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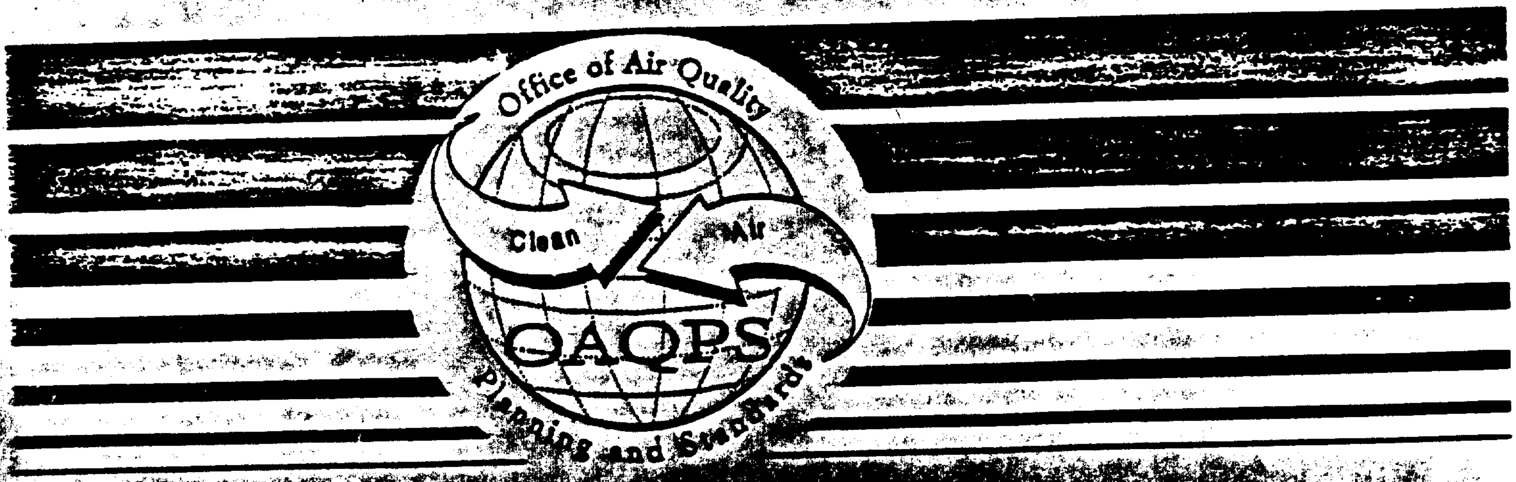
Medical Waste Incineration Emission Test Report

Borgess Medical Center
Kalamazoo, Michigan

EPA



MEDICAL WASTE INCINERATION

EMISSION TEST REPORT

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1. INTRODUCTION

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

The Office of Air Quality Planning and Standards (OAQPS), through its Industrial Studies Branch (ISB) and Emissions Measurement Branch (EMB), is responsible for reviewing the existing air emissions data base and gathering additional data where necessary. A series of MWI emission tests were conducted to support the regulatory development program. One testing program was conducted at the MWI facility at Borgess Medical Center in Kalamazoo, Michigan.

The pollutants being studied for standards development are the criteria pollutants: particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and total hydrocarbons (THC); as well as acid gases, such as hydrogen chloride (HCl); chlorinated organics, including dioxins and furans; and trace metals.

1.1 TEST OBJECTIVES

The purpose of the testing program at the Borgess Medical Center was to obtain uncontrolled and controlled emission data from a well designed controlled-air, continuous ram-fed MWI. These data will be used in the regulatory development program for MWIs.

The MWI located at Borgess Medical Center was selected for emissions testing for the following reasons:

- The MWI system is representative of well-designed, controlled-air MWIs currently in use;
- Of known MWI systems, this MWI possesses the proper combination of hardware and operations to facilitate testing of dry carbon injection directly into the flue gas duct as a means of mercury (Hg) and dioxin control. The MWI system employs a waste heat recovery boiler to cool flue gas upstream of the dry lime injection/fabric filter (DI/FF) air pollution control system (APCS); and

- This MWI system was tested last year in a joint test program between EPA and the State of Michigan. EPA and Midwest Research Institute (MRI) personnel are familiar with the facility. Test ports were already in place and a large body of test data (23 runs) is available with which to compare the test data from this test.

Another consideration in performing emissions testing at this facility was the cooperative attitude of the hospital personnel. All parties involved expressed an interest in and a willingness to cooperate in the source test program.

Eight tests were conducted; three without carbon injection, two with carbon injection at 1 lb/hr, and three with carbon injection at 2.5 lb/hr. Only two tests were conducted at 1 lb/hr of carbon injection due to time and budgetary restraints.

The specific objectives of the test program are to:

- Determine the levels of uncontrolled CO, PM, SO_2, NO_x, HCl (acid gases), metals, THC and polychlorinated dibenzo-p-dioxins (CDD) and polychlorinated dibenzofurans (CDF) emitted from the combustor when burning medical wastes (measured at the APCS inlet);
- Determine the levels of controlled PM, acid gases, metals including Hg, and CDD/CDF emissions associated with a dry lime injection fabric filter (DI/FF) control technology (measured at the APCS outlet);
- Determine the levels of PM and CDD/CDF at the waste heat boiler inlet upstream of the APCS inlet location;
- Calculate the control efficiencies for PM, acid gases, metals, and CDD/CDF and investigate Hg and CDD/CDF removal efficiency of in-duct carbon injection at two injection rates; and
- Determine the degree of combustion of the feed wastes based on percent carbon and loss on ignition (LOI) of the bottom ash and fly ash collected in the fabric filter.

Key process operating variables, including flue gas oxygen (O_2), carbon dioxide (CO_2), primary and secondary chamber temperatures, air flows, and the total amount of waste charged, were monitored and recorded to document the operating conditions during each test.

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

1.2 SITE DESCRIPTION

Borgess Medical Center is located in Kalamazoo, Michigan. The MWI at this facility is a Cleaver Brooks Model 780-A/31 controlled (starved)-air incinerator that consists of a primary chamber, a thermal reactor (secondary chamber), and a retention chamber (tertiary chamber). The MWI is designed for intermittent duty, and the unit must be shut down and the primary chamber opened to remove the bottom ash from the chamber. The incinerator is rated at a heat input rate of 5.8 x 10^6 kJ/hr (5.5 x 10^6 Btu/hr).

A mechanical hopper/ram charging system feeds waste into the primary chamber of the incinerator. Ash is manually removed from the primary chamber of the incinerator on the morning after each burning day.

The waste heat boiler is a 200 horsepower (1960 kilowatt) Cleaver-Brooks unit with a maximum steam production rating of 6800 lb/hr (3090 kg/hr).

The air pollution control system (APCS) consists of dry lime injection for HCl gas control and a fabric filter baghouse for PM control. Hydrated lime is injected into the duct between the waste heat boiler and the fabric filter baghouse. The fabric filter baghouse is a MicroPul pulse-jet baghouse with continuous cleaning.

Both the incinerator/boiler system and the APCS are described in greater detail in Section 3 of this report.

1.3 PROCESS DATA ACQUISITION

During the emissions tests performed at the Borgess Medical Center MWI facility, process data were collected to document the operating conditions. Process data acquisition was the primary responsibility of the MRI Process Monitor.

Waste charges were weighed on a scale and recorded manually on log sheets by the MRI representative. Natural gas flow rates were read from the utility gas meter and recorded on log sheets. Primary and secondary temperatures, as indicated by the temperature controllers, were recorded manually by MRI. Other pertinent conditions and equipment positions were observed at the control panel and manually recorded by the MRI process monitor.

Primary and secondary chamber temperature signals from the unit's process controller were wired to a data acquisition system. The data logger provided a hard copy record of the temperatures measured. A portable PC computer was connected to the data logger via a parallel port connection. Commercial software was used to collect the output from the data logger and record it on the PC's hard drive.

1.4 EMISSIONS MEASUREMENT PROGRAM

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

1.4.1 Test Matrix

The sampling and analytical matrix performed at the Borgess Medical Center is presented in Table 1-1. Both manual emissions tests and continuous emission monitors (CEMs) were employed for the MWI test program. In addition to flue gas sampling, incinerator bottom ash and fabric filter fly ash samples were taken.

1.4.2 Sampling Methods

Total PM emissions and emissions of 13 toxic metals [aluminum (Al), lead (Pb), chromium (Cr), cadmium (Cd), copper (Cu), 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) rinses was determined gravimetrically. Metals analyses wer 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 were collected on the filter, on a chilled adsorbent trap, and in the impingers. The analysis was completed using high resolution gas chromatography (HRCG) coupled with high resolution mass spectrometry (HRMS) detection.

TABLE 1-1. BORGESS MEDICAL CENTER MWI TEST MATRIX

Sample Location	Number of Runs	Sample Type	Sample Method	Sample Duration	Analysis Method	Laboratory
Boiler Inlet	8	CDD/CDF	EPA Method 23 with	4 hours	GCMS 8290 Mass Spectrometry and High Resolution MS for CDD/CDF	Triangle Labs, Inc.
Boiler Inlet	8	PM	EPA Method 5	4 hours	Gravimetric	Radian
Baghouse Inlet	8	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, respectively	Radian
Baghouse Inlet	8	CDD/CDF	EPA Method 23	4 hours	GCMS 8290 Mass Spectrometry and High Resolution MS for CDD/CDF	Triangle Labs, Inc.
Baghouse Inlet	24	HCl/HBr/HF	EPA Method 26	1 hour	Ion Chromatography	Radian
Baghouse Inlet	8	SO_2 O_2/CO_2 NO_x CO THC HCl	EPA Method 6C EPA Method 3A EPA Method 7E EPA Method 10 EPA Method 25A HCl CEM using dilution probe	Continuous	UV Analyzer CEM Zirconium Oxide Cell/NDIR CEM Chemiluminescence CEM NDIR CEM FID CEM NDIR CEM	Radian

TABLE 1-1. CONTINUED

Sample Location	Number of Runs	Sample Type	Sample Method	Sample Duration	Analysis Method	Laboratory
Stack	8	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, respectively	Radian
Stack	8	CDD/CDF	EPA Method 23 and GC/MS Method 8290	4 hours	Mass Spectrometry and High Resolution MS for CDD/CDF	Triangle Labs, Inc.
Stack	8	HCl/HBr/HF	EPA Method 26	1 hour	Ion Chromatography	Radian
Stack	8	SO_2 O_2/CO_2 THC HCl	EPA Method 6C EPA Method 3A EPA Method 25A HCl CEM using dilution probe	Continuous	UV Analyzer CEM Zirconium Oxide Cell/NDIR CEM FID CEM NDIR CEM	Radian
Incinerator	8	Incinerator Bottom Ash	Representative Composite Sample	1/day	LOI, Carbon, Metals	Radian, McCoy Labs
Incinerator	8	Incinerator Bottom Ash	Representative Composite Sample	1/day	Dioxins/Furans	Triangle Labs, Inc.
Incinerator	8	Baghouse Flyash	Representative Composite Sample	1/day	LOI, Carbon, Metals	Radian, McCoy Labs
Incinerator	8	Baghouse Flyash	Representative Composite Sample	1/day	Dioxins/Furans	Triangle Labs, Inc.

TABLE 1-1. CONTINUED

Sample Location	Number of Runs	Sample Type	Sample Method	Sample Duration	Analysis Method	Laboratory
Lime	8	Lime	Representative Composite Sample	1/day	Metals	Radian
Lime	8	Lime	Representative Composite Sample	1/day	Dioxins/Furans	Triangle Labs, Inc.

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

Gaseous emissions (NO_x, CO, SO_2, THC, and HCl) were measured using CEMs continuously during the day. Hydrogen chloride emissions were measured both manually and with CEMs. The concentration of diluent gases (O_2, CO_2) were measured using CEMs while all 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 in the calculation of flue gas molecular weight for stack gas flow rate calculations.

In addition to the flue gas samples, incinerator bottom ash and baghouse flyash were also sampled during the test program. Daily composites were directed to one laboratory for LOI/carbon content analyses and to another laboratory for metals and CDD/CDF analyses. Lime was also collected and analyzed for metals and CDD/CDF.

Additional descriptions of the sampling and analytical procedures are provided in Section 5.

1.4.3 Laboratory Analyses

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

Samples from particulate matter/metals emission tests were analyzed by Radian's Perimeter Park (PPK) laboratory. Analytical procedures included inductively coupled argon plasma spectroscopy (ICAPS), graphite furnace atomic absorption spectroscopy (GFAAS), and cold vapor atomic absorption spectroscopy (CVAAS). Incinerator ash was also analyzed for metals content using these techniques. Particulate matter was analyzed using gravimetric techniques following EPA Method 5 guidelines. Samples from halogen emission tests were also analyzed at Radian's PPK laboratory. Quantities of chloride, bromide, and fluoride ions in the impinger solutions were determined using IC techniques.

The incinerator ash was analyzed by McCoy Labs for volatile matter (LOI) by ASTM D3174 and for carbon content by ASTM Method D 3178.

1.5 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

All flue gas testing procedures followed comprehensive QA/QC procedures as outlined in the Borgess Medical Center Test Plan and the EPA reference methods. A full description of the resulting QA parameters is given in Section 6 of this report. All post-test leak check criterion were met for all 10 trains. The allowable isokinetic QC range of ±10 percent was met in all test runs except for two runs with the PM/MM5 train at the boiler inlet. Since the deviation was minor, the runs were accepted. All post-test dry gas meter calibration checks were within 5 percent of the full calibration factor.

Field blank results showed CDD/CDF levels similar to the levels in the samples taken from the baghouse outlet during Conditions 2 and 3. This indicates that CDD/CDF emissions at the baghouse outlet during these conditions were near to or below the levels measurable by the testing procedures. The halogen field blank showed no contamination. No contamination was found in the mercury 101A field blank. The front halves of the metals field blanks contained high levels of Al, Cr, and Ni relative to the inlet samples, and high levels of all metals relative to the outlet samples. The back halves of the metals field blanks also showed similar contamination levels relative to the samples especially for Cu and As at the inlet, and for all metals at the outlet. This means that the reported emissions for these metals at the inlet and outlet are probably biased high. Furthermore, where measured levels of metals at only the outlet location were similar to the levels in the field blanks, reported removal efficiencies are lower than the actual removal efficiencies of the metals. This can explain the high degree of dissimilarity between the removal efficiencies of different metals in some runs.

1.6 DESCRIPTION OF REPORT CONTENTS

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

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

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

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

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

2.0 DISCUSSION OF RESULTS

This section presents results of the test program conducted at the Borgess Medical Center from September 7 through 16, 1991. Included in this section are results of manual flue gas tests conducted for CDD/CDF, toxic metals, mercury, PM, and halogens. This section also contains the results of continuous emissions monitoring for O_2, CO_2, CO, NO_x, SO_2, THC, and HCl gases. Results from analyses of incinerator bottom ash and baghouse ash are also included.

Test conditions are defined by the rate of carbon injection into the duct at the baghouse inlet. The carbon injection point was just upstream of a venturi where lime was also injected. Carbon injection rates were 0 lb/hr for 3 tests, 1 lb/hr for the next 2 tests, and 2.5 lb/hr for the last 3 tests. A dry solids screw feeder was used to feed carbon into a funnel and pipe connected to the duct. The carbon was drawn into the duct by negative pressure and mixed with the flue gas in the venturi. The venturi was about 50 feet upstream of the baghouse, which allowed a residence time of approximately 1.4 seconds in the duct before entering the baghouse. Test conditions were as follows:

Condition	Carbon Injection Rate (lb/hr)	Runs
1	0	2 through 4
2	1	5 through 6
3	2.5	7 through 9

The ID fan was adjusted during Run 1 so that the volumetric flow rate of gas through the system was above the target range for the test. Results from Run 1 were, therefore, archived and are not included in this report.

2.1 EMISSIONS TEST LOG

Eight test runs were conducted over eight test days. Flue gas sample locations were at the waste heat boiler inlet, baghouse inlet, and baghouse outlet. One test run was conducted on each day with all sampling trains except the HCl train running simultaneously. Gas concentrations were monitored with the CEMS during the testing period. Table 2-1 presents the emissions test log. This table shows the test date, run number and condition, test type, run times, and port change times for all the flue gas testing conducted during this program.

2.2 CDD/CDF EMISSIONS

2.2.1 Overview

Simultaneous CDD/CDF test runs were conducted at the boiler inlet, baghouse inlet, and baghouse outlet of the Borgess MWI. One 4-hour run was conducted each day, with all trains sampling at the same time.

Daily ash samples from the incinerator and baghouse were also collected. Each ash sample was analyzed for tetra through octa CDD/CDF isomers.

Table 2-2 presents a summary of the CDD/CDF flue gas emissions and ash discharge rates. Flue gas emission rates were found to be higher at the baghouse inlet than at the boiler inlet, indicating that CDD/CDF were formed in the boiler. Baghouse outlet values were lower than baghouse inlet values, indicating a removal of CDD/CDF in the baghouse. Boiler inlet CDD/CDF averages ranged from 101.6 μg/hr to 231.6 μg/hr. Baghouse inlet values ranged from 325.0 μg/hr to 590.7 μg/hr. Baghouse outlet values ranged from 10.24 μg/hr to 201.4 μg/hr.

All CDD/CDF congeners were detected in both the baghouse and bottom ash samples. CDD/CDF baghouse ash discharge rates were higher for Conditions 2 and 3 than Condition 1 indicating that the carbon injection removed CDD/CDF from the flue gas.

Dioxins/furans average emission test results are reported in Section 2.2.2, results from each run in Section 2.2.3, sample parameters are shown in Section 2.2.4, and incinerator ash and baghouse ash CDD/CDF concentrations in Section 2.2.5. All field data and analytical data are shown in Appendices A and E, respectively.

TABLE 2-1. BORGESS MWI SAMPLING TEST LOG

SAMPLE LOCATION	SAMPLE TRAIN	RUN #	DATE	START	STOP	RESTART	END
Boiler Inlet	PM	2	09/07/91	1215	1415	1528	1728
	CDD/CDF	2	09/07/91	1215	1415	1528	1728
Baghouse Inlet	Mercury	2	09/07/91	1215	1415	1525	1725
	PM/Metals	2	09/07/91	1215	1415	1525	1725
	CDD/CDF	2	09/07/91	1215	1415	1525	1725
Baghouse Outlet	Mercury	2	09/07/91	1215	1415	1525	1725
	PM/Metals	2	09/07/91	1215	1415	1525	1725
	CDD/CDF	2	09/07/91	1215	1415	1525	1725
Boiler Inlet	PM	3	09/09/91	1130	1425	1540	1745
	CDD/CDF	3	09/09/91	1130	1425	1540	1745
Baghouse Inlet	Mercury	3	09/09/91	1132	1425	1542	1748
	PM/Metals	3	09/09/91	1132	1425	1542	1748
	CDD/CDF	3	09/09/91	1130	1423	1540	1747
Baghouse Outlet	Mercury	3	09/09/91	1130	1424	1540	1746
	PM/Metals	3	09/09/91	1130	1424	1540	1746
	CDD/CDF	3	09/09/91	1130	1424	1540	1746
Boiler Inlet	PM	4	09/10/91	1205	1405	1515	1715
	CDD/CDF	4	09/10/91	1205	1405	1515	1715
Baghouse Inlet	Mercury	4	09/10/91	1207	1407	1518	1718
	PM/Metals	4	09/10/91	1207	1407	1518	1718
	CDD/CDF	4	09/10/91	1205	1405	1516	1716
Baghouse Outlet	Mercury	4	09/10/91	1207	1407	1516	1716
	PM/Metals	4	09/10/91	1207	1407	1516	1716
	BHO-D4	4	09/10/91	1206	1406	1516	1716
Boiler Inlet	PM	5	09/11/91	1115	1315	1415	1615
	CDD/CDF	5	09/11/91	1115	1315	1415	1615
Baghouse Inlet	Mercury	5	09/11/91	1117	1317	1417	1617
	PM/Metals	5	09/11/91	1117	1317	1417	1617
	CDD/CDF	5	09/11/91	1115	1315	1415	1615
Baghouse Outlet	Mercury	5	09/11/91	1115	1315	1415	1615
	PM/Metals	5	09/11/91	1115	1315	1415	1615
	CDD/CDF	5	09/11/91	1115	1315	1415	1615
Boiler Inlet	PM	6	09/12/91	1230	1510	1620	1820
	CDD/CDF	6	09/12/91	1230	1510	1620	1820
Baghouse Inlet	Mercury	6	09/12/91	1230	1512	1512	1622
	PM/Metals	6	09/12/91	1230	1512	1512	1622
	CDD/CDF	6	09/12/91	1230	1510	1510	1620
Baghouse Outlet	Mercury	6	09/12/91	1230	1512	1620	1820
	PM/Metals	6	09/12/91	1230	1512	1620	1820
	CDD/CDF	6	09/12/91	1230	1512	1620	1820

TABLE 2-1 (CONT'D). BORGESS MWI SAMPLING TEST LOG

SAMPLE LOCATION	SAMPLE TRAIN	RUN #	DATE	START	STOP	RESTART	END
Boiler Inlet	PM	7	09/13/91	948	1148	1245	1445
	CDD/CDF	7	09/13/91	945	1145	1246	1446
Baghouse Inlet	Mercury	7	09/13/91	947	1147	1245	1445
	PM/Metals	7	09/13/91	947	1147	1245	1445
	CDD/CDF	7	09/13/91	945	1145	1245	1445
Baghouse Outlet	Mercury	7	09/13/91	945	1145	1245	1445
	PM/Metals	7	09/13/91	945	1145	1245	1445
	CDD/CDF	7	09/13/91	945	1145	1245	1445
Boiler Inlet	PM	8	09/14/91	1015	1215	1425	1625
	CDD/CDF	8	09/14/91	1015	1215	1425	1625
Baghouse Inlet	Mercury	8	09/14/91	1015	1215	1425	1625
	PM/Metals	8	09/14/91	1015	1215	1425	1625
	CDD/CDF	8	09/14/91	1015	1215	1425	1625
Baghouse Outlet	Mercury	8	09/14/91	1015	1215	1425	1625
	PM/Metals	8	09/14/91	1015	1215	1425	1625
	BHO-D4	8	09/14/91	1015	1215	1425	1625
Boiler Inlet	PM	9	09/16/91	1030	1305	1415	1615
	CDD/CDF	9	09/16/91	1030	1305	1415	1615
Baghouse Inlet	Mercury	9	09/16/91	1030	1305	1416	1616
	PM/Metals	9	09/16/91	1030	1305	1416	1616
	CDD/CDF	9	09/16/91	1030	1305	1416	1616
Baghouse Outlet	Mercury	9	09/16/91	1030	1305	1416	1616
	PM/Metals	9	09/16/91	1030	1305	1416	1616
	BHO-D4	9	09/16/91	1030	1305	1416	1616

TABLE 2-2. SUMMARY OF CDD/CDF TESTS
(FLUE GAS)
BORGESS MEDICAL CENTER (1991)

AVERAGE DAILY EMISSION RATES

	Condition 1			Condition 2			Condition 3		
CONGENER	Boiler Inlet (ug/hr)	Baghouse Inlet (ug/hr)	Baghouse Outlet (ug/hr)	Boiler Inlet (ug/hr)	Baghouse Inlet (ug/hr)	Baghouse Outlet (ug/hr)	Boiler Inlet (ug/hr)	Baghouse Inlet (ug/hr)	Baghouse Outlet (ug/hr)
DIOXINS						[a]			
2378 TCDD	0.07	0.15	0.06	0.07	0.41	[0.04]	0.05	0.38	[0.04]
Other TCDD	0.66	1.18	0.67	4.66	3.58	0.05	1.57	2.97	[0.05]
12378 PCDD	0.23	0.45	0.26	0.27	0.99	[0.13]	0.30	0.90	[0.09]
Other PCDD	0.89	2.05	1.47	1.72	4.96	0.16	2.35	4.97	[0.10]
123478 HxCDD	0.16	0.52	0.47	0.19	1.32	[0.15]	0.35	1.21	[0.10]
123678 HxCDD	0.20	0.77	0.54	0.23	1.39	(0.21)	0.52	1.42	[0.06]
123789 HxCDD	0.35	1.45	0.91	0.44	2.45	0.36	1.07	2.73	[0.08]
Other HxCDD	1.17	4.36	3.68	1.73	8.17	0.83	3.53	9.02	0.20
1234678-HpCDD	1.92	11.63	7.09	2.51	19.98	1.60	6.60	20.24	0.62
Other Hepta-CDD	1.68	9.09	6.93	2.36	18.46	1.71	6.20	19.66	0.47
Octa-CDD	6.41	39.82	15.60	10.46	66.93	4.02	20.60	66.66	2.33
Total CDD	13.73	71.47	37.69	24.63	128.66	8.66	43.13	130.15	3.69
FURANS									
2378 TCDF	6.94	2.49	0.56	4.74	2.64	0.11	2.00	3.63	0.06
Other TCDF	12.65	17.49	15.17	17.24	40.69	1.41	20.48	31.63	0.74
12378 PCDF	1.41	1.90	1.23	1.44	3.84	(0.18)	1.62	3.45	0.09
23478 PCDF	1.58	3.08	2.48	1.86	6.81	0.25	2.59	6.08	0.11
Other PCDF	12.46	25.12	18.68	15.00	58.13	1.33	20.10	54.52	0.17
123478 HxCDF	4.38	16.72	10.11	5.02	26.50	1.06	10.13	25.53	0.34
123678 HxCDF	1.72	5.10	3.30	2.07	9.51	0.36	3.73	9.12	0.12
234678 HxCDF	3.11	17.43	11.79	4.44	27.29	1.18	9.39	25.28	0.41
123789 HxCDF	0.21	0.99	0.35	0.24	0.97	0.00	0.54	1.04	[0.08]
Other HxCDF	7.81	28.23	13.33	9.31	50.00	[0.12]	16.43	42.33	0.10
1234678-HpCDF	8.32	35.49	21.93	10.79	49.44	2.59	24.14	59.02	1.06
1234789-HpCDF	2.01	11.17	5.11	2.27	12.11	0.41	5.78	12.40	0.25
Other Hepta-CDF	8.85	42.13	24.03	10.73	51.75	2.30	22.86	53.26	0.75
Octa-CDF	16.46	46.22	35.70	20.81	122.41	2.94	48.68	118.46	2.40
Total CDF	87.91	253.56	163.75	105.98	462.08	15.15	188.47	445.76	6.55
Total CDF + CDF	101.6	325.03	201.44	130.60	590.74	23.80	231.60	575.92	10.24

[a] [] = Detection limit; () = Estimated maximum possible concentration

TABLE 2-2 (CONT'D). SUMMARY OF CDD/CDF TESTS
(INCINERATOR BOTTOM ASH AND BAGHOUSE ASH)
BORGESS MEDICAL CENTER (1991)

AVERAGE DAILY DISCHARGE RATES (ug/day)[a]

	Condition 1		Condition 2		Condition 3	
CONGENER	Incinerator Bottom Ash	Baghouse Ash	Incinerator Bottom Ash	Baghouse Ash	Incinerator Bottom Ash	Baghouse Ash
DIOXINS						
2378 TCDD	4.38	0.51	1.08	2.81	4.01	4.41
Other TCDD	249.36	6.08	54.17	47.89	260.45	104.92
12378 PCDD	27.03	3.39	6.82	18.25	25.43	22.43
Other PCDD	388.29	23.03	76.89	97.16	391.40	233.01
123478 HxCDD	44.42	6.91	6.87	21.15	32.92	53.05
123678 HxCDD	52.77	9.07	11.36	23.16	42.55	57.75
123789 HxCDD	111.86	17.32	16.43	47.25	82.71	114.99
Other HxCDD	588.79	69.41	84.89	222.94	497.80	690.82
1234678-HpCDD	435.17	168.24	95.74	329.90	348.94	957.49
Other Hepta-CDD	425.32	162.59	88.94	334.39	364.90	877.91
Octa-CDD	822.53	667.35	192.13	928.21	556.41	1,979.81
Total CDD	3,149.9	1,133.89	635.3	2,073.11	2,607.5	5,096.59
FURANS						
2378 TCDF	55.28	4.48	13.35	23.16	57.25	44.83
Other TCDF	1,974.16	126.17	458.13	699.28	1,933.02	1,662.17
12378 PCDF	76.41	12.36	16.66	55.31	67.30	108.52
23478 PCDF	186.56	29.68	38.56	98.54	144.64	232.94
Other PCDF	1,861.19	256.48	451.21	1,165.05	1,519.66	2,181.66
123478 HxCDF	690.34	96.80	109.46	326.92	335.35	892.13
123678 HxCDF	178.30	54.99	38.16	160.46	136.00	306.62
234678 HxCDF	380.86	108.22	90.57	267.00	231.62	658.52
123789 HxCDF	8.18	4.88	52.31	8.96	4.78	24.12
Other HxCDF	892.31	214.00	93.73	715.94	397.88	1,846.06
1234678-HpCDF	930.28	446.63	189.79	972.06	544.73	1,879.45
1234789-HpCDF	79.79	98.07	18.26	164.20	29.76	434.69
Other Hepta-CDF	478.26	450.72	100.27	910.14	288.63	1,932.58
Octa-CDF	500.79	1,132.11	125.62	1,898.27	287.90	3,021.15
Total CDF	8,292.7	3,035.6	1,796.1	7,465.3	6,125.6	15,225.5
Total CDF + CDF	11,442.6	4,169.5	2,431.4	9,538.4	8,733.1	20,322.0

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[a] Baghouse ash discharge rate assumes 12 hr/day operation of the baghouse.

2.2.2 CDD/CDF Average Emission Results

Tables 2-3 through 2-6 present the average CDD/CDF emissions for the test program. 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 through octa homologue total (total CDD, total CDF).

Average CDD/CDF gas concentrations measured at the boiler inlet and the baghouse outlet for the three test conditions are presented in Table 2-3. Stack gas concentrations of all target CDD/CDF congeners were detected during each test condition throughout the program at both the boiler inlet and baghouse inlet. Higher concentrations for the majority of congeners were observed at the baghouse inlet than at the boiler inlet, which indicates that CDD/CDF were formed in the boiler. Dioxins and furans are known to form through several chemical mechanisms. One mechanism is CDD/CDF formation from heavy organics and a chlorine donor (2). The optimum temperature window for this reaction is 500 to 600°F. At temperatures above 750°F, this reaction is slowed considerably (2). The CDD/CDF species may have formed inside the boiler where temperatures of 500 to 600°F occurred. The average boiler inlet temperature was about 1150°F, and the average baghouse inlet temperature was about 360°F. Thus, the flue gas passed through the temperature window of optimum CDD/CDF formation in the boiler.

Average CDD/CDF concentrations corrected to 7 percent O_2 are presented in Table 2-4. Average boiler inlet CDD/CDF concentrations ranged from 70.79 ng/dscm at Condition 1 to 134.9 ng/dscm for Condition 3.

Average total CDD/CDF concentrations at 7 percent O_2 at the baghouse inlet ranged from 237 ng/dscm at Condition 1 to 415 ng/dscm at Condition 3.

Average total CDD/CDF concentrations at 7 percent O_2 at the baghouse outlet ranged from 6.3 ng/dscm for Condition 3 to 131.9 ng/dscm for Condition 1, indicating significant reductions resulting from carbon injection.

TABLE 2-3. CDD/CDF AVERAGE FLUE GAS CONCENTRATIONS AS MEASURED FOR CONDITION 1, 2, AND 3 BORGESS MEDICAL CENTER (1991)[a]

CDD/CDF CONCENTRATION AS MEASURED (ng/dscm)[b]

	CONDITION 1			CONDITION 2			CONDITION 3		
	Boiler Inlet	Baghouse Inlet	Baghouse Outlet	Boiler Inlet	Baghouse Inlet	Baghouse Outlet	Boiler Inlet	Baghouse Inlet	Baghouse Outlet
CONGENER									
DIOXINS									
2378 TCDD	0.023	0.053	0.016	0.021	0.138	[0.012]	0.014	0.135	[0.010][c]
Other TCDD	0.234	0.406	0.172	1.297	1.196	0.014	0.453	1.040	0.014
12378 PCDD	0.080	0.157	0.066	0.075	0.329	[0.033]	0.088	0.314	[0.022]
Other PCDD	0.308	0.725	0.376	0.484	1.663	0.042	0.677	1.754	0.023
123478 HxCDD	0.055	0.182	0.119	0.052	0.440	[0.039]	0.100	0.426	[0.022]
123678 HxCDD	0.069	0.269	0.138	0.066	0.464	0.053	0.150	0.498	0.014
123789 HxCDD	0.121	0.519	0.231	0.124	0.815	0.089	0.307	0.961	0.021
Other HxCDD	0.410	1.533	0.939	0.490	2.715	0.211	1.019	3.173	0.052
1234678-HpCDD	0.666	4.086	1.800	0.718	6.612	0.411	1.900	7.129	0.157
Other Hepta-CDD	0.577	3.117	1.759	0.674	6.114	0.436	1.787	6.918	0.120
Octa-CDD	2.200	14.022	3.964	3.013	21.965	1.047	5.899	23.516	0.598
Total CDD	4.742	25.069	9.581	7.014	42.451	2.232	12.394	45.862	0.944
FURANS									
2378 TCDF	2.282	0.868	0.143	1.366	0.866	0.028	0.581	1.303	0.015
Other TCDF	4.504	6.071	3.876	4.874	13.571	0.359	5.903	11.085	0.188
12378 PCDF	0.490	0.668	0.313	0.407	1.282	0.044	0.470	1.216	0.023
23478 PCDF	0.542	1.081	0.633	0.527	2.268	0.064	0.749	2.137	0.029
Other PCDF	4.371	8.781	4.772	4.246	19.370	0.338	5.803	19.250	0.043
123478 HxCDF	1.486	5.933	2.581	1.428	8.797	0.274	2.921	8.990	0.087
123678 HxCDF	0.592	1.797	0.843	0.586	3.165	0.092	1.076	3.211	0.030
234678 HxCDF	1.042	6.261	3.001	1.260	9.076	0.304	2.709	8.887	0.105
123789 HxCDF	0.072	0.359	0.088	0.069	0.322	[0.028]	0.155	0.368	[0.019]
Other HxCDF	2.719	9.925	3.402	2.640	16.608	0.279	4.745	14.967	0.024
1234678-HpCDF	2.811	12.532	5.578	3.079	16.292	0.670	6.952	20.800	0.269
1234789-HpCDF	0.688	3.978	1.300	0.649	3.966	0.108	1.668	4.370	0.064
Other Hepta-CDF	2.984	14.911	6.118	3.071	17.003	0.601	6.598	18.762	0.193
Octa-CDF	5.602	16.126	9.077	5.990	40.243	0.783	13.996	41.723	0.609
TOTAL CDF	30.184	89.291	41.726	30.191	152.829	3.921	54.325	157.069	1.663
TOTAL CDD+CDF	34.926	114.360	51.306	37.205	195.281	6.153	66.719	202.931	2.607

[a] Detection limits are not considered in the calculation of averages.

[b] Standard conditions are defined as 1 atm and 68 °F.

[c] [] = Average was calculated entirely from detection limits

TABLE 2-4. CDD/CDF AVERAGE FLUE GAS CONCENTRATIONS[a] CORRECTED TO 7% O2 FOR CONDITIONS 1, 2, AND 3 BORGESS MEDICAL CENTER (1991)

CDD/CDF CONCENTRATION AT 7 PERCENT OXYGEN (ng/dscm @ 7% O2)[b]

	CONDITION 1			CONDITION 2			CONDITION 3		
	Boiler Inlet	Baghouse Inlet	Baghouse Outlet	Boiler Inlet	Baghouse Inlet	Baghouse Outlet	Boiler Inlet	Baghouse Inlet	Baghouse Outlet
CONGENER									
DIOXINS									
2378 TCDD	0.048	0.110	0.042	0.043	0.291	[c] [0.030]	0.028	0.278	[0.026]
Other TCDD	0.481	0.860	0.440	2.718	2.513	0.036	0.924	2.168	0.036
12378 PCDD	0.164	0.327	0.168	0.158	0.691	[0.086]	0.180	0.651	[0.055]
Other PCDD	0.626	1.517	0.956	1.017	3.492	0.108	1.375	3.580	0.059
123478 HxCDD	0.111	0.378	0.308	0.110	0.925	[0.102]	0.203	0.875	[0.058]
123678 HxCDD	0.142	0.565	0.357	0.140	0.975	0.140	0.305	1.027	0.036
123789 HxCDD	0.247	1.058	0.596	0.262	1.714	0.117	0.618	1.971	[0.051]
Other HxCDD	0.829	3.177	2.428	1.031	5.712	0.553	2.099	6.524	0.125
1234678-HpCDD	1.354	8.593	4.636	1.515	13.924	1.073	3.823	14.613	0.380
Other Hepta-CDD	1.170	6.755	4.540	1.422	12.872	1.140	3.617	14.215	0.291
Octa-CDD	4.503	29.319	10.105	6.376	46.352	2.720	11.571	48.044	1.427
Total CDD	9.675	52.659	24.578	14.793	89.460	5.818	24.745	93.948	2.266
FURANS									
2378 TCDF	4.561	1.829	0.367	2.891	1.828	0.072	1.225	2.555	0.037
Other TCDF	9.216	12.775	10.022	10.256	28.521	0.940	11.959	22.993	0.465
12378 PCDF	1.005	1.373	0.802	0.856	2.693	0.116	0.970	2.496	0.059
23478 PCDF	1.103	2.255	1.628	1.109	4.767	0.168	1.549	4.403	0.070
Other PCDF	8.819	18.388	12.320	8.937	40.717	0.885	11.864	39.241	0.110
123478 HxCDF	3.025	12.262	6.681	3.012	18.509	0.715	5.931	18.450	0.210
123678 HxCDF	1.206	3.732	2.175	1.234	6.655	0.239	2.195	6.593	0.074
234678 HxCDF	2.124	12.856	7.792	2.653	19.088	0.792	5.509	18.329	0.251
123789 HxCDF	0.147	0.722	0.224	0.145	0.679	[0.073]	0.316	0.747	[0.047]
Other HxCDF	5.440	20.681	8.814	5.559	34.939	0.732	9.740	30.480	0.061
1234678-HpCDF	5.698	26.019	14.380	6.498	34.343	1.745	14.018	42.625	0.649
1234789-HpCDF	1.396	8.174	3.319	1.370	8.375	0.280	3.396	8.951	0.154
Other Hepta-CDF	6.024	31.006	15.728	6.486	35.869	1.562	13.454	38.476	0.456
Octa-CDF	11.349	32.226	23.085	12.671	84.887	2.022	27.995	85.561	1.464
TOTAL CDF	61.114	184.298	107.336	63.676	321.870	10.209	110.122	321.899	4.022
TOTAL CDD+CDF	70.789	236.957	131.914	78.469	411.330	16.028	134.867	415.847	6.288

[a] Detection limits are not considered when calculating averages.

[b] Standard conditions are defined as 1 atm and 68 °F.

[c] [] = Average was calculated entirely from detection limits.

TABLE 2-5. CDD/CDF AVERAGE FLUE GAS TOXIC EQUIVALENCIES

2378 TOXIC EQUIVALENCY CONCENTRATIONS (ng/dscm adjusted to 7 percent O2)[a,b,c]

		Condition 1			Condition 2			Condition 3		
CONGENER	2378 TCDD Toxic Equivalency Factor	Boiler Inlet (ng/dscm)	Baghouse Inlet (ng/dscm)	Baghouse Outlet (ng/dscm)	Boiler Inlet (ng/dscm)	Baghouse Inlet (ng/dscm)	Baghouse Outlet (ng/dscm)	Boiler Inlet (ng/dscm)	Baghouse Inlet (ng/dscm)	Baghouse Outlet (ng/dscm)
DIOXINS										
2378 TCDD	1.000	0.048	0.110	0.042	0.043	0.291	[0.030]	0.028	0.278	[0.026]
Other TCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDD	0.500	0.082	0.163	0.084	0.079	0.346	[0.044]	0.090	0.326	[0.028]
Other PCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.100	0.011	0.038	0.031	0.011	0.092	[0.011]	0.020	0.088	[0.006]
123678 HxCDD	0.100	0.014	0.056	0.036	0.014	0.098	0.014	0.031	0.103	[0.004]
123789 HxCDD	0.100	0.025	0.106	0.060	0.026	0.171	0.023	0.062	0.197	[0.005]
Other HxCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.010	0.014	0.086	0.046	0.015	0.139	0.011	0.038	0.146	0.004
Other Hepta-CDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDD	0.001	0.005	0.029	0.010	0.006	0.046	0.003	0.012	0.048	0.001
Total CDD		0.198	0.589	0.309	0.195	1.183	0.051	0.281	1.186	0.007
FURANS										
2378 TCDF	0.100	(0.456)	0.183	0.037	0.290	0.183	0.007	0.123	0.256	0.004
Other TCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDF	0.050	0.044	0.069	0.040	0.043	0.135	0.006	0.049	0.125	0.003
23478 PCDF	0.500	0.465	1.127	0.814	0.555	2.384	0.084	0.775	2.202	0.035
Other PCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	0.100	0.263	1.226	0.668	0.301	1.851	0.071	0.593	1.845	0.021
123678 HxCDF	0.100	0.100	0.373	0.217	0.123	0.666	0.024	0.219	0.659	0.007
234678 HxCDF	0.100	0.197	1.286	0.779	0.265	1.909	0.079	0.551	1.833	0.025
123789 HxCDF	0.100	0.013	0.072	0.022	0.014	0.068	[0.007]	0.032	0.075	[0.005]
Other HxCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.010	0.047	0.260	0.144	0.065	0.343	0.017	0.140	0.426	0.006
1234789-HpCDF	0.010	0.011	0.082	0.033	0.014	0.084	0.003	0.034	0.090	0.002
Other Hepta-CDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDF	0.001	0.009	0.032	0.023	0.013	0.085	0.002	0.028	0.086	0.001
TOTAL CDF		1.791	4.710	2.778	1.683	7.706	0.291	2.543	7.595	0.103
TOTAL CDD+CDF		1.988	5.299	3.087	1.878	8.890	0.342	2.824	8.781	0.110

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

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

c Non-detects are not included in the totals.

TABLE 2-6. CDD/CDF AVERAGE FLUE GAS EMISSIONS AND BAGHOUSE INLET TO[a] BOILET INLET EMISSIONS RATIOS FOR CONDITIONS 1, 2, AND 3; BORGESS MEDICAL CENTER (1991)

CONGENER	Condition 1 (No Carbon Inj.)			Condition 2 (Carbon Inj. = 1 lb/hr)			Condition 3 (Carbon Inj. = 2.5 lb/hr)		
	Emissions			Emissions			Emissions		
	Boiler Inlet (ug/hr)	Baghouse Inlet (ug/hr)	Baghouse/ Boiler Ratio	Boiler Inlet (ug/hr)	Baghouse Inlet (ug/hr)	Baghouse/ Boiler Ratio	Boiler Inlet (ug/hr)	Baghouse Inlet (ug/hr)	Baghouse/ Boiler Ratio
DIOXINS									
2378 TCDD	0.075	0.150	2.009	0.073	0.415	5.708	0.027	0.384	14.294
Other TCDD	0.749	1.175	1.569	4.658	3.581	0.769	1.077	2.975	2.763
12378 PCDD	0.256	0.446	1.743	0.266	0.987	3.715	0.214	0.896	4.182
Other PCDD	0.987	2.052	2.079	1.719	4.963	2.887	1.560	4.972	3.188
123478 HxCDD	0.175	0.519	2.972	0.185	1.320	7.119	0.228	1.210	5.313
123678 HxCDD	0.222	0.767	3.453	0.234	1.395	5.956	0.354	1.417	4.001
123789 HxCDD	0.389	1.455	3.744	0.437	2.452	5.612	0.651	2.729	4.189
Other HxCDD	1.310	4.363	3.330	1.728	8.170	4.729	2.611	9.019	3.454
1234678-HpCDD	2.136	11.634	5.447	2.515	19.981	7.945	4.010	20.238	5.047
Other Hepta-CDD	1.853	9.087	4.905	2.356	18.460	7.836	3.979	19.659	4.941
Octa-CDD	7.075	39.822	5.629	10.456	66.933	6.401	9.789	66.655	6.809
Total CDD	15.226	71.471	4.694	24.627	128.657	5.224	24.500	130.152	5.312
FURANS									
2378 TCDF	7.378	2.493	0.338	4.740	2.639	0.557	1.728	3.634	2.102
Other TCDF	14.381	17.490	1.216	17.242	40.693	2.360	13.194	31.626	2.397
12378 PCDF	1.573	1.899	1.207	1.441	3.841	2.665	1.208	3.454	2.858
23478 PCDF	1.741	3.083	1.770	1.863	6.805	3.654	1.953	6.082	3.115
Other PCDF	13.972	25.124	1.798	15.000	58.125	3.875	13.963	54.517	3.904
123478 HxCDF	4.787	16.716	3.492	5.020	26.500	5.279	6.631	25.529	3.850
123678 HxCDF	1.901	5.099	2.683	2.067	9.510	4.602	2.530	9.120	3.605
234678 HxCDF	3.365	17.430	5.179	4.442	27.291	6.144	6.214	25.276	4.068
123789 HxCDF	0.231	0.987	4.275	0.242	0.974	4.021	0.361	1.041	2.884
Other HxCDF	8.694	28.233	3.247	9.315	49.999	5.368	11.787	42.335	3.592
1234678-HpCDF	9.058	35.487	3.918	10.789	49.436	4.582	14.898	59.024	3.962
1234789-HpCDF	2.212	11.166	5.049	2.273	12.114	5.330	3.873	12.398	3.201
Other Hepta-CDF	9.614	42.128	4.382	10.730	51.745	4.822	15.475	53.261	3.442
Octa-CDF	18.025	46.225	2.565	20.813	122.413	5.882	27.964	118.465	4.236
TOTAL CDF	96.931	253.559	2.616	105.977	462.084	4.360	121.778	445.763	3.660
TOTAL CDD+CDF	112.156	325.030	2.898	130.604	590.741	4.523	146.278	575.916	3.937

[a] Detection limits are not considered when calculating averages.

Table 2-5 presents average corrected CDD/CDF gas concentrations in 2378 TCDD Toxic Equivalents. The concentration of each congener corrected to 7 percent O_2 was multiplied by its respective Toxic Equivalency Factor (TEF) to determine 2378 Toxic Equivalents. The TEF's used in this report are the international TEF (I-TEF) developed by the North Atlantic Treaty Organization Committee on the Challenges of Modern Society (NATO/CCMS) (1). The average 2378 Toxic Equivalent concentrations (TEC) for total CDD/CDF for Conditions 1, 2 and 3 at the baghouse outlet were 3.1 ng/dscm, 0.34 ng/dscm and 0.11 ng/dscm at 7 percent O_2, respectively.

Table 2-6 presents the boiler inlet and baghouse inlet average CDD/CDF mass emission rates. The ratio of baghouse inlet emissions divided by boiler inlet emissions indicates the amount of CDD/CDF formed in the boiler. This ratio ranges from 2.9 to 4.5 for total CDD/CDF; thus, approximately three to five times more CDD/CDF exited the boiler than entered the boiler.

Table 2-7 shows average CDD/CDF mass emission rates and removal efficiencies for the baghouse inlet and outlet. Total average CDD/CDF removal efficiency for Condition 1 is 38.0 percent, which may be attributable to CDD/CDF adsorption onto the lime and flyash particulate, and subsequent removal in the baghouse. For Conditions 2 and 3, removal efficiencies are 96.0 percent and 98.2 percent, respectively, which indicates improved removal due to carbon injection.

2.2.3 CDD/CDF Flue Gas Results for Each Run

Tables 2-8 through 2-13 present results for the individual CDD/CDF flue gas test runs (Runs 2 through 9). Table 2-8 presents uncorrected CDD/CDF flue gas concentrations at the boiler inlet, baghouse inlet, and baghouse outlet. All congeners were detected at the boiler inlet and baghouse inlet. For Condition 1 with no carbon injection, all congeners were also detected at the baghouse outlet. For Conditions 2 and 3, with carbon injection at 1 lb/hr and 2.5 lb/hr, respectively, several congeners were not detected. Fewer congeners were detected for Condition 3 than for Condition 2, indicating that the additional carbon injection improved removal efficiency for Condition 3. Table 2-9 presents the CDD/CDF flue gas concentrations corrected to 7 percent oxygen.

TABLE 2-7. CDD/CDF AVERAGE STACK EMISSIONS AND BAGHOUSE REMOVAL EFFICIENCIES[a] FOR CONDITIONS 1, 2, AND 3; BORGESS MEDICAL CENTER (1991)

	Condition 1 (No Carbon Inj.)			Condition 2 (Carbon Inj. = 1 lb/hr)			Condition 3 (Carbon Inj. = 2.5 lb/hr)		
	Emissions			Emissions			Emissions		
CONGENER	Baghouse Inlet (ug/hr)	Baghouse Outlet (ug/hr)	Removal Efficiency Ratio	Baghouse Inlet (ug/hr)	Baghouse Outlet (ug/hr)	Removal Efficiency Ratio	Baghouse Inlet (ug/hr)	Baghouse Outlet (ug/hr)	Removal Efficiency Ratio
DIOXINS					[b]				
2378 TCDD	0.150	0.064	57.3%	0.415	[0.045]	89.2%	0.384	[0.041]	89.3%
Other TCDD	1.175	0.672	42.8%	3.581	0.054	98.5%	2.975	0.055	98.2%
12378 PCDD	0.446	0.259	41.9%	0.987	[0.127]	87.1%	0.896	[0.090]	90.0%
Other PCDD	2.052	1.469	28.4%	4.963	0.161	96.8%	4.972	0.090	98.2%
123478 HxCDD	0.519	0.466	10.2%	1.320	[0.151]	88.6%	1.210	[0.096]	90.4%
123678 HxCDD	0.767	0.542	29.3%	1.395	0.214	84.7%	1.417	0.055	96.1%
123789 HxCDD	1.455	0.907	37.6%	2.452	0.179	92.7%	2.729	[0.084]	96.9%
Other HxCDD	4.363	3.682	15.6%	8.170	0.832	89.8%	9.019	0.203	97.7%
1234678-HpCDD	11.634	7.093	39.0%	19.981	1.600	92.0%	20.238	0.617	97.0%
Other Hepta-CDD	9.087	6.927	23.8%	18.460	1.708	90.7%	19.659	0.473	97.6%
Octa-CDD	39.822	15.604	60.8%	66.933	4.017	94.0%	66.655	2.330	96.5%
Total CDD	71.471	37.687	47.3%	128.657	8.657	93.3%	130.152	3.689	97.2%
FURANS									
2378 TCDF	2.493	0.560	77.5%	2.639	0.107	95.9%	3.634	0.060	98.3%
Other TCDF	17.490	15.166	13.3%	40.693	1.413	96.5%	31.626	0.744	97.6%
12378 PCDF	1.899	1.225	35.5%	3.841	0.178	95.4%	3.454	0.090	97.4%
23478 PCDF	3.083	2.477	19.6%	6.805	0.249	96.3%	6.082	0.114	98.1%
Other PCDF	25.124	18.679	25.7%	58.125	1.333	97.7%	54.517	0.175	99.7%
123478 HxCDF	16.716	10.108	39.5%	26.500	1.063	96.0%	25.529	0.342	98.7%
123678 HxCDF	5.099	3.303	35.2%	9.510	0.358	96.2%	9.120	0.120	98.7%
234678 HxCDF	17.430	11.794	32.3%	27.291	1.179	95.7%	25.276	0.413	98.4%
123789 HxCDF	0.987	0.346	65.0%	0.974	[0.108]	88.9%	1.041	[0.078]	92.5%
Other HxCDF	28.233	13.325	52.8%	49.999	1.110	97.8%	42.335	0.096	99.8%
1234678-HpCDF	35.487	21.928	38.2%	49.436	2.590	94.8%	59.024	1.061	98.2%
1234789-HpCDF	11.166	5.107	54.3%	12.114	0.410	96.6%	12.398	0.251	98.0%
Other Hepta-CDF	42.128	24.033	43.0%	51.745	2.303	95.5%	53.261	0.753	98.6%
Octa-CDF	46.225	35.702	22.8%	122.413	2.941	97.6%	118.465	2.395	98.0%
TOTAL CDF	253.559	163.753	35.4%	462.084	15.146	96.7%	445.763	6.554	98.5%
TOTAL CDD+CDF	325.030	201.439	38.0%	590.741	23.803	96.0%	575.916	10.243	98.2%

[a] Detection limits are not considered when calculating averages.

[b] [] = Average was calculated entirely from detection limits.

TABLE 2-8. CDD/CDF FLUE GAS CONCENTRATIONS AS MEASURED FOR CONDITION 1; BORGESS MEDICAL CENTER (1991)

CDD/CDF CONCENTRATIONS AS MEASURED (ng/dscm)[a]

CONGENER	Condition 1 (No Carbon Injection)											
	Boiler Inlet				Baghouse Inlet				Baghouse Outlet			
	RUN 2	RUN 3	RUN 4	AVG.	RUN 2	RUN 3	RUN 4	AVG.	RUN 2	RUN 3	RUN 4	AVG.
DIOXINS	[b]											
2378 TCDD	(0.020)	(0.031)	0.019	0.023	0.030	0.066	0.061	0.053	0.022	(0.013)	(0.014)	0.016
Other TCDD	0.166	0.362	0.174	0.234	0.109	0.597	0.513	0.406	0.220	0.172	0.123	0.172
12378 PCDD	0.062	0.116	0.061	0.080	0.109	0.181	0.179	0.157	0.094	0.066	(0.038)	0.066
Other PCDD	0.297	0.420	0.207	0.308	0.588	0.691	0.897	0.725	0.535	0.374	0.218	0.376
123478 HxCDD	0.046	0.080	0.038	0.055	0.126	0.230	0.190	0.182	0.117	0.150	0.090	0.119
123678 HxCDD	(0.062)	0.094	0.052	0.069	0.174	0.304	0.330	0.269	0.144	0.181	(0.090)	0.138
123789 HxCDD	0.114	0.170	0.080	0.121	0.566	0.523	0.467	0.519	0.256	0.286	0.152	0.231
Other HxCDD	0.395	0.595	0.240	0.410	1.093	1.909	1.597	1.533	1.011	1.101	0.706	0.939
1234678-HpCDD	0.652	0.894	0.452	0.666	2.657	4.361	5.240	4.086	1.753	3.126	0.521	1.800
Other Hepta-CDD	0.619	0.715	0.395	0.577	0.000	4.361	4.989	3.117	1.663	2.950	0.663	1.759
Octa-CDD	2.087	2.772	1.740	2.200	10.192	14.969	16.906	14.022	4.719	6.605	0.568	3.964
Total CDD	4.520	6.249	3.457	4.742	15.645	28.193	31.371	25.069	10.535	15.024	3.183	9.581
FURANS												
2378 TCDF	(3.554)	(1.833)	(1.458)	2.282	(0.375)	(1.151)	(1.077)	0.868	0.189	0.137	0.104	0.143
Other TCDF	3.261	7.242	3.010	4.504	2.308	8.653	7.251	6.071	4.396	3.782	3.449	3.876
12378 PCDF	0.424	0.671	0.376	0.490	0.523	0.872	0.610	0.668	0.409	0.313	0.218	0.313
23478 PCDF	0.554	0.671	0.400	0.542	0.697	1.326	1.220	1.081	0.764	0.661	0.474	0.633
Other PCDF	4.434	6.303	2.375	4.371	4.878	11.200	10.266	8.781	5.524	4.795	3.998	4.772
123478 HxCDF	1.630	1.699	1.129	1.486	5.618	5.792	6.389	5.933	2.831	2.686	2.226	2.581
123678 HxCDF	0.587	0.760	0.428	0.592	1.394	2.024	1.974	1.797	0.944	0.969	0.616	0.843
234678 HxCDF	1.206	1.073	0.847	1.042	7.709	4.396	6.676	6.261	2.742	4.271	1.990	3.001
123789 HxCDF	0.065	0.094	0.056	0.072	0.566	0.216	0.294	0.359	0.126	(0.101)	0.038	0.088
Other HxCDF	3.195	3.706	1.256	2.719	6.969	11.542	11.263	9.925	3.649	3.611	2.946	3.402
1234678-HpCDF	3.326	3.084	2.023	2.811	10.235	13.433	13.927	12.532	5.798	8.190	2.748	5.578
1234789-HpCDF	0.750	0.849	0.466	0.688	4.181	3.733	4.020	3.978	1.573	1.937	(0.388)	1.300
Other Hepta-CDF	3.750	3.174	2.027	2.984	12.848	14.655	17.229	14.911	6.787	8.631	2.937	6.118
Octa-CDF	6.423	6.527	3.857	5.602	10.976	31.193	6.210	16.126	11.416	14.443	1.374	9.077
TOTAL CDF	33.159	37.685	19.708	30.184	69.277	110.188	88.407	89.291	47.146	54.526	23.505	41.726
TOTAL CDD+CDF	37.679	43.934	23.165	34.926	84.922	138.381	119.778	114.360	57.681	69.550	26.688	51.306

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

[b] () = Estimated Maximum Possible Concentration

TABLE 2-8 (CONT'D). CDD/CDF FLUE GAS CONCENTRATIONS AS MEASURED FOR CONDITION 2; BORGESS MEDICAL CENTER (1991)

CDD/CDF CONCENTRATIONS AS MEASURED (ng/dscm)[a]

	Condition 2 (Carbon Injection = 1 lb/hr)								
	Boiler Inlet			Baghouse Inlet			Baghouse Outlet[c]		
CONGENER	RUN 5	RUN 6	AVERAGE	RUN 5	RUN 6	AVERAGE	RUN 5	RUN 6	AVERAGE
DIOXINS									
2378 TCDD	0.015	0.027	0.021	0.063	0.213	0.138	[0.013][b]	[0.010]	[0.012]
Other TCDD	0.147	2.448	1.297	0.507	1.885	1.196	0.013	0.015	0.014
12378 PCDD	0.044	0.106	0.075	0.168	0.490	0.329	[0.036]	[0.030]	[0.033]
Other PCDD	0.235	0.734	0.484	0.529	2.798	1.663	0.049	0.034	0.042
123478 HxCDD	0.034	0.071	0.052	0.215	0.665	0.440	[0.044]	[0.034]	[0.039]
123678 HxCDD	0.049	0.084	0.066	0.263	0.665	0.464	(0.053)	[0.020]	0.053
123789 HxCDD	0.103	0.146	0.124	0.475	1.154	0.815	0.089	[0.025]	0.089
Other HxCDD	0.352	0.627	0.490	1.548	3.882	2.715	0.324	0.098	0.211
1234678-HpCDD	0.684	0.751	0.718	4.655	8.569	6.612	0.533	0.290	0.411
Other Hepta-CDD	0.684	0.663	0.674	4.148	8.080	6.114	0.621	0.251	0.436
Octa-CDD	3.861	2.165	3.013	21.089	22.840	21.965	1.110	0.984	1.047
Total CDD	6.207	7.821	7.014	33.661	51.242	42.451	2.792	1.672	2.232
FURANS									
2378 TCDF	(1.760)	(0.972)	1.366	(0.823)	0.909	0.866	0.036	0.020	0.028
Other TCDF	3.030	6.717	4.874	6.365	20.776	13.571	0.542	0.177	0.359
12378 PCDF	0.239	0.574	0.407	0.570	1.994	1.282	(0.044)	[0.015]	0.044
23478 PCDF	0.347	0.707	0.527	1.108	3.428	2.268	(0.084)	0.044	0.064
Other PCDF	2.835	5.656	4.246	9.500	29.241	19.370	0.533	0.143	0.338
123478 HxCDF	1.222	1.635	1.428	5.351	12.242	8.797	0.342	0.207	0.274
123678 HxCDF	0.420	0.751	0.586	1.678	4.652	3.165	0.124	0.059	0.092
234678 HxCDF	0.929	1.591	1.260	5.035	13.116	9.076	0.382	(0.226)	0.304
123789 HxCDF	0.049	0.088	0.069	0.225	0.420	0.322	[0.031]	[0.025]	[0.028]
Other HxCDF	1.877	3.403	2.640	9.782	23.435	16.608	0.484	0.074	0.279
1234678-HpCDF	2.933	3.226	3.079	13.521	19.063	16.292	0.799	0.541	0.670
1234789-HpCDF	0.635	0.663	0.649	4.085	3.847	3.966	0.098	(0.118)	0.108
Other Hepta-CDF	3.226	2.916	3.071	15.643	18.363	17.003	0.613	0.590	0.601
Octa-CDF	7.429	4.551	5.990	36.415	44.071	40.243	0.533	1.033	0.783
TOTAL CDF	26.931	33.451	30.191	110.101	195.558	152.829	4.611	3.231	3.921
TOTAL CDD+CDF	33.138	41.272	37.205	143.762	246.800	195.281	7.402	4.904	6.153

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

[b] [] = Minimum detection limit; () = Estimated maximum possible concentration.

[c] Detection limits are not considered when calculating averages.

TABLE 2-8 (CONT'D). CDD/CDF FLUE GAS CONCENTRATIONS AS MEASURED FOR CONDITION 3; BORGESS MEDICAL CENTER (1991)

CDD/CDF CONCENTRATIONS AS MEASURED (ng/dscm)[a]

CONGENER	Condition 3 (Carbon Injection = 2.5 lb/hr)											
	Boiler Inlet				Baghouse Inlet				Baghouse Outlet			
	RUN 7	RUN 8	RUN 9	AVG.	RUN 7	RUN 8	RUN 9	AVG.	RUN 7	RUN 8	RUN 9	AVG.[c]
DIOXINS												
2378 TCDD	0.002	0.019	0.020	0.014	0.168	0.128	0.109	0.135	[0.017][b]	[0.009]	[0.005]	[0.010]
Other TCDD	0.394	0.514	0.451	0.453	1.402	1.039	0.680	1.040	[0.017]	(0.014)	[0.005]	0.014
12378 PCDD	0.092	0.090	0.083	0.088	0.392	0.317	0.233	0.314	[0.039]	[0.014]	[0.014]	[0.022]
Other PCDD	0.379	0.928	0.724	0.677	2.033	1.433	1.796	1.754	[0.039]	(0.023)	[0.014]	0.023
123478 HxCDD	0.077	0.114	0.110	0.100	0.464	0.437	0.376	0.426	[0.039]	[0.014]	[0.019]	[0.022]
123678 HxCDD	0.134	0.165	0.150	0.150	0.606	0.474	0.413	0.498	[0.022]	(0.014)	[0.010]	0.014
123789 HxCDD	0.225	0.315	0.381	0.307	1.034	0.948	0.902	0.961	[0.035]	[0.014]	[0.014]	0.021
Other HxCDD	0.728	1.491	0.838	1.019	3.602	3.099	2.817	3.173	(0.052)	0.051	0.053	0.052
1234678-HpCDD	1.337	1.987	2.376	1.900	7.917	6.744	6.724	7.129	0.161	0.161	0.149	0.157
Other Hepta-CDD	1.213	2.109	2.040	1.787	7.846	6.672	6.236	6.918	0.122	0.124	0.115	0.120
Octa-CDD	2.822	4.968	9.908	5.899	24.465	22.603	23.479	23.516	(0.522)	0.552	(0.719)	0.598
Total CDD	7.401	12.700	17.081	12.394	49.929	43.894	43.764	45.862	0.857	0.939	1.036	0.944
FURANS												
2378 TCDF	(0.792)	(0.703)	(0.247)	0.581	(0.963)	(0.729)	2.216	1.303	0.017	0.018	0.010	0.015
Other TCDF	4.653	6.374	6.680	5.903	13.873	11.192	8.189	11.085	0.200	0.258	0.106	0.188
12378 PCDF	0.520	0.509	0.381	0.470	1.355	1.167	1.127	1.216	[0.026]	0.023	[0.010]	0.023
23478 PCDF	0.792	0.873	0.583	0.749	2.675	1.896	1.841	2.137	0.030	(0.032)	0.024	0.029
Other PCDF	4.752	7.029	5.627	5.803	19.864	17.900	19.985	19.250	0.065	0.064	0.000	0.043
123478 HxCDF	2.624	2.933	3.206	2.921	9.736	8.968	8.264	8.990	0.100	0.083	0.077	0.087
123678 HxCDF	1.015	1.115	1.098	1.076	3.495	3.208	2.930	3.211	0.039	0.032	0.019	0.030
234678 HxCDF	2.475	2.739	2.914	2.709	9.237	10.062	7.363	8.887	0.126	0.074	0.115	0.105
123789 HxCDF	0.146	0.158	0.161	0.155	0.357	0.335	0.413	0.368	[0.035]	[0.009]	[0.014]	[0.019]
Other HxCDF	3.715	6.265	4.255	4.745	12.839	16.435	15.627	14.967	0.026	0.046	0.000	0.024
1234678-HpCDF	5.743	6.641	8.473	6.952	21.719	21.035	19.647	20.800	0.322	0.230	0.254	0.269
1234789-HpCDF	1.485	1.769	1.748	1.668	4.494	4.448	4.170	4.370	(0.065)	0.060	0.067	0.064
Other Hepta-CDF	6.238	6.786	6.770	6.598	20.150	18.629	17.506	18.762	0.200	0.124	0.254	0.193
Octa-CDF	10.569	12.433	18.987	13.996	46.362	39.738	39.068	41.723	0.697	0.506	0.624	0.609
TOTAL CDF	45.520	56.326	61.130	54.325	167.118	155.742	148.347	157.069	1.889	1.550	1.549	1.663
TOTAL CDD+CDF	52.921	69.026	78.212	66.719	217.047	199.635	192.111	202.931	2.746	2.489	2.585	2.607

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

[b] [] = Minimum detection limit; () = Estimated maximum possible concentration.

TABLE 2-9. CDD/CDF FLUE GAS CONCENTRATIONS CORRECTED TO 7% O2 FOR CONDITION 1; BORGESS MEDICAL CENTER (1991)

CDD/CDF CONCENTRATIONS CORRECTED TO 7 PERCENT 0XYGEN (ng/dscm @ 7% O2)[a]

	Condition 1 (No Carbon Injection)											
	Boiler Inlet				Baghouse Inlet				Baghouse Outlet			
CONGENER	RUN 2	RUN 3	RUN 4	AVG.	RUN 2	RUN 3	RUN 4	AVG.	RUN 2	RUN 3	RUN 4	AVG.
DIOXINS	[b]											
2378 TCDD	(0.037)	(0.062)	0.044	0.048	0.057	0.131	0.142	0.110	0.053	(0.034)	(0.039)	0.042
Other TCDD	0.309	0.729	0.405	0.481	0.202	1.183	1.195	0.860	0.523	0.456	0.342	0.440
12378 PCDD	0.115	0.234	0.142	0.164	0.202	0.360	0.418	0.327	0.224	0.175	(0.106)	0.168
Other PCDD	0.551	0.847	0.482	0.626	1.091	1.370	2.089	1.517	1.271	0.993	0.606	0.956
123478 HxCDD	0.085	0.162	0.088	0.111	0.234	0.457	0.443	0.378	0.278	0.397	0.250	0.308
123678 HxCDD	(0.115)	0.189	0.120	0.142	0.323	0.602	0.769	0.565	0.342	0.479	(0.250)	0.357
123789 HxCDD	0.212	0.342	0.186	0.247	1.051	1.038	1.086	1.058	0.609	0.759	0.421	0.596
Other HxCDD	0.732	1.198	0.559	0.829	2.029	3.784	3.719	3.177	2.403	2.920	1.962	2.428
1234678-HpCDD	1.210	1.801	1.051	1.354	4.930	8.648	12.201	8.593	4.165	8.293	1.449	4.636
Other Hepta-CDD	1.150	1.441	0.920	1.170	0.000	8.648	11.616	6.755	3.951	7.826	1.844	4.540
Octa-CDD	3.873	5.583	4.052	4.503	18.914	29.681	39.362	29.319	11.213	17.521	1.580	10.105
Total CDD	8.387	12.588	8.049	9.675	29.033	55.903	73.042	52.659	25.031	39.853	8.850	24.578
FURANS												
2378 TCDF	(6.596)	(3.693)	(3.395)	4.561	(0.696)	(2.282)	(2.508)	1.829	0.449	0.362	0.290	0.367
Other TCDF	6.051	14.589	7.009	9.216	4.284	17.158	16.881	12.775	10.444	10.034	9.587	10.022
12378 PCDF	0.787	1.351	0.876	1.005	0.970	1.730	1.421	1.373	0.972	0.829	0.606	0.802
23478 PCDF	1.029	1.351	0.931	1.103	1.293	2.629	2.841	2.255	1.815	1.752	1.317	1.628
Other PCDF	8.229	12.698	5.531	8.819	9.053	22.209	23.902	18.388	13.124	12.720	11.115	12.320
123478 HxCDF	3.025	3.422	2.628	3.025	10.427	11.485	14.876	12.262	6.728	7.125	6.189	6.681
123678 HxCDF	1.089	1.531	0.997	1.206	2.586	4.013	4.596	3.732	2.243	2.570	1.712	2.175
234678 HxCDF	2.239	2.161	1.971	2.124	14.307	8.717	15.544	12.856	6.514	11.330	5.531	7.792
123789 HxCDF	0.121	0.189	0.131	0.147	1.051	0.429	0.685	0.722	0.299	(0.268)	0.105	0.224
Other HxCDF	5.930	7.465	2.924	5.440	12.932	22.887	26.225	20.681	8.671	9.578	8.191	8.814
1234678-HpCDF	6.172	6.214	4.709	5.698	18.995	26.637	32.426	26.019	13.776	21.726	7.638	14.380
1234789-HpCDF	1.392	1.711	1.084	1.396	7.759	7.403	9.360	8.174	3.738	5.139	(1.079)	3.319
Other Hepta-CDF	6.959	6.394	4.720	6.024	23.844	29.058	40.114	31.006	16.125	22.894	8.165	15.728
Octa-CDF	11.920	13.148	8.980	11.349	20.369	61.853	14.458	32.226	27.125	38.312	3.819	23.085
TOTAL CDF	61.538	75.916	45.887	61.114	128.566	218.489	205.838	184.298	112.022	144.641	65.344	107.336
TOTAL CDD+CDF	69.925	88.504	53.937	70.789	157.599	274.392	278.88	236.957	137.054	184.49	74.194	131.914

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

[b] () = Estimated maximum possible concentration

TABLE 2-9 (CONT'D). CDD/CDF FLUE GAS CONCENTRATIONS CORRECTED TO 7% O2 FOR CONDITION 2; BORGESS MEDICAL CENTER (1991)

CDD/CDF CONCENTRATIONS CORRECTED TO 7 PERCENT 0XYGEN (ng/dscm @ 7% O2)[a]

	Condition 2(Carbon Injection = 1 lb/hr)								
	Boiler Inlet			Baghouse Inlet			Baghouse Outlet[c]		
CONGENER	RUN 5	RUN 6	AVERAGE	RUN 5	RUN 6	AVERAGE	RUN 5	RUN 6	AVERAGE
DIOXINS									
2378 TCDD	0.031	0.056	0.043	0.135	0.447	0.291	[b] [0.034]	[0.026]	[0.030]
Other TCDD	0.312	5.125	2.718	1.078	3.947	2.513	0.035	0.038	0.036
12378 PCDD	0.094	0.222	0.158	0.357	1.025	0.691	[0.095]	[0.077]	[0.086]
Other PCDD	0.499	1.536	1.017	1.126	5.858	3.492	0.129	0.088	0.108
123478 HxCDD	0.073	0.148	0.110	0.458	1.391	0.925	[0.116]	[0.087]	[0.102]
123678 HxCDD	0.104	0.176	0.140	0.559	1.391	0.975	(0.140)	[0.051]	0.140
123789 HxCDD	0.218	0.305	0.262	1.011	2.416	1.714	0.234	[0.064]	0.117
Other HxCDD	0.749	1.314	1.031	3.296	8.127	5.712	0.855	0.251	0.553
1234678-HpCDD	1.457	1.573	1.515	9.908	17.939	13.924	1.405	0.742	1.073
Other Hepta-CDD	1.457	1.388	1.422	8.830	16.914	12.872	1.639	0.641	1.140
Octa-CDD	8.219	4.533	6.376	44.891	47.813	46.352	2.927	2.514	2.720
Total CDD	13.213	16.373	14.793	71.651	107.268	89.460	7.363	4.273	5.818
FURANS									
2378 TCDF	(3.746)	(2.035)	2.891	(1.752)	1.904	1.828	0.094	0.050	0.072
Other TCDF	6.450	14.061	10.256	13.548	43.493	28.521	1.428	0.452	0.940
12378 PCDF	0.510	1.203	0.856	1.213	4.174	2.693	(0.116)	[0.038]	0.116
23478 PCDF	0.739	1.480	1.109	2.359	7.176	4.767	(0.222)	0.113	0.168
Other PCDF	6.034	11.841	8.937	20.221	61.212	40.717	1.405	0.364	0.885
123478 HxCDF	2.601	3.423	3.012	11.391	25.627	18.509	0.901	0.528	0.715
123678 HxCDF	0.895	1.573	1.234	3.572	9.738	6.655	0.328	0.151	0.239
234678 HxCDF	1.977	3.330	2.653	10.717	27.458	19.088	1.007	(0.577)	0.792
123789 HxCDF	0.104	0.185	0.145	0.479	0.879	0.679	[0.082]	[0.064]	[0.073]
Other HxCDF	3.995	7.123	5.559	20.821	49.058	34.939	1.276	0.189	0.732
1234678-HpCDF	6.242	6.753	6.498	28.782	39.905	34.343	2.107	1.383	1.745
1234789-HpCDF	1.353	1.388	1.370	8.695	8.054	8.375	0.258	(0.302)	0.280
Other Hepta-CDF	6.867	6.105	6.486	33.298	38.441	35.869	1.616	1.508	1.562
Octa-CDF	15.814	9.528	12.671	77.515	92.258	84.887	1.405	2.639	2.022
TOTAL CDF	57.326	70.026	63.676	234.365	409.376	321.870	12.162	8.257	10.209
TOTAL CDD+CDF	70.539	86.40	78.469	306.02	516.64	411.330	19.525	12.53	16.028

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

[b] [ ] = Detection limit; () = Estimated maximum possible concentration.

[c] Detection limits are not considered when calculating averages.

TABLE 2-10 (CONT'D). CDD/CDF FLUE GAS TOXIC EQUIVALENCIES FOR CONDITION 2

2378 TOXIC EQUIVALENCY CONCENTRATIONS (ng/dscm adjusted to 7 percent O2)[a,b,c]

	2378 TCDD Toxic Equivalency Factor	Condition 2 (Carbon Injection = 1 lb/hr)								
		BOILER INLET			BAGHOUSE INLET			BAGHOUSE OUTLET		
CONGENER		RUN 5	RUN 6	AVERAGE	RUN 5	RUN 6	AVERAGE	RUN 5	RUN 6	AVERAGE
DIOXINS										
2378 TCDD	1.000	0.031	0.056	0.043	0.135	0.447	0.291	[0.034]	[0.026]	[0.030]
Other TCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDD	0.500	0.047	0.111	0.079	0.179	0.513	0.346	[0.048]	[0.039]	[0.044]
Other PCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.100	0.007	0.015	0.011	0.046	0.139	0.092	[0.012]	[0.009]	[0.011]
123678 HxCDD	0.100	0.010	0.018	0.014	0.056	0.139	0.098	(0.014)	[0.005]	0.014
123789 HxCDD	0.100	0.022	0.031	0.026	0.101	0.242	0.171	0.023	[0.006]	0.023
Other HxCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.010	0.015	0.016	0.015	0.099	0.179	0.139	0.014	0.007	0.011
Other Hepta-CDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDD	0.001	0.008	0.005	0.006	0.045	0.048	0.046	0.003	0.003	0.003
Total CDD		0.189	0.312	0.195	0.660	1.706	1.183	0.148	0.095	0.051
FURANS										
2378 TCDF	0.100	(0.375)	(0.204)	0.290	(0.175)	0.190	0.183	0.009	0.005	0.007
Other TCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDF	0.050	0.025	0.060	0.043	0.061	0.209	0.135	[0.006]	[0.002]	0.006
23478 PCDF	0.500	0.369	0.740	0.555	1.180	3.588	2.384	[0.111]	0.057	0.084
Other PCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	0.100	0.260	0.342	0.301	1.139	2.563	1.851	0.090	0.053	0.071
123678 HxCDF	0.100	0.089	0.157	0.123	0.357	0.974	0.666	0.033	0.015	0.024
234678 HxCDF	0.100	0.198	0.333	0.265	1.072	2.746	1.909	0.101	(0.058)	0.079
123789 HxCDF	0.100	0.010	0.019	0.014	0.048	0.088	0.068	[0.008]	[0.006]	[0.007]
Other HxCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.010	0.062	0.068	0.065	0.288	0.399	0.343	0.021	0.014	0.017
1234789-HpCDF	0.010	0.014	0.014	0.014	0.087	0.081	0.084	0.003	[0.003]	0.003
Other Hepta-CDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDF	0.001	0.016	0.010	0.013	0.078	0.092	0.085	0.001	0.003	0.002
TOTAL CDF		1.419	1.946	1.683	4.484	10.929	7.706	0.383	0.215	0.291
TOTAL CDD+CDF		1.609	2.258	1.878	5.144	12.635	8.890	0.531	0.310	0.342

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

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

c Non-detects are not included in the totals.

TABLE 2-10 (CONT'D). CDD/CDF FLUE GAS TOXIC EQUIVALENCIES FOR CONDITION 3

2378 TOXIC EQUIVALENCY CONCENTRATIONS (ng/dscm adjusted to 7 percent O2)[a,b,c]

CONGENER	2378 TCDD Toxic Equivalency Factor	Condition 3 (Carbon Injection = 2.5 lb/hr)											
		BOILER INLET				BAGHOUSE INLET				BAGHOUSE OUTLET			
		RUN 7	RUN 8	RUN 9	AVG.	RUN 7	RUN 8	RUN 9	AVG.	RUN 7	RUN 8	RUN 9	AVG.
DIOXINS													
2378 TCDD	1.000	0.005	0.042	0.036	0.028	0.364	0.274	0.197	0.278	[0.043]	[0.023]	[0.011]	[0.026]
Other TCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDD	0.500	0.099	0.096	0.075	0.090	0.426	0.341	0.210	0.326	[0.049]	[0.018]	[0.015]	[0.028]
Other PCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDD	0.100	0.017	0.024	0.020	0.020	0.101	0.094	0.068	0.088	[0.010]	[0.004]	[0.004]	[0.006]
123678 HxCDD	0.100	0.029	0.035	0.027	0.031	0.132	0.102	0.075	0.103	[0.006]	[0.004]	[0.002]	[0.004]
123789 HxCDD	0.100	0.049	0.068	0.069	0.062	0.225	0.204	0.163	0.197	[0.009]	[0.004]	[0.003]	[0.005]
Other HxCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDD	0.010	0.029	0.043	0.043	0.038	0.172	0.145	0.122	0.146	0.004	0.004	0.003	0.004
Other Hepta-CDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDD	0.001	0.006	0.011	0.018	0.012	0.053	0.049	0.042	0.048	(0.001)	0.001	(0.002)	0.001
Total CDD		0.235	0.319	0.288	0.281	1.472	1.208	0.877	1.186	0.122	0.059	0.040	0.007
FURANS													
2378 TCDF	0.100	(0.172)	(0.151)	(0.045)	0.123	(0.209)	(0.157)	0.401	0.256	0.004	0.005	0.002	0.004
Other TCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12378 PCDF	0.050	0.056	0.055	0.034	0.049	0.147	0.125	0.102	0.125	[0.003]	0.003	[0.001]	0.003
23478 PCDF	0.500	0.860	0.937	0.527	0.775	2.905	2.036	1.664	2.202	0.038	[0.042]	0.026	0.035
Other PCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123478 HxCDF	0.100	0.570	0.630	0.579	0.593	2.115	1.927	1.494	1.845	0.025	0.021	0.017	0.021
123678 HxCDF	0.100	0.220	0.240	0.199	0.219	0.759	0.689	0.530	0.659	0.010	0.008	0.004	0.007
234678 HxCDF	0.100	0.538	0.588	0.527	0.551	2.006	2.162	1.331	1.833	0.032	0.019	0.025	0.025
123789 HxCDF	0.100	0.032	0.034	0.029	0.032	0.077	0.072	0.075	0.075	[0.009]	[0.002]	[0.003]	[0.005]
Other HxCDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1234678-HpCDF	0.010	0.125	0.143	0.153	0.140	0.472	0.452	0.355	0.426	0.008	0.006	0.005	0.006
1234789-HpCDF	0.010	0.032	0.038	0.032	0.034	0.098	0.096	0.075	0.090	[0.002]	0.002	0.001	0.002
Other Hepta-CDF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Octa-CDF	0.001	0.023	0.027	0.034	0.028	0.101	0.085	0.071	0.086	0.002	0.001	0.001	0.001
TOTAL CDF		5.319	4.956	2.159	2.543	8.888	7.801	6.097	7.595	0.119	0.129	0.086	0.103
TOTAL CDD+CDF		5.554	5.275	2.447	2.824	10.360	9.009	6.974	8.781	0.241	0.188	0.126	0.110

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

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

c Non-detects are not included in the totals.

TABLE 2-12. CDD/CDF BAGHOUSE INLET AND OUTLET EMISSIONS AND REMOVAL EFFICIENCIES FOR CONDITION 1; BORGESS MEDICAL CENTER (1991)

CONGENER	RUN 2 EMISSIONS			RUN 3 EMISSIONS			RUN 4 EMISSIONS		
	INLET (ug/hr)	OUTLET (ug/hr)	REMOVAL EFFICIENCY	INLET (ug/hr)	OUTLET (ug/hr)	REMOVAL EFFICIENCY	INLET (ug/hr)	OUTLET (ug/hr)	REMOVAL EFFICIENCY
DIOXINS									
2378 TCDD	0.08	0.087	-9.4%	0.20	(0.052)[a]	74.0%	0.18	(0.054)	69.3%
Other TCDD	0.28	0.851	-200.2%	1.76	0.686	61.1%	1.48	0.479	67.6%
12378 PCDD	0.28	0.365	-28.7%	0.54	0.264	50.8%	0.52	(0.148)	71.5%
Other PCDD	1.53	2.066	-35.0%	2.04	1.494	26.9%	2.58	0.848	67.2%
123478 HxCDD	0.33	0.451	-37.3%	0.68	0.598	12.2%	0.55	0.350	36.1%
123678 HxCDD	0.45	0.556	-22.5%	0.90	0.721	19.7%	0.95	(0.350)	63.2%
123789 HxCDD	1.47	0.990	32.8%	1.55	1.143	26.2%	1.34	0.590	56.1%
Other HxCDD	2.85	3.907	-37.3%	5.64	4.394	22.1%	4.60	2.746	40.3%
1234678-HpCDD	6.92	6.772	2.1%	12.89	12.480	3.2%	15.09	2.027	86.6%
Other Hepta-CDD	0.00	6.425	NA	12.89	11.777	8.7%	14.37	2.580	82.0%
Octa-CDD	26.53	18.233	31.3%	44.26	26.366	40.4%	48.68	2.211	95.5%
Total CDD	40.72	40.703	0.0%	83.35	59.973	28.0%	90.34	12.383	86.3%
FURANS									
2378 TCDF	(0.976)	0.729	25.3%	(3.403)	0.545	84.0%	(3.101)	0.405	86.9%
Other TCDF	6.01	16.983	-182.7%	25.58	15.099	41.0%	20.88	13.416	35.7%
12378 PCDF	1.36	1.580	-16.2%	2.58	1.248	51.6%	1.76	0.848	51.8%
23478 PCDF	1.81	2.952	-62.8%	3.92	2.637	32.7%	3.51	1.843	47.6%
Other PCDF	12.70	21.342	-68.1%	33.11	19.142	42.2%	29.56	15.554	47.4%
123478 HxCDF	14.62	10.940	25.2%	17.12	10.722	37.4%	18.40	8.662	52.9%
123678 HxCDF	3.63	3.647	-0.5%	5.98	3.867	35.4%	5.68	2.396	57.9%
234678 HxCDF	20.07	10.593	47.2%	13.00	17.050	-31.2%	19.23	7.740	59.7%
123789 HxCDF	1.47	0.486	67.0%	0.64	(0.403)	37.0%	0.85	0.147	82.6%
Other HxCDF	18.14	14.100	22.3%	34.13	14.413	57.8%	32.44	11.463	64.7%
1234678-HpCDF	26.64	22.401	15.9%	39.72	32.694	17.7%	40.10	10.689	73.3%
1234789-HpCDF	10.88	6.078	44.2%	11.04	7.734	29.9%	11.58	(1.509)	87.0%
Other Hepta-CDF	33.44	26.221	21.6%	43.33	34.451	20.5%	49.61	11.426	77.0%
Octa-CDF	28.57	44.107	-54.4%	92.22	57.653	37.5%	17.88	5.344	70.1%
TOTAL CDF	180.3	182.158	-1.0%	325.8	217.658	33.2%	254.6	91.442	64.1%
TOTAL CDD+CDF	221.0	222.862	-0.8%	409.1	277.631	32.1%	344.9	103.825	69.9%

[a] [ ] = Detection limit; () = Estimated maximum possible concentration.

TABLE 2-13. CDD/CDF BAGHOUSE INLET AND OUTLET EMISSIONS AND REMOVAL REMOVAL EFFICIENCIES FOR CONDITION 2; BORGESS MEDICAL CENTER (1991)

CONGENER	RUN 5 EMISSIONS			RUN 6 EMISSIONS		
	INLET (ug/hr)	OUTLET (ug/hr)	REMOVAL EFFICIENCY	INLET (ug/hr)	OUTLET (ug/hr)	REMOVAL EFFICIENCY
DIOXINS		[a]				
2378 TCDD	0.20	[0.053]	73.5%	0.63	[0.036]	94.3%
Other TCDD	1.60	0.054	96.6%	5.57	0.053	99.0%
12378 PCDD	0.53	[0.145]	72.6%	1.45	[0.108]	92.6%
Other PCDD	1.67	0.197	88.2%	8.26	0.124	98.5%
123478 HxCDD	0.68	[0.178]	73.8%	1.96	[0.123]	93.7%
123678 HxCDD	0.83	(0.214)	74.2%	1.96	[0.072]	96.3%
123789 HxCDD	1.50	0.359	76.0%	3.41	[0.090]	97.4%
Other HxCDD	4.88	1.309	73.2%	11.46	0.355	96.9%
1234678-HpCDD	14.66	2.151	85.3%	25.30	1.048	95.9%
Other Hepta-CDD	13.07	2.510	80.8%	23.85	0.906	96.2%
Octa-CDD	66.44	4.481	93.3%	67.43	3.553	94.7%
Total CDD	106.04	11.274	89.4%	151.27	6.040	96.0%
FURANS						
2378 TCDF	(2.593)	0.143	94.5%	2.68	0.071	97.4%
Other TCDF	20.05	2.187	89.1%	61.33	0.640	99.0%
12378 PCDF	1.80	(0.178)	90.1%	5.89	[0.054]	99.1%
23478 PCDF	3.49	(0.339)	90.3%	10.12	0.160	98.4%
Other PCDF	29.93	2.151	92.8%	86.32	0.515	99.4%
123478 HxCDF	16.86	1.380	91.8%	36.14	0.746	97.9%
123678 HxCDF	5.29	0.502	90.5%	13.73	0.213	98.4%
234678 HxCDF	15.86	1.542	90.3%	38.72	(0.816)	100.0%
123789 HxCDF	0.71	[0.125]	82.4%	1.24	[0.090]	92.7%
Other HxCDF	30.82	1.954	93.7%	69.18	0.266	99.6%
1234678-HpCDF	42.60	3.227	92.4%	56.28	1.954	96.5%
1234789-HpCDF	12.87	0.394	96.9%	11.36	(0.426)	100.0%
Other Hepta-CDF	49.28	2.474	95.0%	54.21	2.132	96.1%
Octa-CDF	114.72	2.151	98.1%	130.10	3.731	97.1%
TOTAL CDF	346.9	18.622	94.6%	577.3	11.670	98.0%
TOTAL CDD+CDF	452.9	29.896	93.4%	728.6	17.710	97.6%

[a] [ ] = Detection limit; () = Estimated maximum possible concentration.

TABLE 2-15. CDD/CDF EMISSIONS SAMPLING AND FLUE GAS PARAMETERS AT THE BOILER INLET; BORGESS MEDICAL CENTER (1991)

RUN NUMBER DATE	CONDITION 1			
	Run 2 09/07/91	Run 3 09/09/91	Run 4 09/10/91	AVERAGE
Total Sampling Time (min.)	240	239	240	239.67
Average Sampling Rate (dscfm)	0.45	0.33	0.31	0.36
Metered Volume (dscf)	108.31	79	75.07	87.46
Metered Volume (dscm)	3.067	2.237	2.126	2.477
Average Stack Temperature (°F)	1377	1205	1122	1234
O2 Concentration (%V)*	13.4	14.0	14.9	14.1
CO2 Concentration (%V)*	5.0	5.0	4.1	4.7
Stack Gas Moisture (%V)	13.0	21.9	12.9	16.0
Volumetric Flow Rate (dscfm)	1914	1819	1986	1906
Volumetric Flow Rate (dscmm)	54.20	51.51	45.24	50.32
Percent Isokinetic	109.6	109.9	98.9	106.1

RUN NUMBER DATE	CONDITION 2		
	Run 5 09/11/91	Run 6 09/12/91	AVERAGE
Total Sampling Time (min.)	240	240	240.00
Average Sampling Rate (dscfm)	0.3	0.33	0.32
Metered Volume (dscf)	72.26	79.92	76.09
Metered Volume (dscm)	2.046	2.263	2.15
Average Stack Temperature (°F)	1127	1086	1106
O2 Concentration (%V)*	14.4	14.3	14.3
CO2 Concentration (%V)*	4.2	3.9	4.1
Stack Gas Moisture (%V)	13.1	15.1	14.1
Volumetric Flow Rate (dscfm)	1999	2120	2059
Volumetric Flow Rate (dscmm)	56.61	60.03	58.32
Percent Isokinetic	94.6	98.6	96.6

RUN NUMBER DATE	CONDITION 3			
	Run 7 09/13/91	Run 8 09/14/91	Run 9 09/16/91	AVERAGE
Total Sampling Time (min.)	240	240	240	240.00
Average Sampling Rate (dscfm)	0.59	0.61	0.66	0.62
Metered Volume (dscf)	142.67	145.7	157.51	148.63
Metered Volume (dscm)	4.04	4.126	4.461	4.209
Average Stack Temperature (°F)	1166	1166	1302	1211
O2 Concentration (%V)*	14.5	14.4	13.2	14.0
CO2 Concentration (%V)*	3.3	3.1	5.0	3.8
Stack Gas Moisture (%V)	13.5	13.6	15.9	14.3
Volumetric Flow Rate (dscfm)	2006	2025	2084	2038
Volumetric Flow Rate (dscmm)	56.81	57.35	59.01	57.72
Percent Isokinetic	92.9	94.0	98.8	95.2

* O2 and CO2 were measured at the baghouse inlet.

TABLE 2-16. CDD/CDF EMISSIONS SAMPLING AND FLUE GAS PARAMETERS AT THE BAGHOUSE INLET; BORGESS MEDICAL CENTER (1991)

RUN NUMBER DATE	CONDITION 1 Run 2 09/07/91	 Run 3 09/09/91	 Run 4 09/10/91	 AVERAGE
Total Sampling Time (min.)	240	240	240	240
Average Sampling Rate (dscfm)	0.34	0.42	0.41	0.39
Metered Volume (dscf)	81.07	101.19	98.36	93.54
Metered Volume (dscm)	2.296	2.866	2.786	2.649
Average Stack Temperature (°F)	365	359	357	360
O2 Concentration (%V)	13.4	13.9	14.9	14.1
CO2 Concentration (%V)	5.0	4.2	4.1	4.4
Stack Gas Moisture (%V)	12.3	12.5	12.1	12.3
Volumetric Flow Rate (dscfm)	1532	1740	1695	1655
Volumetric Flow Rate (dscmm)	43.38	49.28	48.00	46.88
Percent Isokinetic	104.6	102.7	102.5	103.3

RUN NUMBER DATE	CONDITION 2 Run 5 09/11/91	 Run 6 09/12/91	 AVERAGE
Total Sampling Time (min.)	240	240	240
Average Sampling Rate (dscfm)	0.46	0.42	0.44
Metered Volume (dscf)	111.51	100.96	106.24
Metered Volume (dscm)	3.158	2.859	3.01
Average Stack Temperature (°F)	359	369	364
O2 Concentration (%V)	14.4	14.3	14.3
CO2 Concentration (%V)	4.2	3.9	4.1
Stack Gas Moisture (%V)	12.4	13.5	13.0
Volumetric Flow Rate (dscfm)	1854	1737	1796
Volumetric Flow Rate (dscmm)	52.51	49.20	50.85
Percent Isokinetic	106.3	102.7	104.5

RUN NUMBER DATE	CONDITION 3 Run 7 09/13/91	 Run 8 09/14/91	 Run 9 09/16/91	 AVERAGE
Total Sampling Time (min.)	240	240	240	240
Average Sampling Rate (dscfm)	0.41	0.40	0.39	0.40
Metered Volume (dscf)	99.01	96.86	93.98	96.62
Metered Volume (dscm)	2.804	2.743	2.662	2.736
Average Stack Temperature (°F)	368	360	373	367
O2 Concentration (%V)	14.5	14.4	13.2	14.0
CO2 Concentration (%V)	3.3	3.1	5.0	3.8
Stack Gas Moisture (%V)	13.1	13.3	15.1	13.8
Volumetric Flow Rate (dscfm)	1723	1690	1590	1668
Volumetric Flow Rate (dscmm)	48.79	47.69	45.03	47.17
Percent Isokinetic	101.5	101.2	104.4	102.4

TABLE 2-18. CDD/CDF CONCENTRATIONS IN THE INCINERATOR BOTTOM ASH; BORGESS MEDICAL CENTER (1991)

DATE: RUN NUMBER CONGENER	09/07 2 (ppt.wt)	09/09 3 (ppt.wt)	09/10 4 (ppt.wt)	09/11 5 (ppt.wt)	09/12 6 (ppt.wt)	09/13 7 (ppt.wt)	09/14 8 (ppt.wt)	09/16 9 (ppt.wt)	AVERAGE (ppt.wt)
2378 TCDD	14.0	29.9	12.1	4.0	3.2	11.7	14.7	13.7	12.9
Other TCDD	1,266.0	1,240.1	510.9	207.0	153.8	717.3	489.3	1,426.3	751.3
12378 PCDD	82.7	191.0	71.5	31.2	15.1	86.6	73.6	95.6	80.9
Other PCDD	1,267.3	2,639.0	1,038.5	285.8	224.9	993.4	784.4	2,174.4	1,176.0
123478 HxCDD	114.0	334.0	128.0	27.7	18.3	91.3	103.0	136.0	119.0
123678 HxCDD	169.0	372.0	127.0	54.4	23.2	141.0	106.0	182.0	146.8
123789 HxCDD	273.0	870.0	305.0	65.9	44.1	208.0	252.0	370.0	298.5
Other HxCDD	1,744.0	4,244.0	1,540.0	347.0	222.4	729.7	1,279.0	2,992.0	1,637.3
1234678-HpCDD	1,420.0	3,040.0	1,040.0	442.0	209.0	1,080.0	895.0	1,540.0	1,208.3
Other Hepta-CDD	1,290.0	3,030.0	1,110.0	412.0	193.0	1,040.0	925.0	1,710.0	1,213.8
Octa-CDD	3,240.0	5,110.0	1,890.0	873.0	431.0	1,840.0	1,710.0	2,040.0	2,141.8
Total CDD	10,880.0	21,100.0	7,773.0	2,750.0	1,538.0	6,939.0	6,632.0	12,680.0	8,786.5
FURANS									
2378 TCDF	144.0	408.0	167.0	51.0	37.9	181.0	159.0	236.0	173.0
Other TCDF	4,786.0	15,222.0	5,643.0	1,749.0	1,302.1	6,239.0	5,001.0	8,234.0	6,022.0
12378 PCDF	192.0	550.0	265.0	72.4	40.1	209.0	189.0	279.0	224.6
23478 PCDF	483.0	1,420.0	504.0	165.0	94.9	467.0	411.0	577.0	515.2
Other PCDF	5,585.0	12,920.0	5,481.0	2,022.6	1,035.0	4,874.0	3,950.0	6,484.0	5,294.0
123478 HxCDF	2,080.0	4,850.0	1,930.0	458.0	278.0	(1260.0)	1,370.0	1,960.0	1,773.3
123678 HxCDF	484.0	1,310.0	511.0	179.0	81.0	463.0	378.0	528.0	491.8
234678 HxCDF	1,450.0	2,460.0	827.0	379.0	230.0	858.0	588.0	890.0	960.3
123789 HxCDF	18.3	62.4	27.3	6.5	308.0	19.2	(15.90)	29.8	60.9
Other HxCDF	2,367.7	6,207.6	3,184.7	627.5	44.0	(500.2)	1,498.1	2,952.2	2,047.7
1234678-HpCDF	2,800.0	6,520.0	2,630.0	890.0	403.0	1,230.0	1,890.0	2,330.0	2,336.6
1234789-HpCDF	156.0	684.0	194.0	79.3	44.0	143.0	153.0	(241.0)	211.8
Other Hepta-CDF	1,194.0	3,606.0	1,426.0	450.7	229.0	767.0	947.0	1,179.0	1,224.8
Octa-CDF	1,980.0	2,970.0	1,350.0	556.0	294.0	1,100.0	734.0	1,070.0	1,256.8
TOTAL CDF	23,720.0	59,190.0	24,140.0	7,686.0	4,421.0	17,310.0	17,284.0	26,990.0	22,592.6
TOTAL CDD+CDF	34,600.0	80,290.0	31,913.0	10,436.0	5,959.0	24,249.0	23,916.0	39,670.0	31,379.1

a

ppt.wt = Parts per trillion by weight.

b

( ) = Estimated maximum possible concentration.

TABLE 2-19. CDD/CDF 2378 TCDD TOXIC EQUIVALENCY CONCENTRATIONS IN BOTTOM ASH; BORGESS MEDICAL CENTER (1991)

2378 TCDD TOXIC EQUIVALENCY (ppt.wt)[a,b]

CONGENER	2378 TCDD Toxic Equivalency Factor	Condition 1			Condition 2		Condition 3			Average
		Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	
DIOXINS										
2378 TCDD	1.000	14.0	29.9	12.1	4.0	3.2	11.7	14.7	13.7	12.9
Other TCDD	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12378 PCDD	0.500	41.4	95.5	35.8	15.6	7.6	43.3	36.8	47.8	40.5
Other PCDD	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
123478 HxCDD	0.100	11.4	33.4	12.8	2.8	1.8	9.1	10.3	13.6	11.9
123678 HxCDD	0.100	16.9	37.2	12.7	5.4	2.3	14.1	10.6	18.2	14.7
123789 HxCDD	0.100	27.3	87.0	30.5	6.6	4.4	20.8	25.2	37.0	29.9
Other HxCDD	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1234678-HpCDD	0.010	14.2	30.4	10.4	4.4	2.1	10.8	9.0	15.4	12.1
Other Hepta-CDD	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Octa-CDD	0.001	3.2	5.1	1.9	0.9	0.4	1.8	1.7	2.0	2.1
Total CDD		128.4	318.5	116.1	39.7	21.8	111.7	108.3	147.7	124.0
FURANS										
2378 TCDF	0.100	14.4	40.8	16.7	5.1	3.8	18.1	15.9	23.6	17.3
Other TCDF	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12378 PCDF	0.050	9.6	27.5	13.3	3.6	2.0	10.5	9.5	14.0	11.2
23478 PCDF	0.500	241.5	710.0	252.0	82.5	47.5	233.5	205.5	288.5	257.6
Other PCDF	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
123478 HxCDF	0.100	208.0	485.0	193.0	45.8	27.8	0.0	137.0	196.0	177.3
123678 HxCDF	0.100	48.4	131.0	51.1	17.9	8.1	46.3	37.8	52.8	49.2
234678 HxCDF	0.100	145.0	246.0	82.7	37.9	23.0	85.8	58.8	89.0	96.0
123789 HxCDF	0.100	1.8	6.2	2.7	0.7	30.8	1.9	0.0	3.0	6.1
Other HxCDF	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1234678-HpCDF	0.010	28.0	65.2	26.3	8.9	4.0	12.3	18.9	23.3	23.4
1234789-HpCDF	0.010	1.6	6.8	1.9	0.8	0.4	1.4	1.5	0.0	2.1
Other Hepta-CDF	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Octa-CDF	0.001	2.0	3.0	1.4	0.6	0.3	1.1	0.7	1.1	1.3
TOTAL CDF		700.3	1,721.6	641.1	203.7	147.7	410.9	485.6	691.2	641.5
TOTAL CDD+CDF		828.7	2,040.1	757.2	243.4	169.5	522.6	593.9	838.9	765.5

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

[b] ppt.wt = Parts per trillion by weight.

TABLE 2-22. CDD/CDF 2378 TCDD TOXIC EQUIVALENCY CONCENTRATIONS IN BAGHOUSE ASH; BORGESS MEDICAL CENTER (1991)

2378 TCDD TOXIC EQUIVALENCY (ppt.wt)[a]

CONGENER	2378 TCDD Toxic Equivalency Factor	Condition 1			Condition 2		Condition 3		
		Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
DIOXINS									
2378 TCDD	1.000	0.0	1.5	0.0	4.6	11.7	15.5	12.7	0.0
Other TCDD	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12378 PCDD	0.500	2.9	4.6	7.2	27.4	28.6	41.1	29.0	24.5
Other PCDD	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
123478 HxCDD	0.100	1.2	1.5	3.4	4.1	8.3	15.8	12.5	16.3
123678 HxCDD	0.100	1.9	2.1	3.9	4.4	9.2	16.7	12.2	19.7
123789 HxCDD	0.100	3.5	3.7	8.0	8.4	19.2	37.7	27.6	31.5
Other HxCDD	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1234678-HpCDD	0.010	4.2	4.1	6.6	6.9	12.6	23.5	18.2	38.8
Other Hepta-CDD	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Octa-CDD	0.001	2.0	1.9	2.0	2.4	3.2	5.3	4.7	6.7
Total CDD		15.5	19.4	31.1	58.1	92.8	155.6	116.8	137.4
FURANS									
2378 TCDF	0.100	0.7	1.2	2.0	3.8	9.7	15.5	12.3	9.9
Other TCDF	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12378 PCDF	0.050	1.1	1.6	2.7	4.5	11.5	18.9	14.6	12.2
23478 PCDF	0.500	23.8	33.0	72.5	86.0	201.0	396.5	312.5	270.5
Other PCDF	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
123478 HxCDF	0.100	20.5	21.4	43.1	47.0	141.0	276.0	240.0	233.0
123678 HxCDF	0.100	9.3	12.6	26.0	29.8	64.1	97.5	81.4	78.7
234678 HxCDF	0.100	29.6	21.6	45.0	46.5	109.0	205.0	156.0	193.0
123789 HxCDF	0.100	1.3	1.3	1.7	0.0	0.0	8.5	0.0	7.3
Other HxCDF	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1234678-HpCDF	0.010	9.7	10.8	18.6	20.6	36.9	56.8	51.2	49.7
1234789-HpCDF	0.010	2.3	2.5	3.8	4.4	5.5	14.0	10.1	12.5
Other Hepta-CDF	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Octa-CDF	0.001	3.3	2.9	3.8	5.0	6.5	9.8	8.4	7.1
TOTAL CDF		101.7	108.8	219.2	247.6	585.2	1,098.5	886.5	873.9
TOTAL CDD+CDF		117.2	128.2	250.3	305.7	677.9	1,254.1	1,003.3	1,011.3

[a] ppt.wt = Parts per trillion by weight

NOTE: Condition 1: No Carbon Injection
Condition 2: Carbon Injection = 1 lb/hr
Condition 3: Carbon Injection = 2.5 lb/hr

TABLE 2-23. CDD/CDF DISCHARGE RATE IN THE BAGHOUSE ASH

BORGESS MEDICAL CENTER (1991)

CDD/CDF Discharge Rate (ug/hr)

CONGENER	Condition 1				Condition 2			Condition 3			
	Run 2	Run 3	Run 4	Avg.	Run 5	Run 6	Avg.	Run 7	Run 8	Run 9	Avg.
2378 TCDD	0.02	0.05	0.06	0.04	0.11	0.36	0.23	0.44	0.40	0.27	0.37
Other TCDD	0.36	0.64	0.52	0.51	1.71	6.27	3.99	10.15	6.61	9.47	8.74
12378 PCDD	0.14	0.30	0.41	0.28	1.28	1.76	1.52	2.34	1.81	1.46	1.87
Other PCDD	1.18	1.81	2.76	1.92	3.12	13.08	8.10	24.19	15.27	18.79	19.42
123478 HxCDD	0.29	0.49	0.95	0.58	0.96	2.57	1.76	4.50	3.91	4.85	4.42
123678 HxCDD	0.46	0.69	1.11	0.76	1.02	2.84	1.93	4.75	3.82	5.87	4.81
123789 HxCDD	0.86	1.21	2.27	1.44	1.95	5.92	3.94	10.73	8.64	9.38	9.58
Other HxCDD	3.75	5.15	8.45	5.78	9.00	28.15	18.58	55.16	40.27	77.28	57.57
1234678-HpCDD	10.31	13.16	18.58	14.02	16.12	38.86	27.49	66.89	56.94	115.54	79.79
Other Hepta-CDD	9.60	12.81	18.24	13.55	16.87	38.86	27.87	63.47	61.01	94.99	73.16
Octa-CDD	49.22	59.83	57.79	55.61	56.61	98.09	77.35	151.14	145.48	198.33	164.98
Total CDD	76.19	96.14	111.14	94.49	108.75	236.76	172.76	393.76	344.16	536.23	424.72
FURANS											
2378 TCDF	0.17	0.40	0.55	0.37	0.88	2.98	1.93	4.41	3.85	2.95	3.74
Other TCDF	4.92	9.01	17.61	10.51	22.99	93.56	58.27	147.87	142.58	125.10	138.51
12378 PCDF	0.53	1.04	1.52	1.03	2.12	7.09	4.61	10.76	9.10	7.27	9.04
23478 PCDF	1.18	2.13	4.11	2.47	4.02	12.40	8.21	22.57	19.55	16.11	19.41
Other PCDF	11.01	19.36	33.75	21.37	39.71	154.47	97.09	209.46	186.91	149.04	181.80
123478 HxCDF	5.07	6.92	12.21	8.07	11.00	43.49	27.24	78.56	75.09	69.38	74.34
123678 HxCDF	2.31	4.08	7.37	4.58	6.97	19.77	13.37	27.75	25.47	23.44	25.55
234678 HxCDF	7.32	6.99	12.75	9.02	10.88	33.62	22.25	58.35	48.81	57.47	54.88
123789 HxCDF	0.32	0.41	0.48	0.41	0.42	1.08	0.75	2.41	1.46	2.16	2.01
Other HxCDF	12.18	14.92	26.40	17.83	20.80	98.52	59.66	165.10	157.04	139.37	153.84
1234678-HpCDF	24.04	34.93	52.69	37.22	48.19	113.82	81.00	161.67	160.19	148.00	156.62
1234789-HpCDF	5.71	7.96	10.85	8.17	10.34	17.03	13.68	39.85	31.60	37.22	36.22
Other Hepta-CDF	24.41	35.38	52.89	37.56	52.12	99.57	75.84	164.80	154.56	163.78	161.05
Octa-CDF	82.36	92.17	108.49	94.34	116.50	199.87	158.19	279.80	264.06	211.43	251.76
TOTAL CDF	181.5	235.7	341.7	253.0	346.9	897.3	622.1	1,373.4	1,280.3	1,152.7	1,268.8
TOTAL CDD+CDF	257.7	331.8	452.8	347.5	455.7	1,134.0	794.9	1,767.1	1,624.4	1,689.0	1,693.5

( ) = Estimated Maximum Possible Detection Limit.

- 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 (i.e., non detects = zero)
- If a metal was not detected in any fraction of a sample train, the sum of the non-detects for each fraction was used as the overall sample detection limit.

For the purpose of calculating average results:

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

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

2.3.3 Metals Emissions

Tables 2-25 through 2-27 present the metals emissions results for each test condition. During the emission tests without carbon injection, Hg had the highest average mass rate at the inlet with 10.7 g/hr, followed by Pb with 2.32 g/hr. Beryllium and Tl were not collected in detectable amounts for any of the runs at the inlet or outlet during these emissions test conditions. Mercury was the most prevalent element collected for the three runs at the outlet during this condition with an average emission rate of 12.5 g/hr, followed by Al with 0.341 g/hr. Sample results for Ag showed negative removal efficiencies for two of the three runs. Analysis of samples from Run 2 indicated a substantially higher mass emission rate of Ag at the outlet of 0.0140 g/hr versus 0.00750 g/hr at the inlet. Run 4 showed similar outlet and inlet mass emission rates of Ag of 0.00726 g/hr and 0.00517 g/hr , respectively. Chromium showed a negative removal efficiency in Run 4 with inlet and outlet mass rates of 0.00343 g/hr

Table 2-25

AVERAGE METALS EMISSION RATES AND REMOVAL EFFICIENCIES FOR- BORGESS MEDICAL CENTER (1991)

*** WITHOUT CARBON INJECTION ***

Condition	Without Carbon Injection											
	Run 2			Run 3			Run 4			Average Burn Emissions		
Location	Inlet (g/hr)	Outlet (g/hr)	RE (%)	Inlet (g/hr)	Outlet (g/hr)	RE (%)	Inlet (g/hr)	Outlet (g/hr)	RE (%)	Inlet (g/hr)	Outlet (g/hr)	RE (%)
Aluminum	1.22	0.328	73.1%	1.82	0.342	81.2%	1.23	0.352	71.3%	1.42	0.341	76.1%
Antimony	0.214	0.0267	87.5%	0.631	0.0239	96.2%	0.500	0.0205	95.9%	0.448	0.0237	94.7%
Arsenic	0.00839	[0.00148]	> 82.4%	0.0119	0.000782	93.5%	0.00977	0.00184	81.2%	0.0100	0.00131	86.9%
Barium	0.139	0.00697	95.0%	0.234	0.00900	96.1%	0.0934	0.00880	90.6%	0.155	0.00826	94.7%
Beryllium	[0.000312]	[0.000370]	NA	0.00100	[0.000329]	> 67.1%	[0.000311]	[0.000365]	NA	0.00100	[0.000355]	>64.5%
Cadmium	0.623	0.00161	99.7%	0.595	0.00285	99.5%	0.619	0.00377	99.4%	0.612	0.00274	99.6%
Chromium	0.0431	0.0152	64.8%	0.0756	0.0502	33.6%	0.0343	0.0344	-0.238%	0.0510	0.0333	34.8%
Copper	1.20	0.284	76.3%	2.00	0.0919	95.4%	1.20	0.0637	94.7%	1.47	0.147	90.0%
Lead	1.50	0.00501	99.7%	3.57	0.00496	99.9%	1.91	0.0113	99.4%	2.32	0.00708	99.7%
Mercury	15.1	17.4	-15.5%	11.9	14.1	-18.4%	5.23	6.06	-15.9%	10.7	12.5	-16.6%
Nickel	0.0521	0.0290	44.4%	0.0849	0.0550	35.2%	0.0790	0.0672	15.0%	0.0720	0.0504	30.1%
Silver	0.00750	0.0140	-87.3%	0.0325	0.00241	92.6%	0.00517	0.00726	-40.3%	0.0151	0.00791	47.5%
Thallium	[0.0312]	[0.0369]	NA	[0.0311]	[0.0352]	NA	[0.0311]	[0.0365]	NA	[0.0311]	[0.0362]	NA

NA = Not Applicable

[ ] = Minimum Detection Limit

and 0.00344 g/hr, respectively. The differences can be attributed to round-off error. Analytical values for Ag and Cr showed values less than five times the detection limit. The test results also showed negative Hg removal efficiencies.

During the emission tests with carbon injection at 1 lb/hr, Hg had the highest average mass rate for the inlet runs with 11.3 g/hr, followed by Pb with 3.21 g/hr. As with the emission tests without carbon injection, Be and Tl were not collected in detectable amounts for any of the runs at the inlet and outlet. Mercury was emitted at the highest rate for the runs at the outlet during this condition, with an average emission rate of 1.52 g/hr.

During the emission tests with carbon injection at 2.5 lb/hr, Hg had the highest average mass rate for the inlet runs at 14.5 g/hr, followed by Pb at 2.26 g/hr. As with the conditions above, Be and Tl were not collected in detectable amounts for any of the runs at the inlet and outlet. Mercury was again emitted at the highest rate for these runs at the outlet with an average emission rate of 0.714 g/hr. Sample results for Ag and Ni showed negative removal efficiencies for Run 7. Results for Ag showed a substantially higher mass rate at the outlet of 0.0166 g/hr versus 0.0135 g/hr at the inlet. Results for Ni showed similar outlet and inlet mass rates of 0.0503 g/hr at the outlet, and 0.0495 g/hr at the inlet.

The average removal efficiencies calculated for Cr increased with increasing carbon injection from 34.8 percent without carbon, to 67.6 percent with carbon injection at 1 lb/hr, to 70.9 percent with carbon injection at 2.5 lb/hr. The removal efficiencies calculated for Hg increased from -16.6 percent without carbon, to 87.0 percent with carbon injection at 1 lb/hr, to 95.1 percent with carbon injection at 2.5 lb/hr. For the other metals analyzed, the removal efficiencies did not change significantly with carbon injection rates.

2.3.4 Metals Flue Gas Concentrations

Metal concentrations, mass rates, and removal efficiencies are presented for each run in Tables 2-28 through 2-35. Also shown for each run are the location, date, metered volume, O_2 concentration, and flow rate. Flue gas concentrations are given in

Table 2-28

METALS CONCENTRATION EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 2 - BORGESS MEDICAL CENTER (1991) WITHOUT CARBON INJECTION

Location		Inlet	Outlet	Removal Efficiencies (%)
Date		09/07/91	09/07/91	
Metered Volume (dscm)		3.354	2.394	
O2 Concentration (%V)		13.41	15.05	
Flow Rate (dscmm)		48.643	69.208	
Aluminum	(ug/dscm)	417	78.9	
	(ug/dscm @ 7% O2)	775	188	
	(g/hr)	1.22	0.328	73.1%
Antimony	(ug/dscm)	73.3	6.43	
	(ug/dscm @ 7% O2)	136	15.3	
	(g/hr)	0.214	0.0267	87.5%
Arsenic	(ug/dscm)	2.87	[0.356]	
	(ug/dscm @ 7% O2)	5.33	[.846]	
	(g/hr)	0.00839	[0.00148]	> 82.4%
Barium	(ug/dscm)	47.7	1.68	
	(ug/dscm @ 7% O2)	88.5	3.99	
	(g/hr)	0.139	0.00697	95.0%
Beryllium	(ug/dscm)	[0.107]	[0.089]	
	(ug/dscm @ 7% O2)	[0.198]	[0.211]	
	(g/hr)	[0.000312]	[0.000370]	NA
Cadmium	(ug/dscm)	213	0.388	
	(ug/dscm @ 7% O2)	396	0.923	
	(g/hr)	0.623	0.00161	99.7%
Chromium	(ug/dscm)	14.8	3.65	
	(ug/dscm @ 7% O2)	27.4	8.67	
	(g/hr)	0.0431	0.0152	64.8%
Copper	(ug/dscm)	411	68.5	
	(ug/dscm @ 7% O2)	764	163	
	(g/hr)	1.20	0.284	76.3%
Lead	(ug/dscm)	513	1.21	
	(ug/dscm @ 7% O2)	952	2.87	
	(g/hr)	1.50	0.00501	99.7%
Mercury	(ug/dscm)	5160	4180	
	(ug/dscm @ 7% O2)	9580	9930	
	(g/hr)	15.1	17.4	-15.5%
Nickel	(ug/dscm)	17.9	6.98	
	(ug/dscm @ 7% O2)	33.1	16.6	
	(g/hr)	0.0521	0.0290	44.4%
Silver	(ug/dscm)	2.57	3.38	
	(ug/dscm @ 7% O2)	4.77	8.04	
	(g/hr)	0.00750	0.0140	-87.3%
Thallium	(ug/dscm)	[10.7]	[8.90]	
	(ug/dscm @ 7% O2)	[19.8]	[21.1]	
	(g/hr)	[0.0312]	[0.0369]	NA

NA = Not Applicable

[ ] = Minimum Detection Limit

Table 2-31

METALS CONCENTRATION EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 5 - BORGESS MEDICAL CENTER (1991)

CARBON INJECTION @ 1 lb/hr.

Location		**Inlet**	**Outlet**	**Removal Efficiencies (%)**
Date		09/07/91	09/07/91	
Metered Volume (dscm)		3.714	2.747	
O2 Concentration (%V)		14.37	15.63	
Flow Rate (dscmm)		53.117	79.401	
Aluminum	(ug/dscm)	409	74.6	
	(ug/dscm @ 7% O2)	871	197	
	(g/hr)	1.30	0.356	72.7%
Antimony	(ug/dscm)	296	3.71	
	(ug/dscm @ 7% O2)	630	9.79	
	(g/hr)	0.944	0.0177	98.1%
Arsenic	(ug/dscm)	3.12	[0.310]	
	(ug/dscm @ 7% O2)	6.65	[0.818]	
	(g/hr)	0.00995	[0.00148]	> 85.1%
Barium	(ug/dscm)	58.7	1.48	
	(ug/dscm @ 7% O2)	125	3.90	
	(g/hr)	0.187	0.00704	96.2%
Beryllium	(ug/dscm)	[0.0961]	[0.0761]	
	(ug/dscm @ 7% O2)	[0.205]	[0.201]	
	(g/hr)	[0.000306]	[0.000362]	NA
Cadmium	(ug/dscm)	162	0.790	
	(ug/dscm @ 7% O2)	346	2.08	
	(g/hr)	0.517	0.00376	99.3%
Chromium	(ug/dscm)	16.3	3.68	
	(ug/dscm @ 7% O2)	34.6	9.70	
	(g/hr)	0.0518	0.0175	66.2%
Copper	(ug/dscm)	590	6.55	
	(ug/dscm @ 7% O2)	1255	17.3	
	(g/hr)	1.88	0.0312	98.3%
Lead	(ug/dscm)	1220	2.26	
	(ug/dscm @ 7% O2)	2600	5.96	
	(g/hr)	3.89	0.0108	99.7%
Mercury	(ug/dscm)	2960	291	
	(ug/dscm @ 7% O2)	6300	767	
	(g/hr)	9.43	1.39	85.3%
Nickel	(ug/dscm)	36.3	4.33	
	(ug/dscm @ 7% O2)	77.4	11.4	
	(g/hr)	0.116	0.0206	82.2%
Silver	(ug/dscm)	6.30	[0.455]	
	(ug/dscm @ 7% O2)	13.4	[1.20]	
	(g/hr)	0.0201	[0.00217]	> 89.2%
Thallium	(ug/dscm)	[9.61]	[7.61]	
	(ug/dscm @ 7% O2)	[20.5]	[20.1]	
	(g/hr)	[0.0306]	[0.0362]	NA

NA = Not Applicable

[ ] = Minimum Detection Limit

Table 2-32

METALS CONCENTRATION EMISSION RATES AND REMOVAL EFFICIENCIES
FOR RUN 6 - BORGESS MEDICAL CENTER (1991)
CARBON INJECTION @ 1 lb/hr.

Location		Inlet	Outlet	
Date		09/07/91	09/07/91	Removal Efficiencies (%)
Metered Volume (dscm)		3.814	2.506	
O2 Concentration (% V)		14.26	15.46	
Flow Rate (dscmm)		54.406	67.901	
Aluminum	(ug/dscm)	288	83.0	
	(ug/dscm @ 7% O2)	604	212	
	(g/hr)	0.941	0.338	64.1%
Antimony	(ug/dscm)	194	4.19	
	(ug/dscm @ 7% O2)	406	10.7	
	(g/hr)	0.633	0.0171	97.3%
Arsenic	(ug/dscm)	3.12	0.575	
	(ug/dscm @ 7% O2)	6.53	1.47	
	(g/hr)	0.0102	0.00234	77.0%
Barium	(ug/dscm)	76.3	2.07	
	(ug/dscm @ 7% O2)	160	5.28	
	(g/hr)	0.249	0.00842	96.6%
Beryllium	(ug/dscm)	[0.0939]	[0.0830]	
	(ug/dscm @ 7% O2)	[0.196]	[0.212]	
	(g/hr)	[0.000306]	[0.000338]	NA
Cadmium	(ug/dscm)	1680	0.942	
	(ug/dscm @ 7% O2)	3520	2.41	
	(g/hr)	5.48	0.00384	99.9%
Chromium	(ug/dscm)	31.2	7.94	
	(ug/dscm @ 7% O2)	65.3	20.3	
	(g/hr)	0.102	0.0324	68.2%
Copper	(ug/dscm)	372	7.46	
	(ug/dscm @ 7% O2)	779	19.1	
	(g/hr)	1.22	0.0304	97.5%
Lead	(ug/dscm)	773	1.48	
	(ug/dscm @ 7% O2)	1620	3.78	
	(g/hr)	2.52	0.00603	99.8%
Mercury	(ug/dscm)	4040	407	
	(ug/dscm @ 7% O2)	8460	1040	
	(g/hr)	13.2	1.66	87.4%
Nickel	(ug/dscm)	62.9	7.22	
	(ug/dscm @ 7% O2)	132	18.5	
	(g/hr)	0.205	0.0294	85.7%
Silver	(ug/dscm)	5.37	2.77	
	(ug/dscm @ 7% O2)	11.3	7.07	
	(g/hr)	0.0175	0.0113	35.8%
Thallium	(ug/dscm)	[9.36]	[8.30]	
	(ug/dscm @ 7% O2)	[19.6]	[21.2]	
	(g/hr)	[0.0306]	[0.0338]	NA

NA = Not Applicable
[ ] = Minimum Detection Limit

Table 2-35

METALS CONCENTRATION EMISSION RATES AND REMOVAL EFFICIENCIES FOR RUN 9 - BORGESS MEDICAL CENTER (1991) CARBON INJECTION @ 2.5 lb/hr.

Location		Inlet	Outlet	Removal Efficiencies (%)
Date		09/07/91	09/07/91	
Metered Volume (dscm)		3.616	2.545	
O2 Concentration (%V)		13.21	14.45	
Flow Rate (dscmm)		49.014	71.42	
Aluminum	(ug/dscm)	293	68.4	
	(ug/dscm @ 7% O2)	530	147	
	(g/hr)	0.862	0.293	66.0%
Antimony	(ug/dscm)	110	3.69	
	(ug/dscm @ 7% O2)	198	7.95	
	(g/hr)	0.323	0.0158	95.1%
Arsenic	(ug/dscm)	3.15	[0.328]	
	(ug/dscm @ 7% O2)	5.70	[0.707]	
	(g/hr)	0.00927	[0.00141]	> 84.8%
Barium	(ug/dscm)	47.0	2.25	
	(ug/dscm @ 7% O2)	85.0	4.84	
	(g/hr)	0.138	0.00963	93.0%
Beryllium	(ug/dscm)	[0.0987]	0.2094	
	(ug/dscm @ 7% O2)	[0.178]	0.451	
	(g/hr)	[0.000290]	0.000897	NA
Cadmium	(ug/dscm)	382	0.833	
	(ug/dscm @ 7% O2)	690	1.80	
	(g/hr)	1.12	0.00357	99.7%
Chromium	(ug/dscm)	11.7	4.56	
	(ug/dscm @ 7% O2)	21.1	9.82	
	(g/hr)	0.0344	0.0195	43.2%
Copper	(ug/dscm)	572	3.77	
	(ug/dscm @ 7% O2)	1040	8.12	
	(g/hr)	1.68	0.0161	99.0%
Lead	(ug/dscm)	973	3.54	
	(ug/dscm @ 7% O2)	1760	7.63	
	(g/hr)	2.86	0.0152	99.5%
Mercury	(ug/dscm)	7330	141	
	(ug/dscm @ 7% O2)	13200	303	
	(g/hr)	21.6	0.603	97.2%
Nickel	(ug/dscm)	15.7	8.25	
	(ug/dscm @ 7% O2)	28.3	17.8	
	(g/hr)	0.0461	0.0354	23.3%
Silver	(ug/dscm)	5.17	2.29	
	(ug/dscm @ 7% O2)	9.35	4.95	
	(g/hr)	0.0152	0.00983	35.3%
Thallium	(ug/dscm)	[9.87]	[8.21]	
	(ug/dscm @ 7% O2)	[17.8]	[17.7]	
	(g/hr)	[0.0290]	[0.0352]	NA

NA = Not Applicable

[ ] = Minimum Detection Limit

terms of μg/dscm, both with and without correction to 7 percent O_2. Oxygen concentrations were calculated from CEM data, which were averaged over the time period in which manual testing was performed.

2.3.5 Flue Gas Metals to PM Ratios

A summary of the ratio of metals to PM for the emission tests without carbon injection is presented in Table 2-36. Metals to PM ratios are given in units of milligrams of metal to grams of PM collected by the sampling train. The inlet values range from 0.0208 mg Ag per gram of PM during Run 4 to 57.2 mg Hg per gram during Run 2. Mercury had the highest inlet ratios for Runs 3 and 4 also, with 39.9 and 21.0 mg metal/gram PM, respectively. Outlet values range from 0.0912 mg Cd per gram of PM during Run 2 to 2270 mg Hg per gram of PM during Run 3. High Hg-to-PM ratios can be misleading, however, since most Hg is in a volatile form at the particulate filter temperature, and is, therefore, not associated with PM, but is captured in the back-half impinger solutions.

Table 2-37 presents a summary of the ratio by weight of metals to PM for the emission tests with carbon injection at 1 lb/hr. Inlet values range from 0.037 mg As per gram of PM in Run 5 to 53.4 mg Hg per gram of PM in Run 6. Mercury had the highest ratio for Run 5 also, with 34.9 mg metal per gram of PM. Values at the outlet range from 0.293 mg of As per gram of PM in Run 6 to 316 mg of Hg per gram of PM in Run 5. Mercury also had the highest outlet ratio for Run 6 with 208 mg of metal per gram of PM.

Table 2-38 presents a summary of the ratio by weight of metals to PM for the emission tests with carbon injection at 2.5 lb/hr. Inlet values range from 0.009 mg As per gram of PM in Run 7 to 86.3 mg Hg per gram of PM in Run 9. Mercury also had the highest ratio for Runs 7 and 8 with 46.4 and 34.3 mg Hg per gram of PM, respectively. Outlet values range from 0.188 mg Ag per gram of PM in Run 8 to 172 mg of Hg per gram of PM in Run 7. Aluminum had the highest ratio in Run 8 with 26.2 mg metal per gram of PM, and Hg in Run 9, with 87.4 mg metal per gram of PM.

Table 2-38
RATIO OF METALS TO PARTICULATE MATTER - BORGESS MEDICAL CENTER (1991)
* CARBON INJECTION AT 2.5 lb/hr *

	METALS/PARTICULATE RATIO (mg metal per gram of particulate)							
Location	INLET				OUTLET			
Run	Run 7 (mg/g)	Run 8 (mg/g)	Run 9 (mg/g)	Average (mg/g)	Run 7 (mg/g)	Run 8 (mg/g)	Run 9 (mg/g)	Average (mg/g)
Aluminum	3.25	4.34	3.45	3.68	38.4	26.2	42.5	35.7
Antimony	0.448	1.75	1.29	1.16	2.21	1.14	2.29	1.88
Arsenic	0.00909	0.0269	0.0371	0.0244	[0.182]	[0.0902]	[0.204]	[0.159]
Barium	0.233	1.05	0.554	0.613	0.978	0.639	1.40	1.00
Beryllium	[0.00112]	[0.00107]	[0.00116]	[0.00112]	[0.0455]	[0.0224]	0.130	0.130
Cadmium	1.32	6.08	4.49	3.96	0.217	3.13	0.517	1.29
Chromium	0.288	0.276	0.138	0.234	2.01	1.29	2.83	2.04
Copper	1.04	5.57	6.74	4.45	2.89	3.53	2.34	2.92
Lead	2.51	11.4	11.5	8.47	0.443	1.24	2.20	1.29
Mercury	46.4	34.3	86.3	55.7	172	11.6	87.4	90.5
Nickel	0.191	0.240	0.185	0.205	6.36	2.19	5.13	4.56
Silver	0.0521	0.102	0.0609	0.0718	2.10	0.188	1.43	1.24
Thallium	[0.112]	[0.107]	[0.116]	[0.111]	[4.55]	[2.24]	[5.10]	[3.97]

[ ] = Minimum Detection Limit

2.3.6 Flue Gas Metals by Sample Fraction and Sample Parameters

Table 2-39 presents the metal amounts in the inlet flue gas samples by fraction for each run. The highest proportion of Hg was consistently collected in the nitric acid impingers (Impingers 1-3). All other metals detected, except Cr in Runs 2, 7, and 8, and Ni in Runs 2 and 3, were collected in the highest proportions in the front half (filter, nozzle/probe rinse).

The amounts of metals in the outlet flue gas samples are presented in Table 2-40 by sample fraction. As in the inlet, the highest proportion of Hg was collected in the nitric acid impingers for all runs. Other metals were collected in the highest proportions in the front half fraction, except for Cr in Run 2, As, Cr, Cu, and Ni in Run 3, Ba, Cr, and Cu in Run 4, Cr and Cu in Runs 5 and 7, As, Cr, Cr, Ni, and Ag in Run 6, and Cr in Runs 8 and 9. Laboratory analytical results for each sample fraction are presented in detail in Appendix E.

Sampling and flue gas parameters for the PM/metals runs at the three sampling locations are shown in Tables 2-41 through 2-43. Total sampling times, sample volume and isokinetic results for each sampling run are presented. Appendix A contains a complete listing of these and additional sampling and flue gas parameters for each run, along with the field data sheets.

2.3.7 Metals in Ash

A sample of the baghouse ash was collected in the afternoon following each test day. Incinerator bottom ash was collected in the morning following its respective test run. Concentrations of the metals in the ash in units of mg/kg were determined by microwave digesting a half gram in acid and hydrogen peroxide and diluting the solution to 100 mL. The analyses were then completed as discussed in Section 5.

The metals in the ash are shown in Table 2-44. Aluminum was the metals with the highest concentration in the baghouse ash for every run. Beryllium and Tl were not detected in any of the baghouse ash samples. Copper was the most prevalent metal in the bottom ash from Day 6 with 232,000 mg/kg. Aluminum showed the highest concentration of metals in the ash for the other runs sampled. Thallium was not detected in any of the bottom ash samples.

Table 2-39 (Continued)

METALS AMOUNT IN INLET FLUE GAS - SAMPLES BY SAMPLE FRACTION

BORGESS MEDICAL CENTER (1991)

METALS	Run 7				Run 8				Run 9			
	Front Half (Total ug)	Impinger 1,2,3 (Total ug)	Impinger 4,5,6 (Total ug)	Total ug	Front Half (Total ug)	Impinger 1,2,3 (Total ug)	Impinger 4,5,6 (Total ug)	Total ug	Front Half (Total ug)	Impinger 1,2,3 (Total ug)	Impinger 4,5,6 (Total ug)	Total ug
Aluminum	940	92.9		1030	1330	105		1440	939	123		1060
Antimony	93.0	48.7		142	528	52.3		580	251	146		397
Arsenic	2.18	0.701		2.88	8.50	0.454		8.95	10.8	0.649		11.4
Barium	72.5	1.21		73.7	349	1.17		350	163	7.27		170
Beryllium	[0.250]	[0.107]		[0.357]	[0.250]	[0.107]		[0.357]	[0.250]	[0.107]		[0.357]
Cadmium	417	0.344		417	2010	5.91		2020	1380	[0.213]		1380
Chromium	44.5	46.6		91.1	27.5	64.2		91.7	23.6	18.7		42.3
Copper	328	3.38		331	1830	20.8		1850	2070	4.44		2070
Lead	795	0.878		796	3800	6.06		3810	3520	0.464		3520
Mercury	4.38	14700	10.7	14700	7.38	11400	29.3	11400	22.0	26400	44.8	26500
Nickel	49.5	11.0		60.5	61.3	18.5		79.8	48.3	8.39		56.7
Silver	15.1	1.43		16.5	34.0	[0.640]		34.0	18.7	[0.640]		18.7
Thallium	[25.0]	[10.7]		[35.7]	[25.0]	[10.7]		[35.7]	[25.0]	[10.7]		[35.7]

NOTE: Impingers 4,5, and 6 sample fractions analyzed for mercury content only.

[ ]= Minimum Detection Limit

Table 2-40

METALS AMOUNTS IN OUTLET FLUE GAS - SAMLES BY SAMPLE FRACTION - BORGESS MEDICAL CENTER (1991)

METALS	Run 2				Run 3				Run 4			
	Front Half (Total ug)	Impinger 1,2,3 (Total ug)	Impinger 4,5,6 (Total ug)	Total ug	Front Half (Total ug)	Impinger 1,2,3 (Total ug)	Impinger 4,5,6 (Total ug)	Total ug	Front Half (Total ug)	Impinger 1,2,3 (Total ug)	Impinger 4,5,6 (Total ug)	Total ug
Aluminum	171	17.5		189	172	30.9		203	179	22.2		201
Antimony	11.8	3.56		15.4	11.7	2.45		14.2	11.7	[1.62]		11.7
Arsenic	[0.400]	[0.452]		[0.852]	[0.400]	0.464		0.464	[0.400]	1.05		1.05
Barium	3.65	0.373		4.02	4.83	0.511		5.34	4.64	0.379		5.02
Beryllium	[0.100]	[0.113]		[0.213]	[0.100]	[0.109]		[0.209]	[0.100]	[0.108]		[0.208]
Cadmium	0.930	[0.226]		0.930	1.07	0.620		1.69	1.73	0.422		2.15
Chromium	4.10	4.64		8.74	5.14	24.7		29.8	4.00	15.6		19.6
Copper	141	22.7		164	19.6	34.9		54.5	9.37	26.9		36.3
Lead	2.18	0.708		2.89	1.78	1.16		2.94	5.61	0.816		6.43
Mercury	[0.980]	9970	51.3	10000	[0.980]	8340	45.8	8390	[0.980]	3460	9.43	3470
Nickel	12.3	4.40		16.7	7.11	25.5		32.6	22.2	16.1		38.3
Silver	4.83	3.27		8.10	1.43	[0.653]		1.43	4.14	[0.649]		4.14
Thallium	[10.0]	[11.3]		[21.3]	[10.0]	[10.9]		[20.9]	[10.0]	[10.8]		[20.8]

NOTE: Impingers 4,5, and 6 sample fractions analyzed for mercury content only.

[ ]= Minimum Detection Limit

Table 2-41

METALS/PM EMISSIONS SAMPLING AND FLUE GAS PARAMETERS AT THE BOILER INLET BORGESS MEDICAL CENTER (1991)

Run No. Date	Run 2 09/07/91	Run 3 09/09/91	Run 4 09/10/91	Run 5 09/11/91	Run 6 09/12/91	Run 7 09/13/91	Run 8 09/14/91	Run 9 09/16/91	Average
Total Sampling Time (min)	240	241	240	240	240	240	240	240	NA
Average Sampling Rate (dscfm)	0.62	0.34	0.35	0.33	0.28	0.26	0.26	0.27	0.34
Metered Volume (dscf)	148.38	81.45	85.14	78.17	66.55	62.60	62.52	65.56	81.30
Metered Volume (dscm)	4.202	2.31	2.411	2.214	1.885	1.773	1.770	1.857	2.302
Average Stack Temperature (F)	1329	1255	1082	1230	1272	1206	1216	1247	1230
O2 Concentration (%V)	13.4	13.9	14.9	14.4	14.3	14.5	14.4	13.2	14.1
CO2 Concentration (%V)	5.0	4.2	4.1	4.2	3.9	3.3	3.1	5.0	4.1
Stack Gas Moisture (%V)	13.9	11.7	15.0	12.6	14.7	13.4	13.5	15.8	13.8
Volumetric Flow Rate (dscfm)	1923	2132	1960	1959	1941	1979	1947	1963	1976
Volumetric Flow Rate (dscmm)	54.47	60.39	55.50	55.49	54.98	56.05	55.13	55.59	55.95
Percent Isokinetic	95.6	133.3	109.5	104.4	89.7	108.0	109.6	114.0	NA
Particulate Catch (grams)	1.0073	0.4649	0.2839	0.3577	0.2469	0.1567	0.3064	0.291	0.3894

NA = Not Applicable

* O2 and CO2 values were obtained form the baghouse inlet.

Table 2-42

METALS/PM EMISSIONS SAMPLING AND FLUE GAS PARAMETERS AT BAGHOUSE INLET BORGESS MEDICAL CENTER (1991)

Run No. Date	Run 2 09/07/91	Run 3 09/09/91	Run 4 09/10/91	Run 5 09/11/91	Run 6 09/12/91	Run 7 09/13/91	Run 8 09/14/91	Run 9 09/16/91	Average
Total Sampling Time (min)	240	240	240	240	240	240	240	240	NA
Average Sampling Rate (dscfm)	0.49	0.55	0.54	0.55	0.56	0.55	0.53	0.53	0.54
Metered Volume (dscf)	118.42	131.32	130.71	131.16	134.67	132.93	126.70	127.68	129.20
Metered Volume (dscm)	3.354	3.719	3.702	3.714	3.814	3.765	3.588	3.616	3.659
Average Stack Temperature (F)	361	356	354	357	369	363	357	372	361
O2 Concentration (%V)	13.4	13.9	14.9	14.4	14.3	14.5	14.4	13.2	14.1
CO2 Concentration (%V)	5.0	4.2	4.1	4.2	3.9	3.3	3.1	5.0	4.1
Stack Gas Moisture (%V) *	12.8	11.7	12.0	12.2	13.4	12.8	13.0	14.8	12.8
Volumetric Flow Rate (dscfm)	1718	1909	1901	1876	1921	1814	1819	1731	1836
Volumetric Flow Rate (dscmm)	48.64	54.06	53.83	53.12	54.41	51.38	51.50	49.01	51.99
Percent Isokinetic	95.3	97.3	95.8	97.4	96.2	100.6	95.6	101.3	NA
Particulate Catch (grams)	0.3023	0.3427	0.2852	0.3148	0.2885	0.3168	0.3322	0.3071	0.3112

NA = Not Applicable

* Moisture values are average values from the CDD/CDF and M101A sampling trains. Moisture data obtained from the metals trains was determined to be inaccurate.

Table 2-45 shows the hourly mass rate of each metal removed from the incinerator in the baghouse ash and the daily mass rate of metals removed from the incinerator in the bottom ash.

2.4 PARTICULATE MATTER EMISSIONS

Particulate matter emissions were determined from the same sampling train used for metals determinations at the baghouse inlet and outlet. At the boiler inlet, PM emissions were sampled with a standard Method 5 train. Before metals analysis, PM collected in the filter and in the front half acetone rinse (probe, nozzle, filter holder) was analyzed gravimetrically as discussed in Section 5.

The average PM stack gas concentrations and mass rates for the boiler and baghouse inlets and baghouse outlet are presented in Table 2-46. Uncorrected concentrations and concentrations adjusted to 7 percent O_2 are shown. As shown, average removal efficiency, based on the mass rates at the baghouse inlet and outlet, is 96.5 percent.

Particulate matter concentrations, emission rates, and removal efficiencies for the individual runs are summarized in Table 2-47. Run 2 showed the highest PM concentration and emission rate at the outlet with 0.00426 g/dscm and 0.0177 kg/hr, respectively. Removal efficiencies ranged from 93.3 percent for Run 2 to 98.4 percent for Run 5.

A brief summary of the sampling and flue gas parameters for the PM runs is given in Table 2-41 and 2-42. Appendix A.2 presents a detailed listing of the parameters for each sampling run. Appendix E.2 shows the gravimetric PM analytical results.

2.5 MERCURY EMISSIONS BY METHOD 101A

A Method 101A train was used to sample Hg because a toxic metals train cannot be used if particulate sampling is run in conjunction with the multi-metal trains. A comparison of the Method 101A Hg values to the multi-metals train is discussed in more detail in Section 2.5.6.

Table 2-45.

METALS DAILY DISCHARGE RATES IN THE ASH STREAM
BAGHOUSE ASH AND BOTTOM ASH BORGESS MEDICAL CENTER (1991)

Run	2	3	4	5	6	7	8	9	Average Runs 2-9
BAGHOUSE ASH	**(g/hr)**	**(g/hr)**	**(g/hr)**	**(g/hr)**	**(g/hr)**	**(g/hr)**	**(g/hr)**	**(g/hr)**	**(g/hr)**
Aluminum	12.7	13.9	12.3	11.6	11.8	17.9	14.6	14.6	13.7
Antimony	0.420	0.828	0.542	0.821	0.622	0.402	0.994	0.459	0.636
Arsenic	0.0242	0.0233	0.0205	0.0205	0.0196	0.0308	0.0328	0.0318	0.0254
Barium	0.223	0.253	0.177	0.221	0.321	0.400	0.317	0.241	0.269
Beryllium	[0.00371]	[0.00402]	[0.00420]	[0.00355]	[0.00405]	[0.00428]	0.00499	[0.00393]	0.00499
Cadmium	0.413	0.551	0.841	0.414	16.6	3.08	1.61	1.28	3.10
Chromium	0.253	0.265	0.275	0.232	0.261	0.280	0.257	0.347	0.271
Copper	3.31	3.94	2.84	2.99	2.65	3.29	2.74	2.88	3.08
Lead	1.58	3.03	1.68	2.58	1.97	2.50	2.73	2.20	2.29
Mercury	0.145	0.127	0.102	8.42	7.10	8.24	6.45	11.7	5.28
Nickel	0.0774	0.0655	0.0643	0.0732	0.0778	0.0911	0.0994	0.1381	0.0859
Silver	0.0632	0.108	0.0416	0.0761	0.0774	0.0988	0.0568	0.0334	0.0694
Thallium	[0.371]	[0.402]	[0.420]	[0.355]	[0.401]	[0.428]	[0.384]	[0.378]	[0.349]
Total Ash Collected (lb)	218.1	285.2	249.8	206.3	272.0	251.0	275.9	262.6	252.6
BOTTOM ASH	**(g/day)**	**(g/day)**	**(g/day)**	**(g/day)**	**(g/day)**	**(g/day)**	**(g/day)**	**(g/day)**	**(g/day)**
Aluminum	16600	13300	9350	6590	7760	16700	15300	NA	12200
Antimony	[0.884]	[0.716]	[0.475]	[0.828]	8.77	[0.871]	1.30	NA	1.73
Arsenic	17.7	12.4	9.49	5.68	6.52	16.4	14.4	NA	11.8
Barium	692	599	231	988	549	1500	1210	NA	824
Beryllium	0.118	0.0955	0.0633	[0.0552]	[0.0669]	0.0988	0.0940	NA	0.0739
Cadmium	1.77	1.36	0.883	0.364	14.4	3.69	1.63	NA	3.44
Chromium	17.3	10.5	5.41	5.38	6.22	13.6	16.3	NA	10.7
Copper	1178	764	73.1	148	77600	831	636	NA	11604
Lead	30.9	58.7	13.9	32.0	24.4	65.1	47.6	NA	38.9
Mercury	0.577	2.67	0.310	0.541	0.656	0.569	0.614	NA	0.849
Nickel	11.0	45.6	2.97	2.57	4.55	9.29	11.8	NA	12.5
Silver	1.12	0.716	0.320	1.66	1.35	0.651	0.376	NA	0.885
Thallium	[5.89]	[4.77]	[3.16]	[5.52]	[6.69]	[5.81]	[6.26]	NA	[4.76]
Total Ash Collected (lb)	648	525	348	607	736	639	689	NA	524

[ ] = Minimum Detection Limits

NA = Not Applicable; Sample bottle broke before a weight was determined.

2.5.1 Overview

A single sampling train was used to determine emission rates of Hg by Method 101A. Two to three sampling runs were performed under each of the three test conditions (without carbon injection, carbon injection at 1 lb/hr, and carbon injection at 2.5 lb/hr) to ensure representative test results. Sampling locations, method, and QA/QC are discussed in Sections 4, 5, and 6, respectively. The average Hg emission rates and removal efficiencies are summarized in Section 2.5.3. The results for each individual run are presented in Section 2.5.4. Concentrations at dry standard conditions, adjusted to 7 percent O_2, and emission rates are shown. A comparison of the Hg collected in Method 101A versus the toxic metals trains is presented in Section 2.5.6.

2.5.2 Mercury Data Reduction

The following mercury results were calculated using the same guidelines outlined for the metals in Section 2.3.2.

2.5.3 Mercury Emissions

Table 2-48 presents the mercury emission rate results for each test condition. No Hg removal was observed during the emission tests without carbon injection. The removal efficiencies during the emission tests with carbon injection at 1 lb/hr were higher, at an average of 86.4 percent. Average emission rates were 10.3 g/hr at the inlet and 1.40 g/hr at the outlet. The removal efficiencies during the emission tests with carbon injection at 2.5 lb/hr were even higher, at an average 96.3 percent. Average emission rates were 14.9 g/hr at the inlet and 0.557 g/hr at the outlet.

2.5.4 Mercury Flue Gas Concentrations

Mercury concentrations, mass rates, and removal efficiencies are presented for each run in Table 2-49. Also shown for each run are the location, date, metered volume, O_2 concentration, and flow rate. Flue gas concentrations are given in terms of μg/dscm, both with and without correction to 7 percent O_2. Oxygen concentrations were calculated from CEM data.

Table 2-48
MERCURY 101A EMISSION RATES AND REMOVAL EFFICIENCIES BORGESS MEDICAL CENTER (1991)

Condition	Run	Inlet (g/hr)	Outlet (g/hr)	RE (%)
Without Carbon Injection	2	12.8	12.9	-0.781%
	3	11.5	11.5	0.0%
	4	5.18	5.19	-0.193%
	Average	9.83	9.87	-0.407%
Carbon Injection @ 1 lb/hr	5	8.41	1.25	85.1%
	6	12.1	1.55	87.2%
	Average	10.3	1.40	86.4%
Carbon Injection @ 2.5 lb/hr	7	12.9	0.880	93.2%
	8	10.3	0.180	98.2%
	9	21.5	0.610	97.2%
	Average	14.9	0.557	96.3%

TABLE 2-50

MERCURY 101A AMOUNTS IN FLUE GAS SAMPLES - BORGESS MEDICAL CENTER (1991)

Location	Run 2 (total ug)	Run 3 (total ug)	Run 4 (total ug)	Run 5 (total ug)	Run 6 (total ug)	Run 7 (total ug)	Run 8 (total ug)	Run 9 (total ug)
Inlet	13900	12500	5760	9550	14400	15200	12200	26000
Outlet	7310	6470	2990	719	955	517	106	361

Table 2-51

MERCURY 101A SAMPLING AND FLUE GAS PARAMETERS AT INLET - BORGESS MEDICAL CENTER (1991)

Run No.	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Average
Date	09/07/91	09/09/91	09/10/91	09/11/91	09/12/91	09/13/91	09/14/91	09/16/91	
Total Sampling Time (min)	240	240	240	240	240	240	240	240	NA
Average Sampling Rate (dscfm)	0.46	0.51	0.52	0.52	0.54	0.53	0.52	0.52	0.52
Metered Volume (dscf)	111.26	123.30	123.98	124.90	130.09	128.17	125.52	125.54	124.10
Metered Volume (dscm)	3.151	3.492	3.511	3.537	3.684	3.630	3.555	3.555	3.514
Average Stack Temperature (F)	361.02	355.52	354.40	356.90	369.15	363.13	357.29	371.67	361.14
O2 Concentration (%V)	13.41	13.89	14.93	14.37	14.26	14.50	14.43	13.21	14.12
CO2 Concentration (%V)	5.01	4.18	4.05	4.20	3.90	3.33	3.10	4.98	4.09
Stack Gas Moisture (%V)	13.39	10.90	11.93	12.02	13.25	12.47	12.67	14.47	12.64
Volumetric Flow Rate (dscfm)	1711.99	1890.29	1857.15	1834.05	1827.01	1817.34	1760.73	1732.84	1803.92
Volumetric Flow Rate (dscmm)	48.483	53.533	52.595	51.940	51.741	51.467	49.864	49.074	51.087
Percent Isokinetic	93.31	95.09	97.32	99.28	103.80	102.81	103.92	105.61	NA

2.6.1 Halogen Gas Emissions Results

Table 2-54 provides a summary of the HCl results at the baghouse inlet. Concentrations are reported in mg/dscm and ppmv, both at measured conditions and corrected to a 7 percent O_2 basis. The HCl concentrations at 7 percent O_2 ranged from 341.1 ppmv to 3591.0 ppmv with a mean of 1912.3 ppmv. The calculated emission rates ranged from 1.62 lb/hr to 17.57 lb/hr with a mean of 9.55 lb/hr.

Table 2-55 provides a summary of the HCl results at the baghouse outlet. The HCl concentrations at 7 percent O_2 ranged from 1.4 ppmv to 204.3 ppmv with a mean of 49.9 ppmv. Emission rates ranged from 0.007 lb/hr to 1.16 lb/hr at the baghouse outlet.

Table 2-56 presents a summary of HCl inlet and outlet concentrations and emission rates determined by manual sampling and provides the HCl removal efficiencies across the baghouse. Twenty-four runs were completed during eight days of testing. The removal efficiency for Run 8A could not be properly validated because the inlet and outlet sampling was not conducted at the same time. Hydrogen chloride removal efficiencies ranged from 82.4 percent to 99.9 percent with a mean of 96.6 percent.

Table 2-57 presents a summary of HF results obtained through sampling at the baghouse inlet. Noticeable concentrations of HF were detected during all the runs. The HF concentrations at 7 percent O_2 ranged from 6.0 ppmv to 49.6 ppmv with a mean of 18.3 ppmv. Calculated emission rates for HF ranged from 0.015 lb/hr to 0.147 lb/hr and averaged 0.051 lb/hr.

Table 2-58 provides the HF results at the baghouse outlet for all of the runs conducted. Detectable quantities of HF were present in only 2 of the 24 samples. Within the 24 runs, the concentrations at 7 percent O_2 ranged from 0.39 ppmv to 2.7 ppmv with a mean of 0.73 ppmv. Hydrogen fluoride emission rates recorded at the baghouse outlet ranged from 0.001 lb/hr to 0.009 lb/hr with an average of 0.002 lb/hr.

TABLE 2-54. MEASURED HYDROGEN CHLORIDE CONCENTRATIONS AND EMISSION RATES FOR THE BAGHOUSE INLET

TEST RUN NUMBER		MEASURED CONCENTRATIONS				EMISSION RATES	
		(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	(g/hr)	(lb/hr)[b]
2	A	1825	3388	1204	2235	5310	11.707
	B	838	1555	553	1026	2437	5.373
	C	1297	2408	856	1588	3774	8.320
AVERAGE		1320	2450	871	1616	3840	8.467
3	A	930	1844	613	1216	2986	6.584
	B	1860	3688	1227	2433	5975	13.172
	C	1727	3425	1139	2259	5548	12.231
AVERAGE		1506	2986	993	1969	4836	10.662
4	A	317	737	209	486	1000	2.204
	B	910	2118	600	1397	2871	6.329
	C	1551	3610	1023	2381	4893	10.788
AVERAGE		926	2155	611	1422	2921	6.440
5	A	969	2062	639	1360	3019	6.655
	B	2128	4529	1403	2988	6631	14.619
	C	2558	5444	1687	3591	7971	17.572
AVERAGE		1885	4012	1243	2646	5873	12.949
6	A	1100	2303	726	1519	3415	7.530
	B	1469	3075	969	2029	4561	10.055
	C	1370	2869	904	1892	4254	9.379
AVERAGE		1313	2749	866	1813	4077	8.988
7[a]	A	238	517	157	341	735	1.621
	B	1708	3709	1126	2447	5274	11.626
	C	1481	3216	977	2121	4573	10.081
AVERAGE		1142	2481	753	1636	3527	7.776
8	A	854	1834	563	1210	2554	5.631
	B	1628	3497	1074	2306	4869	10.735
	C	2116	4545	1395	2998	6329	13.954
AVERAGE		1532	3292	1011	2171	4584	10.106
9	A	2428	4389	1602	2895	7150	15.762
	B	1196	2163	789	1426	3523	7.767
	C	1469	2656	969	1752	4327	9.539
AVERAGE		1698	3069	1120	2025	5000	11.023

[a] The results for Runs 7B and 7C were originally reported as baghouse outlet results.

[b] An average of the flow rates determined by the Method 101A sampling trains was used for HCl emission rate calcultions.

TABLE 2-57. MEASURED HYDROGEN FLOURIDE CONCENTRATIONS AND EMISSION RATES FOR THE BAGHOUSE INLET

TEST RUN NUMBER	MEASURED CONCENTRATIONS				EMISSION RATE	
	(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	(g/hr)	(lb/hr)[b]
2 A	2.781	5.160	3.343	6.203	8.089	0.018
2 B	3.406	6.320	4.094	7.598	9.907	0.022
2 C	9.542	17.71	11.47	21.29	27.76	0.061
AVERAGE	5.243	9.729	6.302	11.70	15.25	0.034
3 A	4.403	8.731	5.293	10.50	14.14	0.031
3 B	20.81	41.27	25.02	49.61	66.85	0.147
3 C	12.85	25.49	15.45	30.64	41.29	0.091
AVERAGE	12.69	25.16	15.25	30.25	40.76	0.090
4 A	2.509	5.841	3.016	7.021	7.916	0.017
4 B	5.206	12.12	6.259	14.57	16.43	0.036
4 C	3.990	9.291	4.797	11.17	12.59	0.028
AVERAGE	3.902	9.085	4.690	10.92	12.31	0.027
5 A	8.107	17.26	9.746	20.75	25.27	0.056
5 B	10.25	21.81	12.32	26.22	31.93	0.070
5 C	4.026	8.570	4.840	10.30	12.55	0.028
AVERAGE	7.460	15.88	8.968	19.09	23.25	0.051
6 A	7.256	15.19	8.722	18.26	22.53	0.050
6 B	9.638	20.18	11.59	24.25	29.92	0.066
6 C	8.474	17.74	10.19	21.32	26.31	0.058
AVERAGE	8.456	17.70	10.16	21.28	26.25	0.058
7 A[a]	4.554	9.890	5.474	11.89	14.06	0.031
7 B	7.393	16.057	8.888	19.30	22.83	0.050
7 C	4.147	9.007	4.985	10.83	12.81	0.028
AVERAGE	5.365	11.65	6.449	14.01	16.57	0.037
8 A	2.323	4.990	2.792	5.998	6.949	0.015
8 B	7.585	16.29	9.118	19.59	22.69	0.050
8 C	4.543	9.759	5.461	11.73	13.59	0.030
AVERAGE	4.817	10.35	5.790	12.44	14.41	0.032
9 A	17.50	31.64	21.04	38.03	51.54	0.114
9 B	11.17	20.19	13.43	24.27	32.89	0.073
9 C	8.390	15.16	10.09	18.23	24.70	0.054
AVERAGE	12.35	22.33	14.85	26.84	36.38	0.080

[a] The results for Runs 7B and 7C were originally reported as baghouse outlet results.

[b] An average of the flow rates determined by the Method 101A sampling trains was used for HF emission rate calculations.

TABLE 2-58. MEASURE HYDROGEN FLOURIDE CONCENTRATIONS AND EMISSION RATES FOR THE BAGHOUSE OUTLET

TEST RUN NUMBER		MEASURED CONCENTRATIONS				EMISSION RATES	
		(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	(g/hr)	(lb/hr) [b]
	A	[0.194] [c]	[0.461]	[0.233]	[0.554]	[0.813]	[0.002]
2	B	[0.219]	[0.519]	[0.263]	[0.624]	[0.915]	[0.002]
	C [d]	[0.218]	[0.519]	[0.263]	[0.624]	[0.914]	[0.002]
AVERAGE		[0.210]	[0.500]	[0.253]	[0.601]	[0.881]	[0.002]
	A	[0.184]	[0.488]	[0.221]	[0.587]	[0.828]	[0.002]
3	B	[0.211]	[0.560]	[0.254]	[0.673]	[0.950]	[0.002]
	C	[0.208]	[0.553]	[0.250]	[0.664]	[0.938]	[0.002]
AVERAGE		[0.201]	[0.534]	[0.242]	[0.641]	[0.905]	[0.002]
	A	(0.198)	(0.550)	(0.238)	(0.661)	(0.909)	(0.002)
4	B	[0.211]	[0.587]	[0.254]	[0.706]	[0.970]	[0.002]
	C	[0.191]	[0.532]	[0.230]	[0.639]	[0.879]	[0.002]
AVERAGE		0.198	0.550	0.238	0.661	0.909	0.002
	A	[0.169]	[0.445]	[0.203]	[0.535]	[0.805]	[0.002]
5	B	0.865	2.281	1.040	2.742	4.125	0.009
	C	0.816	2.151	0.980	2.586	3.890	0.009
AVERAGE		0.840	2.216	1.010	2.664	4.007	0.009
	A	(0.180)	(0.460)	(0.216)	(0.553)	(0.727)	(0.002)
6	B	[0.255]	[0.652]	[0.307]	[0.784]	[1.030]	[0.002]
	C	[0.180]	[0.459]	[0.216]	[0.552]	[0.725]	[0.002]
AVERAGE		0.180	0.460	0.216	0.553	0.727	0.002
	A [a]	(0.204)	(0.510)	(0.245)	(0.613)	(0.916)	(0.002)
7	B	[0.151]	[0.377]	[0.181]	[0.453]	[0.676]	[0.001]
	C	[0.163]	[0.407]	[0.196]	[0.490]	[0.731]	[0.002]
AVERAGE		0.204	0.510	0.245	0.613	0.916	0.002
	A	[0.156]	[0.404]	[0.188]	[0.486]	[0.707]	[0.002]
8	B	[0.125]	[0.324]	[0.151]	[0.390]	[0.567]	[0.001]
	C	[0.126]	[0.325]	[0.151]	[0.390]	[0.568]	[0.001]
AVERAGE		[0.135]	[0.351]	[0.163]	[0.422]	[0.614]	[0.001]
	A	[0.157]	[0.339]	[0.189]	[0.407]	[0.673]	[0.001]
9	B	[0.156]	[0.335]	[0.187]	[0.403]	[0.666]	[0.001]
	C	[0.156]	[0.336]	[0.187]	[0.404]	[0.667]	[0.001]
AVERAGE		[0.156]	[0.336]	[0.188]	[0.404]	[0.668]	[0.001]

a The results for Runs 7B and 7C were originally reported as baghouse inlet results.

b An average of the flow rates determined by the CDD/CDF sampling trains was used for HBr emission rate calculations.

c [] = Detection limit; () = Estimated maximum possible concentration

d Detection limits are not considered when calculating averages.

TABLE 2-60. MEASURED HYDROGEN BROMIDE CONCENTRATIONS AND EMISSION RATES FOR THE BAGHOUSE INLET

	MEASURED CONCENTRATIONS				EMISSION RATE	
TEST RUN NUMBER	(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	(g/hr)	(lb/hr)[b]
2 A	3.425	6.356	1.018	1.889	9.963	0.022
2 B	2.965	5.503	0.881	1.636	8.625	0.019
2 C[d]	2.609	4.841	0.775	1.439	7.589	0.017
AVERAGE	3.000	5.567	0.892	1.655	8.726	0.019
3 A	0.520	1.032	0.155	0.307	1.671	0.004
3 B	3.288	6.519	0.977	1.938	10.560	0.023
3 C	3.024	5.997	0.899	1.782	9.714	0.021
AVERAGE	2.277	4.516	0.677	1.342	7.315	0.016
4 A	3.502	8.154	1.041	2.424	11.051	0.024
4 B	2.386	5.554	0.709	1.651	7.528	0.017
4 C	2.648	6.164	0.787	1.832	8.355	0.018
AVERAGE	2.845	6.624	0.846	1.969	8.978	0.020
5 A	4.786	10.187	1.423	3.028	14.915	0.033
5 B	5.601	11.923	1.665	3.544	17.456	0.038
5 C	1.846	3.930	0.549	1.168	5.753	0.013
AVERAGE	4.078	8.680	1.212	2.580	12.708	0.028
6 A	6.218	13.016	1.848	3.869	19.303	0.043
6 B	4.547	9.519	1.352	2.829	14.117	0.031
6 C	2.322	4.860	0.690	1.445	7.208	0.016
AVERAGE	4.362	9.132	1.297	2.714	13.543	0.030
7 A[a]	3.112	6.758	0.925	2.009	9.609	0.021
7 B	[0.0519]	[0.1128]	[0.0154]	[0.0335]	[0.1603]	[0.0004]
7 C	8.318	18.065	2.472	5.370	25.685	0.057
AVERAGE	5.715	12.412	1.699	3.689	17.647	0.039
8 A	4.620	9.926	1.373	2.950	13.823	0.030
8 B	6.167	13.250	1.833	3.938	18.452	0.041
8 C	6.389	13.727	1.899	4.080	19.116	0.042
AVERAGE	5.726	12.301	1.702	3.656	17.130	0.038
9 A	[c] [0.057]	[0.102]	[0.017]	[0.030]	[0.166]	[0.0004]
9 B	[0.050]	[0.090]	[0.015]	[0.027]	[0.146]	[0.0003]
9 C	[0.058]	[0.105]	[0.017]	[0.031]	[0.170]	[0.0004]
AVERAGE	[0.055]	[0.099]	[0.016]	[0.029]	[0.161]	[0.0004]

a The results for Runs 7B and 7C were originally reported as baghouse outlet results.

b An average of the flow rates determined by the Method 101A sampling trains was used for HBr emission rate calculations.

c [] = Detection limit; () = Estimated maximum possible concentration

d Detection limits are not considered when calculating averages.

TABLE 2-61. MEASURED HYDROGEN BROMIDE CONCENTRATIONS AND EMISSION RATES FOR THE BAGHOUSE OUTLET

TEST RUN NUMBER		MEASURED CONCENTRATIONS				EMISSION RATE	
		(mg/dscm)	(mg/dscm @7% O2)	(ppmv)	(ppmv @7% O2)	(g/hr)	(lb/hr) [b]
	A	[c] [0.0547]	[0.1301]	[0.0163]	[0.0387]	[0.2292]	[0.0005]
2	B	0.378	0.897	0.112	0.267	1.582	0.003
	C [d]	(0.178)	(0.424)	(0.053)	(0.126)	(0.747)	(0.002)
AVERAGE		0.278	0.661	0.083	0.196	1.164	0.003
	A	[0.0486]	[0.1290]	[0.0145]	[0.0384]	[0.2190]	[0.0005]
3	B	[0.0645]	[0.1710]	[0.0192]	[0.0508]	[0.2901]	[0.0006]
	C	(0.224)	(0.593)	(0.066)	(0.176)	(1.006)	(0.002)
AVERAGE		0.224	0.593	0.066	0.176	1.006	0.002
	A	[0.0578]	[0.1606]	[0.0172]	[0.0477]	[0.2654]	[0.0006]
4	B	[0.0645]	[0.1793]	[0.0192]	[0.0533]	[0.2963]	[0.0007]
	C	[0.0584]	[0.1624]	[0.0174]	[0.0483]	[0.2683]	[0.0006]
AVERAGE		[0.0602]	[0.1674]	[0.0179]	[0.0498]	[0.2767]	[0.0006]
	A	(0.213)	(0.563)	(0.063)	(0.167)	(1.017)	(0.002)
5	B	(0.295)	(0.778)	(0.088)	(0.231)	(1.406)	(0.003)
	C	(0.230)	(0.607)	(0.068)	(0.180)	(1.097)	(0.002)
AVERAGE		0.246	0.649	0.073	0.193	1.174	0.003
	A	[0.0529]	[0.1351]	[0.0157]	[0.0401]	[0.2134]	[0.0005]
6	B	[0.0779]	[0.1990]	[0.0232]	[0.0592]	[0.3145]	[0.0007]
	C	[0.0548]	[0.1401]	[0.0163]	[0.0416]	[0.2214]	[0.0005]
AVERAGE		[0.0619]	[0.1581]	[0.0184]	[0.0470]	[0.2498]	[0.0006]
	A	[0.0622]	[0.1555]	[0.0185]	[0.0462]	[0.2791]	[0.0006]
7 [a]	B	[0.0460]	[0.1149]	[0.0137]	[0.0342]	[0.2062]	[0.0005]
	C	[0.0498]	[0.1245]	[0.0148]	[0.0370]	[0.2235]	[0.0005]
AVERAGE		[0.0527]	[0.1316]	[0.0157]	[0.0391]	[0.2363]	[0.0005]
	A	[0.0478]	[0.1235]	[0.0142]	[0.0367]	[0.2160]	[0.0005]
8	B	[0.0383]	[0.0990]	[0.0114]	[0.0294]	[0.1733]	[0.0004]
	C	[0.0384]	[0.0993]	[0.0114]	[0.0295]	[0.1738]	[0.0004]
AVERAGE		[0.0415]	[0.1073]	[0.0123]	[0.0319]	[0.1877]	[0.0004]
	A	[0.0478]	[0.1031]	[0.0142]	[0.0306]	[0.2048]	[0.0005]
9	B	[0.0475]	[0.1023]	[0.0141]	[0.0304]	[0.2032]	[0.0004]
	C	[0.0487]	[0.1049]	[0.0145]	[0.0312]	[0.2084]	[0.0005]
AVERAGE		[0.0480]	[0.1034]	[0.0143]	[0.0307]	[0.2055]	[0.0005]

[a] The results for Runs 7B and 7C were originally reported as baghouse inlet results.

[b] An average of the flow rates determined by the Method 101A sampling trains was used for HBr emission rate calculations.

[c] [] = Detection limit; () = Estimated maximum possible concentration

[d] Detection limits are not considered when calculating averages.

Appendix C.5	CEM Response Time & NO_x Converter Checks
Section 6.5	CEM Coefficients of Variation

The CEM run averages are presented In Table 2-63. Both inlet and outlet concentrations are given. Moisture contents are also presented because these values were used to correct the wet CEM values to a dry basis in the following tables. Inlet O_2 run averages varied from 12.9 to 14.9, while outlet values were 1 to 2 percent higher by volume. Inlet CO_2 values were approximately 4 to 5 percent by volume, except for Runs 6 through 8 which averaged near 3 percent. These latter values are lower than the corresponding outlet averages. All QA/QC criterion for that monitor were met.

Nitrogen oxides concentrations were approximately 60 to 80 ppmv, dry at the inlet and somewhat lower (approximately 40 to 70 ppmv dry) at the outlet. As detailed in Section 6, the NO_x converter for the inlet instrument used for Runs 2 through 7 only showed about 50 percent conversion efficiency. When comparing the inlet NO_x data to the outlet NO_x data, the lower NO_x conversion efficiency did not appear to have affected the quality of the inlet data. It is postulated that the majority of NO_x in a flue gas stream is typically in the form of NO and, therefore, does not need to be converted from NO_2 to NO for accurate measurement.

Average values for SO_2 are also presented in Table 2-63. Both inlet and outlet values were typically lower than 10 ppmv.

Concentrations of THC were also monitored, with the resulting inlet concentrations consistently below 5 ppmv/wet. Outlet concentrations were only monitored for one day with the resulting run average equaling 1.9 ppmv/wet.

Concentrations of HCl were monitored and determined using EPA Reference Method 26. Averages for the inlet concentrations ranged from approximately 500 to 800 ppmv/wet. Outlet concentrations ranged from 10 to 40 ppmv/wet. Hydrogen chloride removal efficiencies based on the reference method results were presented in Section 2.5.3.

TABLE 2-63. CONTINUOUS EMISSIONS MONITORING DAILY TEST AVERAGES FOR ACTUAL CONCENTRATIONS. BORGESS MEDICAL CENTER (1991)

DATE	RUN NO.	TEST TIME	H2O a (%V,wet by manual methods)		O2 (%V,dry)		CO2 (%V,dry)		CO (ppmv,dry)		NOx (ppmv,dry)		SO2 (ppmv,dry)		THC (ppmv,wet)		HCl (ppmv,wet)	
			Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
9/7	2	12:15-17:25	12.8	11.9	13.5	15.1	4.9	4.7	6.5	0.9	75.7	69.8	5.4	4.8	4.2	1.9	753	39.4
9/9	3	11:32-17:48	11.7	10.3	13.8	15.6	4.2	4.2	8.1	2.9	76.6	71.9	3.8	5.7	5.6	NR	797	39.2
9/10	4	12:07-17:18	12.0	9.3	14.9	15.9	4.0	4.2	4.9	0.6	59.3	56.7	0.4	0.4	2.3	NR	515	9.7
9/11	5	11:17-16:17	12.2	9.1	14.4	15.6	4.2	4.3	4.6	0.2	67.9	61.5	2.5	3.9	2.2	NR	612	26.3
9/12	6	12:30-16:22	13.4	13.8	14.3	15.5	b 2.2	4.4	3.9	0.7	66.3	38.8	2.2	11.1	1.6	NR	486	10.6
9/13	7	09:47-14:45	12.8	10.1	14.4	15.3	3.2	4.5	3.6	0.9	63.8	57.4	4.5	5.9	2.0	NR	625	16.1
9/14	8	10:15-16:25	13.0	12.0	14.4	15.5	3.1	4.5	4.6	0.3	69.6	NR	2.1	5.3	1.8	NR	627	19.6
9/16	9	10:30-16:16	14.8	11.5	12.9	14.4	5.3	5.3	4.3	0.2	97.8	NR	6.4	8.6	1.5	NR	777	29.5

a Average moisture value from the CDD/CDF and 101A trains.

b Inlet CO2 values appear low in runs 6 - 8. All CEM QA/QC criteria for that monitor were met however the CEM operator expressed lower confidence in that instrument.

NC = Data not compiled yet.

NR = Not recorded (instrument was inoperative for these test runs).

Table 2–65. Hourly Averages of Actual CEM Measurements
Run 4 Burndown
Borgess Medical Center (1991)

	O2 %V		SO2 ppmV		CO ppmV		CO2 %V		NOx ppmV		HCl ppmV		THC ppmV
Time	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet
1800-1859	6.89	7.06	12.1	11.1	7.9	7.5	2.10	2.22	16.5	16.3	200.5	19.8	9.2
1900-1959	15.80	17.43	-1.0	-0.5	4.3	1.4	2.29	2.42	18.6	18.0	141.4	6.7	1.9
2000-2059	15.94	17.60	-1.1	-0.2	4.2	1.4	2.06	2.19	20.4	19.8	63.2	5.7	1.7
2100-2159	17.48	19.48	-0.7	-0.1	5.1	3.2	0.96	0.90	8.3	7.1	38.8	3.7	2.4
2200-2259	18.53	20.69	-0.1	-0.4	3.8	2.0	0.19	0.10	1.3	0.7	36.8	1.3	3.0
2300-2332	18.61	20.69	-0.1	-0.6	3.9	2.1	0.12	0.05	0.5	0.2	37.4	0.6	3.0

Note: THC concentrations were not measured at the baghouse outlet location.

TABLE 2-66. COMPARISON OF MANUAL AND CEM HCl RESULTS
BAGHOUSE INLET SAMPLING LOCATION
BORGESS MEDICAL CENTER (1991)

TEST RUN NUMBER		MANUAL HCl RESULTS		CEM HCl RESULTS	
		(ppmV)	(ppmV @7% O2)	(ppmV)[a,b]	(ppmV @7% O2)
2	A	1204.1	2234.6	990.9	1843.3
	B	552.6	1025.6	964.0	1721.2
	C	855.7	1588.0	748.1	1362.4
AVERAGE		870.8	1616.1	901.0	1642.3
3	A	613.3	1216.0	960.2	1778.7
	B	1227.0	2432.9	753.9	1531.1
	C	1139.3	2259.1	818.8	1752.6
AVERAGE		993.2	1969.3	844.3	1687.5
4	A	208.9	486.4	487.2	1115.3
	B	600.1	1397.1	504.6	1170.8
	C	1022.8	2381.4	623.4	1447.3
AVERAGE		610.6	1421.6	538.4	1244.5
5	A	638.9	1360.0	533.9	1114.8
	B	1403.5	2987.5	907.5	1742.1
	C	1687.0	3591.1	492.9	1084.2
AVERAGE		1243.1	2646.2	644.8	1313.7
6	A	725.7	1519.1	558.8	1183.1
	B	969.0	2028.5	326.1	781.0
	C	903.9	1892.2	NA	NA
AVERAGE		866.2	1813.3	442.5	982.0
7	A	157.1	341.1	496.8	1049.3
	B	1126.5	2446.5	732.2	1716.8
	C	976.7	2121.4	616.6	1309.6
AVERAGE		753.4	1636.3	615.2	1358.6
8	A	563.1	1209.7	NA	NA
	B	1073.5	2306.3	693.1	1518.1
	C	1395.4	2997.9	733.3	1463.4
AVERAGE		1010.7	2171.3	475.5	993.8
9	A	1601.6	2895.0	958.9	1499.3
	B	789.2	1426.5	686.5	1356.4
	C	969.3	1752.0	NA	NA
AVERAGE		1120.0	2024.5	822.7	1427.9

NA = No results are available.

[a] CEM Run concentrations are calculated as averages over the same time period as the manual sampling.

[b] CEM daily concentrations are an average of the three test run concentrations.

TABLE 2-68. BOTTOM ASH LOI AND CARBON CONTENT BORGESS MEDICAL CENTER (1991)

Run Number	Moisture (%)	Hydrated Water (%)	LOI (%)	Total Loss (%)	Carbon	
					As Received (%)	Dry (%)
2	22.08	1.51	8.57	29.84	3.34	4.29
3	18.35	1.24	5.12	23.49	1.15	1.41
4	0.47	0.46	6.28	7.15	3.66	3.68
5	42.38	2.66	10.55	49.83	1.32	2.29
6	35.92	1.64	10.22	43.41	3.37	5.26
7	14.56	1.38	9.96	24.13	4.60	5.38
8	15.39	2.14	8.44	24.19	1.55	1.83
9	19.08	0.91	9.61	27.53	4.79	5.92

TABLE 2-69. BAGHOUSE ASH LOI AND CARBON CONTENT BORGESS MEDICAL CENTER (1991)

Run Number	Moisture (%)	Hydrated Water (%)	LOI (%)	Total Loss (%)	Carbon		Carbon Injection Rate (lb/hr)
					As Received (%)	Dry (%)	
2	0.60	0.91	17.63	18.87	0.52	0.52	0
3	0.76	0.89	18.45	19.79	0.67	0.68	0
4	0.57	0.90	21.27	22.42	1.07	1.08	0
5	0.43	0.86	20.51	21.54	1.35	1.36	1.07
6	0.58	0.95	20.53	21.74	1.81	1.82	1.06
7	0.63	0.89	21.42	22.61	3.04	3.06	2.60
8	0.90	1.06	22.32	23.83	4.29	4.33	2.87
9	0.97	1.09	22.30	23.89	2.36	2.38	2.85

3.2.2.1 Incinerator Operating Cycle. During the test, the following incinerator operating cycles will be used:

Charging period:	8 to 11 hours
Burndown period:	6 hours
Cooldown period:	5 to 8 hours
Ash removal/preheat:	2 hours

The proposed operating schedule and key sampling events are summarized in Table 3-1. Sampling will not commence within 2 hours of initiating charging of waste to the incinerator.

3.2.2.2 Charge Rate. Based on previous experience, the incinerator will be charged at a rate of 245 to 263 kg/hr (540 to 580 lb/hr) for a period of 8 to 11 hours. This charge rate corresponds to charging 7 to 9 charges per hour with each charge weighing approximately 32 kg (70 lb). The total weight of waste charged per day will be limited to 2,722 kg (6,000 lb).

3.2.2.3 Incinerator Temperatures

Primary Chamber --

The primary chamber temperature will be allowed to vary within its normal operating range of 593° to 760°C (1100° to 1400°F). Testing will be stopped only if a very unusual temperature condition occurs in the primary chamber. The temperature setpoint for the primary chamber quench water spray will be 704°C (1300°F).

Retention Chamber --

During testing, the setpoint temperature on the control panel will be set at 1010°C (1850°F). The retention chamber temperature will be maintained within ±28°C (50°F) of the setpoint. If the temperature exceeds ±28°C (±50°F) of the setpoint, 5 minutes will be allowed for the trend to reverse prior to stopping the test. If the trend reverses within 5 minutes, an additional 5 minutes will be allowed for the temperature to return within the ±28°C (50°F) range prior to stopping the test.

TABLE 3-1. DAILY OPERATING SCHEDULE
BORGESS MEDICAL CENTER

Time	Incinerator	Fabric Filter
0500-0600	Clean out ash	
0600-0630	Check hearth	
0630-0730	Preheat; weigh bottom ash	Fill lime hopper; fill carbon hopper; check lime injection; check carbon injection; set lime rate; set carbon rate; check baghouse hopper
0730	Charge unit; establish setpoints; boiler auxiliary burner off	Begin lime injection
0730-0930	Line-out unit	
0930	Begin test	
1530	Complete test	
1530-1630		Check lime level; calculate lime rate; reset lime rate; calculate carbon rate
1630-1730	Summarize process data	
1930	Stop charging	
1930-0130	Burndown	
0130-0500	Cooldown; boiler auxiliary burner on when baghouse temperature drops to 300°F	

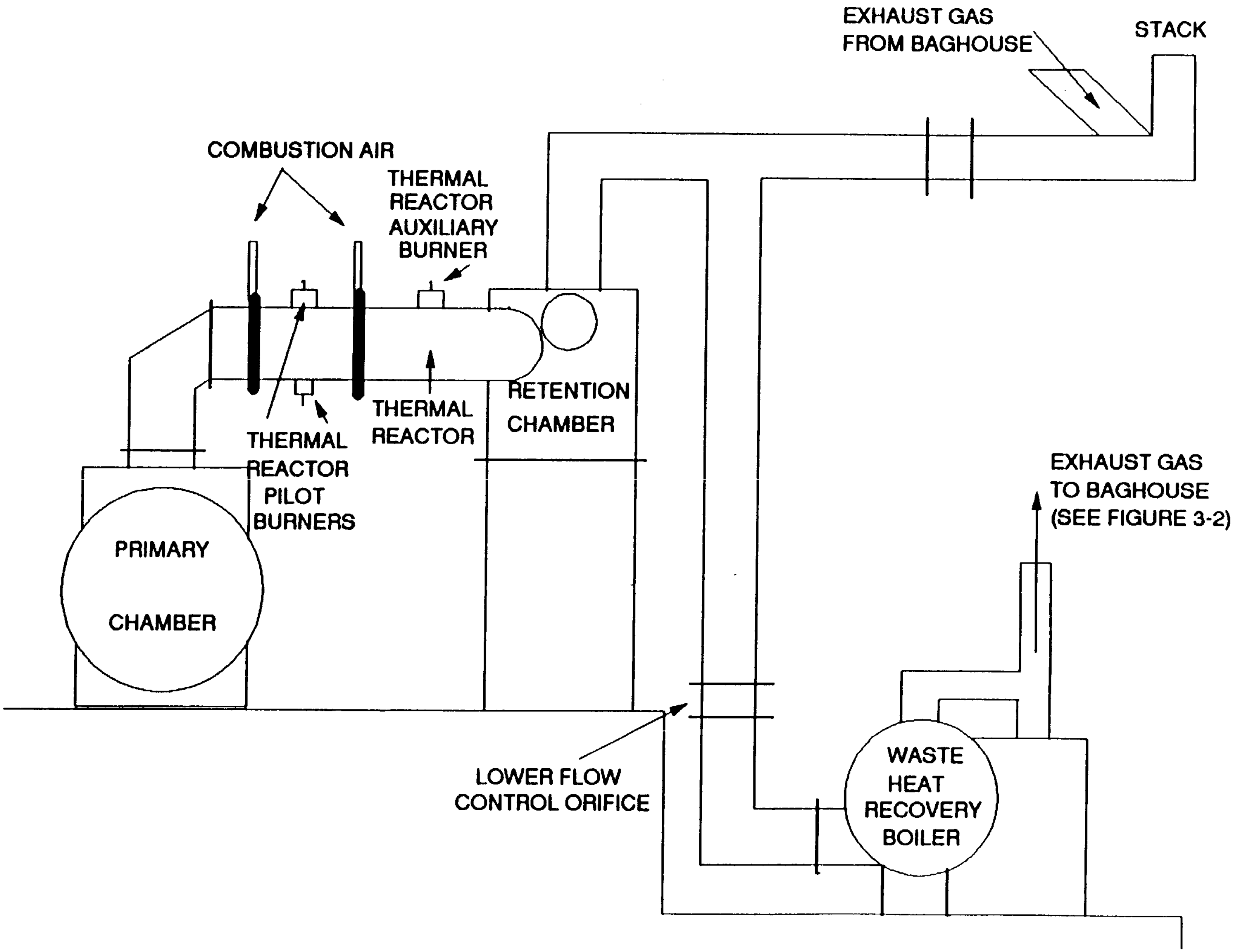

FIGURE 3-1. SCHEMATIC OF MEDICAL WASTE INCINERATOR/WASTE HEAT BOILER SYSTEM AT BORGESS MEDICAL CENTER.

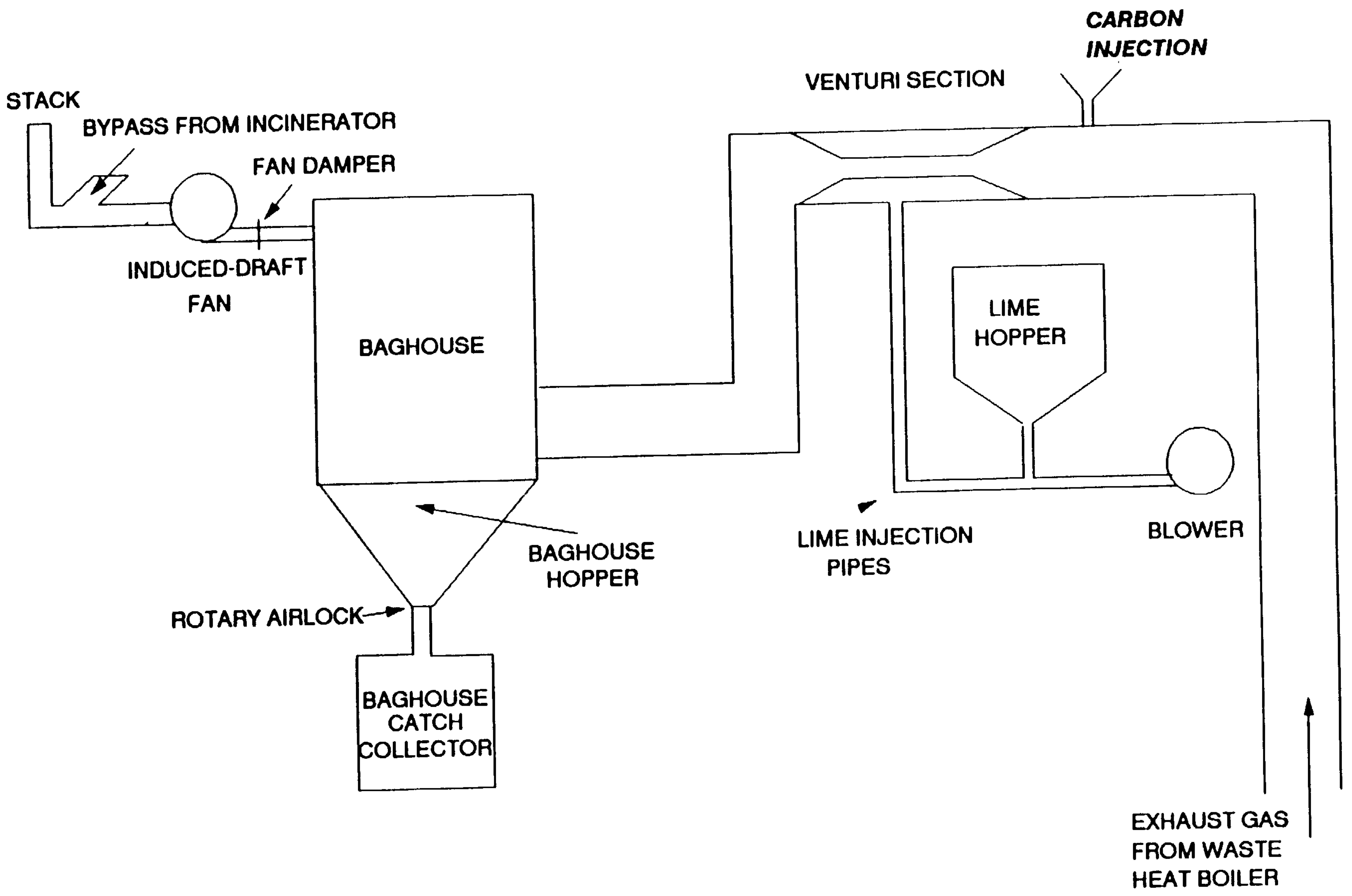

FIGURE 3-2. SCHEMATIC OF DRY LIME INJECTION/FABRIC FILTER AIR POLLUTION CONTROL SYSTEM AT BORGESS MEDICAL CENTER.

with an automatic cart dumper to lift each cart and dump the load into the hopper of the hopper/ram charging system. Each charge consists of a single cartload typically weighing between 27 and 39 kg (60 and 85 lb). During the tests, the weight of each charge was controlled.

3.3.3 Bottom Ash Removal System

Ash from the incinerator is removed manually from the primary chamber the morning after the burn. The rear of the incinerator has a refractory-lined door that is opened by sliding straight upward while remaining in position against the end of the chamber. The rear of the incinerator also is hinged on one side and can be opened by pulling the back end away from the chamber and pivoting the door assembly on the hinges. An ash cart is placed against the rear of the incinerator such that the top of the open cart is below the level of the hearth. The rear door assembly includes a three-sided shroud that can be hydraulically lowered over the cart. The shroud contains a row of water sprays which can be manually activated to wet the ash as it is being discharged to the ash cart. (The water sprays were not used during testing so that the dry ash could be weighed). During ash removal, the rear door assembly is raised such that there is about a 0.9 m (2 ft) high opening along the width of the hearth; this opening between the hearth and the ash cart is covered by the shroud. The ash ram is used to push ash through the opening into the ash cart. Once the ash ram is no longer effective at removing the ash, the rear door is unlatched and swung open exposing the primary chamber hearth to the operator. The operator, wearing protective clothing and a full face respirator, rakes the remaining ash from the hearth into the shrouded cart. After all the ash is raked off of the hearth, the shroud is lifted and the cart rolled away from the rear of the incinerator. A hoist is used to lift the cart and to dump the ash into a large dumpster located outside. During the tests, the ash carts containing the bottom ash from each run were weighed prior to dumping.

3.3.4 Waste Heat Boiler

The waste heat boiler is a 1,960 kilowatt (kW) (200 horsepower [hp]) Cleaver Brooks unit rated at 3,090 kg (6,800 lb) of steam per hour. The waste heat boiler design includes an auxiliary gas burner, which is capable of providing about half of the rated output. The boiler can be operated in the waste heat recovery mode, auxiliary fuel mode, or dual mode. During the tests, the boiler was operated in the waste heat recovery mode only, i.e., the auxiliary burner was turned off during all testing so that emissions from the boiler burner would not interfere with the emissions from the MWI. The boiler is equipped with an automatic, continuous-cycle soot blowing system. The soot blower was operated normally throughout the testing.

3.3.5 Air Pollution Control System

The APCS consists of dry lime injection for hydrochloric acid gas control followed by a fabric filter baghouse for PM control.

3.3.5.1 Dry Lime Injection. Hydrated lime (Mississippi Lime Company) is injected into the flue gas duct between the waste heat boiler and the baghouse. Lime is received in 22.7 kg (50 lb) bags. The lime is dumped by the operator, as needed, into a feed hopper. The lime is discharged via gravity from the bottom of the feed hopper into a flexible pipe that is connected to the discharge end of an air blower rated at 2.8 scm/min (98 scfm). The lime discharged from the hopper is blown through the pipe by the blower (as well as pulled through the pipe by the draft created by the baghouse induced-draft fan) and is injected into a venturi section of the duct about 15 m (50 ft) upstream of the baghouse.

The rate of discharge of lime from the lime hopper is controlled by a rotary air lock valve. To assist with gravity flow of the lime, the hopper is vibrated and a screw auger is used within the hopper. Operation of the vibrator, auger, and rotary valve are all controlled by a programmable microprocessor system. The primary control for the feed rate is the frequency and duration of the operation of the rotary valve. The injector system is designed to feed reagent in the range of 2.3 to 14 kg/hr (5 to 30 lb/hr). However, during the previous test program, lime injection rates greater than 27 kg/hr (60 lb/hr) were achieved. During the latest test program (September 1991), lime injection rates of greater than 18 kg/hr (40 lb/hr) were achieved.

One of the major drawbacks to this lime injection system discovered during the previous test program was the piping system used to transport the lime to the inlet duct. The lime feed hopper is located on the mezzanine adjacent to the waste heat boiler relatively constant differential pressure across the baghouse in the range of 249 to 1,245 pascals (1 to 5 inch water column [in. w.c.]) is maintained. Draft through the system is maintained by a single ID fan downstream of the baghouse; an automatically controlled damper on the ID fan is used for airflow control.

The ID-fan damper is controlled by a proportional controller based on the measurement of primary chamber draft. Since the previous test, a new controller had been installed. This new controller made adjustments to the ID-fan damper too quickly and overcompensated for each change in primary chamber draft. As a result, the ID-fan damper tended to fluctuate significantly as the proportional controller tried to maintain the primary chamber draft within the upper and lower draft setpoints. This fluctuation in the ID-fan damper also caused fluctuations in stack gas flow rate and baghouse pressure drop. As a result of these fluctuations, a decision was made to remove the ID-fan damper controller linkage and to tighten down the damper in one position that produced the system design stack gas flow rate. Prior to testing each day, the flow rate was measured and the damper position adjusted, as necessary, to maintain the design stack gas flow rate.

The baghouse residue is continuously discharged from the collection hopper through a rotary air lock valve into a 132.5 liter (L) (35 gallon [gal]) container. The containers are lined with plastic bags and when a container is full, the bag is removed by the operator, sealed, and discarded into a dumpster and later removed to a hazardous waste landfill. The residue has a high lead content that classifies the waste as hazardous under the Resource Conservation and Recovery Act.

3.4 TYPICAL OPERATING SCHEDULE

At the beginning of each day, the ash from the previous burn cycle is removed from the incinerator. After the ash is removed, the hearth is covered with cardboard and the chamber is sealed. The cardboard provides an ash bed that inhibits clinker formation and slagging on the hearth. The thermal reactor burners are turned on to preheat the thermal reactor and the retention chamber. After a minimum temperature is achieved in the retention chamber, typically 968°C (1800°F), the primary chamber burner is started and the waste bed ignited. The first three charges to the incinerator are cartloads of cardboard (to assist in developing a good ash bed) and are made in rapid succession. The fourth charge is medical waste. Once the waste bed is ignited, the primary chamber burner is no longer needed because combustion is self-sustaining. Subsequent charges are made at regular intervals so that seven to eight charges per hour are typically made. The charging is continued for up to 12 hours, but the manufacturer recommends that not more than a total of 2,727 kg (6,000 lb) is charged during any single burn cycle. When charging is completed for the day, the incinerator is put into an automatic burndown cycle. During the 6-hour burndown period, the large auxiliary thermal reactor burner remains operational for 3 hours while the remaining two thermal reactor pilot burners operate for the entire 6-hour period. The operating permit specifies that tertiary chamber temperatures be maintained at a minimum of 871°C (1600°F) during burndown while any waste is still burning. The combustion air blowers continue to operate until the unit is shut down for ash removal. After the incinerator has gone through the burndown cycle and the primary chamber has cooled (usually about 4 to 6 hours after the burndown cycle is completed), the ash removal process begins.

During operation, the operators stoke the waste bed on a regular basis through operation of the ash ram. The purpose of stoking is to agitate the waste bed thereby exposing all waste surfaces to heat and air and resulting in improved burnout. Stoking is initiated by the operator after every six charges. The first two stokes of each trio of stokes are automatic stokes where the ash ram travels approximately two-thirds of the length of the waste bed. Every third stoke is a manual stoke where the ash ram is manually operated such that the ash ram travels to the end of the waste bed. The results of stoking are increased temperatures in all three chambers as waste burns and volatiles are released. The temperature surges in the tertiary chamber were unpredictable. However, manual stokes typically caused larger temperature increases than automatic stokes. Typically, manual stokes were not conducted during testing because manual stokes tended to boost tertiary chamber temperature above the target temperature range. Automatic stokes were conducted in some cases. The stoking cycles used during testing are described in the test run summaries in Section 3.5.3.

3.5.2 Summary of Process Operation

For the most part, the MWI system at Borgess performed well during the test program. The most common process problem was high temperature excursions that required withholding waste charges to allow the system to cool. Additionally, because stoking generally caused high temperature excursions over 1038°C (1900°F), stoking was often conducted during the port change. As a result, charging was not conducted during the port change when temperatures exceeding 1038°C (1900°F) were experienced. Therefore, in reporting the process data for each of the test runs, both total test period (period of time from the beginning of the test to the end of the test including the port change) and actual sampling period (same as the total test period with the process data removed for the port change and for any sampling or process anomalies) process data sets were developed. These data are presented in Appendix _____ along with graphs of the chamber temperature profiles during testing.

Tables 3-3 and 3-4 show the MWI process and DI/FF process data generated during each of the test runs conducted at Borgess. The process data presented are averages of all of the data collected during the actual sampling period of each test run. Therefore, the averages do not include data taken during port changes or any anomalies where sampling did not occur.

3.5.3 Test Run Summaries

The following paragraphs briefly summarize each test run by describing the quantity of waste charged during both the total test period and the actual sampling period, the weight of charges to the incinerator, and any process anomalies such as stoppages and high temperature excursions. The high temperature excursions were those periods of time when temperatures in the tertiary chamber exceeded the 982° to 1038°C (1800° to 1900°F) target temperature range. Typically, manual stoking was not conducted during testing. However, automatic stokes were conducted except where tertiary chamber temperatures were close to the upper limit of the target temperature range.

3.5.3.1 Test No. 1. Test No. 1 was conducted on September 6, 1991. Because of problems with one of the sampling trains, this test was aborted.

TABLE 3-3. INCINERATOR PROCESS DATA
BORGESS MEDICAL CENTER

Run Number	Date	Testing Charge Rate (lb/hr)		Daily Operation Charging			Ash (%)	Average Chamber Temperature (°F)			Boiler Inlet Temperature (°F)
		TTP	ASP	hr	lb	lb/hr		Primary	Secondary	Tertiary	
2	9/07/91	548	577	9.8	5176	528	12.5	1281	1854	1839	1406
3	9/09/92	443	506	9.8	4690	479	11.2	1220	1888	1846	1236
4	9/10/91	510	565	8.6	4270	497	8.1	1291	1860	1831	1172
5	9/11/91	523	554	11.6	6075	524	10	1298	1856	1836	1280
6	9/12/91	484	551	11.3	6051	535	12.2	1289	1883	1866	1335
7	9/13/91	526	591	12.1	6085	503	10.5	1294	1846	1827	1293
8	9/14/91	454	528	12.2	5880	482	11.7	1293	1850	1819	1240
9	9/16/91	522	525	13	6720	517	NA	1305	1848	1823	1452

NA = Not Available.

3.5.3.6 Test No. 6. Test No. 6 was conducted on September 12, 1991. The average charge rate for the total test period was 219.6 kg/hr (484.1 lb/hr), while that for the actual sampling period was 249.7 kg/hr (550.6 lb/hr). Charges were maintained between 31 and 33 kg/charge (69 and 73 lb/charge) during testing. Of the two automatic stokes and one manual stoke scheduled during the first traverse, one of the automatic stokes was conducted. A manual stoke was conducted during the port change. One of the three scheduled automatic stokes was conducted during the second traverse.

3.5.3.7 Test No 7. Test No. 7 was conducted on September 13, 1991. The average charge rate for the total test period was 238.7 kg/charge (526.2 lb/hr), while that for the actual sampling period was 267.6 kg/hr (590.5 lb/hr). Charges were maintained between 32 and 34 kg/charge (70 and 74 lb/charge) during testing with most charges weighing 32 kg (70 lb). Two of the three scheduled automatic stokes were conducted during the first traverse. A manual stoke was conducted during the port change. One of the two scheduled automatic stokes was conducted during the second traverse.

3.5.3.8 Test No. 8. Test No. 8 was conducted on September 14, 1991. The average charge rate for the total test period was 206.0 kg/hr (454.1 lb/hr), while that for the actual sampling period was 239.4 kg/hr (527.8 lb/hr). Charges were maintained between 32 and 35 kg/charge (70 and 78 lb/charge) with most charges weighing between 32 and 33 kg/charge (70 and 72 lb/charge). During the port change, another rag was drawn through the baghouse system and was jammed in the rotary air lock. This incident caused the rotary air lock fuses to be blown and testing to be delayed for about an hour. The fuses were replaced and the system was placed back in operation. Stoking was not conducted during this test. However, a manual stoke was conducted during the port change.

3.5.3.9 Test No. 9. Test No. 9 was conducted on September 16, 1991. The average charge rate for the total test period was 236.8 kg/hr (522.0 lb/hr), while that for the actual sampling period was 238.1 kg/hr (525.0 lb/hr). Charges were maintained at 32 kg/charge (70 lb/charge) throughout testing. During the first traverse, two scheduled automatic stokes and one scheduled manual stoke were conducted. A manual and an automatic stoke were conducted during the port change. One of the two scheduled automatic stokes was conducted during the second traverse.

3.5.4 Process Operation During 24-Hour CEM Operation

In addition to operating the CEMS during the testing periods, several attempts were made early in the test program to operate the CEMS for 24-hour periods in order to measure emissions during the startup, burndown, and cooldown periods of the MWI operating cycle. However, on each of these occasions, the system ID fan would shutdown during burndown causing MWI exhaust gases to flow through the bypass system instead of through the waste heat boiler and DI/FF system. Several different hypotheses were postulated to explain the ID fan failure. The following paragraphs explain the problem and solution in detail.

As explained earlier, when the system goes into burndown, the large auxiliary thermal reactor burner and Pilot Burners No. 1 and No. 2 cycle on and off to maintain their setpoint temperatures. After hours, the large auxiliary burner cycles off and remains off while the two smaller pilot burners continue to cycle on and off to maintain set point temperatures. During the early attempts to perform 24-hour CEMS monitoring, the ID fan would shutdown a few minutes after the large auxiliary burner cycled off for good (approximately 3 hours into the burndown period). The two small pilot burners cannot maintain the approximately 982° to 1010°C (1800° to 1850°F) setpoint temperatures without the auxiliary burner. Therefore, the secondary and tertiary chamber temperatures drop quickly when the auxiliary burner remains off. While several solutions were postulated regarding the ID fan shutdown, the problem turned out to be the improper setting of the high temperature setpoint on the retention chamber.

Almost all setpoints are adjusted using proportional controllers located behind the main control panel. The exceptions include the high temperature setpoint and the minimum temperature lockout for the retention chamber, and the high and low setpoints for the fabric filter. These setpoints are adjusted using the retention chamber and fabric filter LED readouts/controllers. These readouts/controllers are located on the front of the control panel and are accessed by removing the plastic view-glass. The LED readout

4. SAMPLING LOCATIONS

The sampling locations used during the emission testing program at the Borgess Medical Center MWI are described in this section. Flue gas samples were collected at three sampling locations.

Flue gas samples for CDD/CDF and PM were collected at the boiler inlet. This was a refractory-lined 21-inch ID duct with a gas temperature of approximately 1,400°F. Two 3-inch ports were used to access the duct. A total of 20 sampling points were used. A general schematic of this location is shown in Figure 4-1. The traverse point layout for this location is shown in Figure 4-2.

Flue gas was also sampled at the baghouse inlet which consisted of a horizontal 16-inch ID duct located on top of the roof of the facility. There were three sets of two 4-inch port nipples used to gain access to the flue gas. A general schematic is shown in Figure 4-3. Figure 4-4 gives the traverse point layout for this location.

The third sampling location was at the baghouse outlet. A schematic is presented in Figure 4-5. Figure 4-6 depicts the traverse point layout for the baghouse outlet. There were four sets of two ports (4-inch nipples) on this horizontal duct located on the roof of the facility. A total of 24 sampling points was used at this location.

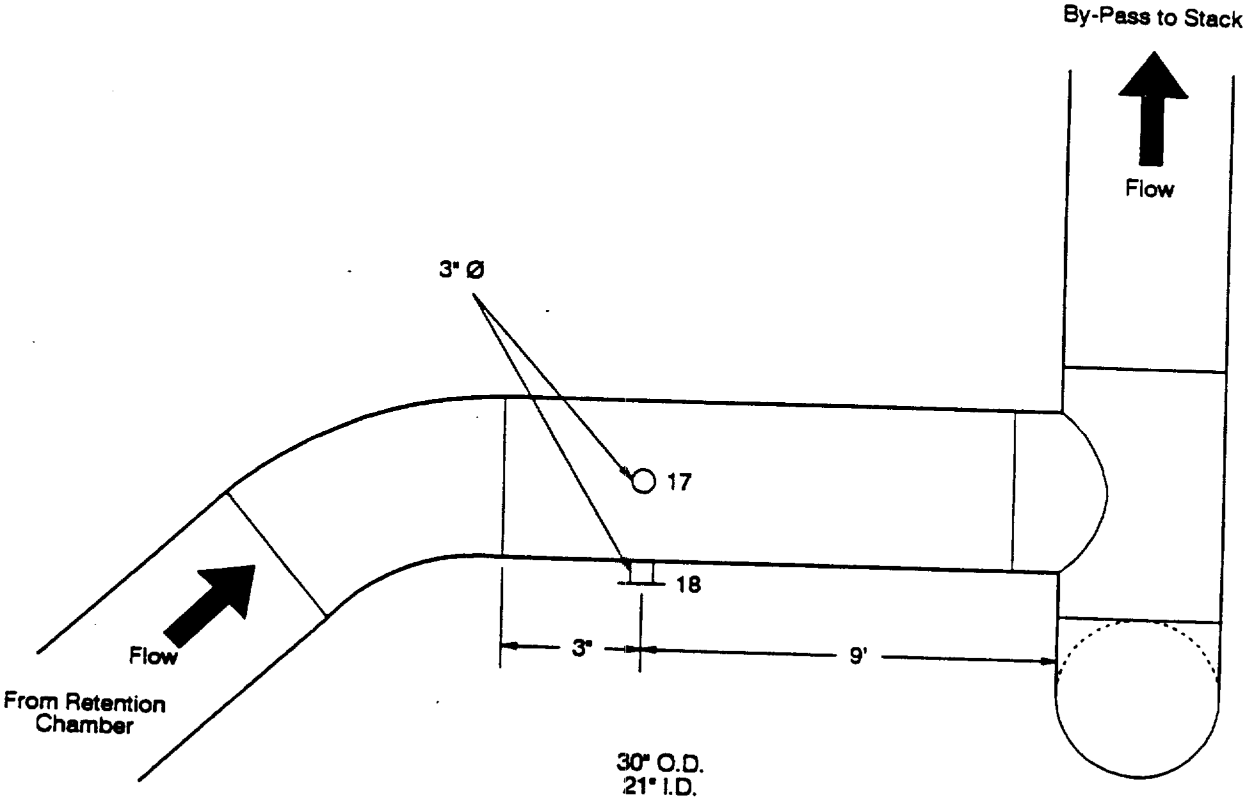

Figure 4-1. Borgess MWI Boiler Inlet Location

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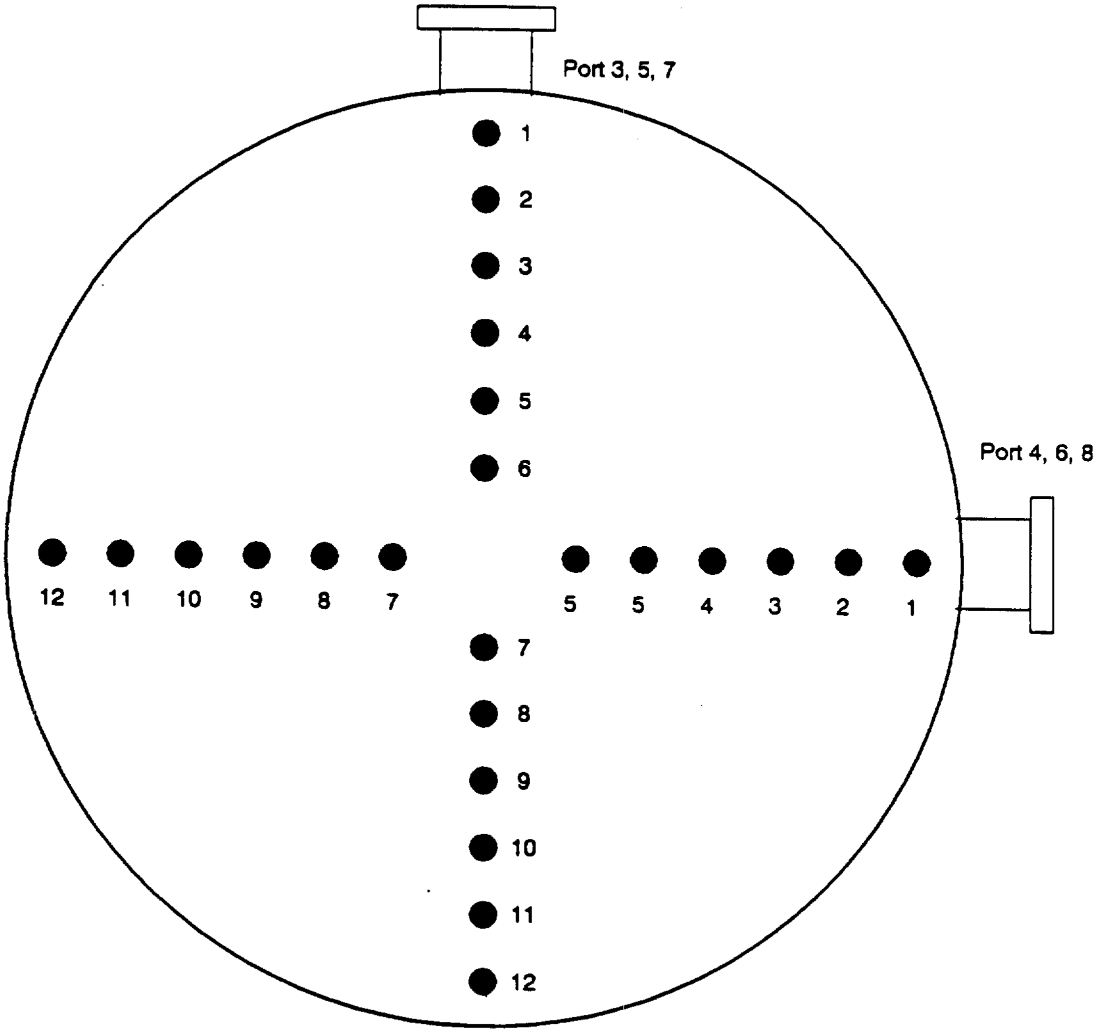

Duct Diameter: 16"
Wall Thickness (including port length): 4"
Port Diameter: 4"

Point	% of Diameter	Distance from Inner Wall (inches)	Distance from Outside of Port (inches)
1	2.1	0.5	4.5
2	6.7	1.0	5.0
3	11.8	1.8	5.8
4	17.7	2.7	6.7
5	25.0	3.9	7.9
6	35.6	5.5	9.5
7	64.4	10.0	14.0
8	75.0	11.6	15.6
9	82.3	12.8	16.8
10	88.2	13.7	17.7
11	93.3	14.5	18.5
12	97.9	15.0	19.0

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Figure 4-4. Traverse Point Layout - Baghouse Inlet

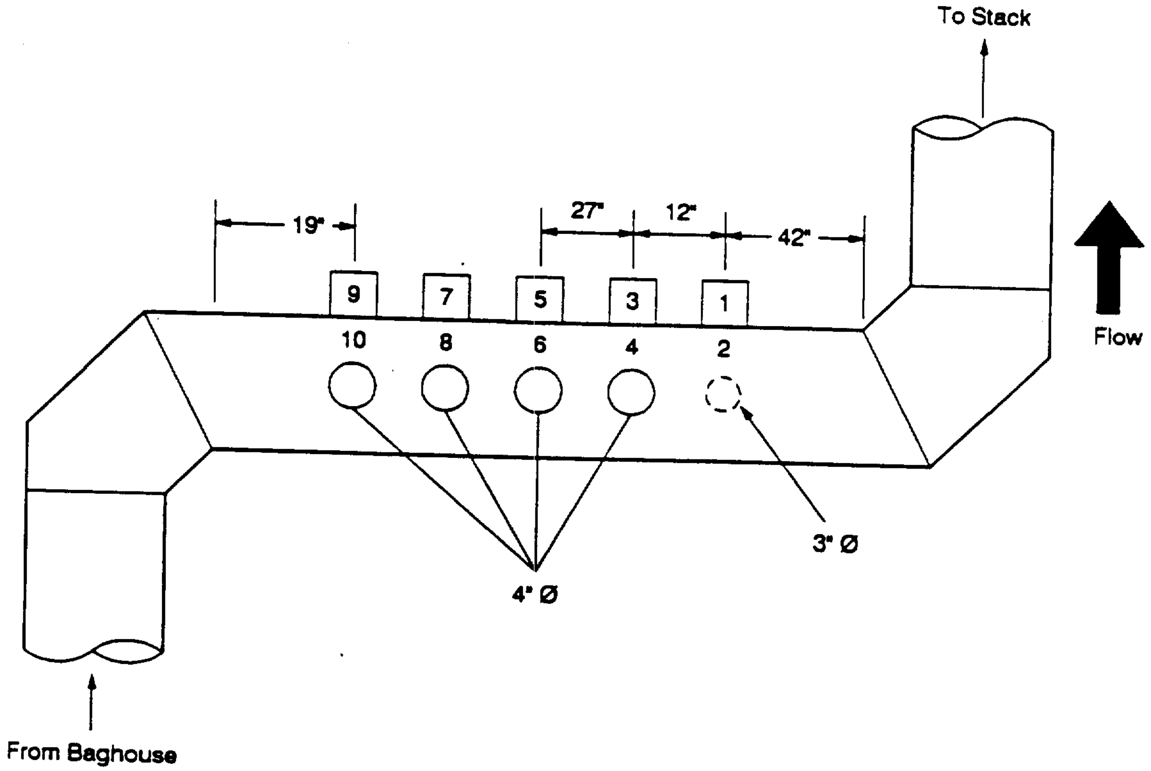

Figure 4-5. Borgess MWI Baghouse - Outlet Location

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5. SAMPLING AND ANALYTICAL PROCEDURES

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

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

5.1 CDD/CDF EMISSIONS TESTING METHOD

The sampling and analytical method for determining flue gas emissions of CDD/CDF 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. (For proprietary reasons, Triangle Laboratories has requested that a copy of their standard operating procedures not be included in this test report.)

Sample recovery techniques incorporated the latest EPA development of replacing the methylene chloride rinses with toluene rinses.

5.1.1 CDD/CDF Sampling Equipment

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

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

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

TABLE 5-1. TEST METHODS BORGESS MEDICAL CENTER MWI

Analyte	Method	
CDD/CDF	EPA Proposed Method 23 with GC/MS Method 8290	
Mercury	EPA Method 101A	
Particulates	EPA/EMSL Multi-Metals 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
HCl	NDIR CEM Analyzer	
HCl	EPA Draft Method 26	
HBr	EPA Draft Method 26	
HF	EPA Draft Method 26	
Loss-On-Ignition	ASTM D3174	
Carbon	ASTM D 3178	

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 could interfere with analysis. The glassware, glass fiber filters and absorbing resin were cleaned, and the filters and resin were checked for residuals before they were packed.

5.1.2.1 Glassware Preparation. Glassware was cleaned as shown in Table 5-3. Glassware was washed in soapy water, rinsed with distilled water, baked and then rinsed with acetone followed by methylene chloride. Clean glassware was loosely covered with foil and allowed to dry under a hood to prevent laboratory contamination. Once the glassware was dry, the ends exposed to air were sealed with methylene chloride-rinsed aluminum foil. All the glass components of the sampling train, including the glass nozzles and any sample bottles, flasks, petri dishes, graduated cylinders and pipets that were used during sampling and recovery, were cleaned according to this procedure. Non-glass components (such as the Teflon®-coated filter screens and seals, tweezers, Teflon® squeeze bottles, nylon probe brushes and nylon nozzle brushes) were cleaned following the same procedure, except that no baking was performed (Step 4 omitted).

This cleaning procedure deviates from the EPA proposed method. However, Radian believes that the use of chromic acid solution may result in 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 were pre-cleaned by separate procedures according to the specified method. Only pesticide grade solvents and HPLC grade water were used to prepare for organic sampling and to recover these samples. The lot number, manufacturer and grade of each reagent used was recorded in the laboratory notebook.

To prepare the filters, a batch of 50 filters were placed in a soxhlet pre-cleaned by extraction with toluene. The soxhlet was charged with fresh toluene and reflexed for 16 hours. After the extraction, the toluene was analyzed as described in Sections 5.2 and 5.3 of the reference method for the presence of tetrachloro dibenzo-p-dioxins (TCDD) or tetrachloro dibenzofurans (TCDF). (If these analytes are found, the filters are re-extracted until no TCDD or TCDF is detected.) The filters were then dried

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. Rinse with distilled/deionized H_2O (X3).[a]
4. Bake at 450°F for 2 hours.[b]
5. Rinse with acetone (X3), (pesticide grade).
6. Rinse with 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. Immediately rinse glassware 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 baking sufficiently removes organic artifacts. Baking 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).

completely under a clean nitrogen (N_2) gas stream. Each filter was individually checked for holes, tears, creases or discoloration. If any had been found, the filter would have been discarded. Acceptable filters were 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 was cleaned in the following sequential order:

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

Once the resin was completely dry, it was checked for the presence of methylene chloride, TCDD and TCDF as described in Section 3.1.2.3.1 of the reference method. (If TCDD or TCDF are found, the resin is re-extracted. If methylene chloride is found, the resin is dried until the excess solvent is removed.) The absorbent was used within four weeks of cleaning as specified by the method.

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

5.1.2.3 <u>CDD/CDF Method 5 Equipment Preparation</u>. The remaining preparation included calibration and leak checking of all sampling train equipment. This included: meterboxes, thermocouples, nozzles, pitot tubes, and umbilicals. Referenced calibration procedures were followed. The results were properly documented in a laboratory notebook and retained. The techniques used to calibrate this equipment followed EPA guidelines.

5.1.3 CDD/CDF Sampling Operations

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

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

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

The second step was to load the filter into the filter holder in the recovery trailer. The filter holder was capped and placed with the resin trap and condenser coil (capped)

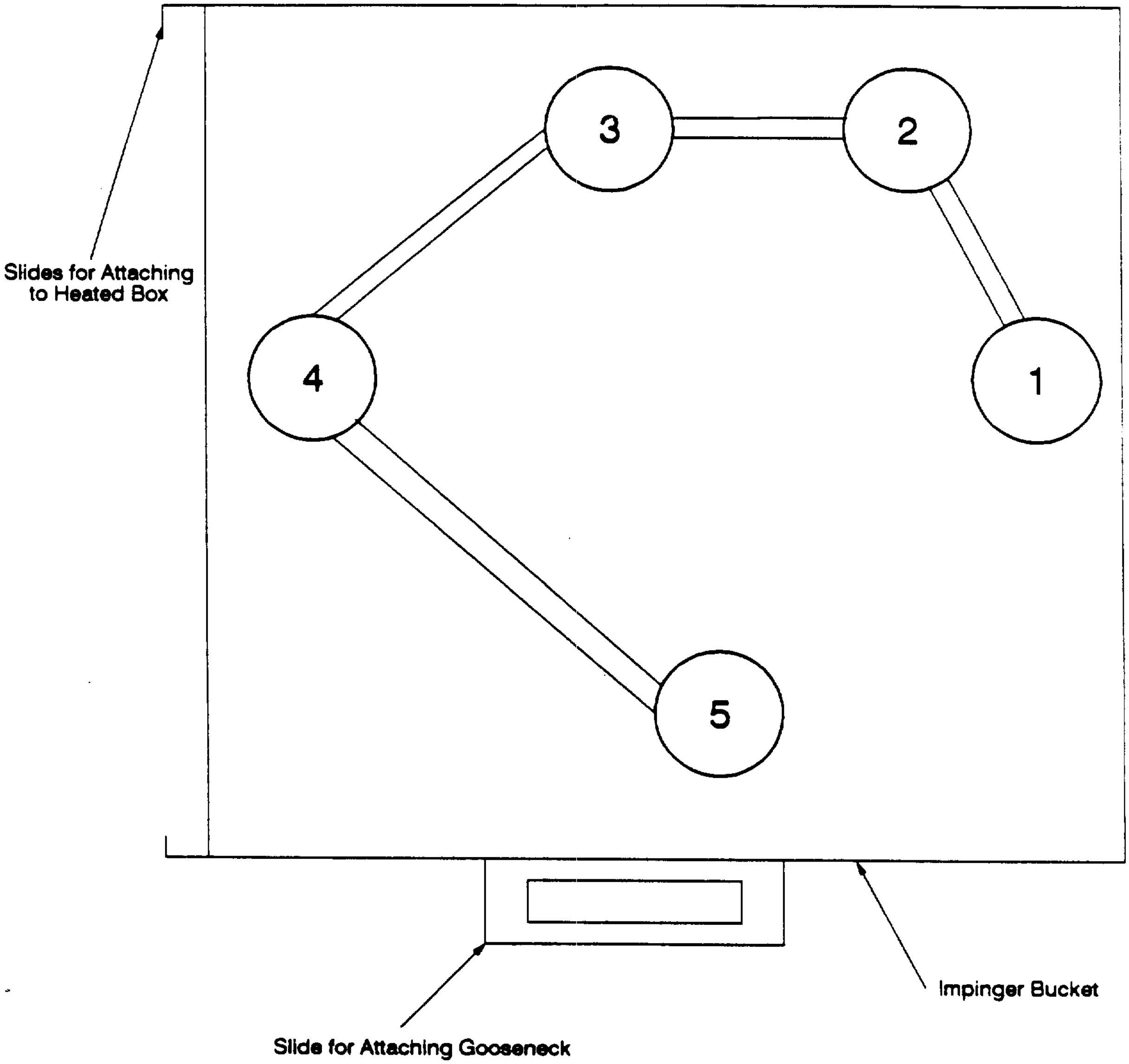

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Figure 5-2. Impinger Configuration for CDD/CDF Sampling (optional knock out impinger not shown) into the impinger bucket. A supply of pre-cleaned foil and socket joints was also placed in the bucket in a clean plastic bag for use by the samplers. Sealing greases were not used to avoid contamination of the sample. The train components were transferred to the sampling location and assembled as shown in Figure 5-1.

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

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

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

After a successful pre-test leak check had been conducted and all train components were at their specified temperatures, initial data were recorded (DGM reading) and the test was initiated. Sampling train data were recorded periodically on standard data forms. A checklist for CDD/CDF sampling is included in Table 5-4. A sampling requirement unique to CDD/CDF sampling is that the gas temperature entering the resin trap must be below 68°F. The gas was cooled by a water jacket condenser which circulated water at 0°C (32°F).

The leak rates and sampling start and stop times were recorded on the sampling log. Any events occurring during sampling that could potentially affect sampling results were also recorded on the sampling log.

At the conclusion of the test run, the sample pump (or flow) was turned off, the probe was removed from the duct, a final DGM reading was taken, and a post-test leak check was completed. The procedure was identical to the pre-test procedure, except that the vacuum pulled was at least one inch Hg higher than the highest vacuum attained during sampling. A leak rate of less than 4 percent of the average sample rate or 0.02 acfm (whichever is lower) is acceptable. If a final leak rate did not meet the acceptable level, the test run could still be accepted upon approval of the EPA Test Administrator. If approved, the measured leak rate was reduced by subtracting the allowable leak rate and then multiplying by the period of time in which the leak occurred. This "leaked volume" was then subtracted from the measured gas volume 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 was disassembled into the following sections: the probe liner, filter holder, filter to condenser glassware, condenser sorbent module, and the impingers in their bucket. Each of these sections was capped with methylene chloride-rinsed aluminum foil or ground glass caps before removal to the recovery trailer. Once in the trailer, field recovery followed the scheme shown in Figure 5-3. The samples were recovered and stored in cleaned amber glass bottles to prevent light degradation.

For the Borgess Medical Center test program, all CDD/CDF recovery rinses were completed using toluene instead of methylene chloride. This is the most recent development in EPA CDD/CDF testing methodology. The solvents used for train recovery were all pesticide grade. The use of the highest grade reagents for train

TABLE 5-4. CDD/CDF SAMPLING CHECKLIST

Pretest:

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. Obtain data sheets and record barometric pressure on log sheet.
4. Bag sampling equipment for CO_2/O_2 needs to be ready if not using CEMs for CO_2/O_2 determinations.
5. Examine the meter box - level it, zero the manometers and confirm that the pump is operational.
6. Verify the filter is loaded correctly and as tight as possible; place filter in line with the train and leak check at 15 inches Hg.
7. Add probe to train.
8. Check thermocouples - make sure they are reading correctly.
9. Conduct pitot leak check, recheck manometer zero.
10. Do final leak check; record leak rate and vacuum on sampling log sheet.
11. Turn on variacs and verify that the heat is increasing.
12. Check that cooling water is flowing and on. Add ice to impinger buckets.
13. Check isokinetic K-factor - make sure it is correct. (Refer to previous results to confirm assumptions). (Two people should calculate this independently to double check it.)

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

Test:

1. Notify crew chief of any sampling problems immediately. The meterbox operator must fill in sampling log and document any abnormalities.
2. Perform simultaneous/concurrent testing with other locations (if applicable). Maintain filter temperature between 248°F ±25°F. Keep temperature as steady as possible. Maintain the resin trap and impinger temperatures below 68°F. Maintain probe temperature above 212°F.
3. Leak check between ports and record on sampling log. 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 if moisture entrapment is expected.
6. Stop test and 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 reinstate it in the train.
8. Check silica gel impinger every 1/2 hour; if indicator color begins to fade, request a pre-filled, pre-weighed impinger from the recovery trailer, stop test and replace silica gel impinger.
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 condenser coil and silica gel impinger gas temperatures below 68°F.

Post-test:

1. Record final meter reading and record on log sheet.
2. Do final leak check of sampling train at maximum vacuum during test and record on log sheet.
3. Do final pitot leak check.

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

4. Check completeness of data sheet(s). Verify that impinger bucket identification is recorded on the data sheets. Note any abnormal conditions experienced during the test.

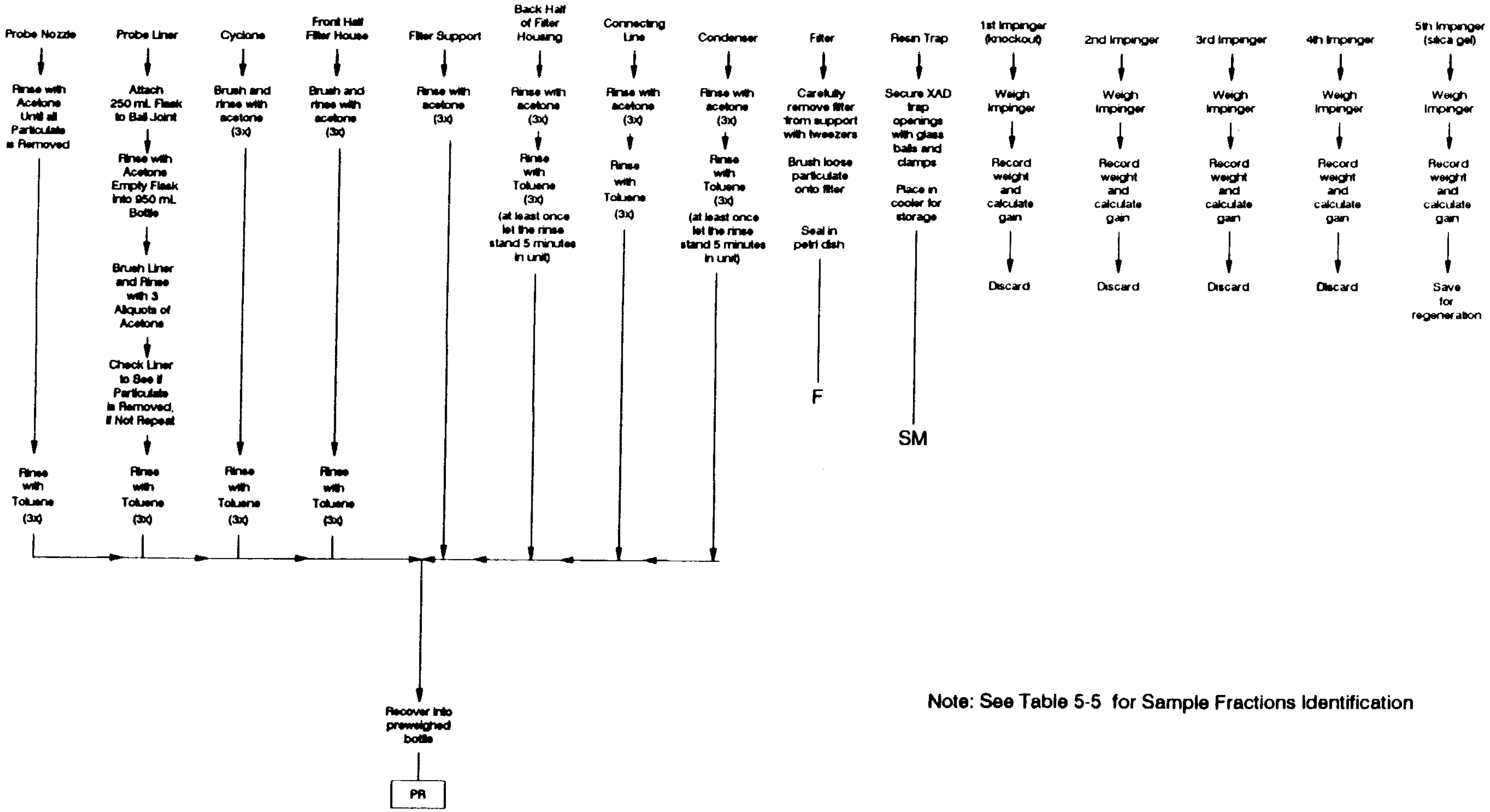
5. Leak check function (level, zero, etc.) of the pitot tubes and inspect for tip damage.

6. Disassemble train, cap sections, and take each section and all data sheets to the recovery trailer.

7. Probe recovery (use clean 950 ml bottles)
    a) Bring probes into recovery trailer (or other enclosed area).
    b) Wipe the exterior of the probe to remove any loose material that could contaminate the sample.
    c) Carefully remove the nozzle/probe liner and cap it with pre-rinsed aluminum foil. (Rinsed with methylene chloride.)
    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 pre-weighed, pre-labeled sample container
    e) Follow the procedure outlined in (d) using toluene, except do not brush. Recover the solvent into the same acetone recovery bottle.

8. Cap both ends of nozzle/probe liner for the next day, and store in dry safe place.

9. Make sure data sheets are completely filled out, legible, and give them to the Field Test Leader.



Note: See Table 5-5 for Sample Fractions Identification

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Figure 5-3. CDD/CDF Field Recovery Scheme recovery is essential to prevent the introduction of chemical impurities which interfere with the quantitative analytical determinations.

Field recovery resulted in the sample components listed in Table 5-5. The sorbent module was stored on ice in coolers at all times. The samples were shipped with written analysis instructions to the analytical laboratory by truck.

5.1.5 CDD/CDF Analytical Procedures

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

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

Data from the mass spectrometer were recorded and stored on a computer file and on paper. Results for the amount detected, detection limit, retention time, and internal standard and surrogate standard recoveries were calculated by computer. The chromatograms were retained by the analytical laboratory and were also included in the analytical report delivered to Radian Corporation.

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

5.1.5.2 Calibration of GC/MS System. A five-point calibration of the GC/MS system was performed to demonstrate instrument linearity over the concentration range of interest. Relative response factors were calculated for each congener or compound of

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

Container/ Component	Code	Fraction
1	F	Filter(s)
2	PR[a]	Acetone and toluene rinses of nozzle/probe, front half/back half filter holder, filter support, connecting glassware, condenser
3	SM	XAD-II® resin trap (sorbent module)

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

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)

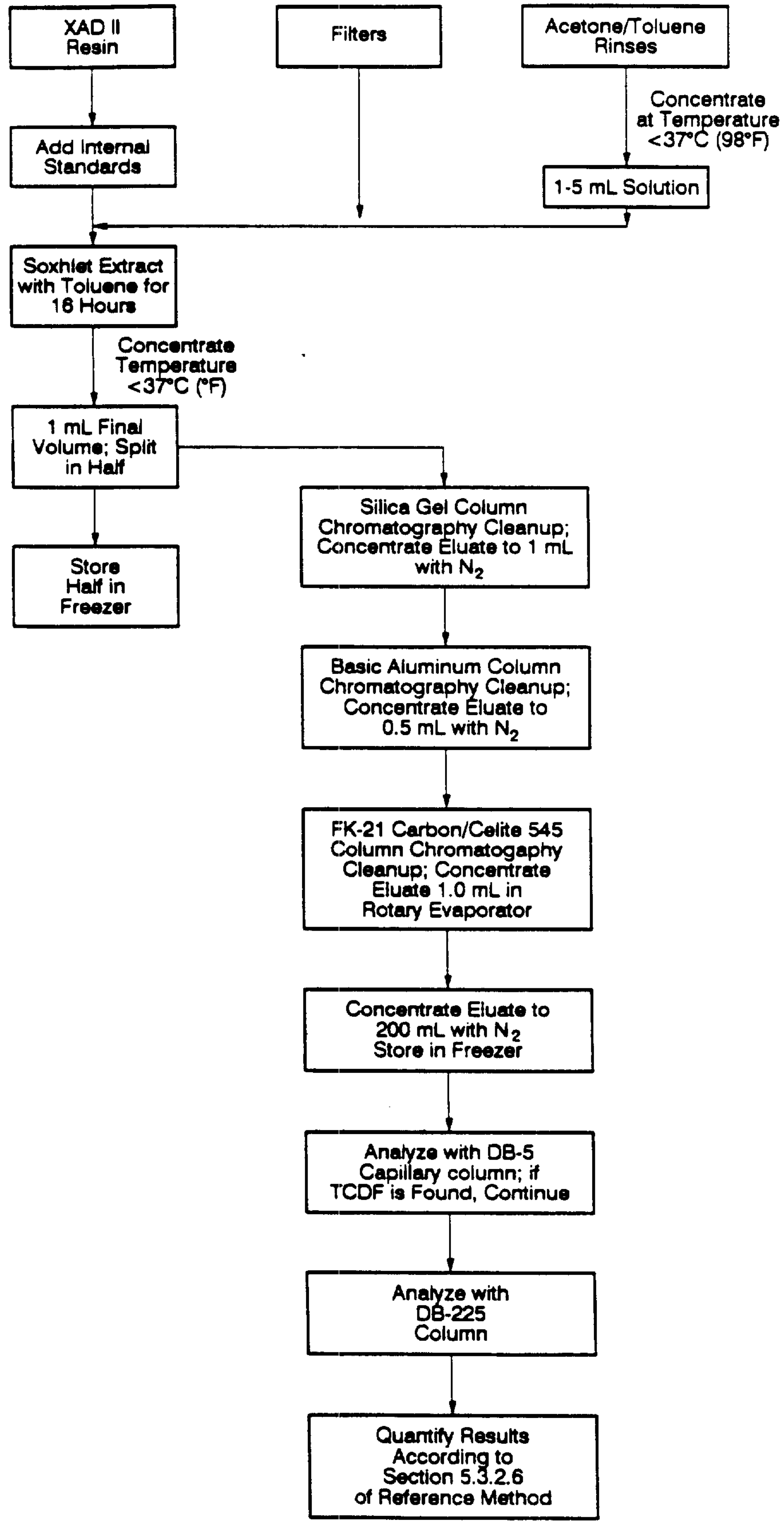

Figure 5-4. Extraction and Analysis Schematic for CDD/CDF Samples

interest. The response factors were verified on a daily basis using a continuing calibration standard consisting of a mid-level mixed isomer standard. The instrument performance 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 were followed. Blanks were used to determine analytical contamination; calibration standards were used for instrument calibration and linearity checks; internal standards were used to determine isomer recoveries and adjust response factors for matrix effects; surrogate standards were used to measure the collection efficiency of the sampling methodology; and an alternate standard was used as a column efficiency check.

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

Reagent blanks of 1,000 ml of each reagent used at the test site were saved for analysis. Each reagent blank was of the same lot used during the sampling program. Each lot number and reagent grade was recorded on the field blank label and in the laboratory notebook.

A field blank was collected from a set of CDD/CDF glassware that had been used to collect at least one sample and had been recovered. The train was re-loaded and left at a sampling location during a test run. The train was then recovered. The purpose of the field blank is to measure the level of contamination that occurs from handling, loading, recovering, and transporting the sampling train. The field blanks were analyzed with the flue gas samples. If they were unsatisfactory in terms of contamination, reagent blanks were analyzed to determine the specific source of contamination.

In addition to the two types of blanks that are required for the sampling program, the analytical laboratory analyzed a method blank with each set of flue gas samples. This consists of preparing and analyzing reagent water by the exact procedure used for

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.
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.

the samples analysis. The purpose of this procedure was 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 25 to 130 percent for the hepta- and octachlorinated homologues. Surrogate standard recoveries must be between 70 to 130 percent. 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.

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

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

5.2 PARTICULATE MATTER AND METALS EMISSIONS TESTING METHOD

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

The PM emissions were also determined from this sampling train. Particulate concentrations were based on the weight gain of the filter and the front half acetone rinses (probe, nozzle, and filter holder). After the gravimetric analyses were completed, the sample fractions were 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 standard EPA Method 5 meterbox and vacuum pump. The sample is not exposed to any metal surfaces in this train. The contents of the sequential impingers are: two impingers with a 5 percent HNO_3/10 percent H_2O_2 solution, two impingers with a 4 percent $KMnO_4$/10 percent sulfuric acid (H_2SO_4) solution, and an impinger containing silica gel. (An optional empty knockout impinger may be added if the moisture content of the flue gas is high.) The second impinger containing HNO_3/H_2O_2 was of the Greenburg-Smith design; the other impingers had straight tubes. The impingers were connected with clean glass U-tube connectors and arranged in an impinger bucket as shown in Figure 5-6. Sampling train components were recovered and analyzed in separate front and back half fractions according to the described method.

5.2.2 PM/Metals Sampling Equipment Preparation

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

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

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

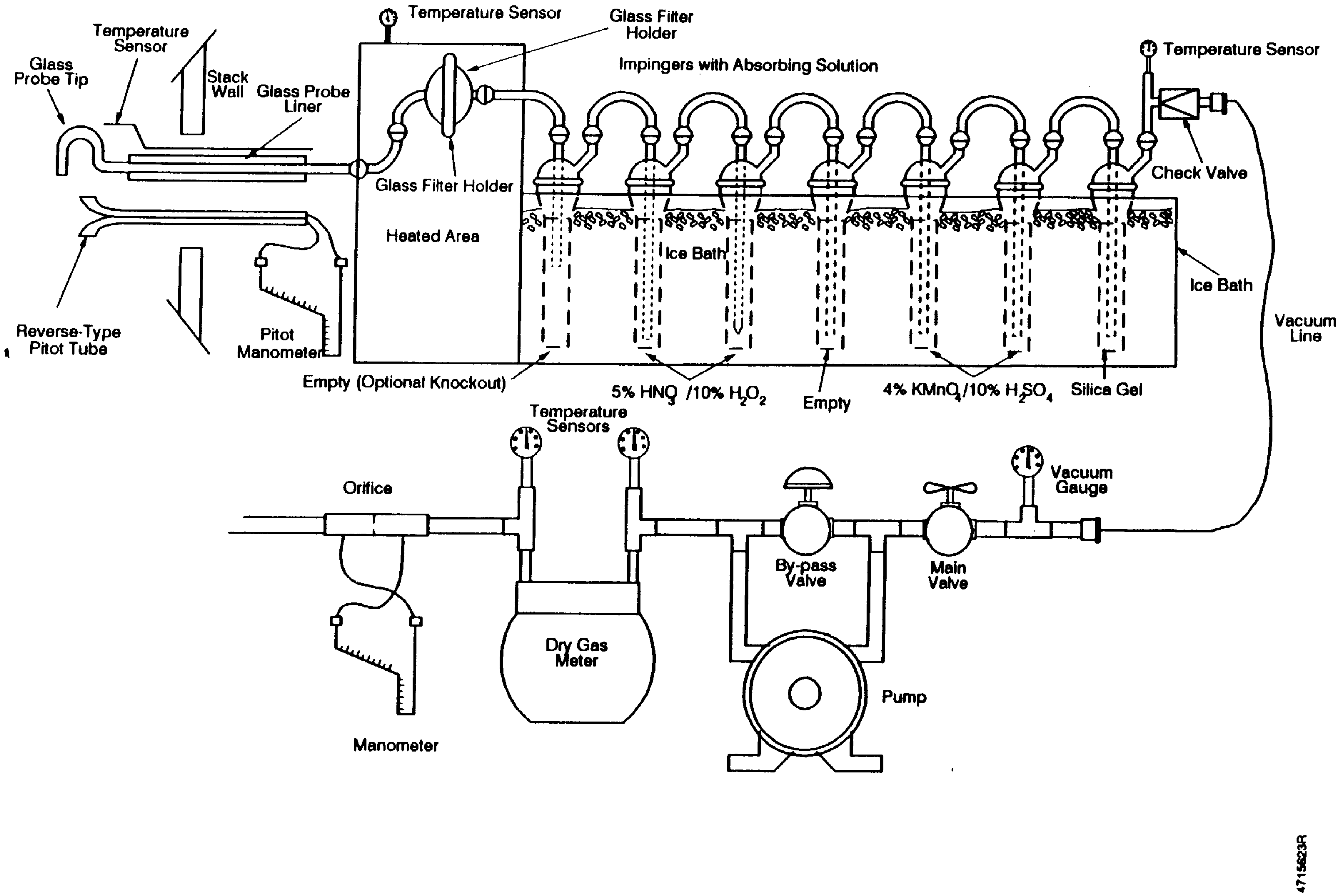

Figure 5-5. Schematic of Multiple Metals Sampling Train

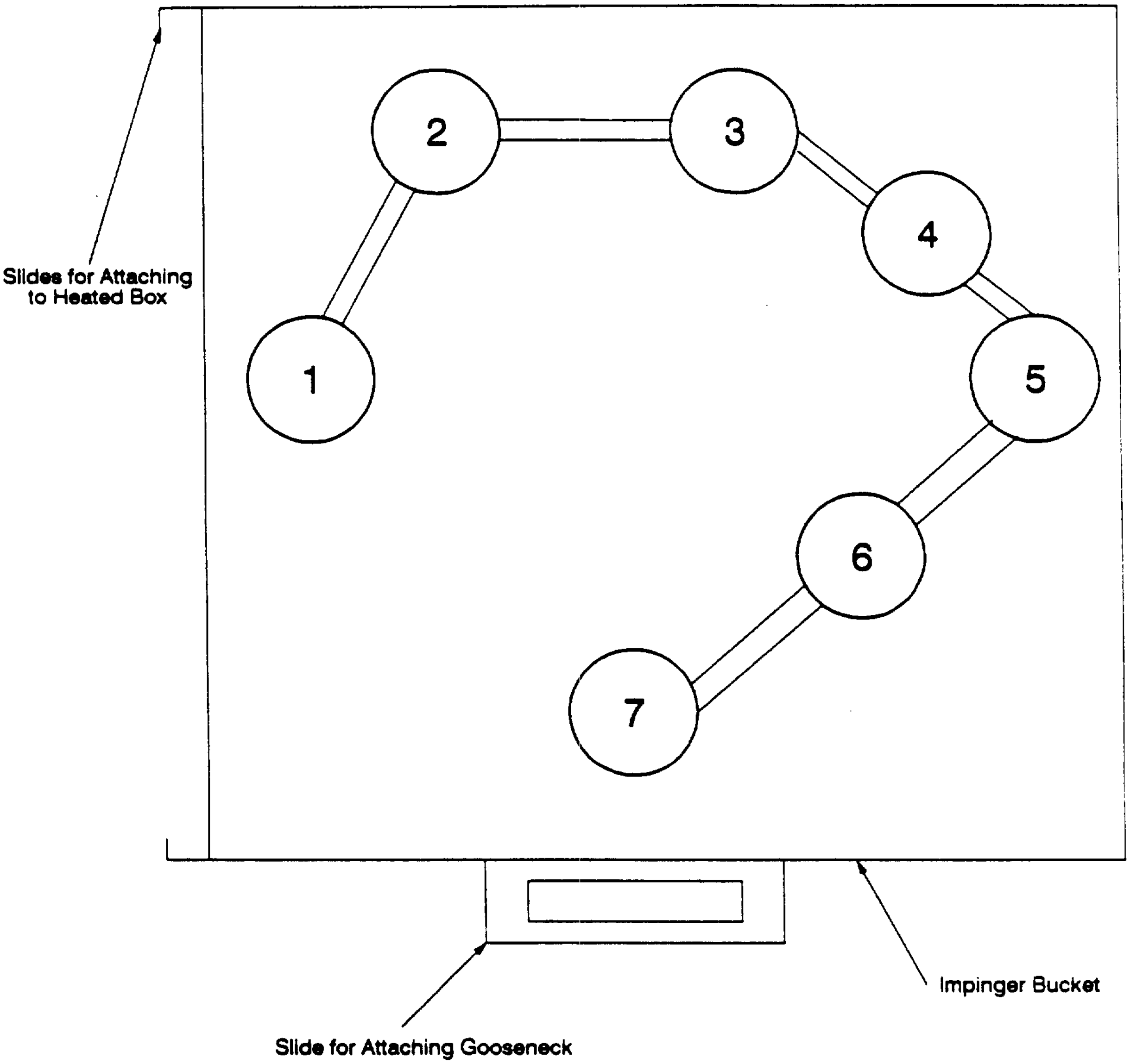

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Figure 5-6. Impinger Configuration for PM/Metals Sampling (optional knock out impinger not shown)

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

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

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

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

- Quantitatively measured 400 ml from a 4 liter bottle of Baker "Analyzed HPLC" water into a clean glass bottle. Labeled this bottle 4.4 percent $KMnO_4$ in water.

- Quantitatively added 160 g of $KMnO_4$ crystals to the bottle; stirred with a Teflon® stirring bar and stirring plate as thoroughly as possible. This reagent was stored on the counter in a plastic tub at all times.

- Each morning the acidic reagent was needed, decanted 900 ml of $KMnO_4$ solution into a 1000 ml volumetric flask. Carefully added 100 ml of concentrated H_2SO_4 and mixed. This reagent was volatile and was mixed cautiously. By holding the flask cap on the flask, it was mixed once and vented quickly. Completed the mixing slowly until the mixture was homogenous. Allowed the solution to cool and brought the final volume to 1000 ml with H_2O.

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

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

5.2.3 PM/Metals Sampling Operations

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

5.2.4 PM/Metals Sample Recovery

Recovery procedures began as soon as the probe was removed from the stack and the post-test leak check was completed.

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

Once in the trailers, the sampling train was recovered as separate front and back half fractions. A diagram illustrating front half and back half sample recovery procedures is shown in Figure 5-7. No equipment with exposed metal surfaces was used in the sample recovery procedures. The weight gain in each of the impingers was recorded to determine the moisture content in the flue gas. Following weighing of the impingers, the front half of the train, which includes the filter and all sample-exposed surfaces upstream of the filter was recovered. The probe liner was rinsed with acetone by tilting and rotating the probe while squirting acetone into the higher end to wet all inside surfaces. The acetone was quantitatively collected into the appropriate bottle. This rinse was followed by additional brush/rinse procedures using a non-metallic brush; the probe was held in an inclined position and acetone was squirted into the higher end as the brush was pushed through with a twisting action. All of the acetone and PM were

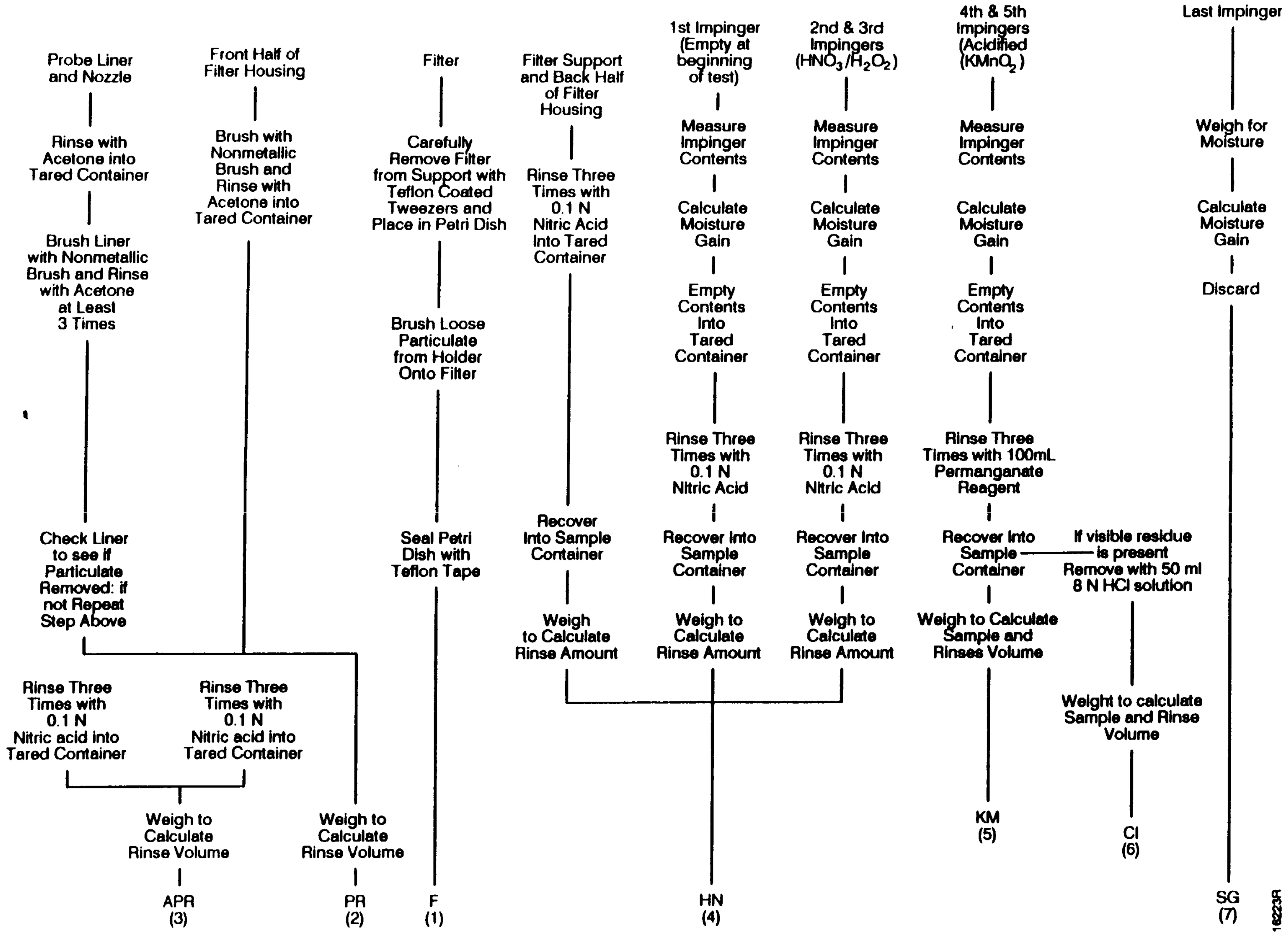

Figure 5-7. Metals Sample Recovery Scheme

caught in the sample container. This procedure was repeated until no visible particulate remained and was finished with a final acetone rinse of the probe and brush. The front-half of the filter was also rinsed with acetone until all visible particulate was removed. After all front-half acetone washes were collected, the cap was tightened, the liquid level marked, and the bottle weighed to determine the acetone rinse volume. The method specifies a total of 100 ml of acetone may be used for rinsing these components. However, Radian feels that a thorough rinse requires more reagent. An acetone reagent blank of approximately the same volume as the acetone rinses was collected with the samples.

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

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

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

The impingers that contain the acidified $KMnO_4$ solution were poured together into a preweighed, prelabeled bottle. The impingers and connecting glassware were 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 were added to the sample recovery bottle. A final 50 ml 8N hydrochloric acid (HCl) rinse was conducted and placed into the sample recovery bottle. A final weight was recorded, and the liquid level was marked on the bottle. The bottle cap was applied loosely to allow venting.

After final weighing, the silica gel from the train was saved in a bag for regeneration. The ground glass fittings on the silica gel impinger were cleaned after sample recovery to ensure a leak-tight fit for the next test.

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

- Acetone blank - 100 ml sample size;
- 0.1N HNO_3 blank - 1,000 ml sample size;
- 5 percent HNO_3/10 percent H_2O_2 blank - 200 ml sample size;
- Acidified $KMnO_4$ blank - 1,000 ml sample size; this blank required a vented cap;
- 8N HCl blank - 50 ml sample size;
- Dilution water; and
- Filter blank - one each.

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

The liquid level of each sample container was marked on the bottle to determine if any sample loss occurred during shipment. If sample loss had occurred, the sample would be voided or a method would be used to incorporate a correction factor to scale the final results according to the volume of the loss.

5.2.5 Particulate Analysis

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

The acetone rinses were evaporated under a clear hood at 20°C (68°F) in a tared beaker. The filter was also desiccated under the same conditions to a constant weight. Weight gain was reported to the nearest 0.1 mg. Each replicate weighing agreed to within 0.5 mg or 1 percent of total weight minus the tare weight, whichever is greater, between two consecutive weighings 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 were digested with concentrated HNO_3 and hydrofluoric (HF) acid in a microwave pressure vessel. The microwave digestion took place over a period of approximately 10 to 12 minutes in intervals of 1 to 2 minutes at 600 watts. Both the digested filter and the digested probe rinses were combined to yield the front half sample fraction. The fraction was diluted with water to a specified volume and divided for analysis.

The absorbing solutions from the HNO_3/H_2O_2 impingers were combined. An aliquot was removed for the analysis of Hg by CVAAS, and the remainder was acidified and reduced to near dryness. The sample was then digested in a microwave with 50 percent HNO_3 and 3 percent H_2O_2. After the fraction had cooled, it was filtered and diluted with water to a specified volume.

Each sample fraction was analyzed by ICAPS using EPA Method 200.7. All target metals except Hg, Fe, and Al, were quantified. If Fe and Al were present, the samples were diluted to reduce interference with As and Pb analysis. If As or Pb levels were less than 2 ppm, GFAAS was used to analyze for these elements by EPA Methods 7060 and 7421. The total volume of the absorbing solutions and rinses for the various fractions were measured and recorded in the field notebook.

To prepare for Hg analysis by CVAAS, an aliquot from the $KMnO_4$ impingers, HNO_3/H_2O_2 impingers, filter digestion, and front half rinses were digested with acidic reagents at 95°C in capped BOD bottles for approximately 3 hours. Hydroxylamine hydrochloride solution and stannous chloride were added immediately before analysis. Cold vapor AAS analysis for Hg followed the procedure outlined in EPA Method 7470 or in Standard Methods for Water and Wastewater Analysis, Method 303F.

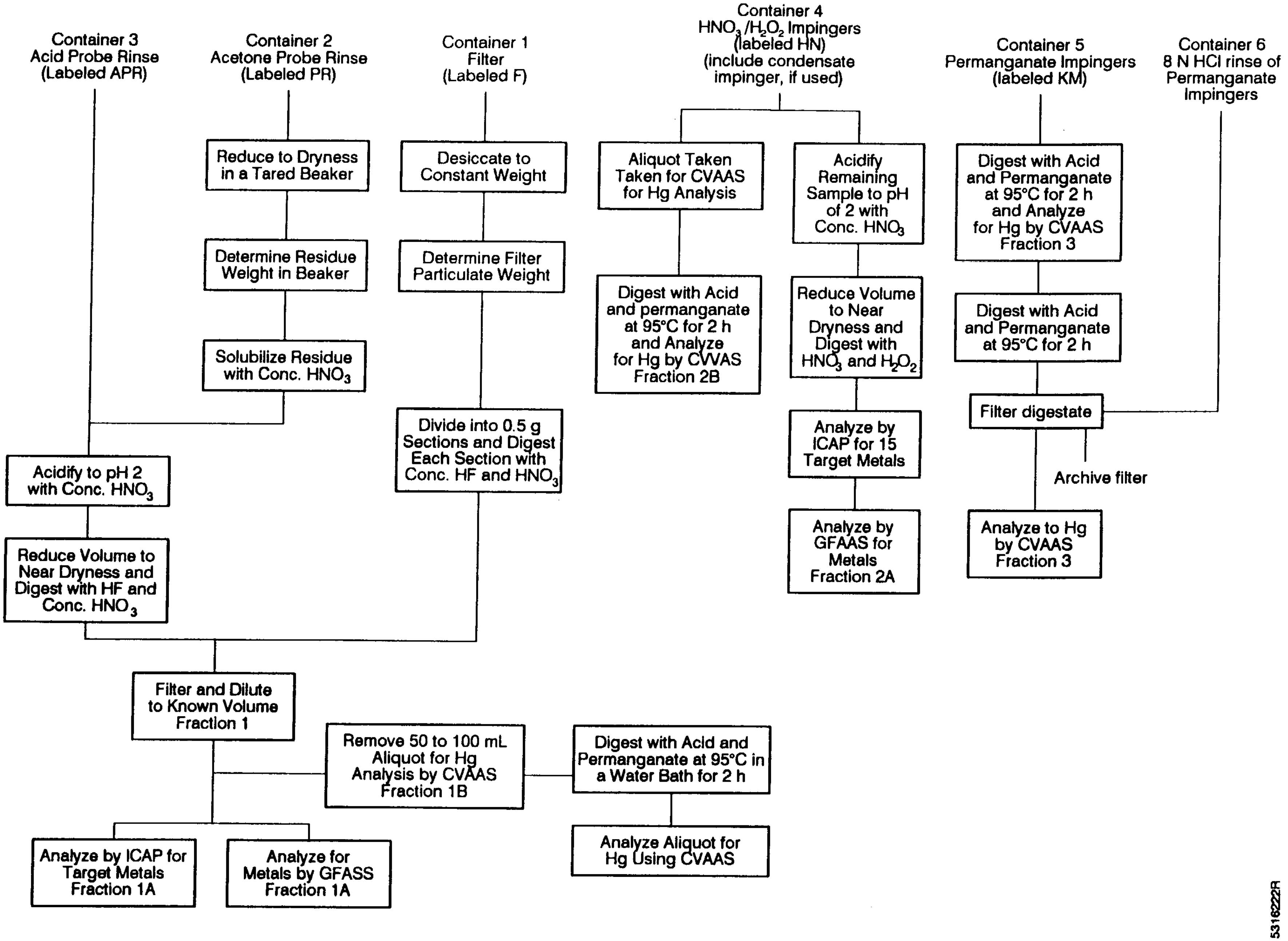

Figure 5-8. Metals Sample Preparation and Analysis Scheme

5.2.7 Quality Control for Metals Analytical Procedures

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

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

Standards less than 1 μg/ml for an individual metal were prepared daily; those with concentrations greater than this were made weekly or bi-monthly.

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

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

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

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

5.3 MERCURY EMISSIONS BY METHOD 101A

Mercury emissions testing by Method 101A was performed as specified in 40 CFR Part 61, Appendix B. The method calls for isokinetic extraction of flue gas through a sample train similar to the standard EPA Method 5 train. The sample stream passes through the filter (optional) and bubbles through acidified $KMnO_4$ solution. Not counting blanks, there were two fractions of the sample train, the probe rinse/impinger catch and the filter. Following sample recovery, the $KMnO_4$ and filter solutions were shipped back to the laboratory for analysis. The analytical preparation procedures consisted of filtering the $KMnO_4$ solutions, and analyzing the filtrate by CVAAS. Studies recently conducted by EPA show that after a certain sample hold time, the analytical filtering procedures may remove a certain portion of the collected Hg contained in the MnO_2 precipitate. This may be the case only when visible precipitate is present. For this test program, the analytical filter was archived and analyzed at a later date. A graphical representation was provided for each analysis.

The following sections briefly describe Method 101A testing procedures.

5.3.1 Method 101A Sampling Equipment

The Method 101A sampling train, including the use of the optional heated filter, is shown in Figure 5-9. The front half of this train is similar to an EPA Method 5 train incorporating all isokinetic sampling apparatus. A glass nozzle/probe liner was used to prevent the sample stream from touching any metal surfaces. Four impingers were used with the first 3 containing 50 ml, 100 ml, and 100 ml, respectively, of acidified 4 percent $KMnO_4$. The last impinger was filled with silica gel to remove water prior to the sampling train meter and pump. All reagent preparation followed strict QA/QC guidelines as dictated by the Method 101A protocol.

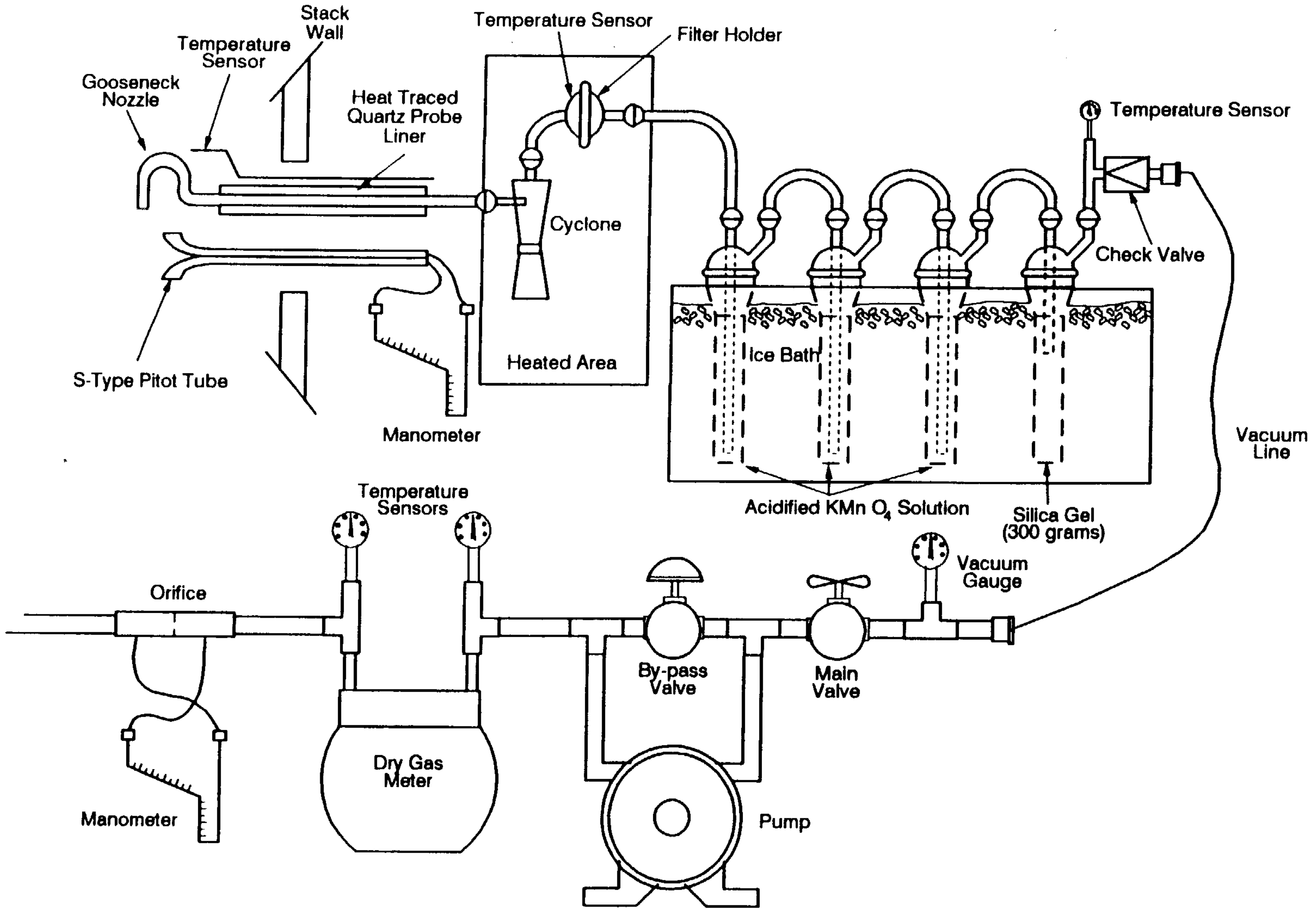

Figure 5-9. EPA Method 101A Sampling Train

5.3.2 Equipment Preparation

All sampling equipment was calibrated accordancing to EPA Method 5 guidelines. This included dry gas meters, pitot tubes, nozzle orifice, and other equipment.

All glassware was cleaned as follows:

- Soaked in 10% HNO_3 acid bath;
- Rinsed 3 times with 50% HNO_3;
- Rinsed 3 times with tap water;
- Rinsed 3 times with 8N HCl;
- Rinsed 3 times with tap water; and
- Rinsed 3 times with deionized/distilled (or equivalent) water.

Glassware was then sealed with Parafilm™, wrapped in bubble wrap, packed, and shipped to the testing facility.

All nozzles and probe liners were cleaned on site by following the above rinsing procedures. Nozzles were then calibrated on site.

5.3.3 Reagent Preparation

The following reagents were used during sampling operations:

- 8N HCl = 67 ml concentrated HCl/100 ml deionized (DI) H_2O;
- 4 percent $KMnO_4$ = see Section 5.2.2.2; and
- 50 percent HNO_3 = (Equal parts acid to DI H_2O must be added very slowly using extreme caution.)

Blank samples of all reagents used were taken to determine if Hg contamination was present.

5.3.4 Sample Operation

The Method 101A sample train was operated similar to an EPA Method 5 train. Care was taken to determine the proper isokinetic sample rate. Sampling rates never exceeded 1.0 cfm. Temperatures of the stack gas, oven (filter skin), silica gel impinger, and inlet and outlet to the gas meter were monitored. Additional recordings of dry gas meter readings, velocity head (ΔH), orifice pressure (Δp), and sample vacuum were taken. The above data were collected at each sample point every 5 minutes. The test duration was divided by the number of sample points to determine the interval of time spent at each sample point.

Leak checks of the sampling train were performed prior to the test, following train removal from a port (port change), and following completion of the test. The maximum acceptable leak rate was 0.02 cfm or 4 percent of the average sample rate, whichever was less.

5.3.5 Sample Recovery

The Method 101A flue gas samples were recovered as shown in Figure 5-10. The first step, after completion of the post-test leak check, was to dismantle and seal the train into the following components:

- Probe nozzle and liner,
- Filter holder, and
- Impinger train.

These components were transported back to the laboratory trailer for recovery operations. The impingers were weighed to determine flue gas moisture levels. Two sample bottles were collected from each flue gas sample.

The contents of the $KMnO_4$ impingers were poured into a 950-ml sample bottle. The nozzle and probe were then brushed/rinsed three times with fresh 4 percent $KMnO_4$ and deionized water and added to the 950-ml bottle. The front half filter holder was also rinsed into the same sample bottle. If any visible deposits were left on these pieces of glassware, a small amount (approximately 50 ml) of 8N HCl was used to rinse them, and the rinse was added to a separate sample bottle.

A second sample bottle (third if an HCl rinse was performed) was collected. The filter was carefully placed in a 150 ml sample jar, and 20 to 40 ml of fresh 4 percent $KMnO_4$ was added. Any residual filter pieces left on the filter holder were carefully removed using a sharpened edge blade and/or nylon bristle brush so as not to lose any material and added to this container. A filter and reagent blank were also collected.

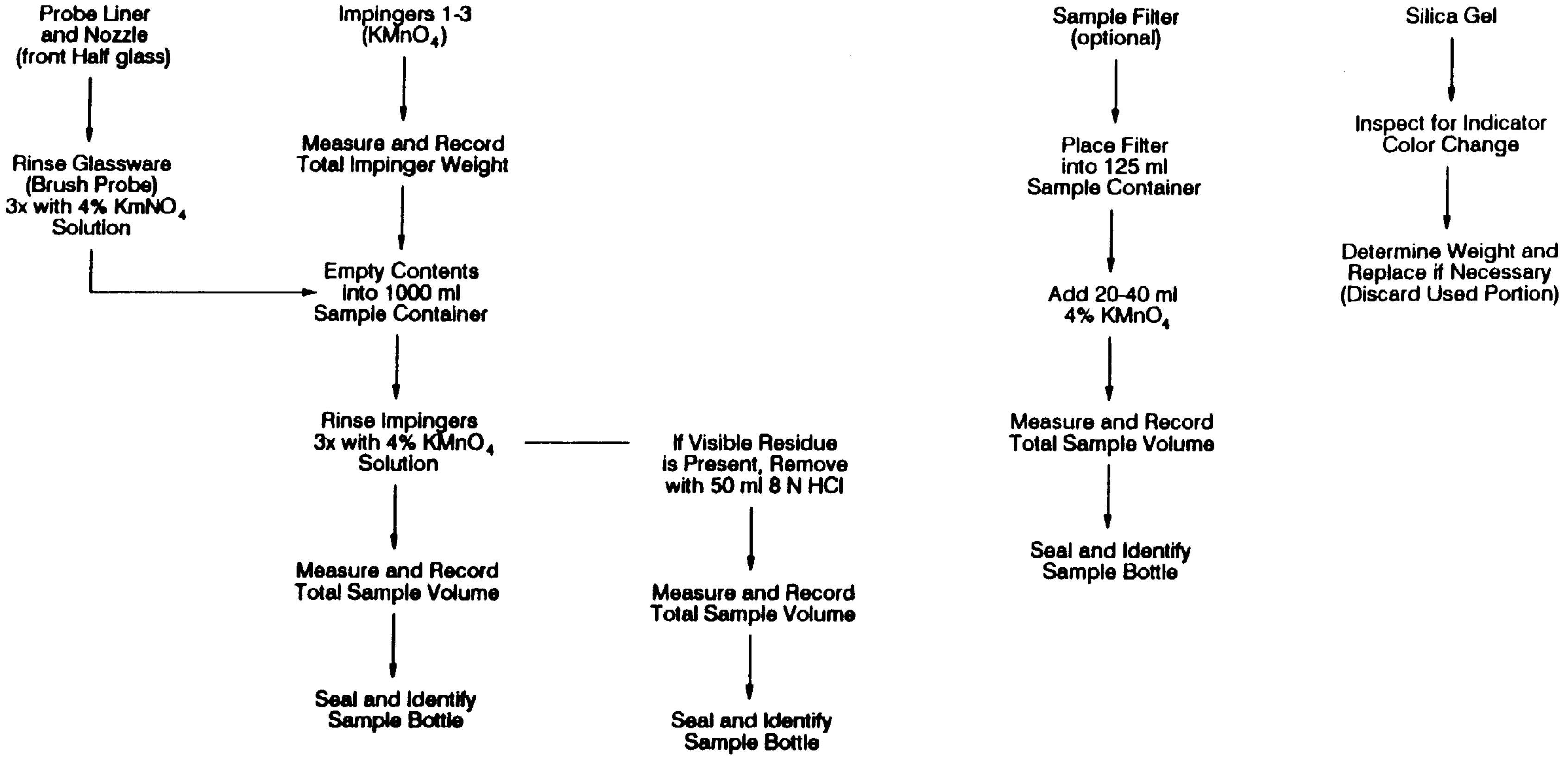

Figure 5-10. Method 101A Sample Recovery Scheme

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Following recovery operations, the samples were fully labeled and logged in the sample log book, and chain of custody forms were filled out.

5.3.6 Analytical Preparation

A simplified diagram of the sample preparation and analysis scheme for the 101A Hg analysis is shown in Figure 5-11. After the samples were recovered by the laboratory, the chain of custody forms were signed and fluid levels checked to determine if any sample loss occurred during transport. As stated in the previous section, there were two sample containers: one for the front half rinse/impinger contents, and one for the filter/$KMnO_4$ digestion. However, all sample fractions were combined and analyzed together.

Prior to analysis, the front half rinse/impinger sample was filtered. The filter was washed, and the rinsings were combined with the filtrate for analysis. At this point the filter is normally discarded. However, recent concern has arisen regarding this procedure. It seems that if visible precipitate in the $KMnO_4$ is present, a portion of the sampled Hg contained in the precipitate may be lost if the filter is discarded. For this test program, all analytical filters were archived pending a decision on analytical procedure. If sample hold time is kept to a minimum (i.e., < 7 days), the precipitate has typically not formed and this matter is not as critical. If, however, precipitate has formed and is visible on the filter, a digestion of the filter in 8N HCl may be warranted. If this procedure is completed, the digestion solution is again filtered with the filtrate added to the original $KMnO_4$ filtrate.

The sample from the sample filter/$KMnO_4$ was transferred to a beaker and placed in a steam bath and evaporated until most of the liquid has disappeared (not dryness). Twenty ml of concentrated HNO_3 was then added to the sample; it was placed on a hot plate (with watch glass cover) and heated for 2 hours at 70°C. This solution was allowed to cool and was then filtered. The filtrate was combined with the front half rinse/impinger sample filtrate prior to analysis.

5.3.7 Analysis

The final combined $KMnO_4$ sample was increased to a fixed volume using DI water. A 5 ml aliquot was removed and placed in 25 ml of DI water in an aeration bottle. Then 5 ml of 15 percent HNO_3 was added, followed by 5 ml of 5 percent

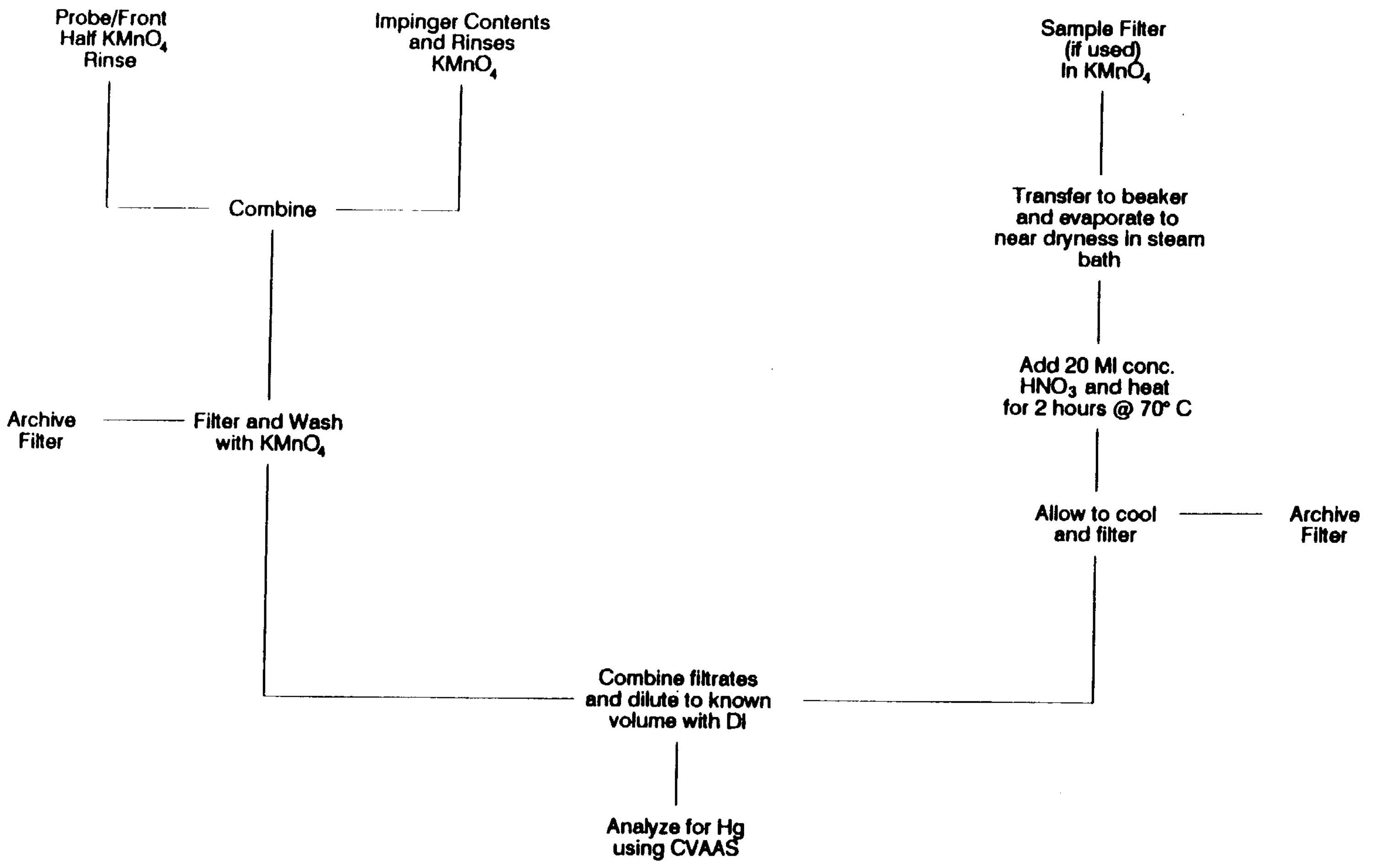

Figure 5-11. Method 101 A
Sampling Preparation and Analysis Scheme

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$KMnO_4$. The solution was mixed thoroughly with the exit arm stopcock closed. The reducing agents, sodium chloride, hydroxylamine and tin (II), were then added as specified in the method, and aeration was initiated. Absorbance was then read at 253.7 nm.

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

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

5.4.1 HCl/HBr/HF Sampling Equipment

A diagram of the HCl/HBr/HF sampling train is shown in Figure 5-12. The sampling train consisted of a quartz probe with a pallflex Teflon/glass filter to remove PM, a series of chilled midget impingers, and a DGM system. A small amount of quartz glass wool was placed in the front half of the filter holder to help remove excessive PM in this gas stream. Because the high temperatures in the stack and the short sampling probe kept the sample gas in the probe above the acid dewpoint, the probe was not heated. The train consisted 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 one impinger containing silica gel.

5.4.2 HCl/HBr/HF Sampling Preparation

5.4.2.1 Equipment Preparation. Sampling preparation included calibration and leak checking of all train equipment including meterboxes, thermocouples, and umbilicals. Referenced calibration procedures were followed when available, and the results properly documented and retained. If a referenced calibration technique for a

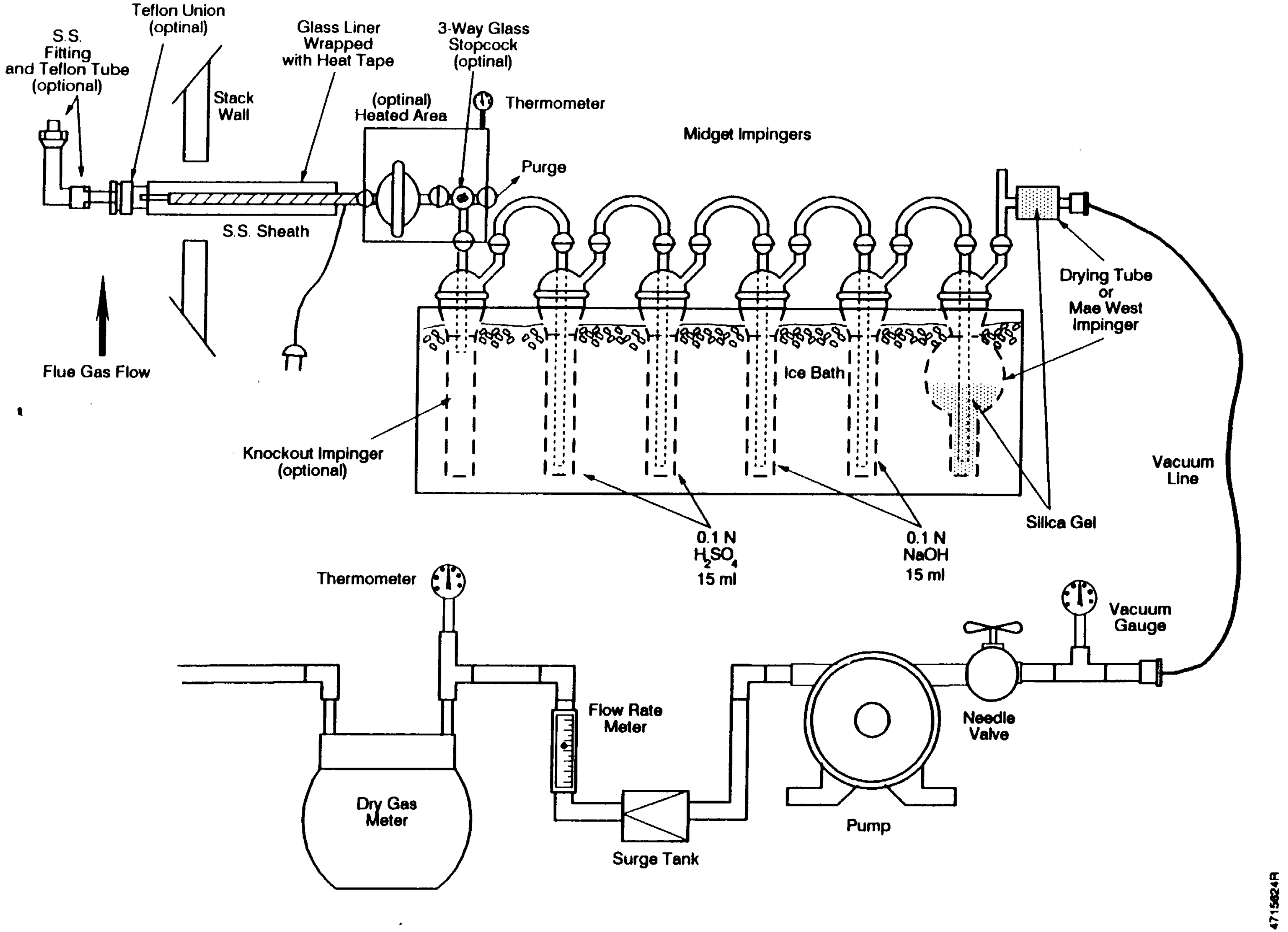


Figure 5-12. HCl Sample Train Configuration

particular piece of apparatus was not available, then a state-of-the-art technique was used.

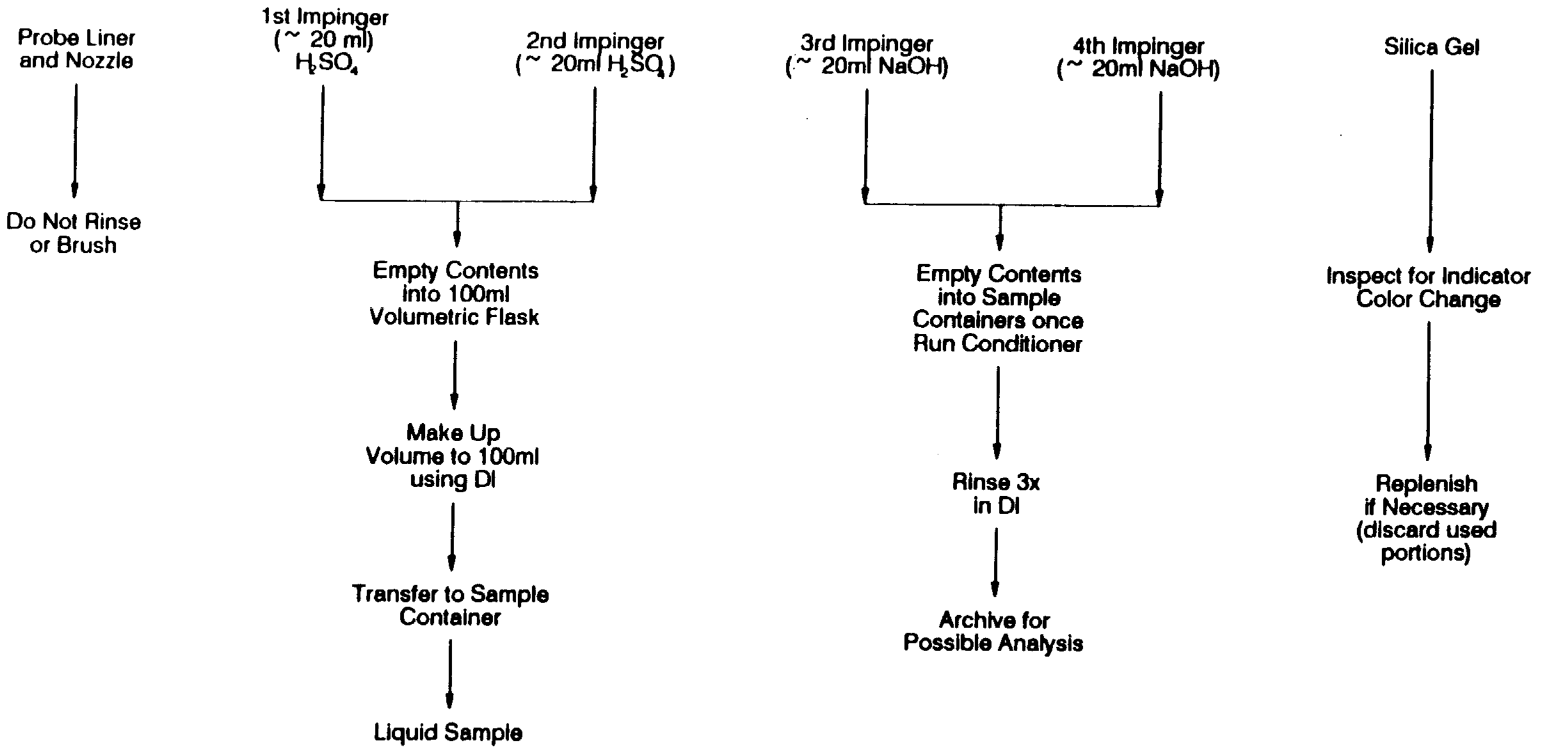
5.4.2.2 Assembling the Train. Assembly of the sampling train was done both in the recovery trailer and at the stack location. First, the empty, clean impingers were assembled and laid out in the proper order. The optional knockout impinger was not used for testing at this facility. The first two impingers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

5.4.3 HCl/HBr/HF Sampling Operations

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

5.4.4 HCl/HBr/HF Sample Recovery

The impingers were disconnected from the probe and filter and moved to the recovery trailer. Once in the trailer, the contents of the two acidified impingers were quantitatively recovered with deionized distilled water and placed into a clean sample bottle. The sample bottle was sealed, mixed and labeled, and the fluid level marked. The contents of the second set of impingers (containing the 0.1 N NaOH) were discarded, except for one set from every triplicate series (i.e., 3 test runs). These were archived for possible future analyses. The sample recovery scheme is shown in Figure 5-13.



Figrue 5-13. HCl/HBr/HF Sample Recovery Scheme

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5.4.5 HCl/HBr/HF Analytical Procedures

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

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

5.4.6 HCl/HBr/HF Analytical Quality Control

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

5.5 EPA METHODS 1-4

5.5.1 Traverse Point Location By EPA Method 1

The number and location of sampling traverse points necessary for isokinetic and flow sampling was dictated by EPA Method 1 protocol. These parameters were based upon how much duct distance separated 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 in diameter is 4 (8 total sample points). Several sets of perpendicular sampling ports were established at each sampling location. Traverse point locations were determined for each port depending on the distances to duct disturbances (see Section 4).

5.5.2 Volumetric Flow Rate Determination by EPA Method 2

Volumetric flow rate was measured according to EPA Method 2. A Type K thermocouple and S-type pitot tube were used to measure flue gas temperature and velocity, respectively. All of the isokinetically sampled methods that were used (CDD/CDF, PM/metals, Mercury 101A) incorporate Method 2.

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

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

5.5.3 O_2 and CO_2 Concentrations by EPA Method 3A

The O_2 and CO_2 concentrations were determined by CEMs following EPA Method 3A. Flue gas was extracted from the duct and delivered to the CEM system through heated Teflon® tubing. The sample stream was then conditioned (PM and moisture removed) and was directed to the analyzers. The O_2 and CO_2 concentrations were, therefore, determined on a dry basis. Average concentrations were calculated to coincide with each respective sampling time period. More information on the CEM system is given in Section 5.6.

5.5.4 Average Moisture Determination by EPA Method 4

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

5.6 CONTINUOUS EMISSIONS MONITORING (CEM) METHODS

EPA Methods 3A, 7E, 6C, and 10 are continuous monitoring methods for measuring CO_2, O_2, NO_x, SO_2, and CO concentrations. Total hydrocarbons were analyzed by EPA Method 25A. Flue gas HCl concentrations were also monitored using CEMs with state-of-the-art equipment and procedures. A diagram of the CEM system is shown in Figure 5-14.

Two extractive systems were used to obtain flue gas samples for the CEM systems. One system was for HCl monitoring, and the other system was for all other CEMs. For the main CEM extraction system, samples were withdrawn continuously from a single point in the incinerator outlet duct and transferred to the CEM trailer through heat-traced Teflon® line. The flue gas was conditioned (temperature lowered and moisture removed) before the flue gas stream was divided using a manifold and sent to the various analyzers. Hydrocarbon measurements were made on a wet basis; therefore, its sample stream bypassed the gas conditioner.

5.6.1 CEM Sampling Equipment

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

5.6.1.2 Heated Lines. Heated sample lines were used to transfer the flue gas samples to the instrument trailer for O_2, CO_2, NO_x, SO_2, CO, and THC analyses. These lines were heated to prevent condensation. (Condensate could clog sample lines or provide a medium for the flue gas sample to react and change composition.)

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

5.6.1.3 Gas Conditioning. Special gas conditioners are used to reduce the moisture content of the flue gas. A Radian-designed gas conditioning system uses a chiller (antifreeze liquid) system to cool a series of glass cyclones. The hot flue gas is chilled by convecting cooling through the glass wall causing the moisture to condense

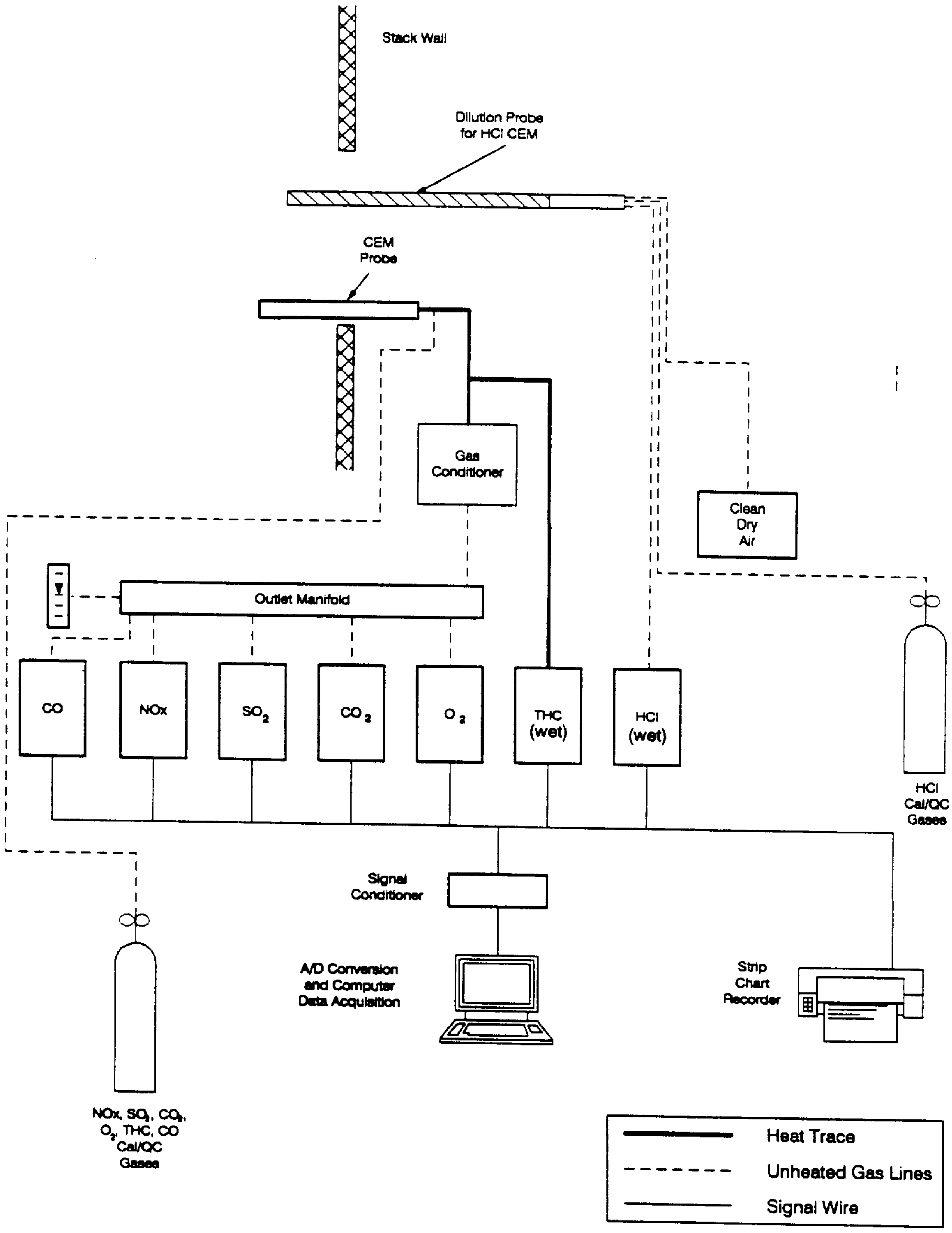

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Figure 5-14. Schematic of CEM System
(2 CEM systems will be used)

into droplets. The droplets and any particulate are flung outward toward the glass walls by centrifugal force, impact the glass walls and fall to the bottom of the cyclone, where they are drained from the system. In this manner, both moisture and PM are effectively removed from the flue gas sample stream. This system operates under positive pressure, eliminating the possibility of a leak. The gas conditioner is located in the CEM trailer.

5.6.1.4 HCl CEM Sample System. The HCl flue gas concentrations were monitored using a CEM analyzer as well as by manual test runs (EPA Method 26). The HCl CEM sampling system used a GMD Model 797 dilution probe. A nominal dilution ratio of 200:1 was used.

5.6.2 CEM Principles of Operation

5.6.2.1 SO_2 Analysis. The Western 721A SO_2 analyzer is essentially a continuous spectrophotometer in the ultraviolet (UV) range. The SO_2 selectively absorbs UV light at a wavelength of 202.5 nm. To take advantage of this property of SO_2, the analyzer emits UV light at 202.5 nm and measures the absorbance (A) of the radiation through the sample cell by the decrease in intensity. Beer's law, $A = abc$, was used to convert the absorbance into SO_2 concentration (A = absorbance, a = absorbitivity, b = path length, c = concentration). The SO_2 measurements were performed in accordance with 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 and is detected by a photomultiplier tube. The instrument is capable of analyzing total oxides of nitrogen ($NO + NO_2$) by thermally converting NO_2 to NO in a separate reaction chamber prior to the photomultiplier tube, if desired. The NO_x measurements were performed specified by EPA Method 7E.

5.6.2.3 <u>O_2 Analysis</u>. Oxygen measurements were performed using EPA Method 3A. Oxygen analysis was completed using the Thermox WDG III analyzer. This instrument measures O_2 using an electrochemical cell. Porous platinum electrodes, which are attached to the inside and outside of the cell, provide the instrument voltage response. Zirconium oxide contained in the cell conducts electrons when it is hot due to the mobility of O_2 ions in its crystal structure. A difference in O_2 concentration between the sample side of the cell and the reference (outside) side of the cell produces a voltage. This response voltage is proportional to the logarithm of the O_2 concentration ratio. A linearizer circuit board is used to make the response linear. Reference gas is ambient air at 20.9 percent O_2 by volume.

5.6.2.4 <u>CO_2 Analysis</u>. Non-dispersive infrared (NDIR) CO_2 analyzers emit a specific wavelength of infrared (IR) radiation which is selectively absorbed by CO_2 molecules through the sample cell. The intensity of radiation that 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 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 were performed by EPA Method 3A.

5.6.2.5 <u>CO Analysis</u>. A Thermo Electron Corporation (TECO) 48 analyzer was used to monitor CO emissions. 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 were performed by EPA Method 10.

5.6.2.6 <u>Total Hydrocarbon Analysis</u>. A Ratfisch RS55 was used to monitor THC emissions. By allowing the THC sample stream to bypass the gas conditioners, concentrations were determined on a wet basis. This analyzer employs 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 were reported on a methane basis, and methane was used as the calibration gas.

5.6.2.7 HCl CEM Analysis. HCl flue gas concentrations were continuously monitored using an NDIR/GFC instrument manufactured by TECO. HCl is detected by alternately passing an 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 were calibrated once during the test program (and linearized, if necessary) using a minimum of three certified calibration gases (zero and two upscale points). Radian performed the multipoint calibrations with four general categories of certified gases: zero gas (generally N_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 did not meet these requirements, it was linearized by adjusting potentiometers on the linerarity card within the instrument or by other adjustments, if necessary.

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

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

Table 5-8 lists the concentration of all calibration and QC gases used on this test program.

5.6.4 Data Acquisition

The data acquisition system consists of a Dianachart PC Acquisitor data logger, a signal conditioner and a 386 Desktop computer. All instrument outputs were connected in parallel to stripchart recorders and the data acquisition system. The stripchart recorders were used to backup the data logger. The PC Acquisitor scanned the instrument output and logged digitized voltages. A Radian computer program translated 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.

5.6.5 Daily Operating Procedure

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

1. Turn on computer and 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 DAS clock with sample location leaders and the test leader.

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 SCR's 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 CEM's 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 2.0 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 and 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. Check the calibration table on the computer, and make a hardcopy. Put the computer in the standby mode.

16. 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.

17. Begin sampling routine with the computer on standby.

18. Start the data acquisition system when signaled by radio that system is in stack.

19. 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.

TABLE 5-8. CEM OPERATING RANGES AND CALIBRATION GASES

Analyte	Gas Concentration
$\underline{CO_2}$	
Instrument	Beckman 865
Range	0-20%
Span Gas Value	18%
Zero Gas	N_2
Midrange QC Gas Value	10%
Low Range QC Gas Value	5%
<u>CO</u> - 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
<u>CO</u> - wet	
Instrument	TECO 48
Range	0-100, 0-200, 0-5000 ppm
Span Gas Value	1000, 180 or 90 ppm[a]
Zero Gas	N_2
Midrange QC Gas Value	180 ppm
Low Range QC Gas Value	90 ppm
$\underline{O_2}$	
Instrument	Thermox WDG III
Range	0-25%
Span Gas Value	20%
Zero Gas	0.2% O_2
Midrange QC Gas Value	10%
Low Range QC Gas Value	5%

TABLE 5-8. CEM OPERATING RANGES AND CALIBRATION GASES, continued

Analyte	Gas Concentration
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
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
THC	
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
HCl	
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.

20. Stop the data acquisition system at the end of the test when signaled.

21. Perform final leak check of system.

22. Perform the final calibration (Repeat steps 6-16) except make no adjustments to the system.

23. Check for drift on each channel.

6. QUALITY ASSURANCE/QUALITY CONTROL

Specific QA/QC procedures were strictly followed during this test program to ensure the production of useful and valid data. A detailed presentation of QC procedures for all manual flue gas sampling, process sample collection, and CEM operations can be found in the Borgess Test Plan. This section will report the test program QA parameters so that the degree of data quality may be ascertained.

Ten days of testing were conducted at Borgess Medical Center. During the first day of testing, a miscue resulted in nonuniform sampling times between the APCS inlet and outlet locations. Since one of the goals of this project was to run all testing simultaneously for comparison purposes, the data from the first testing day were not considered useful. During the second day, the ID fan flow rates drifted to unusually high values during most of the sampling period. After the run (Run 1) was completed, it was decided to archive the data and repeat the run at a more representative condition.

Eight runs were completed successfully at three different operating conditions. The incinerator and APCS operating conditions were identical for all the runs except for varying carbon injection rates. The first three runs (Runs 2, 3, and 4) were conducted with no carbon injection (baseline). The last three runs (Runs 7, 8, and 9) were performed at a carbon injection rate of 2.5 lb/hr. The remaining 2 runs (Runs 5 and 6) were executed at a carbon injection rate of 1 lb/hr. Due to time and budgetary restraints it was decided that a third run at this rate would not be performed.

In summary, a high degree of data quality was maintained throughout the project. Post-test leak checks for all sampling trains were within acceptable limits except for one instance. All post-test calibration checks of the dry gas meters were within acceptable limits. Manual isokinetic sampling trains at the inlet and outlet met the isokinetic criterion of 100 ±10 percent for all but 4 of the test runs. The deviation from this criterion was so low that the runs were not repeated. Dioxin field blanks for all three sample locations showed slight detection of the target CDD/CDF compounds. Most recovery percentages met the acceptable criterion. An unusually high number of isomers exhibited recovery percentages outside QA parameters for CDD/CDF Run 2 at the baghouse inlet location, however. This analytical result was accepted as valid by

Triangle Laboratory's QA officer after an assessment of additional analytical QA parameters (i.e., signal to noise ratio, etc.).

Metals blank results showed some contamination; these results are discussed in Section 6.4.1. Method spike recovery values for the metals analyzed were all within acceptable limits except for Ag in the ash analysis, which is also discussed in section 6.4.1. The manual halogen gas tests met acceptable reagent blank and field blank levels, as well as acceptable method spike results.

The CEM results showed good calibration drift values and QC gas responses. All CEM QC procedures and objectives were followed as described in the Borgess Test Plan.

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 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:

- Quality Control: The overall system of activities whose purpose is to provide a quality product or service. QC procedures are routinely followed to ensure high data quality.
- Quality Assurance: A system of activities whose purpose is to provide assurance that the overall quality control is being done effectively. Assessments can be made from QA parameters on what degree of data quality was achieved.
- Data Quality: The characteristics of a product (measurement data) that bear on its ability to satisfy a given purpose. These characteristics are defined as follows:
    - Precision - A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is best expressed in terms of the standard deviation and in this report will be expressed as the relative standard deviation or coefficient of variation.

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

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

- Comparability - A measure of the confidence with which one data set can be compared to 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 into the quality of the emissions test data produced from manual tests during the test program.

6.2.1 Dioxin/Furan Sampling Quality Assurance

Table 6-2 lists both the pre-test and post-test leak checks completed on the CDD/CDF sampling trains. The acceptance criterion is that all post-test leak checks must be less than 0.02 cfm or 4 percent of the average sampling rate (whichever is less). All of the leak rates were lower than 0.02 cfm; therefore, sample volume corrections were not performed.

Table 6-3 presents the isokinetic sampling rates for CDD/CDF, PM/metals, and Hg sampling trains. The acceptance criterion is that the average sampling rate must be within 10 percent of 100 percent isokinetic. Isokinetic rates for the CDD/CDF trains were within the 10 percent criterion for all of the test runs.

All dry gas meters were fully calibrated within the last six months against an EPA approved intermediate standard. The full calibration factor or meter Y was used to correct actual metered sample to true sample volume. To verify the full calibration, a post-test calibration was performed. The full and post-test calibration coefficients must

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
CEM Concentrations	±20	±15	95
Velocity/Volumetric Flow Rate	±6	±10	95
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.

[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:

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

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

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

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

TABLE 6-2. LEAK CHECK RESULTS FOR CDD/CDF SAMPLE TRAINS BORGESS MEDICAL CENTER (1991)

Date	Run Number	Maximum Vacuum	Port	Avg. Sample Rate (acfm)	Measured Leak Rate	Vacuum (in. Hg)	Leak Corrected (Y or N)
9/07/91	2 BOI Inlet	5	A	0.511	0.008	15	N
		5	B	0.464	0.009	9	N
9/07/91	2 BH Inlet	3	A	0.360	0.015	15	N
		4	B	0.383	0.006	5	N
9/07/91	2 BH Outlet	5	A	0.366	0.018	15	N
		4	B	0.355	0.018	6	N
9/09/91	3 BOI Inlet	4.5	A	0.363	0.008	8	N
		4	B	0.364	0.008	15	N
9/09/91	3 BH Inlet	7	A	0.452	0.014	15	N
		8	B	0.456	0.008	7	N
9/09/91	3 BH Outlet	3.8	A	0.345	0.014	15	N
		3	B	0.398	0.004	5	N
9/10/91	4 BOI Inlet	2.1	A	0.353	0.008	6	N
		2.9	B	0.325	0.007	15	N
9/10/91	4 BH Inlet	6.8	A	0.445	0.008	15	N
		7	B	0.425	0.007	8	N
9/10/91	4 BH Outlet	2	A	0.350	0.018	15	N
		2	B	0.334	0.016	4	N
9/11/91	5 BOI Inlet	5	A	0.330	0.012	15	N
		6.2	B	0.315	0.004	5	N
9/11/91	5 BH Inlet	3.6	A	0.522	0.010	15	N
		4.4	B	0.460	0.008	15	N
9/11/91	5 BH Outlet	4	A	0.399	0.014	15	N
		3	B	0.322	0.012	5	N
9/12/91	6 BOI Inlet	3.5	A	0.385	0.014	17	N
		3.5	B	0.331	0.006	10	N
9/12/91	6 BH Inlet	3.0	A	0.436	0.008	15	N
		3.8	B	0.442	0.004	5	N
9/12/91	6 BH Outlet	2	A	0.360	0.016	15	N
		2	B	0.285	0.014	5	N
9/13/91	7 BOI Inlet	4	A	0.684	0.008	17	N
		7	B	0.606	0.012	9	N
9/13/91	7 BH Inlet	4	A	0.441	0.014	15	N
		3.6	B	0.439	0.008	5	N
9/13/91	7 BH Outlet	4	A	0.379	0.018	15	N
		3	B	0.357	0.012	5	N
9/14/91	8 BOI Inlet	4.2	A	0.649	0.008	15	N
		9	B	0.681	0.008	5	N
9/14/91	8 BH Inlet	3.8	A	0.422	0.014	16	N
		3.4	B	0.426	0.006	5	N
9/14/91	8 BH Outlet	2	A	0.366	0.018	15	N
		2	B	0.333	0.019	5	N
9/16/91	9 BOI Inlet	8.0	A	0.701	0.014	15	N
		9	B	0.725	0.008	15	N
9/16/91	9 BH Inlet	4.2	A	0.411	0.016	15	N
		5	B	0.423	0.004	7	N
9/16/91	9 BH Outlet	3	A	0.346	0.016	15	N
		2	B	0.328	0.010	5	N

TABLE 6-3. ISOKINETIC SAMPLING RATES FOR MANUAL SAMPLING TEST RUNS BORGESS MEDICAL CENTER (1991)

Date	Run Number	Location	CDD/CDF Isokinetic Sample Rate (%)	Toxic Metals Isokinetic Sample Rate (%)	Mercury Isokinetic Sample Rate (%)	PM Isokinetic Sample Rate (%)
9/07/91	2	BOI Inlet	109.60	a	a	95.62
		BH Inlet	104.62	95.34	93.31	b
		BH Outlet	103.15	103.26	100.37	b
9/09/91	3	BOI Inlet	109.93	a	a	103.29
		BH Inlet	102.74	97.30	95.09	b
		BH Outlet	101.93	106.28	101.01	b
9/10/91	4	BOI Inlet	98.89	a	a	109.49
		BH Inlet	102.53	95.81	97.32	b
		BH Outlet	97.22	102.15	101.46	b
9/11/91	5	BOI Inlet	94.57	a	a	104.39
		BH Inlet	106.25	97.43	99.28	b
		BH Outlet	99.94	103.28	101.87	b
9/12/91	6	BOI Inlet	98.63	a	a	89.69
		BH Inlet	102.66	96.23	103.80	b
		BH Outlet	100.82	110.17	108.72	b
9/13/91	7	BOI Inlet	92.91	a	a	107.97
		BH Inlet	101.53	100.57	102.81	b
		BH Outlet	98.49	104.36	104.63	b
9/14/91	8	BOI Inlet	94.00	a	a	109.62
		BH Inlet	101.23	95.63	103.92	b
		BH Outlet	99.59	110.23	104.56	b
9/16/91	9	BOI Inlet	98.76	a	a	113.99
		BH Inlet	104.42	101.27	105.61	b
		BH Outlet	101.35	106.38	105.35	b

a No test at this location.

b PM testing was performed with the toxic metals train at the baghouse inlet and outlet locations.

be within 5 percent to meet Radian's internal QA/QC acceptance criterion. As can be seen from Table 6-4, the post-test calibration factor for all meter boxes used for CDD/CDF, PM/metals, and Hg were well within the 5 percent criterion of the full calibration factor. Field blanks were collected at the boiler inlet, baghouse inlet, and baghouse outlet to verify the absence of any sample contamination. The CDD/CDF sampling train was fully prepared, taken to the sample location, leak checked, and then recovered. Table 6-5 compares the CDD/CDF analytical results for the MM5 field blanks and reagent blanks versus average MM5 samples for the test runs. No 2378 TCDD was detected in any of the field blanks. A small amount of 2378 TCDF was found in all of the field blanks, but only at levels less than six times the detection limit. The heavier CDD/CDF isomers were detected in the MM5 field blanks, with most contamination found at the boiler inlet and baghouse outlet at levels much lower than detected in the actual runs. However, field blank corrections were not made on the emissions results. Analytical blank results are further discussed in Section 6.4.1.

6.2.2 PM/Metals Sampling Quality Assurance

Table 6-6 presents the leak check results for the PM/metals. All runs met the leak rate criterion of 0.02 cfm. Leak check results for the Method 5 train at the boiler inlet are shown in Table 6-7. None of the leak checks were above 0.02 cfm, therefore, a leak correction of the PM results was not made. The isokinetic sampling rates for the PM/metals trains are listed in Table 6-3. All isokinetic values were within 10 percent of 100 percent except Run 6 and Run 8 at the baghouse outlet which had isokinetic sampling rates of 110.17 and 110.23, respectively.

The post-test dry gas meter calibration checks for boxes used for PM/metals sampling are shown in Table 6-4. The results were well within the 5 percent acceptance criterion.

6.2.3 Mercury 101A Sampling Quality Assurance

Table 6-8 presents the leak check results for the Hg trains. Only the leak check for Run 2 did not meet the leak rate criterion. However, the exceedance was so small that no leak correction was applied to the data.

Mercury isokinetic results are shown in Table 6-3. All of the test runs met the isokinetic criterion of 100 ± 10 percent.

TABLE 6-4. DRY GAS METER POST-TEST CALIBRATION RESULTS BORGESS MEDICAL CENTER (1991)

Meter Box ID	Sample Trains	Full Calibration Factor	Post-Test Calibration Factor	Post-Test Deviation (%)[1]
A-36	CDD/CDF-BOI	0.9968	1.0060	0.91
N-33	CDD/CDF-BHI	0.9875	0.9788	-0.89
R-4	CDD/CDF-BHO	0.9912	0.9929	0.17
N-34	Metals-BHI	1.0032	1.0147	1.13
N-31	Metals-BHO	1.0108	0.9937	-1.72
N-32	Mercury-BHI	1.0006	0.9897	-1.10
N-30	Mercury-BHO	0.9998	1.0218	2.15
A-35	Method 5-BOI	1.0010	0.9972	-0.38

[1] [(Post-Test)-(Full)]/(Full)*100

TABLE 6-5. CDD/CDF FIELD BLANK AND REAGENT BLANK RESULTS COMPARED TO AVERAGE RUN RESULTS BORGESS MEDICAL CENTER (1991)

		BOILER INLET				BAGHOUSE INLET				BAGHOUSE OUTLET			
COGENER	MM5 REAGENT BLANK (total ng)	MM5 FIELD BLANK (total ng)	MM5 COND. 1 AVG. (total ng)	MM5 COND. 2 AVG. (total ng)	MM5 COND. 3 AVG. (total ng)	MM5 FIELD BLANK (total ng)	MM5 COND. 1 AVG. (total ng)	MM5 COND. 2 AVG. (total ng)	MM5 COND. 3 AVG. (total ng)	MM5 FIELD BLANK (total ng)	MM5 COND. 1 AVG. (total ng)	MM5 COND. 2 AVG. (total ng)	MM5 COND. 3 AVG. (total ng)
DIOXINS													
2378 TCDD	[0.008]	[0.010]	0.057	0.045	0.060	[0.020]	0.143	0.405	0.370	[0.020]	0.037	[0.025]	[0.0233]
TOTAL TCDD	[0.008]	[0.010]	0.577	2.965	1.967	[0.020]	1.273	3.900	3.233	[0.020]	0.397	0.030	0.030
12378 PCDD	[0.010]	[0.020]	0.193	0.165	0.370	[0.030]	0.423	0.965	0.863	[0.030]	0.147	[0.070]	[0.050]
TOTAL PCDD	[0.010]	(0.150)	0.957	1.235	3.233	[0.030]	2.367	5.800	5.667	(1.000)	0.953	0.090	0.050
123478 HxCDD	[0.010]	0.010	0.133	0.115	0.423	[0.030]	0.493	1.290	1.167	[0.030]	0.263	[0.085]	[0.053]
123678 HxCDD	[0.008]	0.030	0.170	0.145	0.630	[0.020]	0.730	1.365	1.367	(0.020)	0.307	0.120	0.030
123789 HxCDD	[0.010]	0.040	0.300	0.270	1.303	[0.030]	1.367	2.400	2.633	[0.030]	0.513	0.200	[0.047]
TOTAL HxCDD	[0.008]	0.170	1.557	1.600	6.633	[0.030]	6.733	13.050	13.867	(0.090)	3.100	0.565	0.113
1234678-HpCDD	0.040	0.500	1.653	1.550	8.067	0.080	11.067	19.600	19.533	0.270	4.033	0.895	0.343
TOTAL Hepta-CDD	0.060	0.900	3.100	3.000	15.633	0.080	19.867	37.700	38.500	0.540	7.967	1.850	0.607
Octa-CDD	(0.022)	1.500	5.433	6.400	25.367	0.390	37.800	65.950	64.367	0.900	8.900	2.250	1.300
FURANS													
2378 TCDF	(0.008)	(0.030)	6.033	2.900	2.400	(0.020)	2.387	2.600	15.633	0.020	0.317	0.060	0.033
TOTAL TCDF	(0.008)	0.050	10.867	10.700	24.967	(0.020)	16.767	41.050	32.300	0.240	8.867	0.850	0.447
12378 PCDF	[0.010]	(0.050)	1.200	0.895	1.967	[0.020]	1.800	3.750	3.333	(0.030)	0.693	0.100	0.050
23478 PCDF	[0.010]	(0.070)	1.350	1.155	3.133	[0.020]	2.933	6.650	5.867	(0.040)	1.400	0.140	0.063
TOTAL PCDF	[0.010]	0.260	13.467	11.350	29.533	[0.020]	28.700	67.200	61.867	0.260	12.633	0.790	0.153
123478 HxCDF	[0.010]	0.330	3.733	3.100	12.333	[0.020]	15.767	25.950	24.633	0.210	5.700	0.595	0.190
123678 HxCDF	[0.008]	0.160	1.470	1.280	4.533	[0.020]	4.833	9.300	8.800	0.070	1.867	0.200	0.067
234678 HxCDF	(0.010)	0.390	2.633	2.750	11.433	0.030	16.300	26.700	24.367	0.210	6.667	0.660	0.230
123789 HxCDF	[0.010]	0.030	0.177	0.150	0.653	[0.020]	0.913	0.955	1.007	[0.030]	0.197	[0.060]	[0.043]
TOTAL HxCDF	(0.010)	1.200	14.933	13.050	48.900	0.030	64.633	111.850	99.700	0.540	21.867	1.845	0.540
1234678-HpCDF	[0.008]	1.300	7.133	6.650	29.467	0.100	33.600	48.600	56.967	0.640	12.433	1.450	0.590
1234789-HpCDF	[0.010]	0.440	1.730	1.400	7.033	[0.030]	10.500	11.950	11.967	(0.170)	2.907	0.230	0.140
TOTAL Hepta-CDF	[0.010]	3.300	16.500	14.650	64.300	0.130	83.933	111.500	120.333	1.100	28.700	2.850	1.100
Octa-CDF	[0.020]	3.500	14.167	12.750	59.567	0.200	43.967	120.500	114.333	1.500	20.367	1.650	1.333

[] = Detection limit

() = Estimated maximum possible concentration

TABLE 6-6. LEAK CHECK RESULTS FOR TOXIC METALS SAMPLE TRAINS BORGESS MEDICAL CENTER (1991)

Date	Run Number	Maximum Vacuum	Port	Avg. Sample Rate (acfm)	Measured Leak Rate	Vacuum (in. Hg)	Leak Corrected (Y or N)
9/07/91	2 BH Inlet	2.5	A	0.529	0.012	15	N
		3.2	B	0.536	0.004	3.5	N
9/07/91	2 BH Outlet	1	A	0.408	0.014	17	N
		1	B	0.356	0.014	5	N
9/09/91	3 BH Inlet	2.5	A	0.571	0.014	15	N
		3.3	B	0.600	0.006	3.5	N
9/09/91	3 BH Outlet	1	A	0.413	0.007	15	N
		1	B	0.391	0.003	4	N
9/10/91	4 BH Inlet	2.2	A	0.563	0.010	15	N
		3.1	B	0.589	0.006	3.5	N
9/10/91	4 BH Outlet	1	A	0.411	0.008	15	N
		1	B	0.399	0.006	5	N
9/11/91	5 BH Inlet	2.3	A	0.562	0.008	16	N
		3.3	B	0.581	0.004	4	N
9/11/91	5 BH Outlet	1	A	0.428	0.010	15	N
		1	B	0.410	0.012	5	N
9/12/91	6 BH Inlet	2.8	A	0.577	0.016	15	N
		3.8	B	0.588	0.004	4	N
9/12/91	6 BH Outlet	1	A	0.397	0.014	15	N
		1	B	0.362	0.012	5	N
9/13/91	7 BH Inlet	2	A	0.573	0.016	15	N
		3	B	0.597	0.004	6	N
9/13/91	7 BH Outlet	1	A	0.419	0.016	15	N
		1	B	0.382	0.006	5	N
9/14/91	8 BH Inlet	2	A	0.550	0.008	15	N
		2	B	0.556	0.004	5	N
9/14/91	8 BH Outlet	1	A	0.419	0.018	15	N
		1	B	0.383	0.005	5	N
9/16/91	9 BH Inlet	2	A	0.560	0.010	15	N
		2	B	0.555	0.005	7	N
9/16/91	9 BH Outlet	1	A	0.405	0.006	15	N
		1	B	0.379	0.005	5	N

TABLE 6-7. LEAK CHECK RESULTS FOR METHOD 5 SAMPLE TRAINS BORGESS MEDICAL CENTER (1991)

Date	Run Number	Maximum Vacuum	Port	Avg. Sample Rate (acfm)	Measured Leak Rate	Vacuum (in. Hg)	Leak Corrected (Y or N)
9/07/91	2 BOI Inlet	9	A	0.684	0.019	16	N
		3	B	0.694	0.014	6	N
9/09/91	3 BOI Inlet	1	A	0.374	0.017	15	N
		1	B	0.355	0.010	15	N
9/10/91	4 BOI Inlet	1	A	0.374	0.010	15	N
		1	B	0.329	0.016	5	N
9/11/91	5 BOI Inlet	1	A	0.344	0.016	15	N
		1	B	0.358	0.020	5	N
9/12/91	6 BOI Inlet	1	A	0.278	0.012	15	N
		1	B	0.320	0.018	10	N
9/13/91	7 BOI Inlet	1	A	0.296	0.014	12	N
		1	B	0.270	0.008	5	N
9/14/91	8 BOI Inlet	1	A	0.263	0.010	15	N
		1	B	0.305	0.010	5	N
9/16/91	9 BOI Inlet	1	A	0.312	0.018	15	N
		1	B	0.275	0.018	12	N

TABLE 6-8. LEAK CHECK RESULTS FOR MERCURY SAMPLE TRAINS BORGESS MEDICAL CENTER (1991)

Date	Run Number	Maximum Vacuum	Port	Avg. Sample Rate (acfm)	Measured Leak Rate	Vacuum (in. Hg)	Leak Corrected (Y or N)
9/07/91	2 BH Inlet	3	A	0.499	0.010	15	N
		3.6	B	0.521	0.010	4	N
9/07/91	2 BH Outlet	1	A	0.403	0.014	17	N
		1	B	0.354	0.015	5	N
9/09/91	3 BH Inlet	2.4	A	0.537	0.008	15	N
		2.8	B	0.566	0.006	6	N
9/09/91	3 BH Outlet	1	A	0.411	0.006	15	N
		1	B	0.380	0.008	4.5	N
9/10/91	4 BH Inlet	2.5	A	0.535	0.014	15	N
		3.1	B	0.566	0.005	3.5	N
9/10/91	4 BH Outlet	1	A	0.416	0.010	15	N
		1	B	0.401	0.003	5	N
9/11/91	5 BH Inlet	2.2	A	0.538	0.010	15	N
		3	B	0.562	0.008	4	N
9/11/91	5 BH Outlet	1	A	0.437	0.014	15	N
		1	B	0.407	0.006	5	N
9/12/91	6 BH Inlet	2.7	A	0.552	0.002	15	N
		3.5	B	0.568	0.008	4	N
9/12/91	6 BH Outlet	1	A	0.399	0.012	15	N
		1	B	0.360	0.004	5	N
9/13/91	7 BH Inlet	2	A	0.554	0.008	15	N
		2	B	0.576	0.009	7	N
9/13/91	7 BH Outlet	1	A	0.426	0.010	15	N
		1	B	0.384	0.004	5	N
9/14/91	8 BH Inlet	2	A	0.541	0.016	15	N
		2	B	0.547	0.010	6	N
9/14/91	8 BH Outlet	1	A	0.426	0.012	15	N
		1	B	0.385	0.005	5	N
9/16/91	9 BH Inlet	2	A	0.557	0.008	15	N
		2	B	0.541	0.006	5	N
9/16/91	9 BH Outlet	1	A	0.398	0.010	15	N
		1	B	0.384	0.004	5	N

The Hg field blank results are presented in Table 6-9. The amount of Hg detected in the field blanks was negligible compared to amounts detected in the run samples.

6.2.4 Halogen Flue Gas Sampling Quality Assurance

Halogen flue gas concentration tests by EPA Method 26 did not require isokinetic sampling. A constant flow of flue gas was extracted from the stack through a heated 3 foot quartz probe. The sample stream was bubbled through a series of impinger collection solutions and sent to the laboratory for analysis of Cl^-, F^-, and Br^-. A slight modification to the method (EPA Method 26) was incorporated into the test scheme by placing a small amount of quartz wool into the upstream side of the HCl filter housing.

Leak checks were completed before and after each halogen test run. They were conducted by establishing approximately 10 inches of vacuum on the train, plugging the end of the probe, turning off the flow, and checking for any detectable vacuum loss over a 30-second period. If a leak was observed in the system, the run was invalidated. There was no quantitation of leak rate. All halogen tests met the post-test leak check criterion.

Halogen field blank results are shown in Table 6-10. No Cl-, Br^- or F^- was detected in either the baghouse inlet or outlet field blanks. Neither were any of the halogen ions detected in any of the three method blanks.

6.3 QC PROCEDURES FOR ASH SAMPLING

Daily samples of both incinerator bottom ash and baghouse ash were collected. Incinerator ash was collected before each test day (from the previous test run), and baghouse ash was collected on the afternoon of its respective test run. The ash was analyzed for metals, CDD/CDF, carbon, loss on ignition, and moisture content. All ash was removed from the incinerator bed every morning and placed in a large 55-gallon drum. Three 1000-gram samples were taken and placed in pre-cleaned, amber glass bottles. This same procedure was used to collect baghouse ash. All material used for sampling, sample compositing, and sample aliquoting was cleaned to prevent sample contamination.

Table 6-9

Mercury Method 101A Blank Results

Blank Type	Results (total μg)	Percent Recovery (%)
Baghouse Inlet Field Blank	3.08	NA
Baghouse Outlet Field Blank	12.5	NA
Method Blank	[0.299]	NA
Matrix Spike (Outlet Run 6)	NA	97.8
Matrix Spike Duplicate (Outlet Run 6)	NA	92.7

NA = Not Applicable

[ ] = Minimum Detection Limit

TABLE 6-10. HALOGEN FIELD BLANK AND METHOD BLANK RESULTS; BORGESS MEDICAL CENTER (1991) a

ANALYTE	INLET FIELD BLANK (total mg)	OUTLET FIELD BLANK (total mg)	METHOD BLANK 1 (total mg)	METHOD BLANK 2 (total mg)	METHOD BLANK 3 (total mg)
Cl	[0.00342]	[0.00405]	[0.595]	[0.488]	[0.00484]
F	[0.012]	[0.0142]	[0.180]	[0.111]	[0.0170]
Br	[0.00381]	[0.00451]	[0.444]	[0.253]	[0.00539]

a Values are reported as respective anions.

[] = Detection limit.

6.4 ANALYTICAL QUALITY ASSURANCE

The following section reports QA parameters for the CDD/CDF, metals, halogen, and Hg analytical results.

6.4.1 CDD/CDF Analytical Quality Assurance

6.4.1.1 Flue Gas (MM5) Analytical Procedure. The full screen analyses were conducted using a DB-5 GC column which separates each class of chlorination (i.e., tetra, penta, etc.) and fully resolves 2378 TCDD from the other TCDD isomers. The confirmation analysis, performed on a DB-225 GC column, is needed to fully resolve the 2378 TCDF from the other TCDF isomers. The 2378 TCDD and total TCDD isomers are also reported on the confirmation analysis. The final results for 2378 TCDF and other TCDF concentrations were taken from the confirmation analysis. All other CDD/CDF results were taken from the full screen analysis unless directed otherwise by the analytical "case narratives," which are shown in Appendix E.1.

A component of the CDD/CDF analytical laboratory's QA/QC program is adding isotopically labeled standards to each sample during various stages of analysis to determine recovery efficiencies and to aid in the quantitation of "native" CDD/CDF on the XAD absorbent trap prior to the sampling session. (Toluene surrogates are added to species. Four different type standards are added. Surrogate standards are usually spiked in the sample prior to extraction.) Recovery of these compounds allows for the evaluation of overall sample collection efficiency and analytical matrix effects. Internal standards are spiked after the sampling session but prior to extraction. Alternate standards are also spiked at this stage. Recovery percentage of internal standards are used in quantifying the flue gas native CDD/CDF isomers. Recovery of alternate standards allows for extraction/fractionation efficiencies to be determined. Finally, recovery standards are added after fractionation, just prior to the HRGC/HRMS analysis. Internal standards recovery are determined relative to recovery standards recovery. Recovery standards recovery efficiencies are not typically reported with the analytical results.

Poor recovery percentage of the various standards can reveal poor data quality. In some cases, if an analysis with a poor recovery is also accompanied by a suitable QA/QC "flag", the sample result can be validated. A full discussion of the analytical

QA/QC program cannot 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 Blank Results. The method blank and the field blank were analyzed for CDD/CDF isomers. Small quantities of several isomers were detected in the method blanks. Levels were all less than one third the "theoretical method quantitation limit" and were, therefore, within analytical QA guidelines. As discussed in Section 6.2.1, some of the heavier CDD/CDF isomers were detected in the field blanks at minute levels. These results are shown in Table 6-5. No correction was made for the field blank contamination.

6.4.1.3 CDD/CDF Standard Recoveries. Tables 6-11, 6-12, and 6-13, present the standard recovery values for the MM5 flue gas samples, respectively. Both full screen and confirmation values are presented. Confirmation analyses were only completed when positive detections of 2378 TCDD or 2378 TCDF were found in the full screen (DB-5) analysis. The analytical acceptance criterion for internal standard recoveries is 40 percent to 130 percent for tetra- through hexa-chlorinated compounds, while the range is 25 percent to 130 percent for hepta- and octa-chlorinated compounds. Recoveries outside of these limits may still be acceptable if other identification criteria are met.

The majority of the CDD/CDF internal standard recoveries for the boiler inlet, baghouse inlet, and baghouse outlet met the acceptable criteria. A few isomers exceeded the acceptance criterion for some test runs at each location. However, because the majority of the standards recoveries are within acceptable QC limits, the quality of the outlet CDD/CDF data appears reasonable.

All CDD/CDF data was inspected and released as valid by the Triangle Laboratory QA officer.

Table 6-14 presents the recovery standards for the incinerator and baghouse ash samples. For the flue gas, a few isomers exceeded the standard recoveries acceptance

TABLE 6-11. STANDARDS RECOVERIES FOR THE CDD/CDF MODIFIED METHOD 5 BOILER INLET ANALYSE BORGESS MEDICAL CENTER (1991)

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Field Blank	TLI
Full Screen Analyses										
Surrogate Standards Recovery (%)										
37Cl-TCDD	97.4	95.1	90.2	99.6	94.2	96.4	87.7	91.7	94.5	94.4
13Cl2-PeCDF 234	89.5	101.0	101.0	98.7	106.0	96.3	90.4	66.8	91.0	93.8
13Cl2-HxCDF 478	104.0	100.0	111.0	109.0	98.8	107.0	101.0	104.0	95.4	114.0
13Cl2-HxCDD 478	84.8	88.9	81.3	86.8	85.7	75.8	93.7	78.5	75.7	82.4
13Cl2-HpCDF 789	94.2	95.4	105.0	105.0	94.4	92.7	97.0	81.9	95.8	110.0
Alternate Standards Recovery (%)										
13Cl2-HxCDF 789	88.2	93.6	104.0	93.1	90.2	96.5	98.3	71.9	96.8	88.9
13Cl2-HxCDF 234	103.0	104.0	122.0	107.0	122.0	123.0	125.0	82.8	129.0	97.7
Internal Standards Recovery (%)										
13Cl2-2378-TCDF	82.0	73.5	78.2	81.8	82.1	85.2	80.3	116.0	89.5	86.7
13Cl2-2378-TCDD	73.8	69.9	76.9	73.0	81.0	78.3	74.7	76.0	84.3	83.9
13Cl2-PeCDF 123	83.2	72.7	93.3	83.0	94.7	95.2	85.7	112.0	92.1	90.7
13Cl2-PeCDD 123	91.3	85.0	121.0	101.0	126.0	134.0	93.6	120.0	133.0	140.0
13Cl2-HxCDF 678	96.7	100.0	87.3	91.0	85.6	90.7	95.6	68.4	89.7	65.2
13Cl2-HxCDD 678	117.0	110.0	135.0	119.0	128.0	146.0	115.0	97.5	148.0	113.0
13Cl2-HpCDF 678	92.4	94.9	105.0	94.8	96.9	110.0	110.0	87.9	103.0	90.8
13Cl2-HpCDD 678	77.6	84.0	105.0	89.1	95.4	99.8	96.8	72.7	104.0	107.0
13Cl2-OCDD	72.5	66.4	92.0	74.6	86.5	79.6	90.0	73.3	95.3	90.4
Confirmation Data										
Surrogate Standards Recovery (%)										
37Cl-TCDD	86.4	89.2	90.8	93.7	90.8	89.9	84.8	85.3	86.1	86.2
Internal Standards Recovery (%)										
13Cl2-2378-TCDF	80.2	61.5	57.6	54.6	71.6	51.3	75.6	76.6	45.1	63.0
13Cl2-2378-TCDD	61.3	57.7	53.3	50.2	65.9	48.7	66.6	76.4	45.5	64.9

TABLE 6-12. STANDARDS RECOVERIES FOR THE CDD/CDF MODIFIED METHOD 5 BAGHOUSE INLET ANALYSES BORGESS MEDICAL CENTER (1991)

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Field Blank	TLI
Full Screen Analyses										
Surrogate Standards Recovery (%)										
37Cl-TCDD	94.8	102.0	105.0	102.0	106.0	101.0	42.0	106.0	104.0	101.0
13Cl2-PeCDF 234	78.9	101.0	94.1	96.6	111.0	102.0	38.5	94.3	103.0	99.3
13Cl2-HxCDF 478	134.0	115.0	118.0	114.0	113.0	107.0	48.1	113.0	97.2	107.0
13Cl2-HxCDD 478	82.0	81.5	70.5	81.9	113.0	87.9	46.4	106.0	115.0	86.0
13Cl2-HpCDF 789	185.0	96.9	98.4	112.0	76.1	85.8	40.8	85.5	101.0	119.0
Alternate Standards Recovery (%)										
13Cl2-HxCDF 789	63.8	94.7	87.7	70.7	103.0	94.5	94.3	114.0	99.4	88.1
13Cl2-HxCDF 234	40.2	108.0	114.0	86.2	167.0	133.0	143.0	117.0	131.0	108.0
Internal Standards Recovery (%)										
13Cl2-2378-TCDF	69.5	92.2	94.2	70.0	106.0	88.9	89.5	102.0	81.7	71.7
13Cl2-2378-TCDD	75.0	81.5	75.9	61.3	92.0	77.9	75.6	80.6	79.3	68.4
13Cl2-PeCDF 123	37.9	65.9	77.7	68.5	98.1	91.2	83.5	90.4	76.3	78.0
13Cl2-PeCDD 123	44.1	103.0	102.0	107.0	124.0	119.0	97.0	87.0	90.1	126.0
13Cl2-HxCDF 678	14.5	92.1	76.6	62.0	98.4	96.5	80.4	89.4	91.9	74.6
13Cl2-HxCDD 678	41.8	126.0	142.0	93.3	135.0	117.0	98.7	99.9	99.1	107.0
13Cl2-HpCDF 678	17.5	90.0	89.8	74.5	134.0	110.0	91.5	96.0	85.4	86.2
13Cl2-HpCDD 678	43.1	82.6	83.6	80.0	101.0	88.8	77.7	74.0	85.2	97.5
13Cl2-OCDD	59.1	55.4	69.1	75.1	97.6	79.1	68.6	67.1	79.0	78.2
Confirmation Data										
Surrogate Standards Recovery (%)										
37Cl-TCDD	100.0	103.0	99.5	100.0	101.0	99.2	41.6	101.0	94.6	92.7
Internal Standards Recovery (%)										
13Cl2-2378-TCDF	95.7	88.3	92.8	66.0	107.0	91.7	92.8	82.1	65.4	106.0
13Cl2-2378-TCDD	87.2	82.3	92.8	62.0	87.5	78.3	78.4	85.7	66.5	116.0

TABLE 6-13. STANDARDS RECOVERIES FOR THE CDD/CDF MODIFIED METHOD 5 BAGHOUSE OUTLET ANALYSES
BORGESS MEDICAL CENTER (1991)

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Field Blank	TLI
Full Screen Analyses										
Surrogate Standards Recovery (%)										
37Cl-TCDD	97.7	97.3	102.0	99.8	103.0	99.3	98.8	99.6	102.0	101.0
13Cl2-PeCDF 234	109.0	99.1	97.8	97.8	101.0	97.5	109.0	109.0	92.8	99.3
13Cl2-HxCDF 478	107.0	102.0	111.0	107.0	120.0	105.0	109.0	111.0	99.1	107.0
13Cl2-HxCDD 478	95.8	115.0	112.0	130.0	110.0	96.1	114.0	108.0	71.3	86.0
13Cl2-HpCDF 789	108.0	99.8	102.0	108.0	101.0	84.1	109.0	113.0	86.3	119.0
Alternate Standards Recovery (%)										
13Cl2-HxCDF 789	99.7	79.1	95.7	104.0	97.2	89.7	97.2	88.1	93.5	88.6
13Cl2-HxCDF 234	126.0	135.0	133.0	132.0	121.0	158.0	141.0	141.0	116.0	139.0
Internal Standards Recovery (%)										
13Cl2-2378-TCDF	102.0	89.9	87.4	88.6	90.9	94.1	89.9	87.0	86.5	86.6
13Cl2-2378-TCDD	96.1	83.8	76.6	82.9	81.0	86.0	86.4	83.6	79.6	83.2
13Cl2-PeCDF 123	93.3	70.6	72.3	75.0	78.1	81.4	87.5	71.6	75.8	71.3
13Cl2-PeCDD 123	115.0	79.5	76.1	67.8	72.4	90.3	99.6	79.1	102.0	76.6
13Cl2-HxCDF 678	84.9	71.1	93.7	94.1	72.9	102.0	80.2	71.9	91.4	61.3
13Cl2-HxCDD 678	111.0	92.9	116.0	93.4	96.4	149.0	105.0	106.0	141.0	91.8
13Cl2-HpCDF 678	85.6	63.5	88.4	84.7	77.2	88.2	79.3	71.0	82.3	74.0
13Cl2-HpCDD 678	86.1	63.5	80.0	81.7	73.8	80.1	78.7	72.5	83.0	73.8
13Cl2-OCDD	81.8	56.5	51.8	70.7	60.5	46.0	70.8	56.8	60.8	62.9
Confirmation Data										
Surrogate Standards Recovery (%)										
37Cl-TCDD	93.8	95.2	93.7	95.0	96.2	95.2	95.3	95.8	95.6	92.7
Internal Standards Recovery (%)										
13Cl2-2378-TCDF	81.1	84.1	76.4	78.7	59.2	71.3	78.4	81.6	101.0	106.0
13Cl2-2378-TCDD	77.1	78.8	69.6	77.3	58.1	68.9	78.0	82.5	110.0	116.0

TABLE 6-14. STANDARDS RECOVERIES FOR THE BAGHOUSE ASH AND INCINERATOR ASH CDD/CDF ANALYSES
BORGESS MEDICAL CENTER (1991)

	Run 2		Run 3		Run 4		Run 5		Run 6		Run 7		Run 8		Run 9		TLI
	BAG H.	INCIN.	BAG H.	INCIN.	BAG H.	INCIN.	BAG H.	INCIN.	BAG H.	INCIN.	BAG H.	INCIN.	BAG H.	INCIN.	BAG H.	INCIN.	
Full Screen Analyses																	
Surrogate Standards Recovery (%)																	
37Cl-TCDD	69.5	58.3	50.9	70.8	52.3	77.9	65.1	76.1	63.0	66.5	71.8	76.4	54.5	59.1	70.4	70.2	39.1
13Cl2-PeCDF 234	84.1	98.6	67.2	101.0	70.8	85.0	77.9	82.0	75.8	84.1	119.0	129.0	74.4	78.5	91.9	75.0	88.7
13Cl2-HxCDF 478	97.1	135.0	105.0	101.0	110.0	103.0	121.0	97.5	128.0	88.1	104.0	127.0	100.0	88.2	95.1	119.0	45.2
13Cl2-HxCDD 478	110.0	114.0	114.0	106.0	114.0	103.0	118.0	104.0	113.0	100.0	106.0	117.0	108.0	96.1	138.0	113.0	55.9
13Cl2-HpCDF 789	72.6	75.1	69.9	84.1	75.2	54.8	73.7	64.7	70.8	61.3	93.4	71.1	77.1	73.5	75.3	71.3	52.2
Alternate Standards Recovery (%)																	
13Cl2-HxCDF 789	106.0	88.0	95.5	86.0	89.6	86.5	94.2	79.4	93.8	77.6	91.9	90.4	78.8	79.3	85.5	93.5	51.9
13Cl2-HxCDF 234	146.0	190.0	120.0	95.8	130.0	92.0	146.0	163.0	128.0	138.0	103.0	151.0	91.4	83.7	97.9	98.6	77.0
Internal Standards Recovery (%)																	
13Cl2-2378-TCDF	61.1	64.9	46.3	66.3	47.8	79.0	70.0	82.9	63.0	66.9	71.4	83.4	51.0	54.9	64.0	74.1	36.4
13Cl2-2378-TCDD	74.2	63.3	55.7	78.2	56.9	89.5	74.4	84.7	67.9	69.3	82.4	81.0	58.4	65.0	69.6	82.7	41.8
13Cl2-PeCDF 123	76.9	103.0	59.3	97.5	64.3	90.5	88.0	84.7	75.3	82.2	105.0	126.0	68.4	79.3	88.8	85.5	75.0
13Cl2-PeCDD 123	97.9	111.0	78.6	104.0	81.6	94.9	94.9	126.0	90.2	90.2	116.0	172.0	77.1	80.8	99.3	79.2	110.0
13Cl2-HxCDF 678	100.0	116.0	128.0	92.9	142.0	94.4	198.0	124.0	132.0	90.6	92.8	126.0	80.5	78.9	78.0	105.0	51.8
13Cl2-HxCDD 678	115.0	114.0	115.0	91.4	116.0	86.2	115.0	149.0	110.0	97.0	93.0	125.0	82.5	82.4	88.5	95.1	61.2
13Cl2-HpCDF 678	89.9	135.0	87.5	85.4	97.8	81.8	110.0	83.8	107.0	74.4	99.8	128.0	64.8	71.5	70.5	85.8	49.9
13Cl2-HpCDD 678	85.5	109.0	84.2	99.5	90.8	70.1	89.2	83.0	85.3	77.7	108.0	104.0	67.7	84.7	80.1	83.6	51.4
13Cl2-OCDD	74.7	98.2	70.6	110.0	81.6	44.8	75.4	71.6	66.6	62.3	135.0	102.0	62.5	94.7	88.2	87.6	49.0
Confirmation Data																	
Surrogate Standards Recovery (%)																	
37Cl-TCDD	70.2	63.5	60.5	75.6	59.3	94.0	76.8	79.7	77.8	74.1	85.2	72.3	47.0	66.3	60.8	90.2	NA
Internal Standards Recovery (%)																	
13Cl2-2378-TCDF	74.8	74.3	60.5	86.8	58.9	94.7	89.9	93.3	77.3	76.5	93.6	76.8	47.3	75.2	63.8	103.0	NA
13Cl2-2378-TCDD	68.5	69.4	57.8	76.8	60.5	102.0	83.2	87.5	80.0	75.6	88.7	74.0	52.4	65.3	64.3	94.8	NA

criterion. This is not expected to affect the quality of the data. More information on standards recoveries can be found in Appendix E.

6.4.2 Metals Analytical Quality Assurance

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

Table 6-15 presents the metals method blank results for the ash and flue gas samples. No metals were detected in the ash blank. Aluminum, Ba, and Pb were detected in the flue gas method blank at low levels. Table 6-16 presents the field blank metal results with the field blank for the flue gas samples. There was a noticeable contamination in the field blanks. The front half samples were contaminated with Al, Sb, Cr, and Ni. The back half samples were contaminated with Al, As, Cr, Cu, Hg, and Ni. The samples were not blank corrected, but it should be noted that the contamination is present.

Table 6-17 presents the method and matrix spike results for the metals analysis. All spiked recoveries were within the QA allowance of ±20 percent of 100 percent. Silver, in the matrix spike for the ash sample, had low recoveries probably due to the presence of anions precipitating the Ag out of solution. No matrix corrections were applied.

6.4.3 Mercury 101A Analytical Quality Assurance

Table 6-9 presents the method blank Hg 101A analysis. No Hg was detected in the blank. Table 6-9 presents the matrix spike results. All spike recoveries were within ±10 percent of 100 percent acceptance.

6.4.4 Halogen Analytical Quality Assessment

The analysis for Cl^-, F^-, and Br^- incorporate stringent QA/QC guidelines. Table 6-10 presented the method blank results for the IC analysis. None of the target halogen ions were detected in any of the method blanks or the reagent blank. The field blank revealed very low amounts of HCl, which represented a small percentage of the sample run amounts.

The matrix spike recoveries are shown in Table 6-18. Results for all 3 ions were within the 20 percent criteria.

Table 6-15
METALS ASH AND FLUE GAS METHOD BLANK RESULTS - BORGESS MEDICAL CENTER (1991)

Metal	Ash Method Blank (mg/kg)	Flue Gas Method Blank		
		Front Half (total ug)	Impingers 1,2,3 (total ug)	Impingers 4,5,6 (total ug)
Aluminum	[3.00]	5.81	8.04	
Antimony	[0.600]	[1.50]	[0.109]	
Arsenic	[0.800]	[0.400]	[0.436]	
Barium	[3.00]	0.130	[0.109]	
Beryllium	[0.200]	[0.100]	[0.109]	
Cadmium	[0.200]	[0.200]	[0.218]	
Chromium	[0.400]	[0.600]	[0.654]	
Copper	[1.20]	[0.400]	[0.436]	
Lead	[1.20]	0.471	[0.327]	
Mercury	[1.96]	[2.45]	[6.91]	[7.53]
Nickel	[0.600]	[0.300]	[0.327]	
Silver	[0.600]	[0.600]	[0.646]	
Thallium	[1.20]	[10.0]	[10.9]	

NOTE: Impingers 4,5 and 6 sample fractions analyzed for Mercury content only.

[ ] = Minimum Detection Limit.

Table 6-16

METALS AMOUNT IN FIELD BLANK FLUE GAS BY SAMPLE FRACTION - BORGESS MEDICAL CENTER (1991)

	INLET				OUTLET			
METALS	Front Half (total ug)	Impinger 1,2,3 (total ug)	Impinger 4,5,6 (total ug)	Total ug	Front Half (total ug)	Impinger 1,2,3 (total ug)	Impinger 4,5,6 (total ug)	Total ug
Aluminum	468	22.0		490	152	23.2		175
Antimony	30.0	[1.85]		30.0	10.2	[1.71]		10.2
Arsenic	[1.00]	0.655		0.655	[0.400]	[0.457]		[0.857]
Barium	15.8	1.03		16.8	3.79	0.503		4.29
Beryllium	[0.250]	[0.124]		[0.374]	[0.100]	[0.114]		[0.214]
Cadmium	8.93	[0.247]		8.93	0.490	0.263		0.753
Chromium	47.5	4.21		51.7	4.90	6.63		11.5
Copper	46.5	9.65		56.2	16.2	79.8		96.0
Lead	27.3	0.538		27.8	2.62	1.04		3.66
Mercury	[2.45]	20.0	30.6	50.6	[0.980]	18.5	[0.529]	18.5
Nickel	59.5	3.49		63.0	94.3	6.48		101
Silver	[1.50]	[1.85]		[3.35]	4.72	0.800		5.52
Thallium	[25.0]	[12.4]		[37.4]	[10.0]	[11.4]		[21.4]

[ ] = Minimum Detection Limit

NOTE: Analyzed impingers 4,5 and 6 for mercury only

Table 6-17

METALS METHOD AND MATRIX SPIKE RESULTS - BORGESS MEDICAL CENTER (1991)

Metal	Method Spike (% rec)			Method Spike Duplicate (% rec)			Ash Samples (% rec)	
	Front Half	Impingers 1,2,3	Impingers 4,5,6	Front Half	Impingers 1,2,3	Impingers 4,5,6	Matrix Spike	Matrix Spike Dup
Aluminum	106%	107%		106%	109%		85.4%	109%
Antimony	101%	103%		102%	103%		87.9%	91.2%
Arsenic	107%	103%		105%	93.8%		97.9%	97.9%
Barium	95.0%	93.7%		94.2%	94.4%		87.4%	90.2%
Beryllium	95.6%	97.2%		95.6%	98.0%		83.1%	85.7%
Cadmium	101%	102%		101%	103%		83.0%	85.2%
Chromium	102%	103%		103%	103%		85.3%	87.4%
Copper	99.6%	95.8%		99.3%	97.0%		81.6%	86.2%
Lead	96.2%	97.0%		93.2%	101%		85.6%	88.6%
Mercury	97.8%	97.6%	97.6%	103%	103%	96.8%	100%	105%
Nickel	100%	102%		101%	102%		82.2%	84.4%
Silver	86.2%	92.7%		104%	95.7%		8.00%	35.2%
Thallium	97.7%	102%		106%	99.0%		85.9%	86.1%

NOTE: Impingers 4,5 and 6 sample fractions analyzed for Mercury content only.

TABLE 6-18. HALOGEN MATRIX SPIKE AND MATRIX SPIKE DUPLICATES RECOVERY VALUES; BORGESS MEDICAL CENTER (1991)

ANALYTE	RUN 4A		RUN 5B		RUN 6C		RUN 7C		RUN 8C	
	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)
Cl	118.0%	118.0%	101.0%	101.0%	160.0%	119.0%	94.5%	97.3%	107.0%	105.0%
F	91.2%	91.7%	81.4%	81.1%	94.4%	112.0%	91.7%	93.6%	96.0%	94.1%
Br	119.0%	119.0%	101.0%	103.0%	114.0%	109.0%	101.0%	105.0%	127.0%	118.0%

6.5 CEM QUALITY ASSURANCES

Flue gas was analyzed for O_2, CO_2, CO, SO_2, NO_x, and THC, using EPA Methods 10, 3A, 6C, 7E, and 25A, respectively. An additional CEM analyzer was also employed for real time HCl gas concentrations. The following section will report the CEM QA parameters specific for each of those methods and analyzers.

6.5.1 CEM Data Overview

Daily QA/QC procedures were performed on the CEM sampling system and instruments. These included calibration drift checks and corrections (if necessary) , QC gas challenges, sample system bias checks, response time checks, leak checks, sample systems blow back, probe maintenance, filter replacement, conditioner inspection and maintenance, and others. The aim was to ensure that quality data were produced. Details of the CEM QC procedures and objectives are fully outlined in the Borgess Test Plan. The following sections will report QA parameters specific to the previously mentioned QA/QC procedures and also data variation.

Table 6-19 presents the CEM internal QA/QC checks along with their respective acceptance criteria which were conducted at the Borgess MWI tests.

6.5.2 Calibration Drift Checks

All CEM analyzers were calibrated daily with a zero gas (generally nitrogen), and a high-range span gas. Calibrations were performed prior to and at the completion of each test run. By comparing the post-test calibration to the pre-test calibration, the calibration drift was determined (zero drift and span drift).

Daily drift criteria between calibrations for both zero and span was ±5 percent of full scale. Although Method 10 for CO allows ±10 percent of full scale drift, the CO drift requirements were ±5 percent for this test program to ensure the high quality of data produced. The HCl drift criteria was set at ±10 percent of full scale. This was because the calibration routines using the HCl dilution probe necessitate a constant sample gas temperature. While testing a fluctuating process like MWIs, this can be difficult to achieve. Pre-test calibrations are typically conducted after the incinerator has reached full operating temperature. The gas temperature during the post-test calibrations may have differed enough to produce false calibration drift estimates.

TABLE 6-19. CEM INTERNAL QA/QC CHECKS

Check	Frequency	Criteria
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	±2% Span
Sample System Bias	Once/Site	< 5% Span
Response Time	Once/Site	85% of time for stable SO_2 measurements
NO_x Convertor	Once/Site	> 90% conversion efficiency
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
Stratification Test	Once/Site	Within 10% of average
Calibration Drift	Daily	< ±3% Span zero and upscale gas (can use ±10 ppm limit for HCl if less restrictive)

However, the constant temperature problem was minimized during this test program by the use of a CEM probe heater, which minimizes probe gas temperature fluctuations.

The zero and span calibration drift results for each CEM analyzer on each test day are listed in Appendix D.3. All analyzers met the drift criteria throughout the program (over 100 drift checks), except the outlet CO monitor for Run 3. The outlet CO drifts for this day were 6.76 and -3.24 percent of full scale, respectively. These data were drift corrected assuming linear drift between calibrations.

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. 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 full range. Post test QC gases were analyzed after the test run (with no adjustment) as well.

The results of the daily QC gas challenges are shown in Appendix D.4. The QC responses were not quantitated in terms of percent of full scale deviation; however, if a QC gas challenge did show any calibration problems in the field, these would have been noted and rectified.

6.5.4 Multipoint Linearity Check

Multipoint linearity can be determined for each CEM analyzer based on the response of the calibration and QC gases. A linearity calibration is important because flue gas concentrations are determined from a two point linear regression analysis (zero calibration and span calibration gas) bracketing the expected flue gas concentrations. Multipoint calibrations can be 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 was a correlation coefficient (R^2) of greater than or equal to .998, where the independent variable is the cylinder gas concentration and the dependent variable is the instrument response.

CEM linearity was calculated for the inlet and outlet instruments from calibration and pre-test QC gas data from September 7, 1991; these calculations are listed in Appendix D.5. All linearity checks met the acceptance criteria except the outlet HCl

CEM, which had an R^2 value of 0.997. No corrective action was taken for this occurrence. The inlet HCl linearity for that day was $R^2 = 0.9999$. Linearity can be calculated for any test day by using the calibration and QC data included in Appendix D.4.

6.5.5 Sample Bias

Sample bias can be described as any CEM inaccuracies caused by the CEM sampling system. Normal calibrations are performed by directing calibration gas straight to the analyzers. Sample bias is determined by directing QC gases to the probe and pulling them through the entire sampling system (heat trace, conditioner/pump, manifold, etc.). Any deviation that the "through-the-system" response showed from the QC response of a direct QC gas challenge would be defined as sample bias.

All HCl calibrations were performed through the sampling system which would correct for any bias which may have occurred. Sample bias on the other instruments was checked on September 15 and 16, 1991. September 15 bias checks were completed on the SO_2 analyzers during the response time check. Bias checks were completed on all analyzers on September 16, 1991 as each QC gas was directed to the probe and back through the entire sampling system. The sample bias criterion for the Borgess test program was that bias response deviation was to be no greater than ±5 percent of span. The sample bias data is listed in Appendices D.4 and D.5. The data have not been quantitatively assessed in terms of percent of full scale but (as with the QC gas challenges), if any sample bias was detected in the field, it would have been noted and rectified.

6.5.6 Response Time

CEM response time was determined on September 15, 1991, and the results are shown in Appendix D.5. Response time for the Borgess test program was defined as the amount of time taken for the SO_2 analyzer to reach 85 percent of a QC gas value when the gas was directed through the entire sampling system. Both inlet and outlet extractive systems had response times of approximately 2 minutes.

6.5.7 Stratification Checks

Because the size of the ducts sampled in the Borgess Test Program were so small (inlet diameter = 15.5 inches, outlet diameter = 26.5 inches), stratification of CEM gases in the ducts was assumed to be negligible.

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 expressing it as a percentage. Coefficient of variations from several distinct groups of data can be combined into a "Pooled CV". The pooled CV is calculated as follows:

$$CV = \frac{S}{M} \times 100$$

where:

CV = Coefficient of variation

S = Standard deviation (calculated using LOTUS 123™ which uses n and not n-1 where n = number of data points.)

M = mean

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

CV_p = Pooled coefficient of variation

CV_i = Coefficient of variation for a simple sample set i.

n_i = Number of data points in that sample set.

The CV values expressed in the following tables are not intended to represent sampling/analytical precision. They reflect the variability of the data as a whole, including process-caused emission variability.

6.6.2 CDD/CDF Data Variation

Tables 6-20, 6-21, and 6-22 present 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 eight runs. Pooled CVs are also compiled for all of the congeners at each location and for the entire test program (overall). The overall pooled CVs for the CDD/CDF flue gas concentrations was 16.67 percent at the boiler inlet, 19.07 percent at the baghouse inlet, and 26.03 percent baghouse outlet.

6.6.3 Metals and Mercury 101A Data Variation

Table 6-23 presents the CVs for the metal flue gas concentrations for the three test conditions. Table 6-24 presents the CVs for the Hg 101A results for the three test conditions.

6.6.4 Halogen Data Variation

The halogen gas test CVs are listed in Table 6-25. Values were calculated for each run, which consisted of three "sub-runs" during the course of the day's test run. The CVs were calculated for HCl, HF, and HBr for the runs at the baghouse inlet and outlet. The overall pooled CVs for the halogen gas results ranged from 38.32 percent to 67.93 percent.

6.6.5 CEM Data Variation

The variability of the CEM data has been quantified in this section by calculating CV for each analyzer on each day. The CV's were calculated by dividing the standard deviation by the mean for each set of daily data and expressing it as a percentage. It is important to note that the variability expressed by these values is not an indicator of the precision of the test method. These values are mostly a reflection of the variability of the process itself with respect to emissions of specific compounds. In addition to CV values for data from one compound for one day, pooled CV values were also calculated for various combined data sets. Pooled CVs are calculated by taking the square root of the sum of the squares of the individual CV values. Pooled CVs were calculated for all the data sets from each sample location per day, for each analyzer data set for the entire test program (i.e., inlet CO), and for the entire CEM data set.

TABLE 6-20. COEFFICIENTS OF VARIATION FOR CDD/CDF FLUE GAS EMISSIONS; BORGESS MEDICAL CENTER (1991)

BOILER INLET

	Coefficients of Variation (CV)			
CONGENER	RUNS 2,3,4	RUNS 5,6	RUNS 7,8,9	Pooled CV
DIOXINS				
2378 TCDD	7.530	31.451	58.633	39.468
Other TCDD	21.181	89.308	11.169	47.000
12378 PCDD	14.879	43.770	2.630	23.761
Other PCDD	15.087	53.660	33.692	35.084
123478 HxCDD	17.077	37.335	17.488	23.928
123678 HxCDD	9.857	29.122	8.978	16.694
123789 HxCDD	16.310	20.214	22.275	19.697
Other HxCDD	22.138	30.820	32.640	28.649
1234678-HpCDD	14.643	7.590	23.981	17.620
Other Hepta-CDD	16.555	1.347	23.592	17.662
Octa-CDD	6.088	25.415	51.876	34.417
Total CDD	10.634	14.395	33.375	22.626
FURANS				
2378 TCDF	47.102	26.131	40.156	40.092
Other TCDF	25.376	40.310	16.314	27.340
12378 PCDF	9.426	43.563	11.979	23.697
23478 PCDF	11.719	36.723	15.114	21.779
Other PCDF	25.291	35.815	16.231	25.677
123478 HxCDF	15.018	17.323	9.702	13.961
123678 HxCDF	11.558	30.923	5.133	17.293
234678 HxCDF	18.986	28.995	8.177	19.246
123789 HxCDF	6.430	31.451	5.636	16.574
Other HxCDF	33.391	31.568	22.869	29.383
1234678-HpCDF	21.356	7.688	18.033	17.543
1234789-HpCDF	17.635	5.048	8.813	12.334
Other Hepta-CDF	26.856	2.103	5.067	16.769
Octa-CDF	19.975	21.233	27.530	23.378
TOTAL CDF	19.228	13.691	13.424	15.908
TOTAL CDD+CDF	17.907	13.823	17.110	16.667

TABLE 6-21. COEFFICIENTS OF VARIATION FOR CDD/CDF FLUE GAS EMISSIONS; BORGESS MEDICAL CENTER (1991)

BAGHOUSE INLET

	Coefficients of Variation (CV)			
CONGENER	RUNS 2,3,4	RUNS 5,6	RUNS 7,8,9	Pooled CV
DIOXINS				
2378 TCDD	33.843	51.888	21.124	35.636
Other TCDD	54.570	55.426	31.094	47.405
12378 PCDD	25.796	46.440	23.674	31.605
Other PCDD	20.962	66.434	15.167	36.803
123478 HxCDD	27.963	48.614	11.871	30.609
123678 HxCDD	29.062	40.643	19.165	29.452
123789 HxCDD	5.787	38.972	8.851	20.534
Other HxCDD	26.458	40.291	13.303	27.106
1234678-HpCDD	29.697	26.609	10.546	23.440
Other Hepta-CDD	71.019	29.209	12.831	46.545
Octa-CDD	24.041	0.738	5.338	15.085
Total CDD	30.685	17.577	9.031	21.469
FURANS				
2378 TCDF	43.315	1.737	46.535	38.941
Other TCDF	47.702	50.725	23.886	41.358
12378 PCDF	26.727	53.246	11.102	31.982
23478 PCDF	29.598	48.694	20.554	32.859
Other PCDF	35.450	48.512	5.089	32.701
123478 HxCDF	9.380	36.380	9.888	20.013
123678 HxCDF	20.540	44.405	10.383	26.298
234678 HxCDF	18.085	41.881	15.357	25.487
123789 HxCDF	35.919	27.257	6.008	26.136
Other HxCDF	25.401	38.368	9.279	25.343
1234678-HpCDF	17.634	13.834	7.447	13.611
1234789-HpCDF	2.663	6.235	6.575	5.347
Other Hepta-CDF	15.801	4.763	8.962	11.376
Octa-CDF	70.997	6.283	10.709	44.081
TOTAL CDF	23.422	24.936	8.098	19.641
TOTAL CDD+CDF	24.019	23.333	8.249	19.441

TABLE 6-22. COEFFICIENTS OF VARIATION FOR CDD/CDF FLUE GAS EMISSIONS; BORGESS MEDICAL CENTER (1991)

BAGHOUSE OUTLET

	Coefficients of Variation (CV)			
CONGENER	RUNS 2,3,4	RUNS 5,6	RUNS 7,8,9	Pooled CV
DIOXINS				
2378 TCDD	24.840	19.101	53.457	37.340
Other TCDD	22.634	0.448	46.242	31.528
12378 PCDD	34.208	14.625	57.370	41.552
Other PCDD	33.881	22.648	45.305	36.447
123478 HxCDD	21.777	18.272	49.761	34.494
123678 HxCDD	27.968	49.650	37.330	37.844
123789 HxCDD	25.688	59.867	51.726	46.333
Other HxCDD	18.776	57.291	4.891	31.012
1234678-HpCDD	60.244	34.474	8.395	41.043
Other Hepta-CDD	54.440	46.947	7.570	41.035
Octa-CDD	64.310	11.554	9.731	40.247
Total CDD	51.861	30.228	2.641	35.208
FURANS				
2378 TCDF	23.693	33.731	29.059	28.489
Other TCDF	9.606	54.745	35.032	35.271
12378 PCDF	24.440	53.448	38.729	38.738
23478 PCDF	18.837	35.902	15.700	23.404
Other PCDF	12.770	61.354	70.881	53.724
123478 HxCDF	10.155	29.821	16.606	19.089
123678 HxCDF	19.613	40.376	31.789	30.508
234678 HxCDF	33.019	30.777	23.759	29.280
123789 HxCDF	41.717	16.279	62.852	46.907
Other HxCDF	9.930	75.997	76.802	60.768
1234678-HpCDF	40.995	24.560	19.067	30.288
1234789-HpCDF	51.545	3.857	6.296	31.858
Other Hepta-CDF	39.639	7.423	25.695	29.165
Octa-CDF	62.088	26.857	16.135	41.516
TOTAL CDF	32.453	22.948	14.603	24.629
TOTAL CDD+CDF	36.017	25.596	8.524	26.029

Table 6-23

COEFFICEINTS OF VARIATION OF THE FLUE GAS METALS CONCENTRATIONS AT THE INLET AND OUTLET BORGESS MEDICAL CANTER (1991)

Condition	Without Carbon Injection		Carbon Injection @ 1 lb/hr		Carbon Injecton @ 2.5 lb/hr	
Run	Inlet 2 thru 4 CV (%)	Outlet 2 thru 4 CV (%)	Inlet 5 & 6 CV (%)	Outlet 5 & 6 CV (%)	Inlet 7 thru 9 CV (%)	Outlet 7 thru 9 CV (%)
Aluminum	24.3%	3.63%	22.8%	3.54%	22.8%	16.4%
Antimony	47.6%	13.1%	27.9%	2.52%	61.3%	5.24%
Arsenic	17.9%	71%	1.62%	70.7%	56.2%	NA
Barium	46.0%	13.5%	20.1%	12.6%	73.8%	11.9%
Beryllium	NA	NA	NA	NA	NA	NA
Cadmium	2.51%	39.4%	117%	1.36%	65.6%	147%
Chromium	42.7%	52.8%	46.0%	42.1%	39.2%	11.3%
Copper	31.3%	81.9%	30.3%	1.87%	66.9%	63.8%
Lead	47.1%	51.3%	30.1%	39.9%	62.3%	63.6%
Mercury	46.7%	46.6%	23.5%	12.7%	43.1%	84.5%
Nickel	24.3%	38.7%	39.4%	24.8%	22.2%	23.9%
Silver	101%	73.9%	9.52%	70%	44.8%	70.8%
Thallium	NA	NA	NA	NA	NA	NA

NA = Not Applicable

Table 6-24

COEFFICEINTS OF VARIATION OF THE MERCURY 101A CONCENTRATIONS AT THE INLET AND OUTLET - BORGESS MEDICAL CENTER (1991)

Condition Run	Without Carbon Injection	
	Inlet 2 thru 4 CV (%)	Outlet 2 thru 4 CV (%)
Mercury	41.6%	41.6%

Condition Run	Carbon Injection @ 1 lb/hr	
	Inlet 5 & 6 CV (%)	Outlet 5 & 6 CV (%)
Mercury	25.6%	15.4%

Condition Run	Carbon Injecton @ 2.5 lb/hr	
	Inlet 7 thru 9 CV (%)	Outlet 7 thru 9 CV (%)
Mercury	39.4%	63.3%

TABLE 6-25. COEFFICIENTS OF VARIATION FOR HALOGEN
MANUAL FLUE GAS CONCENTRATIONS
BORGESS MEDICAL CENTER (1991)

TEST RUN NUMBER	HYDROGEN CHLORIDE		HYDROGEN FLOURIDE		HYDROGEN BROMIDE	
	B.H. INLET CV,(%)	B.H. OUTLET CV,(%)	B.H. INLET CV,(%)	B.H. OUTLET CV,(%)	B.H. INLET CV,(%)	B.H. OUTLET CV,(%)
AVERAGE 1-3	30.57%	72.36%	58.19%	5.49%	11.14%	65.61%
AVERAGE 4-6	27.29%	81.65%	52.80%	6.01%	54.76%	70.95%
AVERAGE 7-9	54.43%	49.36%	28.27%	4.14%	16.75%	5.18%
AVERAGE 10-12	35.61%	78.89%	34.59%	51.43%	39.55%	14.36%
AVERAGE 13-15	11.87%	59.40%	11.50%	17.25%	36.59%	18.60%
AVERAGE 16-18	56.55%	56.54%	26.92%	13.14%	89.17%	13.27%
AVERAGE 19-21	33.91%	71.53%	44.78%	10.60%	13.74%	10.35%
AVERAGE 22-24	31.11%	53.71%	30.87%	0.30%	6.47%	1.00%
TOTAL POOLED HALOGEN	37.69%	66.42%	38.71%	20.34%	42.56%	35.71%

The CEM CVs are listed in Table 6-26. The overall pooled CV value was 126 percent. Individual analyzer pooled CVs ranged from 4.7 percent for the outlet O_2 values to 303 percent for the outlet SO_2 values. Outlet CVs were generally higher than the corresponding inlet values.

TABLE 6-26. COEFFICIENTS OF VARIATION FOR THE CONTINUOUS EMISSIONS MONITORING DATA. BORGESS MEDICAL CENTER (1991)

DATE	RUN NO.	O2 CV (%)		CO2 CV (%)		CO CV (%)		NOx CV (%)		SO2 CV (%)		THC CV (%)		HCl CV (%)		Inlet Pooled by Day (%)	Outlet Pooled by Day (%)	Total Pooled by Day (%)
		Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet			
9/7	2	5.7	4.7	13.1	13.0	7.9	112.7	29.3	28.1	77.4	118.1	10.7	87.0	25.3	114.7	33.5	83.1	63.4
9/9	3	4.8	4.3	12.5	13.4	40.2	111.6	21.2	22.8	111.8	97.7	32.8	NR	29.4	114.9	48.8	77.4	63.6
9/10	4	4.0	3.6	11.9	12.7	13.3	118.4	21.5	21.9	467.5	507.0	15.3	NR	41.6	135.9	177.8	219.9	198.4
9/11	5	4.9	4.7	15.3	16.9	17.5	353.3	29.8	29.7	205.1	169.5	24.4	NR	43.8	124.0	81.1	168.4	129.0
9/12	6	6.5	4.6	43.4	14.2	10.1	88.3	31.0	52.0	212.8	24.8	17.7	NR	26.1	45.1	83.9	47.2	69.4
9/13	7	5.3	4.9	23.2	14.3	10.0	66.5	27.4	38.0	57.8	42.3	30.3	NR	21.6	62.1	29.6	44.2	37.1
9/14	8	8.0	4.7	22.6	13.6	38.4	381.7	25.2	NR	148.3	83.6	13.3	NR	30.7	33.4	60.7	175.5	122.4
9/16	9	10.4	5.9	20.8	13.5	35.7	640.9	26.0	NR	60.2	49.2	16.4	NR	28.3	67.4	32.0	289.1	188.2
POOLED		6.5	4.7	22.6	14.0	25.3	302.6	26.6	33.7	210.2	200.3	21.5	87.0	31.7	94.7			

OVERALL
POOLED 121.6

NC = Data not compiled yet.
NR = Not recorded (instrument was inoperative for these test runs).