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Medical Waste Incineration Emission Test Report

Lenoir Memorial Hospital
Kinston, North Carolina

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MEDICAL WASTE INCINERATION
EMISSION TEST REPORT

Lenoir Memorial Hospital
Kinston, North Carolina

VOLUME I

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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.

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. Section 11008 of the MWTA requires EPA to evaluate the efficiency of incineration as a treatment technology. Additionally, there was a need to evaluate incineration emissions from existing medical waste incinerators (MWI's). These data are required to assess the actual potential impacts on health and the environment from existing sources, the vast majority of which 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 MWI facilities. The emission test program described in this report is one of the studies.

The MWI facility at Lenoir Memorial Hospital in Kinston, North Carolina, was selected for emissions testing because it is typical of existing ram-fed units with a secondary chamber gas retention time of less than 0.5 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, North Carolina, (RTP), 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 Lenoir Memorial Hospital MWI were:

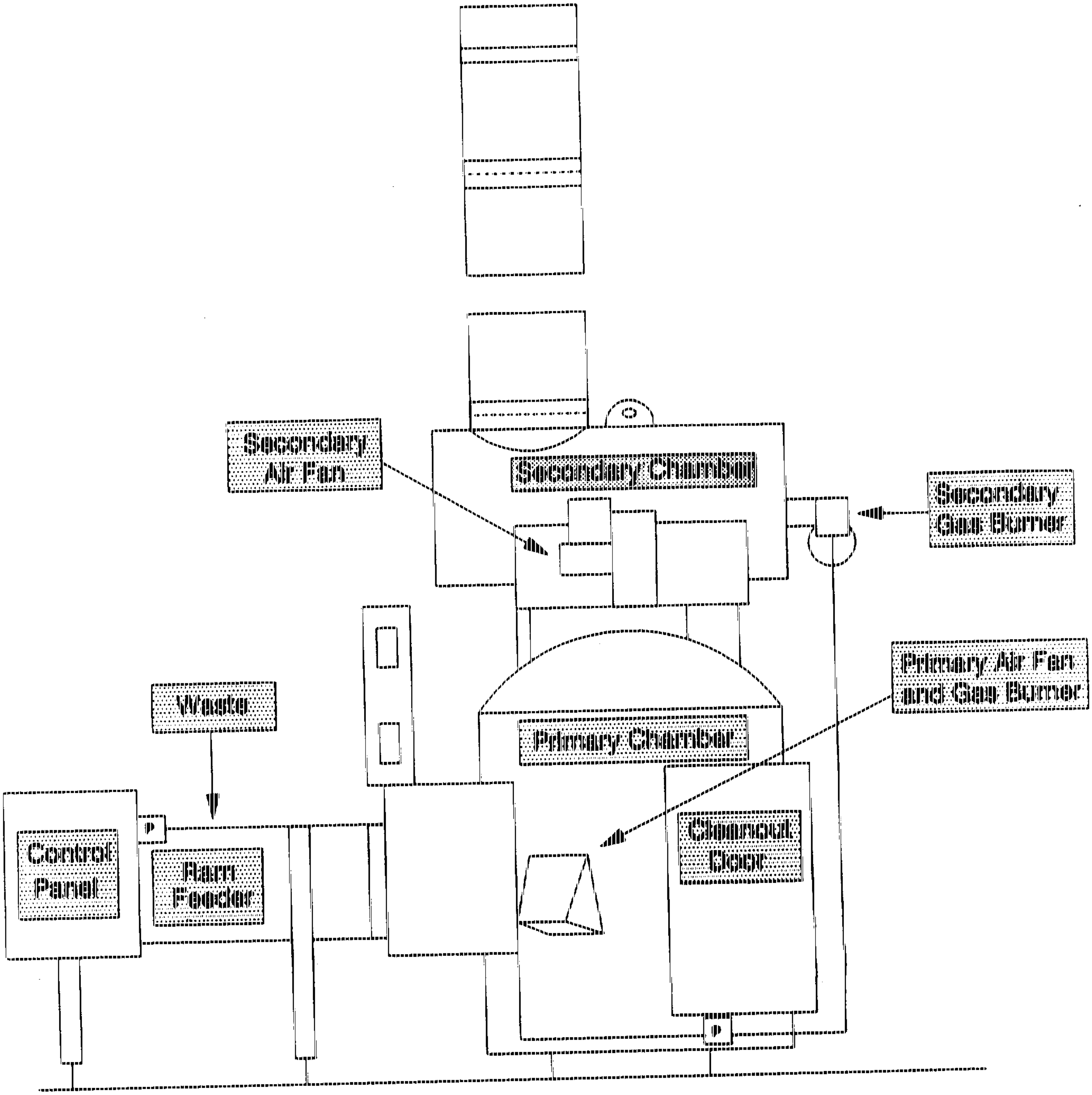

Figure 1-1. Lenoir Memorial Hospital Incinerator

- 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 generation as factors 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 the general effectiveness of incineration as a medical waste treatment technology by spiking a surrogate indicator organism to the incinerator feed during each test run and determining the quantity of microbes surviving the process.
- 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:

- Set 1 - Design feed rate (300 lb/hr) at a high charge frequency (6 minute cycle) and a high secondary chamber temperature setpoint of 1900-2000°F.
- Set 2 - Below-design feed rate (200 lb/hr) at a high charge frequency (6 minute cycle) and a high secondary chamber temperature setpoint (1900-2000°F).

- Set 3 - Design feed rate (300 lb/hr) at the design charging frequency (10 minute cycle), and the design secondary chamber temperature setpoint of about 1600°F.

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

Lenoir Memorial Hospital is a 226-bed hospital located in Kinston, North Carolina. The MWI for this facility is located behind the facility near the loading dock area. The MWI is a 320 pound per hour (lb/hr) rated, ram-fed unit manufactured by Environmental Control Products (now known as Joy Energy Systems). The facility is located beside a dumpster near the maintenance shop area and existing boiler facilities. Wastes are brought out of the main building via the loading dock area by hospital housekeeping staff in plastic carts. Cafeteria waste, office waste and cardboard are separated to some degree and placed in the dumpster which is then deposited in a local landfill. The remainder of the waste is burned in the incinerator. The waste is brought out periodically, some is burned and some is stored outdoors in large plastic bins.

There is no full time operator for the MWI facility. The housekeeping staff alternately loads waste into the charge hopper as their schedule permits. The facility is maintained by the hospital's engineering and maintenance department who removes the ash on a daily or bi-daily basis. The ash is stored in 35 gallon trash cans and taken to the local landfill on a weekly basis.

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 Lenoir Memorial Hospital. Included in this section are summaries of the 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 Lenoir Memorial 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 particulate matter/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 and placed in the bulk ash containers where it was sampled using a sample thief to obtain a representative sample.

1.3.3 Sampling Methods

Total particulate matter emissions along with a series of 11 toxic metals [lead (Pb), chromium (Cr), cadmium (Cd), mercury (Hg), nickel (Ni), arsenic (As), beryllium (Be), antimony (Sb), barium (Ba), silver (Ag), and thallium (Tl)], were determined using a single sample train. Particulate loading on the filter and front half (nozzle/probe, filter holder) rinse was determined gravimetrically. Metals analyses were then completed on the filter front half rinses and back half impinger catches using atomic absorption (AA) and inductively coupled argon plasma (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, a chilled adsorbent trap, and in the

TABLE 1-1. LENOIR MEMORIAL 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
Stack	27[a]	HCl/HBr/HF	EPA Method 26	1 hour	Ion Chromatography	Radian
Stack	20[b]	Indicator Spores	Draft EPA Method	1.8 hours	Microbial Draft Method	RTI
Stack	9	SO_2	EPA Method 6C	Continuous	UV Analyzer CEM	Radian
Stack	9	O_2 /CO_2	EPA Method 3A	Continuous	Zirconium Oxide Cell/ NDIR CEM	Radian
Stack	9	NO_x	EPA Method 7E	Continuous	Chemilumenesence CEM	Radian
Stack	9	CO	EPA Method 10	Continuous	NDIR CEM	Radian
Stack	9	THC	EPA Method 25A	Continuous	FID CEM	Radian
Stack	9	HCl	CEM	Continuous	NDIR CEM	Radian
Stack	9	Opacity	EPA Method 9	4 hour	Visual	Radian
Incinerator	9	Incinerator Ash	Representative Composite Sample/Manual	1 day	LOI, Carbon	McCoy Labs
	9		Representative Composite Sample/Manual	1 day	Metals	Radian
	9		Representative Composite Sample/Manual	1 day	Dioxins	Triangle Labs
	9		Representative Composite Sample/Manual	1 day	Microbial Draft Method	RTI
Incinerator	27	Indicator Spore Pipes	Manual	1 day	Microbial Draft Method	RTI

[a] Three runs comprised one complete test for the HCl/HBr/HF (halogen) tests.
[b] Three runs comprised a complete test for Tests 1 and 2; two runs for Tests 3 through 9.

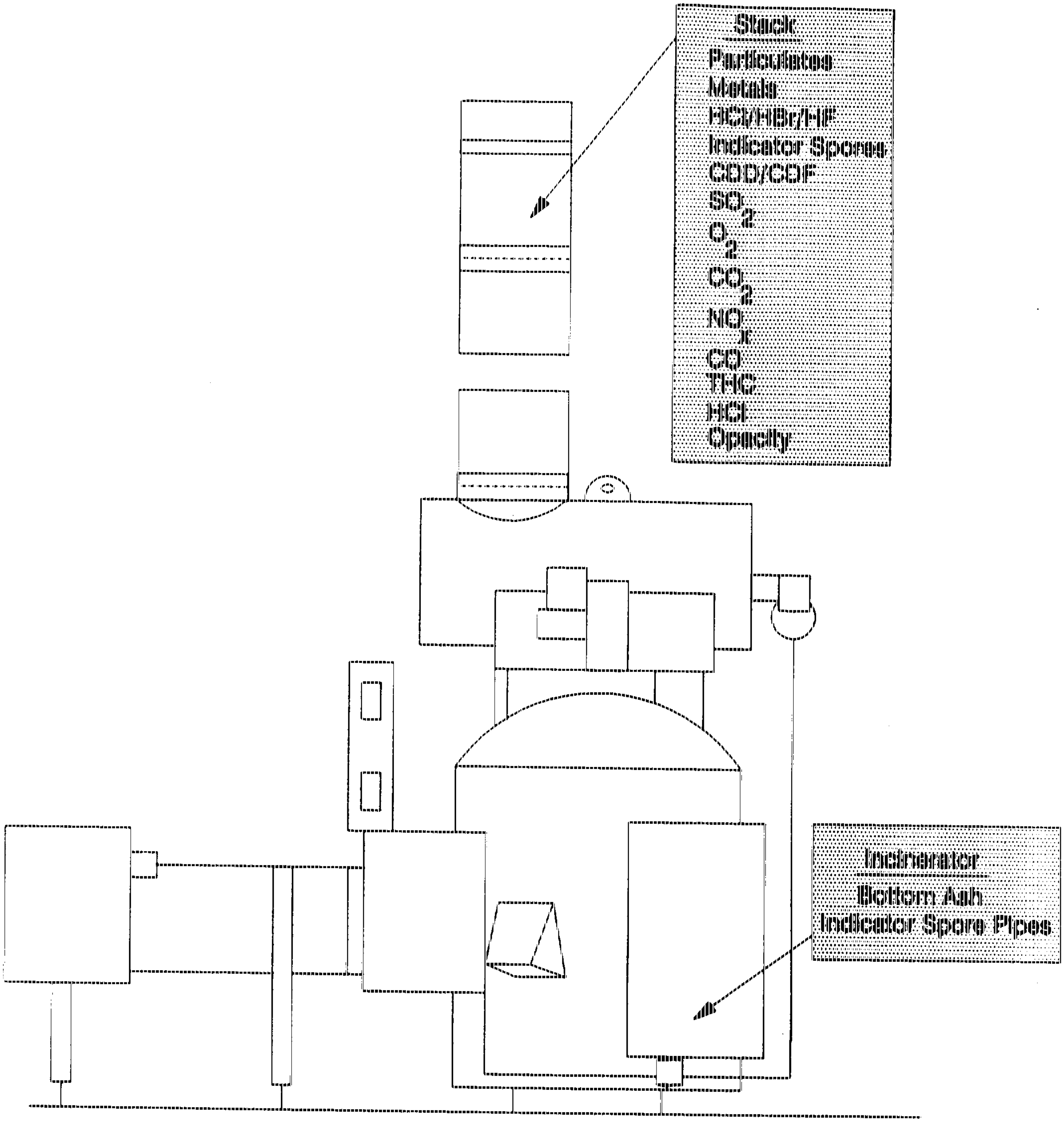

Figure 1-2. Sampling Locations at the Lenoir Memorial Hospital MWI

impingers. The analysis was completed using high resolution gas chromatography coupled with mass spectrometry detection (GC/MS).

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

In order to adequately evaluate the efficiency of the incinerator process, three types of microbial survivability tests were completed on the incinerator. These tests were intended to generally evaluate the effectiveness of the medical waste incinerator in destroying the most heat resistent microbes found in the waste. This was achieved by emissions testing, direct ash sampling, and by using spiked pipe containers. In order to test the flue gases and ash, indicator spores were loaded to material commonly found in the medical waste stream and then charged into the incinerator. This approach was used to determine the ability of the indicator organisms to survive in the combustion gases and the incinerator bottom ash. The flue gas testing for spore emissions was conducted simultaneously with the other emissions testing. Pipe samples were spiked with 1×10^6 organisms, and added to the waste stream at appropriate time intervals. Following the daily burn cycle, ash samples and pipe samples were recovered and analyzed for spore viability. Direct ash sampling and pipe recovery was conducted daily as 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 and quantification techniques outlined in the EPA draft method "Microbial Survivability Test for Medical Waste Incinerator Emissions." 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 using a sample thief 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. The reference methods are included in the Test Plan and Quality Assurance Project Plan prepared for this project.

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. 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. Because of the quantity of organics present in the CDD/CDF samples, a representative flue gas sample was analyzed for polychlorinated biphenyls (PCBs) as well as polycyclic aromatic hydrocarbons (PAHs).

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 (ICAP), Graphite Furnace Atomic Absorption (GFAA) and Cold Vapor Atomic Absorption (CVAA). 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 Ion Chromatographic techniques.

Microbial survivability samples from the emissions tests and the ash and pipe tests were analyzed for viable spores of Bacillus 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 (included in the test plan for this test program).

The incinerator ash was analyzed by McCoy Labs for volative matter (LOI) by Standard Methods of Water and Wastes, 209G and 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 Lenoir 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 19 out of 20 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 virtually no contamination in the MM5 CDD/CDF FB, PM/Metals FB, microbial FB or halogen FB samples. The CDD/CDF toluene rinse field blank had higher levels of most CDD/CDF congeners than most of the runs. This would not affect any emission rate values as toluene results are not incorporated into those calculations.

From an analytical QA perspective, all analyses were completed under a strict QA/QC regimen. The initial CDD/CDF MM5 analyses experienced high organic concentrations posing interference and saturation problems. These samples were diluted and reanalyzed without any further problems.

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 38.5 percent for CDD/CDF flue gas concentrations to 51.5 percent for metals flue gas concentrations.

The overall pooled CV for the CEM data was 254 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 Lenoir Memorial Hospital in Kinston, 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, particulate matter/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 Lenoir 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 particulate matter 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, and process sampling procedures.

Section 6 provides details of the quality assurance/quality control 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 Lenoir Memorial Hospital MWI from May 30 to June 8, 1990. Included in this section are results of manual tests conducted for CDD/CDF, toxic metals, particulate matter, 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.

2.1 EMISSIONS TEST LOG

Ten tests were conducted over a nine day period. Test Run 5 was repeated due to problems encountered with high particulate loadings in the flue gas which resulted in unreliable CEM results.

Table 2-1 is the emissions test log. This table shows the test date, run number, test type, run times and port change times for all the manual 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 Lenoir Memorial Hospital during the May/June 1990 test program. One of the runs (Run 5) was invalidated due to poor CEM performance caused by high particulate loadings and was therefore, repeated (Run 5R). Three runs were completed under each of three test conditions. Testing protocol followed EPA Method 23 which requires a final sample recovery rinse of toluene to be analyzed separately from the rest of the sample. Because this data is not incorporated into the final emission results, it will be presented with the sampling QA parameters in Section 6.3.1.

Daily ash samples were taken and composited into a single sample for each test condition (i.e., three samples total). The ash samples were also analyzed for tetra through octa CDD/CDF isomers.

TABLE 2-1. EMISSIONS TEST LOG
LENOIR MEMORIAL HOSPITAL (1990)

DATE	LOCATION	RUN NUMBER	TEST TYPE	RUN TIME	PORT CHANGES
5/30/90	Stack	1	Toxic Metals	14:56--20:22	16:56--18:22
5/30/90	Stack	1	CDD/CDF	14:55--20:22	16:55--18:22
5/30/90	Stack	1A	HCl	15:11--16:11	
5/30/90	Stack	1B	HCl	16:25--17:25	
5/30/90	Stack	1C	HCl	18:37--19:38	
5/30/90	Stack	1A	Spore	14:53--15:53	
5/30/90	Stack	1B	Spore	17:16--18:01	
5/30/90	Stack	1C	Spore	20:02--20:47	
5/31/90	Stack	2	Toxic Metals	12:47--17:11	14:52--15:11
5/31/90	Stack	2	CDD/CDF	12:47--17:11	14:54--15:11
5/31/90	Stack	2A	HCl	12:56--13:50	
5/31/90	Stack	2B	HCl	14:05--15:05	
5/31/90	Stack	2C	HCl	16:00--17:05	
5/31/90	Stack	2A	Spore	12:52--13:52	
5/31/90	Stack	2B	Spore	14:40--15:40	
5/31/90	Stack	2C	Spore	16:13--17:13	
6/01/90	Stack	3	Toxic Metals	10:19--14:40	12:19--12:40
6/01/90	Stack	3	CDD/CDF	10:19--14:40	12:19--12:40
6/01/90	Stack	3A	HCl	10:19--11:19	
6/01/90	Stack	3B	HCl	11:30--12:31	
6/01/90	Stack	3C	HCl	12:55--13:55	
6/01/90	Stack	3A	Spore	10:17--12:05	
6/01/90	Stack	3B	Spore	12:40--14:28	
6/02/90	Stack	4	CDD/CDF	10:02--14:23	12:02--12:23
6/02/90	Stack	4A	HCl	10:00--11:00	
6/02/90	Stack	4B	HCl	11:10--12:10	
6/02/90	Stack	4C	HCl	13:05--14:05	
6/02/90	Stack	4A	Spore	10:00--11:48	
6/02/90	Stack	4B	Spore	12:22--14:10	
6/04/90 *	Stack	5	Toxic Metals	10:50--15:01	12:50--13:01
6/04/90 *	Stack	5	CDD/CDF	10:50--15:01	12:50--13:01
6/04/90 *	Stack	5A	HCl	10:50--11:50	
6/04/90 *	Stack	5B	HCl	12:00--13:00	
6/04/90 *	Stack	5C	HCl	13:10--14:10	
6/04/90 *	Stack	5A	Spore	10:51--12:39	
6/04/90 *	Stack	5B	Spore	13:58--15:46	
6/04/90	Stack	4R	Toxic Metals	15:43--19:47	17:43--17:47

* Bad CEM data. All runs invalidated.

TABLE 2-1. EMISSIONS TEST LOG, (continued)
LENOIR MEMORIAL HOSPITAL (1990)

DATE	LOCATION	RUN NUMBER	TEST TYPE	RUN TIME	PORT CHANGES
6/05/90	Stack	6	Toxic Metals	11:21--15:32	13:21--13:32
6/05/90	Stack	6	CDD/CDF	11:21--15:32	13:21--13:32
6/05/90	Stack	6A	HCl	12:20--13:20	
6/05/90	Stack	6B	HCl	13:30--14:30	
6/05/90	Stack	6C	HCl	15:00--16:00	
6/05/90	Stack	6A	Spore	11:20--13:08	
6/05/90	Stack	6B	Spore	13:37--15:25	
6/06/90	Stack	7	Toxic Metals	10:14--14:33	12:14--12:28
6/06/90	Stack	7	CDD/CDF	10:14--14:28	12:14--12:28
6/06/90	Stack	7A	HCl	10:15--11:15	
6/06/90	Stack	7B	HCl	13:13--14:15	
6/06/90	Stack	7C	HCl	14:35--15:15	
6/06/90	Stack	7A	Spore	10:12--12:00	
6/06/90	Stack	7B	Spore	12:30--14:18	
6/06/90	Stack	5R	Toxic Metals	16:57--21:07	18:57--19:07
6/06/90	Stack	5R	CDD/CDF	16:57--21:07	18:57--19:07
6/06/90	Stack	5RA	HCl	16:59--17:59	
6/06/90	Stack	5RB	HCl	18:15--19:15	
6/06/90	Stack	5RC	HCl	19:46--20:46	
6/06/90	Stack	5RA	Spore	16:57--18:45	
6/06/90	Stack	5RB	Spore	19:19--21:05	
6/07/90	Stack	8	Toxic Metals	12:55--17:04	14:55--15:04
6/07/90	Stack	8	CDD/CDF	12:55--17:04	14:55--15:04
6/07/90	Stack	8A	HCl	12:55--13:55	
6/07/90	Stack	8B	HCl	14:25--15:25	
6/07/90	Stack	8C	HCl	15:36--16:37	
6/07/90	Stack	8A	Spore	12:54--14:42	
6/07/90	Stack	8B	Spore	15:12--17:00	
6/08/90	Stack	9	Toxic Metals	11:20--14:27	13:20--13:27
6/08/90	Stack	9	CDD/CDF	11:20--15:27	13:25--13:27
6/08/90	Stack	9A	HCl	11:23--12:23	
6/08/90	Stack	9B	HCl	12:34--13:34	
6/08/90	Stack	9C	HCl	14:38--15:38	
6/08/90	Stack	9A	Spore	11:22--13:10	
6/08/90	Stack	9B	Spore	13:41--15:29	

The following sections report CDD/CDF emission test results in Section 2.2.2 and incinerator ash CDD/CDF concentrations in Section 2.2.3. Emission values incorporating the final toluene rinse amounts are given in Section 2.9.

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 substituted CDD/CDF isomers. Results are presented for each isomer as well as for each tetra octa homologue total (Total CDD, Total CDF).

Average CDD/CDF stack gas concentrations for each test condition are presented in Table 2-2. Stack gas concentrations of all target CDD/CDF congeners were detected in every test run throughout the program. Condition 3 showed the highest concentration for all targeted CDD/CDF congeners except Octa CDD and Octa CDF. The average concentration of 2378 TCDD for Condition 3 was 16.2 ng/dscm. Averages for 2378 TCDD for Conditions 1 and 2 were 2.40 and 1.20 ng/dscm, respectively. The average concentration of Total CDD/CDF for Condition 3 was 19,100 ng/dscm. Values for Conditions 1 and 2 were 4,540 and 5,150 ng/dscm, respectively.

Average CDD/CDF concentrations corrected to 7 percent O_2 for each test condition are shown in Table 2-3. Average O_2 concentrations for Conditions 1, 2, and 3 were 11.8, 12.4, and 13.6 percent by dry volume, respectively. Because of the higher O_2 values, corrected concentrations for Condition 3 increased from actual concentrations more than did corrected concentrations from the other two test conditions. Corrected concentrations of 2378 TCDD for Conditions 1, 2, and 3 were 3.84, 1.95, and 31.0 ng/dscm at 7 percent O_2, respectively. Corrected concentrations of Total CDD/CDF for Conditions 1, 2, and 3 were 7,260, 9,090, and 35,500 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 5.11, 2.48, and 30.7 ug/hr, respectively. Average total CDD/CDF emissions for Conditions 1, 2, and 3 were 9,650, 10,600, and 35,800 ug/hr, respectively.

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

CONGENER	CONCENTRATION [a] (ng/dscm, as measured)		
	CONDITION 1	CONDITION 2	CONDITION 3
DIOXINS			
2378 TCDD	2.40	1.20	16.2
Other TCDD	26.3	12.8	200
12378 PCDD	15.3	8.64	88.7
Other PCDD	64.2	47.7	371
123478 HxCDD	21.3	19.4	86.0
123678 HxCDD	20.9	18.2	85.2
123789 HxCDD	46.4	34.1	198
Other HxCDD	128	115	546
1234678--HpCDD	160	226	440
Other Hepta--CDD	145	205	394
Octa--CDD	280	608	371
TOTAL CDD	910	1,296	2,794
FURANS			
2378 TCDF	12.1	6.0	79.6
Other TCDF	430	214	1885
12378 PCDF	41.4	25.0	214
23478 PCDF	65.5	53.0	304
Other PCDF	644	524	3,096
123478 HxCDF	229	192	895
123678 HxCDF	129	88.3	560
234678 HxCDF	153	188	507
123789 HxCDF	9.30	6.09	56.4
Other HxCDF	685	564	2,812
1234678--HpCDF	484	522	2,974
1234789--HpCDF	76.1	90.6	447.1
Other Hepta--CDF	349	450	2,002
Octa--CDF	327	927	460
TOTAL CDF	3,630	3,850	16,300
TOTAL CDD+CDF	4,540	5,150	19,100

[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; LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	CONCENTRATION (ng/dscm, adjusted to 7 percent O2)		
	CONDITION 1	CONDITION 2	CONDITION 3
DIOXINS			
2378 TCDD	3.84	1.95	31.0
Other TCDD	41.5	20.7	380
12378 PCDD	23.2	14.3	169
Other PCDD	99.0	79.0	701
123478 HxCDD	32.3	33.3	164
123678 HxCDD	32.6	31.0	161
123789 HxCDD	72.1	57.7	374
Other HxCDD	200	195	1,030
1234678-HpCDD	256	397	825
Other Hepta-CDD	231	367	736
Octa-CDD	446	1,105	693
TOTAL CDD	1440.0	2300.0	5260.0
FURANS			
2378 TCDF	19.1	9.70	152
Other TCDF	679	362	3565
12378 PCDF	64.8	41.3	403
23478 PCDF	102.2	89.4	570
Other PCDF	989	899	5,788
123478 HxCDF	362	338	1,666
123678 HxCDF	201	152	1,044
234678 HxCDF	249	333	946
123789 HxCDF	14.9	10.2	105.9
Other HxCDF	1,085	974.2	5,242
1234678-HpCDF	780	920	5,465
1234789-HpCDF	127	155	820
Other Hepta-CDF	580	787	3,668
Octa-CDF	573	1,718	831
TOTAL CDF	5,830	6,790	30,300
TOTAL CDD+CDF	7,260	9,090	35,500

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

CONGENER	EMISSIONS (μg/hr)		
	CONDITION 1	CONDITION 2	CONDITION 3
DIOXINS			
2378 TCDD	5.11	2.48	30.7
Other TCDD	56.0	26.5	378
12378 PCDD	32.6	17.8	167
Other PCDD	136.7	98.4	697
123478 HxCDD	45.2	40.0	162
123678 HxCDD	44.4	37.6	160
123789 HxCDD	98.9	70.3	372
Other HxCDD	272	236	1,025
1234678-HpCDD	341	466	823
Other Hepta-CDD	309	423	736
Octa-CDD	592	1,250	692
TOTAL CDD	1930.0	2670.0	5240.0
FURANS			
2378 TCDF	25.9	12.3	150
Other TCDF	916	442	3553
12378 PCDF	88.2	51.5	403
23478 PCDF	139	109	572
Other PCDF	1,373	1,079	5,826
123478 HxCDF	487	396	1676.9
123678 HxCDF	274	182	1049.7
234678 HxCDF	324	388	950
123789 HxCDF	19.8	12.6	106.0
Other HxCDF	1,456	1,161	5,272
1234678-HpCDF	1,027	1,074	5,549
1234789-HpCDF	161.0	187	833
Other Hepta-CDF	737.8	927	3,729
Octa-CDF	687.5	1,905	852
TOTAL CDF	7,720	7,930	30,500
TOTAL CDD+CDF	9,650	10,600	35,800

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 values.(1) The average 2378 Toxic Equivalent Concentrations for Total CDD/CDF for Conditions 1, 2, and 3 were 181, 170, and 955 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. Run 4 and Runs 7, 8, and 9 have values which are classified as estimated maximum possible concentration (EMPC). These values, shown in parenthesis, 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.

Table 2-9 presents 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, gas flow, and other parameters are given.

2.2.3 CDD/CDF Ash Results

Three daily ash samples were taken and composited into a single sample per test condition. Results from the composite sample CDD/CDF analyses are shown in Table 2-13. Values are given in parts per billion (ppb). All target CDD/CDF congeners were detected on every run except for 123478 HxCDD during Condition 2, 2378 TCDF for Condition 2, and 123789 HxCDF for Conditions 1 and 2. The average concentration of 2378 TCDD in ash was 0.032 ppb.

Ash 2378 Toxic Equivalencies are also shown in Table 2-13. The total CDD/CDF 2378 Toxic Equivalency averaged over all three conditions was 0.69 ppb.

TABLE 2-5. AVERAGE CDD/CDF 2378 TOXIC EQUIVALENT STACK GAS CONCENTRATIONS ADJUSTED TO 7 PERCENT O2 FOR EACH TEST CONDITION LENOIR MEMORIAL HOSPTIAL (1990)

CONGENER	2378-TCDD a TOXIC EQUIV. FACTOR	2378 TOXIC EQUIVALENCIES (ng/dscm, @ 7 percent O2) CONDITION 1	CONDITION 2	CONDITION 3
DIOXINS				
2378 TCDD	1.00000	3.84	1.95	31.05
Other TCDD	0.00000	0.00	0.00	0.00
12378 PCDD	0.50000	11.58	7.15	84.44
Other PCDD	0.00000	0.00	0.00	0.00
123478 HxCDD	0.10000	3.23	3.33	16.40
123678 HxCDD	0.10000	3.26	3.10	16.09
123789 HxCDD	0.10000	7.21	5.77	37.40
Other HxCDD	0.00000	0.00	0.00	0.00
1234678-HpCDD	0.01000	2.56	3.97	8.25
Other Hepta-CDD	0.00000	0.00	0.00	0.00
Octa-CDD	0.00100	0.45	1.10	0.69
TOTAL CDD		32.1	26.4	194
FURANS				
2378 TCDF	0.10000	1.91	0.97	15.24
Other TCDF	0.00000	0.00	0.00	0.00
12378 PCDF	0.05000	3.24	2.07	20.17
23478 PCDF	0.50000	51.11	44.72	285.22
Other PCDF	0.00000	0.00	0.00	0.00
123478 HxCDF	0.10000	36.22	33.77	166.56
123678 HxCDF	0.10000	20.14	15.18	104.41
234678 HxCDF	0.1000	24.92	33.29	94.57
123789 HxCDF	0.1000	1.49	1.02	10.59
Other HxCDF	0.0000	0.00	0.00	0.00
1234678-HpCDF	0.0100	7.80	9.20	54.65
1234789-HpCDF	0.0100	1.27	1.55	8.20
Other Hepta-CDF	0.0000	0.00	0.00	0.00
Octa-CDF	0.0010	0.57	1.72	0.83
TOTAL CDF		149	143	760
TOTAL CDD+CDF		181	170	955

[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.

TABLE 2-6. CDD/CDF STACK GAS CONCENTRATIONS AND EMISSIONS RATES AT CONDITION 1

	CONCENTRATION a (ng/dscm, as measured)				EMISSIONS (µg/hr)			
CONGENER	RUN 1	RUN 2	RUN 3	AVERAGE	RUN 1	RUN 2	RUN 3	AVERAGE
DIOXINS								
2378 TCDD	0.79	3.76	2.64	2.40	1.60	8.19	5.53	5.11
Other TCDD	9.7	42.5	26.6	26.3	19.7	92.5	55.8	56.0
12378 PCDD	6.04	28.0	11.8	15.3	12.3	60.8	24.8	32.6
Other PCDD	30.8	106.3	55.5	64.2	62.8	231.2	116	136.7
123478 HxCDD	13.3	34.3	16.1	21.3	27.2	74.7	33.7	45.2
123678 HxCDD	9.64	33.6	19.4	20.9	19.7	73.0	40.6	44.4
123789 HxCDD	18.6	78.1	42.5	46.4	37.9	169.8	88.9	98.9
Other HxCDD	56.1	205.0	122.4	128	114.5	445.8	256	272.3
1234678--HpCDD	85.0	228.1	168.3	160	173.3	496.2	353	340.7
Other Hepta--CDD	73.9	211.9	150.1	145	150.7	460.8	315	308.7
Octa--CDD	212.5	345.9	282.2	280	433.4	752.3	591	592.3
TOTAL CDD	516	1,317	897	910	1,053	2,865	1,880	1,933
FURANS								
2378 TCDF	4.39	20.1	11.9	12.1	8.94	43.7	24.9	25.9
Other TCDF	166	687	436	430	339	1494	913	916
12378 PCDF	18.0	66.9	39.3	41.4	36.8	145.5	82.4	88.2
23478 PCDF	31.1	104.5	60.8	65.5	63.5	227.3	127	139.4
Other PCDF	316.3	1,080	537	644	645.0	2,349	1,124	1,373
123478 HxCDF	116.4	343.3	228	229	237.4	746.8	478	487.3
123678 HxCDF	57.9	205.7	122	129	118.1	447.5	256	273.9
234678 HxCDF	72.0	205.5	181	153	146.9	446.9	379	324.3
123789 HxCDF	3.3	14.4	10.2	9.3	6.8	31.3	21.3	19.8
Other HxCDF	337.8	1,027	691	685	688.8	2,233	1,447	1,456
1234678--HpCDF	265.8	653.6	533	484	542.1	1,422	1,117	1,027
1234789--HpCDF	38.2	88.0	102	76.1	77.8	191.4	214	161.0
Other Hepta--CDF	183.3	410.5	452	349	373.8	892.8	947	737.8
Octa--CDF	201.4	253.3	525	327	410.7	550.9	1,101	687.5
TOTAL CDF	1,810	5,160	3,930	3,630	3,700	11,200	8,230	7,720
TOTAL CDD+CDF	2,330	6,480	4,830	4,540	4,750	14,100	10,110	9,650

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

TABLE 2-7. CDD/CDF STACK GAS CONCENTRATIONS AND EMISSIONS RATES AT CONDITION 2

CONGENER	CONCENTRATION a (ng/dscm, as measured)				EMISSIONS (µg/hr)			
	RUN 4	RUN 5R	RUN 6	AVERAGE	RUN 4	RUN 5R	RUN 6	AVERAGE
DIOXINS								
2378 TCDD	(1.331)	0.84	1.42	1.20	(2.783)	1.72	2.92	2.48
Other TCDD	12.7	7.98	17.8	12.8	26.5	16.3	36.6	26.5
12378 PCDD	7.83	7.40	10.7	8.64	16.4	15.2	22.0	17.8
Other PCDD	45.0	42.2	55.8	47.7	94.1	86.5	114.7	98.4
123478 HxCDD	12.8	23.5	22.0	19.4	26.7	48.1	45.1	40.0
123678 HxCDD	15.2	21.3	18.3	18.2	31.8	43.6	37.5	37.6
123789 HxCDD	26.1	37.1	39.2	34.1	54.5	75.9	80.5	70.3
Other HxCDD	95.4	132.7	115.9	115	199.4	271.9	238.0	236
1234678--HpCDD	167.3	345.0	166.2	226	349.8	707.0	341.1	466
Other Hepta--CDD	150.2	353.4	112.3	205	314.0	724.2	230.6	423
Octa--CDD	355.5	1160.3	306.9	608	743.4	2377.5	630.2	1,250
TOTAL CDD	889	2,132	867	1,296	1,859	4,368	1,779	2,669
FURANS								
2378 TCDF	5.32	4.05	8.50	5.96	11.1	8.29	17.5	12.3
Other TCDF	177	235	230	214	370	481	473	442
12378 PCDF	20.2	21.0	33.8	25.0	42.1	43.0	69.4	51.5
23478 PCDF	39.9	55.3	63.8	53.0	83.5	113.4	131.1	109
Other PCDF	343.0	645.0	583.1	524	717.1	1,322	1,197	1,079
123478 HxCDF	122.4	289.3	164.6	192	256.0	592.8	338.0	396
123678 HxCDF	66.5	112.2	86.2	88.3	139.1	229.9	176.9	182
234678 HxCDF	129.3	299.6	135.8	188	270.3	613.9	278.8	388
123789 HxCDF	5.51	5.76	7.00	6.09	11.5	11.8	14.4	12.6
Other HxCDF	394.9	743.5	552.6	564	825.7	1,523	1,135	1,161
1234678--HpCDF	344.5	805.3	415.4	522	720.3	1,650	852.9	1,074
1234789--HpCDF	73.8	114.1	83.8	90.6	154.2	233.8	172.2	187
Other Hepta--CDF	308.0	656.9	385.4	450	644.0	1,346	791.3	927
Octa--CDF	380.2	1,958	442.3	927	795.1	4012.0	908.1	1,905
TOTAL CDF	2,410	5,950	3,190	3,850	5,040	12,200	6,560	7,930
TOTAL CDD+CDF	3,300	8,080	4,060	5,150	6,900	16,500	8,330	10,590

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

CONGENER	CONCENTRATION [a] (ng/dscm, as measured)				EMISSIONS (μg/hr)			
	RUN 7	RUN 8	RUN 9	AVERAGE	RUN 7	RUN 8	RUN 9	AVERAGE
DIOXINS								
2378 TCDD	13.9	15.7	19.1	16.2	25.4	29.9	36.8	30.7
Other TCDD	165.5	179.2	254.7	200	302.5	342.1	490.2	378
12378 PCDD	88.0	81.0	97.1	88.7	160.8	154.6	186.8	167
Other PCDD	441.7	311.8	358.4	371	807.3	595.2	689.6	697
123478 HxCDD	99.5	81.9	76.4	86.0	181.9	156.4	147.0	162
123678 HxCDD	109.4	71.0	75.2	85.2	199.9	135.4	144.7	160
123789 HxCDD	230.2	165.3	197.8	198	420.8	315.6	380.6	372
Other HxCDD	722.8	418.7	495.7	546	1,321	799.2	953.7	1,025
1234678-HpCDD	645.0	338.0	335.6	440	1,179	645.2	645.8	823
Other Hepta-CDD	619.4	280.1	281.7	394	1,132	534.8	542.0	736
Octa-CDD	627.9	266.7	218.5	371	1,148	509.2	420.3	692
TOTAL CDD	3,763	2,210	2,410	2,794	6,879	4,218	4,638	5,245
FURANS								
2378 TCDF	74.8	78.6	85.4	79.6	137	150	164	150
Other TCDF	2053	1572	2030	1885	3752	3000	3907	3553
12378 PCDF	229.4	173.6	237.9	214	419.3	331.3	457.8	403
23478 PCDF	359.7	227.8	323.6	304	657.4	434.8	622.7	572
Other PCDF	3,734	2,144	3,409	3,096	6,825	4,093	6,559	5,826
123478 HxCDF	1,290	587.7	806.1	894.62	2,358	1,122	1,551	1,677
123678 HxCDF	786.0	380.6	512.4	559.69	1436.6	726.6	986.0	1049.7
234678 HxCDF	717.6	347.1	455.5	506.76	1311.7	662.6	876.4	950
123789 HxCDF	(69.63)	(42.63)	(56.94)	(56.39)	(127.3)	(81.4)	(109.5)	(106.0)
Other HxCDF	4,028	1,888	2,520	2,812	7,363	3,604	4,849	5,272
1234678-HpCDF	5,186	1,526	2,212	2,974	9,479	2,912	4,255	5,549
1234789-HpCDF	811.6	221.1	308.7	447	1,483	422.0	593.9	833
Other Hepta-CDF	3,695	969.5	1,343	2,002	6,754	1,851	2,583	3,729
Octa-CDF	982.5	158.0	238.8	460	1,796	301.7	459.6	852
TOTAL CDF	24,000	10,300	14,500	16,300	43,900	19,700	28,000	30,500
TOTAL CDD+CDF	27,800	12,500	16,900	19,100	50,800	23,900	32,600	35,800

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

( ) = estimated maximum possible concentration.

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

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV.	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 1	RUN 2	RUN 3	AVERAGE	FACTOR	RUN 1	RUN 2	RUN 3	AVERAGE
DIOXINS									
2378 TCDD	1.09	4.84	5.59	3.84	1.00000	1.09	4.84	5.59	3.84
Other TCDD	13.5	54.7	56.3	41.5	0.00000	0.00	0.00	0.00	0.00
12378 PCDD	8.42	36.0	25.0	23.2	0.50000	4.21	18.00	12.51	11.58
Other PCDD	42.9	136.8	117.4	99.0	0.00000	0.00	0.00	0.00	0.00
123478 HxCDD	18.6	44.2	34.1	32.3	0.10000	1.86	4.42	3.41	3.23
123678 HxCDD	13.4	43.2	41.0	32.6	0.10000	1.34	4.32	4.10	3.26
123789 HxCDD	25.9	100.5	89.8	72.1	0.10000	2.59	10.05	8.98	7.21
Other HxCDD	78.3	263.8	259.0	200	0.00000	0.00	0.00	0.00	0.00
1234678-HpCDD	118.5	293.6	356.0	256	0.01000	1.19	2.94	3.56	2.56
Other Hepta-CDD	103.0	272.7	317.7	231	0.00000	0.00	0.00	0.00	0.00
Octa-CDD	296.3	445.2	597.0	446	0.00100	0.30	0.45	0.60	0.45
TOTAL CDD	720.0	1,696	1,899	1,438		12.6	45.0	38.7	32.1
FURANS									
2378 TCDF	6.11	25.9	25.2	19.1	0.10000	0.61	2.59	2.52	1.91
Other TCDF	232	884	922	679	0.00000	0.00	0.00	0.00	0.00
12378 PCDF	25.1	86.1	83.2	64.8	0.05000	1.26	4.30	4.16	3.24
23478 PCDF	43.4	134.5	128.7	102	0.50000	21.70	67.27	64.35	51.11
Other PCDF	441.0	1,390	1,135	989	0.00000	0.00	0.00	0.00	0.00
123478 HxCDF	162.3	441.9	482.5	362	0.10000	16.23	44.19	48.25	36.22
123678 HxCDF	80.8	264.8	258.5	201	0.10000	8.08	26.48	25.85	20.14
234678 HxCDF	100.4	264.5	382.8	249	0.1000	10.04	26.45	38.28	24.92
123789 HxCDF	4.6	18.5	21.5	14.9	0.1000	0.46	1.85	2.15	1.49
Other HxCDF	470.9	1,321	1,462	1,085	0.0000	0.00	0.00	0.00	0.00
1234678-HpCDF	370.6	841.2	1,128	780	0.0100	3.71	8.41	11.28	7.80
1234789-HpCDF	53.2	113.3	215.8	127	0.0100	0.53	1.13	2.16	1.27
Other Hepta-CDF	255.5	528.3	956.2	580	0.0000	0.00	0.00	0.00	0.00
Octa-CDF	280.8	326.0	1,112	573	0.0010	0.28	0.33	1.11	0.57
TOTAL CDF	2,527	6,640	8,314	5,827		62.9	183	200	149
TOTAL CDD+CDF	3,247	8,336	10,213	7,265		75.5	228	239	181

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.

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

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV.	2378 TOXIC EQUIVALENCES (ng/dscm, adjusted to 7 percent O2)			
	RUN 4	RUN 5R	RUN 6	AVERAGE	FACTOR	RUN 4	RUN 5R	RUN 6	AVERAGE
DIOXINS									
2378 TCDD	(1.943)	1.68	2.22	1.95	1.000	(1.943)	1.68	2.22	1.95
Other TCDD	18.5	15.9	27.7	20.7	0.000	0.00	0.00	0.00	0.00
12378 PCDD	11.4	14.8	16.7	14.3	0.500	5.72	7.39	8.33	7.15
Other PCDD	65.7	84.3	87.0	79.0	0.000	0.00	0.00	0.00	0.00
123478 HxCDD	18.7	46.9	34.2	33.3	0.100	1.87	4.69	3.42	3.33
123678 HxCDD	22.2	42.5	28.5	31.0	0.100	2.22	4.25	2.85	3.10
123789 HxCDD	38.1	74.0	61.1	57.7	0.100	3.81	7.40	6.11	5.77
Other HxCDD	139.2	265.0	180.6	195	0.000	0.00	0.00	0.00	0.00
1234678--HpCDD	244.3	689.1	258.9	397	0.010	2.44	6.89	2.59	3.97
Other Hepta--CDD	219.3	705.9	175.0	367	0.000	0.00	0.00	0.00	0.00
Octa--CDD	519.1	2,317	478.3	1,105	0.001	0.52	2.32	0.48	1.10
TOTAL CDD	1,298	4,257	1,350	2,302		18.5	34.6	26.0	26.4
FURANS									
2378 TCDF	7.77	8.08	13.25	9.70	0.100	0.78	0.81	1.32	0.97
Other TCDF	259	469	359	362	0.000	0.00	0.00	0.00	0.00
12378 PCDF	29.4	41.9	52.7	41.3	0.050	1.47	2.10	2.63	2.07
23478 PCDF	58.3	110.5	99.5	89.4	0.500	29.15	55.26	49.75	44.72
Other PCDF	500.8	1,288	908.7	899	0.000	0.00	0.00	0.00	0.00
123478 HxCDF	178.8	577.8	256.5	338	0.100	17.88	57.78	25.65	33.77
123678 HxCDF	97.2	224.1	134.3	152	0.100	9.72	22.41	13.43	15.18
234678 HxCDF	188.8	598.4	211.6	333	0.100	18.88	59.84	21.16	33.29
123789 HxCDF	8.05	11.5	10.9	10.2	0.100	0.80	1.15	1.09	1.02
Other HxCDF	576.5	1,485	861.1	974	0.000	0.00	0.00	0.00	0.00
1234678--HpCDF	503.0	1,608	647.3	920	0.010	5.03	16.08	6.47	9.20
1234789--HpCDF	107.7	227.9	130.7	155	0.010	1.08	2.28	1.31	1.55
Other Hepta--CDF	449.7	1,312	600.5	787	0.000	0.00	0.00	0.00	0.00
Octa--CDF	555.2	3,910	689.2	1,718	0.001	0.56	3.91	0.69	1.72
TOTAL CDF	3,520	11,873	4,975	6,789		85.3	222	123	143
TOTAL CDD+CDF	4,818	16,130	6,325	9,091		104	256	149	170

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.

c ( ) = 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 LENOIR MEMORIAL 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 7	RUN 8	RUN 9	AVERAGE		RUN 7	RUN 8	RUN 9	AVERAGE
DIOXINS									
2378 TCDD	24.27	34.70	34.17	31.0	1.000	24.27	34.70	34.17	31.05
Other TCDD	289.4	397.3	454.6	380	0.000	0.00	0.00	0.00	0.00
12378 PCDD	153.9	179.6	173.2	169	0.500	76.93	89.78	86.62	84.44
Other PCDD	772.3	691.3	639.5	701	0.000	0.00	0.00	0.00	0.00
123478 HxCDD	174.0	181.6	136.4	164	0.100	17.40	18.16	13.64	16.40
123678 HxCDD	191.2	157.3	134.2	161	0.100	19.12	15.73	13.42	16.09
123789 HxCDD	402.6	366.6	352.9	374	0.100	40.26	36.66	35.29	37.40
Other HxCDD	1,264	928.2	884.4	1,025	0.000	0.00	0.00	0.00	0.00
1234678--HpCDD	1,128	749.3	598.9	825	0.010	11.28	7.49	5.99	8.25
Other Hepta--CDD	1,083	621.1	502.6	736	0.000	0.00	0.00	0.00	0.00
Octa--CDD	1,098	591.4	389.8	693	0.001	1.10	0.59	0.39	0.69
TOTAL CDD	6,580	4,898	4,301	5,260		190	203	190	194
FURANS									
2378 TCDF	131	174	152	152	0.100	13.07	17.42	15.24	15.24
Other TCDF	3589	3485	3623	3565	0.000	0.00	0.00	0.00	0.00
12378 PCDF	401.1	384.8	424.6	403	0.050	20.05	19.24	21.23	20.17
23478 PCDF	628.9	504.9	577.5	570	0.500	314.43	252.47	288.75	285.22
Other PCDF	6,528	4,754	6,083	5,788	0.000	0.00	0.00	0.00	0.00
123478 HxCDF	2,256	1,303	1,438	1,666	0.100	225.56	130.29	143.84	166.56
123678 HxCDF	1,374	843.8	914.4	1,044	0.100	137.42	84.38	91.44	104.41
234678 HxCDF	1,255	769.6	812.8	946	0.100	125.47	76.96	81.28	94.57
123789 HxCDF	(121.7)	(94.5)	(101.6)	(105.9)	0.100	(12.17)	(9.45)	(10.15)	10.59
Other HxCDF	7,043	4,185	4,497	5,242	0.000	0.00	0.00	0.00	0.00
1234678--HpCDF	9,067	3,382	3,946	5,465	0.010	90.67	33.82	39.46	54.65
1234789--HpCDF	1,419	490.1	550.8	820	0.010	14.19	4.90	5.51	8.20
Other Hepta--CDF	6,460	2,149	2,396	3,668	0.000	0.00	0.00	0.00	0.00
Octa--CDF	1,718	350.4	426.2	831	0.001	1.72	0.35	0.43	0.83
TOTAL CDF	41,870	22,776	25,841	30,162		955	629	697	760
TOTAL CDD+CDF	48,450	27,674	30,142	35,422		1,145	832	887	955

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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.

c ( ) = estimated maximum possible concentration.

TABLE 2-12. CDD/CDF EMISSIONS SAMPLING AND FLUE GAS PARAMETERS LENOIR MEMORIAL HOSPITAL (1990)

Run Number Date	Test Condition 1			
	1 05/30/90	2 05/31/90	3 06/01/90	Average
Total Sampling Time (min.)	240	240	240	240
Average Sampling Rate (dscfm)	0.543	0.579	0.568	0.563
Standard Metered Volume,Vm(std) (dscm)	3.694	3.932	3.863	3.830
Average Stack Temperature (°F)	1306.75	1381.50	1349.29	1345.85
Carbon Dioxide Concentration (%V)	6.91	7.20	4.49	6.20
Oxygen Concentration (%V)	10.93	10.10	14.33	11.79
Stack Moisture (%V)	11.83	12.74	13.52	12.70
Volumetric Flow Rate (acfm)	4579.37	5101.21	4911.73	4864.10
Volumetric Flow Rate (dscfm)	1200.19	1280.00	1232.94	1237.71
Volumetric Flow Rate (dscmm)	33.99	36.25	34.92	35.05
Percent Isokinetic	99.61	99.44	101.41	100.16

Run Number Date	Test Condition 2			
	4 06/02/90	5R 06/06/90	6 06/05/90	Average
Total Sampling Time (min.)	240	240	240.00	240
Average Sampling Rate (dscfm)	0.39	0.39	0.38	0.38
Standard Metered Volume,Vm(std) (dscm)	2.63	2.62	2.60	2.62
Average Stack Temperature (°F)	1208.35	1319.58	1258.73	1262.22
Carbon Dioxide Concentration (%V)	6.35	4.89	6.01	5.75
Oxygen Concentration (%V)	11.38	13.94	11.98	12.43
Stack Moisture (%V)	11.74	11.48	11.14	11.45
Volumetric Flow Rate (acfm)	4400.13	4572.90	4426.55	4466.53
Volumetric Flow Rate (dscfm)	1230.67	1205.80	1208.27	1214.91
Volumetric Flow Rate (dscmm)	34.85	34.15	34.22	34.41
Percent Isokinetic	100.55	104.29	103.27	102.70

Run Number Date	Test Condition 3			
	7 06/06/90	8 06/07/90	9 06/08/90	Average
Total Sampling Time (min.)	240	240	240	240
Average Sampling Rate (dscfm)	0.344	0.483	0.491	0.440
Standard Metered Volume,Vm(std) (dscm)	2.34	3.28	3.34	2.99
Average Stack Temperature (°F)	1329.73	1274.19	1301.48	1301.80
Carbon Dioxide Concentration (%V)	5.94	4.59	5.86	5.46
Oxygen Concentration (%V)	12.95	14.63	13.11	13.56
Stack Moisture (%V)	12.78	13.01	13.32	13.03
Volumetric Flow Rate (acfm)	4163.79	4241.62	4349.81	4251.74
Volumetric Flow Rate (dscfm)	1075.66	1123.39	1132.39	1110.48
Volumetric Flow Rate (dscmm)	30.46	31.81	32.07	31.45
Percent Isokinetic	104.53	100.53	101.35	102.14

TABLE 2-13. CDD/CDF ASH RESULTS
LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	CONDITION 1 (ppb)	CONDITION 2 (ppb)	CONDITION 3 (ppb)	AVERAGE (ppb)	TOXIC EQUIV. FACTOR a	2378 TOXIC EQUIVALENCIES CONDITION 1 (ppb)	2378 TOXIC EQUIVALENCIES CONDITION 2 (ppb)	2378 TOXIC EQUIVALENCIES CONDITION 3 (ppb)	2378 TOXIC EQUIVALENCIES AVERAGE (ppb)
DIOXINS									
2378 TCDD	0.080	0.005	(0.010)	0.032	1.000	0.0800	0.0050	(0.010)	0.02833
Other TCDD	6.220	0.255	0.560	2.345	0.000	0.0000	0.0000	0.0000	0.00000
12378 PCDD	0.250	(0.009)	(0.040)	0.100	0.500	0.1250	(0.005)	(0.02)	0.05000
Other PCDD	8.450	0.160	0.740	3.117	0.000	0.0000	0.0000	0.0000	0.00000
123478 HxCDD	0.300	[0.005]	0.050	0.175	0.100	0.0300	0.0000	0.0050	0.01167
123678 HxCDD	0.660	(0.009)	0.080	0.250	0.100	0.0660	(0.001)	0.0080	0.02500
123789 HxCDD	1.300	(0.020)	0.160	0.493	0.100	0.1300	(0.002)	0.0160	0.04933
Other HxCDD	16.240	0.190	1.010	5.813	0.000	0.0000	0.0000	0.0000	0.00000
1234678-HpCDD	6.900	0.090	0.450	2.480	0.010	0.0690	0.0009	0.0045	0.02480
Other Hepta-CDD	14.300	0.150	0.650	5.033	0.000	0.0000	0.0000	0.0000	0.00000
Octa-CDD	17.600	0.130	0.860	6.197	0.001	0.0176	0.0001	0.0009	0.00620
TOTAL CDD	72.30	1.02	4.61	26.0		0.518	0.014	0.064	0.199
FURANS									
2378 TCDF	7.200	[0.003]	1.100	4.150	0.100	0.7200	0.0000	0.1100	0.27667
Other TCDF	30.500	1.200	4.900	12.200	0.000	0.0000	0.0000	0.0000	0.00000
12378 PCDF	1.100	0.040	0.240	0.460	0.050	0.0550	0.0020	0.0120	0.02300
23478 PCDF	2.600	0.080	0.510	1.063	0.500	1.3000	0.0400	0.2550	0.53167
Other PCDF	39.500	0.590	5.250	15.113	0.000	0.0000	0.0000	0.0000	0.00000
123478 HxCDF	10.200	0.100	0.940	3.747	0.100	1.0200	0.0100	0.0940	0.37467
123678 HxCDF	2.800	0.040	0.320	1.053	0.100	0.2800	0.0040	0.0320	0.10533
234678 HxCDF	5.100	0.060	0.610	1.923	0.100	0.5100	0.0060	0.0610	0.19233
123789 HxCDF	[0.020]	[0.005]	(0.020)	0.020	0.100	0.0000	0.0000	(0.002)	0.00200
Other HxCDF	22.300	0.280	1.930	8.170	0.000	0.0000	0.0000	0.0000	0.00000
1234678-HpCDF	20.500	0.150	1.400	7.350	0.010	0.2050	0.0015	0.0140	0.07350
1234789-HpCDF	0.640	0.020	0.110	0.257	0.010	0.0064	0.0002	0.0011	0.00257
Other Hepta-CDF	13.760	0.090	0.890	4.913	0.000	0.0000	0.0000	0.0000	0.00000
Octa-CDF	14.300	0.130	0.850	5.093	0.001	0.0143	0.0001	0.0009	0.00509
TOTAL CDF	171	2.78	19.1	64.1		4.11	0.06	0.58	1.59
TOTAL CDD+CDF	243	3.80	23.7	90.1		4.63	0.08	0.65	1.78

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.

[ ] = minimum detection limit

( ) = estimated maximum possible concentration

2.2.4 PAH, CB, CP and PCB Emission Results

Because of the high concentration of organics found in the CDD/CDF Modified Method 5 (MM5) flue gas samples, it was decided to quantify some of the organic species. A single sample was selected for analyses of polyaromatic hydrocarbons (PAHs), chlorobenzenes (CBs), chlorophenols (CPs) and polychlorinated biphenyls (PCBs). The Run 7 MM5 sample was chosen for analysis because it was collected during the worst case emissions scenario (Condition 3). Because EPA instructed Radian to conduct the analyses after the samples had already been collected, typical analytical quantification procedures were not performed. This was due to the fact that it is necessary to spike the XAD traps with a series of standards prior to sampling, in order to accurately quantify the results. Therefore, only the presence of PCB isomers can be confirmed without any quantitation. PAH, CB, and CP results are semi-qualitative and only represent the amount of compounds in the sample extract and not necessarily in the MM5 sample (biased low).

The PAH results are presented in Table 2-14. Results are reported in total μg detected, stack gas concentrations in ug/dscm and ug/dscm at 7 percent O_2 and emissions in mg/hr. These units are 1000-fold higher than the units used for CDD/CDF results - total ng, ng/dscm, ug/hr. Napthelene, Z-Methylanaphthalene, Acenaphylene Phenanthrene, Fluoranthene, Pyrene and Benzo(g,h,i)perylene were the only PAH species detected. Concentrations for those species ranged from 5.13 ug/dscm for Acenapthylene to 270 ug/dscm for Naphthalene. Emission rates for those two species ranged from 9.39 to 493 mg/hr, respectively. However, because there was no archived laboratory blank extract available, laboratory contamination could not be checked. There is usually some naphthalene found in the laboratory blank as it is a known constituent of XAD resin and toluene. Therefore, the naphthalene value should be flagged as suspect. Values for other PAHs are based on minimum detection limits or estimated maximum possible concentrations.

The CB and CP flue gas results are shown in Table 2-15. One congener of chlorophenol was detected out of the seventeen CP target compounds. Two congeners of chlorobenzene were detected out of the eleven CB target compounds.

TABLE 2-14. POLYCYCLIC AROMATIC HYDROCARBONS FLUE GAS RESULTS LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	ANALYSIS (total µg)	GAS CONC. (µg/dscm)	GAS CONC. @7% O2 (µg/dscm)	EMISSIONS (mg/hr)
Naphthalene[a]	631	270	471	493
2-methylnaphtalene	(12.02)	(5.135)	(8.978)	(9.386)
2-Chloronapthalene	[0.180]	[0.077]	[0.135]	[0.141]
Acenapthylene	118.0	50.4	88.1	92.1
Acenapthene	[0.160]	[0.068]	[0.119]	[0.124]
Fluorene	[0.160]	[0.068]	[0.119]	[0.124]
Phenathrene	159	67.8	119	124
Anthracene	[0.110]	[0.047]	[0.082]	[0.086]
Fluoranthene	178	76.1	133	139
Pyrene	158	67.6	118	124
Benzo(a)anthracene	[0.080]	[0.034]	[0.059]	[0.062]
Chrysene	[0.080]	[0.034]	[0.059]	[0.062]
Benzo(b)fluoranthene	[0.080]	[0.034]	[0.059]	[0.062]
Benzo(k)fluoranthene	[0.080]	[0.034]	[0.059]	[0.062]
Benzo(a)pyrene	[0.080]	[0.034]	[0.059]	[0.062]
Benzo(e)pyrene	[0.090]	[0.038]	[0.066]	[0.069]
Perylene	[0.140]	[0.060]	[0.105]	[0.110]
Indeno(1,2,3-cd)pyrene	[0.110]	[0.047]	[0.082]	[0.086]
Dibenz(a,h)anthracene	[0.100]	[0.043]	[0.075]	[0.079]
Benzo(g,h,i)perylene	78.2	33.4	58.4	61.1
TOTAL	1334	570	997	1042

a This value is suspect high as the sample adsorbent (XAD II) is known to have naphthalene present.

b [ ] = minimum detection limit.

c ( ) = estimated maximum possible concentration.

TABLE 2-15. CHLORINATED PHENOLS AND CHLORINATED BENZENES FLUE GAS RESULTS CDD/CDF RUN 7; LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	ANALYSIS (total µg)	GAS CONC. (µg/dscm)	GAS CONC. @7% O2 (µg/dscm)	EMISSIONS (mg/hr)
2-Chlorophenol	[0.340]	[0.145]	[0.254]	[0.265]
3-Chlorophenol	[0.080]	[0.034]	[0.059]	[0.062]
4-Chlorophenol	[0.080]	[0.034]	[0.059]	[0.062]
2,4-Dichlorophenol	[0.220]	[0.094]	[0.164]	[0.172]
2,5-Dichlorophenol	[0.220]	[0.094]	[0.164]	[0.172]
2,3-Dichlorophenol	[0.210]	[0.090]	[0.157]	[0.165]
2,6-Dichlorophenol	[0.420]	[0.179]	[0.313]	[0.327]
3,5-Dichlorophenol	[0.370]	[0.158]	[0.276]	[0.289]
3,4-Dichlorophenol	[0.370]	[0.158]	[0.276]	[0.289]
2,3,5-Trichlorophenol	[0.690]	[0.295]	[0.516]	[0.539]
2,4,6-Trichlorophenol	[0.600]	[0.256]	[0.448]	[0.468]
2,4,5-Trichlorophenol	[0.500]	[0.214]	[0.374]	[0.391]
2,3,4-Trichlorophenol	[0.550]	[0.235]	[0.411]	[0.430]
2,3,6-Trichlorophenol	[0.600]	[0.256]	[0.448]	[0.468]
2,3,5,6-Tetrachlorophenol	71.8	30.671	53.625	56.06
2,3,4,6-Tetrachlorophenol	[0.670]	[0.286]	[0.500]	[0.523]
Pentachlorophenol	[0.890]	[0.380]	[0.664]	[0.695]
TOTAL CHLOROPHENOLS	71.8	30.7	53.6	56.1
1,3-Dichlorobenzene	[0.310]	[0.132]	[0.231]	[0.241]
1,4-Dichlorobenzene	[0.390]	[0.167]	[0.292]	[0.305]
1,2-Dichlorobenzene	[0.320]	[0.137]	[0.240]	[0.250]
1,3,5-Trichlorobenzene	[0.410]	[0.175]	[0.306]	[0.320]
1,2,4-Trichlorobenzene	[0.410]	[0.175]	[0.306]	[0.320]
1,2,3-Trichlorobenzene	[0.420]	[0.179]	[0.313]	[0.327]
1,2,3,5-Tetrachlorobenzene	(9.570)	(4.088)	(7.148)	(7.472)
1,2,4,5-Tetrachlorobenzene	(10.59)	(4.524)	(7.910)	(8.269)
1,2,3,4-Tetrachlorobenzene	[0.330]	[0.141]	[0.247]	[0.258]
Pentachlorobenzene	74.3	31.717	55.455	57.97
Hexachlorobenzene	27.6	11.781	20.599	21.53
TOTAL CHLOROBENZENES	122.0	52.1	91.1	95.2

[ ] = minimum detection limit.

( ) = estimated maximum possible concentration.

The PCB analysis was also performed on flue gas sample Run 7 (MM5-7). Because no PCB internal standards were added prior to extraction, there could be no quantitation. Only the presence of mono through deca isomers could be confirmed. Table 2-16 lists the PCB results. The presence of hexa, hepta, octa, and nona polychlorinated biphenyls were observed in the MM5-7 sample.

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 [antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), silver (Ag), and thallium (Tl)], and particulate matter. 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 2-17. The results for each individual run are presented in Tables 2-18 through 2-20. Actual concentrations and concentrations adjusted to 7 percent O_2 are shown.

The values reported in Tables 2-17 through 2-20 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 6 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.

TABLE 2-16. QUALITATIVE PCB FLUE GAS RESULTS
CDD/CDF RUN 7
LENOIR MEMORIAL HOSPITAL (1990)

ISOMER	COMPOUND DETECTED (Yes/No)
TOTAL MONO PCB	No
TOTAL DI PCB	No
TOTAL TRI PCB	NA
TOTAL TETRA PCB	No
TOTAL PENTA PCB	No
TOTAL HEXA PCB	Yes
TOTAL HEPTA PCB	Yes
TOTAL OCTA PCB	Yes
TOTAL NONA PCB	Yes
DECA PCB	NA

NA = Results not confirmed

TABLE 2-17. AVERAGE METALS/STACK GAS CONCENTRATIONS AND EMISSION RATES AT EACH CONDITION; LENOIR MEMORIAL HOSPITAL (1990)

Test Condition		1	2	3
Run Numbers		1,2,3	4R,5R,6	7,8,9
Antimony	(μg/dscm)	420	309	1060
	(μg/dscm @7% O2)	646	599	2000
	(g/hr)	0.838	0.606	1.96
Arsenic	(μg/dscm)	6.40	5.45	9.91
	(μg/dscm @7% O2)	10.0	10.4	18.9
	(g/hr)	0.013	0.011	0.018
Barium	(μg/dscm)	65.7	79.3	90.8
	(μg/dscm @7% O2)	102	146	174
	(g/hr)	0.131	0.153	0.169
Beryllium	(μg/dscm)	[0.078]	[0.061]	[0.065]
	(μg/dscm @7% O2)	[0.127]	[0.114]	[0.124]
	(g/hr)	[0.0002]	[0.0001]	[0.0001]
Cadmium	(μg/dscm)	150	164	192
	(μg/dscm @7% O2)	214	312	370
	(g/hr)	0.297	0.321	0.355
Chromium	(μg/dscm)	15.4	18.1	32.4
	(μg/dscm @7% O2)	25.2	34.2	59.7
	(g/hr)	0.031	0.035	0.060
Lead	(μg/dscm)	1,180	1,820	1,430
	(μg/dscm @7% O2)	1,870	3,540	2,670
	(g/hr)	2.36	3.51	2.65
Mercury	(μg/dscm)	90.6	96.0	1,170
	(μg/dscm @7% O2)	139	186	2,060
	(g/hr)	0.181	0.188	2.14
Nickel	(μg/dscm)	12.24	9.45	28.7
	(μg/dscm @7% O2)	19.0	17.9	52.5
	(g/hr)	0.024	0.018	0.053
Silver	(μg/dscm)	[1.283]	12.0	6.57
	(μg/dscm @7% O2)	[2.079]	24.2	11.7
	(g/hr)	[0.003]	0.023	0.012
Thallium	(μg/dscm)	[2.083]	[1.664]	[1.738]
	(μg/dscm @7% O2)	[3.371]	[3.104]	[3.331]
	(g/hr)	[0.004]	[0.003]	[0.003]

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

TABLE 2-18. METALS/STACK GAS CONCENTRATIONS AND EMISSION RATES FOR CONDITION 1; LENOIR MEMORIAL HOSPITAL (1990)

Date		05/30/90	05/31/90	06/01/90	
Time		14:56-20:22	12:47-17:11	10:19-14:40	
Run No.		1	2	3	
O2 Concentration (%V)		10.9	10.1	14.3	
Flow Rate (dscmm)		32.99	32.69	34.49	AVERAGE
Antimony	(ug/dscm)	381.97	547.50	330.83	420
	(ug/dscm @7% O2)	532.54	704.66	699.94	646
	(g/hr)	0.76	1.07	0.68	0.838
Arsenic	(ug/dscm)	4.35	9.05	5.82	6.40
	(ug/dscm @7% O2)	6.06	11.65	12.30	10.0
	(g/hr)	0.01	0.02	0.01	0.013
Barium	(ug/dscm)	45.55	93.70	57.94	65.7
	(ug/dscm @7% O2)	63.50	120.60	122.58	102
	(g/hr)	0.09	0.18	0.12	0.131
Beryllium	(ug/dscm)	[0.059]	[0.089]	[0.087]	[0.078]
	(ug/dscm @7% O2)	[0.082]	[0.115]	[0.184]	[0.127]
	(g/hr)	[0.0001]	[0.0002]	[0.0002]	[0.0002]
Cadmium	(ug/dscm)	78.95	304.35	66.32	150
	(ug/dscm @7% O2)	110.07	391.71	140.32	214
	(g/hr)	0.16	0.60	0.14	0.297
Chromium	(ug/dscm)	17.79	11.47	17.05	15.4
	(ug/dscm @7% O2)	24.80	14.77	36.08	25.2
	(g/hr)	0.04	0.02	0.04	0.031
Lead	(ug/dscm)	943.80	1441.43	1152.78	1,180
	(ug/dscm @7% O2)	1315.83	1855.17	2438.92	1,870
	(g/hr)	1.87	2.83	2.39	2.36
Mercury	(ug/dscm)	109.21	96.70	66.01	90.6
	(ug/dscm @7% O2)	152.26	124.46	139.65	139
	(g/hr)	0.22	0.19	0.14	0.181
Nickel	(ug/dscm)	17.78	9.46	9.47	12.2
	(ug/dscm @7% O2)	24.78	12.18	20.05	19.0
	(g/hr)	0.035	0.019	0.020	0.024
Silver	(ug/dscm)	[0.980]	[1.449]	[1.421]	[1.283]
	(ug/dscm @7% O2)	[1.366]	[1.865]	[3.006]	[2.079]
	(g/hr)	[0.002]	[0.003]	[0.003]	[0.003]
Thallium	(ug/dscm)	[1.624]	[2.335]	[2.290]	[2.083]
	(ug/dscm @7% O2)	[2.264]	[3.005]	[4.845]	[3.371]
	(g/hr)	[0.003]	[0.005]	[0.005]	[0.004]

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

TABLE 2-19. METALS/STACK GAS CONCENTRATIONS AND EMISSION RATES FOR CONDITION 2; LENOIR MEMORIAL HOSPITAL (1990)

Date		06/04/90	06/06/90	06/05/90	
Time		15:43-19:47	16:57-21:07	11:21-15:32	
Run Number		4R	5R	6	
O2 Concentration (%V)		14.1	13.9	12.0	
Flow Rate (dscmm)		32.20	33.33	31.21	AVERAGE
Antimony	(μg/dscm)	254.54	517.11	155.76	309
	(μg/dscm @7% O2)	521.08	1032.73	242.72	599
	(g/hr)	0.49	1.03	0.29	0.606
Arsenic	(μg/dscm)	5.96	6.34	4.04	5.45
	(μg/dscm @7% O2)	12.21	12.67	6.29	10.4
	(g/hr)	0.01	0.01	0.01	0.011
Barium	(μg/dscm)	87.27	58.04	92.59	79.3
	(μg/dscm @7% O2)	178.65	115.91	144.28	146
	(g/hr)	0.17	0.12	0.17	0.153
Beryllium	(μg/dscm)	[0.064]	[0.058]	[0.061]	[0.061]
	(μg/dscm @7% O2)	[0.131]	[0.116]	[0.095]	[0.114]
	(g/hr)	[0.0001]	[0.0001]	[0.0001]	[0.0001]
Cadmium	(μg/dscm)	79.83	300.60	110.82	164
	(μg/dscm @7% O2)	163.41	600.33	172.69	312
	(g/hr)	0.15	0.60	0.21	0.321
Chromium	(μg/dscm)	25.81	12.74	15.64	18.1
	(μg/dscm @7% O2)	52.83	25.44	24.38	34.2
	(g/hr)	0.05	0.03	0.03	0.035
Lead	(μg/dscm)	3425.40	1029.21	994.15	1,820
	(μg/dscm @7% O2)	7012.24	2055.46	1549.18	3,540
	(g/hr)	6.62	2.06	1.86	3.51
Mercury	(μg/dscm)	101.98	137.47	48.54	96.0
	(μg/dscm @7% O2)	208.77	274.54	75.64	186
	(g/hr)	0.20	0.27	0.09	0.188
Nickel	(μg/dscm)	15.33	4.73	8.29	9.45
	(μg/dscm @7% O2)	31.38	9.44	12.92	17.9
	(g/hr)	0.03	0.01	0.02	0.018
Silver	(μg/dscm)	12.42	11.49	[1.023]	12.0
	(μg/dscm @7% O2)	25.43	22.94	[1.594]	24.2
	(g/hr)	0.02	0.02	[0.002]	0.023
Thallium	(μg/dscm)	[1.684]	[1.613]	[1.696]	[1.664]
	(μg/dscm @7% O2)	[3.447]	[3.221]	[2.643]	[3.104]
	(g/hr)	[0.003]	[0.003]	[0.003]	[0.003]

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

TABLE 2-20. METALS/STACK GAS CONCENTRATIONS AND EMISSION RATES FOR CONDITION 3; LENOIR MEMORIAL HOSPITAL (1990)

Date		06/06/90	06/07/90	06/08/90	
Time		10:14-14:33	12:55-17:04	11:20-15:27	
Run Number		7	8	9	
O2 Concentration (%V)		13.0	14.6	13.1	
Flow Rate (dscmm)		30.33	31.63	30.80	AVERAGE
Antimony	(μg/dscm)	796.64	854.78	1524.01	1,060
	(μg/dscm @7% O2)	1392.86	1894.97	2719.35	2,000
	(g/hr)	1.45	1.62	2.82	1.96
Arsenic	(μg/dscm)	11.69	9.33	8.71	9.91
	(μg/dscm @7% O2)	20.45	20.68	15.53	18.89
	(g/hr)	0.02	0.02	0.02	0.018
Barium	(μg/dscm)	60.50	85.81	126.13	90.8
	(μg/dscm @7% O2)	105.77	190.24	225.05	174
	(g/hr)	0.11	0.16	0.23	0.169
Beryllium	(μg/dscm)	[0.063]	[0.065]	[0.066]	[0.065]
	(μg/dscm @7% O2)	[0.110]	[0.144]	[0.118]	[0.124]
	(g/hr)	[0.0001]	[0.0001]	[0.0001]	[0.0001]
Cadmium	(μg/dscm)	246.02	215.76	113.03	192
	(μg/dscm @7% O2)	430.15	478.32	201.69	370
	(g/hr)	0.45	0.41	0.21	0.355
Chromium	(μg/dscm)	19.28	14.52	63.40	32.4
	(μg/dscm @7% O2)	33.71	32.19	113.13	59.7
	(g/hr)	0.04	0.03	0.12	0.060
Lead	(μg/dscm)	1991.59	956.58	1354.26	1,430
	(μg/dscm @7% O2)	3482.15	2120.65	2416.46	2,670
	(g/hr)	3.62	1.82	2.50	2.65
Mercury	(μg/dscm)	3389.31	38.52	96.63	1,170
	(μg/dscm @7% O2)	5925.96	85.39	172.42	2,060
	(g/hr)	6.17	0.07	0.18	2.14
Nickel	(μg/dscm)	15.47	9.89	60.84	28.7
	(μg/dscm @7% O2)	27.05	21.92	108.56	52.5
	(g/hr)	0.03	0.02	0.11	0.053
Silver	(μg/dscm)	3.03	[1.063]	10.11	6.57
	(μg/dscm @7% O2)	5.30	[2.357]	18.04	11.7
	(g/hr)	0.01	[0.002]	0.02	0.012
Thallium	(μg/dscm)	[1.742]	[1.741]	[1.730]	[1.738]
	(μg/dscm @7% O2)	[3.046]	[3.860]	[3.087]	[3.331]
	(g/hr)	[0.003]	[0.003]	[0.003]	[0.003]

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

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.
- 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 composited 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 2-17 presents the metals emission parameters averaged for each condition. Actual concentrations, concentrations corrected to 7 percent O_2, and emission rates are shown. Results from Test Condition 3 showed the highest concentrations and emission rates of metals, with the exception of lead and silver which showed higher values during Test Condition 2. Lead was the most prevalent element detected in each of the three test conditions, with emission rates at 2.36, 3.51, and 2.65 g/hr for Conditions 1, 2, and 3, respectively. Silver was detected in the samples from Test Conditions 2 and 3 with emission rates of 0.023 and 0.012 g/hr, but not in the samples from Test Condition 1. Beryllium and thallium were not detected in any of the samples collected during the three test conditions.

Table 2-18 presents the metals emission results for Condition 1 (300 lb/hr, 6 minute cycle, 1900°F secondary setpoint). Lead and antimony had the highest average flue gas concentrations under this condition at 1,180 and 420 μg/dscm (2.36 and 0.84 g/hr), respectively.

The metals emission results for Condition 2 (200 lb/hr, 6 minute cycle, 1900°F secondary setpoint) are presented in Table 2-19. Silver was detected in 2 of the 3 runs

(4R and 5R) with flue gas concentrations of 12.4 and 11.5 μg/dscm (0.024 and 0.023 g/hr), respectively.

Table 2-20 presents the metals emission results for Condition 3 (300 lb/hr, 10 minute cycle, 1600°F secondary setpoint). Lead, mercury, and antimony were the most prevalent elements detected under this condition, with average concentrations of 1,430, 1,170, and 1,060 μg/dscm, respectively (emission rates of 2.65, 2.14, and 1.96 g/hr, respectively). Run 7 produced an emission rate for mercury of 6.17 g/hr, while Runs 8 and 9 produced emission rates for mercury of 0.073 and 0.179 g/hr, respectively.

A summary of the ratio by weight of metals to particulate matter is presented in Table 2-21. Metals to particulate matter ratios are given in units of milligrams of metal to grams of particulate matter collected by the sampling train. Lead has the highest ratio of all the metals in each of the three test conditions (5.48, 10.8, 2.63 mg/g, respectively). Antimony had the second highest metals to particulate matter ratios except for Condition 3 in which mercury had the second highest ratio. The high average for mercury under Condition 3 was a result of the Run 7 value of 5.87 mg/g, compared to a range of 0.077 to 0.843 mg/g for mercury for all other runs combined.

Table 2-22 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 probe/filter holder rinse and the filter itself. The back half fraction included the HNO_3/H_2O_2 impinger contents (Impingers 1 and 2), and the third fraction consisted of the $KNMO_4$ impinger contents analyzed only for mercury. Except for mercury, the higher proportion of most metals was collected in the front half fractions. The fraction with the highest amount of mercury was in the Impingers 1 and 2 fractions in all runs except Run 9. Runs 7 and 8 had higher proportions of antimony collected in Impingers 1 and 2 than in the front half. Laboratory analytical results for each sample fraction are presented in detail in Appendix E.3.

Sampling and flue gas parameters for the metals and particulate matter runs are shown in Table 2-23. Total sampling times, sample volumes and isokinetic results for each sampling run are presented. Appendix C.2 contains a complete listing of these and

TABLE 2-21. RATIO OF METALS TO PARTICULATE MATTER
LENOIR MEMORIAL HOSPITAL (1990)

METALS/PARTICULATE RATIO
(mg metal per gram of particulate)

Test Condition	Condition 1				Condition 2				Condition 3			
Run Number	1	2	3	Average	4R	5R	6	Average	7	8	9	Average
Antimony	2.447	1.825	1.677	1.976	1.353	3.170	1.025	1.863	1.379	1.713	2.754	1.949
Arsenic	0.028	0.030	0.030	0.029	0.032	0.039	0.027	0.033	0.020	0.019	0.016	0.018
Barium	0.292	0.312	0.294	0.301	0.464	0.356	0.610	0.471	0.105	0.172	0.228	0.167
Beryllium (a)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.506	1.014	0.336	0.669	0.424	1.843	0.730	0.989	0.426	0.432	0.204	0.353
Chromium	0.114	0.038	0.086	0.075	0.137	0.078	0.103	0.107	0.033	0.029	0.115	0.060
Lead	6.047	4.803	5.845	5.477	18.205	6.309	6.545	10.774	3.448	1.917	2.447	2.635
Mercury	0.700	0.322	0.335	0.442	0.542	0.843	0.320	0.577	5.869	0.077	0.175	2.146
Nickel	0.114	0.032	0.048	0.062	0.081	0.029	0.055	0.056	0.027	0.020	0.110	0.053
Silver	ND	ND	ND	ND	0.066	0.070	ND	0.048	0.005	ND	0.018	0.008
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

a ND = metal not detected in the flue gas.

TABLE 2-22. METALS AMOUNTS IN FLUE GAS SAMPLES BY SAMPLE FRACTIONS
LENOIR MEMORIAL HOSPITAL (1990)

CONDITION 1

Amount Collected, μg

	RUN 1			RUN 2			RUN 3		
METAL	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)
Antimony	1300	64.4		856	504		556	282	
Arsenic	15	0.523		19.4	3.09		13.4	1.33	
Barium	162	0.696		232	0.756		146	0.755	
Beryllium (a)	[0.500]	[0.210]		[0.500]	[0.220]		[0.500]	[0.220]	
Cadmium	282	[0.540]		756	[0.540]		168	[0.540]	
Chromium	62	1.55		28.5	[1.100]		41.8	1.4	
Lead	3370	1.26		3500	0.513		2920	[0.320]	
Mercury	104	272	14.1	44.2	196	[0.600]	48.2	119	[0.550]
Nickel	63.5	[2.100]		23.5	[2.200]		24	[2.200]	
Silver	[8.200]	[3.500]		[8.200]	[3.600]		[8.200]	[3.600]	
Thallium	[14.00]	[5.800]		[14.00]	[5.800]		[14.00]	[5.800]	

CONDITION 2

Amount Collected, μg

	RUN 4R			RUN 5R			RUN 6		
METAL	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)
Antimony	834	42.9		1710	149		461	71.7	
Arsenic	20.1	0.447		22.8	[0.430]		13.8	[0.430]	
Barium	300	0.647		208	0.641		31.6	0.644	
Beryllium (a)	[0.500]	[0.220]		[0.500]	[0.210]		[0.500]	[0.210]	
Cadmium	275	[0.540]		1000	0.641		379	[0.540]	
Chromium	87.5	1.40		45.8	[1.100]		52	1.5	
Lead	11800	0.512		3700	[0.320]		3400	[0.320]	
Mercury	3.33	348	[0.520]	48.2	446	[0.710]	[2.400]	166	[0.550]
Nickel	52.8	[2.200]		17	[2.100]		26	2.36	
Silver	[8.200]	42.8		[8.200]	41.3		[8.200]	[3.500]	
Thallium	[14.00]	[5.800]		[14.00]	[5.800]		[14.00]	[5.800]	

CONDITION 3

Amount Collected, μg

	RUN 7			RUN 8			RUN 9		
METAL	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 (b)
Antimony	1072	1580		976	1920		2820	2290	
Arsenic	33.2	5.73		22.2	9.4		26.5	2.69	
Barium	200	1.39		289	1.74		402	20.9	
Beryllium	[0.500]	[0.210]		[0.500]	[0.220]		[0.500]	[0.220]	
Cadmium	819	[0.540]		731	[0.540]		379	[0.540]	
Chromium	62.8	1.39		46.8	2.39		210	2.59	
Lead	6630	[0.320]		3240	0.901		4540	0.840	
Mercury	4015	6280	988	35	95.5	[0.490]	324	[2.700]	[11.00]
Nickel	51.5	[2.100]		33.5	[2.200]		204	[2.200]	
Silver	[8.200]	10.1		[8.200]	[3.600]		[8.200]	33.9	
Thallium	[14.00]	[5.800]		[14.00]	[5.900]		[14.00]	[5.800]	

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

b Impingers 3&4 only sample fractions analyzed for mercury content.

TABLE 2-23. METALS AND PM EMISSIONS SAMPLING AND FLUE GAS PARAMETERS LENOIR MEMORIAL HOSPITAL (1990)

	TEST CONDITION 1			
Run Number	1	2	3	Average
Date	05/30/90	05/31/90	06/01/90	
Total Sampling Time (min.)	240	240	240	240
Average Sampling Rate (dscfm)	0.526	0.366	0.373	0.422
Metered Volume (dscm)	3.572	2.484	2.533	2.863
Average Stack Temperature (°F)	1,289	1,341	1,341	1,324
O2 Concentration (%V)	10.9	10.1	14.3	11.8
CO2 Concentration (%V)	6.9	7.2	4.5	6.2
Stack Gas Moisture (%V)	12.2	12.7	13.2	12.7
Volumetric Flow Rate (acfm)	4,421	4,498	4,811	4,577
Volumetric Flow Rate (dscfm)	1,165	1,154	1,218	1,179
Volumetric Flow Rate (dscmm)	32.99	32.69	34.49	33.39
Percent Isokinetic	99.3	103	99.9	100.7
	TEST CONDITION 2			
Run Number	4R	5R	6	Average
Date	06/04/90	06/06/90	06/05/90	
Total Sampling Time (min.)	240	240	240	240
Average Sampling Rate (dscfm)	0.507	0.529	0.503	0.513
Metered Volume (dscm)	3.445	3.595	3.420	3.487
Average Stack Temperature (°F)	1,282	1,312	1,254	1,283
O2 Concentration (%V)	14.1	13.9	12.0	13.3
CO2 Concentration (%V)	4.6	4.9	6.0	5.2
Stack Gas Moisture (%V)	11.6	11.8	10.9	11.4
Volumetric Flow Rate (acfm)	4,277	4,460	4,017	4,251
Volumetric Flow Rate (dscfm)	1,137	1,177	1,102	1,139
Volumetric Flow Rate (dscmm)	32.20	33.33	31.21	32.25
Percent Isokinetic	98.1	98.9	100	99.0
	TEST CONDITION 3			
Run Number	7	8	9	Average
Date	06/06/90	06/07/90	06/08/90	
Total Sampling Time (min.)	240	240	240	240
Average Sampling Rate (dscfm)	0.490	0.498	0.493	0.494
Metered Volume (dscm)	3.329	3.388	3.353	3.357
Average Stack Temperature (°F)	1,312	1,268	1,289	1,289
O2 Concentration (%V)	13.0	14.6	13.1	13.6
CO2 Concentration (%V)	5.9	4.6	5.9	5.5
Stack Gas Moisture (%V)	12.6	13.0	13.1	12.9
Volumetric Flow Rate (acfm)	4,092	4,198	4,138	4,143
Volumetric Flow Rate (dscfm)	1,071	1,117	1,087	1,092
Volumetric Flow Rate (dscmm)	30.33	31.63	30.80	30.92
Percent Isokinetic	98.1	98.9	100	99.0

additional sampling and flue gas parameters for each run. The field data sheets are contained in Appendix A.2.

2.3.3 Metals In Ash

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. Ash samples from the three runs during each test condition were composited to represent a single sample for the respective test condition. 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.

The metals in ash results are shown in Table 2-24 for each test condition. Barium has the highest concentrations in the ash samples from Test Conditions 1 and 2 (383 and 252 mg/kg) and lead was the most prevalent metal found in the ash from Test Condition 3 (252 mg/kg). Beryllium, mercury, silver, and thallium were not detected in any of the ash samples. Analytical results of the ash analyses are contained in Appendix E.3.

2.4 PARTICULATE MATTER/VISIBLE EMISSIONS

2.4.1 Particulate Matter Results

Particulate matter (PM) emissions were determined from the same sampling train used for metals analysis. Before metals analysis, particulate matter collected on the filter and in the front half acetone rinse (probe, nozzle, filter holder) was analyzed gravimetrically. PM stack gas concentrations and emission rates for each sampling run, and averaged for each test condition are presented in Table 2-25. Uncorrected concentrations and concentrations adjusted to 7 percent O_2 are shown. Test Condition 3 had the highest concentrations and emission rates (0.237 gr/dscf and 2.217 lb/hr) while Test Condition 2 had the lowest (0.073 gr/dscf and 0.716 lb/hr). A brief summary of the sampling and flue gas parameters for the particulate matter runs is given in Table 2-22 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.

TABLE 2-24. METALS IN ASH CONCENTRATIONS LENOIR MEMORIAL HOSPITAL (1990)

Test Condition Run Numbers	1 1,2,3 (mg/kg)	2 3,4R,5R (mg/kg)	3 6,7,8 (mg/kg)
Antimony	166	188	212
Arsenic	13.5	15.9	14.4
Barium	383	252	212
Beryllium (a)	[0.200]	[0.200]	[0.200]
Cadmium	10.9	12.1	16.4
Chromium	126	114	68.9
Lead	147	185	252
Mercury	[0.980]	[0.980]	[0.980]
Nickel	199	55.8	65.2
Silver	[3.300]	[3.300]	[3.300]
Thallium	[5.400]	[5.400]	[5.400]

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

TABLE 2-25. PARTICULATE MATTER CONCENTRATIONS AND EMISSIONS RESULTS
LENOIR MEMORIAL 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)
5/30/90	1	1	14:56-20:22	0.068	0.095	0.156	0.218	0.681	0.309
5/31/90	1	2	12:47-17:11	0.131	0.169	0.300	0.386	1.298	0.589
6/1/90	1	3	10:19-14:40	0.086	0.182	0.197	0.417	0.900	0.408
		AVERAGES:		0.095	0.149	0.218	0.340	0.960	0.435
6/4/90	2	4R	15:47-19:47	0.082	0.168	0.188	0.385	0.802	0.364
6/6/90	2	5R	16:57-21:07	0.071	0.142	0.163	0.326	0.719	0.326
6/5/90	2	6	11:21-15:32	0.066	0.103	0.152	0.237	0.627	0.284
		AVERAGES:		0.073	0.138	0.168	0.316	0.716	0.325
6/6/90	3	7	10:14-14:33	0.252	0.441	0.577	1.010	2.317	1.051
6/7/90	3	8	12:55-17:04	0.218	0.483	0.499	1.106	2.087	0.947
6/9/90	3	9	11:20-15:27	0.242	0.432	0.553	0.988	2.246	1.023
		AVERAGES:		0.237	0.452	0.543	1.034	2.217	1.007

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 particulate matter/metals sampling run, except for Run 5R, where observations were curtailed because of darkness. Also, observations were not recorded during particulate matter/metals Run 4R, but were taken during the original Run 4. Both of these runs were conducted under the same test condition.

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 sets 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 2-26. Test Condition 3 had the highest percent opacity, with each of the 3 runs having higher run averages than the 6 runs under the other 2 test conditions. The observations data sheets for each run are contained in Appendix A.5. Plots of opacity are contained in Appendix J.

2.5 HALOGEN GAS EMISSIONS

Hydrogen chloride (HCl), hydrogen fluoride (HF), and hydrogen bromide (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. HCl solubilizes and forms chloride (Cl^-) ions in acidified water. Ion chromatography (IC) 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 2-27 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. Condition 3 had the highest average concentrations of all three halogen gases. Condition 1 had the next highest values for both HCl and HF whereas Condition 2 had the second highest values for HBr.

TABLE 2-26. PERCENT OPACITY OBSERVATIONS SUMMARY
LENOIR MEMORIAL HOSPITAL (1990)

	TEST CONDITION 1		
Run Number	1	2	3
Date	5/30/90	5/31/90	6/1/90
Time	14:50--20:00	12:13--17:08	09:59--14:38
Range of Individual Observations (% opacity) (a)	0--80	0--85	0--80
Range of Set Averages (% opacity) (b)	0--10	0--21	0--21
Run Average (% opacity) (c)	1	3	3
Test Conditons Average (% opacity)		2	
	TEST CONDITION 2		
Run Number	4 (d)	5R (e)	6
Date	6/2/90	6/6/90	6/5/90
Time	10:00--14:22	16:54--20:13	11:16--15:29
Range of Individual Observations (% opacity)	0--75	0--80	0--75
Range of Set Averages (% opacity)	0--5	0--5	0--9
Run Average (% opacity)	1	1	1
Test Conditons Average (%opacity)		1	
	TEST CONDITION 3		
Run Number	7	8	9
Date	6/6/90	6/7/90	6/8/90
Time	10:10--14:25	12:52--17:08	11:19--15:27
Range of Individual Observations (% opacity)	0--100	0--100	0--100
Range of Set Averages (% opacity)	0--34	0--35	0--38
Run Average (% opacity)	10	13	12
Test Conditons Average (%opacity)		12	

a Individual observations recorded at 15 second intervals, to the nearest 5 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.

d Opacity ovservations were taken during PM/Metals Run 4 but not during PM/Metals Run 4R. The test conditions were the same for both runs.

e Opacity observations during PM/Metals Run 5R were curtailed at 20:13 because of darkness. The sampling run was completed at 21:07.

TABLE 2-27. SUMMARY OF HALOGEN ACID TESTING RESULTS
LENOIR MEMORIAL 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	753	1040	1.90	2.66	[0.022]	[0.030]
AVERAGE 2	680	866	7.26	8.69	[0.023]	[0.028]
AVERAGE 3	982	2370	6.55	15.7	[0.030]	[0.070]
AVERAGE COND 1	805	1430	5.24	9.01	[0.080]	[0.130]
AVERAGE 4	654	964	6.67	10.0	[0.025]	[0.036]
AVERAGE 5R	684	1320	3.84	7.41	[0.022]	[0.042]
AVERAGE 6	652	1020	2.94	4.37	0.122	0.206
AVERAGE COND 2	663	1100	4.48	7.27	0.122	0.206
AVERAGE 7	945	1740	9.28	16.8	0.763	1.24
AVERAGE 8	1,020	2310	2.68	6.10	0.317	0.793
AVERAGE 9	819	1450	9.52	16.3	0.578	1.01
AVERAGE COND 3	927	1830	7.16	13.1	0.553	1.01

ND = Not Determined; Run 5RC was not analyzed due to strong organics

[ ] = minimum detection limit

NOTE: Run 5RC was not analyzed due to strong organics; the average of Run 5R was calculated using 5RA and 5RB.

HCl concentrations were much higher than either of the other two halogen gases. HCl concentrations for Conditions 1, 2, and 3 were 805, 663, and 927 ppmV, respectively. HF concentrations for Conditions 1, 2, and 3 were 5.24, 4.48, and 7.16 ppmV, respectively. HBr was not detected in the flue gas during Condition 1 and average concentrations for Conditions 2 and 3 were 0.12 and 0.55 ppmV, respectively.

Table 2-28 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. HCl concentrations ranged from 402 ppmV for Run 2A to 1,410 ppmV for Run 3B. The corresponding HCl emission rates were 1,261 and 4,439 g/hr, respectively.

Table 2-29 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 derived by the analytical laboratory as estimates, however, they are included in all averages. Runs 2B and 4C had concentrations substantially higher than the rest of the runs at 16.0 and 16.3 ppmV, respectively. The range of concentrations for the other runs were 1.09 to 11.4 ppmV. Emissions rates ranged from 1.79 to 28.7 g/hr.

Table 2-30 presents the HBr emission results for all test runs. No HBr was detected in the flue gas in 18 out of 26 test runs. Detected flue gas concentrations were found in the later runs (6-9) and ranged from 0.069 to 0.763 ppmV. Corresponding emission rates were 0.45 to 4.68 g/hr.

2.5.2 HCl CEM Results

Continuous emissions monitoring (CEM) was performed to measure HCl in addition to other gas concentrations. The average HCl CEM concentration 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 2-31 present HCl CEM data averaged over the same time period as each manual halogen sub-run. A

TABLE 2-28. SUMMARY OF HCl RESULTS FOR EACH TEST RUN
LENOIR MEMORIAL HOSPITAL (1990)

TEST RUN NUMBER	MEASURED CONCENTRATIONS (mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	EMISSION RATE (g/hr)
RUN 1A	989	1280	652	844	1987
RUN 1B	1350	1820	892	1290	2716
RUN 1C	1090	1640	716	1080	2181
AVERAGE	1140	1580	753	1040	2295
RUN 2A	610	793	402	523	1261
RUN 2B	1130	1290	746	853	2339
RUN 2C	1360	1850	893	1220	2802
AVERAGE	1030	1310	680	866	2134
RUN 3A	1180	2750	776	1810	2450
RUN 3B	2130	6000	1410	3960	4439
RUN 3C	1160	2050	762	1350	2406
AVERAGE	1490	3600	982	2370	3099
RUN 4A	892	1290	588	853	1864
RUN 4B	1010	1460	663	965	2103
RUN 4C	1080	1630	710	1080	2250
AVERAGE	991	1460	654	964	2072
RUN 5RA	1170	2240	770	1480	2363
RUN 5RB	906	1770	598	1170	1835
RUN 5RC	NA	NA	NA	NA	NA
AVERAGE	1040	2010	684	1320	2099
RUN 6A	1110	1950	732	1290	2180
RUN 6B	878	1320	579	871	1724
RUN 6C	978	1360	645	896	1919
AVERAGE	989	1540	652	1020	1941
RUN 7A	1340	2175	885	1440	2446
RUN 7B	1770	3391	1170	2240	3226
RUN 7C	1190	2343	783	1550	2164
AVERAGE	1430	2636	945	1740	2612
RUN 8A	1690	4392	1110	2900	3211
RUN 8B	1290	2878	849	1900	2451
RUN 8C	1650	3224	1040	2130	3138
AVERAGE	1540	3498	1020	2310	2934
RUN 9A	1270	2160	836	1430	2391
RUN 9B	882	1419	582	936	1664
RUN 9C	1570	3022	1040	1990	2969
AVERAGE	1240	2200	819	1450	2341

NA = Not Analyzed; Run 5RC was not analyzed due to strong organics.

TABLE 2-29. SUMMARY OF HF RESULTS FOR EACH TEST RUN LENOIR MEMORIAL HOSPITAL (1990)

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE (g/hr)
	(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	
RUN 1A	1.72	2.22	2.06	2.67	3.45
RUN 1B	(0.916)	(1.23)	(1.10)	(1.48)	(1.841)
RUN 1C	2.12	3.19	2.55	3.83	4.26
AVERAGE	1.58	2.21	1.90	2.66	3.18
RUN 2A	1.80	2.34	2.16	2.82	3.72
RUN 2B	13.3	15.2	16.0	18.3	27.5
RUN 2C	3.04	4.15	3.65	4.99	6.28
AVERAGE	6.04	7.23	7.26	8.69	12.50
RUN 3A	6.19	14.5	7.44	17.4	12.90
RUN 3B	6.39	18.0	7.68	21.6	13.31
RUN 3C	3.77	6.68	4.54	8.04	7.86
AVERAGE	5.45	13.0	6.55	15.7	11.35
RUN 4A	1.64	2.38	1.97	2.86	3.43
RUN 4B	(1.47)	(2.14)	(1.77)	(2.57)	(3.076)
RUN 4C	13.5	20.5	16.3	24.6	28.3
AVERAGE	5.55	8.34	6.67	10.0	11.60
RUN 5RA	4.37	8.38	5.25	10.1	8.84
RUN 5RB	2.02	3.94	2.42	4.73	4.08
RUN 5RC	NA	NA	NA	NA	NA
AVERAGE	3.19	6.16	3.84	7.41	6.46
RUN 6A	(0.910)	(1.60)	(1.09)	(1.92)	(1.786)
RUN 6B	3.21	4.82	3.86	5.80	6.29
RUN 6C	3.23	4.49	3.88	5.39	6.34
AVERAGE	2.45	3.64	2.94	4.37	4.81
RUN 7A	9.52	15.4	11.4	18.6	17.36
RUN 7B	9.18	17.6	11.0	21.2	16.75
RUN 7C	4.46	8.80	5.36	10.6	8.13
AVERAGE	7.72	13.9	9.28	16.8	14.08
RUN 8A	2.33	6.06	2.80	7.28	4.43
RUN 8B	2.30	5.14	2.76	6.17	4.37
RUN 8C	(2.06)	(4.03)	(2.48)	(4.84)	(3.921)
AVERAGE	2.23	5.07	2.68	6.10	4.24
RUN 9A	9.52	16.2	11.4	19.5	17.95
RUN 9B	8.98	14.4	10.8	17.4	16.94
RUN 9C	5.26	10.1	6.32	12.1	9.91
AVERAGE	7.92	13.6	9.52	16.3	14.93

NA = Not Analyzed; Run 5RC was not analyzed due to strong organics.

( ) = maximum estimated concentration

TABLE 2-30. SUMMARY OF HBr RESULTS AT EACH TEST RUN
LENOIR MEMORIAL HOSPITAL (1990)

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE (g/hr)
	(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	
RUN 1A	[0.064]	[0.083]	[0.019]	[0.025]	[0.129]
RUN 1B	[0.089]	[0.120]	[0.026]	[0.035]	[0.179]
RUN 1C	[0.066]	[0.099]	[0.020]	[0.030]	[0.133]
AVERAGE	[0.073]	[0.101]	[0.022]	[0.030]	[0.147]
RUN 2A	[0.060]	[0.078]	[0.018]	[0.023]	[0.124]
RUN 2B	[0.095]	[0.109]	[0.028]	[0.032]	[0.196]
RUN 2C	[0.073]	[0.100]	[0.022]	[0.030]	[0.151]
AVERAGE	[0.076]	[0.096]	[0.023]	[0.028]	[0.157]
RUN 3A	[0.101]	[0.236]	[0.030]	[0.070]	[0.210]
RUN 3B	[0.101]	[0.284]	[0.030]	[0.084]	[0.210]
RUN 3C	[0.104]	[0.184]	[0.031]	[0.055]	[0.217]
AVERAGE	[0.102]	[0.235]	[0.030]	[0.070]	[0.212]
RUN 4A	[0.075]	[0.109]	[0.022]	[0.032]	[0.157]
RUN 4B	[0.091]	[0.132]	[0.027]	[0.039]	[0.190]
RUN 4C	[0.084]	[0.127]	[0.025]	[0.038]	[0.176]
AVERAGE	[0.083]	[0.123]	[0.025]	[0.036]	[0.174]
RUN 5RA	[0.077]	[0.148]	[0.023]	[0.044]	[0.156]
RUN 5RB	[0.068]	[0.133]	[0.020]	[0.039]	[0.138]
RUN 5RC	NA	NA	NA	NA	NA
AVERAGE	[0.073]	[0.141]	[0.022]	[0.042]	[0.147]
RUN 6A	0.590	1.036	0.175	0.308	1.157
RUN 6B	0.231	0.348	0.069	0.103	0.454
RUN 6C	[0.076]	[0.106]	[0.023]	[0.032]	[0.149]
AVERAGE	0.411	0.692	0.122	0.206	0.806
RUN 7A	2.57	4.17	0.763	1.24	4.68
RUN 7B	[0.056]	[0.107]	[0.017]	[0.033]	[0.102]
RUN 7C	[0.102]	[0.201]	[0.030]	[0.059]	[0.186]
AVERAGE	2.57	4.17	0.763	1.24	4.68
RUN 8A	1.52	3.96	0.452	1.18	2.90
RUN 8B	0.615	1.37	0.183	0.408	1.17
RUN 8C	[0.129]	[0.252]	[0.038]	[0.074]	[0.246]
AVERAGE	1.07	2.67	0.317	0.793	2.03
RUN 9A	2.10	3.58	0.624	1.06	3.96
RUN 9B	1.87	3.01	0.556	0.89	3.53
RUN 9C	1.87	3.58	0.555	1.07	3.52
AVERAGE	1.95	3.39	0.578	1.01	3.67

NA = Not Analyzed; Run 5RC was not analyzed due to strong organics

[ ] = minimum detection limit

TABLE 2-31. COMPARISON OF MANUAL AND CEM HCl RESULTS LENOIR MEMORIAL HOSPITAL (1990)

TEST RUN NUMBER	MANUAL HCl RESULTS		CEM HCl RESULTS	
	(ppmv)	(ppmv) (@7% O2)	(ppmv)	(ppmv) (@7% O2)
RUN 1A	652	844	10.3	13.36
RUN 1B	892	1200	29.5	39.63
RUN 1C	716	1080	15.9	23.88
AVERAGE	753	1040	18.6	12.35
RUN 2A	402	523	152	197.58
RUN 2B	746	853	233	266.35
RUN 2C	893	1220	280	382.31
AVERAGE	680	866	222	147.34
RUN 3A	776	1820	121	282.64
RUN 3B	1410	3960	172	483.04
RUN 3C	762	1350	152	269.02
AVERAGE	982	2370	148	98.56
RUN 4A	588	853	21.5	31.25
RUN 4B	663	965	28.7	41.72
RUN 4C	710	1080	54.4	82.35
AVERAGE	654	964	34.9	23.19
RUN 5RA	770	1480	7.47	14.34
RUN 5RB	598	1170	9.13	17.83
RUN 5RC	NA	NA	12.7	25.63
AVERAGE	684	1320	8.30	5.52
RUN 6A	732	1290	NA	NA
RUN 6B	579	871	NA	NA
RUN 6C	645	896	101	140.77
AVERAGE	652	1020	101	67.35
RUN 7A	885	1440	40.7	66.06
RUN 7B	1170	2240	10.8	20.66
RUN 7C	783	1550	12.3	24.28
AVERAGE	945	1740	21.3	14.14
RUN 8A	1110	2900	108	279.98
RUN 8B	849	1900	91.3	204.13
RUN 8C	1090	2130	110	214.64
AVERAGE	1020	2310	103	68.44
RUN 9A	836	1430	108	183.46
RUN 9B	582	936	107	172.21
RUN 9C	1040	1990	247	473.33
AVERAGE	819	1450	154	102.26

NA = Not Analyzed; Run 5RC was not analyzed due to strong organics and the HCl analyzer was not operative during Runs 6A and 6B.

direct comparison can then be made between the CEM HCl data and the manual HCl data.

The CEM HCl concentrations vary from an average of 8.3 ppmV for the manual halogen test periods 5RA, 5RB, and 5RC to 222 ppmV for manual halogen test periods 2A, 2B, and 2C. There is very little similarity between the CEM and manual HCl data. Comparing Conditions 1, 2 and 3 averages for CEM versus manual HCl data reveals the following values:

	CEM HCl	Manual HCl
Condition 1	130 ppmV-dry	805 ppmV-dry
Condition 2	48.1 ppmV-dry	663 ppmV-dry
Condition 3	92.8 ppmV-dry	927 ppmV-dry

The reason for this discrepancy between manual HCl and CEM HCl data is not known at this time. A possible explanation may be that the HCl CEM sample extraction system did not allow the system to respond quickly enough to fully resolve the high, sharp concentration peaks exhibited by the Lenoir incinerator stack gases. More information on this phenomenon will be gained through additional MWI HCl CEM testing. However, because the halogen test method followed an EPA reference protocol (EPA Method 26), the data produced by the manual halogen method should be considered the valid HCl data.

2.6 CEM RESULTS

Three test runs were performed at each of three operating conditions while the incinerator was burning hospital waste. A description of these conditions are repeated here for reference:

- Set 1 - Design feed rate (300 lb/hr) at a high charge frequency (6 minute cycle) and a high secondary chamber temperature setpoint of 1900°F to 2000°F.
- Set 2 - Below-design feed rate (200 lb/hr) at a high charge frequency (6 minute cycle) and a high secondary chamber temperature setpoint of 1900°F to 2000°F.

- Set 3 - Design feed rate (300 lb/hr) at the design charging frequency (10 minute cycle), and the design secondary chamber temperature setpoint of about 1600°F.

Continuous emissions monitoring (CEM) 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_2, and O_2 were measured on a dry basis. Concentrations of CO were measured during the first condition using a dilution probe system which was on a wet basis. For Conditions 2 and 3, CO was measured on a dry basis. The HCl monitor used a dilution probe and therefore, results are on a ppm volume wet basis. THC concentrations were also monitored on a wet basis. 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 corrected values are summarized in Tables 2-32 and 2-33. All data is reported in actual concentrations and concentrations corrected to 7 percent O_2/dry (HCl and THC for all conditions and CO for Condition 1 were measured wet and corrected to a dry basis). Overall averages are presented for each CEM parameter under each of the three incinerator operating conditions.

Average O_2 concentrations varied by 4.5 percent by volume during the 9 test runs ranging from 10.1 to 14.6 percent O_2. The average O_2 values for each set of tests was 11.8 (Condition 1), 12.4 (Condition 2), and 13.6 (Condition 3). The CO_2 concentrations varied inversely with the O_2 concentrations at 6.2, 5.8, and 5.5 for Conditions 1 through 3, respectively. The CO_2 run averages ranged from 4.5 to 7.2 percent by volume over the nine test runs.

Average CO concentrations ranged from 63.2 ppmV to 231 ppmV at 7 percent O_2 under Condition 1 with the overall average concentration at 154 ppmV. For the second condition, the CO run averages ranged from 52.5 ppmV to 134.1 ppmV, with an overall average CO concentration of 84.3 ppmV. For the third condition, the CO run averages

TABLE 2-32. CONTINUOUS EMISSIONS MONITORING DAILY TEST AVERAGES FOR O2, CO, CO2, AND HCl LENOIR MEMORIAL HOSPITAL (1990)

DATE	RUN NUMBER/ MANUAL TEST TYPE	CONDITION	TEST a TIME	MOISTURE	OXYGEN (%V,dry)	CO2 (%V,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
05/30/90	1	1	14:56-20:22	12.03	10.93	6.91	145.8 (wet) e	167.0 d	25.3	34.8
05/31/90	2	1	12:47-17:11	12.72	10.10	7.20	112.8 (wet) e	149.0 d	208.5	321.0
06/01/90	3	1	10:19-14:40	13.38	14.33	4.49	25.9 (wet) e	63.8 d	129.3	355.0
	AVERAGE:				11.79	6.20	94.8 (wet) e	126.6 d	121.0	236.9
06/02/90	4	2	10:02-14:23	11.74	11.38	6.35	36.0	54.4	33.3	61.7
06/04/90	4R f	2	15:43-19:47	11.61	14.11	4.55	65.5	97.4		
06/06/90	5R	2	16:57-21:07	11.64	13.94	4.89	62.7	105.0	8.8	18.0
06/05/90	6	2	11:21-15:32	11.03	11.98	6.01	48.3	75.0	90.1	116.0
	AVERAGE:				12.43	5.75	49.0	78.1	44.1	65.2
06/06/90	7	3	10:14-14:33	12.67	12.95	5.94	1698.4	2193.0	21.7	44.3
06/07/90	8	3	12:55-17:04	12.99	14.63	4.59	491.0	774.0	92.6	279.0
06/08/90	9	3	11:20-15:27	13.24	13.11	5.86	1330.5	2061.0	140.8	339.0
	AVERAGE:				13.56	5.46	1173.3	1676.0	85.0	220.8

a For metals/CDD/CDF runs.

b 30 second averages were corrected to 7% oxygen (corrected value = actual * (13.9 /(20.9 - O2)).

c HCl concentrations were determined by manual methods as well. A comparison of CEM vs. manual results is presented in Section 2.6.

d 30 second averages were corrected to 7% oxygen and for moisture, where the corrected value = actual * 13.9/(20.9 - O2) * (1/(1 - moist).

e These values were determined using a dilution probe system. Because the CEM concentration trends were extremely noisy with very high, sharp peaks, this system may not have been able to fully resolve CO concentrations and values may biased low.

f Toxic metals Run 4 originally scheduled to be performed on 6/02 was performed on 6/04. CEM values for this run are not included in condition averages.

TABLE 2-33. CONTINUOUS EMISSIONS MONITORING DAILY TEST AVERAGES FOR O2, SO2, NOx AND THC LENOIR MEMORIAL HOSPITAL (1990)

DATE	RUN NUMBER	CONDITION	TEST TIME a	MOISTURE (%V)	OXYGEN (%V,dry)	SO2 actual (ppmv,dry)	SO2 corrected b (ppmv,dry)	NOx actual (ppmv,dry)	NOx corrected b (ppmv,dry)	THC actual (ppmC,wet)	THC corrected c (ppmC,dry)
05/30/90	1	1	14:56-20:22	12.03	10.93	10.96	12.60	44.6	62.2	7.43	10.90
05/31/90	2	1	12:47-17:11	12.72	10.10	16.09	15.30	66.7	88.0	12.61	19.00
06/01/90	3	1	10:19-14:40	13.38	14.33	3.92	7.83	43.7	94.6	12.02	29.50
	AVERAGE:				11.79	10.32	11.91	51.7	81.6	10.69	19.80
06/02/90	4	2	10:02-14:23	11.74	11.38	5.20	6.71	56.3	85.5	2.43	4.11
06/04/90	4R	2	15:43-19:47	11.61	14.11	7.41	10.99	31.6	70.2	18.47	16.60
06/06/90	5R	2	16:57-21:07	11.64	13.94	8.60	12.76	45.8	93.8	e	e
06/05/90	6	2	11:21-15:32	11.03	11.98	4.78	4.59	51.1	84.2	6.66	10.90
	AVERAGE:g				12.43	6.19	8.02	51.0	87.8	4.55	7.51
06/06/90	7	3	10:14-14:33	12.67	12.95	12.37	16.50	56.9	95.8	11.39	17.80
06/07/90	8	3	12:55-17:04	12.99	14.63	6.28	8.61	43.4	95.5	e	e
06/08/90	9	3	11:20-15:27	13.24	13.11	23.14	31.90	56.6	102.0	48.3 f	75.80
	AVERAGE:				13.56	13.93	19.00	52.3	97.8	11.39	46.80

a Time is for metals and CDD/CDF runs.

b SO2 and NOx are corrected to 7% oxygen, where the corrected value = actual * 13.9/(20.9 - O2).

c THC is corrected to 7% oxygen and corrected for moisture where the corrected value = actual * 13.9/(20.9 - O2) * 1/(1 - moist).

d Toxic metals Run 4 originally scheduled to be performed on 6/02 was performed on 6/04. CEM values for this run are not included in condition averages.

e THC analyzer failure

f The total hydrocarbon concentration was recorded on a wet basis for all test days except 6/08 in which the sample stream was conditioned and therefore THC was monitored on a dry basis.

g Averages do not include Run 4R.

ranged from 1089 ppmV to 2969 ppmV with the overall average for this condition being 2144 ppmV at 7 percent O_2.

The average NO_x concentrations varied from 62.2 ppmV to 102 ppmV at 7 percent O_2 over the nine test runs. Averages for Condition 1 ranged from 62.2 ppmV to 94.6 with an overall average of 81.6 ppmV. Averages for Condition 2 ranged from 70.2 to 93.8 ppmV with an overall average of 87.8 ppmV, and the Condition 3 range was 95.5 to 102 ppmV with the average value being 97.8 ppmV.

The SO_2 run averages corrected to 7 percent O_2 for each condition ranged from 7.83 to 15.3 ppmV for Condition 1, 4.59 to 12.8 ppmV for Condition 2, and 8.61 to 31.9 ppmV for Condition 3. The condition averages were 11.9 ppmV, 8.02 ppmV, and 19.0 ppmV for the Conditions 1 through 3, respectively.

Average THC concentrations corrected to 7 percent O_2 varied from 4.11 ppmV to 75.8 ppmV over the nine runs. The average THC for each condition ranged from 10.9 to 29.5 ppmV for Condition 1, 4.1 to 16.6 ppmV for Condition 2, and 17.8 to 75.8 ppmV for Condition 3. The Condition 1 average was 19.8 ppmV, the Condition 2 average was 7.51 ppmV, and the Condition 3 average was 46.8 ppmV. All THC concentrations were given on a dry basis at 7 percent O_2.

2.7 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, weighed and placed in 35 gallon metal cans. After the ash was allowed to cool, samples were taken manually with a sample thief and composited to obtain a representative sample. The ash was screened so that only material less than one-half inch in diameter was obtained. Portions were taken from the composite sample for the various analyses including one sample which was analyzed for moisture content, loss-on-ignition and carbon content.

Samples were collected for three replicate tests at three different incinerator operating conditions (total of 9 runs).

Table 2-34 presents a summary of the ash analysis results. The moisture content of the samples ranged from 0.2 percent for Run 9 (Test Condition 3) to 6.14 percent for Run 7 (Test Condition 3).

The average moisture values for each test condition show fairly close grouping with the lowest value shown for Condition 1 (1.04 percent) and the highest value for Condition 3 (2.33 percent).

Loss-on-ignition results varied from 1.42 percent for Run 4 (Condition 2) to 10.18 percent for Run 5 (Condition 2). Average values for each test condition ranged from 4.94 percent for Condition 1 to 7.17 percent for Condition 2.

Carbon content in the ash samples varied from 0.0 percent for Run 4 (Condition 2) to 5.79 percent for Run 5 (Condition 2). Average values for each test condition showed close grouping with a low value of 2.11 percent for Condition 3 and a high value of 3.56 percent for Condition 1.

2.8 MICROBIAL SURVIVABILITY RESULTS

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

2.8.1 Background and Test Matrix

The objectives of this portion of the test program were to refine testing methods for measuring microbial survivability in incinerator processes and utilize these methods to evaluate this incinerator unit. As part of the medical waste incineration test program at Lenoir Memorial Hospital, microbial survivability was evaluated by adding a known quantity of indicator organisms to the normal waste stream and measuring the quantity of organisms surviving the process. The surrogate indicator organism used was Bacillus stearothermophilus, which is a non-pathogenic spore forming bacteria normally found in soil. This organism was chosen because it is resistant to high temperatures, not normally found in the medical waste stream, and is easy to culture because few organisms will grow at the high culture temperatures.

Two types of testing procedures were performed. The first test method was used to determine overall microbial survivability both in the combustion gases (emissions) and the bottom ash. For these tests, a known quantity of B. stearothermophilus in solution

TABLE 2-34. SUMMARY OF ASH CARBON CONTENT, LOI AND MOISTURE RESULTS LENOIR MEMORIAL HOSPITAL (1990)

CONDITION *	TEST DATE	TEST NUMBER	SAMPLE DATE	MOISTURE (%)	L.O.I. (%)	TOTAL LOSS (%)	CARBON (%)
1	05/30/90	1	05/31/90	0.91	7.40	8.24	3.34
1	05/31/90	2	06/01/90	0.43	1.73	2.15	1.63
1	06/01/90	3	06/02/90	1.79	5.69	7.38	5.72
			AVERAGE:	1.04	4.94	5.92	3.56
2	06/02/90	4	06/03/90	0.32	1.42	1.74	0.00
2	06/04/90	5, 4R	06/05/90	3.83	10.18	13.31	5.79
2	06/05/90	6	06/06/90	1.77	9.90	11.50	0.85
			AVERAGE:	1.97	7.17	8.85	2.21
3	06/06/90	7, 5R	06/07/90	6.14	6.52	12.26	2.72
3	06/07/90	8	06/08/90	0.66	6.08	6.70	2.39
3	06/08/90	9	06/09/90	0.20	3.83	4.02	1.23
			AVERAGE:	2.33	5.48	7.66	2.11

* CONDITIONS:

(1) 300 lb/hr., 1900° F, 30 lb/6 min.

(2) 200 lb/hr., 1900° F, 20 lb/6 min.

(3) 300 lb/hr., 1600° F, 50 lb/10 min.

(wet spores) was inoculated onto materials commonly found in the medical waste stream (i.e., gauze, paper, bandages, etc.) and introduced into the incinerator with the normal waste stream 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). Ash samples were taken each morning following the 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). Waste inoculated material were charged into the incinerator four times during a 4-hour test run (essentially once per hour).

The second test method utilized freeze dried samples (dry spores) encased in double iron pipes which were insulated. This test method was used as a comparison to the direct ash method to aid in the assessment of microbial survivability in the ash. Three spiked pipes were charged daily at nearly even intervals: (1) the first loading of waste of the day, (2) midday, and (3) last load of the day. Three triplicate runs (1 run/day) were performed at three different incinerator operating conditions for a total of nine runs.

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

Four wet spore spikes and three dry spore spikes were performed for each run. One run was performed daily with the exception of June 6, 1990 when Runs 7 and 5R were performed. On this day, eight wet spore spikes were performed, but only three dry spore spikes were performed because ash could not be removed between runs.

Table 2-35 summarizes the wet and dry spore spiking times and quantities and totals the waste feed and total ash quantities (wet spore spike amounts were based on the preparation laboratory's count). It should be noted that the total waste feed quantities for Runs 4 and 8 could be in error since the hospital staff may have burned wastes in the evening after testing had been completed

TABLE 2-35. SUMMARY OF INCINERATOR FEED AMOUNTS AND ASH GENERATION PER RUN LENOIR MEMORIAL HOSPITAL (1990)

RUN NUMBER	DATE	CONDITION	WET SPORE SPIKES d		DRY SPORE (PIPE) SPIKES d		TOTAL WASTE FEED (lbs)	TOTAL ASH WEIGHT (lbs) *
			TIMES	AMOUNTS (spores)	TIMES	AMOUNTS (spores)		
1	5/30/90	1	15:14	7.0E+11	11:05	3.4E+05	2237 a	283.8
			16:38	7.0E+11	15:35	3.4E+05		
			17:41	7.0E+11	20:54	3.4E+05		
			19:41	7.0E+11				
2	5/31/90	1	13:18	7.0E+11	10:02	3.4E+05	1959	178.9
			14:55	7.0E+11	16:11	3.4E+05		
			15:38	7.0E+11	17:32	3.4E+05		
			16:33	7.0E+11				
3	6/01/90	1	10:40	7.0E+11	9:55	3.4E+05	1536	149.7
			11:44	7.0E+11	14:04	3.4E+05		
			13:20	7.0E+11	14:53	3.4E+05		
			14:14	7.0E+11				
4	6/02/90	2	10:19	7.0E+11	9:10	3.4E+05	1070[a]	129.2
			11:10	7.0E+11	14:19	3.4E+05		
			12:26	7.0E+11	19:17	3.4E+05		
			13:16	7.0E+11				
5	6/04/90	2	11:15	7.0E+11	9:32	3.4E+05	2089	186.3
			12:05	7.0E+11	15:05	3.4E+05		
			14:13	7.0E+11	19:55	3.4E+05		
			15:11	7.0E+11				

NOTE:

Condition 1 = 300 lb/hr; 1900°F; 30 lb/6 min.

Condition 2 = 200 lb/hr; 1900°F; 20 lb/6 min.

Condition 3 = 300 lb/hr; 1600°F; 50 lb/10 min.

Four wet spore spikes and three dry spore spikes were performed each day.

* Total ash weight includes relatively large pieces of material (glass, metal, etc.) which were extracted from the ash sample.

a Includes an estimated 400 lbs burned in the first 1.5 hours of charging.

b The hospital may have burned later in the day.

c The hospital may have burned later in the day but it is unlikely.

d All amounts are in units of "total spores" added (total spores/500 ml bag).

TABLE 2-35. SUMMARY OF INCINERATOR FEED AMOUNTS AND ASH GENERATION PER RUN, (continued)
LENOIR MEMORIAL HOSPITAL (1990)

RUN NUMBER	DATE	CONDITION	WET SPORE SPIKES d		DRY SPORE (PIPE) SPIKES d		TOTAL WASTE FEED (lbs)	TOTAL ASH WEIGHT (lbs) *
			TIMES	AMOUNTS	TIMES	AMOUNTS		
6	6/05/90	2	11:32	4.0E+11	9:31	3.4E+05	1310 b	145.7
			12:28	4.0E+11	14:42	3.4E+05		
			13:51	4.0E+11	20:22	3.4E+05		
			14:42	4.0E+11				
7	6/06/90	3	10:42	4.0E+11	9:13	3.4E+05	2783	243.9
			11:22	4.0E+11	15:23	3.4E+05		
			12:44	4.0E+11	21:10	3.4E+05		
			13:56	4.0E+11				
5R	6/06/90	3	17:08	4.0E+11			2783	243.9
			18:18	4.0E+11				
			19:48	4.0E+11				
			20:26	4.0E+11				
8	6/07/90	3	13:23	4.0E+11	11:20	3.4E+05	1790 c	144.7
			14:15	4.0E+11	15:28	3.4E+05		
			15:39	4.0E+11	20:30	3.4E+05		
			16:20	4.0E+11				
9	6/08/90	3	11:43	4.0E+11	9:20	3.4E+05	2025	189.8
			12:35	4.0E+11	15:19	3.4E+05		
			14:12	4.0E+11	17:38	3.4E+05		
			14:47	4.0E+11				

NOTE:

Condition 1 = 300 lb/hr; 1900°F; 30 lb/6 min.

Condition 2 = 200 lb/hr; 1900°F; 20 lb/6 min.

Condition 3 = 300 lb/hr; 1600°F; 50 lb/10 min.

Four wet spore spikes and three dry spore spikes were performed each day.

* Total ash weight includes relatively large pieces of material (glass, metal, etc.) which were extracted from the ash sample.

a Includes an estimated 400 lbs burned in the first 1.5 hours of charging.

b The hospital may have burned later in the day.

c The hospital may have burned later in the day but it is unlikely.

d All amounts are in units of "total spores" added (total spores/500 ml bag).

2.8.2 Overall Microbial Survivability

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

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

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

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. Microbial log reduction values are also reported. The equation for calculating the microbial log reduction is shown in Table 2-36 as well as in Appendix F.

Table 2-36 presents the microbial survivability and microbial log reduction of the wet indicator spores. The values presented here are determined from a quantitative summary of all microbial analytical results completed by RTI laboratories (see Appendix E.3). It was determined that there were no emissions of spores in the stack gas during any of the nine test runs. Spores were found in ash from Run 1. The other runs had ash results ranging from none detected to greater than 2.21×10^9 total spores in the ash stream. Quantitative Microbial Survivability values could only be calculated for Run 1 at 0.11 percent. The corresponding microbial log reduction value was 3.0. Five of

TABLE 2-36. OVERALL MICROBIAL SURVIVABILITY
LENOIR MEMORIAL HOSPITAL (1990)

RUN NO.	DATE	CONDITION	NUMBER INDICATOR SPORES SPIKED TO INCINERATOR [a] (total spores)	NUMBER INDICATOR SPORES EXITING THE STACK (total spores)	NUMBER OF INDICATOR SPORES IN ASH [b] (total spores)	MICROBIAL SURVIVABILITY (%) [c]	MICROBIAL LOG REDUCTION [d]
1	5/30/90	300/6	2.80E+12	< 5.21E04	3.03E+09	1.1E-01	3.0
2	5/31/90	300/6	2.80E+12	< 6.43E04	> 1.62E09	> 5.8E-02	< 3.2
3	6/01/90	300/6	2.80E+12	< 3.73E04	< 3.40E04	< 2.6E-06	> 7.6
4	6/02/90	200/6	2.80E+12	< 5.50E04	< 1.17E09	< 4.2E-02	> 3.4
5	6/04/90	200/6	2.80E+12	< 5.68E04	> 1.69E09	> 6.1E-02	< 3.2
6	6/05/90	200/6	2.80E+12	< 6.41E04	> 1.32E09	> 4.7E-02	< 3.3
7	6/06/90	300/10	5.60E+12 [a]	< 6.49E04	< 2.21E09	< 7.9E-02	> 3.4
8	6/07/90	300/10	2.80E+12	< 5.55E04	< 1.31E09	< 4.7E-02	> 3.3
9	6/08/90	300/10	2.80E+12	< 67.2E04	< 4.30E04	< 2.6E-05	> 6.6

[a] 2.8E+12 spores were spiked during Run 7 emissions test and an additional 2.8E+12 spores were spiked during Run 5R emissions tests (completed later the same day).

[b] Ash results were calculated from the higher of 2 analyses.

[c] MS = (stack spores + ash spores)/(spiked spores) * 100

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

NOTES:

--- For calculating MS or MLR, detection limits were considered zero when either stack or ash results were positive (Run 1) In all other cases, DLs were summed in order to calculate the MS or MLR value.

--- Analytical confirmation results on the indicator spiking slurry were used for calculating the MS and MLR values (see Table 6-22)

--- All Values calculated from results of repetitive analytical runs. All analytical results are listed in Appendix E.3

--- All calculations are shown in Appendix F the test runs had MS values determined to be less than 0.079 percent. The corresponding microbial log reduction values were all greater than 3.4. The remaining three test runs had MS results calculated to be greater than 0.047 percent (>0.047, >0.058, and >0.061 percent). These values were flagged with a greater than qualifier because replicate analyses resulted in high variability with both detected and non-detected values. Flue gas microbial survivability and ash microbial survivability are further discussed in the following sections. All microbial survivability calculations are shown in Appendix F.

2.8.3 Microbial Survivability in Emissions

Microbial Survivability in flue gas emissions was aimed at quantifying the number of viable spores exiting in 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.

Each test run for viable spore emissions was actually made up of 2 to 3 "sub-runs." Runs 1 and 2 has three sub-runs (A, B, and C) and Runs 3-9 has two sub-runs each (A and B). Each sub-run sample was collected for 45 to 108 minutes through one of the 2 sample ports. An approximate 1.5 liter sample of impinger collection solution was generated for each sub-run. The 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 cultures were quantified after approximately a 48 hour incubation period.

Table 2-37 presents the Microbial Survivability in Emissions test results. It was determined that no spores were present in the flue gas samples. The Microbial Survivability sampling and flue gas parameters are shown in Table 2-38.

TABLE 2-37. VIABLE SPORE EMISSIONS
LENOIR MEMORIAL HOSPITAL (1990)

RUN NUMBER	ALIQUOT SIZE (ml)	NUMBER OF INDICATOR SPORES DETECTED (spores/aliquot)	NUMBER OF INDICATOR SPORES IN SAMPLE (spores/sample)	CONCENTRATION OF OF INDICATOR SPORES IN FLUE GAS (spores/dscm)	NUMBER OF INDICATOR SPORES EXITING STACK DURING TEST PERIOD (total spores)
1	100	ND	ND	ND	< 5.21E+04
2	100	ND	ND	ND	< 6.43E+04
3	100	ND	ND	ND	< 3.73E+04
4	100	ND	ND	ND	< 5.50E+04
5	100	ND	ND	ND	< 5.68E+04
6	100	ND	ND	ND	< 6.41E+04
7	100	ND	ND	ND	< 6.49E+04
8	100	ND	ND	ND	< 5.55E+04
9	10	ND	ND	ND	< 6.72E+05

NOTE: Values taken from averages of repetitive analytical runs as shown in Appendix E.3.
All calculations are shown in Appendix F
ND = Not Detected. Detection limits were determined to be 1 spore/100 ml aliquot

TABLE 2-38. INDICATOR SPORE EMISSIONS SAMPLING AND FLUE GAS PARAMETERS LENOIR MEMORIAL HOSPITAL (1990)

RUN NUMBER:	01A	01B	01C	AVERAGE	02A	02B	02C	AVERAGE	03A	03B	AVERAGE
Total Sampling Time (min.)	60	45	45	50	60	60	60	60.00	108	108	108
Average Stack Temperature (°F)	1,198	1,142	1,182	1,174	1,246	1,241	1,287	1,258	1,218	1,285	1,251
Carbon Dioxide Concentration (%V)	7.53	6.97	6.80	7.10	7.33	7.55	7.31	7.40	3.61	5.27	4.44
Oxygen Concentration (%V)	10.16	11.04	11.05	10.75	10.23	8.75	10.40	9.79	15.63	13.14	14.39
Average Sampling Rate (dscfm)	0.622	0.526	0.373	0.507	0.505	0.468	0.432	0.468	0.525	0.550	0.538
Standard Metered Volume, Vm(std) (dscm)	1.06	0*	0.48	0.73	0.86	0.79	0.73	0.80	1.61	1.68	1.64
Stack Moisture (%V)	12.03	12.03	12.03	12.03	12.72	12.72	12.72	12.72	13.38	13.38	13.38
Volumetric Flow Rate (acfm)	5,251	4,203	5,018	4,824	4,493	4,270	4,017	4,260	4,394	4,680	4,537
Volumetric Flow Rate (dscmm)	41.44	34.32	39.97	38.58	34.47	32.86	30.10	32.48	34.16	34.97	34.56
Percent Isokinetic	97.1	95.5	90.9	94.5	94.8	92.2	92.9	93.3	99.6	102	101
RUN NUMBER:	**04A**	**04B**		**AVERAGE**	**05A**	**05B**		**AVERAGE**	**06A**	**06B**	**AVERAGE**
Total Sampling Time (min.)	108	108		108	108	108		108	108	108	108
Average Stack Temperature (°F)	1,121	1,175		1,148	1,154	1,150		1,266	1,102	1,213	1,158
Carbon Dioxide Concentration (%V)	6.22	6.31		6.27	6.5 **	6.5 **		4.88	5.26	6.59	5.93
Oxygen Concentration (%V)	11.60	11.44		11.52	12	12		13.91	13.02	11.33	12.18
Average Sampling Rate (dscfm)	0.523	0.526		0.524	0.480	0.340		0.303	0.336	0.334	0.335
Standard Metered Volume, Vm(std) (dscm)	1.60	1.61		1.60	1.47	1.04		0.93	1.03	1.02	1.02
Stack Moisture (%V)	11.74	11.74		11.74	11.42	11.42		11.64	11.03	11.03	11.03
Volumetric Flow Rate (acfm)	4,102	4,693		4,397	3,967	4,104		3,890	3,889	4,129	4,009
Volumetric Flow Rate (dscmm)	34.55	38.19		36.37	32.30	33.50		29.89	33.12	32.83	32.97
Percent Isokinetic	97.9	89.2		93.6	96.5	99.4		98.8	98.9	99.1	99.0
RUN NUMBER:	**07A**	**07B**		**AVERAGE**	**08A**	**08B**		**AVERAGE**	**09A**	**09B**	**AVERAGE**
Total Sampling Time (min.)	108	108		108	108	108		108	108	108	108
Average Stack Temperature (°F)	1,258	1,225		1,241	1,211	1,163		1,187	1,215	1,196	1,206
Carbon Dioxide Concentration (%V)	6.51	5.49		6.00	4.15	5.00		4.58	6.29	5.24	5.77
Oxygen Concentration (%V)	12.33	13.47		12.90	15.26	14.00		14.63	12.58	13.80	13.19
Average Sampling Rate (dscfm)	0.305	0.299		0.302	0.297	0.295		0.296	0.295	0.302	0.299
Standard Metered Volume, Vm(std) (dscm)	0.93	0.91		0.92	0.91	0.90		0.91	0.90	0.92	0.91
Stack Moisture (%V)	12.67	12.67		12.67	12.99	12.99		12.99	13.24	13.24	13.24
Volumetric Flow Rate (acfm)	3,900	3,895		3,898	3,697	3,544		3,621	3,673	3,723	3,698
Volumetric Flow Rate (dscmm)	29.75	30.31		30.03	28.76	28.38		28.57	28.48	29.19	28.83
Percent Isokinetic	99.9	96.0		98	101	101		101	101	101	101

* Impinger broke, no sample was recovered.

** CO2 and O2 values for this run were assumed to be ~ 6.5/12 for moisture weight calculations.

2.8.4 Microbial Survivability in Ash

Incinerator ash was completely removed from the incinerator every day and stored in three to five 35-gallon metal trash containers. A composite ash sample was then taken from the containers using a sample thief and deposited in a sterilized, amber glasssample bottles. The composite samples were then submitted to the laboratory for culturing and enumeration of B. stearothermophilus.

Both an initial spore analysis and a reanalysis of the same ash samples were completed on the Lenoir samples. The initial analysis consisted of three aliquots of 1 gram of ash from each sample with triplicate enumerations performed on each aliquot (9 replicates/sample). The results of the initial analyses were, in most cases, either too numerous to count (TNTC) or nothing detected. All ash samples were then retested using a serial dilution technique in order to determine more quantitative values. Two hundred was determined to be the maximum number of spores on a filter that could be quantified. Using a typical dilution factor of 100:1, the TNTC samples were assigned a minimum or maximum value of 20,000 (>20,000 or <20,000 spores/gram) based on the number of analytical repetitions that resulted in TNTC. For the purpose of Microbial Survivability calculations, results from the higher of the two analyses were used for all Microbial Survivability calculations.

A summary of the ash results is presented in Table 2-39. Ash from Runs 3 and 9 in both analyses showed no spores detected. All other runs from the initial analysis were either <20,000 or >20,000 spores/gram based on the typical dilution factor of 100:1. The reanalysis results showed viable spores detected in the Run 1 sample at 23,500 spores/gram. All other reanalysis samples yielded non-quantitative values and were assigned either a minimum or maximum value of 20,000 spores/gram ash, or if no spores were seen in any of the repetitions, <1 spores/gram ash. All values were taken as the average of multiple enumerations. Standard deviations from each analysis is listed in the analytical data found in Appendix E.3.

2.8.5 Microbial Survivability in Pipes

Three pipe samples were loaded into the incinerator during each test day. The pipes were recovered on the following morning during ash removal. After allowing the

TABLE 2-39. VIABLE SPORES IN ASH LENOIR MEMORIAL HOSPITAL (1990)

RUN NUMBER	NUMBER OF INDICATOR SPORES	
	FIRST ANALYSIS (spores/g ash)	SECOND ANALYSIS (spores/g ash)
1	> 20,000	23,500
2	> 20,000	< 300
3	ND	ND
4	< 20,000	ND
5	> 20,000	ND
6	> 20,000	< 20,000
7	< 20,000	< 20,000
8	< 20,000	< 20,000
9	ND	ND

Note:

Values were taken from average of repetitve analyses. Values of < 200 or > 200 spores/filterwere assigned to samples with one or more enumerations of TNTC (Too Numerous to Count). Values were then adjusted to ~ 20,000 based on a dilution ratio of 1:100. The higher of the two analytical results was used to calculate Microbial Survivability. All calculations are shown in Appendix F.

All analytical results are presented in Appendix E.3.

ND = Not Detected. Detection limits were determined to be (1 spore/gram of ash)/2.

pipes to cool, the inner containers were removed from the outer containers and sent to the laboratory for analysis. Pipe samples were cultured for 48 hours and no reanalysis was performed.

Microbial Survivability in pipes at 48 hours are presented in Table 2-40. Results from the majority of pipe samples showed no spores detected. One out of 27 sample results showed 1 viable spore and three were TNTC. The raw analytical data used to compile this table can be found in Appendix E.3.

2.9 CDD/CDF EMISSION VALUES INCORPORATING THE TOLUENE RECOVERY RESULTS

In accordance with EPA Method 23, a final toluene rinse was completed on the CDD/CDF sampling train after the methylene chloride ($MeCl_2$) 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 are 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 2-41 through 2-43. 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 2-40. VIABLE SPORES IN PIPES [a]
LENOIR MEMORIAL HOSPITAL (1990)

RUN NUMBER	LOADING TIME OF DAY	NUMBER OF INDICATOR SPORES DETECTED [b]
1	11:05	TNTC
	15:35	ND
	20:54	ND
2	10:02	TNTC
	16:11	ND
	17:32	ND
3	9:55	ND
	14:04	ND
	14:53	ND
4	14:19	ND
	19:17	ND
	10:19	ND
5	9:32	ND
	15:05	TNTC
	19:55	ND
6	9:31	ND
	14:42	ND
	20:22	ND
7	9:13	ND
	15:23	1
	21:10	ND
8	11:20	ND
	15:28	ND
	20:30	ND
9	9:20	ND
	15:19	ND
	17:38	ND

[a] Three pipe samples were taken during each run.

[b] This number is the highest value detected between first count and second count.

Note:

TNTC = Too Numerous To Count

ND = Not detected; Detection limits were determined to be 1 spore/aliquot.

TABLE 2-41. 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; LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV.	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 1	RUN 2	RUN 3	AVERAGE	FACTOR	RUN 1	RUN 2	RUN 3	AVERAGE
DIOXINS									
2378 TCDD	1.09	4.85	5.61	3.85	1.000	1.095	4.850	5.606	3.850
Other TCDD	13.5	54.7	56.5	41.6	0.000	0.000	0.000	0.000	0.000
12378 PCDD	8.4	36.0	25.1	23.2	0.500	4.212	18.012	12.574	11.600
Other PCDD	42.9	136.9	117.9	99.2	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	18.6	44.2	34.3	32.4	0.100	1.862	4.422	3.425	3.237
123678 HxCDD	13.5	43.2	41.2	32.6	0.100	1.345	4.324	4.123	3.264
123789 HxCDD	26.0	100.6	90.2	72.3	0.100	2.596	10.057	9.024	7.226
Other HxCDD	83.4	265.0	253.3	200.6	0.000	0.000	0.000	0.000	0.000
1234678--HpCDD	118.7	293.9	357.8	256.8	0.010	1.187	2.939	3.578	2.568
Other Hepta--CDD	103.0	272.9	319.3	231.8	0.000	0.000	0.000	0.000	0.000
Octa--CDD	296.9	445.7	600.6	447.7	0.001	0.297	0.446	0.601	0.448
TOTAL CDD	726	1,698	1,902	1,442		12.6	45.0	38.9	32.2
FURANS									
2378 TCDF	6.1	25.9	26.0	19.3	0.100	0.614	2.590	2.596	1.933
Other TCDF	232.1	884.3	925.2	680.5	0.000	0.000	0.000	0.000	0.000
12378 PCDF	25.2	86.1	83.7	65.0	0.050	1.258	4.307	4.184	3.250
23478 PCDF	43.4	134.6	129.5	102.5	0.500	21.724	67.299	64.752	51.258
Other PCDF	441.3	1390.3	1143.9	991.8	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	162.4	442.2	484.7	363.1	0.100	16.243	44.220	48.473	36.312
123678 HxCDF	80.8	265.0	259.7	201.9	0.100	8.085	26.498	25.973	20.185
234678 HxCDF	100.5	264.6	384.8	250.0	0.100	10.050	26.464	38.478	24.997
123789 HxCDF	4.6	18.5	21.6	14.9	0.100	0.464	1.854	2.160	1.493
Other HxCDF	471.2	1321.8	1468.5	1087.2	0.000	0.000	0.000	0.000	0.000
1234678--HpCDF	371.1	842.2	1133.8	782.4	0.010	3.711	8.422	11.338	7.824
1234789--HpCDF	53.3	113.4	216.7	127.8	0.010	0.533	1.134	2.167	1.278
Other Hepta--CDF	255.8	528.8	960.7	581.8	0.000	0.000	0.000	0.000	0.000
Octa--CDF	281.3	326.4	1116.8	574.8	0.001	0.281	0.326	1.117	0.575
TOTAL CDF	2,529	6,644	8,356	5,843		63.0	183	201	149
TOTAL CDD+CDF	3,255	8,342	10,258	7,285		75.6	228	240	181

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.

TABLE 2-42. 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; LENOIR MEMORIAL 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 4	RUN 5R	RUN 6	AVERAGE		RUN 4	RUN 5R	RUN 6	AVERAGE
DIOXINS									
2378 TCDD	0.01	1.69	2.22	1.31	1.000	0.008	1.691	2.224	1.307
Other TCDD	18.5	15.9	27.8	20.7	0.000	0.000	0.000	0.000	0.000
12378 PCDD	11.4	14.8	16.7	14.3	0.500	5.725	7.394	8.350	7.156
Other PCDD	65.7	84.3	87.1	79.1	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	18.7	46.9	34.3	33.3	0.100	1.873	4.692	3.428	3.331
123678 HxCDD	22.3	42.5	28.5	31.1	0.100	2.233	4.253	2.854	3.114
123789 HxCDD	38.1	74.2	61.3	57.9	0.100	3.813	7.416	6.129	5.786
Other HxCDD	136.1	269.8	186.6	197.5	0.000	0.000	0.000	0.000	0.000
1234678--HpCDD	246.0	690.9	259.8	398.9	0.010	2.460	6.909	2.598	3.989
Other Hepta--CDD	220.6	707.4	175.6	367.9	0.000	0.000	0.000	0.000	0.000
Octa--CDD	524.5	2327.7	480.4	1110.9	0.001	0.525	2.328	0.480	1.111
TOTAL CDD	1,302	4,276	1,360	2,313		16.635	34.683	26.063	25.794
FURANS									
2378 TCDF	8.00	8.22	13.41	9.88	0.100	0.800	0.822	1.341	0.988
Other TCDF	259.4	469.4	359.5	362.8	0.000	0.000	0.000	0.000	0.000
12378 PCDF	29.6	42.0	52.8	41.5	0.050	1.480	2.100	2.641	2.074
23478 PCDF	58.7	110.7	99.8	89.7	0.500	29.327	55.360	49.885	44.857
Other PCDF	503.2	1289.8	910.6	901.2	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	179.8	578.8	257.3	338.6	0.100	17.978	57.876	25.726	33.860
123678 HxCDF	97.7	224.5	134.7	152.3	0.100	9.771	22.454	13.468	15.231
234678 HxCDF	190.7	599.7	212.5	334.3	0.100	19.067	59.974	21.246	33.429
123789 HxCDF	8.13	11.5	11.0	10.2	0.100	0.813	1.154	1.098	1.021
Other HxCDF	579.6	1487.4	863.0	976.7	0.000	0.000	0.000	0.000	0.000
1234678--HpCDF	505.6	1612.3	649.2	922.4	0.010	5.056	16.123	6.492	9.224
1234789--HpCDF	107.8	228.6	131.2	155.9	0.010	1.078	2.286	1.312	1.559
Other Hepta--CDF	452.4	1315.6	602.2	790.1	0.000	0.000	0.000	0.000	0.000
Octa--CDF	563.0	3924.8	692.7	1726.9	0.001	0.563	3.925	0.693	1.727
TOTAL CDF	3,544	11,904	4,990	6,812		85.9	222	124	144
TOTAL CDD+CDF	4,846	16,180	6,350	9,125		103	257	150	170

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.

TABLE 2-43. 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; LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	CONCENTRATION a (ng/dscm, adjusted to 7 percent O2)				2378-TCDD b TOXIC EQUIV.	2378 TOXIC EQUIVALENCIES (ng/dscm, adjusted to 7 percent O2)			
	RUN 7	RUN 8	RUN 9	AVERAGE	FACTOR	RUN 7	RUN 8	RUN 9	AVERAGE
DIOXINS									
2378 TCDD	24.3	34.7	34.2	31.1	1.000	24.302	34.710	34.209	31.074
Other TCDD	289.6	397.8	454.8	380.7	0.000	0.000	0.000	0.000	0.000
12378 PCDD	153.9	179.9	173.4	169.1	0.500	76.936	89.943	86.712	84.530
Other PCDD	772.3	692.2	639.9	701.5	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	174.3	182.0	136.5	164.3	0.100	17.431	18.204	13.651	16.428
123678 HxCDD	191.5	157.8	134.4	161.2	0.100	19.155	15.775	13.442	16.124
123789 HxCDD	402.6	367.6	353.3	374.5	0.100	40.262	36.760	35.333	37.452
Other HxCDD	1247.9	955.0	886.6	1029.8	0.000	0.000	0.000	0.000	0.000
1234678--HpCDD	1130.5	752.3	600.0	827.6	0.010	11.305	7.523	6.000	8.276
Other Hepta--CDD	1085.2	623.7	502.6	737.2	0.000	0.000	0.000	0.000	0.000
Octa--CDD	1103.3	595.4	390.8	696.5	0.001	1.103	0.595	0.391	0.697
TOTAL CDD	6,575	4,938	4,307	5,273		190	204	190	195
FURANS									
2378 TCDF	131.3	175.3	152.9	153.1	0.100	13.126	17.529	15.286	15.314
Other TCDF	3591.2	3490.2	3624.2	3568.5	0.000	0.000	0.000	0.000	0.000
12378 PCDF	401.6	386.0	425.2	404.3	0.050	20.082	19.301	21.260	20.215
23478 PCDF	630.1	506.5	578.1	571.6	0.500	315.038	253.243	289.066	285.782
Other PCDF	6537.1	4765.5	6087.2	5796.6	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	2258.7	1306.3	1439.8	1668.3	0.100	225.871	130.631	143.979	166.827
123678 HxCDF	1376.0	845.7	915.2	1045.6	0.100	137.596	84.571	91.520	104.562
234678 HxCDF	1254.7	771.8	813.8	946.8	0.100	125.475	77.181	81.380	94.679
123789 HxCDF	121.9	94.6	101.7	106.1	0.100	12.189	9.463	10.167	10.606
Other HxCDF	7052.8	4195.3	4497.7	5248.6	0.000	0.000	0.000	0.000	0.000
1234678--HpCDF	9073.5	3387.1	3948.1	5469.6	0.010	90.735	33.871	39.481	54.696
1234789--HpCDF	1419.2	490.7	551.1	820.3	0.010	14.192	4.907	5.511	8.203
Other Hepta--CDF	6465.0	2152.8	2395.5	3671.1	0.000	0.000	0.000	0.000	0.000
Octa--CDF	1723.3	353.0	427.1	834.5	0.001	1.723	0.353	0.427	0.834
TOTAL CDF	42,036	22,921	25,958	30,305		956	631	698	762
TOTAL CDD+CDF	48,612	27,859	30,264	35,578		1,147	835	888	956

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.

3.0 PROCESS DESCRIPTION

3.1 FACILITY DESCRIPTION

Lenoir Memorial Hospital is a 322-bed hospital located in Kinston, North Carolina. The medical waste incinerator (MWI) at this facility is a model 480-E manufactured by Environmental Control Products (now known as Joy Energy Systems). The MWI, which was installed in 1983, is a dual-chamber unit with an automatic ram feeder. Ash is removed manually. According to the manufacturer, the design feed rate is 145 kilograms per hour (kg/h) (320 pounds per hour [lb/h]) for waste with a heating value of 8,500 Btu/lb. Waste heat is not recovered from the stack gases of the MWI, and it has no add-on air pollution control device. Figure 3-1 is a schematic of the MWI.

3.1.1 Incinerator

The primary combustion chamber has a volume of 3.85 cubic meters (m^3) (136 cubic feet [ft^3]) and operates in a controlled-air (starved-air) mode. A natural-gas-fired auxiliary burner in the primary chamber is used to preheat and maintain the chamber temperature above about 540°C (1000°F). After the first two or three loads are charged, the burner is not needed again (under normal operating conditions) until the burndown period. Waste is fed into the primary chamber by means of a mechanical hopper/ram charging system, which is manually loaded.

A timer and the temperature in the primary chamber are used to control the frequency of charges. The timer setting can be varied, but is typically between 6 and 10 minutes. The ram activates immediately if the "start" button on the control panel is pushed when the time since the last charge exceeds the timer setting. Pushing the "start" button before the timer cycle is complete puts the ram in standby mode; when the timer cycle is complete, the ram activates. A controller locks out the ram when the primary chamber temperature exceeds a setpoint. The timer cycle is reset when the temperature falls below the setpoint.

The secondary chamber has a volume of 0.85 m^3 (30 ft^3) and a design gas retention time of about 0.4 second. The gas-fired auxiliary burner in this chamber is activated automatically when the temperature falls below a preset level. This chamber operates with excess combustion air.

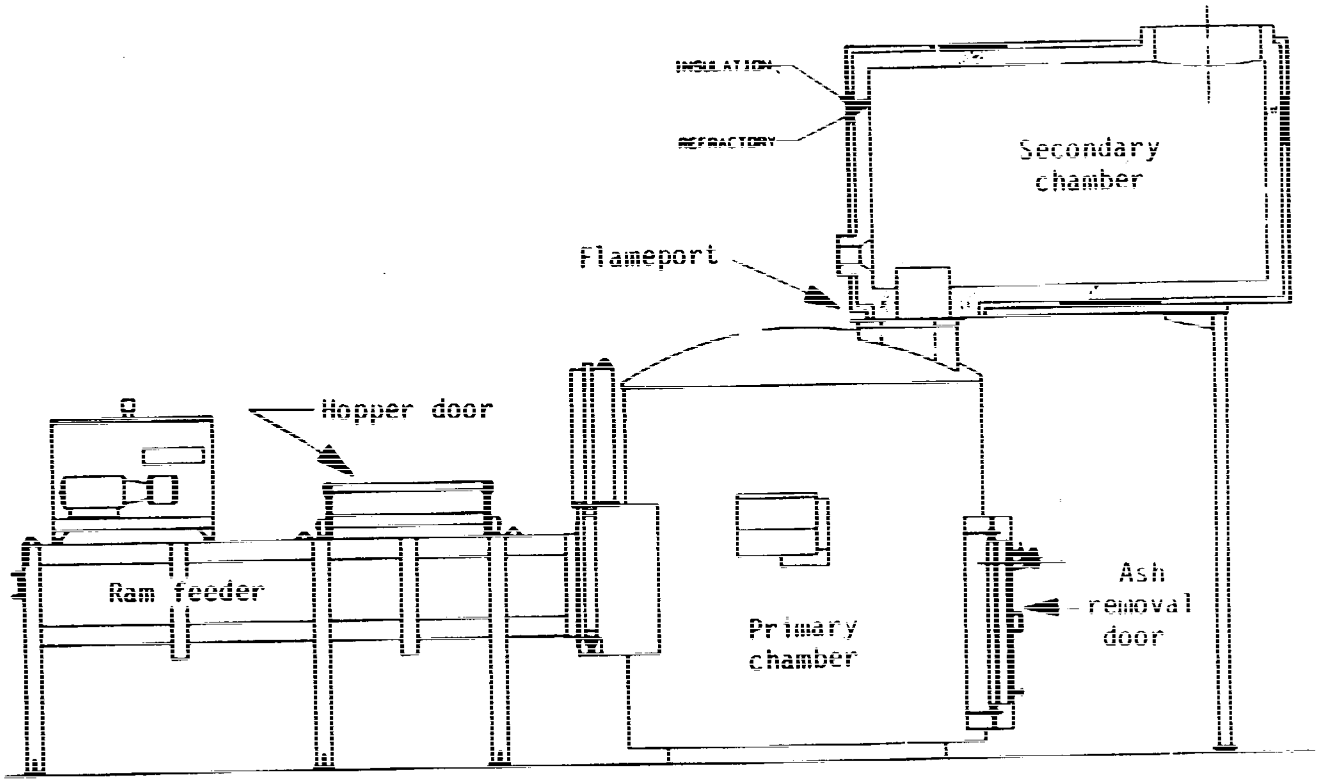


Figure 3-1. Schematic of Incinerator at Lenoir Memorial Hospital

Combustion air is introduced into the primary chamber through air ports in the chamber wall. The air ports are about 3.8 centimeters (cm) (1.5 inches [in.]) in diameter, 7.6 cm (3 in.) above the hearth, and spaced about 0.3 m (1 ft) apart around the hearth (except for the space for the ash door). Additional combustion air is added in the flameport. One blower supplies the air to both the primary chamber and the flameport. A manually adjustable damper in the duct to the primary chamber is positioned to restrict flow to about 15 percent of what it would be with the valve fully open. A damper in the duct to the flameport is automatically modulated based on the temperature in the secondary chamber. This modulated damper is partially closed when waste is charged to the primary chamber. It gradually opens as the secondary chamber temperature increases, and it returns to the partially closed position as the temperature decreases.

The primary and secondary chamber setpoint temperatures are changed by adjusting a set screw rather than a calibrated dial. Therefore, the new setpoint is not known until the burner turns on or off in the secondary chamber or the ram is locked out in the primary chamber. Achieving the desired setpoint often requires adjustments during several charging cycles.

3.1.2 Waste

"Brown bag" waste (i.e., general refuse) is the most prevalent component of the waste stream. The hospital also burns "red bag," "blue bag," and "orange bag" wastes and sharps. Red bags contain infectious waste, primarily from isolation rooms. Blue bags contain body fluids, swabs, suction materials, and other operating room wastes. Orange bags contain laboratory wastes, primarily glass that has been exposed to cultures and to stocks of infectious agents and associated biologicals. Sharps are placed in either red or almost clear plastic containers. Small amounts of pathological waste, chemotherapy waste, and outdated medicines are also incinerated. Cafeteria waste and cardboard boxes are separated from the waste stream, compacted, and landfilled. Coffee shop and lounge waste also is supposed to go to the trash compactor, but some of it is incinerated.

3.2 PRETEST ACTIVITIES

The objectives of the pretest were to identify any necessary equipment repairs or modifications to accommodate testing and to determine whether proposed operating conditions could be achieved.

3.2.1 Equipment Issues

Two equipment problems that would affect testing were identified during pretest activities. First, there were no sampling ports in the original stack. To accommodate testing, the spark arrestor was removed from the original 4.9-m (16-ft) stack and a 3.7-m (12-ft) extension with sampling ports was added. The second problem was that temperature controllers/monitors in both chambers are biased high. The incinerator manufacturer's service representative checked the calibration of the controllers and determined that both were biased about 55°C (100°F) high in the typical operating ranges. The equipment was not replaced because the actual temperatures would be monitored during testing with new thermocouples attached to a data logger. In addition, the bias would be compensated for by setting the secondary burner setpoint temperature on the control panel about 55°C (100°F) above the desired temperature. However, as indicated in Section 3.3, after testing was completed the actual differences were determined to be about 16°C (60°F) in the primary chamber and 71°C (160°F) in the secondary chamber.

3.2.2 Proposed Test Condition Trials

Three conditions that cover the potential range of operation for this type of incinerator were proposed before the pretest and a fourth condition was developed while onsite. A short trial of each condition was performed during the pretest. Based on the trials, one of the three proposed conditions was revised for the actual tests and the fourth condition was discarded. Table 3-1 lists the proposed and final test condition parameters. Observations made during each of the four trials are presented below. General refuse was burned during the trials, except as noted. The temperatures presented in this section were estimated by subtracting about 55°C (100°F) from the temperatures displayed on the control panel. These temperatures are presented because

TABLE 3-1. OPERATING PARAMETERS FOR EMISSIONS TESTS

	Proposed operating parameters				Revised operating parameters			
Condition	Feed rate, kg/hr (lb/hr)	Charge rate, kg/charge (lb/charge)	Charge cycle, min	Secondary chamber burner setpoint temp., °C (°F)	Feed rate, kg/hr (lb/hr)	Charge rate, kg/charge (lb/charge	Charge cycle, min	Secondary chamber burner setpoint temp., °C (°F)
I	136 (300)	14 (30)	6	1038-1093 (1900-2000)	136 (300)	14 (30)	6	1038 (1900)
II	91 (200)	9.1 (20)	6	1038-1093 (1900-2000)	91 (200)	9.1 (20)	6	1038 (1900)
III	145 (320)	36 (80)	15	870 (1600)	136 (300)	23 (50)	10	870 (1600)
IV	136 (300)	23 (50)	10	1093 (2000)	None			

it was believed during the pretest, based on the calibrations from the service representative, that they were close to the actual temperatures. However, as the results in Section 3.3 indicate, the actual differences were 16°C (60°F) and 71°C (160°F) in the primary and secondary chambers, respectively.

3.2.2.1 Condition I. The proposed Condition I operating parameters were design feed rates with frequent charges and a high secondary chamber burner setpoint temperature. For this trial, the ram was activated manually by pushing the "start" button every 6 minutes, and each load contained about 14 kg (30 lb) of waste. The secondary chamber burner setpoint was adjusted so that the burner turned on and off at a little less than 1038°C (1900°F). Nine loads were charged in 48 minutes during this trial.

Peak secondary chamber temperatures were lower than those for the Condition III trial and the burner could not maintain the setpoint temperature in the secondary chamber. The temperatures climbed between 55° and 110°C (100° and 200°F) in the 2 minutes after each charge, fell rapidly in the next 2 minutes, and continued to fall at a slower rate for the last 2 minutes before the next charge. The temperature was typically about 955°C (1750°F) when a charge was introduced. The average temperature during each charging cycle increased slightly as the trial proceeded.

Average primary chamber temperatures during each charging cycle increased as the trial proceeded, closing the gap between primary and secondary chamber temperatures. After the last charge, the primary chamber temperature exceeded the secondary chamber temperature for more than 2 minutes.

3.2.2.2 Condition II. The proposed Condition II operating parameters consisted of frequent charges at less than design rates and a high secondary chamber burner setpoint temperature. For this trial, each load contained about 9.1 kg (20 lb) of waste, and the ram was again activated manually every 6 minutes. The secondary chamber burner setpoint was increased so that the burner would turn on and off at about 1093°C (2000°F). Five loads were charged in 24 minutes during this trial.

Secondary chamber temperatures increased less than 110°C (200°F) after each charge, and the peaks were always less than 1065°C (1950°F) (and less than the burner setpoint). Even though the burner was always on, the temperature fell steadily from the peak until the next charge, just as for Condition I. Temperatures fell to an average of about 955°C (1750°F) at the start of each charging cycle. Primary chamber temperatures were always well below the secondary chamber temperatures.

3.2.2.3 Condition III. The proposed Condition III operating parameters were design feed rates with infrequent charges and a low secondary chamber burner setpoint temperature. An attempt was made to charge 36 kg (80 lb) every 15 minutes, but the hopper typically could only hold about 23 kg (50 lb) of waste. Therefore, the charging parameters were revised to 23 kg (50 lb) every 10 minutes. For the trial, the ram cycle timer was set to about 1 minute and the ram was activated manually by pressing the "start" button every 10 minutes. The position of the set screw that controls operation of the secondary chamber burner was adjusted so that the burner would turn on and off at about 870°C (1600°F).

Seven loads were charged during the trial. Secondary chamber temperatures increased by 28° to 330°C (50° to 600°F) in the 3 minutes after each charge. The 330°C (600°F) increase occurred after charging a combination of blue bags (operating room waste) and brown bags. This effect indicates that operating room waste has a high heating value. Waste from an unknown source also has a high heating value because the second largest increase in the secondary chamber temperature (260°C [500°F]) occurred after an all-brown-bag charge. The temperatures dropped back to about 870°C (1600°F) in the 2 minutes after each peak and remained at that level until the next charge.

Primary chamber temperatures were not closely monitored during this trial. Nearly all of the primary chamber temperatures that were recorded were 55°C (100°F) or more below the secondary chamber temperatures. Some of the primary chamber temperatures that were recorded may be incorrect due to a weak element in the LCD that made temperatures in the 1800's look like 1600's. The weak element was a problem for subsequent trials as well, but it was replaced during the first run of the emissions tests.

3.2.2.4 Condition IV. A fourth condition was examined to determine whether a minimum secondary chamber temperature could be maintained by charging 23 kg (50 lb) every 10 minutes with the secondary chamber burner setpoint temperature at

2000°F. This goal was not achieved. The results of this trial were similar to those for Condition I except that the average primary and secondary chamber temperatures both showed a steady rise during the trial. After 40 minutes (and 6 hours since the start of the first trial), the primary chamber temperature exceeded the lockout temperature (about 1024°C [1875°F]) for the first time during the pretest. In addition, while the ram was locked out and for 2 minutes thereafter, the primary chamber temperatures exceeded the secondary chamber temperatures.

3.2.3 Selected Test Conditions

Except for the change in the charge size and frequency for Condition III, the three proposed conditions were selected for the actual tests. All three conditions were demonstrated to be feasible based on the trials, but, as the trial of Condition IV showed, temperatures in the primary chamber could increase over time and cause the ram feeder to lock out before the end of a 4-hr test. During the trials, a temperature spike occurred in both chambers after each waste charge. The magnitude of the spikes varied depending on the characteristics of the waste in each charge. The trials also showed that the secondary chamber burner could maintain a minimum temperature of 871°C (1600°F) but not 1038°C (1900°F). The fourth condition was discarded because the results were similar to those for Condition I.

3.3 PROCESS CONDITIONS DURING TESTING

The primary purpose of this source test was to characterize uncontrolled emissions from an older-generation MWI under a range of operating conditions. Three emission test runs were scheduled at each of three conditions for a total of nine runs. However, two runs (Runs 4 and 5) were repeated due to sampling problems. The process data for Run 4 are presented in this discussion because only the particulate and metals data were invalidated. Process data for Run 5 are not presented because all of the test data were invalidated. The target and actual operating conditions for each valid test run are presented in Table 3-2.

The primary chamber temperature often was above the secondary chamber temperature during all six runs with a target charge rate of 136 kg/hr (300 lb/hr). In addition, at some point between 3.5 and 6 hours after the first charge on days when the charging rate was 136 kg/h (300 lb/h), the primary chamber temperature exceeded the

Table 3-2. Process Data Summary for Emissions Testing at Lenoir Memorial Hospital

Test Run No.	Test Date	Target Test Conditions				Daily Operation (a)					Actual Test Conditions (b)							
		Charge rate lb/h	Charge rate lb/charge	Charge freq., min	Sec. chamb. burner setpoint temp., F	Preheat time, min	Charging before test, min	Hours of charging, h/d	Total waste charged, lb/d	Ash, % of waste charged	Charge rate lb/h	Charge rate lb/charge	Charge freq., min	Avg. prim. chamber temp., F	Avg. sec. chamber temp., F	Prim. burner, % on	Sec. burner, % on (c)	Natural gas use, ft3/h (d)
1	05/30/90	300	30	6	1900	15	267	10.5	2237 (e)	12.7	220	30.7	8.4	1783 (f)	1767 (f)	(g)	(g)	(h)
2	05/31/90	300	30	6	1900	65	162	7.5	1959	9.1	250	30.8	7.4	1920	1831	(g)	(g)	(h)
3	06/01/90	300	30	6	1900	58	35	5.33	1536	9.9	294	32.3	6.6	1767	1783	(g)	(g)	(h)
4	06/02/90	200	20	6	1900	24	55	5.5	1070 (i)	12.1	191	20.4	6.4	1504	1616	0	98.9	1160
4R	06/04/90	200	20	6	1900	37	396 (j)	10.8	2089	8.9	189	20.2	6.4	1801 (f)	1770 (f)	(g)	(g)	1090
6	06/05/90	200	20	6	1900	38	116	6.67	1310 (i)	11.1	190	20.5	6.5	1568	1660	0	89.4	1170
7	06/06/90	300	50	10	1600	39	61	12	2783	8.8	266	49.7	11.2	1841	1680	0	53.3	500
5R	06/06/90	200	20	6	1900						195	20.8	6.4	1805	1783	0	94.9	1130
8	06/07/90	300	50	10	1600	80	105	5.9	1790 (k)	8.1	296	51.3	10.4	1850	1641	0	46.2	500
9	06/08/90	300	50	10	1600	59	61	7.33 (l)	2025	9.4	285	51.0	10.7	1820	1658	0	43.9	550

(a) From the time the incinerator is turned on until burndown is initiated

(b) Includes port changes and times for all trains, not just the Method 5 trains

(c) The tabulated percentages may be slightly low because the data logger occasionally indicated the burner was off when it actually was on. There are no known instances of the logger indicating the burner was on when it actually was off

(d) Natural gas meter readings were taken when convenient. Therefore, some consumption values are based on as little as 2.5 hours of data during the test period

(e) Includes an estimated 400 lbs in the first 1.5 hours of charging

(f) Temperatures are based on manually recorded values rather than values obtained with the data logger. The averages are not statistically valid because the temperatures were not recorded at uniform intervals.

(g) Data logger inoperative

(h) Not recorded

(i) The hospital may have burned more later in the day

(j) Charging time includes time for invalidated Run 5

(k) The hospital may have burned more later in the day, but it is not likely

(l) Includes 2 hours after the test

setpoint (1024°C or 1116°C [1875° or 2045°F]) and locked out the feeder ram for the first time. Temperatures continued to lock out the ram periodically from this time until the testing was completed for the day. Lockouts were especially common during the first run because the setpoint temperature (1024°C [1875°F]) was too low. On days when the charging rate was 91 kg/hr (200 lb/hr), the ram locked out only once during one run. Clearly, the heating value of the waste is higher than that assumed when the design charging rate was specified by the manufacturer.

The time elapsed between the first charge and the start of testing varied among the runs. The time was much longer for the first two runs because it took longer than expected to set up the sampling equipment. Charging the incinerator was not delayed until the sampling equipment was ready because it took several charges (30 to 60 minutes) to increase the temperatures from preheat levels to the operating range. Furthermore, proper calibration of the HCl continuous emission monitor required temperatures in the normal operating range.

The incinerator operating parameters monitored during each test run were the charge weight, charge frequency, type of waste, primary and secondary chamber temperatures, and the percentage of time the burners were on. In addition, natural gas meter readings were recorded for some runs, and the ash was weighed after each run. The temperatures and times when the burners were on were recorded every 10 seconds with the data logger; other data were recorded manually. Temperatures were also recorded manually as a backup.

The temperatures for Runs 1 and 4R are based on the manually recorded values because the data logger did not operate properly during these runs. However, the manually recorded temperatures had to be corrected for the bias in the temperature monitor/controller. The correction factor was determined by comparing the manually recorded temperatures for Run 9 with the corresponding temperatures that were recorded with the data logger. This comparison showed the primary and secondary chamber temperatures were biased about 16°C (60°F) and 71°C (160°F) high, respectively. It was assumed that the biases were the same for all of the runs.

Averages for the recorded operating parameters are presented in Table 3-2, and data sheets documenting the process parameters that were recorded during each test run are presented in Appendix B. For all runs, there are discrepancies between the results of the data logger and manual observations of when the secondary chamber burner was on or off. The major discrepancy occurred during Run 6. The data logger showed the burner to be off from 13:46 to 13:59, but manual observations (and the setpoint) indicated that the burner was on for most of this time.

Temperature profiles for each run are shown in Figures 3-2 through 3-11. Each temperature spike corresponds with a waste charge. The time at which charges occurred is shown by tick marks along the top side of the X-axis of each figure. Calculated gas residence times in the secondary chamber are presented in Table 3-3 for each run. These residence times range from 0.30 sec for Run 3 to 0.36 sec for several runs, and the average over the nine runs is 0.34 sec. To calculate the residence time, the chamber volume was divided by the average stack gas flow rate, which was corrected for the difference between the average stack and secondary chamber temperatures.

A summary of each test run is presented below.

3.3.1 Condition I

For the first three runs, the target charging rate was 14 kg (30 lb) of waste every 6 minutes (136 kg/hr [300 lb/h]). The target secondary chamber burner setpoint temperature was 1038°C (1900°F). Figures 3-2 through 3-4 present the temperature profiles for each run. Each of the profiles show the primary chamber temperatures were often above the secondary chamber temperatures. Furthermore, as shown in Table 3-2, the average primary chamber temperatures were above the secondary chamber temperatures for Runs 1 and 2. Information about the percentage of time the burners were on is not available because the data logger was not working properly during any of the runs. The natural gas meter was not read during these runs. Summaries of each of the three runs are presented in the subsections below.

3.3.1.1 Run 1. The first load of waste was charged to the incinerator after about 15 minutes of preheat. Charging continued at irregular intervals for the next 2.5 hours. At this time, the ram cycle timer was adjusted for about 6.3 minutes, and regular charging at about 14 kg/charge (30 lb/charge) was begun. No attempt was made to reduce the cycle to exactly 6 minutes because the dial on the timer controller was not sensitive enough to make such fine-tuning adjustments.

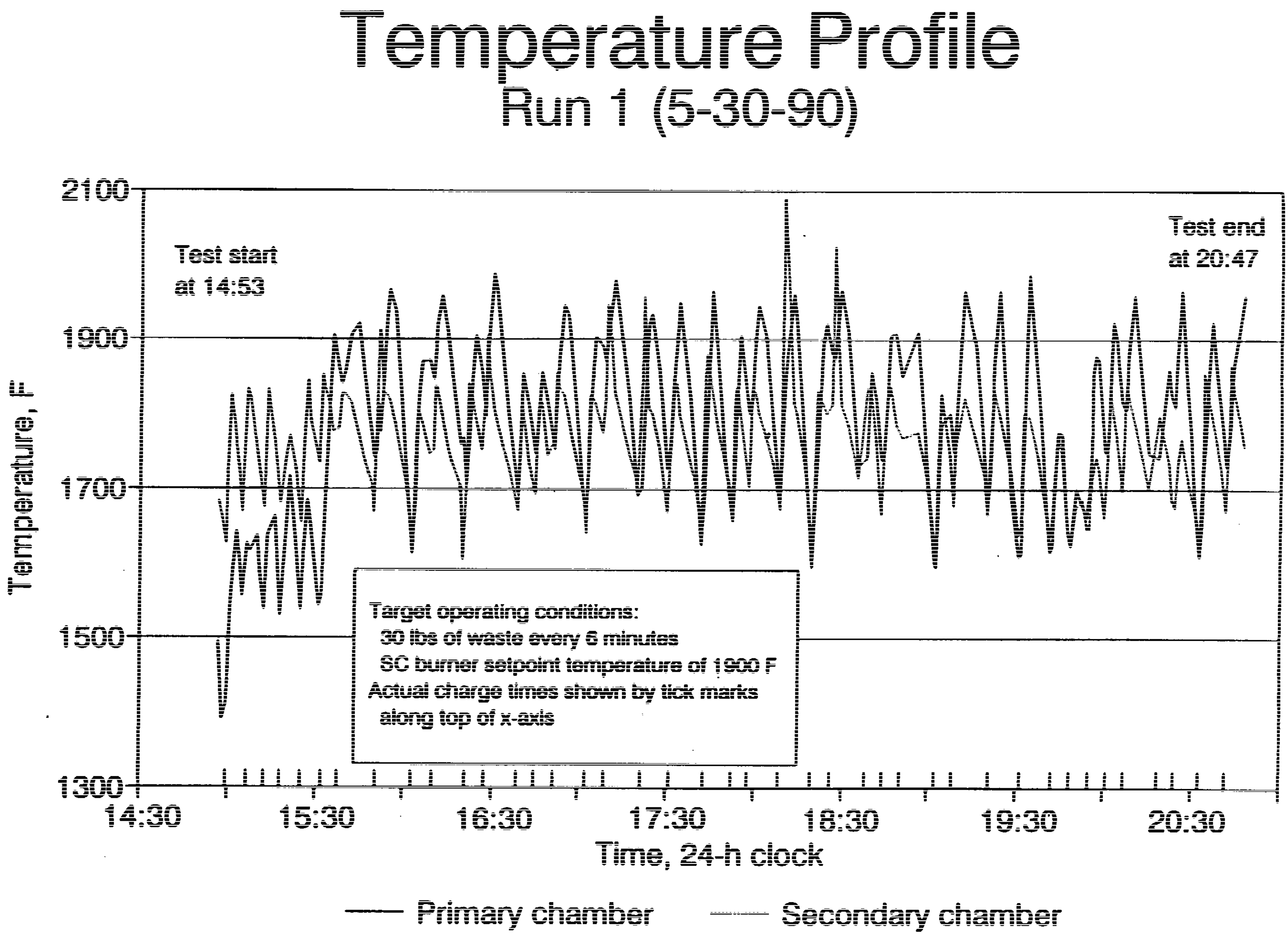


Figure 3-2. Temperature Profile for Run 1

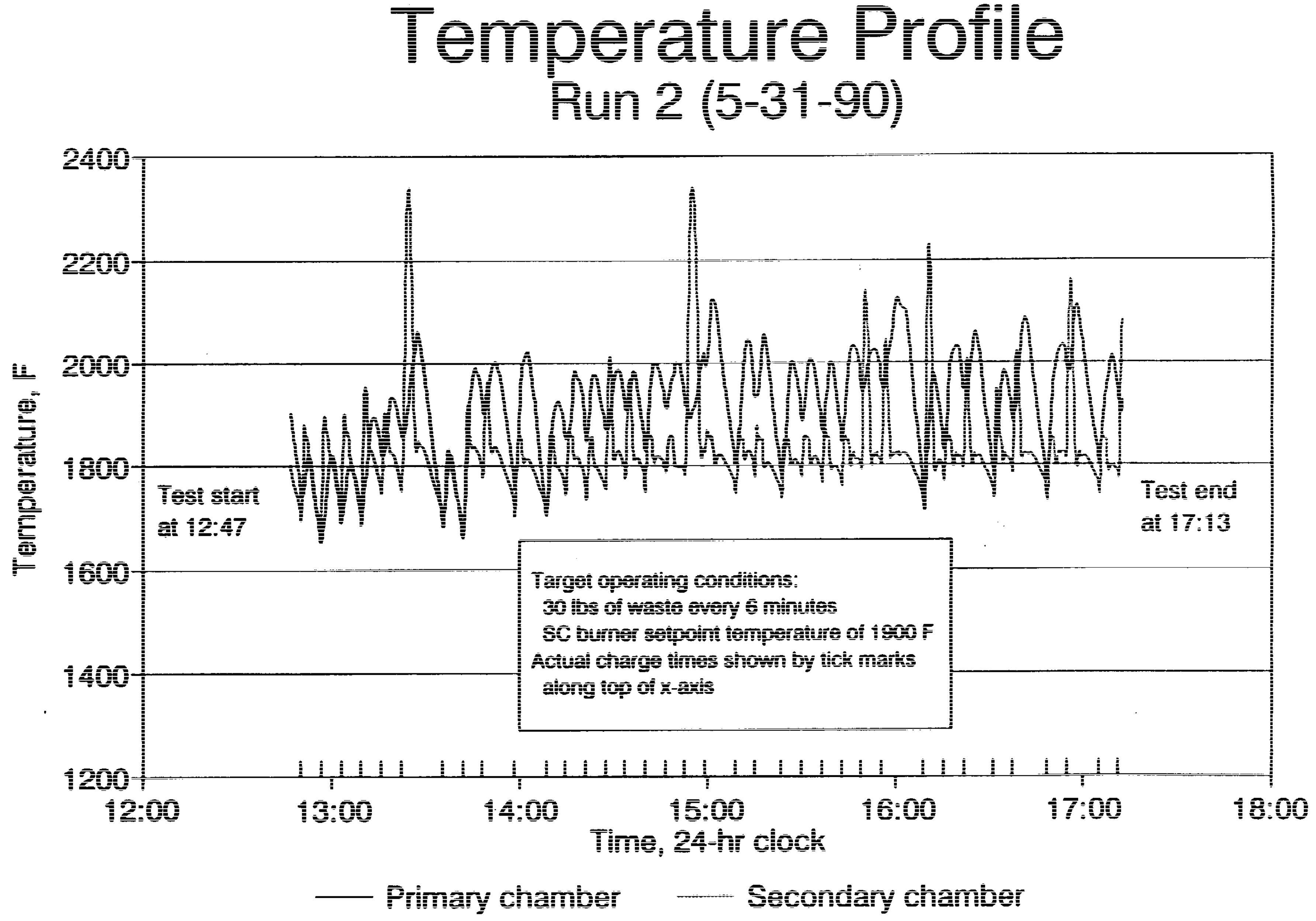


Figure 3-3. Temperature Profile for Run 2

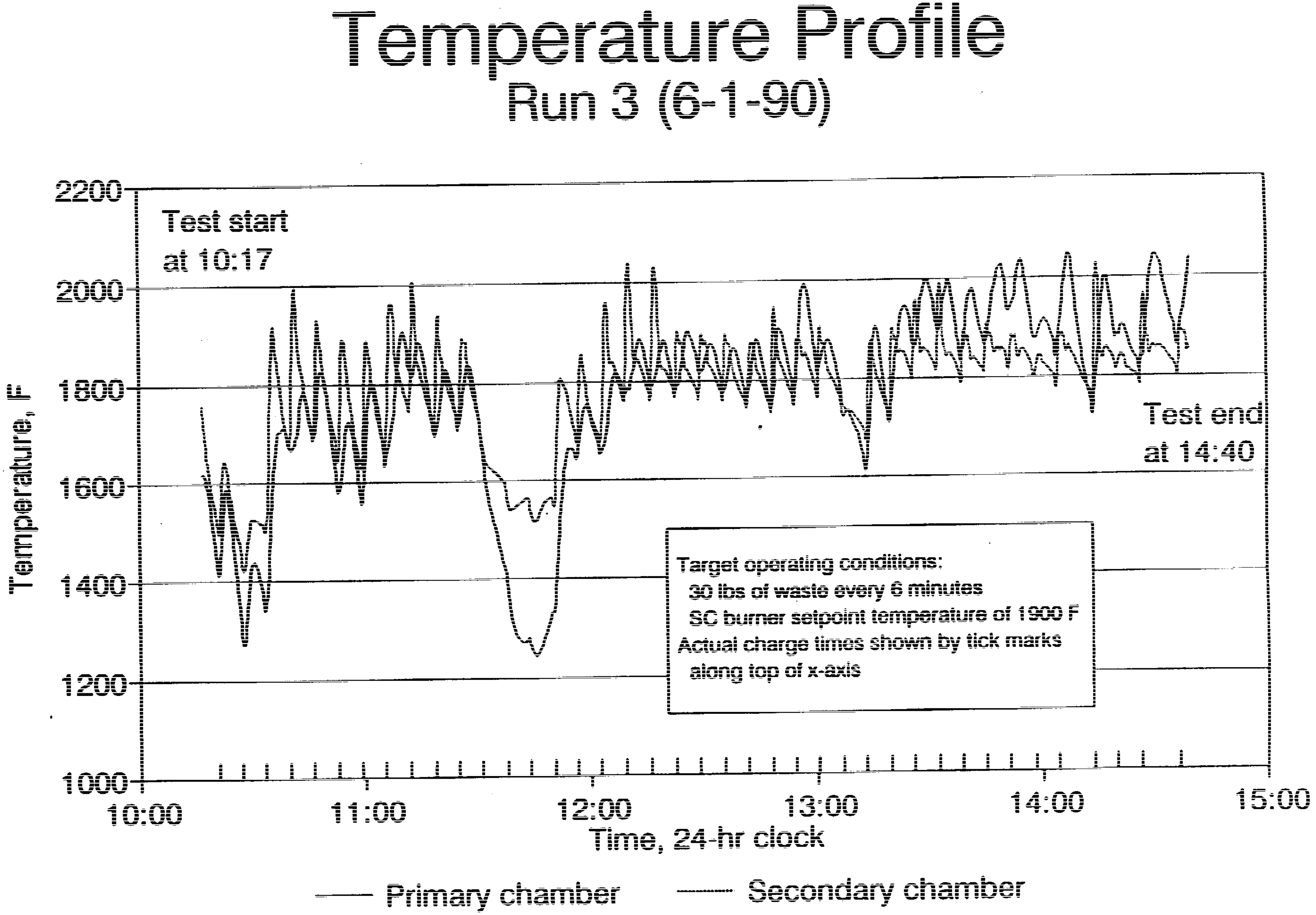


Figure 3-4. Temperature Profile for Run 3

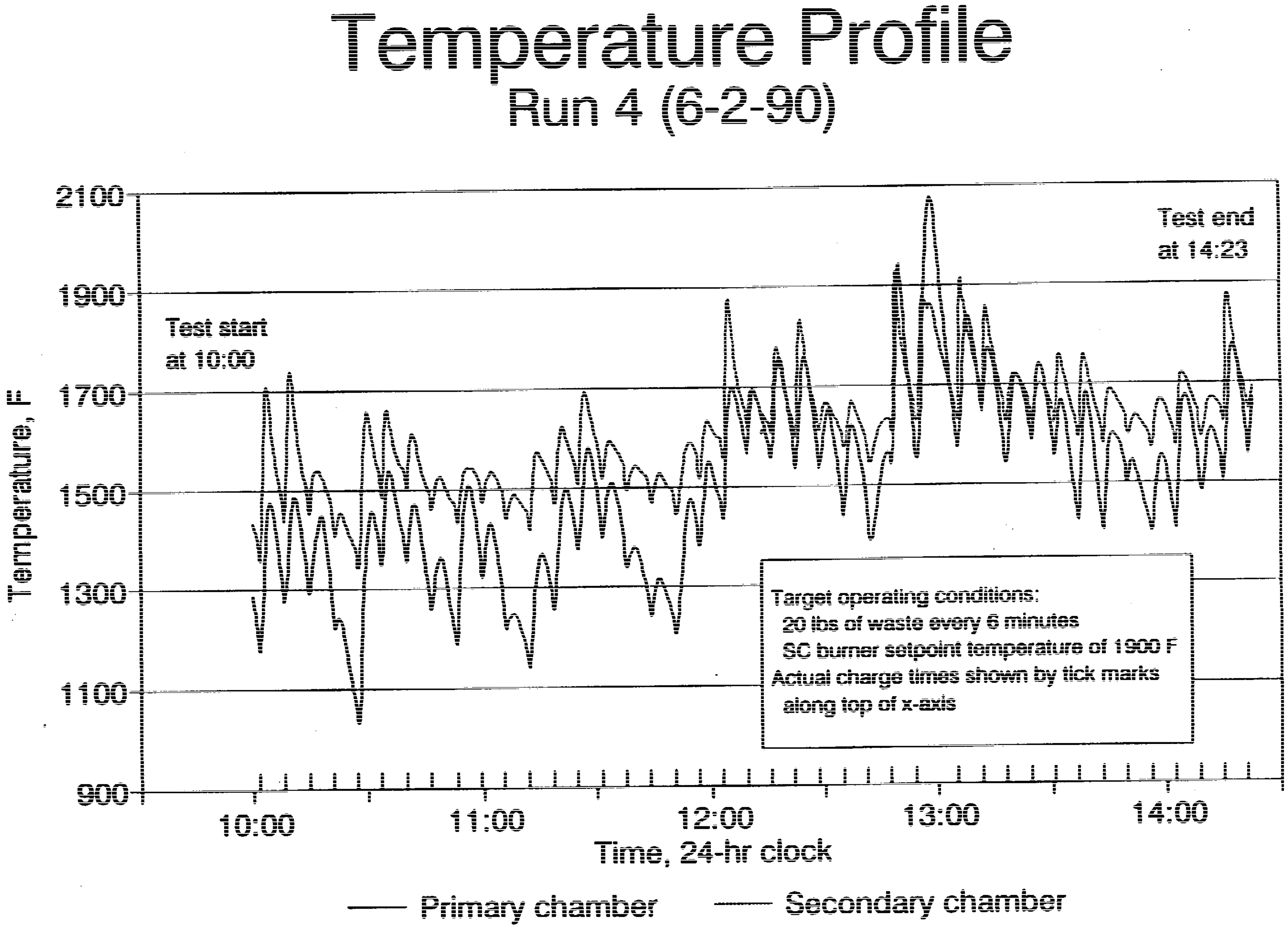


Figure 3-5. Temperature Profile for Run 4

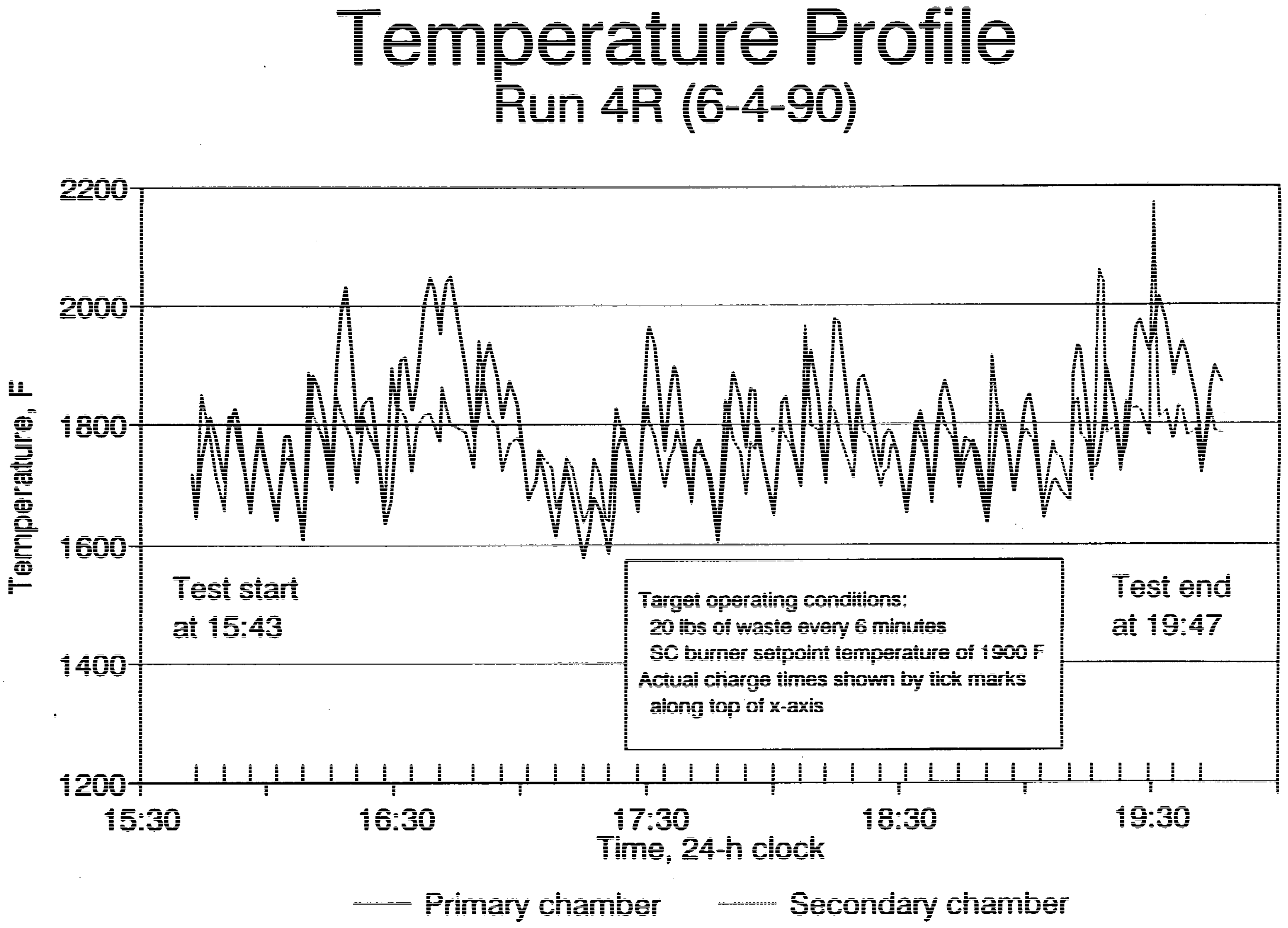


Figure 3-6. Temperature Profile for Run 4R

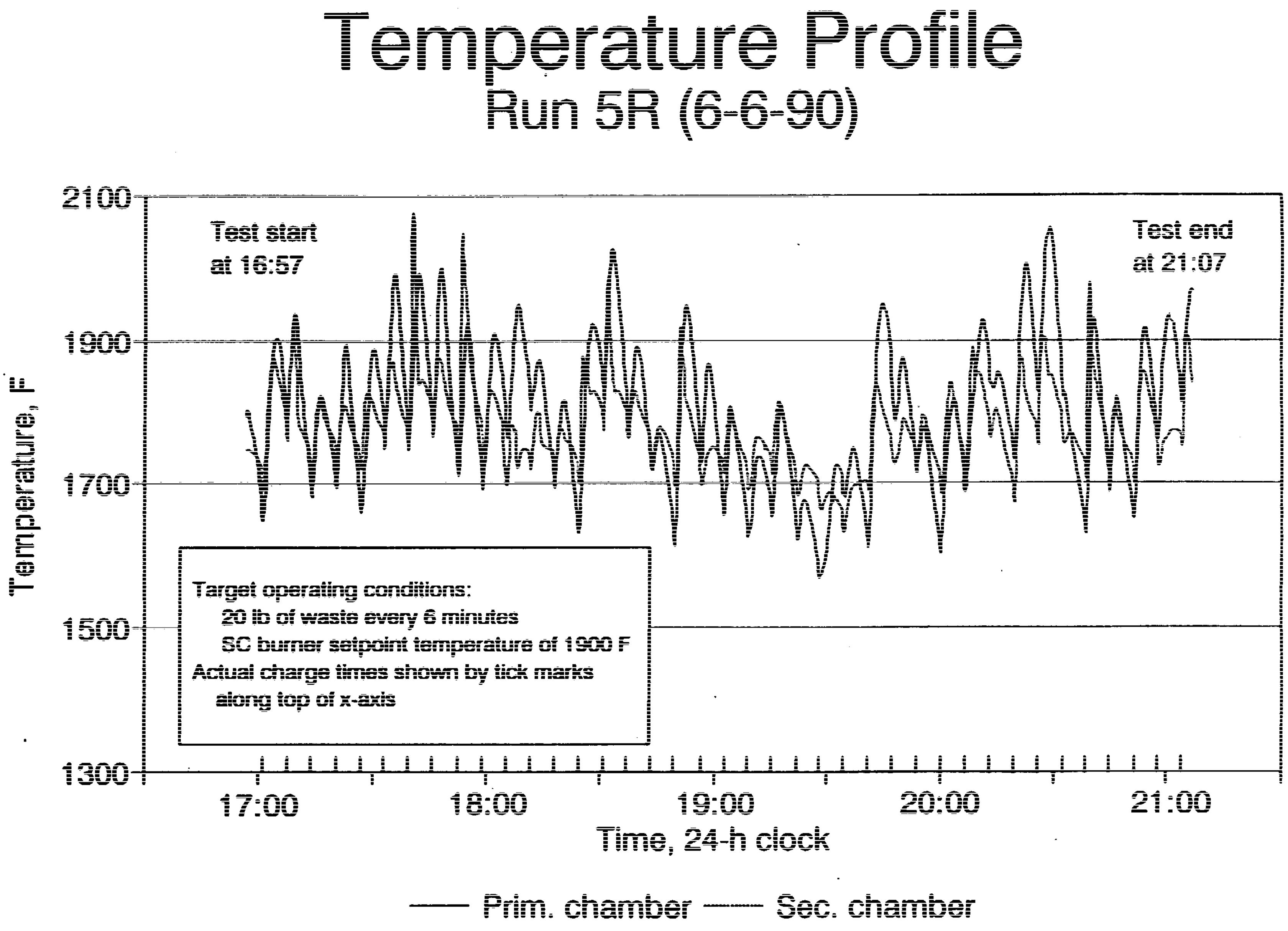


Figure 3-7. Temperature Profile for Run 5R

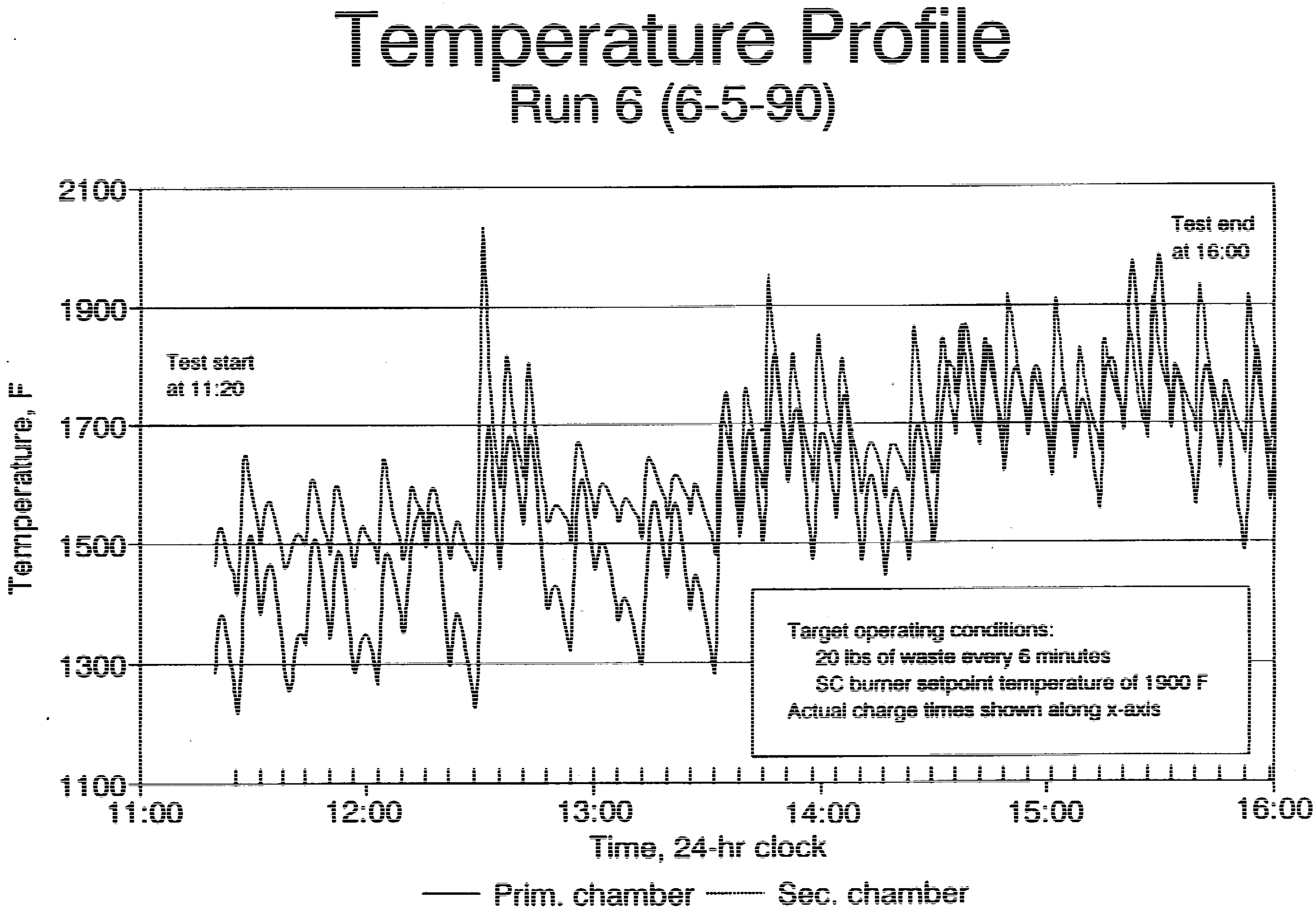


Figure 3-8. Temperature Profile for Run 6

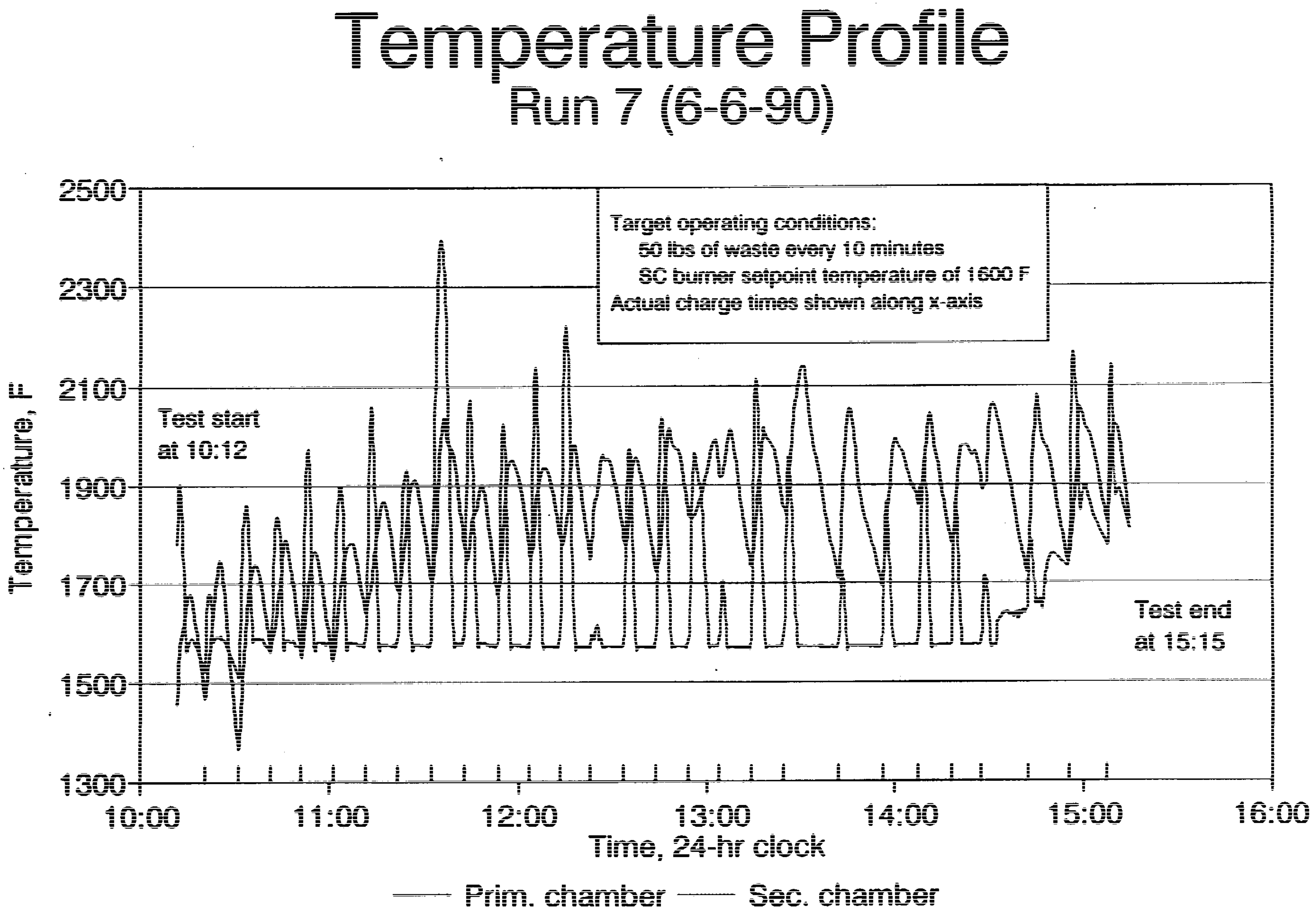


Figure 3-9. Temperature Profile for Run 7

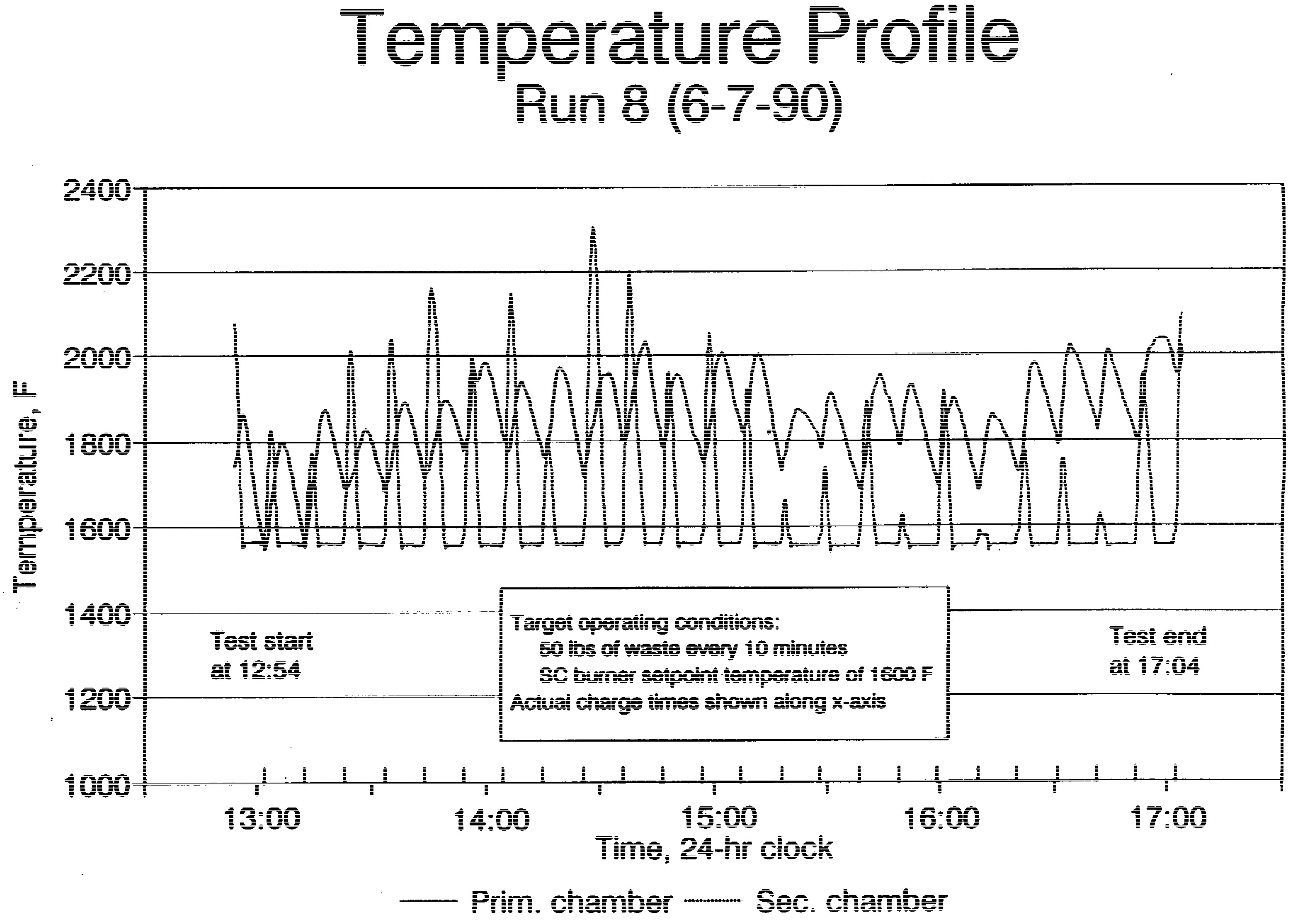


Figure 3-10. Temperature Profile for Run 8

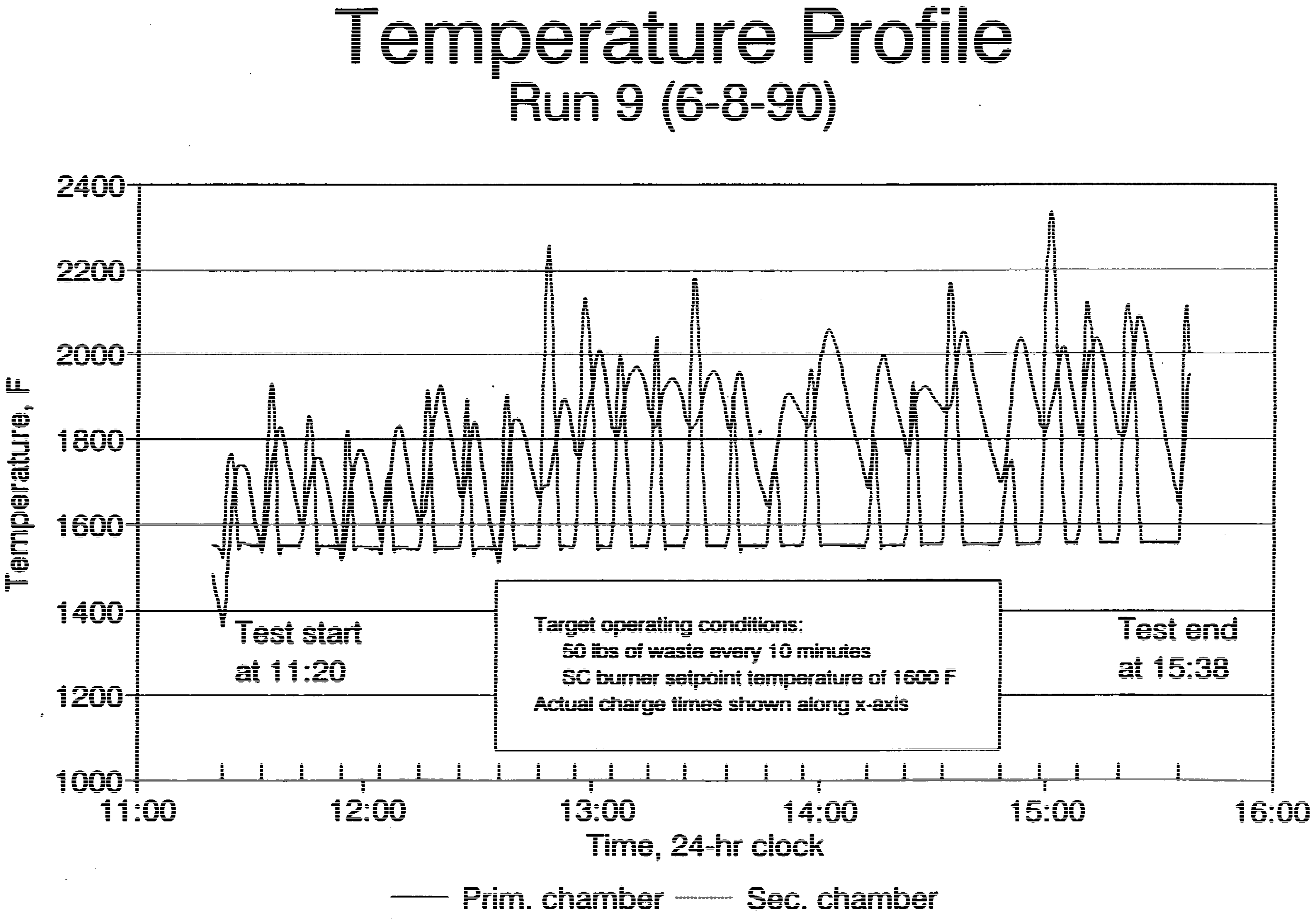


Figure 3-11. Temperature Profile for Run 9

Table 3-3. Calculated Gas Residence Time in Secondary Chamber

Run No.	Stack gas conditions: flow rate, acfm	Stack gas conditions: average temp., F	Average secondary chamber temp., F	Average gas residence time in secondary chamber, s (a)
1	4421	1289	1767	0.32
2	4498	1341	1831	0.31
3	4811	1341	1783	0.30
4R	4277	1282	1770	0.33
5R	4460	1312	1783	0.32
6	4017	1254	1660	0.36
7	4092	1312	1680	0.36
8	4198	1268	1641	0.35
9	4138	1289	1658	0.36
average				0.34

(a) Residence time is based on the secondary chamber volume of 0.85 m3 (30 ft3) and is calculated as follows for Run 1:

$$\text{Res. time, s} = \frac{(30\ \text{ft3})(60\ \text{s/min})(1289 + 460\ \text{R})}{(4421\ \text{acfm})(1767 + 460\ \text{R})}$$

Before the start of emissions testing, the secondary chamber burner setpoint temperature was adjusted from what was believed to be about 1093°C (2000°F) to about 1038°C (1900°F). However, because the bias was greater than expected, the actual setpoint temperature was about 1010°C (1850°F). The primary chamber temperature setpoint at which the ram would lock out was not adjusted because lockouts were not a problem during the pretest. According to the display on the control panel, the setpoint was about 1085°C (1985°F), the value recommended by the incinerator manufacturer. However, because of the bias in the controllers, the actual setpoint was about 1052°C (1925°F).

Emissions testing began 2 hours after the ram timer was adjusted to 6.3 minutes, or nearly 5 hours after the incinerator was turned on. By this time, the ram had already locked out twice because of high temperatures in the primary chamber. Lockouts continued to occur frequently during the test period, which resulted in an average cycle time of 8.4 minutes and an average charge rate of about 100 kg/hr (220 lb/hr) during the test period. Although the goal was to charge 136 kg/hr (300 lb/hr), the testing was not suspended during the lockout periods because the incinerator was operating normally. However, after the test it was decided that the bias in the primary chamber temperature monitor may have been responsible for the frequency of lockouts. Therefore, as indicated below, the setpoint was increased during Run 2.

Most of the available waste was general, "brown bag" refuse. Five red bags, one blue bag, and numerous sharps containers were apportioned to the loads during the first 2 hours of the test. None of these items had any noticeable effect on the temperatures. Other charges that did cause large temperature fluctuations had no distinguishable characteristics.

3.3.1.2 Run 2. Waste was charged at about 14 kg/charge (30 lb/charge) for 2.7 hours before emissions testing began. At about the time testing was starting, the ram locked out and a hospital engineer adjusted the set screw slightly to increase the lockout temperature. This procedure was repeated during subsequent lockout periods in the first 1.5 hours of the test. After the third adjustment, the lockout setpoint temperature was about 1121°C (2050°F). This setpoint was not adjusted again during any of the subsequent test runs.

The frequency of lockouts was much lower during this run than during Run 1. As a result, the average charge rate was about 118 kg/hr (260 lb/hr), and the average charge frequency was about 7.4 minutes during this test.

One of the highest secondary chamber temperatures of the day, 1281°C (2338°F), occurred after a brown bag full of blue sheets was charged. Later in the day the temperature reached 1282°C (2340°F) after a bag full of yellow cloth (either gowns or sheets) was charged. Small blue bags and red bags, both of which were charged with brown bags throughout the day, had no observable effect on temperatures.

3.3.1.3 Run 3. Waste charging began after about 1 hour of preheat. In an effort to get as much of the test completed before a lockout, this run began about 35 minutes after the first charge. Almost 3.5 hours of the test were completed before the first lockout. Three heavy loads, about 20 kg (45 lb) each, of frozen pathological waste also delayed the first lockout. The pathological waste was added between 1.25 and 1.5 hours into the test. Primary and secondary chamber temperatures dropped to 673°C (1244°F) and 824°C (1515°F), respectively, during this time. During this test, a bag full of blue sheets did not cause the temperatures to increase more than other charges. General refuse predominated for the rest of the day. The only exceptions were one small blue bag, four small red bags, and two sharps containers.

3.3.2 Condition II

For the second set of runs, the target charging rate was 9.1 kg (20 lb) of waste every 6 minutes (91 kg/hr [200 lb/hr]), and the target secondary chamber burner setpoint temperature was 1038°C (1900°F). Again, because the bias was more than expected, the actual setpoint temperature was about 1850°F. Natural gas consumption averaged 32.2 cubic meters per hour (m^3/hr) (1,140 cubic feet per hour [ft^3/hr]) during runs 4, 4R, 5R, and 6, and the burner was on an average of 94 percent of the time during three of these runs. Summaries of the runs are presented in the subsections below.

3.3.2.1 Run 4. The first charge was introduced after about 25 minutes of preheat and testing began about 1 hour later. One lockout occurred after 3 hours of testing. The charge before the lockout contained a 12-lb sharps container. This container did not necessarily affect the temperature because similar containers had no such effect on other days. This test was conducted on Saturday, and it appeared that coffee shop, lounge, and patient room trash comprised a higher percentage of the waste stream than on other days. Housekeeping personnel indicated that this mix was normal for weekends because there are more visitors in the patients' rooms, and they buy food; the nurses have 12-hour shifts on weekends and are more likely to order out for food; and less surgery occurs on the weekends.

3.3.2.2 Run 4R. This run began about 40 minutes after the invalidated Run 5 ended. Even though waste had been charged for almost 7 hours before the start of the test, the ram locked out only once during the test. The average charge rate during the test was 85 kg/hr (187 lb/hr). Waste was primarily brown bag refuse. Three small blue bags and four large sharps containers (4.5 to 7.7 kg/container [10 to 17 lb/container]) had no distinguishable effect on the temperatures. The highest secondary chamber temperature of the day, 1189°C (2172°F), was reached after a brown bag with operating room waste was incinerated. This charge contained a brown bag full of blue sheets.

3.3.2.3 Run 6. The incinerator was preheated for about 35 minutes. Waste was charged for almost 2 hours before emissions testing began. The ram did not lock out during the test. The average charge rate was 86 kg/hr (190 lb/hr), and the average ram cycle was 6.5 minutes. The largest secondary chamber temperature spike (322°C [580°F]) occurred after a brown bag full of blue sheets was charged at 12:28.

3.3.2.4 Run 5R. This run was conducted after Run 7. Therefore, the control settings for the ram cycle timer and the secondary chamber burner setpoint temperature were readjusted at the end of Run 7. After these adjustments, the secondary chamber burner was shutting off at about 1038°C (1900°F). The setpoint would not have been adjusted again during this test except that about 30 minutes before the start of emissions testing the burner shut off at about 1010°C (1850°F). At that time, the setpoint was adjusted upward. Several more adjustments were necessary during the next 2 hours before the desired cutoff was achieved. After about 1.5 hours into the test, the burner was cutting off at about 1038°C (1900°F), and it continued to do so for the rest of the test.

This run was conducted after almost 8 hours of charging, whereas Runs 4 and 6 were conducted after only 1 to 2 hours of charging. As a result, both average primary and average secondary chamber temperatures were higher for this run. Primary chamber temperatures were affected to a greater degree and they exceeded secondary chamber temperatures during most of the run. No lockouts occurred during the test. The average charge rate was 88 kg/hr (195 lb/hr), and the average ram cycle was 6.4 minutes.

Beginning with the last charge during the HCl test in Run 7, waste was charged at about 9.1 kg/charge (20 lb/charge) for 1.75 hours before the Run 5R testing began. Two minutes before the test started, several small boxes and paper bags that contained outdated medicines from the pharmacy were incinerated. Because the glass content of this charge was high, the secondary chamber temperature rose less than 55°C (100°F) after it was introduced. One charge consisted of operating room waste, but the secondary chamber temperature did not increase significantly. Two small blue bags and five small red bags added with brown bags at various times during the run caused no unusual temperature effects.

3.3.3 Condition III

For the final three runs, the target charging rate was 23 kg (50 lb) every 10 minutes (136 kg/hr [300 lb/hr]), and the target secondary chamber burner setpoint temperature was 870°C (1600°F). The incinerator operated normally during all three runs. Table 3-2 shows that average primary chamber temperatures were 89° to 106°C (160° to 190°F) higher than the average secondary chamber temperatures for these three runs. Furthermore, as Figures 3-9 through 3-11 show, the primary chamber temperatures were higher than secondary chamber temperatures throughout the runs except for occasional secondary chamber temperature spikes. Figures 3-9 through 3-11 also show that after the secondary chamber temperature spikes, the burner maintained a minimum temperature between 843°C (1550°F) and 860°C (1580°F). Natural gas consumption averaged 14.6 m^3/hr (520 ft^3/hr) during the three runs, and the secondary chamber burner was on about 48 percent of the time. Summaries of all three runs are presented in the subsections below.

3.3.3.1 Run 7. Waste was charged at 23 kg/charge (50 lb/charge) for an hour before the emissions test began. During this time the secondary chamber burner setpoint temperature was reduced to about 870°C (1600°F). The ram cycle timer was also adjusted before the start of the test. When the ram was operating without lockouts, it was activated every 10 to 10.5 minutes. Two lockouts occurred before 14:30, the time at which all but one HCl test had been completed. For two charges during the test, the ram had to activate a second time to clear material that blocked the ram door from closing.

Three more lockouts occurred before the last HCl run was completed at 15:15. Between 14:30 and 15:15, only three charges were introduced; in anticipation of Run 5R, the last charge was only 9.1 kg (20 lb). Consequently, the average charge rate was 121 kg/hr (266 lb/hr) and the ram cycle was 11.2 minutes for the total test period. The average charge rate was 128 kg/hr (283 lb/hr) between 10:12 (the start of emission testing) and 14:30. During this time, Figure 3-9 shows that the secondary chamber burner maintained a minimum temperature of about 857°C (1575°F) after the temperature spikes. At about 14:45, the secondary chamber burner setpoint temperature was prematurely adjusted upward. After the adjustment the cutoff was about 1038°C (1900°F).

The highest secondary chamber temperature spike during the run (1310°C [2390°F]) occurred after one charge that consisted of waste from the operating room. Other waste charges had no distinguishable characteristics that could be correlated with temperatures.

3.3.3.2 Run 8. Before testing began, the ram cycle timer was adjusted to about 10.5 minutes, and the secondary burner setpoint temperature was adjusted to about 860°C (1580°F). These adjustments were necessary because Run 5R was conducted after Run 7. After 80 minutes of preheat, the first load was charged to the incinerator. Waste was charged at about 23 kg/charge (50 lb/charge) for 1.75 hours before the test began. The only lockout occurred less than 1 minute after the last test was completed. The average charge rate was 134 kg/hr (296 lb/hr), and the ram cycle was 10.4 minutes. As shown in Figure 3-10, the secondary chamber temperature was maintained at about 849°C (1560°F) after the temperature spikes. Several charges in the last 2 hours of the test caused very little change in the secondary chamber temperature; the contents of the bags did not appear unusual. The highest secondary chamber temperature spike (1263°C [2306°F]) occurred after a brown bag charge at 14:25. Three other temperature spikes to about 1177°C (2150°F) occurred after various mixtures of brown, red, and blue bags were charged.

3.3.3.3 Run 9. After 1 hour of preheat, waste was charged for another hour before testing began. The secondary chamber burner setpoint temperature setting was unchanged from Run 8 (860°C [1580°F]), and as shown in Figure 3-11, a minimum temperature of about 843°C (1550°F) was maintained after the temperature spikes. The dial on the ram cycle timer was adjusted several times in an attempt to achieve a 10-minute cycle; these adjustments resulted in cycles between about 9.5 and 11 minutes.

Two lockouts occurred during the test. The average charge rate was 129 kg/hr (285 lb/hr), and the average ram cycle was 10.8 minutes. A secondary chamber temperature spike to 1238°C (2260°F) occurred after a charge at 12:46 that contained mostly operating room waste. A secondary chamber temperature spike to 1280°C (2336°F) occurred after a charge with blue sheets in one of several brown bags at 14:58. Two mixed red and brown bag charges at 12:25 and 14:33 caused secondary chamber spikes to about 1193°C (2180°F). A mixed charge with one blue bag at 12:55 caused a similar spike.

4. SAMPLE LOCATIONS

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

The exhaust stack at this facility has a 26-inch steel shell with refractory lining. The inside diameter of the refractory lining is 22 inches. The existing stack is 16 feet in height above the secondary chamber. A spark arrestor is presently installed at the stack exit.

There are no test ports available in the existing stack, and due to the risk of damaging the refractory, installation of ports in the existing stack was not attempted.

An unlined steel stack extension was fabricated for temporary installation at the top of the existing stack. The extension was 22 inches in diameter and 12 feet high. Three sets of test ports were provided as shown in Figure 4-1. The lower set of ports was used for the CEM, HCl/CEM, and manual HCl tests. The center set of ports was used for metals and CDD/CDF testing. The upper ports was 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 were at least two stack diameters of undisturbed flow downstream of the ports, and greater than eight diameters of undisturbed flow upstream of the ports. (NOTE: CDD/CDF and metals sampling probes are not treated as upstream disturbances for the upper set of ports.)

The number of traverse points used for CDD/CDF, metals, and microorganism sampling was eight. Four points on each of two diameters was used as shown in Figure 4-2.

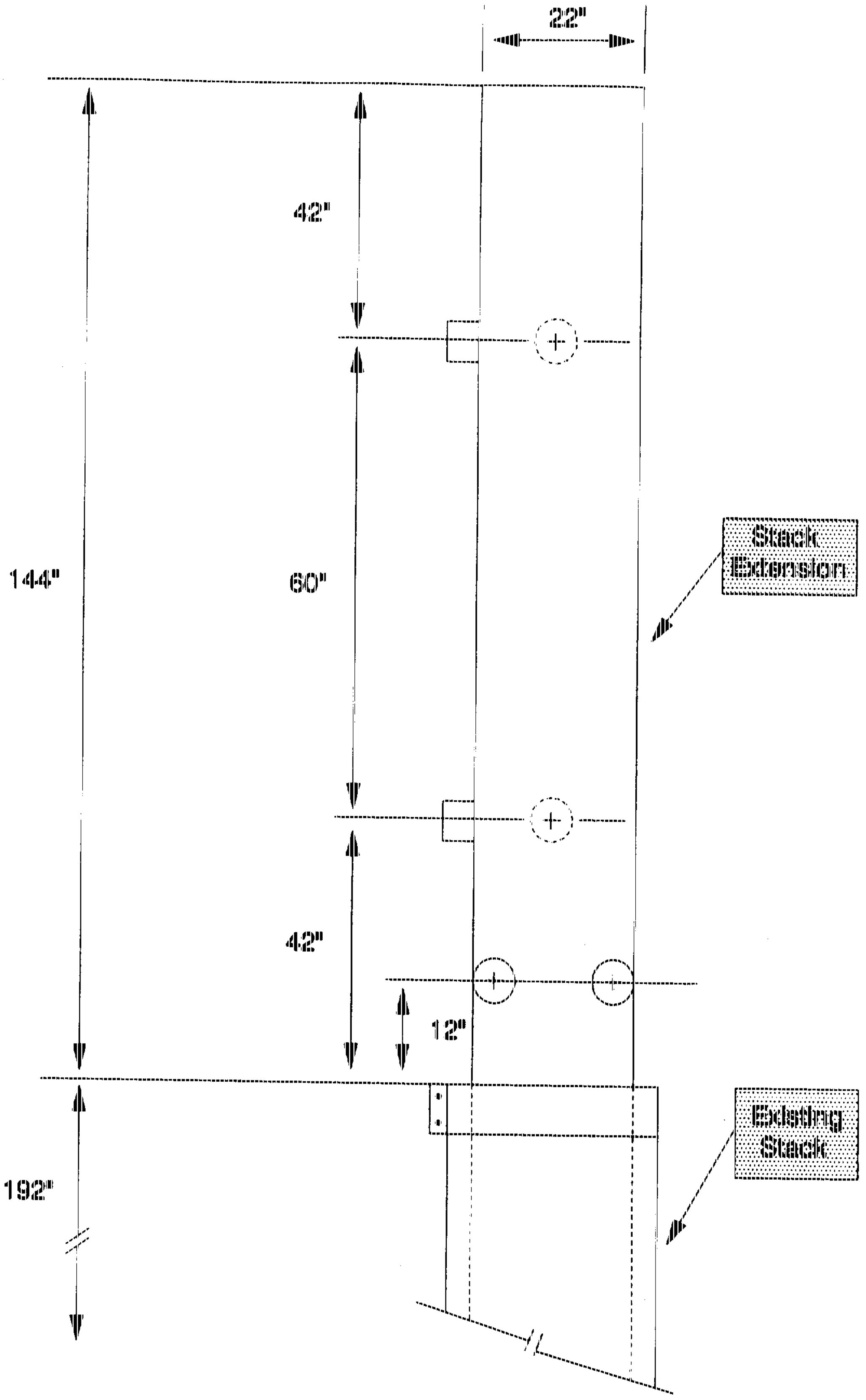
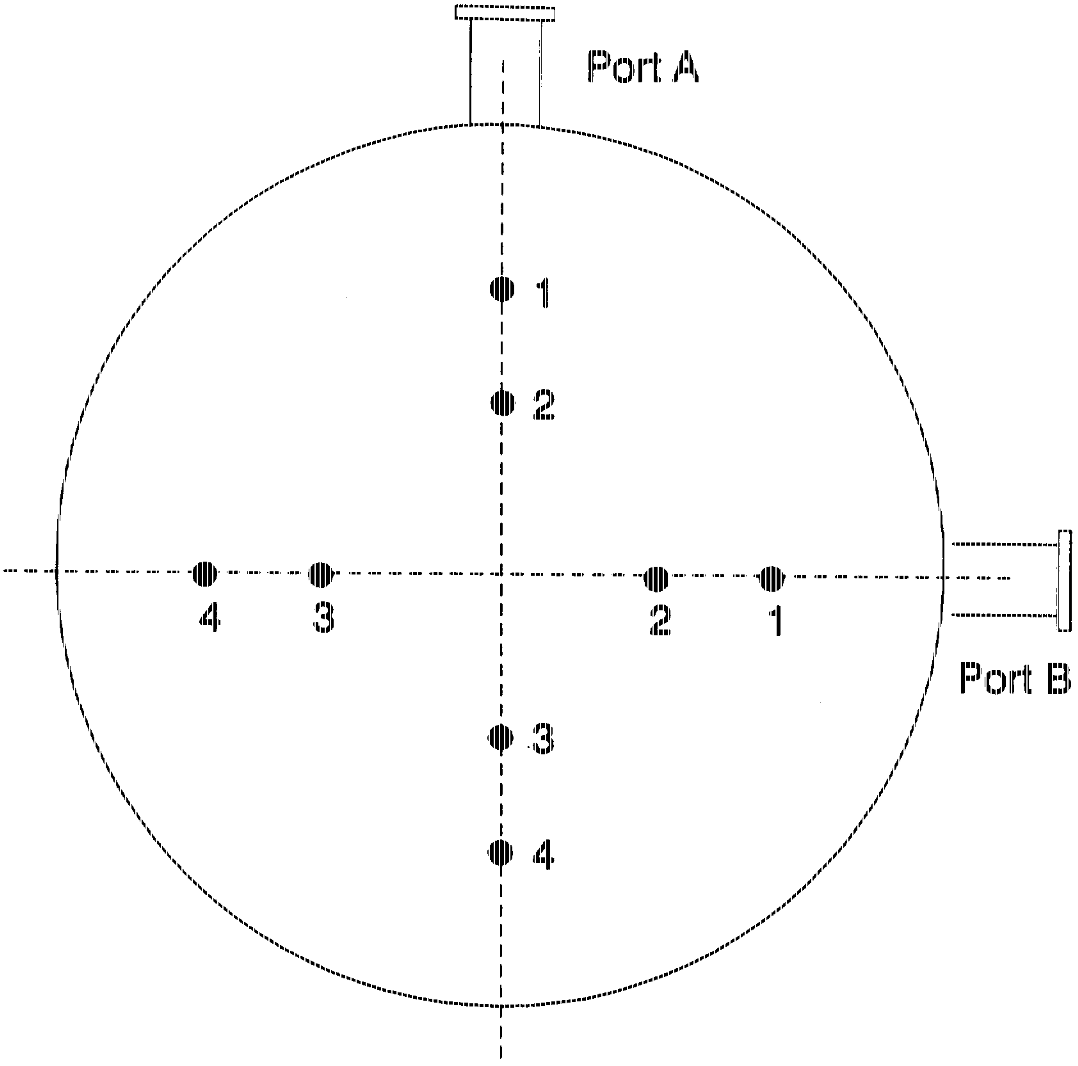


Figure 4-1. Sample Port Location at the Exhaust Stack



Diameter = 22 inches

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

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

5. SAMPLING AND ANALYTICAL PROCEDURES BY ANALYTE

The sampling and analytical procedures used for the Lenoir Memorial Hospital Medical Waste Incinerator (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 Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans (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 (RTP), North Carolina, who performs 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 K.

TABLE 5-1. TEST METHODS FOR THE LENOIR MEMORIAL 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. SAMPLING TIMES, MINIMUM SAMPLING VOLUMES AND DETECTION LIMITS FOR THE LENOIR MEMORIAL 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 g/dscm	0.002 g/ml
			Cd	0.6 g/dscm	0.006 g/ml
			Cr	1.6 g/dscm	0.015 g/ml
			Pb	0.2 g/dscm	0.002 g/ml
			Hg	25 g/dscm	0.25 g/ml
			Ni	1.6 g/dscm	0.015 g/ml
			Be	0.3 g/dscm	0.0003 g/ml
			Ba	0.2 g/dscm	0.002 g/ml
			Sb	3.3 g/dscm	0.032 g/ml
			Ag	0.71 g/dscm	0.007 g/ml
			Tl	4.2 g/dscm	0.040 g/ml
HCl/HBr/HF	1.0	120 liters[b]	Cl^-	28 g/dscm	0.11 g/ml
			Br^-	32 g/dscm	0.127 g/ml
			F^-	100 g/dscm	0.40[c] g/ml
Microorganisms	3.2	30	Indicator spores[d]	30 viable spores[c] / dscm	1 viable spores / aliquot

[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.

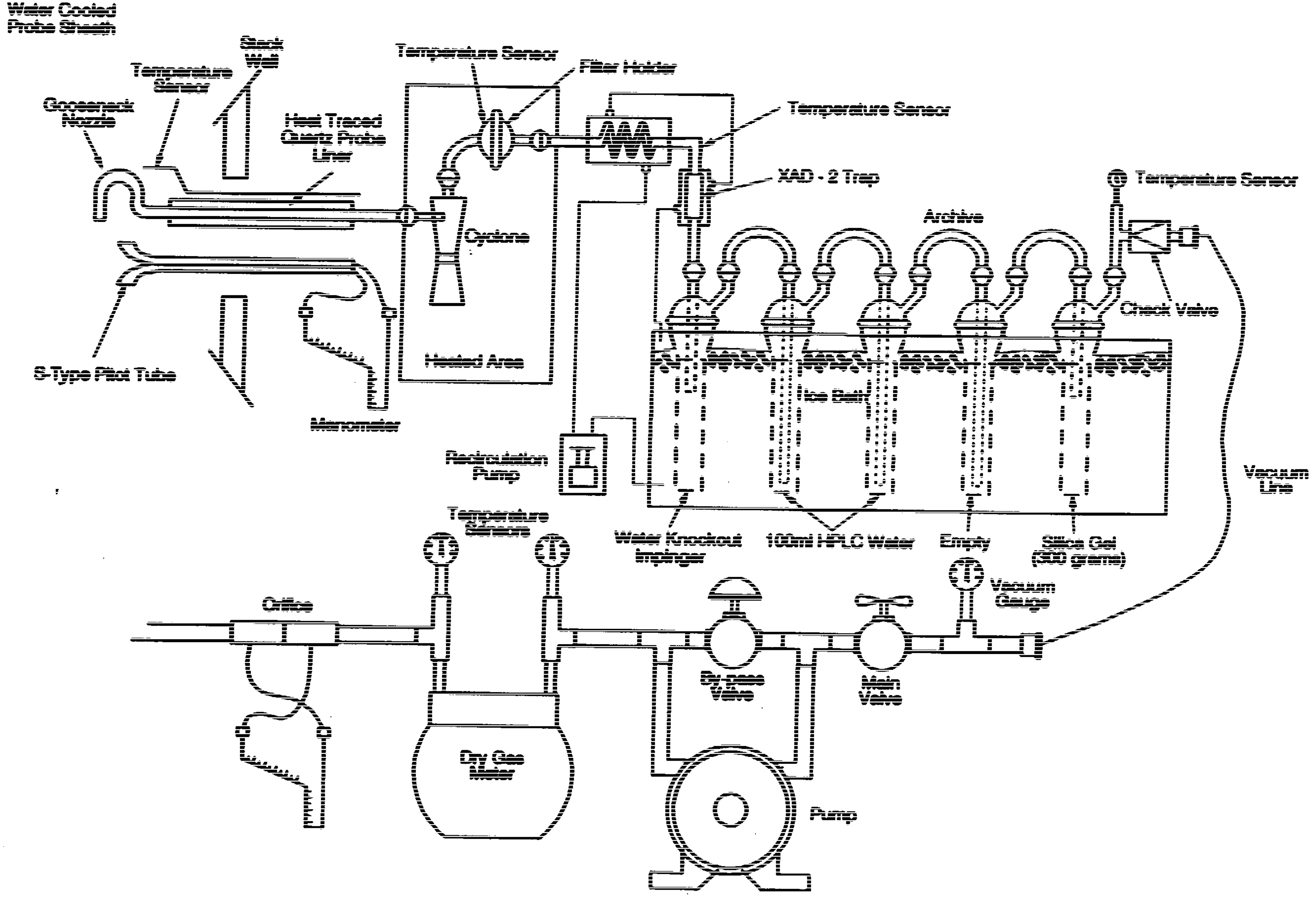


Figure 5-1. CDD/CDF Sampling Train Configuration

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 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, Radian feels 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. 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 reflexs 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 analyses 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. The data forms used are included in Appendix B. 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. Assembly of 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, the initial weight and contents of each impinger is 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 are 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

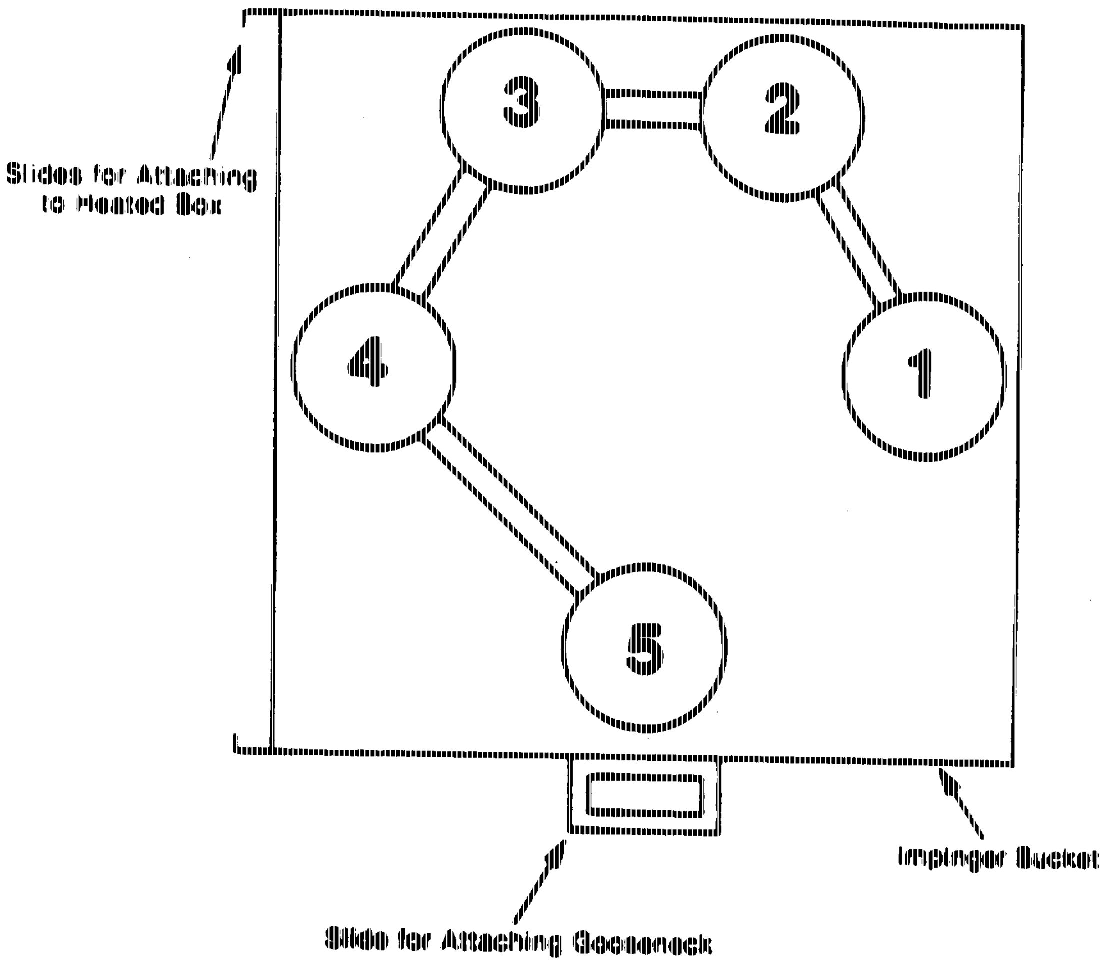


Figure 5-2. Impinger Configuration for CDD/CDF Sampling

(capped) into the impinger bucket. A supply of pre-cleaned foil and socket joints are also placed in the bucket in a clean plastic bag for the convenience of the samplers. Sealing greases are not used to avoid contamination of the sample. 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 leak checks and recommends pre-test leak checks.) 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 ("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 inches 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, and initial data is recorded (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 entering the resin trap

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

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.

must be below 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 coolers on ice at all times. The samples are shipped to the analytical laboratory by truck accompanied by written information designating target analyses.

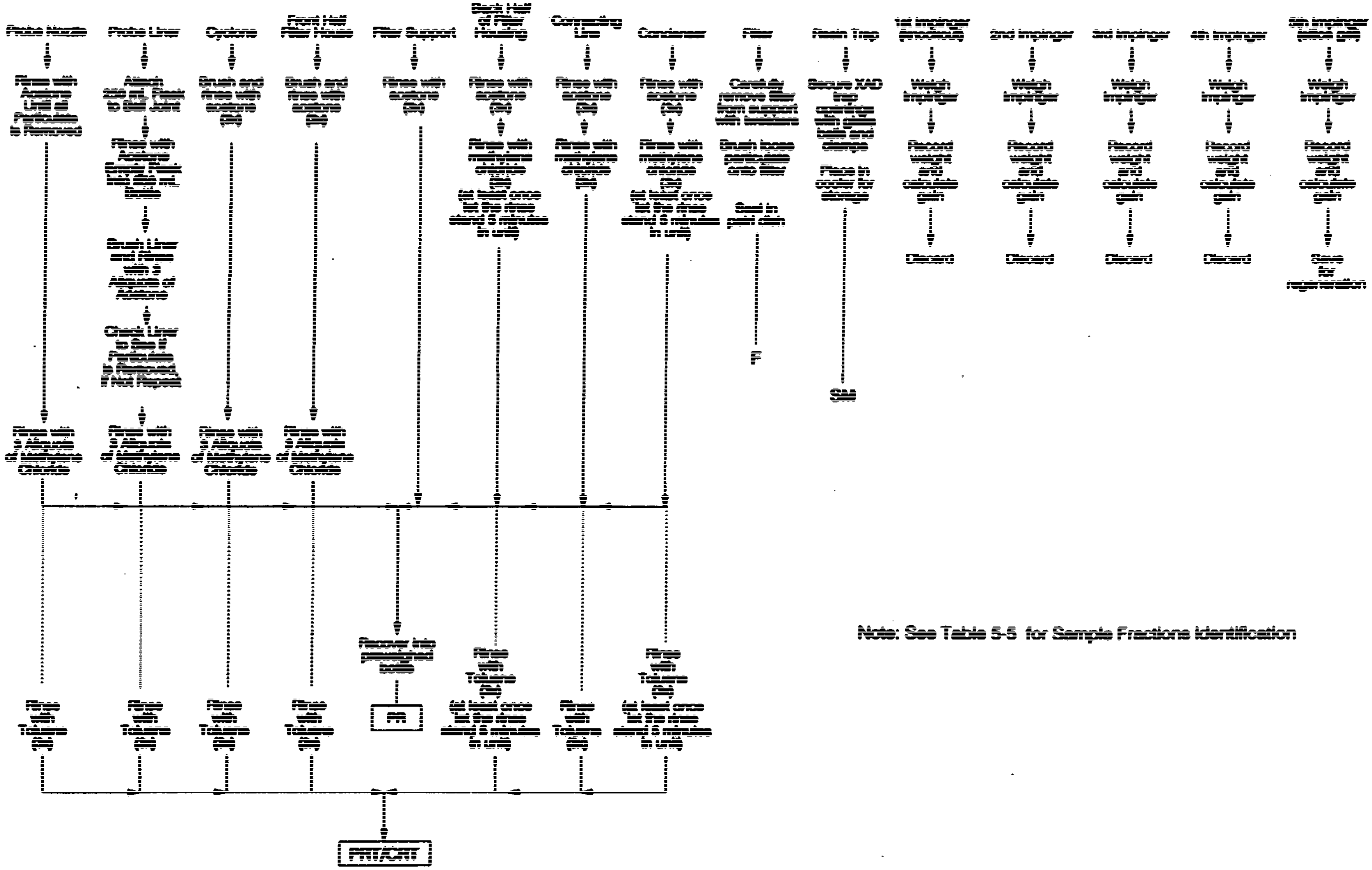
5.1.5 CDD/CDF Analytical Procedures

The analytical procedure used to obtain CDD/CDF concentrations from a single flue gas sample is by high resolution gas chromatography (HRGC) and high resolution mass spectrometry (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 Preparation of Samples for Extraction. 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 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)

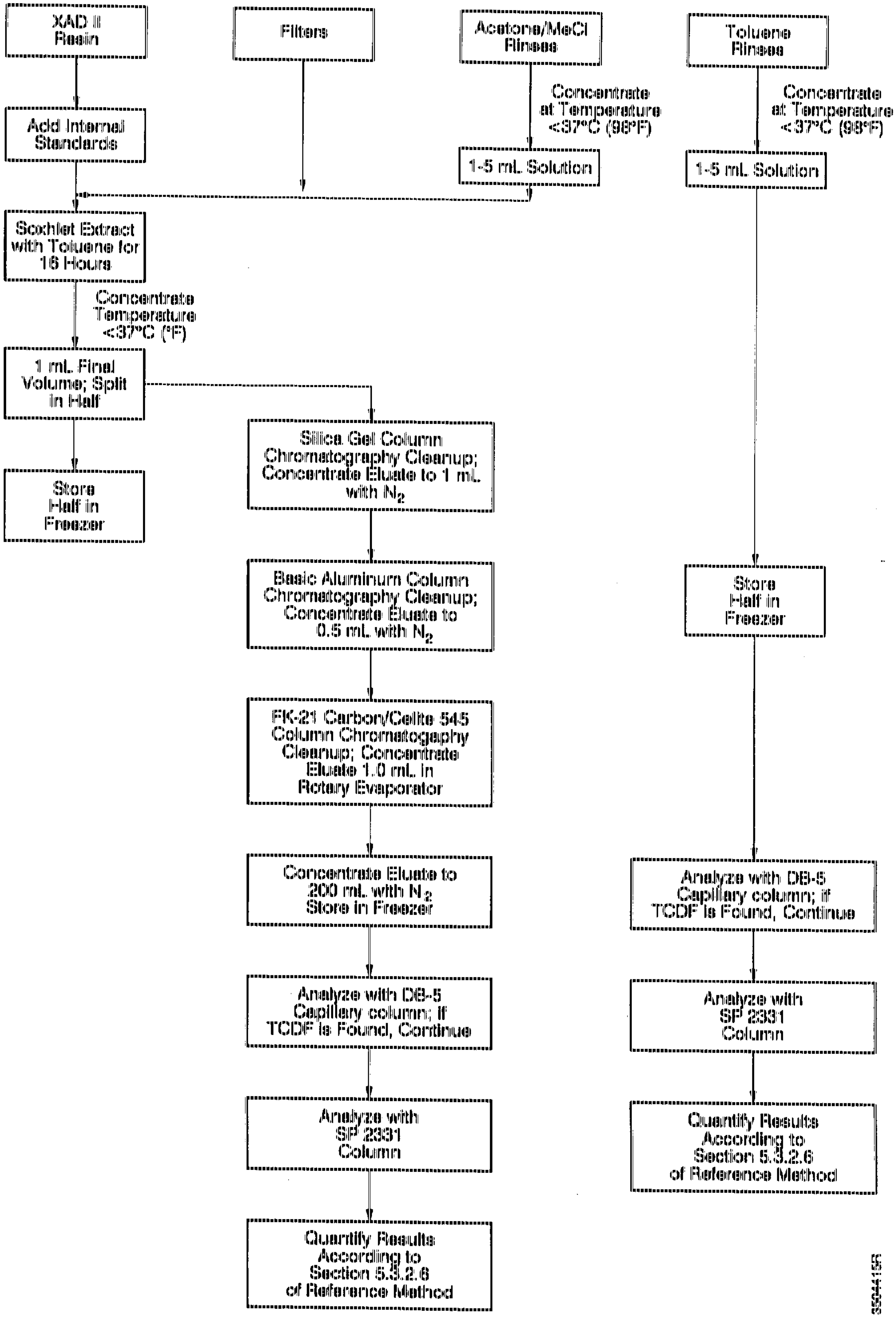


Figure 5-4. Extraction and Analysis Schematic for CDD/CDF Samples

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, condenser coil, and impinger set, is loaded as if for sampling and then quantitatively recovered exactly as the samples will be. Analysis of the generated fractions will be 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 will be used as QA/QC indicators.

In addition to the three types of blanks that are required for the sampling program, the analytical laboratory will analyze a method blank with each set of flue gas samples. This will consist 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 the range is 25 to 130 percent for the hepta- and octachlorinated homologues. If these requirements are not met, the data will be 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 will be notified immediately to determine if the surrogate results will be used to adjust the results of the native species.

Duplicate analyses are 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 Particulate Matter (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, Zn, P, Cr, Cu, Mn, Se, Be, Tl, Ag, Sb, Ba, Cd, As, and Hg emissions from various types of incinerators. Analyses of the Lenoir Memorial Hospital MWI test samples will be performed for As, Cd, Cr, Hg, Ni, Pb, Sb, Ag, Ba, Be, and Tl.

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 nitric acid (HNO_3)/10 percent hydrogen peroxide (H_2O_2) solution, two impingers with a 4 percent potassium permanganate ($KMnO_4$)/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 nitric acid solution for a minimum of 4 hours;
- Rinse with deionized distilled water rinse (3X); and
- Rinse with acetone rinse.

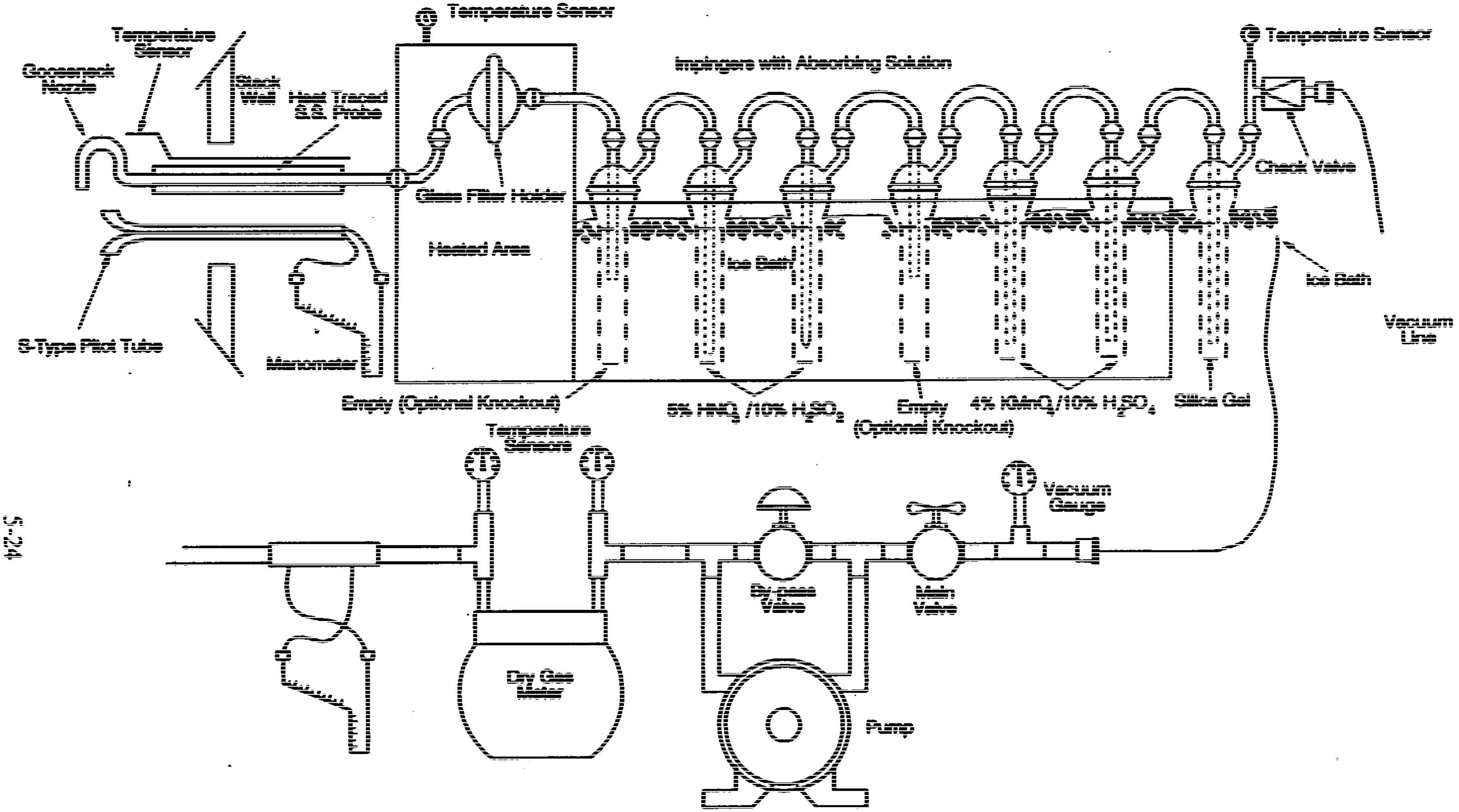


Figure 5-5. Schematic of Multiple Metals Sampling Train

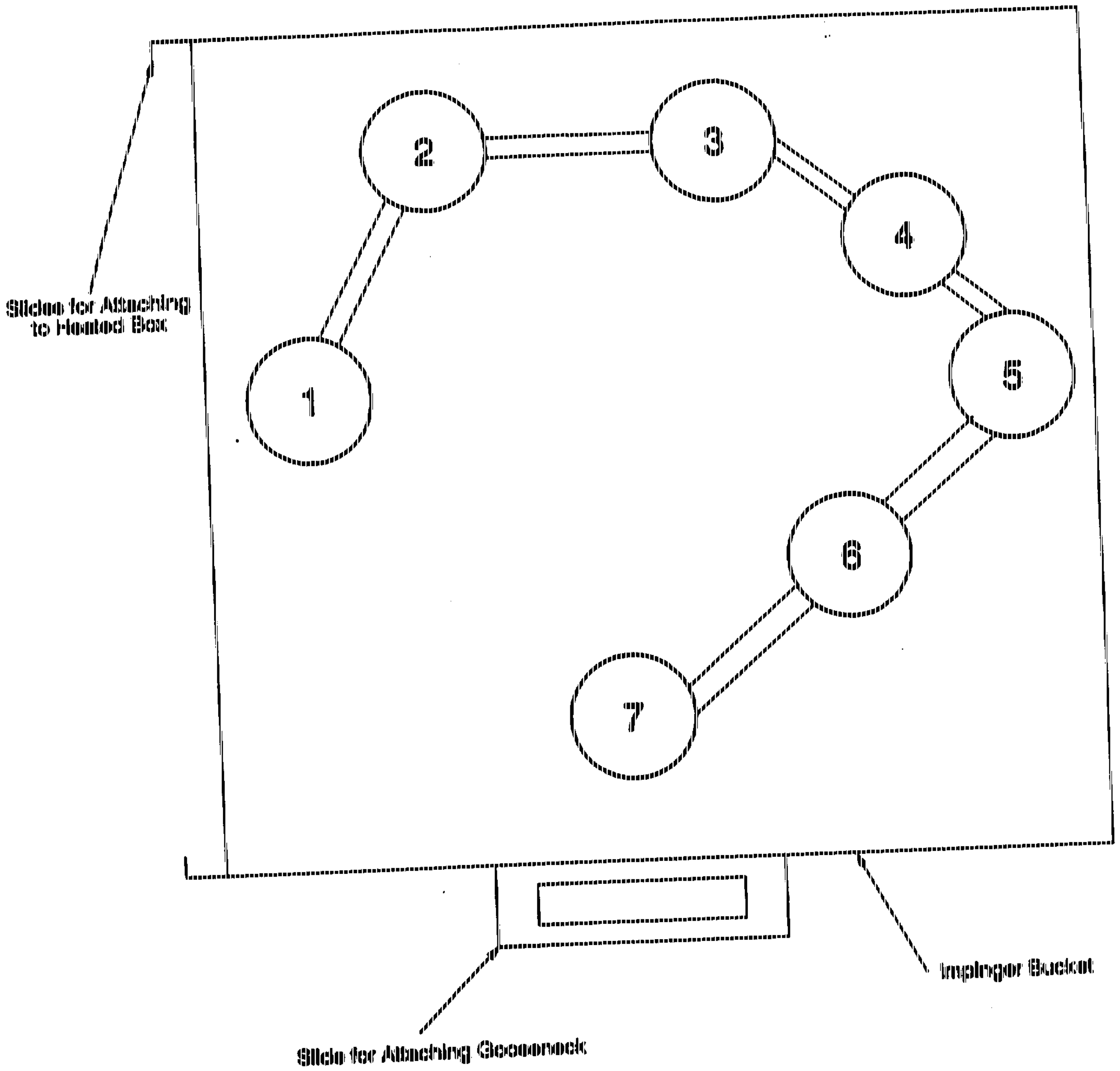


Figure 5-6. Impinger Configuration for PM/Metals Sampling
(optional knock out impinger not shown)

The cleaned glassware is allowed to air dry in a sterile 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 hydrogen 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 Waltman 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 leak check 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.

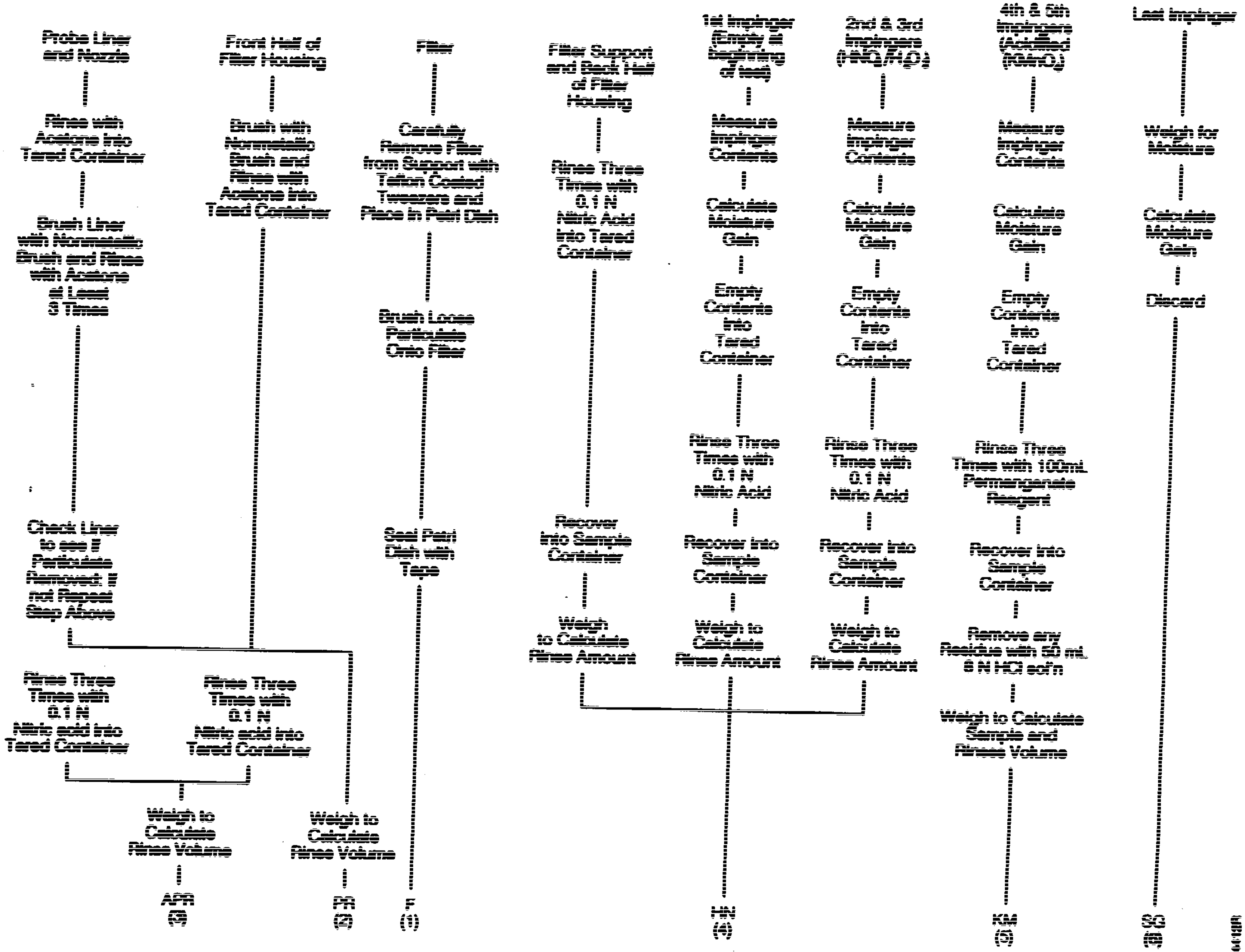


Figure 5-7. Metals Sample Recovery Scheme

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 will be 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 are 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. Cap tightly, record the weight of the combined rinse and mark the liquid level. 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 nitric acid reagent blank of approximately the same volume as the rinse volume is analyzed with the samples.

The impingers that contain the acidified potassium permanganate 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 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 loosley tightened to allow venting.

After final washing, 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 nitric acid blank - 1000 ml sample size;
- 5 percent nitric acid/10 percent hydrogen peroxide blank - 200 ml sample size;
- Acidified potassium permanganate blank - 1000 ml sample size; this blank should have a vented cap;
- 8N hydrochloric acid 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 (g/ml)	Instack Method Detection Limits[b]	
			Front Half (300 ml sample size) (g/m^3)	Back Half (150 ml sample size) (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 70°F in a tared beaker. 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 that are 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 nitric acid 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 Cold Vapor Atomic Absorption Spectroscopy (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 Inductively Coupled Argon Plasma Spectroscopy (ICAP) using EPA Method 200.7. All target metals except mercury, iron and aluminum, are quantified. If iron and aluminum are present, the sample are diluted to reduce their interferences on arsenic and lead. If arsenic or lead levels are less than 2 ppm, Graphite Furnace Atomic Absorption Spectroscopy (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.

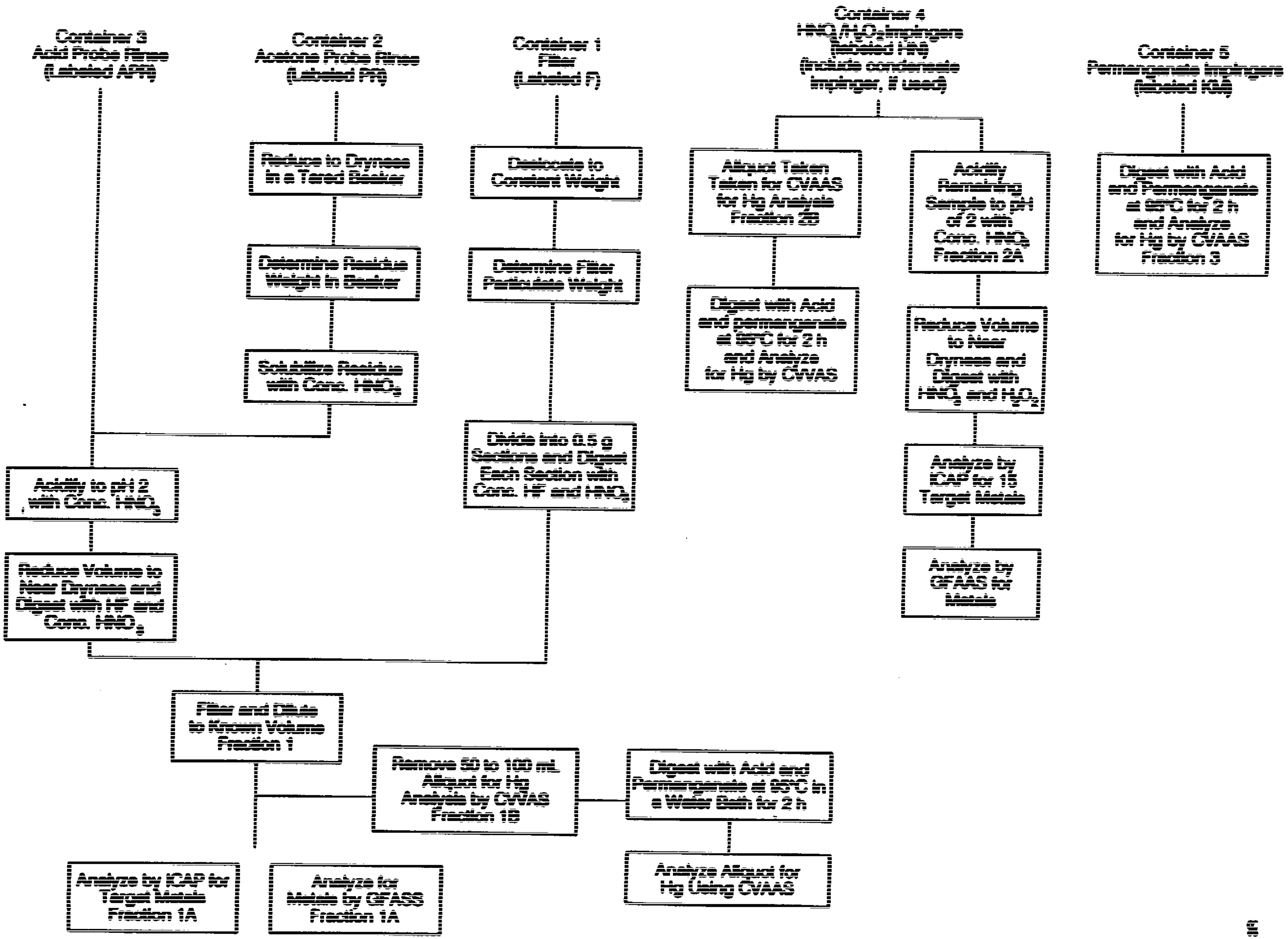


Figure 5-8. Metals Sample Preparation and Analysis Scheme

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 μg/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 μg/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 will be analyzed to check the accuracy of the calibration standards. The results must be within 10 percent or the calibration will be 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 will be 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 will be analyzed by the method of standard addition.

5.3 MICROBIAL SURVIVABILITY TESTING

The Lenoir Memorial Hospital Medical Waste Incinerator was loaded with waste inoculated with indicator spores in order to evaluate the effectiveness of the incinerator by measuring the ability of microbes to survive the incineration process. This evaluation should directly reflect the 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 K.3 and K.4 of the test plan.

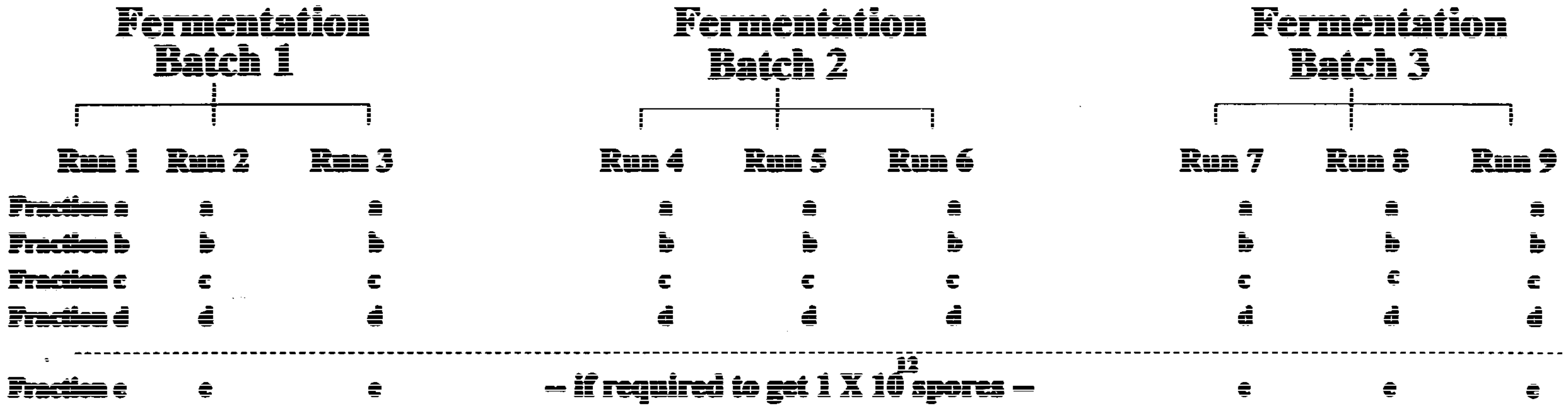
The second test method utilizes spore samples encased in insulated iron pipes which are charged to the incinerator with the waste stream. These tests are aimed at comparing this method with the direct ash sampling method and should provide a general assessment of microbial survivability. However, the pipe method cannot determine destruction efficiency because it cannot measure the actual number of spores surviving in flue gases and the ash. 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 pipe. Testing procedures used here follow an EPA draft method entitled "Microbial Survivability Test for Medical Waste Incinerator Ash." (See Appendix K.4). The following sections detail both spiking procedures (emissions/ash and pipe) as well as the 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 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 to 2 x 10^{12} spores are charged into the incinerator per sample run (the quantity of the bag is recorded). The total charge is separated into four bag. 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 0,1,2,3, hours from the start of testing.



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 (Lenoir Memorial Hospital MWI)

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 (see Appendix K.3). 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 filtered, cultured, and colonies are 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. 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 hydrogen peroxide/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 hydrogen peroxide/alcohol. After completing this procedure, all components are sealed with Parafilm® to prevent contamination. Additional sample containers, recovery items, and analytical equipment is sterilized by autoclaving or another equivalent method. Some of the items which will need to be sterilized are wash bottles, two liter glass

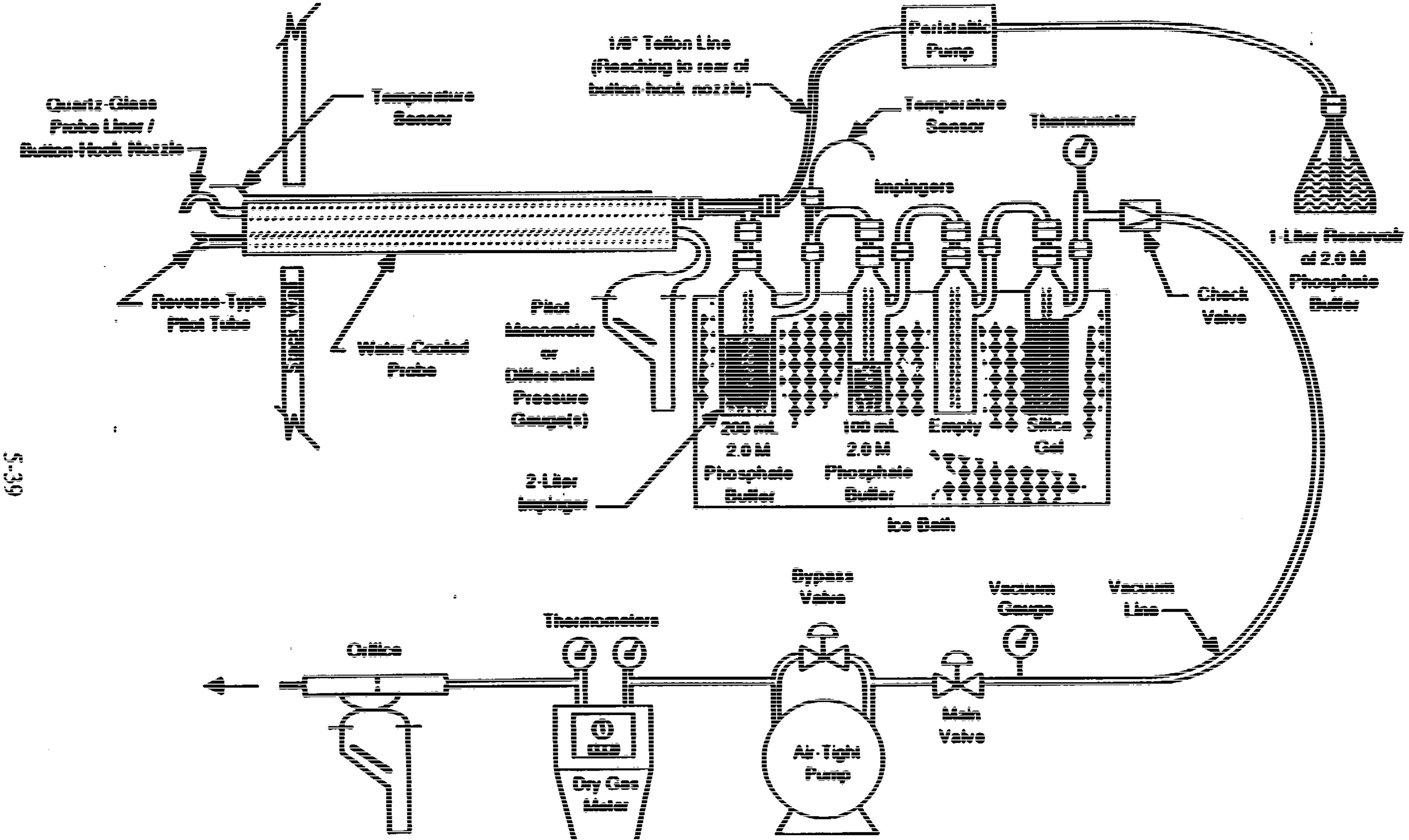


Figure 5-10. Sampling Train for Determination of Indicator Spore Emissions

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 leak check on the impinger train is completed at approximately 15 inches 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 (ΔP, gas meter readings, stack temperature, meter temperatures, meter ΔH, meter vacuum, first impinger temperature, and silica gel impinger temperature) will be periodically monitored, adjusted, and recorded throughout the test run.

Two different trains will be used. When the first traverse is completed, the second traverse will immediately start 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 leak checks are completed at a vacuum equal to or greater than the maximum vacuum reached during the sampling run. Acceptable post-test leak check criterion is the same as was previously mentioned for the pre-test leak checks.

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. (However, a glass nozzle will break when scraped against the port nipple so the presence of port scrapings, etc., are highly unlikely.) The probe is disconnected from

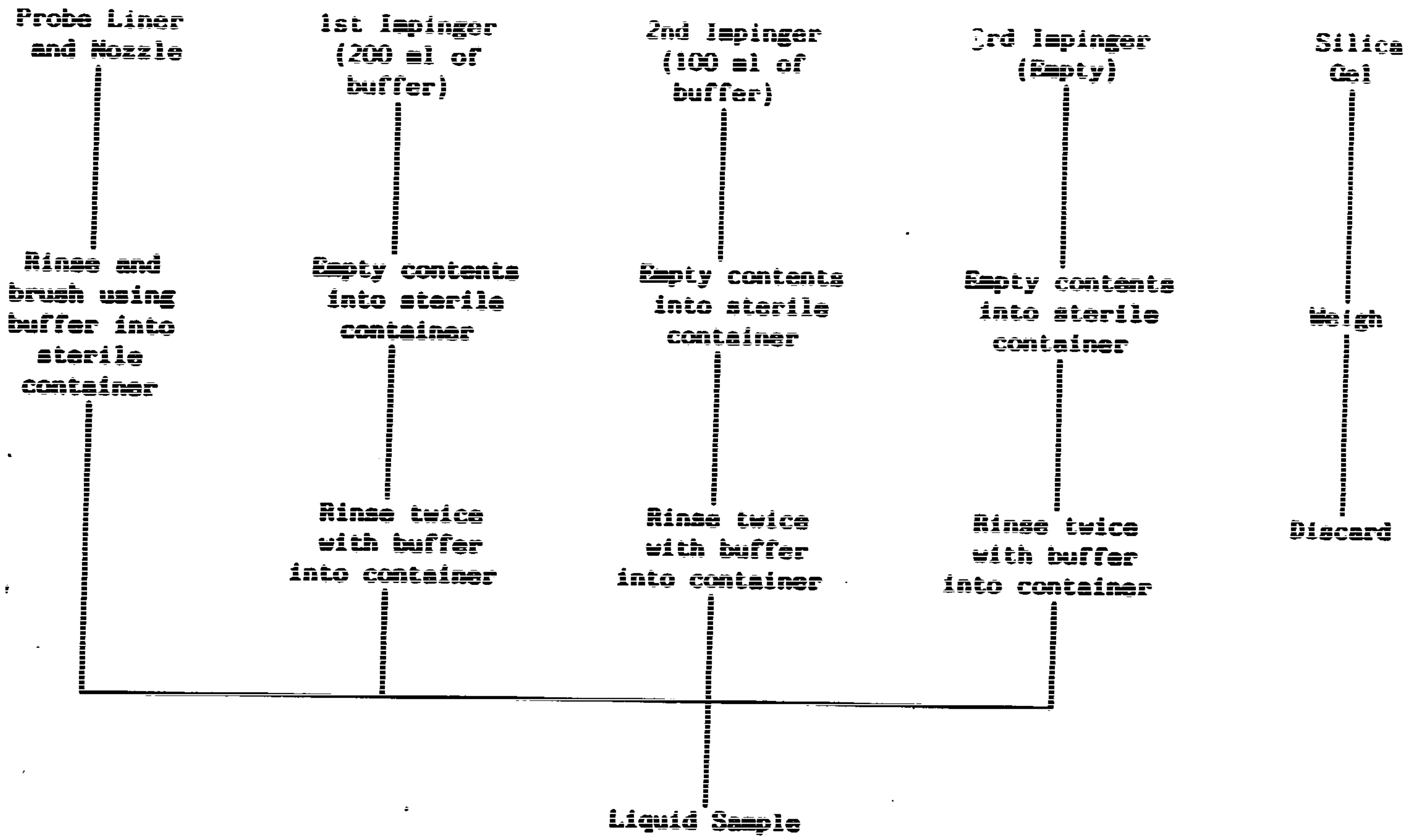


Figure 5-11. Sample Recovery Scheme for Microbial Viability Testing

the impinger train and 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, for shipment to the laboratory.

5.3.3 Direct Ash Sampling for Indicator Spores

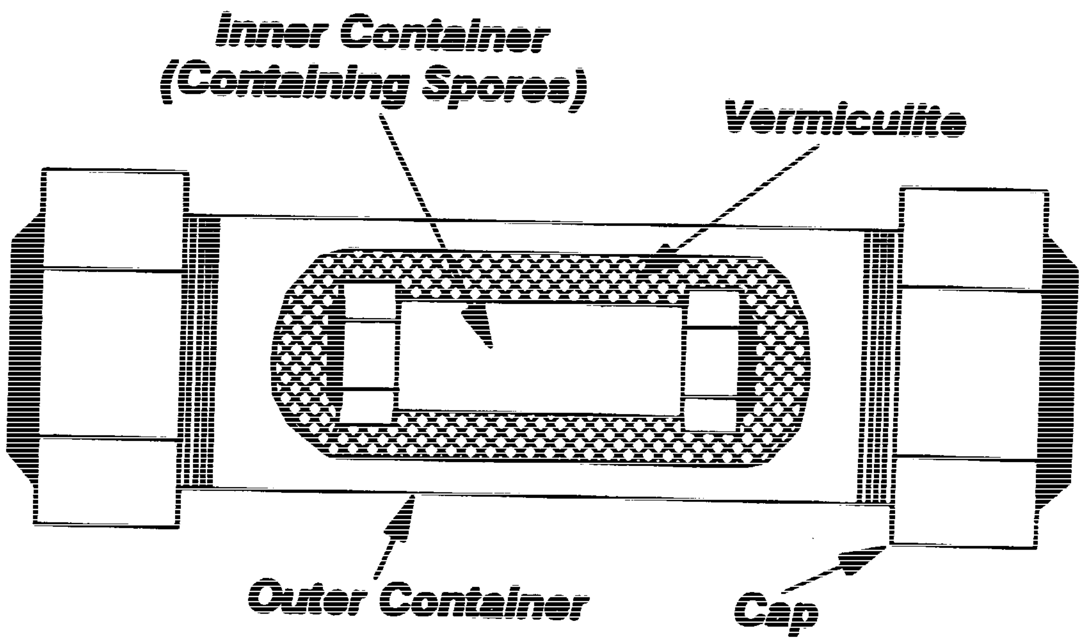
Direct ash sampling provides an indication of the ability of the indicator organism to survive the incinerator process under various conditions. An outline of the proposed ash sampling protocol can be found in Appendix K. Ash samples are recovered from the ash when it has cooled sufficiently. Ash samples are taken using a sampling thief. During each sampling run, three samples are taken. Two are transported to the laboratory for culture and identification and the third sample is used to determine the pH of the material.

5.3.3.1 Equipment. Ash samples are taken using a precleaned sample thief 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 B. stearothermophilus contained in insulated pipes. Upon recovery, the samples are cultured according to the Draft Method found in Appendix K.4 of the test plan. Colonies of B. stearothermophilus are enumerated and gram stained to ensure correct cellular morphology.

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 10^5 spores is prepared and placed in a small glass vial. The contents of one vial was emptied into a



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

Figure 5-12. Ash Quality Pipe Assemblies sterilized pipe to constitute a single pipe sample. Each pipe sample uses the contents of 1 spore vial.

After the vial contents were placed in a short piece (2-4 inch) of 3/8 stainless steel tubing, both ends were capped with Swagelock™ caps. This "inner container" is then placed in an "outer container" which is a 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 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 10^5) inside the inner container and then sealing with 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 spiking procedure varied according to the loading procedure. The Lenoir Memorial Hospital MWI is 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 each morning. The ash cleanout door is opened at about 7:00 a.m., and the ignition chamber allowed to cool until about 7:30 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. Ash samples are also taken during this time as discussed in Section 5.3. 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 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 5-13a and 5-13b. 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 a sterile incubation tube. The inside of the sample containers are rinsed with sterile phosphate buffer solution into the incubation tube. Any glassware used for this transfer procedure is rinsed with sterile deionized water into the 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 5-13c. 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 5-13a. 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, filtered and placed onto agar plates as discussed in the following sections.

5.3.5.3 Colonial Enumeration and Identification Procedure. Trypticase soy agar is used for culturing B. stearothermophilus. 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

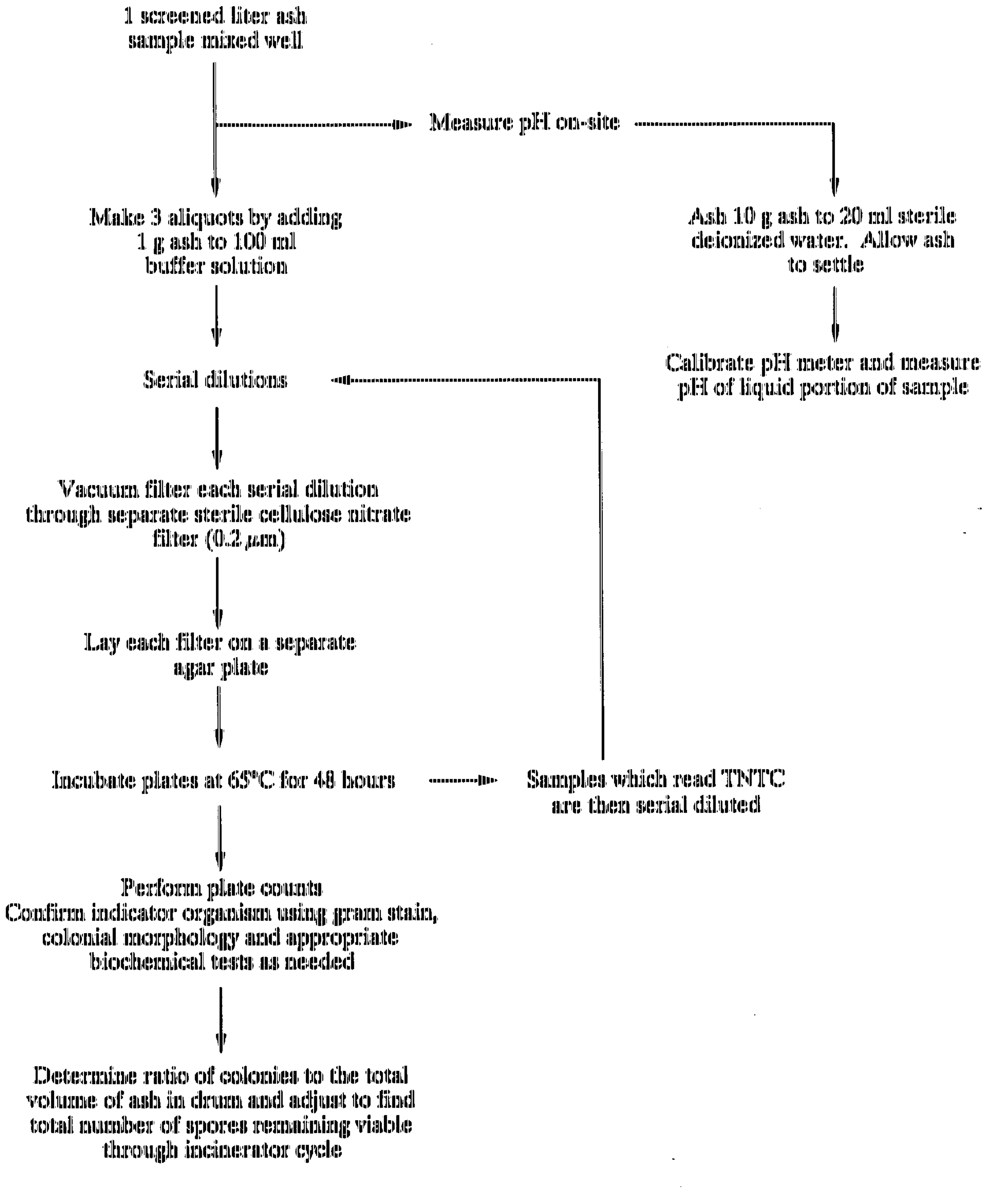


Figure 5-13a. Sample and Analysis Scheme for Microbial Testing of Ash Samples

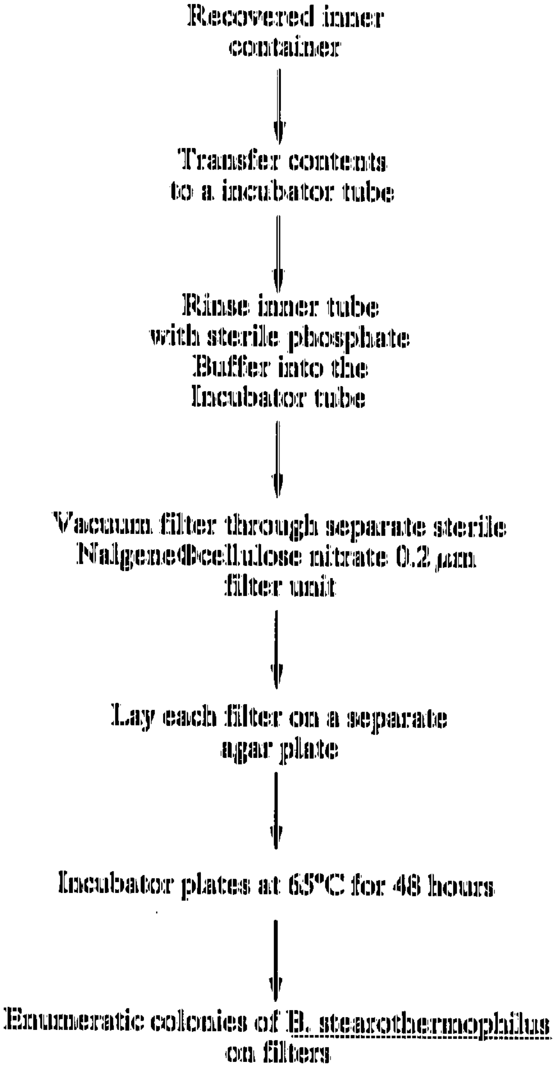


Figure 5-13b. Analysis Scheme for Pipe Sample Microbial Viability Tests

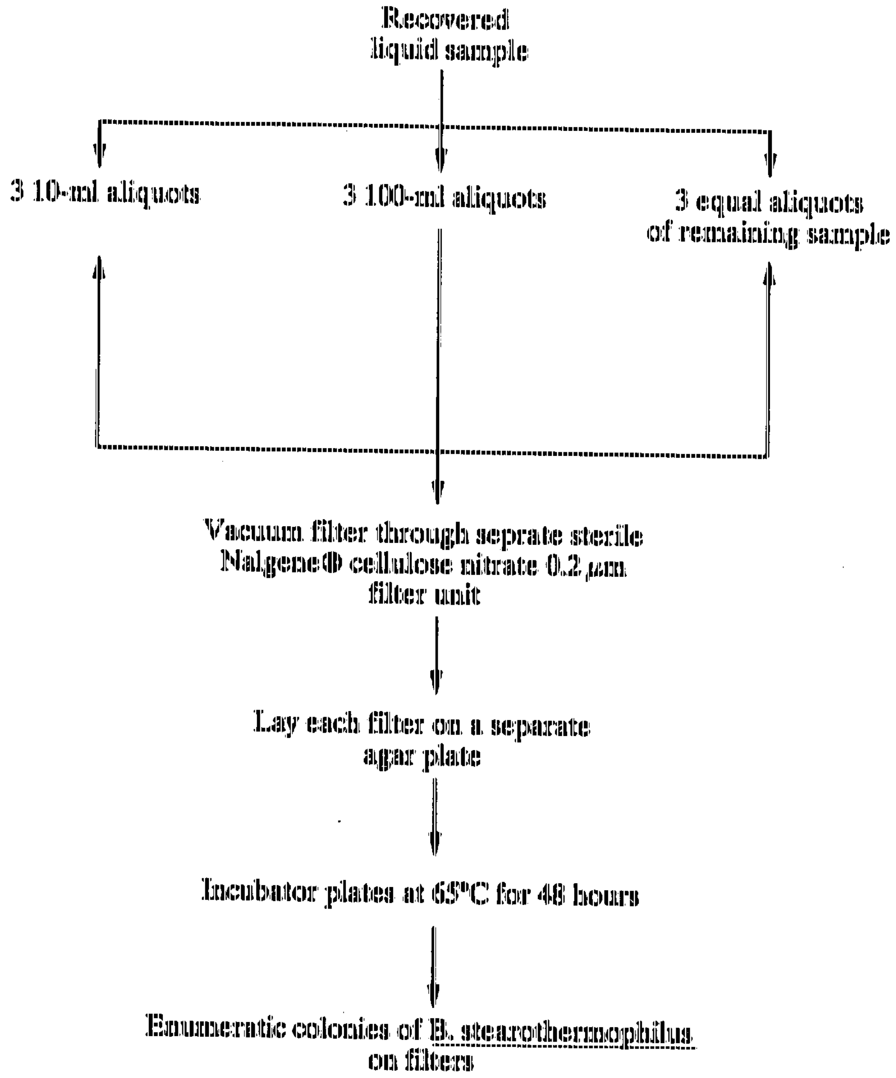


Figure 5-13c. Sample Preparation and Analysis Scheme for Microbial Testing

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 plastic bags at 65°C for 48 hours prior to final colonial enumeration. 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. Quality Assurance/Quality Control (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 Research Triangle Institute (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 will be 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 (HCl), Hydrogen Bromide (HBr), and Hyrdogen Fluoride (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 Chloride (Cl^-) ions. Ion chromatography (IC) is used to detect the Cl^- ions present in the sample. For this test program, the presence of Bromide (Br^-) and Fluoride (F^-) ions will 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 5-14. The sampling train consists of a quartz probe with a pallflex Teflon/glass filter to remove particulate matter, and a series of chilled midget impingers and a DGM system. 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 will not be heated. The train

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

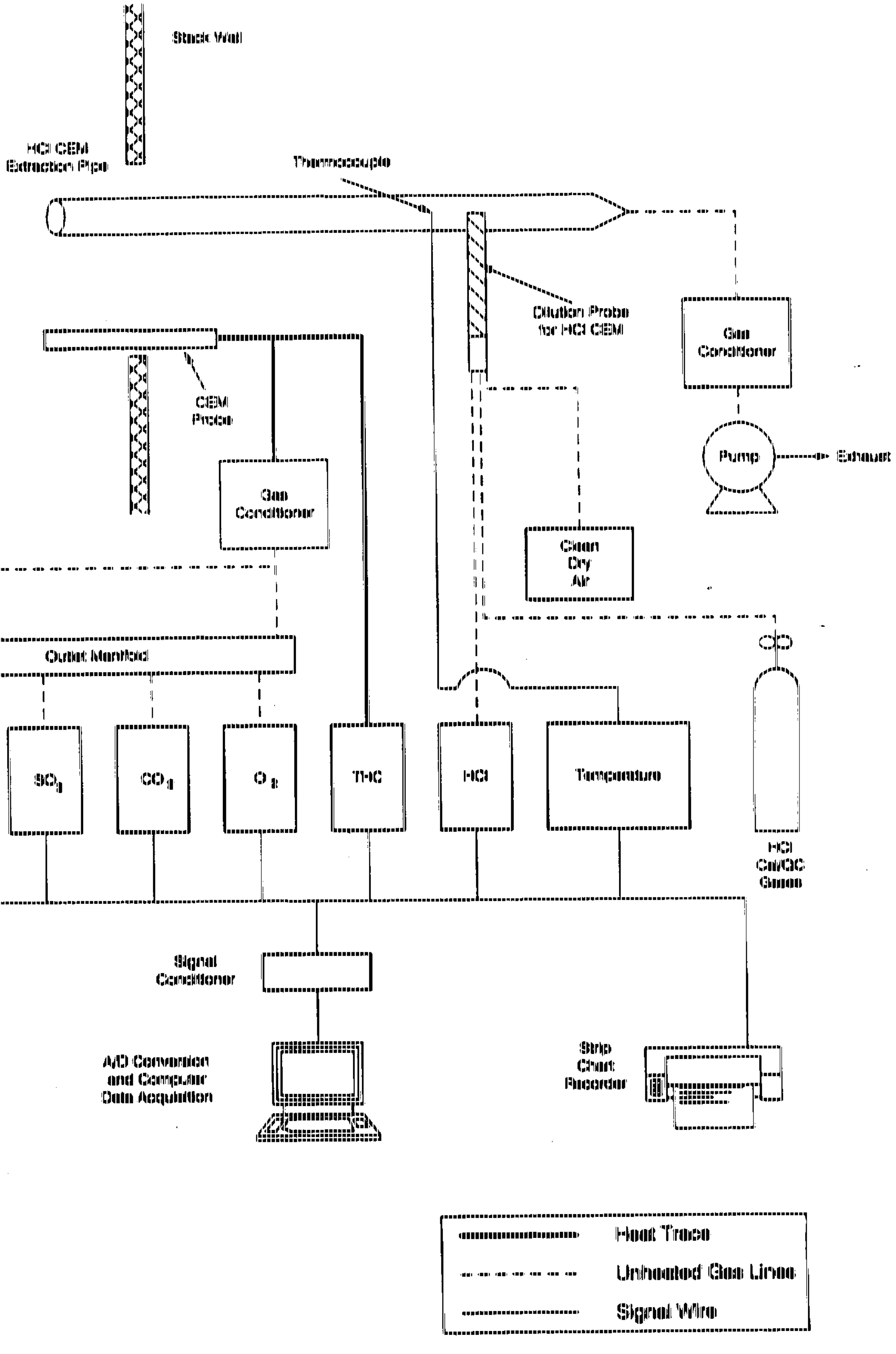


FIGURE 5-14. HCl SAMPLE TRAIN CONFIGURATION
LENOIR MEMORIAL HOSPITAL (1990)

consists of an optional knockout impinger followed by two impingers containing 0.1 N H_2SO_4 to collect HCl, HBr and HF, two impingers containing 0.1 N NaOH to capture any pollutants present in the flue gas that might cause DGM damage, and finally one silica gel impinger.

5.4.2 HCl/HBr/HF Sampling Preparation

5.4.2.1 Equipment Preparation. Sampling preparation 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 is not being used for testing at this facility. The first two impingers contain 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 thesame 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 leak checked 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 leak check 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, 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 5-15.

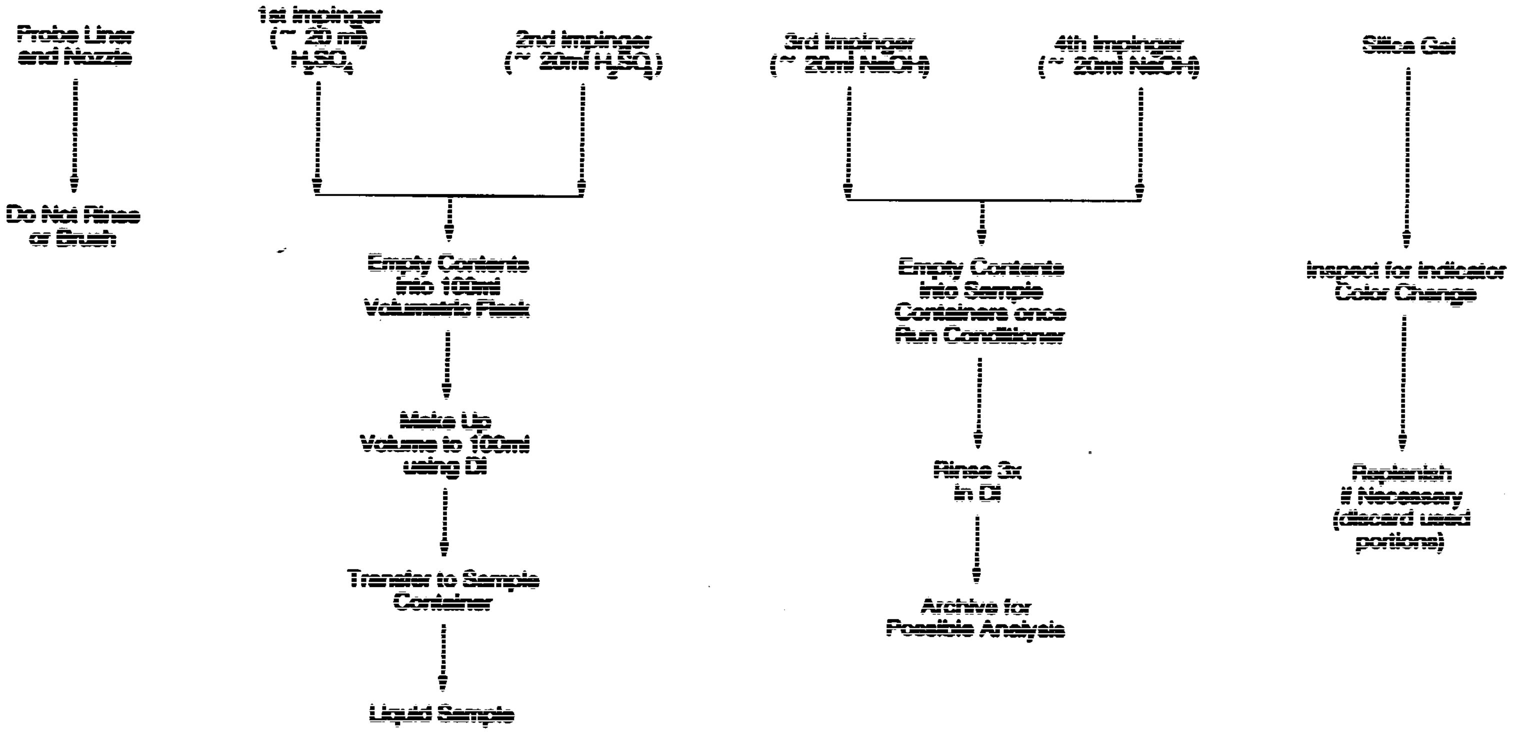
5.4.5 HCl/HBr/HF Analytical Procedures

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 Ion Chromatographic (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.



Figrue 5-15. 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, 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 5-16.

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.

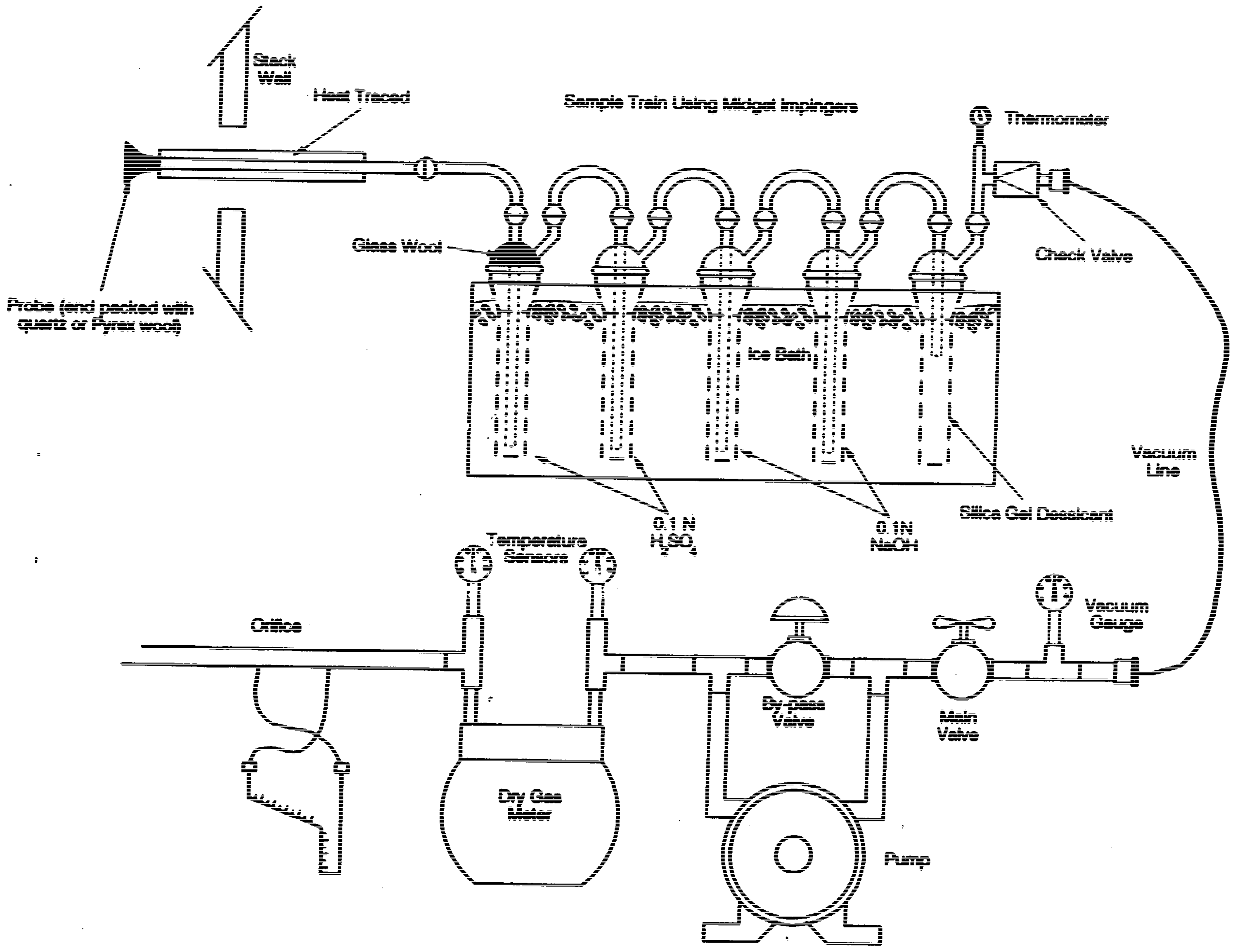


FIGURE 5-16. SCHEMATIC OF CEM SYSTEM
LENOIR MEMORIAL HOSPITAL (1990)

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. 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 range. SO_2 selectively absorbs ultraviolet (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). 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. NO_x measurements are performed using EPA Method 7E.

5.6.2.3 $\underline{O_2}$ Analysis. Oxygen analysis is completed using one of the instruments discussed below.

The Thermox WDG III measures oxygen 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 oxygen 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 $\underline{CO_2}$ Analysis. Non-dispersive infrared (NDIR) CO_2 analyzers emit a specific wavelength of infrared 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 calibrations 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 the Lenoir Memorial 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
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%
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
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
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%
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
$\underline{NO_x}$	
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 CEM system:

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 leak check 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.

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 Lenoir 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 and CDD/CDF test runs. Isokinetics criteria was also met for 19 out of 20 microbial emission test runs. Metals analytical QA results revealed good spike recovery data. Dioxins analytical procedures 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. CEM quality assurance is presented in Section 6.5. Microbial indicator spore analyses were completed using up to nine aliquots/sample and two enumeration per aliquot. Microbial Survivability in emissions quality assurance is further discussed in Section 6.4.4.

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 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:

- <u>Quality Control</u>: The overall system of activities whose purpose is to provide a quality product or service. QC procedures are routinely followed to ensure high data quality.

- Quality Assurance: A system of activities whose purpose is to provide assurance that the overall quality control is being done effectively. Assessments can be made from QA parameters on what degree of data quality was achieved.

- Data Quality: The characteristics of a product (measurement data) that bear on its ability to satisfy a given purpose. These characteristics are defined as follows:

  - Precision - A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is best expressed in terms of the standard deviation and in this report will be expressed as the relative standard deviation or coefficient of variation.

  - Accuracy - The degree of agreement of a measurement (or an average of measurements of the same thing), X, with an accepted reference or true value, T, can be expressed as the difference between two values, X-T, the ratio X/T, or the difference as a percentage of the reference or true value, 100 (X-T)/T.

  - Completeness - A measure of the amount of valid data obtained from a measurement system compared with the amount that was expected to be obtained under prescribed test conditions.

  - Comparability - A measure of the confidence with which one data set can be compared with another.

  - Representativeness - The degree to which data accurately and precisely represent a characteristic of a population, variations of a parameter at a sampling point, or an environmental condition.

A summary of the estimated precision, accuracy, and completeness objectives is presented in Table 6-1.

6.2 MANUAL FLUE GAS SAMPLING AND RECOVERY PARAMETERS

The following section will report method-specific sampling QA parameters so that insight can be gained at the quality of emissions test data produced from manual tests during the test program.

6.2.1 CDD/CDF Sampling Quality Assurance

Table 6-2 lists both the pre-test and post-test leak checks completed on the CDD/CDF sampling trains. The acceptance criterion is that all post-test leak checks

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.

TABLE 6-2. LEAK CHECK RESULTS FOR CDD/CDF EMISSIONS TESTS
LENOIR MEMORIAL HOSPITAL (1990)

DATE	RUN NUMBER	PRE-TEST LEAK RATE (acfm)	INCHES FOR PRE-TEST CHECK	AVG. SAMPLE RATE (dscfm)	4% SAMPLE RATE (dscfm) a	ACCEPTABLE LEAK LEVEL (acfm)	MEASUREMENTS POST-TEST LEAK RATE	INCHES FOR SECOND CHECK
05/30/90	1	0.015	15	0.54	0.022	0.020	0.003	8
05/31/90	2	0.010	10	0.58	0.023	0.020	0.008	15
06/01/90	3	0.003	15	0.57	0.023	0.020	0.016	12
06/02/90	4	0.010	15	0.39	0.016	0.016	0.008	6
06/05/90	5R	b	b	0.39	0.016	0.016	0.016	5
06/05/90	6	0.010	15	0.38	0.015	0.015	0.012	8
06/06/90	7	0.120		0.34	0.014	0.014	0.010	10
06/07/90	8	b	b	0.48	0.019	0.019	0.014	15
06/08/90	9	0.010	20	0.49	0.020	0.020	0.018	15

NOTE:

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

b No Data Recorded

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 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 5 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 meter box used for CDD/CDF was well within the 5 percent criterion.

Field blanks are collected to verify the absence of any sample contamination. The CDD/CDF sampling train was fully prepared, leak checked, and then recovered. Table 6-5 presents the CDD/CDF analytical results for the MM5 field blank (toluene field blank results are presented in the following section). All 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 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 all sample train glassware. Following the test, the nozzle/probe, filter housing, and condenser coil were recovered using methylene chloride. This sample fraction is 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.

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

DATE	RUN NUMBER	CDD/CDF ISOKINETIC SAMPLE RATE, %	TOXIC METALS ISOKINETIC SAMPLE RATE, %	MICROORGANISMS ISOKINETIC SAMPLE RATE, %
05/30/90	1A	99.6	99.3	97.1
	1B			95.5
	1C			90.9
05/31/90	2A	99.4	103.0	94.8
	2B			92.2
	2C			92.9
06/01/90	3A	101.0	99.9	99.6
	3B			102.0
06/02/90	4A	101.0	98.0	97.9
	4B		(4R)	89.2
06/06/90	5A	104.0	98.9	98.6
	5B			98.9
06/05/90	6A	103.0	100.0	98.9
	6B			99.1
06/06/90	7A	105.0	101.0	99.9
	7B			96.0
06/07/90	8A	101.0	98.2	101.0
	8B			101.0
06/08/90	9A	101.0	99.8	101.0
	9B			101.0

TABLE 6-4. DRY GAS METER POST-TEST CALIBRATION RESULTS LENOIR MEMORIAL HOSPITAL (1990)

SAMPLING TRAIN	METER BOX NUMBER	FULL CALIBRATION FACTOR	POST-TEST CALIBRATION FACTOR	POST-TEST DEVIATION (%) [a]
CDD/CDF	N-30	1.0066	0.9955	-1.1
PM/METAL	N-31	1.0070	0.9916	-1.53
MICROORGANISMS	N-32	0.9973	0.9959	-0.14
-------	7	0.9929	0.9848	-0.82
HALOGENS	V5	1.0153	1.0028	-1.23

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

TABLE 6-5. CDD/CDF FIELD BLANK RESULTS.
LENOIR MEMORIAL HOSPITAL (1990)

FULL SCREEN ANALYSES	MM5 FIELD BLANK	MM5 COND 1 AVG	MM5 COND 2 AVG	MM5 COND 3 AVG
	(TOTAL ng)			
2378 TCDD	0.13	9.3	2.0	49.3
TOTAL TCDD	1.50	111.2	35.5	658.0
12378 PCDD	0.68	59.3	22.6	265.3
TOTAL PCDD	3.80	308.0	147.3	1350.0
123478 HxCDD	0.82	82.2	50.7	252.3
123678 HxCDD	1.00	80.8	47.7	246.7
123789 HxCDD	2.20	179.9	89.2	580.7
TOTAL HxCDD	8.80	838.3	487.7	2653.3
1234678-HpCDD	5.70	620.3	592.0	1246.7
TOTAL Hepta-CDD	10.00	1182.3	1129.7	2350.0
Octa-CDD	5.40	1078.3	1591.0	1025.0
FURANS				
2378 TCDF	2.20	232.7	122.3	807.0
TOTAL TCDF	15.40	1470.0	687.3	6010.0
12378 PCDF	1.50	160.5	65.3	633.7
23478 PCDF	2.50	253.7	138.7	890.0
TOTAL PCDF	28.20	2910.0	1573.3	10576.7
123478 HxCDF	5.40	887.0	502.7	2546.7
123678 HxCDF	3.20	498.3	231.0	1600.0
234678 HxCDF	3.20	591.0	492.7	1446.7
123789 HxCDF	0.47	36.1	15.9	0.0
TOTAL HxCDF	29.30	4663.3	2716.7	13606.7
1234678-HpCDF	7.70	1870.7	1365.3	8176.7
1234789-HpCDF	0.89	293.7	237.0	1218.7
TOTAL Hepta-CDF	1.40	3510.0	2780.0	14833.3
Octa-CDF	2.90	1256.7	2426.7	1205.3

[illegible]	MM5 FIELD BLANK	MM5 COND 1 AVG	MM5 COND 2 AVG	MM5 COND 3 AVG
	(TOTAL ng)			
2378-TCDD	0.22	8.7	6.8	62.3
2378-TCDF	0.42	47.1	15.6	239.3
TOTAL TCDD	1.60	173.9	65.6	803.7
TOTAL TCDF	8.90	1713.7	575.7	5820.0

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 through 3), T/M ratios range from 0 to 0.59 percent. Condition 2 values range from 0 to 0.75 percent (Run 8, octa-CDF). T/M ratios for 2378 TCDD for all conditions range from 0 to 0.39 percent.

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 2.21 percent (Run 1).

The toluene field blank analytical results are compared to the toluene test run analytical results in Table 6-10. The field blank values for most congeners are relatively high compared to the average run values. The 2378 field blank result is 74.2 pg compared to 18.0, 8.2, and 66.0 average pg collected for Conditions 1, 2, and 3, respectively. Additional insight into these results can be gained by reviewing method blank results shown in Section 6.4.1 (Table 6-15).

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 3 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 -1.53 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. Antimony, barium, chromium, and lead were detected at relatively low levels compared to the total amounts collected during the tests. No blank corrections were made.

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

	RUN 1			RUN 2			RUN 3			AVERAGE		
CONGENER	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	[20.90]	0.00	14,800	(17.80)	0.12	10,200	36	0.36	9,300	27.1	0.29
Other TCDD	35,700	[20.90]	0.00	167,200	37	0.02	102,800	374	0.36	101,900	205.5	0.20
12378 PCDD	22,300	(22.70)	0.10	110,000	58	0.05	45,700	218	0.48	59,333	99.4	0.17
Other PCDD	113,700	(22.70)	0.02	418,000	97	0.02	214,300	922	0.43	248,667	347.4	0.14
123478 HxCDD	49,300	45	0.09	135,000	93	0.07	62,200	342	0.55	82,167	159.9	0.19
123678 HxCDD	35,600	44	0.12	132,000	95	0.07	74,900	382	0.51	80,833	173.4	0.21
123789 HxCDD	68,700	(74.90)	0.11	307,000	235	0.08	164,000	775	0.47	179,900	361.6	0.20
Other HxCDD	207,400	0	0.00	806,000	511	0.06	472,900	2361	0.50	495,433	943.5	0.19
1234678-HpCDD	314,000	582	0.19	897,000	941	0.10	650,000	3270	0.50	620,333	1597.7	0.26
Other Hp-CDD	273,000	0	0.00	833,000	839	0.10	580,000	3000	0.52	562,000	1919.5	0.34
Octa-CDD	785,000	1560	0.20	1,360,000	1660	0.12	1,090,000	6720	0.62	1,078,333	3313.3	0.31
TOTAL CDD	1,907,600	2350	0.12	5,180,000	4584	0.09	3,467,000	18400	0.53	3,518,200	8430.9	0.24
FURANS												
2378 TCDF	116,000	57	0.05	344,000	141	0.04	238,000	1400	0.59	232,667	532.7	0.23
Other TCDF	564,000	101	0.02	2,016,000	616	0.03	1,132,000	5390	0.48	1,237,333	2035.6	0.16
12378 PCDF	66,600	57	0.08	263,000	163	0.06	152,000	787	0.52	160,533	335.5	0.21
23478 PCDF	115,000	121	0.11	411,000	205	0.05	235,000	1460	0.62	253,667	595.3	0.23
Other PCDF	1,168,400	787	0.07	4,246,000	1582	0.04	2,073,000	15653	0.76	2,495,800	6007.2	0.24
123478 HxCDF	430,000	373	0.09	1,350,000	943	0.07	881,000	4070	0.46	887,000	1795.3	0.20
123678 HxCDF	214,000	218	0.10	809,000	527	0.07	472,000	2240	0.47	498,333	995.0	0.20
234678 HxCDF	266,000	295	0.11	808,000	489	0.06	699,000	3570	0.51	591,000	1451.3	0.25
123789 HxCDF	12,300	[22.00]	0.00	56,600	32	0.06	39,300	136	0.35	36,067	83.8	0.23
Other HxCDF	1,247,700	814	0.07	4,036,400	1819	0.05	2,668,700	12674	0.47	2,650,933	5102.5	0.19
1234678-HpCDF	982,000	1310	0.13	2,570,000	2850	0.11	2,060,000	10180	0.49	1,870,667	4780.0	0.26
1234789-HpCDF	141,000	(227.0)	0.16	346,000	332	0.10	394,000	1720	0.44	293,667	759.7	0.26
Other Hp-CDF	677,000	670	0.10	1,614,000	1508	0.09	1,746,000	8130	0.47	1,345,667	3436.0	0.26
Octa-CDF	744,000	1380	0.19	996,000	1220	0.12	2,030,000	9160	0.45	1,256,667	3920.0	0.31
TOTAL CDF	6,744,000	6409	0.10	19,866,000	12427	0.06	14,820,000	76570	0.52	13,810,000	31802.0	0.23
CDD+CDF	8,651,600	8759	0.10	25,046,000	17011	0.07	18,287,000	94970	0.52	17,328,200	40232.9	0.23

a [] = 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) - LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	RUN 4			RUN 5R			RUN 6			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	(3500.)	14	0.39	2,200	[13.00]	0.00	3,700	11	0.29	3,133	12	0.39
Other TCDD	33,300	78	0.23	20,900	[13.00]	0.00	46,300	57	0.12	33,500	68	0.20
12378 PCDD	20,600	(80.10)	0.39	19,400	(25.90)	0.13	27,800	63	0.23	22,600	56	0.25
Other PCDD	118,400	283	0.24	110,600	56	0.05	145,200	102	0.07	124,733	147	0.12
123478 HxCDD	33,600	143	0.43	61,500	59	0.10	57,100	96	0.17	50,733	100	0.20
123678 HxCDD	40,000	216	0.54	55,700	99	0.18	47,500	127	0.27	47,733	147	0.31
123789 HxCDD	68,600	336	0.49	97,100	191	0.20	102,000	263	0.26	89,233	263	0.30
Other HxCDD	250,800	725	0.29	347,700	423	0.12	301,400	423	0.14	299,967	524	0.17
1234678-HpCDD	440,000	3,130	0.71	904,000	2,390	0.26	432,000	1,420	0.33	592,000	2,313	0.39
Other Hp-CDD	395,000	2,420	0.61	926,000	2,050	0.22	292,000	940	0.32	537,667	1,803	0.34
Octa-CDD	935,000	9,840	1.05	3,040,000	13,690	0.45	798,000	3,620	0.45	1,591,000	9,050	0.57
TOTAL CDD	2,338,800	17,265	0.74	5,585,100	18,984	0.34	2,253,000	7,122	0.32	3,392,300	14,457	0.43
FURANS												
2378 TCDF	87,800	410	0.47	132,000	184	0.14	147,000	278	0.19	122,267	291	0.24
Other TCDF	406,200	1,180	0.29	539,000	436	0.08	750,000	962	0.13	565,067	859	0.15
12378 PCDF	53,000	333	0.63	55,000	100	0.18	87,900	243	0.28	65,300	225	0.34
23478 PCDF	105,000	651	0.62	145,000	251	0.17	166,000	466	0.28	138,667	456	0.33
Other PCDF	902,000	4,386	0.49	1,690,000	2,099	0.12	1,516,100	3,191	0.21	1,369,367	3,225	0.24
123478 HxCDF	322,000	1,830	0.57	758,000	1,270	0.17	428,000	1,240	0.29	502,667	1,447	0.29
123678 HxCDF	175,000	1,010	0.58	294,000	565	0.19	224,000	704	0.31	231,000	760	0.33
234678 HxCDF	340,000	3,450	1.01	785,000	1,790	0.23	353,000	1,480	0.42	492,667	2,240	0.45
123789 HxCDF	14,500	137	0.94	15,100	40	0.26	18,200	112	0.62	15,933	96	0.60
Other HxCDF	1,038,500	5,503	0.53	1,947,900	3,405	0.17	1,436,800	3,174	0.22	1,474,400	4,027	0.27
1234678-HpCDF	906,000	4,760	0.53	2,110,000	5,180	0.25	1,080,000	3,140	0.29	1,365,333	4,360	0.32
1234789-HpCDF	194,000	1,450	0.75	299,000	941	0.31	218,000	851	0.39	237,000	1,081	0.46
Other Hp-CDF	810,000	4,880	0.60	1,721,000	4,899	0.28	1,002,000	2,769	0.28	1,177,667	4,183	0.36
Octa-CDF	1,000,000	14,170	1.42	5,130,000	18,890	0.37	1,150,000	5,810	0.51	2,426,667	12,957	0.53
TOTAL CDF	6,354,000	44,150	0.69	15,621,000	40,050	0.26	8,577,000	24,420	0.28	10,184,000	36,207	0.36
CDD+CDF	8,692,800	61,415	0.71	21,206,100	59,034	0.28	10,830,000	31,542	0.29	13,576,300	50,664	0.37

a [] = 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) - LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	RUN 7			RUN 8			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	32,500	38	0.12	51,400	83	0.16	63,900	77	0.12	49,267	66	0.13
Other TCDD	387,500	203	0.05	588,600	659	0.11	850,100	397	0.05	608,733	420	0.07
12378 PCDD	206,000	223	0.11	266,000	472	0.18	324,000	332	0.10	265,333	342	0.13
Other PCDD	1,034,000	463	0.04	1,024,000	1,378	0.13	1,196,000	676	0.06	1,084,667	839	0.08
123478 HxCDD	233,000	380	0.16	269,000	661	0.25	255,000	297	0.12	252,333	446	0.18
123678 HxCDD	256,000	467	0.18	233,000	683	0.29	251,000	395	0.16	246,667	515	0.21
123789 HxCDD	539,000	946	0.18	543,000	1,540	0.28	660,000	789	0.12	580,667	1,092	0.19
Other HxCDD	1,692,000	1,777	0.11	1,375,000	3,696	0.27	1,654,000	0	-0.01	1,573,667	1,794	0.11
1234678-HpCDD	1,510,000	3,700	0.25	1,110,000	4,480	0.40	1,120,000	2,030	0.18	1,246,667	3,403	0.27
Other Hp-CDD	1,450,000	2,960	0.20	920,000	3,860	0.42	940,000	0	-0.07	1,103,333	2,067	0.19
Octa-CDD	1,470,000	7,220	0.49	876,000	6,060	0.69	729,000	1,900	0.26	1,025,000	5,060	0.49
TOTAL CDD	8,810,000	18,377	0.21	7,256,000	23,572	0.32	8,043,000	6,181	0.08	8,036,333	16,043	0.20
FURANS												
2378 TCDF	667,000	745	0.11	754,000	1,660	0.22	1,000,000	876	0.09	807,000	1,094	0.14
Other TCDF	4,193,000	3,305	0.08	4,816,000	8,200	0.17	6,600,000	2,898	0.04	5,203,000	4,801	0.09
12378 PCDF	537,000	762	0.14	570,000	1,840	0.32	794,000	1,200	0.15	633,667	1,267	0.20
23478 PCDF	842,000	1,620	0.19	748,000	2,280	0.30	1,080,000	1,200	0.11	890,000	1,700	0.19
Other PCDF	8,741,000	11,578	0.13	7,042,000	17,380	0.25	11,376,000	8,020	0.07	9,053,000	12,326	0.14
123478 HxCDF	3,020,000	4,220	0.14	1,930,000	5,090	0.26	2,690,000	2,640	0.10	2,546,667	3,983	0.16
123678 HxCDF	1,840,000	2,290	0.12	1,250,000	2,790	0.22	1,710,000	1,580	0.09	1,600,000	2,220	0.14
234678 HxCDF	1,680,000	(3210.)	0.19	1,140,000	3,320	0.29	1,520,000	1,940	0.13	1,446,667	2,823	0.20
123789 HxCDF	(163000.0)	206	0.13	(140000.0)	179	0.13	(190000.0)	141	0.07	164333.3	175.3	0.11
Other HxCDF	9,430,000	13,124	0.14	6,200,000	14,711	0.24	8,410,000	1,498	0.02	8,013,333	9,778	0.12
1234678-HpCDF	12,140,000	8,660	0.07	5,010,000	7,410	0.15	7,380,000	3,670	0.05	8,176,667	6,580	0.08
1234789-HpCDF	1,900,000	1,340	0.07	726,000	865	0.12	1,030,000	571	0.06	1,218,667	925	0.08
Other Hp-CDF	8,650,000	6,130	0.07	3,184,000	4,975	0.16	4,480,000	0	-0.04	5,438,000	3,101	0.06
Octa-CDF	2,300,000	7,370	0.32	519,000	3,910	0.75	797,000	1,770	0.22	1,205,333	4,350	0.36
TOTAL CDF	56,103,000	64,560	0.12	34,029,000	74,610	0.22	49,057,000	26,202	0.05	46,396,333	55,124	0.12
CDD+CDF	64,913,000	82,937	0.13	41,285,000	98,182	0.24	57,100,000	32,383	0.06	54,432,667	71,167	0.13

a [] = 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 (Total pg entrained) LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	RUN 1			RUN 2			RUN 3			AVERAGE		
	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUEN (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)
DIOXINS												
2378 TCDD	220	[9.300]	0.00	6,500	19.7	0.30	19,600	87.1	0.44	8,773	53.4	0.61
Other TCDD	1,380	[9.300]	0.00	55,300	94.3	0.17	309,400	689.9	0.22	122,027	392.1	0.32
FURANS												
2378 TCDF	420	9.3	2.21	16,200	27.2	0.17	79,000	160.0	0.20	31,873	65.5	0.21
Other TCDF	8,480	169.7	2.00	614,800	659.8	0.11	2,701,000	5570.0	0.21	1,108,093	2133.2	0.19

CONGENER	RUN 4			RUN 5R			RUN 6			AVERAGE		
	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUEN (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)
DIOXINS												
2378 TCDD	6,000	27.5	0.46	6,100	10.3	0.17	8,200	18.0	0.22	6,767	18.6	0.27
Other TCDD	55,100	98.5	0.18	52,200	14.4	0.03	69,200	68.8	0.10	58,833	60.6	0.10
FURANS												
2378 TCDF	14,000	66.5	0.48	10,600	19.9	0.19	22,100	51.8	0.23	15,567	46.1	0.30
Other TCDF	466,000	1403.5	0.30	615,400	519.1	0.08	598,900	811.2	0.14	560,100	911.3	0.16

CONGENER	RUN 7			RUN 8			RUN 9			AVERAGE		
	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUEN (pg)	TOL/MM5 (%)	MM5 (pg)	TOLUENE (pg)	TOL/MM5 (%)
DIOXINS												
2378 TCDD	45,300	65	0.14	66,500	162	0.24	75,200	128	0.17	62,333	118	0.19
Other TCDD	504,700	364	0.07	835,500	1108	0.13	883,800	711	0.08	741,333	728	0.10
FURANS												
2378 TCDF	175,000	127	0.07	258,000	317	0.12	285,000	211	0.07	239,333	218	0.09
Other TCDF	4,805,000	2563	0.05	5,162,000	6303	0.12	6,775,000	3069	0.05	5,580,667	3978	0.07

a [] = minimum detection limit. (not used in the averages or summations)
() = estimated maximum possible concentration (included in mmations)

TABLE 6-10. CDD/CDF TOLUENE FIELD BLANK RESULTS. LENOIR MEMORIAL HOSPITAL (1990)

FULL SCREEN ANALYSES	TOL FIELD BLANK	TOL COND 1 AVG	TOL COND 2 AVG	TOL COND 3 AVG
	(TOTAL PG)			
2378 TCDD	74.2	18.0	8.2	66.0
TOTAL TCDD	94.3	149.1	53.2	511.3
12378 PCDD	81.2	99.4	56.3	342.3
TOTAL PCDD	175.0	439.2	167.8	1292.0
123478 HxCDD	105.0	159.9	99.5	446.0
123678 HxCDD	112.0	173.4	147.5	515.0
123789 HxCDD	284.0	361.6	263.3	1091.7
TOTAL HxCDD	999.0	1613.4	1034.0	4340.0
1234678-HpCDD	767.0	1597.7	2313.3	3403.3
TOTAL Hepta-CDD	1270.0	2877.3	4116.7	6146.7
Octa-CDD	1020.0	3313.3	9050.0	5060.0
FURANS				
2378 TCDF	157.0	532.7	290.7	1093.7
TOTAL TCDF	743.0	2568.3	1150.0	6186.7
12378 PCDF	197.0	335.5	225.2	1267.3
23478 PCDF	224.0	595.3	456.0	1700.0
TOTAL PCDF	1870.0	6938.0	3906.7	16093.3
123478 HxCDF	703.0	1795.3	1446.7	3983.3
123678 HxCDF	384.0	995.0	759.7	2220.0
234678 HxCDF	350.0	1451.3	2240.0	2823.3
123789 HxCDF	[71.20]	55.9	96.3	175.3
TOTAL HxCDF	2950.0	9400.0	8570.0	20010.0
1234678-HpCDF	1120.0	4780.0	4360.0	6580.0
1234789-HpCDF	125.0	759.7	1080.7	925.3
TOTAL Hepta-CDF	1750.0	8900.0	9623.3	12020.0
Octa-CDF	519.0	3920.0	12956.7	4350.0
[illegible]	TOL FIELD BLANK	TOL COND 1 AVG	TOL COND 2 AVG	TOL COND 3 AVG
	(TOTAL PG)			
2378-TCDD	27.3	35.6	21.7	81.5
2378-TCDF	47.8	65.5	44.7	165.3
TOTAL TCDD	168.0	294.7	106.2	595.3
TOTAL TCDF	763.0	2198.7	924.0	3391.0

TABLE 6-11. LEAK CHECK RESULTS FOR TOXIC METALS. LENOIR MEMORIAL HOSPITAL (1990).

DATE	RUN NUMBER	PRELIMINARY LEAK RATE (acfm)	INCHES FOR PRELIM. CHECK	AVG. SAMPLE RATE (dscfm) a	4% SAMPLE RATE (acfm)	ACCEPTABLE LEAK LEVEL (acfm)	MEASUREMENT POST-TEST LEAK RATE	INCHES FOR SEC. CHK.
05/30/90	1	0.012	b	0.53	0.021	0.020	0.008	8
05/31/90	2	0.012	b	0.37	0.015	0.015	0.006	5
06/01/90	3	0.012	b	0.37	0.015	0.015	0.008	5
06/04/90	4	0.010	b	0.51	0.020	0.020	b	b
06/06/90	5	0.012	b	0.53	0.021	0.020	0.012	6
06/05/90	6	0.012	b	0.50	0.020	0.020	0.008	8
06/06/90	7	0.010	b	0.49	0.020	0.020	0.012	18
06/07/90	8	0.012	b	0.50	0.020	0.020	0.016	16
06/08/90	9	0.010	b	0.49	0.020	0.020	0.016	16

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

b No data recorded.

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

METAL	FIELD BLANK			CONDITION 1			CONDITION 2			CONDITION 3		
	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 b	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 b	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 b	FRONT HALF	IMPINGERS 1,2	IMPINGERS 3 & 4 b
Antimony	(20.8)	[7.60]		904.00	283.47		1001.67	87.87		1622.67	1930.00	
Arsenic	[5.00]	[0.47]		15.93	1.65		18.90	0.15		27.30	5.94	
Barium	13	(0.354)		180.00	0.74		274.67	0.64		297.00	8.01	
Beryllium	a [0.50]	[0.024]		0.00	0.00		0.00	0.00		0.00	0.00	
Cadmium	[1.20]	[0.059]		402.00	0.00		578.00	0.21		643.00	0.00	
Chromium	c (3.00)	[1.20]		44.10	0.98		61.77	0.97		106.53	2.12	
Lead	[25.0]	(1.04)		3290.00	0.59		6300.00	0.17		4803.33	0.58	
Mercury	[2.40]	(4.42)	[0.44]	65.47	195.67	4.70	17.18	320.00		1458.00	2125.17	329.33
Nickel	[5.00]	[2.40]		37.00	0.00		31.93	0.79		96.33	0.00	
Silver	[8.20]	[3.90]		0.00	0.00		0.00	28.03		0.00	14.67	
Thallium	[14.0]	[6.40]		0.00	0.00		0.00	0.00		0.00	0.00	

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

b Impingers 3 & 4 only sample fractions analyzed for mercury content.

c Values enclosed in parenthesis represent estimates as they are less than 5 times the detection limit.

6.2.3 Microbial Survivability in Emissions Quality Assurance

The post-test dry gas meter calibration check for the microbial emissions meter is shown in Table 6-4. Post-test calibration factors were within the 5 percent acceptance criterion at -0.14 percent.

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. Nineteen out of the 20 test runs met the isokinetic criterion of ± 10 percent of 100 percent. Run 4B resulted in an isokinetic rate of 89.2 percent. This slightly low value would not be expected to effect the results.

The microbial emissions field blank results showed no positive detection in any of the nine aliquots analyzed. Data from the analysis is shown in Appendix E.3.

6.2.4 Halogen Flue Gas Sampling Quality Assurance

Halogen flue gas concentration tests did 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^-.

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.

The halogen test dry gas meter post-test calibration results are listed in Table 6-4. The post-test calibration factor was within 5 percent criterion of the full calibration factor at -1.23 percent.

Halogen field blank results are shown in Table 6-14. No Cl^-, F^-, or Br^- were detected in the field blank sample.

TABLE 6-13. LEAK CHECK RESULTS FOR MICROBIAL SURVIVABILITY IN EMISSIONS SAMPLING RUNS LENOIR MEMORIAL HOSPITAL (1990)

DATE	RUN NUMBER	PRE-TEST LEAK RATE (acfm)	INCHES FOR PRE-TEST CHECK	AVG. SAMPLE RATE (dscfm)	4% SAMPLE RATE (dscfm) a	ACCEPTABLE LEAK LEVEL (acfm)	MEASUREMENT POST-TEST LEAK RATE	INCHES FOR SECOND CHECK
05/30/90	1A	0.020	10	0.622	0.025	0.020	0.003	3
	1B	0.015	6	0.526	0.021	0.020	b	
	1C	0.007	5	0.373	0.015	0.015	0.008	5
05/31/90	2A	0.006	6	0.505	0.020	0.020	0.004	7
	2B	0.001	5	0.468	0.019	0.019	0.000	5
	2C	0.003	6	0.432	0.017	0.017	0.002	3
06/01/90	3A	0.006	6	0.521	0.021	0.020	0.005	6
	3B	0.008	6	0.550	0.022	0.020	c	5
06/02/90	4A	0.020	3	0.523	0.021	0.020	0.005	5
	4B	0.018	5	0.526	0.021	0.020	0.008	5
06/06/90	5A	0.018	6	0.306	0.012	0.012	0.009	3
	5B	0.008	6	0.299	0.012	0.012	0.008	6
06/05/90	6A	0.002	5	0.336	0.013	0.013	0.060	5
	6B	0.006	6	0.334	0.013	0.013	0.010	5
06/06/90	7A	0.010	6	0.305	0.012	0.012	0.005	6
	7B	0.010	5	0.299	0.012	0.012	0.010	5
06/07/90	8A	0.009	6	0.298	0.012	0.012	0.001	5
	8B	0.005	5	0.295	0.012	0.012	0.003	4
06/08/90	9A	0.018	5	0.295	0.012	0.012	0.015	5
	9B	0.004	6	0.302	0.012	0.012	0.010	5

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

b Sample run was invalidated due to lost sample.

c No Data Recorded

TABLE 6-14. HALOGEN FIELD BLANK RESULTS COMPARED TO RUN RESULTS
LENOIR MEMORIAL HOSPITAL (1990)

ANALYTE	FIELD BLANK (total µg)	CONDITION 1 AVERAGE (total µg)	CONDITION 2 AVERAGE (total µg)	CONDITION 3 AVERAGE (total µg)
HCl	[6.99] [a]	141,451	119,550	160,686
HF	[26.33]	174	662	896
HBr	[8.00]	[10.0]	50	207

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

6.3 QC PROCEDURES FOR ASH AND PIPE SAMPLING

As stated in Section 5.3, the incinerator waste charges were spiked with B. steareothermophilus in both wet and dry forms. Solutions of B. steareothermophilus were spiked into the incinerator to coincide with simultaneous emissions testing and daily ash sampling. Assessments of B. steareothermophilus 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 were placed in sealed pipes (See Figure 5-12) to determine the viability of "thermally shaded" microbial matter. A single sample was placed into the charging bin three times daily.

For both wet and dry spore spiking procedures, only pre-cleaned/disinfected materials were used for handling, application, and transport. The wet spore aliquots were divided and sealed at the manufacturer. This prevented any losses of material during shipment or upon application. (The empty solution container was also placed in the spiked waste charge.) The spiked charge was tied closed and placed in a upright position in the ram feeder. 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 sealed, 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 and placed in 4 - 5 garbage cans. 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.

6.4 ANALYTICAL QUALITY ASSURANCE

The following section reports QA parameters for the CDD/CDF, Metals, Microbial Survivability, and Halogen 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.

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. 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 to the impinger solutions at this stage. Recovery percentage of internal standards are used in quantifying the flue gas or "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.

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 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 Initial Analyses and Data Qualifiers. The MM5 samples from Lenoir Memorial Hospital MWI tests were originally analyzed and high concentrations of organics were determined. Microgram levels of polycyclic aromatic hydrocarbons were found. High levels of the target CDD/CDF isomers were also found. Because of this, the initial analyses experienced several problems.

Quantitative interferences were found in MM5 samples from Runs 2, 3, 7, 8, and 9, which did not allow for quantitation of the full screen CDD/CDF isomers. Therefore, sample extracts from these runs were diluted, additional internal and surrogate standards added, and another analysis was completed. Confirmation analyses for these runs were completed on the original sample extract.

Full screen analyses of samples from Runs 1, 4, 5R, and 6 had high enough CDD/CDF concentrations to saturate the detector. Confirmation analyses of these compounds did not exhibit this problem and were, therefore, completed initially. Sample extracts were diluted and reanalyzed (no additional standards) for the full screen isomers.

Therefore, data from the reanalysis of the MM5 samples exhibit the following qualifiers:

- Runs 2, 3, 7, 8, and 9 - Full Screen: Because viable internal standards were added after extraction, the values presented are corrected for fractionation losses but not for extraction losses.
- Runs 2, 3, 7, 8, and 9 - Full Screen: The dilution of the original sample extract negates accurate resolution of the pre-spiked surrogate standards and will, therefore, not be reported.

- Runs 1, 4, 5R, and 6 - Full Screen: Analyses of these samples represent a 10-fold extract dilution and, therefore, surrogate standard recovery will also not be reported.

6.4.1.3 CDD/CDF MM5 Blank Results. Both method blanks and field blanks were analyzed for CDD/CDF isomers for both the MM5 samples as well as the toluene rinses. Table 6-15 presents these results. The MM5 method blanks had very little detected. The toluene TLI method Blank-L had 18.5 pg of 2378 TCDD detected as well as 29.5 and 59.1 pg of Total PeCDD and Octa-CDD. The toluene TLI Method Blank LR1 had small amounts of HpCDF and Octa-CDF present. The ash TLI Method Blank only had a small amount of Octa-CDD detected.

6.4.1.4 CDD/CDF Standard Recoveries. Tables 6-16 and 6-17 present the standard recovery values for the MM5 flue gas and toluene flue gas samples, respectively. The analytical acceptance criterion for internal standard recoveries is 40 percent to 130 percent for tetra- through hexa-chlorinated compounds, while the range is 25 percent to 130 percent for hepta- and octa-chlorinated compounds. Recoveries outside of these limits may still be acceptable if other identification criteria are met. Internal standard recoveries for Runs 1-9 FS, all met the acceptable criteria except for Run 7, PCDD. This value of 23 percent was flagged as valid even with the low recovery. Many Toluene FS internal standard recoveries were out of the acceptable range, however these results were still accepted by the laboratory QA officer.

Surrogate recoveries are listed for Runs 1, 4, 5R, and 6. These values represent recoveries of pre-sampled standards and are an indication of overall collection and extraction efficiency. All recoveries at 37Cl-TCDD are within 8 percent of 100 percent. Several recoveries of 13C12 HxCDD are above 130 percent and are probably the result of slight quantitative interferences. Results from these samples are still considered valid.

Table 6-18 present the recovery standards for the ash samples. All recoveries appear to be less than 50 percent, however no data was invalidated for these samples. Further information on standards recoveries can be found in Appendix E.1.

TABLE 6-15. METHOD BLANK AND FIELD BLANK RESULTS FOR THE MM5 AND TOLUENE FLUE GAS SAMPLES
LENOIR MEMORIAL HOSPTIAL (1990)

FULL-SCREEN ANALYSES	MM5 TLI-METHOD BLANK-H	MM5 TLI-METHOD BLANK-HCl	MM5 FIELD BLANK	TOL TLI-METHOD BLANK-L	TOL TLI-METHOD BLANK-LR1	TOL FIELD BLANK	ASH TLI-METHOD
	(total ng)	(total ng)	(total ng)	(total pg)	(total pg)	(total pg)	(ppb)
2378 TCDD	[0.010]	[5.300]	0.13	18.5	[5.8]	74.20	[0.008]
TOTAL TCDD	[0.010]	[5.300]	1.50	18.5	[5.8]	94.3	[0.008]
12378 PCDD	[0.010]	[8.800]	0.68	[9.60]	[8.8]	81.20	[0.008]
TOTAL PCDD	(0.030)	[8.800]	3.80	(29.5)	[8.8]	175.0	[0.008]
123478 HxCDD	[0.020]	[8.000]	0.82	[7.7]	[8.2]	105.00	[0.01]
123678 HxCDD	[0.020]	[7.800]	1.00	[6.9]	[8.0]	112.0	[0.01]
123789 HxCDD	[0.020]	[9.200]	2.20	[8.9]	[9.4]	284.00	[0.01]
TOTAL HxCDD	[0.020]	[8.300]	8.80	[7.7]	[8.5]	999.0	[0.01]
1234678-HpCDD	[0.040]	[10.60]	5.70	[12.4]	[15.3]	767.00	[0.02]
TOTAL Hepta-CDD	[0.040]	[10.60]	10.00	[12.4]	[15.3]	1270.00	[0.02]
Octa-CDD	0.170	[24.90]	5.40	(59.1)	60.5	1020.00	0.05
FURANS							
2378 TCDF	[0.008]	[3.300]	2.200	[12.0]	[3.3]	157.000	[0.005]
TOTAL TCDF	[0.008]	[3.300]	15.400	[12.0]	[3.3]	743.000	[0.005]
12378 PCDF	[0.010]	[5.700]	1.500	[12.1]	[8.2]	197.000	[0.008]
23478 PCDF	[0.010]	[6.100]	2.500	[13.2]	[8.7]	224.000	[0.008]
TOTAL PCDF	[0.010]	[5.900]	28.200	[12.6]	[8.5]	1870.000	[0.008]
123478 HxCDF	[0.010]	[4.900]	5.400	[8.7]	[5.3]	703.000	[0.008]
123678 HxCDF	[0.010]	[4.600]	3.200	[7.5]	[5.0]	384.000	[0.008]
234678 HxCDF	[0.010]	[6.000]	3.200	[11.1]	[6.5]	350.000	[0.008]
123789 HxCDF	[0.020]	[7.500]	0.470	[15.3]	[8.1]	[71.20]	[0.01]
TOTAL HxCDF	[0.010]	[5.500]	29.300	[9.9]	[6.0]	2950.000	[0.008]
1234678-HpCDF	0.020	[5.300]	7.700	[6.3]	14.5	1120.000	[0.008]
1234789-HpCDF	[0.020]	[8.400]	0.890	[11.4]	[11.2]	125.000	[0.01]
TOTAL Hepta-CDF	0.030	[6.500]	1.400	[8.1]	17.7	1750.000	[0.01]
Octa-CDF	[0.100]	[21.60]	2.900	[24.9]	47.2	519.000	[0.04]

CONFIRMATION ANALYSES	MM5 TLI-METHOD BLANK-H	MM5 TLI-METHOD BLANK-HCl	MM5 FIELD BLANK	TOL TLI-METHOD BLANK-L	TOL TLI-METHOD BLANK-LR1	TOL FIELD BLANK	ASH TLI-METHOD
	(total ng)	(total ng)	(total ng)	(total pg)	(total pg)	(total pg)	(ppb)
2378-TCDD			0.22			27.3	
2378-TCDF			0.42			47.8	
TOTAL TCDD			1.60			168.0	
TOTAL TCDF			8.90			763.0	

TABLE 6-16. STANDARDS RECOVERY RESULTS FOR CDD/CDF ANALYSES
LENOIR MEMORIAL HOSPITAL (1990)

SAMPLE ID	MM5-RUN 1	MM5-RUN 2	MM5-RUN 3	MM5-RUN 4	M5-RUN 5	MM5-RUN 6	MM5-RUN 7	MM5-RUN 8	MM5-RUN 9	MM5-FIELD BLANK
FULL SCREEN ANALYSES										
SURROGATE STANDARDS RECOVERY (%)										
37C1-TCDD	105.0			102.0	108.0	103.0				95.7
13C12-PeCDF 234	101.0			112.0	101.0	113.0				121.0
13C12-HxCDF 478	116.0			113.0	123.0	103.0				112.0
13C12-HxCDD 478	199.0			147.0	225.0	138.0				99.0
13C12-HpCDF 789	73.6			81.0	61.2	68.3				90.0
ALTERNATE STANDARDS RECOVERY										
13C12-HxCDF 789	55.9	55.8	52.6	67.0	64.3	85.1	46.8	64.6	52.3	53.1
13C12-HxCDF 234	65.4	57.5	59.6	78.0	78.5	98.4	54.0	74.6	56.8	62.3
INTERNAL STANDARDS RECOVERY										
13C12-2378-TCDF	67.2	61.2	53.0	76.2	69.9	65.8	43.9	75.9	56.1	50.3
13C12-2378-TCDD	66.2	66.1	56.8	82.7	76.1	70.1	59.9	80.1	56.9	61.3
13C12-PeCDF 123	87.8	80.3	59.3	85.0	70.2	81.2	75.8	111.0	67.2	57.7
13C12-PeCDD 123	97.9	106.0	63.0	82.2	84.9	87.2	84.5	147.0	99.6	89.6
13C12-HxCDF 678	77.7	51.7	52.3	78.6	79.6	94.1	57.8	67.7	51.0	60.1
13C12-HxCDD 678	94.0	65.0	64.1	88.7	95.9	105.0	66.4	80.1	59.5	85.9
13C12-HpCDF 678	79.5	47.6	44.5	68.8	114.0	105.0	37.4	59.4	47.9	58.7
13C12-HpCDD 678	76.0	53.0	50.5	75.0	83.1	97.3	52.1	65.4	54.3	65.1
13C12-OCDD	86.2	44.6	34.0	81.2	111.0	88.4	23.0	50.9	47.2	33.6
CONFIRMATION DATA										
SURROGATE STANDARDS RECOVERY (%)										
37C1-TCDD	107.0	109.0	103.0	114.0	111.0	108.0	110.0	112.0	109.0	105.0
INTERNAL STANDARDS RECOVERY (%)										
13C12-2378-TCDF	76.6	86.6	80.5	80.5	74.5	79.4	73.4	65.2	48.2	66.3
13C12-2378-TCDD	68.7	102.0	68.6	68.6	62.6	67.9	86.4	80.1	59.6	61.6

TABLE 6-17. STANDARDS RECOVERY RESULTS FOR CDD/CDF TOLUENE ANALYSES
LENOIR MEMORIAL HOSPITAL (1990)

SAMPLE ID	TOL-RUN 1	TOL-RUN 2	TOL-RUN 3	TOL-RUN 4	TOL-RUN 5	TOL-RUN 6	TOL-RUN 7	TOL-RUN 8	TOL-RUN 9	TOL-FIELD BLANK
FULL SCREEN ANALYSES										
SURROGATE STANDARDS RECOVERY (%)										
37Cl-TCDD	NA	77.2	70.1	56.7	25.6	49.4	29.1	66.2	59.8	57.6
13C12-PeCDF 234	NA	70.7	70.5	76.6	42.3	72.3	49.4	89.0	94.4	68.8
13C12-HxCDF 478	NA	92.1	84.1	74.2	37.2	52.8	33.8	89.7	87.6	74.2
13C12-HxCDD 478	NA	108.0	136.0	138.0	52.6	88.0	50.2	117.0	126.0	95.2
13C12-HpCDF 789	NA	58.4	57.8	47.5	26.8	53.2	30.0	68.8	77.6	48.7
ALTERNATE STANDARDS RECOVERY										
13C12-HxCDF 789	NA	82.3	75.8	69.9	29.2	54.3	30.3	72.0	77.3	58.7
13C12-HxCDF 234	NA	107.0	95.4	113.0	41.0	65.1	36.9	96.5	106.0	70.7
INTERNAL STANDARDS RECOVERY										
13C12-2378-TCDF	NA	80.8	76.2	59.7	29.0	48.8	29.2	59.4	56.4	60.5
13C12-2378-TCDD	NA	79.8	75.6	69.5	31.0	48.7	31.1	66.8	60.1	59.6
13C12-PeCDF 123	NA	65.4	64.9	64.8	37.8	55.6	33.1	65.5	73.0	64.4
13C12-PeCDD 123	NA	85.4	105.0	119.0	62.5	100.0	66.9	108.0	134.0	97.6
13C12-HxCDF 678	NA	93.0	81.2	68.7	37.4	46.3	28.3	72.2	74.9	66.3
13C12-HxCDD 678	NA	96.9	88.9	144.0	64.9	82.1	51.7	100.0	126.0	91.0
13C12-HpCDF 678	NA	68.7	70.0	61.2	39.6	57.1	34.8	83.3	91.9	70.6
13C12-HpCDD 678	NA	65.2	66.3	59.4	41.8	69.1	39.8	80.7	97.9	76.5
13C12-OCDD	NA	46.4	53.4	14.7	22.3	31.9	14.0	36.2	48.1	35.5
CONFIRMATION DATA										
SURROGATE STANDARDS RECOVERY (%)										
37Cl-TCDD	45.3	69.0	64.8	63.3	72.5	81.2	59.1	82.7	78.1	78.7
INTERNAL STANDARDS RECOVERY (%)										
13C12-2378-TCDF	49.3	65.4	60.1	85.1	91.0	91.3	63.9	83.4	83.2	94.8
13C12-2378-TCDD	50.3	75.0	70.4	69.2	65.5	83.8	63.8	83.0	79.1	86.2

TABLE 6-18. STANDARDS RECOVERY RESULTS FOR CDD/CDF ASH ANALYSES
LENOIR MEMORIAL HOSPITAL (1990)

FULL SCREEN DATA FOR ASH ANALYTICAL DATE	TLI BLANK 08/21/90	LMH-061590 CASH 1T & 1T2 COND 1 08/11/90	LMH-061590 CASH 2T & 2T2 COND 2 08/11/90	LMH-061590 CASH 3T & 3T2 COND 3 08/21/90
SURROGATE STANDARDS RECOVERY (%)				
37C1--TCDD	32.3	37.5	41.7	46.7
13C12--PeCDF 234	35.5	22.7	32.5	42.4
13C12--HxCDF 478	39.4	58.2	40.1	37.4
13C12--HxCDD 478	42.7	40.6	33.0	40.3
13C12--HpCDF 789	40.5	34.3	28.4	47.1
ALTERNATE STANDARDS RECOVERY				
13C12--HxCDF 789	38.1	40.8	33.8	39.9
13C12--HxCDF 234	35.0	42.5	42.2	38.3
INTERNAL STANDARDS RECOVERY				
13C12--2378--TCDF	27.5	40.4	40.0	40.6
13C12--2378--TCDD	33.0	36.8	41.5	46.2
13C12--PeCDF 123	29.8	21.3	27.0	37.1
13C12--PeCDD 123	47.2	26.5	37.2	48.6
13C12--HxCDF 678	30.5	52.6	44.1	33.8
13C12--HxCDD 678	35.3	48.0	39.5	40.1
13C12--HpCDF 678	39.1	44.7	34.2	41.5
13C12--HpCDD 678	42.8	34.6	29.5	50.1
13C12--OCDD	23.8	15.8	13.3	34.5
CONFIRMATION DATA FOR ASH		LMH-061590 CASH 1T & 1T2 08/25/90	LMH-061590 CASH 2T & 2T2 08/25/90	LMH-061590 CASH 3T & 3T2 08/25/90
SURROGATE STANDARDS RECOVERY (%)				
37C1--TCDD		36.0	33.7	35.3
INTERNAL STANDARDS RECOVERY (%)				
13C12--2378--TCDF		45.2	44.2	44.3
13C12--2378--TCDD		37.4	35.0	35.8

6.4.2 Metals Analytical Quality Assurance

The analytical methods used for the flue gas samples, the ash samples for the metals analyses are fully discussed in Section 5. The following paragraph will briefly report metals analytical QA parameters.

Table 6-19 present the method blank metals results for both the ash and flue gas samples. Only a small amount of Barium (0.40 mg/kg and 1.00 ug) were reported detected for the ash and flue gas sample, respectively.

Table 6-20 presents the method spike and matrix spike results for the metals analyses. Method spikes are performed using water where as matrix spikes are added to an actual sample. All spiked recoveries were within the QA allowance of ±20 percent of 100 percent.

6.4.3 Halogen Analytical Quality Assessment

The analysis for Cl^-, F^-, and Br^- incorporate stringent QA/QC guidelines. Table 6-21 presents the method blank results for the IC analysis. The analyses were completed in four batch runs and a method blank was included for each set. None of the target halogen ions were detected in any of the method blanks.

The matrix spike recoveries are also shown in Table 6-21. Results for all 3 ions was within the 20 percent criteria. Recoveries for HCl, HF and HBr were 98.2, 100, and 95.2 percent, respectively.

6.4.4 Microbial Survivability Quality Assurance

Field blank results for the microbial impinger sampling train as reported in Section 6.2.3 revealed no viable spores were detected in the nine 24-hour counts and 1 spore was detected in 1 out of the nine 48-hour counts.

Two of the stock wet spore solutions, that were used for spiking the incinerator were also analyzed. These results are listed in Table 6-22. The first sample had a manufacturer's count of 8×10^8 viable spores/ml, and the confirmation count resulted in too numerous to count (TNTC). The second sample had a manufacturer's count and confirmation count of 8×10^8 and 1.4×10^9 viable spores/ml, respectively. All microbial survivability calculations used the average confirmation count of 1.4×10^9 spores/ml.

Two dry spore samples were also sent in for QA analysis. These results are shown in Table 6-23. The first sample was sent to the laboratory as it was received from

TABLE 6-19. METALS ASH AND FLUE GAS METHOD BLANK RESULTS
LENOIR MEMORIAL HOSPITAL (1990)

METAL	ASH	FLUE GAS METHOD BLANK			FIELD BLANK		
	METHOD BLANK (mg/kg)	FRONT HALF (total µg)	IMPINGERS 1,2 (total µg)	IMPINGERS 3 & 4 [a] (total µg)	FRONT HALF (total µg)	IMPINGERS 1,2 (total µg)	IMPINGERS 3&4 [a] (total µg)
Antimony	[6.40]	[16.0]	[7.20]		(20.8)	[7.60]	
Arsenic	[2.00]	[5.00]	[0.45]		[5.00]	[0.47]	
Barium	(0.40)	(1.00)	[0.22]		13	(0.354)	
Beryllium	[0.20]	[0.50]	[0.22]		[0.50]	[0.024]	
Cadmium	[0.50]	[1.20]	[0.56]		[1.20]	[0.059]	
Chromium	[1.00]	[2.50]	[1.10]		(3.00)	[1.20]	
Lead	[10.0]	[25.0]	[0.34]		[25.0]	(1.04)	
Mercury	[0.98]	[2.40]	[0.88]	[0.52]	[2.40]	(4.42)	[0.44]
Nickel	[2.00]	[5.00]	[2.20]		[5.00]	[2.40]	
Silver	[3.30]	[8.20]	[3.70]		[8.20]	[3.90]	
Thallium	[5.40]	[14.0]	[6.00]		[14.0]	[6.40]	

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

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 5 times the detection limit.

TABLE 6-20. METALS METHOD SPIKE RESULTS
LENOIR MEMORIAL HOSPITAL (1990)

	METHOD SPIKE 1				MATRIX SPIKE	MATRIX SPIKE DUPLICATE
METAL	FRONT HALF	IMPINGERS 1,2	FRONT HALF	IMPINGERS 1,2		
Antimony	97.3	102	104	77.4		
Arsenic	97.8	100	96.2	100		
Barium	94.2	99.4	95.8	98.6		
Beryllium	96.7	102	98.7	101		
Cadmium	100	106	102	107		
Chromium	96.8	104	100	103		
Lead	98.7	95.6	100	95.6		
Mercury	96	94.3	108	89.1	88	89.8
Nickel	90.5	105	92.8	106		
Silver	172	NC	107	NC		
Thallium	95.5	112	95.5	104		

NC = Not Calculated

TABLE 6-21. HALOGEN METHOD BLANK AND FIELD BLANK RESULTS AND MATRIX SPIKE RECOVERY LENOIR MEMORIAL HOSPITAL (1990)

ANALYTE	METHOD BLANK (Runs 1,2) (µg/ml)a	METHOD BLANK (Runs 3,4) (µg/ml)	METHOD BLANK (Runs 5,6) (µg/ml)	METHOD BLANK (Runs 5R,7-9) (total µg)	FIELD BLANK (total µg)
HCl	[0.11]	[0.11]	[0.11]	[8.95]	[6.99]
HF	[0.42]	[0.42]	[0.42]	[33.7]	[26.33]
HBr	[0.13]	[0.13]	[0.13]	[10.1]	[8.00]

ANALYTE	MATRIX SPIKE RECOVERY (%)
HCl	98.20
HF	100.00
HBr	95.20

a Total sample volume was typically 100 mls.

TABLE 6-22. WET SPORE SPIKE SOLUTION CONFIRMATION ANALYSIS
LENOIR MEMORIAL HOSPITAL (1990)

SAMPLE ID	MANUFACTURER'S COUNT (viable spores/ml)	CONFIRMATION AVERAGE (viable spores/ml)	CONFIRMATION COUNT STANDARD DEVIATION (viable spores/ml)
10 ml Spore Suspension Vial	8.0E+08	1 ml Aliquot 42 hr count -- TNTC [a]	NA
		10 ml Aliquot 42 hr count -- TNTC [a]	NA
200 ml Spore Suspension Bag	8.0E+08	1 ml Aliquot 1.6E+09	3.2E+08
		10 ml Aliquot 1.2E+09	3.5E+07
		Average 1.4E+09	3.3E+08

[a] TNTC = Too numerous to count

NOTE: ALL MICROBIAL SURVIVABILITY CALCULATIONS USED THE AVERAGE CONFIRMATION VALUE.

TABLE 6-23. DRY SPORE CONFIRMATION ANALYSIS
LENOIR MEMORIAL HOSPITAL (1990)

SAMPLE ID	MANUFACTURER'S COUNT (viable spores/ml)	CONFIRMATION AVERAGE (viable spores/ml)	CONFIRMATION COUNT STANDARD DEVIATION (viable spores/ml)
Dry Spore Glass Vial	3.45E+05	9.1E+05	9.2E+04
Dry Spores Loaded Into A Pipe	3.45E+05	8.4E+05	1.4E+04

the manufacturer (in a glass vial). The second sample was loaded into a pipe and then sent to the laboratory with the other samples to determine possible preparation or recovery losses. The confirmation count in both cases exceeded the manufacturer's count (9.1×10^5 and 8.4×10^5 spores vs. 3.45×10^5 spores, respectively).

6.5 CEM QUALITY ASSURANCE

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.

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.

The CEM data is a unique form of emissions testing in that it provides real time, minute by minute indications of stack gas pollutant and diluent gas concentrations. The Lenoir incinerator stack gas emissions were characterized by extreme, very quick fluctuations in concentrations at various times during the test, CO concentrations varied from low ppmV values (10 - 50 ppmV) to over 50,000 ppmv. In addition to concentration fluctuations, short episodes of high organic, "sooty" emissions occurred which made steady CEM operation very difficult. However, all data reported in this report is considered valid and is verified by the following QA parameters.

Table 6-24 presents the CEM internal QA/QC checks along with their respective acceptance criteria which were conducted at the Lenoir 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).

Drift requirements between calibrations for both zero and span was ±3 percent for each run of full scale as required by EPA Methods 6C and 3A. Although Method 10

TABLE 6-24. 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

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. For days where the drift exceeded 3 percent, the CEM data was drift corrected as shown in Appendix H.

Table 6-25 lists the zero and span calibration drift results for each CEM analyzer on each test day.

6.5.3 Daily QC Gas Challenges

After initial calibration, mid-range QC gases for all instruments were analyzed with no adjustment, as a quality control check of daily calibrations and to provide day-to-day precision estimates for each instrument. The calibration was considered acceptable if the difference between the measured response and the certified concentration was within ±2 percent of full scale of the analyzer.

Table 6-26 presents the results of the daily QA gas challenges.

6.5.4 Stratification Check

Following the tests, NO_x concentrations were recorded at eight sampling points to check for possible flue gas stratification. The procedure called for NO_x to be continuously monitored for approximately 10 minutes/point while an additional CEM NO_x system monitored concentrations at a stationary reference point in the stack. In this way, fluctuations in concentrations caused by process operation and not due to stratification, could be monitored.

Stratification is normally determined as the percent difference that a point concentration deviates from the average of all point concentrations. However, when the flue gas concentration is not stable, each point value is compared to the reference concentration determined during that same time interval. This is an acceptable method when the average reference concentration approximates the average of all the point concentrations.

The stratification results are given in Table 6-27. Stratification is typically defined as any point concentration deviating from the average concentration by more than 10 percent. The largest deviation present during the test series was -4.1 percent. This then shows that there was no flue gas stratification present.

TABLE 6-25. DAILY CALIBRATION DRIFTS
LENOIR MEMORIAL HOSPITAL (1990)

DATE	RUN NUMBER	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
PARAMETER: O2 ZERO CALIBRATION GAS: 0.2% O2 FULL SCALE: 25			
05/30/90	1	-0.0804	-0.9644
05/31/90	2	-0.0801	0.6410
06/01/90	3	0.3151	0.0788
06/02/90	4	0.1575	0.0000
06/04/90	4R	*	*
06/05/90	6	-0.9533	0.1589
06/06/90	7	0.0000	0.0000
06/06/90	5R	0.1564	0.3911
06/07/90	8	ND	-0.8000
06/08/90	9	0.0000	0.0000
PARAMETER: CO ZERO CALIBRATION GAS: N2 FULL SCALE: 5000			
05/30/90	1	0.0247	-0.2539
05/31/90	2	0.0397	0.0056
06/01/90	3	0.0080	0.0095
06/02/90	4	-0.0172	0.0719
06/04/90	4R	*	*
06/05/90	6	0.0016	0.0000
06/06/90	7	0.0000	0.0000
06/06/90	5R	0.0045	0.0719
06/07/90	8	ND	-0.1700
06/08/90	9	0.0000	0.0000
PARAMETER: CO2 ZERO CALIBRATION GAS: N2 FULL SCALE: 20			
05/30/90	1	0.0000	-0.7531
05/31/90	2	-0.1448	-2.3168
06/01/90	3	0.7838	-0.9975
06/02/90	4	0.0000	0.0000
06/04/90	4R	*	*
06/05/90	6	0.0719	-0.0719
06/06/90	7	0.0000	0.0000
06/06/90	5R	-0.0721	0.1441
06/07/90	8	ND	-0.1000
06/08/90	9	0.0000	0.0000

* No final calibration was performed on 06/04/90 due to equipment problems.

** CEM data was drift corrected.

ND = Not determined

TABLE 6-25. DAILY CALIBRATION DRIFTS, (continued) LENOIR MEMORIAL HOSPITAL (1990)

DATE	RUN NUMBER	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
PARAMETER: HCl ZERO CALIBRATION GAS: N2 FULL SCALE: 2000			
05/30/90	1	1.6043	-1.0027
05/31/90	2	0.8074	4.4406 **
06/01/90	3	0.7322	0.1831
06/02/90	4	0.8721	2.5292
06/04/90	4R	*	*
06/05/90	6	1.4566	1.3561
06/06/90	7	-0.0427	19.7988 **
06/06/90	5R	0.2072	-0.8289
06/07/90	8	ND	7.58 **
06/08/90	9	0.0000	0.0000
PARAMETER: SO2 ZERO CALIBRATION GAS: N2 FULL SCALE: 500			
05/30/90	1	0.0000	-0.2699
05/31/90	2	-0.1797	0.7069
06/01/90	3	0.9408	1.1180
06/02/90	4	0.0000	0.5337
06/04/90	4R	*	*
06/05/90	6	0.1815	0.5446
06/06/90	7	0.0000	0.0000
06/06/90	5R	0.0000	3.5321
06/07/90	8	ND	0.2800
06/08/90	9	0.0000	0.0000
PARAMETER: NOx ZERO CALIBRATION GAS: N2 FULL SCALE: 250			
05/30/90	1	0.0000	-2.605
05/31/90	2	0.0000	-0.1681
06/01/90	3	0.9138	-0.2492
06/02/90	4	0.0000	-1.0833
06/04/90	4R	*	*
06/05/90	6	0.1667	0.3333
06/06/90	7	0.0000	0.0000
06/06/90	5R	0.0000	2.4334
06/07/90	8	ND	0.4000
06/08/90	9	0.9979	-0.1663

* No final calibration was performed on 06/04/90 due to equipment problems.

** CEM data was drift corrected.

ND = Not determined

TABLE 6-25. DAILY CALIBRATION DRIFTS, (continued)
LENOIR MEMORIAL HOSPITAL (1990)

DATE	RUN NUMBER	ZERO INSTRUMENT DRIFT (% of Span)	SPAN INSTRUMENT DRIFT (% of Span)
PARAMETER: THC ZERO CALIBRATION GAS: N2 FULL SCALE: 100			
05/30/90	1	0.0000	-8.5961
05/31/90	2	7.7119 **	15.9322 **
06/01/90	3	1.4493	7.4638 **
06/02/90	4	1.3855	1.2048
06/04/90	4R	*	*
06/05/90	6	13.3429 **	0.0000
06/06/90	7	0.0000	0.0000
06/06/90	5R	ND	ND
06/07/90	8	ND	ND
06/08/90	9	0.0000	0.0000

* No final calibration was performed on 06/04/90 due to equipment problems.

** CEM data was drift corrected.

ND = Not determined

TABLE 6-26. QC GAS RESPONSES
LENOIR MEMORIAL HOSPITAL (1990)

DATE	PARAMETER	TRUE CONCENTRATION	MEASURED CONCENTRATION	PERCENT a DIFFERENCE
05/30/90	O2 b	9.99	9.8	-0.76%
05/31/90		9.99	9.7	-1.16%
		4.99	4.8	-0.76%
06/01/90		0.20	0.2	0.00%
		4.99	4.7	-1.16%
		9.99	9.7	-1.16%
06/02/90		9.99	9.8	-0.76%
06/05/90		9.99	9.8	-0.76%
06/06/90		20.10	20.2	0.40%
		9.99	10.0	0.04%
06/07/90		9.99	9.8	-0.76%
		4.99	4.8	-0.76%
		20.10	20.1	0.00%
06/08/90		9.99	10.0	0.04%
05/30/90	CO(dry) c	90.50	88.2	-0.05%
05/31/90		90.50	26.5	-1.28%
		181.00	182.4	0.03%
06/01/90		181.00	184.4	0.07%
		90.50	93.2	0.05%
		181.00	174.9	-0.12%
06/02/90		95.80	94.5	-0.03%
06/05/90		190.00	192.8	0.06%
06/06/90		450.00	461.9	0.24%
		95.80	97.8	0.04%
		95.80	97.2	0.03%
06/07/90		19.05	17.4	-0.03%
		450.00	475.8	0.52%
		190.00	188.5	-0.03%
06/08/90		450.00	421.4	-0.57%
		95.80	96.0	0.00%

NOTE:

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

b in units of percent by Volume

c in units of ppm by Volume

TABLE 6-26. QC GAS RESPONSES, (continued)
LENOIR MEMORIAL HOSPITAL (1990)

DATE	PARAMETER	TRUE CONCENTRATION	MEASURED CONCENTRATION	PERCENT a DIFFERENCE
05/30/90	CO2 b	10.09	10.0	-0.45%
05/31/90		10.09	9.8	-1.45%
		5.04	4.9	-0.70%
06/01/90		5.04	4.9	-0.70%
		10.09	9.8	-1.45%
06/02/90		10.09	10.0	-0.45%
06/05/90		8.90	9.0	0.50%
06/06/90		18.00	18.0	0.00%
06/07/90		8.90	8.7	-1.00%
		5.04	4.9	-0.70%
		18.00	17.8	-1.00%
06/08/90		8.90	8.8	-0.50%
05/30/90	SO2 c	49.20	48.6	-0.12%
05/31/90		49.20	49.5	0.06%
06/01/90		49.20	44.5	-0.94%
06/02/90		49.20	45.0	-0.84%
06/05/90		49.20	46.7	-0.50%
06/06/90		49.20	53.3	0.82%
06/07/90		49.20	48.3	-0.18%
		25.20	20.9	-0.86%
		102.10	103.5	0.28%
06/08/90		49.20	48.6	-0.12%
05/30/90	NOx c	90.10	90.5	0.20%
05/31/90		49.60	50.2	0.30%
		91.00	90.4	-0.30%
06/01/90		91.00	91.9	0.45%
		50.60	49.4	-0.60%
06/02/90		91.00	88.9	-1.05%
06/05/90		49.30	47.9	-0.70%
06/07/90		200.00	206.0	3.00%
		91.00	92.8	0.90%
06/08/90		49.60	49.6	0.00%
		91.00	92.0	0.50%
06/09/90		49.30	49.5	0.10%
		49.30	48.9	-0.20%

NOTE:

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

b in units of percent by Volume

c in units of ppm by Volume

TABLE 6-26. QC GAS RESPONSES, (continued)
LENOIR MEMORIAL HOSPITAL (1990)

DATE	PARAMETER	TRUE CONCENTRATION	MEASURED CONCENTRATION	PERCENT a DIFFERENCE
05/30/90	THC (wet) c	5.00	6.4	1.40%
05/31/90		5.00	7.0	2.00%
06/01/90		5.00	6.0	1.00%
		3.00	3.2	0.20%
06/02/90		5.00	4.5	-0.50%
06/05/90		45.00	45.5	0.50%
06/06/90		45.00	43.9	-1.10%
06/08/90		45.00	44.3	-0.70%
05/30/90	HCL (wet) c	465.10	546.5	4.07%
05/31/90		465.10	535.5	3.52% **
06/01/90		1848.90	1850.9	0.10%
		465.10	536.2	3.56%
06/02/90		465.10	525.7	3.03%
06/05/90		202.50	207.7	0.26%
06/07/90		465.10	442.8	-1.12%
		202.1	223.8	1.09%
		1848.1	1999.6	7.58%
06/08/90		465	507	2.10%

NOTE:

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

b in units of percent by Volume

c in units of ppm by Volume

TABLE 6-27. NOx STRATIFICATION CHECK
LENOIR MEMORIAL HOSPITAL (1990)

POINT NUMBER	DISTANCE FROM WALL (inches)	TIME INTERVAL	REFERENCE AVERAGE NOx CONCENTRATION	POINT AVERAGE NOx CONCENTRATION	PERCENT DIFFERENCE FROM REFERENCE * (%)
A1	1.2	16:59–17:02	68.5	65.7	-4.1
A2	4.5	17:03–17:06	90.4	92.1	1.9
A3	13.5	17:06–17:10	89.1	89.2	0.1
A4	16.8	17:11–17:15	54.5	56.0	2.8
B1	1.2	17:19–17:22	55.9	54.8	-2.0
B2	4.5	17:22–17:25	64.8	67.2	3.7
B3	13.5	17:28–17:30	67.8	66.8	-1.5
B4	16.8	17:31–17:35	46.7	46.8	0.2
		AVERAGE:	67.21	67.33	0.2

* Percent drift = 100 * (point value − ref value)

6.5.5 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 6-28 presents the results of CEM linearity checks. All linearity checks met the acceptance criteria.

6.5.6 NO_x Converter Efficiency

After all test runs were completed an NO_2 to NO converter efficiency test was performed as prescribed in Method 20. The procedure used for testing the converter efficiency is given below:

- Fill a leak-free Tedlar bag approximately half full with an NO in N_2 blend.
- Fill the remainder of the bag with 0.1 grade air.
- Immediately attach the NO/Air mixture to the inlet of the NO_x monitor being used.
- Allow the monitor to sample the gas in the bag for 30 minutes.

As the O_2 and NO in the bag are exposed to each other a reaction occurs which changes the NO to NO_2. An attenuation in response over time of less than five percent absolute indicates that the converter efficiency is acceptable. Approximately halfway through the procedure the NO/Air mixture in the Tedlar bag was depleted and the measured NO_x concentration dropped as expected. Sufficient data had been accumulated however to indicate acceptable converter efficiency.

TABLE 6-28. LINEARITY RESULTS
LENOIR MEMORIAL HOSPITAL (1990)

PARAMETER	DATE	TRUE CONCENTRATION	MEASURED CONCENTRATION	CORRELATION (R)
O2 *	06/01/90	0.20	0.2	0.99988
		0.20	0.2	
		4.99	4.7	
		9.99	9.7	
O2 *	06/07/90	0.20	0.2	0.99992
		4.99	4.8	
		9.99	9.8	
		20.10	20.1	
CO *	06/06/90	0.00	0.0	0.99999
		49.60	49.5	
		91.00	90.8	
		222.00	220.4	
CO *	06/07/90	0.00	0.0	0.99965
		19.05	17.4	
		95.80	97.2	
		190.00	188.5	
		450.00	475.8	
CO2 *	06/07/90	0.00	0.0	0.99992
		5.04	4.9	
		9.00	8.7	
		18.00	17.8	
SO2 **	06/07/90	0.00	0.0	0.99890
		25.20	20.9	
		49.20	48.3	
		102.10	103.5	
NOx *	06/19/90	0.00	0.0	0.99997
		25.20	20.9	
		49.20	48.3	
		102.10	103.5	
HCl (wet) **	06/07/90	0.00	0.0	0.99942
		202.10	223.8	
		465.10	442.8	
		1848.10	1999.6	

* in units of percent

** in units of ppm

6.5.7 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 DATA VARIABILITY

6.6.1 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

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

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.

6.6.2 CDD/CDF Data Variation

Table 6-29 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 38.5 percent.

Table 6-30 presents CVs for the metal flue gas concentrations. The Condition 3, mercury CV is uncharacteristicly high at 133.3 percent. This value results from a high concentration of 3,390 ug/dscm for Run 7 compared to 38.5 and 96.3 ug/dscm for Runs 8 and 9, respectively. The overall pooled CV for 6 metals concentrations in 51.5 percent.

The Halogen gas test CVs are listed in Table 6-31. 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 45.3 percent.

Table 6-32 presents the CV values for the CEM 30 second readings. 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 an "average concentration" for that time period. The overall pooled CV for the CEM data 253.5 percent. Results from manual tests did not fluctuate nearly as much as the 30 second CEM readings, therefore have much lower CVs.

TABLE 6-29. COEFFICIENTS OF VARIATIONS FOR THE CDD/CDF FLUE GAS CONCENTRATIONS
LENOIR MEMORIAL HOSPITAL (1990)

CONGENER	CV:1-3 (%)	CV:4-6 (%)	CV:7-9 (%)	POOLED CV
DIOXINS				
2378 TCDD	51.3	77.4	13.5	54.2
Other TCDD	51.1	31.3	19.6	36.4
12378 PCDD	60.7	16.9	7.4	36.7
Other PCDD	49.0	12.3	14.5	30.3
123478 HxCDD	43.8	24.4	11.5	29.7
123678 HxCDD	47.1	13.5	20.2	30.6
123789 HxCDD	52.7	16.9	13.4	32.9
Other HxCDD	47.6	13.3	23.7	31.6
1234678-HpCDD	36.6	37.2	33.1	35.6
Other Hepta-CDD	38.8	51.6	40.5	44.0
Octa-CDD	19.4	64.4	49.2	48.1
FURANS				
2378 TCDF	38.1	20.9	11.1	25.9
Other TCDF	46.4	25.5	12.1	31.4
12378 PCDF	48.3	25.0	13.4	32.3
23478 PCDF	46.0	18.7	18.3	30.6
Other PCDF	49.8	24.9	22.1	34.6
123478 HxCDF	40.4	36.9	32.8	36.8
123678 HxCDF	47.1	21.2	30.2	34.5
234678 HxCDF	38.0	41.9	30.7	37.1
123789 HxCDF	49.0	10.7	19.6	31.1
Other HxCDF	41.1	25.3	31.9	33.4
1234678-HpCDF	33.5	38.8	53.4	42.7
1234789-HpCDF	36.0	18.9	58.2	41.0
Other Hepta-CDF	33.9	33.2	60.3	44.3
Octa-CDF	43.5	78.7	80.7	69.8
POOLED CV	44.3	36.3	34.2	
OVERALL POOLED CV	38.5			

TABLE 6-30. COEFFICIENTS OF VARIATION OF THE FLUE GAS METALS CONCENTRATIONS
LENOIR MEMORIAL HOSPITAL (1990)

FLOW RATE (dscmm)	CONDITION 1 CV (%)	CONDITION 2 CV (%)	CONDITION 3 CV (%)	POOLED CV
Antimony	22.0	49.3	31.2	36.0
Arsenic	30.7	18.5	13.0	22.0
Barium	31.1	19.2	29.8	27.2
Beryllium	ND	ND	ND	ND
Cadmium	73.0	59.6	29.7	57.0
Chromium	18.3	31.0	67.9	44.4
Lead	17.3	62.7	29.7	41.3
Mercury	20.0	38.1	133.3	80.9
Nickel	32.0	46.6	79.4	56.3
Silver	ND	3.9	96.7	68.4
Thallium	ND	ND	ND	ND
POOLED CV	35.0	44.5	66.8	
OVERALL POOLED CV	51.5			

TABLE 6-31. COEFFICIENTS OF VARIATION FOR HALOGEN FLUE GAS CONCENTRATIONS LENOIR MEMORIAL HOSPITAL (1990)

TEST RUN	HBr (CV-%)	HCl (CV-%)	HF (CV-%)
Average-1	ND	13.44	31.55
Average-2	ND	30.25	85.22
Average-3	ND	30.59	21.81
Condition 1	ND	26.02	53.96
Average-4	ND	7.67	101.80
Average-5R	ND	72.37	83.86
Average	88.63	9.63	44.43
Condition 2	88.63	36.96	79.91
Average-7		17.20	29.95
Average-8	42.46	11.68	5.39
Average-9	5.60	22.80	23.93
Condition 3	27.20	17.81	22.35
ANALYTE POOLED	52.66	27.65	56.08
TOTAL HALOGEN	45.30		

ND = Not Detected; CV's were not calculated for non-detect result

TABLE 6-32. COEFFICIENTS OF VARIATION OF CEM GAS CONCENTRATIONS LENOIR MEMORIAL HOSPITAL (1990)

RUN NUMBER	DATE	COEFFICIENTS OF VARIATION (percent)							POOLED CV
		O2	CO	CO2	HCl	SO2	NOx	THC	
1	05/30/90	28.2	677.1	39.7	359.3	216.5	54.8	165.7	308.7
2	05/31/90	33.1	128.0	36.4	52.8	346.7	35.5	80.2	146.1
3	06/01/90	17.0	381.1	41.9	50.3	412.5	40.9	326.3	247.3
4	06/02/90	25.2	169.0	37.3	59.0	168.4	29.8	101.7	102.6
4R	06/04/90	17.8	493.5	40.4		265.0	53.9	139.1	237.3
5R	06/06/90	11.0	823.2	28.4	100.5	432.8	17.2		382.2
6	06/05/90	24.9	272.9	40.6	55.0	863.6	24.9	109.6	346.0
7	06/06/90	18.3	390.0	39.4	143.8	338.2	52.9	508.0	280.3
8	06/07/90	16.5	483.0	53.1	119.6	360.6	59.1		253.1
9	06/08/90	20.1	554.6	44.1	132.1	329.7	53.9	530.8	320.9
POOLED CV		21.2	450.5	38.1	143.7	401.7	41.2	234.6	
OVERALL POOLED CV			253.5						

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.