit is operated on pathological waste (wet mode). A gas-fired pilot burner is used to drive moisture and volatiles from the wastes, and initiate the ignition of the fixed carbon portion of 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. Heat input from the gas burner is modulated to keep the lower chamber temperature within a certain range and to maintain the oxidation of fixed carbon at varying levels of waste moisture only when burning pathological waste (wet mode).

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. 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.

Detailed descriptions of the MWI facility, its operation, the waste and waste handling procedures are given in Section 3.

1.3 EMISSIONS MEASUREMENT PROGRAM

This section provides an overview of the emissions measurement program conducted at Central Carolina Hospital. Included in this section are summaries of the test matrix, sampling locations, sampling methods, and laboratory analysis. Greater detail on these topics is provided in the sections that follow.

1.3.1 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 continuous emission monitors (CEM) were employed for the Central Carolina Hospital MWI test program. In addition to flue gas sampling, incinerator bottom ash and ash quality pipe samples were also taken. Each of the tests are briefly described in Sections 1.3.3 and 1.3.4.

1.3.2 Sampling Locations

The stack gas sampling was conducted at a series of three sets of double ports in the stack wall. The double ports were located 90° from each other. The top-most ports were used for microbial survivability emission tests. The middle set of ports was used for PM/metals tests as well as CDD/CDF tests. The bottom set of ports was used for halogen emission tests and for the CEM probes. Incinerator ash was sampled every day. Ash was completely removed from the incinerator every day, screened through 1/2" mesh, and placed in the bulk ash containers where it was sampled to obtain a representative sample.

1.3.3 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

TABLE 1-1. AMI CENTRAL CAROLINA HOSPITAL MWI TEST MATRIX

Sample Location	Number of Runs	Sample Type	Sample Method	Sample Duration	Analysis Method	Laboratory
Stack	9	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
Stack	9	CDD/CDF	EPA Method 23 and GC/MS Method 8290	4 hours	Mass Spectrometry and High Resolution MS for CDD/CDF	Triangle Labs, Inc.
Stack	25[a]	HCl/HBr/HF	EPA Method 26	1 hour[a]	Ion Chromatography	Radian
Stack	18[b]	Indicator Spores	Draft EPA Method	2 hours[b]	Microbial Draft Method	RTI
Stack	9[c]	SO_2	EPA Method 6C	Continuous[c]	UV Analyzer CEM	Radian
Stack	9[c]	O_2 /CO_2	EPA Method 3A	Continuous[c]	Zirconium Oxide Cell/ NDIR CEM	Radian
Stack	9[c]	NO_x	EPA Method 7E	Continuous[c]	Chemiluminescence CEM	Radian
Stack	9[c]	CO	EPA Method 10	Continuous[c]	NDIR CEM	Radian
Stack	9[c]	THC	EPA Method 25A	Continuous[c]	FID CEM	Radian
Stack	9[c]	HCl	CEM	Continuous[c]	NDIR CEM	Radian
Stack	9[d]	Opacity	EPA Method 9	4 hour[d]	Visual	Radian
Incinerator	9	Incinerator Ash	Representative Composite Sample	1 day	LOI, Carbon, Metals	Radian
	9		Representative Composite Sample	1 day	Dioxins	Triangle Labs, Inc.
	9		Representative Composite Sample	1 day	Microbial Draft Method	RTI
Incinerator	54	Indicator Spore Pipes	Manual	1 day	Microbial Draft Method	RTI

[a] 3 one-hour runs per test day (2 runs out of 27 planned were not completed).
[b] 2 one-hour 45 minute runs per test day.
[c] Continuous during test periods.
[d] Four-hour run concurrent with particulate/metals run.

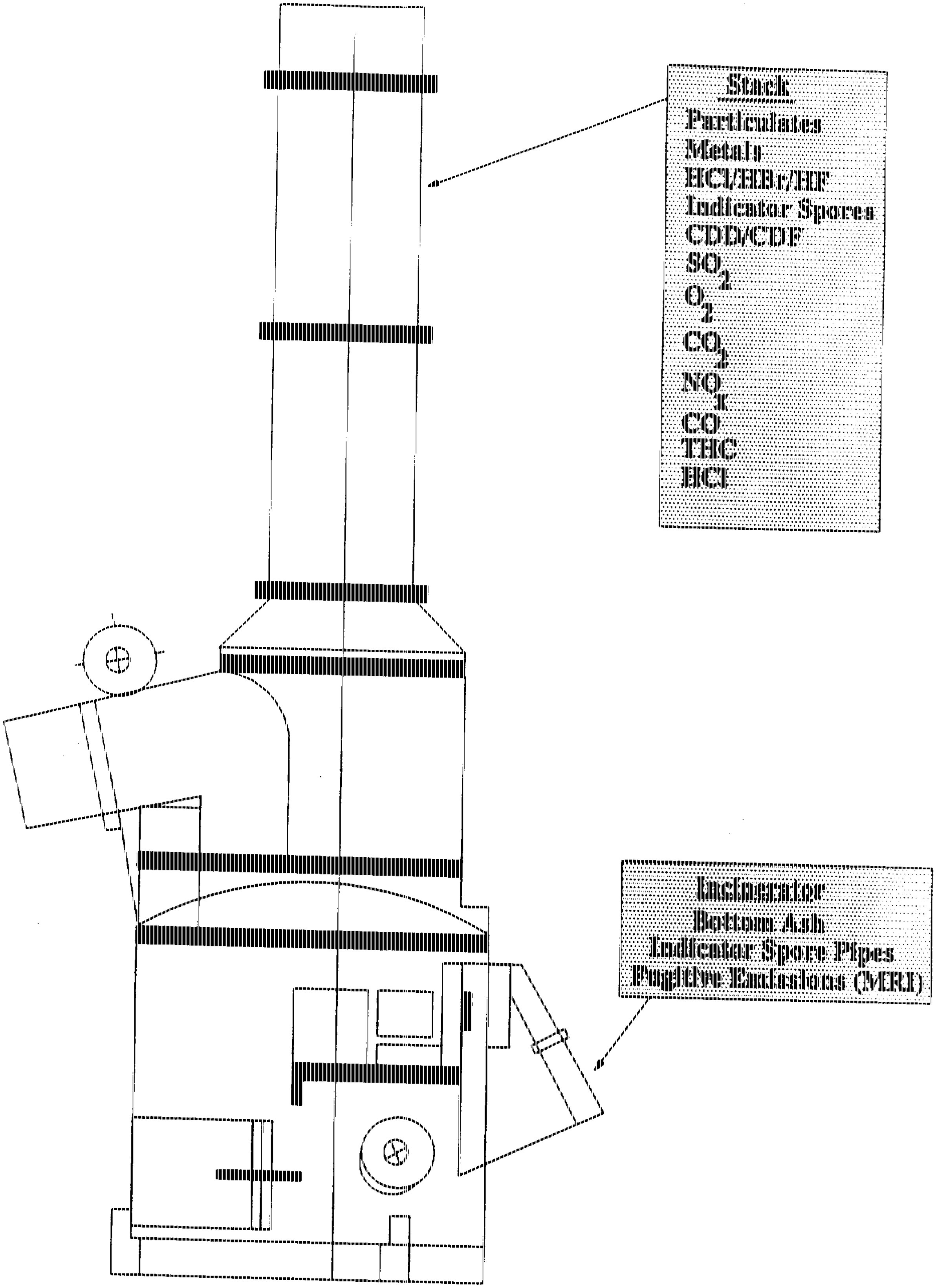

Figure 1-2. Sampling Locations at the AMI Central Carolina Hospital MWI

(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 (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 (HRCG) 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 a acidified collection solution which stabilized the respective halogen ions (Cl^-, Br^-, F^-). The quantity of ions collected was then determined using ion chromatography (IC) analyses.

Three types of microbial survivability tests were completed on the incinerator. These tests were intended to evaluate the effectiveness of the MWI in destroying indicator organisms in the waste. This was achieved by direct ash sampling and by spiking the incinerator with surrogate indicator spores encased in insulated double-pipe containers. Indicator spore spikes 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. Flue gas testing for spore emissions was conducted simultaneously with the other emissions testing. 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 was 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 culturing, identification, 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_x, CO, SO_2, THC, and HCl) were measured using CEMs continuously during the day. The diluent gases (O_2, CO_2) were measured using CEMs at all times when tests were being performed so that the emission results could be normalized to a reference O_2 or CO_2 basis. The O_2 and CO_2 results were also used for flue gas molecular weight calculations 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: LOI, carbon, toxic metals, dioxins, and microbial analysis. An archive sample was also saved for each test condition. Indicator spore pipes were charged at regular intervals into the incinerator and recovered manually for microbial analysis. Detailed descriptions of the sampling and analytical procedures are provided in Section 5.

1.3.4 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 High Resolution Gas Chromatography/High Resolution Mass Spectrometry (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 Inductively Coupled Argon Plasma Spectroscopy (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.

1.4 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

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

All post-test leak check criteria were met for all four manual sampling trains. The allowable isokinetic QC range of ± 10 percent of 100 percent was met for all CDD/CDF, PM/Metals and Microbial emissions test runs. All post-test dry gas meter calibration checks were within 5 percent of the full calibration factor. Field blanks (FB) results showed no contamination in the CDD/CDF MM5; sample however, the toluene FB had relatively high concentrations. The halogen FB showed virtually no contamination; however, the PM/metals FB had high levels of arsenic, chromium, and nickel. Also the front half analysis for metals Run 10 has not been completed at this time. Final toluene rinses of the CDD/CDF samples collected only a small portion of the total MM5 catch.

From an analytical QA perspective, all analyses were completed under a strict QA/QC regimen. The CDD/CDF MM5 analytical protocol was varied to accommodate the expected high organic loading of the Runs 2, 4, and 8 (Condition 2) MM5 samples.

The manual flue gas test data reflected variation from run to run as indicated by the coefficient of variation (CV) analyses. Overall pooled CVs ranged from 64.4 percent for CDD/CDF flue gas concentrations to 65.0 percent for metals flue gas concentrations. The overall pooled CV for the CEM data was 159 percent. These values reflect a strong variability in process operation.

1.5 DESCRIPTION OF REPORT CONTENTS

Section 1 of this report provides an introduction to the medical waste testing program conducted at Central Carolina Hospital in Sanford, North Carolina. 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 Central Carolina incinerator and gives process results. Included in the process results are the waste feed rates and incineration 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 emissions test program conducted at the Central Carolina Hospital MWI from September 20 to October 2, 1990. Included in this section are results of manual 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_2, CO_2, CO, NO_x, SO_2, THC, and HCl gases as well as particle size distribution (PSD) results.

2.1 EMISSIONS TEST LOG

Ten tests were conducted over a 13 day period. A probe liner for the CDD/CDF sampling train broke during Run 7 and the entire run was invalidated and repeated (samples from other sampling trains for Run 7 were not analyzed). Table 2-1 presents the emissions test log. This table shows the test date, run number, test type, run times and port change times for all the stack testing conducted during this program.

2.2 CDD/CDF RESULTS

2.2.1 Overview

Nine 4-hour CDD/CDF emission test runs were completed at Central Carolina Hospital during the September 1990 test program. Three runs were completed under each of three test conditions. 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 this data was not incorporated into the final emission results, it will be presented with the sampling QA parameters in Section 6.2.1.

As well as flue gas samples, daily ash samples were also taken. Each ash sample was also analyzed for tetra through octa CDD/CDF isomers.

The following sections report CDD/CDF emissions test results in Section 2.2.2 and incinerator ash CDD/CDF concentrations in Section 2.2.3.

2.2.2 CDD/CDF Emission Results

Tables 2-2 through 2-5 present the average emission parameters for each of the three test conditions. Data from each individual test run are presented in Tables 2-6 through 2-12. Emission tests analyses were targeted for the tetra through octa 2378

TABLE 2-1. EMISSIONS TEST LOG; CENTRAL CAROLINA HOSPITAL (1990)

DATE	LOCATION	RUN NUMBER	OPERATING CONDITION[a]	TEST TYPE	RUN TIME	PORT CHANGES
9/20/90	Stack	1	1	Toxic Metals	14:00--18:18	16:10--16:18
9/20/90	Stack	1	1	CDD/CDF	14:00--18:18	16:10--16:18
9/20/90	Stack	1A	1	HCl	14:09--15:09	
9/20/90	Stack	1B	1	HCl	15:21--16:21	
9/20/90	Stack	1C	1	HCl	16:35--17:35	
9/20/90	Stack	1A	1	Spore	13:58--15:58	
9/20/90	Stack	1B	1	Spore	15:58--17:58	
9/21/90	Stack	2	2	Toxic Metals	09:46--13:57	11:47--11:58
9/21/90	Stack	2	2	CDD/CDF	09:45--13:57	11:45--11:57
9/21/90	Stack	2A	2	HCl	09:53--11:43	
9/21/90	Stack	2B	2	HCl	12:23--14:36	
9/21/90	Stack	2A	2	Spore	09:43--11:28	
9/21/90	Stack	2B	2	Spore	11:28--13:43	
9/22/90	Stack	3	1	Toxic Metals	09:47--14:00	11:47--12:00
9/22/90	Stack	3	1	CDD/CDF	09:45--14:00	11:45--12:00
9/22/90	Stack	3A	1	HCl	09:53--11:53	
9/22/90	Stack	3B	1	HCl	12:22--13:22	
9/22/90	Stack	3C	1	HCl	13:35--14:35	
9/22/90	Stack	3A	1	Spore	09:43--11:43	
9/22/90	Stack	3B	1	Spore	11:43--13:43	
9/23/90	Stack	4	2	Toxic Metals	11:40--15:47	13:40--13:47
9/23/90	Stack	4	2	CDD/CDF	11:40--15:47	13:40--13:47
9/23/90	Stack	4A	2	HCl	11:42--12:42	
9/23/90	Stack	4B	2	HCl	12:52--13:52	
9/23/90	Stack	4C	2	HCl	14:03--15:03	
9/23/90	Stack	4A	2	Spore	11:38--13:40	
9/23/90	Stack	4B	2	Spore	13:40--15:40	
9/24/90	Stack	5	3	Toxic Metals	11:45--15:52	13:45--13:52
9/24/90	Stack	5	3	CDD/CDF	11:45--15:52	13:45--13:52
9/24/90	Stack	5A	3	HCl	11:54--12:54	
9/24/90	Stack	5B	3	HCl	13:17--14:17	
9/24/90	Stack	5C	3	HCl	14:29--15:29	
9/24/90	Stack	5A	3	Spore	11:44--13:44	
9/24/90	Stack	5B	3	Spore	13:44--15:44	

[a] Condition 1: 100 percent pathological wastes (100 lb/hr, 15 min. cycle, 1800--1900°F)

Condition 2: Pathological/red bag waste mix (250 lb/hr, 15 min. cycle, 1600°F)

Condition 3: 100 percent pathological wastes (160 lb/hr, 15 min. cycle, 1600°F)

TABLE 2-1. EMISSIONS TEST LOG (continued); CENTRAL CAROLINA HOSPITAL (1990)

DATE	LOCATION	RUN NUMBER	OPERATING CONDITION [a]	TEST TYPE	RUN TIME	PORT CHANGES
9/25/90	Stack	6	3	Toxic Metals	10:10--14:15	12:10--12:15
9/25/90	Stack	6	3	CDD/CDF	10:10--14:15	12:10--12:15
9/25/90	Stack	6A	3	HCl	10:22--11:22	
9/25/90	Stack	6B	3	HCl	11:33--12:33	
9/25/90	Stack	6C	3	HCl	12:41--13:41	
9/25/90	Stack	6A	3	Spore	10:08--12:08	
9/25/90	Stack	6B	3	Spore	12:08--14:08	
9/26/90	Stack	7 [b]	1	Toxic Metals	10:00--14:06	12:00--12:06
9/26/90	Stack	7 [b]	1	CDD/CDF	10:00--14:06	12:00--12:06
9/26/90	Stack	7A [b]	1	HCl	10:06--11:06	
9/26/90	Stack	7B [b]	1	HCl	11:17--12:17	
9/26/90	Stack	7C [b]	1	HCl	12:27--13:27	
9/26/90	Stack	7A [b]	1	Spore	09:58--11:58	
9/26/90	Stack	7B [b]	1	Spore	11:58--13:58	
9/27/90	Stack	8	2	Toxic Metals	13:45--17:50	15:45--15:50
9/27/90	Stack	8	2	CDD/CDF	13:45--17:50	15:45--15:50
9/27/90	Stack	8A	2	HCl	13:51--14:51	
9/27/90	Stack	8B	2	HCl	15:01--16:01	
9/27/90	Stack	8C	2	HCl	16:12--17:12	
9/27/90	Stack	8A	2	Spore	13:43--15:44	
9/27/90	Stack	8B	2	Spore	15:44--17:56	
9/28/90	Stack	9	3	Toxic Metals	11:00--15:05	13:00--13:05
9/28/90	Stack	9	3	CDD/CDF	11:00--15:05	13:00--13:05
9/28/90	Stack	9A	3	HCl	11:11--12:11	
9/28/90	Stack	9B	3	HCl	12:22--13:22	
9/28/90	Stack	9C	3	HCl	13:32--14:32	
9/28/90	Stack	9A	3	Spore	10:58--12:58	
9/28/90	Stack	9B	3	Spore	12:58--14:58	
10/02/9	Stack	10	1	Toxic Metals	10:15--14:21	12:15--12:21
10/02/9	Stack	10	1	CDD/CDF	10:15--14:21	12:15--12:21
10/02/9	Stack	10A	1	HCl	10:26--11:26	
10/02/9	Stack	10B	1	HCl	11:38--12:38	
10/02/9	Stack	10C	1	HCl	12:47--13:47	
10/02/9	Stack	10A	1	Spore	10:13--12:13	
10/02/9	Stack	10B	1	Spore	12:13--14:13	

[a] Condition 1: 100 percent pathological wastes (100 lb/hr, 15 min. cycle, 1800--1900°F)
Condition 2: Pathological/red bag waste mix (250 lb/hr, 15 min. cycle, 1600°F)
Condition 3: 100 percent pathological wastes (160 lb/hr, 15 min. cycle, 1600°F)

[b] Run 7 data were invalidated due to an incomplete data set (CDD/CDF sampling probe broke during run)

TABLE 2-2. AVERAGE CDD/CDF STACK GAS CONCENTRATIONS FOR EACH TEST CONDITION; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CONCENTRATION [a] (ng/dscm, as measured)		
	CONDITION 1	CONDITION 2	CONDITION 3
DIOXINS			
2378 TCDD	0.26	11.7	0.38
Other TCDD	22.5	242	23.9
12378 PCDD	0.85	47.01	0.94
Other PCDD	19.1	311	18.2
123478 HxCDD	0.80	45.5	0.58
123678 HxCDD	1.35	53.4	0.89
123789 HxCDD	2.49	98.6	1.58
Other HxCDD	16.6	410	10.8
1234678-HpCDD	8.27	249	4.75
Other HpCDD	9.89	270	5.51
Octa-CDD	10.4	259	6.21
Total CDD	92.5	2,000	73.8
FURANS			
2378 TCDF	1.43	32.2	1.75
Other TCDF	73.6	934	67.2
12378 PCDF	2.14	149	2.03
23478 PCDF	5.27	184	3.28
Other PCDF	58.7	2367	38.1
123478 HxCDF	8.44	474	4.26
123678 HxCDF	3.74	294	2.21
234678 HxCDF	7.33	233	3.03
123789 HxCDF	0.24	18.4	0.15
Other HxCDF	25.0	1614	13.5
1234678-HpCDF	13.4	681	6.71
1234789-HpCDF	2.23	86.9	0.94
Other HpCDF	12.0	500	5.15
Octa-CDF	14.6	285	5.82
Total CDF	228	7,850	154
Total CDD+CDF	321	9,850	228

[a] dscm = dry standard cubic meter. Standard conditions are defined as 1 atm and 68°F.

TABLE 2-3. CDD/CDF STACK GAS CONCENTRATIONS ADJUSTED TO 7% OXYGEN FOR EACH TEST CONDITION; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CONCENTRATION (ng/dscm, adjusted to 7 percent O2)		
	CONDITION 1	CONDITION 2	CONDITION 3
DIOXINS			
2378 TCDD	0.72	29.35	0.97
Other TCDD	64.6	613	60.3
12378 PCDD	2.41	118	2.37
Other PCDD	54.6	782	46.0
123478 HxCDD	2.27	115	1.46
123678 HxCDD	3.83	135	2.25
123789 HxCDD	7.07	248	4.01
Other HxCDD	47.4	1034	27.4
1234678-HpCDD	23.3	631	12.1
Other HpCDD	27.9	683	14.0
Octa-CDD	29.4	661	15.8
Total CDD	264	5,050	187
FURANS			
2378 TCDF	4.06	80.1	4.40
Other TCDF	210	2324	169
12378 PCDF	6.06	373	5.13
23478 PCDF	14.9	461	8.29
Other PCDF	167	5906	96.0
123478 HxCDF	24.0	1189	10.8
123678 HxCDF	10.6	736	5.61
234678 HxCDF	20.9	585	7.70
123789 HxCDF	0.67	46.1	0.38
Other HxCDF	71.0	4045	34.2
1234678-HpCDF	38.2	1716	17.1
1234789-HpCDF	6.32	219	2.41
Other HpCDF	34.2	1262	13.1
Octa-CDF	41.5	728	14.9
Total CDF	650	19,700	389
Total CDD+CDF	914	24,700	576

a dscm = dry standard cubic meter. Standard conditions are defined as 1 atm and 68°F.

TABLE 2-4. AVERAGE CDD/CDF STACK GAS EMISSIONS FOR EACH TEST CONDITION; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	EMISSIONS (ug/hr) CONDITION 1	CONDITION 2	CONDITION 3
DIOXINS			
2378 TCDD	0.41	18.6	0.64
Other TCDD	36.7	387	39.7
12378 PCDD	1.38	75.6	1.56
Other PCDD	31.1	499	30.3
123478 HxCDD	1.30	73.3	0.96
123678 HxCDD	2.20	85.9	1.48
123789 HxCDD	4.05	159	2.63
Other HxCDD	27.1	658	18.0
1234678-HpCDD	13.4	402	7.90
Other HpCDD	16.1	435	9.18
Octa-CDD	16.9	416	10.3
Total CDD	151	3,210	123
FURANS			
2378 TCDF	2.32	51.2	2.91
Other TCDF	120	1481	112
12378 PCDF	3.48	240	3.38
23478 PCDF	8.56	296	5.45
Other PCDF	95.5	3,799	63.44
123478 HxCDF	13.7	764	7.09
123678 HxCDF	6.08	473	3.69
234678 HxCDF	11.9	374	5.05
123789 HxCDF	0.39	29.6	0.25
Other HxCDF	40.6	2,598	22.5
1234678-HpCDF	21.8	1,097	11.2
1234789-HpCDF	3.63	140	1.57
Other HpCDF	19.6	805	8.57
Octa-CDF	23.8	457	9.71
Total CDF	371	12,600	256
Total CDD+CDF	522	15,800	379

TABLE 2-5. AVERAGE CDD/CDF 2378 TOXIC EQUIVELENT STACK GAS CONCENTRATIONS ADJUSTED TO 7 PERCENT O2 FOR EACH TEST CONDITION; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	2378-TCDD a TOXIC EQUIV. FACTOR	2378 TOXIC EQUIVALENCIES (ng/dscm, @ 7 percent O2) b CONDITION 1	CONDITION 2	CONDITION 3
DIOXINS				
2378 TCDD	1.000	0.719	29.348	0.967
Other TCDD	0.000	0.000	0.000	0.000
12378 PCDD	0.500	1.203	59.161	1.183
Other PCDD	0.000	0.000	0.000	0.000
123478 HxCDD	0.100	0.227	11.505	0.146
123678 HxCDD	0.100	0.383	13.457	0.225
123789 HxCDD	0.100	0.707	24.807	0.401
Other HxCDD	0.000	0.000	0.000	0.000
1234678-HpCDD	0.010	0.233	6.310	0.121
Other HpCDD	0.000	0.000	0.000	0.000
Octa-CDD	0.001	0.029	0.661	0.016
Total CDD		3.50	145	3.06
FURANS				
2378 TCDF	0.100	0.406	8.014	0.440
Other TCDF	0.000	0.000	0.000	0.000
12378 PCDF	0.050	0.303	18.642	0.257
23478 PCDF	0.500	7.471	230.514	4.143
Other PCDF	0.000	0.000	0.000	0.000
123478 HxCDF	0.100	2.405	118.859	1.081
123678 HxCDF	0.100	1.063	73.562	0.561
234678 HxCDF	0.100	2.089	58.528	0.770
123789 HxCDF	0.100	0.067	4.612	0.038
Other HxCDF	0.000	0.000	0.000	0.000
1234678-HpCDF	0.010	0.382	17.155	0.171
1234789-HpCDF	0.010	0.063	2.195	0.024
Other HpCDF	0.000	0.000	0.000	0.000
Octa-CDF	0.001	0.041	0.728	0.015
Total CDF		14.3	533	7.50
Total CDD+CDF		17.8	678	10.6

a 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.

b ng/dscm = nanogram per dry standard cubic meter. Standard conditions defined as 1 atm. and 68aF.

TABLE 2-6. CDD/CDF STACK GAS CONCENTRATIONS AND EMISSIONS RATES AT CONDITION 1; CENTRAL CAROLINA HOSPITAL (1990)

	CONCENTRATION a (ng/dscm, as measured)				EMISSIONS (ug/hr)			
CONGENER	RUN 1	RUN 3	RUN 10	AVERAGE	RUN 1	RUN 3	RUN 10	AVERAGE
DIOXINS								
2378 TCDD	0.22	(0.419)	(0.130)	0.26	0.34	(0.688)	(0.208)	0.41
Other TCDD	6.17	54.5	6.77	22.5	9.73	89.5	10.8	36.7
12378 PCDD	0.52	1.61	0.42	0.85	0.82	2.64	0.68	1.38
Other PCDD	5.45	44.9	6.84	19.1	8.61	73.7	11.0	31.1
123478 HxCDD	0.34	1.57	0.49	0.80	0.53	2.58	0.79	1.30
123678 HxCDD	0.52	2.55	0.99	1.35	0.82	4.19	1.58	2.20
123789 HxCDD	1.10	4.89	1.48	2.49	1.74	8.03	2.37	4.05
Other HxCDD	5.12	35.4	9.45	16.6	8.07	58.1	15.1	27.1
1234678-HpCDD	2.93	14.6	7.30	8.27	4.63	23.9	11.7	13.4
Other HpCDD	3.52	17.9	8.21	9.89	5.56	29.4	13.2	16.1
Octa-CDD	3.45	18.7	9.13	10.4	5.45	30.6	14.6	16.9
Total CDD	29.3	197	51.2	92.5	46.3	323	82.1	151
FURANS								
2378 TCDF	0.72	2.73	0.85	1.43	1.14	4.47	1.36	2.32
Other TCDF	24.7	165	30.9	73.6	38.9	271	49.5	120
12378 PCDF	1.10	3.95	1.37	2.14	1.74	6.48	2.20	3.48
23478 PCDF	2.11	10.4	3.31	5.27	3.32	17.0	5.31	8.56
Other PCDF	23.5	125	27.4	58.7	37.1	205	44.0	95.5
123478 HxCDF	2.59	18.2	4.55	8.44	4.08	29.8	7.29	13.7
123678 HxCDF	1.35	7.55	2.33	3.74	2.12	12.39	3.73	6.08
234678 HxCDF	1.66	15.65	4.69	7.33	2.61	25.7	7.51	11.9
123789 HxCDF	0.06	0.45	0.20	0.24	0.10	0.75	0.32	0.39
Other HxCDF	7.98	51.5	15.4	25.0	12.6	84.5	24.7	40.6
1234678-HpCDF	3.31	28.4	8.49	13.4	5.23	46.6	13.6	21.8
1234789-HpCDF	0.41	4.40	1.87	2.23	0.65	7.23	2.99	3.63
Other HpCDF	2.38	24.8	8.81	12.0	3.76	40.8	14.1	19.6
Octa-CDF	2.00	29.0	12.9	14.6	3.16	47.6	20.6	23.8
TOTAL CDF	73.9	407	123	228	117	800	197	371
TOTAL CDD+CDF	103	604	174	321	163	1,120	279	522

a ng/dscm = nanogram per dry standard cubic meter. Standard conditions are defined as 1 atm and 68° F.
( ) = estimated maximum possible concentration. [ ] = minimum detection limit

TABLE 2-7. CDD/CDF STACK GAS CONCENTRATIONS AND EMISSIONS RATES AT CONDITION 2; CENTRAL CAROLINA HOSPITAL (1990)

	CONCENTRATION [a] (ng/dscm, as measured)				EMISSIONS (ug/hr)			
CONGENER	RUN 2	RUN 4	RUN 8	AVERAGE	RUN 2	RUN 4	RUN 8	AVERAGE
DIOXINS								
2378 TCDD	7.27	19.2	8.54	11.7	10.8	30.9	14.2	18.6
Other TCDD	171	341	215	242	254	549	357	387
12378 PCDD	22.6	75.1	43.4	47.0	33.6	121	72.0	75.6
Other PCDD	150	503	280	311	223	810	465	499
123478 HxCDD	21.5	64.6	50.5	45.5	32.0	104	83.8	73.3
123678 HxCDD	25.4	82.3	52.5	53.4	37.8	133	87.2	85.9
123789 HxCDD	45.1	156.4	94.2	98.6	67.3	252	156	159
Other HxCDD	209	614	406	410	312	990	674	658
1234678--HpCDD	120	335	292	249	180	540	485	402
Other HpCDD	126	365	318	270	188	589	528	435
Octa--CDD	156	254	366	259	233	409	608	416
Total CDD	1,050	2,810	2,130	2,000	1,570	4,530	3,530	3,210
FURANS								
2378 TCDF	22.1	70.8	3.86	32.2	32.9	114	6.41	51.2
Other TCDF	659	1991	151	934	982	3210	250	1481
12378 PCDF	63.5	288	96.5	149	94.6	465	160	240
23478 PCDF	88.3	341	123	184	132	550	205	296
Other PCDF	1015	4596	1491	2367	1512	7409	2476	3799
123478 HxCDF	189	831	403	474	282	1339	670	764
123678 HxCDF	114	524	244	294	169	844	406	473
234678 HxCDF	111	372	214	233	166	600	356	374
123789 HxCDF	7.88	32.5	14.8	18.4	11.7	52.5	24.6	29.6
Other HxCDF	649	2809.6	1382.9	1613.8	967	4529	2297	2598
1234678--HpCDF	301	1058	684	681	449	1706	1137	1097
1234789--HpCDF	45.5	128	87.4	86.9	67.8	206	145	140
Other HpCDF	242	743	516	500	361	1197	856	805
Octa--CDF	210	324	322	285	313	523	535	457
TOTAL CDF	3,720	14,100	5,730	7,850	5,540	22,700	9,520	12,600
TOTAL CDD+CDF	4,770	16,900	7,860	9,850	7,110	27,300	13,100	15,800

[a] ng/dscm = nanogram per dry standard cubic meter. Standard conditions are defined as 1 atm and 68° F.

( ) = estimated maximum possible concentration

TABLE 2-8. CDD/CDF STACK GAS CONCENTRATIONS AND EMISSIONS RATES AT CONDITION 3; CENTRAL CAROLINA HOSPITAL (1990)

	CONCENTRATION a (ng/dscm, as measured)				EMISSIONS (ng/hr)			
CONGENER	RUN 5	RUN 6	RUN 9	AVERAGE	RUN 5	RUN 6	RUN 9	AVERAGE
DIOXINS								
2378 TCDD	0.25	(0.074)	0.83	0.38	0.41	(0.125)	1.37	0.64
Other TCDD	19.7	3.77	48.1	23.9	32.6	6.38	80.0	39.7
12378 PCDD	0.66	0.23	1.92	0.94	1.09	0.39	3.19	1.56
Other PCDD	12.4	3.87	38.4	18.2	20.5	6.56	63.9	30.3
123478 HxCDD	0.42	0.19	1.12	0.58	0.69	0.32	1.87	0.96
123678 HxCDD	0.63	0.32	1.72	0.89	1.04	0.55	2.86	1.48
123789 HxCDD	1.29	0.61	2.84	1.58	2.13	1.03	4.73	2.63
Other HxCDD	8.25	3.93	20.3	10.8	13.6	6.65	33.8	18.0
1234678-HpCDD	4.31	2.12	7.80	4.75	7.14	3.59	13.0	7.90
Other HpCDD	4.66	2.49	9.39	5.51	7.71	4.22	15.6	9.18
Octa-CDD	5.98	2.56	10.1	6.21	9.90	4.33	16.8	10.3
Total CDD	58.6	20.2	143	73.8	96.9	34.1	237	123
FURANS								
2378 TCDF	1.18	0.29	3.77	1.75	1.96	0.49	6.27	2.91
Other TCDF	44.7	9.77	147	67.2	74.0	16.6	245	112
12378 PCDF	1.43	0.54	4.13	2.03	2.36	0.91	6.87	3.38
23478 PCDF	2.44	0.94	6.45	3.28	4.03	1.60	10.72	5.45
Other PCDF	22.1	8.31	84.0	38.1	36.6	14.1	140	63.4
123478 HxCDF	3.17	1.62	8.00	4.26	5.24	2.74	13.3	7.09
123678 HxCDF	1.64	0.81	4.20	2.21	2.71	1.37	6.98	3.69
234678 HxCDF	2.26	1.28	5.56	3.03	3.74	2.17	9.24	5.05
123789 HxCDF	0.11	0.06	0.27	0.15	0.19	0.10	0.45	0.25
Other HxCDF	9.28	4.62	26.6	13.5	15.4	7.82	44.3	22.5
1234678-HpCDF	6.19	2.86	11.08	6.71	10.2	4.84	18.4	11.2
1234789-HpCDF	0.80	0.57	1.46	0.94	1.32	0.97	2.42	1.57
Other HpCDF	4.63	2.32	8.50	5.15	7.66	3.93	14.1	8.57
Octa-CDF	4.18	4.51	8.76	5.82	6.91	7.64	14.6	9.71
TOTAL CDF	104	38.5	320	154	172	65.2	532	256
TOTAL CDD+CDF	163	58.7	462	228	269	99.3	769	379

a ng/dscm = nanogram per dry standard cubic meter. Standard conditions are defined as 1 atm and 68° F.

() = estimated maximum possible concentration

TABLE 2-9. CDD/CDF STACK GAS CONCENTRATIONS AND 2378 TOXIC EQUIVALENT STACK GAS CONCENTRATIONS ADJUSTED TO 7 PERCENT O2 FOR CONDITION 1; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV. FACTOR	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 1	RUN 3	RUN 10	AVERAGE		RUN 1	RUN 3	RUN 10	AVERAGE
DIOXINS									
2378 TCDD	0.59	(1.221)	(0.349)	0.72	1.000	0.588	(1.221)	(0.349)	0.719
Other TCDD	16.7	159	18.2	64.6	0.000	0.000	0.000	0.000	0.000
12378 PCDD	1.40	4.68	1.14	2.41	0.500	0.700	2.342	0.568	1.203
Other PCDD	14.7	131	18.3	54.6	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.91	4.58	1.32	2.27	0.100	0.091	0.458	0.132	0.227
123678 HxCDD	1.40	7.43	2.65	3.83	0.100	0.140	0.743	0.265	0.383
123789 HxCDD	2.99	14.3	3.97	7.07	0.100	0.299	1.425	0.397	0.707
Other HxCDD	13.8	103	25.3	47.4	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	7.93	42.5	19.6	23.3	0.010	0.079	0.425	0.196	0.233
Other HpCDD	9.52	52.2	22.0	27.9	0.000	0.000	0.000	0.000	0.000
Octa-CDD	9.33	54.4	24.5	29.4	0.001	0.009	0.054	0.024	0.029
Total CDD	79.3	574	137	264		1.91	6.67	1.93	3.50
FURANS									
2378 TCDF	1.96	7.94	2.27	4.06	0.100	0.196	0.794	0.227	0.406
Other TCDF	66.7	482	82.9	210	0.000	0.000	0.000	0.000	0.000
12378 PCDF	2.99	11.51	3.69	6.06	0.050	0.149	0.575	0.184	0.303
23478 PCDF	5.69	30.2	8.89	14.9	0.500	2.847	15.120	4.446	7.471
Other PCDF	63.6	365	73.6	167	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	7.00	52.9	12.2	24.0	0.100	0.700	5.295	1.220	2.405
123678 HxCDF	3.64	21.99	6.24	10.6	0.100	0.364	2.199	0.624	1.063
234678 HxCDF	4.48	45.6	12.6	20.9	0.100	0.448	4.561	1.258	2.089
123789 HxCDF	0.17	1.32	0.53	0.67	0.100	0.017	0.132	0.053	0.067
Other HxCDF	21.6	150	41.4	71.0	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	8.96	82.8	22.8	38.2	0.010	0.090	0.828	0.228	0.382
1234789-HpCDF	1.12	12.8	5.01	6.32	0.010	0.011	0.128	0.050	0.063
Other HpCDF	6.44	72.4	23.6	34.2	0.000	0.000	0.000	0.000	0.000
Octa-CDF	5.41	84.5	34.5	41.5	0.001	0.005	0.085	0.035	0.041
Total CDF	200	1,420	330	650		4.83	29.7	8.32	14.3
Total CDD+CDF	279	1,990	468	914		6.73	36.4	10.3	17.8

a ng/dscm = nanogram per dry standard cubic meter. Standard conditions are defined as 1 atm and 68° F.

b 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.

[ ] = minimum detection limit. ( ) = estimated maximum possible concentration.

TABLE 2-10. CDD/CDF STACK GAS CONCENTRATIONS AND 2378 TOXIC EQUIVALENT STACK GAS CONCENTRATIONS ADJUSTED TO 7 PERCENT O2 FOR CONDITION 2; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CONCENTRATION [a] (ng/dscm, adjusted to 7 percent O2)				2378-TCDD [b] TOXIC EQUIV. FACTOR	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 2	RUN 4	RUN 8	AVERAGE		RUN 2	RUN 4	RUN 8	AVERAGE
DIOXINS									
2378 TCDD	19.4	46.4	22.2	29.3	1.000	19.385	46.438	22.221	29.348
Other TCDD	455	825	560	613	1.000	0.000	0.000	0.000	0.000
12378 PCDD	60.2	182	113	118	0.500	30.097	90.952	56.434	59.161
Other PCDD	399	1,217	728	782	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	57.2	157	131	115	0.100	5.724	15.654	13.138	11.505
123678 HxCDD	67.6	199	137	135	0.100	6.764	19.940	13.667	13.457
123789 HxCDD	120	379	245	248	0.100	12.039	37.868	24.513	24.807
Other HxCDD	558	1,487	1,056	1,034	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	321	812	760	631	0.010	3.214	8.116	7.601	6.310
Other HpCDD	337	885	827	683	0.000	0.000	0.000	0.000	0.000
Octa-CDD	417	614	952	661	0.001	0.417	0.614	0.952	0.661
Total CDD	2,810	6,800	5,530	5,050		77.6	220	139	145
FURANS									
2378 TCDF	59.0	171	10.1	80.1	0.100	5.897	17.141	1.005	8.014
Other TCDF	1,757	4,822	392	2,324	0.000	0.000	0.000	0.000	0.000
12378 PCDF	169	698	251	373	0.050	8.468	34.894	12.565	18.642
23478 PCDF	236	826	321	461	0.500	117.839	413.220	160.483	230.514
Other PCDF	2,707	11,130	3,881	5,906	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	505	2,011	1,049	1,189	0.100	50.502	201.144	104.931	118.859
123678 HxCDF	303	1,268	636	736	0.100	30.301	126.808	63.576	73.562
234678 HxCDF	297	901	558	585	0.100	29.689	90.078	55.816	58.528
123789 HxCDF	21.0	78.8	38.5	46.1	0.100	2.102	7.880	3.853	4.612
Other HxCDF	1,731	6,804	3,600	4,045	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	803	2,562	1,781	1,716	0.010	8.029	25.624	17.812	17.155
1234789-HpCDF	121	310	227	219	0.010	1.214	3.096	2.275	2.195
Other HpCDF	647	1,798	1,342	1,262	0.000	0.000	0.000	0.000	0.000
Octa-CDF	560	785	838	728	0.001	0.560	0.785	0.838	0.728
Total CDF	9,920-	34,200	14,900	19,700		255	921	423	533
Total CDD+CDF	12,700	41,000	20,500	24,700		332	1140	562	678

[a] ng/dscm = nanogram per dry standard cubic meter. Standard conditions are defined as 1 atm and 68° F.

[b] 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.

[ ] = minimum detection limit. ( ) = estimated maximum possible concentration.

TABLE 2-11. CDD/CDF STACK GAS CONCENTRATIONS AND 2378 TOXIC EQUIVALENT STACK GAS CONCENTRATIONS ADJUSTED TO 7 PERCENT O2 FOR CONDITION 3; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV. FACTOR	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 5	RUN 6	RUN 9	AVERAGE		RUN 5	RUN 6	RUN 9	AVERAGE
DIOXINS									
2378 TCDD	0.66	(0.198)	2.04	0.97	1.000	0.657	(0.198)	2.045	0.967
Other TCDD	51.7	10.1	119	60.3	0.000	0.000	0.000	0.000	0.000
12378 PCDD	1.73	0.62	4.74	2.37	0.500	0.867	0.310	2.372	1.183
Other PCDD	32.5	10.4	95.0	46.0	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	1.10	0.51	2.78	1.46	0.100	0.110	0.051	0.278	0.146
123678 HxCDD	1.64	0.86	4.25	2.25	0.100	0.164	0.086	0.425	0.225
123789 HxCDD	3.38	1.62	7.03	4.01	0.100	0.338	0.162	0.703	0.401
Other HxCDD	21.6	10.5	50.2	27.4	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	11.3	5.67	19.3	12.1	0.010	0.113	0.057	0.193	0.121
Other HpCDD	12.2	6.66	23.2	14.0	0.000	0.000	0.000	0.000	0.000
Octa-CDD	15.7	6.84	24.9	15.8	0.001	0.016	0.007	0.025	0.016
Total CDD	154	54	353	187		2.26	0.87	6.04	3.06
FURANS									
2378 TCDF	3.10	0.77	9.32	4.40	0.100	0.310	0.077	0.932	0.440
Other TCDF	117	26.1	364	169	0.000	0.000	0.000	0.000	0.000
12378 PCDF	3.74	1.44	10.2	5.13	0.050	0.187	0.072	0.511	0.257
23478 PCDF	6.39	2.52	15.9	8.29	0.500	3.194	1.260	7.974	4.143
Other PCDF	57.9	22.2	207.7	96.0	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	8.30	4.32	19.8	10.8	0.100	0.830	0.432	1.979	1.081
123678 HxCDF	4.29	2.16	10.4	5.61	0.100	0.429	0.216	1.039	0.561
234678 HxCDF	5.93	3.42	13.7	7.70	0.100	0.593	0.342	1.374	0.770
123789 HxCDF	0.30	0.16	0.67	0.38	0.100	0.030	0.016	0.067	0.038
Other HxCDF	24.3	12.3	65.8	34.2	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	16.2	7.65	27.4	17.1	0.010	0.162	0.076	0.274	0.171
1234789-HpCDF	2.10	1.53	3.60	2.41	0.010	0.021	0.015	0.036	0.024
Other HpCDF	12.1	6.21	21.0	13.1	0.000	0.000	0.000	0.000	0.000
Octa-CDF	11.0	12.1	21.7	14.9	0.001	0.011	0.012	0.022	0.015
Total CDF	273	103	791	389		5.77	2.52	14.2	7.50
Total CDD+CDF	427	157	1,140	576		8.03	3.39	20.3	10.6

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b 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.

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TABLE 2-12. CDD/CDF EMISSIONS SAMPLING AND FLUE GAS PARAMETERS; CENTRAL CAROLINA HOSPITAL (1990)

	Test Condition 1			
Run No.	1	3	10	Average
Date	9/20/90	9/22/90	10/02/90	
Total Sampling Time (min.)	240	240	240	NA
Average Stack Temperature (°F)	753	734	697	728
Carbon Dioxide Concentration (%V)	3.14	3.07	3.37	3.19
Oxygen Concentration (%V)	15.8	16.1	15.7	15.9
Average Sampling Rate (dscfm)	0.426	0.421	0.417	0.422
Standard Metered Volume, Vm (dscm)	2.897	2.862	2.837	2.87
Stack Moisture (%V)	9.42	9.24	7.61	8.76
Volumetric Flow Rate (acfm)	2359	2431	2311	2367.28
Volumetric Flow Rate (dscfm)	929	966	943	946.07
Volumetric Flow Rate (dscmm)	26.3	27.4	26.7	26.8
Percent Isokinetic	101	95.7	97.2	NA
	Test Condition 2			
Run No.	2	4	8	Average
Date	9/21/90	9/23/90	9/27/90	
Total Sampling Time (min.)	240	240	240	NA
Average Stack Temperature (°F)	813	773	750	779
Carbon Dioxide Concentration (%V)	3.76	4.01	3.86	3.88
Oxygen Concentration (%V)	15.7	15.2	15.6	15.5
Average Sampling Rate (dscfm)	0.385	0.407	0.434	0.409
Standard Metered Volume, Vm (dscm)	2.61	2.77	2.95	2.78
Stack Moisture (%V)	7.60	6.93	6.71	7.08
Volumetric Flow Rate (acfm)	2293	2405	2404	2367
Volumetric Flow Rate (dscfm)	877	949	978	934
Volumetric Flow Rate (dscmm)	24.8	26.9	27.7	26.5
Percent Isokinetic	96.3	94.3	97.6	NA
	Test Condition 3			
Run No.	5	6	9	Average
Date	9/24/90	9/25/90	9/28/90	
Total Sampling Time (min.)	240	240	240	NA
Average Stack Temperature (F)	748	727	735	736
Carbon Dioxide Concentration (%V)	3.46	3.4	3.67	3.51
Oxygen Concentration (%V)	15.6	15.7	15.3	15.5
Average Sampling Rate (dscfm)	0.423	0.437	0.445	0.435
Standard Metered Volume, Vm (dscm)	2.87	2.97	3.02	2.96
Stack Moisture (%V)	7.60	8.08	8.83	8.17
Volumetric Flow Rate (acfm)	2415	2424	2432	2424
Volumetric Flow Rate (dscfm)	974	997	979	983
Volumetric Flow Rate (dscmm)	27.6	28.2	27.7	27.8
Percent Isokinetic	95.4	96.9	99.9	NA

NA = Not Applicable

substituted CDD/CDF isomers. Results are presented for each isomer as well as for each tetra octa homologue total (Total CDD, Total CDF). All CDD/CDF results have been formatted to three significant figures.

Average CDD/CDF stack gas concentrations for each test condition are presented in Table 2-2. Stack gas concentrations of all target CDD/CDF congeners were detected during each test condition throughout the program. However, flue gas concentrations from Condition 2 (250 lbs/hr-medical waste) were substantially higher than for either of the other conditions. The average 2378 TCDD concentration for Condition 2 was 11.7 ng/dscm compared to 0.26 and 0.38 for Conditions 1 and 3, respectively. The Total CDD/CDF concentrations for Condition 2 was 9,850 ng/dscm compared to 321 and 228 ng/dscm for Conditions 1 and 3, respectively.

Average oxygen concentrations for the 3 conditions varied by only 0.9 percent by volume (see Section 2.7). Therefore, relative corrected flue gas concentrations for each condition are proportionately similar to the uncorrected values. Corrected 2378 TCDD flue gas concentrations for Conditions 1, 2, and 3 were 0.72, 29.35, and 0.97 ng/dscm at 7 percent 0_2, respectively. Total CDD/CDF corrected concentrations for the above conditions were 914, 24,700, and 576 ng/dscm at 7 percent O_2, respectively.

Average CDD/CDF emission rates for each condition are shown in Table 2-4. Average emissions of 2378 TCDD for Conditions 1, 2, and 3 were 0.41, 18.6, and 0.64 ug/hr, respectively. Average Total CDD/CDF emissions for Conditions 1, 2, and 3 were 522, 15,800, and 379 μg/hr, respectively.

Table 2-5 presents average corrected CDD/CDF gas concentrations in 2378 Toxic Equivalents. The concentration of each congener corrected to 7 percent 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)).were developed by EPA.(1) The average 2378 Toxic Equivalent Concentrations for Total CDD/CDF for Conditions 1, 2, and 3 were 17.8, 678, and 10.6 ng/dscm at 7 percent O_2, respectively.

Table 2-6 gives both the CDD/CDF stack gas concentrations and emission rates for each test run in Condition 1. Tables 2-7 and 2-8 give similar information for Conditions 2 and 3, respectively. Non-detected results are presented in brackets (i.e., [1.023]) and other values classified as estimated maximum possible concentration (EMPC) are presented in parenthesis. The EMPCs represent analytical results which have a signal to noise ratio above 2.5:1, but do not meet all of the qualitative identification criteria. These values are included in all averages and summations. Non-detected values are considered to be zero in calculating averages and summations. Condition 1 was made up of Runs 1, 3, and 10, whereas Conditions 2 and 3 were made up of Runs 2, 4, and 8 and Runs 5, 6, and 9, respectively.

Table 2-9 presents both the CDD/CDF stack gas concentration corrected to 7 percent O_2 and the 2378 Toxic Equivalent Concentrations for each run in Condition 1. Tables 2-10 and 2-11 give similar information for Conditions 2 and 3, respectively.

The CDD/CDF sampling and flue gas parameters for each run are shown in Table 2-12. Information on sample rates, sample gas volumes, O_2/CO_2 concentrations, moisture content, stack gas flow, and other parameters are given.

2.2.3 CDD/CDF Ash Results

Incinerator ash was completely removed from the incinerator every morning following a test day. 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. Three daily ash samples from each run from a given condition were composite into a single ash sample per Condition.

Ash samples were analyzed for the same CDD/CDF isomers that the flue gas samples were analyzed for. Average ash CDD/CDF concentrations for each condition are presented in Table 2-13.

Average ash CDD/CDF concentrations are given in units of parts-per-billion by weight (ppb.wt). Ash 2378 TCDD Toxic Equivalencies are also presented. As was the case with CDD/CDF flue gas emissions, ash from Condition 2 had the highest concentration of congeners. The 2378 TCDD concentration for Conditions 1, 2, and 3

TABLE 2-13. CDD/CDF AVERAGE ASH RESULTS FOR EACH CONDITION; CENTRAL CAROLINA HOSPITAL HOSPITAL (1990)

CONGENER	COND 1 ASH (ppb.wt)	COND 2 ASH (ppb.wt)	COND 3 ASH (ppb.wt)	2378-TCDD [b] TOXIC EQUIV. FACTOR	COND 1 TEF (ppb.wt)	COND 2 TEF (ppb.wt)	COND 3 TEF (ppb.wt)
DIOXINS							
2378 TCDD	0.030	0.120	(0.010)	1.00000	0.030	0.120	(0.0100)
Other TCDD	1.070	13.080	0.350	0.00000	0.000	0.000	0.000
12378 PCDD	0.110	0.630	0.030	0.50000	0.055	0.315	0.015
Other PCDD	1.190	18.970	0.550	0.00000	0.000	0.000	0.000
123478 HxCDD	0.120	0.810	0.040	0.10000	0.012	0.081	0.004
123678 HxCDD	0.110	1.400	0.050	0.10000	0.011	0.140	0.005
123789 HxCDD	0.350	2.500	0.100	0.10000	0.035	0.250	0.010
Other HxCDD	1.120	26.090	0.490	0.00000	0.000	0.000	0.000
1234678--HpCDD	0.620	10.800	0.270	0.01000	0.006	0.108	0.003
Other HpCDD	0.780	14.900	0.380	0.00000	0.000	0.000	0.000
Octa--CDD	0.830	12.500	0.360	0.00100	0.001	0.013	0.000
Total CDD	6.330	101.800	2.630		0.150	1.027	0.067
FURANS							
2378 TCDF	7.100	9.900	1.700	0.10000	0.710	0.990	0.170
Other TCDF	22.700	32.900	4.100	0.00000	0.000	0.000	0.000
12378 PCDF	0.830	1.400	0.160	0.05000	0.042	0.070	0.008
23478 PCDF	2.500	4.000	0.650	0.50000	1.250	2.000	0.325
Other PCDF	24.570	37.800	5.890	0.00000	0.000	0.000	0.000
123478 HxCDF	6.000	10.300	1.700	0.10000	0.600	1.030	0.170
123678 HxCDF	1.200	3.200	0.360	0.10000	0.120	0.320	0.036
234678 HxCDF	3.300	7.500	1.200	0.10000	0.330	0.750	0.120
123789 HxCDF	0.030	(0.180)	0.010	0.10000	0.003	(0.0180)	0.001
Other HxCDF	8.570	19.800	2.430	0.00000	0.000	0.000	0.000
1234678--HpCDF	6.000	15.600	2.100	0.01000	0.060	0.156	0.021
1234789--HpCDF	0.210	1.300	0.090	0.01000	0.002	0.013	0.001
Other HpCDF	2.590	8.400	1.010	0.00000	0.000	0.000	0.000
Octa--CDF	1.300	8.000	0.550	0.00100	0.001	0.008	0.001
Total CDF	86.9	160	22.0		3.118	5.355	0.852
Total CDD+CDF	93.2	262	24.6		3.268	6.382	0.900

a [ ] = minimum detection limit

( ) = estimated maximum possible concentration.

b 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.

were 0.03, 0.12 and 0.010 ppb, respectively. Total CDD/CDF concentrations for the three conditions were 93.2, 262, and 24.6 ppb, respectively. The total CDD/CDF TEF concentrations for the three conditions were 3.27, 6.38, and 0.90 ppb wt., respectively.

2.3 TOXIC METALS RESULTS

2.3.1 Data Reduction Overview

A single sampling train was used to determine emission rates of a series of 11 metals (Sb, As, Ba, Be, Cd, Cr, Pb, Hg, Ni, Ag, and Tl) and PM. Three sampling runs were performed under each of the three test conditions in order to assure representative test results. Sampling locations, methods, and QA/QC are discussed in Sections 4, 5, and 6, respectively. The average metals concentrations and emission rates for each test condition are summarized in Table 2-14. The results for each individual run are presented in Tables 2-15 through 2-17. Concentrations at dry, standard conditions, and concentrations adjusted to 7 percent O_2 are shown.

The values reported in Tables 2-14 through 2-17 include the 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.

TABLE 2-14. AVERAGE METALS STACK GAS CONCENTRATIONS AND EMISSION RATES AT EACH CONDITION; CENTRAL CAROLINA HOSPITAL (1990)

TEST CONDITION		1[a]	2	3
RUN NUMBERS		1,3,10	2,4,8	5,6,9
Antimony	(ug/dscm)	51.9	237	22.8
	(ug/dscm @7% O2)	142	612	59.0
	(g/hr)	0.078	0.368	0.037
Arsenic	(ug/dscm)	16.1	4.29	33.5
	(ug/dscm @7% O2)	43.9	11.1	83.3
	(g/hr)	0.026	0.007	0.056
Barium	(ug/dscm)	8.43	33.5	11.5
	(ug/dscm @7% O2)	23.9	86.2	29.7
	(g/hr)	0.013	0.052	0.019
Beryllium	(ug/dscm)	[0.080]	0.442	[0.075]
	(ug/dscm @7% O2)	[0.222]	1.11	[0.196]
	(g/hr)	[0.0001]	0.001	[0.0001]
Cadmium	(ug/dscm)	89.5	21.3	7.91
	(ug/dscm @7% O2)	260	55.0	20.5
	(g/hr)	0.130	0.033	0.013
Chromium	(ug/dscm)	8.74	14.1	71.61
	(ug/dscm @7% O2)	25.0	36.3	190
	(g/hr)	0.013	0.022	0.112
Lead	(ug/dscm)	234	726	119
	(ug/dscm @7% O2)	663	1878	307
	(g/hr)	0.356	1.12	0.197
Mercury	(ug/dscm)	22.5	3.08	69.6
	(ug/dscm @7% O2)	60.3	7.96	182
	(g/hr)	0.034	0.005	0.115
Nickel	(ug/dscm)	10.0	10.0	112
	(ug/dscm @7% O2)	29.2	25.8	298
	(g/hr)	0.014	0.016	0.177
Silver	(ug/dscm)	[1.312]	5.516	[1.230]
	(ug/dscm @7% O2)	[3.634]	14.233	[3.189]
	(g/hr)	[0.002]	0.008	[0.002]
Thallium	(ug/dscm)	2.34	[2.116]	[2.005]
	(ug/dscm @7% O2)	6.34	[5.428]	[5.196]
	(g/hr)	0.004	[0.003]	[0.003]

[a] Condition 1 averages do not include Run 10, front half, and therefore are biased low.

NOTE: Values enclosed in brackets represent the minimum detection limits for compounds not detected in the samples. Detection limits are only presented if the compound was not detected in any of the three test runs.

TABLE 2-15. METALS STACK GAS CONCENTRATIONS AND EMISSION RATES FOR CONDITION 1; CENTRAL CAROLINA HOSPITAL (1990)

DATE		09/20/90	09/22/90	10/02/90	
TIME		14:00–18:18	09:47–14:00	10:15–14:21	
RUN NUMBER		RUN 1	RUN 3	RUN 10	
O2 CONCENTRATION (%V)		15.8	16.1	15.7	
FLOW RATE (dscmm)		27.1	24.1	25.0	AVERAGE
Antimony	(ug/dscm)	20.8	32.3	103	51.9
	(ug/dscm @7% O2)	56.3	94.1	275	142
	(g/hr)	0.034	0.047	0.154	0.078
Arsenic	(ug/dscm)	43.7	4.20	0.48	16.1
	(ug/dscm @7% O2)	118	12.2	1.30	43.9
	(g/hr)	0.071	0.006	0.001	0.026
Barium	(ug/dscm)	8.82	16.2	0.275	8.43
	(ug/dscm @7% O2)	23.9	47.2	0.737	23.9
	(g/hr)	0.014	0.023	0.000	0.013
Beryllium	(ug/dscm)	[0.076]	[0.084]	[0.080]	[0.080]
	(ug/dscm @7% O2)	[0.206]	[0.245]	[0.215]	[0.222]
	(g/hr)	[0.0001]	[0.0001]	[0.0001]	[0.0001]
Cadmium	(ug/dscm)	5.94	173	[0.197]	89.5
	(ug/dscm @7% O2)	16.1	504	[0.529]	260
	(g/hr)	0.010	0.250	[0.000]	0.130
Chromium	(ug/dscm)	5.87	19.84	0.509	8.74
	(ug/dscm @7% O2)	15.9	57.8	1.37	25.0
	(g/hr)	0.010	0.029	0.001	0.013
Lead	(ug/dscm)	189	279	[0.116]	234
	(ug/dscm @7% O2)	512	814	[0.311]	663
	(g/hr)	0.308	0.404	[0.000]	0.356
Mercury	(ug/dscm)	1.60	[0.316]	43.3	22.5
	(ug/dscm @7% O2)	4.32	[0.921]	116	60.3
	(g/hr)	0.003	[0.000]	0.065	0.034
Nickel	(ug/dscm)	[0.763]	10.0	[0.801]	10.0
	(ug/dscm @7% O2)	[2.063]	29.2	[2.149]	29.2
	(g/hr)	[0.001]	0.014	[0.001]	0.014
Silver	(ug/dscm)	[1.249]	[1.376]	[1.310]	[1.312]
	(ug/dscm @7% O2)	[3.378]	[4.010]	[3.515]	[3.634]
	(g/hr)	[0.002]	[0.002]	[0.002]	[0.002]
Thallium	(ug/dscm)	2.34	[2.254]	[2.111]	2.34
	(ug/dscm @7% O2)	6.34	[6.568]	[5.665]	6.34
	(g/hr)	0.004	[0.003]	[0.003]	0.004

Note: Run 10 Values do not include the front half catch and therefore are biased low

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

TABLE 2-16. METALS STACK GAS CONCENTRATIONS AND EMISSION RATES FOR CONDITION 2; CENTRAL CAROLINA HOSPITAL (1990)

DATE		09/21/90	09/23/90	09/27/90	
TIME		09:46--13:57	11:40--15:47	13:45--17:50	
RUN NUMBER		2	4	8	
O2 CONCENTRATION (%V)		15.69	15.16	15.56	
FLOW RATE (dscmm)		24.45	26.26	27.04	AVERAGE
Antimony	(ug/dscm)	265	164	282	237
	(ug/dscm @7% O2)	706	398	733	612
	(g/hr)	0.388	0.259	0.457	0.368
Arsenic	(ug/dscm)	6.40	3.81	2.65	4.29
	(ug/dscm @7% O2)	17.1	9.23	6.90	11.1
	(g/hr)	0.009	0.006	0.004	0.007
Barium	(ug/dscm)	40.3	31.4	28.9	33.5
	(ug/dscm @7% O2)	108	76.1	75.1	86.2
	(g/hr)	0.059	0.049	0.047	0.052
Beryllium	(ug/dscm)	[0.083]	0.446	0.437	0.442
	(ug/dscm @7% O2)	[0.221]	1.08	1.14	1.11
	(g/hr)	[0.0001]	0.001	0.001	0.001
Cadmium	(ug/dscm)	20.8	17.5	25.8	21.3
	(ug/dscm @7% O2)	55.4	42.4	67.1	55.0
	(g/hr)	0.030	0.028	0.042	0.033
Chromium	(ug/dscm)	16.3	12.9	13.1	14.1
	(ug/dscm @7% O2)	43.6	31.2	34.1	36.3
	(g/hr)	0.024	0.020	0.021	0.022
Lead	(ug/dscm)	891	500	786	726
	(ug/dscm @7% O2)	2380	1210	2050	1880
	(g/hr)	1.31	0.787	1.28	1.12
Mercury	(ug/dscm)	4.02	2.14	[0.266]	3.08
	(ug/dscm @7% O2)	10.7	5.19	[0.692]	7.96
	(g/hr)	0.006	0.003	[0.0004]	0.005
Nickel	(ug/dscm)	5.34	5.28	19.4	10.0
	(ug/dscm @7% O2)	14.2	12.8	50.5	25.8
	(g/hr)	0.008	0.008	0.031	0.016
Silver	(ug/dscm)	7.11	3.93	[1.258]	5.52
	(ug/dscm @7% O2)	19.0	9.51	[3.275]	14.2
	(g/hr)	0.010	0.006	[0.002]	0.008
Thallium	(ug/dscm)	[2.180]	[2.106]	[2.062]	[2.116]
	(ug/dscm @7% O2)	[5.816]	[5.100]	[5.367]	[5.428]
	(g/hr)	[0.003]	[0.003]	[0.003]	[0.003]

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.

TABLE 2-17. METALS STACK GAS CONCENTRATIONS AND EMISSION RATES FOR CONDITION 3;
CENTRAL CAROLINA HOSPITAL (1990)

DATE		09/24/90	09/25/90	09/28/90	
TIME		11:45--15:52	10:10--14:15	11:00--15:05	
RUN NUMBER		5	6	9	
O2 CONCENTRATION (%V)		15.60	15.70	15.28	
FLOW RATE (dscmm)		27.49	25.90	28.21	AVERAGE
Antimony	(ug/dscm)	22.0	21.0	25.6	22.8
	(ug/dscm @7% O2)	57.6	56.1	63.3	59.0
	(g/hr)	0.036	0.033	0.043	0.037
Arsenic	(ug/dscm)	3.78	4.90	91.7	33.5
	(ug/dscm @7% O2)	9.92	13.1	227	83.3
	(g/hr)	0.006	0.008	0.155	0.056
Barium	(ug/dscm)	9.00	13.5	11.9	11.5
	(ug/dscm @7% O2)	23.6	36.0	29.4	29.7
	(g/hr)	0.015	0.021	0.020	0.019
Beryllium	(ug/dscm)	[0.075]	[0.078]	[0.073]	[0.075]
	(ug/dscm @7% O2)	[0.197]	[0.209]	[0.181]	[0.196]
	(g/hr)	[0.0001]	[0.0001]	[0.0001]	[0.0001]
Cadmium	(ug/dscm)	5.11	9.72	8.91	7.91
	(ug/dscm @7% O2)	13.4	26.0	22.0	20.5
	(g/hr)	0.008	0.015	0.015	0.013
Chromium	(ug/dscm)	14.1	189	11.5	71.6
	(ug/dscm @7% O2)	37.1	506	28.4	190
	(g/hr)	0.023	0.294	0.019	0.112
Lead	(ug/dscm)	125	75.6	157	119
	(ug/dscm @7% O2)	329	202	389	307
	(g/hr)	0.207	0.117	0.266	0.197
Mercury	(ug/dscm)	69.6	[0.273]	[0.215]	69.6
	(ug/dscm @7% O2)	182	[0.730]	[0.532]	182
	(g/hr)	0.115	[0.0004]	[0.0004]	0.115
Nickel	(ug/dscm)	12.2	292	33.3	112
	(ug/dscm @7% O2)	32.0	780	82.4	298
	(g/hr)	0.020	0.454	0.056	0.177
Silver	(ug/dscm)	[1.226]	[1.277]	[1.188]	[1.230]
	(ug/dscm @7% O2)	[3.215]	[3.414]	[2.938]	[3.189]
	(g/hr)	[0.002]	[0.002]	[0.002]	[0.002]
Thallium	(ug/dscm)	[2.010]	[2.057]	[1.947]	[2.005]
	(ug/dscm @7% O2)	[5.272]	[5.499]	[4.816]	[5.196]
	(g/hr)	[0.003]	[0.003]	[0.003]	[0.003]

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.

- If the metal was not detected in any of the three runs, then the average results was reported as not detected at the average detection limit.

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 sample. These results will be reported in Section 2.3.3.

2.3.2 Metals Emission Results

Table 2-14 presents the metals emission parameters averaged for each condition. Concentrations at standard conditions, concentrations corrected to 7 percent O_2, and emission rates are shown. No condition consistently had higher emission rates of all metals. Average emissions of antimony, barium, beryllium, lead, and silver were highest for Condition 2. Emissions of cadmium and thallium were highest during Condition 1 and emissions of arsenic, chromium, mercury, and nickel were highest during Condition 3. Lead had the highest emission rates of all metals under each condition at 0.356, 1.12, and 0.197 g/hr for Conditions 1, 2, and 3, respectively. Beryllium, silver, and thallium were not detected in two out of the three test conditions.

Table 2-15 presents the metals emission results for Condition 1 (100 lb/hr pathological waste, 15 minute cycle, 1800-1900°F secondary setpoint). The results for Run 10 do not include the front half catch (probe rinses, filter). The results for this run should therefore be considered suspect low. Lead had the highest emission rates during Runs 1 and 3 at 0.308 and 0.404 g/hr, respectively. Arsenic emissions during run 1 were substantially higher than those from run 3 with values of 0.071 and 0.006 g/hr, respectively.

The metals emission results for Condition 2 (250 lb/hr-medical waste, 15 minute cycle) are presented in Table 2-16. Lead showed the highest metals flue gas concentrations of 891, 500, and 786 μg/dscm (1.31, 0.787, and 1.28 g/hr) for Runs 2, 4, and 8, respectively.

Table 2-17 presents the metals emission results for Condition 3 (160 lb/hr pathological waste, 15 minute cycle). Emission rates of nickel during Run 6 at 0.454 g/hr were higher than any other metals. Arsenic emissions during Run 9 at 0.155 g/hr were substantially higher than for Runs 5 and 6 (0.006 and 0.008 g/hr), respectively.

A summary of the ratio by weight of metals to PM is presented in Table 2-18. Metals to PM ratios are given in units of milligrams of metal to grams of PM collected by the sampling train. The range of values were 0.001 mg beryllium per gram of PM during run 4 to 8.092 mg lead per gram of PM during Run 3.

Table 2-19 presents a summary of the amounts of metals collected in each of the sample fractions from each run. The front half fraction includes the acetone probe/filter holder rinse, nitric acid (HNO_3) probe/filter holder rinse, and the filter itself. The back half fraction included the HNO_3/hydrogen peroxide (H_2O_2) impinger contents (Impingers 1 and 2), and the third fraction consisted of the potassium permanganate ($KMnO_4$) impinger contents analyzed only for mercury. Except for thallium (Run 1), silver (Runs 2 and 4) and mercury, (Run 5), the higher proportion of most metals was collected in the front half fractions. The above metals had higher catches in the Impingers 1 and 2 fractions. Laboratory analytical results for each sample fraction are presented in detail in Appendix E.2.

Sampling and flue gas parameters for the metals and PM runs are shown in Table 2-20. Total sampling times, sample volumes, and isokinetic results for each sampling run are presented. 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.

2.3.3 <u>Metals In Ash</u>

A sample of the incinerator bottom ash was collected after each sampling run (the following day) to determine metals concentrations in the ash. The metals of interest were the same as those sampled for in the flue gas. Concentrations of the metals in the ash 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.

TABLE 2-18. RATIO OF METALS TO PARTICULATE MATTER; CENTRAL CAROLINA HOSPITAL (1990)

	METALS/PARTICULATE RATIO (mg metal per gram of particulate)											
TEST CONDITION	CONDITION 1				CONDITION 2				CONDITION 3			
RUN NUMBER	1	3	10	AVERAGE	2	4	8	AVERAGE	5	6	9	AVERAGE
Antimony	0.592	0.936	2.896	1.475	1.709	0.187	1.320	1.072	0.657	0.401	0.579	0.546
Arsenic	1.244	0.122	0.014	0.460	0.041	0.004	0.012	0.019	0.113	0.093	2.075	0.761
Barium	0.251	0.469	0.008	0.243	0.260	0.036	0.135	0.144	0.269	0.257	0.269	0.265
Beryllium	ND	ND	ND	ND	ND	0.001	0.002	0.001	ND	ND	ND	ND
Cadmium	0.169	5.013	ND	2.591	0.134	0.020	0.121	0.092	0.153	0.186	0.202	0.180
Chromium	0.167	0.575	0.014	0.252	0.105	0.015	0.061	0.061	0.423	3.612	0.260	1.432
Lead	5.392	8.092	ND	6.742	5.755	0.568	3.686	3.336	3.749	1.442	3.561	2.918
Mercury	0.046	0.000	1.222	0.422	0.026	0.002	ND	0.014	2.082	ND	ND	2.082
Nickel	ND	0.290	ND	0.290	0.034	0.006	0.091	0.044	0.365	5.573	0.754	2.231
Silver	ND	ND	ND	ND	0.046	0.004	ND	0.025	ND	ND	ND	ND
Thallium	0.067	ND	ND	0.067	ND	ND	ND	ND	ND	ND	ND	ND

ND = Metal not detected in the flue gas.

TABLE 2-19. METALS AMOUNTS IN FLUE GAS SAMPLES BY SAMPLE FRACTION; CENTRAL CAROLINA HOSPITAL (1990)

CONDITION 1									
	RUN 1			RUN 3			RUN 10		
METAL	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]
Antimony	60	[6.900]		76.5	8.05		NC	282	
Arsenic	126	[0.430]		11.0	[0.440]		NC	1.33	
Barium	25.0	0.433		41.8	0.544		NC	0.755	
Beryllium	[0.500]	[0.220]		[0.500]	[0.220]		NC	[0.220]	
Cadmium	16.2	0.92		452	0.871		NC	[0.540]	
Chromium	14.6	2.33		48.0	3.92		NC	1.4	
Lead	546	[3.200]		731	[3.300]		NC	[0.320]	
Mercury	[2.400]	[6.500]	4.61	[2.400]	[6.000]	[0.826]	NC	119	[0.550]
Nickel	[5.000]	[2.200]		26.2	[2.200]		NC	[2.200]	
Silver	[8.200]	[3.600]		[8.200]	[3.600]		NC	[3.600]	
Thallium	[14.00]	6.76		[14.00]	[5.900]		NC	[5.800]	

CONDITION 2									
	RUN 2			RUN 4			RUN 8		
METAL	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]
Antimony	655	49.0		412	47.8		748	58.0	
Arsenic	15.8	1.23		8.93	1.75		6.80	0.780	
Barium	106.0	1.19		85.8	2.18		80.2	2.39	
Beryllium	[0.500]	[0.220]		1.25	[0.220]		1.25	[0.220]	
Cadmium	55.2	[0.540]		49.0	[0.540]		73.8	[0.540]	
Chromium	40.0	3.45		27.0	9.05		32.8	4.68	
Lead	2370	[3.200]		1400	[3.300]		2250	[3.300]	
Mercury	[2.400]	[6.700]	10.7	6.00	[5.900]	[0.670]	[2.400]	[6.100]	[0.760]
Nickel	14.2	[2.200]		14.8	[2.200]		55.5	[2.200]	
Silver	[8.200]	18.9		[8.200]	11.0		[8.200]	[3.600]	
Thallium	[14.00]	[5.800]		[14.00]	[5.900]		[14.00]	[5.900]	

CONDITION 3									
	RUN 5			RUN 6			RUN 9		
METAL	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]	FRONT HALF	IMPINGERS 1,2	IMPINGER 3,4 [b]
Antimony	64.5	[7.000]		59.2	[6.900]		77.5	[7.000]	
Arsenic	11.1	[0.440]		13.8	[0.430]		278	[0.440]	
Barium	26.0	0.435		33.2	4.76		34.8	1.20	
Beryllium	[0.500]	[0.220]		[0.500]	[0.220]		[0.500]	[0.220]	
Cadmium	15.0	[0.540]		26.0	1.41		27.0	[0.540]	
Chromium	41.5	[1.100]		532.0	1.41		33.5	1.30	
Lead	368	[3.300]		213	[3.200]		477	[3.300]	
Mercury	4.80	113	86.5	[2.400]	[6.400]	[0.770]	[2.400]	[6.100]	[0.650]
Nickel	35.8	[2.200]		823	[2.200]		101	[2.200]	
Silver	[8.200]	[3.600]		[8.200]	[3.600]		[8.200]	[3.600]	
Thallium	[14.00]	[5.900]		[14.00]	[5.800]		[14.00]	[5.900]	

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

b Impingers 3 & 4 analyzed for mercury content only.

NC = Analysis not completed at this time.

TABLE 2-20. METALS AND PM EMISSIONS SAMPLING AND FLUE GAS PARAMETERS CENTRAL CAROLINA HOSPITAL (1990)

	TEST CONDITION 1			
RUN NUMBER	1	3	10	AVERAGE
DATE	09/20/90	09/22/90	10/02/90	
Total Sampling Time (min.)	240	240	240	NA
Average Sampling Rate (dscfm)	0.42	0.39	0.40	0.40
Metered Volume (dscf)	101.81	92.41	97.02	97.08
Metered Volume (dscm)	2.883	2.617	2.748	2.749
Average Stack Temperature (°F)	751.5	759.0	749.4	753.3
O2 Concentration (%V)	15.8	16.1	15.7	15.9
CO2 Concentration (%V)	3.1	3.1	3.4	3.2
Stack Gas Moisture (%V)	9.4	9.9	8.1	9.1
Volumetric Flow Rate (dscfm)	956.00	850.54	882.08	896.21
Volumetric Flow Rate (dscmm)	27.07	24.09	24.98	25.38
Percent Isokinetic	97.0	98.9	100	NA
	TEST CONDITION 2			
RUN NUMBER	2	4	8	AVERAGE
DATE	09/21/90	09/23/90	09/27/90	
Total Sampling Time (min.)	240	240	240	NA
Average Sampling Rate (dscfm)	0.39	0.41	0.42	0.41
Metered Volume (dscf)	93.92	98.89	101.01	97.94
Metered Volume (dscm)	2.660	2.801	2.861	2.774
Average Stack Temperature (°F)	809.4	778.9	766.3	784.9
O2 Concentration (%V)	15.7	15.2	15.6	15.5
CO2 Concentration (%V)	3.76	4.0	3.9	3.9
Stack Gas Moisture (%V)	8.4	7.8	6.8	7.7
Volumetric Flow Rate (dscfm)	863.34	927.14	954.69	915.05
Volumetric Flow Rate (dscmm)	24.45	26.26	27.04	25.91
Percent Isokinetic	99.1	97.1	96.3	NA
	TEST CONDITION 3			
RUN NUMBER	5	6	9	AVERAGE
DATE	09/24/90	09/25/90	09/28/90	
Total Sampling Time (min.)	240	240	240	NA
Average Sampling Rate (dscfm)	0.43	0.42	0.45	0.43
Metered Volume (dscf)	103.67	99.55	106.98	103.40
Metered Volume (dscm)	2.936	2.819	3.030	2.928
Average Stack Temperature (°F)	746.4	724.6	770.9	747.3
O2 Concentration (%V)	15.6	15.7	15.3	15.5
CO2 Concentration (%V)	3.5	3.4	3.7	3.5
Stack Gas Moisture (%V)	8.3	8.6	9.0	8.6
Volumetric Flow Rate (dscfm)	970.52	914.65	996.12	960.43
Volumetric Flow Rate (dscmm)	27.49	25.90	28.21	27.20
Percent Isokinetic	97.3	99.1	97.8	NA

NA = Not Applicable

The metals in ash results are shown in Table 2-21 for each test condition. Barium was the most prevalent metal found in the ash from all test conditions at 2,630, 7,260, and 245 mg/kg for Conditions 1, 2, and 3, respectively. All metals except silver were detected in at least 1 of the samples. Analytical results of the ash analyses are contained in Appendix E.2.

2.4 PARTICULATE MATTER/VISIBLE EMISSIONS

2.4.1 Particulate Matter Results

Particulate matter emissions were determined from the same sampling train used for metals analysis. Before metals analysis, PM collected on the filter and in the front half acetone rinse (probe, nozzle, filter holder) was analyzed gravimetrically. The PM stack gas concentrations and emission rates for each sampling run, as well as averages for each test condition are presented in Table 2-22. Uncorrected concentrations and concentrations adjusted to 7 percent O_2 are shown. Test Condition 2 had the highest concentrations and emission rates (0.182 gr/dscf and 1.439 lb/hr) while Test Condition 1 had the lowest (0.015 gr/dscf and 0.118 lb/hr). A brief summary of the sampling and flue gas parameters for the PM runs is given in Table 2-20 and Appendix C.2 presents a detailed listing of the parameters for each sampling run. The results of the gravimetric analyses are presented in Appendix E.2.

2.4.2 Visible Emissions

The opacity of emissions from the stack were determined visually by a qualified observer following EPA Method 9 protocol. Observations were recorded during the full duration of each PM/metals sampling run.

Opacity observations were recorded at 15 second intervals to the nearest 5 percent. Opacity for each run was determined by grouping the 15-second field observations into set of 24 (6 minutes) consecutive observations and then calculating the average percent opacity of each set. An average percent opacity for each run was also calculated as well as a test condition average. A summary of the observations is presented in Table 2-23. Test Conditions 1 and 3 both had an average percent opacity of 0 and Test Condition 2 had an average percent opacity of 13.

TABLE 2-21. METALS IN ASH CONCENTRATIONS; CENTRAL CAROLINA HOSPITAL (1990)

Test Condition	1	2	3
Run No.'s	1,3,10 (mg/kg)	2,4,8 (mg/kg)	5,6,9 (mg/kg)
Antimony	9.60	19.2	[6.4]
Arsenic	11.7	45.5	[4.0]
Barium	2630	7260	245
Beryllium	1.60	4.10	1.00
Cadmium	3.30	1.20	[0.50]
Chromium	30.4	26.7	8.30
Lead	78.4	232	[15.7]
Mercury	[0.039]	0.0450	[0.039]
Nickel	7.20	15.1	[2.0]
Silver	[3.3]	[3.3]	[3.3]
Thallium	72.7	1820	410

a Values enclosed in brackets represent minimum detection limits for elements not dectected in the samples.

TABLE 2-22. PARTICULATE MATTER CONCENTRATIONS AND EMISSIONS RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

DATE	SAMPLING CONDITION	RUN NUMBER	TIME	FLUE GAS CONCENTRATION				FLUE GAS EMISSION RATE	
				(grains/dscf)	(grains/dscf @7% O2)	(grams/dscm)	(grams/dscm @7% O2)	(lb/hr)	(kg/hr)
09/20/90	1	1	14:00-18:18	0.015	0.042	0.035	0.095	0.126	0.057
09/22/90	1	3	09:47-14:00	0.015	0.044	0.035	0.101	0.110	0.050
10/02/90	1	10	10:15-14:21	0.015	0.042	0.035	0.095	0.117	0.053
			AVERAGES:	0.015	0.043	0.035	0.097	0.118	0.053
09/21/90	2	2	09:46-13:57	0.068	0.181	0.155	0.413	0.501	0.227
09/23/90	2	4	11:40-15:47	0.384	0.931	0.879	2.129	3.054	1.385
09/27/90	2	8	13:45-17:50	0.093	0.243	0.213	0.555	0.763	0.346
			AVERAGES:	0.182	0.451	0.416	1.033	1.439	0.653
09/24/90	3	5	11:45-15:52	0.015	0.038	0.033	0.088	0.122	0.055
09/25/90	3	6	10:10-14:15	0.023	0.061	0.052	0.140	0.179	0.081
09/28/90	3	9	11:00-15:05	0.019	0.048	0.044	0.109	0.165	0.075
			AVERAGES:	0.019	0.049	0.043	0.112	0.155	0.070

TABLE 2-23. PERCENT OPACITY OBSERVATIONS SUMMARY; CENTRAL CAROLINA HOSPITAL (1990)

	TEST CONDITION 1		
RUN NUMBER	**1**	**3**	**10**
DATE	**09/20/90**	**09/22/90**	**10/02/90**
TIME	**14:00-18:18**	**09:47-14:00**	**10:15-14:21**
Range of Individual Observations (% opacity) (a)	0-5	0-5	0-10
Range of Set Averages (% opacity) (b)	0	0-1	0-1
Run Average (% opacity) (c)	0	0	0
Test Conditions Average (% opacity)		0	

	TEST CONDITION 2		
RUN NUMBER	**2**	**4**	**8**
DATE	**09/21/90**	**09/23/90**	**09/27/90**
TIME	**09:46-13:57**	**11:40-15:47**	**13:45-17:50**
Range of Individual Observations (% opacity)	0-100	0-100	0-80
Range of Set Averages (% opacity)	0-23	0-71	0-21
Run Average (% opacity)	5	28	6
Test Conditions Average (% opacity)		13	

	TEST CONDITION 3		
RUN NUMBER	**5**	**6**	**9**
DATE	**09/24/90**	**09/25/90**	**09/28/90**
TIME	**11:45-15:52**	**10:10-14:15**	**11:00-15:05**
Range of Individual Observations (% opacity)	0-25	0-25	0-25
Range of Set Averages (% opacity)	0-1	0-3	0-2
Run Average (% opacity)	0	0	0
Test Conditions Average (% opacity)		0	

a Individual observations recorded at 15 second intervals, to the nearest five percent

b A set is composed of 24 consecutive individual observations.

c The run average is calculated by averaging the set averages in a run, or averaging all the individual observations.

2.5 HALOGEN GAS EMISSIONS

Hydrogen chloride (HCl), HF, and HBr, incinerator stack gas concentrations were manually sampled following EPA Method 26 procedures. In this method, flue gas was extracted from the stack and passed through acidified water. The HCl solubilizes and forms chloride (Cl^-) ions in acidified water. Ion chromatography was used to detect the Cl^-, bromide (Br^-), and fluoride (F^-) ions present in the sample. Three test runs were performed at each of the three operating conditions described previously.

2.5.1 Halogen Gas Emissions Results

Table 2-24 presents a summary of the average HCl, HF, and HBr test results with concentrations reported on a ppmV and ppmV corrected to 7 percent O_2 basis. Conditions 1 and 3 had similar average HCl concentrations at 45.1 and 43.7 ppmV, respectively. The Condition 2 average was 593 ppmV HCl. When compared to the HCl gas concentrations, substantially lower amounts of HF and HBr were found. Average HF concentrations for Conditions 1, 2, and 3 were 2.15, 9.96, and 1.28 ppmV, respectively. Average HBr concentrations were 0.20, 0.55, and 0.16 ppmV for the above conditions, respectively.

Table 2-25 presents the HCl results for each run performed under each condition. Three "sub-runs" were conducted during each day's overall test interval (i.e, 1A, 1B, and 1C). Concentrations as well as emission rates are presented. Emission rates used an average of the stack gas flows determined from the PM/Metals and CDD/CDF sampling trains. The HCl concentrations ranged from 19.4 ppmV for Run 1A to 943 ppmV for Run 8C. The corresponding HCl emission rates were 47.1 and 2,347 g/hr, respectively.

Table 2-26 presents the HF emissions results for all test runs. Certain values in this table are enclosed in parenthesis, denoting them as "maximum estimated concentration." These numbers were flagged by the analytical laboratory as estimates because they were less than five times the detection limit. These values are included in all averages. Run 2B had a concentration substantially higher than the rest of the runs at 23.7 ppmV, respectively. The range of concentrations for the other runs was 0.755 to 10.7 ppmV for Runs 1A and 8A, respectively. Emissions rates ranged from 1.006 to 29.1 g/hr.

TABLE 2-24. SUMMARY OF HALOGEN ACID TESTING RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

TEST RUN NUMBER	HCl CONCENTRATION		HF CONCENTRATION		HBr CONCENTRATION	
	(ppmv)	(ppmv @7% O2)	(ppmv)	(ppmv @7% O2)	(ppmv)	(ppmv @7% O2)
AVERAGE 1	32.1	84.1	(1.17)	(3.07)	0.21	0.54
AVERAGE 3	65.3	186	3.11	8.96	0.21	0.60
AVERAGE 10	38.1	99.0	2.16	5.64	0.19	0.49
AVERAGE COND 1	**45.1**	**123**	**1.76**	**4.87**	**0.20**	**0.54**
AVERAGE 2	487	1,277	16.2	46.6	0.47	1.15
AVERAGE 4	647	1,583	5.75	13.44	0.47	1.09
AVERAGE 8	644	1,753	7.95	20.06	0.71	1.88
AVERAGE COND 2	**593**	**1,537**	**9.96**	**26.7**	**0.55**	**1.37**
AVERAGE 5	37.6	100	(1.431)	(3.771)	[0.032]	[0.084]
AVERAGE 6	31.1	81.2	(0.942)	(2.46)	(0.158)	(0.412)
AVERAGE 9	62.3	153	(1.456)	(3.58)	0.17	0.42
AVERAGE COND 3	**43.7**	**111**	**0.00**	**0.00**	**0.16**	**0.42**

[ ] = Minimum Detection Limit

TABLE 2-25. SUMMARY OF HCl RESULTS FOR EACH CONDITION; CENTRAL CAROLINA HOSPITAL (1990)

TEST RUN NUMBER	MEASURED CONCENTRATIONS (mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	EMISSION RATE (g/hr)
RUN 1A	29.4	79.3	19.4	52.3	47.1
RUN 1B	54.1	135	35.7	88.9	86.6
RUN 1C	62.3	169	41.1	111	99.8
AVERAGE	48.6	128	32.1	84.1	77.8
RUN 2A	802	1,764	529	1,164	1,186
RUN 2B	674	2,109	444	1,391	996
RUN 2C	NA	NA	NA	NA	NA
AVERAGE	738	1,936	487	1,277	1,091
RUN 3A	101	278	66.8	184	156
RUN 3B	96.7	285	63.8	188	149
RUN 3C	NA	NA	NA	NA	NA
AVERAGE	99.0	282	65.3	186	153
RUN 4A	327	715	216	471	521
RUN 4B	1,276	3,068	841	2,024	2,033
RUN 4C	1,342	3,415	885	2,253	2,138
AVERAGE	981	2,399	647	1,583	1,564
RUN 5A	49.7	131	32.8	86.4	82.0
RUN 5B	48.1	117	31.7	77.1	79.4
RUN 5C	73.1	206	48.2	136	121
AVERAGE	57.0	151	37.6	100	94.1
RUN 6A	47.8	125	31.5	82.2	77.6
RUN 6B	43.3	111	28.6	73.1	70.3
RUN 6C	50.5	134	33.3	88.2	82.0
AVERAGE	47.2	123	31.1	81.2	76.6
RUN 8A	630	1,334	416	880	1,035
RUN 8B	868	2,436	572	1,607	1,424
RUN 8C	1,430	4,201	943	2,771	2,347
AVERAGE	976	2,657	644	1,753	1,602
RUN 9A	120	283	79.1	187	201
RUN 9B	60.0	141	39.6	93.0	101
RUN 9C	104	271	68.4	179	174
AVERAGE	94.5	232	62.3	153	159
RUN 10A	97.0	252	64.0	166	150
RUN 10B	40.0	97.9	26.4	64.6	62.0
RUN 10C	36.1	100.5	23.8	66.3	56.0
AVERAGE	57.7	150.1	38.1	99.0	89.5

NA = Not Applicable (Runs not completed)

TABLE 2-26. SUMMARY OF HF RESULTS FOR EACH CONDITION; CENTRAL CAROLINA HOSPITAL (1990)

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE (g/hr)
	(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	
RUN 1A	(0.628)	(1.695)	(0.755)	(2.038)	(1.006)
RUN 1B	(1.075)	(2.678)	(1.292)	(3.218)	(1.721)
RUN 1C	(1.216)	(3.288)	(1.462)	(3.954)	(1.947)
AVERAGE	**0.97**	**2.55**	**1.17**	**3.07**	**1.56**
RUN 2A	7.23	15.9	8.69	19.1	10.7
RUN 2B	19.7	61.7	23.7	74.2	29.1
RUN 2C	NA	NA	NA	NA	NA
AVERAGE	**13.5**	**38.8**	**16.2**	**46.6**	**19.9**
RUN 3A	(1.825)	(5.013)	(2.194)	(6.027)	(2.817)
RUN 3B	3.35	9.90	4.03	11.9	5.18
RUN 3C	NA	NA	NA	NA	NA
AVERAGE	**2.59**	**7.45**	**3.11**	**8.96**	**4.00**
RUN 4A	7.17	15.7	8.61	18.8	11.4
RUN 4B	2.98	7.17	3.58	8.62	4.75
RUN 4C	4.21	10.7	5.06	12.9	6.71
AVERAGE	**4.79**	**11.2**	**5.75**	**13.4**	**7.63**
RUN 5A	(0.835)	(2.202)	(1.004)	(2.648)	(1.379)
RUN 5B	(1.296)	(3.149)	(1.558)	(3.786)	(2.141)
RUN 5C	(1.439)	(4.057)	(1.730)	(4.878)	(2.377)
AVERAGE	**1.19**	**3.14**	**1.43**	**3.77**	**1.97**
RUN 6A	(0.734)	(1.914)	(0.882)	(2.300)	(1.192)
RUN 6B	(0.670)	(1.715)	(0.805)	(2.061)	(1.088)
RUN 6C	(0.948)	(2.510)	(1.140)	(3.018)	(1.539)
AVERAGE	**0.78**	**2.05**	**0.94**	**2.46**	**1.27**
RUN 8A	8.89	18.8	10.7	22.6	14.6
RUN 8B	6.96	19.5	8.37	23.5	11.4
RUN 8C	3.99	11.7	4.79	14.1	6.54
AVERAGE	**6.61**	**16.7**	**7.95**	**20.1**	**10.9**
RUN 9A	(0.939)	(2.220)	(1.129)	(2.669)	(1.576)
RUN 9B	(1.279)	(3.008)	(1.538)	(3.617)	(2.146)
RUN 9C	(1.416)	(3.707)	(1.702)	(4.455)	(2.376)
AVERAGE	**1.21**	**2.98**	**1.46**	**3.58**	**2.03**
RUN 10A	3.32	8.63	3.99	10.4	5.15
RUN 10B	(0.955)	(2.337)	(1.148)	(2.809)	(1.481)
RUN 10C	(1.117)	(3.111)	(1.343)	(3.741)	(1.732)
AVERAGE	**1.80**	**4.69**	**2.16**	**5.64**	**2.79**

NA = Not Applicable (runs not completed)

( ) = Maximum estimated concentration

Table 2-27 presents the HBr emission results for all test runs. Hydrogen bromide was detected in the flue gas in 19 out of 25 test runs. Detected concentrations ranged from 0.18 to 0.76 ppmV for Runs 10A and 8C, respectively. Corresponding emission rates were 0.96 to 4.21 g/hr.

2.5.2 HCl CEM-Manual Comparison

Continuous emissions monitoring was performed to measure HCl in addition to other gas concentrations. The average HCl CEM concentrations calculated over the duration of the PM/Metals, CDD/CDF, and Microbial Survivability emissions test runs are presented in Section 2.7. The following paragraphs and Table 2-28 present HCl CEM data averaged over the same time period as each manual halogen "sub-run." A direct comparison can then be made between the CEM HCl data and the manual HCl data.

The results show generally good agreement between the manual and CEM concentrations. The CEM values in 7 out of 18 runs were within 30 percent of the manual values. Eleven out of 18 runs were within 40 percent. Only did Run 10 exhibit deviations greater than 100 percent. Recent state-of-the art HCl CEM sampling and instrument methods were employed during this test program. Especially important hardware developments included the use of a high temperature in-stack probe which allowed for fast, accurate responses to extreme and quick changes in stack gas HCl concentrations.

Additional agreement may have been gained if more post-test HCl calibrations could have been performed. The HCl CEM calibrations needed to be completed at the same stack gas temperature as during the test. However, following several tests, the incinerator went into a burn down mode (decrease in temperature) before final calibrations could be performed. Post-test calibrations may have revealed slight calibration drift which could be incorporated into data drift corrections for more accurate data.

For the purpose of determining the most accurate HCl flue gas concentrations, data generated by the EPA test protocol (EPA Method 26) should be used.

TABLE 2-27. SUMMARY OF HBr RESULTS AT EACH CONDITION; CENTRAL CAROLINA HOSPITAL (1990)

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE (g/hr)
	(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	
RUN 1A	0.69	1.85	0.20	0.55	1.10
RUN 1B	0.73	1.82	0.22	0.54	1.17
RUN 1C	0.66	1.78	0.20	0.53	1.05
AVERAGE	**0.69**	**1.82**	**0.21**	**0.54**	**1.11**
RUN 2A	2.32	5.11	0.69	1.52	3.43
RUN 2B	0.85	2.65	0.25	0.79	1.25
RUN 2C	NA	NA	NA	NA	NA
AVERAGE	**1.58**	**3.88**	**0.47**	**1.15**	**2.34**
RUN 3A	0.66	1.82	0.20	0.54	1.02
RUN 3B	0.74	2.20	0.22	0.65	1.15
RUN 3C	NA	NA	NA	NA	NA
AVERAGE	**0.70**	**2.01**	**0.21**	**0.60**	**1.09**
RUN 4A	1.80	3.93	0.53	1.17	2.86
RUN 4B	2.02	4.85	0.60	1.44	3.22
RUN 4C	0.89	2.26	0.26	0.67	1.41
AVERAGE	**1.57**	**3.68**	**0.47**	**1.09**	**2.50**
RUN 5A	[0.108]	[0.285]	[0.032]	[0.084]	[0.178]
RUN 5B	[0.109]	[0.265]	[0.032]	[0.078]	[0.180]
RUN 5C	[0.108]	[0.305]	[0.032]	[0.090]	[0.178]
AVERAGE	**[0.108]**	**[0.285]**	**[0.032]**	**[0.084]**	**[0.179]**
RUN 6A	(0.530)	(1.382)	(0.158)	(0.412)	(0.861)
RUN 6B	[0.109]	[0.279]	[0.032]	[0.082]	[0.177]
RUN 6C	[0.111]	[0.294]	[0.033]	[0.087]	[0.180]
AVERAGE	**0.53**	**1.38**	**0.16**	**0.41**	**0.86**
RUN 8A	2.10	4.43	0.62	1.32	3.44
RUN 8B	2.48	6.96	0.74	2.07	4.07
RUN 8C	2.57	7.54	0.76	2.24	4.21
AVERAGE	**2.38**	**6.31**	**0.71**	**1.88**	**3.91**
RUN 9A	0.63	1.49	0.19	0.44	1.06
RUN 9B	[0.113]	[0.266]	[0.034]	[0.080]	[0.190]
RUN 9C	(0.521)	(1.364)	(0.155)	(0.406)	(0.874)
AVERAGE	**0.58**	**1.43**	**0.17**	**0.42**	**0.96**
RUN 10A	0.62	1.60	0.18	0.48	0.96
RUN 10B	0.73	1.80	0.22	0.53	1.14
RUN 10C	(0.541)	(1.507)	(0.161)	(0.448)	(0.839)
AVERAGE	**0.63**	**1.64**	**0.19**	**0.49**	**0.98**

NA = Not applicable (runs not completed)

[ ] = Minimum detection limit; ( ) = maximum estimated concentration

TABLE 2-28. COMPARISON OF MANUAL AND CEM HCl RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

TEST RUN NUMBER	MANUAL HCl RESULTS		CEM HCl RESULTS	
	(ppmV/ dry)	(ppmV @7% O2)	(ppmV/ dry)	(ppmV @7% O2) a
RUN 1A	19.4	52.3	NC	NC
RUN 1B	35.7	88.9	NC	NC
RUN 1C	41.1	111	42.7	120
AVERAGE	32.1	84.1	NA	NA
RUN 2A	529	1164	548	1279
RUN 2B	444	1391	397	1253
RUN 2C	NC	NC	NC	NC
AVERAGE	487	1277	473	1266
RUN 3A	66.8	184	93.8	284
RUN 3B	63.8	188	18.6	60.0
RUN 3C	NC	NC	32.7	123
AVERAGE	65.3	186	NA	NA
RUN 4A	216	471	NC	NC
RUN 4B	841	2024	625	1441
RUN 4C	885	2253	659	1633
AVERAGE	647	1583	NA	NA
RUN 5A	32.8	86.4	NC	NC
RUN 5B	31.7	77.1	39.9	89.3
RUN 5C	48.2	136	31.0	81.0
AVERAGE	37.6	99.8	NA	NA
RUN 6A	31.5	82.2	NC	NC
RUN 6B	28.6	73.1	41.5	107
RUN 6C	33.3	88.2	55.2	148
AVERAGE	31.1	81.2	NA	NA
RUN 8A	416	880	NC	NC
RUN 8B	572	1607	351	1006
RUN 8C	943	2771	594	1737
AVERAGE	644	1753	NA	NA
RUN 9A	79.1	187	NC	NC
RUN 9B	39.6	93.0	74.2	179
RUN 9C	68.4	179	65.1	185
AVERAGE	62.3	153	NA	NA
RUN 10A	64.0	166	NC	NC
RUN 10B	26.4	64.6	84.9	225
RUN 10C	23.8	66.3	55.2	181
AVERAGE	38.1	99.0	NA	NA

a Averages of corrected 30 second readings

NC = Run not completed.

NA = Averages not valid for comparisons.

2.6 CEM RESULTS

Three test runs were performed at each of three operating conditions while the incinerator was burning hospital waste. Continuous emissions monitoring was performed using an extractive sample system and instrument methods to measure NO_x, CO, SO_2, THC, and HCl concentrations. The diluent gases (O_2, CO_2) were measured using CEMs at all times so that the emission results could be normalized to a reference 7 percent O_2. Concentrations of NO_x, SO_2, CO, CO_2, and O_2 were measured on a dry basis with the sample stream conditioned as shown in Figure 5-16. Concentrations of HCl using a separate monitor were measured using a dilution probe system and were on a wet basis. The THC concentrations were also monitored on a wet basis, but did not employ the dilution probe system. All CEM data were recorded as 30-second averages over each sampling interval, a copy of which are included in Appendix D.

The 30-second CEM values were averaged over the sampling interval for each test run. Both actual and values corrected to 7 percent O_2 are summarized in Tables 2-29 and 2-30. Actual concentrations are presented as they were measured (NO_x, SO_2, CO, CO_2, and O_2-dry; THC and HCl-wet). All values corrected to 7 percent O_2 are presented on a dry basis. Each 30-second CEM reading was corrected to 7 percent O_2 based on the corresponding O_2 value. Averages of the corrected values were then calculated. For HCl and THC, stack gas moisture determined from the average of the PM/Metals and CDD/CDF sampling trains was used for the corrections. Overall averages are presented for each CEM parameter under each of the three incinerator operating conditions.

Average O_2 concentrations varied by only 0.9 percent by volume during the 9 test runs, ranging from 15.2 to 16.1 percent/dry. The average percent O_2 values for each set of tests was 15.9 (Condition 1), 15.5 (Condition 2), and 15.5 (Condition 3). The CO_2 concentrations varied inversely with the O_2 concentrations at 3.19, 3.88, and 3.51 percent by volume (%V) for Conditions 1 through 3, respectively. The CO_2 run averages ranged from 3.07 to 4.01 percent by volume over the nine test runs.

Average CO concentrations ranged from 14.9 ppmV to 42.1 ppmV under Condition 1, with the overall average concentration at 29.2 ppmV. For the second

TABLE 2-29. CONTINUOUS EMISSIONS MONITORING TEST AVERAGES FOR O2, CO2, C0, and HCl; CENTRAL CAROLINA HOSPITAL (1990)

DATE	RUN NUMBER/ MANUAL TEST TYPE	CONDITION	TEST TIME a	MOISTURE	OXYGEN (%vol.dry)	CO2 (%vol.dry)	CO actual (ppmV,dry)	CO corrected b (ppmV,dry) @7% O2	HCL c actual (ppmV,wet)	HCL c corrected d (ppmV,dry) @7% O2
09/20/90	1	1	14:00 - 18:18	9.39	15.8	3.14	42.1	119	107	305
09/22/90	3	1	9:47 - 14:00	9.57	16.1	3.07	14.9	40.6	33.6	110
10/02/90	10	1	10:15-14:21	7.88	15.7	3.37	30.6	81	64.6	143
	AVERAGE			8.95	15.9	3.19	29.2	80.2	68.4	186
09/21/90	2	2	9:45 - 13:57	7.98	15.7	3.76	132	407	413	1273
09/23/90	4	2	11:43 - 15:47	7.35	15.2	4.01	1187	2780	568	1480
09/27/90	8	2	13:45 - 17:50	6.78	15.6	3.87	181	453	445	1350
	AVERAGE			7.37	15.5	3.88	500	1213	475	1368
09/24/90	5	3	11:45 - 15:52	7.96	15.6	3.46	37.6	104	33.9	90.3
09/25/90	6	3	10:10 - 14:15	8.29	15.7	3.40	65.3	196	45.8	138
09/28/90	9	3	11:00 - 15:05	8.93	15.3	3.67	36.1	107	55.6	164
	AVERAGE			8.39	15.5	3.51	46.3	136	45.1	131

a For metals/CDD/CDF runs.
b Averages are corrected to 7% oxygen (corrected value = actual * (13.9 /(20.9 - O2)). 30 second values were corrected and then averaged.
c HCl concentrations were determined by manual methods as well. A comparison of CEM vs. manual results is presented in Section 2.6.
d Averages are corrected to 7% oxygen and for moisture, where the corrected value = actual * 13.9/(20.9 - O2) * (1/(1 - moist). Thirty second values were corrected and then averaged.

TABLE 2-30. CONTINUOUS EMISSIONS MONITORING TEST AVERAGES FOR O2, SO2, NOx, and THC; CENTRAL CAROLINA HOSPITAL (1990)

DATE	RUN NUMBER	CONDITION	TEST TIME a	MOISTURE (%volume)	OXYGEN (%vol.dry)	SO2 actual (ppmV,dry)	SO2 corrected b (ppmV,dry)	NOX actual mV,d	NOX corrected b (ppmV,dry)	THC actual (ppm C,wet)	THC corrected c (ppm C, dry)
09/20/90	1	1	14:00-18:18	9.39	15.8	40.2	106	132	340	7.15	23.0
09/22/90	3	1	9:47-14:00	9.57	16.1	42.1	119	109	289	9.84	32.3
10/02/90	10	1	10:15-14:21	7.88	15.7	31.4	80.7	125	313	2.52	7.74
	AVERAGE			8.95	15.9	37.9	102	122	314	6.50	21.0
09/21/90	2	2	9:45-13:57	7.98	15.7	15.0	37.2	79.9	208	23.0	82.7
09/23/90	4	2	11:40-15:47	7.35	15.2	18.2	44.2	62.9	143	60.2	183
09/27/90	8	2	13:45-17:50	6.78	15.6	19.0	47.0	73.7	195	30.0	91.3
	AVERAGE:			7.37	15.5	17.4	42.8	72.2	182	37.7	119
09/24/90	5	3	11:45-15:52	7.96	15.6	51.5	134	150	384	3.79	11.7
09/25/90	6	3	10:10-14:15	8.29	15.7	51.1	135	153	402	5.63	17.9
09/28/90	9	3	11:00-15:05	8.93	15.3	43.1	108	165	397	3.62	11.7
	AVERAGE:			8.39	15.5	48.6	126	156	394	4.35	13.8

a Time is for metals and CDD/CDF runs.

b SO2 and NOx are corrected to 7.0% oxygen, where the corrected value = actual * 13.9/(20.9 - O2).

c THC is corrected to 7.0% oxygen and corrected for moisture where the corrected value = actual * 13.9/(20.9 - O2) * 1/(1 - moist).

NOTE: For all CEM Data, 30 second values were corrected and then averaged.

condition, the CO run averages ranged from 132 ppmV to 1187 ppmV, with an overall average CO concentration of 500 ppmV. For the third condition, the CO run averages ranged from 36.1 ppmV to 65.3 ppmV, with the overall average for this condition being 46.3 ppmV.

The average NO_x concentrations varied from 62.9 ppmV to 165 ppmV over the nine test runs. Averages for Condition 1 ranged from 109 to 132 ppmV, with an overall average of 122 ppmV. Averages for Condition 2 ranged from 62.9 to 79.9 ppmV, with an overall average of 72.2 ppmV, and the Condition 3 range was 150 to 165 ppmV, with the average value being 156 ppmV.

The SO_2 run averages for each condition ranged from 31.4 to 42.1 ppmV for Condition 1, 15.0 to 19.0 ppmV for Condition 2, and 43.1 to 51.5 ppmV for Condition 3. The condition averages were 37.9 ppmV, 17.4 ppmV, and 48.6 ppmV SO_2 for Conditions 1 through 3, respectively.

Average THC concentrations varied from 2.52 to 60.2 ppmV-wet over the nine runs. The average THC for each condition ranged from 2.52 to 9.84 ppmV for Condition 1, 23.0 to 60.2 ppmV for Condition 2, and 3.62 to 5.63 ppmV for Condition 3. The Condition 1 average was 6.50 ppmV, the Condition 2 average was 37.7 ppmV, and the Condition 3 average was 4.35 ppmV.

2.7 CEM BURN DOWN RESULTS

After the daily test run was completed, combustion gas concentrations were continuously analyzed and recorded during a "burn down" period by the CEMS. At this time no waste was fed to the incinerator. The primary and secondary chambers operated under burn down set point routines. Two days of burn down conditions were monitored with all CEM analyzers operational. Concentrations of O_2, CO_2, SO_2, NO_x, CO, HCl, and THC were monitored. The 30-second CEM averages were reported in ppm or percent by volume as measured and also corrected to 7 percent O_2.

Table 2-31 reports the burn down CEM data. Burn down parameters were measured after test Run 6 (9/25/90) and Run 10 (10/2/90). Oxygen values were 17.5 and 17.7 percent by volume for these two runs. Carbon dioxide values were 2.14 and 1.92, respectively. The CO concentrations were 8.5 and 6.2 ppmV dry and NO_x values

TABLE 2-31. CEM BURN DOWN AVERAGES
CENTRAL CAROLINA HOSPITAL (1990)

DATE	RUN NUMBER	COND.	BURNDOWN TEST TIME a	OXYGEN (%vol.dry)	SO2 actual (ppmV,dry)	SO2 corrected b (ppmV,dry)	NOX actual (ppmV,dry)	NOX corrected b (ppmV,dry)	THC actual (ppm C, wet)	THC corrected c (ppm C, dry)
09/25/90	6	3	14:15-17:28	17.5	26.1	92.6	62.8	217	1.1	3.1
10/02/90	10	1	14:22-17:35	17.7	7.10	24.6	38.5	154	0.0	0.0
				CO2 (%vol.dry)	CO actual (ppmV,dry)	CO corrected b (ppmV,dry) @7% O2	HCL c,d actual (ppmV,wet)	HCL c,d corrected (ppmV,dry) @7% O2		
09/25/90	6	3	14:15-17:28	2.14	8.5	31.4	16.6	67.9		
10/02/90	10	1	14:22-17:35	1.92	6.2	24.5	31.1	141		

a Time is for approximate burndown period.

b Thirty-second CEM averages were corrected to 7% oxygen (corrected value = actual * (13.9 /(20.9 - O2)).

c THC and HCl is corrected to 7% oxygen and corrected for moisture where the corrected value = actual * 13.9/(20.9 - O2) / (1 - moist)). Moistu assumed to be the same as during the test run conducted on the same day.

d HCl concentrations were determined by manual methods as well. A comparison of CEM vs. manual results is presented in Section 2.5. HCl calibrations were performed at different stack gas temperatures than the burndown stack temperatures thereby affecting the sampling rate/dilution ratio which may have affected the HCl accuracy.

were 62.8 and 38.5 ppmV dry, respectively. The THC average concentrations were below 2 ppm for both runs.

2.8 ASH LOSS-ON-IGNITION AND CARBON CONTENT RESULTS

This section presents results of laboratory analyses of ash samples collected daily. During the test period, ash was removed manually from the incinerator each morning, screened through 1/2-inch mesh, weighed and placed in 35-gallon metal cans. After the ash was allowed to cool, samples were taken manually and composited to obtain a representative sample. 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 tests at the three different incinerator operating conditions (total of 9 runs).

Table 2-32 presents a summary of the ash analysis results. The moisture content of the samples ranged from 0.27 percent for Run 10 (Test Condition 1) to 44.26 percent for Run 8 (Test Condition 2). The average moisture values for each test condition are shown. The lowest value shown was for Condition 1 (0.33 percent) and the highest value for Condition 2 (27.10 percent). The ash from Runs 4, 8, and 6 were cooled down in the incinerator using a water spray. This was done in order to allow the ash to be removed and the next test run to be started. Ash moisture values for these runs reflect the presence of this additional water.

Loss-on-ignition results varied from 17.8 percent for Run 10 (Condition 1) to 78.0 percent for Run 8 (Condition 2). Average values for each test condition ranged from 22.2 percent for Condition 1 to 53.2 percent for Condition 2.

Carbon content in the ash samples varied from 9.77 percent for Run 10 (Condition 1) to 35.7 percent for Run 8 (Condition 2). Average values for each test condition showed a low value of 14.2 percent for Condition 1 and a high value of 27.4 percent for Condition 2.

TABLE 2-32. SUMMARY OF ASH CARBON CONTENT, LOI AND MOISTURE RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

CONDITION a	TEST DATE	TEST NUMBER	SAMPLE DATE	MOISTURE (%)	L.O.I. (%)	TOTAL LOSS (%)	CARBON (%)
PRE TEST 1	PRE TEST	NA	9/20/90	28.55	62.68	73.34	18.12
PRE TEST 2	PRE TEST	NA	9/20/90	15.83	58.88	65.39	28.25
			AVERAGE	22.19	60.78	69.37	23.19
1	9/20/90	1	9/21/90	0.41	29.66	24.17	15.03
1	9/22/90	3	9/23/90	0.30	19.19	19.48	17.87
1	10/02/90	10	10/03/90	0.27	17.80	18.02	9.77
			AVERAGE	0.33	22.22	20.56	14.22
2	9/21/90	2	9/22/90	2.12	45.72	46.87	30.17
2	9/23/90	4	9/24/90	34.92 b	35.90	58.28	16.39
2	9/27/90	8	9/25/90	44.26 b	78.02	87.75	35.70
			AVERAGE	27.10	53.21	64.30	27.42
3	9/24/90	5-MC c	9/25/90	3.16	23.64	26.05	20.36
3	9/24/90	5-MF	9/25/90	0.64	23.79	24.28	22.80
3	9/25/90	6-MC	9/26/90	30.03 b	40.39	50.29	21.85
3	9/25/90	6-MF	9/26/90	0.47	32.45	32.77	16.66
3	9/28/90	9	9/29/90	1.13	27.63	28.45	20.41
			AVERAGE	7.09	29.58	32.37	20.42

a CONDITIONS:

(1) 100 lb/hr., 1800-1900° F, 25 lb/15 min.
(2) 250 lb/hr., 1600° F, 62.5 lb/15 min.
(3) 160 lb/hr., 1600° F, 40 lb/15 min.

b For these runs, a water spray was used to extinguish the fire in order to allow ash to be removed.

c MF = Fine Ash (sifted through 1/2" mesh) MC = Course Ash (would not pass through 1/2" mesh). Course and fine ash comparison was only completed during Runs 5 and 6 to examine any relative differences in properties.

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 Central Carolina 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 Bacillus stearothermophilus. This organism as 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 was absorbed onto materials commonly found in the medical waste stream (i.e., gauze, paper, bandages, etc.) and introduced into the incinerator at regular intervals. Simultaneous emissions testing was conducted at the incinerator stack following the EPA draft method "Microbial Survivability Test for Medical Waste Incinerator Emissions." This testing was performed concurrently with other emissions testing (PM/Metals, CDD/CDF, halogens, and CEMs). Spiked waste was charged into the incinerator four times during a 4-hour test run (essentially once per hour). Ash samples were taken daily each morning following the previous days' test run 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 encased in double pipes which were insulated. These tests were performed as a comparison to the direct ash method. Two sizes of pipes were used during this test program to determine if pipe size was a determining factor in microbial survivability.

Large pipes samples (6 in. x 2.0 in. diameter) were compared to small pipes (6 in. x 1.25 in. diameter). Three spiked pipes sets (1 large, 1 small) were charged daily at nearly even intervals: (1) the first charge of the day, (2) midday, and (3) last charge of the day.

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

Three triplicate runs were performed at the three different incinerator operating conditions for a total of nine runs. Four medical waste (wet spore) spikes and three pipe samples (dry spore) spikes were added during each run. One run was performed daily.

Table 2-33 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 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 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

TABLE 2-33. SUMMARY OF INCINERATOR FEED AMOUNTS AND ASH GENERATION PER RUN; CENTRAL CAROLINA HOSPITAL (1990)

RUN NUMBER	DATE	CONDITION	WET SPORE SPIKES [a]		DRY SPORE (PIPE) SPIKES [a]		TOTAL WASTE FEED (lbs) AND TYPE	TOTAL ASH WEIGHT (lbs)
			TIMES	AMOUNTS (TOTAL SPORES)	TIMES	AMOUNTS (TOTAL SPORES)		
1	09/20/90	1	14:00	1.5E+12	14:00	5.2E+06	21.2 PATHOLOGICAL	503.4
			15:15	1.5E+12	16:15	5.2E+06		
			16:00	1.5E+12	16:00	5.2E+06		
			17:00	1.5E+12				
2	09/21/90	2	09:45	1.5E+12	09:45	5.2E+06	139 MEDICAL	1015.8
			11:00	1.5E+12	12:03	5.2E+06		
			12:03	1.5E+12	15:45	5.2E+06		
			12:45	1.5E+12				
3	09/22/90	1	09:45	1.5E+12	09:45	5.2E+06	22.4 PATHOLOGICAL	649.5
			11:00	1.5E+12	12:15	5.2E+06		
			12:00	1.5E+12	14:30	5.2E+06		
			13:00	1.5E+12				
4	09/23/90	2	11:40	1.5E+12	11:40	5.2E+06	172.7 MEDICAL	905.3
			12:45	1.5E+12	14:15	5.2E+06		
			13:45	1.5E+12	17:15	5.2E+06		
			14:45	1.5E+12				
5	09/24/90	3	11:45	1.5E+12	11:45	5.2E+06	45.1 PATHOLOGICAL	674.6
			12:40	1.5E+12	13:45	5.2E+06		
			13:45	1.5E+12	15:50	5.2E+06		
			14:40	1.5E+12				

TABLE 2-33. SUMMARY OF INCINERATOR FEED AMOUNTS AND ASH GENERATION PER RUN; (continued)
CENTRAL CAROLINA HOSPITAL (1990)

RUN NUMBER	DATE	CONDITION	WET SPORE SPIKES a		DRY SPORE (PIPE) SPIKES a		TOTAL WASTE FEED (lbs) AND TYPE	TOTAL ASH WEIGHT (lbs)
			TIMES	AMOUNTS (TOTAL SPORES)	TIMES	AMOUNTS (TOTAL SPORES)		
6	09/25/90	3	10:10	1.5E+12	10:10	5.2E+06	411.4 PATHOLOGICAL	697.2
			11:15	1.5E+12	12:10	5.2E+06		
			12:10	1.5E+12	14:15	5.2E+06		
			13:15	1.5E+12				
8	09/27/90	2	13:45	1.5E+12	13:45	5.2E+06	137.3 MEDICAL	727.3
			14:45	1.5E+12	16:15	5.2E+06		
			15:56	1.5E+12	18:00	5.2E+06		
			16:45	1.5E+12				
9	09/29/90	3	11:00	1.5E+12	11:00	5.2E+06	77 PATHOLOGICAL	867.2
			12:00	1.5E+12	13:15	5.2E+06		
			13:00	1.5E+12	15:53	5.2E+06		
			14:00	1.5E+12				
10	10/02/90	1	10:15	1.5E+12	10:15	5.2E+06	17.2 PATHOLOGICAL	453.5
			11:15	1.5E+12	12:15	5.2E+06		
			12:15	1.5E+12	14:30	5.2E+06		
			13:15	1.5E+12				

NOTE:
Condition 1 = 100 lb/hr; 1800–1900°F; 25 lb/15 min
Condition 2 = 250 lb/hr; 1600°F; 62.5 lb/15 min
Condition 3 = 160 lb/hr; 1600°F; 40 lb/15 min

a Spike amounts were taken from the confirmation analysis results (see Tables 6–24 and 6–25).

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 2-34 presents the overall survivability of the indicator spores. Four test run results had viable spores found in the stack gas. Spores were found in several isolated ash aliquots; however, definitive quantitative results could not be provided and all test run results were assigned no spores detected. For those runs in which positive Microbial Survivability values could be calculated, the numbers ranged from survivability for 3.1 x 10^{-5} percent Run 6 to >2.6 x 10^{-4} percent for Run 8. 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 emission 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 run for viable spore emissions was actually made up of 2 "sub-runs" (A and B). Each sub-run sample was collected for 120 minutes through one of the 2 sample ports. An approximate 1.5 liter sample of impinger collection solution was generated for each sub-run. These sub-run samples were recovered in a disinfected mobile laboratory, sealed and sent to the analytical laboratory where they were combined into one sample for each test run.

For each run performed, 9 aliquots were prepared for analysis: three 10 ml aliquots, three 100 ml aliquots, and 3 equal aliquots of a remaining filterable amount of sample. Both a first and second count on each aliquot were performed. The first count was conducted after approximately 24 hours incubation, and the second after approximately a 48 hour incubation period. Additional research showed that the spore count did not increase after the 48-hour count incubation period. Therefore, all values presented here are from the second (typically a 48-hour) count.

TABLE 2-34. OVERALL MICROBIAL SURVIVABILITY; CENTRAL CAROLINA HOSPITAL (1990)

RUN NO.	FEED RATE/ FREQUENCY/TYPE (lb/hr/min)	TOTAL NUMBER OF WET SPORES SPIKED TO INCINERATOR [a]	NUMBER INDICATOR SPORES EXITING THE STACK [b]	NUMBER OF INDICATOR SPORES IN ASH [c]	SPORE SURVIVABILITY (%) [d]	MICROBIAL LOG REDUCTION [f]
1	100/15-P	6.0E+12	<3.84E+04	<9.6E+05	<1.7E-05	>6.8
3	100/15-P	6.0E+12	~13.8E+06	<1.0E+06	~2.3E-04	~5.7
10	100/15-P	6.0E+12	<3.22E+04	<3.9E+03	<6.0E-07	>8.2
2	250/15-M	6.0E+12	<4.36E+04	<6.3E+06	<1.1E-04	>6.0
4	250/15-M	6.0E+12	<4.31E+04	<7.8E+06	<1.3E-04	>5.9
8	250/15-M	6.0E+12	>15.5E+06 [e]	<6.2E+06	>2.6E-04	<5.6
5	160/15-P	6.0E+12	<13.5E+06	<1.0E+04	<2.3E-04	>5.6
6	160/15-P	6.0E+12	~18.5E+05	<1.9E+06	~3.1E-05	~6.5
9	160/15-P	6.0E+12	~6.94E+06	<1.8E+04	~1.2E-04	~5.9

[a] Four 500 ml wet spore aliquots were spiked during each test run. This value represents the total spores spiked/test run as determined by the confirmation count (see Table 6-24).

[b] Values taken from repetitive analytical runs as detailed in Appendix E.3. Detection limits are presented in Table 2-35.

[c] Detection liits are presented in Table 2-37.

[d] Calculated using (number spores in flue gas + number of spores in ash/number wet spores spiked) x 100. If spores were not detected in either fraction, the non-detected values were used in calculation. Otherwise non-detects were considered zero.

[e] Maximum value could not be determined for this flue gas sample (see Appendix E.3).

[f] MLR = log(spiked spores) - log(stack spores + ash spores)

P = Pathological Waste M = Medical Waste

Table 2-35 presents the Microbial Survivability in Emissions test results. There were four test runs where viable spores were determined to be present in the flue gas (Runs 3, 8, 6, and 9).

The Microbial Survivability sampling and flue gas parameters are shown in Table 2-36.

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. A composite ash sample was then taken from the drum using a sample thief and deposited in a sterilized, amber glass sample bottles. The composite samples were then submitted to the laboratory for filtering culturing, and enumeration of B. stearothermophilus.

Microbial Survivability in ash for the Central Carolina MWI tests are presented in Table 2-37. Three ash aliquots of approximately one gram were prepared from each sample. Six serial dilutions were prepared on each ash aliquot and triple plated. B. stearothermophilus colonies were found in several of the cultures. However, because repetitive analyses of these aliquots did not consistently reveal B. stearothermophilus colonies, the final values were determined to be <100 spores per gram of ash. (Several samples had no spores detected at all, ND, and were assigned <0.5 spores per gram of ash). 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

Three pipe samples were loaded into the incinerator during each test day. The pipes were recovered the following morning during ash removal. After allowing the pipes to cool, the inner containers were removed from the outer containers and sent to the laboratory for analysis. The entire contents of the pipe were rinsed, filtered, and cultured.

Microbial Survivability in pipes is presented in Table 2-38. Results ranged from not-detected to too numerous to count (TNTC). The TNTC results were assigned a value of greater than 200 spores (>200). All runs except Run 6 showed some spore survivability in the pipe samples.

TABLE 2-35. VIABLE SPORE EMISSIONS; CENTRAL CAROLINA HOSPITAL (1990)

RUN NUMBER	FEED RATE/ FREQUENCY/TYPE (lb/hr/min)	NUMBER OF INDICATOR SPORES IN ALIQUOT (spores/100 ml)	NUMBER OF INDICATOR SPORES IN SAMPLE (spores)	CONCENTRATION OF INDICATOR SPORES IN FLUE GAS (spores/dscm)	NUMBER OF INDICATOR SPORES EXITING STACK DURING TEST PERIOD (spores)
1	100/15-P	ND	ND	ND	<3.84E+04
3	100/15-P	~200	~8785	~2183	~13.8E+06
10	100/15-P	ND	ND	ND	<3.22E+04
2	250/15-M	ND	ND	ND	<4.36E+04
4	250/15-M	ND	ND	ND	<4.31E+04
8	250/15-M	>200 a	>9761	>2572	>15.5E+06
5	160/15-P	<200 b	<8378	<2289	<13.5E+06
6	160/15-P	~30	~1166	~271	~18.5E+05
9	160/15-P	~100	~4567	~1120	~6.94E+06

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.

ND = Not Detected. Detection limits were determined to be 0.5 spores/100ml (1 spore/100 ml aliquot / 2).

a Maximum value could not be determined for this flue gas sample (see Appendix E.3).

b One aliquot out of nine repitions resulted in "Too Numerous To Count" (TNTC), and, therefore, was assigned the above detection limit.

TABLE 2-36. INDICATOR SPORE EMISSIONS SAMPLING AND FLUE GAS PARAMETERS; CENTRAL CAROLINA HOSPITAL (1990)

RUN NUMBER:	1A	1B	AVERAGE	3A	3B	AVERAGE	10A	10B	AVERAGE
Total Sampling Time (min.)	120	120	NA	120	120	NA	120	120	NA
Average Stack Temperature (°F)	644	796	720	688	741	714	693	745	719
Carbon Dioxide Concentration (%V)	3.08	3.26	3.17	3.25	3.1	3.175	3.51	3.28	3.395
Oxygen Concentration (%V)	15.7	15.6	15.7	15.8	16.2	16.0	15.4	16.0	15.7
Average Sampling Rate (dscfm)	0.592	0.600	0.596	0.589	0.596	0.592	0.611	0.594	0.603
Standard Metered Volume, Vm(std) (dscm)	2.011	2.039	2.025	2.000	2.025	2.012	2.077	2.019	2.048
Stack Moisture (%V)	9.39	9.39	9.39	9.57	9.57	9.57	7.88	7.88	7.88
Volumetric Flow Rate (acfm)	2180	2472	2326	2279	2349	2314	2381	2358	2370
Volumetric Flow Rate (dscmm)	26.7	26.6	26.7	26.6	26.2	26.4	27.5	26.1	26.8
Percent Isokinetic	95.2	96.9	NA	95.1	96.1	NA	95.4	96.3	NA

RUN NUMBER:	2A	2B	AVERAGE	4A	4B	AVERAGE	8A	8B	AVERAGE
Total Sampling Time (min.)	105	135	NA	120	120	NA	120	120	NA
Average Stack Temperature (°F)	848	757	802	707	706	706	770	708	739
Carbon Dioxide Concentration (%V)	4.40	3.41	3.91	4.22	4.01	4.12	4.17	3.59	3.88
Oxygen Concentration (%V)	14.5	16.3	15.4	14.85	15.16	15.005	15.09	15.98	15.535
Average Sampling Rate (dscfm)	0.592	0.544	0.568	0.555	0.574	0.565	0.560	0.557	0.558
Standard Metered Volume, Vm(std) (dscm)	1.760	2.081	1.921	1.885	1.952	1.919	1.904	1.891	1.897
Stack Moisture (%V)	7.98	7.98	7.98	7.35	7.35	7.35	6.78	6.78	6.78
Volumetric Flow Rate (acfm)	2604	2177	2391	2141	2238	2190	2268	2056	2162
Volumetric Flow Rate (dscmm)	27.3	24.6	26.0	25.2	26.3	25.7	25.7	24.5	25.1
Percent Isokinetic	93.1	93.6	NA	94.8	92.2	NA	93.8	95.9	NA

RUN NUMBER:	5A	5B	AVERAGE	6A	6B	AVERAGE	9A	9B	AVERAGE
Total Sampling Time (min.)	120	120	NA	120	120	NA	120	120	NA
Average Stack Temperature (°F)	687	761	724	672	796	734	729	764	746
Carbon Dioxide Concentration (%V)	3.48	3.44	3.46	3.34	3.5	3.42	3.79	3.58	3.685
Oxygen Concentration (%V)	15.5	15.7	15.6	15.6	15.7	15.7	15.0	15.5	15.3
Average Sampling Rate (dscfm)	0.580	0.500	0.540	0.648	0.620	0.634	0.611	0.589	0.600
Standard Metered Volume, Vm(std) (dscm)	1.965	1.695	1.830	2.202	2.107	2.154	2.076	2.001	2.038
Stack Moisture (%V)	7.96	7.96	7.96	8.29	8.29	8.29	8.93	8.93	8.93
Volumetric Flow Rate (acfm)	2186	2024	2105	2414	2507	2461	2345	2232	2289
Volumetric Flow Rate (dscmm)	26.2	22.8	24.5	29.4	27.5	28.4	26.8	24.8	25.8
Percent Isokinetic	95.0	92.6	NA	94.7	95.2	NA	97.9	100.3	NA

NA = Not applicable.

TABLE 2-37. VIABLE SPORES IN ASH; CENTRAL CAROLINA HOSPITAL (1990)

RUN NUMBER	CONCENTRATION OF INDICATOR SPORES IN ASH (spores/g ash)	NUMBER OF INDICATOR SPORES EXITING INCINERATOR IN ASH
1	<100	<9.6E+05
3	<100	<1.0E+06
10	ND	<3.9+03
2	<100	<6.3E+06
4	<100	<7.8E+06
8	<100	<6.2E+06
5	ND	<1.02E+04
6	<100	<1.9E+06
9	ND	<1.75E+04

Note: Values were taken from the average of replicate analyses as presented in the analytical quantitative summary in Appendix E.3.

ND = Not Detected. Detection limits for these samples were determined to be 0.5 spores / gram ash(1 spore/g ash/2). All calculations are shown in Appendix F.

Detection limits for all other samples were determined to be 1 spore/1 ml filtration or 100 spores/g ash.

TABLE 2-38. VIABLE SPORES IN PIPES; CENTRAL CAROLINA HOSPITAL (1990)

RUN NUMBER	SAMPLE ID	LOADING ORDER	PIPE SIZE	APPROXIMATE TEMPERATURE RANGE (deg F)	NUMBER OF INDICATOR SPORES DETECTED (spores)
1	CCH-085	2	L	1750 - 2000	14
	CCH-086	3	L	1750 - 2000	3
	CCH-087	2	S	2000 - 2200	0
	CCH-088	3	S	2000 - 2200	1
	CCH-089	1	L	1750 - 2000	20
	CCH-090	1	S	1500 - 1750	>200
2	CCH-096	3	S	1750 - 2000	>1
	CCH-097	2	S	750 - 1000	>32
	CCH-098	1	S	750 - 1000	20
	CCH-099	3	L	750 - 1000	>20
	CCH-100	2	L	1250 - 1500	3
	CCH-101	1	L	750 - 1000	7
3	CCH-154	3	L	1750 - 2000	0
	CCH-155	3	S	1750 - 2000	>1
	CCH-156	2	L	1500 - 1750	0
	CCH-157	2	S	1750 - 2000	1
	CCH-158	1	S	1750 - 2000	4
	CCH-159	1	L	1750 - 2000	5
4	CCH-175	1	L	1500 - 1750	0
	CCH-176	3	S	1750 - 2000	2
	CCH-177	3	L	1500 - 1750	4
	CCH-178	2	S	1250 - 1500	3
	CCH-179	2	L	1000 - 1250	0
	CCH-180	1	S	750 - 1000	0
5	CCH-193	3	L	1500 - 1750	>200
	CCH-194	3	S	750 - 1000	0
	CCH-195	2	L	750 - 1000	>200
	CCH-196	1	L	750 - 1000	>166
	CCH-197	2	S	1250 - 1500	79
	CCH-198	1	S	750 - 1000	0

NA = Not available at this time

L = Large (2.25" diameter); S = Small (1.5 " diameter)

TABLE 2-38. VIABLE SPORES IN PIPES (continued); CENTRAL CAROLINA HOSPITAL (1990)

RUN NUMBER	SAMPLE ID	LOADING ORDER	PIPE SIZE	APPROXIMATE TEMPERATURE RANGE (deg F)	NUMBER OF INDICATOR SPORES DETECTED (spores)
6	CCH-280	NA	L	NA	0
	CCH-281	NA	S	NA	0
	CCH-282	NA	L	NA	0
	CCH-283	NA	S	NA	0
	CCH-284	NA	L	NA	0
	CCH-285	NA	S	NA	0
8	CCH-292	NA	S	NA	1
	CCH-293	NA	L	NA	17
	CCH-294	NA	L	NA	0
	CCH-295	NA	L	NA	2
	CCH-296	NA	S	NA	0
	CCH-297	NA	S	NA	0
9	CCH-304	NA	L	NA	0
	CCH-305	NA	S	NA	1
	CCH-306	NA	L	NA	0
	CCH-307	NA	L	NA	0
	CCH-308	NA	S	NA	1
	CCH-309	NA	S	NA	0
10	CCH-378	NA	L	NA	0
	CCH-379	NA	L	NA	1
	CCH-380	NA	S	NA	0
	CCH-381	NA	L	NA	0
	CCH-382	NA	S	NA	0
	CCH-383	NA	S	NA	0

NA = Not available at this time

L = Large (2.25" diameter); S = Small (1.5 " diameter)

As part of the microbial survivability in pipes method development, a single pipe's temperature was measured and recorded during four test runs (Runs 7 through 10). A large pipe (2 in. ID) containing no spores was configured with a thermocouple placed through a hole drilled in one of the capped ends. The pipe was placed in the incinerator and internal pipe temperatures were measured and manually recorded. Temperatures varied considerably. A general range was from 500 to 1500°F. However, no data analysis has been completed (averages, standard deviation, etc.). All pipe temperature data is listed in Appendix B.4.

2.10 PARTICLE SIZE DISTRIBUTION RESULTS

Six PSD test runs were conducted during the Central Carolina Hospital MWI test program. An eight stage MK III cascade impactor sampling device was used (See Section 5.9 for PSD Method). 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" (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 six PSD runs, the first two did not meet recovery QC objectives and therefore are not included in these results (Raw Field Data and Analytical data are shown in Appendix A.6 and E.5). The test results for PSD Runs 3 through 6 will be reported in the following section.

The PSD Runs 3 and 4 were conducted on September 26, 1990 during test No. 7. Other results from this test No. were not reported due to an invalidated CDD/CDF run (See Section 2.2). Test No. 7 was conducted during Condition 2 (250 lbs/hr, 15 minute long cycle, 1600°F). The PSD Runs 5 and 6 were conducted on September 28, 1990 and October 2, 1990 under Conditions 3 and 1, respectively.

Tables 2-39 and 2-40 report the results from PSD Runs 3 and 4 (Condition 2), respectively. Approximately 70 percent of the particulate was less than 8.8 um.

TABLE 2-39. PSD RUN 3 RESULTS (TEST NO 7); CENTRAL CAROLINA HOSPITAL (1990)

FLUE GAS AND SAMPLING PARAMETERS	
Total Sampling Time (min.)	2.5
Average Stack Temperature (°F)	1122.00
Average Sampling Rate (dscfm)	0.2960
Standard Metered Volume, Vm(std) (dscf)	0.7320
Standard Metered Volume, Vm(std) (dscm)	0.021
Stack Moisture (%V)	6.8100
Percent Isokinetic	111.0
Date	09/26/90

STAGE	Dp50 (microns)	NET WEIGHT (grams)	MASS FRACTION	MASS FRACTION LESS THAN	INTERVAL GEOMETRIC MIDPOINT (microns)	dM/dlog DP (gr/dscf)	CONCENTRATION (gr/dscf)
Prelim & 1	13.2	0.06236	0.1978	0.8022*	25.7	2.1019	1.2161
2	8.65	0.03040	0.0964	0.7057	10.7	3.2332	0.5928
3	5.65	0.03014	0.0956	0.6101	6.99	3.1749	0.5877
4	3.99	0.03238	0.1027	0.5074	4.75	4.1935	0.6314
5	2.37	0.03334	0.1058	0.4016	3.08	2.8803	0.6501
6	1.37	0.02838	0.0900	0.3116	1.80	2.3096	0.5533
7	0.866	0.03056	0.0970	0.2146	1.09	3.0046	0.5959
8	0.588	0.03127	0.0992	0.1154	0.714	3.6283	0.6097
Back-up		0.03639	0.1154	0.0000*	0.054	0.3426	0.7095
Total		0.31521	1.0000				

* These values assume top end and bottom end dp50s of 50 and .005 um.

TABLE 2-40. PSD RUN 4 RESULTS (TEST NO 7); CENTRAL CAROLINA HOSPITAL (1990)

FLUE GAS AND SAMPLING PARAMETERS	
Total Sampling Time (min.)	15
Average Stack Temperature (°F)	773
Average Sampling Rate (dscfm)	0.305
Standard Metered Volume, Vm(std) (dscf)	4.57
Standard Metered Volume, Vm(std) (dscm)	0.129
Stack Moisture (%V)	6.81
Percent Isokinetic	111
Date	9/26/90

STAGE	Dp50 (microns)	NET WEIGHT (grams)	MASS FRACTION	MASS FRACTION LESS THAN	INTERVAL GEOMETRIC MIDPOINT (microns)	dM/dlog Dp (gr/dscf)	CONCENTRATION gr/dscf
Prelim & 1	13.7	0.07749	0.2050	0.795*	26.2	0.4654	0.2618
2	8.97	0.03221	0.0852	0.710	11.1	0.5932	0.1088
3	5.86	0.03592	0.0950	0.615	7.25	0.6547	0.1213
4	4.14	0.03533	0.0935	0.521	4.92	0.7908	0.1194
5	2.45	0.03725	0.0985	0.423	3.19	0.5540	0.1258
6	1.40	0.03849	0.1018	0.321	1.85	0.5329	0.1300
7	0.865	0.03986	0.1055	0.215	1.10	0.6458	0.1347
8	0.559	0.03836	0.1015	0.114	0.696	0.6841	0.1296
Back-up		0.04310	0.1140	0.000*	0.053	0.0711	0.1456
Total		0.37799	1.0000				

* These values assume top end and bottom end dp50s of 50 and .005 um.

Table 2-41 reports the results for PSD Run 5 (Condition 3). Again, approximately 70 percent of the particulate was less than 9 um. Grainloading (concentration-grains/dry standard cubic foot) was much lower during this condition than it was during Condition 2 (0.04 gr/dscf total PM for Condition 3 versus 0.7 and 0.1 gr/dscf for total PM for Condition 2).

Table 2-42 reports the results from PSD Run 6 (Condition 1). Again, approximately 70 percent of the particulate is less than 9 um. Grainloading is comparable to that observed during Condition 3.

Figures 2-1 through 2-4 show the log-normal plots of PSD Runs 3 through 6, respectively. The log of Particle cut size (Dp50) at each impactor stage is plotted against mass fraction of particulate less than that Dp50, on a probability (normal) scale. Linear regressions analyses were conducted and the correlation coefficients (R^2) are shown on each figure.

2.11 CDD/CDF EMISSION VALUES INCORPORATING THE TOLUIENE RECOVERY RESULTS

In accordance with EPA Method 23, a final toluene rinse was completed on the CDD/CDF sampling train after the methylene chloride ($MeCl_2$) rinse procedure. This was done to determine how well the $MeCl_2$ 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 are 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 effect the gas phase CDD/CDF concentrations, stack gas CDD/CDF concentrations incorporating the toluene recovery amounts are given in Tables 2-43 through 2-45. Concentrations are given corrected to 7 percent 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, 2-10, and 2-11.

TABLE 2-41. PSD RUN 5 RESULTS (TEST NO 9); CENTRAL CAROLINA HOSPITAL (1990)

FLUE GAS AND SAMPLING PARAMETERS	
Total Sampling Time (min.)	45
Average Stack Temperature (°F)	789
Average Sampling Rate (dscfm)	0.299
Standard Metered Volume, Vm(std) (dscf)	13.5
Standard Metered Volume, Vm(std) (dscm)	0.382
Stack Moisture (%V)	6.78
Percent Isokinetic	85.6
Date	9/28/90

STAGE	Dp50 (microns)	NET WEIGHT (grams)	MASS FRACTION	MASS FRACTION LESS THAN	INTERVAL GEOMETRIC MIDPOINT (microns)	dM/dlog DP (gr/dscf)	CONCENTRATION (gr/dscf)
Prelim & 1	13.8	0.05878	0.1821	0.8179*	26.3	0.1207	0.0673
2	9.07	0.03241	0.1004	0.7175	11.2	0.2024	0.0371
3	5.92	0.03293	0.1020	0.6155	7.33	0.2035	0.0377
4	4.18	0.03372	0.1045	0.5111	4.98	0.2559	0.0386
5	2.48	0.03763	0.1165	0.3945	3.22	0.1898	0.0431
6	1.41	0.01637	0.0507	0.3438	1.87	0.0769	0.0188
7	0.875	0.03404	0.1054	0.2384	1.11	0.1871	0.0390
8	0.566	0.03203	0.0992	0.1392	0.704	0.1939	0.0367
Back-up		0.04493	0.1392	0.0000*	0.053	0.0251	0.0515
Total		0.32283	1.0000				

* These values assume top end and bottom end dp50s of 50 and .005 um.

TABLE 2-42. PSD RUN 6 RESULTS (TEST NO 10); CENTRAL CAROLINA HOSPITAL (1990)

FLUE GAS AND SAMPLING PARAMETERS	
Total Sampling Time (min.)	60
Average Stack Temperature (°F)	723
Average Sampling Rate (dscfm)	0.293
Standard Metered Volume, Vm(std) (dscf)	17.6
Standard Metered Volume, Vm(std) (dscm)	0.498
Stack Moisture (%V)	7.88
Percent Isokinetic	88.8
Date	10/02/90

STAGE	Dp50 (microns)	Net Weight (grams)	MASS FRACTION	MASS FRACTION LESS THAN	INTERVAL GEOMETRIC MIDPOINT (microns)	dM/dlog DP (gr/dscf)	CONCENTRATION (gr/dscf)
Prelim & 1	13.7870	0.05572	0.1796	0.8204	26.2555	8.406E-02	0.047031
2	9.0369	0.02918	0.0941	0.7263	11.1620	1.343E-01	0.024632
3	5.8974	0.02817	0.0908	0.6356	7.3002	1.283E-01	0.023775
4	4.1655	0.03175	0.1023	0.5332	4.9564	1.775E-01	0.026797
5	2.4684	0.02752	0.0887	0.4445	3.2066	1.022E-01	0.023226
6	1.4060	0.03336	0.1075	0.3370	1.8629	1.152E-01	0.028160
7	0.8677	0.02659	0.0857	0.2513	1.1045	1.071E-01	0.022445
8	0.5579	0.02842	0.0916	0.1597	0.6958	1.250E-01	0.023986
Back-up		0.04955	0.1597	0.0000	0.0528	2.043E-02	0.041822
Total		0.31023	1.0000				

* These values assume top end and bottom end dp50s of 50 and .005 um.

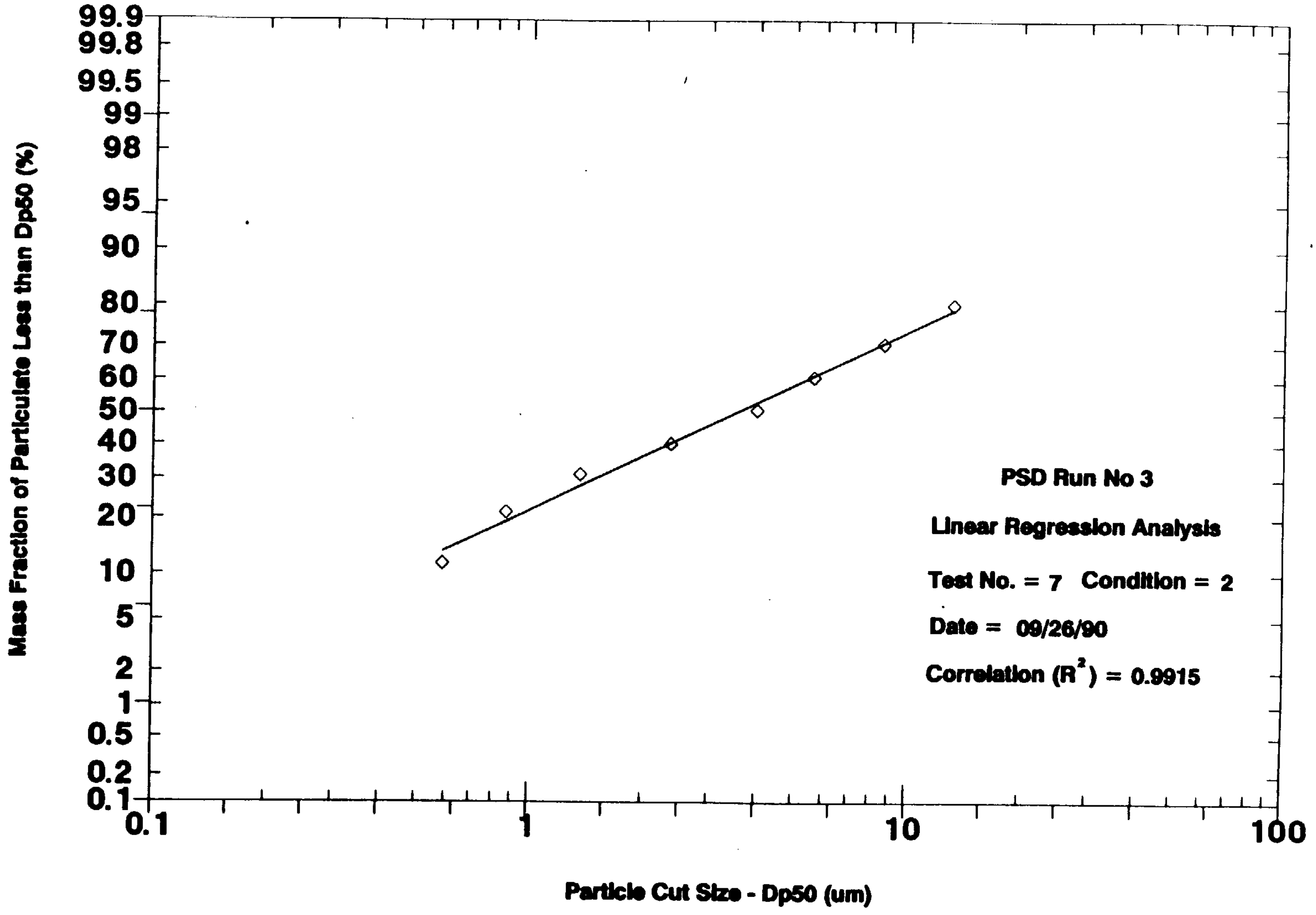


FIGURE 2-1. Run 3 (Test No 7) PSD Results - Log Particle Size vs Mass Fraction Less Than Particle Size. Central Carolina Hospital (1990)

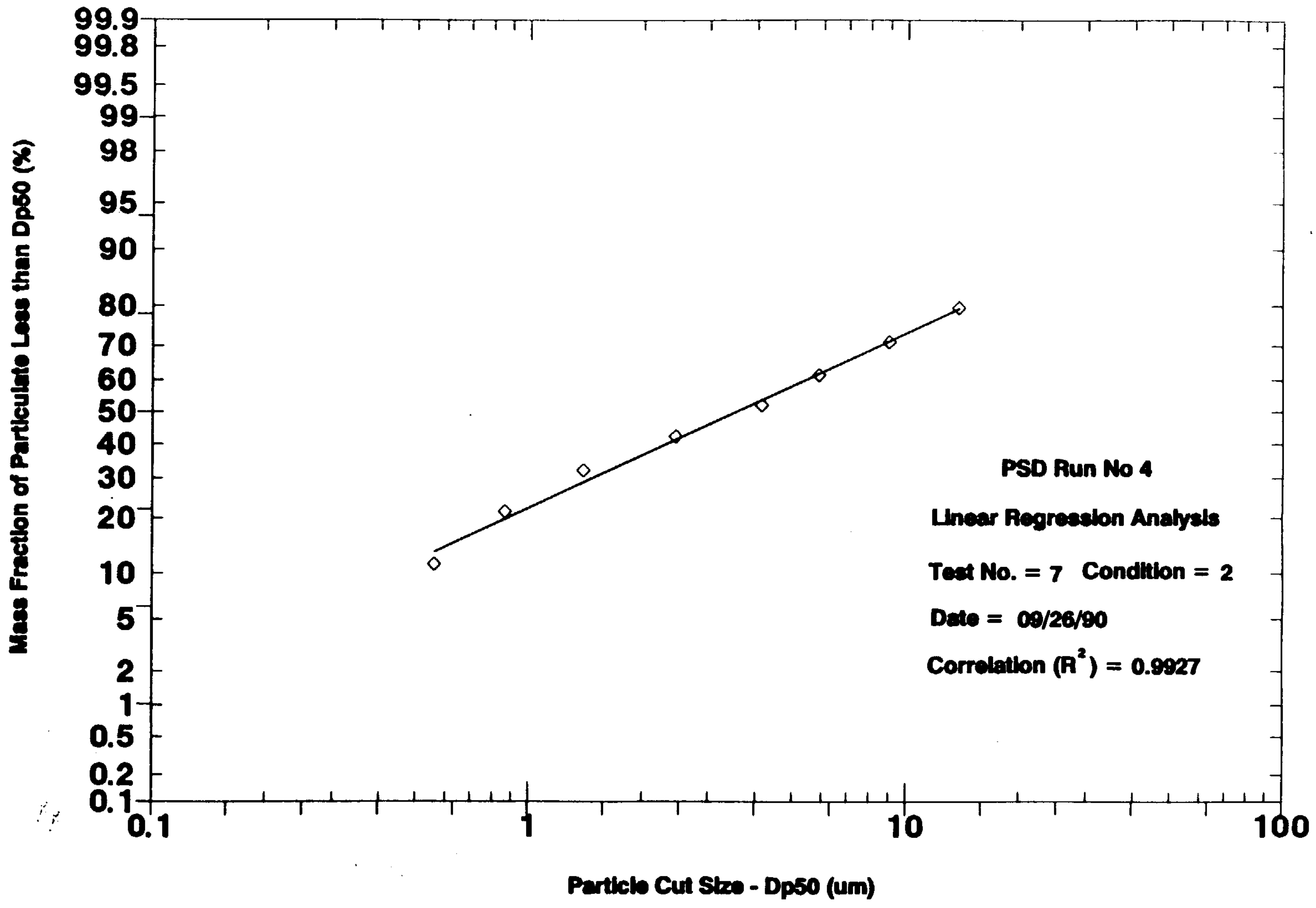


FIGURE 2-2. Run 4 (Test No 7) PSD Results - Log Particle Size vs Mass Fraction Less Than Particle Size. Central Carolina Hospital (1990)

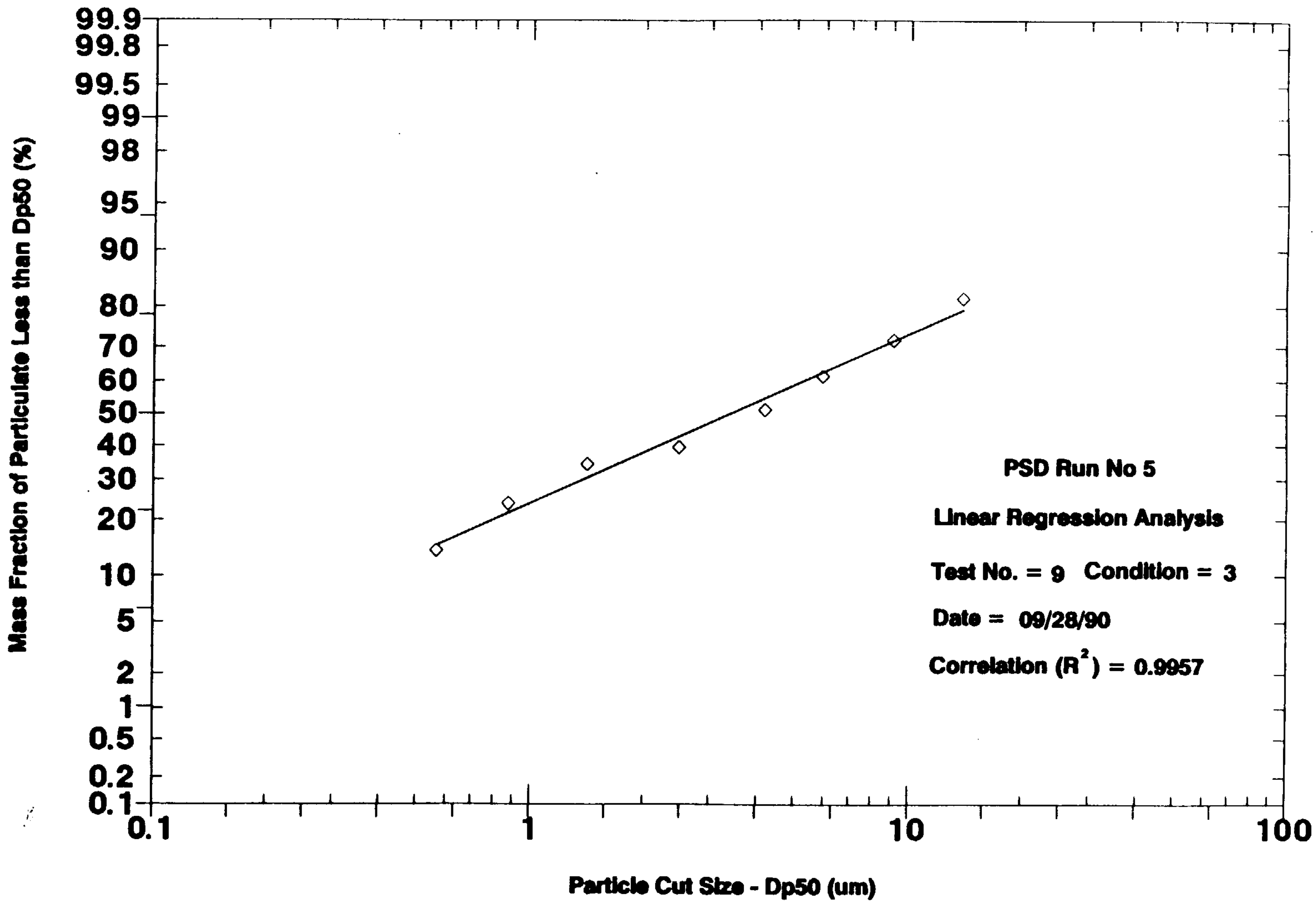


FIGURE 2-3. Run 5 (Test No 9) PSD Results - Log Particle Size vs Mass Fraction Less Than Particle Size. Central Carolina Hospital (1990)

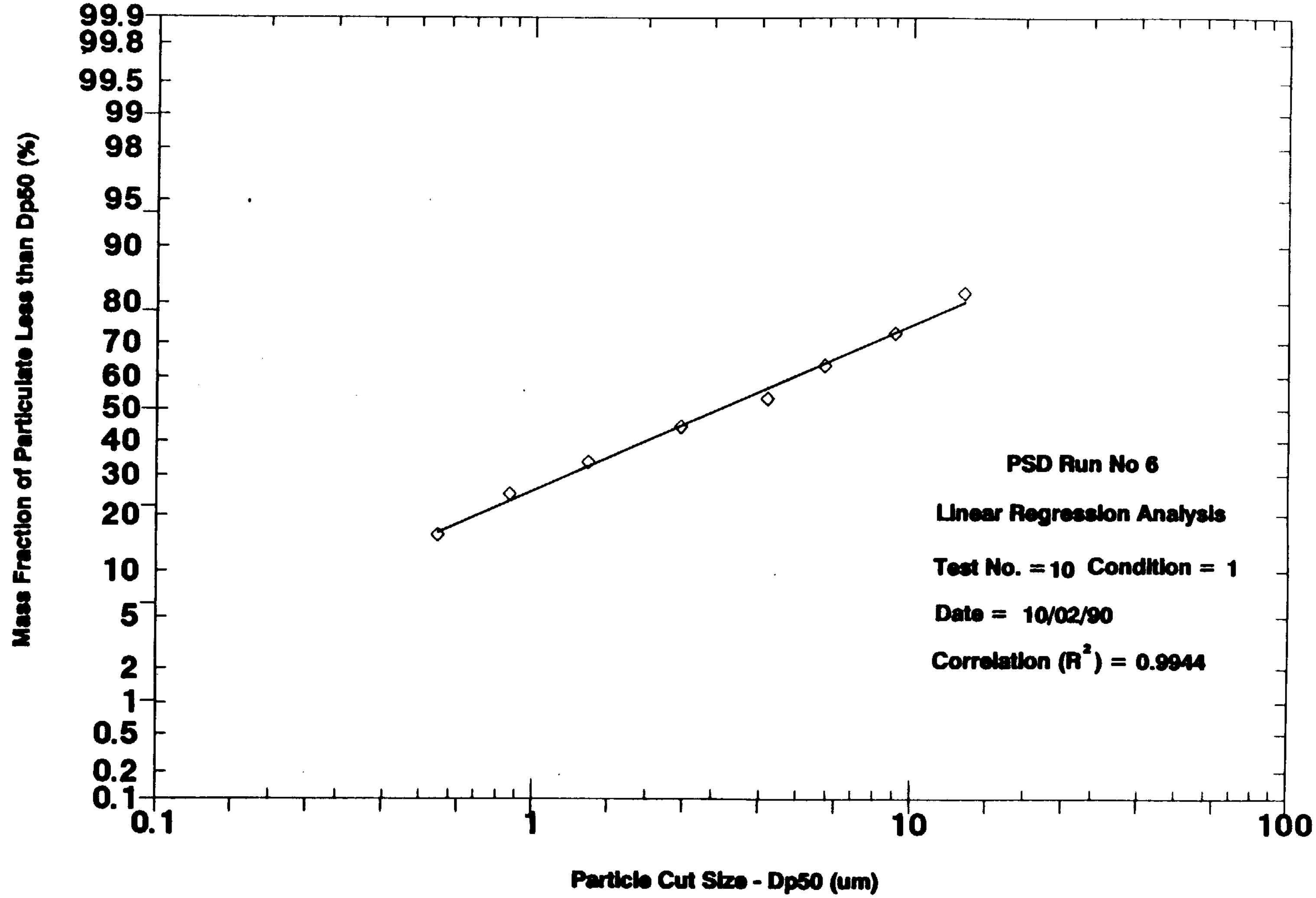


FIGURE 2-4. Run 6 (Test No 10) PSD Results - Log Particle Size vs Mass Fraction Less Than Particle Size. Central Carolina Hospital (1990)

TABLE 2-43. CDD/CDF STACK GAS CONCENTRATIONS AND 2378 TOXIC EQUIVALENT STACK GAS CONCENTRATIONS ADJUSTED TO 7 PERCENT O2 FOR CONDITION 1 INCORPORATING THE TOLUENE RECOVERY RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV. FACTOR	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 1	RUN 3	RUN 10	AVERAGE		RUN 1	RUN 3	RUN 10	AVERAGE
DIOXINS									
2378 TCDD	0.59	(1.221)	(0.349)	0.72	1.00000	0.588	(1.221)	(0.349)	0.719
Other TCDD	16.68	159.08	18.25	64.67	0.00000	0.000	0.000	0.000	0.000
12378 PCDD	1.40	4.69	1.14	2.41	0.50000	0.700	2.347	0.568	1.205
Other PCDD	14.76	130.98	18.47	54.73	0.00000	0.000	0.000	0.000	0.000
123478 HxCDD	0.91	4.59	1.37	2.29	0.10000	0.091	0.459	0.137	0.229
123678 HxCDD	1.41	7.45	2.72	3.86	0.10000	0.141	0.745	0.272	0.386
123789 HxCDD	2.99	14.28	4.05	7.11	0.10000	0.299	1.428	0.405	0.711
Other HxCDD	13.83	103.21	25.43	47.49	0.00000	0.000	0.000	0.000	0.000
1234678-HpCDD	8.02	42.62	20.06	23.56	0.01000	0.080	0.426	0.201	0.236
Other HpCDD	9.60	52.43	22.47	28.17	0.00000	0.000	0.000	0.000	0.000
Octa-CDD	9.62	54.75	25.57	29.98	0.00100	0.010	0.055	0.026	0.030
Total CDD	**79.8**	**575**	**140**	**265**		**1.909**	**6.681**	**1.957**	3.516
FURANS									
2378 TCDF	1.97	8.21	2.47	4.22	0.10000	0.197	0.821	0.247	0.422
Other TCDF	66.75	482.41	83.37	210.84	0.00000	0.000	0.000	0.000	0.000
12378 PCDF	2.99	11.53	3.74	6.09	0.05000	0.149	0.577	0.187	0.304
23478 PCDF	5.70	30.31	9.02	15.01	0.50000	2.852	15.156	4.511	7.506
Other PCDF	63.59	365.18	74.40	167.73	0.00000	0.000	0.000	0.000	0.000
123478 HxCDF	7.01	53.07	12.46	24.18	0.10000	0.701	5.307	1.246	2.418
123678 HxCDF	3.64	22.05	6.36	10.68	0.10000	0.364	2.205	0.636	1.068
234678 HxCDF	4.48	45.72	12.82	21.01	0.10000	0.448	4.572	1.282	2.101
123789 HxCDF	0.17	1.35	0.60	0.71	0.10000	0.017	0.135	0.060	0.071
Other HxCDF	21.60	150.10	41.92	71.21	0.00000	0.000	0.000	0.000	0.000
1234678-HpCDF	8.99	83.02	23.44	38.48	0.01000	0.090	0.830	0.234	0.385
1234789-HpCDF	1.12	12.85	5.17	6.38	0.01000	0.011	0.129	0.052	0.064
Other HpCDF	6.46	72.60	23.32	34.13	0.00000	0.000	0.000	0.000	0.000
Octa-CDF	5.41	84.72	36.81	42.31	0.00100	0.005	0.085	0.037	0.042
Total CDF	**200**	**1,420**	**336**	**653**		**4.84**	**29.8**	**8.49**	14.4
Total CDD+CDF	**280**	**2,000**	**476**	**918**		**6.74**	**36.5**	10.4	17.9

a ng/dscm = nanogram per dry standard cubic meter. Standard conditions are defined as 1 atm and 68° F.

b 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.

[ ] = minimum detection limit. ( ) = estimated maximum possible concentration.

TABLE 2-44. CDD/CDF STACK GAS CONCENTRATIONS AND 2378 TOXIC EQUIVALENT STACK GAS CONCENTRATIONS ADJUSTED TO 7 PERCENT O2 FOR CONDITION 2 INCORPORATING THE TOLUENE RECOVERY RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV. FACTOR	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 2	RUN 4	RUN 8	AVERAGE		RUN 2	RUN 4	RUN 8	AVERAGE
DIOXINS									
2378 TCDD	19.38	46.44	22.24	29.35	1.00000	19.385	46.442	22.237	29.355
Other TCDD	455.05	824.60	560.19	613.28	0.00000	0.000	0.000	0.000	0.000
12378 PCDD	60.21	181.92	112.93	118.35	0.50000	30.106	90.962	56.463	59.177
Other PCDD	398.94	1217.39	728.62	781.65	0.00000	0.000	0.000	0.000	0.000
123478 HxCDD	57.25	156.57	131.43	115.08	0.10000	5.725	15.657	13.143	11.508
123678 HxCDD	67.67	199.42	136.73	134.61	0.10000	6.767	19.942	13.673	13.461
123789 HxCDD	120.43	378.72	245.24	248.13	0.10000	12.043	37.872	24.524	24.813
Other HxCDD	557.79	1486.85	1056.77	1033.80	0.00000	0.000	0.000	0.000	0.000
1234678-HpCDD	321.62	811.76	760.44	631.27	0.01000	3.216	8.118	7.604	6.313
Other HpCDD	336.68	885.18	827.45	683.10	0.00000	0.000	0.000	0.000	0.000
Octa-CDD	417.74	614.12	952.82	661.56	0.00100	0.418	0.614	0.953	0.662
Total CDD	2,810	6,800	5,530	5,050		77.7	220	139	145
FURANS									
2378 TCDF	59.03	171.50	10.49	80.34	0.10000	5.903	17.150	1.049	8.034
Other TCDF	1757.26	4822.55	394.11	2324.64	0.00000	0.000	0.000	0.000	0.000
12378 PCDF	169.40	697.96	251.50	372.95	0.05000	8.470	34.898	12.575	18.648
23478 PCDF	235.72	826.53	321.24	461.16	0.50000	117.862	413.265	160.620	230.582
Other PCDF	2706.91	11130.98	3882.92	5906.94	0.00000	0.000	0.000	0.000	0.000
123478 HxCDF	505.16	2011.66	1049.81	1188.88	0.10000	50.516	201.166	104.981	118.888
123678 HxCDF	303.09	1268.23	636.07	735.80	0.10000	30.309	126.823	63.607	73.580
234678 HxCDF	296.98	900.89	558.40	585.42	0.10000	29.698	90.089	55.840	58.542
123789 HxCDF	21.02	78.82	38.56	46.13	0.10000	2.102	7.882	3.856	4.613
Other HxCDF	1730.97	6804.35	3601.04	4045.45	0.00000	0.000	0.000	0.000	0.000
1234678-HpCDF	803.30	2562.79	1782.03	1716.04	0.01000	8.033	25.628	17.820	17.160
1234789-HpCDF	121.46	309.63	227.63	219.57	0.01000	1.215	3.096	2.276	2.196
Other HpCDF	647.03	1798.33	1342.50	1262.62	0.00000	0.000	0.000	0.000	0.000
Octa-CDF	560.44	785.47	838.12	728.01	0.00100	0.560	0.785	0.838	0.728
Total CDF	9,920	34,200	14,900	19,700		255	921	423	533
Total CDD+CDF	12,700	41,000	20,500	24,700		332	1,140	562	678

a ng/dscm = nanogram per dry standard cubic meter. Standard conditions are defined as 1 atm and 68° F.

b 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.

[ ] = minimum detection limit. ( ) = estimated maximum possible concentration.

TABLE 2-45. CDD/CDF STACK GAS CONCENTRATIONS AND 2378 TOXIC EQUIVALENT STACK GAS CONCENTRATIONS ADJUSTED TO 7 PERCENT O2 FOR CONDITION 3 INCORPORATING THE TOLUENE RECOVERY RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV. FACTOR	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 5	RUN 6	RUN 9	AVERAGE		RUN 5	RUN 6	RUN 9	AVERAGE
DIOXINS									
2378 TCDD	0.66	(0.198)	2.05	0.97	1.00000	0.657	(0.198)	2.048	0.968
Other TCDD	51.72	10.08	119.00	60.27	0.00000	0.000	0.000	0.000	0.000
12378 PCDD	1.73	0.62	4.75	2.37	0.50000	0.867	0.310	2.375	1.184
Other PCDD	32.51	10.38	95.08	45.99	0.00000	0.000	0.000	0.000	0.000
123478 HxCDD	1.10	0.51	2.79	1.47	0.10000	0.110	0.051	0.279	0.147
123678 HxCDD	1.64	0.86	4.26	2.26	0.10000	0.164	0.086	0.426	0.226
123789 HxCDD	3.38	1.62	7.05	4.02	0.10000	0.338	0.162	0.705	0.402
Other HxCDD	21.63	10.50	50.28	27.47	0.00000	0.000	0.000	0.000	0.000
1234678-HpCDD	11.32	5.69	19.30	12.10	0.01000	0.113	0.057	0.193	0.121
Other HpCDD	12.23	6.66	23.28	14.06	0.00000	0.000	0.000	0.000	0.000
Octa-CDD	15.70	7.15	25.06	15.97	0.00100	0.016	0.007	0.025	0.016
Total CDD	154	54.3	353	187		2.264	0.872	6.051	3.062
FURANS									
2378 TCDF	3.12	0.78	9.41	4.44	0.10000	0.312	0.078	0.941	0.444
Other TCDF	117.35	26.13	363.91	169.13	0.00000	0.000	0.000	0.000	0.000
12378 PCDF	3.74	1.44	10.25	5.14	0.05000	0.187	0.072	0.513	0.257
23478 PCDF	6.39	2.52	15.99	8.30	0.50000	3.194	1.260	7.995	4.150
Other PCDF	57.97	22.23	208.09	96.10	0.00000	0.000	0.000	0.000	0.000
123478 HxCDF	8.30	4.32	19.85	10.83	0.10000	0.830	0.432	1.985	1.083
123678 HxCDF	4.29	2.16	10.42	5.62	0.10000	0.429	0.216	1.042	0.562
234678 HxCDF	5.93	3.42	13.78	7.71	0.10000	0.593	0.342	1.378	0.771
123789 HxCDF	0.30	0.16	0.67	0.38	0.10000	0.030	0.016	0.067	0.038
Other HxCDF	24.36	12.35	65.93	34.21	0.00000	0.000	0.000	0.000	0.000
1234678-HpCDF	16.27	7.66	27.48	17.14	0.01000	0.163	0.077	0.275	0.171
1234789-HpCDF	2.10	1.53	3.61	2.41	0.01000	0.021	0.015	0.036	0.024
Other HpCDF	12.14	6.21	21.08	13.14	0.00000	0.000	0.000	0.000	0.000
Octa-CDF	10.95	12.09	21.74	14.93	0.00100	0.011	0.012	0.022	0.015
Total CDF	273	103	792	389		5.77	2.52	14.3	7.51
Total CDD+CDF	427	157	1,150	576		8.03	3.39	20.3	10.6

a ng/dscm = nanogram per dry standard cubic meter. Standard conditions are defined as 1 atm and 68° F.

b 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.

[ ] = minimum detection limit. ( ) = estimated maximum possible concentration.

3.0 PROCESS DESCRIPTION AND OPERATION

3.1 FACILITY DESCRIPTION

Central Carolina Hospital is a 137-bed hospital located in Sanford, North Carolina. The medical waste incinerator (MWI) at this facility is a Consumat C-75-P with a design capacity of 176 pounds per hour (lb/hr) of Type IV (pathological) waste. The unit is also designed to burn general medical (nonpathological) waste at a rate of about 250 lb/hr. Two natural-gas-fired auxiliary burners in the primary chamber are used to maintain a pre-set minimum combustion temperature. Primary chamber temperatures normally range between 1200 and 1600°F. The hospital burns red bag waste, sharps containers, and a small amount of waste from nearby doctors' offices. Cafeteria waste, cardboard boxes, and general waste is compacted and landfilled.

The MWI is charged manually by opening a large refractory-lined charging door that opens at the front of the primary chamber. As a safety feature, the primary burners and blowers switch off automatically when the charging door is opened. The MWI is designed for 8 to 12 hours of operation each day, with ashes removed manually after cooldown.

The secondary chamber on this unit is sized for a design gas retention time of about 0.3 to 0.4 second. A gas-fired auxiliary burner in the secondary chamber is activated automatically when the temperature falls below a preset level, normally about 1600°F. Setpoint and actual temperatures in each chamber are displayed on a dial in the control panel.

Combustion air is supplied to the unit by two combustion air blowers, one for the primary chamber and one for the secondary chamber. The primary chamber blower supplies air to a plenum to which three separate air ducts are attached. One of these ducts supplies air to the combustion air ports inside the primary chamber. The 20 primary chamber air ports are equally spaced around the wall of the chamber, about 8 inches off the floor. The other two ducts supply air to the primary chamber burners. All three of these air ducts have manually adjustable dampers that are set at about

45 degrees (half way between totally open and totally closed) and were not moved during the test program.

The secondary chamber combustion air blower supplies air to the secondary burner and to the secondary chamber flameport area. The distribution of the airflow is controlled by a manual damper that was set at about 45 degrees and not adjusted during testing. The secondary chamber blower is on during operation of the MWI; there is no modulation of the airflow.

The Consumat "P"-designated MWI's are dual-mode units that are designed to burn either wet (pathological) or dry (general medical) waste. This is accomplished through the use of a "wet waste"-"dry waste" switch on the control panel door. The switch controls the operation of the primary chamber burners and the combustion air blowers. Teting was conducted with the unit operating in the "wet waste" mode for both types of waste. Burndown was set at 4 hours. The unit operates in the following manner while on the "dry waste" setting. During the initial warmup period, the primary chamber burners <u>and</u> blower are controlled by a timer that was set at 1.5 hours (adjustable up to 3 hours) <u>and</u> the temperature setpoint. If the temperature setpoint is reached before the timer has cut off, burners and blower shut off until the temperature falls to about 50°F below the setpoint, where both cut on again. Once the preset warmup time has elapsed, the burners shut off, but the blower operation is controlled by the temperature setpoint. If after 4 hours of operation, for example, the temperature falls 50°F below the setpoint, the blower (but not the burners) comes on until the setpoint is reached. The unit operates in this manner until burndown is completed. The secondary chamber blower runs continuously while the unit is in operation, and the burner cycles off and on based on the secondary chamber temperature setpoint.

The warmup timer is not operative in the "wet waste" mode. In this mode the primary chamber burners and blower always operate simultaneously. When started cold, the burners and blower run until the temperature setpoint is reached, then both cutoff. When the primary chamber temperature falls to 50°F below the setpoint, the burners and blower come back on. The unit operates in this manner until burndown is completed. The time for burndown is set by the burndown timer and is the same for both wet and dry settings. The secondary chamber blower is always on and the burner cycles off and on based on the secondary chamber temperature setpoint.

There is no add-on air pollution control device on this MWI. Because of the inadequate length of the original stack, a stack extension with sampling ports was added for the test.

The general medical waste burned during the test program was red bag waste generated by the hospital. Because the hospital does not generate sufficient pathological waste to charge at the target test condition, pathological waste was obtained from two research labs located in Research Triangle Park, North Carolina. This pathological waste, comprised of animal carcasses, was transported to the site in double plastic bags inside cardboard boxes.

3.2 PRETEST ACTIVITIES

The proposed test program at this MWI included operating the unit under three different operating conditions. Condition I was a reduced rate of pathological waste (about 100 lb/hr, 15 minute charges, 1900°F secondary chamber setpoint). Condition II was the design rate for general medical waste (about 250 lb/hr, 15 minute charges, 1600°F secondary chamber setpoint). Condition III was the design rate for pathological waste (about 160 to 170 lb/hr, 15 minute charges, 1600°F secondary chamber setpoint). A pretest trial burn was conducted for the two design conditions (Conditions II and III) to determine the operational readiness of the incinerator and the ability of the incinerator to operate successfully at the desired operating conditions. Because Condition I was defined as a "reduced" rate, it was decided that a pretest at this condition was not necessary if Condition III could be achieved.

3.2.1 Pretests--General Medical Waste

September 11, 1990

The purpose of this pretest was to investigate the operating procedures of the MWI and to verify that it could be successfully operated for a period of at least 4 to 5 hours at the waste charging rate specified for the test period. During this pretest, general medical waste was to be charged at a rate of about 240 to 250 lb/hr (60 lb/charge, 15 minute charging frequency). The secondary burner setpoint was 1600°F.

When Radian and MRI personnel arrived at the hospital at 9:00 am, the MWI was not operating and, when opened, it was obvious that the unit was cold and had not been operated for several days. Most of the loose ashes had been removed, exposing a 6- to 10-inch thick layer of solid, clinker-like material (slag) that had accumulated on the hearth.

Hospital personnel explained that, although Consumat representatives indicated that combustion capability of the unit would be improved if the air ports were routinely cleaned, the hospital employees were not familiar with the proper cleaning procedures. Loose ash was routinely cleaned out after each burn but the air ports were not cleaned.

At the request of EPA, removal of the slag was undertaken. By around 2 p.m. the slag had been removed from the hearth and 19 of the 20 air ports had been located and drilled out with a masonry drill bit. This was considered sufficient to allow the pretest activities to continue.

Soon after completing the cleaning activities, an attempt was made to fire up the unit to begin the preheat period. When the unit was switched on, the secondary burner and primary chamber blower came on, but the primary burners did not ignite. After some investigation, an engineering services employee from the hospital manually adjusted the reset timer, and one of the primary burners came on. Hospital personnel indicated earlier in the day that the second burner had not been functioning recently. This burner would not ignite despite repeated attempts. Further efforts to identify the problem with the second burner indicated that the relay that opens the main gas valve might be malfunctioning.

At about 3:30, the decision was made to proceed with the burning of some waste with only one burner on because the primary burners are not generally needed after the initial few charges have brought the temperature up in the primary. Sixty-pound charges were fed to the MWI every 15 minutes for the next 1.5 hours. At about 4:25, the incinerator operator had to leave, and a decision was made to load only 1 or 2 more charges and stop rather than locate another operator. The last charge was loaded at 4:52, and the last temperature was recorded at 5:07.

While a complete pretest was not performed during this visit, several important observations were made. It was agreed that a service technician (from Consumat, if possible) needed to be brought in to correct the problems with the inoperative primary burner and the reset timer and to calibrate the thermocouples. The accuracy of the thermocouples was questioned because the highest recorded secondary temperature was only about 1400°F. This is essentially the lowest that the gauge will read when the setpoint is 1600°F. The temperature gauge was, therefore, pegged at the bottom of the scale during the burn period. The primary chamber temperature went up to about 1500°F once during the burn. Based on previous experience and the fact that the MWI was burning exclusively high-plastic, red bag waste, this indicated that the recorded secondary chamber temperature seemed too low.

The unit operated reasonably well during the 1.5-hour burn. On the second charge, dense black smoke was emitted from the door seals, burner port assemblies, thermocouple wire conduits, and stack for a period of about 90 seconds. The smoke then gradually ceased. Subsequent charges did not cause a repeat of this heavy smoke, although while the charging door was open, there was a significant amount of smoke emitted from the door. When the door was closed, the unit operated without visible emissions.

The following actions were planned as a result of this pretest: (1) the hospital would attempt to arrange for a service technician to visit the site as soon as possible, (2) a tentative schedule of test-related activities for the next 2 weeks would be prepared for the hospital so that they could schedule the operators and the storage and burning of their waste, and (3) if possible, a complete pretest on medical waste would be conducted on Friday, September 14.

<u>September 14, 1990</u>

On Friday, September 14, 1990, a followup pretest was conducted at the hospital. The purpose of this pretest was to observe the repairs made to the MWI as a result of the problems that arose during the September 11, 1990, pretest visit. Southern Electronic Controls, Inc., had been contracted by Consumat to service and repair the unit.

The inspection and servicing of the MWI began by removing and checking the secondary chamber burner assembly. This unit was basically in good condition. A minor adjustment was made to the burner igniter so that a better spark would be produced. The burner assembly was then returned to the secondary chamber burner housing.

Each of the primary burners was then removed, inspected, and returned, with only minor adjustments to the igniters being required. The "flame rods," which detect the presence of a flame from the burner and keep the gas valve open, were also removed and cleaned.

The unit was then switched on and, as occurred on September 11, 1990, the secondary burner ignited, but the primary burners did not. A check of the switches and relays that control the operation of the burners followed. It was discovered that two of the lead wires in the control box were cross-wired. This error prevented the correct operation of the primary chamber burner timer. After the wiring problem was corrected, one primary burner ignited, but the other did not. The relay boxes for each burner were then inspected and a faulty relay was found that prevented the gas valve from opening on the inoperative burner. The relay was removed and cleaned, the contact points were realigned, and the unit was replaced. Upon restarting the unit, all burners ignited.

Although the equipment necessary to check the accuracy of the thermocouples was not available, the upper and lower thermocouple assemblies were removed and inspected. It was found that the upper unit was wired backwards and that some of the insulation had chipped off. The result of these problems was that the secondary chamber thermocouple did not work at all. After the unit was rewired, the indicated temperature fluctuated drastically because of the damage to the insulation. Therefore, a new thermocouple was installed. The lower unit appeared to operate properly.

After these repairs had been completed, the unit was restarted and appeared to operate as designed. Red bag waste was charged to the MWI at a rate of 200 to 240 lb/hr (50 to 60 lb/charge, with a 15-minute charging frequency) for about 4 hours. All of the MWI systems (burners, thermocouples, timers, and temperature displays) seemed to be operating properly; however, an accumlation of material in the primary chamber indicated that the charging rate might be too high.

The extent of the repairs that were required for this MWI were unexpected. The problems at this unit appear to have been compounded by a lack of routine maintenance, recent changes in hospital personnel, and the fact that the operation of the unit and the maintenance of the unit are under two different departments in the hospital administration. It became apparent during the September 11, 1990, pretest that certain basic repairs to the unit would be necessary prior to operating the unit in a manner that would be considered "typical" of 6- to 10-year-old units.

The current Director of Engineering at the facility was aware that the MWI was not in good working condition and was anxious for the unit to be repaired. Other hospital personnel appeared to be interested in learning about the proper operation and maintenance of the unit. It appears that the operating condition of this unit was poor, but that most of the problems were easily corrected and that proper attention by hospital staff is needed.

September 18, 1990

The target charge rate was revised based on observations made during the September 14, 1990, pretest. The purpose of this pretest was to confirm that the MWI could be operated at this revised target test condition (200 lb/hr; 50 lb every 15 minutes; secondary chamber setpoint of 1600°F) for at least 5 hours. Red bag medical waste generated at the hospital was charged to the unit during this pretest.

The MWI was cleaned out and allowed to preheat for about 15 minutes prior to loading the first charge. At 11:15 am, the first charge of the day was placed in the incinerator. Temperature readings were taken immediately after the loading door was closed and at 5-minute intervals thereafter. Between 11:15 am and 4:15 pm, 19 charges ranging from 45.3 to 56.7 lb were loaded into the MWI at 15-minute intervals.

The following observations were made during the pretest burn:

1. The temperature in the primary chamber climbed to about 1300°F (the setpoint) in about 30 minutes, and after about 1 hour it had reached 1500°F. The temperature stayed between 1400° and 1500°F for the remainder of the burn period.

2. The secondary chamber temperature was very erratic and was influenced greatly by the charging cycle and the condition of the primary burners/blowers. When the

primary burners are on, the secondary chamber temperature peaks are much higher than if the primary burners are off. The secondary chamber temperature peaks about 5 minutes after each charge, and the peaks tended to get higher after the unit had been operating for several hours. Very high peaks also occurred during the first hour while the primary burners were operating.

3. Near the end of the burn period, the ash bed in the unit had become so high that it was causing some difficulty in loading additional waste. Flames and dense black smoke came out when the charging door was opened, and large bags were difficult to load because the ash bed restricted access to the interior of the unit.

4. The unit appeared to operate well during the pretest; there was very little smoke from the stack, the temperatures were fairly stable within the expected range, and the burners/blowers cycled off and on as expected. The most obvious problem observed during the pretest was the continuing accumulation of material in the primary chamber. It was apparent that the unit was not capable of burning the waste completely at the charge rate being used. By the end of the burn period, the primary chamber was so full that it was difficult to charge.

When the incinerator was opened the following morning a large accumulation of hot, smoldering material was found in the primary chamber. Burnout was poor in terms of quality and quantity. The material flamed up immediately when efforts to remove it began. As was the case with other MWI's tested, this unit appears to be significantly overrated in terms of the quantity of red bag waste that can be burned per hour. Therefore, the charge rate for actual testing was further reduced to 160 lb/hr.

3.2.2 Pretests--Pathological Waste

September 19, 1990

The purpose of this pretest was to determine if the MWI could be operated at the target test condition (160 lb/hr; 40 lb every 15 minutes; 1600°F secondary chamber setpoint) for at least 4 hours. Pathological waste was charged to the unit during this pretest.

After the ash had been removed, the unit was allowed to preheat for about 40 minutes before charging began. The first charge was loaded into the unit at 1:20 pm.

The first few boxes ranged from 43 to 57 lb in weight. It was decided that 20-minute charging cycles would be used because the boxes were somewhat heavier than expected and no one believed that the boxes should be opened. The target feed rate was changed to about 55 lb every 20 minutes.

Because of the size of the large boxes, it was very difficult to load two in the same charge. The first box ignited and flamed out the door before the second could be pushed through the charging door. (The boxes are 16 in. x 16 in. x 30 in., generally weigh 25 to 50 lb, and must be placed through a waist-high opening about 24 in. x 24 in.) After the first charge, the loads consisted of one large box and two to six smaller boxes to total near the target weight. The smaller boxes could be tossed far enough into the unit to allow charging of the one large box.

After about an hour, the temperatures leveled out around the setpoints. Deviations occurred with each charge but were generally small and brief. After about 3 hours, the primary burners cycled off and on occasionally but the temperature stayed between 1475° and 1525°F. Each time the primary burners cut off, the secondary temperature fell sharply to the 1400° to 1450°F range. Within a few minutes, the primary burners came back on, and the increased airflow caused the secondary chamber temperature to return to the 1600° to 1625°F range.

The unit operated in this pattern until charging was completed at 5:20 (out of waste). There do not appear to be any temperature limitations that would affect the duration of the burn period. The waste bed inside the unit appeared to have good burnout; only a moderate amount of buildup from the 608 lb of waste charged remained. The other possible limitation is the size/weight of the boxes. The amount of variation in the weight of the boxes may cause the individual charges to vary, but attempts were made to maintain the target rate on a per hour basis.

During the period from 1:20 to 5:20 pm, 608 lb of waste were burned (three charges per hour for 4 hours) at an average rate of about 152 lb/hr. During the actual test period, the maximum target rate will be slightly higher. The "reduced rate" test will be conducted with a target rate of about 100 lb/hr. Neither of the pathological waste conditions are believed to present an operational problem.

3.3 PROCESS CONDITIONS DURING TESTING

The primary purpose of this source test was to characterize the uncontrolled emissions from a pathological MWI when both pathological waste and general medical waste are burned. Therefore, all testing was conducted with the unit operating in the "wet-waste" (pathological) mode. Also, this facility is typical of the size and design of many existing units in which pathological wastes are burned.

The incinerator appeared to operate properly throughout all the test runs for all three test conditions. The burnout, however, was visibly good only for the 100 lb/hr pathological waste condition and was very poor for the 160 lb/hr pathological waste condition and the 160 lb/hr medical waste condition.

The incinerator operating parameters monitored during each test run were the charge weight, charge frequency, type of waste, primary and secondary chamber temperatures, actual times the burners and blowers were on, and ash weights. A data logger was used to record all the above parameters except for the charge weight, type of waste, and ash weight, 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 3-10 show the temperature profiles for each run. A summary of each test run is given below.

3.3.1 Condition I, Run 1 (Test Run 1)

For this condition, the target operating parameters were a charge of 100 lb/hr of pathological waste in 25-lb charges every 15 minutes and a secondary chamber temperature setpoint of 1900°F. The controller setpoints for the three runs at this condition were: primary chamber burner on/off temperature, 1500°F; primary chamber blower on/off temperature, 1500°F; secondary chamber burner on/off temperature, 1900°F; burndown time, 3 hours.

Thursday, September 20, 1990: The hearth was cleaned and the air ports cleared in preparation for the test. Preheat began at 1:40 p.m., and testing began when the first charge was introduced at 2:00, in keeping with the typical warmup time of this facility. This was also the recommended minimum warmup time by Consumat.

TABLE 3-1. PROCESS DATA SUMMARY FOR EMISSIONS TESTING AT AMI CENTRAL CAROLINA HOSPITAL

Test Run No.	Test Date	Target Test Conditions					Daily Operation (a)					Actual Test Conditions (b)							
		Charge Rate		Charge Type (c)	Charge Freq (min)	Secondary Chamber Setpoint Temp (F)	Preheat time (min)	Charge Time before test (min)	Hours of Charging (hr/d)	Total Waste Charged (lb/d)	Ash (% of Waste Charged)	Charge Rate		Charge Freq (min)	Avg Primary Chamber Temp (F)	Avg Sec. Chamber Temp (F)	Stack Gas Conditions		Avg gas Res. time in Sec Chamb (d) (sec)
		(lb/hr)	(lb/chrg)									(lb/hr)	(lb/chrg)				Flow Rate (acfm)	Avg Temp (F)	
1	9/20/90	100	25	P	15	1900	20	0	4.3	503	4.2	106	36	20	1418	1485	2425	752	0.12
2	9/21/90	160	40	H	15	1600	20	0	6	1016	13.7 (e)	163	41	15	1397	1734	2270	809	0.11
3	9/22/90	100	25	P	15	1900	20	0	4.5	588	3.8	118	45	23	1499	1499	2201	759	0.13
4	9/23/90	160	40	H	15	1600	20	0	6.1	905	19.1 (e)	153	39	15	1555	1576	2383	779	0.11
5	9/24/90	160	40	P	15	1600	20	0	4.1	675	6.7 (e)	169	48	17	1444	1481	2423	746	0.12
6	9/25/90	160	40	P	15	1600	20	0	4.1	697	5.9	144	46	19	1421	1462	2233	725	0.12
7	9/26/90	160	40	H	15	1600	20	0	4.5	769	19.1 (e)	163	41	15	1297	1669	(f)	(f)	(f)
8	9/27/90	160	40	H	15	1600	20	0	4.3	727	18.9 (e)	161	40	15	1458	1691	2383	766	0.11
9	9/28/90	160	40	P	15	1600	20	0	4.8	867	8.9	168	42	15	1445	1523	2556	771	0.11
10	10/2/90	100	25	P	15	1900	20	0	4.3	454	3.8	100	28	17	1445	1474	2272	749	0.12

(a) From start-up until burndown is initiated.

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

(c) P = Pathological waste and H = Hospital waste.

(d) Residence time is based on the secondary chamber volume of 0.21 m3 (7.5 ft3) and is calculated as follows for Run 1:

$$\text{Res. time, sec} = \frac{(7.5\ \text{ft3})(60\text{s/min})(752+460\text{R})}{(2425\ \text{acfm})(1485+460\text{R})}$$

(e) Ash was wet due to quenching.

(f) Not reported because Run 7 was invalidated.

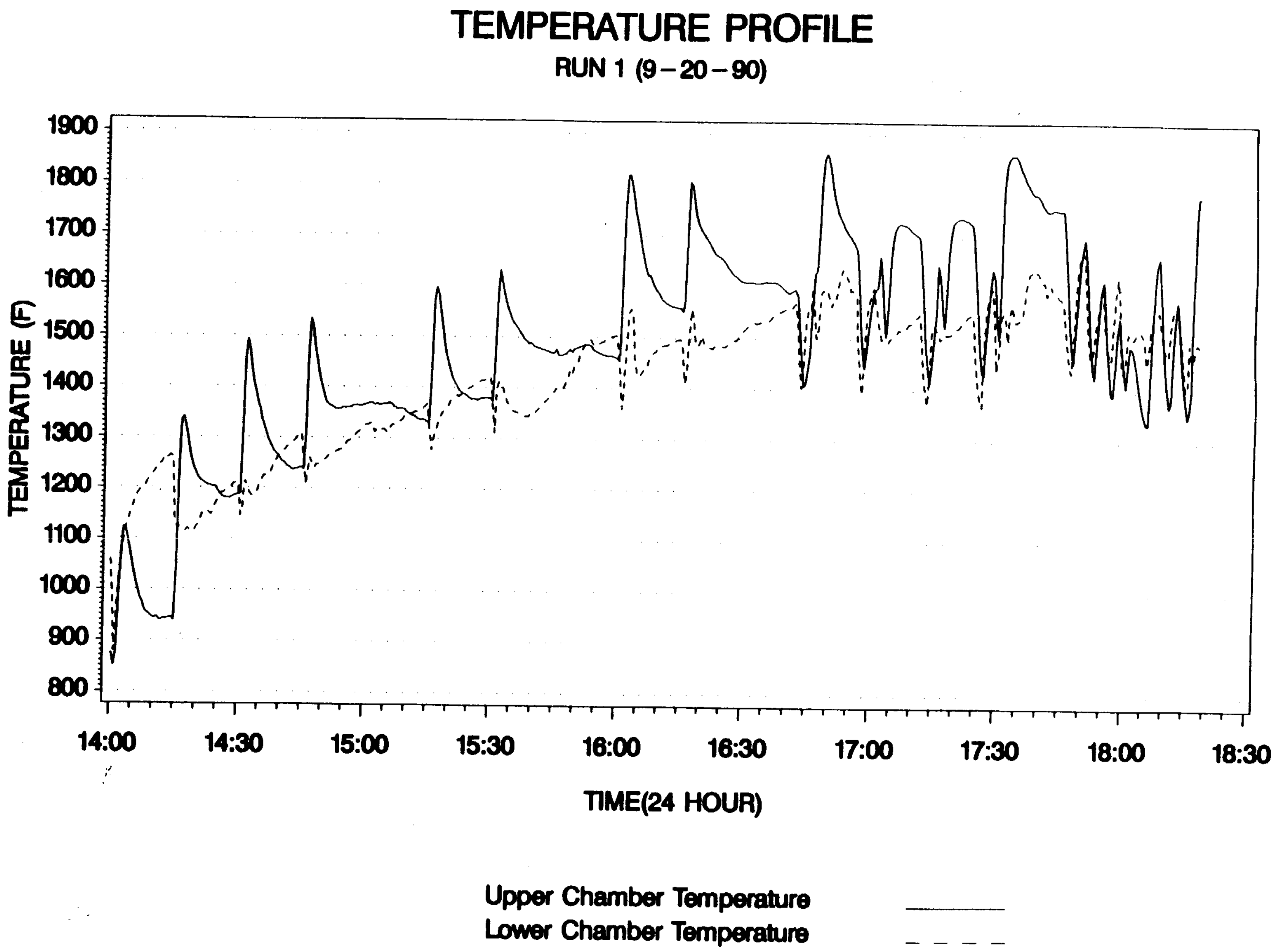


Figure 3-1. Temperature Profile for Run 1

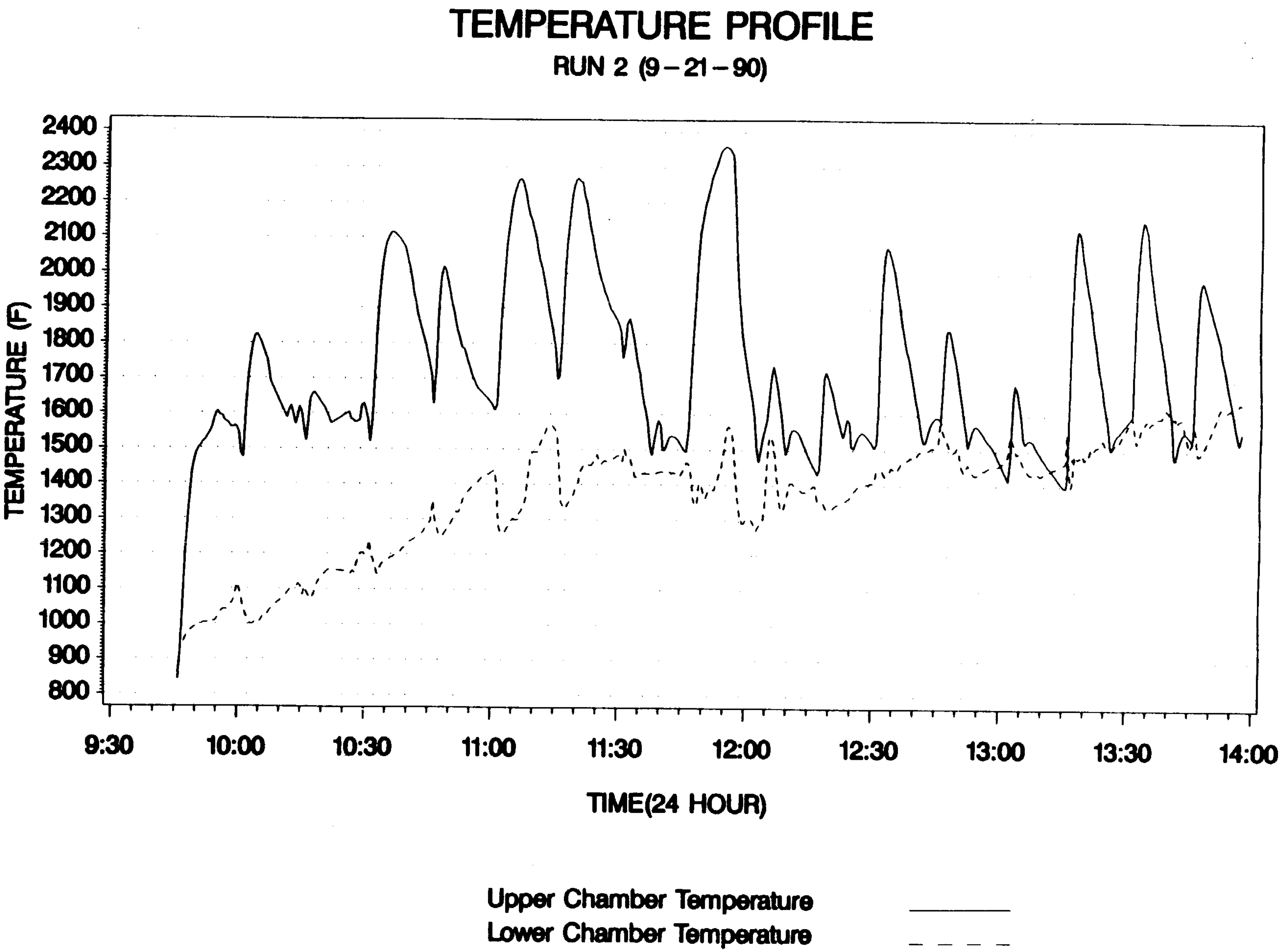


Figure 3-2. Temperature Profile for Run 2

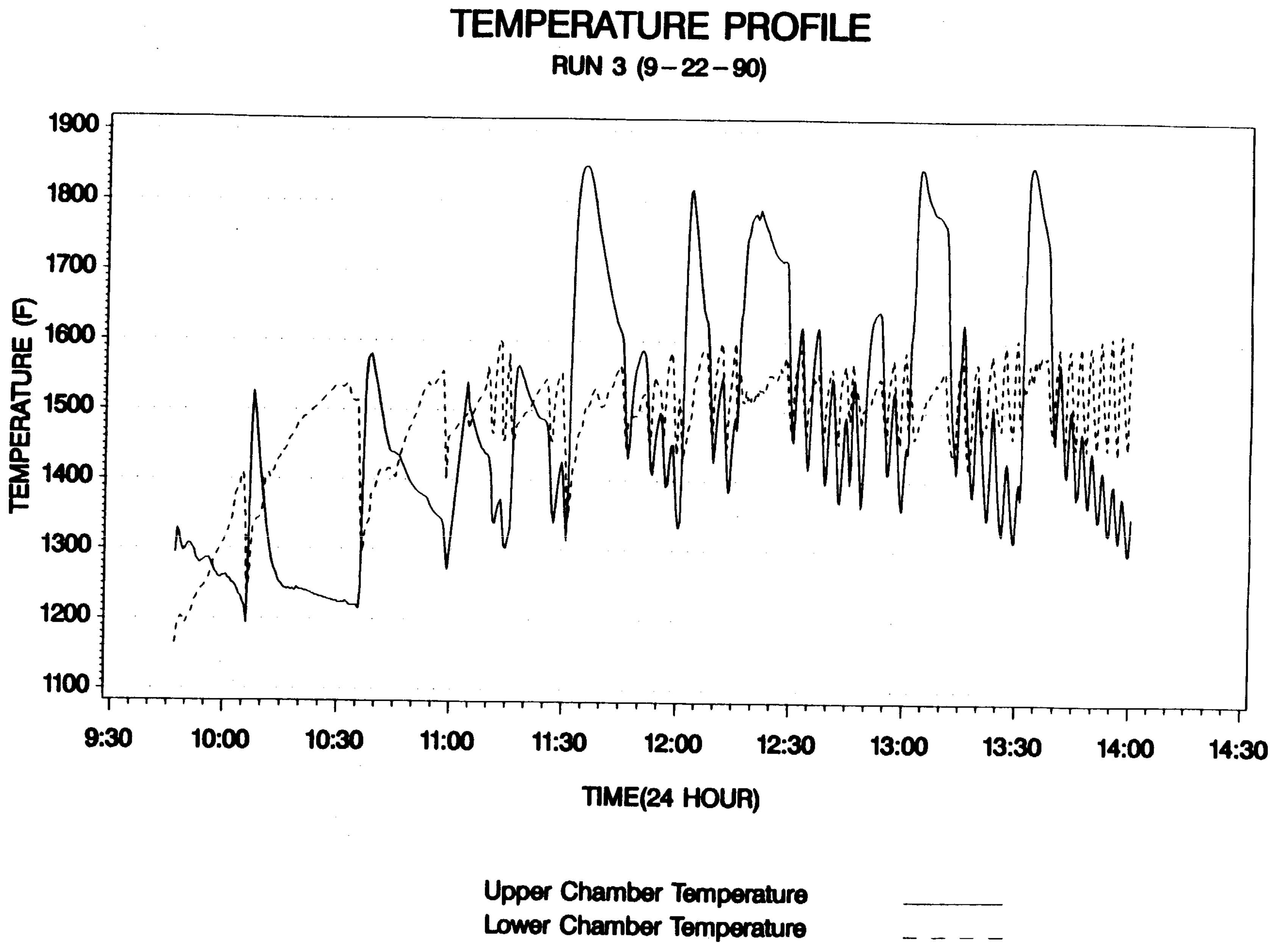


Figure 3-3. Temperature Profile for Run 3

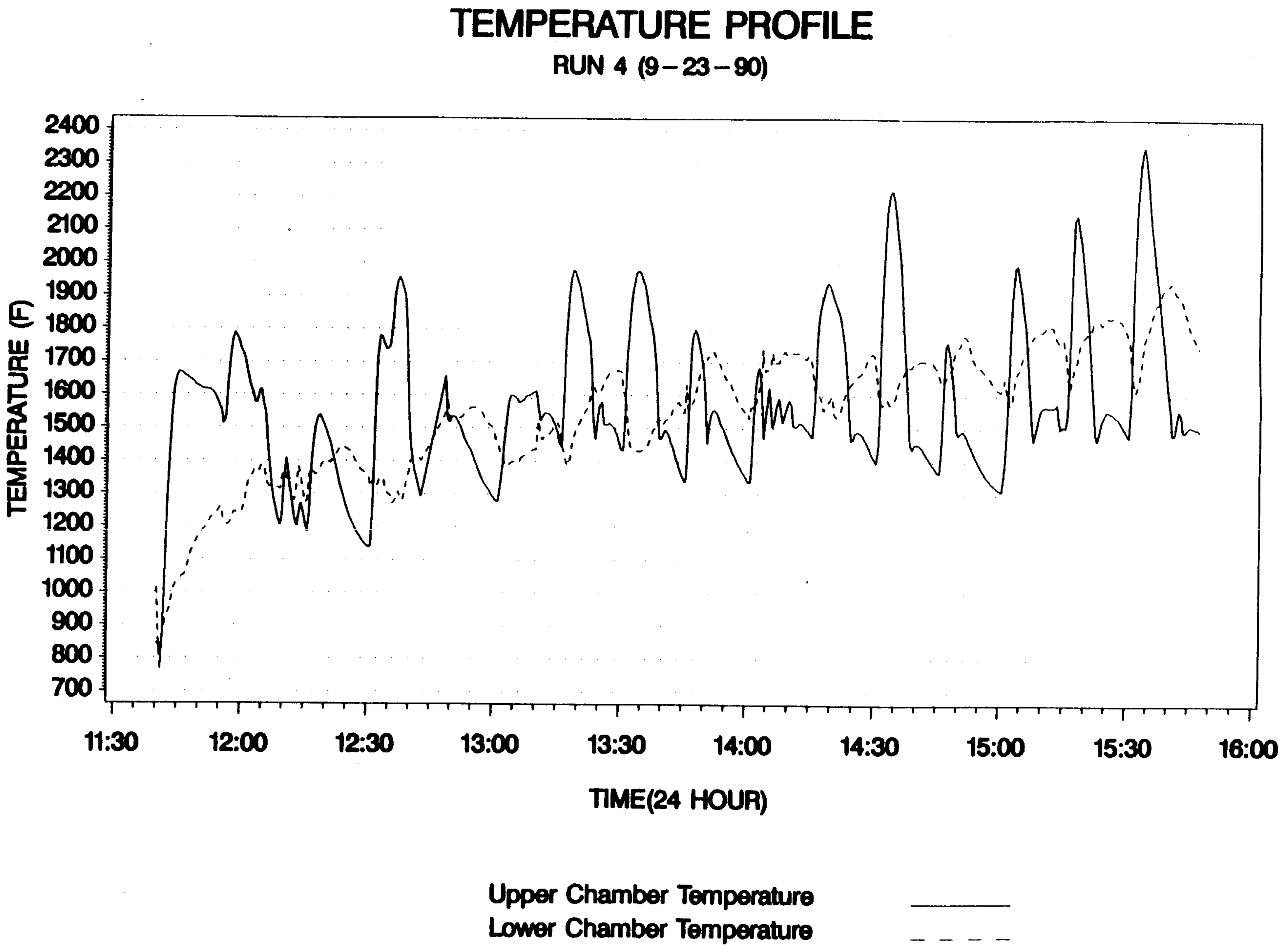


Figure 3-4. Temperature Profile for Run 4

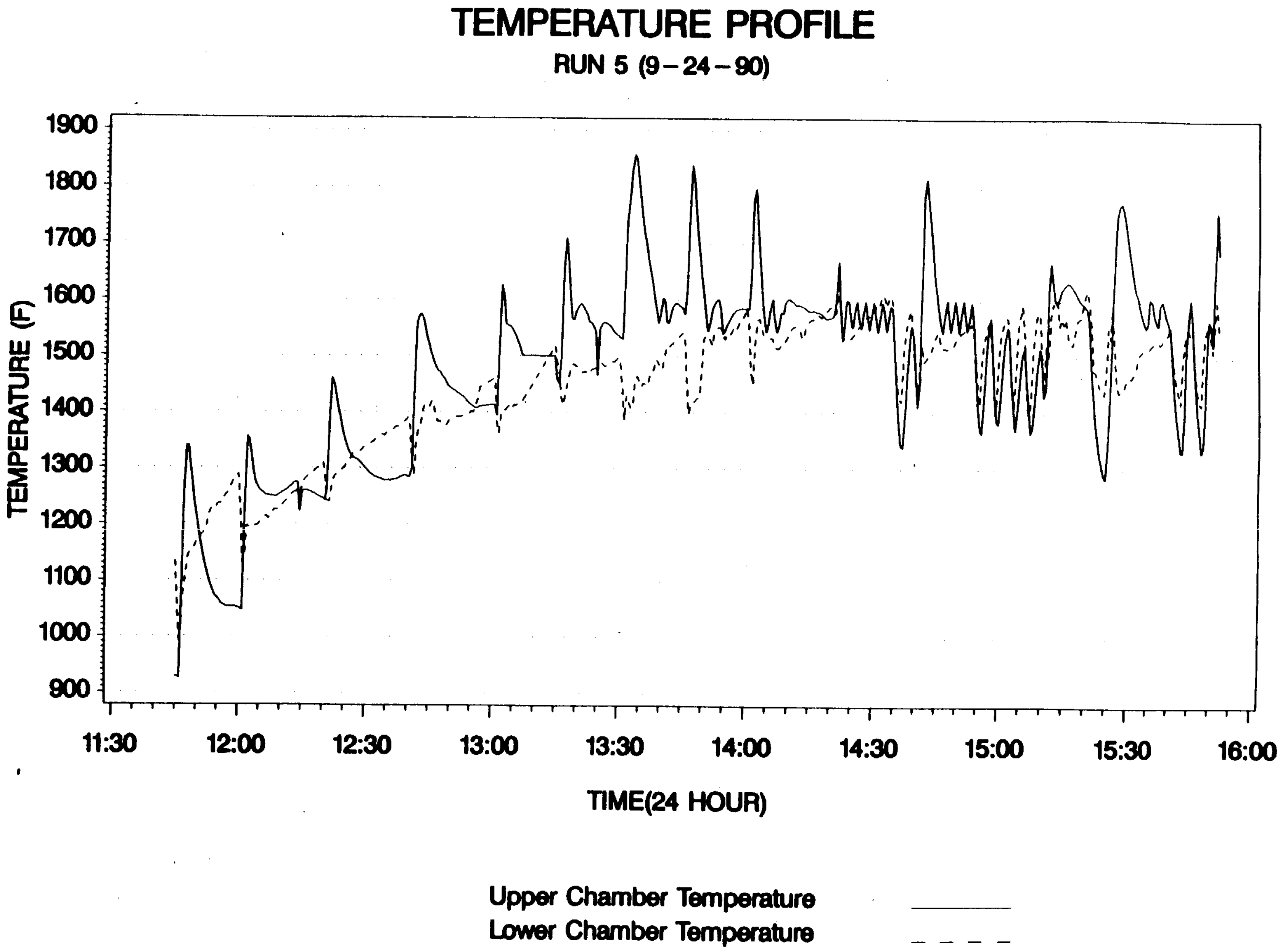


Figure 3-5. Temperature Profile for Run 5

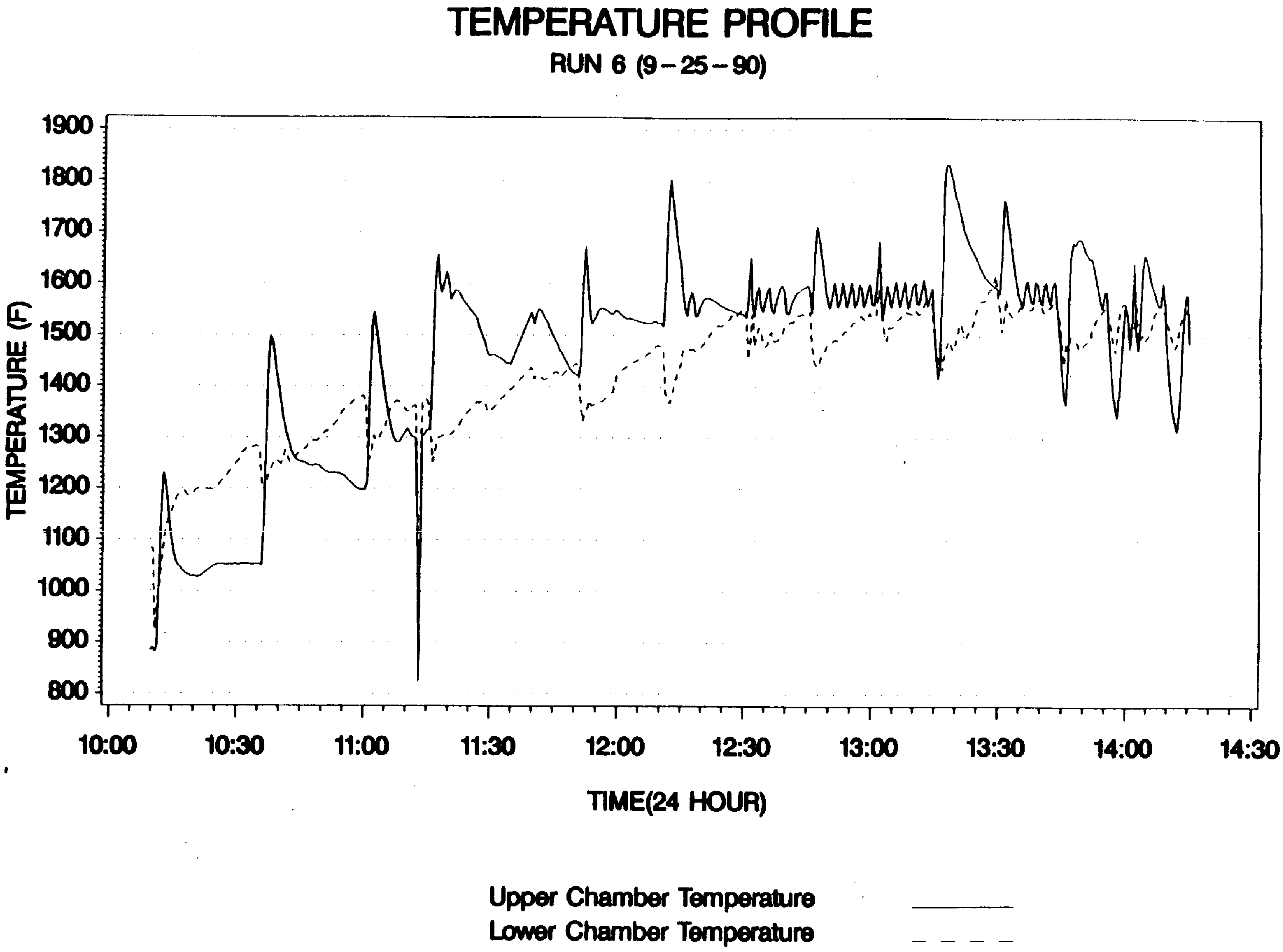


Figure 3-6. Temperature Profile for Run 6

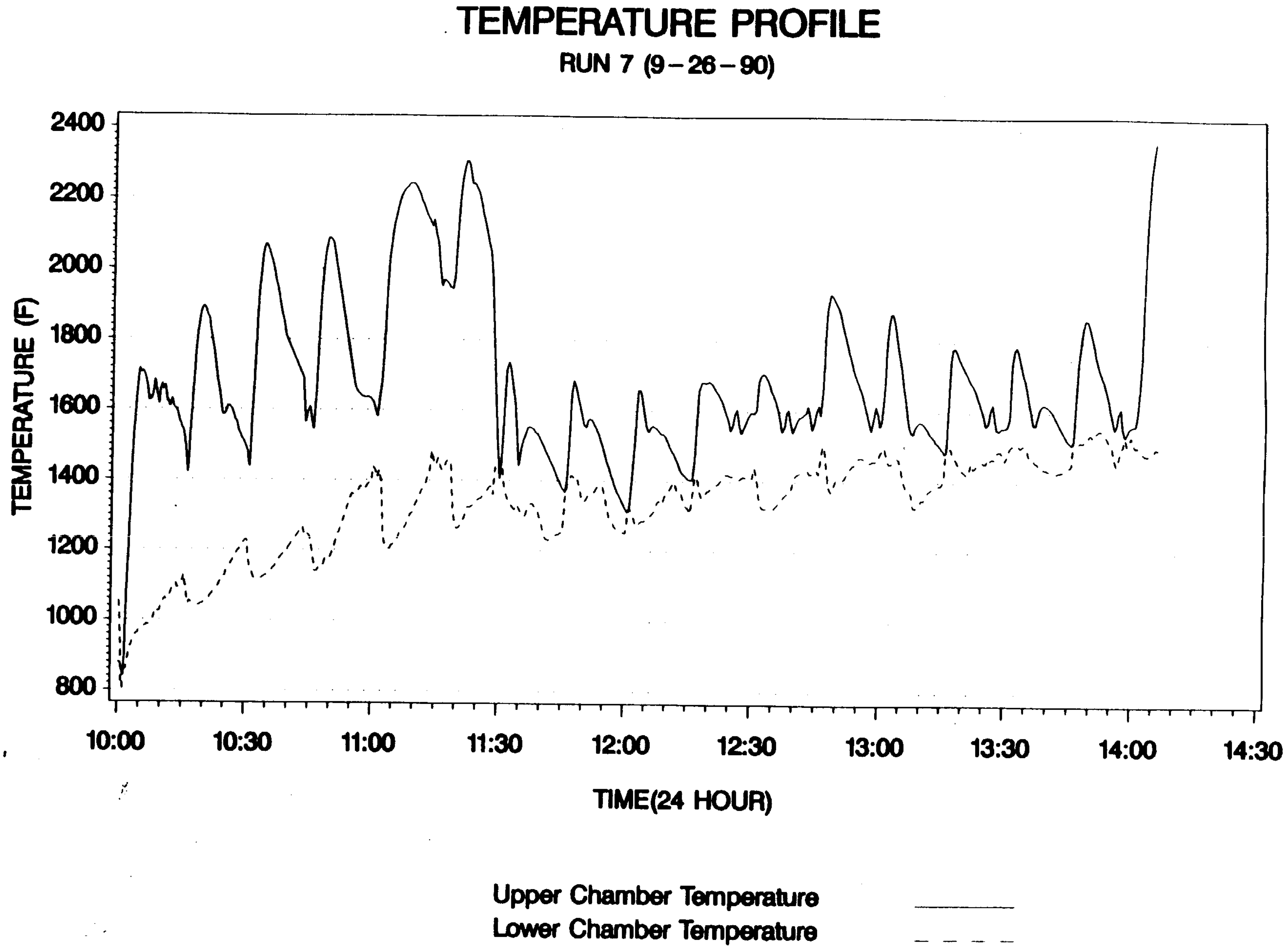


Figure 3-7. Temperature Profile for Run 7

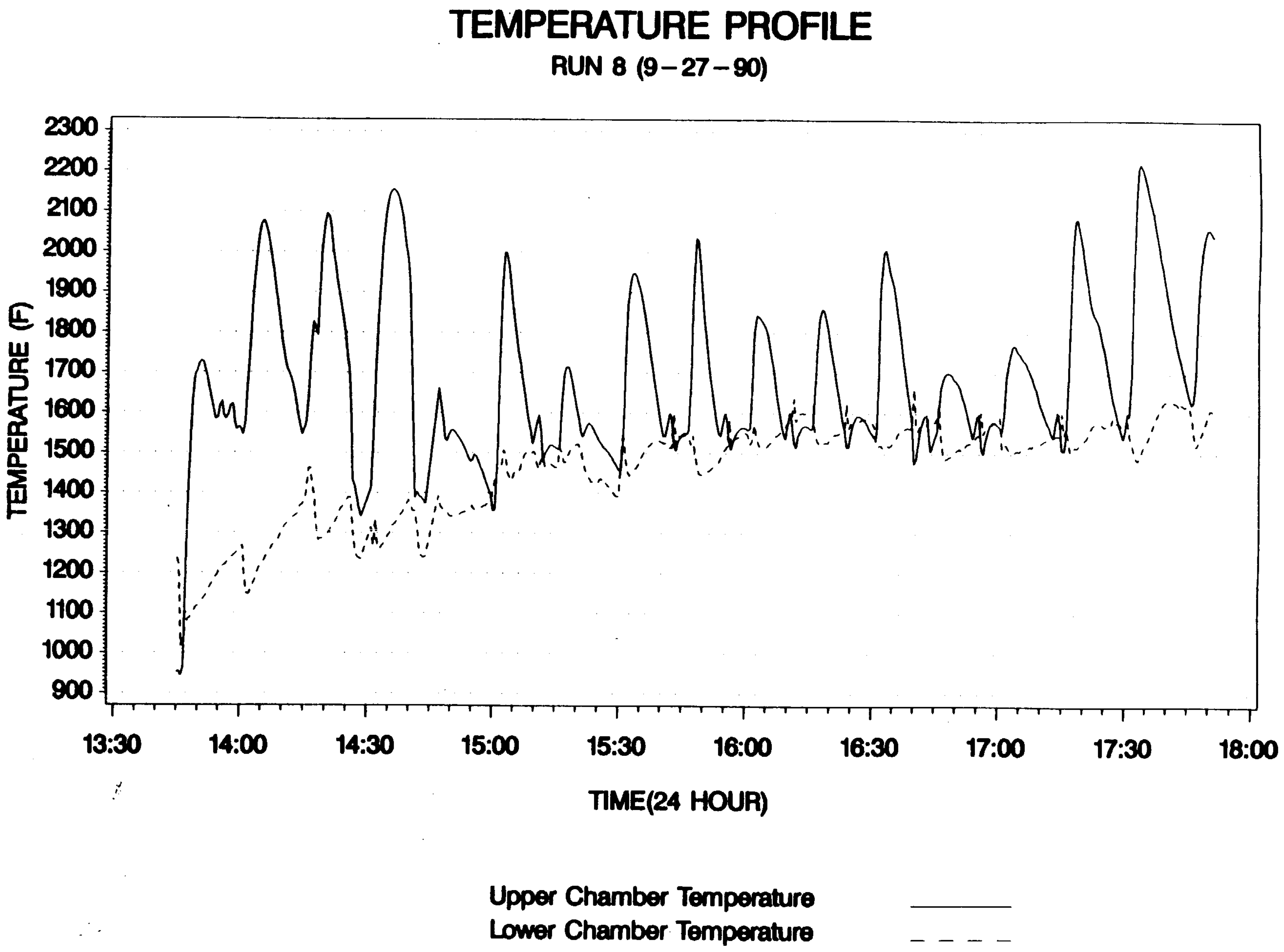


Figure 3-8. Temperature Profile for Run 8

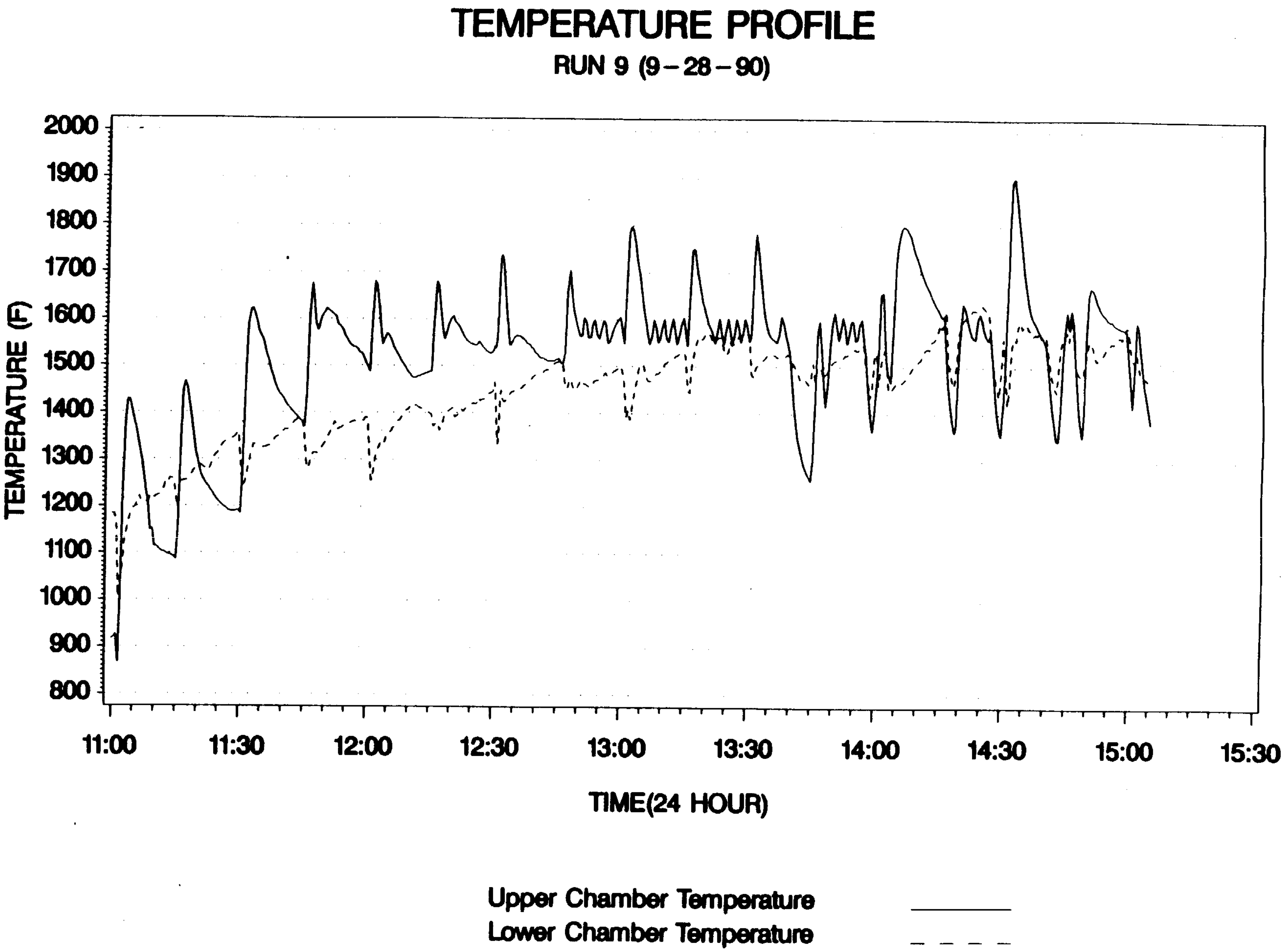


Figure 3-9. Temperature Profile for Run 9

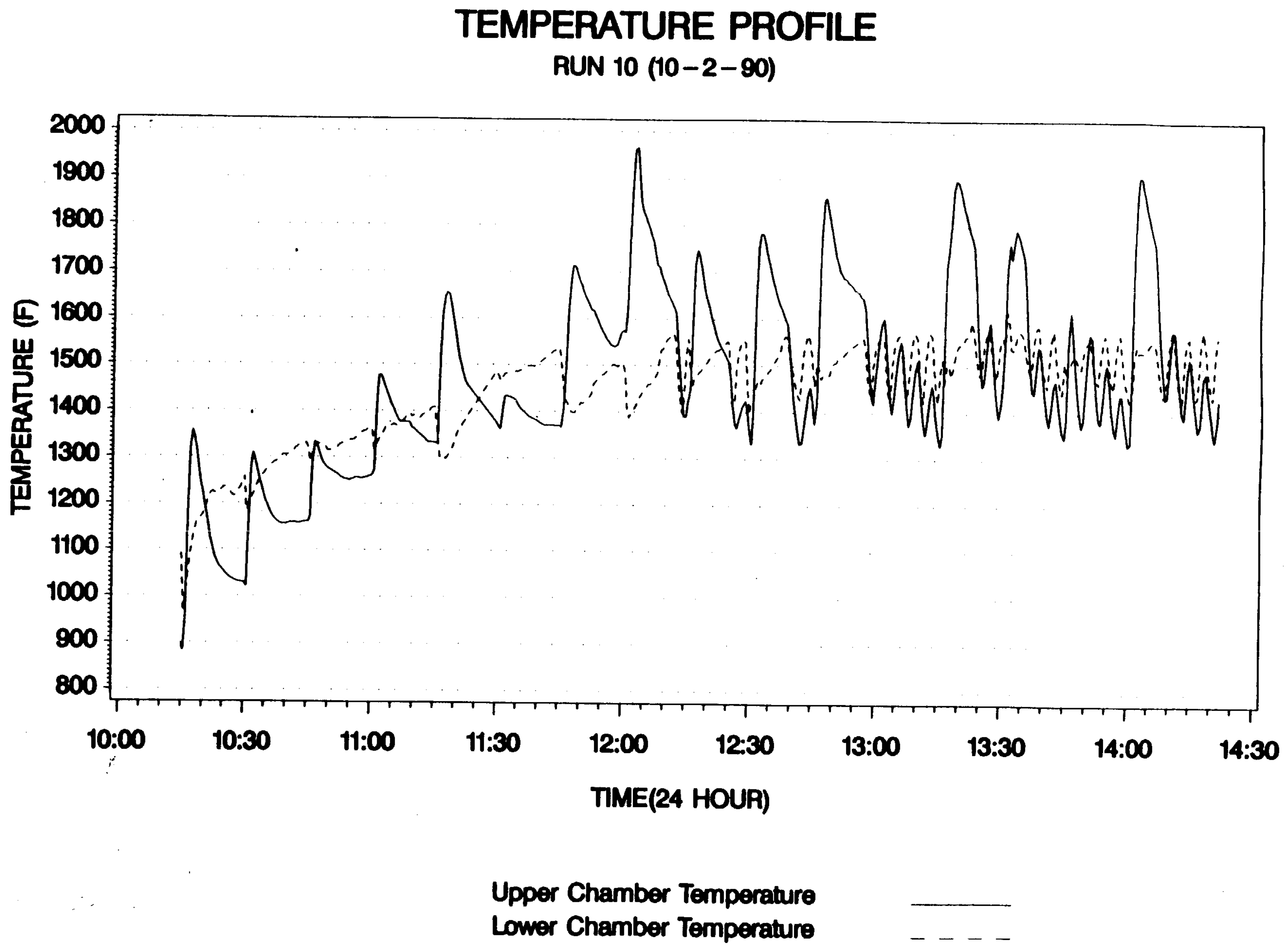


Figure 3-10. Temperature Profile for Run 10

The incinerator ran smoothly with no problems. Because of the weight of the large boxes of pathological waste, the charging frequency had to be varied in order to maintain a charge rate of approximately 100 lb/hr. The primary chamber temperature leveled out at approximately 1500°F at 4:15. After approximately 1 hour of operation, the secondary chamber had reached a temperature of 1500°F and then cycled between a temperature of 1500°F and 1800°F for the remainder of the test. The incinerator secondary chamber temperature approached the setpoint temperature of 1900°F only once, at 5:33, when the temperature reached 1898°F.

The secondary chamber burner appears to be too small to consistently maintain a temperature greater than the primary chamber temperature while burning a low-Btu, high-moisture waste.

The last charge was introduced at 6:15, and testing was completed at 6:20.

The incinerator was opened the following morning (September 21, 1990) at 7:15, with ash cleanout beginning at 8:08 and being completed at 9:05. There was fairly good burnout of the waste, with only a few clumps of smoldering, unburned material. All of the ash was removed.

The total waste charged was 503.4 lb, and the total ash weight was 21.2 lb. The actual feed rate was 106 lb/hr, and the percent burndown was 95.8.

3.3.2 Condition II, Run 1 (Test Run 2)

For this condition, the target operating parameters were a charge of 160 lb/hr of general medical waste (red bag) in 40-lb charges every 15 minutes, with a secondary chamber temperature setpoint of 1600°F. The controller setpoints for these three runs at this condition were: primary chamber burner on/off temperature, 1500°F; primary chamber blower on/off temperature, 1500°F; secondary chamber burner on/off temperature, 1600°F; burndown time, 3 hours.

Friday, September 21, 1990: The hearth was cleaned and the air ports cleared before testing began. Preheat began at 9:25, and testing began with the first charge at 9:45. The incinerator ran smoothly with no major problems. At 11:25, the primary chamber temperature setpoint was changed from 1500°F to 1400°F in order to limit the temperature increase in the secondary chamber just after the charging cycle. With the primary chamber burners and blower still on just after the charging cycle, the secondary chamber temperature was climbing above 2300°F. At 11:56, the primary chamber temperature setpoint was changed again to 1300°F. After this change, the primary chamber burner remained off for the remainder of the test, and the secondary chamber temperature remained between 1300°F and 2100°F.

Testing was completed at 2:37 pm, and the last charge was introduced at 3:45.

The incinerator was opened the following morning (September 22, 1990) at 6:45, with ash being removed starting at 7:33. There was a large amount of unburned, smoldering material remaining in the incinerator; this material burst into flame upon agitation. The ash bed had to be quenched with water in order to complete the ash removal. Ash removal was completed at 9:12.

The total waste charged was 1,015.8 lb, and the total wet ash weight was 139 lb. The actual feedrate was 162.5 lb/hr.

3.3.3 Condition I, Run 2 (Test Run 3)

The target operating parameters were a charge rate of 100 lb/hr pathological waste in 25-lb charges every 15 minutes and a secondary chamber temperature setpoint of 1900°F.

Saturday, September 22, 1990: The hearth was cleaned and the air ports cleared before testing began. The incinerator was started at 9:25 am and charging as well as testing began at 9:45. The charging periods varied from 15 to 30 minutes because of the weight of the large boxes of pathological waste.

The incinerator ran smoothly with no problems. The primary chamber temperature leveled out at 1500°F, and the secondary chamber temperature remained fairly low, only climbing above 1900°F twice at 2:05 and 2:35 pm. The last charge was introduced at 2:30 and testing was completed at 2:40.

The incinerator was opened the following morning (Sunday, September 23, 1990) at 9:20, and there was a small amount of unburned material in the ash bed. Ash removal started at 10:01 and was completed at 11:07. All of the ash was removed.

The total waste charged was 588.3 lb, and the total ash weight was 22.4 lb. The actual feed rate was 112.1 lb/hr, with a 96.2 percent burndown.

3.3.4 Condition II, Run 2 (Test Run 4)

The target operating parameters were a charge rate of 160 lb/hr of general medical waste (red bag) in 40-lb charges every 15 minutes, with a secondary chamber temperature setpoint of 1600°F.

Sunday, September 23, 1990: The ash removal door handle was broken during the ash removal. It had broken during ash removal several times in the past, according to the operator, and another handle latch pin had been welded on. The maintenance crew was not working that day, so the ash door was closed and a wedge was driven into the latching mechanism to hold the door closed tightly. The incinerator was started at 11:20 am, and charging as well as testing began at 11:40. The incinerator appeared to operate smoothly throughout the test, with the exception of the smoking from the stack. There was a constant stream of brown smoke, occasionally changing to dense, black smoke, coming from the stack throughout the test. Because there appeared to be much more smoke than in the previous medical waste test, the incinerator was inspected to determine if everything was operating properly. Everything appeared normal, and the wedge on the ash door was driven in tighter, but the smoking continued. The temperature in the primary chamber during this test run climbed to over 1900°F before the test was completed. During the other medical waste test runs, the primary chamber only reached a temperature of between 1500°F and 1600°F. The testing was completed at 3:54 pm, and the last charge was introduced at 5:45. It was decided to continue burning red bag waste after the testing had been completed in order to dispose of some of the red bag waste in the storage room. The process conditions were maintained during this time.

The incinerator was opened the following morning (September 24, 1990) at 8:28, and there were flaming and smoldering patches of unburned waste in the ash bed. Ash removal started at 8:58 and was completed at 9:31. The waste bed had to be quenched with water in order to complete the ash cleanout.

The total waste charged was 905.3 lb, and the total wet ash weight was 172.7 lb. The actual charge rate was 142.9 lb/hr.

3.3.5 Condition III, Run 1 (Test Run 5)

The target operating parameters were a charge feed rate of 160 lb/hr of pathological waste in 40-lb charges every 15 minutes, with a secondary chamber temperature setpoint of 1600°F. The controller setpoints for the three runs at this condition were: primary chamber burner on/off temperature, 1500°F; primary chamber burner on/off temperature, 1500°F; secondary chamber burner on/off temperature, 1600°F; burndown time, 3 hours.

Monday, September 24, 1990: After the hearth was cleaned and the air ports cleared, the maintenance personnel attempted to fix the ash door handle. They were not able to fix the door handle until a latch pin could be obtained, so a large C-clamp was used to clamp the door closed tightly. This method, which was more effective at sealing the ash door than the original handle, was used for the remainder of the tests.

The incinerator was started at 11:25, and charging as well as testing was started at 11:45. The incinerator ran smoothly with no problems throughout the test. The primary chamber temperature leveled out at around 1500°F, and the secondary chamber temperature alternated between 1400°F and 1700°F. The secondary chamber reached a temperature greater than 1800°F only twice during the test, at 1:47 and at 2:02. Testing was completed at 3:45, and the last charge was introduced at 3:50.

The incinerator was opened the following morning (September 25, 1990) at 8:38, and a large mound of smoldering, unburned waste remained. Cleanout was started at 8:18 and completed at 9:41. There were recognizable remnants of the pathological waste in the center of the waste bed. Burnout, which was fairly good on the 100 lb/hr pathological waste condition, appeared to be very poor on the 160 lb/hr pathological waste condition. Upon agitation, some of the waste burst into flame and had to be quenched with water.

The total waste charged was 674.6 lb, and the total wet ash weight was 45.1 lb. The actual charge rate was 150 lb/hr.

3.3.6 Condition III, Run 2 (Test Run 6)

The target operating parameters were a charge rate of 160 lb/hr of pathological waste in 40-lb charges every 15 minutes, with a secondary chamber temperature setpoint of 1600°F.

Tuesday, September 25, 1990: After the hearth was cleaned and the air ports cleared, the incinerator was started at 9:50 am. Charging as well as testing began at 10:10. The incinerator operated properly with no problems throughout the test. Testing was completed at 2:15, and the last charge was introduced at that time.

The incinerator was opened the following morning (September 26, 1990) and a large amount of smoldering, unburned waste remained. Cleanout was started at 8:54 and completed at 9:27. There were, again, recognizable remnants of the pathological waste in the center of the waste bed. Burnout was very poor.

The total waste charged was 697.2 lb, and the total ash weight was 41.4 lb. The actual charge rate was 156.7 lb/hr, with a 94.1 percent burndown.

3.3.7 Condition II, Run 3 (Test Run 7)

The target operating parameters were a charge rate of 160 lb/hr of hospital waste in 40-lb charges every 15 minutes and a secondary chamber temperature setpoint of 1600°F.

Wednesday, September 26, 1990: The hearth was cleaned and the air ports cleared before testing began. The incinerator was started at 9:40 am, and charging as well as testing began at 10:00. The incinerator operated smoothly throughout the test with no apparent problems. There was occasionally some smoke from the stack, while Run 2 at this condition smoked almost constantly. There was, however, during this run a 7-minute period when heavy smoke emerged from the stack after a large bag of plastic sharps containers had been charged.

A thermocouple sealed inside a pipe was placed in the suspected cold spot of the incinerator to give a continuous readout of the temperature inside the waste bed. The temperature within the pipe climbed from 119°F to 1245°F in approximately 1.5 hours and then started to decline. Within 1 hour, the temperature had dropped to 424°F and within another hour stabilized around 220°F. The temperature in the primary chamber at this time was approximately 1400°F.

Testing was completed at 2:06, and the last charge was introduced at 2:30. At the end of the test, it was discovered that the dioxin sampling probe had broken.

The incinerator was opened the following morning (September 27, 1990) and a large amount of burning waste remained. Ash cleanout started at 9:56 and was completed at 11:45. The waste bed had to be quenched with water in order to complete the cleanout.

The total waste charged was 769.4 lb, and the total wet ash weight was 146.7 lb. The actual charge rate was 162 lb/hr.

3.3.8 Condition II, Run 4 (Test Run 8)

The target operating parameters were a charge rate of 160 lb/hr of hospital waste in 40-lb charges every 15 minutes and a secondary chamber temperature setpoint of 1600°F.

Thursday, September 27, 1990: The hearth was cleaned and the air ports cleared before testing began. The incinerator was started at 11:20, but the secondary chamber burner was flaming out every few seconds. The igniter and the pilot were taken out and cleaned, and the unit was started again at 1:25. Everything appeared to be working properly, so charging as well as testing began at 1:45. The pipe with the thermocouple was placed in the center of the hearth in the line of fire of the primary burners. The pipe heated to 1500°F very quickly and then started to cool as the height of the waste bed was slowly increasing. At the end of the test, the pipe temperature was approximately 440°F, and the primary chamber temperature was approximately 1500°F. The incinerator ran properly throughout the test with no problems. Testing was completed at 5:56, and the last charge was introduced at 6:00.

The incinerator was opened the following morning (September 28, 1990) at 9:03, and a large smoldering and burning mound of ashes and unburned waste remained. Ash removal started at 9:30 and was completed at 10:30. The waste bed had to be quenched with water in order to complete the cleanout.

The total waste charged was 727.3 lb, and the total wet ash weight was 137.3 lb. The actual charge rate was 161.6 lb/hr.

3.3.9 Condition III, Run 3 (Test Run 9)

The target operating parameters were a charge rate of 160 lb/hr of pathological waste in 40-lb charges every 15 minutes and a secondary chamber temperature setpoint of 1600°F.

Friday, September 28, 1990: The hearth was cleaned and the air ports cleared before testing began. The incinerator was started at 10:40, and charging as well as testing began at 11:00. The incinerator operated smoothly with no apparent problems throughout the test. The pipe thermocouple temperature climbed rapidly to 1400°F and then dropped slowly throughout the test as the waste bed depth increased. At the end of the test, the pipe temperature was 685°F, while the primary chamber temperature was 1500°F. Testing was completed at 3:05, and the last charge was introduced at 3:55.

The incinerator was opened the following morning (September 29, 1990) at 9:20, and there was a large mound of black, smoldering, unburned waste. Cleanout began at 9:45 and was completed at 10:56. Once again, many recognizable unburned items were found.

The total waste charged was 867 lb, and the total ash weight was 77 lb. The actual charge rate was 165.1 lb/hr, with a 91.1 percent burndown.

3.3.10 Condition I, Run 3 (Test Run 10)

The target operating parameters were a charge rate of 100 lb/hr of pathological waste in 25-lb charges every 15 minutes and a secondary chamber temperature setpoint of 1900°F.

Tuesday, October 2, 1990: The hearth was cleaned and the air ports cleared before testing began. The incinerator was started at 9:55, and then it was discovered that the temperature indicator pipe had not been placed in the incinerator. The incinerator was shut down at 10:01, the pipe was placed on the hearth, and the incinerator was restarted at 10:03. The first charge was introduced at 10:15, and testing began. The indicator pipe temperature climbed rapidly to 1600°F and then fell slowly to approximately 800°F at the end of the test. The primary chamber temperature was approximately 1500°F at the end of the test. The incinerator ran smoothly with no apparent problems throughout the test. Testing was completed at 2:21, and the last charge was introduced at 2:30.

The incinerator was opened the following morning (October 3, 1990) at 9:25, and there was one small smoldering mass of unburned material in the ash bed. Burnout appeared to be very good.

The total waste charged was 453.3 lb, and the total ash weight was 17.2 lb. The actual charge rate was 100.8 lb/hr, with a 96.2 percent burndown.

4. SAMPLE LOCATIONS

The sampling locations used during the emission testing program at the AMI Central Carolina Hospital MWI are described in this section. Flue gas samples are collected at the exhaust stack using three sets of ports.

The exhaust stack at this facility has a 22-inch steel shell with refractory lining. The inside diameter of the refractory lining is about 18 inches. The existing stack is approximately 8 feet in height above the secondary chamber.

An unlined steel stack extension was fabricated for temporary installation at the top of the existing stack. The extension was 18 inches in diameter and 16 feet high. Three sets of test ports were provided as shown in Figure 4-1. The lower set of ports were used for the CEM, HCl/CEM, and manual HCl tests. The center set of ports were used for CDD/CDF and PM/Metals testing. The upper ports were used for microorganism sampling. 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 are 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 CDD/CDF, PM/metals, and Microbial sampling is eight. Four points on each of two diameters were used as shown in Figure 4-2.

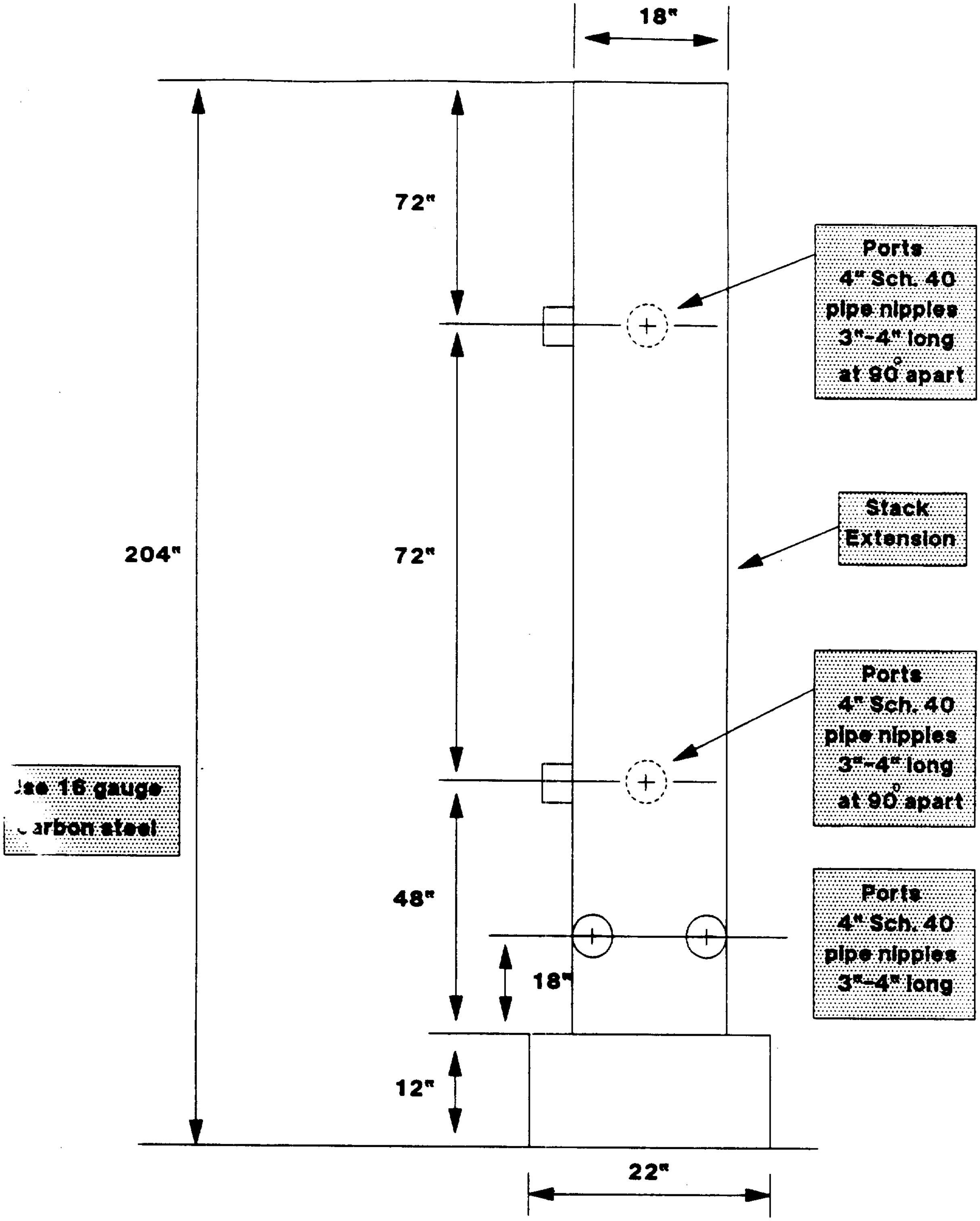
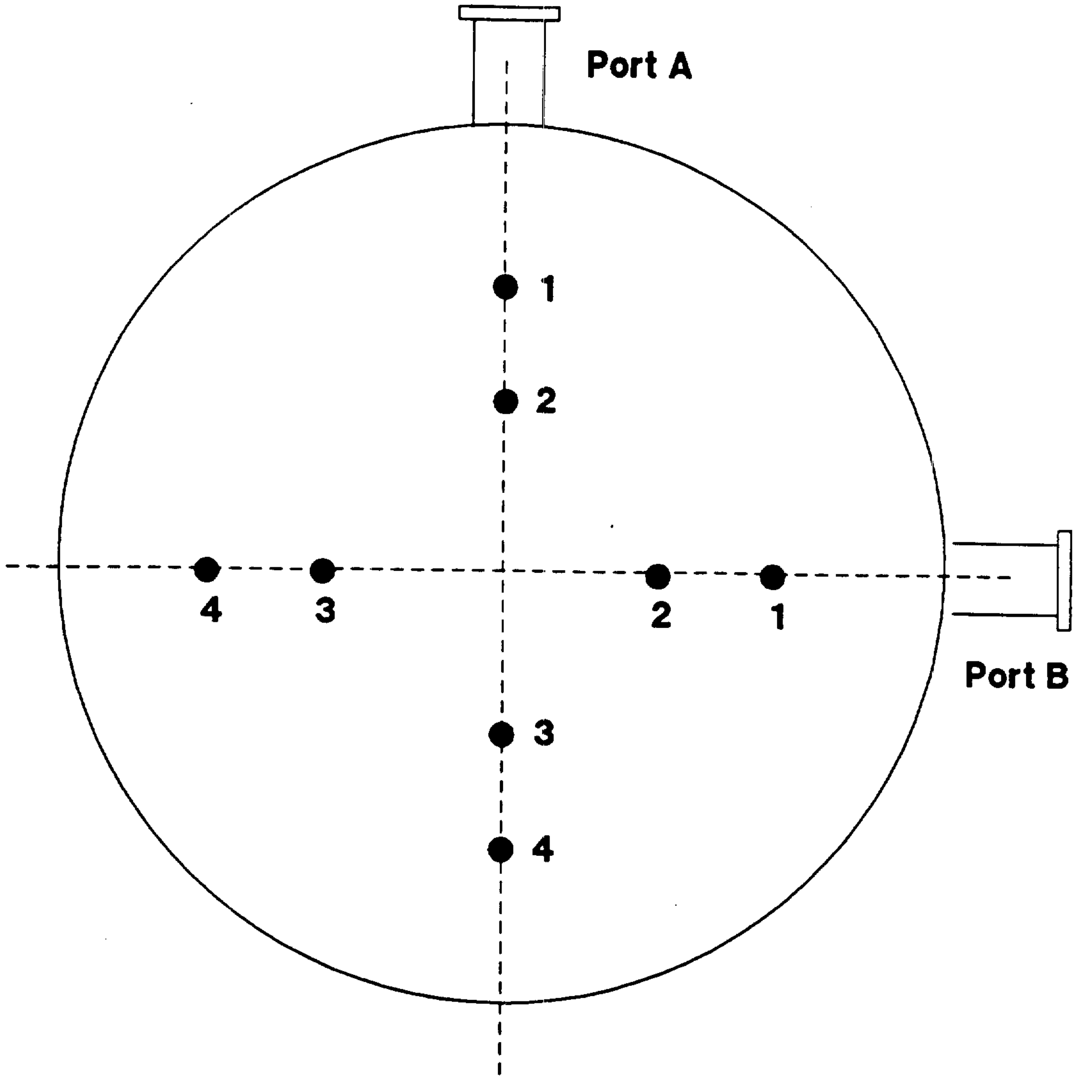


Figure 4-1. AMI Central Carolina Hospital Stack Extension Specifications



Diameter = 21 inches

Point	Percent of Diameter	Inches from Inside Wall
1	6.7	1.2
2	25.0	4.5
3	75.0	13.5
4	93.3	16.8

Figure 4-2. Traverse Point Layout at the Exhaust Stack

5. SAMPLING AND ANALYTICAL PROCEDURES BY ANALYTE

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

A summary of the sampling methods that are 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 is 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 is 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 plan.)

5.1.1 CDD/CDF Sampling Equipment

The CDD/CDF sampling method uses 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:

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

All sampling equipment specifications are detailed in the reference method shown in Appendix A.1 of the test plan.

TABLE 5-1. PROPOSED TEST METHODS AMI CENTRAL CAROLINA 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_2	EPA Instrument Methods 6C
O_2/CO_2	3A
CO	10
NO_x	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. PROPOSED SAMPLING TIMES, MINIMUM SAMPLING VOLUMES AND DETECTION LIMITS FOR THE AMI CENTRAL CAROLINA HOSPITAL MWI TESTS

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

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[a] An average sampling rate of 0.5 ft^3/min was used to calculate sampling time.
[b] An average sampling rate of 2 liters/min was used to calculate the sample volume.
[c] Detection limit based on 100 ml aliquot. Method is still under development. Actual limit may vary.
[d] The indicator spore will be Bacillus stearothermophilus. (only 1 l)
[e] Based on average detection limits for tetra-octa CDD/CDF congeners.

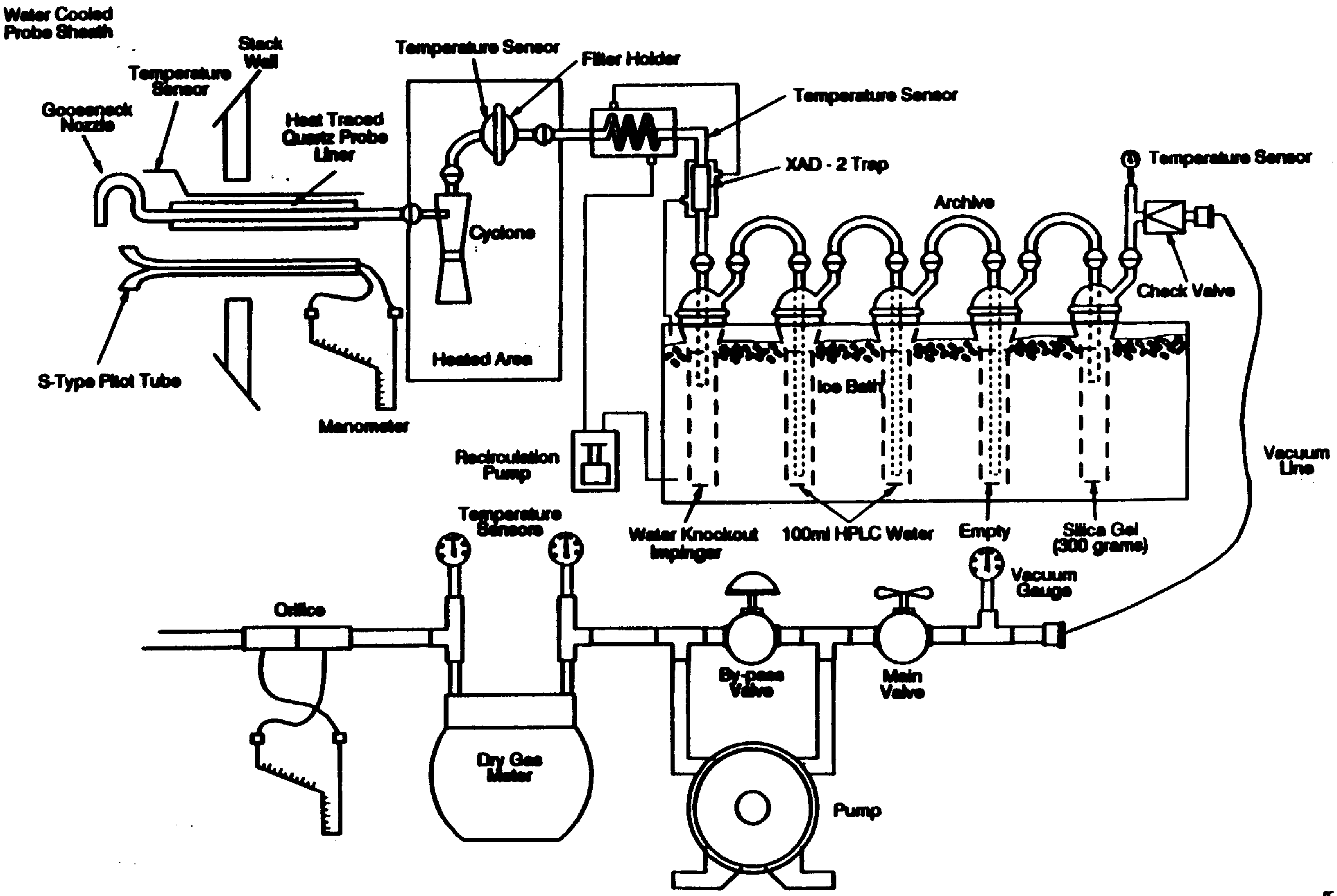

Figure 5-1. CDD/CDF Sampling Train Configuration

5.1.2 CDD/CDF Equipment Preparation

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

5.1.2.1 Glassware Preparation. Glassware is cleaned as shown in Table 5-3. Glassware is washed in soapy water, rinsed with distilled water, baked, and then rinsed with acetone followed by methylene chloride. Clean glassware is allowed to dry under a hood loosely covered with foil to prevent laboratory contamination. Once the glassware is dry, the air-exposed ends are 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 are used during sampling and recovery will be 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) are cleaned following the same procedure except that no baking is 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 are pre-cleaned by separate procedures according to the specified method. Only pesticide-grade solvents and HPLC-grade water are used to prepare for organic sampling and to recover these samples. The lot number, manufacturer, and grade of each reagent used is recorded in the laboratory notebook.

To prepare the filters, a batch of 50 is placed in a soxhlet pre-cleaned by extraction with toluene. The soxhlet is charged with fresh toluene and refluxed for 16 hours. After the extraction, the toluene is 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 are found, the filters are re-extracted until no TCDD or TCDF is detected. The filters are then dried completely

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_2O rinse (X3).[a]
4. Bake at 450°F for 2 hours.[b]
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).

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[a] (X3) = three times.

[b] 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).

under a clean nitrogen (N_2) stream. Each filter is individually checked for holes, tears, creases, or discoloration, and if found, is discarded. Acceptable filters are 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 is 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 is completely dry, it is 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 are found, the resin is re-extracted. If methylene chloride is found, the resin is dried until the excess solvent is removed. The absorbent is to be used within four weeks of cleaning.

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

5.1.2.3 <u>CDD/CDF Method 5 Equipment Preparation</u>. The remaining preparation includes calibration and leak checking of all sampling train equipment. This includes: meterboxes, thermocouples, nozzles, pitot tubes, and umbilicals. Referenced calibration procedures are followed when available. The results are properly documented in a laboratory notebook or project file and retained. If a referenced calibration technique for a particular piece of apparatus is not available, then a state-of-the-art technique is 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 are required to ensure isokinetic sampling. These include determining the traverse point locations, performing a preliminary velocity traverse, cyclonic flow check, and moisture determination. These measurements are used to calculate a "K factor." The K factor is used to determine an isokinetic sampling rate from stack gas flow readings taken during sampling.

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

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

The second step is to load the filter into the filter holder in the recovery trailer. The filter holder is then capped off and placed with the resin trap and condenser coil

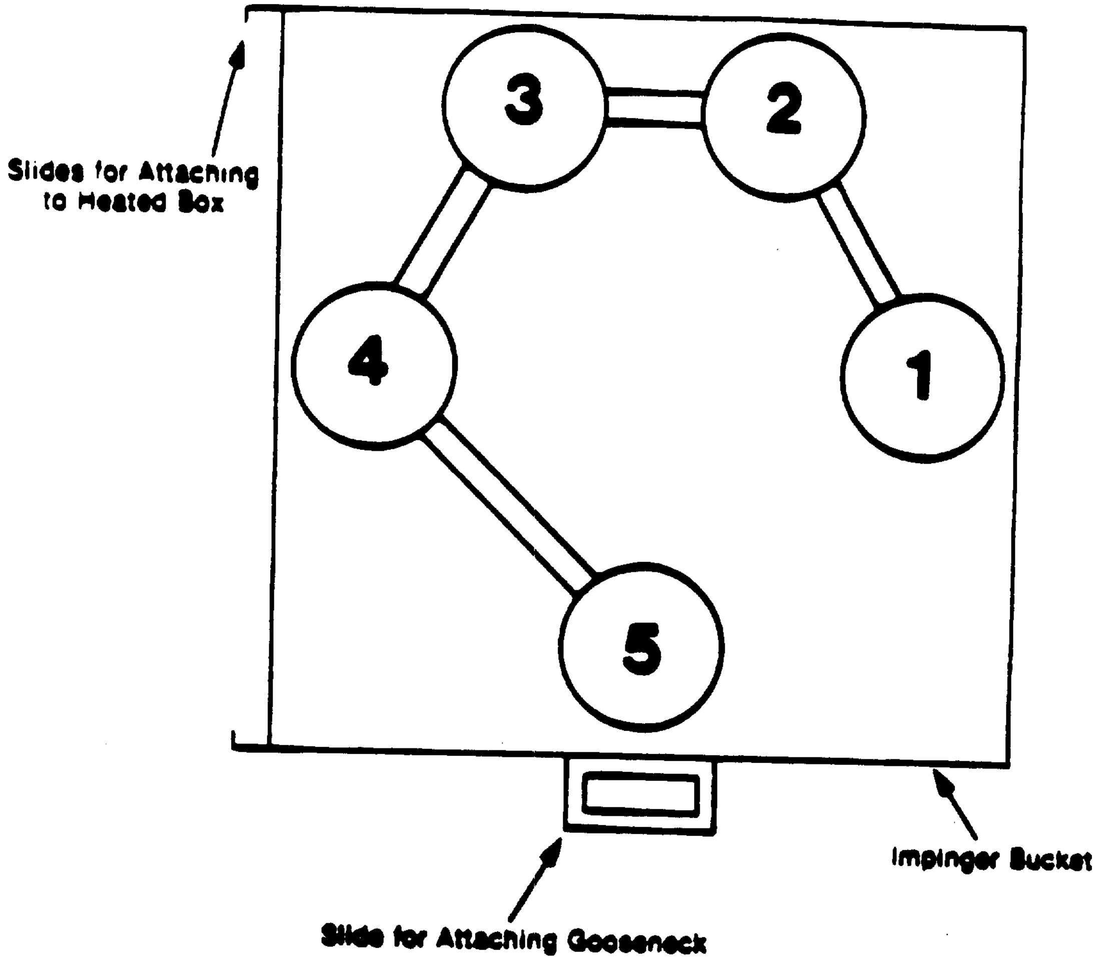

Figure 5-2. Impinger Configuration for CDD/CDF Sampling

(capped) into the impinger bucket. A supply of pre-cleaned foil and socket joints is also placed in the bucket in a clean plastic bag for the convenience of the samplers. To avoid contamination of the sample, sealing greases are not used. The train components are transferred to the sampling location and assembled as previously shown in Figure 5-1.

5.1.3.3 Sampling Procedures. After the train is assembled, the heaters are turned on for the probe liner and heated filter box and the sorbent module/condensor coil recirculating pump is turned on. When the system reaches the appropriate temperatures, the sampling train is 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 is maintained at 120 ± 14°F (248 ± 25°F). The probe temperature is maintained above 100°C (212°F).

The sampling trains are 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 incorporates leak checks before and after every port change. An acceptable pre-test leak rate is less than 0.02 acfm (ft^3/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 is performed before the glassware piece is removed, and after the train is re-assembled.

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

After a successful pre-test leak check has been conducted, all train components are at their specified temperatures, initial data is recorded [dry gas meter (DGM) reading], the test can be initiated. Sampling train data are recorded periodically on standard data forms. A checklist for CDD/CDF sampling is included in Table 5-4. A sampling operation that is unique to CDD/CDF sampling is that the gas temperature

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_2/O_2 needs to be ready except when using CEMs for CO_2/O_2 determinations.
5. Examine meter box - level it, zero the manometers and comfirm 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.)

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.

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

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_2, O_2), if applicable.
5. Blow back pitot tubes periodically is expected mositure 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.
4. Check completeness of data sheet. Verify the impinger bucket identification is recorded on the data sheets. Note any abnormal conditions.
5. Leak check function (level, zero, etc.) of pitot tubes and inpsect 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.

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

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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.

7. Cap both ends of nozzle/probe liner for the next day, and store in dry safe place.
8. Make sure data sheets are completely filled out, legible, and give them to the Crew Chief.

---

entering the resin trap must be below 20°C (68°F). The gas is cooled by a water jacket condenser through which ice water is circulated.

The leak rates and sampling start and stop times are recorded on the sampling task log. Also, any other events that occur during sampling are 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 is not running (i.e., during port changes or after the run is completed), the probe liner is replaced, the run is completed, and sample recovery done on both the broken sections of the glass liner and the replacement liner. If the break occurs while the DGM is running and the exact time of the break is noted, the test is stopped so that the probe liner can be replaced. The run is then completed and sample recovery done on all liner sections. If the recovered sample appears unusual, the sample is discarded and an additional run is performed later. If the recovered sample appears normal, the run is tentatively acceptable.

At the conclusion of the test run, the sample pump (or flow) is turned off, the probe is removed from the duct, a final DGM reading is taken, and a post-test leak check is completed. The procedure is 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 is less than 4 percent of the average sample rate or 0.02 acfm (whichever is 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 is 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" is then subtracted from the measured gas volume in order to determine the final gas sample volume.

5.1.4 CDD/CDF Sample Recovery

To facilitate transfer from the sampling location to the recovery trailer, the sampling train is 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 is capped with methylene chloride-rinsed aluminum foil or ground glass caps before removal to the recovery trailer. Once in the trailer, field recovery follows the scheme shown in Figure 5-3. The samples are recovered and stored in cleaned amber glass bottles to prevent light degradation.

The solvents used for train recovery are all pesticide grade. The use of the highest grade reagents for train recovery is 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 is stored in a cooler on ice at all times. The samples are shipped to the analytical laboratory by truck accompanied by written information designating target analyses.

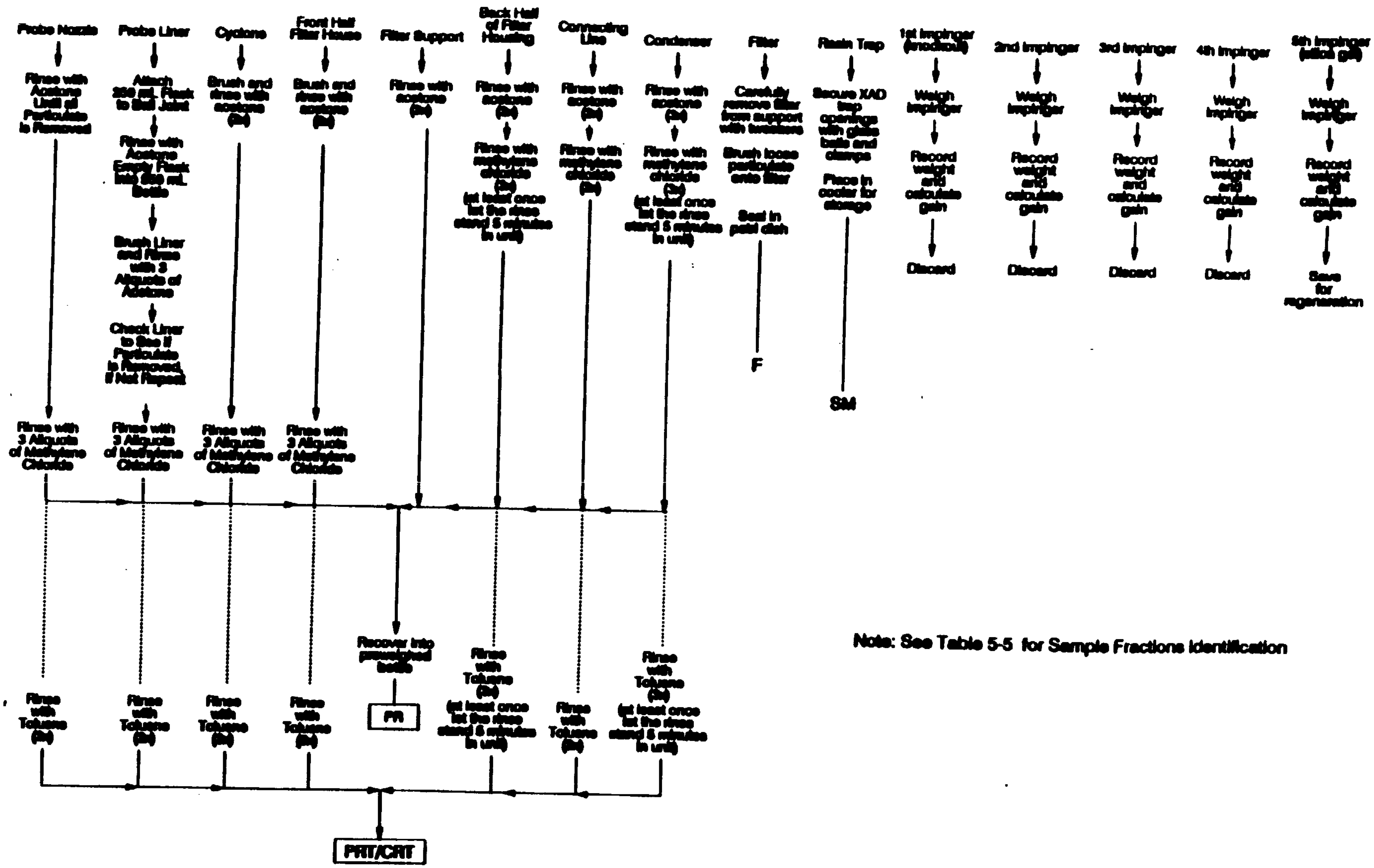
5.1.5 CDD/CDF Analytical Procedures

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

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

Data from the mass spectrometer are 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 are calculated by computer. The chromatograms are retained by the analytical laboratory and also included in the analytical report delivered to Radian Corporation.

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



Note: See Table 5-5 for Sample Fractions Identification

Figure 5-3. PCB/CDD/CDF/TCO Field Recovery Scheme

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

Container/ Component	Code	Fraction
1	F	Filter(s)
2	PR[a]	Acetone and methylene chloride rinses of nozzle/probe, cyclone, front half/back half filter holder, filter support, connecting glassware, condensor
3	PRT[b] CRT[b]	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)

[a] Rinses include acetone and methylene chloride recovered into the same sample bottle.

[b] 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 TO BE 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)

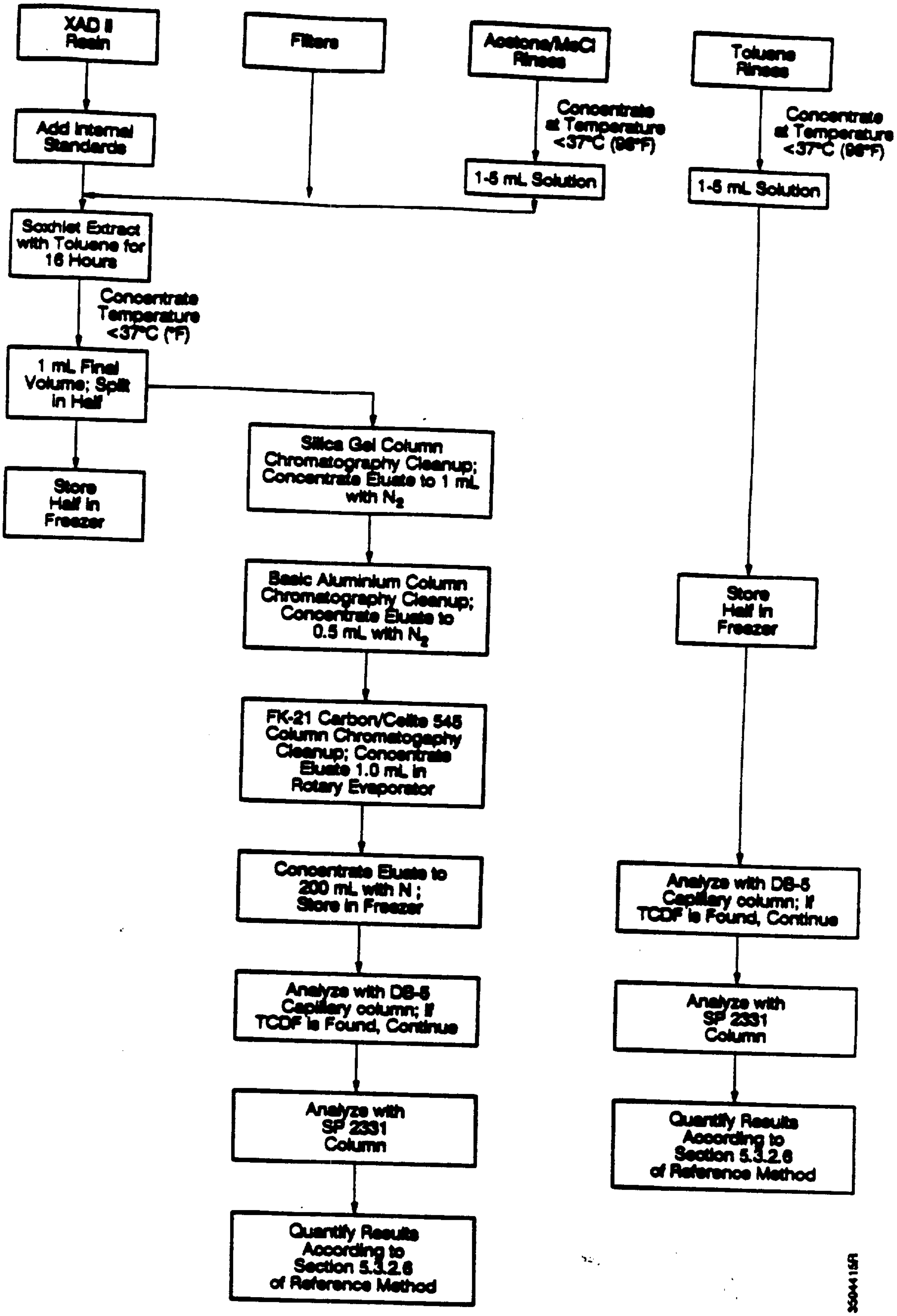


Figure 5-4. Extraction and Analysis Schematic for CDD/CDF Samples

5.1.5.2 Calibration of GC/MS System. A five-point calibration of the GC/MS system is performed to demonstrate instrument linearity over the concentration range of interest. Relative response factors are calculated for each congener or compound of interest. The response factors are verified on a daily basis using a continuing calibration standard consisting of a mid-level mixed isomer standard. The instrument performance is acceptable only if the measured response factors for the labeled and unlabeled compounds and the ion-abundance ratios are 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 are followed. Blanks are used to determine analytical contamination, calibration standards are used for instrument calibration and linearity checks, internal standards are used to determine isomer recoveries and adjust response factors for matrix effects, surrogate standards are used to measure the collection efficiency of the sampling methodology, and an alternate standard is used as a column efficiency check.

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

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

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

A field blank is collected from a set of CDD/CDF glassware that has been used to collect at least one sample and has been recovered. The train is re-loaded and left at a sampling location during a test run. The train is then recovered. The purpose of the

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.

field blank is to measure the level of contamination that occurs from handling, loading, recovering, and transporting the sampling train. The field blanks are analyzed with the flue gas samples. If they are unsatisfactory in terms of contamination, reagent blanks may be analyzed to determine the specific source of contamination.

To verify the flue gas sample was quantitatively recovered, toluene rinses are also analyzed separately from the other fractions. These results are not incorporated into the final emission values; however, they are used as QA/QC indicators.

In addition to the three types of blanks that are required for the sampling program, the analytical laboratory analyzes a method blank with each set of flue gas samples. This consists of prepping and analyzing reagent water by the exact procedure used for the samples analysis. The purpose of this is to verify that there is 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 are not met, the data is acceptable if the signal to noise ratio is greater than or equal to ten. If these requirements are met, the results for the native (sampled) species are adjusted according to the internal standard recoveries.

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

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

A summary of the acceptance, criteria, control limits, and corrective action for the procedures described in this section is shown in Table 7-1.

5.2 PARTICULATE MATTER AND METALS EMISSIONS TESTING METHOD

Sampling for PM and metals is 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 is presented in Appendix A. This method is 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 Central Carolina Hospital MWI test samples will be performed for As, Cd, Cr, Hg, Ni, Pb, Sb, Ag, Ba, Be, and Tl.

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

5.2.1 PM/Metals Sampling Equipment

The methodology uses the sampling train shown in Figure 5-5. The 5-impinger train consists 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 is not exposed to any metal surfaces in this train. The contents of the sequential impingers are: two impingers with a 5 percent HNO_3/10 percent H_2O_2 solution, two impingers with a 4 percent $KMnO_4$/10 percent sulfuric acid (H_2SO_4) solution, and an impinger containing silica gel. An optional empty knockout impinger may be added if the moisture content of the flue gas is high. The second impinger containing HNO_3/H_2O_2 shall be of the Greenburg-Smith design; the other impingers shall have straight tubes. The impingers are connected together with clean glass U-tube connectors and are arranged in an impinger bucket as shown in Figure 5-6. Sampling train components are recovered and analyzed in separate front and back half fractions according to the described method.

5.2.2 PM/Metals Sampling Equipment Preparation

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

- Soak in a 10 percent HNO_3 solution for a minimum of 4 hours;
- Rinse with deionized distilled water rinse (3X); and
- Rinse with acetone rinse.

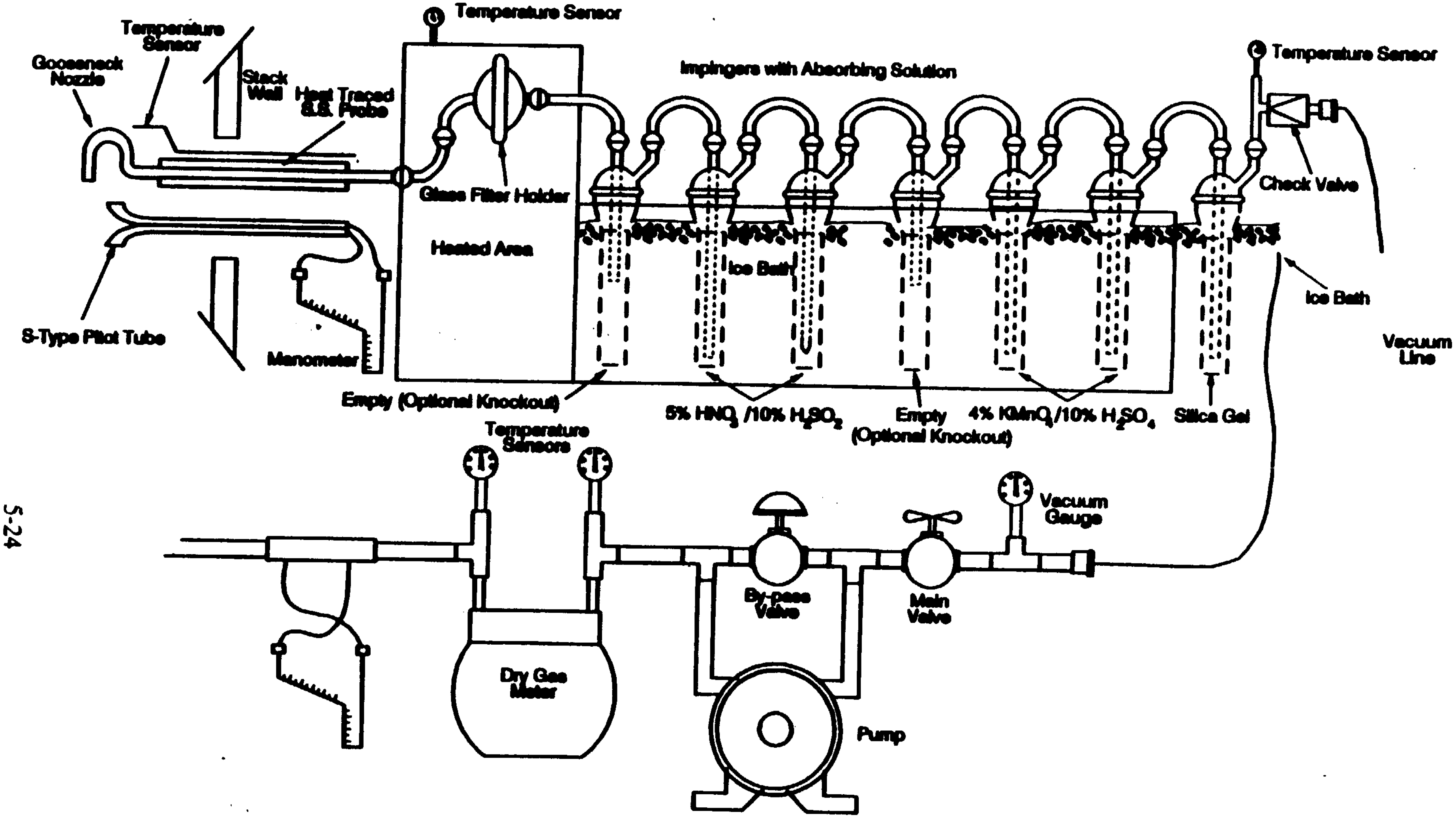


Figure 5-5. Schematic of Multiple Metals Sampling Train

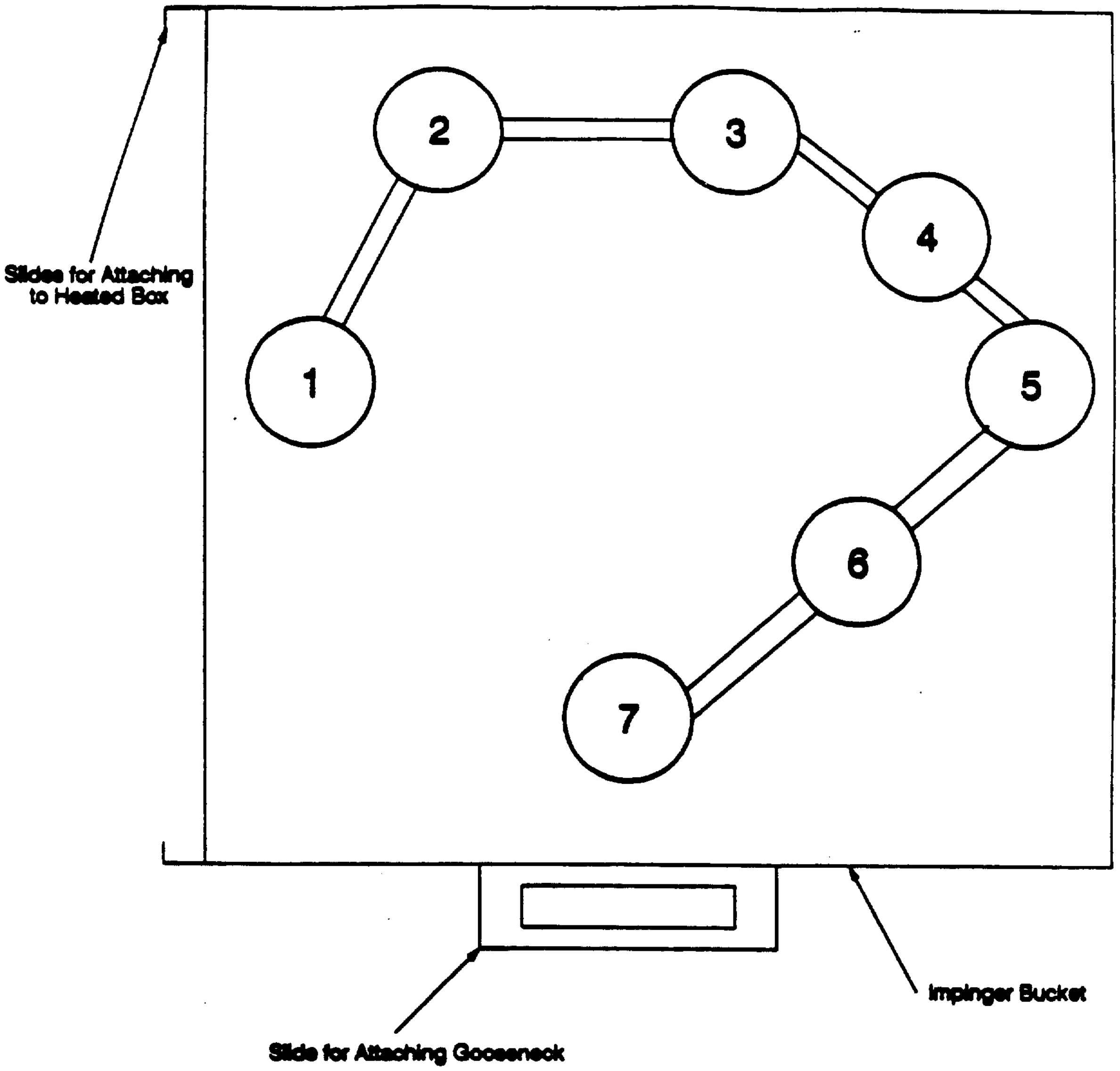


Figure 5-6. Impinger Configuration for PM/Metals Sampling (optional knock out impinger not shown)

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The cleaned glassware is allowed to air dry in a contamination-free environment. The ends are 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 are cleaned according to this procedure.

5.2.2.2 Reagent Preparation. The sample train filters are Pallflex Tissuequartz 2500QAS filters. The acids and H_2O_2 peroxide are Baker "Instra-analyzed" grade or equivalent. The peroxide is purchased specifically for this test site and is kept cold until it is opened.

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

The HNO_3/H_2O_2 absorbing solution and the acidic $KMnO_4$ absorbing solution is prepared fresh daily according to Sections 4.2.1 and 4.2.2 of the reference method. The analyst wears both safety glasses and protective gloves when the reagents are mixed and handled. Each reagent has its own designated transfer and dilution glassware. This glassware is marked for identification with a felt tip glass marking pen and used only for the reagent for which it is designated.

The analyst may save time preparing the acidic $KMnO_4$ solution each day by observing the following procedure, beginning at least one day before the reagent is needed.

- Quantitatively remove 400 ml from a 4 liter bottle of Baker "Analyzed HPLC" water. Label this bottle 4.4 percent $KMnO_4$ in water.
- Quantitatively add 160 g of potassium permanganate crystals to the bottle; stir with a Teflon® stirring bar and stirring plate as thoroughly as possible. This reagent will be stored on the counter in a plastic tub at all times.
- Each morning the acidic reagent is needed, decant 900 ml of $KMnO_4$ solution into a 1000 ml volumetric flask. Carefully add 100 ml of concentrated H_2SO_4 and mix. This reagent is volatile and must be mixed cautiously. Hold the flask cap on the flask, mix once, vent quickly. Complete the mixing slowly until the mixture is homogenous. Allow the solution to cool and bring the final volume to 1000 ml with H_2O.

- Carefully filter this reagent through Wattman 541 filter paper into another volumetric flask or 2 liter amber bottle. Label this bottle 4 percent acidic $KMnO_4$ absorbing solution. Vent the top and store the reagent in a plastic tub at all times.

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

5.2.3 PM/Metals Sampling Operations

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

5.2.4 PM/Metals Sample Recovery

Begin recovery procedures as soon as the probe is removed from the stack and the post-test leakcheck is completed.

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

Once in the trailers, the sampling train is 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 is used in the sample recovery procedures. The weight gain in each of the impingers is recorded to determine the moisture content in the flue gas. Following weighing of the impingers, the front half of the train is recovered, which includes the filter and all sample-exposed surfaces forward of the filter. The probe liner is rinsed with acetone by tilting and rotating the probe while squirting acetone into its upper end so that all inside surfaces are wetted. The acetone will be quantitatively collected into the appropriate bottle.

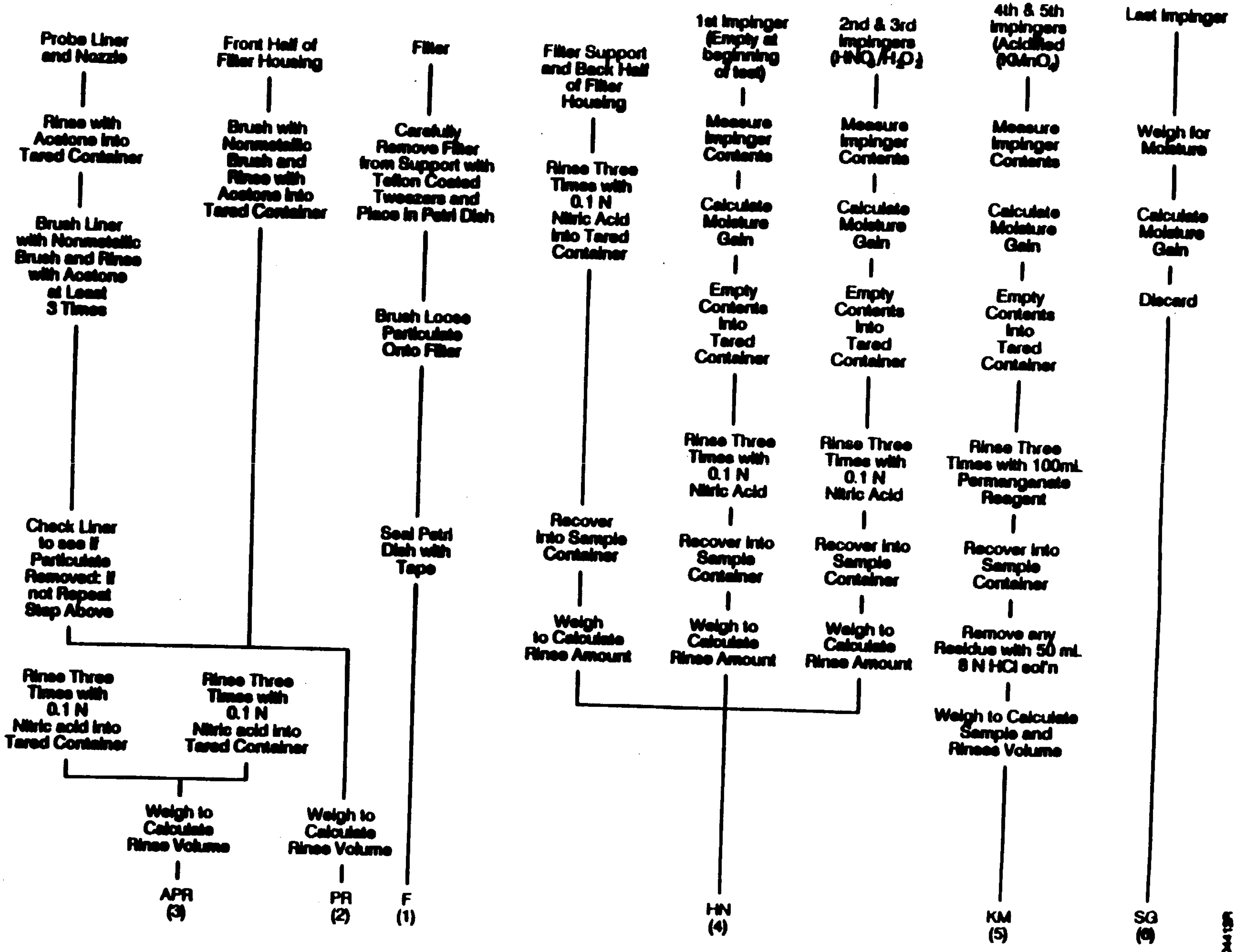


Figure 5-7. Metals Sample Recovery Scheme

This rinse is followed by additional brush/rinse procedures using a non-metallic brush; the probe is held in an inclined position and acetone is squirted into the upper end as the brush is pushed through with a twisting action. All of the acetone and particulate is caught in the sample container. This procedure is repeated until no visible particulate remains and finished with a final acetone rinse of the probe and brush. The front half of the filter is also rinsed with acetone until all visible particulate is removed. After all front half acetone washes are collected, the cap is 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 is analyzed with the samples.

The nozzle/probe liner, and front half of the filter holder is rinsed three times with 0.1N HNO_3 and placed into a separate amber bottle. The bottle is capped tightly, the weight of the combined rinse recorded, and the liquid level marked. The filter is placed in a clean, well-marked glass petri dish and sealed with Teflon® tape.

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

The contents in the knockout impinger (if used) is recovered into a preweighed, prelabeled bottle with the contents from the HNO_3/H_2O_2 impingers. These impingers and connecting glassware are rinsed thoroughly with 0.1N HNO_3, the rinse is captured in the impinger contents bottle, and a final weight is taken. Again, the method specifies a total of 100 ml of 0.1N HNO_3 be used to rinse these components. A HNO_3 reagent blank of approximately the same volume as the rinse volume is analyzed with the samples.

The impingers that contain the acidified $KMnO_4$ solution are poured together into a preweighed, prelabeled bottle. The impingers and connecting glassware are rinsed with at least 100 ml of the acidified $KMnO_4$ solution (from the same batch used for sampling) a minimum of three times. Rinses are added to the sample recovery bottle. A final 50 ml 8N hydrochloric acid (HCl) rinse is conducted and placed into the sample recovery bottle. A final weight is recorded and the liquid level is marked on the bottle. The bottle cap is loosely tightened to allow venting.

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

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

- Acetone blank - 100 ml sample size;
- 0.1N HNO_3 blank - 1000 ml sample size;
- 5 percent HNO_3/10 percent H_2O_2 blank - 200 ml sample size;
- Acidified $KMnO_4$ blank - 1000 ml sample size; this blank should have a vented cap;
- 8N HCl blank - 50 ml sample size;
- Dilution water; and
- Filter blank - one each.

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

The liquid level of each sample container is marked on the bottle in order to determine if any sample loss occurred during shipment. If sample loss has occurred, the sample may be voided or a method may be used to incorporate a correction factor to scale the final results depending on the volume of the loss.

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 is followed. Both filters and precleaned beakers are weighed to a constant weight before use in the field. The same balance used for taring is used for weighing the samples.

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

Metal	Method[a]	Analytical Detection Limits (μg/ml)	Instack Method Detection Limits[b]: Front Half (300 ml sample size) ($\mu g/m^3$)	Instack Method Detection Limits[b]: Back Half (150 ml sample size) ($\mu g/m^3$)
Chromium	ICAP	0.007	1.7	0.8
Cadmium	ICAP	0.004	1.0	0.5
Arsenic[d]	GFAAS	0.001	0.3	0.1
Lead[d]	GFAAS	0.001	0.2	0.1
Mercury	CVAAS	0.0002	0.05	0.03[c]
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

[a] ICAP = Inductively Coupled Argon Plasma
GFAAS = Graphite Furnace Atomic Absorption Spectroscopy
CVAAS = Cold Vapor Atomic Absorption Spectroscopy

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

[c] The detection limit for mercury is the same in the HNO_3/H_2O_2 fraction as it is in the $KMnO_4$ fraction.

[d] If Fe and Al are present, samples will be diluted which may raise analytical detection limits.

The acetone rinses are evaporated under a clear hood at 20°C (68°F) in a tared beaker temperature silica gel. The filter is also desiccated under the same conditions to a constant weight. Weight gain is reported to the nearest 0.1 mg. Each replicate weighing must agree to within 0.5 mg or 1 percent of total weight less tare weight, whichever is greater, between two consecutive weighings, and must be 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 are digested with concentrated HNO_3 and hydrofluoric (HF) acid in either a microwave pressure vessel or a Parr® bomb. The microwave digestion takes place over a period of approximately 10 to 12 minutes in intervals of 1 to 2 minutes at 600 watts; the Parr® bomb digestion is for 6 hours at 140°C (285°F). Both the digested filter and the digested probe rinses are combined to yield the front half sample fraction. The fraction is diluted to a specified volume with water and divided for analysis by applicable instrumentation.

The absorbing solutions from the HNO_3/H_2O_2 impingers are combined. An aliquot is removed for the analysis of mercury by CVAAS and the remainder is acidified and reduced to near dryness. The sample is then digested in either a microwave or by conventional digestion, with 50 percent HNO_3 and 3 percent H_2O_2. After the fraction has cooled, it is filtered and diluted to a specified volume with water.

Each sample fraction is analyzed by ICAPS using EPA Method 200.7. All target metals except mercury, iron, and aluminum, are quantified. If iron and aluminum are present, the samples are diluted to reduce their interferences on arsenic and lead. If arsenic or lead levels are less than 2 ppm, GFAAS is 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 are measured and recorded in the field notebook.

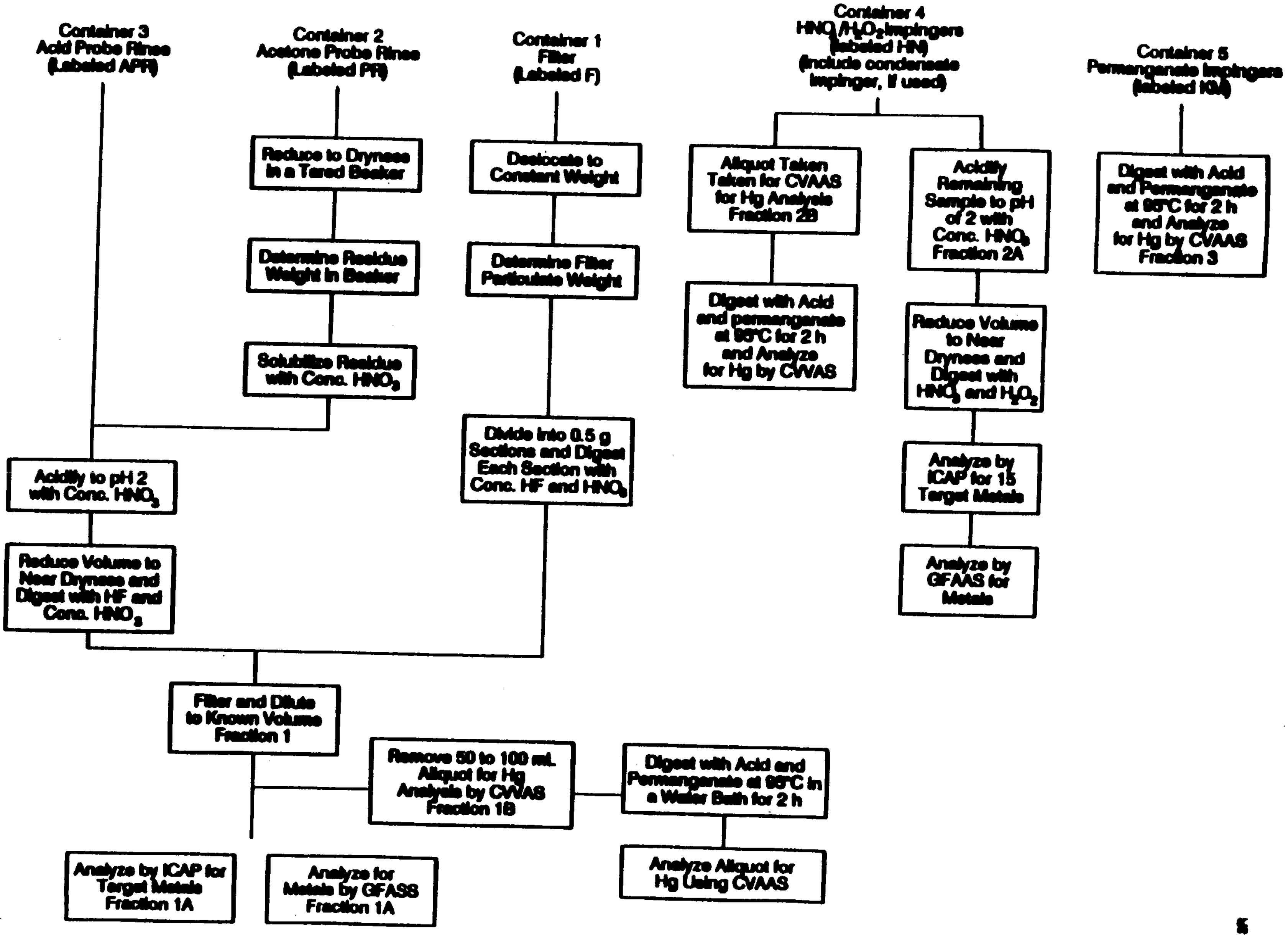


Figure 5-8. Metals Sample Preparation and Analysis Scheme

To prepare for mercury analysis by CVAAS, an aliquot from the $KMnO_4$ impingers, HNO_3/H_2O_2 impingers, filter digestion, and front half rinses are digested with acidic reagents at 95°C in capped BOD bottles for approximately 3 hours. Hydroxylamine hydrochloride solution and stannous chloride is added immediately before analysis. Cold vapor AAS analysis for mercury follows 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 are followed. All field reagent blanks are processed, digested, and analyzed as specified in the test method. To ensure optimum sensitivity in measurements, the concentrations of target metals in the solutions are at least 10 times the analytical detection limits.

5.2.7.1 ICAP Standards and Quality Control Samples. The quality control procedures include 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 $\mu g/ml$ of a metal are prepared daily; those with concentrations greater than this are made weekly or bi-monthly.

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

All samples are analyzed in duplicate. A matrix spike on one front half sample and one back half sample for each 10 field samples is analyzed. If recoveries of less than 75 percent or greater than 120 percent are obtained for the matrix spike, each sample is analyzed by the method of additions. One quality control sample is 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 is prepared weekly; working standards are prepared daily. The calibration curve is made with at least six points. Quality Control samples are prepared from a separate 10 μg/ml standard by diluting it into the range of the samples.

A quality control sample must agree within 10 percent of the calibration, or the calibration repeated. A matrix spike on one of every 10 samples from the HNO_3/H_2O_2 back half sample fraction must be within 20 percent or the samples are analyzed by the method of standard addition.

5.3 MICROBIAL SURVIVABILITY TESTING

The Central Carolina Hospital MWI was loaded with waste containing indicator spores which measure the ability of microbes to survive the incineration process. This directly reflects microbial destruction efficiency for that incinerator. The first test method is aimed at determining microbial survivability in the combustion gases and the ash. This method involves inoculating a known quantity of spores in solution onto materials normally found in the medical waste stream (i.e., petri dishes, gauze, etc.). Direct ash sampling and flue gas testing are conducted in order to determine the destruction efficiency. Test procedures follow guidelines set forth by the EPA draft methods located in Appendix A.3 and A.4 of the test plan.

The second test method utilizes spiked spore samples encased in insulated metal containers charged to the incinerator with the waste stream. These tests are aimed at comparing this method with the direct ash sampling method and should provide a general assessment of microbial survivability and destruction efficiency. Three sets of samples (two different diameters) are periodically charged into the incinerator through out the test day. Following the test, the viability of the indicator spores in each sample is checked to assess the destruction efficiency 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

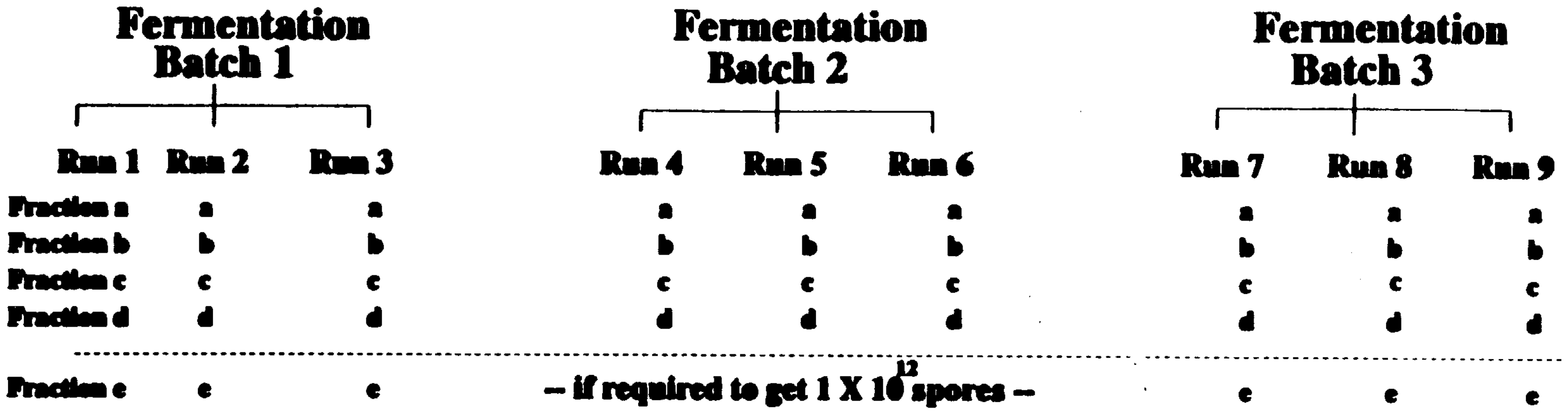
In addition to the pipe samples, a second series of waste materials inoculated with indicator spores are charged into the incinerator. A known quantity of B. stearothermophilus wet spores are inoculated onto or in materials normally found in the medical waste stream such as petri dishes, test tubes, gauze, etc. The waste is loaded into the incinerator to coincide with the emission tests conducted at the incinerator outlet. Direct ash samples are collected after the ash has cooled sufficiently.

5.3.1.1 Equipment. A "wet spore" culture solution is prepared by the University of Alabama. The culture inoculum is divided between the nine sampling runs as shown in Figure 5-9. The spore solution is prepared as a frozen slurry in 1-liter amounts. Inoculation quantities are approximately 600 to 700 mls. The culture inoculum is added to various materials using sterile syringes or other implements as required.

5.3.1.2 Spiking Preparation and Procedure. The spiked waste sample is prepared so that about 1×10^{11} to 1×10^{12} spores are charged into the incinerator per sample run (the exact quantity is recorded). The total charge is separated into four culture batches. Each bag of spiked waste is loaded into the ram feeder at equal time intervals over the course of the emissions test run. For the proposed 4-hour test, spiked bags are loaded at sampling times of 0, 1, 2, and 3 hours from the start of testing.

5.3.2 Indicator Spore Flue Gas Sampling

Flue gas is extracted from the incinerator stack during the burn cycle to determine spore emissions. The testing procedure follows the previously mentioned, draft EPA method. Flue gas samples are collected isokinetically in a buffered solution in impingers (no filter). The recovered samples are divided into different volume aliquots. These samples are cultured and colonies are identified using gram stains to establish cellular morphology, and possibly other biochemical tests as needed.



Notes: Each fraction will be loaded into the incinerator at equally spaced intervals over the duration of the test run during normal charge periods.

At least twelve fractions or doses per test condition. Additional fractions will be added from Batch 4 (fraction e) if necessary to achieve 1 X 10^{12} spores per run.

Figure 5-9. Indicator Spore Spiking Scheme for Combustion Gas Destruction Efficiency Testing

The colonies are then enumerated. The following sections describe the flue gas sampling techniques to be used.

5.3.2.1 Equipment. A schematic of the spore sampling train is shown in Figure 5-10. Flue gas samples are extracted isokinetically through a quartz nozzle/probe system housed in a water-cooled sheath. A smaller tube is located inside the sampling probe to deliver a buffered solution at the nozzle end of the probe. This allows the gas sample stream to be immediately buffered, preventing acid condensate from killing viable spores. From the probe, the sample stream is delivered to a series of chilled impingers. The first two contain 200 ml and 100 ml, respectively, of phosphate-buffered solution to collect indicator spores. The third impinger serves as a knock-out (empty) and the fourth contains 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 is identical to a Method 5 system. (Meter box containing pump, meter, velocity and sampling pressure manometers, etc.)

A Peristaltic pump is used to deliver the buffer solution to the probe tip. The pump is 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, is H_2O_2/alcohol disinfected and washed before each run. The nozzle/probe liner, impingers, impinger connections, and the nozzle/probe brush are first washed using the same procedure as discussed in Section 5.3.4.2. Following washing, all components are disinfected with H_2O_2/alcohol. After completing this procedure, all components are sealed with Parafilm® to prevent contamination. Additional sample containers, recovery items, and analytical equipment are sterilized by autoclaving or another equivalent method. Some of the items which need to be sterilized are wash bottles, two liter glass sample storage bottles, incubation tubes, petri dishes, filter units, reagent water (sterile deionized), and buffering reagent.

The train is assembled by first antiseptically adding the buffer solution to the first two impingers. Silica gel is added to the fourth impinger and the impinger train is connected to the meter box via an umbilical line. A pre-test leakcheck on the impinger

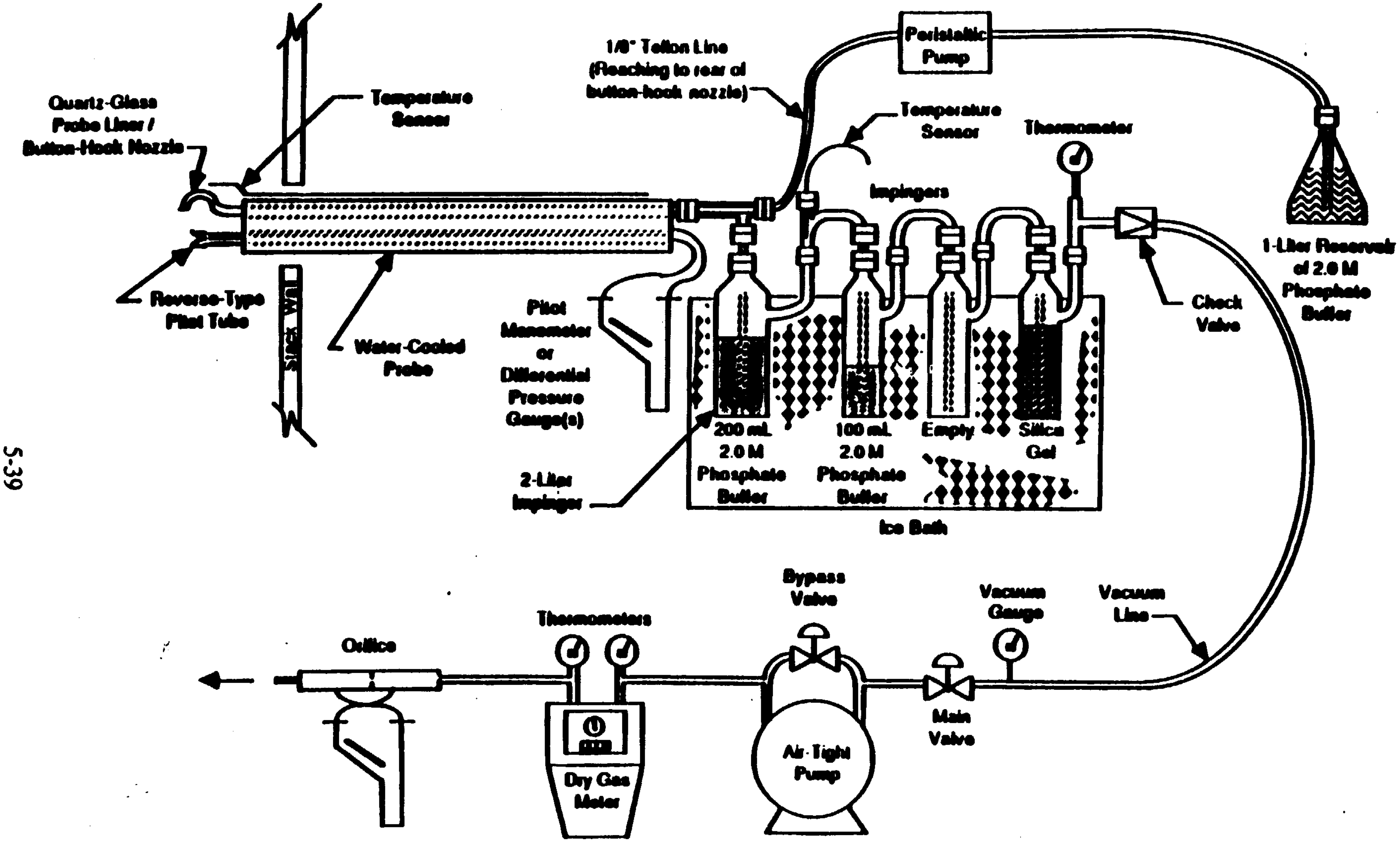


Figure 5-10. Sampling Train for Determination of Indicator Spore Emissions

train is completed at approximately 15 in. Hg. Leakage rates in excess of 4 percent of the average sampling rate or 0.02 cfm, whichever is less, are unacceptable.

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

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

After completion of the test run, the probe is removed from the stack and the flow of buffering solution turned off. The final meter reading is recorded and the sample train is leak checked. Post-test leakchecks are completed at a vacuum equal to or greater than the maximum vacuum reached during the sampling run. Acceptable post-test leakcheck criterion is 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 is turned off. The nozzle tip is inspected for port scrapings or any external matter near the tip and removed if found. The probe is disconnected from the impinger train and along with the probe buffer delivery tube, are rinsed and brushed with sterile buffer solution. All rinses are collected in a sterile sample bottle.

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

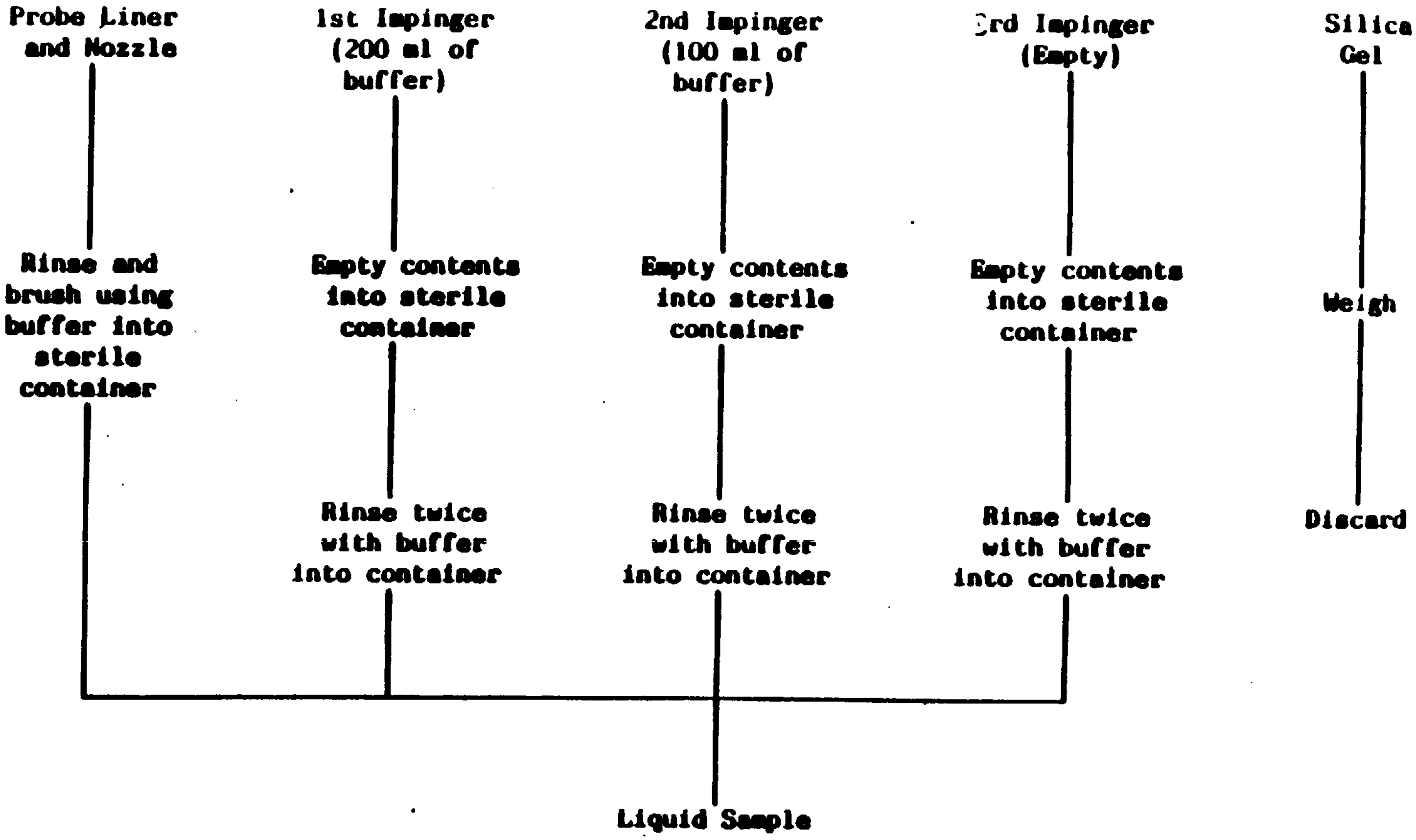


Figure 5-11. Sample Recovery Scheme for Microbial Viability Testing

5.3.3 Direct Ash Sampling for Indicator Spores

Direct ash sampling provides 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 can be found in Appendix A of the test plan. Ash samples are recovered from the ash when it has cooled sufficiently. Ash samples are taken using a sampling thief. During each sampling run, three samples are taken. Two are transported to the laboratory to culture and identify and the third sample is used to determine the pH of the material. Laboratory samples are tested in accordance with proposed Draft Method found in Appendix A of the test plan.

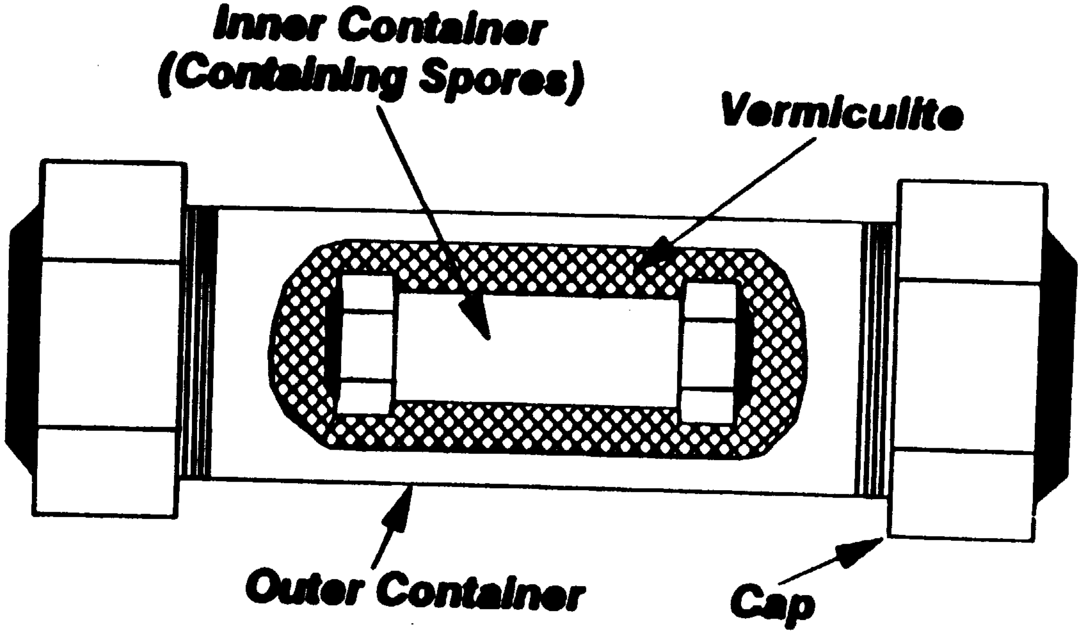
5.3.3.1 Equipment. Ash samples are taken using a precleaned plastic scoop and placed in sample containers for transport to the laboratory. These samples are stored on ice. The pH of the ash is determined by adding a known amount of deionized water to a weighed aliquot of ash and measuring the pH by specific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

5.3.4 Pipe Spiking Procedures

The waste is charged into the incinerator with known quantities of Bacillus stearothermophilus (B. stearothermophilus) contained in insulated pipes. Samples are cultured according to the Draft Method found in Appendix A.4 of the test plan. Colonies of B. stearothermophilus are then gram stained to ensure correct cellular morphology and further identified using biochemical tests as needed. Enumeration of B. stearothermophilus is then completed.

5.3.4.1 Spiking Equipment. A diagram of the pipe sample assembly used for the pipe test is shown in Figure 5-12. The indicator organisms are freeze-dried spores (lyophilized) that were prepared by American Type Culture Collection in Rockville, Maryland. A small amount of lyophilized material equalling approximately 10^6 spores is prepared and placed in a small glass vial. Each pipe sample uses the contents of 1 spore vial.

The sample is placed in a short piece (2-4 inch) of 3/8 stainless steel tubing capped on both ends with Swagelock™ caps. This "inner container" is then placed in an "outer container" which is a 1¼ inch or 2 inch diameter steel pipe nipple about 4 to 6 inches long. Each outer container is identified with a unique identification number for tracking of feed time and location. Enough vermiculite or other thermal insulation



Two sizes will be used:
2" diameter x 6" long and 1 1/2" diameter x long

Figure 5-12. Ash Quality Pipe Assemblies surrounds the inner container to maintain its position in the center of the outer container and to protect it from thermal shock. Both ends of the outer container are capped.

5.3.4.2 Spiking Preparation. The inner container and caps are cleaned and disinfected before use. This procedure consists of soaking the containers for at least one hour in 1.0 N HNO_3, washing with laboratory detergent, rinsing 3 times with tap water, 3 times with sterilized deionized water, and finally, rinsing with 90 percent alcohol.

The spiked sample is prepared by placing a known amount of spores (targeted at 10^6) inside the inner container and then sealed using the end caps. The inner container is placed in the outer container with enough vermiculite to position it in the center. Additional vermiculite is added and tapped down gently. Finally, the outer container is sealed by securing the other end cap.

5.3.4.3 Spiking Procedure. The incinerator spike varies according to the loading procedure. The Central Carolina Hospital MWI is a ram-loading, continuous-burning incinerator, which operates from approximately 7:00 a.m. to 3:00 p.m. each day. A single pipe spike is charged to the incinerator at the beginning, middle, and end of each day's operation. The first pipe is fed in the first load of the day at about 7:00 a.m. The second pipe is added to a load approximately at noon. The last pipe is added with the last load of the day (about 3:00 p.m.). The exact times for charging the spikes are coordinated with hospital personnel.

The pipe sample is placed in the charging hopper at random locations that correspond to where the MWI bags are placed in the hopper.

5.3.4.4 Sample Recovery. The pipes are recovered from the incinerator following a cool down period the morning following the test run. The ash cleanout door is opened at about 7:00 a.m. During this period, the location of the samples on the grate is recorded to the extent possible. The samples are recovered and the hot ashes removed from the ignition chamber. Excess debris is removed from the outer container and each pipe is placed in a plastic bag. The pipe samples are maintained at or below 4°C (39°F) in an ice cooler with care to protect them from contamination from melting ice.

5.3.5 Microbial Analysis

The quantity of viable spores are 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 are presented in Figures 5-13 and 5-14. The analysis is performed within 96 hours after sample recovery. The contents of the inner container of the pipe and the direct ash samples are transferred to separate sterile incubation tubes. The inside of the sample containers are rinsed with sterile phosphate buffer solution into the respective incubation tube. Any glassware used for this transfer procedure is rinsed with sterile deionized water into the respective incubation tubes. The direct ash samples are 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 Figures 5-15. The level of each sample is checked to determine if leakage during shipment occurred. Each sample contains approximately 1.5 to 2.0 liters of sample. The sample is 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 is prepared. The aliquots are placed in sterile incubation tubes, one set is processed without heat-treatment, the other with heat-treatment. Each aliquot is then filtered and placed onto agar plates as discussed in the following sections.

5.3.5.3 Colonial Enumeration and Identification Procedure. Agar plates are prepared by pouring the molten trypticase soy agar into a sufficient number of petri dishes for both sample and field blanks. The media is then allowed to harden. Each sample is then filtered through a separate vacuum filter unit employing a sterile cellulose nitrate filter (0.2 μm). The incubation tube is rinsed with sterile deionized water and poured through the filter as well. Each filter is removed from the filtering unit using sterile forceps and placed face up on an agar plate. The plates are incubated in an air convection incubator at 65°C (49°F) for 18 to 24 hours prior to colonial examination.

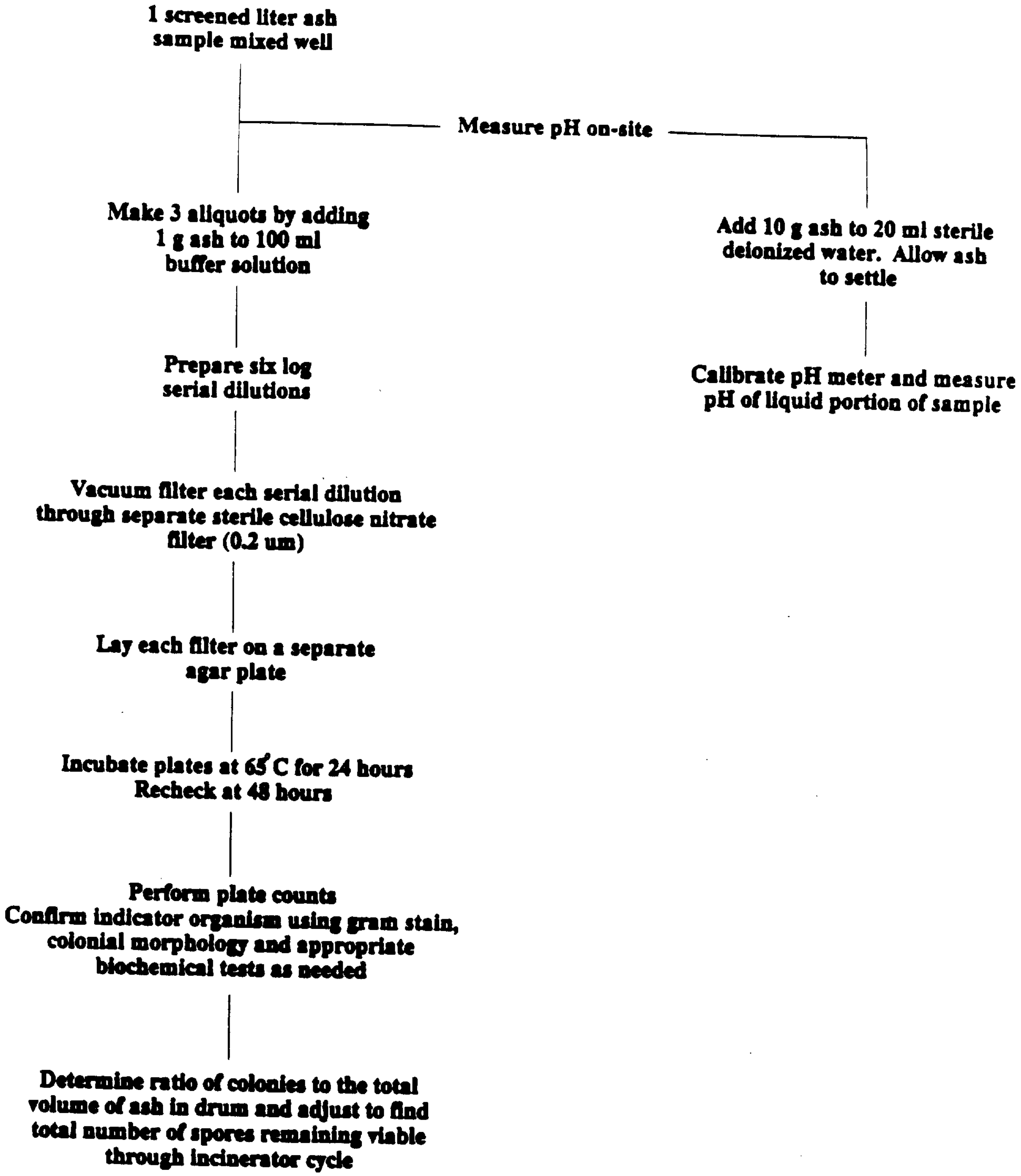


Figure 5-13. Sample and Analysis Scheme for Microbial Testing of Ash Samples

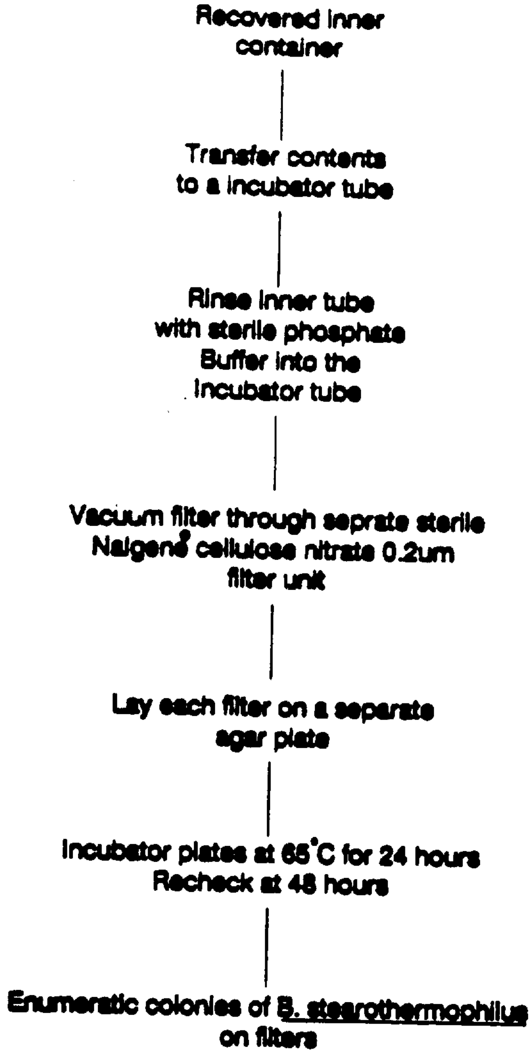


Figure 5-14. Analysis Scheme for Pipe Sample Microbial Viability Tests

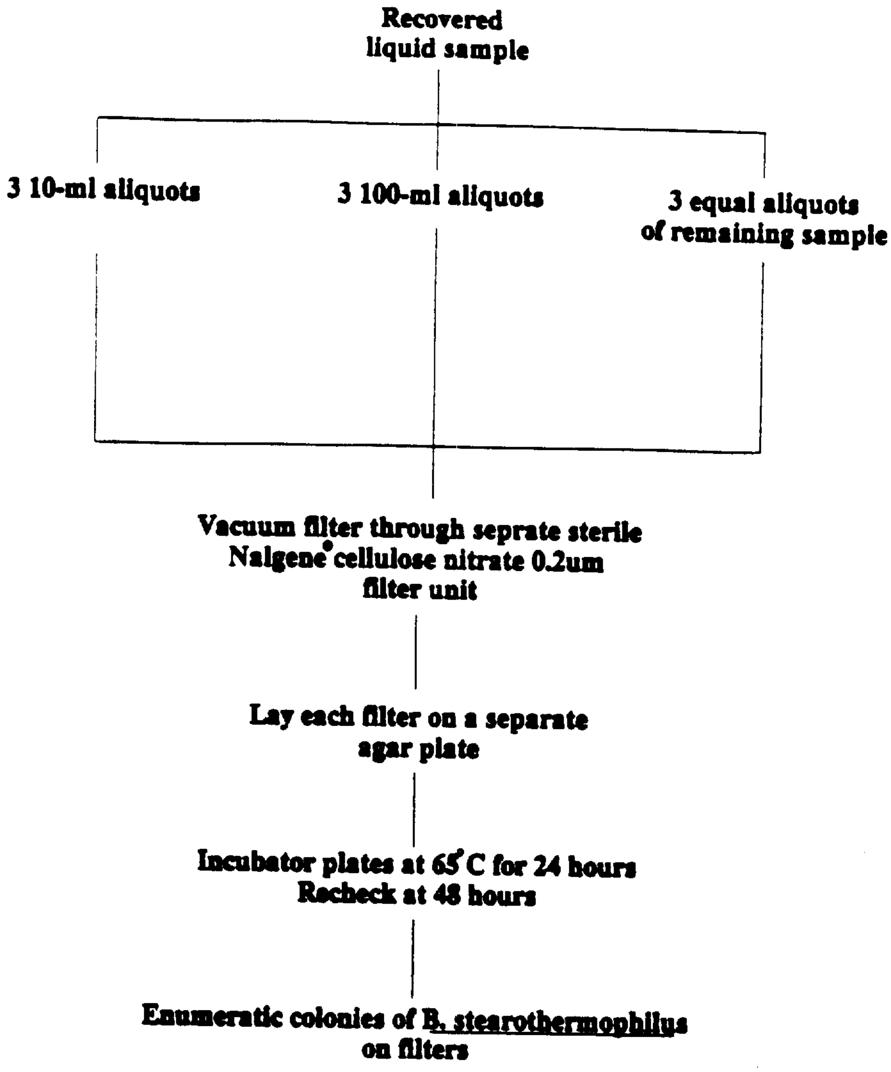


Figure 5-15. Sample Preparation and Analysis Scheme for Microbial Testing

The plates are removed from the incubator and colonies of B. stearothermophilus are quantified. A variety of tests including a gram stain and biochemicals may be used to confirm that the colonies are B. stearothermophilus.

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 is 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, are analyzed to check for contamination during preparation or recovery procedures. Duplicates are analyzed for impinger samples from two test runs.

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

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

Hydrogen chloride HBr, and HF sampling is accomplished using a single sampling train. The procedure follows 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 is extracted from the stack and passed through acidified water. In acidified water, HCl solubilizes and forms Cl^- ions. Ion chromatography is used to detect the Cl^- ions present in the sample. For this test program, the presence of Br^- and F^- ions are also be detected by IC. The method is included in Appendix A.

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 consists 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 keep sample gas in the probe above the acid dewpoint, the probe is not heated. The train consists of an optional knockout impinger followed by two impingers containing 0.1 N sulfuric acid (H_2SO_4) to collect HCl, HBr,

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

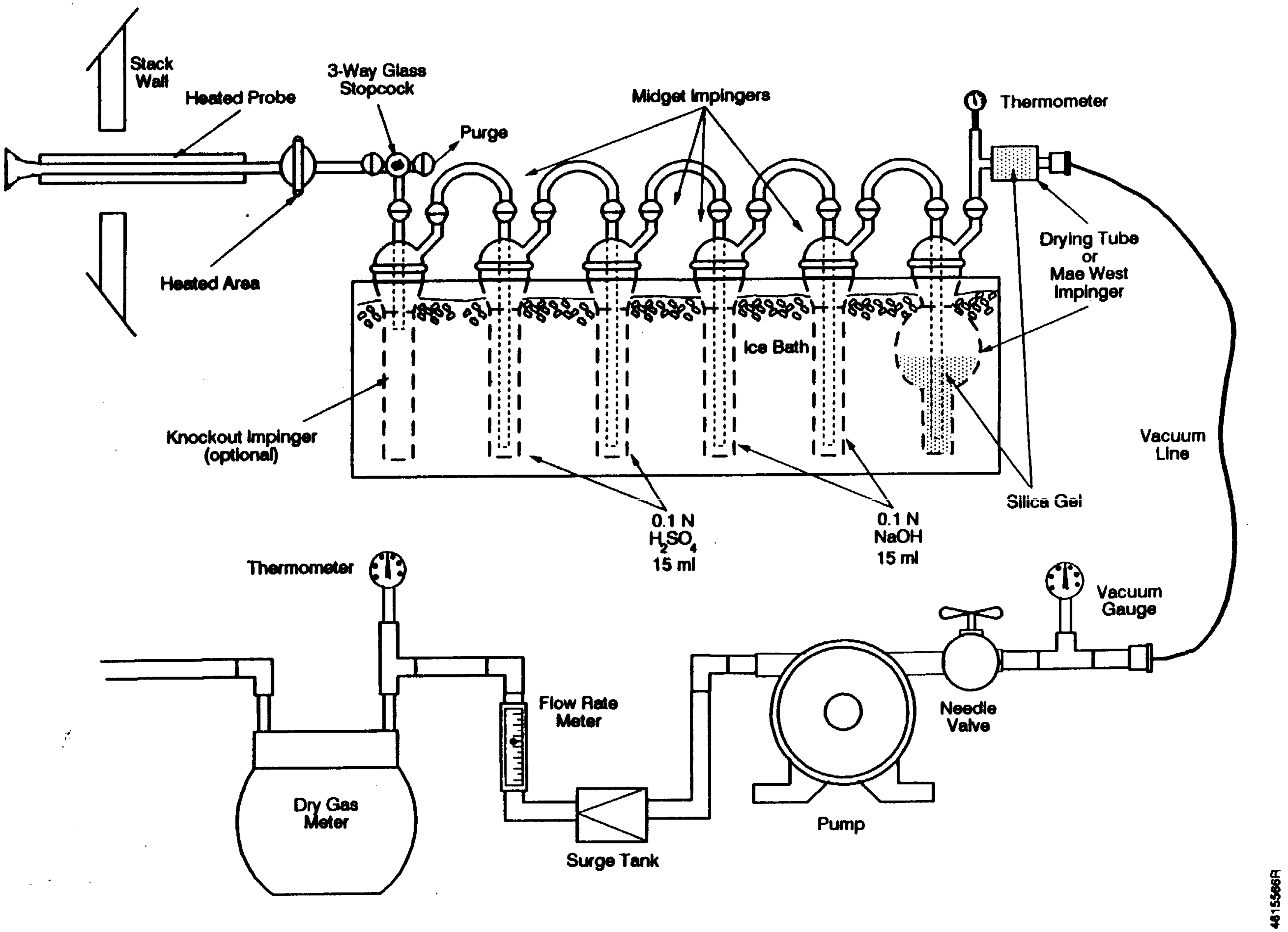


Figure 5-16. HCl Sample Train Configuration

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 includes calibration and leak checking of all train equipment. This includes meterboxes, thermocouples, and umbilicals. Referenced calibration procedures are followed when available, and the results properly documented and retained. If a referenced calibration technique for a particular piece of apparatus is not available, then a state-of-the-art technique is used.

5.4.2.2 Assembling the Train. Assembly of the sampling train is done both in the recovery trailer and at the stack location. First, the empty clean impingers are 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 are loaded, they may be wrapped with Teflon® tape to secure the two sections of the impinger. The impingers are connected together using U-tube connectors and arranged in the impinger bucket. The height of all the impingers should be approximately the same to easily obtain a leak-free seal. The open ends of the train are sealed with aluminum foil.

5.4.3 HCl/HBr/HF Sampling Operations

Prior to sampling, the HCl/HBr/HF train is leakchecked as required by Method 26 protocol. The leak checking procedure is the same as that discussed in Section 5.1. The leak rate, sampling start and stop times, and any other events are be recorded on the sampling task log. Upon completion of a sampling run, repeat the leakcheck procedure. Sampling train data are 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 are disconnected from the probe and filter and moved to the recovery trailer. Once in the trailer, the contents of the two acidified impingers are quantitatively recovered with deionized distilled water and placed into a clean sample bottle. The sample bottle should be sealed, mixed and labeled, and the fluid level marked. The contents of the second set of impingers (containing the 0.1 N NaOH) are discarded for every triplicate series except for one. These will be 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 are checked against the chain-of-custody forms and then given an analytical laboratory sample number. Then, each sample is examined to determine if any leakage occurred and any color or other particulars of the samples are noted.

The IC conditions are described by the type of analytical column and whether suppressed or nonsuppressed IC is used. Prior to sample analysis, a stable baseline is established and water samples are injected until no Cl^-, Br^-, or F^- appears in the chromatogram. Then, the IC is calibrated using standards spanning the appropriate concentration range, starting with the lowest concentration standard. Next, a QC check sample is injected in duplicate, followed by a water blank and the field samples. The calibration standards are 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^-, Br^-, and F^- sample concentrations are 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 is calibrated with a minimum of three concentrations, not including zero. A correlation coefficient of greater than or equal to 0.995 must be achieved to have an acceptable calibration. At least 10 percent of the total number of samples are analyzed in duplicate. Ion concentrations in the duplicates must agree to within ±20 percent.

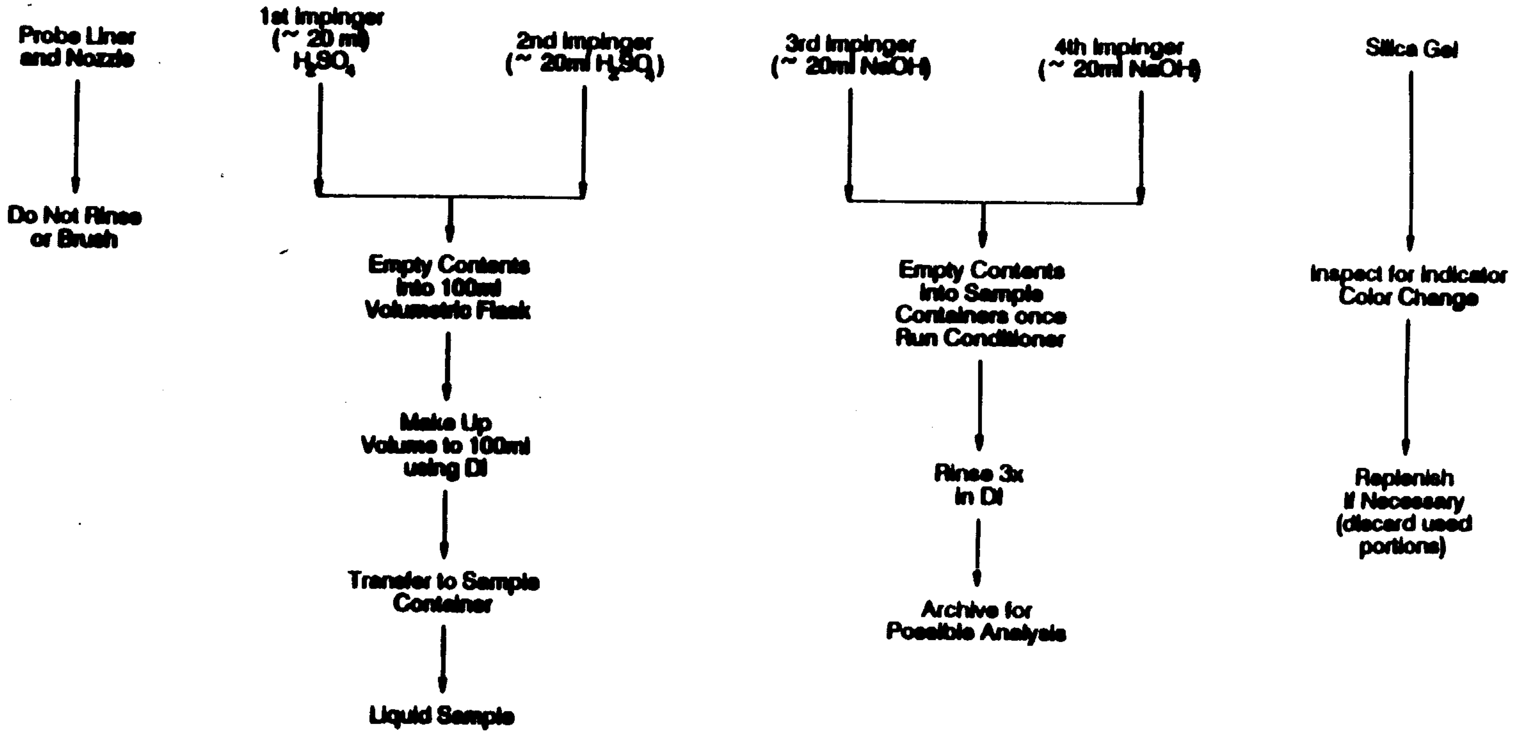


Figure 5-17. HCl/HBr/HF Sample Recovery Scheme

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 will be dictated by EPA Method 1 protocol. These parameters are 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 is 4 (8 total sample points). Several sets of perpendicular sampling ports are established in the incinerator outlet. Traverse point locations are 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 is measured according to EPA Method 2. A Type K thermocouple and S-type pitot tube are used to measure flue gas temperature and velocity, respectively. All of the isokinetically sampled methods that are used incorporate Method 2 (CDD/CDF, PM/Metals, Microorganisms).

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

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

5.5.3 O_2 and CO_2 Concentrations by EPA Method 3A

The O_2 and CO_2 concentrations are determined by CEMs following EPA Method 3A. Flue gas is extracted from the duct and delivered to the CEM system through heated Teflon® tubing. The sample stream is then conditioned (particulate and moisture removed) and is directed to the analyzers. The O_2 and CO_2 concentrations are, therefore, determined on a dry basis. Average concentrations are 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 is determined according to EPA Method 4. Before sampling, the initial weight of the impingers is recorded. When sampling is completed, the final weights of the impingers are recorded, and the weight gain is calculated. The weight gain and the volume of gas sampled are used to calculate the average moisture content (percent) of the flue gas. The calculations are performed by computer. Method 4 is incorporated in the techniques used for all of the manual sampling methods that are used during the test.

5.6 CONTINUOUS EMISSIONS MONITORING (CEM) METHODS

EPA Methods 3A, 7E, 6C, and 10 are continuous monitoring methods for measuring CO_2, O_2, NO_x, SO_2, and CO concentrations. Total hydrocarbons are analyzed by EPA Method 25A. Flue gas HCl concentrations are 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 are used to obtain flue gas samples for the CEM systems. One system is for HCl monitoring and the other system is for all other CEMs. For the main CEM extraction system, samples are 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 is conditioned (temperature lowered and moisture removed) before the flue gas stream is split using a manifold to the various analyzers. Hydrocarbon measurements are 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 consists of a black iron pipe mounted to a Swagelok® reducing union which is attached directly to the heat trace tubing. The probe is 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 are used to transfer the flue gas samples to the instrument trailer for O_2, CO_2, NO_x, SO_2, CO, and THC analyses. These lines are 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.

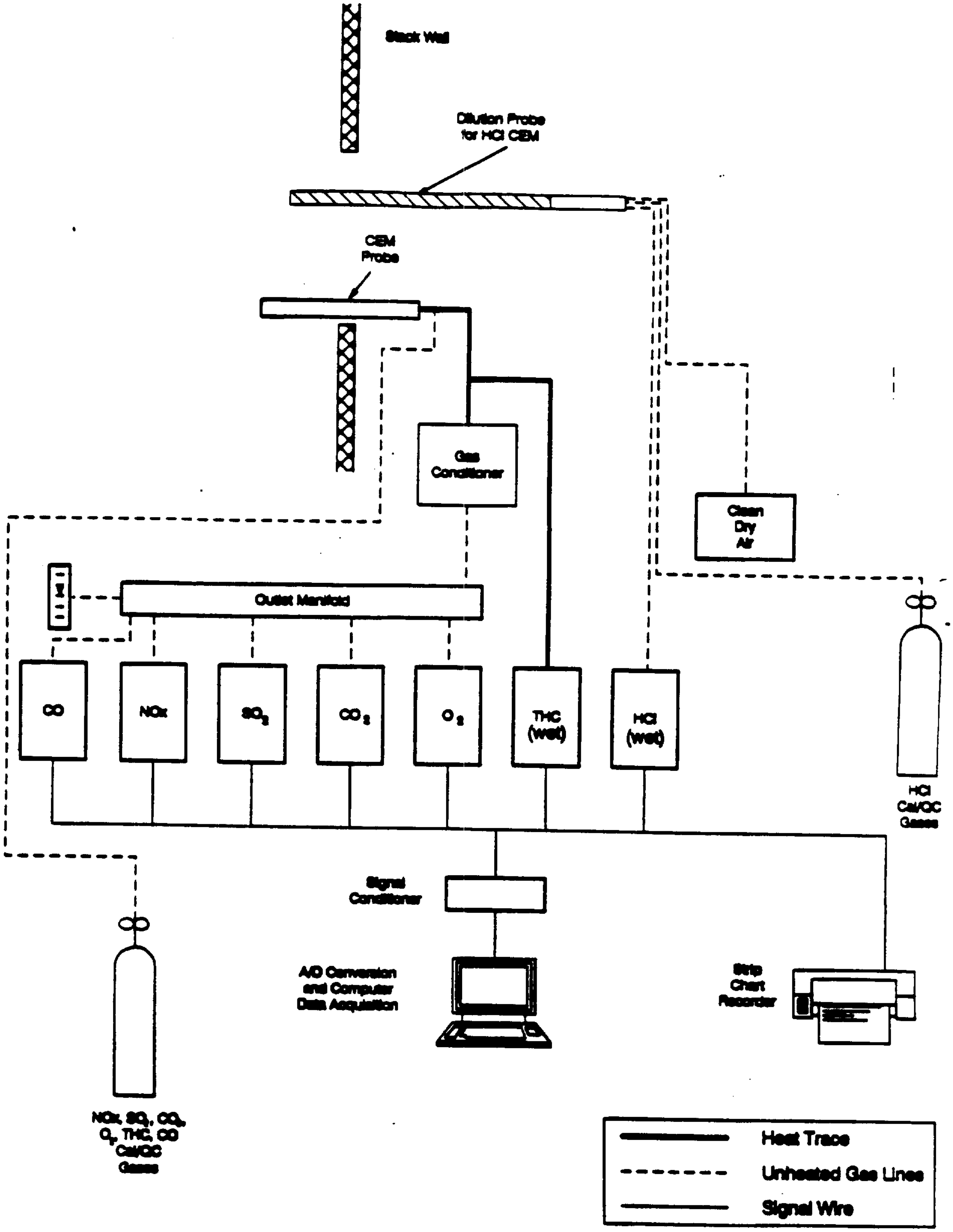


Figure 5-18. Scematic of CEM System

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All heat trace lines contain three 3/8 inch Teflon® tubes. One tube carries the sample, one tube is used for calibration and QC gases, and the other is available as a backup. These gases can then be 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 are 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 is 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 operate under positive pressure eliminating the possibility of a leak. The gas conditioner may be located in the CEM trailer or at the sampling location depending on site conditions.

5.6.1.4 HCl CEM Sample System. The HCl flue gas concentrations are monitored using a CEM analyzer as well as by manual test runs. The HCl CEM sampling system uses a GMD Model 797 dilution probe. This probe cannot be used at the expected flue gas temperature ranges (approximately 1600-1900°F). Therefore, a slip-stream of flue gas is extracted from the stack and allowed to cool to approximately 400 to 500°F as it passes through a length of smaller pipe (i.e., 1 inch ID). The dilution probe is placed in a sampling well in the slipstream pipe for HCl CEM gas extraction. A thermocouple is located adjacent to the probe to monitor gas temperatures (see Figure 5-16). A nominal dilution ratio of 200:1 is used.

5.6.2 CEM Principles of Operation

5.6.2.1 SO_2 Analysis. The Western 721A SO_2 analyzer is essentially a continuous spectrophotometer in the ultraviolet (UV) range. The SO_2 selectively absorbs UV light at a wavelength of 202.5 nm. To take advantage of this property of SO_2, 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, $A = abc$, is used to convert the absorbance into SO_2 concentration (A = absorbance, a = absorbitivity, b = path length, c = concentration). The SO_2 measurements are performed using EPA Method 6C.

5.6.2.2 NO_x Analysis. The principle of operation of this instrument is a chemiluminescent reaction in which ozone (O_3) reacts with nitric oxide (NO) to form oxygen (O_2) and nitrogen dioxide (NO_2). During this reaction, a photon is emitted which is detected by a photomultiplier tube. The instrument is capable of analyzing total oxides of nitrogen ($NO + NO_2$) by thermally converting NO_2 to NO in a separate reaction chamber prior to the photomultiplier tube, if desired. The NO_x measurements are performed using EPA Method 7E.

5.6.2.3 O_2 Analysis. Oxygen analysis is completed using one of the instruments discussed below.

The Thermox WDG III measures O_2 using an electrochemical cell. Porous platinum electrodes are attached to the inside and outside of the cell which provide the instrument voltage response. Zirconium oxide contained in the cell conducts electrons when it is hot due to the mobility of O_2 ions in its crystal structure. A difference in O_2 concentration between the sample side of the cell and the reference (outside) side of the cell produces a voltage. This response voltage is proportional to the logarithm of the O_2 concentration ratio. A linearizer circuit board is used to make the response linear. Reference gas is ambient air at 20.9 percent O_2 by volume.

The Beckman 755 O_2 analyzer uses electron paramagnetic resonance to detect O_2 molecules. Unlike most substances, O_2 has a triplet electron ground state which leaves one electron unpaired, making it a paramagnetic molecule. This electron may have 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_2 analyzer induces resonance between the two spin quantum states. In effect, the O_2 analyzer measures the electromagnetic energy absorbed by O_2 molecules at the resonant frequency. Oxygen measurements are performed using EPA Method 3A.

5.6.2.4 CO_2 Analysis. Non-dispersive infrared (NDIR) CO_2 analyzers emit a specific wavelength of infrared (IR) radiation through the sample cell which is selectively absorbed by CO_2 molecules. The intensity of radiation which reaches the end of the sample cell is compared to the intensity of radiation through a CO_2-free reference cell. A reference cell is used to determine background absorbance which is subtracted from the sample absorbance. The detector uses two chambers filled with CO_2 which are connected by a deflective metallic diaphragm. One side receives radiation from the sample cell and the other side receives radiation from the reference cell. Since more radiation is absorbed in the sample cell than in the reference cell, less radiation reaches the sample side of the detector. This causes a deflection of the diaphragm due to increased heat from radiation absorption on the reference side. Deflection of the diaphragm creates an electrical potential which is proportional to absorbance. Absorbance is directly proportional to CO_2 concentration in the gas. Carbon dioxide measurements are performed using EPA Method 3A.

5.6.2.5 CO Analysis. Either a TECO Model 48 or a Model 48H analyzer will be used to monitor CO emissions. Both TECO analyzers measure CO using the same principle of operation as CO_2 analysis. The instruments are identical except that a different wavelength of infrared radiation is used; 5 nm is selective for CO. Carbon monoxide measurements are performed using EPA Method 10.

5.6.2.6 Total Hydrocarbon Analysis. Either a Beckman Model 400, 402 or 404 will be used to monitor Total Hydrocarbon (THC) emissions. By allowing the THC sample stream to bypass the gas conditioners, concentrations will be determined on a wet basis. All analyses employ Flame Ionization Detectors (FID). As the flue gas enters the detector the hydrocarbons are combusted in a hydrogen flame. The ions and electrons formed in the flame enter an electrode gap, decrease the gas resistance, and permit a current flow in an external circuit. The resulting current is proportional to the instantaneous concentration of the total hydrocarbons. This method is not selective between species. EPA Method 25A applies to the continuous measurement of total gaseous organic concentrations of primarily alkanes, alkenes, and/or arenes (aromatic hydrocarbons). The results are reported on a methane basis and methane is used as the calibration gas.

5.6.2.7 HCl CEM Analysis. HCl flue gas concentrations are continuously monitored using an NDIR/GFC instrument manufactured by Thermo Electron Corporation (TECO). Detection of HCl is 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 passes through the sample cell to the detector. The difference in IR beam strength caused by the absorption of the IR beam is proportional to the HCl concentration.

5.6.3 CEM Calibration

All the CEM instruments are calibrated once during the test program (and linearized, if necessary) using a minimum of three certified calibration gases (zero and two upscale points). Radian performs the multipoint calibrations with four general categories of certified gases: zero gas (generally N_2), a low scale gas concentration, a midrange concentration, and a high scale concentration (span gas). The criterion for acceptable linearity is a correlation coefficient (R^2) of greater than or equal to 0.998, where the independent variable is cylinder gas concentration and the dependent variable is instrument response. If an instrument does not meet these requirements, it is linearized by adjusting potentiometers on the linerarity card within the instrument or by other adjustments, if necessary.

The CEM analyzers are calibrated before and after each test run (test day) on a two point basis: zero gas (generally N_2), and a high-range span gas. These calibrations are used to calculate response factors used for sample gas concentration determinations. Instrument drift as a percent of span is also determined using these calibrating for each test run.

After each initial calibration, midrange gases for all instruments are analyzed, with no adjustment permitted, as a quality control (QC) check. If the QC midrange gas concentration observed is within ±2 percent of full scale, the calibration is accepted and the operator may begin sampling. If the QC check does not fulfill this requirement, another calibration is performed and linearization may be performed if deemed necessary. Calibration procedures are 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 AMI Central Carolina Hospital MWI test program consists of an Omega signal conditioner, a Tecmar A/D converter and a COMPAQ 286 computer. All instrument outputs are connected in parallel to stripchart recorders and the Omega signal conditioner. The stripchart recorders are a back-up system to the computer data acquisition system data. The signal conditioner adjusts the

TABLE 5-10. CEM OPERATING RANGES AND CALIBRATION GASES

Analyte	Gas Concentration
$\underline{CO_2}$	
Instrument	Beckman 865
Range	0-20%
Span Gas Value	18%
Zero Gas	N_2
Midrange QC Gas Value	10%
Low Range QC Gas Value	5%
$\underline{CO}$ - dry	
Instrument	TECO 48H
Range	0-50,000 ppm
Span Gas Value	1000, 9000 or 19,000 ppm[a]
Zero Gas	N_2
Midrange QC Gas Value	1000 or 9000 ppm
Low Range QC Gas Value	2100 ppm
$\underline{CO}$ - wet	
Instrument	TECO 48
Range	0-100, 0-200, 0-5000 ppm
Span Gas Value	1000, 180 or 90 ppm[a]
Zero Gas	N_2
Midrange QC Gas Value	180 ppm
Low Range QC Gas Value	90 ppm
$\underline{O_2}$	
Instrument	Thermox WDG III
Range	0-25%
Span Gas Value	20%
Zero Gas	0.2% O_2
Midrange QC Gas Value	10%
Low Range QC Gas Value	5%
$\underline{SO_2}$	
Instrument	Western 721A
Range	0-500 or 0-5000 ppm
Span Gas Value	200 or 50 ppm
Zero Gas	N_2
Midrange QC Gas	100 ppm
Low Range QC Gas	30 ppm

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

Analyte	Gas Concentration
<u>NO$_x$</u>	
Instrument	TECO 10AR
Range	0-250 ppm
Span Gas Value	200 ppm
Zero Gas	N_2
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_2
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_2
Midrange QC Gas Value	900 ppm
Low Range QC Gas Value	100 ppm

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[a] Several sets of calibration/QC gases were acquired in order to closely approximate stack gas concentrations.

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 translates the digitized voltages into relevant concentrations in engineering units (ppmV, %V, etc.). The computer program has several modes of operation: calibration, data acquisition, data reduction, data view, data edit, and data import. The import function is used to combine other data files for comparison and correlation. On-line color graphics and data manipulation are 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.

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_2 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_2 to set the low scale response for the Thermox O_2 analyzers and repeat Step 7 for these instruments.

9. Introduce the mixed span gases for O_2, CO_2, and CO. Make adjustments as required to these instruments.

10. Enter these values in the computer calibration routine.
11. Introduce the NO_x span gas.
12. Make adjustments to the NO_x instruments as required and enter the value into the computer calibration routine.
13. Introduce the SO_2 span gas for the SO_2 analyzer, repeat Step 12 for the SO_2 analyzer. (Note that all calibration gases are passed through the entire sampling system.)
14. Switch the Western SO_2 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 ±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 are determined visually by a qualified observer following EPA Method 9. The observer is certified within 6 months before the test, as required by the method. Opacity observations are recorded to the nearest 5 percent at 15-second intervals. Twenty-four observations are recorded and averaged per each data set. Observation will continue throughout the 4-hour test run each day.

5.8 PROCESS SAMPLING PROCEDURE

Incinerator ash is composited each test day into a cleaned, 55 gallon plastic drum after initial cooling in 30 gallon cans that are used by the facility. After testing is completed for that day, approximately 1 gallon of ash is taken from the composited sample using a sample thief. This composite is then quartered. The quarters are sent to respective laboratories for analyses of LOI/carbon, metals, and CDD/CDF. The fourth quarter is 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 (Dp50) for each stage. The Dp50 represents the aerodynamic diameter of a particle that has 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 consists of eight stages plus a final filter. Each stage has a number of concentric round jets offset on each succeeding stage such that the one plate serves both as jet and impaction surface. The Anderson MK III is operated in the range from 0.3 to 0.7 acfm and the flue gas is sampled isokinetically (100 ± 20 percent) with a recommended weight gain of 50 mg.

The impactor was prepared by loading the substrates into the impactor and recording 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.

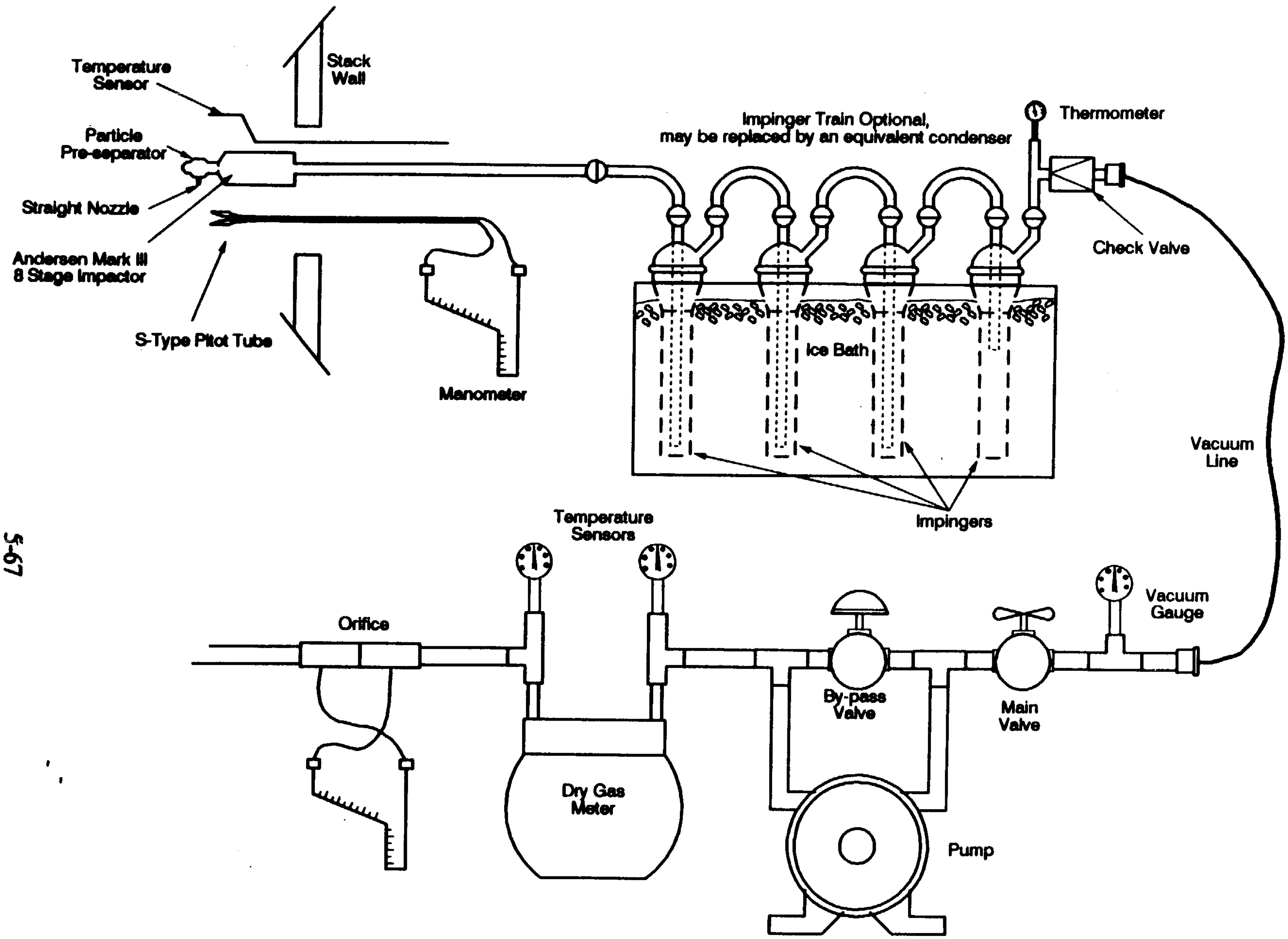

Figure 5-19. Anderson MK III In-Stack Impactor with Particle Pre-Separator Sampling Train

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.

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 Central Carolina 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. All sampling train leak checks met the QC criteria. Isokinetic sampling rates were kept within 10 percent of 100 percent for all the PM/Metals, CDD/CDF, and Microbial emission test runs. Metals analytical QA results revealed good spike recovery data. However, substantial field blank contamination of arsenic and nickel were present. Dioxins analytical procedures for Runs 2, 4, and 8 were modified because of unexpected heavy sample loading. This is further discussed in Section 6.4.1. The CEM data incorporated a variety of QC checks and QA procedures such as QC gas responses, daily drift, and others. The HCl CEM data agreed fairly well with manual HCl data. CEM quality assurance is presented in Section 6.5. Microbial indicator spore analyses were completed using a high number of enumerations per sample. Microbial Survivability Quality Assurance is further discussed in Sections 6.2.3, 6.3, and 6.4.4. Six Particle Size Distributions (PSD) tests were conducted and the following on-site recovery assessment, results from four test runs 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.

TABLE 6-1. SUMMARY OF PRECISION, ACCURACY, AND COMPLETENESS OBJECTIVES[a]

Parameter	Precision (RSD)	Accuracy[b] (%)	Completeness[c] (%)
Dioxins/Furans Emissions	±40[d]	±50	100
Metals Emissions	±15[d]	±30	100
Particulate Matter Emissions	±12	±10	100
HCl/HBr/HF Concentrations	±10[d]	±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.

[a] 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.

[b] Relative error (%) derived from audit analyses, where:

$$\text{Percent Relative Error} = \frac{\text{Measured Value} - \text{Actual Value}}{\text{Actual Value}} \times 100$$

[c] Minimum valid data as a percentage of total tests conducted.

[d] Analytical phase only. Percent difference for duplicate analyses, where:

$$\text{Percent Relative Error} = \frac{\text{First Value} - \text{Second Value}}{0.5\ (\text{First} + \text{Second Values})} \times 100$$

[e] Minimum requirements of EPA Method 6C, based on percent of full scale.

[f] No measureable bias has been detected in the available literature.

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). All CDD/CDF post-test leak checks met the acceptance criterion.

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. All CDD/CDF test runs deviated by no more than 6 percent of 100 percent, thereby meeting the isokinetic criterion.

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 the meter box used for CDD/CDF was well within the 5 percent criterion of the full calibration factor at -0.08 percent.

Field blanks are collected to verify the absence of any sample contamination. The CDD/CDF sampling train was fully prepared, leakchecked, and then recovered. Table 6-5 compares the CDD/CDF analytical results for the MM5 field blank versus average MM5 catches for the test runs (toluene field blank results are presented in the following section). No 2378 TCDD was detected in the MM5 field blank. The confirmation analysis reported a much lower 2378 TCDF value than the full screen at 0.070 ng versus 0.35 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 and the consistency of contamination throughout the test

TABLE 6-2. LEAK CHECK RESULTS FOR CDD/CDF EMISSIONS TESTS; CENTRAL CAROLINA HOSPITAL (1990)

DATE	RUN NUMBER	PRE-TEST LEAK RATE (acfm)	MAXIMUM VACUUM DURING TEST	AVG. SAMPLE RATE (dscfm)	4% SAMPLE RATE (dscfm) a	ACCEPTABLE LEAK LEVEL (acfm)	MEASUREMENTS POST-TEST LEAK RATE	INCHES FOR SECOND CHECK
09/20/90	1	0.011	6	0.43	0.017	0.017	0.012 b	10 b
09/21/90	2	0.005	6	0.38	0.015	0.015	0.012	10
09/22/90	3	0.009	6	0.42	0.017	0.017	0.004	8
09/23/90	4	0.012	15	0.41	0.016	0.016	0.015	18
09/24/90	5	0.010	4	0.42	0.017	0.017	0.018	9
09/25/90	6	0.012	6	0.44	0.018	0.018	0.008	10
09/26/90	7	0.014	5	0.42	0.017	0.017	0.005	10
09/27/90	8	0.010	8	0.43	0.017	0.017	0.008	12
09/28/90	9	0.012	6	0.44	0.018	0.018	0.008	10
10/02/90	10	0.008	6	0.42	0.017	0.017	0.008	9

a This value is in dry standard cubic feet per minute (dscfm) and may be slightly different than actual cfm (acfm).

b This value represents pre-port change leak change. Final value not recorded.

TABLE 6-3. ISOKINETIC SAMPLING RATES FOR CDD/CDF, METALS, AND MICROORGANISMS TEST RUNS; CENTRAL CAROLINA HOSPITAL (1990)

DATE	RUN NUMBER	CDD/CDF ISOKINETIC SAMPLE RATE (%)	TOXIC METALS ISOKINETIC SAMPLE RATE (%)	MICROORGANISMS ISOKINETIC SAMPLE RATE (%)
09/20/90	1A	101	97	95.2
	1B			96.9
09/21/90	2A	96.3	99.1	93.1
	2B			93.6
09/22/90	3A	95.7	98.9	95.1
	3B			96.1
09/23/90	4A	94.3	97.3	94.8
	4B			92.2
09/24/90	5A	95.4	99.1	95
	5B			92.2
09/25/90	6A	96.9	97.9	95
	6B			92.6
09/27/90	8A	97.6	96.3	94.8
	8B			95.2
09/28/90	9A	99.9	97.8	93.8
	9B			95.9
10/02/90	10A	97.2	100	97.9
	10B			100

TABLE 6-4. DRY GAS METER POST-TEST CALIBRATION RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

SAMPLING TRAIN	METER BOX NUMBER	FULL CALIBRATION FACTOR	POST-TEST CALIBRATION FACTOR	POST-TEST DEVIATION (%) a
CDD/CDF	N-30	0.989	0.9882	-0.08
PM/Metal	N-31	0.9992	0.9900	-0.92
Microorganisms (Runs A)	N-32	1.0002	0.9971	-0.31
Microorganisms (Runs B)	9	1.007	NC	NC
Halogens	V5	1.0104	NC	NC

a $\frac{\text{(Post-Test) - (Full)}}{\text{(Full)}} \times 100$

NC = Not Conducted

TABLE 6-5. CDD/CDF FIELD BLANK RESULTS COMPARED TO AVERAGE RUN RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

FULL SCREEN ANALYSES	MM5 FIELD BLANK (total ng)	MM5 CONDITION 1 AVERAGE (total ng)	MM5 CONDITION 2 AVERAGE (total ng)	MM5 CONDITION 3 AVERAGE (total ng)
DIOXINS				
2378 TCDD	[0.060]	0.2	32.4	1.1
TOTAL TCDD	(0.070)	64.6	707.0	72.2
12378 PCDD	[0.080]	2.4	131.7	2.8
TOTAL PCDD	0.29	57.0	1001.3	57.2
123478 HxCDD	[0.100]	2.3	128.0	1.7
123678 HxCDD	[0.100]	3.9	149.8	2.7
123789 HxCDD	(0.180)	7.1	276.3	4.7
TOTAL HxCDD	0.85	60.9	1702.3	41.3
1234678-HpCDD	0.58	23.6	701.7	14.1
TOTAL HpCDD	0.58	51.9	1461.7	30.5
Octa-CDD	(0.950)	29.8	730.3	18.4
FURANS				
2378 TCDF	0.35	48.1	715.7	35.1
TOTAL TCDF	0.63	241.0	4716.7	237.3
12378 PCDF	0.14	6.1	416.3	6.1
23478 PCDF	0.23	15.1	513.3	9.8
TOTAL PCDF	1.9	189.2	7523.3	129.9
123478 HxCDF	(0.680)	24.1	1328.3	12.7
123678 HxCDF	0.38	10.7	822.7	6.6
234678 HxCDF	(0.460)	21.0	651.3	9.0
123789 HxCDF	[0.100]	0.7	51.5	0.4
TOTAL HxCDF	0.72	127.9	7373.3	69.1
1234678-HpCDF	1.60	38.3	1912.3	19.9
1234789-HpCDF	[0.200]	6.4	243.7	2.8
TOTAL HpCDF	3.00	79.0	3560.0	38.0
Octa-CDF	0.91	41.8	799.0	17.3
CONFIRMATION ANALYSES:				
2378-TCDD	[0.040]	3.4	64.7	4.2
2378-TCDF	(0.070)	4.1	111.5	5.2
TOTAL TCDD	0.05	74.7	769.7	80.4
TOTAL TCDF	0.84	214.9	3286.7	206.0

[ ] = minimum detection limit

( ) = estimated maximum possible concentration

program could not be determined, no field blank 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, 6-7, and 6-8 compares the toluene recovery amounts of CDD/CDF congeners to the respective MM5 amounts from full screen analyses for each run in Conditions 1, 2, and 3, respectively (all units in picograms). The ratio of the toluene catch to the MM5 expressed as a percentage (T/M x 100), is also given. The results reveal a relatively small amount of CDD/CDF isomers present in the toluene samples. For Condition 1 (Runs 1, 3, and 10), T/M ratios range from 0 to 6.63 percent (Octa-CDF - Run 10). Condition 2 values range from 0 to 0.111 percent. The Condition 2 toluene amounts are similar to Condition 1; however, the MM5 catches for Condition 2 are much higher resulting in overall lower T/M ratios. Condition 3 T/M ratios ranged from 0 to 4.55 percent (Octa-CDD - Run 6).

The confirmation toluene analytical results are compared to the confirmation MM5 values in Table 6-9. The T/M ratios presented here are also very low. T/M values ranged from 0 to 1.03 percent (Run 10).

The toluene field blank analytical results are compared to the toluene test run analytical results in Table 6-10. The field blank appears to have higher concentrations of all congeners than the average run catches. The laboratory method blank results listed in Section 6.4 did not show any contamination. Therefore, the toluene test results may have been even lower than shown in the previous tables if this sample prep/recovery contamination as revealed by the field blank was consistent throughout the test program.

TABLE 6-6. CDD/CDF TOLUENE RINSE FULL SCREEN ANALYTICAL RESULTS COMPARED TO MM5 ANALYTICAL RESULTS FOR CONDITION 1 (total pg); CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	RUN 1			RUN 3			RUN 10			AVERAGE		
	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)
DIOXINS												
2378 TCDD	630	[10.90]	0.000	(1200.)	[7.900]	0.000	(370.0)	[24.30]	0.000	733	[14.367]	0.000
Other TCDD	17,870	[10.90]	0.000	156,000	235.0	0.151	19,200	97.1	0.506	64,357	166.1	0.258
12378 PCDD	1,500	[11.10]	0.000	4,600	(9.700)	0.211	1,200	[48.30]	0.000	2,433	9.7	0.399
Other PCDD	15,800	11.3	0.072	128,400	247.0	0.192	19,400	123.0	0.634	54,533	127.1	0.233
123478 HxCDD	980	[13.30]	0.000	4,500	(9.400)	0.209	1,400	(45.40)	3.243	2,293	27.4	1.195
123678 HxCDD	1,500	7.80	0.520	7,300	(19.70)	0.270	2,800	(79.00)	2.821	3,867	35.5	0.918
123789 HxCDD	3,200	[14.70]	0.000	14,000	25.0	0.179	4,200	(85.40)	2.033	7,133	55.2	0.774
Other HxCDD	14,820	0.40	0.003	101,200	193.0	0.191	26,800	295.0	1.101	47,607	162.8	0.342
1234678-HpCDD	8,500	87.2	1.026	41,700	155.0	0.372	20,700	506.0	2.444	23,633	249.4	1.055
Other HpCDD	10,200	88.8	0.871	51,300	189.0	0.368	23,300	453.0	1.944	28,267	243.6	0.862
Octa-CDD	10,000	304.0	3.040	53,400	376.0	0.704	25,900	(1130.)	4.363	29,767	603.3	2.027
Total CDD	85,000	500	0.588	563,600	1,459	0.259	145,270	2,814	1.937	264,623	1591	0.601
FURANS												
2378 TCDF	18,500	14.5	0.078	104,000	267.0	0.257	21,700	209.0	0.963	48,067	163.5	0.340
Other TCDF	89,500	11.7	0.013	388,000	594.0	0.153	101,300	540.0	0.533	192,933	381.9	0.198
12378 PCDF	3,200	[9.800]	0.000	11,300	28.0	0.248	3,900	51.1	1.310	6,133	39.6	0.645
23478 PCDF	6,100	9.50	0.156	29,700	71.0	0.239	9,400	138.0	1.468	15,067	72.8	0.483
Other PCDF	68,100	24.5	0.036	358,000	659.0	0.184	77,800	860.9	1.107	167,967	514.8	0.306
123478 HxCDF	7,500	13.3	0.177	52,000	122.0	0.235	12,900	271.0	2.101	24,133	135.4	0.561
123678 HxCDF	3,900	[9.300]	0.000	21,600	(55.50)	0.257	6,600	128.0	1.939	10,700	91.8	0.857
234678 HxCDF	4,800	[12.80]	0.000	44,800	104.0	0.232	13,300	252.0	1.895	20,967	178.0	0.849
123789 HxCDF	180	[16.30]	0.000	1,300	(25.10)	1.931	560	[76.40]	0.000	680	25.1	3.690
Other HxCDF	23,120	17.5	0.076	147,300	204.0	0.138	43,740	659.0	1.507	71,387	293.5	0.411
1234678-HpCDF	9,600	27.2	0.283	81,300	241.0	0.296	24,100	(685.0)	2.842	38,333	317.7	0.829
1234789-HpCDF	1,200	[25.50]	0.000	12,600	24.7	0.196	5,300	(169.0)	3.189	6,367	96.9	1.521
Other HpCDF	6,900	23.1	0.335	71,100	207.3	0.292	25,000	510.0	2.040	34,333	246.8	0.719
Octa-CDF	5,800	[71.10]	0.000	83,000	203.0	0.245	36,500	2420.0	6.630	41,767	1311.5	3.140
Total CDF	248,400	141	0.057	1,406,000	2806	0.200	382,100	6,969	1.824	678,833	3,305	0.487
Total CDD+CDF	333,400	641	0.192	1,969,600	4264	0.217	527,370	9,783	1.855	943,457	4,896	0.519

[ ] = 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 MM5 ANALYTICAL RESULTS FOR CONDITION 2 (total pg); CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	RUN 2 MM5 (pg)	RUN 2 TOLUENE (pg)	RUN 2 TOL/MM5 (%)	RUN 4 MM5 (pg)	RUN 4 TOLUENE (pg)	RUN 4 TOL/MM5 (%)	RUN 8 MM5 (pg)	RUN 8 TOLUENE (pg)	RUN 8 TOL/MM5 (%)	AVERAGE MM5 (pg)	AVERAGE TOLUENE (pg)	AVERAGE TOL/MM5 (%)
DIOXINS												
2378 TCDD	19,000	[9.100]	0.000	53,100	4.6	0.009	25,200	18.6	0.074	32,433	11.6	0.036
Other TCDD	446,000	19.9	0.004	996,000	0.0	0.000	660,000	497.4	0.075	700,667	258.7	0.037
12378 PCDD	59,000	16.4	0.028	208,000	(22.30)	0.011	128,000	67.8	0.053	131,667	35.5	0.027
Other PCDD	391,000	20.1	0.005	1,392,000	52.6	0.004	826,000	312.2	0.038	869,667	128.3	0.015
123478 HxCDD	56,100	16.4	0.029	179,000	25.5	0.014	149,000	54.9	0.037	128,033	32.3	0.025
123678 HxCDD	66,300	24.8	0.037	228,000	26.4	0.012	155,000	68.0	0.044	149,767	39.7	0.027
123789 HxCDD	118,000	40.6	0.034	433,000	49.4	0.011	278,000	125.0	0.045	276,333	71.7	0.026
Other HxCDD	546,600	122.2	0.022	1,700,000	149.7	0.009	1,198,000	457.1	0.038	1,148,200	243.0	0.021
1234678-HpCDD	315,000	(233.0)	0.074	928,000	210.0	0.023	862,000	398.0	0.046	701,667	280.3	0.040
Other HpCDD	330,000	195.0	0.059	1,012,000	162.0	0.016	938,000	391.0	0.042	760,000	249.3	0.033
Octa-CDD	409,000	454.0	0.111	702,000	216.0	0.031	1,080,000	574.0	0.053	730,333	414.7	0.057
Total CDD	2,756,000	1142	0.041	7,778,000	919	0.012	6,274,000	2964	0.047	5,602,667	1675.0	0.030
FURANS												
2378 TCDF	409,000	57.7	0.014	1,130,000	107.0	0.009	608,000	491.0	0.081	715,667	218.6	0.031
Other TCDF	2,171,000	185.3	0.009	6,810,000	386.0	0.006	3,022,000	2349.0	0.078	4,001,000	973.4	0.024
12378 PCDF	166,000	36.5	0.022	798,000	90.7	0.011	285,000	222.0	0.078	416,333	116.4	0.028
23478 PCDF	231,000	45.3	0.020	945,000	101.0	0.011	364,000	310.0	0.085	513,333	152.1	0.030
Other PCDF	2,653,000	188.2	0.007	12,727,000	808.3	0.006	4,401,000	2528.0	0.057	6,593,667	1174.8	0.018
123478 HxCDF	495,000	134.0	0.027	2,300,000	251.0	0.011	1,190,000	571.0	0.048	1,328,333	318.7	0.024
123678 HxCDF	297,000	76.3	0.026	1,450,000	164.0	0.011	721,000	352.0	0.049	822,667	197.4	0.024
234678 HxCDF	291,000	82.5	0.028	1,030,000	130.0	0.013	633,000	267.0	0.042	651,333	159.8	0.025
123789 HxCDF	20,600	[13.40]	0.000	90,100	(24.00)	0.027	43,700	25.0	0.057	51,467	24.5	0.048
Other HxCDF	1,696,400	219.2	0.013	7,779,900	615.0	0.008	4,082,300	1555.0	0.038	4,519,533	796.4	0.018
1234678-HpCDF	787,000	360.0	0.046	2,930,000	442.0	0.015	2,020,000	962.0	0.048	1,912,333	588.0	0.031
1234789-HpCDF	119,000	48.7	0.041	354,000	50.4	0.014	258,000	146.0	0.057	243,667	81.7	0.034
Other HpCDF	634,000	186.3	0.029	2,056,000	308.6	0.015	1,522,000	502.0	0.033	1,404,000	332.3	0.024
Octa-CDF	549,000	315.0	0.057	898,000	155.0	0.017	950,000	489.0	0.051	799,000	319.7	0.040
Total CDF	10,519,000	1,935	0.018	41,298,000	3,633	0.009	20,100,000	10,769	0.054	23,972,333	5,446	0.023
Total CDD+CDF	13,275,000	3,077	0.023	49,076,000	4,552	0.009	26,374,000	13,733	0.052	29,575,000	7,121	0.024

[ ] = minimum detection limit (not used in the averages or summations)

( ) = estimated maximum possible concentration (included in averages and summations)

TABLE 6-8. CDD/CDF TOLUENE RINSE FULL SCREEN ANALYTICAL RESULTS COMPARED TO MM5 ANALYTICAL RESULTS FOR CONDITION 3 (total pg); CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	RUN 5			RUN 6			RUN 9			AVERAGE		
	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)
DIOXINS												
2378 TCDD	720	[24.30]	0.000	(220.0)	[5.900]	0.000	2,500	(3.800)	0.152	1,147	3.80	0.331
Other TCDD	56,680	[24.30]	0.000	11,200	[5.900]	0.000	148,000	[21.6]	0.000	71,960	[17.3]	0.000
12378 PCDD	1,900	[23.70]	0.000	690	[7.200]	0.000	5,800	8.5	0.147	2,797	8.50	0.304
Other PCDD	35,600	(28.70)	0.081	11,510	(22.70)	0.197	116,200	47.3	0.041	54,437	32.9	0.060
123478 HxCDD	1,200	[20.80]	0.000	570	[6.100]	0.000	3,400	(8.200)	0.241	1,723	8.20	0.476
123678 HxCDD	1,800	[20.30]	0.000	960	[6.000]	0.000	5,200	10.2	0.196	2,653	10.2	0.384
123789 HxCDD	3,700	[23.10]	0.000	1,800	[6.800]	0.000	8,600	19.7	0.229	4,700	19.7	0.419
Other HxCDD	23,700	[21.30]	0.000	11,670	[6.300]	0.000	61,400	77.1	0.126	32,257	77.1	0.239
1234678-HpCDD	12,400	[75.60]	0.000	6,300	29.0	0.460	23,600	[70.30]	0.000	14,100	29.0	0.206
Other HpCDD	13,400	[75.60]	0.000	7,400	0.0	0.000	28,400	68.5	0.241	16,400	68.5	0.418
Octa-CDD	17,200	[280.0]	0.000	7,600	346.0	4.553	30,500	143.0	0.469	18,433	245	1.326
Total CDD	168,300	28.7	0.017	59,920	398	0.664	431,100	386	0.900	219,773	271	0.123
FURANS												
2378 TCDF	28,000	20.9	0.075	8,000	(7.300)	0.091	69,200	106.0	0.153	35,067	44.7	0.128
Other TCDF	162,000	0.0	0.000	35,800	(7.300)	0.020	408,800	337.0	0.082	202,200	172.2	0.085
12378 PCDF	4,100	[21.20]	0.000	1,600	[6.500]	0.000	12,500	(34.30)	0.274	6,067	34.3	0.565
23478 PCDF	7,000	[22.00]	0.000	2,800	[6.700]	0.000	19,500	51.2	0.263	9,767	51.2	0.524
Other PCDF	63,500	(25.10)	0.040	24,700	9.8	0.040	254,000	457.8	0.180	114,067	164.2	0.144
123478 HxCDF	9,100	[12.70]	0.000	4,800	6.7	0.140	24,200	66.3	0.274	12,700	36.5	0.287
123678 HxCDF	4,700	[12.20]	0.000	2,400	[4.000]	0.000	12,700	40.3	0.317	6,600	40.3	0.611
234678 HxCDF	6,500	[16.80]	0.000	3,800	[5.500]	0.000	16,800	42.9	0.255	9,033	42.9	0.475
123789 HxCDF	330	[21.50]	0.000	180	[7.000]	0.000	820	[4.000]	0.000	443	[10.833]	0.000
Other HxCDF	26,670	(27.20)	0.102	13,720	1.3	0.009	80,480	130.5	0.162	40,290	53.0	0.132
1234678-HpCDF	17,800	32.9	0.185	8,500	15.4	0.181	33,500	95.3	0.284	19,933	47.9	0.240
1234789-HpCDF	2,300	[31.50]	0.000	1,700	[9.500]	0.000	4,400	13.7	0.311	2,800	13.7	0.489
Other HpCDF	13,300	8.2	0.062	6,900	3.8	0.055	25,700	71.0	0.276	15,300	27.7	0.181
Octa-CDF	12,000	[237.0]	0.000	13,400	(39.20)	0.293	26,500	75.3	0.284	17,300	57.3	0.331
Total CDF	357,300	114	0.032	128,300	90.8	0.071	989,100	1522	0.154	491,567	576	0.117
Total CDD+CDF	525,600	143	0.027	188,220	489	0.260	1,420,200	1908	0.134	711,340	846	0.119

[ ] = 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 CONFIRMATION ANALYTICAL RESULTS COMPARED TO MM5 ANALYTICAL RESULTS FOR ALL CONDITIONS; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	RUN 1			RUN 3			RUN 10			AVERAGE		
	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)
DIOXINS												
2378 TCDD	1,600	[24.40]	0.000	7,500	9.0	0.120	1,100	[6.300]	0.000	3,400	9.0	0.265
Other TCDD	18,600	[24.40]	0.000	176,500	211.0	0.120	18,800	97.1	0.516	71,300	154.1	0.216
FURANS												
2378 TCDF	2,100	[9.100]	0.000	7,800	(16.40)	0.210	2,400	24.8	1.033	4,100	20.6	0.502
Other TCDF	71,500	14.5	0.020	473,200	904.0	0.191	87,600	819.2	0.935	210,767	579.2	0.275

CONGENER	RUN 2			RUN 4			RUN 8			AVERAGE		
	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)
DIOXINS												
2378 TCDD	32,700	[20.80]	0.000	105,000	15.0	0.014	56,300	(47.10)	0.084	64,667	31.1	0.048
Other TCDD	449,300	(97.70)	0.022	1,005,000	13.4	0.001	660,700	294.0	0.044	705,000	135.0	0.019
FURANS												
2378 TCDF	57,800	13.4	0.023	196,000	(23.10)	0.012	80,800	(90.30)	0.112	111,533	42.3	0.038
Other TCDF	1,722,200	233.6	0.014	5,514,000	393.0	0.007	2,289,200	2750.0	0.120	3,175,133	1125.5	0.035

CONGENER	RUN 5			RUN 6			RUN 9			AVERAGE		
	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)
DIOXINS												
2378 TCDD	2,900	28.8	0.993	720	[9.700]	0	9,100	[21.60]	0	4,240	28.8	0.679
Other TCDD	56,300	0	0.000	11,280	[9.700]	0	160,900	[21.60]	0	76,160	[15.7]	0.000
FURANS												
2378 TCDF	3,400	17.9	0.526	860	[5.300]	0	11,400	(20.20)	0.177	5,220	19.1	0.365
Other TCDF	128,600	0	0.000	29,040	[5.300]	0	444,600	340	0.076	200,747	340	0.169

[ ] = minimum detection limit. (not used in the averages or summations)

( ) = estimated maximum possible concentration (included in averages and summations)

TABLE 6-10. CDD/CDF TOLUENE FIELD BLANK RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

FULL SCREEN ANALYSES	TOLUENE FIELD BLANK (total pg)	TOLUENE COND 1 AVG (total pg)	TOLUENE COND 2 AVG (total pg)	TOLUENE COND 3 AVG (total pg)
DIOXINS				
2378 TCDD	10.0	0.0	7.7	1.3
TOTAL TCDD	245.0	102.2	180.2	5.7
12378 PCDD	53.0	3.2	35.5	2.8
TOTAL PCDD	360.0	127.1	156.4	35.7
123478 HxCDD	60.0	18.3	32.3	2.7
123678 HxCDD	82.2	35.5	39.7	3.4
123789 HxCDD	175.0	36.8	71.7	6.6
TOTAL HxCDD	895.0	173.7	386.7	35.7
1234678-HpCDD	618.0	249.4	280.3	9.7
TOTAL HpCDD	1140.0	493.0	452.0	32.5
Octa-CDD	887.0	603.3	414.7	163.0
FURANS				
2378 TCDF	337.0	163.5	218.6	44.7
TOTAL TCDF	1430.0	545.4	1192.0	157.1
12378 PCDF	149.0	26.4	116.4	11.4
23478 PCDF	289.0	72.8	152.1	17.1
TOTAL PCDF	2550.0	614.0	1443.3	172.9
123478 HxCDF	544.0	135.4	318.7	24.3
123678 HxCDF	317.0	61.2	197.4	13.4
234678 HxCDF	366.0	118.7	159.8	14.3
123789 HxCDF	27.2	33.8	16.3	0.0
TOTAL HxCDF	2450.0	590.3	1480.7	105.1
1234678-HpCDF	1210.0	317.7	588.0	47.9
1234789-HpCDF	(219.0)	64.6	81.7	4.6
TOTAL HpCDF	2160.0	344.4	1002.0	80.1
Octa-CDF	1380.0	874.3	319.7	38.2
CONFIRMATION ANALYSES:				
2378-TCDD	(24.10)	4.5	20.7	0.0
2378-TCDF	46.20	8.2	42.3	10.1
TOTAL TCDD	165.00	110.0	140.0	0.0
TOTAL TCDF	1080.00	459.3	1130.0	170.0

[ ] = minimum detection limit

( ) = estimated maximum possible concentration

6.2.2 PM/Metals Sampling Quality Assurance

Table 6-11 presents the leak check results for the PM/Metals. All post-test leak checks met the "0.02 cfm or 4 percent of the sample rate" acceptance criterion.

The isokinetic sampling rates for the PM/Metals trains are listed in Table 6-3. All isokinetic values were within 4 percent of 100 percent, thereby meeting the ± 10 percent criterion.

The post-test dry gas meter calibration check for box number N-31 used for PM/Metals sampling is shown in Table 6-4. The results of -0.92 percent deviation from the full calibration value is well within the 5 percent acceptance criterion.

Table 6-12 presents the results from the metals field blank analysis compared to the average values from the test runs. No metals were detected in the back half fractions (impingers 1,2 and impingers 3,4) except for chromium. Front half field blank results show detections of arsenic, barium, cadmium, chromium, lead, and nickel. Only nickel, chromium, and arsenic field blank amounts are greater than ~4 percent of any of the average run amounts. Arsenic field blank results show the highest relative contamination at 11.4 μg which ranges from 21 to 50 percent of the front half run catches. No arsenic was detected in the field blank back half fraction.

6.2.3 Microbial Survivability in Emissions Quality Assurance

Table 6-13 presents the leak check results for the Microbial Survivability in emissions test runs. All leak checks met the "0.02 cfm or 4 percent of sample rate" acceptance criterion.

Microbial emission testing isokinetic results are presented in Table 6-3. All 18 test runs met the isokinetic criterion of ± 10 percent of 100 percent.

The microbial emissions field blank results are shown in Table 38a. No spores were detected in the 18 enumeration repetitions.

The post-test dry gas meter calibration check for the microbial emissions dry gas meter is shown in Table 6-4. Post-test calibration factors for the "A" runs were within the 5 percent acceptance criterion at -0.31 percent. No post-test calibration was performed on meter box 9 which was used for the "B" runs.

TABLE 6-11. LEAK CHECK RESULTS FOR TOXIC METALS; CENTRAL CAROLINA HOSPITAL (1990)

DATE	RUN NUMBER	PRELIMINARY LEAK RATE (acfm)	MAXIMUM VACUUM DURING TEST	AVG. SAMPLE RATE (dscfm) a	4% SAMPLE RATE (acfm)	ACCEPTABLE LEAK LEVEL (acfm)	MEASUREMENT POST-TEST LEAK RATE	INCHES FOR SEC. CHK.
09/20/90	1	0.009	4	0.42	0.017	0.017	0.005	9
09/21/90	2	0.011	4	0.39	0.016	0.016	0.010	10
09/22/90	3	0.008	2	0.39	0.016	0.016	0.006	10
09/23/90	4	0.006	13	0.41	0.016	0.016	0.018	17
09/24/90	5	0.004	4	0.43	0.017	0.017	0.006	10
09/25/90	6	0.004	2	0.41	0.016	0.016	0.003	8
09/26/90	7	0.006	4	0.41	0.016	0.016	0.003	7
09/27/90	8	0.010	5	0.42	0.017	0.017	0.004	10
09/28/90	9	0.005	4	0.45	0.018	0.018	0.006	11
10/02/90	10	0.004	3	0.40	0.016	0.016	0.006	7

a This value is in dry standard cubic feet per minute (dscfm) and may be slightly different than actual cfm (acfm).

TABLE 6-12. METALS FIELD BLANK RESULTS COMPARED TO AVERAGE AMOUNTS COLLECTED DURING THE TEST RUNS; CENTRAL CAROLINA HOSPITAL (1990)

	FIELD BLANK (ug)			CONDITION 1 (ug)			CONDITION 2 (ug)			CONDITION 3 (ug)		
METAL	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3,4 c	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3,4 c	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3,4 c	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3,4 c
Antimony	(59.5) a	[7.3] b		1520.33	2254.67		1323.33	3160.00		1420.67	2287.33	
Arsenic	11.7	[0.46]		29.17	4.78		55.93	15.04		23.37	11.83	
Barium	22.5	[0.23]		695.67	33.57		1643.33	69.27		581.33	31.23	
Beryllium	[0.50]	[0.23]		0.00	0.00		0.00	0.00		0.92	0.00	
Cadmium	17.0	[0.57]		833.67	0.00		1082.67	0.00		1196.67	0.00	
Chromium	16.0 c	(1.25)		92.27	5.79		87.67	7.22		50.27	5.93	
Lead	32.0	[3.4]		13946.67	1.26		17833.33	1.53		10670.00	0.63	
Mercury	[2.4]	[6.1]	[0.67]	19.40	507.00	1.47	62.13	1214.00	5.59	369.33	4469.00	695.65
Nickel	44.0	[2.3]		41.43	1.03		21.43	0.00		18.43	0.78	
Silver	[8.2]	[3.8]		0.00	23.64		0.00	48.00		0.00	21.70	
Thallium	[14]	[6.2]		338.33	0.00		339.00	5.33		779.33	0.00	

a Values enclosed in parenthesis represent estimates as they are less than five times the detection limit.

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

c Impingers 3 and 4 only sample fractions analyzed for mercury content.

TABLE 6-13. LEAK CHECK RESULTS FOR MICROBIAL SURVIVABILITY IN EMISSIONS SAMPLING RUNS; CENTRAL CAROLINA HOSPITAL (1990)

DATE	RUN NUMBER	PRE-TEST LEAK RATE (acfm)	MAXIMUM VACUUM DURING TEST	AVG. SAMPLE RATE (dscfm)	4% SAMPLE RATE (dscfm) a	ACCEPTABLE LEAK LEVEL (acfm)	MEASUREMENT POST-TEST LEAK RATE	INCHES FOR SEC. CHK.
09/20/90	1A	0.002	2.7	0.59	0.024	0.02	0.003	5
	1B	0.008	3	0.60	0.024	0.02	0.003	6
09/21/90	2A	0.004	19	0.59	0.024	0.02	0.008	28
	2B	0.006	6	0.54	0.022	0.02	0.006	10
09/22/90	3A	0.004	4.5	0.59	0.024	0.02	0.001	6
	3B	0.005	2	0.60	0.024	0.02	0.003	6
09/23/90	4A	0.004	9	0.55	0.022	0.02	0.005	8
	4B	0.006	5	0.57	0.023	0.02	NR	7
09/24/90	5A	0.006	4.5	0.58	0.023	0.02	0.005	9
	5B	0.006	3	0.50	0.02	0.02	0.005	9
09/25/90	6A	0.003	5	0.65	0.026	0.02	0.003	8
	6B	0.004	3	0.62	0.025	0.02	0.008	9
09/27/90	8A	0.001	11.5	0.56	0.022	0.02	0.006	15
	8B	0.008	14	0.56	0.022	0.02	0.01	18
09/28/90	9A	0.003	4	0.61	0.024	0.02	0.006	9
	9B	0.008	1	0.59	0.024	0.02	0.008	5
10/02/90	10A	0.012	4.5	0.61	0.024	0.02	0.014	7
	10B	0.004	1	0.59	0.024	0.02	0.008	3

a This value is in dry standard cubic feet per minute (dscfm) and may be slightly different than actual cfm (acfm).

NR = Data Not Recorded

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 Cl^-, F^-, and 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 6-14. A small amount of HCl was detected in the field blanks (0.245 and 0.25 mg for FB-A and FB-B). These amounts only represent a maximum of 3 percent of the lowest run average amount.

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. steareothermophilus (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

TABLE 6-14. HALOGEN FIELD BLANK RESULTS COMPARED TO RUN RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

ANALYTE	FIELD BLANK A (total mg)	FIELD BLANK B (total mg)	CONDITION 1 AVERAGE (total mg)	CONDITION 2 AVERAGE (total mg)	CONDITION 3 AVERAGE (total mg)
HCl	0.245	0.250	7.31	105	7.85
HF	[0.042]	[0.042]	0.19	0.88	0.13
HBr	(0.0637)	[0.013]	0.08	0.21	0.07

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

( ) Denotes estimate as value is less than 5 times detection limit.

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 (SS) 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, petra, 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. (Toluene Runs 9 and 10,2378 TCDD, Total TCDD were taken from confirmation analyses - see Section 6.4.1.2.)

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

CDD/CDF MM5 samples. Therefore a different analytical protocol was developed for the analysis. One percent of the MM5 extract was used for Runs 2, 4, and 8 (Condition 2) instead of the typical 50 percent. This resulted in a diluted fraction which did not saturate the MS detector. However, surrogate (pre-sample) spike recoveries could not be determined. Additional standards were added at higher than normal amounts to allow full quantitation of the CDD/CDF congeners for Runs 2, 4 and 8.

A slight modification to the CDD/CDF data reduction protocol was also incorporated into the toluene flue gas samples. Values for Runs 9 and 10,2378 TCDD and Total TCDD (Other) were taken from the confirmation analysis as designated by Triangle Laboratories. This is further explained in the TLI Project No. 16653T Case Narrative shown in Appendix E3.

6.4.1.3 CDD/CDF MM5 Blank Results. Both method blanks and field blanks were analyzed for CDD/CDF isomers. Modified Method 5 samples as well as the toluene rinses were submitted. Table 6-15 presents these results. The MM5 method blanks had no CDD/CDF isomers except for a small amount of O_{ctu}-TCDF (0.18 ng). The toluene Field Blank had relatively high quantities of all isomers when compared to the run results (picograms). The toluene method blanks were clean.

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. 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.

As stated before, surrogate recoveries for MM5 Samples 2, 4, and 8 could not be determined because of the modified analytical routine. All other MM5 surrogate recoveries were within ±30 percent.

Internal standard recoveries for MM5 Runs 1-10 FS and C all met the acceptable criteria. All toluene internal standards recoveries were within the acceptance criteria except for Run 1 13C12-HxCDD 678 and several Run 5 isomers. The Run 5 toluene sample had no native hexa-substituted isomers present in hence high standards recoveries

TABLE 6-15. METHOD BLANK AND FIELD BLANK RESULTS FOR THE MM5 AND TOLUENE FLUE GAS SAMPLES; CENTRAL CAROLINA HOSPITAL HOSPTIAL (1990)

FULL-SCREEN ANALYSIS	MM5 TLI-METHOD BLANK (total ng)	MM5 TLI-METHOD BLANK (1/2 OM-50%) (total ng)	MM5 FIELD BLANK (total ng)	TOL TLI-METHOD BLANK (total pg)	TOL FIELD BLANK (total pg)
DIOXINS					
2378 TCDD	[6.500]	[0.050]	[0.060]	[25.50]	10.0
TOTAL TCDD	[6.500]	[0.050]	(0.070)	[25.50]	245.0
12378 PCDD	[8.600]	[0.060]	[0.080]	[31.20]	53.0
TOTAL PCDD	[8.600]	[0.060]	0.29	(34.40)	360.0
123478 HxCDD	[8.500]	[0.050]	[0.100]	[44.40]	60.0
123678 HxCDD	[8.300]	[0.050]	[0.100]	[43.40]	82.2
123789 HxCDD	[9.500]	[0.050]	(0.180)	[49.30]	175.0
TOTAL HxCDD	[8.700]	[0.050]	0.85	[45.60]	895.0
1234678-HpCDD	[14.50]	[0.080]	0.58	[160.0]	618.0
TOTAL HpCDD	[14.50]	[0.080]	0.58	[160.0]	1140.0
Octa-CDD	[26.50]	0.18	(0.950)	[453.0]	887.0
FURANS					
2378 TCDF	[4.500]	[0.040]	0.35	[19.20]	337.0
TOTAL TCDF	[4.500]	[0.040]	0.63	[19.20]	1430.0
12378 PCDF	[6.300]	[0.050]	0.14	[25.50]	149.0
23478 PCDF	[6.600]	[0.050]	0.23	[26.60]	289.0
TOTAL PCDF	[6.400]	[0.050]	1.9	[26.00]	2550.0
123478 HxCDF	[5.000]	[0.030]	(0.680)	[27.30]	544.0
123678 HxCDF	[4.800]	[0.030]	0.38	[26.20]	317.0
234678 HxCDF	[6.600]	[0.040]	(0.460)	[36.20]	366.0
123789 HxCDF	[8.400]	[0.050]	[0.100]	[46.20]	27.2
TOTAL HxCDF	[5.900]	[0.030]	0.72	[32.30]	2450.0
1234678-HpCDF	[6.000]	[0.030]	1.60	[48.50]	1210.0
1234789-HpCDF	[10.10]	[0.060]	[0.200]	[80.70]	(219.0)
TOTAL HpCDF	[7.500]	[0.040]	3.00	[60.60]	2160.0
Octa-CDF	[22.40]	[0.100]	0.91	[383.0]	1380.0

[ ] = minimum detection limit

( ) = estimated maximum possible concentration

TABLE 6-16. STANDARDS RECOVERY RESULTS FOR CDD/CDF ANALYSES, TEST RUN SAMPLES; CENTRAL CAROLINA HOSPITAL (1990)

SAMPLE ID	MM5-RUN 1	MM5-RUN 2	MM5-RUN 3	MM5-RUN 4	MM5-RUN 5	MM5-RUN 6	MM5-RUN 8	MM5-RUN 9	MM5-RUN 10
<u>FULL SCREEN ANALYSES</u>									
SURROGATE STANDARDS RECOVERY (%)									
37Cl-TCDD	86.7		94.9		91.7	91.0		90.2	89.9
13C12-PeCDF 234	107.0		99.7		97.1	100.0		88.0	97.4
13C12-HxCDF 478	90.5		98.5		94.1	94.3		95.0	93.0
13C12-HxCDD 478	86.3		86.1		86.4	71.6		90.6	86.8
13C12-HpCDF 789	78.1		81.7		82.5	87.7		76.2	75.9
ALTERNATE STANDARDS RECOVERY									
13C12-HxCDF 789	81.8	84.7	81.1	91.0	86.2	86.5	82.3	89.6	85.2
13C12-HxCDF 234	102.0	104.0	101.0	105.0	101.0	97.4	107.0	108.0	109.0
INTERNAL STANDARDS RECOVERY									
13C12-2378-TCDF	63.0	78.3	79.7	81.7	75.5	78.6	82.7	87.2	67.4
13C12-2378-TCDD	74.6	84.3	81.7	89.1	81.9	85.1	79.6	82.6	71.4
13C12-PeCDF 123	76.7	96.1	89.1	97.9	82.3	92.2	106.0	99.8	79.1
13C12-PeCDD 123	81.4	120.0	91.5	128.0	77.7	124.0	115.0	98.9	87.6
13C12-HxCDF 678	115.0	105.0	109.0	103.0	115.0	97.5	99.4	113.0	119.0
13C12-HxCDD 678	122.0	106.0	113.0	102.0	119.0	129.0	103.0	119.0	125.0
13C12-HpCDF 678	83.2	84.1	80.3	90.9	81.9	77.5	81.7	81.6	93.7
13C12-HpCDD 678	77.0	75.3	74.9	78.1	77.8	78.3	70.9	74.1	86.1
13C12-OCDD	52.1	55.4	54.0	62.2	55.3	58.4	53.4	54.4	70.8
<u>CONFIRMATION DATA</u>									
SURROGATE STANDARD RECOVERY %									
37Cl-TCDD	98.2		96.5		100.0	101.0		97.2	96.9
INTERNAL STANDARDS RECOVERY %									
13C12-2378-TCDF	76.2	91.3	87.6	98.7	90.9	90.8	93.9	87.5	85.0
13C12-2378-TCDD	78.6	91.6	91.1	98.0	94.7	93.8	95.4	96.2	82.6

TABLE 6-17. STANDARDS RECOVERY RESULTS FOR CDD/CDF ANALYSES BLANK SAMPLES; CENTRAL CAROLINA HOSPITAL (1990)

SAMPLE ID	MM5-FIELD BLANK	MM5-TLI BLANK
FULL SCREEN ANALYSES	(1/2 10 OM)	
SURROGATE STANDARDS RECOVERY (%)		
37Cl-TCDD	90.4	
13C12-PeCDF 234	78.1	
13C12-HxCDF 478	91.6	
13C12-HxCDD 478	86.1	
13C12-HpCDF 789	65.8	
ALTERNATE STANDARDS RECOVERY		
13C12-HxCDF 789	65.1	76.3
13C12-HxCDF 234	87.0	98.8
INTERNAL STANDARDS RECOVERY		
13C12-2378-TCDF	66.2	69.1
13C12-2378-TCDD	73.8	72.0
13C12-PeCDF 123	102.0	83.4
13C12-PeCDD 123	98.4	101.0
13C12-HxCDF 678	104.0	80.1
13C12-HxCDD 678	116.0	83.2
13C12-HpCDF 678	59.9	68.8
13C12-HpCDD 678	49.7	65.9
13C12-OCDD	32.8	53.6
CONFIRMATION DATA		
SURROGATE STANDARD RECOVERY %		
37Cl-TCDD	100.0	
INTERNAL STANDARDS RECOVERY %		
13C12-2378-TCDF	79.8	
13C12-2378-TCDD	75.8	

TABLE 6-18. STANDARDS RECOVERY RESULTS FOR CDD/CDF TOLUENE ANALYSES, TEST RUN SAMPLES CENTRAL CAROLINA HOSPITAL (1990)

SAMPLE ID	TOL-RUN 1	TOL-RUN 2	TOL-RUN 3	TOL-RUN 4	TOL-RUN 5	TOL-RUN 6	TOL-RUN 8	TOL-RUN 9	TOL-RUN 10
FULL SCREEN ANALYSIS									
SURROGATE STANDARDS RECOVERY (%)									
37Cl-TCDD	47.8	53.3	31.6	49.1	31.9	51.8	54.7	69.0	50.9
13C12-PeCDF 234	63.4	75.6	52.4	75.6	48.3	61.8	69.4	79.6	52.8
13C12-HxCDF 478	88.8	76.4	86.0	63.1	170.0	71.1	80.2	77.2	88.7
13C12-HxCDD 478	105.0	93.8	111.0	81.2	171.0	95.0	100.0	110.0	101.0
13C12-HpCDF 789	43.0	44.6	41.2	45.7	71.0	45.8	55.1	56.4	32.4
ALTERNATE STANDARDS RECOVERY									
13C12-HxCDF 789	54.6	54.3	47.6	55.1	78.1	56.4	67.9	68.5	53.9
13C12-HxCDF 234	85.3	82.8	83.9	79.7	128.0	70.2	76.5	87.6	77.8
INTERNAL STANDARDS RECOVERY									
13C12-2378-TCDF	44.9	49.8	30.2	44.8	33.8	53.0	51.9	70.4	50.4
13C12-2378-TCDD	52.8	58.7	35.3	56.3	33.5	56.7	59.2	72.6	61.3
13C12-PeCDF 123	65.9	74.6	53.9	74.3	43.2	58.3	65.5	74.4	59.7
13C12-PeCDD 123	96.5	103.0	74.3	110.0	63.6	86.0	106.0	106.0	57.1
13C12-HxCDF 678	103.0	81.0	95.7	73.7	180.0	77.2	77.6	77.8	89.6
13C12-HxCDD 678	149.0	118.0	142.0	110.0	218.0	104.0	103.0	111.0	105.0
13C12-HpCDF 678	67.5	61.0	64.3	59.1	126.0	58.5	63.7	63.2	52.0
13C12-HpCDD 678	60.9	58.9	52.5	63.4	72.2	62.2	70.1	71.0	47.7
13C12-OCDD	42.1	47.4	34.4	57.7	28.9	43.8	49.4	51.3	33.1
CONFIRMATION DATA									
SURROGATE STANDARD RECOVERY (%)									
37Cl-TCDD	50.4	59.1	40.3	54.2	43.0	59.5	56.2	67.1	61.5
INTERNAL STANDARDS RECOVERY (%)									
13C12-2378-TCDF	60.9	69.1	33.9	48.6	39.4	49.8	53.7	59.3	54.4
13C12-2378-TCDD	48.8	56.4	40.3	56.4	49.1	58.8	60.2	72.5	68.0

TABLE 6-19. STANDARDS RECOVERY RESULTS FOR CDD/CDF TOLUENE ANALYSES, BLANK SAMPLES; CENTRAL CAROLINA HOSPITAL (1990)

SAMPLE ID	TOL-TLI BLANK	TOL-FIELD BLANK
FULL SCREEN ANALYSIS		
SURROGATE STANDARDS RECOVERY (%)		
37Cl-TCDD	31.3	58.1
13C12-PeCDF 234	37.0	73.5
13C12-HxCDF 478	73.1	84.9
13C12-HxCDD 478	83.7	103.0
13C12-HpCDF 789	24.7	53.2
ALTERNATE STANDARDS RECOVERY		
13C12-HxCDF 789	35.6	71.9
13C12-HxCDF 234	61.8	80.8
INTERNAL STANDARDS RECOVERY		
13C12-2378-TCDF	30.0	54.6
13C12-2378-TCDD	34.4	59.8
13C12-PeCDF 123	38.6	67.4
13C12-PeCDD 123	52.2	90.5
13C12-HxCDF 678	78.2	86.3
13C12-HxCDD 678	95.5	112.0
13C12-HpCDF 678	45.8	63.4
13C12-HpCDD 678	31.9	64.0
13C12-OCDD	16.7	30.6
CONFIRMATION DATA		
SURROGATE STANDARD RECOVERY (%)		
37Cl-TCDD		63.7
INTERNAL STANDARDS RECOVERY (%)		
13C12-2378-TCDF		58.8
13C12-2378-TCDD		62.9

these compounds do not present a problem. 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. 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. Only barium was detected in the ash blank. Barium was also detected in the flue gas method blank. Relatively high amounts of arsenic, chromium, and nickel were found in the field blank. This was more fully discussed in Section 6.2.2.

Table 6-22 presents the method spike results for the metals analyses. All spiked recoveries were within the QA allowance of ±20 percent of 100 percent except for the back half fraction of mercury. This does not appear to be significant enough to affect the overall quality of the final results. At this point, no front half method spike duplicate values have been determined.

6.4.3 Halogen Analytical Quality Assessment

The analysis for Cl^-, F^-, and Br^- 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, laboratory proof blanks, or the reagent blank. The field blank revealed very low amounts of HCl but only represented 3 percent of the average 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. Two pre-aliquoted wet spore bags were

TABLE 6-20. STANDARDS RECOVERY RESULTS FOR CDD/CDF ASH ANALYSES; CENTRAL CAROLINA HOSPITAL (1990)

SAMPLE ID	ASH CONDITION 1	ASH CONDITION 2	ASH CONDITION 3	ASH-TLI BLANK
<u>FULL SCREEN ANALYSIS</u>				
SURROGATE STANDARDS RECOVERY (%)				
37Cl-TCDD	73.3	77.3	68.0	37.0
13C12-PeCDF 234	88.8	94.1	88.5	55.6
13C12-HxCDF 478	121.0	108.0	93.2	58.8
13C12-HxCDD 478	119.0	114.0	107.0	80.9
13C12-HpCDF 789	74.4	68.4	59.0	52.1
ALTERNATE STANDARDS RECOVERY				
13C12-HxCDF 789	81.3	86.2	67.4	55.3
13C12-HxCDF 234	112.0	109.0	92.7	78.2
INTERNAL STANDARDS RECOVERY				
13C12-2378-TCDF	98.0	99.5	95.2	33.7
13C12-2378-TCDD	74.0	77.8	69.3	41.6
13C12-PeCDF 123	83.9	84.7	77.7	46.9
13C12-PeCDD 123	73.6	72.1	66.7	77.7
13C12-HxCDF 678	98.1	90.5	79.5	64.3
13C12-HxCDD 678	92.1	94.2	85.7	94.1
13C12-HpCDF 678	89.6	81.4	71.8	58.0
13C12-HpCDD 678	73.0	75.8	63.3	61.6
13C12-OCDD	48.8	57.5	37.6	58.8
<u>CONFIRMATION DATA</u>				
SURROGATE STANDARD RECOVERY (%)				
37Cl-TCDD	77.3	88.0	71.8	
INTERNAL STANDARDS RECOVERY (%)				
13C12-2378-TCDF	67.2	79.0	61.5	
13C12-2378-TCDD	75.9	84.9	70.6	

TABLE 6-21. METALS ASH AND FLUE GAS METHOD BLANK RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

METAL	ASH METHOD BLANK (mg/kg)	FLUE GAS METHOD BLANK			FIELD BLANK		
		FRONT HALF (total ug)	IMPINGERS 1,2 (total ug)	IMPINGERS 3,4 a (total ug)	FRONT HALF (total ug)	IMPINGERS 1,2 (total ug)	IMPINGERS 3,4 a (total ug)
Antimony	[6.4]	[16]	[7.0]		(59.5)	[7.3]	
Arsenic	[4.0]	[1.0]	[0.44]		11.7	[0.46]	
Barium	2.30	6.75	[0.22]		22.5	[0.23]	
Beryllium	[0.20]	[0.50]	[0.22]		[0.50]	[0.23]	
Cadmium	[0.50]	[1.2]	(0.978)		17.0	[0.57]	
Chromium	[1.0]	[2.5]	[1.1]		16.0	(1.25)	
Lead	[3.0]	[0.75]	[3.3]		32.0	[3.4]	
Mercury	[0.039]	[2.4]	[4.0]	[0.37]	[2.4]	[6.1]	[0.67]
Nickel	[2.0]	[5.0]	[2.2]		44.0	[2.3]	
Silver	[3.3]	[8.2]	[3.6]		[8.2]	[3.8]	
Thallium	[5.4]	[14]	[5.9]		[14]	[6.2]	

a Impingers 3 and 4 sample fractions analyzed for mercury content only.

NOTE:

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

-- Values enclosed in parenthesis represent estimates as they are less than five times the detection limit.

TABLE 6-22. METALS METHOD BLANK SPIKE RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

METAL	METHOD SPIKE			METHOD SPIKE DUPLICATE		
	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3,4	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3,4
Antimony	104	95.2		NC	81.0	
Arsenic	98.0	96.2		NC	94.4	
Barium	97.6	96.6		NC	96.0	
Beryllium	99.6	96.0		NC	94.4	
Cadmium	102	101		NC	101	
Chromium	104	99.6		NC	98.2	
Lead	100	95.2		NC	92.8	
Mercury	115	109	64.1	NC	101	80.1
Nickel	92.2	89.6		NC	90.0	
Silver	113	NC		NC	NC	
Thallium	83.4	89.2		NC	85.8	

NC = Analysis not completed

TABLE 6-23. HALOGEN METHOD BLANK, LAB PROOF BLANK, REAGENT BLANK AND MATRIX SPIKE RECOVERY; CENTRAL CAROLINA HOSPITAL (1990)

ANALYTE	METHOD BLANK 1 (total mg)	LAB PROOF BLANK SET 1 (total mg)	LAB PROOF BLANK SET 2 (total mg)	REAGENT BLANK H2SO4 (total mg)	FIELD BLANK A (total mg)	FIELD BLANK B (total mg)	ANALYTE	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)
HCl	[0.011]	[0.011]	[0.011]	[0.0099]	0.245	0.250	HCl	97.20	106
HF	[0.042]	[0.043]	[0.043]	[0.037]	[0.042]	[0.042]	HF	96.20	96.80
HBr	[0.013]	[0.013]	[0.013]	[0.011]	(0.064)	[0.013]	HBr	106.0	96.20

NOTE:
[ ] = Minimum Detection Limit
( ) = Denotes estimated value as number is less than 5 times detection limit.

TABLE 6-24. WET SPORE SPIKE SOLUTION CONIRMATION ANALYSIS; CENTRAL CAROLINA HOSPITAL (1990)

SAMPLE ID	MANUFACTURER'S COUNT (spore/ml)	CONFIRMATION AVERAGE (viable spores/ml)	CONFIRMATION COUNT STANDARD DEVIATION (viable spores/ml)
Spike Aliquot Spore Susp.-1	6.72E+08	3.0E+09	1.0E+09
Spike Aliquot Spore Susp.-2	7.88E+08	3.0E+09	2.0E+09

NOTE: All Values were taken from the average of the 10 ml - 48-hour counts
Spike Aliquot Spore Susp.-1 was labelled 3.68E+11 spores/bag at 500 ml/bag.
Spike Aliquot Spore Susp.-2 was labelled 3.94E+11 spores/bag at 500 ml/bag.

submitted for confirmation analysis. The confirmation counts of 3 x 10^9 and 3 x 10^9 spores/ml were higher than the manufacturer's respective count of 6.72 x 10^8 and 7.88 x 10^8 spores/ml. However, because the final analyses were also completed by the same laboratory conducting confirmation anlayses, 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 exceeded the manufacturer count at 5.2 x 10^6 versus 3.45 x 10^5, respectively.

Two empty pipe samples (blanks) that were not charged to the incinerator were also submitted to the laboratory for analysis. These results are listed on Page 2 in Appendix E.3 (CCH-298, CCH-299). One large and one small pipe field blank were submitted. The results were 10 and >200 spores, respectively. Therefore, either the sample recovery procedures or the analytical methods appear to have contaminated both pipe field blanks.

Two pipes which were loaded with spores and not charged to the incinerator (ambient pipes) were also submitted for analysis (see Apppendix E.3-CCH-300, CCH-301). The results show that the large pipe sample has 10 spores detected and the small pipe sample had >200 spores found. The number of spores detected probably does not represent the total spores present. This is because all pipe samples were rinsed and filtered without any dilutions. Henceforth quantitation of higher numbers of spores (pipes were loaded with 5.2 x 10^6 spores) was not feasible without performing serial dilutions.

6.5 CEM QUALITY ASSURANCES

Flue gas was analyzed for carbon monoxide (CO), oxygen (O_2), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), 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.

TABLE 6-25. DRY SPORE SPIKE SOLUTION CONFIRMATION ANALYSIS; CENTRAL CAROLINA HOSPITAL (1990)

SAMPLE ID	MANUFACTURER'S COUNT (spores/vial)	CONFIRMATION AVERAGE (viable spores/vial)	CONFIRMATION COUNT STANDARD DEVIATION (viable spores/vial)
Dry Spore Glass Vial	3.45E+05	5.2E+06 a	1.0E+06

NOTE: All Values were taken from the average of the 10 ml - 48-hour counts

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 Central Carolina 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 were not completed for 4 out of the 9 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 ±3 percent of full scale as required by EPA Methods 6C and 3A. Although Method 10 for CO allows ±10 percent of full scale drift, the CO drift requirements were ±3 percent for this test program, to ensure the quality of data produced.

Table 6-27 lists the zero and span calibration drift results for each CEM analyzer on each test day. All drifts met QC allowances except HCl-Runs 1 and 9, and THC-Runs 7 and 9. The HCl data for the above runs were drift corrected. The THC CEM data for Run 7 were not included in the final results. No drift corrections were made on the THC-Run 9 data.

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

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_2 with 0.2% O_2 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 3rd Day 3 point for O_2, CO_2, NO_x, SO_2, HCl 4 point for CO, THC	r = 0.998
Sample System Bias	Every 3rd Day Zero and Span	< 5% Span
Response Time	Once/Site	85% of time for stable SO_2 measurements
NO_x Convertor	Once/Site	> 90% conversion efficiency
Stratification Test	Once/Site	Within 10% of average

TABLE 6-27. DAILY CALIBRATION DRIFTS; CENTRAL CAROLINA HOSPITAL (1990)

PARAMETER: O2
ZERO CALIBRATION GAS: 0.2% O2
FULL SCALE: 25

DATE	RUN	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
09/20/90	1	0.0100	-0.5900
09/21/90	2	0.0200	-0.1000
09/22/90	3	0.0100	-0.3300
09/23/90	4	0.0500	-0.3200
09/24/90	5	0.1600	-0.5000
09/25/90	6	0.0200	-0.3100
09/26/90	7	0.1900	-0.6100
09/28/90	9	0.0500	-0.6500
10/02/90	10	-0.0400	-0.4400

PARAMETER: CO
ZERO CALIBRATION GAS: N2
FULL SCALE: 5000

DATE	RUN	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
09/20/90	1	-0.0500	-0.2000
09/21/90	2	0.0000	-0.0400
09/22/90	3	0.0800	-0.2000
09/23/90	4	0.0000	-0.2000
09/24/90	5	-0.0200	-0.0400
09/25/90	6	-0.0100	-0.0900
09/26/90	7	0.0900	-0.1000
09/28/90	9	-0.0500	-0.0900
10/02/90	10	-0.0200	-0.1100

PARAMETER: CO2
ZERO CALIBRATION GAS: N2
FULL SCALE: 20

DATE	RUN	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
09/20/90	1	0.0600	-1.4700
09/21/90	2	0.0200	0.0700
09/22/90	3	0.0700	0.6200
09/23/90	4	-0.0200	0.0300
09/24/90	5	0.0300	0.0400
09/25/90	6	0.0500	0.0100
09/26/90	7	-0.0400	0.2000
09/28/90	9	-0.1700	-0.0400
10/02/90	10	-0.0200	0.0000

TABLE 6-27. DAILY CALIBRATION DRIFTS; (continued)
CENTRAL CAROLINA HOSPITAL (1990)

PARAMETER: HCl
ZERO CALIBRATION GAS: N2
FULL SCALE: 2000

DATE	RUN	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
09/20/90	1	0.3700	-20.0100
09/21/90	2	0.6100	-0.1300
09/22/90	3	no final cal	no final cal
09/23/90	4	-0.1200	-0.5400
09/24/90	5	-0.2600	-0.6900
09/25/90	6	no final cal	no final cal
09/26/90	7	no final cal	no final cal
09/28/90	9	1.4500	9.5500
10/02/90	10	no final cal	no final cal

PARAMETER: SO2
ZERO CALIBRATION GAS: N2
FULL SCALE: 500

DATE	RUN	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
09/20/90	1	-0.0200	-0.1900
09/21/90	2	-0.0100	0.0000
09/22/90	3	0.0500	0.0800
09/23/90	4	-0.0300	-0.1400
09/24/90	5	0.0400	-0.0100
09/25/90	6	-0.0200	-0.1600
09/26/90	7	0.0000	-0.0500
09/28/90	9	-0.0300	-0.0800
10/02/90	10	-0.0200	-0.0700

PARAMETER: NOX
ZERO CALIBRATION GAS: N2
FULL SCALE: 250

DATE	RUN	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
09/20/90	1	0.0200	-2.0900
09/21/90	2	-0.1200	-1.0500
09/22/90	3	-0.3800	-2.0000
09/23/90	4	no final cal	no final cal
09/24/90	5	-0.0700	-1.9300
09/25/90	6	0.0900	0.5700
09/26/90	7	-0.2900	-0.8200
09/28/90	9	0.1000	0.0500
10/02/90	10	0.4500	1.3200

TABLE 6-27. DAILY CALIBRATION DRIFTS; (continued)
CENTRAL CAROLINA HOSPITAL (1990)

PARAMETER: THC
ZERO CALIBRATION GAS: N2
FULL SCALE: 100

DATE	RUN	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
09/20/90	1	0.8900	-0.8800
09/21/90	2	3.9500	0.8700
09/22/90	3	-1.8700	0.9300
09/23/90	4	-1.7100	0.3700
09/24/90	5	-1.1600	-0.9700
09/25/90	6	-1.5100	-1.2500
09/26/90	7	-4.2700	-4.2400
09/28/90	9	-1.4200	-4.7800
10/02/90	10	-1.9600	-1.0600

acceptable if the difference between the measured response and the certified concentration was within ±2 percent of full scale of the analyzer full range.

Table 6-28 presents the results of the daily QC gas challenges. 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.

Table 6-29 presents the results of CEM linearity checks. All linearity checks met the acceptance criteria, except for one CO_2 and one SO_2 check. Other CO_2 and SO_2 linearity checks met the acceptance criteria.

6.5.4 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. Assesments can then be made on the validity of the test run. All PSD test runs were inspected during the Central Carolina 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 Runs 1 and 2 were overloaded and underloaded, respectively, and were, therefore, not accepted as valid test runs. Runs 3

TABLE 6-28. QC GAS RESPONSES; CENTRAL CAROLINA HOSPITAL (1990)

DATE	PARAMETER	TRUE CONCENTRATION	MEASURED CONCENTRATION	PERCENT DIFFERENCE a
09/20/90	O2 b	10.1	10.1	0.00%
		5.0	4.9	-0.40%
09/21/90		10.1	10.1	0.00%
09/22/90		10.1	10.1	0.00%
09/23/90		10.1	10.1	0.00%
09/24/90		10.1	12.3	8.80%
09/25/90		20.2	20.4	0.80%
		10.1	10.1	0.00%
		5.00	5.00	0.00%
09/26/90		10.1	10.1	0.00%
09/27/90		10.1	10.2	0.40%
09/28/90		10.1	11.0	3.60%
		5.0	5.0	0.00%
		20.0	20.0	0.00%
		20.2	20.2	0.00%
10/02/90		5.0	4.9	-0.40%
09/20/90	CO(dry) c	198.0	189.3	-0.17%
		50.0	41.8	-0.16%
09/21/90		198.0	186.7	-0.23%
09/22/90		198.0	182.5	-0.31%
09/23/90		198.0	188.9	-0.18%
09/24/90		198.0	188.4	-0.19%
09/25/90		198.0	188.4	-0.19%
		50.0	44.2	-0.12%
		198.0	192.3	-0.11%
09/27/90		198.0	187.0	-0.22%
09/28/90		198.0	221.0	0.46%
		50.0	48.8	-0.02%
		400.0	402.1	0.04%
10/02/90		50.0	48.6	-0.03%

NOTE:

a percent difference = 100 * (measured value - true value)/span

b in units of percent

c in units of ppm

TABLE 6-28. QC GAS RESPONSES (continued); CENTRAL CAROLINA HOSPITAL (1990)

DATE	PARAMETER	TRUE CONCENTRATION	MEASURED CONCENTRATION	PERCENT DIFFERENCE a
09/20/90	CO2 b	9.03	8.7	-1.65%
		5.03	4.9	-0.65%
09/21/90		9.03	9.0	-0.15%
09/22/90		9.03	9.0	-0.15%
09/23/90		9.03	9.0	-0.15%
09/24/90		9.03	7.9	-5.65%
09/25/90		17.97	18.0	0.15%
		9.03	9.2	0.85%
		5.03	5.1	0.35%
09/26/90		9.03	9.1	0.35%
09/27/90		9.03	9.0	-0.15%
09/28/90		9.03	7.7	-6.65%
		5.03	5.1	0.35%
		17.97	18.0	0.15%
		17.97	18.0	0.15%
10/02/90		5.03	5.1	0.35%
09/20/90	SO2 c	99.9	103.5	0.72%
		50.4	51.5	0.22%
09/21/90		99.9	99.1	-0.16%
09/22/90		99.9	100.1	0.04%
09/23/90		99.9	98.5	-0.28%
09/24/90		99.9	98.5	-0.28%
09/25/90		99.9	100.3	0.08%
		50.4	50.2	-0.04%
		25.2	26.3	0.22%
09/26/90		99.9	97.6	-0.46%
09/27/90		99.9	96.9	-0.60%
09/28/90		99.9	91.5	-1.68%
		50.4	52.8	0.48%
		25.2	25.7	0.10%
10/02/90		99.9	101.6	0.34%
		50.4	50.4	0.00%
		25.2	25.8	0.12%

NOTE:

a percent difference = 100 * (measured value - true value)/span

b in units of percent

c in units of ppm

TABLE 6-28. QC GAS RESPONSES (continued); CENTRAL CAROLINA HOSPITAL (1990)

DATE	PARAMETER	TRUE CONCENTRATION	MEASURED CONCENTRATION	PERCENT DIFFERENCE a
09/20/90	NOX c	102.0	101.7	-0.15%
		51.7	51.5	
09/21/90		51.7	51.5	-0.10%
09/22/90		102.0	102.4	0.20%
09/23/90		102.0	102.0	0.00%
09/24/90		102.0	103.7	0.85%
09/25/90		102.0	104.1	1.05%
		51.7	52.0	0.15%
		250.0	253.2	1.60%
09/26/90		102.0	103.5	0.75%
09/27/90		102.0	104.4	1.20%
09/28/90		102.0	102.8	0.40%
		51.7	52.3	0.30%
10/02/90		102.0	104.2	1.10%
		51.7	52.0	0.15%
09/20/90	THC (wet) c	91.6	91.0	-0.60%
		15.0	15.5	0.50%
09/22/90		91.6	83.7	-7.90%
09/23/90		91.6	88.2	-3.40%
09/24/90		91.6	91.9	0.30%
09/25/90		91.6	89.9	-1.70%
		15.0	14.5	-0.50%
09/26/90		91.6	89.5	-2.10%
09/27/90		91.6	95.2	3.60%
09/28/90		15.0	19.6	4.60%
		240.0	230.8	-9.20%
10/02/90		15.0	15.3	0.30%
09/20/90	HCL (wet) c	1826.8	1845.0	0.91%

NOTE:

a percent difference = 100 * (measured value - true value)/span
b in units of percent
c in units of ppm

TABLE 6-29. LINEARITY RESULTS; CENTRAL CAROLINA HOSPITAL (1990)

PARAMETER	DATE	TRUE CONCENTRATION	MEASURED CONCENTRATION	CORRELATION (R)
02 *	9/25/90	0.20	0.2	0.99980
		5.00	5.0	
		10.10	10.1	
		20.20	20.4	
02 *	9/28/90	0.20	0.2	0.99865
		5.00	5.0	
		10.10	11.0	
		20.20	20.2	
CO **	9/28/90	0.00	0.0	0.99815
		50.00	48.8	
		198.00	221.0	
		400.00	402.1	
CO2 *	9/25/90	0.00	0.0	0.99995
		5.03	5.1	
		9.03	9.2	
		17.97	18.0	
		450.00	475.8	
C02 *	9/28/90	0.00	0.0	0.99596
		5.03	5.1	
		9.03	7.7	
		17.97	18.0	
SO2 **	9/25/90	0.00	0.0	0.99991
		25.20	26.3	
		50.40	50.2	
		99.90	100.3	
SO2 **	9/28/90	0.00	0.00	0.99674
		25.20	25.70	
		50.40	52.80	
		99.90	91.50	
SO2 **	10/02/90	0.00	0.00	0.99994
		25.20	25.80	
		50.40	50.40	
		99.90	101.60	

* in units of percent

** in units of ppm

*** as methane in units of ppm

TABLE 6-29. LINEARITY RESULTS; (continued)
CENTRAL CAROLINA HOSPITAL (1990)

PARAMETER	DATE	TRUE CONCENTRATION	MEASURED CONCENTRATION	CORRELATION (R)
NOx **	9/25/90	0.00	0.0	0.99999
		51.70	52.0	
		102.00	104.1	
		250.00	253.2	
HCl(wet) **	9/28/90	0.00	0.0	0.99982
		101.20	120.2	
		965.90	964.1	
THC ***	9/25/90	0.00	0.00	1.00000
		15.00	14.50	
THC ***	9/28/90	0	0	0.99978
		15	19.6	
		240	230.8	
		91.60	89.90	

* in units of percent

** in units of ppm

*** as methane in units of ppm

through 6 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 can 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

$$CV_p = \sqrt{\frac{\Sigma\,(CV_i)^2\,n_i}{\Sigma n_i}}$$

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 6-30 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 nine runs. Pooled CVs are also compiled for all of the congeners and for the entire test program (overall). The overall pooled CV for the CDD/CDF flue gas concentrations was 64.4 percent.

Table 6-31 presents CVs for the metal flue gas concentrations. The overall pooled CV for the metals flue gas concentrations is 65.0 percent.

The Halogen gas test CVs are listed in Table 6-32. Values were calculated for each run as each run consisted of multiple "sub-runs" (1A, 1B, 1C, etc). The overall pooled CV for all three halogen flue gas concentrations is 29.8 percent.

Table 6-33 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 CV for the CEM data 159 percent. Results from the triplicate manual tests did not fluctuate nearly as much as the 30 second CEM readings, therefore had much lower CVs.

TABLE 6-30. COEFFICIENTS OF VARIATIONS FOR THE CDD/CDF FLUE GAS CONCENTRATIONS; CENTRAL CAROLINA HOSPITAL (1990)

CONGENER	CV:1,3,10 (%)	CV:2,4,8 (%)	CV:5,6,9 (%)	POOLED CV (%)
DIOXINS				
2378 TCDD	47.4	45.8	83.8	61.5
Other TCDD	100.7	29.7	76.8	75.1
12378 PCDD	63.3	46.0	76.3	63.1
Other PCDD	95.8	46.9	80.6	77.2
123478 HxCDD	68.5	39.5	68.7	60.5
123678 HxCDD	64.3	43.6	67.4	59.4
123789 HxCDD	68.4	46.2	59.3	58.7
Other HxCDD	80.2	40.4	64.0	63.7
1234678-HpCDD	58.1	37.2	49.3	48.9
Other HpCDD	60.7	38.3	52.2	51.2
Octa-CDD	60.3	33.1	49.6	48.9
FURANS				
2378 TCDF	64.0	87.6	84.5	79.4
Other TCDF	88.1	83.1	86.7	86.0
12378 PCDF	59.8	66.3	75.2	67.4
23478 PCDF	69.3	60.7	71.0	67.1
Other PCDF	80.1	67.1	86.3	78.2
123478 HxCDF	82.1	56.2	63.8	68.3
123678 HxCDF	72.8	58.2	65.2	65.7
234678 HxCDF	82.0	46.1	60.3	64.5
123789 HxCDF	68.4	56.4	60.0	61.8
Other HxCDF	76.1	55.6	70.1	67.8
1234678-HpCDF	80.7	45.4	50.3	60.8
1234789-HpCDF	74.0	38.7	39.7	53.4
Other HpCDF	78.6	40.9	49.5	58.6
Octa-CDF	75.9	18.7	35.9	49.6
Pooled CV	73.8	51.4	66.6	
Overall Pooled CV	64.4			

TABLE 6-31. COEFFICIENTS OF VARIATION OF THE FLUE GAS METALS CONCENTRATIONS; CENTRAL CAROLINA HOSPITAL (1990)

FLOW RATE (dscmm)	CONDITION 1 CV (%)	CONDITION 2 CV (%)	CONDITION 3 CV (%)	POOLED CV
Antimony	69.7	21.9	8.62	42.4
Arsenic	121	36.6	123	102
Barium	77.1	14.6	16.1	46.3
Beryllium	ND	1.1	ND	1.1
Cadmium	93.4	16.0	25.4	50.2
Chromium	93.2	11.2	116	86.2
Lead	19.2	22.8	28.2	24.2
Mercury	92.9	30.5	ND	69.1
Nickel	ND	66.4	113.1	92.7
Silver	ND	28.8	ND	28.8
Thallium	ND	ND	ND	ND
Pooled CV	87.6	30.8	78.6	
Overall Pooled CV	65.0			

ND = Not Detected

TABLE 6-32. COEFFICIENTS OF VARIATION FOR HALOGEN FLUE GAS CONCENTRATIONS; CENTRAL CAROLINA HOSPITAL (1990)

TEST RUN NUMBER	HCl (%)	HF (%)	HBr (%)
CV-1	28.8	25.8	4.40
CV-3	2.33	29.5	5.89
CV-10	48.2	60.0	12.6
Pooled Condition 1	**34.4**	**42.6**	**8.67**
CV-2	8.71	46.3	46.6
CV-4	47.2	36.7	31.3
CV-8	34.3	30.5	8.61
Pooled Condition 2	**36.0**	**37.3**	**30.6**
CV-5	20.1	21.7	ND
CV-6	6.28	15.2	ND
CV-9	26.8	16.5	9.36
Pooled Condition 3	**19.7**	**18.0**	**9.36**
Pooled Analyte	**30.6**	**33.8**	**21.4**
Total Pooled Halogen		**29.8**	

TABLE 6-33. COEFFICIENTS OF VARIATION OF CEM GAS CONCENTRATIONS; CENTRAL CAROLINA HOSPITAL (1990)

RUN NUMBER	DATE	COEFFICIENTS OF VARIATION (percent)							POOLED CV BY DAY
		O2	CO2	CO	NOx	SO2	HCl	THC	
1	9/20/90	6.09	23.6	325	51.3	58.8	172	174	157
2	9/21/90	10.7	33.5	248	49.7	122	44.8	259	146
3	9/22/90	7.67	28.7	235	71.2	55.8	91.5	177	122
4	9/23/90	9.76	31.1	201	68.7	88.7	62.5	398	176
5	9/24/90	6.15	27.8	252	46.9	43.3	32.9	447	196
6	9/25/90	5.76	24.0	254	49.0	41.0	36.7	323	158
8	9/27/90	10.0	32.6	283	46.6	133	56.2	130	131
9	9/28/90	7.73	28.5	296	44.8	42.6	43.8	411	194
10	10/02/90	8.78	32.2	228	61.3	57.4	39.5	251	133
Pooled Compound		8.26	29.3	260	55.2	78.6	76.6	306	
Overall Pooled		159							

7.0 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.