

Air



Chromium Screening Study Test Report

Refuse To Energy
Incinerator
Baltimore Resco
Baltimore, Maryland

EMISSION TEST REPORT
METHOD DEVELOPMENT AND TESTING
FOR CHROMIUM
No. 2 Refuse-to-Energy Incinerator
Baltimore RESCO
Baltimore, Maryland

ESED Project No. 85/2
EMB Report 85-CHM-8

by

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SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is currently evaluating several potentially toxic metals and their compounds. One of these toxic metals is chromium. Neither New Source Performance Standards (NSPS) for stationary sources nor National Emissions Standards for Hazardous Air Pollutants (NESHAPS) currently include chromium emissions. Available data on the emission of chromium and its impact on air quality are limited.

The Emission Measurement Branch (EMB) of EPA's Environmental Standards and Engineering Division (ESED) requires contractor assistance in obtaining representative chromium emissions data from several source categories so that an accurate assessment of the potential problems can be made and appropriate regulatory action developed.

PEI Associates, Inc. (under contract to ESED-EMB) performed a series of atmospheric emission tests on the No. 2 municipal refuse incinerator operated by Signal Environmental Systems, Inc. (SES) for the city and county of Baltimore, Maryland. All testing took place during the period of May 14 through 16, 1985. Test objectives were met and no major problems were encountered during sampling or analysis.

Triplicate tests were conducted simultaneously at the inlet and outlet of an electrostatic precipitator (ESP) used to control particulate emissions from the incinerator to determine the concentrations and mass emission rates of particulate matter, hexavalent chromium (Cr^{+6}), total chromium (Cr),

beryllium (Be), cadmium (Cd), nickel (Ni), lead (Pb), and zinc (Zn). In addition, particle size distribution tests were conducted during the particulate/chromium tests at each location, and process samples (incinerator bottom ash, and ESP hopper fly ash) were collected and analyzed for Cr^{+6} , total chromium, and metals.

At the completion of the particulate/chromium tests, a single test was conducted simultaneously at each location to determine the concentration and mass emission rate of inorganic arsenic.

Section 2 summarizes and discusses the test results; Section 3 addresses quality assurance considerations specific to this project; Section 4 describes the sampling locations and test procedures; and Section 5 describes source operation. Appendix A presents sample calculations and computer printouts; Appendices B and C contain the field data sheets and laboratory analytical results, respectively; Appendix D details the sampling and analytical procedures; Appendix E summarizes equipment calibration procedures and results; Appendix F presents a project quality assurance summary; Appendix G contains a list of project participants and a sampling log; Appendix H presents the draft test method for hexavalent chromium emissions from stationary sources; and Appendix I presents the draft protocol for determining total chromium emissions from stationary sources.

It should be noted that EPA performed the total chromium, cadmium, and nickel analysis of collected samples by neutron activation analysis (NAA). PEI performed the analysis for the other metals using Inductively Coupled Argon Plasma (ICAP) spectroscopy analytical techniques.

SECTION 2

SUMMARY AND DISCUSSION OF TEST RESULTS

This section details the results of the sampling program. Subsections are used to identify results from each test type (i.e., particulate/Cr⁺⁶, particle size distribution, etc.), and results are expressed in both metric and English units where applicable.

2.1 TEST PROTOCOL

Table 2-1 presents the sampling and analytical protocol followed throughout this project, the test identification, and the sampling times for each specific test type.

In summary, EPA Method 5* sampling trains were used for simultaneous extraction of samples from the ESP inlet and outlet test locations. Samples were collected over a 5-hour period by isokinetic, cross-sectional traverse sampling techniques.

A total of six samples (three inlet and three outlet) were collected for determination of particulate and Cr⁺⁶ concentrations. Method 5 analytical procedures were followed for the particulate analysis, and procedures recently developed by EPA for determination of Cr⁺⁶ content in source emission samples were used for the Cr⁺⁶ analysis. These latter procedures entail extraction of the sample fractions (probe residue and filter particulate)

*40 CFR 60, Appendix A, Reference Method 5, July 1984.

TABLE 2-1. SAMPLING AND ANALYTICAL PARAMETERS, NO. 2 FURNACE AND ESP

Run No.	Date (1985) and time (24-h)	Test or sample type	Sampling location	Sample parameters					Analytical parameters					
				Particulate Methods 1-5	Particle size dis- tribution	Cr ⁺⁶	Total Cr	Arsenic Method 108	Partic- ulate Method 5	Particle size dis- tribution	Cr ⁺⁶	Total Cr by NAA	Arsenic Method 108	Other metals by NAA
PCI-1	5/14 - 0834-1544	Particulate Cr ⁺⁶ Total Cr	Inlet	X	-	X	X	-	X	-	X	X	-	X
PCO-1	5/14 - 0836-1401		Outlet	X	-	X	X	-	X	-	X	X	-	X
PCI-2	5/15 - 0841-1439		Inlet	X	-	X	X	-	X	-	X	X	-	X
PCO-2	5/15 - 0842-1403		Outlet	X	-	X	X	-	X	-	X	X	-	X
PCI-3	5/16 - 0822-1422	Particle size distribution	Inlet	X	-	X	X	-	X	-	X	X	-	X
PCO-3	5/16 - 0822-1344		Outlet	X	-	X	X	-	X	-	X	X	-	X
PSI-1	5/14 - 1413-1613		Inlet	-	X	-	-	-	-	X			-	-
PSO-1	5/14 - 1030-1400		Outlet	-	X	-	-	-	-	X			-	-
PSI-2	5/15 - 1246-1516	Arsenic	Inlet	-	X	-	-	-	-	X		X	-	X
PSO-2	5/15 - 1000-1500		Outlet	-	X	-	-	-	-	X			-	-
PSI-3	5/16 - 1238-1508		Inlet	-	X	-	-	-	-	X			-	-
PSO-3	5/16 - 0945-1445		Outlet	-	X	-	-	-	-	X			-	-
AI-1	5/16 - 1513-1804	Process samples Incinerators bottom ash - fly ash (com- bined from 3 units) No. 2 ESP hopper fly ash	Inlet	-	-	-	-	X	-	-	-	-	X	-
AO-2	5/16 - 1517-1738		Outlet	-	-	-	-	X	-	-	-	-	X	-
PCI(1-3)	5/14-16			-	-	-	-		-	-		X	X	X
PCO(1-3)				-	-	-	-		-	-		X	X	X
AI-1				-	-	-	-		-	-		X	X	X
AO-1				-	-	-	-		-	-		X	X	X

^aAnalysis currently being performed by U.S. EPA.

with an alkaline solution followed by the diphenylcarbazide colorimetric method.* An analytical Cr^{+6} detection limit of 0.1 microgram per gram ($\mu\text{g/g}$) was established for these samples.

Particle size distribution measurements were made at each site during the particulate/ Cr^{+6} tests with an Andersen heavy grain loading impactor (HGLI) at the ESP inlet and an Andersen Mark III multistage impactor at the ESP outlet. Three samples were collected at each location. Particle size fractions were analyzed gravimetrically, and size distribution curves were developed for each site.

At the completion of the particulate/ Cr^{+6} and particle size tests, a single test was conducted simultaneously at each location according to procedures described in EPA Reference Method 108.** Method 108 provides inorganic arsenic concentration. This test was conducted for about 2 hours at each location by isokinetic, cross-sectional traverse techniques. Total arsenic content was then determined by atomic absorption (AA) analysis.

The following process samples were collected during each emission test.

- ° A composite incinerator bottom ash-fly ash sample representing combined material from all three units, and
- ° No. 2 ESP hopper fly ash samples.

Select samples were analyzed for Cr^{+6} using procedures similar to those performed on the Method 5 particulate samples. Process and emission samples were then shipped to EPA for analysis of total Cr by NAA. PEI later performed ICAP analysis on ESP fly ash samples for Be, Pb, and Zn.

The following subsections detail the results of the sampling program.

* Test Methods for Evaluating Solid Waste. U.S. EPA SW-846, 2nd ed., July 1982.

** 40 CFR 60, Appendix A, Reference Method 108, July 1984.

2.2 PARTICULATE, HEXAVALENT CHROMIUM, AND ARSENIC TEST RESULTS

Simultaneous Method 5* tests were conducted at the ESP inlet and outlet test locations. These samples were analyzed for particulate and Cr^{+6} concentrations, and the resulting data were used to characterize the removal efficiency across the ESP. In addition, a single test was conducted simultaneously at each location (by EPA Method 108 sampling and analytical procedures) to characterize uncontrolled and controlled arsenic emissions from this type of source. During all testing, the incinerator load was at least 80 percent of rated capacity (see Section 5).

Table 2-2 summarizes pertinent sample and flue gas data for the particulate/ Cr^{+6} and arsenic tests, and Table 2-3 presents the reported particulate and Cr^{+6} emission results.

Volumetric flow rates are expressed in cubic meters per minute (m^3/min) and actual cubic feet per minute (acfm) at stack conditions. Flow rates corrected to standard conditions [20°C and 760 mmHg (68°F and 29.92 in.Hg) and zero percent moisture] are expressed as dry normal cubic meters per minute (dNm^3/min) and dry standard cubic feet per minute (dscfm).

Filterable particulate concentrations are expressed in milligrams per dry normal cubic meter (mg/dNm^3) and grains per dry standard cubic foot (gr/dscf). Filterable particulate represents that material collected in the sample probe and on the sample filter, which were both maintained at approximately 121°C (250°F). Hexavalent chromium concentrations are expressed in micrograms per gram ($\mu\text{g}/\text{g}$) and micrograms per dry normal cubic meter ($\mu\text{g}/\text{dNm}^3$), where applicable. Mass emission rates are reported in kilograms per hour and pounds per hour.

* 40 CFR 60, Appendix A, Reference Method 5, July 1984.

TABLE 2-2. SUMMARY OF SAMPLE AND FLUE GAS DATA FOR PARTICULATE/ Cr^{+6} AND ARSENIC TESTS

Run No.	Date (1985)	Sampling duration, min	Sample volume		Isokinetic sampling rate, %	Volumetric flow rate ^a				Temperature		Moisture content, %	Gas composition, ^a %			Gas velocity ^c	
						Actual		Standard									
			dNm ³	dscf		m ³ /min	acfm	dNm ³ /min	dscfm	°C	°F		O ₂	CO ₂	CO	mps	fps
PCI-1	5/14	300	6.77	239.228	95.6	6768	239,000	3427	121,000	241	465	11.3	11.2	7.4	0	15.0	49.2
PCO-1	5/14	300	7.61	268.673	95.8	6284	221,900	3172	112,000	235	455	12.0	11.2	7.4	0	17.2	56.3
PCI-2	5/15	300	2.53	89.164	96.2	7117	251,300	3639	128,500	239	463	11.4	11.6	7.1	0	15.8	51.7
PCO-2	5/15	300	7.67	270.671	99.0	6008	212,150	3095	109,300	232	449	11.6	11.6	7.2	0	16.4	53.8
PCI-3	5/16	300	2.30	81.325	94.7	6706	236,800	3370	119,000	239	462	12.2	11.3	8.4	0	14.8	48.7
PCO-3	5/16	300	7.64	269.762	100.3	6006	214,200	3044	107,500	233	452	12.7	11.6	8.0	0	16.6	54.3
PCI (Inlet) average			-	-	-	6864	242,400	3479	122,800	239	463	11.6	11.4	7.6	0	15.2	49.9
PCO (Outlet) average			-	-	-	6119	216,000	3104	109,600	233	452	12.1	11.5	7.5	0	16.7	54.8
AI-1 (Arsenic)	5/16	125	0.97	34.339	95.7	6729	237,600	3381	119,400	238	461	12.4	11.3	8.4	0	14.9	48.9
AO-1	5/16	125	3.10	109.527	100.6	5913	208,800	2959	104,500	232	449	13.1	11.6	8.0	0	16.2	53.0

^aStandard conditions: 20°C (68°F), 760 mmHg (29.94 in.Hg) and zero percent moisture.

^bGas composition as determined from integrated bag samples collected during each test. Analysis performed with an Orsat gas analyzer.

^cMeasured flue gas velocity in meters per second and feet per second.

TABLE 2-3. SUMMARY OF PARTICULATE AND HEXAVALENT CHROMIUM EMISSIONS DATA

Run No.	Date (1985)	Filterable concentration						Mass emission rate				Collection efficiency, ^c %		Particulate concentration ^d in gr/dscf corrected to 12% CO ₂
		Total filterable weight, grams	Particulate ^a			Cr ⁺⁶ (blank corrected) ^b		Particulate		Cr ⁺⁶				
			mg/dNm ³	gr/dscf	ug/g	Total Cr ⁺⁶ in sample, ug	ug/dNm ³	kg/h	lb/h	kg/h	lb/h			
PCI-1	5/14	21.188	3130	1.4	<0.1	<0.5	-	643	1418	-	-	>99.8	-	2.27
PCO-1	5/14	0.0374	4.9	0.002	NA	NA	-	0.95	2.1	-	-	-	-	0.003
PCI-2	5/15	7.07	2795	1.2	<0.1	<0.5	-	611	1348	-	-	>99.8	-	2.03
PCO-2	5/15	0.0316	4.1	0.0018	NA	NA	-	0.8	1.7	-	-	-	-	0.003
PCI-3	5/16	6.849	2978	1.3	<0.1	<0.5	-	601	1325	-	-	>99.8	-	1.86
PCO-3	5/16	0.0253	3.3	0.0014	NA	NA	-	0.6	1.3	-	-	-	-	0.002

^aStandard conditions: 20°C (68°F), 760 mmHg (29.94 in.Hg) and zero percent moisture.

^bA Cr⁺⁶ detection limit of 0.1 ug/g was established for these samples based on a particulate weight of 5 grams using 50 ml total volume.

^cCollection efficiency: $\frac{\text{Inlet concentration} - \text{Outlet concentration}}{\text{Inlet concentration}} \times 100$.

$${}^dC_{12} = \frac{12C}{\% \text{ CO}_2}$$

where C₁₂ = corrected concentration

C = uncorrected concentration

% CO₂ = as measured by Orsat gas analyzer

NA = Not analyzed.

As reported in Table 2-2, sample volumes ranged from 2.30 to 6.77 dNm³ for the inlet trains and from 7.61 to 7.67 dNm³ for the outlet trains. The inlet sample rate was adjusted after Test PCI-1 to account for the heavy particulate loading at this site. The particulate filter was changed four times during this run to prevent excessive pressure drop across the filter frit support. Tests PCI-2 and PCI-3 were run at substantially lower sampling rates to preclude excessive pressure drop and filter changes during testing. No problems were encountered during Runs 2 and 3 and sufficient sample (>5 grams) was collected for Cr⁺⁶ quantification. Isokinetic sampling rates ranged between 94.7 and 100.3 percent, which is within the acceptable range of 90 to 110 percent.

Volumetric gas flow rates at the ESP inlet ranged from 6706 to 7117 m³/min (236,800 to 251,300 acfm) and averaged 6864 m³/min (242,400 acfm) for the three particulate/Cr⁺⁶ tests. The average volumetric flow at standard conditions was 3479 dNm³/min (122,800 dscfm). Flue gas temperatures ranged from 239° to 241°C (462° to 465°F) and averaged 239°C (463°F). The moisture content of the gas stream averaged 11.6 percent, and the average oxygen (O₂) and carbon dioxide (CO₂) contents were 11.4 and 7.6 percent, respectively.

Arsenic sample and flue gas data reported in Table 2-2 are comparable to data associated with the particulate/Cr⁺⁶ tests with the exception of the sample times and metered gas volume.

As shown in Table 2-3, inlet particulate concentrations ranged from 2795 to 3130 mg/dNm³ (1.2 to 1.4 gr/dscf) and averaged 2968 mg/dNm³ (1.3 gr/dscf). The average mass emission rate for the three tests was 618 kg/h (1364 lb/h).

As reported in Table 2-3, hexavalent chromium content of the inlet emission samples was less than 0.1 µg/g, or below the detection limit of the

analytical methodology employed. Because of the extended sampling times and heavy particulate concentration at this location, loose particulate in gram quantities was collected in the front half of each Method 5 sampling train. Considering the extremely low levels of Cr^{+6} indicated by the pretest survey sample analysis ($<0.25 \mu\text{g/g}$), the filters were not cut up and extracted as specified in the method. This precluded the need for a filter blank correction for Cr^{+6} . Rather, the loose particulate was thoroughly mixed with a Teflon spatula and approximately 5 grams of the particulate was transferred to the beaker containing the probe rinse particulate residue. To increase the analytical sensitivity ($0.1 \mu\text{g/g}$), the amount of alkaline extraction solution and the final dilution volume were kept at a minimum consistent with Method 3060 from Test Methods for Evaluating Solid Waste.* This proportion is 4 ml of extraction solution per gram of solid diluted to a final volume of 10 ml. Filters would require larger amounts of extraction solution resulting in increased analytical detection limits ($>1.0 \mu\text{g/g}$).

At the ESP outlet, volumetric gas flow rates ranged from 6006 to 6284 m^3/min (214,200 to 221,900 acfm) and averaged 6119 m^3/min (216,000 acfm). The average gas flow rate at standard conditions was 3104 dNm^3/min (109,600 dscfm). Flue gas temperatures ranged from 232° to 241°C (449° to 465°F) and averaged 233°C (452°F). The moisture content of the gas stream averaged 12.1 percent, and the average O_2 and CO_2 contents were 11.5 and 7.5 percent, respectively.

Outlet particulate concentrations ranged between 3.3 and 4.9 mg/dNm^3 (0.0014 and 0.002 gr/dscf) and averaged 4.1 mg/dNm^3 (0.0017 gr/dscf). The average mass emission rate for the three tests was 0.8 kg/h (1.7 lb/h).

* United States Environmental Protection Agency, SW846, 2nd ed., July 1982.

Since Cr^{+6} levels in the ESP inlet samples were less than detectable, no attempt was made to analyze the ESP outlet particulate samples for Cr^{+6} .

The particulate-removal efficiency of the ESP was greater than 99.8 percent based on the measured inlet and outlet particulate concentrations.

No major problems were encountered during the particulate/ Cr^{+6} tests. Extended sampling times were necessary to assure collection of sufficient loose particulate sample at the ESP inlet so that Cr^{+6} levels could be quantified. It should be noted that one of the six sampling ports at the ESP outlet location was not accessible for sampling because of an I-beam support approximately 4 feet directly in front of the port opening. Each of the remaining 5 sampling ports was sampled using 5 points per port for a total of 25 sampling points. The effect on sample results is believed to be insignificant considering the low particulate weights and extended sampling times.

Table 2-4 summarizes the arsenic emissions data obtained at this source.

TABLE 2-4. SUMMARY OF ARSENIC EMISSIONS DATA

Run No.	Date (1985)	Sampling location	Concentration			Arsenic collection efficiency, %
			Total ^a arsenic sample weight, μg	$\mu\text{g}/\text{dNm}^3$	mg/dNm^3	
AI-1	5/16	Inlet	162.7	167.7	0.17	>97
AO-1	5/16	Outlet	13.1	4.2	0.004	

^aProbe rinse residue, filter and impinger catch.

The inlet sample showed a total arsenic weight of 162.7 μg or 167.7 $\mu\text{g}/\text{dNm}^3$ compared with 13.1 μg (4.2 $\mu\text{g}/\text{dNm}^3$) for the outlet sample. This single test indicated an arsenic collection efficiency of more than 97 percent. Considering the low level of arsenic measured, and based on a single

test, this calculated efficiency is comparable to the overall particulate collection efficiency of the ESP.

2.3 PARTICLE SIZE DISTRIBUTION TEST RESULTS

At the ESP inlet, an Andersen HGLI with a 15- μ m precutter attached was used to measure particle size distribution during each particulate/Cr⁺⁶ test. This in-stack impactor consists of two single-jet impaction chambers followed by a third-stage cyclone and a backup thimble. The impactor is designed for use in extracting samples from a gas stream with a heavy particulate concentration and its use was advantageous in this case because it contains no filter media (except the backup thimble). This eliminates the need for filter blank corrections for Cr⁺⁶ and permits a more accurate quantification of Cr⁺⁶ size distribution. A total of three inlet samples (designated PSI) were collected during 120- to 150-minute periods at a single point representing the average gas velocity and temperature in the duct.

At the ESP outlet, an Andersen Mark III in-stack impactor was used to measure size distribution during the particulate/Cr⁺⁶ tests. The Mark III impactor consists of eight stages and a backup filter from which eight cut-point sizes can be determined.

Three samples (designated PS0) were collected from a single point representing the average velocity head and temperature in the duct. Sample times ranged from 210 to 300 minutes.

Each particle size test was conducted according to the procedures described in the impactor operations manuals. Isokinetic sampling rates were set initially, and constant cut-point characteristics were maintained throughout the sampling period. Specifications state that the gas flow rate

through the impactor at stack conditions should be maintained between 0.3 and 0.7 acfm to avoid distortion of individual stage cut-points. With the exception of Test PSO-2, which exhibited a 0.71 cfm impactor flow rate, this criterion was met. Isokinetic sampling rates ranged from 99.6 to 103.9 percent for the inlet tests and 103.1 to 106 percent for the outlet tests.

Cumulative size distribution curves representing the total weight of particulate matter smaller than the indicated aerodynamic particle diameter [in micrometers (μm)] were established for each test location. Data reduction for all runs were performed by computer programming with moisture, molecular weight, and temperature data obtained from the particulate/ Cr^{+6} tests. The cut-points for the HGLI tests were determined graphically from information supplied by the manufacturer, and all particle size results are based on a particle density of 1 g/cm^3 . The HGLI data reduction and intermediate calculations are presented in Appendix A of this report.

Cut-points for the Mark III impactor stages were calculated by use of a computer program contained in "A Computer-Based Cascade Impactor Data Reduction System" (CIDRS) developed for EPA by Southern Research Institute (SRI).^{*} All particle size results are based on a particle density of 1 g/cm^3 .

Figures 2-1 and 2-2 present the best-fit nominal curves for the inlet and outlet particle size distribution tests. Table 2-5 presents a comparison of particulate concentrations obtained from the particle size tests with those obtained by Method 5 tests.

For the three inlet runs (PSI-1 through -3), the size distribution curve showed that about 40 percent by weight of the particles had a nominal

^{*}Southern Research Institute. A Computer-Based Cascade Impactor Data Reduction System. Prepared for U.S. EPA under Contract No. 68-022-131, March 1978.

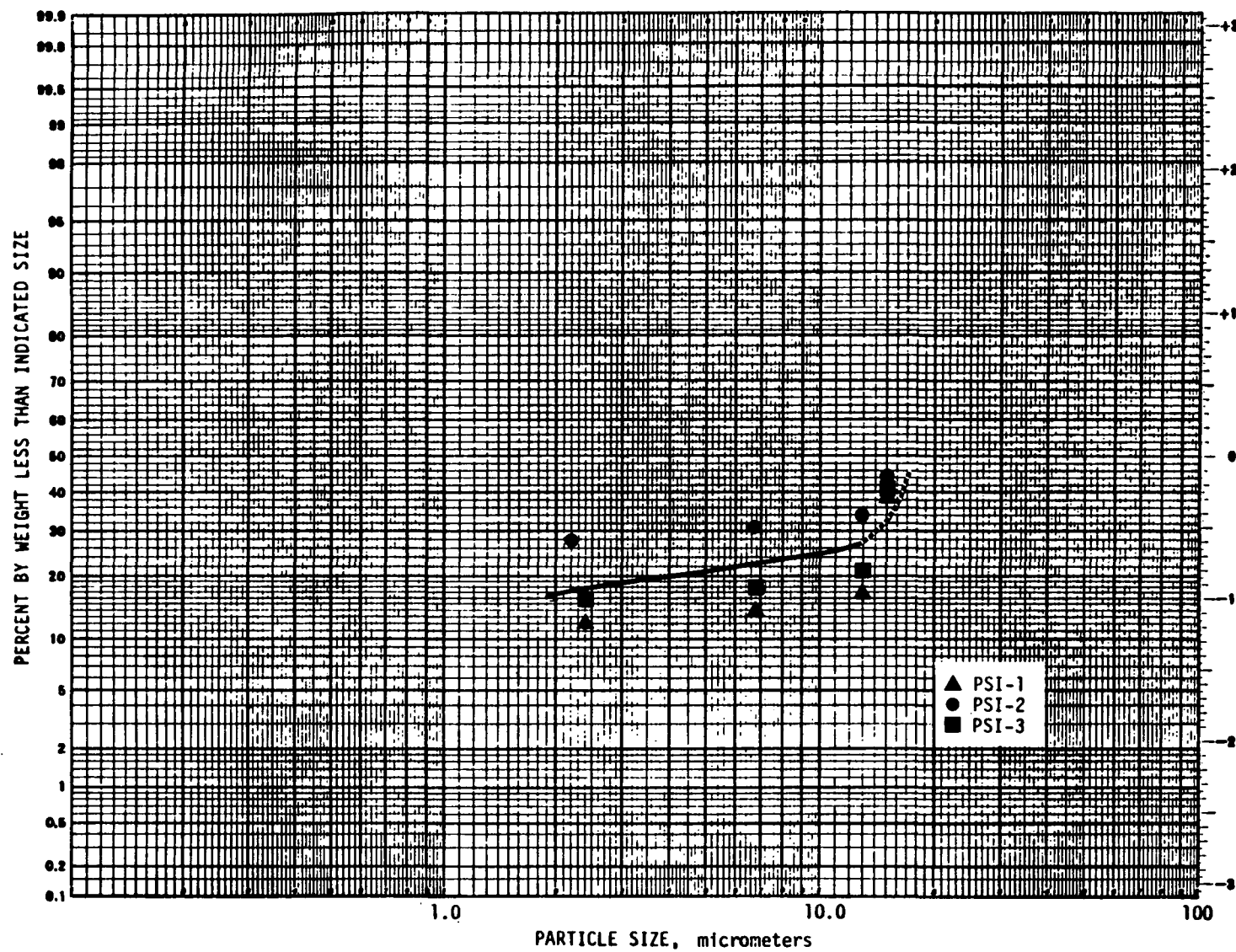


Figure 2-1. No. 2 ESP inlet particle size distribution.

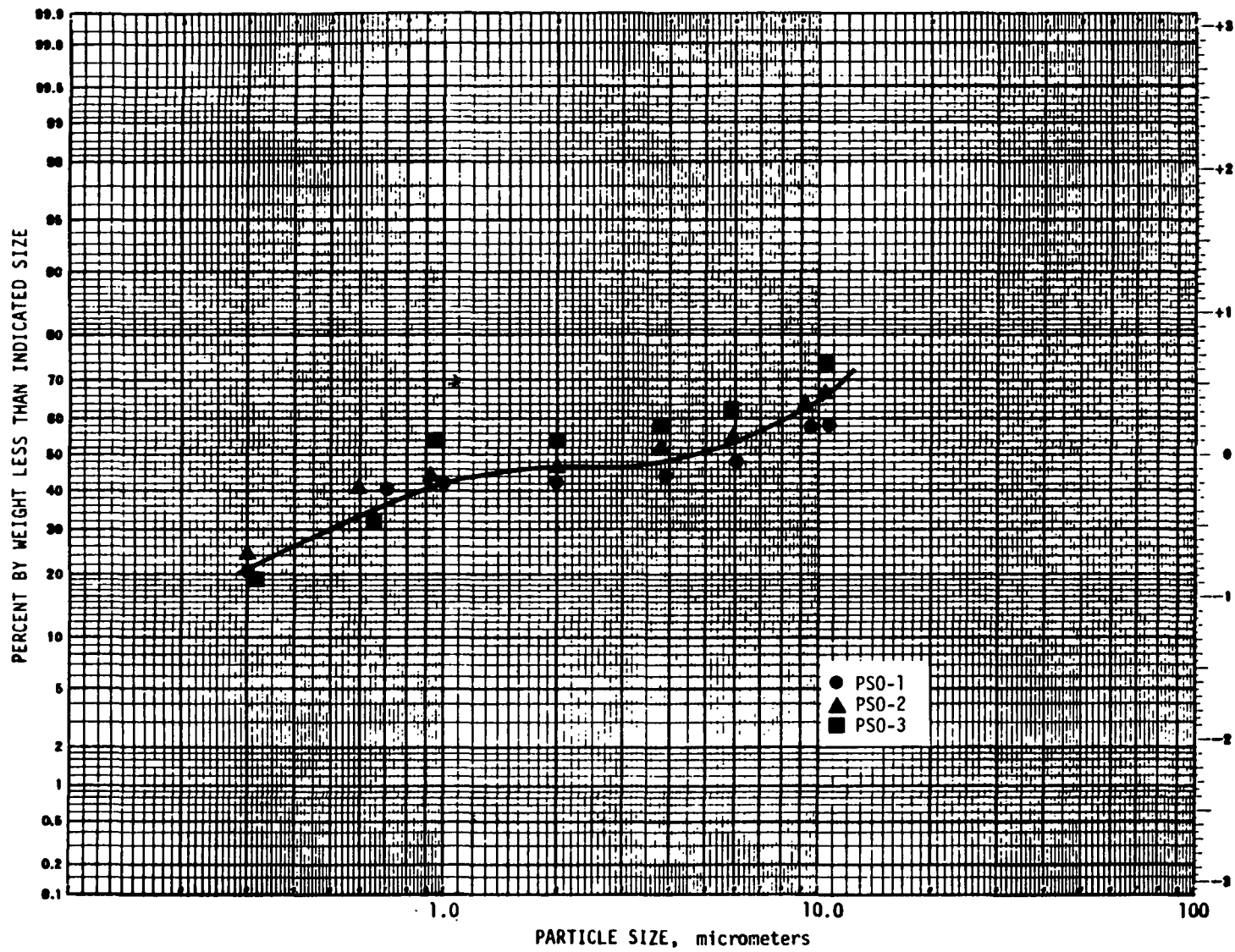


Figure 2-2. No. 2 ESP outlet particle size distribution.

TABLE 2-5. COMPARISON OF PARTICULATE CONCENTRATIONS AS MEASURED BY
EPA METHOD 5 VERSUS PARTICLE SIZE DISTRIBUTION IMPACTORS

Run No.	Test location	Sample type	Particulate concentration	
			mg/dNm ³	gr/dscf
PSI-1	ESP inlet	Particle size - HGLI	2515	1.1
PCI-1		Method 5 - Particulate	3130	1.4
PSI-2		Particle size - HGLI	1756	0.8
PCI-2		Method 5 - Particulate	2795	1.2
PSI-3		Particle size - HGLI	2206	1.0
PCI-3		Method 5 - Particulate	2978	1.3
PSO-1	ESP outlet	Particle size	2.99	0.0013
PCO-1		Method 5 - Particulate	4.9	0.002
PSO-2		Particle size	3.0	0.0013
PCO-2		Method 5 - Particulate	4.1	0.0018
PSO-3		Particle size	2.87	0.00125
PCO-3		Method 5 - Particulate	3.3	0.0014

diameter of 15 micrometers or less. The calculated average particulate concentration for these runs was 2159 mg/dNm³ (0.97 gr/dscf) compared with a three-test Method 5 average of 2968 mg/dNm³ (1.3 gr/dscf). This indicates about a 25 percent difference in average values between the two measurements. The percentage difference between the methods is acceptable according to the applicable criterion in the Inhalable Particulate (IP) protocol.* This protocol states that a comparison of the total mass concentrations between particle size and Method 5 sample runs should not differ from the means by more than 50 percent.

The HGLI Stages 1, 2, and 3 cut-points for Test PSI-1 were 13.0, 6.9, and 2.4 μm , respectively. Seventeen percent of the particles were less than 13.0 μm , 14 percent were less than 6.9 μm , and 12.5 percent were less than 2.4 μm . The stage cut-points for Test PSI-2 were 13.0, 6.9, and 2.2 μm . Thirty-four percent of the particles were less than 13.0 μm , 31 percent were less than 6.9 μm , and 28 percent were less than 2.2 μm . The stage cut-points for Test PSI-3 were identical to those of Test PSI-1. Twenty-one percent of the particles were less than 13 μm , 19 percent less than 6.9 μm , and 16 percent less than 2.4 μm .

The size distribution curves for the three outlet tests (PSO-1 through -3) showed between 60 and 70 percent by weight of the particles had a nominal diameter of 10 μm or less. Approximately 45 percent of the particles were less than 2 μm . The average calculated particulate concentration for these runs was 2.94 mg/dNm³ (0.0013 gr/dscf) compared with a three-test Method 5 average of 4.1 mg/dNm³ (0.0017 gr/dscf).

* Procedures Manual for Inhalable Particulate Samplers Operation, prepared by Southern Research Institute for EPA, Contract No. 68-02-3118, November 1979.

The inlet results are considered representative of particle size distribution in the gas stream at the time of testing. The overall data consistency and comparability to the average Method 5 results substantiate this conclusion.

The outlet results are somewhat suspect because of the extremely low particulate concentration. Some distortion in stage cut-points is also expected as a result of physical forces such as static electricity. However, the data are comparable and correlate favorably with the Method 5 test results.

Based on the nondetectable levels of Cr^{+6} at this source, no attempt was made to quantify Cr^{+6} by size fraction.

2.4 PROCESS SAMPLE ANALYTICAL RESULTS

Table 2-6 summarizes Cr^{+6} analytical results from the composite incinerator bottom ash-fly ash, and ESP hopper fly ash samples.

TABLE 2-6. PROCESS SAMPLE ANALYTICAL RESULTS

Sample type	Laboratory ID	Particulate weight analyzed, g	Total Cr^{+6} , μg	Cr^{+6} concentration, $\mu\text{g/g}$
Incinerator bottom ash (composite)	EL143-145	10.1712	<1	<0.1
ESP hopper fly ash	-	-	-	-
No. 4 field (5/14)	EL155	10.0836	<1	<0.1
No. 4 field (5/15)	EL156	10.0297	<1	<0.1
No. 4 field (5/16)	EL157	10.0133	<1	<0.1

Detection limit: 0.1 $\mu\text{g/g}$.

Samples of the combined bottom ash-ESP fly ash were collected each test day from a vibrating screen conveyor immediately prior to being loaded into

trucks for disposal in a landfill. This material represented a nonhomogeneous mixture of bottom ash and ESP fly ash from each of the three units at this facility. Grab samples were collected 4 to 6 times over a 5-hour test period and placed in a 1-gallon polyethylene container. Samples from each test day were composited into a single sample and analyzed for Cr^{+6} using procedures similar to those used in the analysis of the inlet Method 5 samples. Cr^{+6} content in this sample was less than the detection limit ($<0.1 \mu\text{g/g}$).

Samples of the No. 2 ESP hopper fly ash were collected from each of four ESP fields during each test day. Figure 2-3 depicts the sampling location. Only samples collected from the No. 4 field were analyzed for Cr^{+6} . The Cr^{+6} level in these samples was less than detectable ($<0.1 \mu\text{g/g}$).

2.5 VISIBLE EMISSIONS AND HI-VOLUME SAMPLE

As instructed by EPA, PEI attempted to collect sufficiently large quantities of particulate at the ESP outlet so that Cr^{+6} and other metals of interest could be quantified. Pretest calculations revealed that sampling times in excess of 30 hours, using a hi-volume sampler, would be required to collect $\approx 750 \text{ mg}$ from this source. A hi-volume ambient air sample pump and filter were used as shown in Figure 2-4. However, the sample runs were terminated with less than $2\frac{1}{2}$ hours of sample time due to overheating of the pump motor. Sample volumes corrected to standard conditions for these runs were 433 and 665 dNm^3 (1419 and 2183 dscf), respectively.

No attempt was made to analyze these samples based on the analytical results for Cr^{+6} from the inlet and process samples.

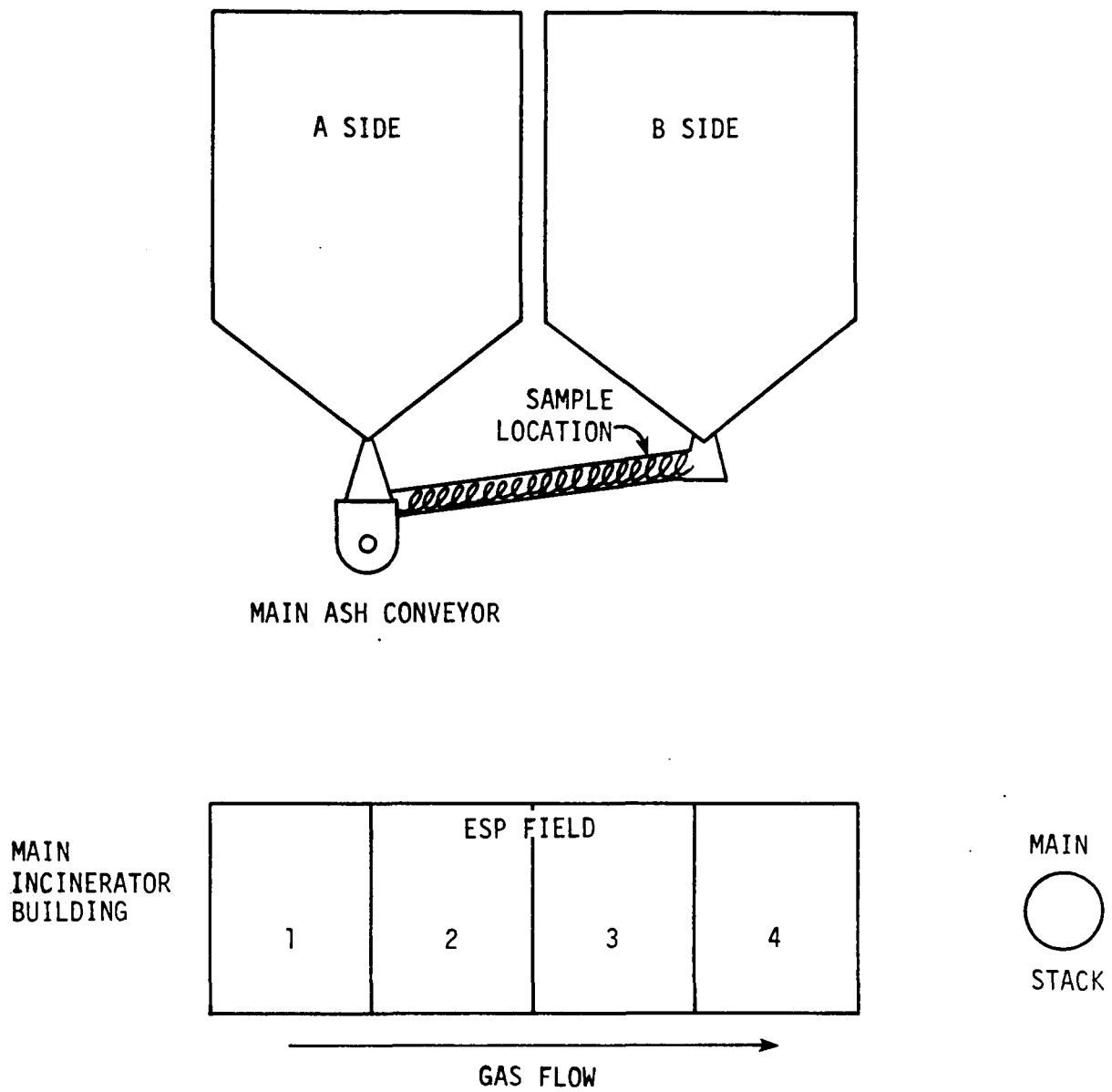


Figure 2-3. ESP hopper fly ash sampling location.

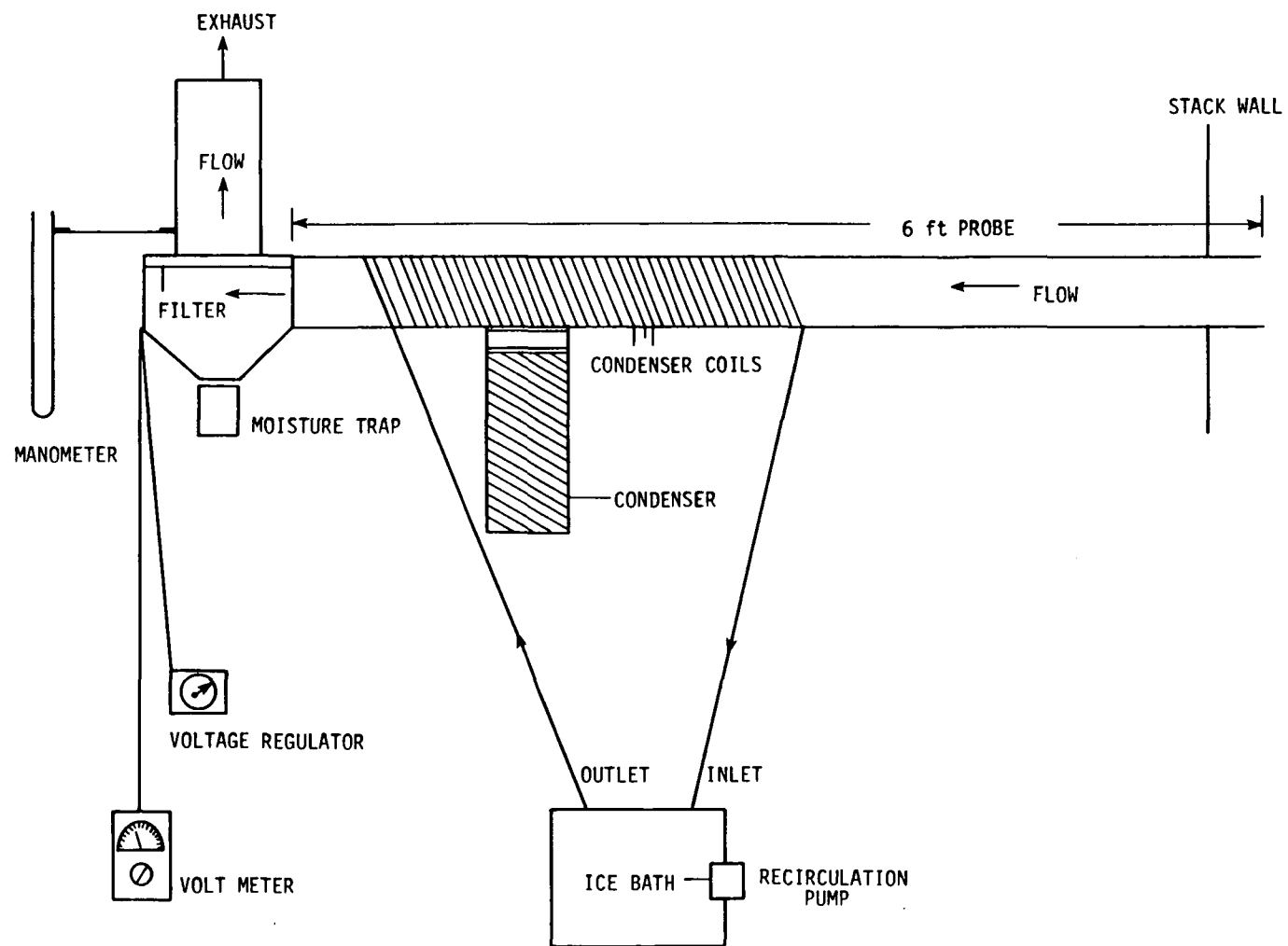


Figure 2-4. Hi-volume sampler.

2.6 TOTAL CHROMIUM AND OTHER METALS TEST RESULTS

Table 2-7 summarizes total Cr concentration and emission data for samples analyzed by NAA. Analytical data as received from EPA are included in Appendix C of this report along with example calculations. Table 2-8 summarizes Be, Pb, and Zn concentration data for process samples analyzed using ICAP techniques.

As reported in Table 2-7, inlet Method 5 tests designated PCI-1 through -3 and outlet Method 5 tests designated PCO-1 through -3 were submitted for analysis. In addition, inlet particle size run PSI-3 was submitted for analysis by individual stage cut point. Process samples (fly ash/bottom ash and ESP fly ash) were also analyzed for total Cr.

The total Cr content of the inlet emission samples ranged between 657 and 861 $\mu\text{g/g}$. Total Cr concentrations ranged between 1836 and 2695 $\mu\text{g/dNm}^3$, with corresponding mass emission rates ranging between 0.40 and 0.55 kg/h (0.90 and 1.04 lb/h).

The total Cr content of the outlet emission samples ranged between 2807 and 7545 $\mu\text{g/g}$. The total Cr concentration ranged between 11.6 and 27.3 $\mu\text{g/dNm}^3$, with corresponding mass emission rates of 0.002 and 0.005 kg/h (0.005 and 0.01 lb/h), respectively. All outlet total Cr data have been corrected for a filter/acetone Cr blank level of 15 μg . These data indicate that the total Cr collection efficiency of the ESP is about 99 percent on a mass rate basis.

A single particle size sample from the ESP inlet was analyzed by individual stages in an attempt to characterize total Cr by size fraction. As reported in Table 2-7, the total Cr content of individually-loaded stages ranged from 330 μg for Stage 1, 13 μm cut point, to 139 μg for Stage 3, 2.4 cut point.

TABLE 2-7. SUMMARY OF TOTAL Cr EMISSION DATA
(Baltimore RESCO)

Run No.	Sample type and location	Total ^a particulate collected, g	Particulate ^b sample weight analyzed by NAA, g	Total Cr ^c results by NAA, µg	Total Cr ^d concentration by NAA, µg/g	Total Cr ^e content of emission sample, µg	Total Cr concentration,		Total Cr mass emission rate,	
							µg/dNm ³	gr/dscf	kg/h	lb/h
PCI-1	Particulate - ESP inlet	21.1876	0.0991	85.3	861	18,243	2,695	0.001	0.55	1.04
PCI-2	Particulate - ESP inlet	7.0703	0.1059	69.6	657	4,645	1,836	0.0008	0.40	0.90
PCI-3	Particulate - ESP inlet	6.8494	0.1097	74.0	675	4,623	2,010	0.0009	0.41	0.92
PCO-1	Particulate - ESP outlet	0.0374	0.0374	208.1	5,564	208.1	27.3	0.00001	0.005	0.01
PCO-2	Particulate - ESP outlet	0.0316	0.0316	88.7	2,807	88.7	11.6	0.000005	0.002	0.005
PCO-3	Particulate - ESP outlet	0.0253	0.0253	190.9	7,545	190.9	25.0	0.00001	0.005	0.01
PSI-3	Particle size - ESP inlet Stage 0	1.3899	0.0962	61.1	635	883	833	0.0004	0.22	0.40
PSI-3	Particle size - ESP inlet Stage 1	0.4523	0.1022	74.6	730	330	311	0.0001	0.06	0.14
ISI-3	Particle size - ESP inlet Stage 2	0.0634	0.0433	96.1	2,219	141	133	0.00006	0.03	0.06
ISI-3	Particle size - ESP inlet Stage 3	0.0606	0.0405	93.1	2,299	139	131	0.00006	0.03	0.06
PSI-3	Particle size - ESP inlet Backup thimble	0.3725	0.3725	166.4	447	166.4	157	0.00007	0.03	0.07
I-3	Fly ash/bottom ash Composite	-	0.1278	56.4	441	56.4	-	-	-	-
(PCI and PCO 1)	ESP fly ash - Field 1	-	0.098	67.9	693	67.9	-	-	-	-
	ESP fly ash - Field 2	-	0.1087	65.0	598	65.0	-	-	-	-
	ESP fly ash - Field 3	-	0.1038	72.3	697	72.3	-	-	-	-
	ESP fly ash - Field 4	-	0.1081	40.0	370	40.0	-	-	-	-
(PCI and PCO 2)	ESP - fly ash - Field 1	-	0.1012	75.7	748	75.7	-	-	-	-
	ESP - fly ash - Field 2	-	0.1134	85.6	755	85.6	-	-	-	-
	ESP - fly ash - Field 3	-	0.1257	81.5	648	81.5	-	-	-	-
	ESP - Fly ash - Field 4	-	0.1193	54.9	460	54.9	-	-	-	-

(continued)

TABLE 2-7 (continued)

Run No.	Sample type and location	Total ^a particulate collected, g	Particulate ^b sample weight analyzed by NAA, g	Total Cr ^c results by NAA, μ g	Total Cr concentration ^d by NAA, μ g/g	Total Cr content of emission sample, μ g	Total Cr concentration,		Total Cr mass emission rate,	
							μ g/dNm ³	gr/dscf	kg/h	lb/h
PCI and PCO-3	ESP - Fly ash - Field 1	-	0.1066	80.8	758	80.8	-	-	-	-
	ESP - Fly ash - Field 2	-	0.0923	70.5	764	70.5	-	-	-	-
	ESP - Fly ash - Field 3	-	0.0989	55.6	562	55.6	-	-	-	-
	ESP - Fly ash - Field 4	-	0.1238	32.9	266	32.9	-	-	-	-

^aTotal particulate (acetone rinse residue and filter) collected during sample run.

^bParticulate weight analyzed by NAA.

^cTotal Cr results by NAA. Run No. PCO-3 (ESP outlet) is a blank corrected value ($\approx 15 \mu$ g Cr for filter/acetone blank). Particle size thimble (backup) values have been blank corrected for $\approx 44 \mu$ g Cr.

^dTotal Cr(C) divided by particulate weight analyzed by NAA(b).

^eTotal Cr concentration (μ g/g) multiplied by total particulate weight collected(a).

The backup thimble (less than 2.4 μm) showed 166 μg total Cr. This figure has been blank corrected by 44 μg to account for the background levels of Cr in the thimble filter. On a concentration basis, Stage 1 (13.0 μm cut point) was 311 $\mu\text{g}/\text{dNm}^3$, Stage 2 (6.9 μm cut point) was 133 $\mu\text{g}/\text{dNm}^3$, Stage 3 (2.4 μm cut point) was 131 $\mu\text{g}/\text{dNm}^3$, and the backup stage (less than 2.4 μm) was 157 $\mu\text{g}/\text{dNm}^3$. These data indicate a fairly uniform distribution of total Cr of less than 13 μm in diameter.

The composite fly ash/bottom ash sample showed 441 $\mu\text{g}/\text{g}$ total Cr. ESP fly ash samples showed total Cr concentrations ranging between 266 and 764 $\mu\text{g}/\text{g}$. It should be noted that EPA attempted to quantify Ni and Cd by NAA. All samples showed nondetectable levels of Ni, and only one process sample (ESP fly ash) showed any Cd at a level of 301 $\mu\text{g}/\text{g}$.

Table 2-8 is a summary of Be, Pb, and Zn concentration data. Single composite samples of incinerator bottom ash and ESP fly ash from each test period were analyzed using ICAP techniques. Sample preparation procedures generally followed those described in EPA Method 3050 of SW-846.* This analysis was performed in July 1986.

* Test Methods for Evaluating Solid Waste. U.S. EPA SW-846, 2nd ed, July 1982, Method 3050.

TABLE 2-8. SUMMARY OF BERYLLIUM, LEAD, AND ZINC ANALYTICAL DATA

Sample type	Test No.	Laboratory No.	Concentration, $\mu\text{g/g}$ (as received)		
			Be	Pb	Zn
Bottom ash	1	EL 143	<0.07	1,450	5,260
	2	EL 144	<0.07	1,640	5,940
	3	EL 145	<0.07	1,500	4,790
ESP fly ash, Field No. 4	1	EL 155	<0.07	10,825	82,600
	2	EL 156	<0.07	2,820	91,200
	3	EL 157	<0.07	7,608	97,200

SECTION 3

PROJECT QUALITY ASSURANCE

The application of quality assurance procedures to source emission measurements ensures accurate emission-testing results. Quality assurance guidelines provide the detailed procedures and actions necessary for defining and producing acceptable data. In this project, five documents were used in the preparation of a source-specific test plan that would ensure the collection of acceptable data: 1) the EPA Quality Assurance Handbook Volume II, EPA-600/4-77-0271; 2) the PEI Emission Test Quality Assurance Plan; 3) the PEI Laboratory Quality Assurance Plan; 4) Determination of Hexavalent Chromium Emissions From Stationary Sources, December 13, 1984; and 5) EPA Protocol for Emissions Sampling for Both Hexavalent and Total Chromium, February 22, 1985. Two of these are PEI's general guideline manuals and define the company's standard operating procedures followed by the company's emission testing and laboratory groups.

In this specific test program, which was reviewed by EPA's Emission Measurement Branch, the following steps were taken to ensure that the testing and analytical procedures produced quality data:

- ° A sample of the combination bottom ash-ESP fly ash was obtained during the April pretest survey and analyzed for Cr^{+6} content. These data were used to define sampling times and rates so that a quantifiable level of Cr^{+6} was collected.
- ° Calibration of all field sampling equipment.
- ° Checks of train configuration and calculations.

- ° Onsite quality assurance checks, such as leak checks of the sampling train, pitot tube, and Orsat line and onsite quality assurance checks of all test equipment prior to use.
- ° Use of designated analytical equipment and sampling reagents.
- ° Internal and external audits to ensure accuracy in sampling and analysis.

Table 3-1 lists the specific sampling equipment used to perform the particulate/Cr⁺⁶, particle size distribution, and arsenic tests as well as the calibration guidelines and limits. In addition to the pre- and post-test calibrations, a field audit was performed on the metering systems and temperature-measurement devices used during sampling. These data are summarized in Table 3-1, and copies of the field audit data sheets are presented in Appendix B of this report.

The PEI project manager performed the onsite sample calculations, and computer programming was used to validate the data upon return to PEI's Cincinnati laboratory. Minor discrepancies between the hand calculations and computer printouts are due primarily to rounding off of values. Computerized example calculations are presented in Appendix A.

The following subsections summarize the quality assurance activities performed during the analytical phase of this project. As a check of the gravimetric analytical procedure, blank filter and reagent (acetone) were analyzed in a fashion similar to that used for the actual field samples. Table 3-2 summarizes the blank analysis data. These data indicate good analytical technique.

Emission and process samples were analyzed in four separate batches. Table 3-3 summarizes the linear regression data of the spectrophotometer calibration for the four days.

The detection limit established for the four days was less than 0.004 µg/ml for an absorbance of 0.005 above the linear regression intercept.

TABLE 3-1. FIELD EQUIPMENT CALIBRATION

Equipment	ID No.	Calibrated against	Allowable error	Actual error	Within allowable limits	Comments
Meter box	FB-3 FB-8 FB-11 FB-12	Wet test meter	$\Delta H\theta \pm 0.15$ (Y $\pm 0.5\%$ Y post-test)	$\Delta H\theta$: +0.02; Y: 0.7% $\Delta H\theta$: -0.06; Y: -1.0% $\Delta H\theta$: -0.04; Y: -1.3% $\Delta H\theta$: 0 Y: +1.7%	X X X X	Y = 0.986; Audit $\Delta H\theta$ = 1.86 Y = 1.006; Audit $\Delta H\theta$ = 1.90 Y = 1.058; Audit $\Delta H\theta$ = 1.20 Y = 0.954; Audit $\Delta H\theta$ = 1.07 (Field audit results)
Pitot tube	187 522	Standard pitot tube	$C_p \pm 0.01$	0 0	X X	From Geometric Spec. 40 CFR Appendix A; Reference Method 2 (0.84 coefficient assumed)
Digital indicator	220 262	Millivolt signals	0.5%	-0.45% +0.41%	X X	
Thermocouple and stack thermometer	104 257	ASTM-3F	1.5% ($\pm 2\%$ saturated)	+0.38% +0.19%	X X	Maximum deviation Maximum deviation
Orsat analyzer	141	Standard gas	$\pm 0.5\%$	+0.2% (O_2) -0.2% (CO_2)	X X	Audit value O_2 and CO_2 = 5.0%
Impinger thermometer	I-1 I-5	ASTM-3F	$\pm 2^\circ F$	+1°F +1°F	X X	
Trip balance	Mettler No. 743985	Type S weights	± 0.5 g	<0.1 g	X	Maximum deviation
Barometer	227	NBS traceable barometer	± 0.10 in.Hg (0.20 post-test)	0.01	X	
Dry gas thermometer	FB-3 FB-8 FB-11 FB-12	ASTM-3F	$\pm 5^\circ F$	In: +2°F; Out: +2°F In: +4°F; Out: +3°F In: +1°F; Out: +4°F In: +1°F; Out: 0°F	X X X X	Maximum deviations Maximum deviations Maximum deviations Maximum deviations
Probe nozzle	5-108 5-105 3-111 A-1	Caliper	$D_n \pm 0.004$ in.	0.001 0.004 0.00 0.001	X X X X	

TABLE 3-2. EXAMPLE FILTER AND REAGENT BLANK
ANALYSIS FOR PARTICULATE

Sample type and filter number	Original tare weight, mg	Blank weight, mg	Net weight, mg
Particulate - 8510128 Reeve Angel 934 AH	363.8	364.2	0.4
Acetone blank ^a	99530.6	99534.1	3.5 mg ^b (0.032 mg/g)
Water blank	NA ^c	NA	NA

^a137 ml evaporated and desiccated before weighing.

^bMethod 5 and particle size acetone blank (0.01 mg/g used in calculations).

^cNA = Not applicable.

TABLE 3-3. LINEAR REGRESSION DATA SPECTROPHOTOMETER CALIBRATION

Sample description	Date (1985)	Cr ⁺⁶ standard concentration, $\mu\text{g/ml}$	Absorbance ^a	Y-Intercept	Slope	Correlation coefficient
Process samples	5/22	0.0	0.000	0.0032	1.3197	0.99982
		0.1	0.136			
		0.2	0.267			
		0.3	0.403			
		0.4	0.537			
		0.5	0.656			
PCI-3	6/5	0.0	0.000	0.0008	1.3097	0.99998
		0.1	0.130			
		0.2	0.262			
		0.3	0.390			
		0.4	0.522			
		0.5	0.656			
PCI-1 PCI-1 + spike	6/11	0.0	0.000	0.0039	1.2666	0.99986
		0.1	0.130			
		0.2	0.262			
		0.3	0.386			
		0.4	0.513			
		0.5	0.632			
PCI-2 PCI-3 + duplicate	6/12	0.0	0.000	-0.0020	1.3329	0.99995
		0.1	0.128			
		0.2	0.263			
		0.3	0.401			
		0.4	0.532			
		0.5	0.663			

Because the concentration of hexavalent chromium in these solid samples were extremely low, the amount of alkaline extraction solution and the final dilution volume of this extract were kept at a minimum consistent with Method 3060 from Test Methods for Evaluating Solid Waste.* This proportion is 4 ml of alkaline extraction solution per gram of solid diluted to a final volume of 10 ml.

All reagent blanks were less than the detection limit. No other blanks were necessary because all analyses were performed on loose particulate; i.e., no filter or thimbles were extracted. Duplicate analysis (extraction and colorimetric determination) was performed on the inlet particulate of Run 3. Also, the inlet particulate from Run 1 was checked by method of addition. The results for these samples are presented in Table 3-4.

TABLE 3-4. RESULTS OF QC SAMPLES

Sample	QC type	Results
Particulate Run 3 Particulate Run 1	Duplicate Spike	0.15, <0.1 $\mu\text{g/g}$ 94% recovery

One problem was encountered with the analysis of the inlet particulate samples and the composite bottom ash samples. After the alkaline extract was filtered, the samples were slightly cloudy (white opaqueness). This interfered with the colorimetric determination and the absorbance of an aliquot not containing the color reagent was subtracted from the absorbance of the sample to correct for this interferent.

Arsenic samples were analyzed on June 4, 1985. The least square fit of the data to quadratic equations for the graphite furnace atomic absorption calibration gave a correlation coefficient of 0.9990. The results of blank analyses were 8.56 μg for the filter and <0.006 mg/liter (detection limit)

for the rinse and impinger samples. The filter blank value is typical for glass fiber filters. Duplicate analysis of the bomb fraction and rinse fraction for the outlet runs gave 3.26, 4.48, 4.91, and 4.61 μg , respectively. Spike recoveries were 95.4, 92.1, 101.9, and 0 percent for the filter, rinse, impingers, and bomb fractions, respectively.

Table 3-5 presents QC data relative to the total Cr analysis by NAA. Duplicate, audit, and blank data are presented.

TABLE 3-5. QC DATA FOR TOTAL CHROMIUM BY NAA

Sample test type	Analysis	Results total Cr
Test No. PCI-1 (acetone residue/particulate sample)	Duplicate analysis	85.3/106.9 μg
NBS coal fly ash	Audit	182.8 $\mu\text{g/g}$ (196 $\mu\text{g/g}$ accepted)
NBS fly ash	Audit	32.2 $\mu\text{g/g}$ (34.4 $\mu\text{g/g}$ accepted)
Alkaline extract	Blank	Not detected
Type I H_2O	Blank	Not detected
Method 5 filter/acetone	Blank	15.0 μg
Particle size thimble - backup	Blank	44.0 μg

SECTION 4

SAMPLING LOCATIONS AND TEST PROCEDURES

This section describes the sampling sites and the test methods used to characterize particulate and chromium emissions from Incinerator No. 2.

4.1 SAMPLING LOCATION

Flue gas samples were extracted from existing sampling ports prior to and after the ESP that controls particulate emissions from Incinerator No. 2. Figures 4-1 and 4-2 show the test locations.

At the ESP inlet, five 10-cm (4-in.) i.d. sampling ports were located approximately 2.9 equivalent duct diameters (EDD) downstream and 2 EDD upstream from the nearest flow disturbances in a rectangular duct with an i.d. of 2.1 x 3.7 m (6.75 x 12 ft). At the ESP outlet, six 10-cm (4-in.) i.d. sampling ports were located approximately 4.2 EDD downstream and 0.8 EDD upstream of the nearest flow disturbances in a rectangular duct with an i.d. of 3.1 x 2.0 m (10 ft 2½ in. x 6 ft 5½ in.). Both locations conformed to the minimum requirements for sampling port locations specified in EPA Reference Method 1.*

4.2 PARTICULATE AND HEXAVALENT CHROMIUM SAMPLE EXTRACTION AND ANALYSIS

Flue gas samples were simultaneously collected at the ESP inlet and outlet test locations according to procedures outlined in EPA Reference Method 5.**

* 40 CFR 60, Appendix A, Reference Method 1, July 1984.

** 40 CFR 60, Appendix A, Reference Method 5, July 1894.

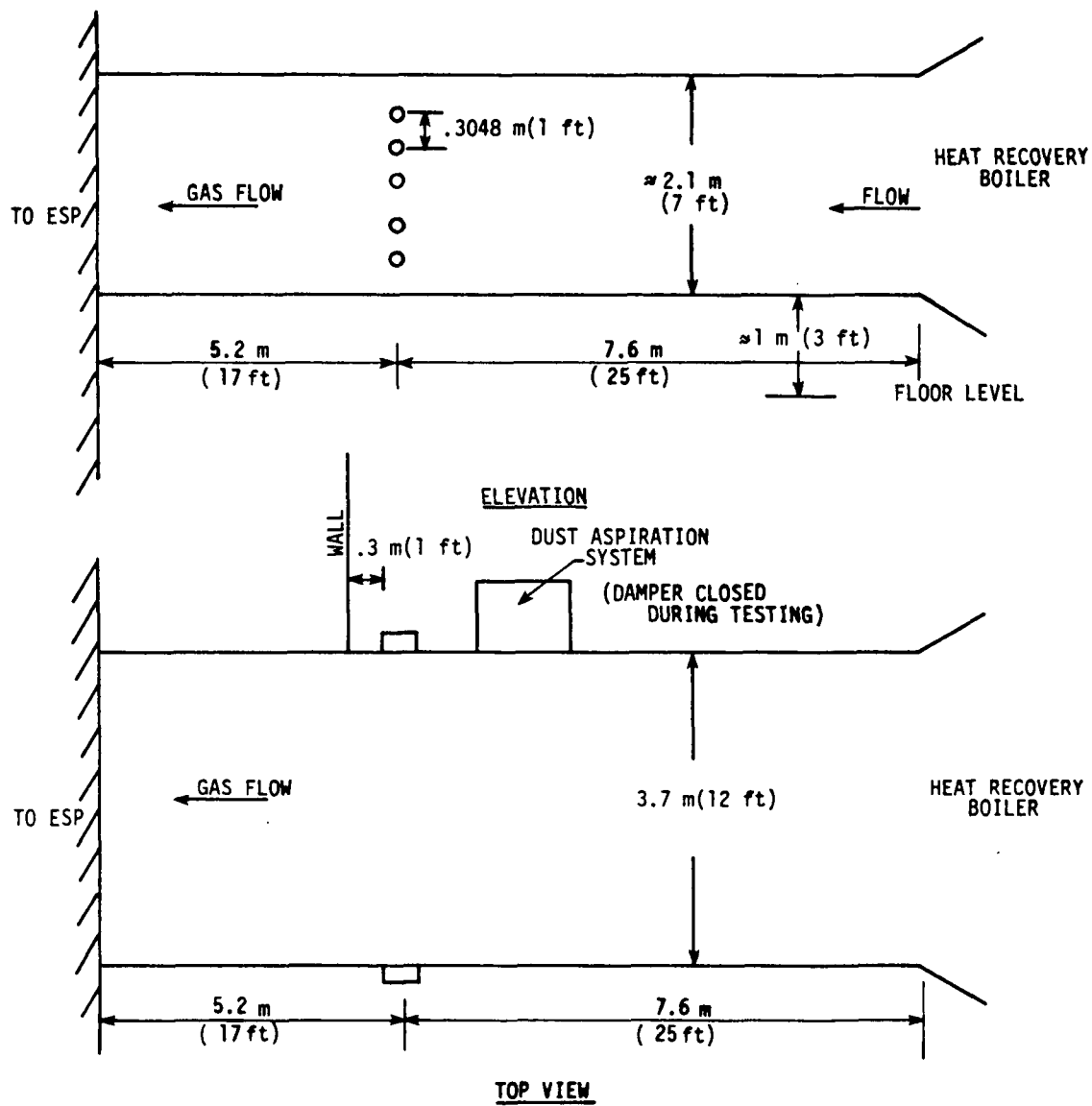
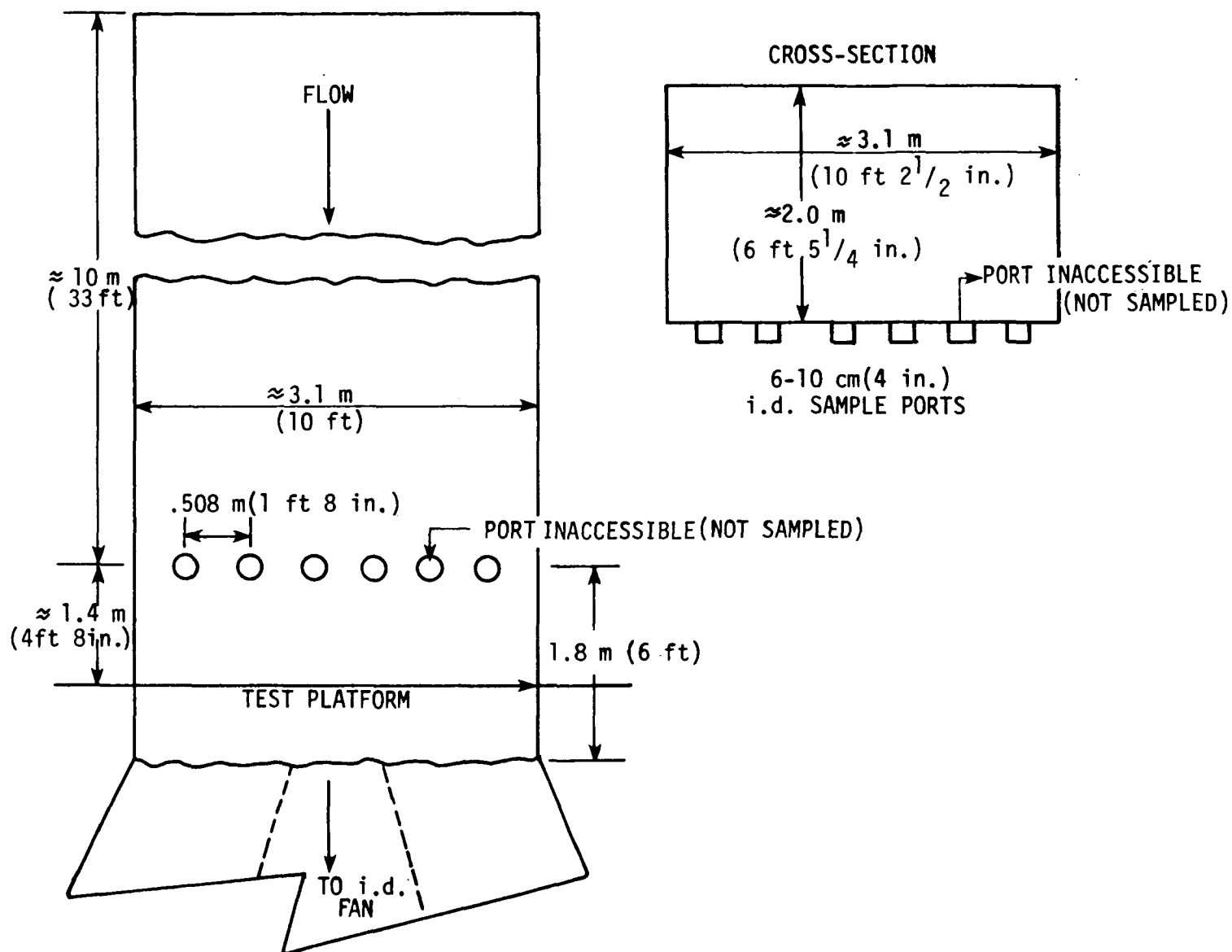


Figure 4-1. No. 2 incinerator ESP inlet sampling location (no scale).

90° BEND
FROM ESP GAS



4-3

Figure 4-2. No. 2 incinerator ESP outlet sampling location (no scale).

Initially, the collected samples were analyzed gravimetrically by Method 5 to determine particulate concentration and mass emission rates. At the completion of the gravimetric analysis, the inlet samples were prepared and analyzed for Cr^{+6} according to procedures described in a draft EPA method entitled "Determination of Hexavalent Chromium Emissions From Stationary Sources." A copy of the draft method is contained in Appendix H of this report.

Before sampling began, velocity, static pressure, molecular weight, moisture content, and temperature were measured to define sampling rates and nozzle sizes are described in EPA Reference Methods 1 through 4.* The degree of turbulent flow at each location also was assessed according to procedures described in EPA Reference Method 2.* In this method, the face opening of the Type-S pitot tube is aligned perpendicularly to the duct cross-sectional plane, designated "0-degree reference." Null (zero) pitot readings obtained at a 0-degree reference indicate an acceptable flow condition at a given point.

If the pitot reading is not zero at 0-degree reference, the pitot is rotated (up to 90 degrees \pm yaw angle) until a null reading is obtained. The value of the rotation angle (yaw) is recorded for each point and averaged across the duct. Method 2 criteria stipulate that average angular rotations greater than ± 10 degrees indicate turbulent (nonaxial) flow conditions in the duct(s). This procedure was used to check several traverse points at each location. In each case, null pitot readings were observed at the 0-degree reference. These data, together with the velocity and temperature profiles established for each location, indicated acceptable flow patterns that would enable the extraction of representative samples at each site.

* 40 CFR 60, Appendix A, Reference Methods 1 through 4, July 1984.

At the ESP inlet, a 5 x 5 sampling matrix, or 25 total sampling points, were used to traverse the cross-sectional area of the duct. Sampling ports located on each side of the ductwork (see Figure 4-1) were used to complete the traverse. Each point was sampled for 12 minutes, yielding a total test time of 300 minutes per test.

At the ESP outlet, a 5 x 5 sampling matrix was established and 25 total sampling points were used to traverse the duct cross-section. Each point was sampled for 12 minutes, yielding a total test time of 300 minutes. It should be noted that one of the six available sampling ports was not sampled due to the close proximity of an I-beam which prevented insertion of the sample probe for this port. Due to the low grain loading and size distribution results at this site, biases in particulate measurements are believed to be insignificant.

The test and analytical procedures used are described briefly here, and detailed procedures are presented in Appendix D.

4.2.1 Velocity and Gas Temperature

A Type-S pitot tube and an inclined draft gauge manometer were used to measure the gas velocity pressures at the test sites. Velocity pressures were measured at each sampling point across the duct to determine an average value. Measurements were taken in the manner prescribed in EPA Reference Method 2.* The temperature at each sampling point was measured with a thermocouple and digital readout.

4.2.2 Molecular Weight

Flue gas composition was determined in accordance with the basic procedures described in EPA Reference Method 3.* Grab samples were collected

* 40 CFR 60, Appendix A, Reference Methods 2 and 3, July 1984.

prior to the start of any sampling to establish baseline contents of oxygen, carbon dioxide, and carbon monoxide. Integrated bag samples were collected during each test and were analyzed with an Orsat gas analyzer. The gas composition at each test site remained consistent throughout the test series.

4.2.3 Particulate/Cr⁺⁶

Particulate and Cr⁺⁶ samples were collected as specified in EPA Reference Method 5.* All tests were conducted isokinetically by regulating the sample flow rate relative to the gas velocity in the duct (as measured by the pitot tube and thermocouple attached to the sample). The basic sampling train consisted of a heated glass-lined probe, a heated 7.6-cm (3-in.) diameter glass-fiber filter (Whatman Reeve Angel 934 AH), and a series of five Greenburg-Smith impingers followed by a vacuum line, vacuum gauge, leak-free vacuum pump, dry gas meter, thermometers, and a calibrated orifice.

For determination of particulate concentration, the nozzle, probe, and filter holder portions were rinsed with acetone at the end of each applicable test. The acetone rinse and particulate caught on the filter media were dried at room temperature, desiccated to a constant weight, and weighed on an analytical balance. Total filterable particulate matter was determined by adding these two values.

Upon completion of the gravimetric analysis, the inlet sample fractions were prepared and analyzed for Cr⁺⁶ according to procedures recently developed by EPA. In summary, the samples were digested in an alkaline solution and analyzed by the diphenylcarbazide colorimetric method.**

* 40 CFR 60, Appendix A, Reference Method 5, July 1984.

** Test Methods for Evaluating Solid Waste. U.S. Environmental Protection Agency, SW-846, 2nd ed., July 1982.

The volume of water collected in the impinger section of the sampling train(s) was measured at the end of each sample run to determine the moisture content of the flue gas. The contents of the impingers were transferred to a polyethylene container. The impingers and all connecting glassware, including the back half of the filter holder, were rinsed with distilled water and the rinse was added to the container.

4.3 PARTICLE SIZE DISTRIBUTION

Samples for particle-size distribution measurements were collected at the ESP inlet and outlet by the use of two different configurations of in-stack cascade impactors. The Andersen Mark III multistage impactor was used at the ESP outlet and the Andersen Heavy Grain Loading Impactor (HGLI) was used at the ESP inlet.

The Andersen Mark III in-stack impactor consists of eight size cut-point stages and a backup filter.

This impactor was assembled by alternating the stage plates, collection media, flat crossbars, and Inconel spacer rings needed to provide weight cut sizes. The collection substrates were Reeve Angel 934 AH glass-fiber filters that have been heated in a 204°C (400°F) oven for 1 or 2 hours, desiccated for 24 hours to a constant weight, and weighed to the nearest 0.1 mg on an analytical balance. A total of three samples were collected at a single point representing the average velocity and temperature in the outlet duct. Sample times ranged from 210 to 300 minutes. Isokinetic sampling rates were set initially and constant cut-point characteristics were maintained throughout the sampling period.

Each size fraction was subjected to a gravimetric analysis using EPA Method 5 procedures.

For each test, size distribution curves were established representing the total weight percent of particulate matter smaller than the indicated aerodynamic particle diameter in micrometers.

Cut-points for the eight Mark III impactor stages were calculated by computer programs contained in "A Computer-Based Cascade Impactor Data Reduction System" (CIDRS) developed for EPA by Southern Research Institute (SRI).^{*} All particle size results are based on a particle density of 1 g/cm³. Data reduction and intermediate results calculations for both types of impactors were performed by the CIDRS program, with moisture contents obtained from the particulate tests.

The Andersen HGLI used at the ESP inlet consists of two single-jet impaction chambers followed by a third-stage cyclone and a backup filter. The sampled gas stream enters the system through the Stage 1 acceleration jet. Particles with sufficient inertia are impacted against the bottom of the Stage 1 impaction chamber. Smaller particles flow with the gas stream and exit the impaction chamber through three vent tubes.

Stage 2 of the HGLI is simply a scaled-down version of Stage 1 in which the jet nozzle diameter and the distance from jet exit to impaction surface have been designed for the proper Stage 2 cut-point.

Stage 3 of the HGLI is a small cyclone of the Southern Research Institute design. A high-efficiency glass-fiber filter removes all particles remaining in the gas stream downstream of the cyclone.

The Andersen HGLI was used at the inlet because of expected heavy particulate concentration, which would overload a standard multistage impactor. Three samples were collected at the ESP inlet from a single point in the duct

^{*} Southern Research Institute. A Computer-Based Cascade Impactor Data Reduction System. Prepared for U.S. Environmental Protection Agency under Contract No. 68-022-131, March 1978.

that was representative of the average velocity and temperature. Sample times ranged from 90 to 120 minutes.

At the completion of each test, the impactor samples were recovered in accordance with procedures described in the HGLI operation manuals.

Each recovered fraction was then subjected to a gravimetric analysis in accordance with EPA Reference Method 5 criteria. Size distribution curves representing the total weight percent of particulate matter smaller than the indicated aerodynamic particle diameter (in micrometers) were established for each run.

The three cut-points for each Andersen HGLI test were determined graphically from information supplied by the manufacturer. All particle size results are based on a particle density of 1 g/cm³. Data reduction and intermediate result calculations were performed by CIDRS programs with moisture contents and gas composition data obtained from the particulate/Cr⁺⁶ tests.*

4.4 PROCESS SAMPLES

During the particulate/chromium tests, the following process samples were collected:

- ° Composite fly ash/incinerator bottom ash
- ° No. 2 ESP fly ash samples from each of 4 fields

Grab samples of the composite bottom ash were collected every 60 to 90 minutes or four to six times during a 6-hour test run. This nonhomogeneous material represents an overall composite of the bottom ash and ESP fly ash from each incinerator. The material was collected from a vibrating screen

*Southern Research Institute. A Computer-Based Cascade Impactor Data Reduction System. Prepared for U.S. Environmental Protection Agency under Contract No. 68-022-131. March 1978.

prior to loading into trucks for disposal in a landfill. The samples from each test were composited using a mortar and pestal and centrifuging so that one representative sample of each sample type per test was available for analysis. Solid samples were extracted and analyzed for Cr^{+6} in accordance with procedures similar to those used for the Cr^{+6} analysis of the particulate samples. ESP fly ash samples were collected in a similar manner as the bottom ash samples except separate samples from each of four ESP electrical fields were collected. For the three tests, 12 samples were collected. All samples were collected sequentially from the B side fly ash hopper. Only the No. 4 field samples were analyzed for Cr^{+6} for each test day. Analytical procedures followed those used for the bottom ash samples. The analyses of the incinerator bottom ash and ESP fly ash were relatively straightforward and no problems were encountered.

Process samples (as designated in Subsection 2.6) were shipped to EPA and analyzed for total Cr, Ni, and Cd using NAA. PEI later analyzed these samples for Be, Pb, and Zn using ICAP.

4.5 ARSENIC

Arsenic concentrations were measured by EPA Reference Method 108.* All tests were conducted isokinetically by regulating the sample flow rate to correspond to the gas velocity in the duct (as measured by the pitot tube and thermocouple attached to the sample probe). The basic sampling train consisted of a heated glass-lined probe, a heated 7.6-cm (3-in.) diameter glass-fiber filter (Whatman Reeve Angel 934 AH), and a series of five Greenburg-Smith impingers followed by a vacuum line, vacuum gauge, leak-free vacuum pump, dry gas meter, thermometers, and a calibrated orifice.

*40 CFR 61, Appendix B, Reference Method 108, July 1984.

For determination of arsenic concentrations, the nozzle, probe, and filter holder portions were rinsed with 0.1 N NaOH at the end of each applicable test.

The filter and solids contained in the 0.1 N NaOH rinse of the front half of the sampling train were prepped, combined, and analyzed for arsenic (by atomic absorption).

The volume of water collected in the impinger section of the sampling train was measured at the end of each sampling run to determine the moisture content of the flue gas. The contents of the impingers were transferred to a polyethylene container. The impingers and all connecting glassware (including the back half of the filter holder) were rinsed with 0.1 N NaOH, and the rinse was added to the container. The contents of the impingers and 0.1 N NaOH rinse also were analyzed for arsenic by atomic absorption.

SECTION 5

PROCESS DESCRIPTION*

Tests were conducted on the exhaust gases of the reciprocating grate Incinerator No. 2 at the Baltimore RESCO refuse-to-energy plant. Figure 5-1 presents an exhaust gas flow schematic with sampling locations. The Baltimore RESCO refuse-to-energy plant was designed and constructed by Signal Environmental Systems, Inc., (SES) to provide for the disposal of up to 2250 tons per day of municipal solid waste from the City and County of Baltimore, Maryland. SES also operates and maintains the facility.

The facility has three identical reciprocating grate incinerators. Each incinerator has a rated capacity of 750 tons/day and typically incinerates 600 tons of waste per day, 24 hours per day, 7 days a week. Natural gas is used as an auxiliary fuel. Each incinerator has its own heat recovery boiler capable of producing 170,000 pounds of steam per hour at 850 psig and 825°F. The electric power capacity of the turbogenerators is 55 megawatts; the Baltimore Gas and Electric Company is the primary customer.

Each incinerator has an ESP to control particulate emissions. ESP emissions are routed to a common stack. The ash handling system for both the incinerator and ESP is the vibrating fan conveyor type. Ash from each system is transferred to a common ash pit for separation of ferrous and aggregate materials. After separation, the ash is transported to a landfill.

* Prepared by Midwest Research Institute.

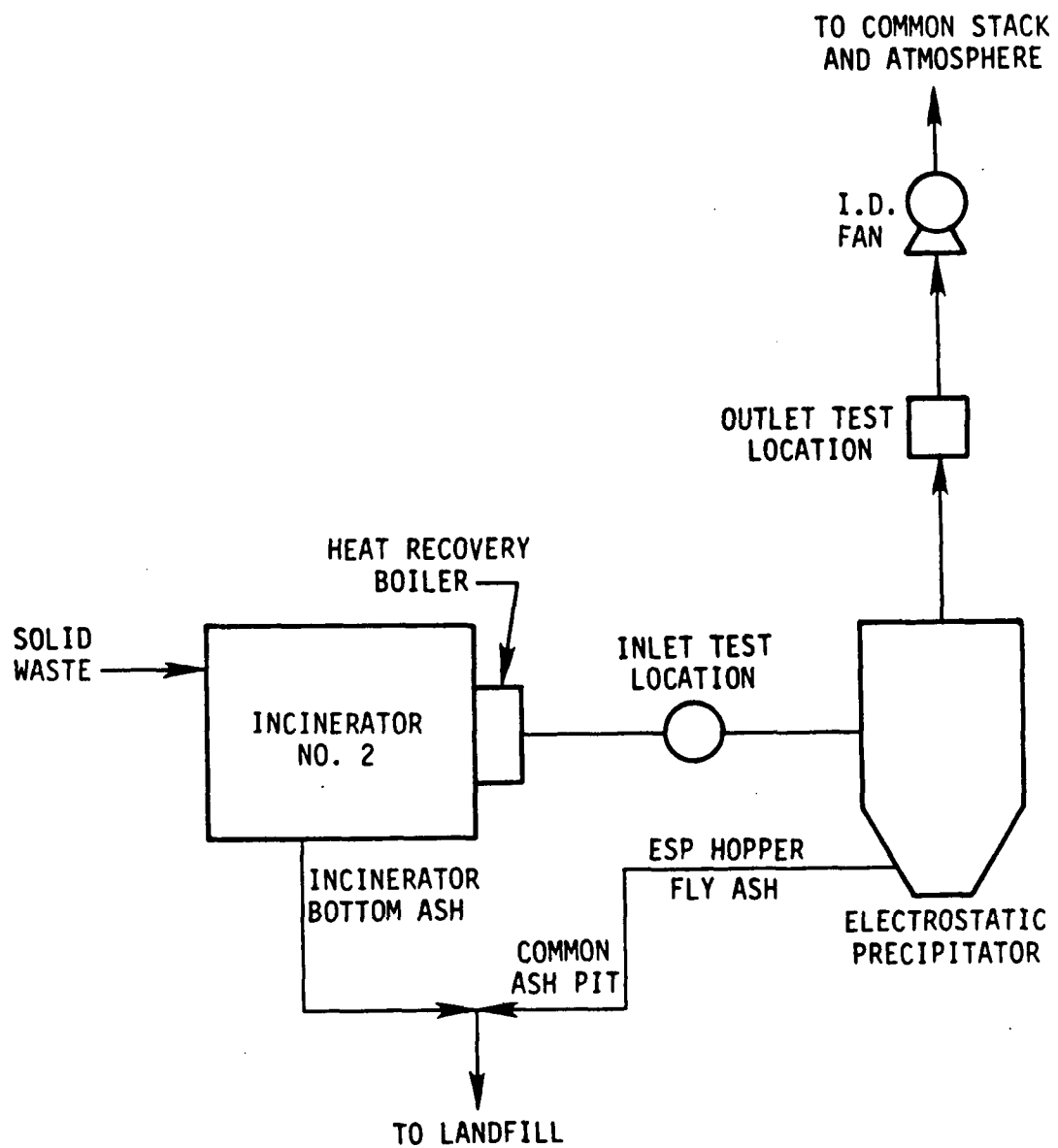


Figure 5-1. No. 2 incinerator exhaust gas flow schematic.