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Emission Test Report

Signal Environmental Systems, Inc.
North Andover RESCO
North Andover, Massachusetts

Volume I: Summary of Results

DCN No. 87-222-124-06-02 EMB Report No. 86-MIN-2

EMISSION TEST REPORT
PCDD/PCDF, METALS AND PARTICULATE TESTING

SIGNAL ENVIRONMENTAL SYSTEMS, INC.
NORTH ANDOVER RESCO
NORTH ANDOVER, MASSACHUSETTS

VOLUME I: SUMMARY OF RESULTS

ESED Project No. 86/19
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April 1987

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RADIAN REPORT CERTIFICATION

This report has been reviewed by the following Radian personnel and is a true representation of the results obtained from the sampling program at Signal Environmental Systems, Inc., North Andover RESCO, North Andover, Massachussetts. The sampling and analytical methods were performed in accordance with procedures outlined in the Revised Sampling and Analytical Plan for Method Development and Testing for Municipal Waste Combustion Incinerators at the North Andover facility dated July 2, 1986. The sampling and analytical plan was reviewed and accepted by the EPA/EMB Task Manager, Clyde E. Riley.

The subcontracting laboratories, N.C. State Nuclear Services and Triangle Laboratories, Inc., have included their report certifications in their respective laboratory reports, which are contained in the appendices.

APPROVAL

Project Director: Winton E. Kelly Date: May 7, 1987
Winton E. Kelly

Program Manager: Robert M. Dykes Date: May 7, 1987
Robert M. Dykes

QA Officer: Donna J. Holder Date: May 7, 1987
Donna J. Holder

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1.0 INTRODUCTION

The results of an EPA emission test on a munipical solid waste incinerator are presented in this report. The Environmental Protection Agency is currently developing a comprehensive source category document for the municipal waste combustor (MWC) source category. The Office of Solid Waste, (OSW), the Office of Air Quality Planning and Standards (OAQPS) and the Office of Research and Development (ORD) are participating in a joint effort to assess the potential environmental impact of municipal solid waste (MSW)-fired resource recovery facilities and to identify any emissions for which additional regulations may be considered.

The Emission Standards and Engineering Division (ESED) of 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. Several MSW emission tests are being performed for this test program. The results of one of these tests are the subject of this report. The data base supplemented by these test results will then be used to estimate emission factors and to evaluate the various emissions reduction alternatives that are available for MWC facilities.

The emissions that are being studied in this assessment are the criteria pollutants--particulate matter, sulfur oxides, nitrogen oxides, carbon monoxide and hydrocarbons; other acid gases, such as HCl; chlorinated organics including polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF); and, specific metals including arsenic, cadmium, chromium, mercury, nickel, lead and beryllium.

The emissions data presented in this report were collected during a joint test program sponsored by EPA and Signal Environmental Systems, Inc. This report presents the results of the EPA-sponsored testing at the North Andover, MA, facility. The results of the test program sponsored by Signal Environmental Systems, Inc., have been reported separately.[1] In addition to

this report, a summary report is being prepared by Radian Corporation that will present the complete set of data that was collected during the joint sampling program. The summary report will discuss and analyze the uncontrolled and controlled data as well as analyses of both the ESP ash and bottom ash. Also, a more detailed analysis of the continuous monitoring, incinerator and ESP operating data will be presented.

It should be noted that the trace metal data presented in this document are the results of an in-house EPA development study. During this study non-established EPA reference test procedures were used to collect and analyze the metals samples. These trace metals data are presented for the convenience of EPA and are not intended to represent the true trace metals emissions being emitted from the facility.

1.1 BACKGROUND

Signal Environmental Systems, Inc. was required by the Massachusetts Department of Environmental Quality Engineering (MDEQE) to conduct a program to measure the PCDD/PCDF emissions in the flue gas and the PCDD/PCDF concentration in the process ash streams at the North Andover RESCO municipal solid waste resource recovery facility in North Andover, Massachusetts. Radian Corporation was retained by Signal Environmental to conduct that program.

In order to provide additional data to evaluate the PCDD/PCDF and metals removal effectiveness of emissions reduction systems, Signal Environmental and EPA agreed to jointly sponsor an expanded program during the MDEQE-required tests. Signal Environmental sponsored PCDD/PCDF and total organic chlorine (TOCL) tests at the ESP outlet, and EPA sponsored both PCDD/PCDF tests at the ESP inlet and metals and particulate testing at the ESP inlet and outlet locations. Ash sampling was sponsored by Signal during the PCDD/PCDF tests and by EPA during the metals test runs. Radian Corporation, under contract to the EMB performed the EPA-sponsored tests.

1.2 OBJECTIVES

The objective of the EPA-sponsored test program was to obtain PCDD/PCDF, metals, and particulate data from a state-of-the-art MWC controlled by an electrostatic precipitator (ESP). The North Andover facility was selected by EPA because the facility was a well-designed and operated mass burn, waterwall, resource recovery system with a state-of-the-art ESP. The EPA-sponsored test program was designed to obtain:

- PCDD/PCDF uncontrolled flue gas emission results that could be compared with the Signal-sponsored PCDD/PCDF controlled results.
- Uncontrolled and controlled flue gas, particulate and specific trace metals for program evaluation.
- The effect that MWC uncontrolled and controlled flue gas emission matrices have on the trace metals analysis as performed by the neutron activation analytical technique.
- The uncontrolled and controlled characteristics and inter-relationship of the particulate matter, PCDD/PCDF, and trace metals flue gas concentrations.
- Trace metal results for the ESP flyash that was being generated during the trace metal air emissions test program.
- Continuous emissions monitoring (CEM) information for oxygen, carbon monoxide and carbon dioxin during the particulate/metals test program.

The results from the North Andover Facility will be incorporated into the data base for the comprehensive study report, and will be used in support of any future regulatory development which is undertaken for the MWC source category.

1.3 BRIEF PROCESS OPERATION AND DESCRIPTION

Figure 1-1 presents a process diagram of the two identical incinerator systems at the North Andover facility. Unit No. 2 was tested during this program. Unit No. 2 is a reciprocating grate, mass-burning type incinerator with a waterwall boiler that produces superheated steam. The flue gas passes from the incinerator into superheater, generator and economizer sections

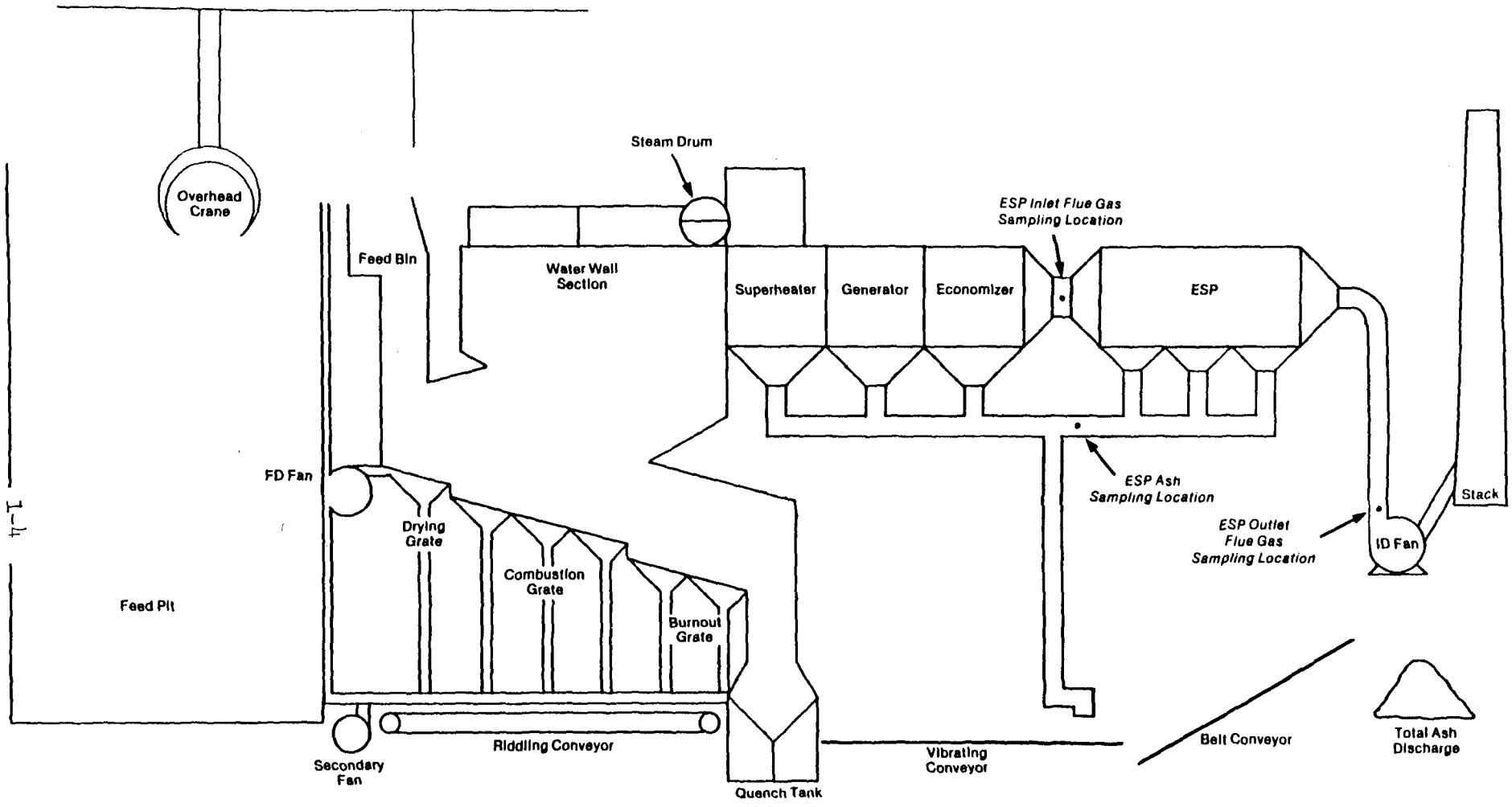


Figure 1 - 1. North Andover RESCO Process Line with Sampling Locations

before the particulate emissions are controlled by an ESP.

The refuse is typical residential and commercial solid waste. No sorting or shredding is performed prior to incineration. The refuse is brought to the enclosed tipping area by truck and unloaded into the receiving pit. A manually-operated overhead crane transfers the refuse from the receiving pit to the incinerator charging chute. A Martin inclined grate and ash discharge system is in operation at the North Andover facility.

Radian Corporation incorporated into this report the process description and operation section (Section 3) that was prepared by Midwest Research Institute (MRI). The incinerator operating data recorded during the test program as well as design data are summarized in Section 3. The operation of the ESP was also monitored during the test program. However, Signal Environmental Systems considers the ESP operating data to be confidential and it is not included in this report. The original incinerator data sheets are included in Appendix G.

1.4 EMISSION MEASUREMENT PROGRAM

1.4.1 Test Program Matrix

The emission measurement program at the North Andover facility was conducted from July 8 to July 16, 1986. Table 1-1 presents the original test matrix that was planned for the program as well as the organizations that sponsored each type of sample.

Once on-site, the test matrix was modified in several ways. Problems with the overhead I-beam used at the ESP inlet to support the vertical sampling trains caused the first PCDD/PCDF and TOCL/PM run at the ESP inlet to be cancelled. Then, due to the logistical problems presented by operating two vertical sampling trains with 10-foot probes at an eight-port sampling location, the TOCL/PM at the ESP inlet was cancelled by the EPA Task Manager.

TABLE 1-1. ORIGINAL TEST MATRIX FOR NORTH ANDOVER RESCO[a]

Run	PCDD/PCDF		TOCL/PM[c]		METALS/PM				
	ESP Inlet	ESP Outlet	ESP Inlet[b]	ESP Outlet	ESP Inlet	ESP Outlet	ESP Ash	Bottom Ash	CEMs[d]
1	EPA[e]	Signal	EPA	Signal-TOCL EPA-PM	--	--	Signal	Signal	Signal
2	EPA[f]	Signal	EPA	Signal-TOCL EPA-PM	--	--	Signal	Signal	Signal
3	EPA	Signal	EPA	Signal-TOCL EPA-PM	--	--	Signal	Signal	Signal
4	EPA	Signal	EPA	Signal-TOCL EPA-PM	--	--	Signal	Signal	Signal
5	EPA	Signal	EPA	Signal-TOCL EPA-PM	--	--	Signal	Signal	Signal
6	EPA[f]	Signal	EPA	Signal-TOCL EPA-PM	--	--	Signal	Signal	Signal
7	--	--	--	--	EPA	EPA	EPA	--	EPA
8	--	--	--	--	EPA	EPA	EPA	--	EPA
9	--	--	--	--	EPA	EPA	EPA	--	EPA

[a]Dashes indicate that the sample was not collected. Also, Signal = Signal Environmental Systems, Inc.

[b]The TOCL/Particulate samples for Runs 1-6 at the ESP inlet was cancelled due to sampling location logistical problems.

[c]PM = particulate matter.

[d]Continuous emissions monitors were used to measure O_2, CO_2, and CO at the ESP outlet.

[e]The ESP Inlet PCDD/PCDF sample for Run 1 was not collected because the sampling location was not ready.

[f]The ESP Inlet PCDD/PCDF samples for Run 2 and Run 6 were not analyzed due to sampling and incinerator operating problems that occurred during these runs.

During PCDD/PCDF Runs 2, 3, 4, 5, and 6, sampling for at the ESP inlet was conducted according to the December 1984 draft of the Environmental Standards Workshop protocol for sampling PCDD's and PCDF's. The PCDD/PCDF sampling at the ESP inlet and ESP outlet was conducted simultaneously. Particulate loading was measured according to EPA Method 5 at the ESP outlet for Runs 1-6.

As part of an EPA in-house study, trace metals testing was conducted simultaneously at the ESP inlet and ESP outlet during Runs 7, 8, and 9. Sampling followed EPA Alternate Method 12, which also allows for the determination of particulate loading concurrently in the sampling train. The EPA Method 12 train has been demonstrated specifically for lead and cadmium only. However, for the purposes of the in-house study the method was used as a screening analysis for the other metals of interest. The method was also modified by using neutron activation (NAA) as the analysis method rather than atomic adsorption. Neutron activation produces results for the full spectrum of detectable metals in one analytical step and is a cost-effective analysis on a per element and per sample basis. The results for arsenic, cadmium, total chromium and nickel are included in this report. The results for other metals are included in Appendix I.

Continuous emission monitoring (CEM) for oxygen (O_2), carbon monoxide (CO) and carbon dioxide (CO_2) was also conducted during Runs 7, 8, and 9. The purpose of the continuous monitoring effort was to 1) observe fluctuations in flue gas parameters, and 2) provide an indication of combustion conditions. Plant personnel collected the incinerator and ESP operating data. The CEM data and the process operating data were reviewed to determine if the incinerator was operating at normal conditions.

A summary of the sampling log for the test program is presented in Table 1-2. The summary shows the samples collected and sampling times for the EPA-sponsored sampling as well as any problems that occurred. A detailed log is included in Appendix H.1.

TABLE 1-2. SUMMARY OF SAMPLING LOG FOR EPA TESTING AT THE NORTH ANDOVER FACILITY: July 8 to 16, 1986

DATE	RUN	SAMPLES COLLECTED	SAMPLING[a] PERIOD	NOTES
7/8/86	1	--	--	Run 1 was cancelled because the ESP inle sampling location was not ready in time to test concurrently with ESP outlet.
7/9/86	2	Uncontrolled PCDD/PCDF	10:15-19:29	For the inlet PCDD/PCDF train, three probe liners were used and recovered. Two of the liners were broken during por changes.
7/10/86	3	Uncontrolled PCDD/PCDF	10:29-16:30	No sampling or incinerator operating problems occurred.
7/11/86	4	Uncontrolled PCDD/PCDF	11:30-16:09	Sampling time increased to 240 mintes from 192 minutes. No sampling or incinerator operating problems occurred.
7/12/86	5	Uncontrolled PCDD/PCDF	11:40-17:52	Incinerator developed a broken grate bar during sampling. Underfire air ports were manually cleaned. Incinerator operation was determined by Signal to be normal. The grate bar was repaired overnight.
7/13/86	6	Uncontrolled PCDD/PCDF	12:40-20:46	The incinerator was determined by Signal not to be operating at normal conditions The operating data basis was not provide by Signal. The PCDD/PCDF samples were not collected simultaneously at the ESP inlet and ESP outlet.
7/14/86	7	Uncontrolled and controlled metals, ESP ash, CEMs	14:20-20:00	Outlet probe liner broke at the nozzle; liner changed.
7/15/86	8	Uncontrolled and controlled metals, ESP ash, CEMs	9:30-13:50	No sampling or incinerator operating problems occurred.
7/16/86	9	Uncontrolled and controlled metals, ESP ash, CEMs	9:38-14:06	No sampling or incinerator operating problems occurred.

[a]The sampling period includes time for port changes and other breaks in sampling.

1.4.2 Laboratory Analysis

The Laboratory analyses were performed by three organizations. The PCDD/PCDF analyses were performed by Triangle Laboratories, Inc., Research Triangle Park, N.C. The trace metals analyses were performed by the Nuclear Energy Services of North Carolina State University in Raleigh, North Carolina. The particulate samples were analyzed in the Radian/RTP Laboratory.

The PCDD/PCDF samples were analyzed by high resolution gas chromatography and high resolution mass spectrometry (GC/MS). The congeners that are reported are listed in Table 1-3. The total mono- through octa- chlorinated homologues are reported, along with all the individual 2378-substituted PCDD/PCDF isomers such as 2378-TCDD.

The trace metals samples were analyzed by neutron activation analysis (NAA). With this method, the samples are exposed to neutrons causing them to emit gamma rays which are counted and compared to standards for quantification. The method reports results for arsenic, cadmium, chromium, and nickel and well as thirty five other metals which are listed in Table 1-4. NAA cannot be used for lead and beryllium because these metals do not emit gamma rays. The results for the specific metals of interest are included in this report. The results for the other metals are included in Appendix I.

1.5 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Completeness and data quality was emphasized during the test program at North Andover RESCO. QA/QC was incorporated into each sampling or analytical task. The QA/QC program and results were reviewed by the Radian Quality Assurance (QA) Officer. The QA/QC results are summarized in Section 6 and presented in more detail in Appendix J.

1.6 DESCRIPTION OF REPORT SECTIONS

The emissions report is presented in three volumes. Volume I includes the Summary of Results (Section 2.0), Process Description and Operation

TABLE 1-3. PCDD/PCDF CONGENERS ANALYZED FOR NORTH ANDOVER TEST PROGRAM

DIOXINS
Monochloro dibenzo-p-dioxin (MCDD)
Total dichlorinated dibenzo-p-dioxins (DCDD)
Total Trichlorinated dibenzo-p-dioxins (TrCDD)
2,3,7,8 Tetrachlorodibenzo-p-dioxin (2,3,7,8 TCCD)
Total Tetrachlorinated dibenzo-p-dioxins (TCDD)
1,2,3,7,8 Pentachlorodibenzo-p-dioxin (1,2,3,7,8 PCDD)
Total Pentachlorinated dibenzo-p-dioxins (PCDD)
1,2,3,4,7,8 Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8 HxCDD)
1,2,3,6,7,8 Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8 HxCDD)
1,2,3,7,8,9 Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9 HxCDD)
Total Hexachlorinated dibenzo-p-dioxins (HxCDD)
Total Heptachlorinated dibenzo-p-dioxins (HpCDD)
Total Octachlorinated dibenzo-p-dioxins (OCDD)
FURANS
Monochloro dibenzofuran (MCDF)
Total dichlorinated dibenzofurans (DCDF)
Total Trichlorinated dibenzofurans (TrCDF)
2,3,7,8 Tetrachlorodibenzofurans (2,3,7,8 TCDF)
Total Tetrachlorinated dibenzofurans (TCDF)
1,2,3,7,8 Pentachlorodibenzofuran (1,2,3,7,8 PCDF)
2,3,4,7,8 Pentachlorodibenzofuran (2,3,4,7,8 PCDF)
Total Pentachlorinated dibenzofurans (PCDF)
1,2,3,4,7,8 Hexachlorodibenzofuran (1,2,3,4,7,8 HxCDF)
1,2,3,7,8,9 Hexachlorodibenzofuran (1,2,3,7,8,9 HxCDF)
2,3,4,6,7,8 Hexachlorodibenzofuran (2,3,4,6,7,8 HxCDF)
Total Hexachlorinated dibenzofurans (HxCDF)
Total Heptachlorinated dibenzofurans (HpCDF)
Total Octachlorinated dibenzofurans (OCDF)

TABLE 1-4. METALS DETECTED BY NEUTRON ACTIVATION IN FLUE GAS SAMPLE MATRIX

Specific Metals of Interest[a]	Other Metals of Interest[b]	
	Toxic[c]	Conventional[d]
Arsenic (As)	Antimony	Aluminum
Cadmium (Cd)	Copper	Barium
Chromium (Cr)	Selenium	Bromine
Nickel (Ni)	Silver	Chlorine
	Zinc	Cobalt
	Uranium	Iron
	Vanadium	Magnesium
		Molybdenum
		Manganese
		Tin
		Titanium

Additional Metals Reported[e]

Calcium	Potassium
Cerium	Rubidium
Cesium	Samarium
Europium	Scandium
Hafnium	Sodium
Indium	Terbium
Lanthanum	Thorium
Lutetium	Ytterbium
Neodymium	

[a] NAA cannot be used for lead and beryllium because these metals do not emit gamma rays when exposed to neutrons.

[b] The results for these metals are reported in Appendix I.

[c] These metals are classified as toxic pollutants by the NPDES regulation 40CFR Part 122, Appendix D.

[d] These metals are classified as conventional pollutants by the NPDES regulation 40CFR Part 122, Appendix D.

[e] The results for these metals are reported in Appendix I.

(Section 3.0), Sampling Locations (Section 4.0), Sampling and Analytical Procedures (Section 5.0) and Quality Assurance/Quality Control (Section 6.0).

The supporting data and calculations for the results presented in Volume I are included as Appendices. The appendices are presented as two volumes. Volume II contains summaries of all the emissions data, sample calculations, CEM one-minute averages, CEM stripcharts, CEM calibration data, field data sheets and laboratory reports. Volume III contains equipment calibration data, correspondence, incinerator and ESP operating data, field test logs, quality assurance information, sampling and analytical protocols, and a list of the project participants.

2.0 SUMMARY OF RESULTS

The results of the PCDD/PCDF, particulates, metals, and CEM sampling conducted for EPA at North Andover RESCO are summarized in this section. In addition to the presentation of the results, variabilities and outliers in the data are qualified. Also, any incinerator or ESP operating abnormalities encountered during sample collection or analysis are analyzed in relation to the results.

Dual units (English and Metric) are presented in each table, where applicable. For some results, such as PCDD/PCDF concentration, only the most suitable units (ng/dscm) are presented and English conversion factors are provided in the footnotes. The results are normalized to a standard CO_2 concentration basis to allow comparison of the results on an equivalent basis. The EPA/MSW database is also normalized to this basis, since many state regulations are based on a 12 percent CO_2 basis. The 12 percent CO_2 basis is appropriate for the MSW source category because the ultimate analysis of refuse on a combustible fraction basis has a reasonably constant carbon content.[2]

The equations used to calculate the results that are presented in the following tables are presented in Appendix A.5. The supporting data for the results presented in this section are included in the appendices to this report.

2.1 PCDD/PCDF EMISSION RESULTS

The PCDD/PCDF results for the flue gas samples collected at the ESP inlet are discussed in this section. Although five flue gas samples were collected, the three samples which were considered the most representative in terms of sampling and incinerator operating parameters were analyzed. The samples analyzed were from Runs 3, 4, and 5. The sample from Run 1 was not collected because the inlet sampling location was not ready. The sample for Run 2 was

not analyzed because the probe liner broke three times, twice during port changes. Since PCDD/PCDF samples were not collected simultaneously during Run 6, the Run 6 sample was not analyzed.

The uncontrolled PCDD/PCDF emissions results are summarized in Table 2-1. The flue gas characteristics and process operations data presented in the table show that the incinerator was operating at similar conditions during each of the runs. The average total PCDD/PCDF concentration was 284 ng/dscm. Normalized to 12 percent CO_2, the average total PCDD/PCDF concentration was 342 ng/dscm @ 12 percent CO_2.

Comparing the data from the three runs, the PCDD isomers from Run 3 are significantly higher than Runs 4 and 5. However, the furan isomers from Run 3 are in good agreement with the other runs and process conditions were normal. Therefore, the PCDD data from Run 3 is considered to be a normal variation of the uncontrolled PCDD/PCDF data.

The homologue and isomer-specific results are summarized in Table 2-2. The results in this table are presented as total train analyses and are normalized to 12 percent CO_2. The average total PCDD result was 169 ng/dscm @ 12 percent CO_2 and the average total PCDF result was 172 ng/dscm @ 12 percent CO_2.

The PCDD/PCDF results are presented for the front half and back half fractions of the sampling train in Table 2-3. The results show that the majority of the PCDDs and PCDFs were captured in the front half of the train. On the average, seventy percent of the PCDDs and fifty five percent of the PCDFs were found in the front half of the train. The front half of the PCDD/PCDF train included the probe, the cyclone and the filter. The back half included the coil condenser, XAD trap and the impingers.

2.1.1 2378-TCDD Toxic Equivalency

The PCDD/PCDF results are expressed in terms of 2378-TCDD toxicity equivalents corrected to 12 percent CO_2 in Table 2-4. Each isomer has

TABLE 2-1. SUMMARY OF UNCONTROLLED PCDD/PCDF EMISSIONS FOR NORTH ANDOVER RESCO

Run No. Date	Run 3 7/10/86			Run 4 7/11/86			Run 5 7/12/86			Average		
Sampling Parameters[a]												
Volume gas sampled (dscf)	75.9			97.0			97.3			90.1		
Stack gas flow rate (dscfm)	84,600			87,500			88,600			86,900		
Stack temperature (^{o}F)	580			584			591			585		
Percent moisture by volume	13.1			12.9			14.2			13.4		
Percent isokinetic	100.1			99.0			98.0			99.0		
CO (ppm by volume)[b]	25.4			45.2			25.7			32.1		
CO_2 (percent by volume)[b]	8.9			9.6			9.8			9.4		
O_2 (percent by volume)[b]	10.5			10.7			10.1			10.4		
Process operations												
Steam load (lbs/hr 10^3)	166			166			167			166		
	Front Half	Back Half	Total	Front Half	Back Half	Total	Front Half	Back Half	Total	Front Half	Back Half	Total
Dioxin Results[c]												
Total PCDD (ng/dscm)	184	96	280	39	17	56	72	15	87	98	43	141
Total PCDD (corrected to 12% CO_2, ng/dscm)	221	115	336	47	20	67	87	18	105	118	51	169
Furan Results[c]												
Total PCDF (ng/dscm)	64	97	161	69	60	129	104	36	140	79	64	143
Total PCDF (corrected to 12% CO_2, ng/dscm)	77	116	193	83	72	155	126	44	170	95	77	172
Dioxin-Furan Results[c]												
Total PCDD-PCDF (ng/dscm)	248	193	441	108	77	185	176	51	227	177	107	284
Total PCDD-PCDF (corrected to 12% CO_2, ng/dscm)	297	232	529	130	92	222	213	62	275	213	129	342

[a] Conversion factors: dscf x 0.028317 = dscm; dscfm x 0.028317 = dscmm; (^{o}F - 32) x 5/9 = ^{o}C
Standard conditions are 68^{o}F (20^{o}C) and 1 atm (1.01325 x 10^5 Pa).

[b] These values are averages of data taken over the sampling period from continuous emissions monitors located at the ESP outlet.

[c] PCDD/PCDF results are adjusted for internal standard recoveries and sample blank results. Results are reported as front half/back half fractions for the convenience of EPA.

TABLE 2-2. UNCONTROLLED PCDD/PCDF EMISSIONS AT NORTH ANDOVER RESCO (NORMALIZED TO 12 PERCENT CO2)

ISOMER	CONCENTRATION (NG/DSCM, CORRECTED TO 12% CO2) RUN 03	RUN 04	RUN 05	AVERAGE
DIOXIN				
Mono-CDD	0	0	0	0
Di-CDD	4	2	2	3
Tri-CDD	22	5	7	11
2378 TCDD	4	0	1	2
Other TCDD	31	6	8	15
12378 PCDD	2	1	1	1
Other PCDD	64	8	12	28
123478 HxCDD	3	1	1	1
123678 HxCDD	7	1	2	3
123789 HxCDD	3	2	0	2
Other HxCDD	86	10	19	38
Hepta-CDD	69	15	24	36
Octa-CDD	42	17	30	29
TOTAL PCDD	336	67	105	169
FURAN				
Mono-CDF	1	3	0	2
Di-CDF	27	26	13	22
Tri-CDF	73	57	62	64
2378 TCDF	11	9	12	11
Other TCDF	36	27	34	32
12378 PCDF	2	2	2	2
23478 PCDF	4	4	4	4
Other PCDF	13	9	13	12
123478 HxCDF	5	3	4	4
123678 HxCDF	2	1	2	1
123789 HxCDF	0	0	0	0
Other HXCDF	7	4	6	6
Hepta-CDF	10	8	12	10
Octa-PCDF	3	2	3	3
TOTAL PCDF	193	155	170	172
TOTAL PCDD/PCDF	529	222	275	341
Norm. ratio (a)	1.20	1.20	1.21	

a Norm. ratio = normalization ratio of 12 percent CO2 to CO2 measured which is used to normalize the results to a standard 12 percent CO2 basis.

TABLE 2-3. UNCONTROLLED PCDD/PCDF EMISSIONS FOR NORTH ANDOVER RESCO (FRONT, BACK, AND TOTAL FRACTION RESULTS)

ISOMER	CONCENTRATION (NG/DSCM) [a] RUN 03 FRONT HALF	RUN 03 BACK HALF	RUN 03 TOTAL	RUN 04 FRONT HALF	RUN 04 BACK HALF	RUN 04 TOTAL	RUN 5 FRONT HALF	RUN 5 BACK HALF	RUN 05 TOTAL	AVERAGE FRONT HALF	AVERAGE BACK HALF	AVERAGE TOTAL
DIOXIN												
Mono-CDD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Di-CDD	0.8	2.7	3.5	0.6	1.2	1.8	1.1	0.5	1.6	0.8	1.5	2.3
Tri-CDD	6.5	11.8	18.3	2.2	2.3	4.6	3.9	1.6	5.5	4.2	5.2	9.5
2378 TCDD	3.1	0.0	3.1	0.2	0.0	0.2	0.3	0.1	0.4	1.2	0.0	1.3
Other TCDD	10.3	15.6	26.0	2.4	2.2	4.6	5.1	1.5	6.6	6.0	6.4	12.4
12378 PCDD	1.1	0.7	1.7	0.4	0.2	0.6	0.6	0.1	0.8	0.7	0.3	1.0
Other PCDD	29.8	23.2	53.0	3.8	2.5	6.3	7.5	2.2	9.7	13.7	9.3	23.0
123478 HxCDD	1.6	0.7	2.2	0.4	0.2	0.6	0.7	0.2	0.8	0.9	0.3	1.2
123678 HxCDD	3.9	1.6	5.5	0.7	0.4	1.0	1.1	0.3	1.4	1.9	0.8	2.6
123789 HxCDD	0.0	2.5	2.5	1.2	0.5	1.7	0.0	0.0	0.0	0.4	1.0	1.4
Other HxCDD	50.1	21.4	71.6	5.2	2.9	8.1	12.0	3.5	15.5	22.4	9.3	31.7
Hepta-CDD	46.1	11.5	57.6	9.5	2.9	12.4	16.7	3.1	19.8	24.1	5.8	29.9
Octa-CDD	30.5	4.3	34.8	12.0	1.9	13.9	22.7	1.9	24.6	21.7	2.7	24.5
TOTAL PCDD	184	96.0	280	38.7	17.1	55.8	71.6	15.1	86.7	98.0	42.7	141
Fraction Detected in Front Half:			0.66			0.69			0.83			0.7
FURAN												
Mono-CDF	0.2	1.0	1.1	0.3	2.4	2.7	0.1	0.0	0.1	0.2	1.1	1.3
Di-CDF	4.3	17.9	22.2	6.3	15.4	21.6	5.5	5.5	11.0	5.4	12.9	18.3
Tri-CDF	18.5	42.6	61.1	23.3	24.5	47.8	36.0	15.5	51.5	25.9	27.6	53.5
2378 TCDF	4.3	5.2	9.5	4.7	2.8	7.5	7.5	2.3	9.7	5.5	3.4	8.9
Other TCDF	12.0	17.7	29.7	13.5	9.0	22.5	21.4	6.9	28.4	15.6	11.2	26.8
12378 PCDF	1.0	0.8	1.8	1.1	0.5	1.6	1.6	0.4	2.0	1.2	0.6	1.8
23478 PCDF	2.1	1.4	3.4	2.1	0.8	2.9	3.0	0.7	3.7	2.4	1.0	3.3
Other PCDF	5.8	4.8	10.6	5.3	2.3	7.6	8.9	2.1	11.0	6.7	3.1	9.8
123478 HxCDF	2.6	1.2	3.8	1.9	0.5	2.4	3.1	0.5	3.6	2.5	0.7	3.3
123678 HxCDF	0.9	0.4	1.3	0.6	0.2	0.8	1.0	0.2	1.2	0.8	0.3	1.1
123789 HxCDF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other HXCDF	3.7	1.8	5.5	2.7	0.6	3.2	4.4	0.7	5.1	3.6	1.0	4.6
Hepta-CDF	6.5	1.6	8.0	5.9	0.8	6.7	9.2	1.1	10.2	7.2	1.2	8.3
Octa-PCDF	2.0	0.4	2.4	1.6	0.0	1.6	2.5	0.2	2.8	2.1	0.2	2.3
TOTAL PCDF	63.8	96.7	161	69.2	59.9	129	104	36.1	140	79.1	64.2	143
Fraction Detected in Front Half:			0.40			0.54			0.74			0.55
TOTAL PCDD/PCDF	248	193	440	108	77.0	185	176	51.1	227	177	107	284
Dioxin Isomer Fraction of Total PCDD/PCDF:			0.64			0.3			0.38			0.50

[a] 0.0 = Not detected. The minimum detection limit is approximately 0.0004 ng/dscm. Specific detection limits are included in Appendix D.1.

TABLE 2-4. UNCONTROLLED PCDD/PCDF CONCENTRATIONS EXPRESSED AS 2378-TCDD TOXIC EQUIVALENTS

ISOMER	2378 TCDD EQUIV. FACTORS	2378 TCDD EQUIVALENT CONCENTRATION (NG/DSCM @ 12% CO2) RUN 03	RUN 04	RUN 05	AVERAGE
DIOXIN					
Mono-CDD	0.0000	0.0	0.0	0.0	0.0
Di-CDD	0.0000	0.0	0.0	0.0	0.0
Tri-CDD	0.0000	0.0	0.0	0.0	0.0
2378 TCDD	1.0000	3.7	0.3	0.5	1.5
Other TCDD	0.0100	0.3	0.1	0.1	0.1
12378 PCDD	0.5000	1.0	0.3	0.5	0.6
Other PCDD	0.0050	0.3	0.0	0.1	0.1
123478 HxCDD	0.0400	0.1	0.0	0.0	0.1
123678 HxCDD	0.0400	0.3	0.0	0.1	0.1
123789 HxCDD	0.0400	0.1	0.1	0.0	0.1
Other HxCDD	0.0004	0.0	0.0	0.0	0.0
Hepta-CDD	0.0010	0.1	0.0	0.0	0.0
Octa-CDD	0.0000	0.0	0.0	0.0	0.0
TOTAL PCDD		6.0	0.9	1.3	2.7
FURAN					
Mono-CDF	0.0000	0.0	0.0	0.0	0.0
Di-CDF	0.0000	0.0	0.0	0.0	0.0
Tri-CDF	0.0000	0.0	0.0	0.0	0.0
2378 TCDF	0.1000	1.1	0.9	1.2	1.1
Other TCDF	0.0010	0.0	0.0	0.0	0.0
12378 PCDF	0.1000	0.2	0.2	0.2	0.2
23478 PCDF	0.1000	0.4	0.4	0.4	0.4
Other PCDF	0.0010	0.0	0.0	0.0	0.0
123478 HxCDF	0.0100	0.0	0.0	0.0	0.0
123678 HxCDF	0.0100	0.0	0.0	0.0	0.0
123789 HxCDF	0.0100	0.0	0.0	0.0	0.0
Other HXCDF	0.0001	0.0	0.0	0.0	0.0
Hepta-CDF	0.0010	0.0	0.0	0.0	0.0
Octa-PCDF	0.0000	0.0	0.0	0.0	0.0
TOTAL PCDF		1.9	1.5	2.0	1.8
TOTAL PCDD/PCDF		7.9	2.4	3.2	4.5

2378-TCDD toxicity equivalency factor[3], (also presented in Table 2-8), that ranks the toxicity of the isomer relative to the toxicity of 2378-TCDD. The equivalency factors were developed by EPA. 2378-TCDD toxic equivalents are used in risk analysis models developed by EPA. In terms of 2378-TCDD equivalents, the average concentration was 2.7 ng/dscm for the dioxins and 1.8 ng/dscm for the furans. The average total 2378-TCDD equivalents concentration was 4.5 ng/dscm.

2.1.2 ISOMER DISTRIBUTIONS

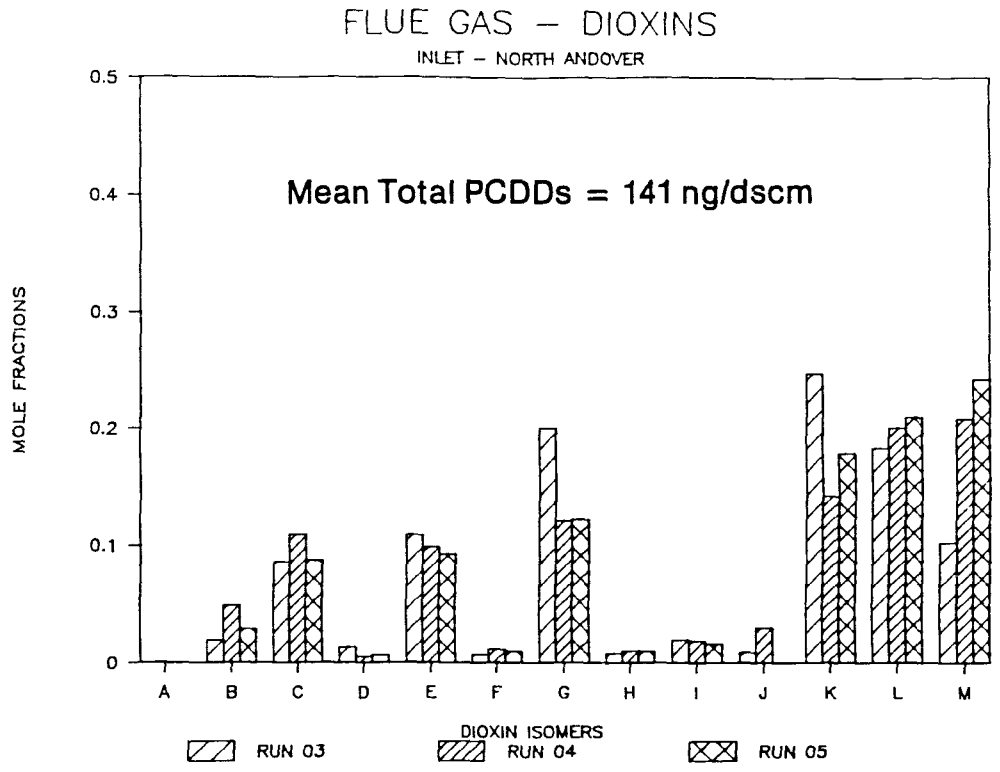
The distributions of the PCDD and PCDF isomers on a mole fraction basis are presented in graphical form in Figure 2-1 and in tabular form in Table 2-6. For the dioxin isomers, hexa-, hepta- and octa-CDDs were the most prevalent at about 20 mole percent, each. For the furan isomers, tri-CDF was the most prevalent at 40 mole percent. Di-CDF and tetra-CDF were present at about 17 mole percent, each. Figure 2-1 also illustrates graphically the repeatability of the data from the three runs except for the penta- and hexa-CDD isomers measured during Run 1.

2.2 PARTICULATE MATTER RESULTS

The particulate matter loading was measured at North Andover RESCO at both the ESP inlet and ESP outlet locations. The uncontrolled and controlled results are summarized in Table 2-7. Table 2-7 also includes flue gas and process operations parameters that were measured during testing. The average controlled result does not include Run 7. This result was determined to be a statistical outlier based on the nine controlled particulate results under the condition where extreme observations in either direction are considered rejectable.[4] The Run 7-controlled train developed a broken glass liner during sampling in one of the ports. Considering this, the concentration would be expected to be lower than the average unless extraneous glass fragments were recovered in the sample. Instead, the concentration is higher. This could be attributed to the higher opacity during Run 7, except that Run 6 had an even higher average opacity while still having a controlled particulate loading

TABLE 2-5. KEY TO ISOMER CODING FOR FIGURE 2-1

CODE	ISOMER
	Dioxins
A =	Mono-CDD
B =	Di-CDD
C =	Tri-CDD
D =	2378-TCDD
E =	Other TCDD
F =	12378 PCDD
G =	Other PCDD
H =	123478 HxCDD
I =	123678 HxCDD
J =	123789 HxCDD
K =	Other HxCDD
L =	Hepta-CDD
M =	Octa-CDD
	Furans
N =	Mono-CDF
O =	Di-CDF
P =	Tri-CDF
Q =	2378-TCDF
R =	Other TCDF
S =	12378 PCDF
T =	Other PCDF
U =	123478 HxCDF
V =	123678 HxCDF
W =	123789 HxCDF
X =	Other HxCDF
Z =	Hepta-CDF
AA =	Octa-CDF



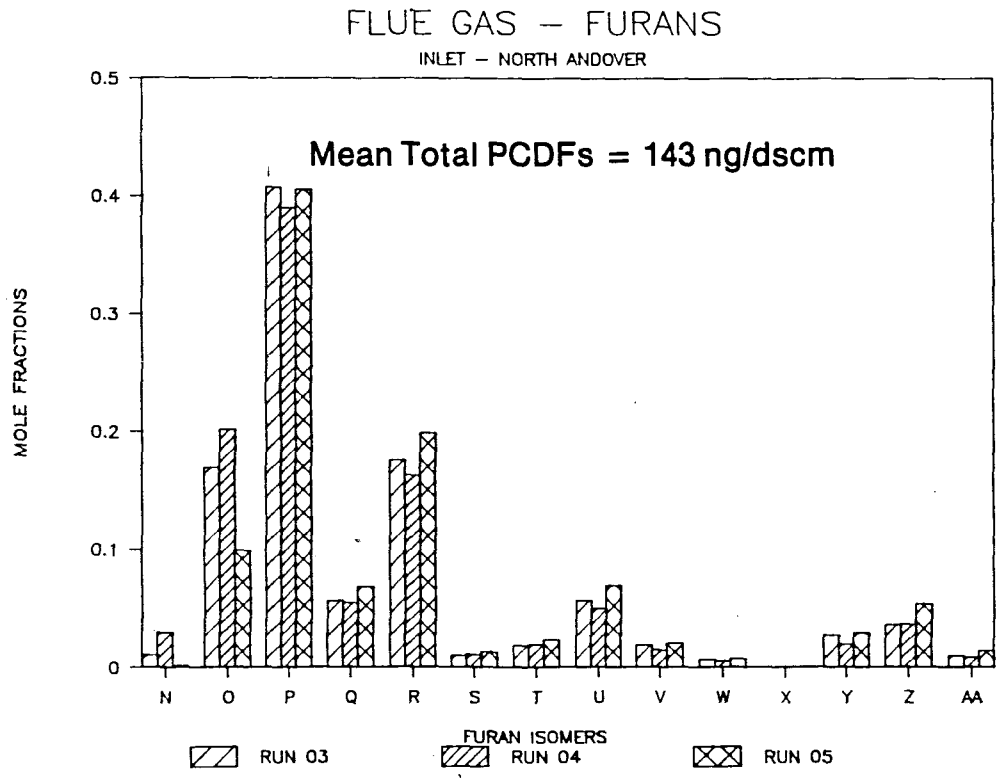


Figure 2 - 1. Uncontrolled PCDD/PCDF Isomer Distribution

TABLE 2-6. UNCONTROLLED PCDD/PCDF CONGENER DISTRIBUTION AT NORTH ANDOVER RESCO

ISOMER	MOLE FRACTION (%) RUN 03	RUN 04	RUN 05	AVERAGE
DIOXIN				
Mono-CDD	0.00	0.00	0.00	0.00
Di-CDD	0.02	0.05	0.03	0.03
Tri-CDD	0.09	0.11	0.09	0.09
2378 TCDD	0.01	0.00	0.01	0.01
Other TCDD	0.11	0.10	0.09	0.10
12378 PCDD	0.01	0.01	0.01	0.01
Other PCDD	0.20	0.12	0.12	0.15
123478 HxCDD	0.01	0.01	0.01	0.01
123678 HxCDD	0.02	0.02	0.02	0.02
123789 HxCDD	0.01	0.03	0.00	0.01
Other HxCDD	0.25	0.14	0.18	0.19
Hepta-CDD	0.18	0.20	0.21	0.20
Octa-CDD	0.10	0.21	0.24	0.18
FURAN				
Mono-CDF	0.01	0.03	0.00	0.01
Di-CDF	0.17	0.20	0.10	0.16
Tri-CDF	0.41	0.39	0.41	0.40
2378 TCDF	0.06	0.05	0.07	0.06
Other TCDF	0.18	0.16	0.20	0.18
12378 PCDF	0.01	0.01	0.01	0.01
23478 PCDF	0.02	0.02	0.02	0.02
Other PCDF	0.06	0.05	0.07	0.06
123478 HxCDF	0.02	0.01	0.02	0.02
123678 HxCDF	0.01	0.00	0.01	0.01
123789 HxCDF	0.00	0.00	0.00	0.00
Other HXCDF	0.03	0.02	0.03	0.02
Hepta-CDF	0.04	0.04	0.05	0.04
Octa-PCDF	0.01	0.01	0.01	0.01

TABLE 2-7. SUMMARY OF UNCONTROLLED AND CONTROLLED PARTICULATE EMISSIONS FOR NORTH ANDOVER RESCO

Run No. / Date / Type Emissions	Run 7 07-14-86 Uncontrolled	Run 7 07-14-86 Controlled	Run 8 07-15-86 Uncontrolled	Run 8 07-15-86 Controlled	Run 9 07-16-86 Uncontrolled	Run 9 07-16-86 Controlled	Average[a] Uncontrolled	Average[a] Controlled
Sampling Parameters[b]								
Volume gas sampled (dscf)	83.8	120.5	85.3	114.9	82.7	119.9	--	--
Stack gas flow rate (dscfm)	91,700	98,300	93,500	94,800	92,200	97,300	92,500	96,050
Stack temperature (^{o}F)	599	579	600	575	609	587	603	581
Moisture (percent by volume)	16.1	15.4	14.3	13.6	14.3	13.7	14.9	13.7
Isokinetics (percent)	101.8	99.7	101.7	98.6	102.1	100.2	101.9	99.4
CO (ppm by volume)[c]		35.9		35.7		27.2		32.9
CO_2 (percent by volume)[c]		8.5		8.6		9.2		8.8
O_2 (percent by volume)[c]		11.5		8.3[d]		10.5		11.0
Average opacity (percent)		0.31		0.14		0.13		0.19
Process operations								
Steam load (lbs/hr x 10^3)	170		168		165		168	
Particulate Results[e] Front Half Catch) (Probe, cyclone, and filter)								
mg - mass	4866.4	152.2	3450	23.6	3580	28.5	--	--
gr/dscf	0.8965	0.0195	0.6242	0.0032	0.6682	0.0037	0.7296	0.0035
gr/dscf (corrected to 12% CO_2)	1.148	0.0250	0.7366	0.0044	0.9221	0.0054	0.9356	0.0049
mg/dscm	2,052	44.6	1,429	7.25	1,529	8.39	1,670	7.82
mg/dscm (corrected to 12% CO_2)	2,627	57.1	1,686	10.0	2,100	12.2		
lbs/hr	705	16.4	501	2.58	528	3.06	578	2.82
Kg/hr	320	7.45	277	1.17	240	1.39	262	1.28
Collection Efficiency Percent	97.67		99.49		99.42		99.46	

[a]Values from Run 7 - controlled are not included in averages. See Section 2.2 for explanation.

[b]Conversion factors: dscf x 0.028317 = dscm; dscfm x 0.028317 = dscmm; (^{o}F - 32) x 5/9 = ^{o}C
Standard conditions are 68^{o}F (20^{o}C) and 1 atm (1.01325 x 10^5 Pa).

[c]These values are averages of data taken over the sampling period from continuous emissions monitors at the ESP outlet location.

[d]This value is not included in the O2 average and is considered an invalid data point.

[e]Particulate results are adjusted for blank results.

within range of the data which was from 0.0013 to 0.0054 grains/dscf normalized to 12 percent CO_2. However, the metal-to-particulate ratios dicussed in Section 2.5 are similar for all three runs which indicates that the ESP may have malfunctioned during Run 7. However, the ESP operating data for Run 7 are not available for review at this time. Therefore, since a broken probe liner developed during Run 7 at the ESP outlet, and a malfunction of the incinerator and/or ESP may have occurred, the Run 7-controlled particulate data are not included in the particulate averages presented.

The average uncontrolled particulate concentration normalized to 12 percent CO_2 was 0.9356 grains/dscf and the average controlled concentration was 0.0049 grains/dscf @ 12 percent CO_2. The average collection efficiency of the ESP was 99.46 percent.

The controlled particulate loading was measured for all nine runs performed at North Andover RESCO. The results are summarized in Table 2-8. The average controlled particulate loading was 0.0036 grains/dscf normalized to 12 percent CO_2. However, the results from Runs 1, 6, and 7 are not included in the average.

The particulate loading results from Run 1 are considered invalid due to port scrapings that were collected on the filter. After Run 1, the ports were lined with stove pipe to prevent rusty flakes from the port from being drawn into the sampling train.

For Run 6, the incinerator was determined by Signal Environmental Systems, Inc. to be operating at abnormal conditions after testing was completed. The incinerator had developed a broken grate bar during Run 5 which was manually cleaned until Run 5 was completed. Then, the incinerator was shut down overnight and repaired. When Run 6 began the next day, the incinerator appeared to be operating normally but Signal later decided that that the incinerator was still in a start-up operating mode. Run 7 was not included in the average for the reasons discussed previously in this section.

TABLE 2-8. SUMMARY OF CONTROLLED PARTICULATE EMISSIONS FOR NORTH ANDOVER RESCO

Run No. Date	Run 1 7-8-86	Run 2 7-9-86	Run 3 7-10-86	Run 4 7-11-86	Run 5 7-12-86	Run 6 7-13-86	Run 7 7-14-86	Run 8 7-15-86	Run 9 7-16-86	Average[a]
Sampling Parameters[b]										
Volume gas sampled (dscf)	54.50	53.4	84.3	107.2	106.5	115.9	120.5	114.9	119.9	--
Stack gas flow rate (dscfm)	96,800	95,000	85,800	87,200	86,200	94,300	98,300	94,800	97,300	91,050
Stack temperature (^{o}F)	582	587	559	567	565	577	579	575	587	573
Moisture (percent by volume)	12.6	13.3	12.8	12.6	13.6	13.0	13.0	13.6	13.7	13.3
Isokinetics (percent)	100.7	100.6	100.0	100.0	100.6	100.0	99.7	98.6	100.2	100.0
CO (ppm by volume)[c]	28.4	37.4	25.4	45.2	25.7	31.1	35.9	35.7	27.2	32.8
CO_2 (percent by volume)[c]	9.0	8.9	8.9	9.6	9.8	9.2	8.5	8.6	9.2	9.2
O_2 (percent by volume)[c]	10.9	10.9	10.5	10.7	10.1	10.8	11.5	8.3[d]	10.5	10.5
Average opacity (percent)	NR	0.10	0.12	0.12	0.13	0.55	0.31	0.14	0.13	0.12
Process operations										
Steam load (lbs/hr x 10^3)	166	165	166	166	167	163	170	168	165	166
Particulate Results[e]										
Front Half Catch)										
(Probe and filter)										
mg - mass	31.8	13.5	5.8	18.7	13.6	29.3	152.2	23.6	28.5	--
gr/dscf	0.0090	0.0039	0.0011	0.0027	0.0020	0.0039	0.0195	0.0032	0.0037	0.0028
gr/dscf (corrected to 12% CO_2)	0.0150	0.0050	0.0013	0.0032	0.0023	0.0048	0.0250	0.0044	0.0054	0.0036
mg/dscm	20.6	8.92	2.43	6.16	4.67	8.93	44.6	7.25	8.39	6.30
mg/dscm (corrected to 12% CO_2)	26.4	11.4	2.94	7.39	5.46	10.9	57.1	10.0	12.2	8.23
lbs/hr	7.47	3.17	0.781	2.01	1.51	3.15	16.4	2.58	3.06	2.19
Kg/hr	3.39	1.44	0.354	0.912	0.684	1.43	7.45	1.17	1.39	0.99

[a] Values from Runs 1, 6, and 7 are not included in the averages. See Section 2.2 for explanation.
[b] Conversion factors: dscf x 0.028317 = dscm; dscfm x 0.028317 = dscmm; (^{o}F - 32) x 5/9 = ^{o}C
Standard conditions are 68^{o}F (20^{o}C) and 1 atm (1.01325 x 10^5 Pa).
[c] These values are averages of data taken over the sampling period from continuous emissions monitors at the ESP outlet location.
[d] This value is not included in the O_2 average and is considered an invalid data point.
[e] Results are adjusted for blank results.
NR = data not recorded by plant.

2.3 METALS EMISSIONS RESULTS

In order to screen the flue gas for a multiple number of metals, the Method 12 samples collected at the ESP inlet and ESP outlet were analyzed by NAA. However, the EPA Method 12 sampling train has only been demonstrated to capture lead and cadmium efficiently. Thus the results for arsenic, total chromium, and nickel should be considered only as screening results.

2.3.1 Flue Gas Metals Results

The metals emission results for the specific metals of interest are summarized in Table 2-9. These results should be considered as screening results except for Cadmium for which the method has been validated. The average normalized arsenic concentration was 934 ug/dscm uncontrolled, and 10.4 ug/dscm controlled. The average ESP collection efficiency for arsenic was 98.66 percent. The average normalized cadmium concentration was 446 ug/dscm uncontrolled, and 22.3 ug/dscm controlled. The average ESP collection efficiency for cadmium was 94.69 percent. For total chromium, the average normalized concentration was 4277 ug/dscm uncontrolled, and 767 ug/dscm controlled. The average ESP collection efficiency for total chromium was 99.87 percent. The average normalized nickel concentration was 523 ug/dscm uncontrolled, and 477 ug/dscm controlled. The average ESP collection efficiency for nickel was 81.75 percent.

Total chromium and arsenic demonstrated the highest collection efficiencies, with collection efficiencies in the greater than 96 percent range. The ESP was less efficient for collecting cadmium, and was the least efficient for collecting nickel.

The specific metals results contain some outliers. Nickel in Run 7 and Chromium in Run 7 have collection efficiencies that are very low or negative caused by a high controlled result. Although the results were adjusted for blanks, precleaned glassware was used, and contact of the train with metal was minimized, contamination may have occurred. Thus, these results are not included in the averages reported.

TABLE 2-9. SUMMARY OF EPA SPECIFIC METALS EMISSIONS FOR NORTH ANDOVER RESCO[a]

Run No. / Date / Type Emissions	Run 7 07-14-86 Uncontrolled	Run 7 07-14-86 Controlled	Run 8 07-15-86 Uncontrolled	Run 8 07-15-86 Controlled	Run 9 07-16-86 Uncontrolled	Run 9 07-16-86 Controlled	Average Uncontrolled	Average Controlled
Sampling Parameters[a]								
Volume gas sampled (dscf)	83.8	120.5	85.3	114.9	82.7	119.9	--	--
Stack gas flow rate (dscfm)	91,700	98,300	93,500	94,800	92,200	97,300	92,500	96,050
Stack temperature (^{o}F)	599	579	600	575	609	587	603	581
Moisture (percent by volume)	16.1	15.4	14.3	13.6	14.3	13.7	14.9	13.7
Isokinetics (percent)	101.8	99.7	101.7	98.6	102.1	100.2	101.9	99.4
CO (ppm by volume)		35.9		35.7		27.2		32.9
CO_2 (percent by volume)		8.5		8.6		9.2		8.8
O_2 (percent by volume)		11.5		8.3[b]		10.5		11.0
Average opacity (percent)		0.31		0.14		0.13		0.19
Process operations								
Steam load (lbs/hr x 10^3)		170		168		165		168
Specific Metals Results[c] (Corrected to 12% CO_2) Element								
Arsenic	786	25.6	96.51	981	2.35	99.79	1,036	3.30	99.68	934	10.4	98.66
Cadmium	402	34.6	90.78	470	6.93	98.72	465	25.4	94.57	446	22.3	94.69
Total chromium	2,494	2,291	1.51[f]	3,370	10.4	99.73	6,968	0.00	100.00	4,277	767	99.87
Nickel	594	1,357	e,f	831	25.6	97.32	143	48.8	66.17	523	477	81.75

[a] Conversion factors: dscf x 0.028317 = dscm; dscfm x 0.028317 = dscmm; (^{o}F - 32) x 5/9 = ^{o}C
Standard conditions are 68^{o}F (20^{o}C) and 1 atm (1.01325 x 10^5 Pa).

[b] This value is not included in the average and is considered an invalid data point.

[c] These results are for the total train. Beryllium and lead determination not possible by NAA analysis. Values are corrected for blank results.

[d] CE = collection efficiency based on mass rates.

[e] The control efficiencies were negative for these runs.

[f] Negative and obviously uncharacteristic collection efficiencies were not included in the average values.

2.3.2 ESP Ash Metals Results

The results of the ESP ash metals analyses are presented in Table 2-10. The most prevalent metals were aluminum, calcium, sodium, zinc, potassium, chlorine, iron, titanium and magnesium. These metals had concentrations from 80,000 to 17,000 ppm. Total chromium was detected at 679 ppm, cadmium was detected at 356 ppm, arsenic was detected at 365 ppm and nickel was detected at 245 ppm.

2.4 CEM RESULTS

The flue gas was continuously monitored for oxygen, carbon monoxide and carbon dioxide at the ESP outlet sampling location. The results are presented in Table 2-11. The Radian data acquisition system scanned each channel 180 times per minute and recorded one-minute averages. The mean of the one-minute averages is reported for each run. Then, the mean from each run is averaged for an overall average. The one-minute averages for each run are listed in Appendix B.

The average oxygen concentration was 11.0 percent by volume. The average carbon dioxide concentration was 8.8 percent by volume and the average carbon monoxide concentration was 32.9 ppm. The standard deviations for each data set are shown in parentheses.

The one-minute averages are plotted against time for each parameter for each run in Figures 2-2 to 2-4. These plots, along with the standard deviations, show the variability of the parameters during each test run.

The CEM and Orsat analysis results were validated based on a combustion stoichiometry method described in Reference 3. This analysis shows that the CEM data for Run 8 is an outlier. The analysis is described in more detail in Section 6.2. The oxygen concentration during Run 8 is lower than Runs 7 and 9 where the same CO_2 and CO concentrations were measured. Also, the oxygen concentration plot in Figure 2-2 shows the oxygen concentration decreasing

TABLE 2-10. SUMMARY OF ESP ASH METALS RESULTS

Element	MICROGRAM OF ELEMENT PER GRAM OF ASH (PPM)[a,b] Run 07	Run 08	Run 09	Average
Aluminum	80208	84888	78073	81056
Calcium	64044	64856	83180	70693
Sodium	42350	46332	43271	43984
Zinc	29631	34904	37267	33934
Potassium	14193	30123	16556	20290
Chlorine	14730	27258	17392	19794
Iron	22791	14642	14928	17453
Titanium	16665	17231	16837	16911
Magnesium	6731	5600	6672	6334
Tin	2390	3813	4099	3434
Bromine	1956	1530	932	1473
Barium	1354	1594	1189	1379
Manganese	1263	1233	1169	1222
Copper	1115	1177	1317	1203
Antimony	1073	1000	973	1015
Chromium[c]	568	441	1029	679
Arsenic	75	465	554	365
Cadmium	274	392	401	356
Nickel	181	448	100	243

[a]When using NAA, sodium in the matrix may interfere with the metals results.

[b]Results for the remaining metals are presented in Appendix I.

[c]Total chromium results are presented.

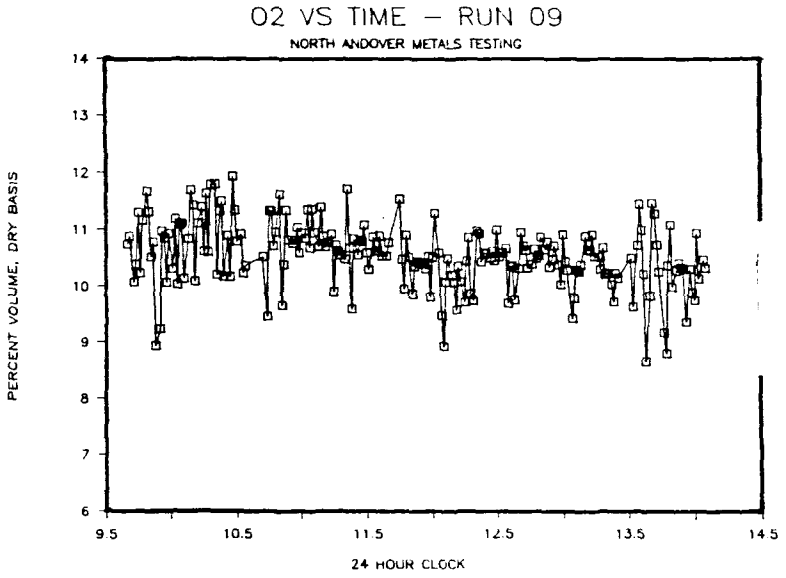
TABLE 2-11. SUMMARY OF CEM RESULTS

Parameter[a]	07	08	09	Average
O_2 (%vol)	11.5	8.3[b]	10.5	11.0
(std dev)	(0.7)	(1.1)	(0.6)	(0.7)
CO (ppm)	35.9	35.7	27.2	32.9
(std dev)	(6.9)	(7.2)	(6.8)	(7.0)
CO_2 (%vol)	8.5	8.6	9.2	8.8
(std dev)	(0.6)	(0.7)	(0.6)	(0.6)

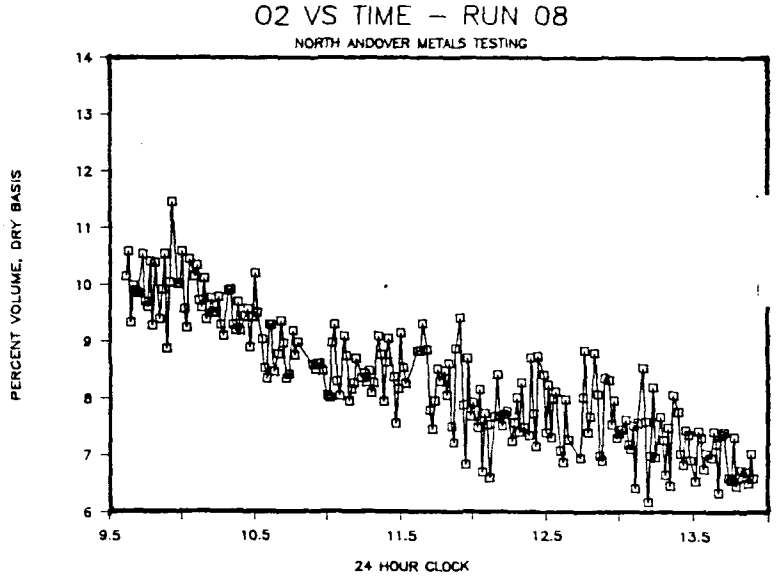
NOTE: Test run averages are the average of the one-minute averages. The data acquisition system scans each channel 180 times per minute.

[a]All results are reported on a dry basis.

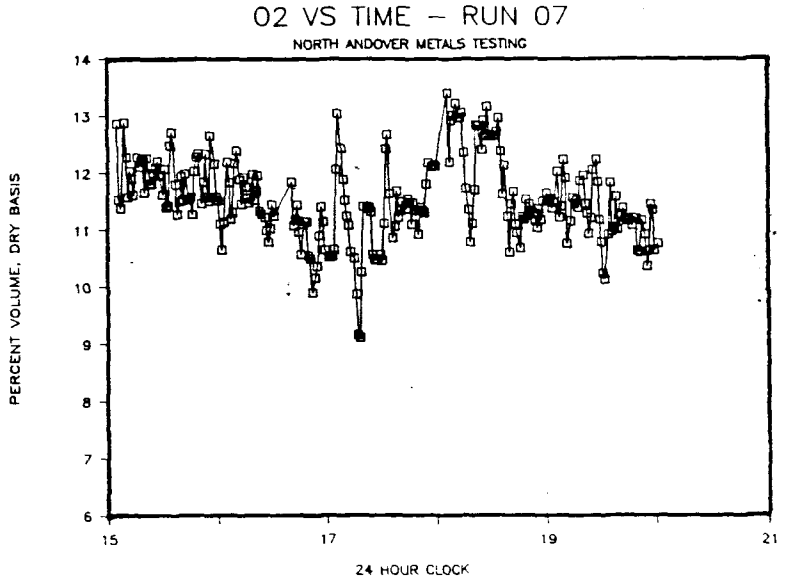
[b]This value is not included in the average and is considered invalid. A problem with the oxygen analyzer, such as condensation in the instrument, may have developed during Run 8.



Mean = 10.5% by volume
Std dev = 0.6% by volume
OBS = 209



Mean = 8.3* % by volume
Stddev = 1.1% by volume
OBS = 211

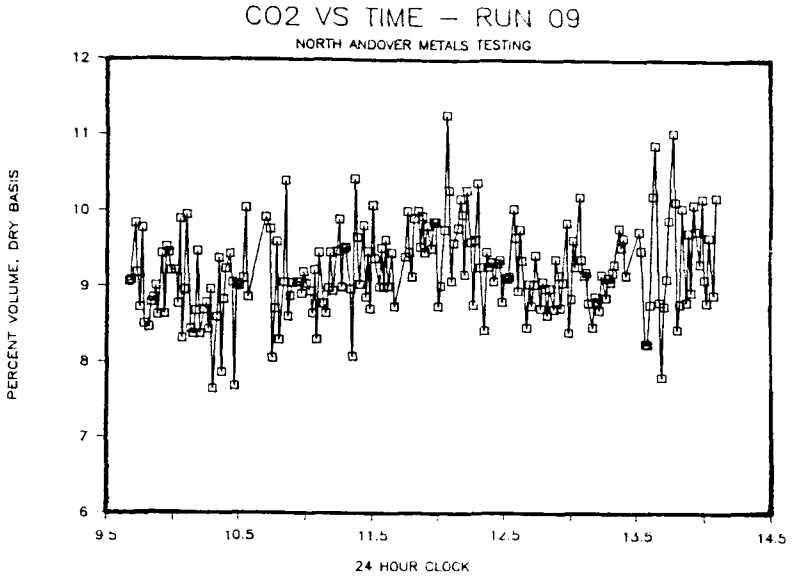


Mean = 11.5% by volume
Std dev = 0.7% by volume
OBS = 242

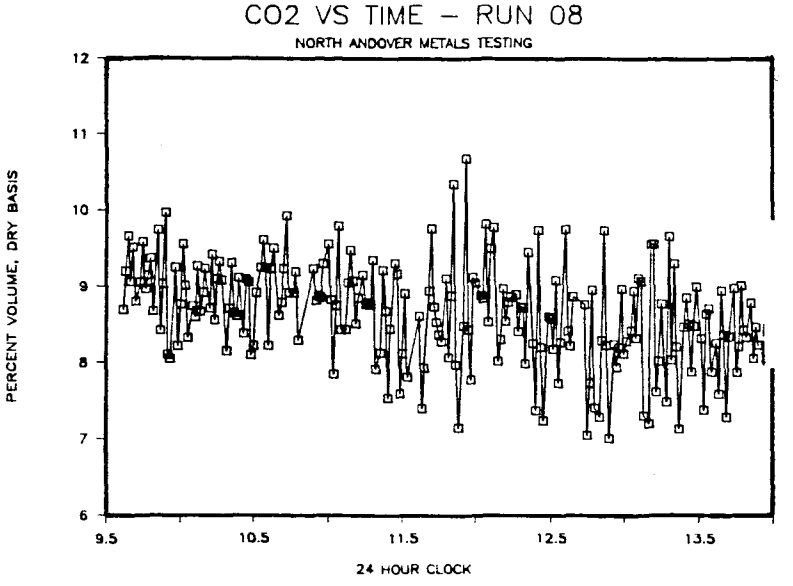
OBS = Number of observations

* Run 8 is considered invalid

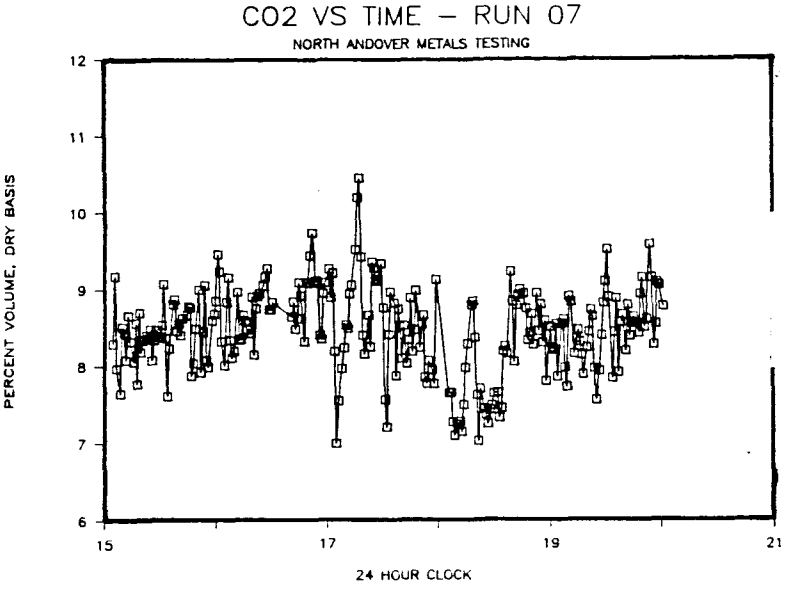
Figure 2 - 2. Oxygen Concentration History for Runs 7, 8 and 9 at North Andover RESCO



Mean = 9.2% by volume
Std dev = 0.6% by volume
OBS = 209



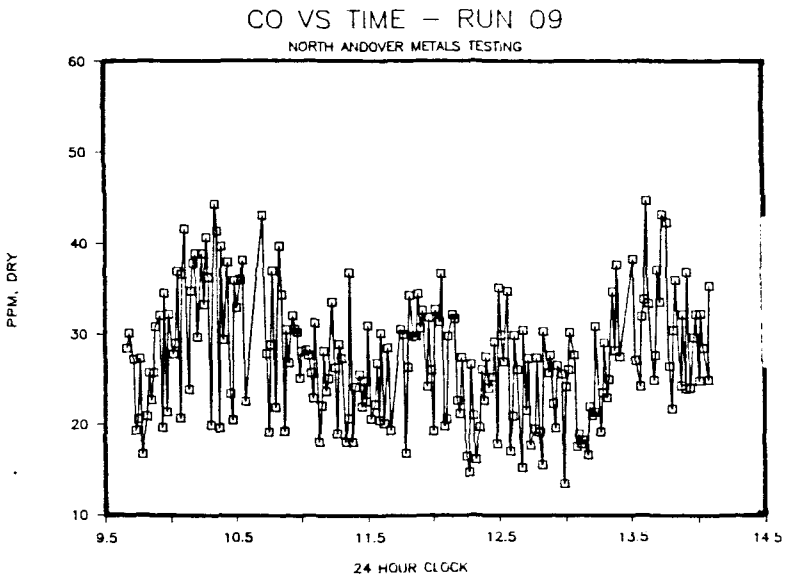
Mean = 8.6% by volume
Std dev = 0.7% by volume
OBS = 211



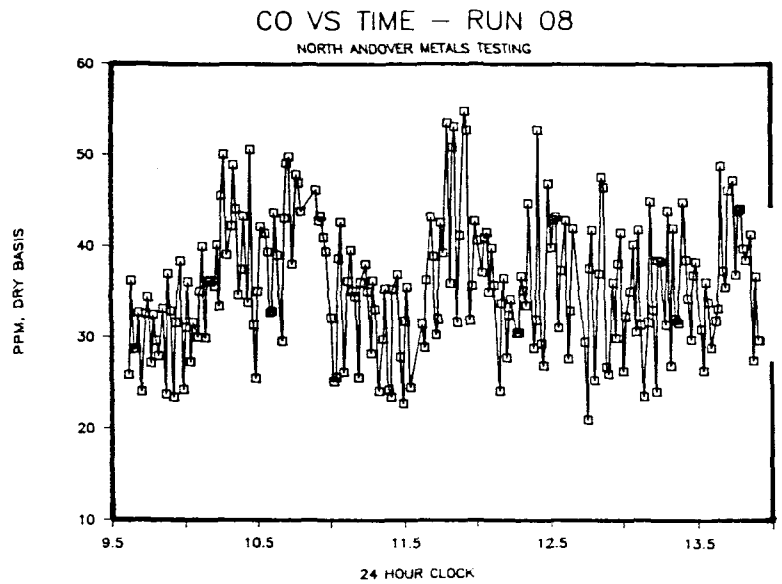
Mean = 8.5% by volume
Std dev = 0.6% by volume
OBS = 242

OBS = Number of observa

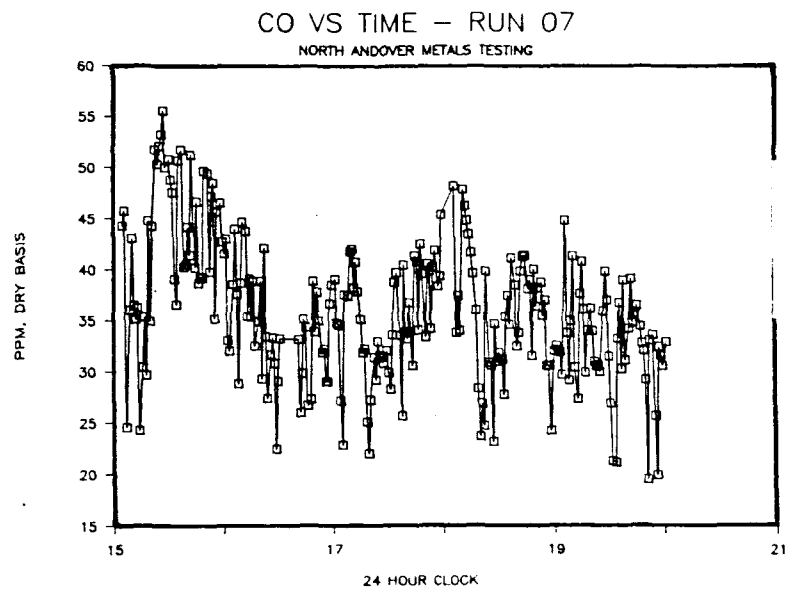
Figure 2 - 3. Carbon Dioxide Concentration History for Runs 7, 8 and 9 at North Andover RESCO



Mean = 27.2 ppm
Std dev = 6.8 ppm
OBS = 209



Mean = 35.7 ppm
Std dev = 7.2 ppm
OBS = 211



Mean = 35.9 ppm
Std dev = 6.9 ppm
OBS = 242

OBS = Number of observations

Figure 2 - 4. Carbon Monoxide Concentration History for Runs 7, 8 and 9 at North Andover RESCO

with no correlating changes in CO_2 or CO (Figures 2-3 and 2-4, respectively). This indicates that a problem with the oxygen analyzer, such as condensation in the instrument, developed during Run 8 and the result should be rejected.

3.0 PROCESS DESCRIPTION AND OPERATION

This section contains a description of the incinerator process and air pollution control system at the North Andover facility. The incinerator and ESP operating conditions during testing are summarized in Section 3.3. The operating data have been summarized as averages calculated over each test run interval. The original field data sheets are included in Appendix G.

3.1 PROCESS DESCRIPTION

The North Andover facility, which began operation in 1985, consists of two identical mass burn waterwall incinerators. Each unit is designed to burn 685 Mg/day (750 ton/day) of municipal waste and produce 93,000 kg/hr (198,000 lb/hr) of steam at 4,130kPa (600 psig) and 400°C (750°F). Steam from both boilers drives a 40 MW turbine-generator. Figure 3-1 presents a diagram of the North Andover process line. Design data for the incinerator are summarized in Tables 3-1 and 3-2.

The refuse is neither shredded nor sorted before it is transferred by overhead cranes from an enclosed pit to gravity-fed hoppers. Hydraulic rams, located at the bottom of the feed hoppers, charge the waste onto Martin reciprocating grates.

Underfire and overfire air is drawn from the pit area to fuel the combustion process, which is designed to achieve temperatures in excess of 1370°C (2500°F). Underfire air is supplied through the grates, and overfire air is distributed through nozzles located on the front and rear walls above the flame zone.

Each furnace has a volume of 820 m^3 (29,000 ft^3), and each furnace/boiler has 4,900 m^2 (53,000 ft^2) of heat transfer area. Bottom ash is quenched before being combined with the boiler fly ash and ESP ash.

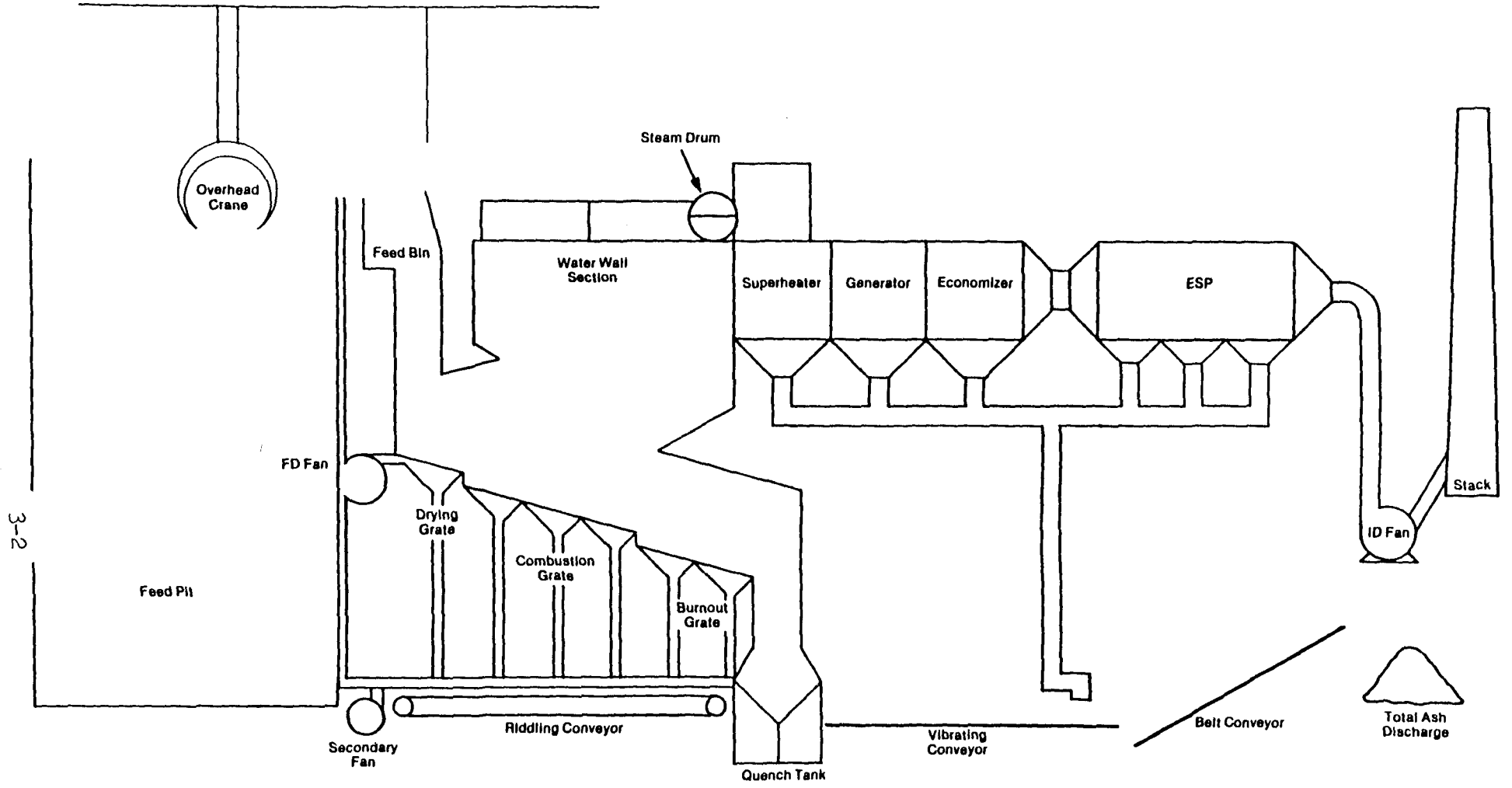


Figure 3 - 1. North Andover RESCO Process Line

TABLE 3-1. NORTH ANDOVER FACILITY STRUCTURAL DESIGN DATA

Chamber configuration				Heat transfer area		Grate data			
Primary chamber		Secondary chamber							
Geometric configuration	Volume, ft^3	Geometric configuration	Volume, ft^3	Radiative ft^2	Convective, ft^2	Type	No. of sections	Pressure drop	Capacity, tons/d
Rectangular	29,000	NA		2,700	50,700	Martin reciprocating			

TABLE 3-2. NORTH ANDOVER FACILITY AIRFLOW DESIGN DATA

Underfire air							Overfire air				
			Flow distribution, percent							Nozzle data	
No. of plenums	No. of controlled flows	Flow rate, acfm	Feed	Dry	Combustion	Burnout	Location	Flow direction	No.	Type	Velocity
		50,000					Front wall	Horizontal	30	2 3/4" diameter	
							Back wall	Inclined	31	2 3/4" diameter	

Each unit is equipped with an in-situ CEM system for carbon monoxide (CO), carbon dioxide (CO_2) oxygen (O_2), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and opacity. The CEM units are located just downstream of the ESP outlet sampling location.

3.2 AIR POLLUTION CONTROL SYSTEM

The air pollution control system consists of two identical ESPs designed to reduce the particulate matter to a level of 115 mg/NM^3 (0.05 grain/dscf) at 12 percent CO_2 which corresponds to about 98 percent collection efficiency. Design data for the ESPs are considered confidential by the ESP manufacturer.

3.3 INCINERATOR AND ESP OPERATING CONDITIONS DURING TESTING

Incinerator and ESP operating conditions were monitored by plant personnel in the control room. The following incinerator process parameters were recorded every 30 minutes: steam flow; steam drum pressure; superheater (SH) outlet temperature and pressure; economizer inlet feedwater (FW) temperature; economizer outlet FW temperature (east and west); gas temperature entering SH; gas temperature exiting economizer; percent oxygen exiting economizer; primary air temperature, pressure, and flow; forced draft (FD) fan percent damper opening; secondary air temperature, pressure (front and rear walls), flow, and fan percent damper opening; and opacity. Table 3-3 presents the average values of process data recorded by the plant. The ESP electrical power data are considered confidential by the ESP manufacturer.

Table 3-4 presents the average CEM data from the plant's instrumentation. Also shown in Table 3-4, for comparison, are the results from Radian CEMs. The instruments used by the plant are in-situ analyzers which give results on a wet basis. The results have been correctd to a dry basis for equivalent comparison to the Radian CEM results. The difference in the results can be attributed to the different sampling and analysis systems used. Appendix G contains copies of the recorded process, CEM, and ESP data sheets.

TABLE 3-3. AVERAGE PROCESS DATA FOR NORTH ANDOVER INCINERATOR TESTS
July 9 through 16, 1986

Date	Run	Steam load, lb/h x 10^3	Steam drum pressure, psig	S.H. out Temp., °F	S.H. out Pressure, psig	Econ. in FW temp., °F	Econ. out FW temp., °F	Gas temp. In S.H., °F	Gas temp. Out econ., °F
07/08/86	1	166	NR	760	600	225	498	1,233	569
07/09/86	2	165	670	759	600	225	498	1,281	570
07/10/86	3	166	674	751	600	226	498	1,245	547
07/11/86	4	166	680	755	600	226	498	1,257	562
07/12/86	5	166	680	757	NR	226	498	1,267	562
07/13/86	6	163	667	745	600	225	498	[1,027]	[607]
								[1,154]	[568]
07/14/86	7	170	680	745	600	227	498	1,217	585
07/15/86	8	168	680	748	600	226	498	1,262	578
07/16/86	9	165	680	750	600	226	498	1,126	586

NR = Not recorded by plant personnel.

TABLE 3-3. AVERAGE PROCESS DATA FOR NORTH ANDOVER INCINERATOR TESTS
July 9 through 16, 1986
(cont'd.)

Date	Run	Primary air			Secondary					FD fan damp open, percent	Refuse Feed rate (Buckets/ hour)
		Temp., °F	Pressure, in w.c.	Flow, ft³/min	Pressure, in w.c.		Flow, ft³/min		Fan damp opening, percent		
					Front	Back	Front	Back			
07/08/86	1	250	16.00	NR	17.4	15.0	NR	NR	NR	NR	12
07/09/86	2	179.5	16.00	43.9	16.5	15.0	NR	NR	35.3	18.5	12
07/10/86	3	187.3	16.46	38.3	16.5	15.0	NR	NR	NR	15.0	12
07/11/86	4	184.6	16.00	38.8	16.3	15.0	NR	NR	NR	15.3	12
07/12/86	5	148.8	16.00	36.8	16.0	15.0	NR	NR	NR	15.5	13
07/13/86	6	82.8	16.00	43.9	16.4	15.4	62.4	41.3	31.9	17.6	12
07/14/86	7	94.3	16.00	44.5	16.1	15.3	66.5	41.4	31.9	17.3	NR
07/15/86	8	94.8	16.00	44.7	16.1	15.0	69.3	40.2	33.6	18.9	15
07/16/86	9	100.3	16.00	45.9	16.5	15.0	69.1	40.1	34.7	18.9	14

NR = Not recorded by plant personnel.

TABLE 3-4. AVERAGE CEM DATA FOR NORTH ANDOVER TESTS
July 9 through 16, 1986

Run	Date	O_2 econ. out, vol %	CO, ppm	CO_2, vol %	SO_2, ppm	NO_x, ppm	Opacity, %
Plant CEM[a] (wet basis)							
Run 1	07/08/86	8.4	--	--	--	--	NR
2	07/09/86	8.4	44	9.1	18	151	0.10
3	07/10/86	7.8	36	10.6	32	162	0.12
4	07/11/86	8.5	25	10.5	40	167	0.12
5	07/12/86	8.1	11	10.4	37	184	0.13
6	07/13/86	8.6	28	9.9	42	162	0.55
7[b]	07/14/86	8.3 (9.5)	48 (55)	8.7 (10.1)	46	172	0.31
8[b]	07/15/86	8.4 (9.7)	46 (53)	9.1 (10.5)	27	189	0.14
9[b]	07/16/86	8.6 (9.9)	--	--	--	--	0.13
Radian CEM[c] (dry basis)							
7	07/14/86	11.5	35	8.5	--	--	--
8	07/15/86	8.3[d]	36	8.6	--	--	--
9	07/16/86	10.5	27	9.2	--	--	--

[a] Plant CEMs except for the O_2 analyzer were located about 10 ft downstream of the ESP outlet sampling locations. The plant used in-situ infrared analyzers and results are reported on a wet basis.

[b] The results on a dry basis are reported in parentheses below the wet basis values. The moisture content of the flue gas was determined by EPA Method 4.

[c] Radian CEMs were extracted at the ESP outlet sampling location. Radian did not measure SO_2, NO_x or opacity. Radian used an extractive system and results are reported on a dry basis.

[d] Value considered invalid due to an instrument malfunction.

NR = not recorded by plant personnel.

Some operating problems did occur during testing. A broken grate block developed during the middle of Run 5. The underfire air ports were cleaned manually during the remainder of the test run. Normal operating conditions were maintained, and the incinerator was brought down for repair immediately after completion of Run 5.

Operating problems are believed to have occurred during Runs 6 and 7. Signal Environmental Systems determined that the incinerator was still in the start-up mode during Run 6. The particulate and metals data from Run 7 indicate that the ESP may have malfunctioned during Run 7.

4.0 SAMPLING LOCATIONS

The locations of the sampling points are shown on the schematic of the process line in Figure 4-1. Each sampling location is discussed in the following paragraphs.

4.1 ESP INLET SAMPLING LOCATION

The ESP inlet sampling location is shown in Figure 4-2. PCDD/PCDF (Runs 2 through 6) and metals/particulate (Runs 7, 8, & 9) samples were obtained at this location.

The breeching at this point is rectangular, measuring 136 inches wide and 76 inches deep. Eight sampling ports with 30 inch long nipples are evenly spaced 1 foot 5 inches apart across the top of the duct in the plane perpendicular to the direction of flow. The equivalent diameter of this duct is 97.5 inches for the purpose of selecting the required number of sampling points by EPA Method 1. ESP inlet testing ports are located approximately 40.0 feet (4.9 duct diameters) downstream of a 30^{o} bend in the breeching, and approximately 6.5 feet (0.8 duct diameters) upstream of the ESP inlet. EPA Method 1 required a minimum of 24 points for this location.

The sampling point locations and dimensions of the duct are shown in Figure 4-3. A 48 point test grid was used to traverse this duct. The ratio of length to width of the sample areas was 1 to 1.3. Twice as many traverse points than were required by EPA Method 1 were used in order to obtain a length to width ratio close to one.

4.2 ESP OUTLET SAMPLING LOCATION

The flue gas was sampled at the ESP outlet breeching prior to the induced draft fan. The sampling port locations and dimensions of the duct are shown

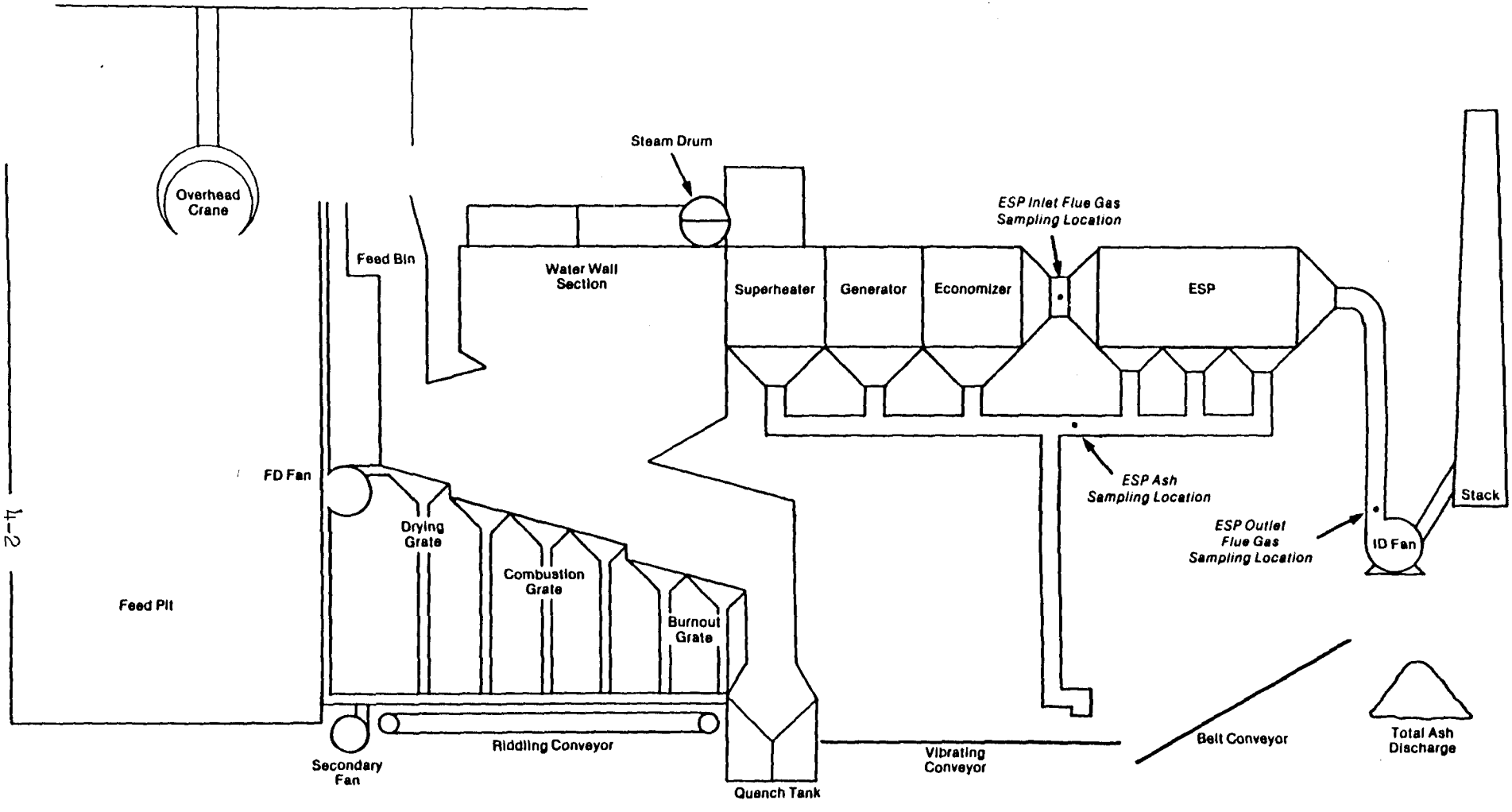


Figure 4 - 1. North Andover RESCO Process Line with Sampling Locations

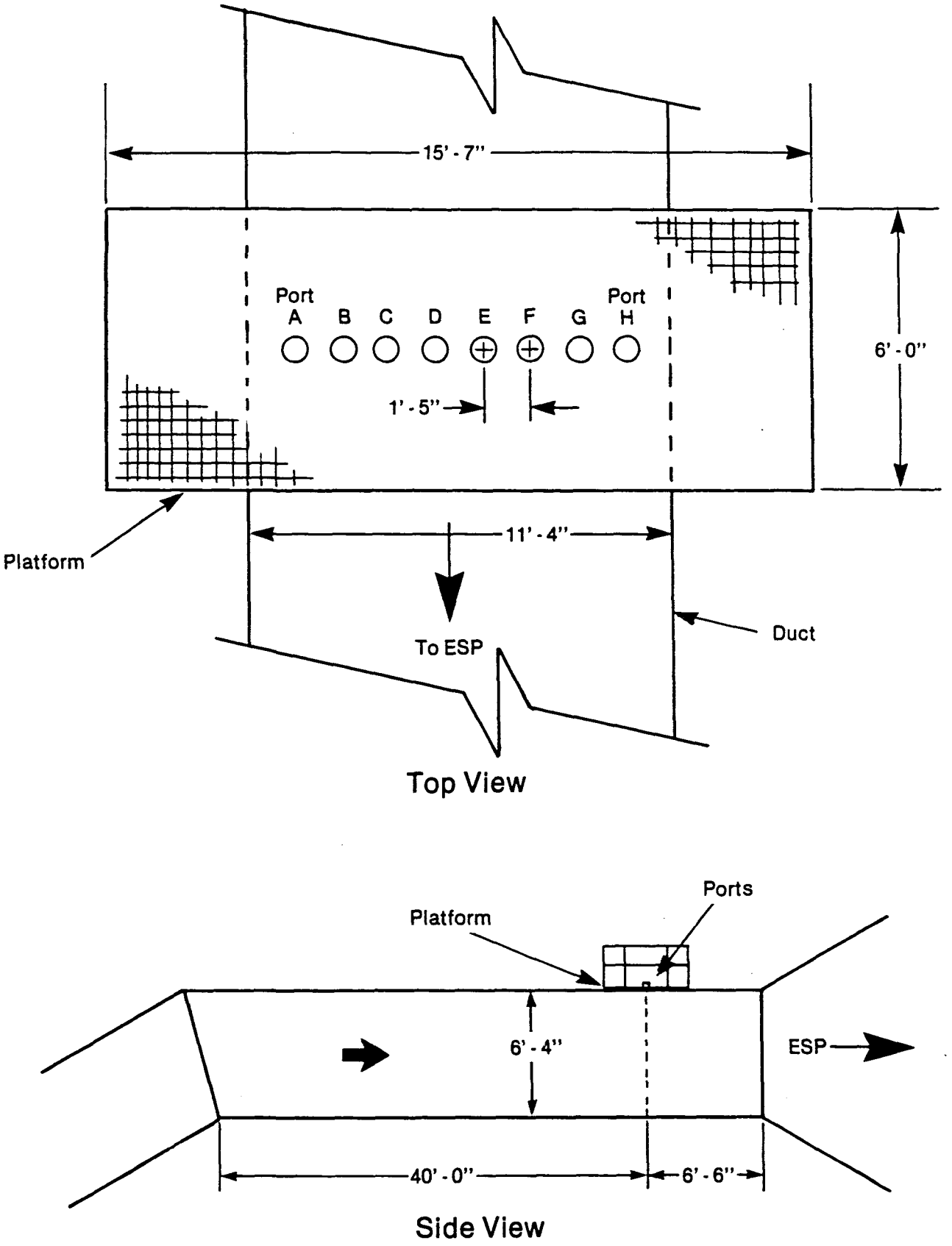


Figure 4 - 2. ESP Inlet Sampling Location

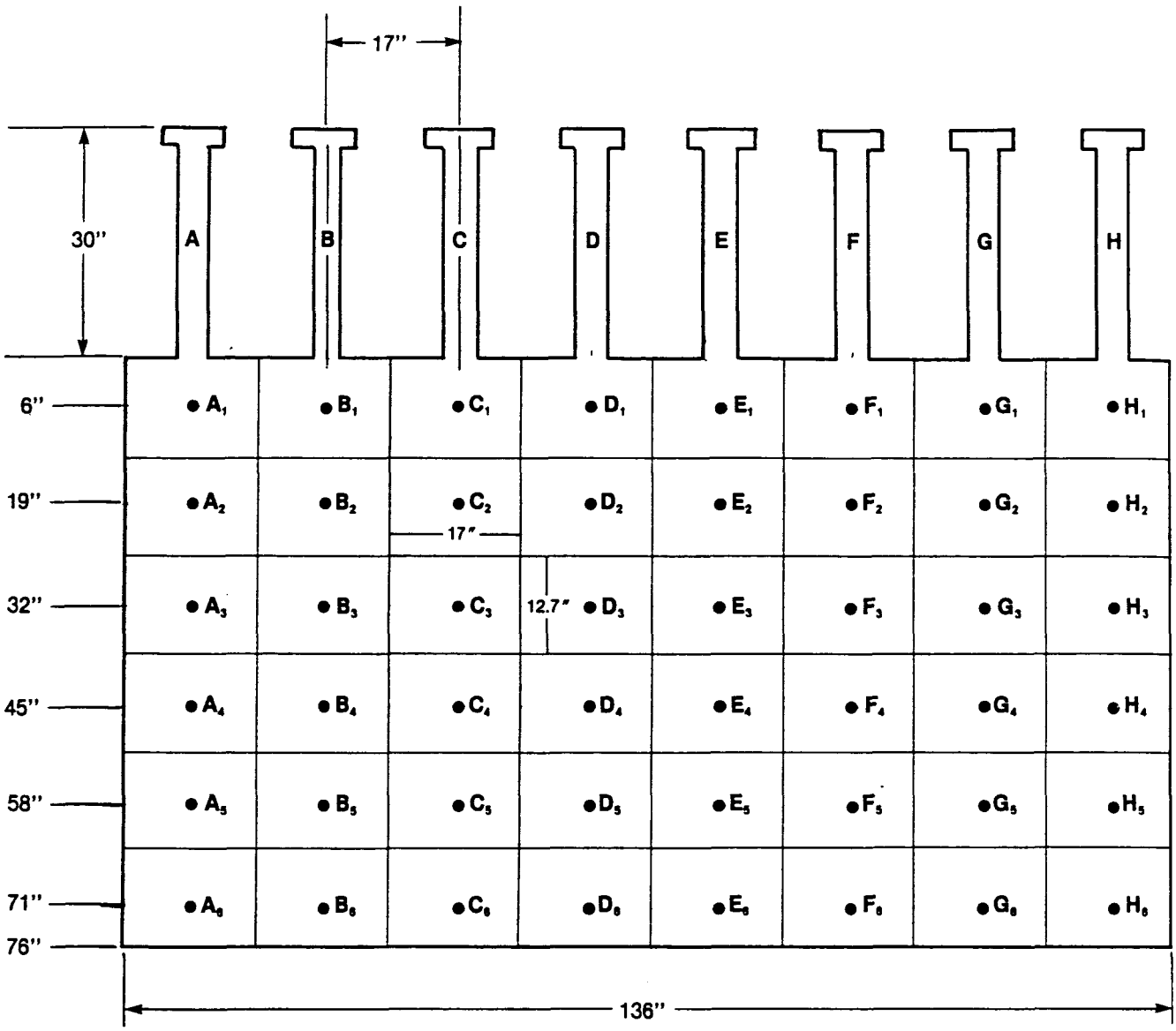


Figure 4 - 3. Traverse Matrix for ESP Inlet Sampling Location

in Figure 4-4. TOCL/particulate (Runs 1 through 6), metals/particulate (Runs 7, 8, and 9) and CEM samples were obtained at this location.

The breeching is rectangular, 124 inches wide by 76 inches deep. Six sampling ports with 8-inch nipples are installed at the sampling location. The equivalent diameter of the duct is 94.2 inches for the purpose of selecting the required number of sampling points by EPA Method 1. The test ports are located approximately 16 feet (2.0 duct diameters) downstream of a 90^{o} bend, and approximately 4.1 feet (0.5 diameters) upstream of the ID fan inlet. EPA Method 1 required at least 24 traverse points for this location.

A 24 point test grid was used, which is shown in Figure 4-5. The ratio of length to width of the sample areas was 1 to 1.1.

4.3 ESP ASH SAMPLING LOCATION

The ESP ash samples were collected from the screw conveyor that transported the ash from the ESP hopper for Unit #2 to a discharge point on the bottom ash conveyor belt. The ash handling system for Unit #2 was completely independent from the ash handling system for Unit #1. The ESP ash handling system and sampling location is shown in Figure 4-6. A plate was removed at the bottom of the screw conveyor and a sample was collected as the ash fell from the conveyor.

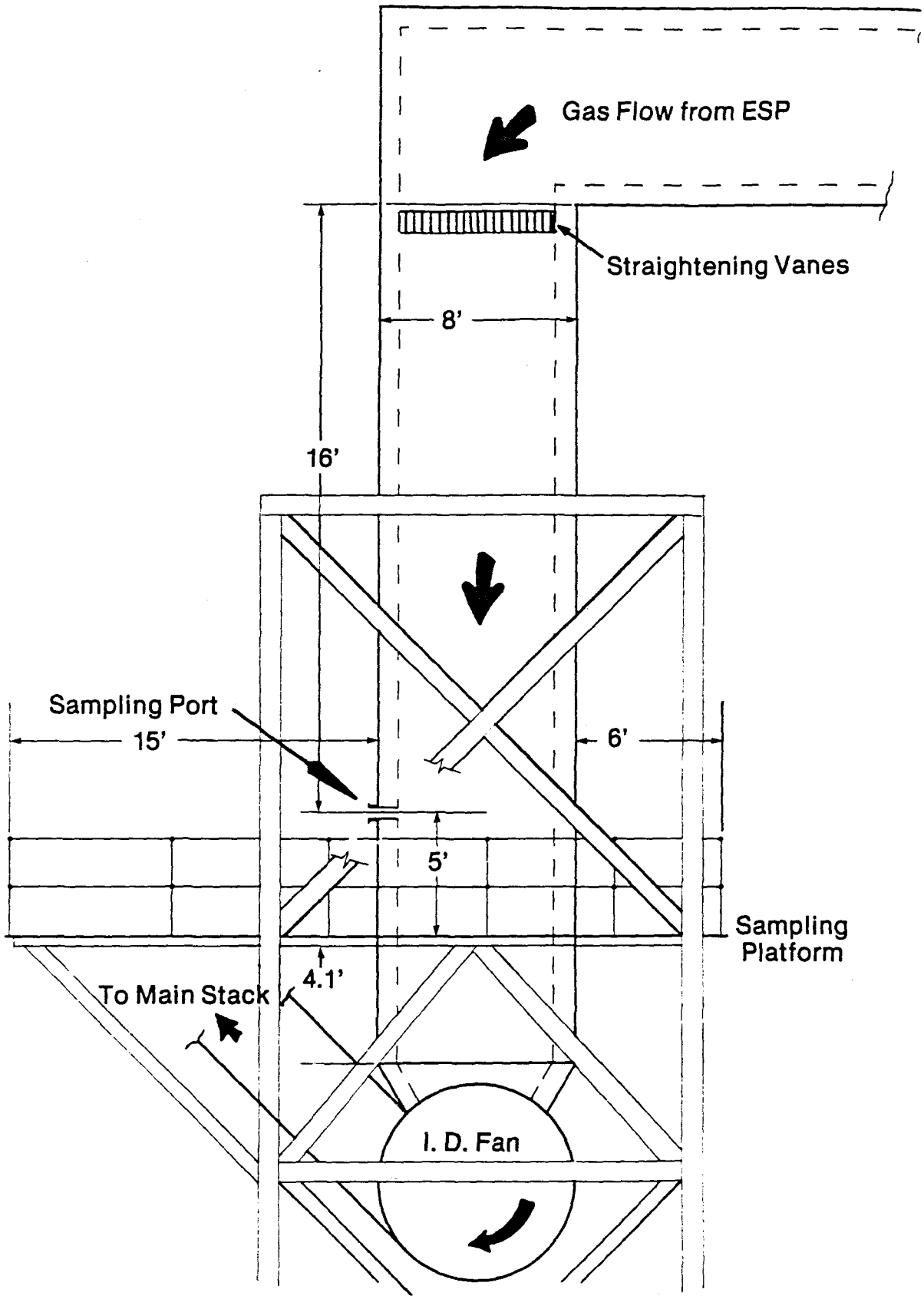


Figure 4 - 4. ESP Outlet Sampling Location at North Andover Facility

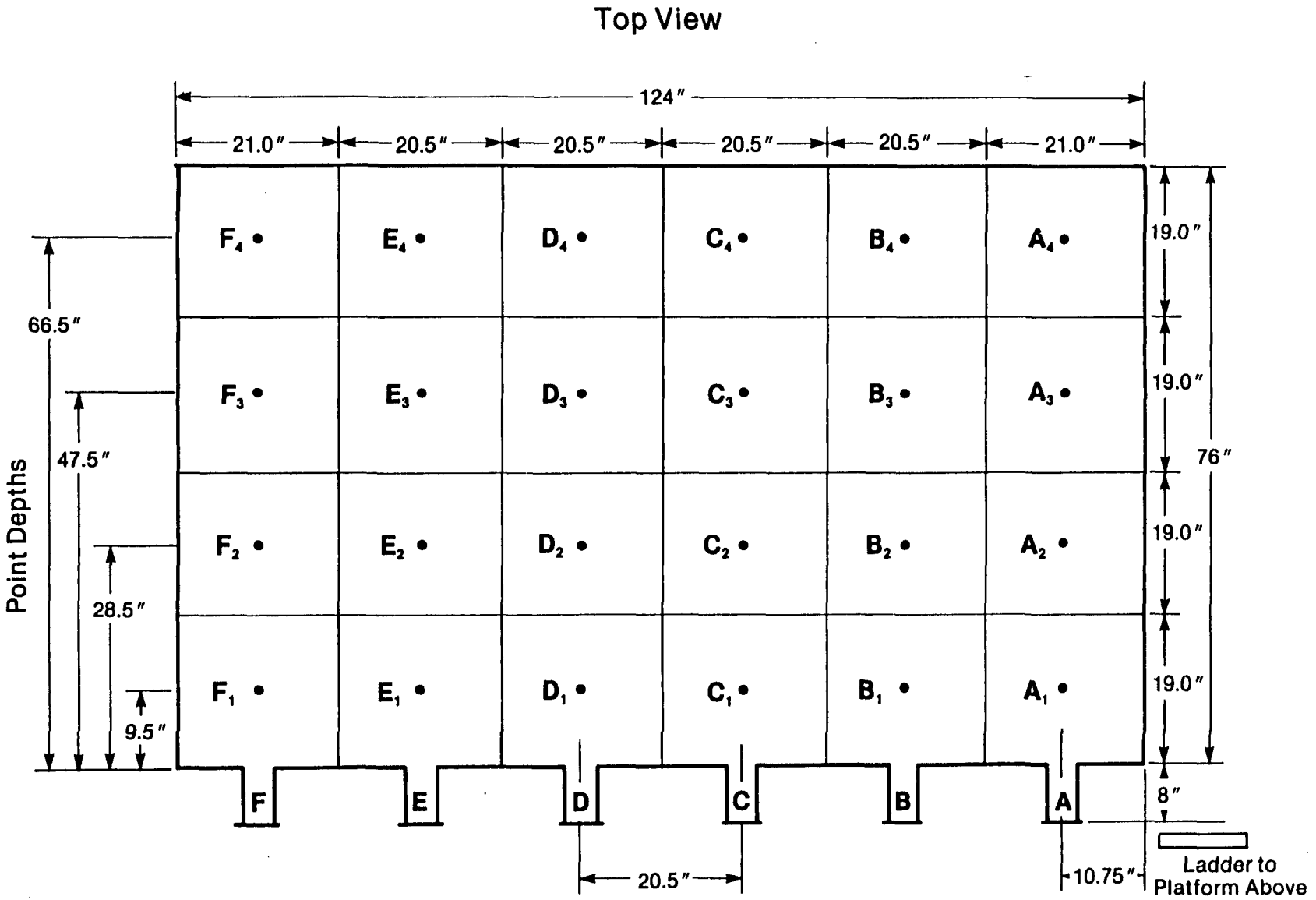


Figure 4 - 5. Traverse Matrix for ESP Outlet Sampling Location

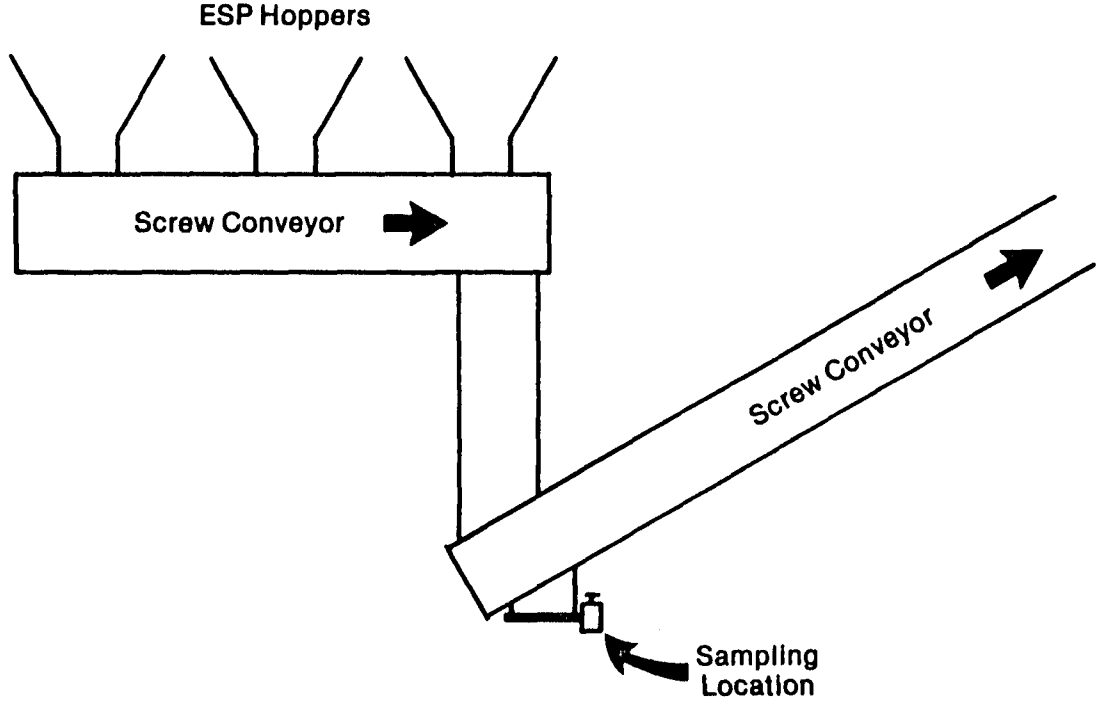


Figure 4 - 6. ESP Ash Handling System and Sampling Location

5.0 SAMPLING AND ANALYTICAL PROCEDURES

The sampling and analytical procedures used at North Andover RESCO were the most recent revisions of the published methods. In some cases, the methods were modified to incorporate the most recent developments which have been accepted by the sampling community. In this section, brief descriptions of each sampling and analytical method are provided. The detailed sampling and analytical methods with modifications are included in Appendix K. A summary of the sampling and analytical methods used for each parameter is presented in Table 5-1.

5.1 PCDD/PCDF SAMPLING AND ANALYSIS

PCDD/PCDF sampling followed the December 1984 draft protocol for the determination of chlorinated organic compounds in stack emissions. The protocol was developed by the Environmental Standards workshop sponsored by the American Society of Mechanical Engineers (ASME) and EPA. The method is based on EPA Reference Method 5.

The PCDD/PCDF analysis followed the ASME/EPA analytical procedures to assay stack effluent samples and residual combustion products for PCDDs and PCDFs also dated December 1984. The sampling and analytical procedures with modifications are discussed in the following sections.

5.1.1 Equipment and Sampling Preparation

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

TABLE 5-1. SAMPLING METHODS AND ANALYTICAL PROCEDURES

Parameters	Sampling Method	Analytical Method
Dioxins/furans	Environmental Standards Workshop (Dec. 1984)	High resolution GC/MS
Particulates	EPA Method 5	Gravimetric
Metals	Alternative Method 12	Neutron Activation Analysis
O_2, CO_2, CO, THC	Extraction	Method 3A and 10 (CEM)
Molecular weight	EPA Method 3	Orsat apparatus
Moisture	EPA Method 4	Analytical balance
Velocity	Method 2	--
Temperature	Type K thermocouple	--
ESP Ash	Composite grab sample	PCDD/PCDF: Environmental Standards Workshop Protocol (Dec. 1984) High resolution GC/MS Metals: Neutron Activation Analysis

The protocol was modified by replacing hexane with methylene chloride during all aspects of sampling preparation and recovery. Methylene chloride was shown to recover the higher chlorinated PCDD/PCDFs better than hexane during the EPA Tier 4 program.

The glassware is washed in soapy water, rinsed with tap water, baked and then rinsed with acetone and methylene chloride. Once in the field, the train glassware is assembled and rinsed with methylene chloride. The rinses are analyzed for residual PCDD/PCDFs.

The XAD resin and glass filber filters were extracted in HPLC grade water, methyl alcohol, methylene chloride and hexane, sequentially. At the conclusion of the soxhlet extractions, a 500 ml aliquot of the final solvent rinse (hexane) was concentrated to 5 ml. A 500 ml aliquot of fresh hexane of the same lot was also concentrated as a blank. Both aliqouts were analyzed by GC/FID for determination of Total Chromatographable Organics (TCO). A standard mixture of n-hydrocarbons that cover the TCO range of boiling points which is from 100°C (C_7 - bp 98°C) to 300°C (C_{17} - bp 303°C) was used to quantify the TCO results in the aliquot. The results were reported as milligrams of TCO per resin weight prepared (mg/g), corrected for the blank. The results for the XAD resin used at North Andover are included in Appendix J.2. The XAD resin was packed in glass traps and the filters in the glass petri dishes for transport to the field.

The remaining preparation includes calibration and leakchecking of all the train equipment. This includes meterboxes, thermocouples, nozzles, pitot tubes, and umbilicals.

5.1.2 Sampling Operations

The PCDD/PCDF sampling method uses the sampling train shown in Figure 5-1. Radian has modified the protocol to include a horizontal condenser rather than a vertical condenser. The horizontal condenser lowers the profile of the train and reduces breakage. The XAD trap following the condenser is still maintained in a vertical position.

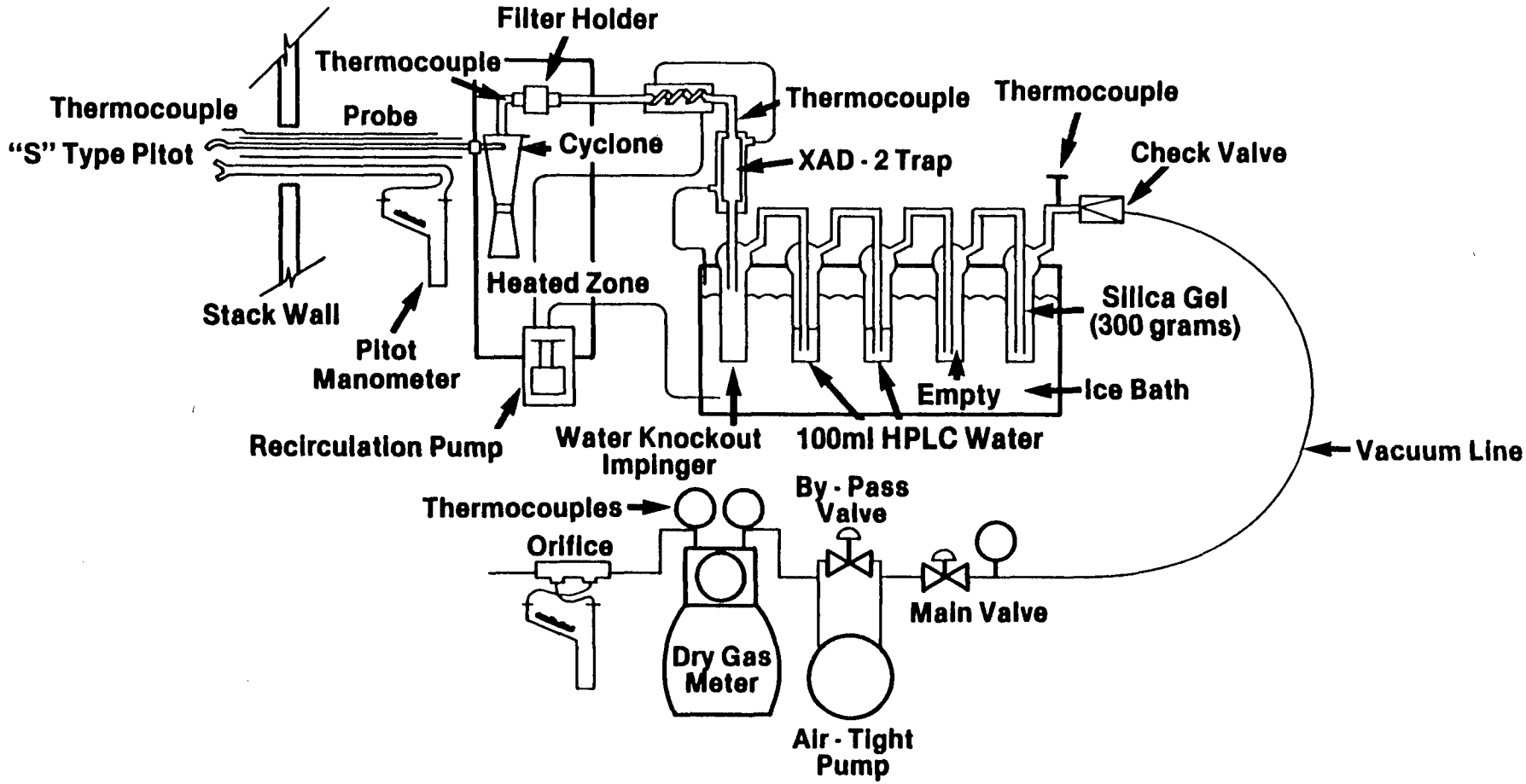


Figure 5 - 1. PCDD/PCDF Sampling Train Configuration Used at North Andover RESCO

The sampling locations at North Andover RESCO had six to eight ports and to insure that the train remained intact during the port changes, the trains were leakchecked after sampling in each port. The trains were also leakchecked at the start and finish of sampling as required in EPA Method 5. In the event that the leakrate was found to be above the minimum acceptable rate (0.02 ft^3/min) after a port, the sample volume was corrected for that port as specified in the sampling protocol. This calculation is shown in more detail in Appendix A.5, but basically, the excessive leakrate was reduced by the minimum acceptable rate and then multiplied by the sampling time of the port.

At the ESP inlet, the duct was traversed following EPA Method 1. The traverse diagrams were shown previously in Figure 4-3. Sampling was conducted simultaneously with the ESP outlet. Since the ESP outlet had a different traverse matrix, sampling at the ESP inlet was stopped during the ESP outlet port changes. During these periods, the pump was turned off, and the train rotated 180 degrees.

Sample was collected for 4 minutes per point for a total of 192 minutes for Runs 1-3 and for 5 minutes per point for a total of 240 minutes for Runs 4-6. The flowrate of the flue gases and the nozzle diameter required the sampling rate to be an average of 0.4 dscfm to insure isokinetic sampling. The sampling time was increased to insure that the sample volumes would be significantly greater than 90 dscf which was the volume needed for the outlet location based on the minimum detection limit.

Other sampling operations that are unique to PCDD/PCDF sampling include maintaining the gas temperature entering the XAD trap below 68°F. The gas is cooled by the condenser and, the XAD trap, itself, has a water jacket in which ice water is circulated. Otherwise, sampling followed EPA Method 5 specifications.

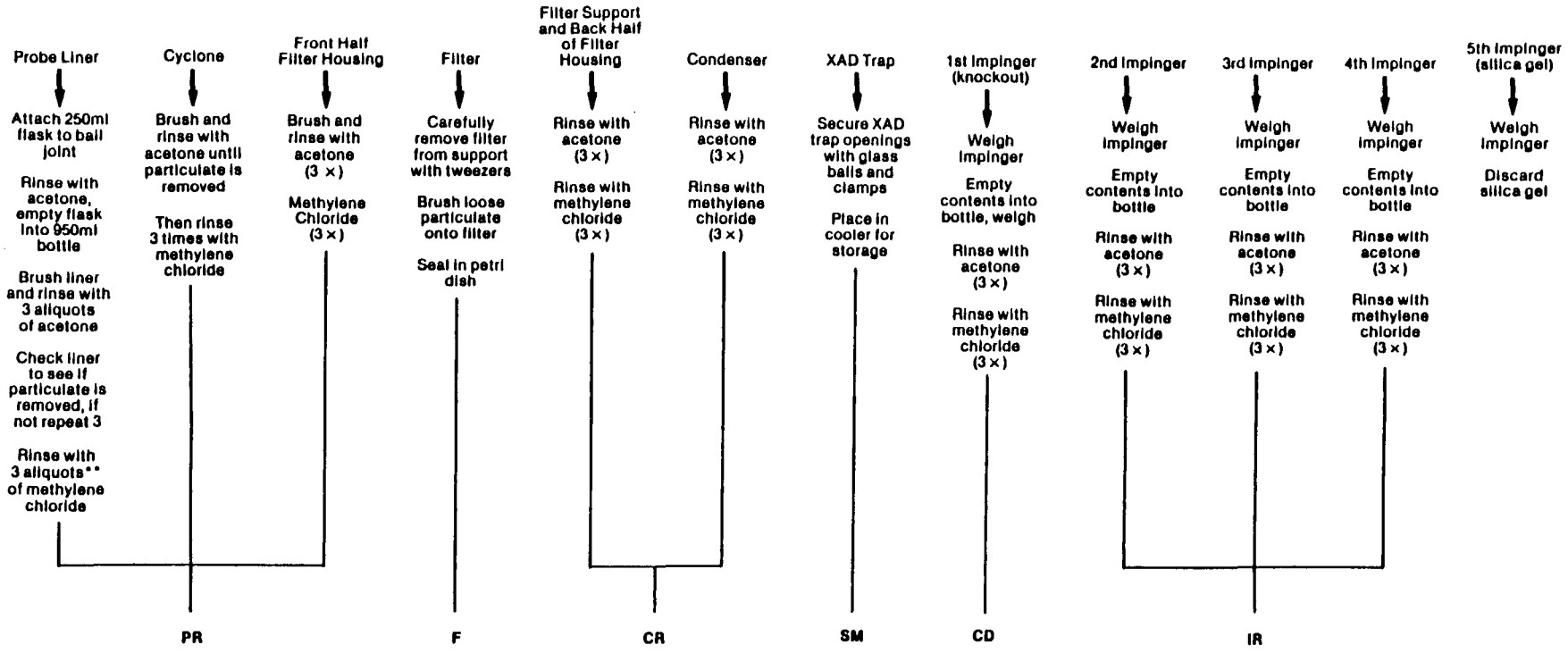
5.1.3 Sample Recovery

To facilitate transfer from the sampling location to the recovery train, the sampling train is disassembled into four sections: the probe liner, the XAD trap and condenser, filter holder, and the impingers in their bucket. Each of these sections are capped with methylene chloride-rinsed aluminum foil before removal to the recovery trailer. Once in the trailer, field recovery follows the scheme shown in Figure 5-2. The liquid fractions were recovered into amber bottles which helped to protect the samples from light damage. Recovery results in the sample components listed in Table 5-2. The sample fractions are shipped to the analytical laboratory via truck.

5.1.4 Analysis

The PCDD/PCDF analyses for the North Andover RESCO samples were performed by Triangle Laboratories, Research Triangle Park, North Carolina. The sample components were extracted, combined and concentrated according to the scheme in Figure 5-3. Isotopically-labelled internal standards and surrogate compounds were added to the samples prior to the extraction process begins. The internal standards included 2378-$^{13}Cl_{12}$-TCDD, $^{13}Cl_{12}$-PCDD, $^{13}Cl_{12}$-HpCDD and $^{13}Cl_{12}$-OCDD. Once added to the samples, the internal standards went through the entire extraction process and were measured on the GC/MS. Then the recoveries of the internal standards were determined and the results of the native species were adjusted according to the internal standard recoveries. The surrogate compounds which included $^{13}Cl_{12}$-TCDF, $^{37}Cl_{12}$-TCDD, and $^{13}Cl_{12}$-HxCDF were added in a similar manner, but the surrogate recoveries were not used to adjust the results of the native species. Surrogates provide additional information of the extraction efficiency of the analytical procedure.

The samples were analyzed as front half and back half fractions. This was a modification requested by EPA. The validity of this separation for the purpose of quantifying filterable and gaseous PCDD/PCDF is questioned by some of the sampling community. However, the purpose of this modification was to



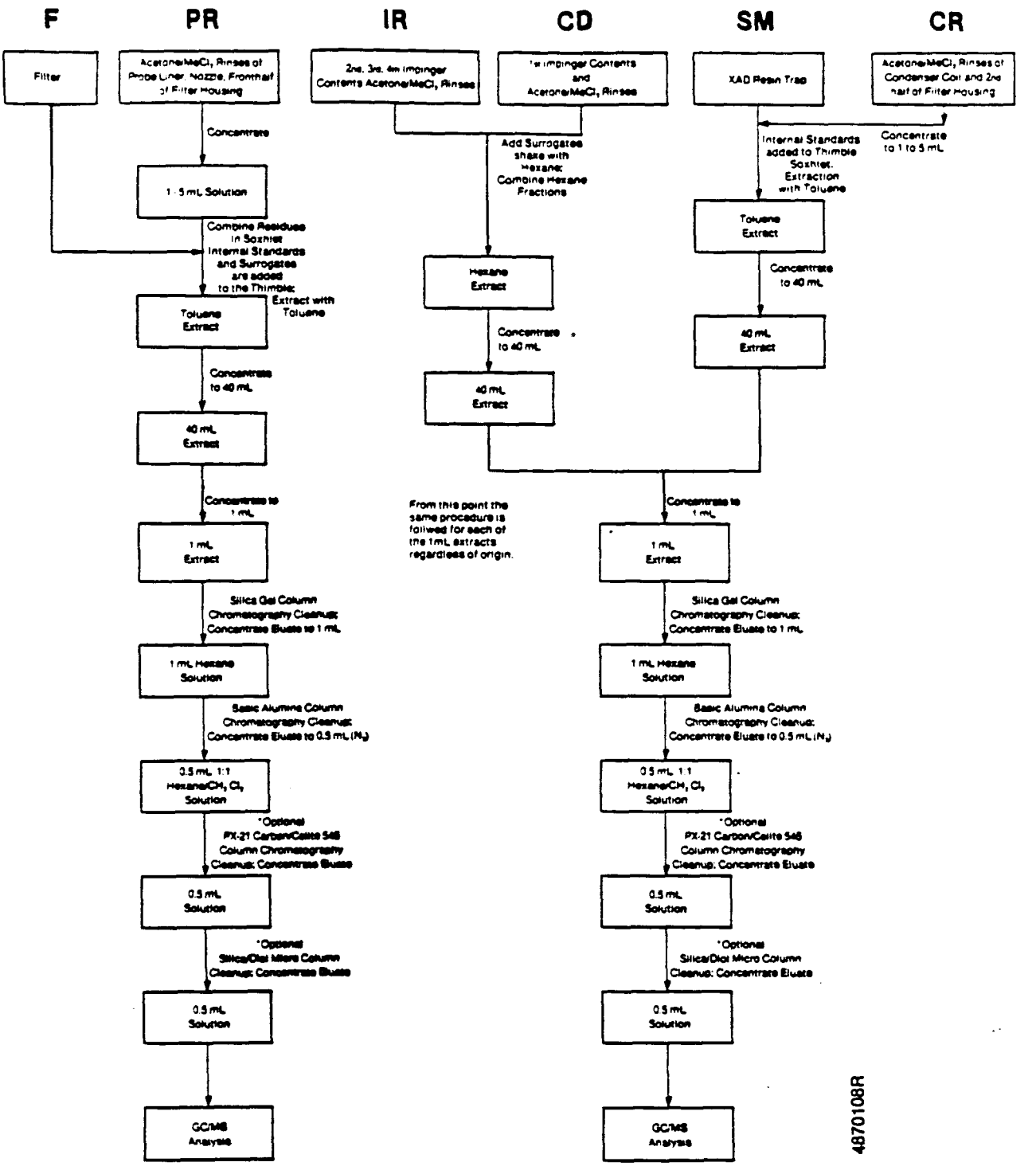
* Aliquot equals about 100ml. Empty all rinses into one 950ml bottle.
3 × = three times

Figure 5 - 2. PCDD/PCDF Field Recovery Scheme

TABLE 5-2. PCDD/PCDF SAMPLING TRAIN COMPONENTS FOR NORTH ANDOVER RESCO SHIPPED TO ANALYTICAL LABORATORY

Container/Component	Code	Glassware
1. Component Number 1	F	Filter(s)
2. Component Number 2	PR	Rinses[a] of nozzle, probe, transfer line (if used), cylcone, and front half of filter holder
3. Component Number 3	CR	Rinses of back half of filter holder, filter support and condenser
4. Component Number 4	CD	First impinger contents and rinses
5. Component Number 5	IR	Second, third and fourth impinger contents and rinses
6. Component Number 6	SM	XAD-2^{R} resin

[a]Rinses include acetone and methylene chloride combined in same container.



*For large volumes, organic solutions are concentrated using a rotary evaporator apparatus
For small volumes, samples are concentrated under nitrogen

Figure 5-3. PCDD/PCDF Analytical Scheme Used at North Andover RESCO

study the internal standards recovery of the front and back half fractions, since the different matrices of the fractions may effect the recovery of the internal standards.

The front half of the sample train consists of the probe rinse, cyclone, front half filter holder rinse, and the filter. The back half includes the back half filter holder rinse, coil condenser rinse, XAD^{R} trap, and impinger contents and rinses.

The samples were analyzed by high resolution gas chromatography followed by high resolution mass spectrometry (GC/MS). The instruments are calibrated daily with external standards. The GC/MS results are recorded and stored onto a computer file. The computer is used to reduce the data and to summarize the results such as amount detected, detection limit, retention time and internal and surrogate recoveries. The analytical report from Triangle Laboratories is included in Appendix D.1.

5.1.5 Data Reduction for PCDD/PCDF Results

The data reduction for PCDD/PCDF results began with correcting for the reagent blank results. Then the concentrations of PCDD/PCDFs in the flue gas are calculated by dividing the nanograms of analyte by the volume of flue gas collected. The volume of flue gas has been corrected to EPA standard conditions and is reported in dscm units.

To normalize the concentrations to 12 percent CO_2, the ratio of 12 to CO_2 measured in the flue gas, is calculated for each run based on EPA Method 3 results. Then the concentrations from each run are multiplied by the respective normalization ratio. The normalized concentrations are multiplied by 2378-TCDD toxic equivalency factors to obtain 2378-TCDD toxic equivalents.

Mole fractions of each isomer are calculated by dividing the concentration of each isomer by its molecular weight. The moles of each isomer are summed for each run, and the fraction is obtained by dividing the

moles for each isomer by the total moles. All of the PCDD/PCDF calculations described above are done on a Lotus 1-2-3 spreadsheet and are also verified by hand. The isomer distribution plots (Figure 2-1) are also prepared using the spreadsheet. The calculations are included in Appendix A.5.

5.2 FLUE GAS TRACE METALS/PARTICULATE DETERMINATION

Gas sampling and analysis for metals and particulates was performed according to EPA Alternate Method 12, "Determination of Inorganic Lead Emissions from Stationary Sources."

5.2.1 Equipment and Sampling Preparation

Equipment and sampling preparation for metals/particulate sampling followed the specifications for EPA Method 5 with some additional glassware preparation. The glassware preparation took place on-site since the same glassware from Runs 1, 2, and 3 were used. The train glassware was washed in soapy water, rinsed with tap water, rinsed with distilled water, rinsed with 0.1 N nitric acid, rinsed with distilled water, and then dried with acetone. The glassware was then capped with Parafilm^{R}. Before the glassware was used for sampling, the glassware was recovered with 0.1 N nitric acid, and the rinses were analyzed for trace metals.

5.2.2 Sampling Operations

The metals and particulate sampling protocol followed EPA Alternate Method 12, where both particulate matter and metal samples were collected using the same train. Alternate Method 12 is a variation of EPA Method 5 where 0.1 N nitric acid replaces water in the impingers, and filter media with a low lead background are used. The metals/particulate sampling train is shown in Figure 5-4. An EPA Method 12 train usually has a Greenburg-Smith impinger as the second impinger. The outlet train during Runs 7, 8 and 9 used two modified-tip impingers in place of the Greenburg-Smith impinger. For Run 7, the contents and rinses from the 1st and 2nd impingers were recovered and

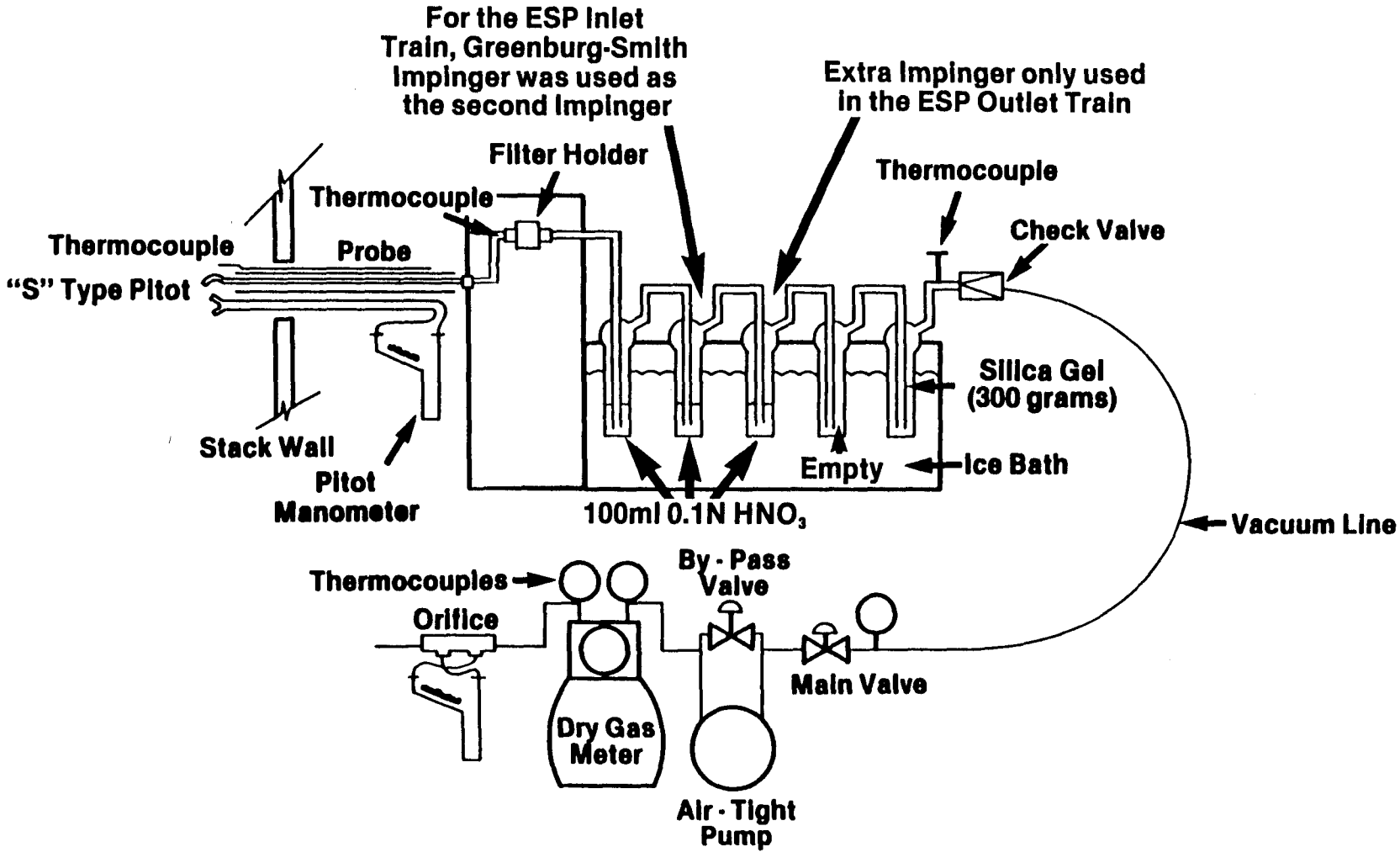


Figure 5 - 4. Metals/Particulate Sampling Train Configuration Used at North Andover RESCO

analyzed separately from the 3rd and 4th impingers. This modification was made due to insufficient number of Greenburg-Smith impingers on-site.

With respect to leakchecks and traversing, the particulate/metals trains followed the same operations as previously discussed in Section 5.1.2.

5.2.3. Sample Recovery

To facilitate transfer from the sampling location to the recovery trailer, the sampling train was disassembled into three sections; the probe liner, the filter holder and the impingers in their bucket. Each section was capped with Parafilm^{R} before being transferred to the recovery trailer. Once in the trailer, the field recovery followed the scheme shown in Figure 5-5. First, the probe line was rinsed and brushed with acetone until particulate was qualitatively removed from the probe liner. The acetone rinse was placed in a borosilicate glass sample bottle. The impingers were weighed and the contents placed in polyethylene sample bottles. The impingers were rinsed with 0.1 N nitric acid and the rinses added to the impinger contents. For the Run 7-outlet train the first two impingers were recovered into a separate bottle than the third and fourth impingers. For Runs 8 and 9 all the impingers were recovered into the same sample bottle. The filter was sealed in a petri dish. The sample components shipped to the laboratory are listed in Table 5-3.

The dessication and evaporation of the particulate sample was performed at the laboratory at Radian/RTP. Although the nozzle was recovered for particulate analysis, the rinse was kept separate, and was analyzed for particulates separately. The nozzle was not rinsed with nitric acid and was not included in the metals analysis because of possible contamination.

5.2.4 Analysis

The analysis for the metals/particulate samples was executed in two steps which are shown in the bottom half of Figure 5-5. First, the acetone rinses

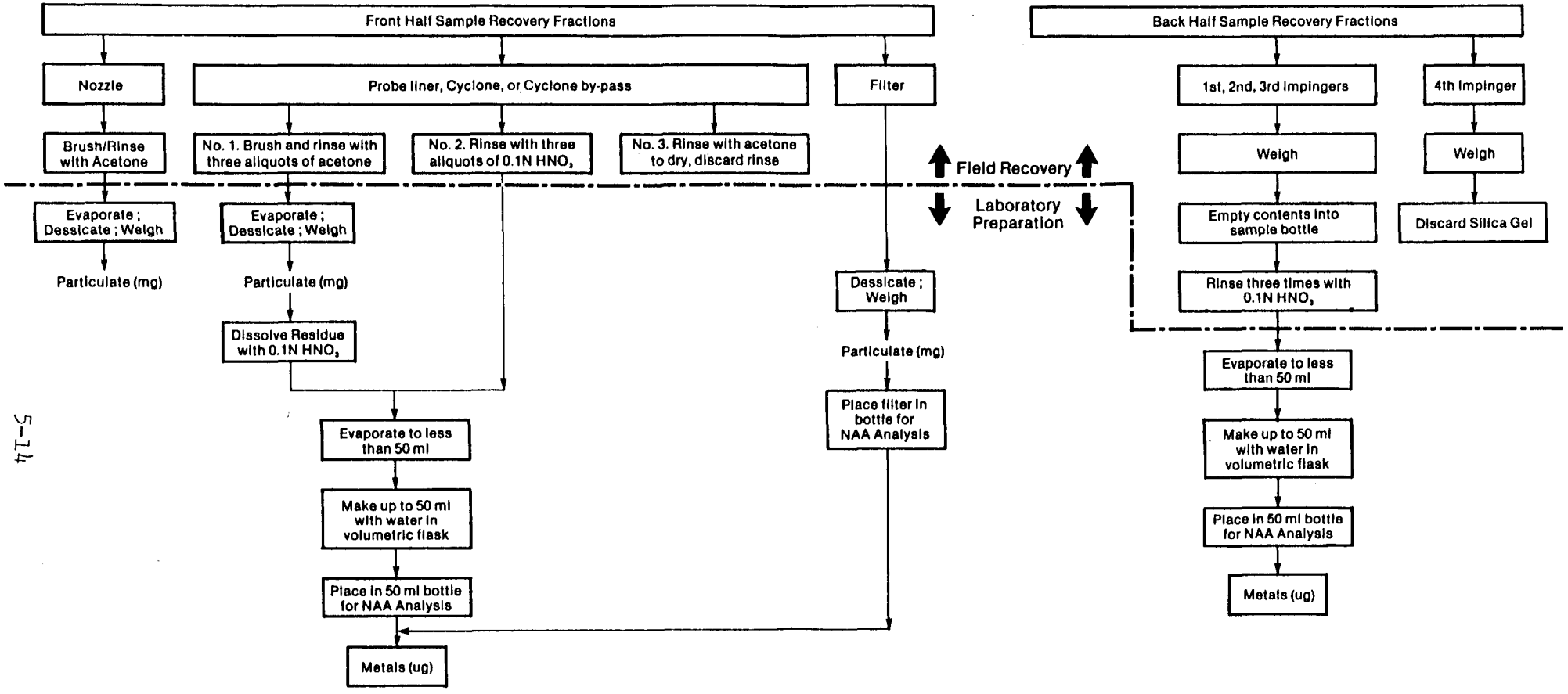


Figure 5 - 5. Sampling and Analysis Protocol for Metals/Particulate Samples

TABLE 5-3. SAMPLE COMPONENTS FOR PARTICULATE/METALS TRAIN

Component	Code	Glassware
1	PR - Acet	Acetone rinses of probe liner cyclone or cyclone bypass, and front half of filter housing
2	PR - HNO_3	0.1 N Nitric rinses of probe liner cyclone or cyclone by-pass, and front half of filter housing
3	F	Filter
4	IR	0.1 N Nitric rinses and contents of impingers, also rinses of back half of filter housing, filter support, and zigzag.
5	NZ	Acetone rinse of nozzle

and filter were dessicated and weighed for the particulate analysis. Then, the particulates were resuspended in 0.1 N Nitric acid and combined with the nitric rinses from the front half. The front half and back half fractions were evaporated separately and placed in separate bottles, so that the samples were analyzed as front half and back half fractions. Front half/back half analyses were performed for the purposes of the EPA study. The sample preparation and particulate analysis was completed by Radian/RTP.

Following the particulate analysis, the samples were analyzed for metals using NAA. The analysis was performed by the Nuclear Services Laboratory at North Carolina State University in Raleigh, N.C. NAA can be used to analyze for all the specific metals except lead and beryllium. Also, the method does not differentiate between different valence states or compounds of a metal such as Cr (III) or Cr (VI).

During the NAA procedure, the samples are exposed to neutrons. The neutrons excite the metal atoms and cause them to emit gamma rays. The density and wavelength of the gamma rays are measured and the information is logged by a computer. Calibration standards with known amounts of the metals are also included in the sample batch, and by comparing the results from these calibration standards to those of the samples, the type and concentration of each metal detected is determined.

However, since lead and beryllium do not emit gamma rays, NAA cannot measure these metals. Also, NAA hay have interferences with certain metals. Depending how mercury is bound in the sample, the mercury results may be variable. The sample is heated during the exposure to neutrons and may cause the mercury to vaporize and migrate out of the polyethylene sample bottles. High levels of sodium (factors of 1000) may cause interference with the metals nearby in the spectrum such as arsenic, bromine, potassium, antimony, samarium and cadmium. If the sodium level can be estimated in the sample, the exposure time can be adjusted to minimize the interference. The analytical report from the Nuclear Services Laboratory is included in Appendix D.2.

5.2.5 Data Reduction For Metals/Particulate Results

The particulate loading was calculated using the following equation.

$$C_p = \frac{(M_p - M_b)_{filter} + (M_p - M_b)_{rinses}}{V_{m(std)}}$$

C_p = particulate loading (mg/dscm)
M_p = mass of particulates (mg)
M_b = mass of the blank (mg)
V_{std} = volume of gas sampled at standard conditions (dscm @ 1 atm and 68°F)

Metals concentrations in the flue gas were determined in ug/dscm with the following equation:

$$C_{metal} = \frac{(C^o_{metal} - C_b)}{V_{m(std)}}$$

where:

C^o = amount of metal detected in sample (ug)
C_b = amount of metal detected in the blank (ug)
$V_{m(std)}$ = volume of gas sampled at standard conditions (dscm @ 1 atm, 68°F)

The metals concentration are normalized using the same procedure described for PCDD/PCDFs in Section 5.1.5.

5.3 CEM SAMPLING AND ANALYSIS

5.3.1 Equipment and Sampling Preparation

Each component of the CEM system was cleaned, leakchecked and calibrated before going into the field. The components of the system include the probe, the umbilical, the gas conditioner and pump, the manifold, the analyzers, the computer data logger, and the strip chart recorder.

The probe was checked for leaks, and the filter was inspected. The umbilical consists of teflon tubing which has been wrapped in heat tracing

within a protective sheath. The umbilical was cleaned with hot water, and then dried and blanked with nitrogen. The umbilical was also leakchecked. The gas conditioner pump, and manifold were leakchecked, cleaned, and the cooling operation was checked prior to operation.

A three point calibration was performed on each of the analyzers. The calibrations also tested the operation of the computer data logger and stripcharts recorder. A correlation coefficient was calculated from the three points to check the linearity of the response of the analyzer. (The criterion is discussed in Section 6). Once the system is prepared, it was disassembled and packed carefully for transport to the site.

5.3.2 Sampling Operations.

A schematic of the CEM system used at the North Andover facility is shown in Figure 5-6. Before each run, the system was leakchecked and a system blank was analyzed. Each of the analyzers was calibrated with a commercially prepared and certified zero and span gas and the response factor was determined. The calibration gases are introduced at the manifold. The calibration results were transmitted to the data logger which also recorded the data during the sampling run. The data logger scanned each analyzer 180 times per minutes, and recorded one-minute averages. The data logger stored the one-minute average instrument response from each analyzer on disk, and also converted the response to a concentration using the initial calibration data which was printed out as a hard copy. The instrument responses were also recorded on a stripchart as a back-up to the data logger. At the end of the sampling run, another zero and span calibration was performed. The final calibration was used to determine the daily drift of the instrument. The listings of the one-minute averages, stripcharts, and calibrations are included in Appendix B.

5.3.3 Data Reduction

The data reduction for the CEM results were performed on computer. The exact equations used are included in Appendix A.5 and are discussed in general

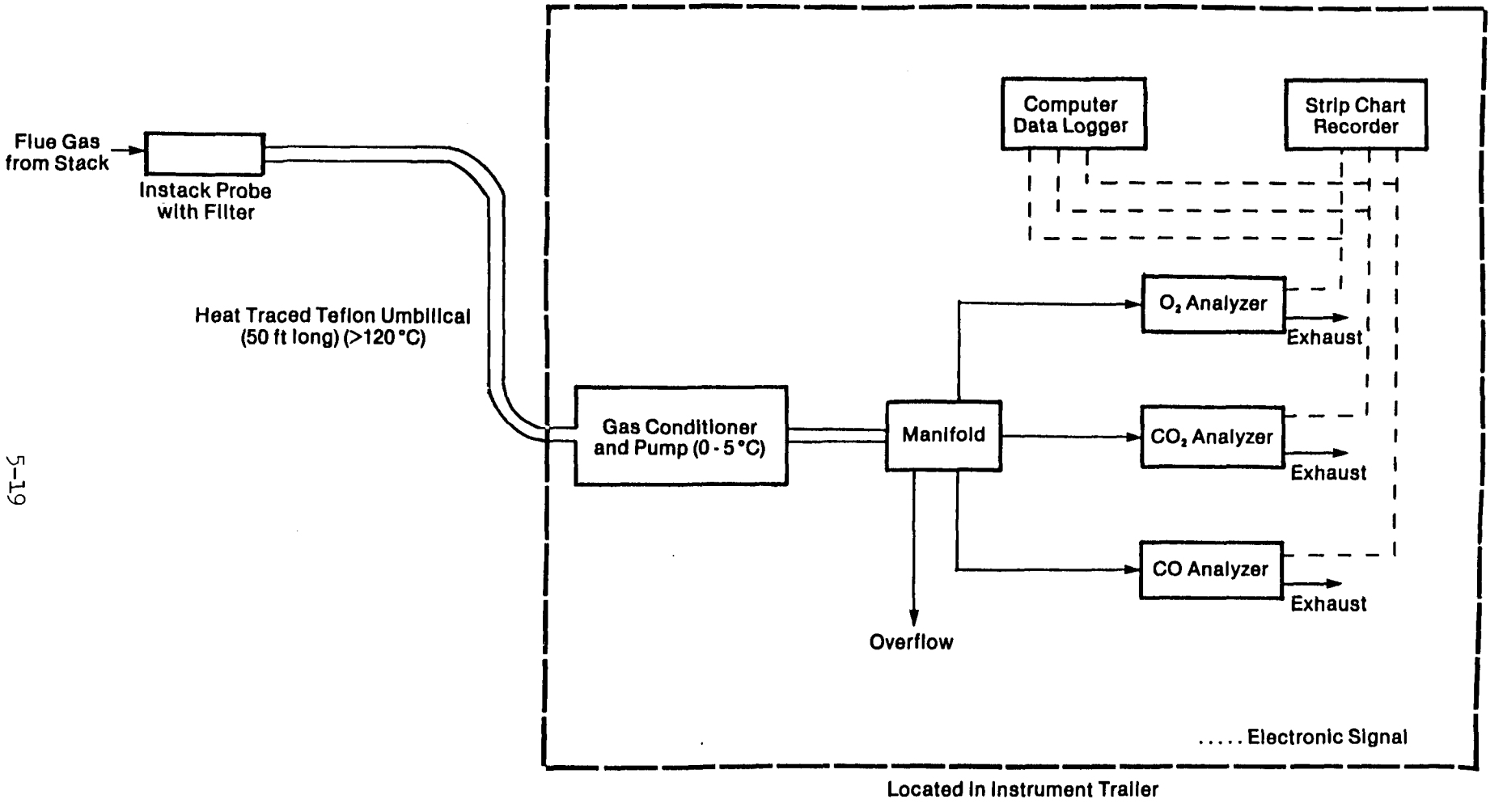


Figure 5 - 6. CEM Analysis Scheme

in this section. At the end of the sampling run, the daily drift of each instrument was evaluated by comparing the initial and final calibrations. Then, each one-minute average was adjusted by assuming the drift was linear throughout the day. Also, any invalid sections of the data (such as blowbacks of the instrument lines to prevent moisture from plugging the lines) were deleted before the averages and standard deviations were calculated for each parameter.

5.4 MOLECULAR WEIGHT DETERMINATION BY EPA METHOD 3

5.4.1 Sampling Operations

The molecular weight of the flue gas was determined using EPA Method 3. During the flue gas sampling an integrated bag sample was extracted at a single point from the sampling location at a rate of 0.5 ml/min for a total sample volume of approximately 1.5 cubic feet. The sampling train used is shown in Figure 5-7. The moisture knockout trap allowed the analysis to be on a dry basis.

5.4.2 Analysis

The integrated bag samples were analyzed with an Orsat^{TM} analyzer for CO_2 and O_2. Nitrogen was determined by difference. Triplicate analyses were performed on each bag, and an average was used as the input for the Method 5 calculations. The absorbing solutions used in the analyzer were potassium hydroxide (45% by volume) for carbon dioxide and pyrogallate (pyrogallol in potassium hydroxide) for oxygen. The Orsat data sheets are included in Appendix C.7.

5.5 VOLUMETRIC FLOWRATE BY EPA METHOD 2

Volumetric flowrate was measured according to EPA Method 2. A type K thermocouple and S-type pitot tube were used to measure flue gas temperature and velocity, respectively.

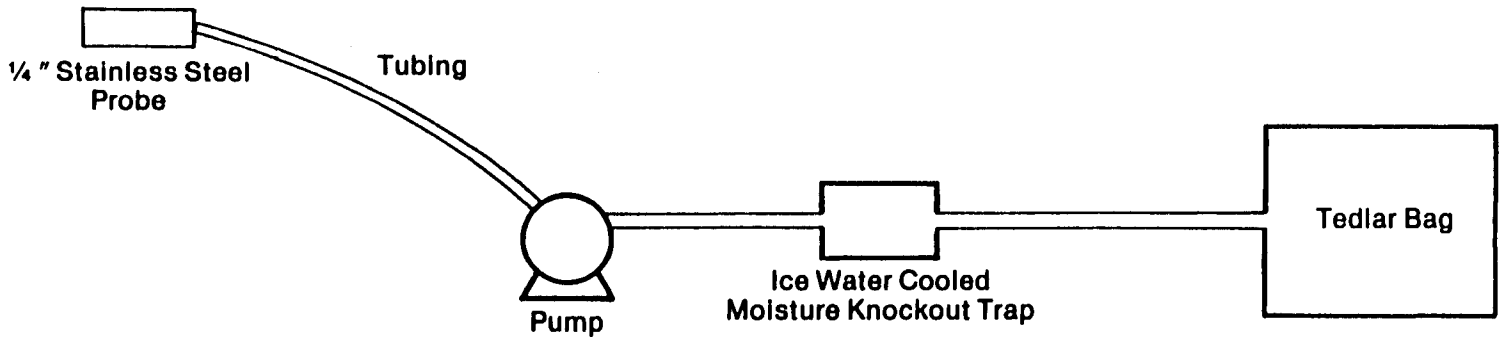


Figure 5 - 7. Method 3 Integrated Bag Sampling Train

5.5.1 Sampling and Equipment Preparation

For EPA Method 2, the pitot tubes were calibrated before use following the directions in the method. Also, the pitots were leakchecked before and after each run.

5.5.2 Sampling Operations

The volumetric flowrate data were recorded simultaneously with the other sampling train data. The parameters that were measured include the pressure drop (P) across the pitots, stack temperature, stack draft and ambient pressure. These parameters were measured at each traverse point. Based on EPA Method 2, a computer program was used to calculate the average velocity during the sampling period. The calculations are included in Appendix A.5.

5.6 MOISTURE DETERMINATION BY EPA METHOD 4

The average flue gas moisture content was determined according to EPA Method 4. Before sampling, the initial weight of the impingers were recorded. When sampling was completed, the final weight of the impingers was recorded, and the weight gained was calculated. The weight gained and the volume of gas sampled were used to calculate the percent by moisture of the flue gas. The calculations are performed by computer, and a sample calculation is included in Appendix A.5.

5.7 ASH SAMPLING FOR METALS ANALYSIS

A standard protocol was not available for sampling the ESP ash at North Andover RESCO. However, ASTM D2234-82[5], a method used in collection of a gross sample of coal, was used for guidance in terms of sampling method, frequency and size. The method does not require that all grabs be of the same volume or weight, just that a minimum number and minimum size be taken.

5.7.1 Sampling Operations

ESP ash samples were collected from the drag conveyor at an intermediate transfer point in the screw conveyor system prior to being combined with the other ash streams. Since the ash was analyzed for metals, all plastic sampling equipment was used. Using the ASTM Method as a guideline and considering the homogeneous nature of the ESP ash, the samples were collected every 30 minutes starting 45 minutes after the start of flue gas sampling. Approximately 4 pounds of ESP ash were collected during each test run which were composited and an aliquot placed in a 950 ml amber glass bottle. A sampling scheme is shown in Figure 5-8.

5.7.2 Analysis

The ESP ash was analyzed by NAA. The analysis was the same as previously described in Section 5.2.4 for the flue gas samples. The NAA method does not require any sample preparation for ash samples. The ash which is placed directly in a prepared sample bottle is ready for irradiation.

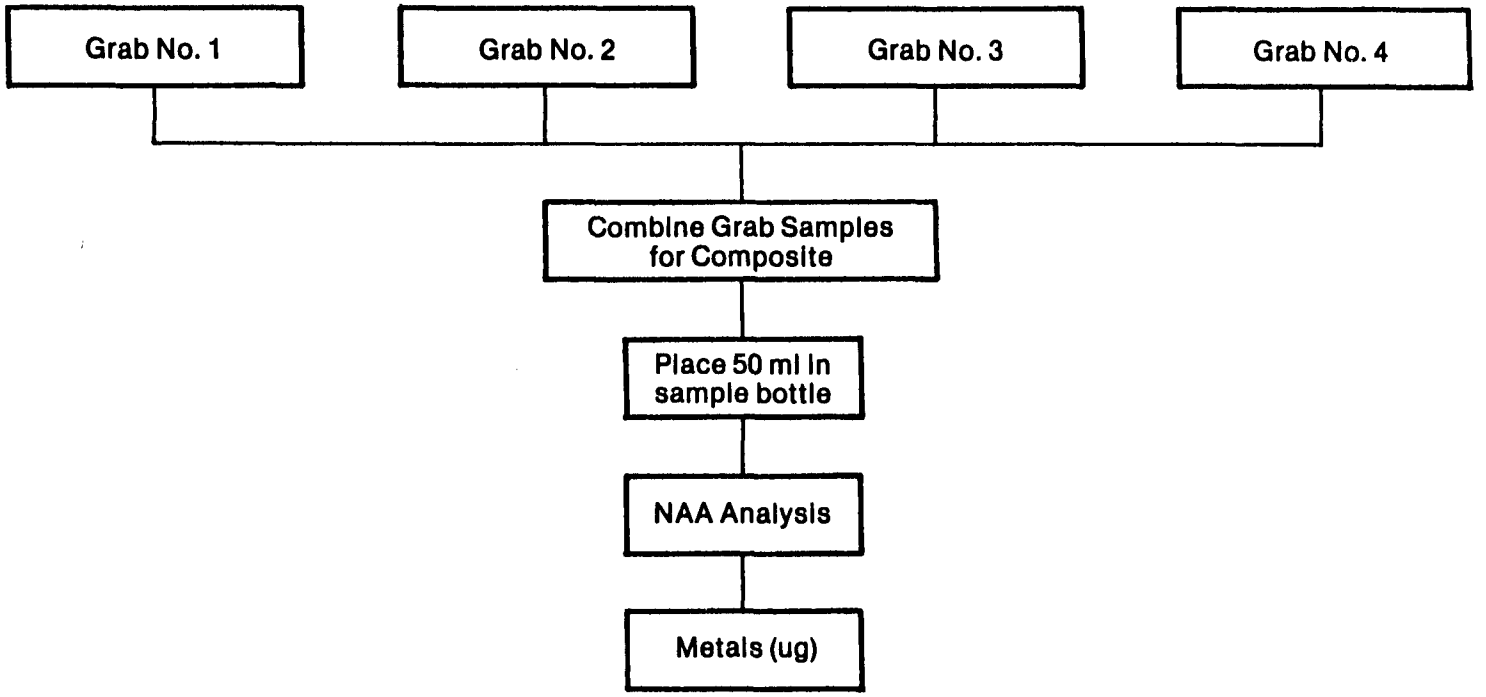


Figure 5 - 8. ESP Ash Sampling and Analysis Scheme

6.0 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

Quality assurance/quality control guidelines outline pertinent steps during the production of analytical and emission data to ensure and quantify the acceptability and reliability of the data generated. The measures outlined in this section were followed to ensure the production of quality data from the sampling and analytical efforts.

6.1 STANDARD QUALITY ASSURANCE PROCEDURES

QA/QC procedures were followed during sampling and analysis to ensure that the data generated were of acceptable quality. These quality control and quality assurance procedures were used during sampling and/or analysis.

6.1.1 Sampling Equipment Preparation

The checkout and calibration of source sampling equipment is vital to maintaining data quality. Referenced calibration procedures were strictly adhered to when available, and all results were documented and retained.

Table 6-1 summarizes the parameters of interest and the types of sampling equipment that were used to measure each parameter. Prior to sampling, all equipment was cleaned and checked to ensure operability. Equipment requiring pretest calibration (Table 6-1) was calibrated in accordance with "Quality Assurance Handbook or Air Pollution Measurements Systems, Volume III, Stationary Source Specific Methods," (EPA 600 4-77-027b).

Pre-test calibration data for type "S" pitot tubes, temperature measuring devices, and dry gas meters can be found in Appendix E.2. Balance calibration data are located in Appendices D.4 (Particulate Operations Log) and H.4 (Field Laboratory Log).

TABLE 6-1. SUMMARY OF EQUIPMENT USED IN PERFORMING SOURCE SAMPLING

Parameter	Method	Calibrated Equipment Used to Measure Parameters						
		Type "S" Pitot Tube	Manometer	Temperature Measuring Device	Orsat	Nozzles	Balances	Dry Gas Meter
Volumetric Flue Gas Flow Rate	EPA 1 & 2	X	X	X				
Gas Phase Composition								
Moisture	EPA 4	X	X	X			X	X
Molecular Weight	EPA 3				X			
Dioxin/Furan	ASME/EPA Protocol	X	X	X	X	X	X	X
TOCL/Particulate	ASME/EPA Protocol (modified)	X	X	X	X	X	X	X
Metals/Particulate	Alternate EPA Method 12	X	X	X	X	X	X	X

6.1.2 General Sampling QC Procedures

The following QC checks were conducted for each of the EPA Methods 2, 3, 4, 5, and PCDD/PCDF, TOCL/Particulate, and Metals/Particulate sampling.

Prior To Sampling

- Sampling equipment was inspected for possible damage from travel, and thoroughly checked to ensure operable components.
- Determined duct size and required dimensional measurements.
- Perform initial preliminary velocity, temperature, and moisture determinations to aid in conducting isokinetic sampling.
- Perform cyclonic or turbulent flow checks.
- Determined the proper sampling nozzle size.

Prior to Testing Each Day

- Assembled the train in an environment free from uncontrolled dust.
- Checked the number and location of the sampling points before taking measurements.
- Visually inspected the S-type pitot tube.
- Leak-checked each leg of the S-type pitot tube.
- Leak-checked the entire sampling train.
- Leveled and zeroed the oil manometer used to measure pressure across the S-type pitot tube.
- Checked the temperature measurement system for operability by measuring the ambient temperature prior to each traverse.
- Checked the heating and cooling systems to ensure proper operation, and stocked cooling systems with ice.
- Visually inspected each sampling train for proper assembly.
- Sealed sampling ports to help prevent possible air inleakage.
- Reviewed data requirements prior to each sampling run.

During Testing Each Day

- Properly maintained the roll and pitch axis of the S-type pitot tube and sampling nozzle.
- Leak checked the train before and after any move from one sampling port to another during a run or if a filter change took place.
- Maintained the probe, filter, sorbent trap, and impinger outlet at the proper temperatures.
- Maintained ice in the impinger bath at all times.
- Made proper readings of the dry gas meter, pressures, temperature, and pump vacuum during sampling at each traverse point.
- Maintained isokinetic sampling velocity within $\pm$ 10 percent of the duct velocity.
- Noted any unusual occurrences involving the sampling train on the appropriate data form.

After Testing Each Day

- Leak checked the entire sampling train.
- Visually inspected the sampling nozzle.
- Visually inspected the S-type pitot tube.
- Leak checked each leg of the S-type pitot tube.
- Immediately recapped the sorbent trap, probe, filter, and impingers as train was disassembled.
- Collected any necessary sample train blanks.
- Checked completion of field data sheets.
- Gave field data sheets to sampling team leader for review.

6.1.3 Sample Recovery

To ensure sample integrity, careful recovery techniques were adhered to by experienced analysts. This section outlines quality control procedures followed to ensure sample integrity. These included:

- Recorded reagent lot numbers.
- Rinsed probe and nozzle brushes, tweezers, and scrapers before use with the proper reagent(s) to prevent sample contamination.
- Clearly labeled reagent dispenser bottles.
- Rezeroed the toploading field balance after every ten weighings or less.
- Sample trains were disassembled and the samples recovered in clean areas to prevent contamination.
- The nozzle was capped prior to and following recovery.
- Filters were handled out of drafts and transferred with tweezers.
- Rinsed sampling glassware three times with each reagent to remove all of the sample.
- The samples were transferred to appropriate storage containers and clearly labeled. Liquid levels were noted, and completed sample containers were weighed and the weights were recorded in the logbook.
- Samples were carefully labeled, logged into the field logbook and assigned a unique identification code immediately after collection.
- Capped all sampling and recovery glassware when not in use.
- Sets of glassware and nozzle brushes were dedicated to each sampling location and method (i.e., ESP outlet PCDD/PCDF train).

6.1.4 Preparation of Samples for Analysis

Prior to analysis, each sample was properly prepared. This section outlines quality control procedures used to ensure proper sample preparation. Included are:

- Each sample identification code was crosschecked for accuracy against the sample logbook.
- The analytical requirements of each sample were reviewed.
- The sample containers were checked for leakage or damage and any anomalies were noted.

Sample Analysis

The quality assurance/quality control procedures followed during the analysis task were dependent on the specific analysis being performed. One or more of the following steps were taken:

- Duplicate analyses were performed on 1 out of every 10 PCDD/PCDF samples. Duplicate analyses were performed on audit samples for NAA.
- Blanks were analyzed to correct for background and/or matrix interferences.
- Blind QC samples were submitted to the analytical laboratories along with the field samples.
- For the PCDD/PCDF analyses, the samples were spiked with known additions of the species of interest and recoveries were calculated.

Data Documentation and Verification

Several measures were taken to verify the completeness and accuracy of the data generated. These included:

- All sampling data were recorded on preformatted data sheets.
- Data tables were prepared and reviewed for completeness and accuracy.
- All data that appeared to be outside expected ranges were carefully scrutinized for sampling, analytical or process problems that may have occured.

6.2. METHOD-SPECIFIC SAMPLING QC PROCEDURES

In addition to the general QC procedures listed in Sections 6.1.1 to 6.1.4, QC procedures specific to each sampling method were also incorporated into the sampling scheme. These method specific procedures are discussed below.

6.2.1 Procedures for Velocity/Volumetric Flow Rate Determination

Data required to determine the volumetric gas flow rate were collected using the methodology specified in EPA Method 2. Quality control procedures followed were:

- Visually inspected the S-type pitot tube before and after sampling.
- Leak-checked both legs of the pitot tube before and after sampling.
- Checked the number and location of the sampling traverse points before taking measurements.
- Maintained proper orientation of the S-type pitot tube while making measurements.
- Leveled and zeroed the oil manometer, and recorded the proper pressures and temperatures.

6.2.2 Quality Control Procedures for Molecular Weight Determinations

Samples used for determination of stack gas molecular weight were collected using the integrated sampling technique specified in EPA Method 3. Quality control for the Method 3 sampling focussed on the following procedures:

- The sampling train was leak checked before and after each run.
- A constant sampling rate ($\pm$ 10 percent) was used in withdrawing the integrated gas sample.
- The sampling train was purged prior to sample collection.
- The sampling port was sealed to prevent air inleakage.

Analytical quality control for Method 3 include the following:

- The Orsat analyzer was leak-checked prior to use.
- The Orsat analyzer was leveled and fluid levels zeroed prior to each use.
- The Orsat analyzer was thoroughly purged with sample prior to analysis.
- Analyses were performed until analysis agreed within 0.2% absolute.
- A control sample of ambient air was analyzed daily.
- Orsat solutions were changed when more than six passes were required to obtain a stable reading for any component.
- Data obtained with the Orsat analyzer was compared to data from other locations, and CEM data.

6.2.3 Quality Control Procedures for Moisture Determination

The moisture content of the gas streams was determined using the technique specified in EPA Method 4. The following internal QC checks were performed as part of the moisture determinations:

- Each impinger will be weighed to the nearest 0.1 grams before and after sampling.
- Rezeroed the field balance after every 10 weighings.
- Used fresh, dry silica gel in the silica gel container.
- Ice was kept in the ice bath to keep the gas exit temperature below 68 degrees F while sampling.
- The sample train was leak checked before and after each run.
- Dry gas meter readings were correctly recorded on the proper data sheet.

6.2.4 Quality Control For PCDD/PCDF Testing

This section summarizes the quality control activities for PCDD/PCDF testing at North Andover RESCO. The aforementioned general quality control activities do apply, as they do to all sampling methods based on EPA Method 5. The specific PCDD/PCDF QC activities discussed in this section include sampling preparation, sampling operations, surrogate and internal standard recoveries, sample blanks and audit analyses.

Equipment and Sampling Preparation

Pre-test calibrations or inspections were conducted on pitot tubes, temperature sensors, dry gas meters, and balances. Precleaning procedures for sample train glassware and amber glass sample bottles were followed as specified in Section 5.1.1. After cleaning, each piece of the sampling glassware was sealed with aluminum foil to prevent contamination. Sample bottles were sealed with teflon lined lids.

The residual analyses results for the XAD resins and filters are contained in Appendix J.2. The residual analysis is a requirement of the PCDD/PCDF sampling protocol.

Sampling Operations

PCDD/PCDF sampling operations followed standard Method 5 operating procedures (Appendix K.4) with the addition of the following:

1) Used only precleaned aluminum foil or ground glass caps to cover sample train components during train assembly, disassembly, and leak checks.
2) The temperature of the gas entering the sorbent trap (XAD) remained below 68°F.
3) The sampling rate averaged 0.4 dscf.
4) All train components which were recovered were made of glass or teflon.
5) All train components and sample bottles were marked according to the cleaning procedure used.

PCDD/PCDF sampling results for isokinetics and leak checks are presented in Table 6-2. These results are acceptable from a QC point of view, but it should be noted that the dry gas meter volume for Run 5 was corrected to reflect an excessive leakrate for one port. The sample volume correction calculation is specified in Appendix A.5.

TABLE 6-2. DIOXIN ISOKINETICS[a] AND LEAK CHECK[b] SUMMARY
ESP INLET, NORTH ANDOVER RESCO

	Run 3	Run 4	Run 5
Percent Isokinetic	100.1	99.0	98.0
Leak rate[c] (cfm)			
Port A	0.015	0.017	0.019
B	0.017	0.017	0.032[d]
C	0.015	0.014	0.018
D	0.012	0.017	0.019
E	0.010	0.015	0.017
F	0.015	0.015	0.018
G	0.010	0.017	0.019
H	0.010	0.017	0.019
Volume correction (cf)	None	None	0.29

[a]The QC objective for isokinetics was 100 ± 10 percent.

[b]The QC objective for leak checks was a leak-free train or leakage rate less than or equal to 0.02 cfm or less than 4% of the average sampling rate (whichever is less).

[c]Leak checks were performed according to EPA Method 5 protocol.

[d]The leak rate of 0.032 cfm for Port B required a volume correction of 0.29 actual cubic feet. This corrected volume consisted of 0.3 percent of the total volume of flue gas collected during Run 5.

Sample Recovery

PCDD/PCDF sample recovery followed the procedure presented in Section 5. In addition to the general recovery QC procedures, these procedures were also implemented:

- All instruments used in the recovery process were either teflon or stainless steel.
- All instruments which come in contact with the sample, or the sampling surfaces were cleaned according to the PCDD/PCDF cleaning procedure.
- Probe liners were recovered using a flask attached to the male end of probe.
- No sealing grease was used on the sampling train. Reagent, lab proof, and field blanks were taken.
- Each sample container lid was individually sealed with teflon tape to prevent leakage.
- Each container lid was covered with an integrity seal (strip of tape) to prevent tampering.
- Samples were weighed in the field and again in the lab to indicate possible sample loss.
- All sample containers were packaged for transport in ziplock^{R} plastic bags, wrapped in bubble wrap, and placed into a second ziplock bag.

Surrogate and Internal Standard Recoveries of the Test Samples.

PCDD/PCDF samples were spiked with internal standards and surrogates prior to extraction. The internal standards were added in the soxhlet extraction step. The surrogates were added to the impinger (condensate) fraction. The internal standard recoveries were used by Triangle Laboratories to adjust the results of the native species reported. The surrogate recoveries were not used to adjust results but were used to provide additional information on the extraction efficiency of the method. The internal standard recoveries are summarized in Table 6-3. The QC objective as required by the ASME/EPA protocol is $\pm$ 50 percent. All of the analyses met this requirement, except for the following:

TABLE 6-3. INTERNAL STANDARDS RECOVERY RESULTS FOR NORTH ANDOVER PCDD/PCDF ANALYSES

Sample Type	Recovery (%) 2378-$^{13}C_{12}$-TCDD	$^{13}C_{12}$-PCDD	$^{13}C_{12}$-HxCDD	$^{13}C_{12}$-HpCDD	$^{13}C_{12}$-OCDD
	FH/BH	FH/BH	FH/BH	FH/BH	FH/BH
MM5 Inlet Samples					
Run 03	90/99	81/83	81/75	79/78	63/67
Run 04	101/102	90/89	83/91	74/82	71/71
Run 05	87/107	69/99	67/100	58/82	50/47
Quality Control Samples					
Field Blank	107/a	94/a	96/a	91/a	84/a
Laboratory Proof Blank	91/97	82/115	91/106	81/137	163[b]/120
Analytical Blank	99	78	86	84	76
Audit Quality Control Blank (spikes) (#25/#26)	129/116	88/111	107/113	94/140	72/130

FH/BH = front half/back half percentages of internal standard recoveries.

[a]Back half lost by Triangle Labs while processing, due to broken sample transfer line.

[b]Front half duplicate analysis = 72%

1) Internal standard recovery of $^{13}C_{12}$-OCDD in the back half of Run 5 was 47 percent.

2) Internal standard recovery for one of the lab proof blank front half duplicate analyses of $^{13}C_{12}$-OCDD was 163%.

The internal standards are used to adjust the responses for extraction efficiency and variable instrument performance. Since the internal standards are spiked as a known amount (2 ng except for $^{13}X_{12}$-OCDD which is spiked a 4 ng), the recovery is determined using the external standard response and the following equation. External standards are the same compounds used for internal standards except that they are in a pure organic matrix rather than a sample matrix.

$$\text{Internal standard recovery} = \frac{\text{(area counts) internal standard}}{\text{(area counts) external standard}}$$

The sample results are calculated:

$$\text{results reported (ng)} = RF \times F_{REC} \times \text{(area counts) sample}$$

where

F_{REC} = the inverse of the internal standard recovery

RF = response factor determined with external standards (ng per are count)

The adjustment is done by computer so that the results reported by Triangle Laboratories are already adjusted. Table 6-4 presents the internal standard adjustment factors for the PCDD/PCDF samples.

The surrogate recoveries are summarized in Table 6-5. All the analyses met the ASME/EPA protocol QC requirement of ±50 percent except for the $^{13}C_{12}$-HxCDF recovery in the front half of the field blank which was 42 percent.

Sample Blanks

Field and laboratory proof blanks were collected and analyzed to evaluate contamination from the glassware, handling of the train and field recovery.

TABLE 6-4. FACTORS USED TO ADJUST RESPONSES FOR EXTRACTION EFFICIENCY AND VARIABLE INSTRUMENT PERFORMANCE

Sample Type	Factors				
	2378-$^{13}C_{12}$-TCDD	$^{13}C_{12}$-PCDD	$^{13}C_{12}$-HxCDD	$^{13}C_{12}$-HpCDD	$^{13}C_{12}$-OCDD
	FH/BH	FH/BH	FH/BH	FH/BH	FH/BH
MM5 Inlet Samples					
Run 03	1.11/1.01	1.23/1.20	1.23/1.33	1.27/1.28	1.59/1.49
Run 04	0.99/0.98	1.11/1.12	1.20/1.10	1.35/1.22	1.41/1.41
Run 05	1.15/0.93	1.45/1.01	1.49/1.0	1.72/1.22	2.0/2.13
Quality Control Samples					
Field Blank	0.93/c	94/c	96/c	91/c	84/c
Laboratory Proof Blank	1.10/1.03	1.22/0.87	1.10/0.94	1.23/0.73	0.61[d]/0.83
Analytical Blank	1.01	1.28	1.16	1.19	1.32
Audit Quality Control Blank (spikes)(#25/#26)	0.78/0.86	1.14/0.91	0.93/0.88	1.06/0.71	1.39/0.77

[a] 2378-$^{13}C_{12}$-TCDD is used to adjust 2378-TCDD and total TCDD, 2378-TCDF, and total TCDF.
$^{13}C_{12}$-PCDD is used to adjust 12378-PCDD, 12378-PCDF, 23478-PCDF, total PCDD and total PCDF.
$^{13}C_{12}$-HxCDD is used to adjust 123478-HxCDD, 123678-HxCDD, 123789-HxCDD, 123478-HxCDF, 123678-HxCDF, 123789-HxCDF, total HxCDD and total HxCDF.
$^{13}C_{12}$-HpCDD is used to adjust 1234678-HpCDD, 1234678-HpCDF, 1234789-HpCDF, total HpCDD and total HpCDF.
$^{13}C_{12}$-OCDD is used to adjust total OCDD and total OCDF.

[b] FH/BH = front half/back half factors.

[c] Back half lost by Triangle Labs while processing, due to broken sample transfer line.

[d] Front half duplicate analysis = 1.39

TABLE 6-5. SURROGATE RECOVERIES FOR PCDD/PCDF ANALYSES FOR NORTH ANDOVER

Sample Type	Recoveries (%) ^{13}C-$_{12}$TCDF	$^{37}Cl_4$-TCDD	$^{13}C_{12}$-HxCDF
MM5 Samples - Inlet	FH/BH	FH/BH	FH/BH
Run 03	91/96	103/98	96/79
Run 04	97/84	106/88	82/64
Run 05	101/90	104/96	80/62
Quality Control Samples			
Field Blank	88/a	102/a	42/a
Laboratory Blank	100/102	103/99	104/89
Analytical Method Blank	97	98	93
Audit Quality Control (Spikes)	105/106	120/125	93/66

FH/BH = front half/back half percentages of surrogate recoveries.

[a]Back half lost by Triangle Labs while processing, due to broken sample transfer line.

The field blank was an assembled and loaded train which was capped off and left at the sampling location for the duration of a test run. The glassware used for the field blank had been used and recovered at least once. The train was then recovered at the end of the test run. This blank was used to measure the background levels of the analytes due to the handling of the train and field recovery.

Laboratory proof blanks were also included for each method. The laboratory proof blank quantifies the background levels of PCDD/PCDF from the glassware and recovery equipment. The laboratory proof blanks were obtained from a complete set of sample train glassware and recovery equipment (brushes, spatulas, etc.) that had been cleaned according to the specified precleaning procedure. This glassware, which consisted of the probe liner, filter holder, condenser coil, and impingers, was loaded and then recovered according to the standard recovery method. Also, blanks of each solvent lot and filters used at the test site (reagent blanks) were saved for potential analysis.

Table 6-6 summarizes the analytical results reported by Triangle Laboratories for laboratory system blanks, field blanks, laboratory proof blanks, and reagent blanks. The laboratory system blank is an analysis of a PCDD/PCDF-free silica gel sample which is carried throughout the entire extraction and analysis procedure. All of the blanks showed insignificant or non-detectable levels of PCDD/PCDFs.

Table 6-7 compares the field blank results to the minimum test values for each isomer attained in Runs 3, 4, and 5 as a group, in the form of a percentage. As the resulting percentages indicate, the maximum bias that background levels of one isomer may have on the final results were insignficant.

Audit Samples

Blind audit samples (spikes) were also submitted to Triangle Laboratories to evaluate the recoveries reported during the analysis of North Andover

TABLE 6-6. ANALYTICAL RESULTS FOR NORTH ANDOVER QUALITY CONTROL SAMPLES[a]

Compound	Flue Gas Quality Control Samples					
	Laboratory System Blank	Field Blank MM5 Train[b]	Laboratory Blank MM5 Train	Reagent Blanks		
				Water	Acetone	Methylene Chloride
Dioxins						
Mono-CDD	ND	ND	ND	ND	ND	ND
Di-CDD	ND	ND	ND	ND	ND	ND
Tri-CDD	ND	0.26	ND	ND	ND	ND
2378-TCDD	ND	0.04	ND	ND	ND	ND
Other TCDD	ND	ND	ND	ND	ND	ND
12378 PCDD	ND	ND	ND	ND	ND	ND
Other PCDD	ND	ND	ND	ND	ND	ND
123478 HxCDD	ND	ND	ND	ND	ND	ND
123678 HxCDD	ND	ND	ND	ND	ND	ND
123789 HxCDD	ND	ND	ND	ND	ND	ND
Other HxCDD	ND	ND	ND	ND	ND	ND
Hepta-CDD	ND	0.70	ND	ND	ND	ND
Octa-CDD	ND	1.21	ND	ND	ND	ND
Total PCCD	ND	2.21	ND	ND	ND	ND
Furans						
Mono-CDF	ND	ND	ND	ND	ND	ND
Di-CDF	ND	ND	ND	ND	ND	ND
Tri-CDF	ND	ND	ND	ND	ND	ND
2378 TCDF	ND	0.15	ND	ND	ND	ND
Other TCDF	ND	0.10	ND	ND	ND	ND
12378 PCDF	ND	ND	ND	ND	ND	ND
23478 PCDF	ND	ND	ND	ND	ND	ND
Other PCDF	ND	ND	ND	ND	ND	ND
123478 HxCDF	ND	0.12	ND	ND	ND	ND
123678 HxCDF	ND	ND	ND	ND	ND	ND
123789 HxCDF	ND	ND	ND	ND	ND	ND
Other HxCDF	ND	0.0	ND	ND	ND	ND
Hepta-CDF	ND	0.27	ND	ND	ND	ND
Octa-CDF	ND	ND	ND	ND	ND	ND
Total PCDF	ND	0.66	ND	ND	ND	ND

[a]All values reported in nanograms (10^{-9} g) per gram of sample.

[b]Values reported are front half values only. Back half lost during processing.

ND = Not detected. Minimum detection limits ranged form 0.001 to 0.009 nanograms per sample.

TABLE 6-7. FIELD BLANK DIOXIN/FURAN DATA FOR MM5 SAMPLES[a]

Compound	Amount Detected[a]		
	Field Blank[b]	Minimum Test Run Value[b]	Percentage
Dioxins			
Mono-CDD	ND	ND	--
Di-CDD	ND	1.72	0
Tri-CDD	0.26	6.17	4.2
2378-TCDD	0.04	0.62	6.4
Other TCDD	ND	6.69	0
12378 PCDD	ND	1.10	0
Other PCDD	ND	10.39	0
123478 HxCDD	ND	1.09	0
123678 HxCDD	ND	1.85	0
123789 HxCDD	ND	ND	--
Other HxCDD	ND	14.23	0
Hepta-CDD	0.70	26.06	2.7
Octa-CDD	1.21	22.05	3.7
Furans			
Mono-CDF	ND	0.32	0
Di-CDF	ND	9.26	0
Tri-CDF	ND	39.78	0
2378 TCDF	0.15	9.22	1.6
Other TCDF	0.10	25.74	0.4
12378 PCDF	ND	2.06	0
23478 PCDF	ND	4.48	0
Other PCDF	ND	12.52	0
123478 HxCDF	0.12	5.23	2.3
123678 HxXCDF	ND	1.88	0
123789 HxCDF	ND	ND	--
Other HxCDF	0.02	7.29	0.3
Hepta-CDF	0.27	13.88	1.9
Octa-CDF	ND	4.32	0

[a]All values reported in nanograms (10^{-9}g).

[b]Front half only. Back half sample was lost during analysis by Triangle Laboratories.

ND = not detected.

dioxin/furan samples. Known quantities of the targeted 2378-TCDD and 2378-TCDF isomers were spiked into XAD-2^{R} resin and impinger solution to assess the extraction and recovery procedure for the front and back halves of the PCDD/PCDF train. Excellent recoveries were reported:

#25	Front Half (XAD-2^{R}):	104% Recovery of 2378-TCDD
		120% Recovery of 2378-TCDF
#26	Back Half (Impinger Solution):	100% Recovery of 2378-TCDD
		111% Recovery of 2378-TCDF

These spike recoveries were well within the quality control criteria of ± 50 percent required by the ASME/EPA protocol.

6.2.5 Quality Control for Particulate Testing

Particulate sampling was incorporated into the ESP outlet TOCL (Runs 1-6) and metals (Runs 7, 8, and 9) ESP inlet and ESP outlet sampling trains. TOCL results are not reported here, but the particulate fraction of that sampling effort is. Since many of the QA procedures used for the Metals/Particulate sampling train are discussed in the next section, (with the exception of results) most of this section will be directed towards the TOCL/particulate sampling.

Equipment and Sampling Preparation.

Preparation for TOCL/particulate sampling is identical to preparation for PCDD/PCDF with the exceptions of using hexane in place of methylene chloride, and using tared filters. Filters were tared in accordance with EPA Method 5 and placed in sealed, precleaned, glass petri dishes prior to leaving for North Andover RESCO. The analytical balance used to tare the filters, and used in later particulate analyses, was calibrated with standard weights (NBS Class S). Measured values agreed within ± 0.1 mg. The balance was calibrated prior to making measurements. This calibration data can be found in the particulate analysis logbook in Appendix D.4.

Sampling Operations

Sampling operations for the TOCL/particulate sampling train are identical to PCDD/PCDF sampling operations. TOCL/Particulate sampling results for isokinetics and leak checks are presented in Table 6-8. None of the sampling trains were determined to have leakrates above the maximum allowable leakrate (0.02 acfm).

Sample Recovery

TOCL/particulate sample recovery followed the PCDD/PCDF QC format except that hexane was used in the place of methylene chloride. Hexane is actually the recovery solvent specified in the method.

With the particulate aspect of the TOCL/particulate and Metals/Particulate sampling effort in mind, it is important to note here that the initial front half washes were performed with acetone, as EPA Method 5 dictates. The acetone and hexane washes were recovered into separate bottles.

Sample Analysis

The QC analyses for particulate involved evaluations of the field, laboratory proof, and reagent particulate blanks of the TOCL/Particulate, Inlet Metals/Particulate, and Outlet Metals/Particulate sampling trains. The sample fractions evaluated were the nozzle and probe/filter holder acetone washes and the filter. Table 6-9 shows the values for these fractions, and their respective sums. When the samples were returned to the laboratory from the field, the front half acetone fraction from the TOCL/particulate-Run 4 sample was determined to have leaked during shipment. The sample result was corrected using the calculations provided in Appendix A.5. Once the particulate analyses were complete, the particulates were resuspended in hexane and combined with the front half hexane and back rinses for a total train TOCL analysis.

TABLE 6-8. TOCL/PARTICULATE ISOKINETICS[a] AND LEAK CHECK[b] SUMMARY
ESP OUTLET, NORTH ANDOVER RESCO

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
Percent Isokinetic	100.7	100.6	100.0	100.0	100.6	100.0
Leak checks[c] (cfm)						
Port A	0.011	0.004	0.011	0.007	0.011	0.007
B	0.007	<0.02[d]	0.010	0.005	0.017	0.010
C	0.006	0.008	0.008	0.008	0.013	0.018
D	0.004	0.005	0.009	0.005	0.009	0.005
E	0.012	0.008	0.008	0.012	0.014	0.007
F	0.003	0.010	0.008	0.011	0.019	0.009
Volume correction (cf)	None	None	None	None	None	None

[a]The QC objective for isokinetics was 100 ± 10 percent.

[b]The QC objective for leak checks was a leak-free train or leakage rate less than or equal to 0.02 cfm or less than 4% of the average sampling rate (whichever is less).

[c]Leak checks were performed according to EPA Method 5 protocol.

[d]No leak rate defined on data sheet.

TABLE 6-9. SUMMARY OF PARTICULATE QC RESULTS BY SAMPLE FRACTION
NORTH ANDOVER RESCO, NORTH ANDOVER, MA

Blank	Filter[2] Weight Gain (g)	Uncorrected Probe Acetone Residue (g)	Volume of Acetone Probe Wash (ml)	Acetone[2] Blank (g)	Blank[1] Correction of Probe Acetone Residue (g)	Uncorrected Acetone Nozzle Wash (g)	Volume of Acetone Nozzle Wash (ml)	Acetone Blank (g)	Blank[1] Correction of Nozzle Acetone Residue (g)	Probe and Nozzle Residue Total (g)	Probe Nozzle & Filter Total (g)
Lab Proof Blanks											
TOCL	0.0000	0.0003	95	0.0000	0.0003	Nozzle wash included in probe wash				0.0003	0.0003
Metals/Particulate Inlet	0.0002	0.0060	185	0.0006	0.0054	Nozzle wash included in probe wash				0.0054	0.0056
Metals/Particulate Outlet	0.0003	0.0022	215	0.0007	0.0016	Nozzle wash included in probe wash				0.0016	0.0019
Field Blanks											
TOCL	0.0002	0.0009	195	0.0000	0.0009	Nozzle wash included in probe wash				0.0009	0.0011
Metals/Particulate Inlet	0.0000	0.0045	250	0.0009	0.0036	0.0003	150	0.0005	0.0000	0.0036	0.0036
Metals/Particulate Outlet	0.0000	0.0037	195	0.0007	0.0030	0.0007	100	0.0004	0.0003	0.0033	0.0033
Reagent Blanks											
Filter	0.0000	--	--	--							
TOCL Acetone (Runs 1-3)	--	--	420	0.0000							
(Runs 4-6)	--	--	275	0.0000							
Metals Acetone	--	--	480	0.0017							

[1]Blank Calculations - Corrected acetone Weight = Uncorrected acetone weight (g) [volume acetone (ml) x acetone blank g/ml)]

[2]Negative weight gains on reagent blanks (filter & acetone) are listed as zero as long as they are within the accuracy of the balance, (0.0005 g). Actual values are located in the laboratory weigh sheets in this section.

6.2.6 Quality Control for Metals/Particulate Testing

This section summarizes the quality control procedures for Metals/Particulate testing. The general EPA Method 5 QC procedures did apply, as Alternative Method 12 is based on Method 5, so only specific Metals/Particulate QC activities are discussed here.

Equipment and Sampling Preparation

Pre-test calibrations and visual inspections were performed on the necessary sampling equipment as specified in EPA Method 5. Precleaning procedures for the sample train glassware, amber glass, and Nalgene sample bottles were specified in Section 5.2.1. After cleaning, each piece of sampling glassware was sealed with parafilm or rubber caps to prevent contamination. Amber glass sample bottles were sealed with teflon lined lids, and Nalgene sample bottles were closed. All glassware and sample bottles were marked to show that they had been prepared for metals sampling. Whatman 934 AH filters were tared according to EPA Method 5 and placed in sealed, precleaned, glass petri dishes.

Sampling Operations

Metals/particulate sampling operations followed standard Method 5 operating procedures with the addition of the following:

1) Use of only round glass caps, parafilm, or rubber caps to cover sampling train components during assembly, leak checks and disassembly of the sampling train.

2) The sampling rate averaged 0.4 dscfm.

3) All train components and sample bottles had been marked previously according to the cleaning procedure used.

Metals/particulate sampling results for isokinetics and leak checks are presented in Tables 6-10 and 6-11, respectively. The ESP outlet run 7 had two leaks prior to breaking the probe during port E. Both leaks occurred at the union between the probe and the nozzle, and the break occurred approximately one half inch below this union.

TABLE 6-10. METALS/PARTICULATE ISOKINETICS[a] AND LEAK CHECK[b] SUMMARY
ESP INLET, NORTH ANDOVER RESCO

	Run 7	Run 8	Run 9
Percent Isokinetic	101.8	101.7	102.1
Leakrate[c] (cfm)			
Port A	0.009	0.009	0.008
B	0.017	0.002	0.003
C	0.010	0.004	0.006
D	0.013	0.004	0.005
E	0.010	0.007	0.002
F	0.032[d]	0.006	0.003
G	0.006	0.006	0.002
H	0.004	0.002	0.003
Volume correction (cf)	0.29	None	None

[a]The QC objective for isokinetics was 100 ± 10 percent.

[b]The QC objective for leak checks was a leak-free train or leakage rate less than or equal to 0.02 cfm or less than 4% of the average sampling rate (whichever is less).

[c]Leak checks were performed according to EPA Method 5 protocol.

[d]The leakrate of 0.032 cfm for Port F required a volume correction of 0.29 actual cubic feet. This corrected volume consisted of 0.3 percent of the total volume of flue gas collected during Run 7.

TABLE 6-11. METALS/PARTICULATE ISOKINETICS[a] AND LEAK CHECK[b] SUMMARY
ESP OUTLET, NORTH ANDOVER RESCO

	Run 7	Run 8	Run 9
Percent Isokinetic	99.7	98.6	100.2
Leakrate[c] (cfm)			
Port A	0.010	0.004	0.004
B	0.017	0.004	0.004
C	0.015	0.007	0.004
D	0.020+[d]	0.003	0.006
E	Broken[e]	0.004	0.003
F	0.008	0.003	0.004
Volume correction (cf)	4.0[f]	None	None

[a]The QC objective for isokinetics was 100 ± 10 percent.

[b]The QC objective for leak checks was a leak-free train or leakage rate less than or equal to 0.02 cfm or less than 4% of the average sampling rate (whichever is less).

[c]Leak checks were performed according to EPA Method 5 protocol.

[d]Leak rate increased dramatically as the probe cooled. Based correction on a leak rate of 0.04 cfm.

[e]Port E was not corrected for since a value for leak rate was not measurable.

[f]The volume correction includes the correction from Port D of 0.8 cf and Port A of 3.2 cf. The volume correction of 4.0 cf consisted of 3.2 percent of the volume of flue gas sampled.

Sample Recovery

Metals/particulate sample recovery followed the procedure located in Chapter 5. In addition to the general recovery QC procedures, the following QC procedures were also implemented:

- All train components which were recovered were made of glass or teflon. Nozzle washes were recovered into a separate sample bottle to prevent the possibility of contaminating the front half metals sample.
- All instruments used in the recovery process were either teflon or teflon coated.
- All instruments which came in contact with the sample or the sampling surfaces were cleaned according to the Metals/Particulate cleaning procedure.
- Probe liners were recovered with a flask attached to the male end of the probe liner.
- Reagent, laboratory proof, and field blanks were taken.
- Each sample container lid was individually sealed with teflon tape to prevent leakage.
- Glassware sets were dedicated to each sampling location.
- Each container lid was covered with an integrity seal (strip of tape) to prevent tampering.
- Samples were weighed prior to and after shipping to indicate possible sample loss.
- All sample containers were packaged for transport in ziplock bags, wrapped in bubble wrap, and placed into a second ziplock bag.
- Nitric acid rinses were placed in polypropylene bottles.
- Acetone rinses were placed in glass bottles.

Analysis

Table 6-12 summarizes the results of the metals field and laboratory proof blanks for sampling at the ESP inlet and outlet. The field and laboratory proof blanks are analyzed in order to evaluate potential contamination from recovery and handling of the trains.

TABLE 6-12. SUMMARY OF LABPROOF BLANKS AND FIELD BLANKS FOR METALS SAMPLES COLLECTED AT NORTH ANDOVER RESCO

Sample		ug/sample[a,b] Arsenic	Cadmium	Total Chromium	Nickel
Labproof Blank					
Uncontrolled:	Front Half	5.3 (3.1)	9.0 (11.2)	14.3 (5.3)	6.6 (20.0)
	Back Half	<0.14	1.8 (13.0)	<0.7	94.1 (4.1)
	Total	5.3	10.8	14.3	100.7
Controlled:	Front Half	1.7 (8.5)	7.6 (18.9)	18.4 (6.7)	17.7 (14.1)
	Back Half	2.4 (6.4)	2.2 (12.0)	6.2 (3.8)	5.4 (17.0)
	Total	4.1	9.8	24.6	23.1
Field Blank					
Uncontrolled:	Front Half	4.3 (4.1)	2.3 (19.2)	10.4 (5.9)	<5
	Back Half	<0.02	<0.1	0.64 (12.0)	1.2 (18.5)
	Total	4.3	2.3	11.0	1.2
Controlled:	Front Half	0.5 (6.1)	10.4 (11.0)	7.0 (6.7)	18.1 (12.0)
	Back Half	<0.02	0.44 (18.0)	0.83 (12.3)	<1
	Total	0.5	10.8	7.8	18.1

[a]Value in parenthesis is range of precision reported as a percent of its respective value.

[b]Minimum detection limits are denoted by a "<" symbol. A range of precision is not reported for the minimum detection limits.

To determine if the field blank concentration is a significant portion of the concentrations reported for the runs, the field blank is compared to the minimum run value in Table 6-13. The minimum run and field blanks concentrations are correctd for the blank results. The comparison indicates that significant contamination was not caused by recovery and handling of the sampling trains.

Neutron Activation Analysis (NAA) of NBS Reference Methods

National Bureau of Standards (NBS) Standard Reference Materials (SRM) were analyzed by N.C. State along with EMB-North Andover metals samples. A total of 197 analyses of different elements were included with the sample batch during the phases of analysis. Of these, ninety-one percent were within the tolerances set by NBS. All were within ten percent of the NBS tolerances. The results are summarized in Appendix I.

Dulicate Analyses

Duplicate analyses were performed on the NBS SRM's to assess the precision of the analytical method. The nature of NAA is such that duplicate analyses are performed either by splitting the sample into aliquots and analyzing both at the same time, or by doing multiple analyses on the same sample. Multiple analyses require extra time since the sample must "cool down" between analysis. However, the NBS SRMs are easily split into aliquots which are included with more than one batch of analyses, enabling duplicate results to be easily obtained.

The percent differences for all the duplicate analyses were less than ten percent, indicating good precision for this data set. Duplicate analyses and metals concentrations in the NBS samples can be found in Appendix I.

6.2.7 Quality Control for Continuous Emissions Monitors

Continuous emissions monitors (CEM) were used to measure the levels of oxygen, carbon dioxide, and carbon monoxide at the ESP outlet sampling

TABLE 6-13. COMPARISON OF MINIMUM RUN VALUES TO FIELD BLANK VALUES FOR NORTH ANDOVER RESCO

Element	Minimum Run Value (MRU) (ug/sample)	Field[a] Blank (FB) (ug/sample)	Ratio of FB: MRV (%)
Uncontrolled			
Arsenic	1459	0	0
Total Chromium	4573	0	0
Nickel	152	0	0
Cadmium	746	0	0
Controlled			
Arsenic	3.5	0	0
Total Chromium	0	0	0
Nickel	60.4	0	0
Cadmium	16.3	1.1	7

[a]Values have been adjusted for reagent blank results.

location during runs 7, 8, and 9. The samples were collected following EPA Method 10 for CO and EPA Method 3A for O_2 and CO_2. The following measures were taken to insure the validity of the CEM data.

Leak Checks

Prior to sampling, the CEM sampling train was leakchecked by introducing zero nitrogen at the probe outlet, and then measuring the oxygen concentration with the calibrated oxygen monitor. Any oxygen present is considered to be proportional to system leakage. An oxygen concentration of 0.5 percent was required to be acceptable.

Linearity Check

A linearity check was also performed on each monitor (O_2 and CO/CO_2) prior to sampling. Three point (zero plus two upscale) measurements of standards which span the range of expected gas concentrations at the North Andover site were performed to ensure linearity. In all cases, the acceptance criteria for the linearity checks were a correlation coefficient (r) of $\geq$ 0.9950. If this criterion was not met, the linearity checks were repeated (following instrument maintenance if judged necessary) until $r \geq 0.9550$ was achieved.

Daily Calibrations

For all continuous monitors, daily calibrations were performed prior to and at the conclusion of testing. These calibrations consisted of an analytical blank (zero nitrogen) and a single point (span) calibration check. The response factor (RF) for the span must be within 20% of the response factor from the previously determined multipoint calibrations, in order to meet the acceptance criterion. The acceptance criteria for the analytical blank was $\pm$ 1 percent of the instrument span. A summary of calibration requirements is shown in Table 6-14.

TABLE 6-14. SUMMARY OF ANALYTICAL CALIBRATION REQUIREMENTS

Parameter	Method of Analysis	Type of Calibration	Calibration Standards	Frequency	Acceptance Criteria
CO/CO_2	Beckman 865 (NDIR)	Multipoint (Zero plus 2 upscale)	CO and CO_2 in N_2	Once per site prior to tesing	Correlation coefficient $\geq$0.9950
		Single point RF	CO and CO_2 in N_2	Daily (prior to testing)	Agreement within 20% of multipoint RF
		Analytical Blank	Zero N_2	Daily (prior to testing)	Zero value $\leq$1% of span
		Single point drift CHECK	CO and CO_2 in N_2	Daily (at conclusion of analysis)	RF agreement within 10% of RF for single point RF check
O_2	Beckman 755 (Paramagnetic)	Same as CO_2	O_2 in N_2	Same as CO/CO_2	Same as CO/CO_2

Comparisons of the RF numbers based on the initial and final daily calibrations served as an instrument drift check. The acceptance criterion for the zero and span drift checks was agreement between initial and final RF numbers within $\pm$ 10 percent. Table 6-15 summarizes the zero and span drift checks for Runs 7, 8, and 9, which all met the acceptance criterion.

The validity of the CEM and Orsat analysis results are confirmed based on a combustion stoichiometry method described in Reference 6. First, the ultimate CO_2 concentration is calculated based on an ultimate analysis of the fuel, if available. Since ultimate analyses were not performed on the refuse from this site, data were used from a similar MSW. The ultimate analyses data used was an average of twelve analyses.[7] Then, on an O_2 versus CO_2 axis, a line is drawn connecting the O_2 intercept, 20.9 %, with the CO_2 intercept, the ultimate % CO_2. The CEM and Orsat results should fall within 10 percent of this line. This analysis for the CEM and Orsat data is shown in Figure 6-1. The figure shows that the CEM data for Run 8 does not fall within the range. This oxygen concentration is lower than the other runs for the same CO_2 and CO concentrations. This indicates that a problem with the oxygen analyzer, such as condensation in the instrument, may have developed during Run 8 and this data point is not included in the averages reported.

TABLE 6-15. SUMMARY OF DRIFT CHECK RESULTS

Test Date	Test Run	Parameter	Zero Drift Check: Instrument Drift, %[a]	Zero Drift Check: Meets QC?[b]	Span Drift Check: Instrument Drift, %[a]	Span Drift Check: Meets QC?[b]
07-14-86	07	CO	1.08	Yes	0.60	Yes
07-15-86	08	CO	0.45	Yes	0.37	Yes
07-16-86	09	CO	1.71	Yes	0.88	Yes
07-14-86	07	CO_2	0.20	Yes	0.15	Yes
07-15-86	08	CO_2	0.31	Yes	1.22	Yes
07-16-86	09	CO_2	0.25	Yes	-1.23	Yes
07-14-86	07	O_2	0.25	Yes	0.17	Yes
07-15-86	08	O_2	0.28	Yes	--	-- [c]
07-16-86	09	O_2	0.34	Yes	3.02	Yes

[a] Instrument drift is defined as the percent difference between the instrument response to the input concentration at the beginning and end of the test run.

[b] QC criteria was daily instrument drift within $\pm$ 10 percent.

[c] Changed span gas between beginning and end of run.

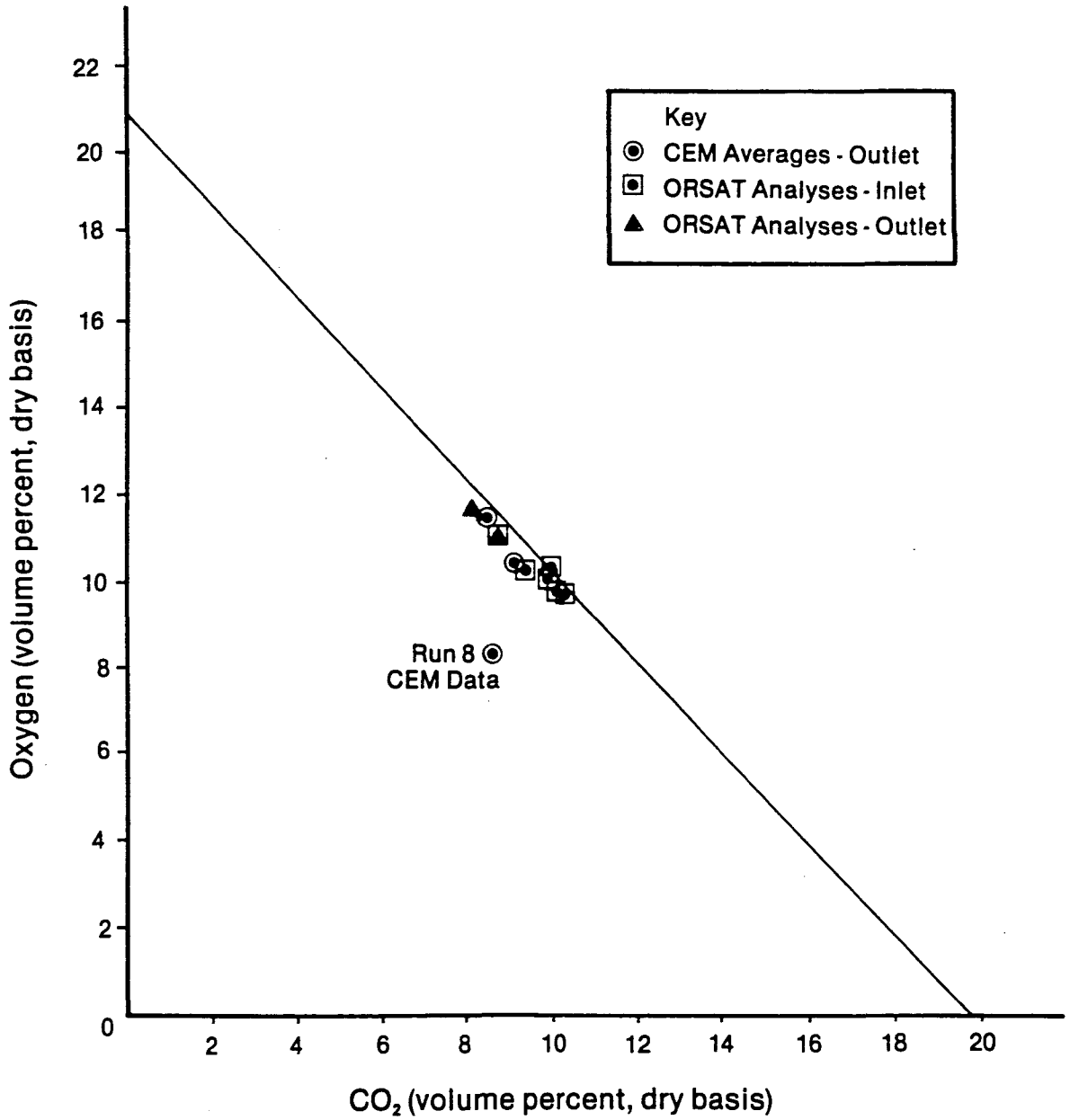


Figure 6 - 1. Validation of Fixed Gas Analysis

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