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United States
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Agency

Office of Air Quality
Planning and Standards
Research Triangle Park, [illegible]

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# Air

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# MEDICAL WASTE INCINERATION

# EMISSION TEST REPORT

Morristown Memorial Hospital
Morristown, New Jersey

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# 1. PROJECT DESCRIPTION

## 1.1 INTRODUCTION

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

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

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

## 1.2 OBJECTIVES

The purpose of the testing program at the Morristown Memorial Hospital in Morristown, New Jersey, is to obtain uncontrolled and controlled emission data from a semi-continuous ram-fed MWI. These data will be used in the regulatory development program for MWIs.

The MWI located at Morristown Memorial Hospital was selected for emissions testing for the following reasons:

- This facility is the first known installation of a spray dryer/fabric filter air pollution control system controlling emissions from a MWI;
- The rotary kiln MWI of this facility is typical of well-designed, rotary kiln MWI's currently being installed and for which no uncontrolled emission test data are available; and

- This facility provides a unique opportunity to obtain both uncontrolled emissions test data for a rotary kiln as well as control device performance data for a spray dryer/fabric filter at one test site.

The specific objectives of the test program are:

- Determine what levels of CO, PM, $SO_2$, $NO_x$, HCl, metals, THC and polychlorinated dibenzo-p-dioxins (CDD) and polychlorinated dibenzofurans (CDF) are emitted from the combustor when burning medical wastes;
- Determine the levels of PM, acid gases, metals including mercury (Hg), and CDD/CDF emissions associated with a spray dryer/fabric filter control technology;
- Calculate the control efficiencies for PM, acid gases, metals, and CDD/CDF;
- Investigate the mercury and dioxin removal efficiency capabilities of carbon injection;
- Determine the degree of combustion of the feed wastes based on percent carbon and loss on ignition (LOI) of the bottom ash, spray dryer flyash, and fabric filter flyash;
- Determine particle size distribution of uncontrolled emissions; and
- Determine the microbial survivability based on a surrogate indicator organism that is spiked into the incinerator feed.

Key process operating variables including flue gas oxygen ($O_2$), carbon dioxide ($CO_2$), primary and secondary chamber temperatures, air flows, lime feed rates, baghouse pressure drop, 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.

## 1.3 TEST MATRIX

The sampling and analytical matrix that was performed is presented in Table 1-1. Both manual emissions tests and CEMs were employed for the Morristown Memorial Hospital MWI test program. In addition to flue gas sampling, incinerator bottom ash, spray dryer flyash, and fabric filter flyash samples were also taken. Each of the tests are briefly described in the following paragraphs.

Tests were conducted under two operating conditions. The first condition called for normal operation of the incinerator and SD/FF. Three test runs were conducted at a frequency of one 4-hour run per day. All test runs at each sampling location were conducted simultaneously. The second condition called for carbon to be injected into the lime slurry at a rate of 4 lb/hr. This was done to examine the effects of in-duct carbon injection on flue gas mercury removal. Three test runs were conducted under this condition at a frequency of one 4-hour run per day. The carbon used for all tests was a coal-based carbon manufactured by American Norit with a surface area of 900 $m^2$/gram. The carbon was mixed into the lime slurry and introduced to flue gas in the spray dryer prior to the baghouse.

Total PM emissions along with a series of 13 metals [lead (Pb), chromium (Cr), cadmium (Cd), mercury (Hg), nickel (Ni), arsenic (As), beryllium (Be), antimony (Sb), barium (Ba), silver (Ag), thallium (Tl), copper (Cu), and aluminum (Al)], were determined using a single sample train. Particulate loading on the filter and front half (nozzle/probe, filter holder) rinse were determined gravimetrically. Metals analyses were then completed on the filter front half rinses and back half impinger catches using atomic absorption (AA) and inductively coupled argon plasma (ICAP) techniques. Mercury emissions were also determined by EPA Method 101A so that a comparison of results between the multi-metals train and the Method 101A train could be made.

Flue gas samples for CDD/CDF were collected using EPA Method 23. Flue gas was extracted isokinetically and CDD/CDF was collected on a filter and a chilled adsorbent trap. Recovery procedures were completed using toluene rinses as per the latest update of EPA CDD/CDF testing methodology. The analysis was completed using

## TABLE 1-1. MORRISTOWN MEMORIAL HOSPITAL MWI TEST MATRIX

| Sample Location | Number of Runs | Sample Type | Sample Method | Sample Duration | Analysis Method | Laboratory |
|---|---|---|---|---|---|---|
| Spray Dryer Inlet | 6 | Particulate/Metals (As, Cd, Cr, Hg, Ni, Pb, Be, Sb, Ba, Ag, Tl, Cu, Al) | EPA Method 5/ Combined Metals Train | 4 hours | Gravimetric/Atomic Absportion/ICAP | Radian |
| | 6 | Hg | EPA Method 101A | 4 hours | Atomic Absorption | |
| | 6 | CDD/CDF | EPA Method 23 and GC/MS Method 8290 | 4 hours | Gas Chromatography and High Resolution MS for CDD/CDF | Triangle Labs, Inc. |
| | 6 | HCl | EPA Method 26 | Three 1-hour samples per run | Ion Chromatography | Radian |
| | 3 | Indicator Spores | EPA Draft Method | 4 hours | Microbial Draft Method | American Type Culture Collection |
| | 6 | HCl<br>$NO_x$<br>$SO_2$<br>$O_2/CO_2$<br>THC<br>CO | HCl CEM<br>EPA Method 7E<br>EPA Method 6C<br>EPA Method 3A<br>EPA Method 25A<br>EPA Method 10 | Continuous | NDIR CEM<br>Chemiluminescence CEM<br>UV Analyzer CEM<br>Zirconium Oxide Cell/NDIR CEM<br>FID CEM<br>NDIR CEM | Radian |
| | 4 | PSD | Diagnostic Technique/ EPA Method 202 | 0.25 hour | Gravimetric | Radian |

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## TABLE 1-1. CONTINUED

| Sample Location | Number of Runs | Sample Type | Sample Method | Sample Duration | Analysis Method | Laboratory |
|---|---|---|---|---|---|---|
| Baghouse Outlet | 6 | Particulate/Metals (As, Cd, Cr, Hg, Ni, Pb, Be, Sb, Ba, Ag, Tl, Cu, Al) | EPA Method 5/ Combined Metals Train | 4 hours | Gravimetric/Atomic Absorption /ICAP | Radian |
| | 6 | CDD/CDF | EPA Method 23 and GC/MS Method 8290 | 4 hours | Gas Chromatography and High Resolution MS for CDD/CDF | Triangle Labs, Inc. |
| | 6 | HCl | EPA Method 26 | Three 1-hour samples per run | Ion Chromatography SW 846 9057 | Radian |
| | 6 | $O_2/CO_2$<br>THC<br>HCl<br>$SO_2$ | EPA Method 3A<br>EPA Method 25A<br>HCl CEM<br>EPA Method 6C | Continuous | Zirconium Oxide Cell/NDIR CEM<br>FID CEM (heated)<br>NDIR CEM<br>UV Analyzer CEM | Radian |
| | 3 | Speciated HC | EPA Method 18 | 3 injections per hour | Gas Chromatograph/Flame Ionization Detector (GC/FID) | Radian |
| | 3 | CO | EPA Method 10 | Continuous | NDIR CEM | Radian |
| | 3 | $NO_x$ | EPA Method 7E | Continuous | Chemiluminescence CEM | Radian |
| | 6 | Hg | EPA Method 101A | 4 hours | Atomic Absorption | Radian |
| Stack | 3 | Opacity | EPA Method 9 | 1 hour | | Radian |

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## TABLE 1-1. CONTINUED

| Sample Location | Number of Runs | Sample Type | Sample Method | Sample Duration | Analysis Method | Laboratory |
|---|---|---|---|---|---|---|
| Rotary Kiln | 6 | Kiln Bottom Ash | Representative Composite Sample | 1 day | LOI, Carbon, Metals | Radian, McCoy Labs |
| | 6 | Kiln Bottom Ash | Representative Composite Sample | 1 day | Dioxins/Furans | Triangle Labs, Inc. |
| | 3 | Kiln Bottom Ash | Representative Composite Sample | 1 day | Microbial Draft Method | American Type Culture Collection |
| Spray Dryer | 6 | Spray Dryer Catch | Representative Composite Sample | 1 day | LOI, Carbon, Metals | Radian, McCoy Labs |
| | 6 | Spray Dryer Catch | Representative Composite Sample | 1 day | Dioxins/Furans | Triangle Labs, Inc. |
| | 3 | Spray Dryer Catch | Representative Composite Sample | 1 day | Microbial Draft Method | American Type Culture Collection |

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## TABLE 1-1. CONTINUED

| Sample Location | Number of Runs | Sample Type | Sample Method | Sample Duration | Analysis Method | Laboratory |
|---|---|---|---|---|---|---|
| Baghouse | 6 | Fabric Filter Catch | Representative Composite Sample | 1 day | LOI, Carbon, Metals | Radian, McCoy Labs |
| | 6 | Fabric Filter Catch | Representative Composite Sample | 1 day | Dioxins/Furans | Triangle Labs, Inc. |
| | 3 | Fabric Filter Catch | Representative Composite Sample | 1 day | Microbial Draft Method | American Type Culture Collection |
| Lime Injection | 6 | Lime Slurry Feed | Representative Composite Sample | 1 day | Metals, Lime | Radian, McCoy Labs |
| | 6 | Lime Slurry Feed | Representative Composite Sample | 1 day | Dioxins/Furans | Triangle Labs, Inc. |
| | 6 | Slurry Water Supply | Representative Composite Sample | 1 day | Metals, Lime, Chlorine | Radian, McCoy Labs |
| | 6 | Slurry Water Supply | Representative Composite Sample | 1 day | Dioxins/Furans | Triangle Labs, Inc. |

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high resolution gas chromatography coupled with high resolution mass spectrometry detection (HRGC/HRMS).

Hydrogen chloride, hydrogen bromide (HBr), and hydrogen fluoride (HF) concentrations in the stack gas were determined using EPA Method 26. Flue 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 determined using ion chromatography (IC) analyses.

Gaseous emissions ($NO_x$, CO, $SO_2$, THC, and HCl) were measured using CEMs continuously during the day at the spray dryer inlet. The diluent gases ($O_2$, $CO_2$) were measured using CEMs at all times when tests were being performed so that the emission results could be normalized to a reference $O_2$ or $CO_2$ basis. The $O_2$ and $CO_2$ results were also used for flue gas molecular weight calculations for stack gas flow rate calculations. Gaseous emissions of $SO_2$, THC, HCl, $O_2$, and $CO_2$ were measured at the baghouse outlet using an additional CEM system.

Three types of microbial survivability tests were performed on the incinerator. These tests were intended to evaluate the effectiveness of the MWI in destroying microbial elements in the waste. Indicator spore spikes were loaded onto material commonly found in the medical waste stream and then charged into the incinerator to determine the ability of the indicator organisms to survive in the combustion gases and the incinerator bottom ash. Surrogate indicator spore spikes were also encased in insulated double pipe containers. Spores were added when no carbon was injected and no spores were added when the carbon was injected. Flue gas testing for spore emissions were conducted simultaneously with the other emissions testing. The next day following the daily burn cycle, ash samples and pipe samples were recovered and subsequently analyzed for spore viability. Direct ash sampling and pipe sampling were conducted daily. Flue gas samples were collected isokinetically and passed through a circulating phosphate buffer solution. Following the test, the buffer solution samples were analyzed for viable spores using microbiological identification, culturing, and quantification techniques outlined in the EPA draft method "*Microbial Survivability Test* for Medical Waste Incinerator Emissions." Ash samples and pipe samples were analyzed as outlined in the EPA draft method "Microbial Survivability Test for Medical Waste Incinerator Ash."

In addition to the flue gas samples, incinerator bottom ash, baghouse flyash, and spray dryer flyash were also sampled during the test program. Daily composites were directed to laboratories for LOI/carbon content analyses as well as metals, CDD/CDF, and microbes.

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

## 1.4 PROCESS DESCRIPTION

The MWI at the Morristown Memorial Hospital is comprised of a rotary kiln and a ram feeder. Waste is fed to the kiln at approximately 800 lb/hr and is ignited by an auxiliary burner at the charging end. Ash falls from the discharge end of the kiln, where it is sprayed with water and collected into an ash cart. Combustion gas flows from the kiln to a secondary chamber with a gas residence time of 2.5 seconds at 2000°F.

The flue gas then flows to a waste heat recovery boiler which cools the gas to approximately 400°F. The cooled gases proceed to the emission control system which consists of a spray dryer and a baghouse. Lime slurry is injected into the spray dryer by a rotary atomizer. Lime and ash that fall to the bottom are collected. After the gas passes through the spray dryer it enters the baghouse where the fly ash, unreacted lime, and reacted lime are also collected. The gas stream subsequently passes to the stack through an induced draft fan.

## 1.5 DESCRIPTION OF REPORT CONTENTS

Section 1 of this report provides an introduction to the medical waste testing program conducted at Morristown Memorial Hospital in Morristown, New Jersey. This section includes the test objective, an overview of the emissions measurement program, a brief process description, and this description of the report contents.

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

Section 3 details the process and operation of the Morristown MWI and gives process results. (This section is being provided by Midwest Research Institute (MRI).)

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, PSD method, microbial draft testing method, the manual halogen emissions testing method, EPA Methods 1 through 4, CEM methods, and process sampling procedures.

Section 6 provides the 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. SUMMARY OF RESULTS

This section provides results of the test program conducted at the Morristown Memorial Hospital from November 18 through 23, 1991. Included in this section are:

- The results of manual flue gas tests conducted for CDD/CDF, toxic metals, Hg, PM, PSD, microbes, and halogens;
- The results of continuous emissions monitoring for $O_2$, $CO_2$, CO, $NO_x$, $SO_2$, THC, and HCl gases; and
- The results from analyses of incinerator bottom ash, spray dryer ash, and baghouse ash.

The test conditions were defined by the injection of carbon into the lime slurry. Condition 1 was conducted with the process running under normal steady-state conditions without carbon being introduced into the lime slurry. Condition 2 was conducted the same as Condition 1, but with a carbon concentration present in the lime slurry that produced a carbon injection rate of 4 lb/hr into the spray dryer. Test Runs 1 through 3 were operated under Condition 1, and test Runs 4 through 6 were operated under Condition 2.

## 2.1 EMISSIONS TEST LOG

Six test runs were conducted over six test days. Flue gas sample locations were at the spray dryer inlet and baghouse outlet. One test run was conducted on each day with all sampling trains operated concurrently. Gas concentrations were monitored with the CEM instruments during the testing period. Table 2-1 presents the emissions test log. This table shows the test date, run number, test type, and run times for all the flue gas testing conducted during this period.

## 2.2 CDD/CDF RESULTS

Simultaneous CDD/CDF emission tests were conducted at the spray dryer inlet and baghouse exit under the two operating conditions. Testing protocol followed EPA Method 23.

Daily ash samples were taken from the kiln, spray dryer, and baghouse. Scrubber water samples were also taken. These samples were analyzed for tetra- through octa-CDD/CDF isomers.

Table 2-1

Test Log
Morristown Memorial Hospital (1991)

| Date | Location | Parameter | Run Number | Start Time | Stop Time |
|---|---|---|---|---|---|
| 11/18/91 | Spray Dryer Inlet | CDD/CDF | 1 | 14:10 | 18:40 |
| 11/18/91 | Spray Dryer Inlet | PM/Metals | 1 | 14:09 | 18:40 |
| 11/18/91 | Spray Dryer Inlet | Mercury | 1 | 14:09 | 18:40 |
| 11/18/91 | Spray Dryer Inlet | HCl | 1A | 14:08 | 15:08 |
| 11/18/91 | Spray Dryer Inlet | HCl | 1B | 15:35 | 17:10 |
| 11/18/91 | Spray Dryer Inlet | HCl | 1C | 17:40 | 18:40 |
| 11/18/91 | Spray Dryer Inlet | Microbes | 1 | 14:14 | 18:08 |
| 11/18/91 | Baghouse Outlet | CDD/CDF | 1 | 14:02 | 18:41 |
| 11/18/91 | Baghouse Outlet | PM/Metals | 1 | 14:01 | 18:40 |
| 11/18/91 | Baghouse Outlet | Mercury | 1 | 14:01 | 18:40 |
| 11/18/91 | Baghouse Outlet | HCl | 1A | 14:00 | 15:00 |
| 11/18/91 | Baghouse Outlet | HCl | 1B | 15:35 | 17:10 |
| 11/18/91 | Baghouse Outlet | HCl | 1C | 17:40 | 18:40 |
| 11/18/91 | Stack | Opacity | | 14:00 | 16:00 |
| 11/19/91 | Spray Dryer Inlet | CDD/CDF | 2 | 15:50 | 20:55 |
| 11/19/91 | Spray Dryer Inlet | PM/Metals | 2 | 15:50 | 20:55 |
| 11/19/91 | Spray Dryer Inlet | Mercury | 2 | 15:50 | 20:55 |
| 11/19/91 | Spray Dryer Inlet | HCl | 2A | 15:53 | 17:16 |
| 11/19/91 | Spray Dryer Inlet | HCl | 2B | 17:23 | 19:25 |
| 11/19/91 | Spray Dryer Inlet | HCl | 2C | 19:55 | 20:55 |
| 11/19/91 | Spray Dryer Inlet | Microbes | 2 | 15:50 | 19:50 |
| 11/19/91 | Baghouse Outlet | CDD/CDF | 2 | 15:52 | 20:55 |
| 11/19/91 | Baghouse Outlet | PM/Metals | 2 | 15:51 | 20:55 |
| 11/19/91 | Baghouse Outlet | Mercury | 2 | 15:51 | 20:55 |
| 11/19/91 | Baghouse Outlet | HCl | 2A | 15:50 | 16:50 |
| 11/19/91 | Baghouse Outlet | HCl | 2B | 17:20 | 19:25 |
| 11/19/91 | Baghouse Outlet | HCl | 2C | 19:55 | 20:55 |
| 11/20/91 | Spray Dryer Inlet | CDD/CDF | 3 | 12:30 | 22:50 |
| 11/20/91 | Spray Dryer Inlet | PM/Metals | 3 | 12:30 | 22:50 |
| 11/20/91 | Spray Dryer Inlet | Mercury | 3 | 12:30 | 22:50 |

Table 2-1, continued

Test Log
Morristown Memorial Hospital (1991)

| Date | Location | Parameter | Run Number | Start Time | Stop Time |
|---|---|---|---|---|---|
| 11/20/91 | Spray Dryer Inlet | HCl | 3A | 12:30 | 13:30 |
| 11/20/91 | Spray Dryer Inlet | HCl | 3B | 13:50 | 21:22 |
| 11/20/91 | Spray Dryer Inlet | HCl | 3C | 21:32 | 22:32 |
| 11/20/91 | Spray Dryer Inlet | Microbes | 3 | 12:30 | 16:54 |
| 11/20/91 | Spray Dryer Inlet | PSD | 1 | 21:31 | 21:51 |
| 11/20/91 | Baghouse Outlet | CDD/CDF | 3 | 12:30 | 22:50 |
| 11/20/91 | Baghouse Outlet | PM/Metals | 3 | 12:30 | 22:50 |
| 11/20/91 | Baghouse Outlet | Mercury | 3 | 12:30 | 22:50 |
| 11/20/91 | Baghouse Outlet | HCl | 3A | 12:30 | 13:30 |
| 11/20/91 | Baghouse Outlet | HCl | 3B | 14:00 | 21:20 |
| 11/20/91 | Baghouse Outlet | HCl | 3C | 21:35 | 22:35 |
| 11/21/91 | Spray Dryer Inlet | CDD/CDF | 4 | 12:45 | 17:50 |
| 11/21/91 | Spray Dryer Inlet | PM/Metals | 4 | 12:45 | 17:50 |
| 11/21/91 | Spray Dryer Inlet | Mercury | 4 | 12:45 | 17:50 |
| 11/21/91 | Spray Dryer Inlet | HCl | 4A | 12:45 | 14:20 |
| 11/21/91 | Spray Dryer Inlet | HCl | 4B | 14:45 | 16:15 |
| 11/21/91 | Spray Dryer Inlet | HCl | 4C | 16:37 | 17:37 |
| 11/21/91 | Spray Dryer Inlet | PSD | 2 | 14:30 | 14:45 |
| 11/21/91 | Baghouse Outlet | CDD/CDF | 4 | 12:45 | 17:50 |
| 11/21/91 | Baghouse Outlet | PM/Metals | 4 | 12:45 | 17:50 |
| 11/21/91 | Baghouse Outlet | Mercury | 4 | 12:45 | 17:50 |
| 11/21/91 | Baghouse Outlet | HCl | 4A | 12:45 | 14:20 |
| 11/21/91 | Baghouse Outlet | HCl | 4B | 14:45 | 16:15 |
| 11/21/91 | Baghouse Outlet | HCl | 4C | 16:40 | 17:40 |
| 11/22/91 | Spray Dryer Inlet | CDD/CDF | 5 | 12:00 | 18:45 |
| 11/22/91 | Spray Dryer Inlet | PM/Metals | 5 | 12:00 | 18:45 |
| 11/22/91 | Spray Dryer Inlet | Mercury | 5 | 12:00 | 18:45 |
| 11/22/91 | Spray Dryer Inlet | HCl | 5A | 12:00 | 13:25 |
| 11/22/91 | Spray Dryer Inlet | HCl | 5B | 13:36 | 17:10 |
| 11/22/91 | Spray Dryer Inlet | HCl | 5C | 17:45 | 18:45 |

Table 2-1, continued

Test Log
Morristown Memorial Hospital (1991)

| Date | Location | Parameter | Run Number | Start Time | Stop Time |
|---|---|---|---|---|---|
| 11/22/91 | Spray Dryer Inlet | PSD | 3 | 12:45 | 13:00 |
| 11/22/91 | Baghouse Outlet | CDD/CDF | 5 | 12:15 | 18:44 |
| 11/22/91 | Baghouse Outlet | PM/Metals | 5 | 12:00 | 18:44 |
| 11/22/91 | Baghouse Outlet | Mercury | 5 | 12:00 | 18:44 |
| 11/22/91 | Baghouse Outlet | HCl | 5A | 12:15 | 13:15 |
| 11/22/91 | Baghouse Outlet | HCl | 5B | 13:34 | 17:20 |
| 11/22/91 | Baghouse Outlet | HCl | 5C | 17:45 | 18:45 |
| 11/23/91 | Spray Dryer Inlet | CDD/CDF | 6 | 09:30 | 13:50 |
| 11/23/91 | Spray Dryer Inlet | PM/Metals | 6 | 09:30 | 13:50 |
| 11/23/91 | Spray Dryer Inlet | Mercury | 6 | 09:35 | 13:50 |
| 11/23/91 | Spray Dryer Inlet | HCl | 6A | 09:30 | 10:30 |
| 11/23/91 | Spray Dryer Inlet | HCl | 6B | 11:10 | 12:25 |
| 11/23/91 | Spray Dryer Inlet | HCl | 6C | 12:45 | 13:45 |
| 11/23/91 | Spray Dryer Inlet | PSD | 4 | 10:40 | 10:55 |
| 11/23/91 | Baghouse Outlet | CDD/CDF | 6 | 09:30 | 13:50 |
| 11/23/91 | Baghouse Outlet | PM/Metals | 6 | 09:30 | 13:50 |
| 11/23/91 | Baghouse Outlet | Mercury | 6 | 09:30 | 13:50 |
| 11/23/91 | Baghouse Outlet | HCl | 6A | 09:30 | 10:30 |
| 11/23/91 | Baghouse Outlet | HCl | 6B | 11:10 | 12:25 |
| 11/23/91 | Baghouse Outlet | HCl | 6C | 12:45 | 13:45 |

Tables 2-2 through 2-5 present the flue gas mass flow rates of CDD/CDF, flue gas concentrations, and removal efficiencies for each of the six runs. All CDD/CDF congeners were detected in every run in the inlet flue gas throughout the program. 2378 TCDD was detected in only one of the six runs at the baghouse outlet. Runs 3 and 5 showed substantially higher CDD/CDF at the inlet with total CDD/CDF at 223.0 and 212.3 ng/dscm versus 101.88, 91.19, 182.6, and 46.0 ng/dscm for Runs 1, 2, 4, and 6, respectively. All test runs showed a decrease in CDD/CDF concentrations from the spray dryer inlet to the baghouse outlet. Average inlet CDD/CDF concentrations ranged from 0.763 ng/dscm for 2378 TCDF for Condition 1 to 0.141 ng/dscm for Condition 2. The average concentration of 2378 TCDF for Conditions 1 and 2 at the baghouse outlet was 0.342 and 0.009 ng/dscm, respectively. Average inlet mass rates of 2378 TCDF for the two conditions were 4.427 and 0.813 $\mu$g/hr, respectively. Removal efficiencies of 2378 TCDF for Conditions 1 and 2 were 37.17 and 95.39 percent, respectively. Removal efficiencies of total CDD/CDF for Conditions 1 and 2 were 83.97 and 98.29 percent, respectively. Removal efficiencies were substantially higher for all runs in test Condition 2 with carbon injection compared to runs in Condition 1 with no carbon injection.

The CDD/CDF concentrations normalized to 7 percent $O_2$ for each test condition are shown in Tables 2-6 and 2-7. The results show the same trends as discussed with uncorrected values. The normalized concentration of 2378 TCDD at the outlet for Condition 1 was 0.014 ng/dscm. The concentration of 2378 TCDD at the outlet for Condition 2 was below the detection limit.

The 2378 Toxic Equivalencies corrected to 7 percent $O_2$ for each run in test Condition 1 and 2 are presented in Tables 2-8 and 2-9.

The flue gas sample parameters are shown in Table 2-10. Values for sampling rate, metered volume, stack temperature, gas $O_2/CO_2/H_2O$ concentrations, stack gas flow rates, and isokinetics are shown.

Daily ash samples were collected from the kiln, baghouse, and spray dryer at the end of the test run and composited into a single sample per test run. The ash was passed through a one-half inch mesh sieve to remove large pieces of glass, metal, or other large objects. The shifted ash was sorted in a pre-cleaned stainless steel drum and

TABLE 2-2. CDD/CDF INLET AND OUTLET STACK GAS EMISSIONS AND REMOVAL EFFICIENCIES FOR CONDITION 1; MORRISTOWN HOSPITAL (1991)

| | RUN 1 | | | RUN 2 | | | RUN 3 | | | Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONGENER | Inlet (ug/hr) | Outlet (ug/hr) | Removal Efficiency (%) | 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 | 0.117 | (0.070) | >40.18 | 0.090 | (0.023) | >74.38 | 0.142 | 0.091 | 36.42 | 0.116 | 0.030 | 74.08 |
| Other TCDD | 0.507 | 1.135 | -123.88 | 0.513 | 0.205 | 60.09 | 1.540 | 0.362 | 76.49 | 0.853 | 0.567 | 33.51 |
| 12378 PCDD | 0.293 | 0.162 | 44.56 | 0.295 | (0.045) | >84.74 | 0.595 | (0.068) | >88.58 | 0.394 | 0.054 | 86.29 |
| Other PCDD | 2.438 | 2.386 | 2.12 | 2.014 | 0.387 | 80.79 | 4.581 | 0.407 | 91.11 | 3.011 | 1.060 | 64.79 |
| 123478 HxCDD | 0.410 | 0.209 | 49.09 | 0.500 | 0.068 | 86.36 | 1.203 | 0.045 | 96.24 | 0.704 | 0.107 | 84.76 |
| 123678 HxCDD | 0.566 | 0.301 | 46.75 | 0.616 | 0.068 | 88.91 | 1.294 | 0.068 | 94.75 | 0.825 | 0.146 | 82.33 |
| 123789 HxCDD | 1.014 | 0.440 | 56.60 | 1.167 | 0.114 | 90.25 | 2.976 | 0.091 | 96.96 | 1.719 | 0.215 | 87.50 |
| Other HxCDD | 5.032 | 3.452 | 31.40 | 5.412 | 0.933 | 82.77 | 13.160 | 0.882 | 93.29 | 7.868 | 1.756 | 77.69 |
| 1234678-HpCDD | 8.972 | 2.549 | 71.59 | 9.106 | 0.591 | 93.50 | 25.363 | 0.430 | 98.31 | 14.480 | 1.190 | 91.78 |
| Other HpCDD | 9.947 | 3.244 | 67.39 | 9.875 | 0.682 | 93.09 | 26.010 | 0.475 | 98.17 | 15.277 | 1.467 | 90.40 |
| Octa-CDD | 43.103 | 4.634 | 89.25 | 36.295 | 1.433 | 96.05 | 94.334 | 1.199 | 98.73 | 57.911 | 2.422 | 95.82 |
| Total CDD | 72.397 | 18.581 | 74.33 | 65.882 | 4.550 | 93.09 | 171.199 | 4.118 | 97.59 | 103.159 | 9.083 | 91.20 |
| FURANS | | | | | | | | | | | | |
| 2378 TCDF | 8.777 | 7.414 | 15.53 | 2.693 | 0.523 | 80.57 | 1.812 | 0.407 | 77.52 | 4.427 | 2.781 | 37.17 |
| Other TCDF | 41.932 | 47.959 | -14.37 | 22.572 | 11.079 | 50.92 | 52.796 | 19.730 | 62.63 | 39.100 | 26.256 | 32.85 |
| 12378 PCDF | 3.121 | 2.317 | 25.76 | 2.309 | 0.364 | 84.23 | 3.364 | 0.385 | 88.57 | 2.931 | 1.022 | 65.14 |
| 23478 PCDF | 8.582 | 6.719 | 21.71 | 7.054 | 1.297 | 81.62 | 10.611 | 1.380 | 86.99 | 8.749 | 3.132 | 64.20 |
| Other PCDF | 63.386 | 51.666 | 18.49 | 45.914 | 14.036 | 69.43 | 100.933 | 18.598 | 81.57 | 70.078 | 28.100 | 59.90 |
| 123478 HxCDF | 20.479 | 12.279 | 40.04 | 22.957 | 3.640 | 84.14 | 49.949 | 3.394 | 93.21 | 31.128 | 6.438 | 79.32 |
| 123678 HxCDF | 5.266 | 3.244 | 38.40 | 6.413 | 0.955 | 85.10 | 13.458 | 0.882 | 93.44 | 8.379 | 1.694 | 79.78 |
| 234678 HxCDF | 21.454 | 8.341 | 61.12 | 21.931 | 3.185 | 85.48 | 51.502 | 2.715 | 94.73 | 31.629 | 4.747 | 84.99 |
| 123789 HxCDF | 0.566 | 0.301 | 46.75 | 2.565 | (0.114) | >95.56 | 1.242 | (0.136) | >89.05 | 1.458 | 0.100 | 93.11 |
| Other HxCDF | 43.902 | 25.647 | 41.58 | 41.810 | 9.623 | 76.98 | 109.008 | 9.842 | 90.97 | 64.907 | 15.038 | 76.83 |
| 1234678-HpCDF | 38.032 | 16.681 | 56.14 | 43.092 | 4.095 | 90.50 | 105.074 | 2.715 | 97.42 | 62.066 | 7.830 | 87.38 |
| 1234789-HpCDF | 14.238 | 3.475 | 75.59 | 16.160 | 1.137 | 92.96 | 38.691 | 0.611 | 98.42 | 23.029 | 1.741 | 92.44 |
| Other HpCDF | 55.195 | 24.327 | 55.93 | 61.817 | 6.370 | 89.70 | 85.276 | 2.104 | 97.53 | 67.429 | 10.934 | 83.79 |
| Octa-CDF | 186.063 | 27.570 | 85.18 | 175.704 | 6.142 | 96.50 | 543.487 | 3.846 | 99.29 | 301.751 | 12.520 | 95.85 |
| Total CDF | 510.991 | 237.940 | 53.44 | 472.989 | 62.561 | 86.77 | 1167.20 | 66.745 | 94.28 | 717.061 | 122.415 | 82.93 |
| Total CDD+CDF | 583.388 | 256.521 | 56.03 | 538.871 | 67.111 | 87.55 | 1338.40 | 70.863 | 94.71 | 820.221 | 131.498 | 83.97 |

Note: Condition 1 is no carbon injection.
( ) = Estimated maximum possible concentration.

TABLE 2-3. CDD/CDF INLET AND OUTLET STACK GAS EMISSIONS AND REMOVAL EFFICIENCIES FOR CONDITION 2; MORRISTOWN HOSPITAL (1991)

| | RUN 4 | | | RUN 5 | | | RUN 6 | | | Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONGENER | Inlet (ug/hr) | Outlet (ug/hr) | Removal Efficiency (%) | Inlet (ug/hr) | Outlet (ug/hr) | Removal Efficiency (%) | Inlet (ug/hr) | Outlet (ug/hr) | Removal Efficiency (%) | Inlet (ug/hr) | Average Outlet (ug/hr) | Removal Efficiency (%) |
| DIOXINS | | | | | | | | | | | | |
| 2378 TCDD | 0.105 | [0.011] | >89.53 | 0.078 | [0.011] | >85.85 | 0.039 | (0.007) | >82.02 | 0.074 | [0.001] | >98.6 |
| Other TCDD | 0.828 | 0.034 | 95.91 | 1.347 | 0.000 | 100.00 | 0.766 | 0.009 | 98.84 | 0.980 | 0.014 | 98.55 |
| 12378 PCDD | 0.368 | (0.011) | >97.01 | 0.350 | [0.011] | >96.85 | 0.130 | 0.009 | 93.14 | 0.282 | 0.003 | 98.95 |
| Other PCDD | 1.865 | 0.011 | 99.40 | 3.277 | 0.102 | 96.89 | 1.168 | 0.080 | 93.14 | 2.103 | 0.064 | 96.94 |
| 123478 HxCDD | 0.723 | 0.014 | 98.13 | 0.945 | 0.045 | 95.21 | 0.273 | (0.022) | >91.93 | 0.647 | 0.020 | 96.97 |
| 123678 HxCDD | 0.828 | 0.020 | 97.55 | 1.114 | 0.045 | 95.94 | 0.324 | 0.045 | 86.28 | 0.755 | 0.037 | 95.14 |
| 123789 HxCDD | 1.708 | 0.045 | 97.36 | 2.331 | 0.090 | 96.12 | 0.597 | 0.089 | 85.09 | 1.545 | 0.075 | 95.15 |
| Other HxCDD | 7.383 | 0.124 | 98.32 | 11.929 | 0.452 | 96.21 | 3.868 | 0.467 | 87.92 | 7.726 | 0.348 | 95.50 |
| 1234678-HpCDD | 16.026 | 0.271 | 98.31 | 23.573 | 0.679 | 97.12 | 5.192 | 0.645 | 87.57 | 14.930 | 0.532 | 96.44 |
| Other HpCDD | 18.522 | 0.226 | 98.78 | 25.774 | 0.611 | 97.63 | 5.581 | 0.712 | 87.24 | 16.626 | 0.516 | 96.90 |
| Octa-CDD | 66.470 | 0.745 | 98.88 | 93.124 | 1.832 | 98.03 | 22.065 | 1.669 | 92.44 | 60.553 | 1.415 | 97.66 |
| Total CDD | 114.826 | 1.500 | 98.69 | 163.842 | 3.857 | 97.65 | 40.003 | 3.747 | 90.63 | 106.224 | 3.035 | 97.14 |
| FURANS | | | | | | | | | | | | |
| 2378 TCDF | 1.169 | (0.113) | >90.33 | 0.868 | 0.068 | 92.18 | 0.402 | 0.045 | 88.94 | 0.813 | 0.037 | 95.39 |
| Other TCDF | 30.096 | 2.821 | 90.63 | 40.837 | 1.290 | 96.84 | 15.043 | 0.912 | 93.94 | 28.659 | 1.674 | 94.16 |
| 12378 PCDF | 2.102 | 0.068 | 96.78 | 2.072 | 0.045 | 97.82 | 0.727 | 0.022 | 96.94 | 1.634 | 0.045 | 97.24 |
| 23478 PCDF | 6.962 | 0.226 | 96.76 | 7.901 | 0.113 | 98.57 | 2.336 | 0.111 | 95.24 | 5.733 | 0.150 | 97.38 |
| Other PCDF | 67.653 | 2.415 | 96.43 | 76.675 | 1.176 | 98.47 | 20.430 | 0.467 | 97.71 | 54.919 | 1.353 | 97.54 |
| 123478 HxCDF | 35.206 | 0.632 | 98.21 | 47.663 | 0.498 | 98.96 | 11.811 | 0.467 | 96.04 | 31.560 | 0.532 | 98.31 |
| 123678 HxCDF | 9.590 | 0.181 | 98.12 | 11.268 | (0.136) | >98.79 | 3.115 | 0.156 | 95.00 | 7.991 | 0.112 | 98.60 |
| 234678 HxCDF | 38.753 | 0.722 | 98.14 | 57.895 | 0.566 | 99.02 | 12.071 | 0.490 | 95.94 | 36.240 | 0.592 | 98.37 |
| 123789 HxCDF | 1.012 | 0.023 | 97.77 | 1.062 | 0.023 | 97.87 | 0.350 | (0.018) | >94.86 | 0.808 | 0.015 | 98.14 |
| Other HxCDF | 79.646 | 1.602 | 97.99 | 85.457 | 0.860 | 98.99 | 22.364 | 0.828 | 96.30 | 62.489 | 1.097 | 98.25 |
| 1234678-HpCDF | 76.848 | 0.925 | 98.80 | 98.953 | 1.086 | 98.90 | 24.142 | 1.135 | 95.30 | 66.648 | 1.049 | 98.43 |
| 1234789-HpCDF | 29.163 | 0.293 | 98.99 | 37.561 | 0.430 | 98.86 | 8.047 | 0.378 | 95.30 | 24.924 | 0.367 | 98.53 |
| Other HpCDF | 115.995 | 1.264 | 98.91 | 153.610 | 1.425 | 99.07 | 32.968 | 1.380 | 95.82 | 100.858 | 1.356 | 98.66 |
| Octa-CDF | 428.248 | 1.647 | 99.62 | 446.842 | 3.620 | 99.19 | 79.564 | 3.783 | 95.25 | 318.218 | 3.017 | 99.05 |
| Total CDF | 922.441 | 12.931 | 98.60 | 1068.66 | 11.334 | 98.94 | 233.371 | 10.191 | 95.63 | 741.492 | 11.486 | 98.45 |
| Total CDD+CDF | 1037.27 | 14.432 | 98.61 | 1232.51 | 15.192 | 98.77 | 273.374 | 13.938 | 94.90 | 847.716 | 14.521 | 98.29 |

Note: Condition 2 is with carbon injection.
( ) = Estimated maximum possible concentration.

TABLE 2–4. CDD/CDF INLET AND OUTLET STACK GAS CONCENTRATIONS FOR CONDITION 1; MORRISTOWN HOSPITAL (1991)

| | INLET CONCENTRATION a (ng/dscm, as measured) | | | | OUTLET CONCENTRATION a (ng/dscm, as measured) | | | |
|---|---|---|---|---|---|---|---|---|
| CONGENER | Run 1 | Run 2 | Run 3 | Average | Run 1 | Run 2 | Run 3 | Average |
| DIOXINS | | | | | | | | |
| 2378 TCDD | 0.020 | 0.015 | 0.024 | 0.020 | (0.009) | (0.003) | 0.011 | 0.007 |
| Other TCDD | 0.089 | 0.087 | 0.257 | 0.144 | 0.140 | 0.024 | 0.043 | 0.069 |
| 12378 PCDD | 0.051 | 0.050 | 0.099 | 0.067 | 0.020 | (0.005) | (0.008) | 0.011 |
| Other PCDD | 0.426 | 0.341 | 0.763 | 0.510 | 0.295 | 0.046 | 0.048 | 0.130 |
| 123478 HxCDD | 0.072 | 0.085 | 0.201 | 0.119 | 0.026 | 0.008 | 0.005 | 0.013 |
| 123678 HxCDD | 0.099 | 0.104 | 0.216 | 0.140 | 0.037 | 0.008 | 0.008 | 0.018 |
| 123789 HxCDD | 0.177 | 0.197 | 0.496 | 0.290 | 0.054 | 0.013 | 0.011 | 0.026 |
| Other HxCDD | 0.879 | 0.916 | 2.193 | 1.329 | 0.426 | 0.110 | 0.105 | 0.214 |
| 1234678–HpCDD | 1.567 | 1.540 | 4.227 | 2.445 | 0.315 | 0.070 | 0.051 | 0.145 |
| Other HpCDD | 1.737 | 1.671 | 4.335 | 2.581 | 0.401 | 0.081 | 0.056 | 0.179 |
| Octa–CDD | 7.527 | 6.140 | 15.721 | 9.796 | 0.572 | 0.170 | 0.142 | 0.295 |
| Total CDD | 12.643 | 11.146 | 28.531 | 17.440 | 2.295 | 0.539 | 0.489 | 1.108 |
| FURANS | | | | | | | | |
| 2378 TCDF | 1.533 | 0.456 | 0.302 | 0.763 | 0.916 | 0.062 | 0.048 | 0.342 |
| Other TCDF | 7.323 | 3.819 | 8.799 | 6.647 | 5.923 | 1.312 | 2.343 | 3.193 |
| 12378 PCDF | 0.545 | 0.391 | 0.561 | 0.499 | 0.286 | 0.043 | 0.046 | 0.125 |
| 23478 PCDF | 1.499 | 1.193 | 1.768 | 1.487 | 0.830 | 0.154 | 0.164 | 0.382 |
| Other PCDF | 11.069 | 7.767 | 16.821 | 11.886 | 6.381 | 1.663 | 2.208 | 3.417 |
| 123478 HxCDF | 3.576 | 3.884 | 8.324 | 5.261 | 1.516 | 0.431 | 0.403 | 0.784 |
| 123678 HxCDF | 0.920 | 1.085 | 2.243 | 1.416 | 0.401 | 0.113 | 0.105 | 0.206 |
| 234678 HxCDF | 3.747 | 3.710 | 8.583 | 5.347 | 1.030 | 0.377 | 0.322 | 0.577 |
| 123789 HxCDF | 0.099 | (0.434) | 0.207 | 0.247 | 0.037 | (0.013) | (0.016) | 0.022 |
| Other HxCDF | 7.667 | 7.073 | 18.167 | 10.969 | 3.167 | 1.140 | 1.169 | 1.825 |
| 1234678–HpCDF | 6.642 | 7.290 | 17.511 | 10.481 | 2.060 | 0.485 | 0.322 | 0.956 |
| 1234789–HpCDF | 2.486 | 2.734 | 6.448 | 3.889 | 0.429 | 0.135 | 0.073 | 0.212 |
| Other HpCDF | 9.639 | 10.458 | 14.212 | 11.436 | 3.004 | 0.755 | 0.250 | 1.336 |
| Octa–CDF | 32.493 | 29.724 | 90.576 | 50.931 | 3.405 | 0.728 | 0.457 | 1.530 |
| Total CDF | 89.237 | 80.017 | 194.522 | 121.259 | 29.385 | 7.410 | 7.926 | 14.907 |
| Total CDD+CDF | 101.880 | 91.163 | 223.054 | 138.699 | 31.680 | 7.949 | 8.415 | 16.015 |

Note: Condition 1 is no carbon injection.
a Standard conditions are defined as 1 atm and 68 F.
( ) = Estimated maximum possible concentration.

TABLE 2-5. CDD/CDF INLET AND OUTLET STACK GAS CONCENTRATIONS FOR CONDITION 2; MORRISTOWN HOSPITAL (1991)

| CONGENER | INLET CONCENTRATION a (ng/dscm, as measured) | | | | OUTLET CONCENTRATION a (ng/dscm, as measured) | | | |
|---|---|---|---|---|---|---|---|---|
| | Run 4 | Run 5 | Run 6 | Average | Run 4 | Run 5 | Run 6 | Average |
| DIOXINS | | | | | | | | |
| 2378 TCDD | 0.019 | 0.013 | 0.007 | 0.013 | [0.001] | [0.001] | [0.001] | 0.000 |
| Other TCDD | 0.146 | 0.232 | 0.129 | 0.169 | 0.004 | 0.000 | 0.001 | 0.003 |
| 12378 PCDD | 0.065 | 0.060 | 0.022 | 0.049 | (0.001) | [0.001] | 0.001 | 0.001 |
| Other PCDD | 0.328 | 0.564 | 0.197 | 0.363 | 0.001 | 0.012 | 0.009 | 0.008 |
| 123478 HxCDD | 0.127 | 0.163 | 0.046 | 0.112 | 0.002 | 0.005 | (0.003) | 0.003 |
| 123678 HxCDD | 0.146 | 0.192 | 0.055 | 0.131 | 0.002 | 0.005 | 0.005 | 0.004 |
| 123789 HxCDD | 0.301 | 0.402 | 0.101 | 0.268 | 0.005 | 0.011 | 0.011 | 0.009 |
| Other HxCDD | 1.300 | 2.055 | 0.652 | 1.335 | 0.015 | 0.053 | 0.055 | 0.041 |
| 1234678-HpCDD | 2.821 | 4.061 | 0.875 | 2.586 | 0.033 | 0.079 | 0.076 | 0.063 |
| Other HpCDD | 3.261 | 4.440 | 0.940 | 2.880 | 0.027 | 0.071 | 0.084 | 0.061 |
| Octa-CDD | 11.702 | 16.042 | 3.717 | 10.487 | 0.091 | 0.213 | 0.197 | 0.167 |
| Total CDD | 20.215 | 28.224 | 6.738 | 18.392 | 0.182 | 0.449 | 0.443 | 0.359 |
| FURANS | | | | | | | | |
| 2378 TCDF | 0.206 | 0.149 | 0.068 | 0.141 | (0.014) | 0.008 | 0.005 | 0.009 |
| Other TCDF | 5.298 | 7.035 | 2.534 | 4.956 | 0.343 | 0.150 | 0.108 | 0.200 |
| 12378 PCDF | 0.370 | 0.357 | 0.122 | 0.283 | 0.008 | 0.005 | 0.003 | 0.005 |
| 23478 PCDF | 1.226 | 1.361 | 0.394 | 0.993 | 0.027 | 0.013 | 0.013 | 0.018 |
| Other PCDF | 11.910 | 13.208 | 3.441 | 9.520 | 0.293 | 0.137 | 0.055 | 0.162 |
| 123478 HxCDF | 6.198 | 8.211 | 1.990 | 5.466 | 0.077 | 0.058 | 0.055 | 0.063 |
| 123678 HxCDF | 1.688 | 1.941 | 0.525 | 1.385 | 0.022 | (0.016) | 0.018 | 0.019 |
| 234678 HxCDF | 6.822 | 9.973 | 2.033 | 6.276 | 0.088 | 0.066 | 0.058 | 0.070 |
| 123789 HxCDF | 0.178 | 0.183 | 0.059 | 0.140 | 0.003 | 0.003 | (0.002) | 0.002 |
| Other HxCDF | 14.022 | 14.721 | 3.767 | 10.837 | 0.195 | 0.100 | 0.098 | 0.131 |
| 1234678-HpCDF | 13.529 | 17.046 | 4.066 | 11.547 | 0.112 | 0.126 | 0.134 | 0.124 |
| 1234789-HpCDF | 5.134 | 6.470 | 1.355 | 4.320 | 0.036 | 0.050 | 0.045 | 0.043 |
| Other HpCDF | 20.421 | 26.461 | 5.553 | 17.478 | 0.154 | 0.166 | 0.163 | 0.161 |
| Octa-CDF | 75.393 | 76.975 | 13.402 | 55.257 | 0.200 | 0.421 | 0.447 | 0.356 |
| Total CDF | 162.396 | 184.092 | 39.309 | 128.599 | 1.572 | 1.319 | 1.205 | 1.365 |
| Total CDD+CDF | 182.611 | 212.316 | 46.047 | 146.991 | 1.755 | 1.771 | 1.649 | 1.725 |

Note: Condition 2 is with carbon injection.
a Standard conditions are defined as 1 atm and 68 F.
( ) = Estimated maximum possible concentration.

TABLE 2-6. CDD/CDF INLET AND OUTLET STACK GAS CONCENTRATIONS FOR CONDITION 1; MORRISTOWN HOSPITAL (1991)

| | INLET CONCENTRATION (ng/dscm, adjusted to 7% O2) | | | | OUTLET CONCENTRATION (ng/dscm, adjusted to 7% O2) | | | |
|---|---|---|---|---|---|---|---|---|
| CONGENER | Run 1 | Run 2 | Run 3 | Average | Run 1 | Run 2 | Run 3 | Average |
| DIOXINS | | | | | | | | |
| 2378 TCDD | 0.029 | 0.022 | 0.032 | 0.028 | (0.018) | (0.006) | 0.020 | 0.014 |
| Other TCDD | 0.126 | 0.123 | 0.346 | 0.198 | 0.287 | 0.050 | 0.080 | 0.139 |
| 12378 PCDD | 0.072 | 0.071 | 0.134 | 0.092 | 0.041 | (0.011) | (0.015) | 0.022 |
| Other PCDD | 0.604 | 0.483 | 1.030 | 0.706 | 0.602 | 0.094 | 0.090 | 0.262 |
| 123478 HxCDD | 0.101 | 0.120 | 0.271 | 0.164 | 0.053 | 0.017 | 0.010 | 0.026 |
| 123678 HxCDD | 0.140 | 0.148 | 0.291 | 0.193 | 0.076 | 0.017 | 0.015 | 0.036 |
| 123789 HxCDD | 0.251 | 0.280 | 0.669 | 0.400 | 0.111 | 0.028 | 0.020 | 0.053 |
| Other HxCDD | 1.246 | 1.299 | 2.960 | 1.835 | 0.871 | 0.226 | 0.194 | 0.430 |
| 1234678-HpCDD | 2.222 | 2.185 | 5.704 | 3.370 | 0.643 | 0.143 | 0.095 | 0.294 |
| Other HpCDD | 2.464 | 2.370 | 5.850 | 3.561 | 0.819 | 0.165 | 0.105 | 0.363 |
| Octa-CDD | 10.676 | 8.709 | 21.216 | 13.534 | 1.170 | 0.347 | 0.264 | 0.594 |
| Total CDD | 17.932 | 15.809 | 38.504 | 24.082 | 4.691 | 1.102 | 0.906 | 2.233 |
| FURANS | | | | | | | | |
| 2378 TCDF | 2.174 | 0.646 | 0.407 | 1.076 | 1.872 | 0.127 | 0.090 | 0.696 |
| Other TCDF | 10.387 | 5.416 | 11.874 | 9.226 | 12.107 | 2.683 | 4.342 | 6.377 |
| 12378 PCDF | 0.773 | 0.554 | 0.757 | 0.695 | 0.585 | 0.088 | 0.085 | 0.253 |
| 23478 PCDF | 2.126 | 1.693 | 2.386 | 2.068 | 1.696 | 0.314 | 0.304 | 0.771 |
| Other PCDF | 15.701 | 11.017 | 22.700 | 16.473 | 13.043 | 3.399 | 4.093 | 6.845 |
| 123478 HxCDF | 5.072 | 5.509 | 11.234 | 7.272 | 3.100 | 0.881 | 0.747 | 1.576 |
| 123678 HxCDF | 1.304 | 1.539 | 3.027 | 1.957 | 0.819 | 0.231 | 0.194 | 0.415 |
| 234678 HxCDF | 5.314 | 5.262 | 11.583 | 7.386 | 2.106 | 0.771 | 0.598 | 1.158 |
| 123789 HxCDF | 0.140 | (0.615) | 0.279 | 0.345 | 0.076 | (0.028) | (0.030) | 0.044 |
| Other HxCDF | 10.874 | 10.032 | 24.517 | 15.141 | 6.475 | 2.330 | 2.166 | 3.657 |
| 1234678-HpCDF | 9.420 | 10.340 | 23.632 | 14.464 | 4.211 | 0.991 | 0.598 | 1.933 |
| 1234789-HpCDF | 3.527 | 3.878 | 8.702 | 5.369 | 0.877 | 0.275 | 0.134 | 0.429 |
| Other HpCDF | 13.672 | 14.833 | 19.179 | 15.895 | 6.141 | 1.542 | 0.463 | 2.716 |
| Octa-CDF | 46.087 | 42.160 | 122.233 | 70.160 | 6.960 | 1.487 | 0.846 | 3.098 |
| Total CDF | 126.571 | 113.494 | 262.511 | 167.525 | 60.066 | 15.148 | 14.689 | 29.968 |
| | | | | | | | | |
| Total CDD+CDF | 144.503 | 129.303 | 301.01 | 191.607 | 64.757 | 16.249 | 15.60 | 32.201 |

Note: Condition 1 is no carbon injection.
( ) = Estimated maximum possible concentration.

TABLE 2-7. CDD/CDF INLET AND OUTLET STACK GAS CONCENTRATIONS FOR CONDITION 2; MORRISTOWN HOSPITAL (1991)

| | INLET CONCENTRATION (ng/dscm, adjusted to 7% O2) | | | | OUTLET CONCENTRATION (ng/dscm, adjusted to 7% O2) | | | |
|---|---|---|---|---|---|---|---|---|
| CONGENER | Run 4 | Run 5 | Run 6 | Average | Run 4 | Run 5 | Run 6 | Average |
| DIOXINS | | | | | | | | |
| 2378 TCDD | 0.024 | 0.018 | 0.009 | 0.017 | [0.003] | [0.003] | [0.001] | 0.000 |
| Other TCDD | 0.193 | 0.319 | 0.176 | 0.229 | 0.008 | 0.000 | 0.002 | 0.005 |
| 12378 PCDD | 0.086 | 0.083 | 0.030 | 0.066 | (0.003) | [0.003] | 0.002 | 0.002 |
| Other PCDD | 0.435 | 0.777 | 0.268 | 0.493 | 0.003 | 0.023 | 0.018 | 0.014 |
| 123478 HxCDD | 0.168 | 0.224 | 0.063 | 0.152 | 0.003 | 0.010 | (0.005) | 0.006 |
| 123678 HxCDD | 0.193 | 0.264 | 0.074 | 0.177 | 0.005 | 0.010 | 0.010 | 0.008 |
| 123789 HxCDD | 0.398 | 0.553 | 0.137 | 0.363 | 0.011 | 0.020 | 0.020 | 0.017 |
| Other HxCDD | 1.721 | 2.828 | 0.888 | 1.812 | 0.030 | 0.100 | 0.104 | 0.078 |
| 1234678-HpCDD | 3.735 | 5.588 | 1.192 | 3.505 | 0.064 | 0.150 | 0.143 | 0.119 |
| Other HpCDD | 4.317 | 6.110 | 1.281 | 3.903 | 0.054 | 0.135 | 0.158 | 0.116 |
| Octa-CDD | 15.491 | 22.078 | 5.065 | 14.211 | 0.177 | 0.406 | 0.371 | 0.318 |
| Total CDD | 26.761 | 38.843 | 9.182 | 24.929 | 0.357 | 0.855 | 0.832 | 0.684 |
| FURANS | | | | | | | | |
| 2378 TCDF | 0.272 | 0.206 | 0.092 | 0.190 | (0.027) | 0.015 | 0.010 | 0.017 |
| Other TCDF | 7.014 | 9.682 | 3.453 | 6.716 | 0.671 | 0.286 | 0.203 | 0.387 |
| 12378 PCDF | 0.490 | 0.491 | 0.167 | 0.383 | 0.016 | 0.010 | 0.005 | 0.010 |
| 23478 PCDF | 1.623 | 1.873 | 0.536 | 1.344 | 0.054 | 0.025 | 0.025 | 0.034 |
| Other PCDF | 15.767 | 18.178 | 4.689 | 12.878 | 0.575 | 0.261 | 0.104 | 0.313 |
| 123478 HxCDF | 8.205 | 11.300 | 2.711 | 7.405 | 0.150 | 0.110 | 0.104 | 0.121 |
| 123678 HxCDF | 2.235 | 2.671 | 0.715 | 1.874 | 0.043 | (0.030) | 0.035 | 0.036 |
| 234678 HxCDF | 9.032 | 13.726 | 2.771 | 8.509 | 0.172 | 0.125 | 0.109 | 0.135 |
| 123789 HxCDF | 0.236 | 0.252 | 0.080 | 0.189 | 0.005 | 0.005 | (0.004) | 0.005 |
| Other HxCDF | 18.562 | 20.260 | 5.133 | 14.652 | 0.381 | 0.191 | 0.184 | 0.252 |
| 1234678-HpCDF | 17.910 | 23.459 | 5.542 | 15.637 | 0.220 | 0.241 | 0.252 | 0.238 |
| 1234789-HpCDF | 6.797 | 8.905 | 1.847 | 5.850 | 0.070 | 0.095 | 0.084 | 0.083 |
| Other HpCDF | 27.033 | 36.417 | 7.567 | 23.673 | 0.301 | 0.316 | 0.306 | 0.308 |
| Octa-CDF | 99.806 | 105.935 | 18.263 | 74.668 | 0.392 | 0.802 | 0.840 | 0.678 |
| Total CDF | 214.981 | 253.354 | 53.568 | 173.968 | 3.077 | 2.512 | 2.263 | 2.618 |
| Total CDD+CDF | 241.742 | 292.197 | 62.75 | 198.897 | 3.434 | 3.367 | 3.096 | 3.301 |

Note: Condition 2 is with carbon injection.
( ) = Estimated maximum possible concentration.

TABLE 2-8. CDD/CDF AVERAGE FLUE GAS TOXIC EQUIVALENCIES CORRECTED TO 7% O2 FOR CONDITION 1; MORRISTOWN HOSPITAL (1991)

| CONGENER | Toxic Equivalency Factor a | INLET TOXIC EQUIVALENCIES (ng/dscm @ 7% O2) Run 1 | Run 2 | Run 3 | Average | OUTLET TOXIC EQUIVALENCIES (ng/dscm @ 7% O2) Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|---|---|---|---|---|
| DIOXINS | | | | | | | | | |
| 2378 TCDD | 1.00000 | 0.029 | 0.022 | 0.032 | 0.028 | (0.018) | (0.006) | 0.020 | 0.014 |
| Other TCDD | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDD | 0.50000 | 0.036 | 0.035 | 0.067 | 0.046 | 0.020 | (0.006) | (0.007) | 0.011 |
| Other PCDD | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDD | 0.10000 | 0.010 | 0.012 | 0.027 | 0.016 | 0.005 | 0.002 | 0.001 | 0.003 |
| 123678 HxCDD | 0.10000 | 0.014 | 0.015 | 0.029 | 0.019 | 0.008 | 0.002 | 0.001 | 0.004 |
| 123789 HxCDD | 0.10000 | 0.025 | 0.028 | 0.067 | 0.040 | 0.011 | 0.003 | 0.002 | 0.005 |
| Other HxCDD | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDD | 0.01000 | 0.022 | 0.022 | 0.057 | 0.034 | 0.006 | 0.001 | 0.001 | 0.003 |
| Other HpCDD | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDD | 0.00100 | 0.011 | 0.009 | 0.021 | 0.014 | 0.001 | 0.000 | 0.000 | 0.001 |
| Total CDD | | 0.147 | 0.142 | 0.300 | 0.197 | 0.070 | 0.019 | 0.033 | 0.041 |
| FURANS | | | | | | | | | |
| 2378 TCDF | 0.10000 | 0.217 | 0.065 | 0.041 | 0.108 | 0.187 | 0.013 | 0.009 | 0.070 |
| Other TCDF | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDF | 0.05000 | 0.039 | 0.028 | 0.038 | 0.035 | 0.029 | 0.004 | 0.004 | 0.013 |
| 23478 PCDF | 0.50000 | 1.063 | 0.846 | 1.193 | 1.034 | 0.848 | 0.157 | 0.152 | 0.386 |
| Other PCDF | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDF | 0.10000 | 0.507 | 0.551 | 1.123 | 0.727 | 0.310 | 0.088 | 0.075 | 0.158 |
| 123678 HxCDF | 0.10000 | 0.130 | 0.154 | 0.303 | 0.196 | 0.082 | 0.023 | 0.019 | 0.041 |
| 234678 HxCDF | 0.10000 | 0.531 | 0.526 | 1.158 | 0.739 | 0.211 | 0.077 | 0.060 | 0.116 |
| 123789 HxCDF | 0.10000 | 0.014 | (0.062) | 0.028 | 0.034 | 0.008 | (0.003) | (0.003) | 0.004 |
| Other HxCDF | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDF | 0.01000 | 0.094 | 0.103 | 0.236 | 0.145 | 0.042 | 0.010 | 0.006 | 0.019 |
| 1234789-HpCDF | 0.01000 | 0.035 | 0.039 | 0.087 | 0.054 | 0.009 | 0.003 | 0.001 | 0.004 |
| Other HpCDF | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDF | 0.00100 | 0.046 | 0.042 | 0.122 | 0.070 | 0.007 | 0.001 | 0.001 | 0.003 |
| Total CDF | | 2.678 | 2.415 | 4.330 | 3.141 | 1.732 | 0.379 | 0.330 | 0.814 |
| Total CDD+CDF | | 2.825 | 2.558 | 4.630 | 3.338 | 1.802 | 0.398 | 0.363 | 0.854 |

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.

Note: Condition 1 is no carbon injection.

( ) = Estimated maximum possible concentration

TABLE 2-9. CDD/CDF AVERAGE FLUE GAS TOXIC EQUIVALENCIES CORRECTED TO 7% O2 FOR CONDITION 2; MORRISTOWN HOSPITAL (1991)

| CONGENER | Toxic Equivalency Factor a | INLET TOXIC EQUIVALENCIES (ng/dscm @ 7% O2) Run 4 | Run 5 | Run 6 | Average | OUTLET TOXIC EQUIVALENCIES (ng/dscm @ 7% O2) Run 4 | Run 5 | Run 6 | Average |
|---|---|---|---|---|---|---|---|---|---|
| DIOXINS | | | | | | | | | |
| 2378 TCDD | 1.00000 | 0.024 | 0.018 | 0.009 | 0.017 | [0.003] | [0.003] | [0.001] | 0.000 |
| Other TCDD | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDD | 0.50000 | 0.043 | 0.041 | 0.015 | 0.033 | (0.001) | [0.001] | 0.001 | 0.001 |
| Other PCDD | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDD | 0.10000 | 0.017 | 0.022 | 0.006 | 0.015 | 0.000 | 0.001 | (0.000) | 0.001 |
| 123678 HxCDD | 0.10000 | 0.019 | 0.026 | 0.007 | 0.018 | 0.000 | 0.001 | 0.001 | 0.001 |
| 123789 HxCDD | 0.10000 | 0.040 | 0.055 | 0.014 | 0.036 | 0.001 | 0.002 | 0.002 | 0.002 |
| Other HxCDD | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDD | 0.01000 | 0.037 | 0.056 | 0.012 | 0.035 | 0.001 | 0.002 | 0.001 | 0.001 |
| Other HpCDD | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDD | 0.00100 | 0.015 | 0.022 | 0.005 | 0.014 | 0.000 | 0.000 | 0.000 | 0.000 |
| Total CDD | | 0.196 | 0.242 | 0.068 | 0.169 | 0.004 | 0.006 | 0.006 | 0.006 |
| FURANS | | | | | | | | | |
| 2378 TCDF | 0.10000 | 0.027 | 0.021 | 0.009 | 0.019 | (0.003) | 0.002 | 0.001 | 0.002 |
| Other TCDF | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDF | 0.05000 | 0.024 | 0.025 | 0.008 | 0.019 | 0.001 | 0.001 | 0.000 | 0.001 |
| 23478 PCDF | 0.50000 | 0.811 | 0.937 | 0.268 | 0.672 | 0.027 | 0.013 | 0.012 | 0.017 |
| Other PCDF | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDF | 0.10000 | 0.820 | 1.130 | 0.271 | 0.741 | 0.015 | 0.011 | 0.010 | 0.012 |
| 123678 HxCDF | 0.10000 | 0.223 | 0.267 | 0.072 | 0.187 | 0.004 | (0.003) | 0.003 | 0.004 |
| 234678 HxCDF | 0.10000 | 0.903 | 1.373 | 0.277 | 0.851 | 0.017 | 0.013 | 0.011 | 0.014 |
| 123789 HxCDF | 0.10000 | 0.024 | 0.025 | 0.008 | 0.019 | 0.001 | 0.001 | (0.000) | 0.000 |
| Other HxCDF | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDF | 0.01000 | 0.179 | 0.235 | 0.055 | 0.156 | 0.002 | 0.002 | 0.003 | 0.002 |
| 1234789-HpCDF | 0.01000 | 0.068 | 0.089 | 0.018 | 0.058 | 0.001 | 0.001 | 0.001 | 0.001 |
| Other HpCDF | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDF | 0.00100 | 0.100 | 0.106 | 0.018 | 0.075 | 0.000 | 0.001 | 0.001 | 0.001 |
| Total CDF | | 3.181 | 4.206 | 1.006 | 2.797 | 0.071 | 0.046 | 0.043 | 0.053 |
| Total CDD+CDF | | 3.377 | 4.448 | 1.074 | 2.966 | 0.074 | 0.052 | 0.049 | 0.059 |

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.

Note: Condition 2 is with carbon injection.

( ) = Estimated maximum possible concentration

TABLE 2-10. SUMMARY OF CDD/CDF FLUE GAS SAMPLING PARAMETERS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Spray Dryer Inlet | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Run 1 | Run 2 | Run 3 | Average | Run 4 | Run 5 | Run 6 | Average |
| Total Sample Time (min) | 240 | 240 | 240 | 240 | 240 | 240 | 240 | 240 |
| Average Sampling Rate (dscfm) | 0.43 | 0.68 | 0.68 | 0.60 | 0.64 | 0.66 | 0.67 | 0.66 |
| Dry Standard Meter Volume (dscf) | 104 | 163 | 164 | 143 | 153 | 158 | 162 | 157 |
| Dry Standard Meter Volume (dscm) | 2.9 | 4.6 | 4.6 | 4.1 | 4.3 | 4.5 | 4.6 | 4.5 |
| Average Stack Temperature (F) | 407 | 408 | 405 | 407 | 409 | 401 | 407 | 406 |
| Oxygen Concentration (% V) | 11.1 | 11.1 | 10.6 | 10.9 | 10.4 | 10.8 | 10.7 | 10.6 |
| Carbon Dioxide Concentration (% V) | 6.4 | 7.8 | 6.7 | 7.0 | 6.6 | 6.5 | 6.5 | 6.5 |
| Percent Moisture (% V) | 15.8 | 15.3 | 14.8 | 15.3 | 14.4 | 13.7 | 13.3 | 13.8 |
| Volumetric Flow Rate (dscfm) | 3370 | 3479 | 3531 | 3460 | 3343 | 3416 | 3494 | 3418 |
| Volumetric Flow Rate (dscmm) | 95.4 | 98.5 | 100.0 | 98.0 | 94.7 | 96.8 | 98.9 | 96.8 |
| Percent Isokinetic (%) | 102.6 | 102.0 | 101.1 | NA | 99.6 | 101.0 | 100.8 | NA |
| | Bag House Outlet | | | | | | | |
| | Run 1 | Run 2 | Run 3 | Average | Run 4 | Run 5 | Run 6 | Average |
| Total Sample Time (min) | 240 | 240 | 240 | 240 | 240 | 240 | 240 | 240 |
| Average Sampling Rate (dscfm) | 0.51 | 0.55 | 0.55 | 0.54 | 0.55 | 0.56 | 0.56 | 0.56 |
| Dry Standard Meter Volume (dscf) | 123 | 131 | 131 | 129 | 129 | 134 | 134 | 132 |
| Dry Standard Meter Volume (dscm) | 3.5 | 3.7 | 3.7 | 3.6 | 3.6 | 3.8 | 3.8 | 3.7 |
| Average Stack Temperature (F) | 279 | 292 | 293 | 288 | 293 | 291 | 292 | 292 |
| Oxygen Concentration (% V) | 14.1 | 14.1 | 13.4 | 13.9 | 13.8 | 13.6 | 13.5 | 13.6 |
| Carbon Dioxide Concentration (% V) | 5.0 | 5.0 | 5.3 | 5.1 | 5.2 | 5.0 | 5.3 | 5.2 |
| Percent Moisture (% V) | 14.7 | 14.7 | 14.6 | 14.6 | 15.0 | 13.3 | 13.3 | 13.8 |
| Volumetric Flow Rate (dscfm) | 4765 | 4968 | 4956 | 4897 | 4842 | 5055 | 4978 | 4958 |
| Volumetric Flow Rate (dscmm) | 135.0 | 140.7 | 140.4 | 138.7 | 137.1 | 143.2 | 141.0 | 140.4 |
| Percent Isokinetic (%) | 92.7 | 94.4 | 94.9 | NA | 96.7 | 94.9 | 96.5 | NA |

NA : Not applicable

allowed to cool. An approximately one liter bottle was filled and sent to the laboratory for CDD/CDF analyses.

Ash samples were analyzed for the same CDD/CDF isomers that the flue gas samples were analyzed for. All CDD/CDF congeners were detected in the test run samples. Tables 2-11 and 2-12 gives CDD/CDF concentrations and toxic equivalencies in the baghouse residue for Condition 1 and 2. The average total CDD/CDF concentrations were 24.2 and 32.7 parts per billion for Conditions 1 and 2. Test Run 5 had the highest total CDD/CDF concentration at 44.7 ppb.wt. Run 5 also showed the highest removal efficiency of 98.77 percent for total CDD/CDF in the flue gas.

Tables 2-13 through 2-16 present the CDD/CDF concentrations and toxic equivalencies in the bottom ash and spray dryer residue. Total CDD/CDF values for Conditions 1 and 2 in the bottom ash were 96.5 and 73.1 ppb.wt, and 9.2 and 6.2 ppb.wt in the spray dryer residue, respectively.

Table 2-17 presents the CDD/CDF make-up water and lime slurry tank analysis results. Spray dryer make-up water was sampled every test day. However, only one sample was analyzed with the results assumed to represent all test days. Results are given in units of parts per trillion by weight (ppt,wt). All congeners were present below the detection limit except for octa-CDD and CDF which were detected at very low levels.

## 2.3 TOXIC METALS RESULTS

### 2.3.1 Overview

A single sampling train was used to determine emission rates of a series of 13 metals [aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), silver (Ag), thallium (Tl)], and particulate matter (PM). Mercury was also sampled by Method 101A and will be discussed in Section 2.5. Three sampling runs were performed under both test conditions (without carbon injection and with carbon injection) in order to ensure representative test results.

Sampling locations, method, and QA/QC are discussed in Sections 4, 5, and 6, respectively. The average metals emission rates and removal efficiencies are summarized in Section 2.3.3. The results for each individual run are presented in Section 2.3.4.

TABLE 2-11. CDD/CDF CONCENTRATIONS AND 2378 TOXIC EQUIVALENT CONCENTRATIONS IN BAGHOUSE RESIDUE FOR CONDITION 1; MORRISTOWN HOSPITAL (1991)

| | CDD/CDF ASH CONCENTRATIONS | | | | 2378 TOXIC EQUIVALENCIES | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CONGENER | RUN 1 (ppb) | RUN 2 (ppb) | RUN 3 (ppb) | Average (ppb) | Toxic Equiv. Factor a | RUN 1 (ppb) | RUN 2 (ppb) | RUN 3 (ppb) | Average (ppb) |
| DIOXINS | | | | | | | | | |
| 2378 TCDD | 0.003 | 0.002 | 0.003 | 0.003 | 1.00000 | 0.003 | 0.002 | 0.003 | 0.003 |
| Other TCDD | 0.034 | 0.011 | 0.038 | 0.028 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDD | 0.014 | 0.007 | 0.014 | 0.012 | 0.50000 | 0.007 | 0.003 | 0.007 | 0.006 |
| Other PCDD | 0.124 | 0.052 | 0.101 | 0.092 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDD | 0.029 | 0.011 | 0.022 | 0.021 | 0.10000 | 0.003 | 0.001 | 0.002 | 0.002 |
| 123678 HxCDD | 0.036 | 0.013 | 0.023 | 0.024 | 0.10000 | 0.004 | 0.001 | 0.002 | 0.002 |
| 123789 HxCDD | 0.080 | 0.028 | 0.085 | 0.064 | 0.10000 | 0.008 | 0.003 | 0.008 | 0.006 |
| Other HxCDD | 0.399 | 0.140 | 0.241 | 0.260 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDD | 0.644 | 0.219 | 0.395 | 0.419 | 0.01000 | 0.006 | 0.002 | 0.004 | 0.004 |
| Other Hepta-CDD | 0.656 | 0.247 | 0.400 | 0.434 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDD | 2.490 | 1.070 | 1.220 | 1.593 | 0.00100 | 0.002 | 0.001 | 0.001 | 0.002 |
| Total CDD | 4.508 | 1.799 | 2.541 | 2.949 | | 0.033 | 0.013 | 0.028 | 0.025 |
| FURANS | | | | | | | | | |
| 2378 TCDF | 0.040 | 0.020 | 0.042 | 0.034 | 0.10000 | 0.004 | 0.002 | 0.004 | 0.003 |
| Other TCDF | 1.350 | 0.631 | 1.438 | 1.140 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDF | 0.096 | 0.047 | 0.086 | 0.076 | 0.05000 | 0.005 | 0.002 | 0.004 | 0.004 |
| 23478 PCDF | 0.264 | 0.104 | 0.192 | 0.187 | 0.50000 | 0.132 | 0.052 | 0.096 | 0.093 |
| Other PCDF | 2.470 | 1.019 | 1.782 | 1.757 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDF | 1.300 | 0.522 | 0.845 | 0.889 | 0.10000 | 0.130 | 0.052 | 0.085 | 0.089 |
| 123678 HxDCF | 0.392 | 0.208 | 0.282 | 0.294 | 0.10000 | 0.039 | 0.021 | 0.028 | 0.029 |
| 234678 HxCDF | 1.180 | 0.463 | 0.793 | 0.812 | 0.10000 | 0.118 | 0.046 | 0.079 | 0.081 |
| 123789 HxCDF | 0.041 | 0.017 | 0.030 | 0.029 | 0.10000 | 0.004 | 0.002 | 0.003 | 0.003 |
| Other HxCDF | 3.008 | 1.380 | 1.921 | 2.103 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDF | 3.300 | 1.770 | 2.170 | 2.413 | 0.01000 | 0.033 | 0.018 | 0.022 | 0.024 |
| 1234789-HpCDF | 0.942 | 0.373 | 0.669 | 0.661 | 0.01000 | 0.009 | 0.004 | 0.007 | 0.007 |
| Other Hepta-CDF | 4.448 | 1.977 | 2.941 | 3.122 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDF | 13.140 | 3.910 | 6.050 | 7.700 | 0.00100 | 0.013 | 0.004 | 0.006 | 0.008 |
| Total CDF | 31.970 | 12.441 | 19.240 | 21.217 | | 0.488 | 0.203 | 0.334 | 0.341 |
| | | | | | | | | | |
| Total CDD+CDF | 36.478 | 14.240 | 21.781 | 24.166 | | 0.521 | 0.216 | 0.362 | 0.366 |

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

TABLE 2-12. CDD/CDF CONCENTRATIONS AND 2378 TOXIC EQUIVALENT CONCENTRATIONS
*IN BAGHOUSE RESIDUE FOR CONDITION 2; MORRISTOWN HOSPITAL (1991)*

| CONGENER | CDD/CDF ASH CONCENTRATIONS RUN 4 (ppb) | RUN 5 (ppb) | RUN 6 (ppb) | Average (ppb) | Toxic Equiv. Factor a | 2378 TOXIC EQUIVALENCIES RUN 4 (ppb) | RUN 5 (ppb) | RUN 6 (ppb) | Average (ppb) |
|---|---|---|---|---|---|---|---|---|---|
| DIOXINS | | | | | | | | | |
| 2378 TCDD | 0.003 | 0.002 | 0.001 | 0.002 | 1.00000 | 0.003 | 0.002 | 0.001 | 0.002 |
| Other TCDD | 0.031 | 0.039 | 0.029 | 0.033 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDD | 0.015 | 0.012 | 0.006 | 0.011 | 0.50000 | 0.007 | 0.006 | 0.003 | 0.005 |
| Other PCDD | 0.113 | 0.157 | 0.081 | 0.117 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDD | 0.030 | 0.028 | 0.012 | 0.024 | 0.10000 | 0.003 | 0.003 | 0.001 | 0.002 |
| 123678 HxCDD | 0.039 | 0.037 | 0.020 | 0.032 | 0.10000 | 0.004 | 0.004 | 0.002 | 0.003 |
| 123789 HxCDD | 0.083 | 0.065 | 0.029 | 0.059 | 0.10000 | 0.008 | 0.006 | 0.003 | 0.006 |
| Other HxCDD | 0.363 | 0.442 | 0.232 | 0.346 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDD | 0.705 | 0.733 | 0.300 | 0.579 | 0.01000 | 0.007 | 0.007 | 0.003 | 0.006 |
| Other Hepta-CDD | 0.755 | 0.857 | 0.352 | 0.655 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDD | 2.570 | 3.710 | 1.010 | 2.430 | 0.00100 | 0.003 | 0.004 | 0.001 | 0.002 |
| Total CDD | 4.707 | 6.083 | 2.073 | 4.288 | | 0.036 | 0.032 | 0.015 | 0.027 |
| FURANS | | | | | | | | | |
| 2378 TCDF | 0.039 | 0.030 | 0.013 | 0.027 | 0.10000 | 0.004 | 0.003 | 0.001 | 0.003 |
| Other TCDF | 1.431 | 1.210 | 0.443 | 1.028 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDF | 0.078 | 0.073 | 0.034 | 0.061 | 0.05000 | 0.004 | 0.004 | 0.002 | 0.003 |
| 23478 PCDF | 0.306 | 0.259 | 0.104 | 0.223 | 0.50000 | 0.153 | 0.130 | 0.052 | 0.112 |
| Other PCDF | 2.976 | 2.719 | 1.062 | 2.252 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDF | 1.460 | 1.290 | 0.506 | 1.085 | 0.10000 | 0.146 | 0.129 | 0.051 | 0.109 |
| 123678 HxDCF | 0.445 | 0.371 | 0.160 | 0.325 | 0.10000 | 0.045 | 0.037 | 0.016 | 0.033 |
| 234678 HxCDF | 1.590 | 1.180 | 0.526 | 1.099 | 0.10000 | 0.159 | 0.118 | 0.053 | 0.110 |
| 123789 HxCDF | 0.040 | 0.027 | 0.012 | 0.026 | 0.10000 | 0.004 | 0.003 | 0.001 | 0.003 |
| Other HxCDF | 3.085 | 3.062 | 1.187 | 2.444 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDF | 3.450 | 3.790 | 1.280 | 2.840 | 0.01000 | 0.035 | 0.038 | 0.013 | 0.028 |
| 1234789-HpCDF | 1.440 | 1.050 | 0.392 | 0.961 | 0.01000 | 0.014 | 0.011 | 0.004 | 0.010 |
| Other Hepta-CDF | 5.700 | 5.860 | 1.898 | 4.486 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDF | 13.040 | 17.690 | 4.040 | 11.590 | 0.00100 | 0.013 | 0.018 | 0.004 | 0.012 |
| Total CDF | 35.080 | 38.610 | 11.656 | 28.449 | | 0.576 | 0.489 | 0.196 | 0.420 |
| Total CDD+CDF | 39.787 | 44.693 | 13.729 | 32.736 | | 0.612 | 0.521 | 0.211 | 0.448 |

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

TABLE 2-13. CDD/CDF CONCENTRATIONS AND 2378 TOXIC EQUIVALENT CONCENTRATIONS IN BOTTOM ASH FOR CONDITION 1; MORRISTOWN HOSPITAL (1991)

| | CDD/CDF ASH CONCENTRATIONS | | | | 2378 TOXIC EQUIVALENCIES | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CONGENER | RUN 1 (ppb) | RUN 2 (ppb) | RUN 3 (ppb) | Average (ppb) | Toxic Equiv. Factor a | RUN 1 (ppb) | RUN 2 (ppb) | RUN 3 (ppb) | Average (ppb) |
| DIOXINS | | | | | | | | | |
| 2378 TCDD | (0.015) | 0.009 | 0.018 | 0.015 | 1.00000 | (0.015) | 0.009 | 0.018 | 0.015 |
| Other TCDD | 3.764 | 0.183 | 0.253 | 1.400 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDD | 0.165 | 0.077 | 0.108 | 0.117 | 0.50000 | 0.083 | 0.039 | 0.054 | 0.058 |
| Other PCDD | 3.875 | 0.587 | 0.761 | 1.741 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDD | 0.351 | 0.184 | 0.242 | 0.259 | 0.10000 | 0.035 | 0.018 | 0.024 | 0.026 |
| 123678 HxCDD | 0.359 | 0.126 | 0.155 | 0.213 | 0.10000 | 0.036 | 0.013 | 0.016 | 0.021 |
| 123789 HxCDD | 0.893 | 0.418 | 0.499 | 0.603 | 0.10000 | 0.089 | 0.042 | 0.050 | 0.060 |
| Other HxCDD | 5.447 | 1.082 | 1.364 | 2.631 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDD | 3.740 | 2.150 | 1.790 | 2.560 | 0.01000 | 0.037 | 0.022 | 0.018 | 0.026 |
| Other Hepta-CDD | 4.930 | 2.200 | 1.890 | 3.007 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDD | 12.200 | 11.780 | 6.480 | 10.153 | 0.00100 | 0.012 | 0.012 | 0.006 | 0.010 |
| Total CDD | 35.740 | 18.796 | 13.560 | 22.699 | | 0.308 | 0.154 | 0.186 | 0.216 |
| FURANS | | | | | | | | | |
| 2378 TCDF | 0.349 | 0.148 | 0.263 | 0.253 | 0.10000 | 0.035 | 0.015 | 0.026 | 0.025 |
| Other TCDF | 16.591 | 7.422 | 11.507 | 11.840 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDF | 0.465 | 0.311 | 0.491 | 0.422 | 0.05000 | 0.023 | 0.016 | 0.025 | 0.021 |
| 23478 PCDF | 1.100 | 0.696 | 1.090 | 0.962 | 0.50000 | 0.550 | 0.348 | 0.545 | 0.481 |
| Other PCDF | 7.495 | 9.733 | 12.759 | 9.996 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDF | 5.030 | 5.490 | 6.440 | 5.653 | 0.10000 | 0.503 | 0.549 | 0.644 | 0.565 |
| 123678 HxDCF | 1.400 | 1.160 | 1.310 | 1.290 | 0.10000 | 0.140 | 0.116 | 0.131 | 0.129 |
| 234678 HxCDF | 2.860 | 2.800 | 2.920 | 2.860 | 0.10000 | 0.286 | 0.280 | 0.292 | 0.286 |
| 123789 HxCDF | 0.078 | 0.079 | 0.104 | 0.087 | 0.10000 | 0.008 | 0.008 | 0.010 | 0.009 |
| Other HxCDF | 0.182 | 9.161 | 10.466 | 6.603 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDF | 7.600 | 12.080 | 7.050 | 8.910 | 0.01000 | 0.076 | 0.121 | 0.071 | 0.089 |
| 1234789-HpCDF | 1.310 | 1.030 | 0.878 | 1.073 | 0.01000 | 0.013 | 0.010 | 0.009 | 0.011 |
| Other Hepta-CDF | 7.850 | 8.260 | 6.052 | 7.387 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDF | 10.400 | 26.440 | 12.610 | 16.483 | 0.00100 | 0.010 | 0.026 | 0.013 | 0.016 |
| Total CDF | 62.710 | 84.810 | 73.940 | 73.820 | | 1.644 | 1.489 | 1.765 | 1.633 |
| Total CDD+CDF | 98.450 | 103.606 | 87.500 | 96.519 | | 1.953 | 1.643 | 1.952 | 1.849 |

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( ) = Estimated maximum possible concentration

TABLE 2-14. CDD/CDF CONCENTRATIONS AND 2378 TOXIC EQUIVALENT CONCENTRATIONS IN BOTTOM ASH FOR CONDITION 2; MORRISTOWN HOSPITAL (1991)

| | CDD/CDF ASH CONCENTRATIONS | | | | 2378 TOXIC EQUIVALENCIES | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CONGENER | RUN 4 (ppb) | RUN 5 (ppb) | RUN 6 (ppb) | Average (ppb) | Toxic Equiv. Factor a | RUN 4 (ppb) | RUN 5 (ppb) | RUN 6 (ppb) | Average (ppb) |
| DIOXINS | | | | | | | | | |
| 2378 TCDD | 0.007 | 0.012 | 0.016 | 0.012 | 1.00000 | 0.007 | 0.012 | 0.016 | 0.012 |
| Other TCDD | 0.178 | 0.285 | 0.193 | 0.219 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDD | 0.046 | 0.099 | 0.114 | 0.086 | 0.50000 | 0.023 | 0.050 | 0.057 | 0.043 |
| Other PCDD | 0.431 | 0.764 | 0.723 | 0.639 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDD | 0.088 | 0.236 | 0.202 | 0.175 | 0.10000 | 0.009 | 0.024 | 0.020 | 0.018 |
| 123678 HxCDD | 0.073 | 0.157 | 0.122 | 0.117 | 0.10000 | 0.007 | 0.016 | 0.012 | 0.012 |
| 123789 HxCDD | 0.199 | 0.543 | 0.383 | 0.375 | 0.10000 | 0.020 | 0.054 | 0.038 | 0.038 |
| Other HxCDD | 0.661 | 1.394 | 1.033 | 1.029 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDD | 0.511 | 2.370 | 1.510 | 1.464 | 0.01000 | 0.005 | 0.024 | 0.015 | 0.015 |
| Other Hepta-CDD | 2.869 | 2.460 | 1.660 | 2.330 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDD | 3.830 | 10.440 | 5.910 | 6.727 | 0.00100 | 0.004 | 0.010 | 0.006 | 0.007 |
| Total CDD | 8.892 | 18.760 | 11.866 | 13.173 | | 0.075 | 0.189 | 0.165 | 0.143 |
| FURANS | | | | | | | | | |
| 2378 TCDF | 0.110 | 0.185 | 0.206 | 0.167 | 0.10000 | 0.011 | 0.019 | 0.021 | 0.017 |
| Other TCDF | 4.600 | 8.885 | 8.744 | 7.410 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDF | 0.165 | 0.385 | 0.463 | 0.338 | 0.05000 | 0.008 | 0.019 | 0.023 | 0.017 |
| 23478 PCDF | 0.364 | 0.917 | 0.920 | 0.734 | 0.50000 | 0.182 | 0.459 | 0.460 | 0.367 |
| Other PCDF | 4.661 | 11.428 | 10.997 | 9.029 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDF | 2.110 | 6.800 | 4.970 | 4.627 | 0.10000 | 0.211 | 0.680 | 0.497 | 0.463 |
| 123678 HxDCF | 0.488 | 1.340 | 1.250 | 1.026 | 0.10000 | 0.049 | 0.134 | 0.125 | 0.103 |
| 234678 HxCDF | 1.030 | 3.080 | 2.270 | 2.127 | 0.10000 | 0.103 | 0.308 | 0.227 | 0.213 |
| 123789 HxCDF | 0.037 | 0.125 | 0.105 | 0.089 | 0.10000 | 0.004 | 0.013 | 0.011 | 0.009 |
| Other HxCDF | 3.495 | 9.895 | 9.295 | 7.562 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDF | 4.570 | 7.760 | 12.170 | 8.167 | 0.01000 | 0.046 | 0.078 | 0.122 | 0.082 |
| 1234789-HpCDF | (0.260) | 7.760 | 0.940 | 2.987 | 0.01000 | (0.003) | 0.078 | 0.009 | 0.030 |
| Other Hepta-CDF | 2.668 | 1.590 | 7.540 | 3.933 | 0.00000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDF | 5.250 | 17.810 | 12.180 | 11.747 | 0.00100 | 0.005 | 0.018 | 0.012 | 0.012 |
| Total CDF | 29.810 | 77.960 | 72.050 | 59.940 | | 0.621 | 1.804 | 1.507 | 1.311 |
| Total CDD+CDF | 38.702 | 96.720 | 83.916 | 73.113 | | 0.696 | 1.993 | 1.672 | 1.454 |

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( ) = Estimated maximum possible concentration

TABLE 2-15. CDD/CDF CONCENTRATIONS AND 2378 TOXIC EQUIVALENT CONCENTRATIONS IN SPRAY DRYER RESIDUE FOR CONDITION 1; MORRISTOWN HOSPITAL (1991)

| CONGENER | CDD/CDF ASH CONCENTRATIONS RUN 1 (ppb) | RUN 2 (ppb) | RUN 3 (ppb) | Average (ppb) | 2378 TOXIC EQUIVALENCIES Toxic Equiv. Factor a | RUN 1 (ppb) | RUN 2 (ppb) | RUN 3 (ppb) | Average (ppb) |
|---|---|---|---|---|---|---|---|---|---|
| DIOXINS | | | | | | | | | |
| 2378 TCDD | (0.001) | 0.001 | (0.001) | 0.001 | 1.000 | (0.001) | 0.001 | (0.001) | 0.001 |
| Other TCDD | 0.006 | 0.008 | 0.006 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDD | 0.004 | 0.004 | 0.004 | 0.004 | 0.500 | 0.002 | 0.002 | 0.002 | 0.002 |
| Other PCDD | 0.027 | 0.021 | 0.022 | 0.023 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDD | 0.008 | 0.008 | 0.009 | 0.008 | 0.100 | 0.001 | 0.001 | 0.001 | 0.001 |
| 123678 HxCDD | 0.011 | 0.009 | 0.010 | 0.010 | 0.100 | 0.001 | 0.001 | 0.001 | 0.001 |
| 123789 HxCDD | 0.021 | 0.018 | 0.021 | 0.020 | 0.100 | 0.002 | 0.002 | 0.002 | 0.002 |
| Other HxCDD | 0.105 | 0.100 | 0.100 | 0.101 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDD | 0.233 | 0.197 | 0.187 | 0.206 | 0.010 | 0.002 | 0.002 | 0.002 | 0.002 |
| Other Hepta-CDD | 0.239 | 0.188 | 0.199 | 0.209 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDD | 1.180 | 1.420 | 0.731 | 1.110 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Total CDD | 1.833 | 1.975 | 1.290 | 1.699 | | 0.010 | 0.010 | 0.009 | 0.010 |
| FURANS | | | | | | | | | |
| 2378 TCDF | 0.007 | 0.004 | 0.013 | 0.008 | 0.100 | 0.001 | 0.000 | 0.001 | 0.001 |
| Other TCDF | 0.202 | 0.098 | 0.436 | 0.245 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDF | 0.020 | 0.012 | 0.027 | 0.020 | 0.050 | 0.001 | 0.001 | 0.001 | 0.001 |
| 23478 PCDF | 0.059 | 0.034 | 0.072 | 0.055 | 0.500 | 0.029 | 0.017 | 0.036 | 0.027 |
| Other PCDF | 0.543 | 0.275 | 0.721 | 0.513 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDF | 0.280 | 0.172 | 0.375 | 0.276 | 0.100 | 0.028 | 0.017 | 0.038 | 0.028 |
| 123678 HxDCF | 0.108 | 0.055 | 0.128 | 0.097 | 0.100 | 0.011 | 0.006 | 0.013 | 0.010 |
| 234678 HxCDF | 0.329 | 0.184 | 0.359 | 0.291 | 0.100 | 0.033 | 0.018 | 0.036 | 0.029 |
| 123789 HxCDF | 0.076 | 0.007 | 0.012 | 0.031 | 0.100 | 0.008 | 0.001 | 0.001 | 0.003 |
| Other HxCDF | 0.727 | 0.379 | 0.927 | 0.678 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDF | 1.140 | 0.657 | 1.100 | 0.966 | 0.010 | 0.011 | 0.007 | 0.011 | 0.010 |
| 1234789-HpCDF | 0.268 | 0.175 | 0.265 | 0.236 | 0.010 | 0.003 | 0.002 | 0.003 | 0.002 |
| Other Hepta-CDF | 1.292 | 0.738 | 1.305 | 1.112 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDF | 3.060 | 2.620 | 3.160 | 2.947 | 0.001 | 0.003 | 0.003 | 0.003 | 0.003 |
| Total CDF | 8.109 | 5.410 | 8.898 | 7.472 | | 0.127 | 0.071 | 0.143 | 0.114 |
| Total CDD+CDF | 9.942 | 7.385 | 10.188 | 9.171 | | 0.137 | 0.081 | 0.152 | 0.123 |

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( ) = Estimated maximum possible concentration

TABLE 2-16. CDD/CDF CONCENTRATIONS AND 2378 TOXIC EQUIVALENT CONCENTRATIONS IN SPRAY DRYER RESIDUE FOR CONDITION 2; MORRISTOWN HOSPITAL (1991)

| | CDD/CDF ASH CONCENTRATIONS | | | | 2378 TOXIC EQUIVALENCIES | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CONGENER | RUN 4 (ppb) | RUN 5 (ppb) | RUN 6 (ppb) | Average (ppb) | Toxic Equiv. Factor a | RUN 4 (ppb) | RUN 5 (ppb) | RUN 6 (ppb) | Average (ppb) |
| DIOXINS | | | | | | | | | |
| 2378 TCDD | 0.000 | (0.001) | 0.001 | 0.001 | 1.000 | 0.000 | (0.001) | 0.001 | 0.001 |
| Other TCDD | 0.003 | 0.005 | 0.007 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDD | 0.002 | 0.003 | 0.002 | 0.002 | 0.500 | 0.001 | 0.001 | 0.001 | 0.001 |
| Other PCDD | 0.016 | 0.028 | 0.026 | 0.023 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDD | 0.005 | 0.007 | 0.005 | 0.006 | 0.100 | 0.000 | 0.001 | 0.001 | 0.001 |
| 123678 HxCDD | 0.006 | 0.009 | 0.008 | 0.008 | 0.100 | 0.001 | 0.001 | 0.001 | 0.001 |
| 123789 HxCDD | 0.011 | 0.018 | 0.014 | 0.014 | 0.100 | 0.001 | 0.002 | 0.001 | 0.001 |
| Other HxCDD | 0.054 | 0.098 | 0.089 | 0.080 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDD | 0.103 | 0.183 | 0.169 | 0.152 | 0.010 | 0.001 | 0.002 | 0.002 | 0.002 |
| Other Hepta-CDD | 0.100 | 0.176 | 0.157 | 0.144 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDD | 0.468 | 0.921 | 1.050 | 0.813 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 |
| Total CDD | 0.769 | 1.449 | 1.528 | 1.249 | | 0.005 | 0.008 | 0.007 | 0.007 |
| FURANS | | | | | | | | | |
| 2378 TCDF | 0.005 | 0.007 | 0.004 | 0.005 | 0.100 | 0.001 | 0.001 | 0.000 | 0.001 |
| Other TCDF | 0.146 | 0.214 | 0.119 | 0.160 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12378 PCDF | 0.012 | 0.016 | 0.010 | 0.013 | 0.050 | 0.001 | 0.001 | 0.000 | 0.001 |
| 23478 PCDF | 0.036 | 0.050 | 0.029 | 0.039 | 0.500 | 0.018 | 0.025 | 0.015 | 0.019 |
| Other PCDF | 0.328 | 0.503 | 0.260 | 0.364 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 123478 HxCDF | 0.166 | 0.259 | 0.161 | 0.195 | 0.100 | 0.017 | 0.026 | 0.016 | 0.020 |
| 123678 HxDCF | 0.051 | 0.081 | 0.052 | 0.061 | 0.100 | 0.005 | 0.008 | 0.005 | 0.006 |
| 234678 HxCDF | 0.156 | 0.271 | 0.173 | 0.200 | 0.100 | 0.016 | 0.027 | 0.017 | 0.020 |
| 123789 HxCDF | 0.006 | 0.006 | 0.006 | 0.006 | 0.100 | 0.001 | 0.001 | 0.001 | 0.001 |
| Other HxCDF | 0.377 | 0.623 | 0.347 | 0.449 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1234678-HpCDF | 0.463 | 0.796 | 0.576 | 0.612 | 0.010 | 0.005 | 0.008 | 0.006 | 0.006 |
| 1234789-HpCDF | 0.130 | 0.211 | 0.161 | 0.167 | 0.010 | 0.001 | 0.002 | 0.002 | 0.002 |
| Other Hepta-CDF | 0.577 | 0.983 | 0.683 | 0.748 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octa-CDF | 1.390 | 2.500 | 1.980 | 1.957 | 0.001 | 0.001 | 0.003 | 0.002 | 0.002 |
| Total CDF | 3.843 | 6.520 | 4.561 | 4.975 | | 0.064 | 0.101 | 0.064 | 0.076 |
| Total CDD+CDF | 4.612 | 7.969 | 6.089 | 6.223 | | 0.070 | 0.109 | 0.071 | 0.083 |

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( ) = Estimated maximum possible concentration

TABLE 2-17. CDD/CDF CONCENTRATIONS IN
MAKE-UP WATER AND LIME SLURRY FOR RUN 1
MORRISTOWN MEMORIAL HOSPITAL (1991)

| CONGENER | MAKE-UP WATER RUN 1 (ppt.wt) | LIME SLURRY TANK RUN 1 (ppt.wt) |
|---|---|---|
| 2378 TCDD | [0.008] | [0.500] |
| Other TCDD | 0.000 | 0.000 |
| 12378 PCDD | [0.005] | [0.600] |
| Other PCDD | 0.000 | 0.000 |
| 123478 HxCDD | [0.005] | [1.500] |
| 123678 HxCDD | [0.003] | [0.900] |
| 123789 HxCDD | (0.010) | [1.300] |
| Other HxCDD | 0.000 | 0.830 |
| 1234678-HpCDD | 0.030 | 5.200 |
| Other Hepta-CDD | 0.020 | 3.300 |
| Octa-CDD | 0.140 | 20.800 |
| Total CDD | 0.196 | 30.130 |
| FURANS | | |
| 2378 TCDF | [0.005] | [0.400] |
| Other TCDF | 0.008 | 0.000 |
| 12378 PCDF | [0.005] | [0.500] |
| 23478 PCDF | [0.003] | [0.500] |
| Other PCDF | 0.000 | 0.000 |
| 123478 HxCDF | [0.005] | [0.900] |
| 123678 HxDCF | [0.003] | [0.600] |
| 234678 HxCDF | 0.006 | 0.620 |
| 123789 HxCDF | [0.005] | [1.000] |
| Other HxCDF | 0.000 | 0.000 |
| 1234678-HpCDF | 0.004 | [0.900] |
| 1234789-HpCDF | [0.005] | [1.600] |
| Other Hepta-CDF | 0.005 | 0.000 |
| Octa-CDF | 0.009 | (2.300) |
| TOTAL CDF | 0.032 | 2.890 |
| | | |
| TOTAL CDD+CDF | 0.228 | 33.020 |

[ ] : Minimum detection limit.
( ) : Estimated maximum possible concentration.

Concentrations at dry, standard conditions, adjusted to 7 percent $O_2$, and emission rates are shown. The metals to PM ratios are presented in Section 2.3.5, flue gas metals by sample fraction are presented in Section 2.3.6, metals concentrations in ash samples is presented in Section 2.3.7, and metals in make-up water and lime slurry are presented in Section 2.3.8.

### 2.3.2 Metals Data Reduction

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

- If a metal was detected in any fraction 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 a detected result was obtained were used in calculating the average. Runs where the metal was not detected were not included for averaging.
- If the metal was not detected in any of the three runs, then the average results were reported as not detected at the average detection limit.

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 2-18 and 2-19 present the metals emissions results for Conditions 1 and 2, respectively. During Condition 1, where carbon was not injected into the lime slurry, Al had the highest average mass rate at the inlet of 98.4 g/hr, followed by Cu with a mass rate of 25.4 g/hr. Thallium was not detected in any of the samples at the spray dryer

TABLE 2-18. AVERAGE METALS EMISSION RATES AND REMOVAL EFFICIENCIES;
MORRISTOWN MEMORIAL HOSPITAL (1991)
* WITHOUT CARBON INJECTION *

| Condition | Without Carbon Injection | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Run 1 | | | Run 2 | | | Run 3 | | | Average 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 | 52.4 | 0.507 | 99.0% | 96.2 | 0.431 | 99.6% | 147 | 0.785 | 99.5% | 98.4 | 0.574 | 99.4% |
| Antimony | 2.59 | 0.0567 | 97.8% | 2.60 | 0.0242 | 99.1% | 1.89 | 0.0238 | 98.7% | 2.36 | 0.0349 | 98.5% |
| Arsenic | 0.0450 | [0.00322] | >92.9% | 0.0521 | [0.00318] | >93.9 | 0.0665 | [0.00307] | >95.4% | 0.0545 | [0.00316] | >94.2% |
| Barium | 12.2 | 0.0258 | 99.8% | 11.2 | 0.0160 | 99.9% | 18.0 | 0.0637 | 99.6% | 13.8 | 0.0352 | 99.7% |
| Beryllium | 0.00544 | 0.00114 | 79.0% | 0.00808 | [0.000798] | >90.1% | 0.00651 | [0.000662] | >89.8% | 0.00668 | 0.00114 | 82.9% |
| Cadmium | 2.14 | 0.00797 | 99.6% | 1.57 | 0.00346 | 99.8% | 2.60 | 0.0105 | 99.6% | 2.10 | 0.00730 | 99.7% |
| Chromium | 0.541 | 0.0162 | 97.0% | 0.476 | 0.0122 | 97.4% | 0.733 | 0.0142 | 98.1% | 0.583 | 0.0142 | 97.6% |
| Copper | 22.2 | 0.105 | 99.5% | 27.7 | 0.0631 | 99.8% | 26.3 | 0.0980 | 99.6% | 25.4 | 0.0887 | 99.7% |
| Lead | 16.4 | 0.0170 | 99.9% | 15.2 | 0.00457 | 100% | 16.1 | 0.0499 | 99.7% | 15.9 | 0.0238 | 99.9% |
| Mercury | 9.51 | 4.67 | 50.9% | 2.73 | 2.76 | NA | 23.4 | 17.6 | 24.6% | 11.9 | 8.35 | 29.6% |
| Nickel | 0.327 | 0.0134 | 95.9% | 0.534 | 0.0214 | 96.0% | 0.463 | 0.00573 | 98.8% | 0.441 | 0.0135 | 96.9% |
| Silver | 0.0148 | 0.0138 | 6.97% | 0.0190 | 0.00975 | 48.8% | 0.0578 | 0.0154 | 73.4% | 0.0305 | 0.0130 | 57.5% |
| Thallium | [0.125] | [0.0802] | NA | [0.123] | [0.0798] | NA | [0.123] | [0.0770] | NA | [0.123] | [0.0770] | NA |

NA = Not Applicable
[ ] = Minimum Detection Limit

TABLE 2-19. AVERAGE METALS EMISSION RATES AND REMOVAL EFFICIENCIES; MORRISTOWN MEMORIAL HOSPITAL (1991)
* WITH CARBON INJECTION *

| Condition | With Carbon Injection | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Run 4 | | | Run 5 | | | Run 6 | | | Average 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 | 106 | 0.379 | 99.6% | 49.4 | 0.445 | 99.1% | 72.5 | 0.364 | 99.5% | 76.1 | 0.396 | 99.5% |
| Antimony | 4.57 | 0.0226 | 99.5% | 2.27 | 0.0221 | 99.0% | 4.23 | 0.0193 | 99.5% | 3.69 | 0.0214 | 99.4% |
| Arsenic | 0.0792 | [0.00303] | >96.2% | 0.0159 | [0.00317] | >80.0% | 0.0321 | [0.00313] | >90.2% | 0.0424 | [0.00311] | >92.7% |
| Barium | 16.3 | 0.0171 | 99.9% | 9.95 | 0.0225 | 99.8% | 9.83 | 0.0169 | 99.8% | 12.0 | 0.0188 | 99.8% |
| Beryllium | 0.00794 | [0.000760] | >90.4% | 0.00785 | [0.000796] | >89.9% | 0.00692 | [0.000784] | >88.7% | 0.00757 | [0.000780] | >89.7% |
| Cadmium | 2.48 | 0.00367 | 99.9% | 1.90 | 0.00419 | 99.8% | 2.54 | 0.00310 | 99.9% | 2.31 | 0.00366 | 99.8% |
| Chromium | 0.809 | 0.00660 | 99.2% | 0.666 | 0.0130 | 98.1% | 0.652 | 0.0156 | 97.6% | 0.709 | 0.0117 | 98.3% |
| Copper | 35.8 | 0.0410 | 99.9% | 31.1 | 0.0853 | 99.7% | 30.4 | 0.0583 | 99.8% | 32.4 | 0.0615 | 99.8% |
| Lead | 20.1 | 0.0117 | 99.9% | 22.4 | 0.0135 | 99.9% | 19.7 | 0.00807 | 100% | 20.7 | 0.0111 | 99.9% |
| Mercury | 11.5 | 1.84 | 83.9% | 10.6 | 0.436 | 95.9% | 14.9 | 1.40 | 90.6% | 12.3 | 1.23 | 90.0% |
| Nickel | 0.824 | 0.00233 | 99.7% | 0.481 | 0.00659 | 98.6% | 0.515 | 0.00734 | 98.6% | 0.607 | 0.00542 | 99.1% |
| Silver | 0.00739 | 0.0136 | NA | 0.00193 | 0.0106 | NA | 0.00103 | 0.0127 | NA | 0.00345 | 0.0123 | NA |
| Thallium | [0.178] | [0.0760] | NA | [0.0991] | [0.0796] | NA | 0.0200 | [0.0784] | >−292% | 0.0200 | [0.0778] | >−289% |

NA = Not Applicable
[ ] = Minimum Detection Limit

inlet during these emissions tests. At the baghouse outlet, Hg was the most prevalent element collected during Condition 1 with an average emission rate of 8.35 g/hr, followed by Al with an average emission rate of 0.574 g/hr. Low levels of Ag were detected at both the spray dryer inlet and baghouse outlet locations. The emission rate at the outlet averaged 0.012 g/hr, which was higher than the average inlet emission rate of .0035. This may be due to trace amounts of silver introduced to the flue gas in the lime slurry at the spray dryer (see Table 2-32). Arsenic and Tl were not detected during any of the runs at the baghouse outlet.

During Condition 2, where carbon was injected into the lime slurry, Al had the highest average mass rate of the metals at the spray dryer inlet with 76.1 g/hr, followed by Cu with 32.4 g/hr. Consistent with Condition 1, Tl was the only metal not detected in any of the runs at the spray dryer inlet. At the baghouse outlet, Hg was the most prevalent element collected with an average emission rate of 1.23 g/hr. Arsenic, Be, and Tl were not collected in detectable amounts for any of the runs at the baghouse outlet. A detectable amount of Tl occurred during only one of the runs at the inlet or outlet.

The emission mass rates at the spray dryer inlet for all of the metals varied only slightly between conditions. This was also true for all of the metals at the baghouse outlet, except Hg. Therefore, all of the elements maintained basically the same removal efficiency with and without carbon injected into the lime slurry, except Hg. During Condition 1, Hg had a removal efficiency of 29.6 percent; whereas, during Condition 2, the removal efficiency increased to 90.0 percent. The results of this test show that the injection of carbon into the spray dryer positively effects the removal of Hg from the flue gas.

Sample results for Hg showed a negative removal efficiency for Run 2 which can be attributed to round-off error. A removal efficiency for Tl could not be calculated for most of the runs because all of the results were detection limits. All of the average removal efficiencies for Condition 2 were greater than 89 percent except for Ag and Tl. A removal efficiency is misleading for Tl because such a small amount is detected. This is also true of the removal efficiencies associated with Ag. Although it is detected during all the runs, the removal efficiencies are misleading because the values reported are only slightly higher than detection limits.

2.3.4 Metals Flue Gas Concentrations

Table 2-20 reports the flue gas concentrations for each of the 6 runs at the spray dryer inlet and baghouse outlet in $\mu$g/dscm. Table 2-21 contains the same data except corrected to $\mu$g/dscm at 7 percent $O_2$. Oxygen concentrations were calculated from CEM data averaged over the same time period as the manual testing was performed.

2.3.5 Flue Gas Metals to Particulate Matter Ratios

A summary of the ratio of total metals to PM for the emission tests without carbon injection is presented in Table 2-22. Metals to PM ratios are given in units of milligrams of metal to grams of PM collected by the sampling train. The metal with the highest ratio at the inlet was Al with an average of 19.8 mg/g and the lowest particulate ratio was Tl, which was not detected. At the outlet, the largest ratio was contributed to Hg, 363 mg/g. Such a large ratio occurred because without carbon injection, Hg is not substantially removed from the flue gas; whereas, the amount of PM is greatly decreased by the emission controls.

Table 2-23 presents a summary of the ratio by weight of total metals to PM for the emission tests with carbon injection. Average spray dryer inlet ratios ranged from 0.000804 mg/g for Ag to 13.7 mg/g for Al. Average ratios at the baghouse outlet ranged from non-detected metals to 166 mg/g of Hg.

A comparison between the spray dryer inlet ratios of both conditions shows that the ratios for each metal do not differ significantly. A comparison of the ratios at the baghouse outlet displays the same conclusion for all the metals except Hg. Without carbon injection, the average Hg ratio increases from 2.41 mg/g at the spray dryer inlet to 363 mg/g at the baghouse outlet. Whereas, with carbon injection, the average Hg ratio increases from 1.99 mg/g at the spray dryer inlet to 166 mg/g at the baghouse outlet. The metals/particulate ratio increases going from inlet to outlet for most of the metals; and for some, this increase is several orders of magnitude.

2.3.6 Flue Gas Metals by Sample Fraction and Sample Parameters

Table 2-24 presents the metal amounts in the inlet flue gas samples by fraction for each run. The highest proportion of Hg and Ag was consistently collected in the nitric acid impingers (Impingers 1-3), although Hg was the only metal to have a large majority of its total mass collected in the nitric acid impingers. All other metals detected, except

TABLE 2-20. METALS CONCENTRATIONS; MORRISTOWN MEMORIAL HOSPITAL (1991)

Toxic Metals Concentration (ug/dscm)

| Without Carbon Injection | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals | Run 1 | | Run 2 | | Run 3 | | Average Concentrations | |
| | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| Aluminum | 8540 | 63.9 | 16000 | 53.3 | 22900 | 97.0 | 15813 | 71.4 |
| Antimony | 422 | 7.15 | 433 | 2.99 | 294 | 2.94 | 383 | 4.36 |
| Arsenic | 7.33 | [0.405] | 8.66 | [0.394] | 10.4 | [0.380] | 8.8 | [0.393] |
| Barium | 1993 | 3.25 | 1860 | 1.98 | 2810 | 7.87 | 2221 | 4.37 |
| Beryllium | 0.887 | 0.144 | 1.34 | [0.0987] | 1.02 | [0.0818] | 1.08 | 0.144 |
| Cadmium | 348 | 1.00 | 260 | 0.427 | 406 | 1.29 | 338 | 0.91 |
| Chromium | 88.2 | 2.05 | 79.1 | 1.51 | 114 | 1.75 | 94 | 1.77 |
| Copper | 3620 | 13.2 | 4600 | 7.80 | 4100 | 12.1 | 4107 | 11.0 |
| Lead | 2680 | 2.14 | 2520 | 0.565 | 2510 | 6.16 | 2570 | 2.96 |
| Mercury | 1550 | 588 | 453 | 341 | 3650 | 2180 | 1884 | 1036 |
| Nickel | 53.3 | 1.69 | 88.8 | 2.64 | 72.2 | 0.709 | 71.5 | 1.678 |
| Silver | 2.41 | 1.74 | 3.17 | 1.21 | 9.02 | 1.90 | 4.87 | 1.61 |
| Thallium | [20.3] | [10.1] | [20.4] | [9.87] | [19.2] | [9.52] | [19.97] | [9.83] |
| With Carbon Injection | | | | | | | | |
| | Run 4 | | Run 5 | | Run 6 | | Average Concentrations | |
| | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| Aluminum | 17000 | 47.0 | 7590 | 52.0 | 11500 | 42.8 | 12030 | 47 |
| Antimony | 730 | 2.80 | 349 | 2.59 | 672 | 2.27 | 584 | 2.55 |
| Arsenic | 12.7 | [0.375] | 2.44 | [0.371] | 5.09 | [0.367] | 6.7 | [0.371] |
| Barium | 2610 | 2.12 | 1530 | 2.63 | 1560 | 1.98 | 1900 | 2.2 |
| Beryllium | 1.27 | [0.0941] | 1.21 | [0.0930] | 1.10 | [0.0921] | 1.19 | [0.0931] |
| Cadmium | 396 | 0.455 | 292 | 0.490 | 403 | 0.364 | 364 | 0.44 |
| Chromium | 129 | 0.818 | 102 | 1.51 | 104 | 1.83 | 112 | 1.39 |
| Copper | 5720 | 5.08 | 4780 | 9.97 | 4830 | 6.84 | 5110 | 7.3 |
| Lead | 3210 | 1.45 | 3440 | 1.58 | 3130 | 0.948 | 3260 | 1.3 |
| Mercury | 1830 | 228 | 1630 | 50.9 | 2360 | 164 | 1940 | 148 |
| Nickel | 132 | 0.288 | 74.0 | 0.770 | 81.8 | 0.861 | 95.8 | 0.64 |
| Silver | 1.18 | 1.69 | 0.297 | 1.24 | 0.164 | 1.50 | 0.5 | 1.47 |
| Thallium | [28.5] | [9.41] | [15.2] | [9.30] | 3.18 | [9.21] | 3.18 | [9.31] |

[] = Detection limit

TABLE 2-21. METALS CONCENTRATIONS; MORRISTOWN MEMORIAL HOSPITAL (1991)

Toxic Metals Concentration (ug/dscm @ 7% O2)

| Without Carbon Injection | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals | Run 1 | | Run 2 | | Run 3 | | Average Concentrations | |
| | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| Aluminum | 12100 | 131 | 22700 | 109 | 30900 | 180 | 21900 | 140 |
| Antimony | 599 | 14.6 | 614 | 6.12 | 397 | 5.45 | 537 | 8.73 |
| Arsenic | 10.4 | [0.828] | 12.3 | [0.805] | 14.0 | [0.704] | 12.2 | [0.779] |
| Barium | 2820 | 6.65 | 2640 | 4.05 | 3790 | 14.6 | 3083 | 8.4 |
| Beryllium | 1.26 | 0.294 | 1.91 | [0.202] | 1.37 | [0.152] | 1.51 | 0.294 |
| Cadmium | 494 | 2.05 | 369 | 0.874 | 549 | 2.40 | 471 | 1.77 |
| Chromium | 125 | 4.18 | 112 | 3.09 | 154 | 3.25 | 131 | 3.50 |
| Copper | 5134 | 27.0 | 6520 | 15.9 | 5530 | 22.4 | 5728 | 21.8 |
| Lead | 3801 | 4.37 | 3570 | 1.16 | 3390 | 11.4 | 3587 | 5.7 |
| Mercury | 2200 | 1200 | 643 | 697 | 4930 | 4040 | 2591 | 1979 |
| Nickel | 75.6 | 3.4 | 126 | 5.40 | 97.5 | 1.31 | 99.7 | 3.39 |
| Silver | 3.42 | 3.55 | 4.49 | 2.46 | 12.2 | 3.52 | 6.7 | 3.18 |
| Thallium | [28.8] | [20.6] | [28.9] | [20.2] | [26.0] | [17.6] | [27.9] | [19.5] |

| With Carbon Injection | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals | Run 4 | | Run 5 | | Run 6 | | Average Concentrations | |
| | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| Aluminum | 22500 | 92.0 | 10400 | 99.1 | 15700 | 80.4 | 16200 | 90 |
| Antimony | 966 | 5.49 | 481 | 4.92 | 916 | 4.27 | 787 | 4.89 |
| Arsenic | 16.7 | [0.735] | 3.36 | [0.706] | 6.94 | [0.690] | 9.0 | [0.710] |
| Barium | 3460 | 4.15 | 2110 | 5.00 | 2130 | 3.72 | 2567 | 4.3 |
| Beryllium | 1.68 | [0.184] | 1.66 | [0.177] | 1.50 | [0.173] | 1.61 | [0.178] |
| Cadmium | 524 | 0.890 | 401 | 0.933 | 549 | 0.683 | 492 | 0.84 |
| Chromium | 171 | 1.60 | 141 | 2.88 | 141 | 3.43 | 151 | 2.64 |
| Copper | 7570 | 9.94 | 6580 | 19.0 | 6580 | 12.9 | 6910 | 13.9 |
| Lead | 4250 | 2.84 | 4730 | 3.00 | 4260 | 1.78 | 4413 | 2.5 |
| Mercury | 2420 | 446 | 2240 | 97.0 | 3220 | 309 | 2627 | 284 |
| Nickel | 174 | 0.564 | 102 | 1.47 | 111 | 1.62 | 129.2 | 1.22 |
| Silver | 1.56 | 3.30 | 0.408 | 2.36 | 0.223 | 2.81 | 0.7 | 2.82 |
| Thallium | [37.7] | [18.4] | [21.0] | [17.7] | 4.33 | [17.3] | 4.33 | [17.8] |

[] = Detection limit

TABLE 2-22. RATIO OF METALS TO PARTICULATE MATTER; MORRISTOWN MEMORIAL HOSPITAL (1991)

* WITHOUT CARBON INJECTION *

| | METALS/PARTICULATE RATIO (mg metal per gram of particulate) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location | INLET | | | | OUTLET | | | |
| Run | Run 1 (mg/g) | Run 2 (mg/g) | Run 3 (mg/g) | Average (mg/g) | Run 1 (mg/g) | Run 2 (mg/g) | Run 3 (mg/g) | Average (mg/g) |
| Aluminum | 10.6 | 18.8 | 30.0 | 19.8 | 68.7 | 41.6 | 8.42 | 39.6 |
| Antimony | 0.522 | 0.508 | 0.385 | 0.472 | 7.68 | 2.34 | 0.255 | 3.43 |
| Arsenic | 0.00908 | 0.0102 | 0.0136 | 0.0109 | [0.436] | [0.306] | [0.0329] | [0.258] |
| Barium | 2.47 | 2.18 | 3.68 | 2.78 | 3.50 | 1.55 | 0.684 | 1.91 |
| Beryllium | 0.00110 | 0.00158 | 0.00133 | 0.00134 | 0.155 | [0.0767] | [0.00710] | 0.155 |
| Cadmium | 0.431 | 0.306 | 0.532 | 0.423 | 1.08 | 0.334 | 0.112 | 0.509 |
| Chromium | 0.109 | 0.0929 | 0.150 | 0.117 | 2.20 | 1.18 | 0.152 | 1.18 |
| Copper | 4.48 | 5.40 | 5.37 | 5.08 | 14.2 | 6.10 | 1.05 | 7.12 |
| Lead | 3.32 | 2.96 | 3.29 | 3.19 | 2.30 | 0.442 | 0.535 | 1.09 |
| Mercury | 1.92 | 0.532 | 4.78 | 2.41 | 632 | 266 | 189 | 363 |
| Nickel | 0.0660 | 0.104 | 0.0946 | 0.0883 | 1.81 | 2.06 | 0.0615 | 1.31 |
| Silver | 0.00299 | 0.00372 | 0.0118 | 0.00617 | 1.87 | 0.942 | 0.165 | 0.991 |
| Thallium | [0.0251] | [0.0239] | [0.0252] | [0.0247] | [10.9] | [7.71] | [0.826] | [6.47] |

[ ] = Minimum Detection Limit

TABLE 2-23. RATIO OF METALS TO PARTICULATE MATTER; MORRISTOWN MEMORIAL HOSPITAL (1991)

* WITH CARBON INJECTION *

| METALS/PARTICULATE RATIO (mg metal per gram of particulate) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location | INLET | | | | OUTLET | | | |
| Run | Run 4 (mg/g) | Run 5 (mg/g) | Run 6 (mg/g) | Average (mg/g) | Run 4 (mg/g) | Run 5 (mg/g) | Run 6 (mg/g) | Average (mg/g) |
| Aluminum | 17.7 | 9.66 | 15.7 | 13.7 | 63.5 | 24.0 | 19.6 | 35.7 |
| Antimony | 0.760 | 0.445 | 0.914 | 0.603 | 3.79 | 1.19 | 1.04 | 2.49 |
| Arsenic | 0.0132 | 0.00310 | 0.00693 | 0.00815 | [0.507] | [0.171] | [1.68] | [0.339] |
| Barium | 2.72 | 1.95 | 2.12 | 2.33 | 2.87 | 1.21 | 0.908 | 2.04 |
| Beryllium | 0.00132 | 0.00154 | 0.00149 | 0.00143 | [0.127] | [0.0428] | [0.0422] | [0.0850] |
| Cadmium | 0.413 | 0.371 | 0.549 | 0.392 | 0.615 | 0.226 | 0.167 | 0.420 |
| Chromium | 0.135 | 0.130 | 0.141 | 0.132 | 1.10 | 0.698 | 0.838 | 0.901 |
| Copper | 5.96 | 6.09 | 6.57 | 6.02 | 6.86 | 4.60 | 3.14 | 5.73 |
| Lead | 3.35 | 4.38 | 4.26 | 3.86 | 1.96 | 0.726 | 0.435 | 1.34 |
| Mercury | 1.91 | 2.08 | 3.21 | 1.99 | 308 | 23.5 | 75.4 | 166 |
| Nickel | 0.137 | 0.0943 | 0.111 | 0.116 | 0.389 | 0.355 | 0.395 | 0.372 |
| Silver | 0.00123 | 0.000378 | 0.000223 | 0.000804 | 2.28 | 0.572 | 0.686 | 1.42 |
| Thallium | [0.0297] | [0.0194] | 0.00433 | 0.00433 | [12.7] | [4.28] | [4.22] | [8.50] |

[ ] = Minimum Detection Limit

TABLE 2-24. METALS AMOUNTS IN INLET FLUE GAS - SAMPLES BY SAMPLE FRACTION; MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Run 1 | | | | Run 2 | | | | Run 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metals | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) |
| Aluminum | 25500 | 42.6 | | 25500 | 47800 | 31.9 | | 47800 | 72000 | 42.3 | | 72000 |
| Antimony | 1160 | 96.4 | | 1260 | 1230 | 56.3 | | 1290 | 885 | 41.4 | | 926 |
| Arsenic | 21.9 | [0.425] | | 21.9 | 25.8 | [0.427] | | 25.8 | 32.7 | [0.424] | | 32.7 |
| Barium | 5950 | 1.57 | | 5950 | 5550 | 1.90 | | 5550 | 8850 | 2.12 | | 8850 |
| Beryllium | 2.65 | [0.106] | | 2.65 | 4.00 | [0.107] | | 4.00 | 3.20 | [0.106] | | 3.20 |
| Cadmium | 1040 | 0.743 | | 1040 | 775 | 0.363 | | 775 | 1280 | 0.53 | | 1280 |
| Chromium | 260 | 3.28 | | 263 | 234 | 1.56 | | 236 | 357 | 2.99 | | 360 |
| Copper | 10800 | 26.5 | | 10800 | 13700 | 33.6 | | 13700 | 12900 | 12.8 | | 12900 |
| Lead | 8000 | 1.08 | | 8000 | 7500 | 0.474 | | 7500 | 7900 | 0.558 | | 7900 |
| Mercury | 213 | 4400 | 8.55 | 4620 | 55.5 | 1290 | 5.03 | 1350 | 867 | 10600 | 3.86 | 11500 |
| Nickel | 157 | 2.25 | | 159 | 263 | 1.45 | | 264 | 225 | 2.45 | | 227 |
| Silver | [3.00] | 7.21 | | 7.21 | 4.10 | 5.33 | | 9.43 | 28.4 | [0.637] | | 28.4 |
| Thallium | [50.0] | [10.6] | | [60.6] | [50.0] | [10.7] | | [60.7] | [50.0] | [10.6] | | [60.6] |

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

[ ] = Minimum Detection Limit

TABLE 2-24 (Continued). METALS AMOUNTS IN INLET FLUE GAS - SAMPLES BY SAMPLE FRACTION; MORRISTOWN MEMORIAL HOSPITAL (1991)

| Metals | Run 4 | | | | Run 5 | | | | Run 6 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) |
| Aluminum | 65400 | 230 | | 65600 | 30200 | 53.7 | | 30200 | 44400 | 43.6 | | 44400 |
| Antimony | 2760 | 62.6 | | 2820 | 1320 | 71.5 | | 1390 | 2500 | 100 | | 2600 |
| Arsenic | 48.9 | [0.422] | | 48.9 | 9.70 | [0.423] | | 9.70 | 19.7 | [0.423] | | 19.7 |
| Barium | 10100 | 3.35 | | 10100 | 6100 | 3.54 | | 6100 | 6100 | 1.88 | | 6100 |
| Beryllium | 4.90 | [0.106] | | 4.90 | 4.80 | [0.106] | | 4.80 | 4.25 | [0.106] | | 4.25 |
| Cadmium | 1520 | 11.1 | | 1530 | 1160 | 0.423 | | 1160 | 1560 | 0.338 | | 1560 |
| Chromium | 496 | 3.03 | | 499 | 399 | 8.26 | | 407 | 398 | 2.55 | | 401 |
| Copper | 22000 | 74.7 | | 22100 | 19000 | 21.0 | | 19000 | 18700 | 18.9 | | 18700 |
| Lead | 12400 | 26.5 | | 12400 | 13700 | 1.08 | | 13700 | 12100 | 0.904 | | 12100 |
| Mercury | 148 | 6780 | 165 | 7090 | 78.5 | 6400 | 1.98 | 6480 | 30.0 | 9090 | 6.95 | 9130 |
| Nickel | 506 | 2.25 | | 508 | 288 | 6.54 | | 295 | 313 | 3.61 | | 317 |
| Silver | [6.00] | 4.56 | | 4.56 | [3.00] | 1.18 | | 1.18 | [3.00] | 0.634 | | 0.634 |
| Thallium | [100] | [10.6] | | [110] | [50.0] | [10.6] | | [60.6] | [50.0] | 12.3 | | 12.3 |

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

Tl in Run 6, were collected in the highest proportions in the front half (filter, nozzle/probe rinse). This indicates that almost all of the Hg, and over half of the Ag in the flue gas, was in a vapor phase at the filter temperature.

The metal amounts in the outlet flue gas samples are presented in Table 2-25 by sample fraction. The highest proportion of Hg was collected in the nitric acid impingers for all runs. Most other metals were collected in the highest proportions in the front half fraction, except for Cu and Ni which had slightly more weight collected in the impingers during four of the six runs, and Cu for three of the six runs.

Sampling and flue gas parameters for the PM/metals runs at both sampling locations are shown in Tables 2-26 and 2-27. Total sampling times, sample volumes, and isokinetic results for each sampling run are presented. Appendix C contains a complete listing of these and additional sampling and flue gas parameters for each run.

2.3.7 Metals in Ash

Incinerator bottom ash, spray dryer ash, and baghouse ash were sampled daily as described in Section 5. Concentrations of the metals in the ash in units of mg/kg were determined by microwave digesting one-half gram of ash in acid and hydrogen peroxide, diluting the solution to 100 mL, and then analyzed as stated in Section 5.

The metals concentrations in the incinerator bottom ash are shown in Table 2-28. The most prevalent metal throughout all of the runs is Al with Cu being the second. Four of the metals are not detected in any of the runs, Sb, Hg, Ag, and Tl. A comparison of the metal to ash concentrations between the two conditions does not show any significant differences.

Table 2-29 presents the metals concentrations in the baghouse ash collected each day. As in the incinerator ash, Al is the most prevalent metal. Silver and Tl were not detected in any of the six samples taken. All of the metals showed no significant increase in average concentration in comparing the two conditions, except for Hg. The

TABLE 2-25. METALS AMOUNTS IN OUTLET FLUE GAS - SAMPLES BY SAMPLE FRACTION; MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Run 1 | | | | Run 2 | | | | Run 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metals | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) |
| Aluminum | 193 | 34.0 | | 227 | 166 | 26.3 | | 192 | 336 | 26.8 | | 363 |
| Antimony | 13.5 | 11.9 | | 25.4 | 10.8 | [1.59] | | 10.8 | 11.0 | [1.59] | | 11.0 |
| Arsenic | [1.00] | [0.435] | | [1.44] | [1.00] | [0.424] | | [1.42] | [1.00] | [0.424] | | [1.42] |
| Barium | 8.58 | 2.98 | | 11.6 | 5.60 | 1.55 | | 7.15 | 27.5 | 1.95 | | 29.5 |
| Beryllium | [0.250] | 0.511 | | 0.511 | [0.250] | [0.106] | | [0.356] | [0.250] | [0.106] | | [0.306] |
| Cadmium | 1.90 | 1.67 | | 3.57 | 1.33 | 0.212 | | 1.54 | 4.35 | 0.487 | | 4.84 |
| Chromium | 3.25 | 4.02 | | 7.27 | 2.95 | 2.50 | | 5.45 | 5.53 | 1.02 | | 6.55 |
| Copper | 23.8 | 23.2 | | 47.0 | 4.65 | 23.5 | | 28.2 | 25.5 | 19.8 | | 45.3 |
| Lead | 6.85 | 0.752 | | 7.60 | 2.04 | [0.318] | | 2.04 | 22.5 | 0.557 | | 23.1 |
| Mercury | [2.45] | 2070 | 23.4 | 2090 | [2.45] | 1230 | 3.23 | 1230 | [2.45] | 8160 | 6.33 | 8170 |
| Nickel | 2.58 | 3.41 | | 5.99 | 7.13 | 2.40 | | 9.53 | 1.65 | 1.00 | | 2.65 |
| Silver | 4.05 | 2.12 | | 6.17 | 4.35 | [0.636] | | 4.35 | 4.73 | 2.38 | | 7.11 |
| Thallium | [25.0] | [10.9] | | [35.9] | [25.0] | [10.6] | | [35.6] | [25.0] | [10.6] | | [35.6] |

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

[ ] = Minimum Detection Limit

TABLE 2-25 (Continued). METALS AMOUNTS IN OUTLET FLUE GAS - SAMPLES BY SAMPLE FRACTION; MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Run 4 | | | | Run 5 | | | | Run 6 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metals | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) | Front Half (Total ug) | Impinger 1,2,3 (Total ug) | Impinger 4,5,6 (Total ug) | Total ug (Total ug) |
| Aluminum | 154 | 23.7 | | 178 | 167 | 32.2 | | 199 | 142 | 23.4 | | 165 |
| Antimony | 10.6 | [1.59] | | 10.6 | 9.90 | [1.60] | | 9.90 | 8.78 | [1.60] | | 8.78 |
| Arsenic | [1.00] | [0.425] | | [1.42] | [1.00] | [0.425] | | [1.42] | [1.00] | [0.425] | | [1.42] |
| Barium | 6.95 | 1.07 | | 8.02 | 8.15 | 1.91 | | 10.1 | 5.35 | 2.30 | | 7.65 |
| Beryllium | [0.250] | [0.106] | | [0.356] | [0.250] | [0.106] | | [0.356] | [0.250] | [0.106] | | [0.356] |
| Cadmium | 1.38 | 0.340 | | 1.72 | 1.43 | 0.447 | | 1.88 | 1.13 | 0.276 | | 1.41 |
| Chromium | 2.20 | 0.892 | | 3.09 | 1.85 | 3.95 | | 5.80 | 1.60 | 5.46 | | 7.06 |
| Copper | 8.20 | 11.0 | | 19.2 | 6.68 | 31.5 | | 38.2 | 4.85 | 21.6 | | 26.5 |
| Lead | 5.10 | 0.384 | | 5.48 | 5.30 | 0.735 | | 6.04 | 3.28 | 0.385 | | 3.67 |
| Mercury | [2.45] | 858 | 3.98 | 862 | [2.45] | 195 | [0.390] | 195 | [2.45] | 634 | 1.8 | 636 |
| Nickel | [0.750] | 1.09 | | 1.09 | [0.750] | 2.95 | | 2.95 | [0.750] | 3.33 | | 3.33 |
| Silver | 5.45 | 0.924 | | 6.37 | 4.75 | [0.638] | | 4.75 | 5.78 | [0.638] | | 5.78 |
| Thallium | [25.0] | [10.6] | | [35.6] | [25.0] | [10.6] | | [35.6] | [25.0] | [10.6] | | [35.6] |

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

TABLE 2-26. METALS/PM EMISSIONS SAMPLING AND FLUE GAS PARAMETERS AT INLET MORRISTOWN MEMORIAL HOSPITAL (1991)

| Run No. Date | Run 1 11/18/91 | Run 2 11/19/91 | Run 3 11/20/91 | Run 4 11/21/91 | Run 5 11/22/91 | Run 6 11/23/91 | Average |
|---|---|---|---|---|---|---|---|
| Total Sampling Time (min) | 240 | 240 | 240 | 240 | 240 | 240 | NA |
| Average Sampling Rate (dscfm) | 0.44 | 0.44 | 0.46 | 0.57 | 0.59 | 0.57 | 0.51 |
| Metered Volume (dscf) | 105 | 105 | 111 | 136 | 140 | 137 | 122 |
| Metered Volume (dscm) | 3.0 | 3.0 | 3.1 | 3.9 | 4.0 | 3.9 | 3.5 |
| Average Stack Temperature (F) | 408 | 408 | 407 | 399 | 409 | 407 | 406 |
| O2 Concentration (%V) | 11.1 | 11.1 | 10.6 | 10.4 | 10.8 | 10.7 | 10.8 |
| CO2 Concentration (%V) | 6.4 | 7.8 | 6.7 | 6.6 | 6.5 | 6.5 | 6.8 |
| Stack Gas Moisture (%V) | 16.2 | 15.9 | 15.8 | 16.1 | 14.3 | 14.4 | 15.5 |
| Volumetric Flow Rate (dscfm) | 3610 | 3539 | 3771 | 3686 | 3827 | 3708 | 3690 |
| Volumetric Flow Rate (dscmm) | 102.2 | 100.2 | 106.8 | 104.4 | 108.3 | 105.0 | 104.5 |
| Percent Isokinetic | 96.4 | 98.1 | 97.3 | 95.5 | 94.7 | 95.1 | NA |
| Particulate Catch (grams) | 2.4130 | 2.5373 | 2.4053 | 3.7079 | 3.1250 | 2.8438 | 2.8387 |

NA = Not Applicable

Note: The accuracy of all calculated results is limited to three significant digits. Summary tables generated by spreadsheet programs report additional digits that are not significant.

TABLE 2-27. METALS/PM EMISSIONS SAMPLING AND FLUE GAS PARAMETERS AT OUTLET MORRISTOWN MEMORIAL HOSPITAL (1991)

| Run No.<br>Date | Run 1<br>11/18/91 | Run 2<br>11/19/91 | Run 3<br>11/20/91 | Run 4<br>11/21/91 | Run 5<br>11/22/91 | Run 6<br>11/23/91 | Average |
|---|---|---|---|---|---|---|---|
| Total Sampling Time (min) | 240 | 240 | 240 | 239 | 240 | 240 | NA |
| Average Sampling Rate (dscfm) | 0.52 | 0.53 | 0.55 | 0.56 | 0.56 | 0.57 | 0.55 |
| Metered Volume (dscf) | 125 | 127 | 132 | 134 | 135 | 137 | 132 |
| Metered Volume (dscm) | 3.6 | 3.6 | 3.7 | 3.8 | 3.8 | 3.9 | 3.7 |
| Average Stack Temperature (F) | 285 | 285 | 285 | 289 | 270 | 287 | 284 |
| O2 Concentration (%V) | 14.1 | 14.1 | 13.4 | 13.8 | 13.6 | 13.5 | 13.8 |
| CO2 Concentration (%V) | 5.0 | 5.0 | 5.3 | 5.2 | 5.0 | 5.3 | 5.1 |
| Stack Gas Moisture (%V) | 14.7 | 12.3 | 15.0 | 14.7 | 13.7 | 12.0 | 13.7 |
| Volumetric Flow Rate (dscfm) | 4671 | 4761 | 4762 | 4753 | 5036 | 5012 | 4832 |
| Volumetric Flow Rate (dscmm) | 132.3 | 134.8 | 134.9 | 134.6 | 142.6 | 141.9 | 136.8 |
| Percent Isokinetic | 101.0 | 97.6 | 99.2 | 100.9 | 96.1 | 102.4 | NA |
| Particulate Catch (grams) | 0.0033 | 0.0046 | 0.0431 | 0.0028 | 0.0083 | 0.0041 | 0.0011 |

NA = Not Applicable

Note: The accuracy of all calculated results is limited to three significant digits. Summary tables generated by spreadsheet programs report additional digits that are not significant.

TABLE 2-28. METALS IN ASH CONCENTRATIONS - BOTTOM ASH
MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Concentration (mg metal/kg ash) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals | Run 1 (mg/kg) | Run 2 (mg/kg) | Run 3 (mg/kg) | Condition 1 Average (mg/kg) | Run 4 (mg/kg) | Run 5 (mg/kg) | Run 6 (mg/kg) | Condition 2 Average (mg/kg) |
| Aluminum | 185000 | 194000 | 192000 | 190333 | 152000 | 79600 | 82200 | 104600 |
| Antimony | [3.00] | [3.00] | [3.00] | [3.00] | [3.00] | [3.00] | [3.00] | [3.00] |
| Arsenic | 65.4 | 84.8 | 194 | 114.7 | 54.8 | 80.4 | 90.8 | 75.3 |
| Barium | 3140 | 4340 | 3760 | 3747 | 6320 | 10000 | 6680 | 7667 |
| Beryllium | 0.440 | 0.440 | 0.420 | 0.433 | [0.200] | 0.480 | 0.440 | 0.460 |
| Cadmium | 21.8 | 10.6 | 11.4 | 14.6 | 20.8 | 8.52 | 11.7 | 13.7 |
| Chromium | 49.2 | 51.2 | 53.6 | 51.3 | 36.8 | 57.2 | 72.2 | 55.4 |
| Copper | 8900 | 32200 | 54800 | 31967 | 14300 | 17400 | 51000 | 27567 |
| Lead | 208 | 296 | 404 | 303 | 476 | 592 | 430 | 499 |
| Mercury | [1.96] | [1.96] | [1.96] | [1.96] | [1.96] | [1.96] | [1.96] | [1.96] |
| Nickel | 66.8 | 148 | 160 | 125 | 71.6 | 74.4 | 476 | 207 |
| Silver | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] |
| Thallium | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] |
| | | | | | | | | |
| % Carbon | 7.01 | 1.62 | 2.38 | 3.67 | 1.04 | 3.83 | 1.52 | 2.13 |
| | | | | | | | | |
| pH | 9.90 | 9.50 | 10.4 | 9.9 | 9.62 | 10.1 | 10.2 | 10.0 |
| | | | | | | | | |
| Ash (in lbs) | 325 | 256 | 404 | 328 | 213 | 241 | 248 | 234 |

[ ] = Minimum Detection Limit

TABLE 2-29. METALS IN ASH CONCENTRATIONS - BAGHOUSE ASH
MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Concentration (mg metal/kg ash) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals | Run 1 (mg/kg) | Run 2 (mg/kg) | Run 3 (mg/kg) | Condition 1 Average (mg/kg) | Run 4 (mg/kg) | Run 5 (mg/kg) | Run 6 (mg/kg) | Condition 2 Average (mg/kg) |
| Aluminum | 15200 | 18400 | 11500 | 15033 | 12800 | 12800 | 12600 | 12733 |
| Antimony | 11.4 | 4.34 | 3.56 | 6.43 | 23.4 | 5.54 | 19.3 | 16.1 |
| Arsenic | 2.44 | 2.22 | 2.06 | 2.2 | 2.66 | 1.91 | 2.96 | 2.5 |
| Barium | 1510 | 1250 | 1100 | 1287 | 1110 | 1240 | 1200 | 1183 |
| Beryllium | [0.200] | 0.300 | 0.220 | 0.173 | 0.220 | 0.220 | 0.320 | 0.270 |
| Cadmium | 108 | 75.6 | 84.4 | 89.3 | 98.0 | 53.2 | 80.6 | 77.3 |
| Chromium | 20.8 | 16.8 | 15.1 | 17.6 | 17.8 | 15.3 | 17.6 | 16.9 |
| Copper | 1100 | 1230 | 802 | 1044 | 1380 | 884 | 1010 | 1091 |
| Lead | 292 | 162 | 98.8 | 184 | 224 | 156 | 159 | 180 |
| Mercury | 34.8 | 10.1 | 40.8 | 28.6 | 208 | 288 | 444 | 313 |
| Nickel | 22.2 | 27.4 | 19.5 | 23.0 | 19.8 | 16.5 | 18.8 | 18.4 |
| Silver | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] |
| Thallium | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] |
| | | | | | | | | |
| % Carbon | 2.21 | 1.22 | 3.88 | 2.44 | 3.89 | 2.22 | 3.67 | 3.26 |
| | | | | | | | | |
| Ash (in lbs) | 185 | 122 | 215 | 174.0 | 99.0 | 292 | 156 | 182.3 |

[ ] = Minimum Detection Limit

average concentration was 28.6 mg/kg for Condition 1 and 313.3 mg/kg for Condition 2, almost a 1000 percent increase.

The metals concentrations in the spray dryer ash are summarized in Table 2-30. Aluminum had the highest concentration of all the metals tested for Conditions 1 and 2, averaging 35,933 mg/kg and 47,200 mg/kg, respectively. Antimony, Ag, and Tl were not detected in any of the samples. Mercury was the only metal to exhibit a significant change in concentration from Condition 1 to Condition 2. It had an average concentration of 12.5 mg/kg for Condition 1 and 31.3 mg/kg for Condition 2.

#### 2.3.8 Metals in Make-Up Water and Lime Slurry

Table 2-31 presents the amount of metals and chloride present in the water used to make the lime slurry. The detected metals were Al, Sb, As, Ba, Cr, and Cu; as well as chloride. Table 2-32 presents the concentration of metals detected in the lime slurry. The metals detected were Al, Ba, Cu, Ni, and Ag. Of these metals, only Al and Ag were introduced into the spray dryer at rates which were significant when compared to the metals in the flue gas at the spray dryer inlet. The average mass flow rate of Al in the lime slurry was approximately half of the average mass flow rate of Al in the inlet flue gas, which was 76 g/hr. The mass flow rate of Ag in the lime slurry was approximately 100 times the mass flow rate of Ag in the inlet flue gas, although the total mass flow rate of Ag into the spray dryer was only 0.3 g/hr.

## 2.4 PARTICULATE MATTER/PARTICLE SIZE DISTRIBUTION

### 2.4.1 Particulate Matter Results

Particulate matter emissions were determined from the same sampling train used for metals determinations at the spray dryer inlet and baghouse outlet. 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 PM stack gas concentrations and mass rates for the spray dryer inlet and baghouse outlet are presented in Table 2-33. Concentrations at standard conditions, concentrations adjusted to 7 percent $O_2$, emission rates, and removal efficiencies are shown.

For Condition 1, where carbon was not added to the lime slurry, the PM concentration and mass rate at the spray dryer inlet averaged 0.45 grains/dscf at

TABLE 2-30. METALS IN ASH CONCENTRATIONS - SPRAY DRYER ASH
MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Concentration (mg metal/kg ash) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals | Run 1 (mg/kg) | Run 2 (mg/kg) | Run 3 (mg/kg) | Condition 1 Average (mg/kg) | Run 4 (mg/kg) | Run 5 (mg/kg) | Run 6 (mg/kg) | Condition 2 Average (mg/kg) |
| Aluminum | 43800 | 45600 | 18400 | 35933 | 53200 | 44000 | 44400 | 47200 |
| Antimony | [3.00] | [3.00] | [3.00] | [3.00] | [3.00] | [3.00] | [3.00] | [3.00] |
| Arsenic | 7.00 | 7.36 | 2.80 | 5.72 | 3.56 | 6.10 | 4.00 | 4.55 |
| Barium | 2400 | 2260 | 1580 | 2080 | 1940 | 2120 | 3080 | 2380 |
| Beryllium | 0.400 | 0.420 | 0.300 | 0.373 | 0.360 | 0.360 | 0.380 | 0.370 |
| Cadmium | 37.8 | 32.8 | 46.2 | 38.9 | 26.8 | 22.6 | 27.6 | 25.7 |
| Chromium | 20.2 | 26.0 | 18.8 | 21.7 | 23.2 | 20.6 | 26.0 | 23.3 |
| Copper | 1020 | 1080 | 700 | 933 | 1020 | 976 | 1300 | 1099 |
| Lead | 312 | 306 | 102 | 240 | 248 | 274 | 234 | 252 |
| Mercury | 10.1 | 10.6 | 16.7 | 12.5 | 42.0 | 28.0 | 24.0 | 31.3 |
| Nickel | 36.0 | 40.2 | 26.2 | 34.1 | 33.0 | 35.8 | 46.2 | 38.3 |
| Silver | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] | [1.20] |
| Thallium | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] | [20.0] |
| % Carbon | 1.72 | 1.57 | 3.68 | 2.32 | 3.18 | 2.92 | 2.67 | 2.92 |
| Ash (in lbs) | 17.0 | 15.0 | 98.0 | 43.3 | 13.0 | 10.0 | 8.00 | 10.3 |

[ ] = Minimum Detection Limit

TABLE 2-31. METALS IN MAKE-UP WATER CONCENTRATIONS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| Metal | Run 1 (ug/L) | Run 2 (ug/L) | Run 3 (ug/L) | Run 4 (ug/L) | Run 5 (ug/L) | Run 6 (ug/L) | Average Runs 1-6 (ug/L) |
|---|---|---|---|---|---|---|---|
| Aluminum | 37.7 | 9.25 | 10.0 | 12.1 | 8.63 | 8.35 | 14.3 |
| Antimony | 4.13 | [3.48] | [3.38] | [3.33] | [3.56] | [3.38] | 4.13 |
| Arsenic | 3.04 | 2.47 | 2.62 | 4.02 | 2.53 | 2.34 | 2.84 |
| Barium | 73.6 | 70.1 | 77.9 | 77.8 | 71.3 | 79.4 | 75.0 |
| Beryllium | [0.236] | [0.231] | [0.225] | [0.222] | [0.238] | [0.226] | [0.230] |
| Cadmium | [0.470] | [0.464] | [0.451] | [0.444] | [0.473] | [0.453] | [0.459] |
| Chromium | 3.32 | [1.39] | [1.35] | [1.34] | 1.57 | 1.47 | 2.12 |
| Copper | 71.7 | 53.1 | 99.6 | 146 | 311 | 184 | 144 |
| Lead | [0.706] | [0.694] | [0.678] | [0.667] | [0.711] | [0.679] | [0.689] |
| Mercury | [0.434] | [0.434] | [0.432] | [0.432] | [0.435] | [0.433] | [0.433] |
| Nickel | 2.10 | [0.694] | [0.678] | [0.667] | 1.09 | 0.837 | 1.34 |
| Silver | 45.7 | 1.95 | [1.35} | [1.34] | [1.42] | [1.36] | 23.8 |
| Thallium | [23.6] | [23.1] | [22.5] | [22.2] | [23.8] | [22.6] | [23.0] |
| | | | | | | | |
| Chloride | 0.00881 | 0.00951 | 0.00981 | 0.00947 | 0.00925 | 0.0103 | 0.00953 |
| | | | | | | | |
| % Solid | 0.024% | 0.017% | 0.030% | NSD | 0.034% | NSD | 0.026% |

[ ] Minimum Detection Limit
NSD = No Solid Detected

TABLE 2–32. METALS IN LIME SLURRY CONCENTRATIONS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| **Metal** | **Concentration (mg metal/kg lime slurry)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Run 1 (mg/kg)** | **Run 2 (mg/kg)** | **Run 3 (mg/kg)** | **Run 4 (mg/kg)** | **Run 5 (mg/kg)** | **Run 6 (mg/kg)** | **Average Runs 1–6 (mg/kg)** |
| Aluminum | 146 | 214 | 80.9 | 42.9 | 29.6 | 113 | 104 |
| Antimony | [1.50] | [1.50] | [1.50] | [1.50] | [1.50] | [1.50] | [1.50] |
| Arsenic | [0.400] | [0.400] | [0.400] | [0.400] | [0.400] | [0.400] | [0.400] |
| Barium | 0.960 | 1.40 | 1.03 | 0.860 | 0.910 | 1.10 | 1.04 |
| Beryllium | [0.100] | [0.100] | [0.100] | [0.100] | [0.100] | [0.100] | [0.100] |
| Cadmium | [0.200] | [0.200] | [0.200] | [0.200] | [0.200] | [0.200] | [0.200] |
| Chromium | [0.600] | [0.600] | [0.600] | [0.600] | [0.600] | [0.600] | [0.600] |
| Copper | 2.40 | 2.11 | [0.400] | [0.400] | [0.400] | [0.400] | 2.26 |
| Lead | [0.300] | [0.300] | [0.300] | [0.300] | [0.300] | [0.300] | [0.300] |
| Mercury | [0.392] | [0.392] | [0.392] | [0.392] | [0.392] | [0.392] | [0.392] |
| Nickel | 0.340 | 0.450 | [0.300] | 0.310 | [0.300] | 0.320 | 0.355 |
| Silver | 0.850 | 1.11 | 0.840 | [0.600] | [0.600] | [0.600] | 0.933 |
| Thallium | [10.0] | [10.0] | [10.0] | [10.0] | [10.0] | [10.0] | [10.0] |
| | | | | | | | |
| % Hydrated Lime(w/w) | 5.24% | 8.35% | 3.07% | 1.62% | 1.06% | 3.75% | 3.85% |

[ ] Minimum Detection Limit

TABLE 2-33. PARTICULATE MATTER CONCENTRATIONS AND EMISSION RATES; MORRISTOWN MEMORIAL HOSPITAL (1991)

| Date | Location | Run # | Time (min) | CONCENTRATION (grains/dscf) | (grains/dscf @ 7% O2) | (grams/dscm) | (grams/dscm @ 7% O2) | EMISSION RATE (lb/hr) | (kg/hr) | Removal Efficiency (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/18/91 | Inlet | 1 | 240 | 0.353 | 0.501 | 0.808 | 1.15 | 10.9 | 4.96 | |
| 11/19/91 | Inlet | 2 | 240 | 0.372 | 0.528 | 0.852 | 1.21 | 11.3 | 5.12 | |
| 11/20/91 | Inlet | 3 | 240 | 0.334 | 0.450 | 0.764 | 1.03 | 10.8 | 4.89 | |
| Condition 1 Averages | | | | 0.353 | 0.493 | 0.808 | 1.13 | 11.0 | 4.99 | |
| 11/21/91 | Inlet | 4 | 240 | 0.419 | 0.555 | 0.959 | 1.27 | 13.2 | 6.01 | |
| 11/22/91 | Inlet | 5 | 240 | 0.343 | 0.472 | 0.786 | 1.08 | 11.2 | 5.11 | |
| 11/23/91 | Inlet | 6 | 240 | 0.321 | 0.438 | 0.735 | 1.00 | 10.2 | 4.63 | |
| Condition 2 Averages | | | | 0.361 | 0.488 | 0.827 | 1.12 | 11.5 | 5.25 | |
| 11/18/91 | Outlet | 1 | 240 | 0.000410 | 0.000838 | 0.000930 | 0.00190 | 0.0162 | 0.00738 | 99.9% |
| 11/19/91 | Outlet | 2 | 240 | 0.000560 | 0.00114 | 0.00128 | 0.00262 | 0.0228 | 0.0104 | 99.8% |
| 11/20/91 | Outlet | 3 | 240 | 0.00504 | 0.00934 | 0.0115 | 0.0214 | 0.205 | 0.0932 | 98.1% |
| Condition 1 Averages | | | | 0.002003 | 0.003775 | 0.00458 | 0.00862 | 0.0814 | 0.03698 | 99.2% |
| 11/21/91 | Outlet | 4 | 239 | 0.000320 | 0.000626 | 0.00074 | 0.00145 | 0.0131 | 0.00598 | 99.9% |
| 11/22/91 | Outlet | 5 | 240 | 0.000950 | 0.001809 | 0.00217 | 0.00413 | 0.0409 | 0.01857 | 99.6% |
| 11/23/91 | Outlet | 6 | 240 | 0.000460 | 0.000864 | 0.00106 | 0.00199 | 0.0199 | 0.00903 | 99.8% |
| Condition 2 Averages | | | | 0.000577 | 0.001100 | 0.00132 | 0.00252 | 0.0246 | 0.01119 | 99.8% |

NOTE: Removal efficiency is based on the inlet and outlet emission rates. [(1-out/in) x 100]

7 percent $O_2$ and 11.0 lb/hr, respectively. At the baghouse outlet, the average concentration and emission rate was 0.0038 grains/dscf at 7 percent $O_2$ and 0.081 lb/hr, respectively.

For Condition 2, where carbon was added to the lime slurry, the average PM concentration at the spray dryer inlet was 0.49 grains/dscf at 7 percent $O_2$. The average emission rate for the three runs was 0.025 lb/hr.

The results at the spray dryer inlet recorded for both conditions were very similar; therefore, the removal efficiencies should not be biased. The results at the baghouse outlet for both conditions were also similar except for Run 3 which had a significantly higher emission rate. This might be explained by the fact that during the test day the "cake" that forms on the baghouse bags was lost due to a pressure drop across the baghouse. This would decrease the filtering performance of the baghouse. Aside from this occurrence, the average removal efficiencies for both conditions was above 99 percent.

A summary of the sampling and flue gas parameters for the PM runs is given in Tables 2-26 and 2-27 for the spray dryer inlet and baghouse outlet, respectively. Appendix A.2 presents a detailed listing of the calculated results for each sampling run. The gravimetric PM analytical results are included in Appendix E.2.

### 2.4.2 Particle Size Distribution Results

Four PSD test runs were conducted during the Morristown Memorial Hospital MWI test program. An eight stage Andersen MK III in-stack cascade impactor sampling device was used (see Section 5 for PSD method). The PSD sampling location was at the spray dryer inlet. Following a test, the impactor was inspected to determine if there was adequate particle loading on each of the filter stages. A properly loaded impactor has distinct particulate "piles" under each stage's acceleration jets (holes). An under-loaded impactor is evidenced by clean, undisturbed filters while an over-loaded impactor has particulate piles which overlap and appear to have "broken-up" (evidence of PM re-entrainment). An assessment of the quality of particulate loading was made by the recovery technician, and all of the runs met the recovery QC objectives. The test results for these runs are reported in the following section.

#### 2.4.2.1 Overview

The figures in this section present the log-normal plot of the particle cut size ($Dp_{50}$) at each impactor stage versus the mass fraction of particulate less than that $Dp_{50}$ for each PSD run. Linear regressions analyses were conducted and the correlation coefficients ($R^2$) are shown on each figure. The mass median particle size is calculated from the graphical representation of the linear regression. It is a particle size that represents a point on the distribution in which half of the weight of the particles collected would be aerodynamically larger than, and half of the weight of the particles collected would be aerodynamically smaller than. A weight percentage of the particles collected less than 10 $\mu$m is also calculated from the linear regression.

2.4.2.2 Particle Size Distribution Results

Table 2-34 presents the Run 1 PSD results. Run 1 was conducted at the end of the third day of testing. The results are presented graphically in Figure 2-1. Approximately 71 percent of the total PM was less than 10 $\mu$m. The mass median particle size for Run 1 is approximately 2.3 $\mu$m.

Table 2-35 presents the results from PSD Run 2. This run was conducted during the fourth day of testing, November 21, 1991. The Run 2 PSD results are presented graphically in Figure 2-2. Slightly larger particle sizes were found in this run, as approximately 49 percent of the particles were less than 10 $\mu$m; as well as a mass median particle size of 11.0 $\mu$m.

Table 2-36 presents the results for PSD Run 3 which was conducted on the fifth day of testing, November 22, 1991. The graphical representation of this distribution, illustrated in Figure 2-3, shows a mass median particle size of 9.6 $\mu$m and has 51 percent of the total PM less than 10 $\mu$m.

Table 2-37 presents the results from Run 4 conducted on the sixth day of testing, November 23, 1991. Figure 2-4 shows the particle size distribution of this run. The mass median particle size as 11.1 $\mu$m, and approximately 48 percent of the weight was less than 10 $\mu$m.

Table 2-38 is a summary of the PSD results for the 4 test runs. Run 1 appears to be different in size distribution from Runs 2, 3, and 4.

TABLE 2-34. PSD RUN 1 RESULTS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| DATE: | 11/20/91 | | | | | | |
|---|---|---|---|---|---|---|---|
| STAGE | Dp50 (microns) | Net Weight (grams) | Mass Fraction | Mass Fract. Less Than | Interval Geometric Midpoint (microns) | dM/dlog DP (gr/dscf) | CONC (gr/dscf) |
| Preim & 1 | 17.2126 | 0.00637 | 0.2026 | 0.7974 * | 29.3365 | 5.698E-02 | 0.026387 |
| 2 | 11.2808 | 0.00144 | 0.0458 | 0.7516 | 13.9346 | 3.251E-02 | 0.005965 |
| 3 | 7.3596 | 0.00272 | 0.0865 | 0.6651 | 9.1117 | 6.075E-02 | 0.011267 |
| 4 | 5.1957 | 0.00276 | 0.0878 | 0.5773 | 6.1837 | 7.561E-02 | 0.011433 |
| 5 | 3.0731 | 0.00237 | 0.0754 | 0.5019 | 3.9959 | 4.305E-02 | 0.009818 |
| 6 | 1.7399 | 0.00223 | 0.0709 | 0.4310 | 2.3123 | 3.739E-02 | 0.009238 |
| 7 | 1.0579 | 0.00130 | 0.0413 | 0.3896 | 1.3567 | 2.492E-02 | 0.005385 |
| 8 | 0.6562 | 0.00215 | 0.0684 | 0.3212 | 0.8332 | 4.294E-02 | 0.008906 |
| BACK-UP | | 0.01010 | 0.3212 | 0.0000 * | 0.0573 | 1.975E-02 | 0.041838 |
| TOTAL | | 0.03144 | 1.0000 | | | | 0.130237 |

* these values asume top end and bottom end dp50s of 50 and .005 um.

TABLE 2-35. PSD RUN 2 RESULTS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| DATE: | 11/21/91 | | | | | | |
|---|---|---|---|---|---|---|---|
| STAGE | Dp50 (microns) | Net Weight (grams) | Mass Fraction | Mass Fract. Less Than | Interval Geometric Midpoint (microns) | dM/dlog DP (gr/dscf) | CONC (gr/dscf) |
| Preim & 1 | 17.3944 | 0.01505 | 0.4421 | 0.5579 * | 29.4910 | 1.839E-01 | 0.084348 |
| 2 | 11.4000 | 0.00110 | 0.0323 | 0.5256 | 14.0818 | 3.360E-02 | 0.006165 |
| 3 | 7.4373 | 0.00216 | 0.0635 | 0.4621 | 9.2079 | 6.526E-02 | 0.012106 |
| 4 | 5.2506 | 0.00193 | 0.0567 | 0.4054 | 6.2490 | 7.153E-02 | 0.010817 |
| 5 | 3.1055 | 0.00190 | 0.0558 | 0.3496 | 4.0380 | 4.669E-02 | 0.010649 |
| 6 | 1.7581 | 0.00147 | 0.0432 | 0.3064 | 2.3366 | 3.334E-02 | 0.008239 |
| 7 | 1.0689 | 0.00085 | 0.0250 | 0.2814 | 1.3708 | 2.204E-02 | 0.004764 |
| 8 | 0.6627 | 0.00069 | 0.0203 | 0.2612 | 0.8416 | 1.863E-02 | 0.003867 |
| BACK-UP | | 0.00889 | 0.2612 | 0.0000 * | 0.0576 | 2.348E-02 | 0.049824 |
| TOTAL | | 0.03404 | 1.0000 | | | | 0.190777 |

* these values asume top end and bottom end dp50s of 50 and .005 um.

TABLE 2-36. PSD RUN 3 RESULTS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| DATE: | 11/22/91 | | | | | | |
|---|---|---|---|---|---|---|---|
| STAGE | Dp50 (microns) | Net Weight (grams) | Mass Fraction | Mass Fract. Less Than | Interval Geometric Midpoint (microns) | dM/dlog DP (gr/dscf) | CONC (gr/dscf) |
| Preim & 1 | 17.6739 | 0.01386 | 0.4510 | 0.5490 * | 29.7270 | 1.839E-01 | 0.079370 |
| 2 | 11.5831 | 0.00046 | 0.0150 | 0.5340 | 14.3080 | 3.360E-02 | 0.002634 |
| 3 | 7.5568 | 0.00125 | 0.0407 | 0.4933 | 9.3558 | 6.526E-02 | 0.007158 |
| 4 | 5.3349 | 0.00170 | 0.0553 | 0.4380 | 6.3494 | 7.153E-02 | 0.009735 |
| 5 | 3.1553 | 0.00145 | 0.0472 | 0.3908 | 4.1028 | 4.669E-02 | 0.008304 |
| 6 | 1.7861 | 0.00118 | 0.0384 | 0.3524 | 2.3740 | 3.334E-02 | 0.006757 |
| 7 | 1.0857 | 0.00074 | 0.0241 | 0.3283 | 1.3925 | 2.204E-02 | 0.004238 |
| 8 | 0.6728 | 0.00150 | 0.0488 | 0.2795 | 0.8546 | 1.863E-02 | 0.008590 |
| BACK-UP | | 0.00859 | 0.2795 | 0.0000 * | 0.0580 | 2.348E-02 | 0.049191 |
| TOTAL | | 0.03073 | 1.0000 | | | | 0.175978 |

* these values asume top end and bottom end dp50s of 50 and .005 um.

TABLE 2–37. PSD RUN 4 RESULTS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| DATE: | 11/23/91 | | | | | | |
|---|---|---|---|---|---|---|---|
| STAGE | Dp50 (microns) | Net Weight (grams) | Mass Fraction | Mass Fract. Less Than | Interval Geometric Midpoint (microns) | dM/dlog DP (gr/dscf) | CONC (gr/dscf) |
| Preim & 1 | 17.5700 | 0.01162 | 0.4602 | 0.5398 * | 29.6395 | 1.839E−01 | 0.0658 |
| 2 | 11.5150 | 0.00064 | 0.0253 | 0.5145 | 14.2239 | 3.360E−02 | 0.0036 |
| 3 | 7.5124 | 0.00175 | 0.0693 | 0.4451 | 9.3008 | 6.526E−02 | 0.0099 |
| 4 | 5.3035 | 0.00154 | 0.0610 | 0.3842 | 6.3121 | 7.153E−02 | 0.0087 |
| 5 | 3.1367 | 0.00160 | 0.0634 | 0.3208 | 4.0787 | 4.669E−02 | 0.0091 |
| 6 | 1.7757 | 0.00146 | 0.0578 | 0.2630 | 2.3601 | 3.334E−02 | 0.0083 |
| 7 | 1.0794 | 0.00049 | 0.0194 | 0.2436 | 1.3844 | 2.204E−02 | 0.0028 |
| 8 | 0.6690 | 0.00032 | 0.0127 | 0.2309 | 0.8498 | 1.863E−02 | 0.0018 |
| BACK−UP | | 0.00583 | 0.2309 | 0.0000 * | 0.0578 | 2.348E−02 | 0.0330 |
| TOTAL | | 0.02525 | 1.0000 | | | | 0.1431 |

* these values asume top end and bottom end dp50s of 50 and .005 um.

TABLE 2–38. SUMMARY OF PARTICLE SIZE DISTRIBUTION RESULTS; MORRISTOWN MEMORIAL HOSPITAL (1991)

| RUN NO. | MASS MEDIAN PARTICLE SIZE (um) | WEIGHT PERCENTAGE LESS THAN 10um (%) | TOTAL PM CONCENTRATION (grains/dscf) |
|---|---|---|---|
| 1 | 2.3 | 71 | 0.130 |
| 2 | 11.0 | 49 | 0.191 |
| 3 | 9.6 | 51 | 0.176 |
| 4 | 11.1 | 48 | 0.143 |
| AVERAGE | 8.5 | 55 | 0.160 |

TABLE 2–39. PSD FLUE GAS AND SAMPLING PARAMETERS
MORRISTOWN MERMORIAL HOSPITAL (1991)

| FLUE GAS AND SAMPLING PARAMETERS | RUN 1 | RUN 2 | RUN 3 | RUN 4 | AVERAGE |
|---|---|---|---|---|---|
| Total Sampling Time (min.) | 20.0 | 15.0 | 15.0 | 15.0 | NA |
| Average Stack Temperature (°F) | 410 | 410 | 410 | 410 | 410 |
| Average Sampling Rate (dscfm) | 0.200 | 0.198 | 0.192 | 0.194 | 0.196 |
| Standard Metered Volume,Vm(std) (dscf) | 4.00 | 2.96 | 2.89 | 2.91 | 3.19 |
| Standard Metered Volume,Vm(std) (dscm) | 0.121 | 0.090 | 0.087 | 0.088 | 0.097 |
| Stack Moisture (%V) | 0.149 | 0.147 | 0.139 | 0.140 | 0.144 |
| Percent Isokinetic | 104.5 | 103.0 | 101.8 | 102.9 | NA |

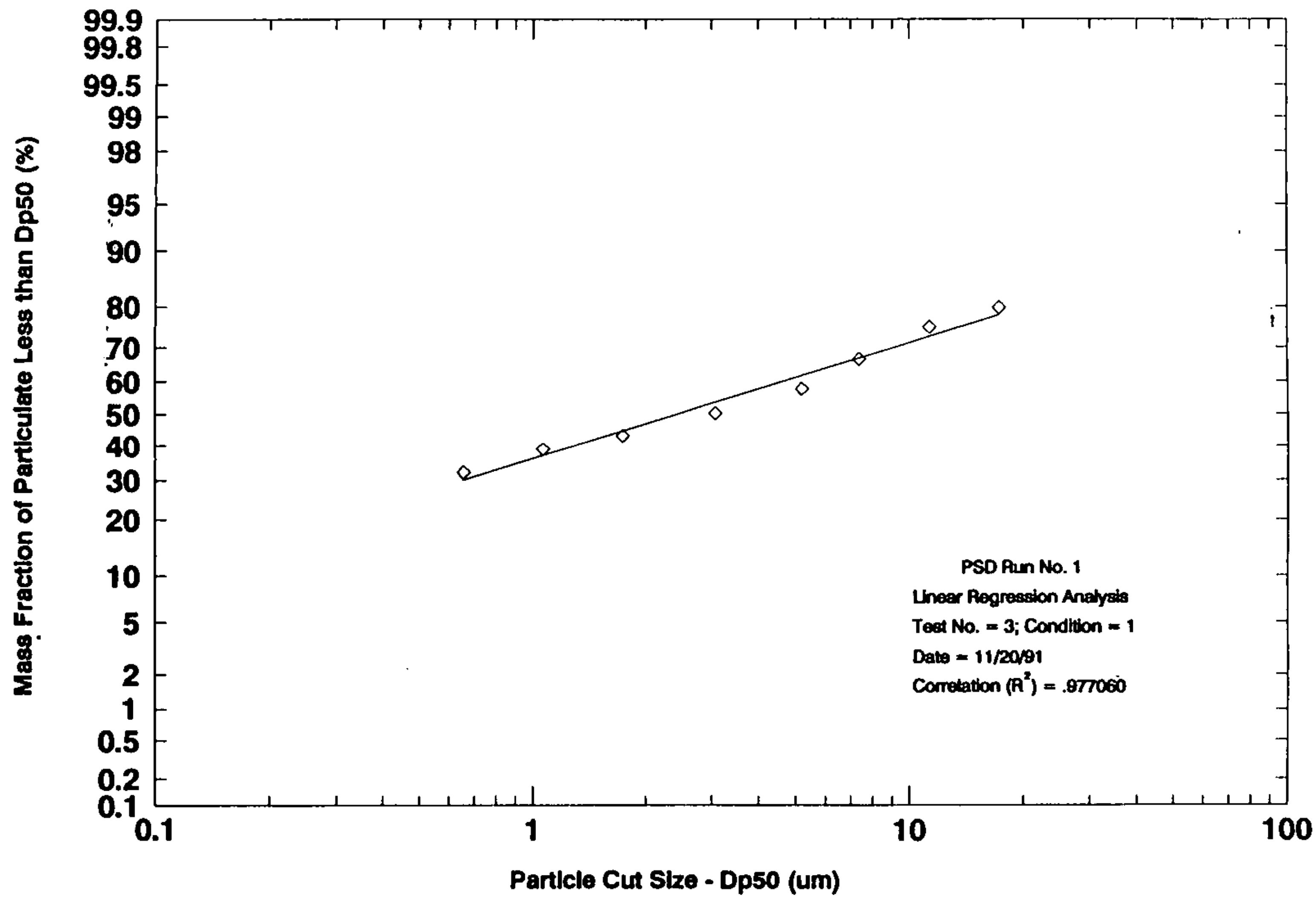


FIGURE 2-1. Run 1 PSD Results - Log Particle Size vs Mass Fraction Less Than Particle Size. Morristown Memorial Hospital (1991)

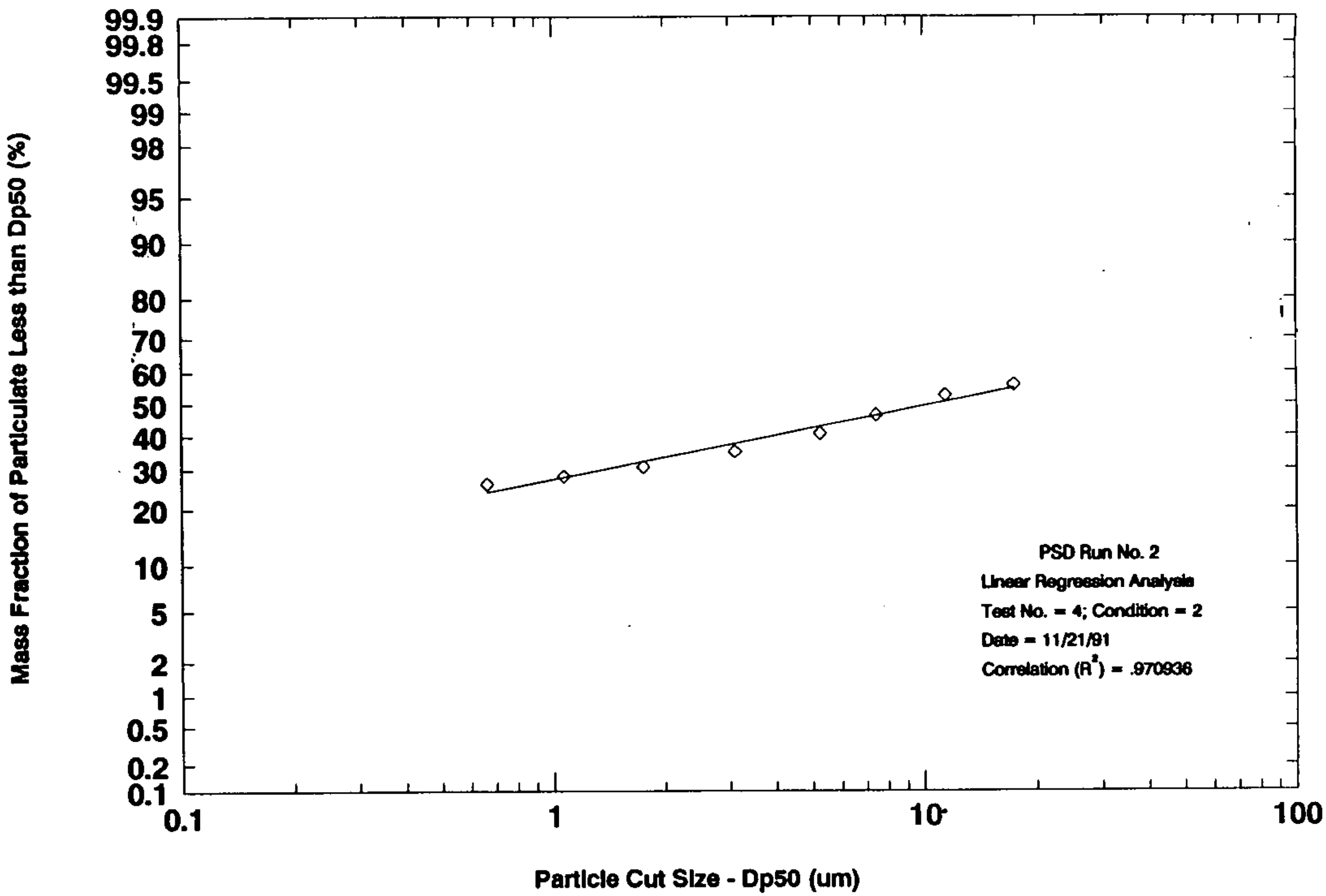


FIGURE 2-2. Run 2 PSD Results - Log Particle Size vs Mass Fraction Less Than Particle Size. Morristown Memorial Hospital (1991)

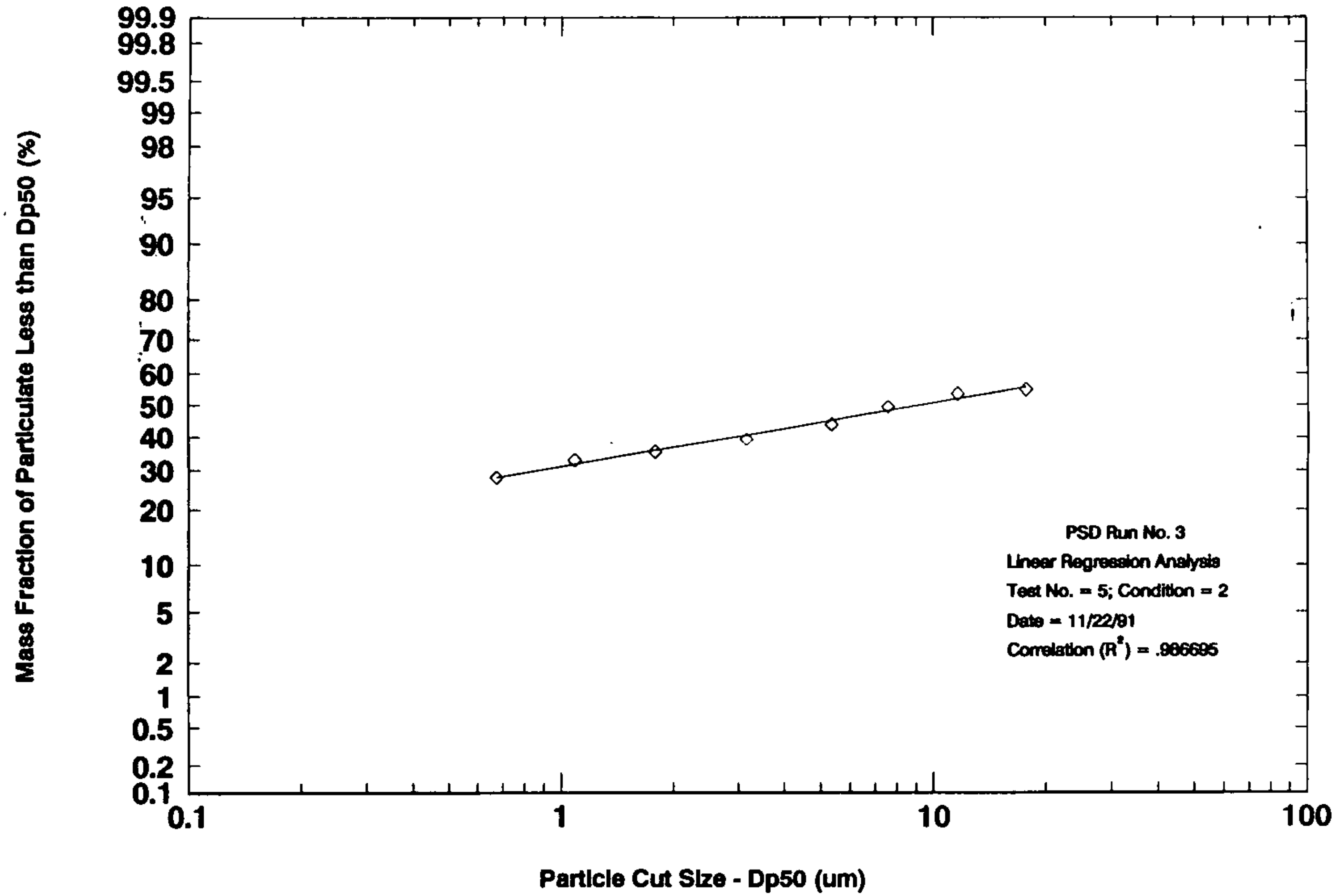


FIGURE 2-3. Run 3 PSD Results - Log Particle Size vs Mass Fraction Less Than Particle Size. Morristown Memorial Hospital (1991)

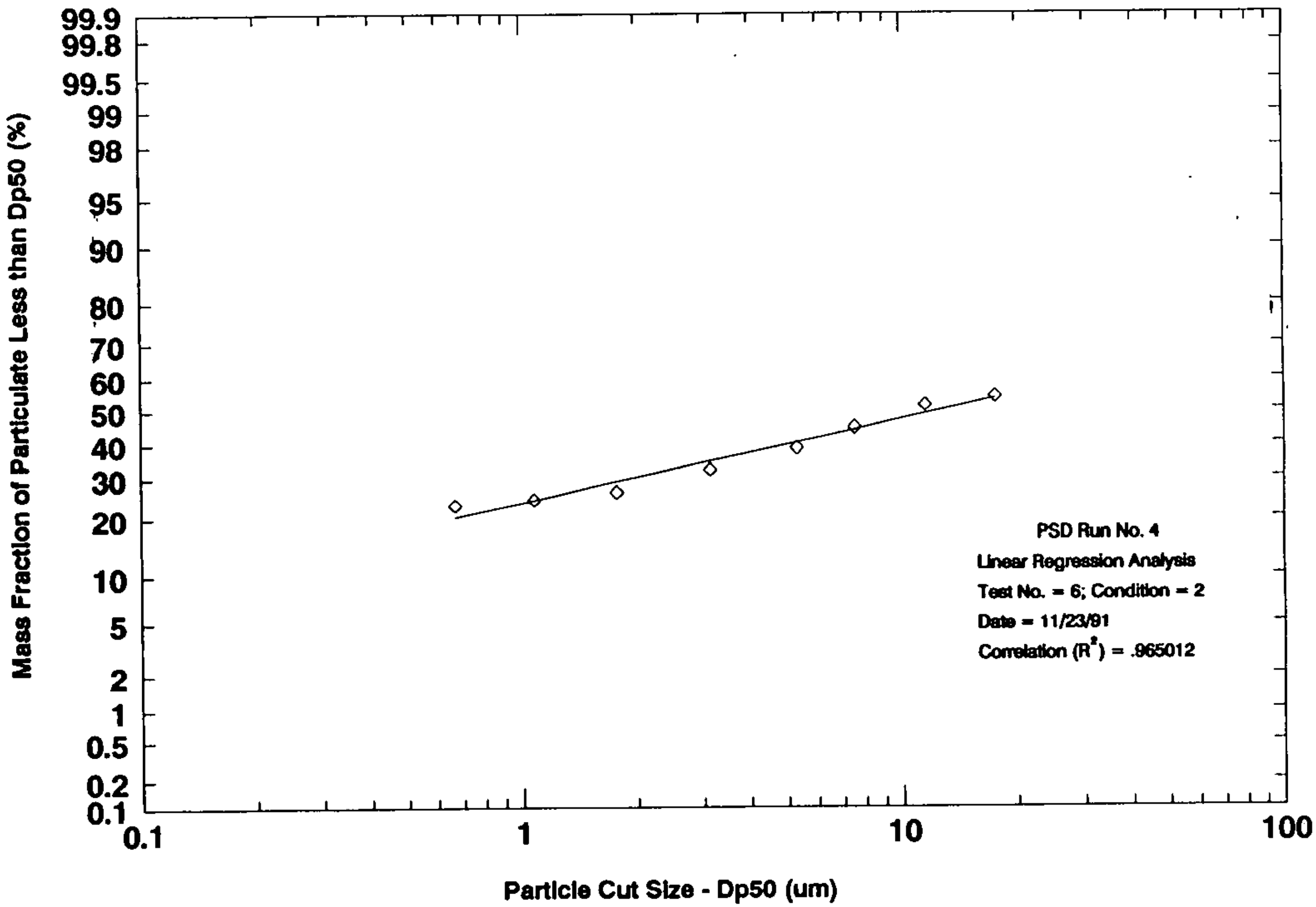


FIGURE 2-4. Run 4 PSD Results - Log Particle Size vs Mass Fraction Less Than Particle Size. Morristown Memorial Hospital (1991)

Table 2-39 is a summary of the PSD flue gas and sampling parameters, including the isokinetic sampling ratios. All of the sampling parameters are consistent throughout the four runs, and the isokinetic ratios are all within ±10 percent of 100 percent.

## 2.5 MERCURY EMISSIONS BY METHOD 101A

A Hg Method 101A sampling train was performed at the Morristown Memorial Hospital to further validate the Hg values from the toxic metal train. A comparison of the Method 101A Hg values to the multi-metals Hg values is discussed in more detail in Section 2.5.6.

### 2.5.1 Overview

A single sampling train was used to determine emission rates of Hg by Method 101A. Three sampling runs were performed under both test conditions (without carbon injection and with carbon injection) in order to ensure representative test results. Sampling locations, method, and QA/QC are discussed in Sections 4, 5, and 6, respectively. The results for each individual run are presented in Section 2.5.3. Concentrations at dry standard conditions, adjusted to 7 percent $O_2$, emission rates, and removal efficiencies are reported. The sample and flue gas parameters are presented in Section 2.5.4. The detected Hg weights separated by analytical filter digestion is discussed in Section 2.5.5. A comparison of the Hg collected in Method 101A versus the toxic metals trains is presented in Section 2.4.6.

### 2.5.2 Mercury Data Reduction

The values reported in the following Hg results were calculated using the same guidelines that are outlined for the metals in Section 2.3.2.

### 2.5.3 Mercury Emissions

Table 2-40 presents a summary of the Hg total weights, standard concentrations, concentrations corrected to 7 percent $O_2$, and emission rate results for each test condition.

For Condition 1, where carbon was not injected into the lime slurry, the Hg emission rate at the spray dryer inlet ranged from 5.20 to 19.8 g/hr with an average of 9.28 g/hr. At the baghouse outlet the emission rate ranged from 3.56 to 20.2 g/hr with an average of 10.4 g/hr.

TABLE 2-40. SUMMARY OF MERCURY 101A RESULTS
MORRISTOWN MEMORIAL HOPSITAL (1991)

| Condition | Run | Location | | | | | | | | RE (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Inlet (total ug) | Outlet (total ug) | Inlet (ug/dscm) | Outlet (ug/dscm) | Inlet (ug/dscm @ 7% O2) | Outlet (ug/dscm @ 7% O2) | Inlet (g/hr) | Outlet (g/hr) | |
| Without Carbon | 1 | 2630 | 3450 | 902 | 943 | 1280 | 1930 | 5.20 | 7.51 | -44.5% |
| | 2 | 1480 | 1640 | 492 | 449 | 698 | 918 | 2.88 | 3.56 | -23.5% |
| | 3 | 9760 | 9350 | 3350 | 2480 | 4520 | 4600 | 19.8 | 20.2 | -2.10% |
| Average | | 4623 | 4813 | 1581 | 1291 | 2166 | 2483 | 9.28 | 10.4 | -12.2% |
| | | | | | | | | | | |
| With Carbon | 4 | 1500 | 998 | 502 | 264 | 664 | 516 | 3.10 | 2.13 | 31.3% |
| | 5 | 4680 | 326 | 1630 | 83.7 | 2240 | 159 | 9.48 | 0.719 | 92.4% |
| | 6 | 6470 | 697 | 2250 | 177 | 3070 | 332 | 13.2 | 1.48 | 88.8% |
| Average | | 4217 | 674 | 1461 | 175 | 1991 | 336 | 8.60 | 1.44 | 83.2% |

For Condition 2, where carbon was injected into the lime slurry, the Hg emission rate at the spray dryer inlet ranged from 3.10 to 13.2 g/hr with an average of 8.6 g/hr. At the baghouse outlet, the mass emission rate ranged from 0.72 to 2.13 g/hr with an average of 1.44 g/hr.

The removal efficiencies during the emission tests without carbon injection display a slight Hg gain across the emission controls. A recent study on the precision of Method 101A when measuring exhaust gases from a municipal waste combustor (EPA 450/4-92-013) reported an average relative standard deviation (RSD) of the method of 15.6% when used without carbon injection. Assuming that the same RSD applies to Runs 1, 2, and 3 of this test program, all pairs of $O_2$-corrected Hg concentrations at the inlet and outlet agree within 2.6 standard deviations. The apparent gain in Hg concentrations over the control device in Runs 1-3 may therefore be due primarily to inherent variability in the sampling method.

The removal efficiencies during the emission tests with carbon injection present an average removal efficiency of 83.2 percent. Therefore, from the Method 101A Hg results, it is apparent that carbon injection into the spray dryer positively affects the removal of Hg in the flue gas.

### 2.5.4 Mercury Sample Parameters

Sampling and flue gas parameters for the Method 101A sampling trains at the inlet are shown in Table 2-41, and Table 2-42 presents the parameters for the runs performed at the outlet. Total sampling times, sample volume, and isokinetic results for each sampling run are presented. All of the runs were within the ±10 percent isokinetic range. Appendix C contains a complete listing of these and additional sampling and flue gas parameters for each run.

### 2.5.5 Mercury Amounts by Sample Fraction

Table 2-43 presents the detected weights of Hg specific to both sample fractions and reports the amount of total weight detected by the first and second filter digestions. The first digestion is performed on the first analytical filter with 8N HCl, and the second digestion is performed on the second analytical filter with aqua regia (3/4 HCl and 1/4 $HNO_3$). Further details of this process are discussed in Section 5.

The first digestion of the front half of the sample train does detect significant additional amounts of Hg at the inlet runs. None of the second filtrations add significantly to the total Hg detected, especially in the back half of the sample.

### 2.5.6 Mercury Emissions Comparison

Table 2-44 presents the comparison of Hg emission rates and removal efficiencies for Method 101A to multi-metal trains. During the emission tests without carbon injection, the results from the Method 101A and multi-metals do not agree, more predominantly at the inlet. The fractional results of the multi-metals sample analysis shown in Table 2-25 show that most of the Hg was captured in the first three nitric acid impingers, before the gas reached the $KMnO_4$ solution. This allows the possibility that some forms of Hg may be captured more efficiently in the $HNO_3$ than in the $KMnO_4$, and that the Method 101A train allows some Hg to break through. The municipal waste incinerator cited previously (EPA 450/4-92-013) also showed higher concentrations of Hg measured with the multi-metals train that with the Method 101A train. Differences in the forms of Hg present at the inlet and outlet locations could account for the difference in relative method performance at these two locations, however, speciation of Hg compounds is beyond the scope of this study.

Valuable data might be gathered in future tests by adding $HNO_3$ impingers to the back end of a Method 101 train, and analyzing impingers individually to further characterize Hg capture through the train fractions.

For Condition 1 at the spray dryer inlet, the average removal efficiency determined by the Method 101A train was -12.2 percent; in comparison, the multi-metals average removal efficiency was 29.7 percent.

For the emission tests with carbon injection, the results from Runs 5 and 6 display similar emission rates for both methods. The average removal efficiency determined from the Method 101A trains was 83.2 percent, and the average removal efficiency determined from the multi-metals trains was 90.0 percent; therefore, portraying more consistent results than the first three runs.

TABLE 2–41. MERCURY 101A SAMPLING AND FLUE GAS PARAMETERS AT THE SPRAY DRYER INLET; MORRISTOWN MEMORIAL HOSPITAL (1991)

| Run No.<br>Date | Run 1<br>11/18/91 | Run 2<br>11/19/91 | Run 3<br>11/20/91 | Run 4<br>11/21/91 | Run 5<br>11/22/91 | Run 6<br>11/23/91 | Average |
|---|---|---|---|---|---|---|---|
| Total Sampling Time (min) | 240 | 240 | 240 | 240 | 240 | 240 | NA |
| Average Sampling Rate (dscfm) | 0.43 | 0.44 | 0.43 | 0.44 | 0.42 | 0.42 | 0.43 |
| Metered Volume (dscf) | 103 | 106 | 103 | 106 | 102 | 101 | 103 |
| Metered Volume (dscm) | 2.9 | 3.0 | 2.9 | 3.0 | 2.9 | 2.9 | 2.9 |
| Average Stack Temperature (F) | 409 | 410 | 410 | 412 | 410 | 407 | 410 |
| O2 Concentration (%V) | 11.1 | 11.1 | 10.6 | 10.4 | 10.8 | 10.7 | 10.8 |
| CO2 Concentration (%V) | 6.4 | 7.8 | 6.7 | 6.6 | 6.5 | 6.5 | 6.8 |
| Stack Gas Moisture (%V) | 15.6 | 15.3 | 14.1 | 13.6 | 13.9 | 14.2 | 14.4 |
| Volumetric Flow Rate (dscfm) | 3393 | 3447 | 3473 | 3639 | 3422 | 3459 | 3472 |
| Volumetric Flow Rate (dscmm) | 96.1 | 97.6 | 98.4 | 103.0 | 96.9 | 98.0 | 98.3 |
| Percent Isokinetic | 101.2 | 102.7 | 94.2 | 96.7 | 99.0 | 97.8 | NA |

NA = Not Applicable

Note: The accuracy of all calculated results is limited to three significant digits. Summary tables generated by spreadsheet programs report additional digits that are not significant.

TABLE 2–42. MERCURY 101A SAMPLING AND FLUE GAS PARAMETERS AT THE BAGHOUSE OUTLET; MORRISTOWN MEMORIAL HOSPITAL (1991)

| Run No.<br>Date | Run 1<br>11/18/91 | Run 2<br>11/19/91 | Run 3<br>11/20/91 | Run 4<br>11/21/91 | Run 5<br>11/22/91 | Run 6<br>11/23/91 | Average |
|---|---|---|---|---|---|---|---|
| Total Sampling Time (min) | 240 | 240 | 240 | 239 | 240 | 240 | NA |
| Average Sampling Rate (dscfm) | 0.54 | 0.54 | 0.56 | 0.56 | 0.57 | 0.58 | 0.56 |
| Metered Volume (dscf) | 129 | 129 | 133 | 134 | 138 | 139 | 134 |
| Metered Volume (dscm) | 3.7 | 3.7 | 3.8 | 3.8 | 3.9 | 3.9 | 3.8 |
| Average Stack Temperature (F) | 285 | 285 | 285 | 289 | 270 | 287 | 284 |
| O2 Concentration (%V) | 14.1 | 14.1 | 13.4 | 13.8 | 13.6 | 13.5 | 13.8 |
| CO2 Concentration (%V) | 5.0 | 5.0 | 5.3 | 5.2 | 5.0 | 5.3 | 5.1 |
| Stack Gas Moisture (%V) | 14.3 | 14.4 | 14.4 | 14.6 | 13.4 | 13.7 | 14.1 |
| Volumetric Flow Rate (dscfm) | 4687 | 4664 | 4790 | 4758 | 5051 | 4932 | 4814 |
| Volumetric Flow Rate (dscmm) | 132.7 | 132.1 | 135.6 | 134.7 | 143.0 | 139.7 | 136.3 |
| Percent Isokinetic | 97.6 | 98.9 | 99.6 | 100.9 | 97.4 | 101.0 | NA |

NA = Not Applicable

Note: The accuracy of all calculated results is limited to three significant digits. Summary tables generated by spreadsheet programs report additional digits that are not significant.

TABLE 2-43. COMPARISON OF MERCURY 101A DATA TO DIGESTED LAB FILTERS; MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Front Half | | | | | Back Half | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Run | Total ug without Lab Filters | Total ug with 1st Lab Filter | % Diff. | Total ug with 2nd Lab Filter | % Diff. | Total ug without Lab Filters | Total ug with 1st Lab Filter | % Diff. | Total ug with 2nd Lab Filter | % Diff. |
| Inlet 1 | 134 | 147 | 9.09% | 150 | 1.73% | 2480 | 2480 | 0.0% | 2480 | 0.0% |
| Inlet 2 | 48.2 | 51.3 | 6.01% | 52.0 | 1.35% | 1430 | 1430 | 0.0% | 1430 | 0.0% |
| Inlet 3 | 976 | 1030 | 5.24% | 1060 | 2.83% | 8690 | 8690 | 0.0% | 8700 | 0.115% |
| Cond. 1 Avg. | 386 | 410 | 6.78% | 421 | 1.97% | 4200 | 4200 | 0.0% | 4200 | 0.0383% |
| | | | | | | | | | | |
| Inlet 4 | 219 | 231 | 5.07% | 233 | 1.17% | 1270 | 1270 | 0.0% | 1270 | 0.0% |
| Inlet 5 | 1640 | 1690 | 2.96% | 1700 | 0.588% | 2980 | 2980 | 0.0% | 2980 | 0.0% |
| Inlet 6 | 132 | 143 | 7.82% | 144 | 0.865% | 6320 | 6320 | 0.0% | 6320 | 0.0% |
| Cond. 2 Avg. | 664 | 688 | 5.28% | 693 | 0.874% | 3523 | 3520 | 0.0% | 3520 | 0.0% |
| | | | | | | | | | | |
| Outlet 1 | 0.378 | 1.50 | 74.8% | 1.66 | 9.60% | 3450 | 3450 | 0.0% | 3450 | 0.0% |
| Outlet 2 | 0.293 | 0.701 | 58.2% | 0.701 | 0.0% | 1640 | 1640 | 0.0% | 1640 | 0.0% |
| Outlet 3 | 2.88 | 3.99 | 27.8% | 3.99 | 0.0% | 9340 | 9340 | 0.0% | 9340 | 0.0% |
| Cond. 1 Avg. | 1.18 | 2.06 | 53.6% | 2.12 | 3.20% | 4810 | 4810 | 0.0% | 4810 | 0.0% |
| | | | | | | | | | | |
| Outlet 4 | 0.378 | 0.566 | 33.2% | 0.566 | 0.0% | 993 | 998 | 0.452% | 998 | 0.0% |
| Outlet 5 | [0.206] | [0.835] | 0% | 0.159 | 100.0% | 326 | 326 | 0.0% | 326 | 0.0% |
| Outlet 6 | [0.206] | 0.320 | >36% | 0.320 | 0.0% | 696 | 697 | 0.0754% | 697 | 0.0% |
| Cond. 2 Avg. | 0.378 | 0.443 | 23.1% | 0.348 | 33.33% | 672 | 673 | 0.176% | 673 | 0.0% |

[ ] = Not detected at the limit shown

a The greater weight is used as a reference point for the calculation of % Difference.

TABLE 2-44. COMPARISON FOR MERCURY EMISSION RATES AND REMOVAL EFFICIENCIES METHOD 101A VERSUS TOXIC METALS; MORRISTOWN MEMORIAL HOSPITAL (1991)

| Condition | Run | Method 101A | | | Toxic Metal Trains | | |
|---|---|---|---|---|---|---|---|
| | | Inlet (g/hr) | Outlet (g/hr) | RE (%) | Inlet (g/hr) | Outlet (g/hr) | RE (%) |
| Without Carbon | 1 | 5.20 | 7.51 | -44.5% | 9.51 | 4.67 | 50.9% |
| | 2 | 2.88 | 3.56 | -23.5% | 2.7 | 2.76 | -1.1% |
| | 3 | 19.8 | 20.2 | -2.10% | 23.4 | 17.6 | 24.6% |
| | Average | 9.28 | 10.4 | -12.2% | 11.9 | 8.35 | 29.7% |
| | | | | | | | |
| With Carbon | 4 | 3.10 | 2.13 | 31.3% | 11.4 | 1.84 | 83.8% |
| | 5 | 9.48 | 0.719 | 92.4% | 10.6 | 0.436 | 95.9% |
| | 6 | 13.2 | 1.48 | 88.8% | 14.9 | 1.40 | 90.6% |
| | Average | 8.60 | 1.44 | 83.2% | 12.3 | 1.23 | 90.0% |

## 2.6 HALOGEN GAS EMISSIONS

Hydrogen chloride (HCl), HF, and HBr gas concentrations were manually sampled at the spray dryer inlet and the baghouse outlet, following EPA Method 26 procedures. In this method, flue gas is extracted from the sample location and passed through acidified water. The halogen gases solubilize and form halide ions. Ion chromatography was used to detect the chloride ($Cl^-$), bromide ($Br^-$), and fluoride ($F^-$) ions present in the sample. Three 1-hour samples were collected during each of the 6 test runs. The results are reported as a concentration (ppmv) and an emission rate (lb/hr) at dry standard conditions. Since a flow rate is not calculated using EPA Method 26, the corresponding flue gas flow rates determined from the CDD/CDF sampling trains were used in the calculation of emission rates.

The results for all 3 halogens from Runs 1 and 2 at the inlet and Runs 1B and 1C at the baghouse outlet were rejected and not reported. A comparison of the Method 26 and the HCl CEM data shows that these results are obvious outliers at a 90 percent confidence level.

### 2.6.1 Hydrogen Chloride Emissions Results

Table 2-45 presents a summary of HCl spray dryer inlet and baghouse outlet concentrations and emission rates determined by manual sampling and provides the HCl removal efficiencies for the emission control system. The removal efficiencies for the six runs conducted on the first two days could not be calculated because the spray dryer inlet results were outside acceptable control limits.

For Condition 1, where carbon was not added to the lime slurry, the HCl concentration at the spray dryer inlet ranged from 398.6 to 952.7 ppmvd at 7 percent $O_2$, with an average of 723.7 ppmvd at 7 percent $O_2$. The HCl mass rate entering the spray dryer ranged from 5.9 to 14.1 lb/hr with an average of 10.8 lb/hr. At the baghouse outlet, the HCl concentration ranged from 3.9 to 8.5 ppmvd at 7 percent $O_2$ with an average of 6.0 ppmvd at 7 percent $O_2$. The HCl emission rate at the baghouse outlet ranged from 0.06 to 0.12 lb/hr with an average of 0.08 lb/hr.

## TABLE 2-45. SUMMARY OF HYDROGEN CHLORIDE RESULTS MORRISTOWN MEMORIAL HOSPITAL (1991)

| RUN NO. | SPRAYDRYER INLET O2 CONC. (% VOL) | SPRAYDRYER INLET FLUE GAS FLOW (dscmm) | SPRAYDRYER INLET GAS CONC. (ppmV) | SPRAYDRYER INLET GAS CONC. (ppmV @7% O2) | SPRAYDRYER INLET EMISSION RATE (lb/hr) | BAGHOUSE OUTLET O2 CONC. (% VOL) | BAGHOUSE OUTLET FLUE GAS FLOW (dscmm) | BAGHOUSE OUTLET GAS CONC. (ppmV) | BAGHOUSE OUTLET GAS CONC. (ppmV @7% O2) | BAGHOUSE OUTLET EMISSION RATE (lb/hr) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | 3.70 | 7.56 | 0.100 | NA |
| 1B | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | b | b | b | NA |
| 1C | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | b | b | b | NA |
| AVERAGE | | | NA | NA | NA | | | 3.70 | 7.56 | 0.100 | NA |
| 2A | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | 4.17 | 8.52 | 0.118 | NA |
| 2B | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | 2.63 | 5.38 | 0.074 | NA |
| 2C | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | 3.32 | 6.79 | 0.094 | NA |
| AVERAGE | | | NA | NA | NA | | | 3.37 | 6.90 | 0.095 | NA |
| 3A | 10.6 | 100.0 | 607 | 820 | 12.2 | 13.4 | 140.4 | 2.12 | 3.93 | 0.060 | 99.5 |
| 3B | 10.6 | 100.0 | 295 | 399 | 5.92 | 13.4 | 140.4 | 2.39 | 4.42 | 0.067 | 98.9 |
| 3C | 10.6 | 100.0 | 706 | 953 | 14.2 | 13.4 | 140.4 | 2.79 | 5.17 | 0.078 | 99.4 |
| AVERAGE | | | 536 | 724 | 10.8 | | | 2.43 | 4.51 | 0.068 | 99.3 |
| COND. 1 AVG. | 10.9 | 98.0 | 536 | 724 | 10.8 | 13.9 | 138.7 | 3.02 | 5.97 | 0.084 | 99.3 |
| 4A | 10.4 | 94.7 | 892 | 1181 | 16.9 | 13.8 | 137.1 | 3.24 | 6.34 | 0.089 | 99.5 |
| 4B | 10.4 | 94.7 | 866 | 1146 | 16.4 | 13.8 | 137.1 | 29.2 | 57.1 | 0.803 | 95.1 |
| 4C | 10.4 | 94.7 | 1015 | 1343 | 19.3 | 13.8 | 137.1 | 7.64 | 15.0 | 0.210 | 98.9 |
| AVERAGE | | | 924 | 1224 | 17.5 | | | 13.4 | 26.1 | 0.367 | 97.8 |
| 5A | 10.8 | 96.8 | 656 | 902 | 12.7 | 13.6 | 143.2 | [0.026] | [0.049] | [0.0007] | >99.99 |
| 5B | 10.8 | 96.8 | 571 | 786 | 11.1 | 13.6 | 143.2 | [0.026] | [0.050] | [0.0008] | >99.99 |
| 5C | 10.8 | 96.8 | 836 | 1151 | 16.2 | 13.6 | 143.2 | [0.025] | [0.047] | [0.0007] | >99.99 |
| AVERAGE | | | 688 | 946 | 13.3 | | | [0.026] | [0.049] | [0.0007] | >99.99 |
| 6A | 10.7 | 98.9 | 724 | 986 | 14.4 | 13.5 | 141.0 | [0.023] | [0.044] | [0.0007] | >99.99 |
| 6B | 10.7 | 98.9 | 493 | 672 | 9.79 | 13.5 | 141.0 | [0.023] | [0.043] | [0.0007] | >99.99 |
| 6C | 10.7 | 98.9 | 1043 | 1421 | 20.7 | 13.5 | 141.0 | [0.026] | [0.049] | [0.0007] | >99.99 |
| AVERAGE | | | 753 | 1026 | 14.9 | | | [0.024] | [0.045] | [0.0007] | >99.99 |
| COND. 2 AVG. | 10.6 | 96.8 | 788 | 1065 | 15.3 | 13.6 | 140.4 | 13.4 | 26.1 | 0.367 | 99.27 |

a The flow rates determined by the CDD/CDF sampling trains were used for HCl emission rate calculations.
b The results are not reported because the data are not within acceptable control limits.
c [] = Not detected at the limit shown.
d Detection limits are not considered when calculating averages.

For Condition 2 where carbon was added to the lime slurry, the HCl concentration at the spray dryer inlet ranged from 672.1 to 1420.9 ppmvd at 7 percent $O_2$, with an average of 1065.4 ppmvd at 7 percent $O_2$. The mass emission rate entering the spray dryer ranged from 9.8 to 20.7 lb/hr with an average of 15.3 lb/hr. The HCl concentration leaving the baghouse ranged from less than 0.04 ppmvd at 7 percent $O_2$ to 57.1 ppmvd at 7 percent $O_2$ with an average of 26.1 ppmvd at 7 percent $O_2$. The mass emission rate at the baghouse outlet ranged from less than 0.0007 lb/hr to 0.8 lb/hr with an average of 0.37 lb/hr.

The mass flow rate of HCl into the spray dryer was approximately 42% higher during Condition 2 than Condition 1, but the difference was not great enough to significantly effect the removal efficiencies. Based on the results from Runs 5 and 6, carbon injection appears to improve HCl removal in the flue gas; however, the results from Run 4 are similar to the results obtained without carbon injection. Therefore, it cannot be concluded with confidence that carbon injection improves removal of HCl in the emission control system.

In addition to Method 26, the flue gas was analyzed for HCl using a CEM monitor as discussed in Section 5. Table 2-46 summarizes the CEM HCl results, including HCl removal efficiencies based on ppmvd corrected to 7 percent $O_2$. The HCl data is corrected to a dry basis using an average moisture percentage taken from the other manual trains. The values reported are averages of the CEM data that correspond to the exact time in which the Method 26 trains were run.

For the runs without carbon injection, the HCl concentration at the spray dryer inlet ranged from 798.3 to 1087.9 ppmvd at 7 percent $O_2$ with an average of 913.0 ppmvd at 7 percent $O_2$. At the baghouse outlet, the HCl concentration ranged from 8.37 to 20.19 ppmvd at 7 percent $O_2$ with an average of 15.6 ppmvd at 7 percent $O_2$.

For the runs with carbon injection, the HCl concentration at the spray dryer inlet ranged from 961.9 to 1090.1 ppmvd at 7 percent $O_2$ with an average of 1013.7 ppmvd at 7 percent $O_2$. At the baghouse outlet, the concentration ranged from 10.6 to 30.7 ppmvd at 7 percent $O_2$ with an average for the 3 runs of 18.6 ppmvd at 7 percent $O_2$.

TABLE 2–46. SUMMARY OF HCl CEM RESULTS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| RUN NO. | SPRAYDRYER INLET | | | | | BAGHOUSE OUTLET | | | | | [c] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $O_2$ (%V) [a] | $H_2O$ (%V) | HCl (ppmV) | HCl (ppmVd) [b] | HCl (ppmVd @7% $O_2$) | $O_2$ (%V) | $H_2O$ (%V) | HCl (ppmV) | HCl (ppmVd) | HCl (ppmVd @7% $O_2$) | REMOVAL EFFICIENCY (%) |
| 1 | 11.1 | 15.9 | 643 | 764 | 1088 | 14.2 | 14.6 | 7.57 | 8.87 | 18.3 | 98.3% |
| 2 | 11.2 | 15.5 | 471 | 557 | 798 | 14.2 | 13.8 | 8.36 | 9.69 | 20.2 | 97.5% |
| 3 | 10.7 | 14.9 | 535 | 629 | 853 | 13.6 | 14.7 | 3.77 | 4.42 | 8.37 | 99.0% |
| COND. 1 AVG. | 11.0 | 15.4 | 550 | 650 | 913 | 14.0 | 14.4 | 6.56 | 7.66 | 15.6 | 98.3% |
| 4 | 10.4 | 14.7 | 703 | 824 | 1090 | 14.2 | 14.8 | 12.5 | 14.7 | 30.6 | 97.2% |
| 5 | 10.7 | 13.9 | 606 | 704 | 962 | 13.8 | 13.4 | 6.44 | 7.44 | 14.5 | 98.5% |
| 6 | 10.6 | 14.0 | 629 | 731 | 989 | 13.9 | 13.0 | 4.67 | 5.36 | 10.6 | 98.9% |
| COND. 2 AVG. | 10.6 | 14.2 | 646 | 753 | 1014 | 14.0 | 13.7 | 7.91 | 9.17 | 18.6 | 98.2% |

a The $O_2$ results are averaged from CEM values corresponding to the three daily HCl runs.
b The HCl data is corrected to a dry basis using an average moisture percentage from the manual trains.
c Removal Efficiency is based on HCl values corrected to 7% $O_2$.

During Condition 1, the HCl removal efficiency ranged from 97.5 to 99.0 percent and averaged 98.3 percent for the 3 runs. During Condition 2, the HCl removal efficiency ranged from 97.5 to 98.9 percent and averaged 98.3 percent. At the spray dryer inlet, an average increase of 11.0 percent in the HCl concentration occurs from Condition 1 to Condition 2; whereas, at the baghouse outlet, an average increase of 18.9 percent in the HCl concentration occurs from Condition 1 to Condition 2. An increase of HCl at the spray dryer inlet is reflected as a similar increase at the baghouse outlet. From this data, one could conclude that the injection of carbon does not increase the removal of HCl in the emission control system.

Table 2-47 presents a comparison of the manual and CEM HCl concentrations (ppmvd at 7 percent $O_2$). The CEM values are data averages that correspond to the exact time periods during which the manual sampling was conducted. At the spray dryer inlet, the percent difference between the manual results and the CEM results ranged from -15.5 to 107.1, with an average difference of -1.7 percent. At the baghouse outlet, the percent difference ranged from -77.3 to 302.0 with an average difference of 42.3 percent.

Figure 2-5 presents a graphical representation of the manual and CEM HCl concentrations at the spray dryer inlet. This table illustrates the common trend between the results of both methods. Figure 2-6 presents a graphical representation of the manual and CEM HCl concentrations at the baghouse outlet. Here the common trend between the two methods is discernable, but is not as obvious at the baghouse outlet as it is at the spray dryer inlet. Actual correlation between methods on individual runs is weak for both locations.

2.6.2 Hydrogen Fluoride Emission Results

Table 2-48 presents a summary of HF inlet and outlet concentrations and emission rates determined by manual sampling, as well as providing emission control removal efficiencies. The removal efficiencies could not be calculated for the first six runs for reasons discussed previously.

For Condition 1, the HF concentrations at the spray dryer inlet ranged from less than 0.7 ppmvd at 7 percent $O_2$ to 1.3 ppmvd at 7 percent $O_2$ with an average of 1.3 ppmvd at 7 percent $O_2$. The HF emission rate entering the spray dryer ranged from

## TABLE 2-47. COMPARISON OF MANUAL AND CEM HCl RESULTS; MORRISTOWN MEMORIAL HOSPITAL (1991)

| TEST RUN NUMBER | SPRAYDRYER INLET | | | BAGHOUSE OUTLET | | |
|---|---|---|---|---|---|---|
| | MANUAL (ppmVd @7% O2) | CEM (ppmVd @7% O2) | % DIFF. | MANUAL (ppmVd @7% O2) | CEM (ppmVd @7% O2) | % DIFF. |
| 1A | b | a 734 | NA | 7.56 | 1.72 | −77.3% |
| 1B | b | 1060 | NA | b | 23.8 | NA |
| 1C | b | 1470 | NA | b | 29.5 | NA |
| AVERAGE | NA | 1088 | NA | 7.56 | 18.3 | 143% |
| 2A | b | 781 | NA | 8.52 | 13.1 | 54.0% |
| 2B | b | 767 | NA | 5.38 | 20.2 | 275% |
| 2C | b | 847 | NA | 6.79 | 27.3 | 302% |
| AVERAGE | NA | 798 | NA | 6.90 | 20.2 | 193% |
| 3A | 820 | 779 | −4.9% | 3.93 | 7.71 | 96.3% |
| 3B | 399 | 825 | 107% | 4.42 | 7.03 | 59.0% |
| 3C | 953 | 954 | 0.1% | 5.17 | 10.4 | 101% |
| AVERAGE | 724 | 853 | 17.9% | 4.51 | 8.37 | 85.7% |
| 4A | 1181 | 998 | −15.5% | 6.34 | 6.26 | −1.31% |
| 4B | 1146 | 1064 | −7.1% | 57.1 | 59.8 | 4.59% |
| 4C | 1343 | 1208 | −10.1% | 15.0 | 25.9 | 73.4% |
| AVERAGE | 1224 | 1090 | −10.9% | 26.1 | 30.6 | 17.2% |
| 5A | 902 | 794 | −12.0% | [0.049] | 6.19 | NA |
| 5B | 786 | 832 | 5.8% | [0.050] | 8.11 | NA |
| 5C | 1151 | 1260 | 9.4% | [0.047] | 29.1 | NA |
| AVERAGE | 946 | 962 | 1.6% | [0.049] | 14.5 | NA |
| 6A | 986 | 888 | −10.0% | [0.044] | 5.48 | NA |
| 6B | 672 | 1056 | 57.2% | [0.043] | 24.1 | NA |
| 6C | 1421 | 1023 | −28.0% | [0.049] | 2.31 | NA |
| AVERAGE | 1026 | 989 | −3.6% | [0.045] | 10.6 | NA |
| TOTAL AVERAGE | 980 | 963 | −1.7% | 12.0 | 17.1 | 42.3% |

a The CEM HCl data is corrected to a dry basis using an average moisture percentage from the manual trains.

b The results are not reported because the data is not within acceptable control limits.

c [] = Not detected at the limit shown.

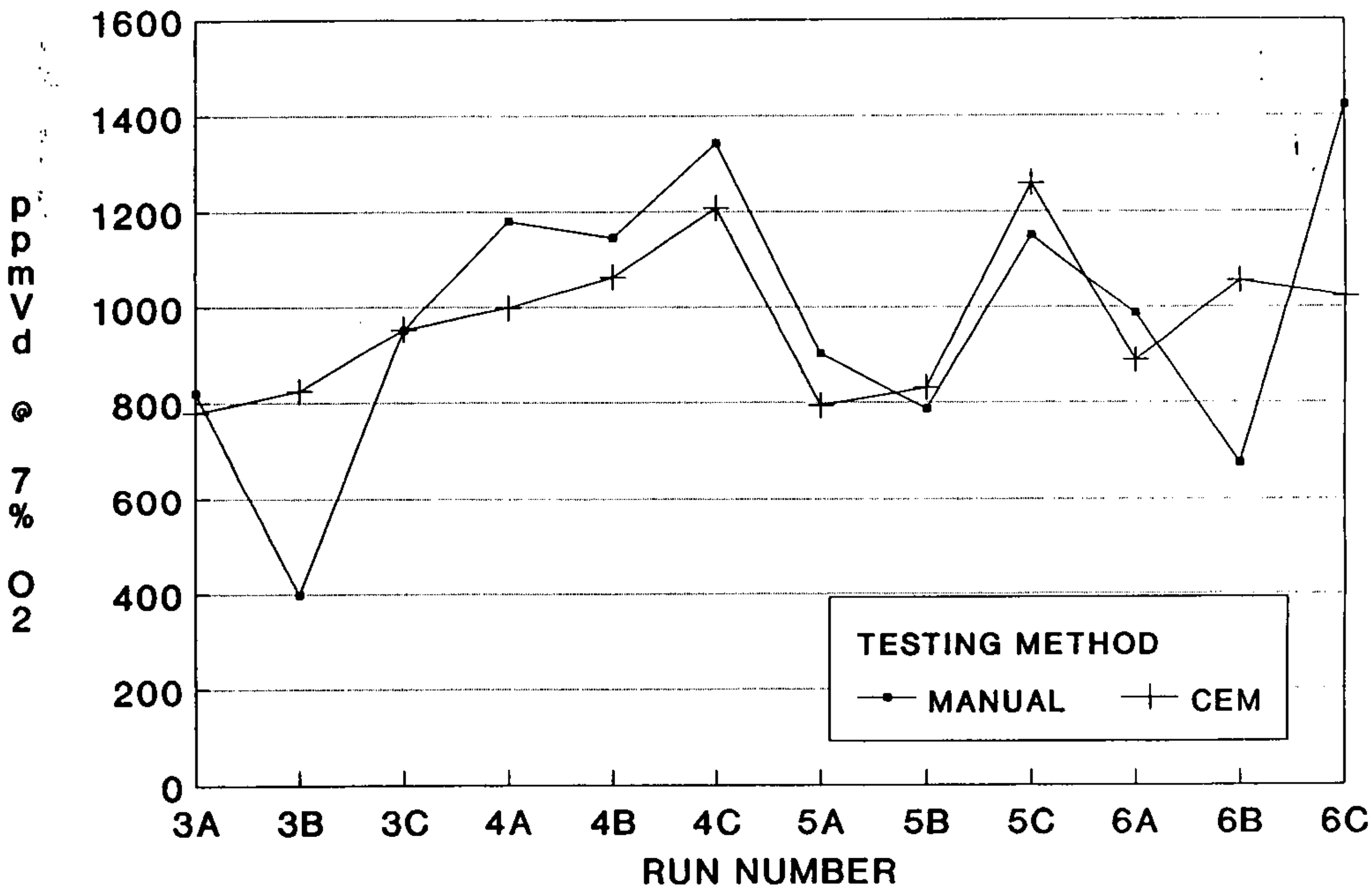


**Figure 2-5.** **HCl Results Comparison - Spray Dryer Inlet Morristown Memorial Hospital (1991)**

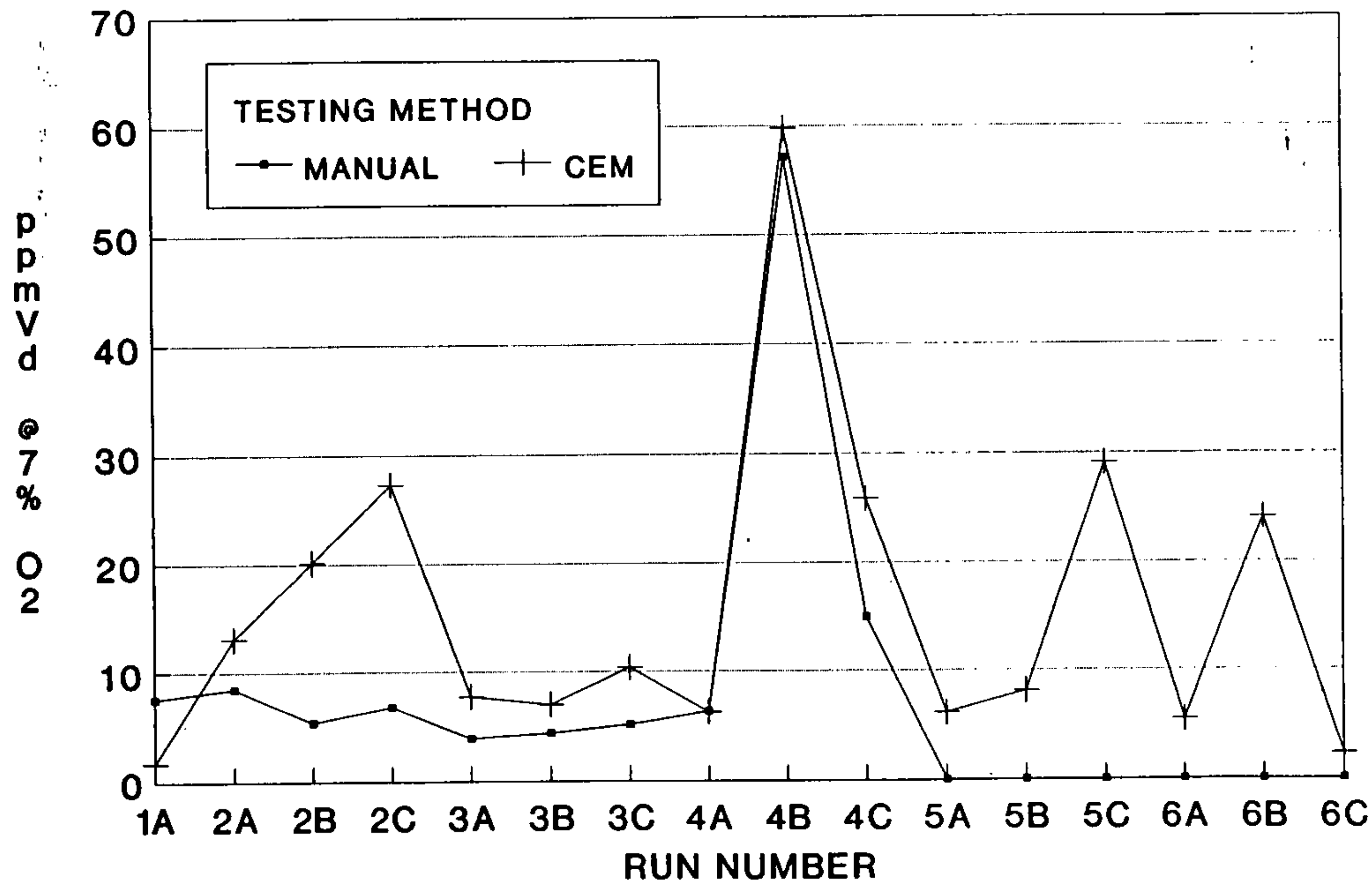


Figure 2-6. HCl Results Comparison - Baghouse Outlet Morristown Memorial Hosptial (1991)

TABLE 2–48. SUMMARY OF HYDROGEN FLUORIDE REMOVAL RESULTS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| RUN NO. | SPRAYDRYER INLET | | | | | BAGHOUSE OUTLET | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | O2 CONC. (% VOL) | FLUE GAS FLOW (dscmm) | GAS CONC. (ppmV) | GAS CONC. (ppmV @7% O2) | EMISSION RATE (lb/hr) | O2 CONC. (% VOL) | FLUE GAS FLOW (dscmm) | GAS CONC. (ppmV) | GAS CONC. (ppmV @7% O2) | EMISSION RATE (lb/hr) | REMOVAL EFFICIENCY (%) |
| 1A | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | (1.56) | (3.20) | (0.0232) | NA |
| 1B | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | b | b | b | NA |
| 1C | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | b | b | b | NA |
| AVERAGE | | | NA | NA | NA | | | 1.565 | 3.198 | 0.023 | NA |
| 2A | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | [0.308] | [0.629] | [0.0048] | NA |
| 2B | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | [0.270] | [0.552] | [0.0042] | NA |
| 2C | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | [0.254] | [0.520] | [0.0039] | NA |
| AVERAGE | | | NA | NA | NA | | | [0.277] | [0.567] | [0.0043] | NA |
| 3A | 10.6 | 100.0 | (0.994) | (1.342) | (0.011) | 13.4 | 140.4 | [0.246] | [0.457] | [0.0038] | 65.2 |
| 3B | 10.6 | 100.0 | [0.721] | [0.972] | [0.008] | 13.4 | 140.4 | [0.332] | [0.615] | [0.0051] | c |
| 3C | 10.6 | 100.0 | [0.540] | [0.729] | [0.006] | 13.4 | 140.4 | [0.225] | [0.417] | [0.0035] | c |
| AVERAGE | | | 0.994 | 1.34 | 0.011 | | | [0.268] | [0.496] | [0.0041] | 65.2 |
| COND. 1 AVG. | 10.9 | 98.0 | 0.994 | 1.34 | 0.011 | 13.9 | 138.7 | 1.565 | 3.198 | 0.023 | 65.2 |
| 4A | 10.4 | 94.7 | 11.1 | 14.7 | 0.115 | 13.8 | 137.1 | [0.284] | [0.556] | [0.0043] | 96.3 |
| 4B | 10.4 | 94.7 | 3.87 | 5.13 | 0.040 | 13.8 | 137.1 | [0.164] | [0.321] | [0.0025] | 93.9 |
| 4C | 10.4 | 94.7 | 5.40 | 7.15 | 0.056 | 13.8 | 137.1 | [0.178] | [0.349] | [0.0027] | 95.2 |
| AVERAGE | | | 6.79 | 8.98 | 0.071 | | | [0.209] | [0.409] | [0.0032] | 95.1 |
| 5A | 10.8 | 96.8 | 3.44 | 4.73 | 0.037 | 13.6 | 143.2 | [0.168] | [0.320] | [0.0027] | 92.8 |
| 5B | 10.8 | 96.8 | 4.03 | 5.55 | 0.043 | 13.6 | 143.2 | [0.173] | [0.329] | [0.0027] | 93.7 |
| 5C | 10.8 | 96.8 | 5.84 | 8.03 | 0.062 | 13.6 | 143.2 | [0.163] | [0.310] | [0.0026] | 95.9 |
| AVERAGE | | | 4.43 | 6.10 | 0.047 | | | [0.168] | [0.320] | [0.0027] | 94.1 |
| 6A | 10.7 | 98.9 | [0.238] | [0.324] | [0.003] | 13.5 | 141.0 | [0.154] | [0.288] | [0.0024] | c |
| 6B | 10.7 | 98.9 | 1.82 | 2.48 | 0.020 | 13.5 | 141.0 | [0.152] | [0.285] | [0.0024] | 88.1 |
| 6C | 10.7 | 98.9 | 2.67 | 3.64 | 0.029 | 13.5 | 141.0 | [0.170] | [0.320] | [0.0026] | 90.9 |
| AVERAGE | | | 2.24 | 3.06 | 0.024 | | | [0.159] | [0.298] | [0.0025] | 89.5 |
| COND. 2 AVG. | 10.6 | 96.8 | 4.77 | 6.42 | 0.050 | 13.6 | 140.4 | [0.178] | [0.342] | [0.0028] | 93.3 |

a The flow rates determined by the CDD/CDF sampling trains were used for HCl emission rate calculations.
b The results are not reported because the data does not fall within acceptable control limits.
c The removal efficiency is not calculated because both inlet and outlet results are non–detects.
d [] = Not detected at the limit shown; () = Less than five times the detection limit.
e Detection limits are not considered when calculating averages.

less than 0.006 lb/hr to 0.01 lb/hr with and average of 0.01 lb/hr. The HF concentrations exiting the baghouse ranged from less than 0.4 ppmvd at 7 percent $O_2$ to 3.2 ppmvd at 7 percent $O_2$ with an average of 2.2 ppmvd at 7 percent $O_2$. The HF emission rate at the baghouse outlet ranged from less than 0.004 lb/hr to 0.02 lb/hr with an average of 0.016 lb/hr.

For Condition 2, the HF concentration at the spray dryer inlet ranged from less than 0.3 ppmvd at 7 percent $O_2$ to 14.7 ppmvd at 7 percent $O_2$ with an average of 6.4 ppmvd at 7 percent $O_2$. The emission rate of HF entering the spray dryer ranged from less than 0.003 lb/hr to 0.1 lb/hr with an average of 0.05 lb/hr. The HF concentration at the baghouse outlet ranged from less than 0.3 ppmvd at 7 percent $O_2$ to less than 0.6 ppmvd at 7 percent $O_2$ with an average of less than 0.34 ppmvd at 7 percent $O_2$. At the baghouse outlet, the HF emission rate ranged from less than 0.002 lb/hr to less than 0.004 lb/hr with an average of less than 0.003 lb/hr.

A comparison of the emission rates for both conditions at the spray dryer inlet cannot be made because only one detectable value at the inlet is reported. The baghouse outlet emission rates for both conditions are consistent. During Condition 1, HF was not detected in any of the 9 samples. The removal efficiency of the only reported run during Condition 2 ranged from 88.1 to 96.3 percent. With only one valid removal efficiency for Condition 1, it cannot be concluded with confidence that the injection of carbon into the lime slurry improves the HF removal efficiency of the emission control system.

### 2.6.3 Hydrogen Bromide Results

Table 2-49 summarizes the HBr spray dryer inlet and baghouse outlet concentrations and emission rates, as well as the removal efficiencies for the emission control system. The removal efficiencies could not be calculated for the first six runs for reasons discussed previously.

For Condition 1, the HBr concentration at the spray dryer inlet ranged from 8.4 to 14.4 ppmvd at 7 percent $O_2$ with an average of 11.0 ppmvd at 7 percent $O_2$. The HBr emission rate at the spray dryer inlet ranged from 0.28 to 0.47 lb/hr with an average of 0.36 lb/hr. At the baghouse outlet, the HBr concentration ranged from less than 0.042 ppmvd at 7 percent $O_2$ to 2.01 ppmvd at 7 percent $O_2$ with an average of

## TABLE 2-49. SUMMARY OF HYDROGEN BROMIDE RESULTS MORRISTOWN MEMORIAL HOSPITAL (1991)

| RUN NO. | SPRAYDRYER INLET O2 CONC. (% VOL) | FLUE GAS FLOW (dscmm) | GAS CONC. (ppmV) | GAS CONC. (ppmV @7% O2) | EMISSION RATE (lb/hr) | BAGHOUSE OUTLET O2 CONC. (% VOL) | FLUE GAS FLOW (dscmm) | GAS CONC. (ppmV) | GAS CONC. (ppmV @7% O2) | EMISSION RATE (lb/hr) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | [0.034] | [0.070] | [0.0021] | NA |
| 1B | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | b | b | b | NA |
| 1C | 11.1 | 95.4 | b | b | b | 14.1 | 135.0 | b | b | b | NA |
| AVERAGE | | | NA | NA | NA | | | [0.034] | [0.070] | [0.0021] | NA |
| 2A | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | [0.023] | [0.048] | [0.0015] | NA |
| 2B | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | [0.020] | [0.042] | [0.0013] | NA |
| 2C | 11.1 | 98.5 | b | b | b | 14.1 | 140.7 | 0.168 | 0.343 | 0.011 | NA |
| AVERAGE | | | NA | NA | NA | | | 0.168 | 0.343 | 0.011 | NA |
| 3A | 10.6 | 100.0 | 10.7 | 14.4 | 0.474 | 13.4 | 140.4 | 0.287 | 0.532 | 0.018 | 96.2 |
| 3B | 10.6 | 100.0 | 7.54 | 10.2 | 0.335 | 13.4 | 140.4 | 0.357 | 0.661 | 0.022 | 93.4 |
| 3C | 10.6 | 100.0 | 6.19 | 8.36 | 0.276 | 13.4 | 140.4 | 1.08 | 2.01 | 0.068 | 75.5 |
| AVERAGE | | | 8.13 | 11.0 | 0.362 | | | 0.576 | 1.07 | 0.036 | 88.3 |
| **COND. 1 AVG.** | **10.9** | **98.0** | **8.13** | **11.0** | **0.362** | **13.9** | **138.7** | **0.474** | **0.886** | **0.030** | **88.3** |
| 4A | 10.4 | 94.7 | 5.80 | 7.68 | 0.244 | 13.8 | 137.1 | 0.348 | 0.680 | 0.021 | 91.3 |
| 4B | 10.4 | 94.7 | 9.64 | 12.8 | 0.406 | 13.8 | 137.1 | 0.277 | 0.541 | 0.017 | 95.8 |
| 4C | 10.4 | 94.7 | 2.73 | 3.61 | 0.115 | 13.8 | 137.1 | 0.256 | 0.502 | 0.016 | 86.4 |
| AVERAGE | | | 6.06 | 8.02 | 0.255 | | | 0.293 | 0.574 | 0.018 | 91.2 |
| 5A | 10.8 | 96.8 | 9.34 | 12.8 | 0.402 | 13.6 | 143.2 | [0.013] | [0.024] | [0.0008] | >99.8 |
| 5B | 10.8 | 96.8 | 7.32 | 10.1 | 0.315 | 13.6 | 143.2 | [0.013] | [0.025] | [0.0008] | >99.7 |
| 5C | 10.8 | 96.8 | 2.15 | 2.96 | 0.093 | 13.6 | 143.2 | [0.012] | [0.023] | [0.0008] | >99.2 |
| AVERAGE | | | 6.27 | 8.63 | 0.270 | | | [0.013] | [0.024] | [0.0008] | >99.6 |
| 6A | 10.7 | 98.9 | [0.018] | [0.024] | [0.0008] | 13.5 | 141.0 | [0.012] | [0.022] | [0.0007] | c |
| 6B | 10.7 | 98.9 | [0.020] | [0.027] | [0.0009] | 13.5 | 141.0 | [0.011] | [0.021] | [0.0007] | c |
| 6C | 10.7 | 98.9 | 2.70 | 3.68 | 0.119 | 13.5 | 141.0 | [0.013] | [0.024] | [0.0008] | >99.3 |
| AVERAGE | | | 2.70 | 3.68 | 0.119 | | | [0.012] | [0.022] | [0.0007] | >99.3 |
| **COND. 2 AVG.** | **10.6** | **96.8** | **5.67** | **7.66** | **0.242** | **13.6** | **140.4** | **0.293** | **0.574** | **0.018** | **95.9** |

a The flow rates determined by the CDD/CDF sampling trains were used for HCl emission rate calculations.
b The results are not reported because the data is not within acceptable control limits.
c The removal efficiency is not calculated because both inlet and outlet results are non-detectible.
d [] = Not detected at the limit shown; () = Less than five times the detection limit.
e Detection limits are not considered when calculating averages.

0.89 ppmvd at 7 percent $O_2$. The emission rate of HBr exiting the baghouse ranged from less than 0.0013 lb/hr to 0.068 lb/hr with an average of 0.030 lb/hr.

For Condition 2, the HBr concentration at the spray dryer inlet ranged from less than 0.024 ppmvd at 7 percent $O_2$ to 12.8 ppmvd at 7 percent $O_2$ with an average of 7.7 ppmvd at 7 percent $O_2$. The emission rate of HBr entering the spray dryer ranged from less than 0.0008 lb/hr to 0.41 lb/hr with an average of 0.24 lb/hr. At the baghouse outlet, the concentration of HBr ranged from less than 0.021 ppmvd at 7 percent $O_2$ to 0.68 ppmvd at 7 percent $O_2$ with an average of 0.57 ppmvd at 7 percent $O_2$. The mass emission rate of HBr exiting the baghouse ranged from less than 0.0007 lb/hr to 0.021 lb/hr, averaging 0.018 lb/hr.

At the spray dryer inlet, the results for Conditions 1 and 2 are similar enough not to bias the removal efficiencies between the two conditions. In comparing the results at the baghouse outlet from both conditions, the average HBr emission rates for each condition showed little difference, 0.03 lb/hr for Condition 1 and 0.018 lb/hr for Condition 2. Although the average removal efficiency during carbon injection was 7.6 percentage points higher than the removal efficiency without carbon injection, there is not enough evidence to show that carbon injection actually improves the removal of HBr through the emission control system.

## 2.7 CEM RESULTS

Continuous emissions monitoring was conducted at the spray dryer inlet and baghouse outlet during all test runs. The CEMs were operated from the beginning to the end of the test run. Monitoring was performed using an extractive sample system and instrument methods to measure $NO_x$, CO, $SO_2$, THC, and HCl concentrations. The diluent gases ($O_2$, $CO_2$) were measured using CEMs at all times so that emission results could be normalized to a reference 7 percent $O_2$. Concentrations of $NO_x$, $SO_2$, CO, $CO_2$, and $O_2$ were measured on a dry basis. The THC concentrations were monitored on a wet basis, by allowing the sample stream to bypass the gas conditioners. All CEM data were recorded as one minute averages over each sampling interval.

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

A leak was detected in the inlet sample line for the $NO_x$, $SO_2$, CO, $CO_2$, THC, and $O_2$ analyzers at the end of the second test run. The $O_2$ values for these two test runs were assumed to be 3 percent lower than the outlet $O_2$ values. This assumption was based on the average difference between inlet and outlet $O_2$ values for Runs 3 through 6. The measured values for $NO_x$, $SO_2$, CO, $CO_2$, and THC for Runs 1 and 2 were corrected for the leakage using the assumed $O_2$ averages.

The one minute CEM values were averaged over the sampling interval for each test run. The averages summarized in Tables 2-50 and 2-51 present actual and normalized values, respectively. Actual concentrations are presented as they were measured ($NO_x$, $SO_2$, CO, $CO_2$, and $O_2$ on a dry basis; THC and HCl-wet and dry). Each one minute CEM reading was corrected to 7 percent $O_2$ based on the corresponding $O_2$ value. Averages of the corrected values were then calculated.

The $SO_2$ concentrations decreased from the inlet to the outlet for both test conditions. The average concentrations for Conditions 1 and 2 at the inlet were 10.5 and 17.8 ppmv (at 7 percent $O_2$) on a dry basis. The outlet concentrations were 9.2 and 3.9 ppmv. The removal was 78 percent for Condition 2 with carbon injection compared to 12.4 percent for Condition 1. The CO concentrations were very low for all runs, showing good combustion efficiency. The measured concentrations were lower at the inlet than at the outlet. Records of the responses of the inlet and outlet CO monitors to QC gases show that the outlet monitor responded with a slightly lower value that the inlet monitor. The actual difference in CO concentrations at these locations, therefore, is probably not significant. CO concentrations were less than 3 ppmv at the outlet for all runs. The CO analyzer used had a scale of 0 to 500 ppm and hence readings near the zero scale might be biased toward the lower end. The $CO_2$ concentrations (at 7% $O_2$) were not significantly different between inlet and outlet. The outlet analyzer was off line for Runs 1 and 2. The averages for the 2 test conditions at the inlet and outlet were 9.7, 8.8, 9.9, and 9.9 percent, respectively. The $NO_x$ concentrations (at 7% $O_2$) were almost the same at the inlet and outlet. The HCl concentrations decreased from the inlet to the outlet and are discussed in more detail in Section 2.6.

Table 2-50

Continuous Emissions Monitoring Test Averages
Morristown Memorial Hospital (1991)

| Date | Run Number | $O_2$ (%V, dry) | CO (ppmv, dry) | $CO_2$ (%V, dry) | $SO_2$ (ppmv, dry) | $NO_x$ (ppmv, dry) | $H_2O$ (%) | THC (ppmv, wet) | THC (ppmv, dry) | HCl (ppmv, wet) | HCl (ppmv,dry) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Spray Dryer Inlet Data** | | | | | | | | | | | |
| 11-18-91 | 1 | 11.1 | 15.5 | 6.4 | 5.9 | 60.3 | 15.9 | 3.9 | 4.6 | 663.1 | 788.5 |
| 11-19-91 | 2 | 11.1 | 8.5 | 7.8 | 9.5 | 57.0 | 15.5 | 2.5 | 3.0 | 498.1 | 589.5 |
| 11-20-91 | 3 | 10.6 | 7.1 | 6.7 | 7.1 | 65.2 | 14.9 | 1.2 | 1.4 | 524.9 | 616.8 |
| Condition 1 Avg | | 10.93 | 10.37 | 6.97 | 7.5 | 60.83 | 15.4 | 2.53 | 3.0 | 562.0 | 664.3 |
| 11-21-91 | 4 | 10.4 | 6.4 | 6.6 | 17.8 | 63.5 | 14.7 | 2.8 | 3.3 | 673.0 | 788.9 |
| 11-22-91 | 5 | 10.8 | 8.7 | 6.5 | 16.0 | 61.3 | 13.9 | 2.5 | 2.9 | 586.0 | 680.6 |
| 11-23-91 | 6 | 10.7 | 4.7 | 6.5 | 6.0 | 58.6 | 14.0 | 0.5 | 0.6 | 593.1 | 689.7 |
| Condition 2 Avg | | 10.63 | 6.6 | 6.53 | 13.27 | 61.13 | 14.2 | 1.93 | 2.3 | 617.4 | 719.6 |
| **Baghouse Outlet Data** | | | | | | | | | | | |
| 11-18-91 | 1 | 14.1 | 1.0 | [a] | 2.6 | 49.6 | 14.6 | 1.1 | 1.3 | 9.2 | 10.8 |
| 11-19-91 | 2 | 14.1 | 0.3 | [a] | 9.3 | 45.7 | 13.8 | 0.7 | 0.8 | 8.5 | 9.9 |
| 11-20-91 | 3 | 13.4 | 0.5 | 5.3 | 1.7 | 47.5 | 14.7 | 0.9 | 1.1 | 3.7 | 4.3 |
| Condition 1 Avg | | 13.87 | 0.6 | 5.3 | 4.53 | 47.6 | 14.4 | 0.9 | 1.1 | 7.13 | 8.3 |
| 11-21-91 | 4 | 13.8 | 0.1 | 5.2 | 2.8 | 47.1 | 14.8 | 1.2 | 1.4 | 10.5 | 12.3 |
| 11-22-91 | 5 | 13.6 | 1.5 | 5.0 | 2.6 | 45.6 | 13.4 | 1.2 | 1.4 | 5.6 | 6.5 |
| 11-23-91 | 6 | 13.5 | 0.6 | 5.3 | 0.6 | 46.4 | 13.0 | 1.1 | 1.3 | 4.0 | 4.6 |
| Condition 2 Avg | | 13.63 | 0.73 | 5.17 | 2.0 | 46.4 | 13.7 | 1.17 | 1.4 | 6.7 | 7.8 |

[a]Instrument off line.

Note: Data for 11/18/91 and 11/19/91 were corrected for inleakage.
$O_2$ was made to be 3 prcent lower than the outlet $O_2$ (3 percent is the average difference in inlet and outlet $O_2$ for 11/19 through 11/23/91). CO, $CO_2$, $SO_2$, $NO_x$, and THC were corrected for the new $O_2$ level.

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Table 2-51

Continuous Emissions Monitoring Test Averages
Normalized to 7 Percent Oxygen
Morristown Memorial Hospital (1991)

| Concentration, ppmv, dry at 7% $O_2$ | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | Run Number | CO | $CO_2$ | $SO_2$ | $NO_x$ | THC | HCl |
| Spray Dryer Inlet Data | | | | | | | |
| 11-18-91 | 1 | 21.9 | 9.0 | 8.4 | 85.2 | 6.5 | 1118.4 |
| 11-19-91 | 2 | 12.0 | 11.0 | 13.5 | 81.1 | 4.3 | 836.1 |
| 11-20-91 | 3 | 9.7 | 9.1 | 9.6 | 88.4 | 1.9 | 832.4 |
| Condition 1 Avg. | | 14.5 | 9.7 | 10.5 | 84.9 | 4.2 | 926.2 |
| 11-21-91 | 4 | 8.4 | 8.7 | 23.4 | 83.7 | 4.4 | 1044.4 |
| 11-22-91 | 5 | 11.9 | 9.0 | 22.0 | 84.4 | 4.0 | 936.7 |
| 11-23-91 | 6 | 6.4 | 8.8 | 8.1 | 79.6 | 0.8 | 939.9 |
| Condition 2 Avg | | 8.9 | 8.8 | 17.8 | 82.6 | 3.1 | 973.9 |
| Baghouse Outlet Data | | | | | | | |
| 11-18-91 | 1 | 2.0 | [a] | 5.2 | 101.0 | 2.7 | 22.1 |
| 11-19-91 | 2 | 0.6 | [a] | 19.1 | 93.9 | 1.6 | 20.2 |
| 11-20-91 | 3 | 0.9 | 9.9 | 3.2 | 88.2 | 2.0 | 7.9 |
| Condition 1 Avg | | 1.2 | 9.9 | 9.2 | 94.4 | 2.2 | 16.4 |
| 11-21-91 | 4 | 0.2 | 10.3 | 5.5 | 92.7 | 2.7 | 24.1 |
| 11-22-91 | 5 | 2.9 | 9.6 | 5.1 | 87.4 | 2.7 | 12.4 |
| 11-23-91 | 6 | 1.2 | 10.0 | 1.2 | 87.8 | 2.4 | 8.6 |
| Condition 2 Avg | | 1.4 | 9.9 | 3.9 | 89.3 | 2.7 | 14.9 |

[a] Instrument off line.

Note: Data for 11/18/91 and 11/19/91 were corrected for inleakage.
$O_2$ was made to be 3 percent lower than the outlet $O_2$ (3 percent is the average difference in inlet and outlet $O_2$ for 11/19 through 11/23/91). CO, $CO_2$, $SO_2$, $NO_x$, and THC were corrected for the new $O_2$ level.

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## 2.8 MICROBIAL SURVIVABILITY RESULTS

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

### 2.8.1 Background and Test Matrix

One of the objectives of this test program was to further develop testing methods to determine microbial survivability in incinerator processes. As part of the MWI test program at Morristown Memorial, testing was conducted to determine microbial survivability based on a surrogate indicator organism that was spiked into the incinerator feed during test Runs 1, 2, and 3. The surrogate indicator organism was the soil spore Bacillus stearothermophilus (B. stearothermophilus). This organism was chosen because it survives at high temperatures and it is easy to culture and identify. Also, it is non-pathogenic and is not commonly found in medical waste streams.

Two types of testing were performed. The purpose of the first test method was to determine microbial survivability in the combustion gases (emissions) and the bottom ash, spray dryer residue, and baghouse ash. For these tests, a known quantity of B. stearothermophilus in solution was absorbed onto materials commonly found in the medical waste stream and introduced into the incinerator at regular intervals during each run. Emissions testing was conducted at the incinerator exit upstream of the air pollution control system following the EPA draft method "Microbial Survivability Test for Medical Waste Incinerator Emissions." This testing was performed concurrently with other emissions testing (PM/Metals, CDD/CDF, halogens, and CEMs) during the burn periods. Ash samples were taken following each test run after the ash was cool enough to handle. The ash was sampled and analyzed as described in the EPA Draft Method "Microbial Survivability Test for Medical Waste Incinerator Ash."

The second Microbial Survivability test method utilized freeze dried spores encapsulated in metal pipes which were insulated with high temperature ceramic insulation and wrapped in wire mesh. This test was used to aid in the assessment of microbial survivability in the ash. Each pipe sample also contained five temperature indicating pellets. The pellets were selected to melt at specific temperatures between

400°F and 1200°F. They were used to record the maximum sample temperature reached in the incinerator.

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

Three test runs were performed at the rated incinerator operating conditions over a period of three days. At the start of each four-hour test run, liquid spores were poured into a plastic garbage bag containing absorbent materials and two dry spore pipe samples. The bag was then charged into the incinerator with the normal waste stream. This procedure was repeated each hour during the test, until a total of four bags of wet spores and eight dry spore pipe samples had been charged into the incinerator. A final dry spore pipe sample was charged into the incinerator at the end of the fourth testing hour, bringing the total number of pipe samples per test to nine.

Table 2-52 summarizes the spore spiking times, the total weight fed to the incinerator, and the total ash weights generated during each test run.

### 2.8.2 Overall Microbial Survivability

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

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

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

This is an adaptation of the destruction efficiency (DE) calculation presented in the reference test protocol which calculates DE based only on stack emissions and a separate DE based on spores in ash. By combining the two DE estimates, a more complete estimate of Microbial Survivability (1 - DE) is obtained. The total number of spores in the ash was calculated by multiplying the number of spores found in 1 gram of ash by

Table 2-52
Summary of Incinerator Feed and Ash Generation
Morristown Memorial Hospital (1991)

| Test Day | Date | Run Number | Time | Wet Spore[a] Samples | Dry (Pipe) Spore[b] Samples | Total Waste Feed (lbs) | Total Ash Weight (lbs) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Bottom | Spray Dryer | Baghouse |
| 1 | 11/18/91 | 1 | 1408 | 1 | 2 | | | | |
| | | | 1506 | 1 | 2 | | | | |
| | | | 1601 | 1 | 2 | | 325 | 17 | 185 |
| | | | 1703 | 1 | 2 | | | | |
| | | | 1803 | 0 | 1 | | | | |
| 2 | 11/19/91 | 2 | 1552 | 1 | 2 | | | | |
| | | | 1700 | 1 | 2 | | | | |
| | | | 1756 | 1 | 2 | | 256 | 15 | 122 |
| | | | 1851 | 1 | 2 | | | | |
| | | | 1958 | 0 | 1 | | | | |
| 3 | 11/20/91 | 3 | 1234 | 1 | 2 | | | | |
| | | | 1331 | 1 | 2 | | | | |
| | | | 1431 | 1 | 2 | | 404 | 98 | 215[c] |
| | | | 1648 | 1 | 2 | | | | |
| | | | 2155 | 0 | 1 | | | | |

[a] Each wet spore sample contained approximately 3.5 x 10E11 spores in 500 ml of solution.
[b] Each dry spore contained approximately 1 x 10E7 freeze-dried spores.
[c] Filter cake was removed during run on 11/20/91. Total ash dropped was 859 lbs in 1.5 hours. The 215 lbs shown in the table does not included any of the ash from cake removal.

the total weight of ash removed from the incinerator per day. The analytical results are shown in Appendix E.3.

Table 2-53 presents the overall survivability of the indicator spores. No viable spores were found either in the stack gas samples or in the incinerator ash. Flue gas microbial survivability are further discussed in the following sections.

2.8.3 Microbial Survivability in Emissions

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

Approximately 1.5 liters of impinger collection solution was generated for each run. These run samples were recovered in a disinfected mobile laboratory, sealed, and sent to the analytical laboratory.

For each run performed, 9 aliquots were prepared for analysis: three 10 ml aliquots, three 100 ml aliquots, and 3 equal aliquots of a remaining filterable amount of sample. Both a first and second count on each aliquot were performed. The first count was conducted after approximately 24 hours incubation, and the second after approximately a 48 hour incubation period. Previous research has shown that the spore count does not increase after the 48-hour count incubation period. No viable spores were seen in any of the run samples after the 48-hour incubation period.

The Microbial Survivability sampling and flue gas parameters are shown in Table 2-54.

2.8.4 Microbial Survivability in Ash

Incinerator bottom ash was removed from the incinerator after each run and stored in a pre-cleaned, disinfected covered steel hopper. A composite ash sample was prepared by first removing large pieces of metal and glass from the hopper, then mixing the remaining ash and placing samples into clean, amber glass sample bottles. Spray dryer ash and baghouse ash were similarly composited into bottles after each run. The composite samples were then submitted to the laboratory for culturing, and enumeration of B. stearothermophilus.

Table 2-53

Overall Microbial Survivability
Morristown Memorial Hospital (1991)

| Test Day | Date | Run Number | Number of Indicator Spores Spiked | Number Indicator Spores Exiting the Stack | Number of Indicator Spores in Ash | Spore Survivability (%) |
|---|---|---|---|---|---|---|
| 1 | 11/18/91 | 1 | 14 x 10E11 | 0 | 0 | 0 |
| 2 | 11/19/91 | 2 | 14 x 10E11 | 0 | 0 | 0 |
| 3 | 11/20/91 | 3 | 14 x 10E11 | 0 | 0 | 0 |

TABLE 2-54. SUMMARY OF FLUE GAS SAMPLING PARAMETERS
FOR INDICATOR SPORE EMISSIONS
MORRISTOWN MEMORIAL HOSPITAL (1991)

| | Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|
| Total Sample Time (min) | 231 | 240 | 151 | 207 |
| Average Sampling Rate (dscfm) | 0.61 | 0.58 | 0.61 | 0.60 |
| Dry Standard Meter Volume (dscf) | 140 | 140 | 91.4 | 123.8 |
| Dry Standard Meter Volume (dscm) | 3.96 | 3.96 | 2.59 | 3.50 |
| Average Stack Temperature (F) | 413 | 411 | 410 | 411 |
| Oxygen Concentration (% V) | 11.1 | 11.1 | 10.6 | 10.9 |
| Carbon Dioxide Concentration (% V) | 6.4 | 7.8 | 6.7 | 7.0 |
| Percent Moisture (% V) | 15.9 | 15.5 | 14.9 | 15.4 |
| Volumetric Flow Rate (dscfm) | 3512 | 3414 | 3617 | 3514 |
| Volumetric Flow Rate (dscmm) | 99.5 | 96.7 | 102 | 99.4 |
| Percent Isokinetic (%) | 96.6 | 95.7 | 93.8 | NA |

NA : Not applicable

No viable spores were found in any ash sample from the Morristown MWI tests. Three ash aliquots of approximately one gram were prepared from each sample. Six serial dilutions were prepared on each ash aliquot and triple plated. A summary of the analytical data is shown in Appendix E.3.

2.8.5 Microbial Survivability in Pipes

Pipe samples were loaded into the incinerator during each test run. The pipes were recovered the following morning during bottom ash sampling. Approximately half of the samples charged into the incinerator were recovered. The rest were lost, probably after becoming imbedded in the masses of molten glass which roll through the incinerator. Pipe samples which were recovered were removed from their insulating wrappings. The condition of the temperature indicating pellets was noted and the inner containers were sent to the laboratory for analysis. The analysis results from the recovered pipes are shown in Table 2-55.

Table 2-55

Spore Pipe Sample Recovery and Analysis Results

| Run Number | Date | Sample Number | Charge Time | Sample Recovery | Maximum Temp. | Spores Cultured |
|---|---|---|---|---|---|---|
| 1 | 11/18/91 | 10 | 1408 | Yes | < 1200 | 0 |
| 1 | 11/18/91 | 11 | 1408 | Yes | < 1000 | 0 |
| 1 | 11/18/91 | 12 | 1506 | Yes | [a] | 0 |
| 1 | 11/18/91 | 13 | 1506 | Yes | > 1200 | 0 |
| 1 | 11/18/91 | 14 | 1601 | Yes | > 1200 | 0 |
| 1 | 11/18/91 | 16 | 1601 | Yes | > 1200 | 0 |
| 1 | 11/18/91 | 17 | 1703 | No | > 1200 | -- |
| 1 | 11/18/91 | 18 | 1703 | No | [d] | -- |
| 1 | 11/18/91 | 19 | 1803 | Yes | > 1200 | 0 |
| 2 | 11/19/91 | 20 | 1552 | No | [d] | -- |
| 2 | 11/19/91 | 21 | 1552 | Yes | < 1200 | 0 |
| 2 | 11/19/91 | 22 | 1700 | No | [d] | -- |
| 2 | 11/19/91 | 23 | 1700 | No | [d] | -- |
| 2 | 11/19/91 | 24 | 1756 | No | [d] | -- |
| 2 | 11/19/91 | 26 | 1756 | No | [d] | -- |
| 2 | 11/19/91 | 27 | 1851 | No | [d] | -- |
| 2 | 11/19/91 | 28 | 1851 | No | [d] | -- |
| 2 | 11/19/91 | 29 | 1958 | No | [d] | -- |
| 3 | 11/20/91 | 30 | 1234 | Yes | [d] | 0 |
| 3 | 11/20/91 | 31 | 1234 | Yes[c] | [d] | 0 |
| 3 | 11/20/91 | 32 | 1331 | Yes | [d] | 0 |
| 3 | 11/20/91 | 33 | 1331 | No | [d] | -- |
| 3 | 11/20/91 | 34 | 1431 | No | [d] | -- |
| 3 | 11/20/91 | 36 | 1431 | Yes | > 1200 | 0 |
| 3 | 11/20/91 | 37 | 1648 | No | [d] | -- |
| 3 | 11/20/91 | 38 | 1648 | Yes | [d] | 0 |

Table 2-55 (Continued)

| Run Number | Date | Sample Number | Charge Time | Sample Recovery | Maximum Temp. | Spores Cultured |
|---|---|---|---|---|---|---|
| 3 | 11/20/91 | 39 | 2155 | No | [d] | -- |
| 1 | 11/18/91 | 71[a] | 1631 | Yes | >1200 | 1 |
| 3 | 11/20/91 | 72[a] | 2120 | Yes | >1200 | 0 |
| -- | -- | 81[b] | -- | Yes | ambient | TNTC[e] |
| -- | -- | 82[b] | -- | Yes | ambient | TNTC |

[a] Pipe samples 71 and 71 were empty sample blanks.
[b] Pipe samples 81 and 82 were field blank control samples, which were not charged into the incinerator.
[c] One sample was recovered from Run 3 without the sample identification tag. It was arbitrarily identified as No. 31.
[d] Temperature pellets not recovered.
[e] TNTC = to numerous to count.