

Air



# Chromium Screening Study Test Report

Municipal Incinerator  
Tuscaloosa,  
Alabama

EMISSION TEST REPORT  
METHOD DEVELOPMENT AND TESTING  
FOR CHROMIUM  
Municipal Refuse Incinerator  
Tuscaloosa Energy Recovery  
Tuscaloosa, Alabama

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by

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Mr. Dennis Holzschuh, Emission Measurement Branch (EMB) Task Manager, provided overall project coordination and guidance and observed the test program. Mr. Ron Myers, Industrial Studies Branch (ISB) project engineer and Mr. Steve Schliesser, representing Midwest Research Institute (MRI) (an EPA contractor), monitored process operation throughout the test period. Mr. Charles Bruffey was the PEI Project Manager. Principal authors were Messrs. Charles Bruffey, David Osterhout, and Thomas Wagner.



## 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 Consumat Municipal Refuse Incinerators operated by Tuscaloosa Energy Recovery in Tuscaloosa, Alabama. All testing took place during the period of May 21 through 23, 1985.

Triplicate tests were conducted simultaneously at the inlet and outlet of an electrostatic precipitator (ESP) used to control particulate emissions from the combined gas streams of four modular incinerators to determine the concentrations and mass emission rates of particulate matter, hexavalent chromium ( $\text{Cr}^{+6}$ ), and total chromium (Cr). In addition, particle size distribution tests were conducted during the particulate/chromium tests at each

location, and process samples (ESP hopper ash) were collected during each test day and analyzed for  $\text{Cr}^{+6}$  and total chromium. EPA representatives obtained opacity (visible emission) data during each particulate/chromium test and also collected samples for determination of nitrogen oxides ( $\text{NO}_x$ ) concentration.

Prior to the commencement of the particulate/chromium tests, a single test was conducted simultaneously at each location to determine the concentration 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 describes the draft test method for hexavalent chromium from stationary sources; and Appendix I presents the draft protocol for determining total chromium emissions from stationary sources.

It should be noted that the U.S. EPA performed the total chromium analysis of selected samples by neutron activation analysis (NAA). These data are included in Section 2 of this report.

## 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<sup>+6</sup>, 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 techniques.

A total of six samples (three inlet and three outlet) were collected for determination of particulate, Cr<sup>+6</sup>, and total Cr concentrations. Method 5 analytical procedures were followed for the particulate analysis, and procedures recently developed by EPA for determination of Cr<sup>+6</sup> content in source emission samples were used for the Cr<sup>+6</sup> analysis. These latter procedures

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

TABLE 2-1. SAMPLE AND ANALYTICAL PARAMETERS

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 <sup>+6</sup>	Total Cr	Arsenic Method 108	Partic- ulate Method 5	Particle size dis- tribution	Cr <sup>+6</sup>	Total Cr	Arsenic Method 108
PCI-1	5/21 - 1247-1823	Particulate Cr <sup>+6</sup> Total Cr	Inlet	X	-	X	X	-	X	-	X	X	-
PCO-1	5/21 - 1246-1735		Outlet	X	-	X	X	-	X	-	-	X	-
PCI-2	5/22 - 1254-1602		Inlet	X	-	X	X	-	X	-	X	X	-
PCO-2	5/22 - 0910-1520		Outlet	X	-	X	X	-	X	-	-	X	-
PCI-3	5/23 - 0841-1427	Particle size distribution	Inlet	X	-	X	X	-	X	-	X	X	-
PCO-3	5/23 - 0846-1140		Outlet	X	-	X	X	-	X	-	-	X	-
PSO-1	5/21 - 1530-1730		Outlet	-	X	-	-	-	-	X	-	-	-
PSI-2	5/22 - 1238-1438		Inlet	-	X	-	-	-	-	X	-	-	-
PSO-2	5/22 - 1208-1508	Arsenic	Outlet	-	X	-	-	-	-	X	-	-	-
PSI-3	5/23 - 1158-1359		Inlet	-	X	-	-	-	-	X	-	-	-
PSO-3	5/23 - 1040-1340		Outlet	-	X	-	-	-	-	X	-	X	-
PSI-4	5/23 - 1512-1642		Inlet	-	X	-	-	-	-	X	-	X	-
AI-1	5/21 - 0836-1127	Process samples ESP hopper ash	Inlet	-	-	-	-	X	-	-	-	-	X
AO-1	5/21 - 0836-1128		Outlet	-	-	-	-	X	-	-	-	-	X
PCI(1-3)	5/21-23												
PCO(1-3)													
AI-1													
AO-1				-	-	-	-	-	-	-	X	X	-

entail extraction of the sample fractions (probe residue and filter particulate) with an alkaline solution followed by the diphenylcarbazide colorimetric method.\* Samples of ESP hopper ash collected during each day of testing were also analyzed for  $\text{Cr}^{+6}$  using this same basic analytical technique.

Particle size distribution measurements were made at each site during the particulate/ $\text{Cr}^{+6}$  tests with an Andersen Mark III in-stack impactor. Four samples were collected at the ESP inlet and three were collected at the ESP outlet. Particle size fractions were analyzed gravimetrically, and size distribution curves were developed for each site.

Prior to the particulate/ $\text{Cr}^{+6}$  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 2 hours at each location by isokinetic, cross-sectional traverse techniques. Total arsenic content was then determined by atomic absorption (AA) analysis.

As indicated in Table 2-1, the selected emission and process samples were analyzed for total chromium (Cr). This analysis was performed by the U.S. EPA using NAA.

The following subsections detail the results of the sampling program.

## 2.2 PARTICULATE, HEXAVALENT CHROMIUM, AND ARSENIC TEST RESULTS

Simultaneous Method 5\* tests were conducted at the ESP inlet and outlet test locations. Samples from both sites were analyzed for particulate and inlet samples were analyzed for  $\text{Cr}^{+6}$  concentrations, and the resulting data

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

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

were used to characterize the removal efficiency across the baghouse. 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.

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

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

Filterable particulate concentrations are expressed in milligrams per dry normal cubic meter ( $\text{mg}/\text{dNm}^3$ ) and grains per dry standard cubic foot ( $\text{gr}/\text{dscf}$ ). Filterable particulate represents that material collected in the sample probe and on the sample filter, which were both maintained at approximately  $121^\circ\text{C}$  ( $250^\circ\text{F}$ ). 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.

As reported in Table 2-2, sample volumes were fairly consistent, ranging from 1.65 to 2.41  $\text{dNm}^3$  for the inlet trains and from 4.14 to 5.82  $\text{dNm}^3$  for the outlet trains. Sampling times varied from the desired time of 300 minutes for a variety of reasons. Test Runs PCI-1 and PCO-1 were abbreviated to 243 and 226.6 minutes, respectively, due to adverse weather conditions. As a result, complete cross-sectional traverses were not completed at either location. Three of twenty total points at the inlet and four of twenty

TABLE 2-2. SUMMARY OF SAMPLE AND FLUE GAS DATA FOR PARTICULATE/Cr<sup>+6</sup> AND ARSENIC TESTS

Run No.	Date (1985)	Sampling duration, min	Sample volume		Isokinetic sampling rate, %	Volumetric flow rate <sup>a</sup>				Temperature		Moisture content, %	Gas composition <sup>b</sup> %		Gas velocity <sup>c</sup>		Static pressure, in.H <sub>2</sub> O
						Actual		Standard									
			dNm <sup>3</sup>	dscf		m <sup>3</sup> /min	acfm	dNm <sup>3</sup> /min	dscfm	°C	°F		O <sub>2</sub>	CO <sub>2</sub>	mps	fps	
PCI-1	5/21	243	1.654	58.409	104.9	2152	76,000	915	32,300	306	583	15.6	9.2	9.0	14.1	46.1	-2.4
PCO-1	5/21	226.6	4.141	146.217	96.4	2685	94,800	1204	42,500	279	534	15.7	10.5	7.5	22.1	72.4	-0.60
PCI-2A	5/22	150	2.204	77.840	99.2	2498	88,200	1065	37,600	326	619	12.4	10.8	8.6	16.3	53.5	-2.4
PCO-2	5/22	300	5.822	205.594	97.0	2772	97,900	1270	44,900	287	549	- <sup>d</sup>	11.8	6.6	22.8	74.8	-0.60
PCI-3	5/23	300	2.413	85.217	100.4	2557	90,300	1085	38,300	336	637	11.6	10.9	8.6	16.7	54.7	-2.4
PCO-3	5/23	150	4.750	167.715	96.3	3050	107,700	1325	46,800	313	595	13.2	11.7	7.0	25.1	82.3	-0.60
PCI (Inlet) average			2.090	73.822	101.5	2402	84,800	1022	36,100	323	613	13.2	10.3	8.7	15.7	51.4	-2.4
PCO (Outlet) average			4.904	173.175	96.3	2834	100,100	1271	44,900	293	559	13.4	11.3	7.0	23.3	76.4	-0.60
AI-1 (Arsenic)	5/21	120	1.728	61.013	103.7	2300	81,200	997	35,200	297	567	15.4	9.2	9.0	15.0	49.2	-2.4
AO-1	5/21	120	2.233	78.856	97.8	2642	93,300	1209	42,700	273	524	14.9	10.5	7.5	21.7	71.2	-0.60

<sup>a</sup>Standard conditions: 20°C (68°F), 760 mmHg (29.94 in.Hg) and zero percent moisture.

<sup>b</sup>Gas composition as determined from integrated bag samples collected during each test. Analysis performed with an Orsat gas analyzer.

<sup>c</sup>Measured flue gas velocity in meters per second and feet per second.

<sup>d</sup>Moisture not determined; broken silica gel impinger. Inlet value used in calculations.

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

Run No.	Date (1985)	Filterable concentration <sup>a</sup>							Mass emission rate				Collection efficiency, % Particulate      Cr <sup>+6</sup>		Particulate concentration <sup>c</sup> in gr/dscf corrected to 12% CO <sub>2</sub>
		Total filterable weight, mg	Particulate		Cr <sup>+6</sup> (blank corrected)			Particulate		Cr <sup>+6</sup>					
					ug/g	Total Cr <sup>+6</sup> in sample, ug	ug/dNm <sup>3</sup>								
			mg/dNm <sup>3</sup>	gr/dscf				kg/h	lb/h	kg/h	lb/h				
PCI-1	5/21	297.1	179.6	0.078				<1.7 <sup>d</sup>	<0.4	<0.24	9.9	21.7	<0.013	<0.029	49
PCO-1	5/21	314.9	76.0	0.033	-	-	-	5.5	12.1	-	-	0.053			
PCI-2	5/22	264.9	120.1	0.052	<1.7 <sup>d</sup>	<0.4	<0.18	7.7	16.9	<0.012	<0.025	3	-	0.073	
PCO-2	5/22	520.0	89.2	0.039	-	-	-	6.8	15.0	-	-			0.071	
PCI-3	5/23	323.3	133.9	0.058	<1.7	<0.4	<0.17	8.7	19.2	<0.011	<0.024	23	-	0.081	
PCO-3	5/23	397.1	83.5	0.036	-	-	-	6.7	14.7	-	-			0.062	

<sup>a</sup>Standard conditions: 20°C (68°F), 760 mmHg (29.94 in.Hg) and zero percent moisture.

<sup>b</sup>Collection efficiency:  $\frac{\text{Inlet concentration} - \text{Outlet concentration}}{\text{Inlet concentration}} \times 100$  based on inlet and outlet concentrations corrected to 12% CO<sub>2</sub>.

<sup>c</sup>Correction factor:

$$C_{12} = \frac{12C}{\%CO_2}$$

where  $C_{12}$  = concentration corrected to 12% CO<sub>2</sub>

C = concentration measured by Method 5

%CO<sub>2</sub> = as measured by Method 3

<sup>d</sup>Note: A detection limit of 1.7 ug/g was established for these samples based on an approximate particulate weight of 0.3 grams using 50 ml total volume.



traverse points at the outlet were not sampled. Sample results were calculated using the total abbreviated test time, number of points sampled, and the metered volume.

Particulate stratification, which could cause large biases in particulate measurement as a result of an incomplete sample traverse, was not a significant factor because of the generally consistent gas flow pattern at the sampling locations and the size of the particles (see Subsection 2.3). Although the results from these runs could be suspect, the overall data comparability would suggest the particulate results are representative of source conditions. Between-run data variability is primarily a process and control equipment related phenomenon (see Section 5).

Run PCI-2 was found to have an excessive leak rate at the port change and was therefore repeated, but at a higher sampling rate and for 150 minutes.

Generally, the inlet sampling rates were kept lower than those at the outlet in order to prevent the filter from plugging. A cyclone was used during Run PCI-1; however, no loose particulate was collected and it was eliminated for subsequent tests.

Isokinetic sampling rates ranged between 99 and 105 percent for the inlet tests and between 96 and 97 percent for the outlet tests, all of which are within the acceptable range of 90 to 110 percent.

Volumetric gas flow rates at the ESP inlet ranged from 2152 to 2557 m<sup>3</sup>/min (76,000 to 90,300 acfm) and averaged 2402 m<sup>3</sup>/min (84,800 acfm) for the three particulate/Cr<sup>+6</sup> tests. The average volumetric flow at standard conditions was 1022 dNm<sup>3</sup>/min (36,100 dscfm). Flue gas temperatures ranged from 306° to 336°C (583° to 637°F) and averaged 323°C (613°F). The moisture

content of the gas stream averaged 13.2 percent, and the average oxygen ( $O_2$ ) and carbon dioxide ( $CO_2$ ) contents were 10.3 and 8.7 percent, respectively.

Arsenic sample and flue gas data reported in Table 2-2 are comparable to data associated with the particulate/ $Cr^{+6}$  tests.

As shown in Table 2-3, inlet particulate concentrations ranged from 120.1 to 179.6 mg/dNm<sup>3</sup> (0.052 to 0.078 gr/dscf) and averaged 144.5 mg/dNm<sup>3</sup> (0.063 gr/dscf). The average mass emission rate for the three tests was 8.8 kg/h (19.3 lb/h).

The inlet hexavalent chromium concentration was less than 1.7  $\mu$ g/g, which was determined to be the analytical detection limit for these samples. The total quantity of  $Cr^{+6}$  per sample was less than 0.4  $\mu$ g.

At the ESP outlet, volumetric gas flow rates ranged from 2685 to 3050 m<sup>3</sup>/min (94,800 to 107,700 acfm) and averaged 2834 m<sup>3</sup>/min (100,100 acfm). The average gas flow rate at standard conditions was 1271 dNm<sup>3</sup>/min (44,900 dscfm). Flue gas temperatures ranged from 279° to 313°C (534° to 595°F) and averaged 293°C (559°F). The moisture content of the gas stream averaged 13.4 percent, and the average  $O_2$  and  $CO_2$  contents were 11.3 and 7.0 percent, respectively.

Outlet particulate concentrations ranged between 76.0 and 89.2 mg/dNm<sup>3</sup> (0.033 and 0.039 gr/dscf) and averaged 82.9 mg/dNm<sup>3</sup> (0.036 gr/dscf). The average mass emission rate for the three tests was 6.3 kg/h (13.9 lb/h). The outlet particulate concentrations corrected to 12 percent  $CO_2$  averaged 0.062 gr/dscf. Based on the inlet  $Cr^{+6}$  analytical results, no attempt was made to analyze the outlet samples for  $Cr^{+6}$ .

The particulate removal efficiency of the ESP was 49 percent for Test 1, 3 percent for Test 2, and 23 percent for Test 3 and averaged 25 percent based on the average inlet and outlet particulate concentrations corrected to 12 percent  $CO_2$ .

Two major problems were encountered during the particulate/Cr<sup>+6</sup> tests. First, a thunderstorm forced the abbreviation of Run 1 after about four hours. Second, during Run 2 at the inlet, an excessive leak rate was found during the port change. The inlet run was voided and repeated. The repeat test was conducted at a higher sampling rate and for half of the scheduled time of 5 hours.

An analysis of the hexavalent chromium content of the ESP hopper fly ash obtained during the April 1985 pretest survey indicated Cr<sup>+6</sup> levels at or below the analytical detection limit for solid samples, or 0.1 µg/g.

Because the concentration of hexavalent chromium in these solid samples was 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. Therefore, solid samples are desirable at these levels since there is no need to cut the sample filter and blank-correct for background Cr<sup>+6</sup> levels. Filters and/or thimbles require larger amounts of extraction solution to cover the volume of material being extracted. This physical requirement increases the analytical detection limit, as evidenced by the 1.7-µg/g detection limit established by analysis of the ESP inlet samples. No loose particulate was collected and the inlet filters were extracted as described in the analytical method.

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

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\* U.S. EPA SW846, 2nd ed., July 1982.

The inlet sample showed a total arsenic weight of 153.8  $\mu\text{g}$  or 89.0  $\mu\text{g/dNm}^3$  compared with 60.0  $\mu\text{g}$  (27.1  $\mu\text{g/dNm}^3$ ) for the outlet sample. This single test indicated an arsenic collection efficiency of more than 69.5 percent.

TABLE 2-4. SUMMARY OF ARSENIC EMISSIONS DATA

Run No.	Concentration					
	Date (1985)	Sampling location	Total arsenic sample weight, $\mu\text{g}$	$\mu\text{g/dNm}^3$	$\text{mg/dNm}^3$	Arsenic collection efficiency, %
AI-1	5/21	Inlet	153.8	89.0	0.089	$\approx 69$
AO-1	5/21	Outlet	60.9	27.3	0.027	

### 2.3 PARTICLE SIZE DISTRIBUTION TEST RESULTS

At each site an Andersen Mark III impactor was used to measure particle size distribution during each particulate/ $\text{Cr}^{+6}$  test. This in-stack impactor consists of eight glass fiber filter impaction stages followed by a glass fiber backup filter. A total of three samples were collected at a single point of average velocity and temperature in each duct. Test times ranged from 90 to 120 minutes at the inlet and 120 to 180 minutes at the outlet. An initial test was conducted at the inlet using an Andersen HGLI, but the results were voided due to insufficient particulate collection.

Each particle size test was conducted according to the procedures described in the Mark III 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. This criterion was

met in test each. Isokinetic sampling rates ranged from 82 to 96 percent for the inlet tests and 82 to 103 percent for the outlet tests.

Cumulative size distribution data points representing the total weight of particulate matter smaller than the indicated aerodynamic particle diameter [in micrometers ( $\mu\text{m}$ )] were established for each test location. The cut-points for each test 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  $1 \text{ g/cm}^3$ . Data reduction for the particle size runs was performed by computer programming with moisture, molecular weight, and temperature data obtained from the particulate/ $\text{Cr}^{+6}$  tests. The Mark III data reduction calculations are presented in Appendix A of this report.

Figures 2-1 and 2-2 present the size distribution plot 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.

Generally, the particle size distribution results indicate that most of the particulate is less than  $2.5 \mu\text{m}$  at both the inlet and outlet sites and that the size distributions at both sites are very similar.

For the three inlet runs (PSI-2 through -4), the size distribution curve showed that about 89 percent by weight of the particles had a nominal diameter of  $1.0 \mu\text{m}$  or less. The calculated average particulate concentration for these runs was  $166.6 \text{ mg/dNm}^3$  ( $0.073 \text{ gr/dscf}$ ) compared with a three-test Method 5 average of  $144.5 \text{ mg/dNm}^3$  ( $0.063 \text{ gr/dscf}$ ). This indicates about a 13

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

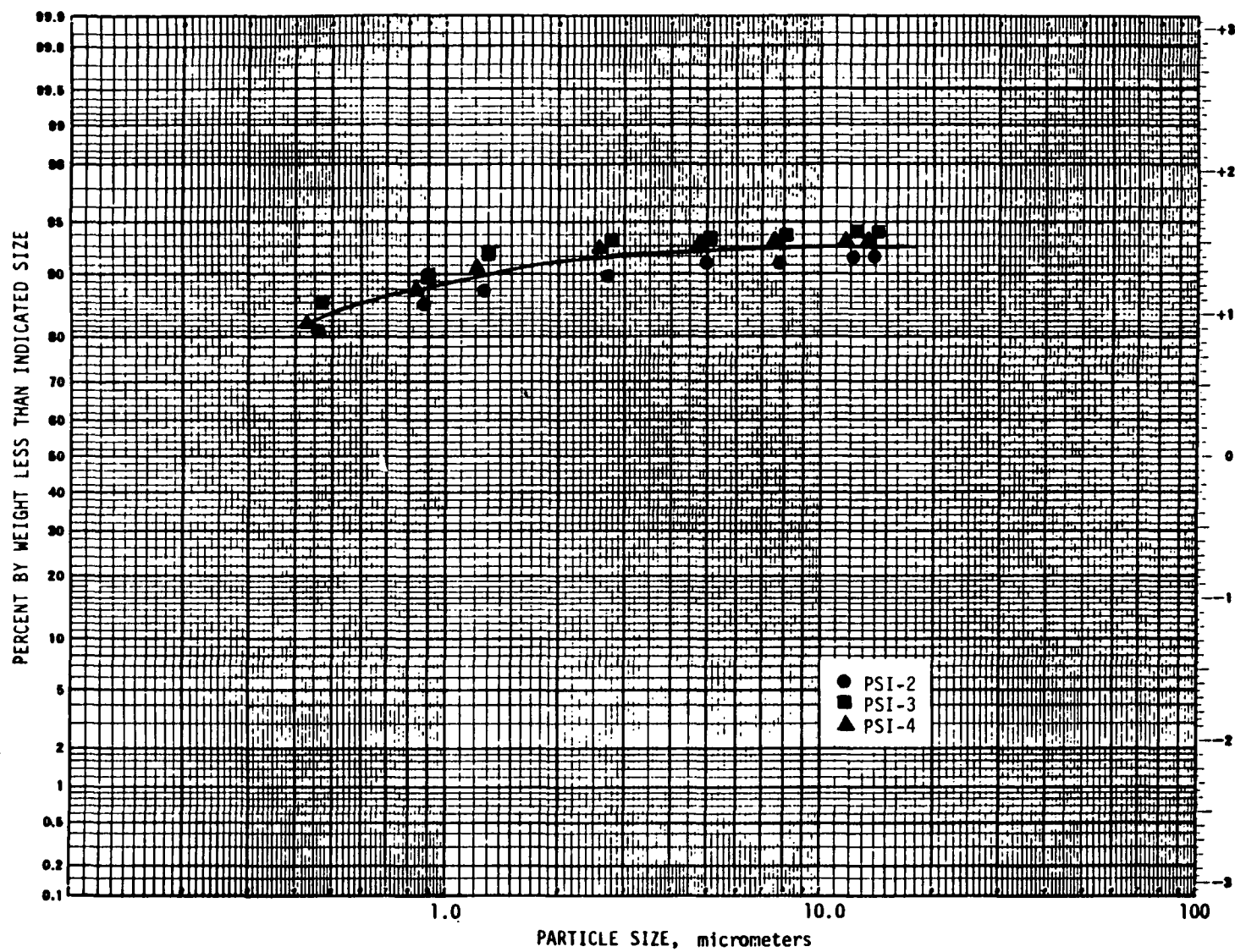


Figure 2-1. Particle size distribution tests PSI-2, -3, and -4 at the ESP inlet.

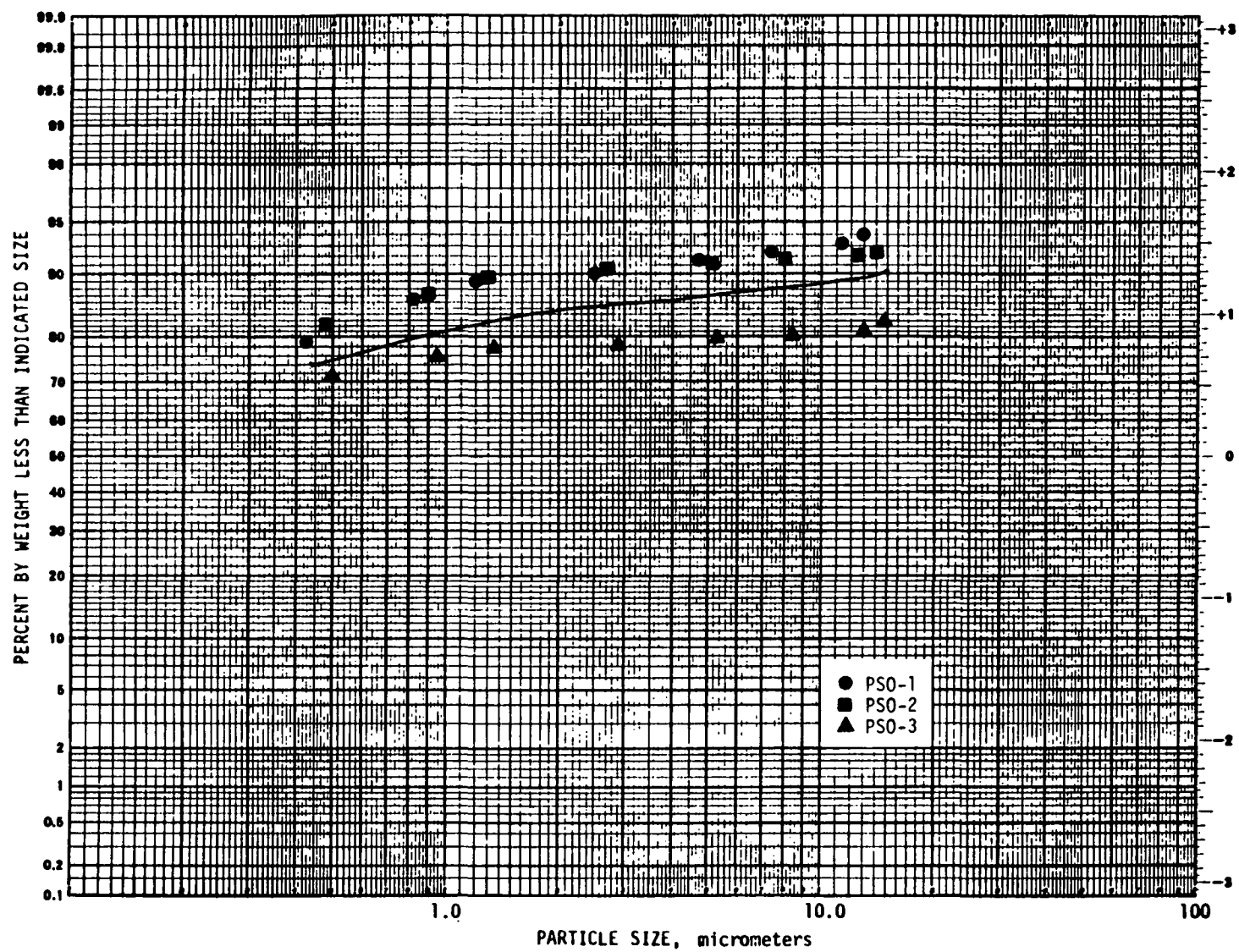


Figure 2-2. Particle size distribution tests PS0-1, -2, and -3 at the ESP outlet.

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 <sup>3</sup>	gr/dscf
PCI-1	ESP inlet	Method 5 - Particulate	179.6	0.078
PSI-2		Particle size - Mark III	125.8	0.055
PCI-2		Method 5 - Particulate	120.1	0.052
PSI-3		Particle size - Mark III	164.1	0.072
PCI-3		Method 5 - Particulate	133.9	0.058
PSI-4		Particle size - Mark III	209.8	0.092
PSO-1		Particle size - Mark III	66.6	0.029
PCO-1		Method 5 - Particulate	76.0	0.033
PSO-2		Particle size - Mark III	85.3	0.037
PCO-2		Method 5 - Particulate	89.2	0.039
PSO-3	ESP outlet	Particle size - Mark III	92.4	0.040
PCO-3		Method 5 - Particulate	83.5	0.036



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 size distribution curves for the first two outlet tests (PS0-1 and -2) showed that about 87 percent by weight of the particles had a nominal diameter of 1.0  $\mu\text{m}$  or less. The third outlet test varied somewhat from the first two tests. The size distribution curve for the third test (PS0-3) showed that about 76 percent by weight of the particles had a nominal diameter of 1.0  $\mu\text{m}$  or less.

The average calculated particulate concentration for these runs was 81.4  $\text{mg/dNm}^3$  (0.035  $\text{gr/dscf}$ ) compared with a three-test Method 5 average of 82.9  $\text{mg/dNm}^3$  (0.036  $\text{gr/dscf}$ ). This indicates about a 2 percent difference between the two measurements.

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

The data are also consistent with general incinerator operation. The primary chamber of the incinerator operates in a substoichiometric condition where refuse loaded into the chamber is partially oxidized. Combustible gases and particulate generated in the primary chamber flow into the secondary chamber where combustion is completed under excess air conditions at

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

temperatures of approximately 1150°C (2100°F). Under normal conditions, only very fine particulate and condensible gases would be expected to pass from the secondary chamber. The similarity of inlet and outlet size distribution data is a function of the ESP used to control emissions. Most of the fine particulate (<2.5 µm) passes through the control device.

No attempt was made to characterize Cr<sup>+6</sup> size distribution due to the low particulate concentrations at both sampling locations and the nondetectable levels of Cr<sup>+6</sup> in the inlet samples.

#### 2.4 PROCESS SAMPLE ANALYTICAL RESULTS

Table 2-6 summarizes Cr<sup>+6</sup> analytical results from the ESP hopper samples collected during each day of testing. Grab samples were collected periodically during the testing period. Samples were composited into a single, representative sample for each day of testing. Weighed portions of each sample type were then extracted and analyzed for Cr<sup>+6</sup> by procedures similar to those used in analyzing the emission test samples.

TABLE 2-6. PROCESS SAMPLE ANALYTICAL RESULTS

Sample type	Laboratory ID	Particulate weight analyzed, g	Total Cr <sup>+6</sup> , µg	Cr <sup>+6</sup> concentration, µg/g
ESP fly ash				
5/21	EL566	10.0079	2.81	0.28
5/22	EL567	10.0540	1.13	0.11
5/23	EL568 <sup>a</sup>	10.0068	1.43	0.14
		10.0136	1.28	0.13

<sup>a</sup>Duplicate analyses.

Note: Detection limit = 0.1 µg/g.

The average total  $\text{Cr}^{+6}$  content of the ESP hopper ash samples was 1.8  $\mu\text{g}$ , and concentrations ranged between 0.11 and 0.28  $\mu\text{g/g}$ . These levels are essentially at the analytical detection limit.

## 2.5 VISIBLE EMISSION OBSERVATIONS

Unofficial visible emission observations were made by an EPA representative during each particulate/ $\text{Cr}^{+6}$  test. Opacity readings were generally less than 5 percent with brief excursions to 10 and 20 percent during the second day of testing. These excursions correlated to ESP operational problems as noted by the calculated collection efficiency of 3 percent for the second test day. Raw data sheets are contained in Appendix B of this report.

## 2.6 NITROGEN OXIDE TEST RESULTS

Nitrogen oxide ( $\text{NO}_x$ ) testing was conducted by EMB personnel during the particulate/ $\text{Cr}^{+6}$  testing. Sample collection and analysis procedures followed those described in EPA Reference Method 7.\* These data are summarized in Table 2-7. Nitrogen oxide concentrations ranged from 90 to 217 ppm and averaged 162 ppm during the test series.

TABLE 2-7. NITROGEN OXIDE EMISSIONS DATA

$\text{NO}_x$ Run No.	Particulate/ $\text{Cr}^{+6}$ Run No.	Date (1985)	Concentration, ppm <sup>a</sup>		
			High	Low	Average
TMI-1 through -8	PCI-1, PCO-1	5/21	217	162	188
TMI-9, -14 <sup>b</sup> and TMI-16 through -18	PCI-2, PCO-2	5/22	178	90	145
TMI-19 through -29	PCI-3, PCO-3	5/23	178	137	154

<sup>a</sup>Data as reported by U.S. EPA.

<sup>b</sup>Run No. TMI-15 was not detectable and was therefore deemed invalid.

\*40 CFR 60, Appendix A, Reference Method 7, July 1984.<sup>2</sup>

## 2.7 HI-VOLUME SAMPLE

As instructed by EPA, PEI attempted to collect sufficiently large quantities of particulate at the ESP outlet so that  $\text{Cr}^{+6}$  and other metals of interest could be quantified. A hi-volume ambient air sample pump and filter were used as shown in Figure 2-3. A single sample run was attempted during the last test day. However, the pump motor overheated about 3½ hours into the test and sampling was terminated.

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

## 2.8 TOTAL CHROMIUM TEST RESULTS

Table 2-8 summarizes the total Cr content of selected emission samples analyzed by NAA. Analytical data as received from EPA are included in Appendix C of this report along with example calculations.

In summary, NAA is an analytical technique dependent on the measurement of the number and energy of gamma and X-rays emitted by the radioactive isotopes produced in the sample matrix by irradiation with thermal neutrons from a nuclear reactor. Typically, the sample matrix plus appropriate standards of the element(s) of interest are irradiated for a selected time period in the neutron flux core region of a research nuclear reactor. After irradiation and appropriate radioactive decay, a gamma-count energy spectrum is obtained by counting the sample on a nuclear detection system.

As reported in Table 2-8, inlet Method 5 samples designated PCI-1 through -3 and outlet Method 5 samples designated PCO-1 through -3 were submitted for analysis. In addition, inlet particle size Run PSI-4 and outlet particle size Run PSO-3 were submitted for analysis by individual stage cut point. Process samples (ESP hopper fly ash) were also analyzed for total Cr content.

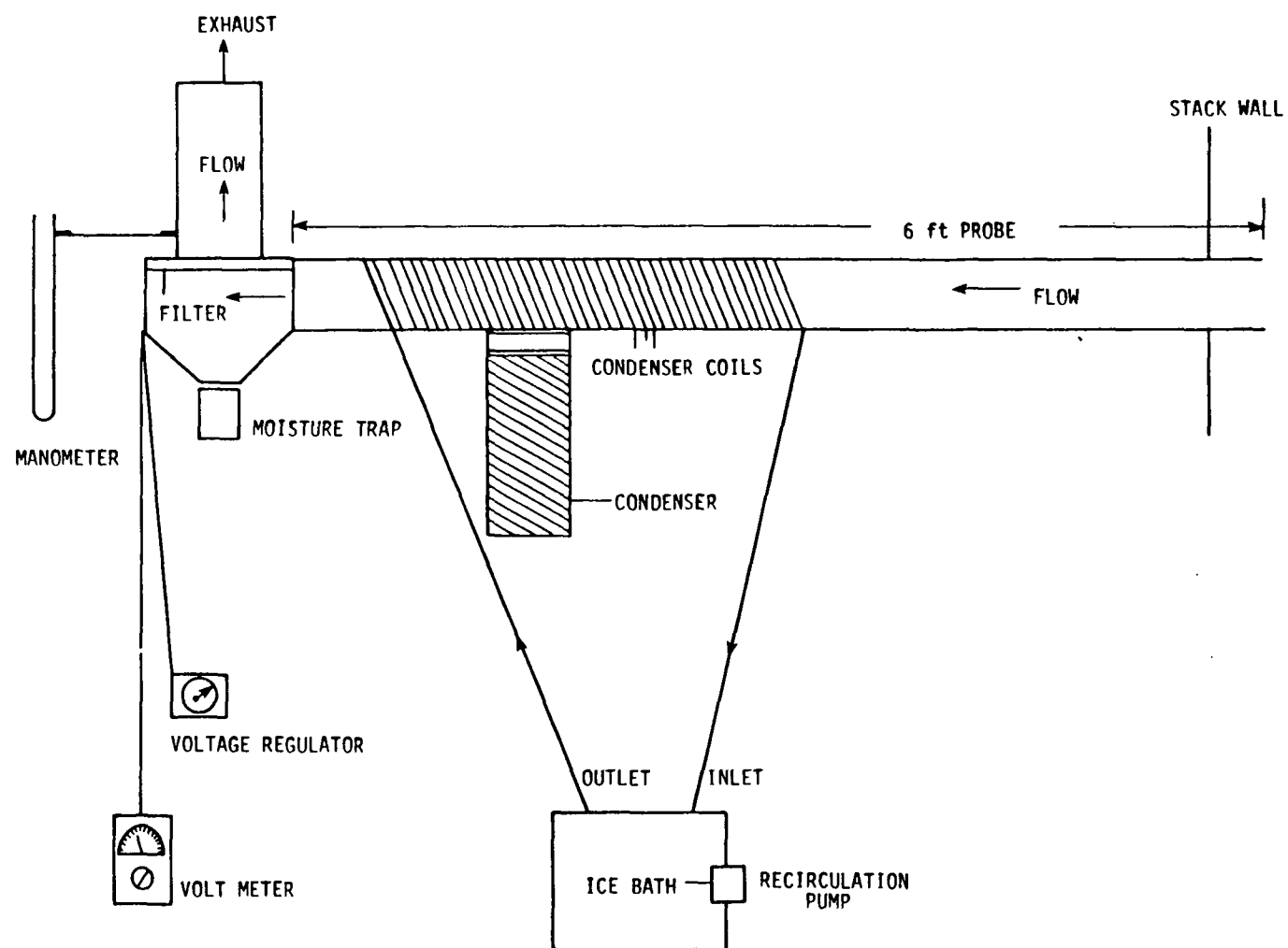


Figure 2-3. Hi-volume sampler.

TABLE 2-8. SUMMARY OF TOTAL Cr EMISSION DATA

Run No.	Sample type and location	Total <sup>a</sup> particulate collected, g	Particulate <sup>b</sup> sample weight analyzed by NAA, g	Total Cr <sup>c</sup> results by NAA, ug	Total Cr <sup>d</sup> concentration by NAA, ug/g	Total Cr <sup>e</sup> content of sample, ug	Total Cr concentration, ug/dNm <sup>3</sup>	Total Cr mass emission rate, kg/h
PCI-1	Filterable particulate ESP inlet	0.2971	0.2971	52.1	175.4	52.1	31.5	0.0017
PCI-2	Filterable particulate ESP inlet	0.2649	0.2649	50.0	188.8	50.0	22.7	0.0015
PCI-3	Filterable particulate ESP inlet	0.3278	0.3278	67.8	206.8	67.8	28.1	0.0018
PCO-1	Filterable particulate ESP outlet	0.3149	0.3149	47.1	149.6	47.1	11.4	0.0008
PCO-2	Filterable particulate ESP outlet	0.5200	0.5200	142.9	274.8	142.9	24.5	0.0019
PCO-3	Filterable particulate ESP outlet	0.3971	0.3971	58.1	146.3	58.1	12.2	0.0010
PSI-4	Particle size ESP inlet							
	Stage 0	0.0068	0.0068	9.95	f	f	f	
	Stage 1	0.0001	0.0001	7.79	f	f	f	
	Stage 2	0.0002	0.0002	9.36	f	f	f	
	Stage 3	0.0000	0.0000	6.72	f	f	f	
	Stage 4	0.0007	0.0007	9.61	f	f	f	
	Stage 5	0.0024	0.0024	8.59	f	f	f	
	Stage 6	0.0028	0.0028	8.28	f	f	f	
	Stage 7	0.0063	0.0063	10.56	f	f	f	
PSO-3	Backup	0.0902	0.0902	14.12	f	f	f	
	Particle size ESP outlet							
	Stage 0	0.0139	0.0139	20.29	801.4	11.14	12.88	
	Stage 1	0.0011	0.0011	8.62	f	f	f	
	Stage 2	0.0009	0.0009	8.98	f	f	f	
	Stage 3	0.0006	0.0006	9.26	f	f	f	
	Stage 4	0.0009	0.0009	7.39	f	f	f	
	Stage 5	0.0007	0.0007	6.85	f	f	f	
	Stage 6	0.0014	0.0014	9.60	f	f	f	
1 2 3	ESP fly ash	-	0.1039	45.7	439.8	-	-	
	ESP fly ash	-	0.1254	89.5	713.7	-	-	
	ESP fly ash	-	0.1144	60.6	529.7	-	-	

<sup>a</sup> Total particulate (acetone rinse residue and filter) collected during sample run.

<sup>b</sup> Particulate weight analyzed by NAA.

<sup>c</sup> Total Cr results by NAA. Run Nos. PCI and PCO are blank corrected values ( $\approx 21$  ug Cr for filter/acetone blank). Particle-size data are uncorrected. ( $\approx 8$  ug Cr for filter stage blank.)

<sup>d</sup> Total Cr(C) divided by particulate weight analyzed by NAA(b).

<sup>e</sup> Total Cr concentration (ug/g) multiplied by total particulate weight collected(a).

<sup>f</sup> Assumed to be below the detection limit since sample values are less than two times the standard deviation of the blank values.

The total Cr content of the inlet samples on a  $\mu\text{g/g}$  basis ranged between 175.4 and 206.8  $\mu\text{g/g}$ . Total Cr concentrations on a  $\mu\text{g/dNm}^3$  basis ranged between 22.7 and 31.5  $\mu\text{g/dNm}^3$  with corresponding mass emission rates ranging between 0.0015 kg/h (0.0033 lb/h) and 0.0018 kg/h (0.0040 lb/h).

The total Cr content of the outlet samples on a  $\mu\text{g/g}$  basis ranged between 146.3 and 274.8  $\mu\text{g/g}$ . The total Cr concentration on a  $\mu\text{g/dNm}^3$  basis ranged between 11.4 and 24.5  $\mu\text{g/dNm}^3$  with corresponding mass emission rates of 0.0008 kg/h (0.0018 lb/h) and 0.0019 kg/h (0.0042 lb/h), respectively. All inlet and outlet total Cr data have been corrected for a filter/acetone Cr blank level of 21  $\mu\text{g}$ , which is reasonable considering the levels of Cr detected in these samples.

Total Cr in the ESP fly ash samples ranged from 439.8  $\mu\text{g/g}$  to 713.7  $\mu\text{g/g}$ . The data were determined from samples obtained during each test.

Particle size samples from each location were analyzed by individual stages in an attempt to characterize total Cr by size fraction. As reported in Table 2-8, the total Cr content of individually-loaded stages ranged from 6.7 to 14.1  $\mu\text{g}$  for the inlet sample, and 6.9 to 20.3  $\mu\text{g}$  for the outlet sample. Filter blank Cr levels ranged from 6.3 to 14  $\mu\text{g}$  and averaged about 8  $\mu\text{g}$  per filter for a set of eight filters (see Section 3). Because the filter blank levels of total Cr are similar to measured Cr values on each stage and the sample values are less than two times the standard deviation of the blank values, no reasonable conclusions can be drawn regarding total Cr size distribution. The uncorrected data reported in Table 2-8 indicate that some Cr is present in the sample fractions of Stage 7 and the backup filter, which represent particle sizes of less than 2  $\mu\text{m}$ .

### 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: the EPA Quality Assurance Handbook Volume II, EPA-600/4-77-0271; the PEI Emission Test Quality Assurance Plan; the PEI Laboratory Quality Assurance Plan; Determination of Hexavalent Chromium Emissions From Stationary Sources, December 13, 1984; and 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 ESP hopper catch was obtained during the April pretest survey and analyzed for  $\text{Cr}^{+6}$  content. These data were used to define sampling times and rates so that a quantifiable level of  $\text{Cr}^{+6}$  could be 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<sup>+6</sup>, particle size distribution, and arsenic tests as well as the calibration guidelines and limits. In addition to the pre- and post-test calibrations, field audits were 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 two separate batches. Table 3-3 summarizes the linear regression data of the spectrophotometer calibration for the two days.

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	$\Delta H @ \pm 0.15$ (Y $\pm 0.5\%$ Y post-test)	$\Delta H@: -0.02; Y: -0.007\%$ $\Delta H@: -0.06; Y: -0.010\%$ $\Delta H@: -0.04; Y: -0.014\%$ $\Delta H@: 0.0; Y: -0.017\%$	X X X X	Y = 0.029; Audit $\Delta H@$ 0.08 Y = 0.019; Audit $\Delta H@$ 0.01 Y = 0.014; Audit $\Delta H@$ 0.01 Not performed (Field audit results)
Pitot tube	020 516	Standard pitot tube	$C_p \pm 0.01$	- -	X X	Visually inspected on site Visually inspected on site
Digital indicator	220 262	Millivolt signals	$\pm 0.5\%$	-0.4% +0.4%	X X	Field audit results: 0.2% Field audit results: 0.3%
Stack thermocouple	139 206	ASTM-3F	$\pm 1.5\%$ ( $\pm 2\%$ saturated)	+0.2% +0.3%	X X	
Orsat analyzer	141	Standard gas	$\pm 0.5\%$	-0.4% ( $CO_2$ ) 0.0% ( $O_2$ )	X X	Audit value $CO_2$ and $O_2 = 5.2\%$
Impinger thermocouple	I-1 I-5	ASTM-3F	$\pm 2^\circ F$	+1°F +1°F	X X	
Balance	Mettler No. 743985	Type S weights	$\pm 0.5$ g	0.0 g	X	
Barometer	227	NBS traceable barometer	$\pm 0.10$ in.Hg (0.20 post-test)	+0.02 in.Hg	X	
Dry gas thermometer	FB-3 FB-8 FB-11 FB-12	ASTM-3F	$\pm 5^\circ F$	In: $-2^\circ F$ ; Out: $-2^\circ F$ In: $-4^\circ F$ ; Out: $-3^\circ F$ In: $-1^\circ F$ ; Out: $-4^\circ F$ In: $-1^\circ F$ ; Out: $0^\circ F$	X X X X	
Probe nozzle	2-120  4-101 5-108 Part. size	Caliper	$D_n \pm 0.004$ in.	0.000 in. 0.000 in. 0.000 in. 0.002 in. 0.002 in. 0.001 in. 0.001 in.	X X X X X X X	Inlet Inlet Inlet Outlet Outlet Inlet Outlet

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

Sample type and filter number	Original tare weight, mg	Blank weight, mg	Blank value
Particulate - 8510139 Reeve Angel 934 AH	363.3	363.8	0.5 mg
Acetone blank <sup>a</sup>	102,545.1	102,547.1	0.013 mg/g <sup>b</sup>

<sup>a</sup>188 ml evaporated and desiccated before weighing.

<sup>b</sup>Exceeds blank value limitations (0.01 mg/g used in calculations).

TABLE 3-3. LINEAR REGRESSION DATA SPECTROPHOTOMETER CALIBRATION

Sample description	Date (1985)	Cr <sup>+6</sup> standard concentration, µg/ml	Absorb- ance <sup>a</sup>	Y-Intercept	Slope	Correlation coefficient
Process, duplicates, plus spike	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			
Inlet and blank	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	0.636			

The analytical detection limit established for the two days was less than 0.004  $\mu\text{g/ml}$  for an absorbance of 0.005 above the linear regression intercept. This detection limit corresponds to the same total micrograms of chromium VI as in previous reports. The established detection limit for the inlet particulate samples was 1.7  $\mu\text{g/g}$  because of the small amount of particulate collected on these filters.

Because the concentrations 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. Filters and thimbles require larger amounts of extraction solution to cover the volume of material being extracted. This physical requirement increased the detection limit.

The filter/acetone blank contained 0.87  $\mu\text{g}$  of  $\text{Cr}^{+6}$ . This value was used to correct the inlet particulate values. Duplicate and spike analyses were performed on the ESP fly ash sample taken on May 23, 1985. The results of the duplicate analyses were 0.14 and 0.13  $\mu\text{g/g}$ , which is just above the detection limit of 0.1  $\mu\text{g/g}$  for process samples having a large quantity of loose particulate available for analysis and requiring no reagent or filter blank correction. The spike recovery was 103 percent.

One problem was encountered with the analysis of the inlet particulate 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.

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\* U.S. EPA SW846, 2nd ed., July 1982.

Arsenic samples were analyzed on June 4, 1985. The least-squares 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 9.60  $\mu\text{g}$  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 impinger fraction for the outlet runs gave 6.22 and 5.27  $\mu\text{g}$ , respectively. Spike recoveries were 95.4, 92.1, 101.9, and 0 percent for the filter, rinse, impingers, and bomb fractions, respectively.

Table 3-4 presents QC data relative to the total Cr analysis by NAA. Duplicate, audit, and blank data are presented.

As discussed in Section 2.8, a filter/acetone Cr blank level of 21  $\mu\text{g}$  is reported. Total Cr results for the inlet and outlet particulate emission samples were corrected for blank levels since the measured Cr content ranged between two and four times the blank values. Particle size Cr data were not corrected for filter blank Cr levels since measured Cr values were less than two times the blank Cr values for the majority of the stages analyzed. This seems prudent considering the low levels of total Cr observed in the samples.

TABLE 3-4. QC DATA FOR TOTAL CHROMIUM BY NAA

Lab No.	Sample type	Results total Cr, μg (except as noted)
ESP fly ash - Run 1 EL 566	Duplicate analysis	45.7; 44.0
ESP fly ash - Run 3 EL 568	Duplicate analysis	60.6; 36.6
NB5 fly ash	Audit	201 μg (196 μg/g accepted)
Alkaline extract	Blank	Not detected
Type I H <sub>2</sub> O	Blank	Not detected
Method 5 filter/ acetone	Blank	21.0
Particle size filter - Stage 0	Blank	9.40
Particle size filter - Stage 1	Blank	7.78
Particle size filter - Stage 2	Blank	14.09
Particle size filter - Stage 3	Blank	6.67
Particle size filter - Stage 4	Blank	6.75
Particle size filter - Stage 5	Blank	5.76
Particle size filter - Stage 6	Blank	6.36
Particle size filter - Stage 7	Blank	8.11
Particles size filter - Backup	Blank	9.68

## SECTION 4

### SAMPLING LOCATIONS AND TEST PROCEDURES

This section describes the sampling sites and the test methods used to characterize particulate, chromium, and arsenic emissions.

#### 4.1 SAMPLING LOCATIONS

Flue gas samples were extracted simultaneously from the inlet duct and outlet stack of the ESP. Figures 4-1 and 4-2 show the sampling locations.

At the ESP inlet, two 10.2-cm (4-in.) i.d. sampling ports were located approximately 5.9 duct diameters downstream and 1.7 duct diameters upstream from the nearest flow disturbances in the 1.8-m (5-ft 11-in.) i.d. duct. At the ESP outlet, two 10.2-cm (4-in.) i.d. sampling ports were located approximately 5.7 stack diameters downstream and 2.1 stack diameters upstream from the nearest flow disturbances in the 1.6-m (5-ft 3½-in.) i.d. stack. 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.\*\*

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

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

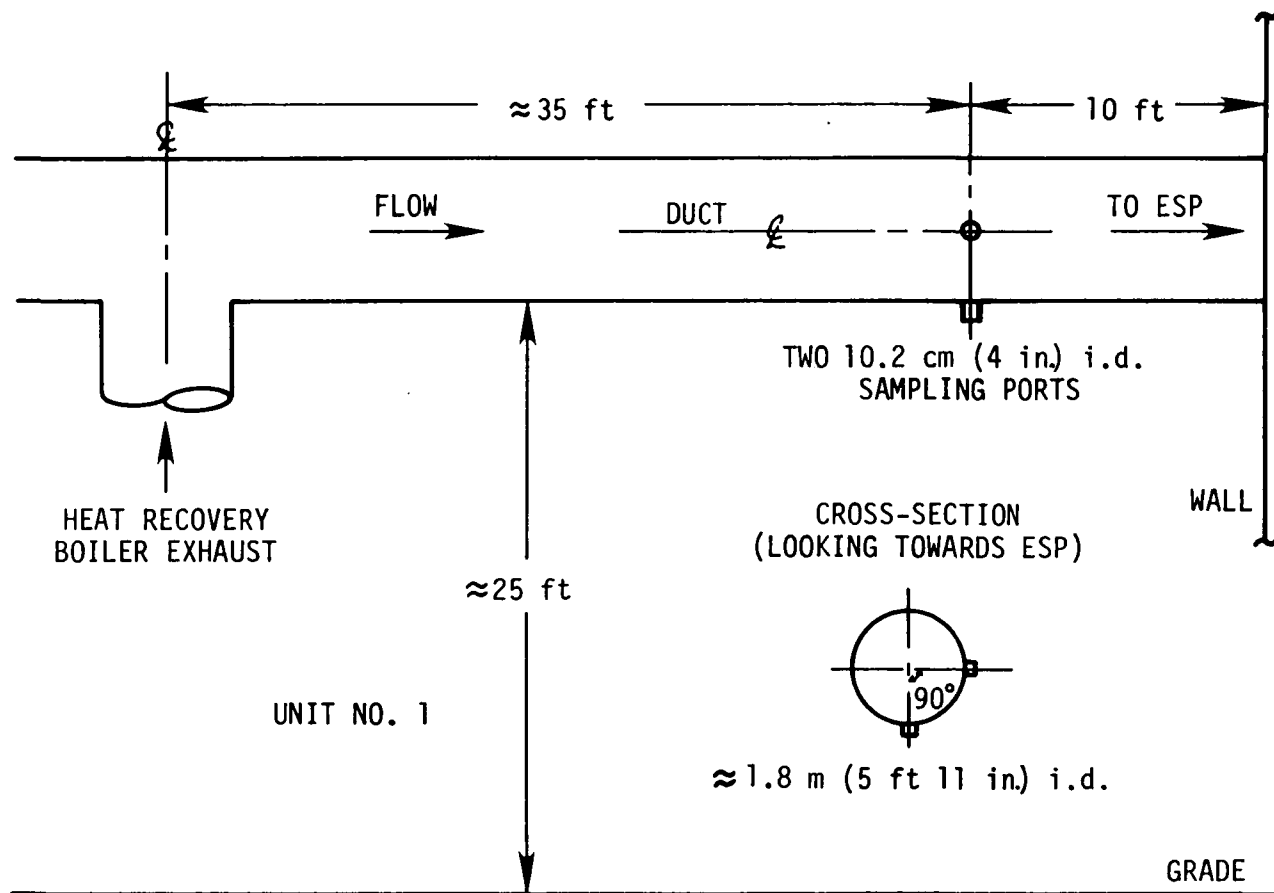


Figure 4-1. ESP inlet sampling location.



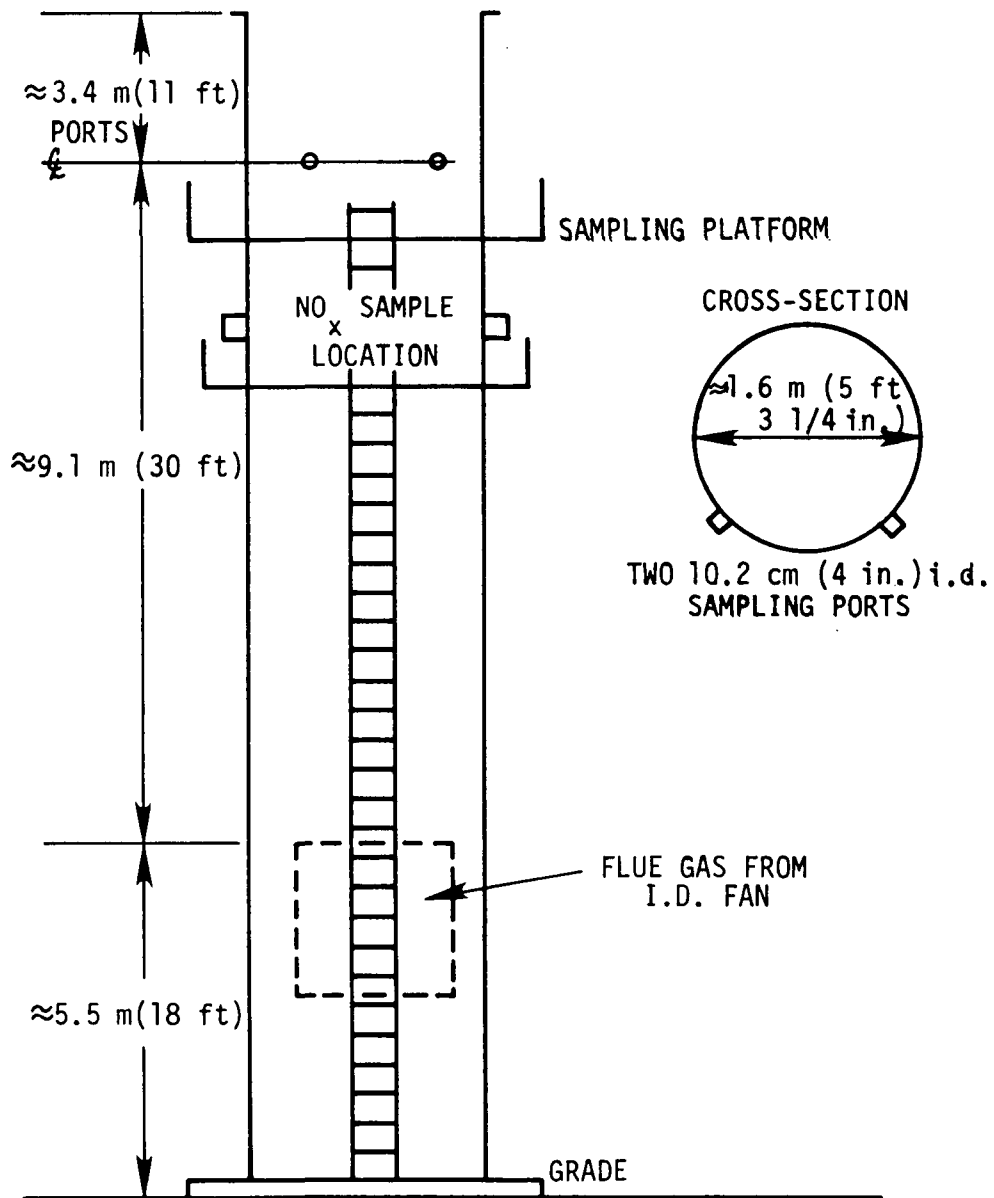


Figure 4-2. ESP outlet sampling location.

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 samples were prepared and analyzed for  $\text{Cr}^{+6}$  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  $\pm 10$  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.

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

A total of 20 sampling points were used to traverse the cross-sectional areas of the ducts. At each site, each point was to be sampled for 15 minutes, thus yielding a total test time of 300 minutes. However, the first test was abbreviated due to adverse weather, and the second inlet test was also abbreviated due to an excessive leak rate following the first half of the test. This second test (PSI-2) was run at a higher sampling rate for 150 minutes.

The testing 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 prior to the start of 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 reasonably consistent throughout the test series.

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

#### 4.2.3 Particulate/Cr<sup>+6</sup>

Samples of particulate, Cr,<sup>+6</sup> and total Cr 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<sup>+6</sup> according to procedures recently developed by EPA. In summary, the samples were digested in an alkaline solution and analyzed by the diphenylcarbazide colorimetric method.\*\* Selected samples were then shipped to EPA, where total chromium content of the samples was determined by NAA.

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\* 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. These samples are being held for further analysis if desired.

#### 4.3 PARTICLE SIZE DISTRIBUTION

Samples for particle-size distribution measurements were collected at the ESP inlet and outlet by an Andersen Mark III impactor. This in-stack impactor consists of eight cut-point stages and a backup filter. The impactor was preceded by a 15- $\mu$ m cyclone precutter. The sampled gas stream enters the system through the precutter. Particles with sufficient inertia are impacted against the sides of the cyclone. Smaller particles flow with the gas stream and exit the cyclone and into the main impactor. Then, particles with sufficient inertia are impacted on the first stage filter with smaller particles passing onto the second stage, and similarly to each succeeding stage. Finally, a glass fiber filter removes all particles remaining in the gas stream downstream of the final stage.

This type of impactor was used at both sites since the particulate concentrations were low at both sites.

Three samples were collected at the ESP inlet and outlet from single points in the ducts that represented average velocities and temperatures. At the inlet, Tests PSI-2 and -3 were run for 120 minutes, with Test PSI-4 running for 90 minutes. At the outlet, Test PSO-1 was conducted for 120 minutes, and Tests PSO-2 and -3 were conducted for 180 minutes. Isokinetic

sampling rates were set initially, and constant cut-point characteristics were maintained throughout the sampling period.

At the completion of each test, the impactor samples were recovered according to procedures described in the Mark III operations manual.

Each recovered fraction was subjected to a gravimetric analysis using EPA Method 5 procedures. 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).<sup>\*</sup> All particle size results are based on a particle density of 1 g/cm<sup>3</sup>. 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.

Samples from Runs PSI-4 and PSO-3 were analyzed for total Cr by NAA.

#### 4.4 PROCESS SAMPLES

Grab samples of ESP hopper ash were collected periodically during each particulate/chromium test. The samples from each test were composited so that one representative sample per test was available for analysis. The samples were extracted and analyzed for Cr<sup>+6</sup> in accordance with procedures

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<sup>\*</sup> 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.

similar to those used for the  $\text{Cr}^{+6}$  analysis of the particulate samples. An aliquot of each sample was also analyzed for total Cr.

#### 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.

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.

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

## SECTION 5

### PROCESS OPERATION

The following process description was prepared by Midwest Research Institute (MRI), the EPA New Source Performance Standards (NSPS) contractor. Personnel from MRI were on site during the test program to monitor and record all pertinent incinerator and ESP data.

#### 5.1 PROCESS DESCRIPTION

Tuscaloosa Energy Recovery incinerator facility consists of four modular municipal refuse incinerators manufactured by Consumat Systems, Incorporated, and installed in 1984. Each incinerator has a rated capacity of 80 Mg/day (90 tons/day) and typically operates 24 hours per day, 5 days a week. During the month preceding testing, each incinerator burned an average of 56 Mg/day (63 tons/day). Exhaust from the four incinerators is fed through two heat recovery boilers to produce 24,900 kg (55,000 lb) of steam per hour. Approximately 99 percent of the refuse incinerated is supplied by residential sources in eight nearby municipalities. The remaining 1 percent [4.5 Mg/day (5 tons/day)] consists of scrap tires from the nearby B.F. Goodrich plant that purchases the steam produced. Large metal items are manually sorted from the refuse prior to incineration.

Figure 5-1 shows a cross section of a typical modular incinerator consisting of a primary and a secondary chamber. During startup, natural gas is introduced via one burner in each chamber. Refuse is loaded into the primary chamber and is partially oxidized under starved air, or substoichiometric,



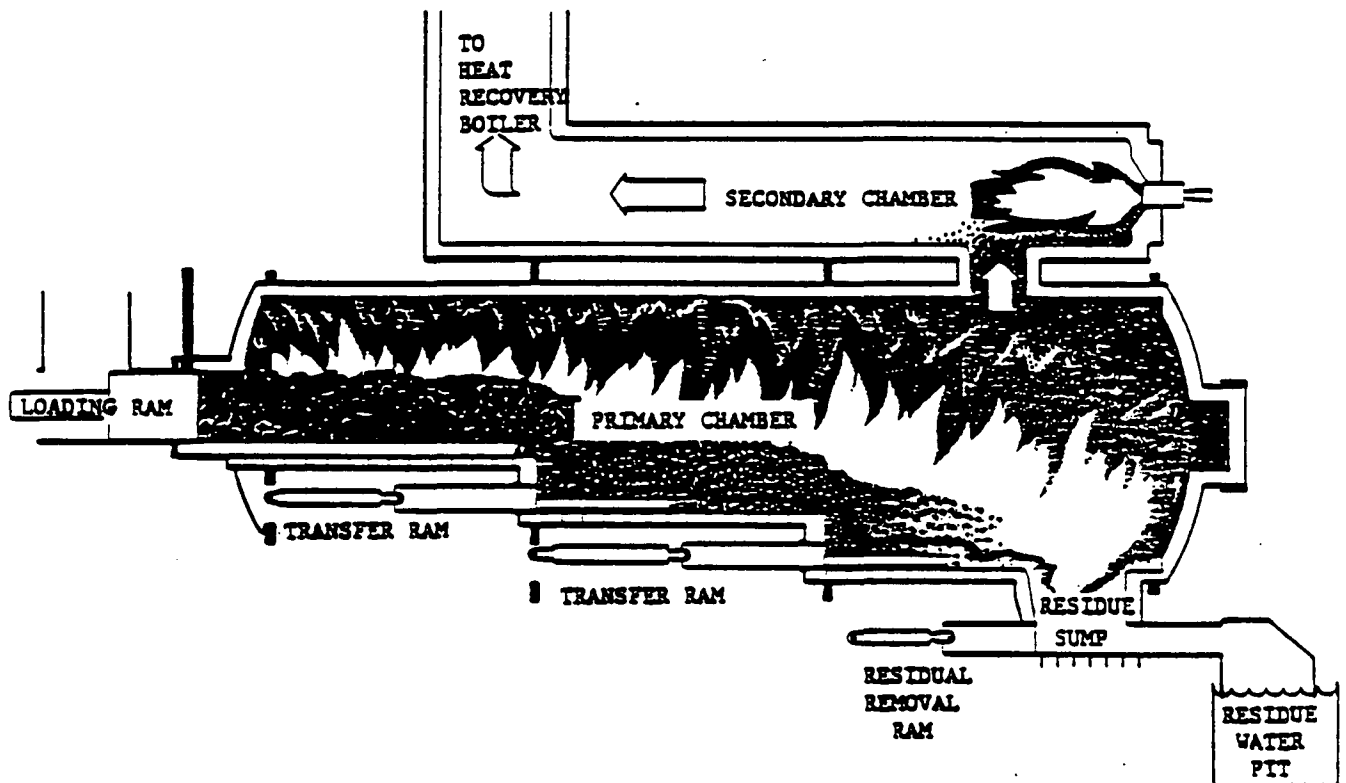


Figure 5-1. Cross section of typical modular incinerator.

conditions. (Primary chambers of modular starved air incinerators typically operate at 25 to 50 percent below stoichiometry.) The combustible gases and particulates generated in the primary chamber flow into the secondary chamber where combustion is completed under excess air conditions, typically 50 to 100 percent above stoichiometry. Temperature in the primary chamber of each incinerator is maintained between 540° and 760°C (1000° and 1400°F). Secondary chamber temperatures are typically 1150°C (2100°F). No auxiliary fuel is used during normal operation.

## 5.2 AIR POLLUTION CONTROL SYSTEM

Particulate emissions are controlled by an electrostatic precipitator (ESP) manufactured by Precipitair Pollution Control Company of Longview, Texas. Exhaust from the four incinerators is routed through the ESP prior to exiting through a single stack. An induced draft (ID) fan is located after the ESP and before the stack. Design specifications for the ESP are presented in Table 5-1.

## 5.3 PROCESS CONDITIONS DURING TESTING

All tests were conducted while the four incinerator modules were operating normally at approximately 320 tons of refuse per day (90 percent of capacity). Table 5-2 outlines the tests conducted on the incinerator. The lower chamber temperatures and upper chamber temperatures were monitored and controlled to operate in the typical ranges of 980° to 1200°F and 2080° to 2120°F, respectively. The following incinerator process parameters were recorded every 15 minutes during testing: lower chamber and upper chamber temperatures for each of the four modules (Nos. 1 through 4), steam flow,

TABLE 5-1. TUSCALOOSA ENERGY RECOVERY INCINERATOR  
ESP DESIGN SPECIFICATIONS

Collection efficiency, %	50
Inlet dust loading, gr/dscf	0.06
Outlet dust loading, gr/dscf	0.03
Gas volume, acfm	76,000
Gas temperature, °F	350
No. of fields	2
Collection plate area, ft <sup>2</sup>	10,617
Specific collection area, ft <sup>2</sup> /1,000 acfm	140
Collection plate height, ft	28
Collection plate length, ft	7.3
Aspect ratio	0.52
Gas velocity, ft/s	4.18
Gas passage spacing, in.	10
No. of gas passages	13
No. of plates	28
Secondary voltage, kV	45
Secondary current, mA	300
ESP power, kVA	27

TABLE 5-2. SUMMARY OF TESTS CONDUCTED ON THE TUSCALOOSA ENERGY RECOVERY INCINERATOR, TUSCALOOSA, ALABAMA<sup>a</sup>

Sampling point	Test type	Test Method	No. per run
ESP inlet	Particulate concentration	EPA Method 5	1
	Particle size	Anderson Mark III	1
ESP outlet	Particulate concentration	EPA Method 5	1
	Particle size	Anderson Mark III	1
	NO <sub>x</sub> concentration	EPA Method 7	~10
Outside observa- tion point	Visible emissions	EPA Method 9	~4 <sup>b</sup>
ESP dust hopper	Fly ash	Grab	~10

<sup>a</sup> Tests consisted of one run per day on May 21, 22, and 23, 1985. Method 5 samples on the first day were gathered for arsenic analyses. All other samples to be analyzed for particulate, total chromium, chromium, and cadmium.

<sup>b</sup> Each observation period was 6 minutes in duration. These data were collected to support transmissometer data.

steam temperature, steam pressure, ID fan amps, carbon monoxide concentration, and stack gas opacity. Integrated steam flow values were recorded daily at the beginning and end of the test period. Tables 5-3, 5-4, and 5-5 present the process parameters recorded during Runs 1, 2, and 3, respectively. Appendix J contains charts of the opacity and steam parameters recorded during the test period.

A local power outage during a thunderstorm stopped the inlet Method 5 and particle sizing sampling at 6:20 p.m. during Run 1. During the temporary power loss, the emergency venting system was engaged to allow the incinerator exhaust to bypass the ESP and stack. Sampling during Run 2 was interrupted due to circuit overload from the sampling equipment. Sampling resumed after an additional electrical circuit was used to power the sampling equipment. Air inleakage at the ID fan flange was discovered and sealed during Run 3.

The ESP operation did not remain steady during the three-day test period, although it was operating as usual according to plant personnel. Prior to Run 1, plant personnel adjusted the electronic controls to obtain the maximum secondary voltages to both ESP fields and to frequent a short in the internals. Plant personnel also questioned the accuracy of the voltage and current meters. During Run 1, power to the ESP inlet field was interrupted several times because the transformer-rectifier tripped off. Primary and secondary current meters both registered a zero value during Runs 1 and 2 even when the inlet field was apparently operating. The average power level to the ESP during Run 1 was estimated to be 1.70 kVA, representing 6 percent of the design power level of 27 kVA. During Run 2, from 8:00 to 11:45 a.m., the inlet field tripped off occasionally and then stayed off after 11:45 a.m.

TABLE 5-3. PROCESS DATA FOR RUN 1--TUSCALOOSA ENERGY RECOVERY  
May 21, 1985

Time	Unit No. 1		Unit No. 2		Unit No. 3		Unit No. 4		Steam temp., °F	Steam pressure, psi	Steam flow, lb/h	I.D. fan, amps	Opacity, %	Steam total x10 lb/ h	
	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C							
<u>a.m.</u>															
7:30	1194	1143	1400	1140	1106	1146	1178	1146	435	355	65,000	210	4	123,040	
8:00	1210	1150	1253	1134	1137	1147	1197	1140	435	355	66,000	205	6		
8:15	1223	1153	1172	1140	1188	1147	1236	1146	435	355	65,000	200	7		
8:30	1195	1146	1171	1142	1215	1150	1220	1149	435	355	64,000	200	6	128,980	
8:36	M5 inlet and outlet test for arsenic started														
8:45	1166	1146	1144	1138	1188	1148	1218	1148	435	350	62,000	200	5		
9:00	1152	1149	1079	1132	1145	1120	1145	1165	430	350	62,500	200	4		
9:15	1131	1150	1058	1142	1091	1153	1151	1152	430	355	63,000	200	5		
9:30	1130	1148	1054	1143	1090	1145	1138	1147	430	355	63,000	200	5		
9:45	1104	1148	1063	1146	1091	1145	1075	1148	435	355	63,000	200	5		
10:00	1095	1146	1081	1149	1076	1144	1036	1146	435	360	68,000	205	4		
10:15	1043	1146	1046	1142	1054	1146	1067	1147	435	360	67,500	200	3		
10:30	1034	1153	1036	1138	1054	1138	1072	1145	435	360	67,500	200	3		
10:45	1014	1144	1039	1140	1052	1144	1123	1142	435	360	65,000	200	4		
11:00	985	1155	1031	1140	1041	1142	1125	1145	435	360	66,000	200	4		
11:15	986	1145	1055	1141	1044	1148	1126	1148	435	355	63,000	200	6		
11:27	M5 inlet and outlet test for arsenic ended														
11:30	986	1148	1083	1141	1045	1127	1123	1165	435	355	62,500	200	7		
<u>p.m.</u>															
12:45	966	1150	1054	1144	1067	1146	1069	1142	430	350	62,000	195	6	156,150	
12:46	M5 outlet started														
12:47	M5 inlet started														
1:00	970	1146	990	1142	1061	1145	1062	1144	430	350	63,000	200	5		
1:15	981	1147	982	1143	1052	1143	1066	1147	430	350	62,000	200	4		
1:30	985	1149	969	1142	1045	1144	1075	1148	430	350	63,000	200	4		
1:45	994	1153	958	1140	1038	1145	1089	1150	430	355	64,000	200	4		
2:00	1010	1150	952	1141	1035	1147	1084	1150	430	355	64,000	200	4		
2:15	1031	1148	948	1142	1030	1150	1080	1148	430	355	63,500	200	5		

(continued)

TABLE 5-3. (continued)

Time	Unit No. 1		Unit No. 2		Unit No. 3		Unit No. 4		Steam temp., °F	Steam pressure, psi	Steam flow, lb/h	I.D. fan, amps	Opacity, %	Steam total x10 lb/ h
	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C						
2:30	1065	1155	961	1143	1012	1148	1046	1149	430	355	63,000	200	4	
2:45	1023	1148	993	1137	1028	1150	1026	1136	435	360	65,000	200	3	
3:00	1029	1148	1000	1138	1029	1143	1047	1137	430	355	64,000	200	3	
3:15	1056	1147	1034	1150	1072	1150	1073	1148	430	355	64,000	200	4	
3:30	Particle sizing outlet started													
3:30	1107	1144	1045	1151	1135	1143	1134	1148	430	355	64,000	200	4	
3:45	1120	1151	1050	1149	1162	1145	1164	1143	430	355	63,000	200	4	
4:00	1115	1150	1095	1142	1121	1142	1121	1142	430	355	64,000	200	5	
4:07	Particle sizing inlet started													
4:15	1102	1151	1148	1134	1074	1140	1085	1142	430	355	64,000	200	5	
4:30	1091	1148	1102	1138	1061	1144	1097	1144	430	350	61,000	200	5	
4:45	1072	1146	1052	1140	1149	1143	1099	1143	430	350	61,000	200	4	
5:00	1057	1142	1018	1144	1035	1144	1103	1141	430	350	61,000	200	3	
5:15	1056	1143	1019	1143	1037	1145	1104	1140	430	350	61,000	200	3	
5:30	1038	1146	1026	1150	1014	1141	1088	1146	430	350	62,000	200	3	
5:30	Particle sizing outlet ended													
5:35	M5 outlet ended													
5:45	1041	1148	1012	1146	1025	1143	1102	1145	430	350	61,000	200	3	
6:00	1047	1150	996	1142	1034	1145	1121	1146	430	350	62,000	200	3	
6:15	1031	1150	1010	1138	1008	1148	1080	1145	430	350	62,000	200	3	190,656
6:20	Power outage; inlet M5 and particle sizing ended.													
6:20	NOTE: at 6:20 p.m. power off due to storm.													

TABLE 5-4. PROCESS DATA FOR RUN 2--TUSCALOOSA ENERGY RECOVERY  
May 22, 1985

Time	Unit No. 1		Unit No. 2		Unit No. 3		Unit No. 4		Steam temp., °F	Steam pressure, psi	Steam flow, lb/h	I.D. fan, amps	Opacity, %	Steam total x10 lb/ h
	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C						
a.m.														
8:30	1110	1150	1074	1140	1030	1144	1072	1155	355	435	65,500	200	1	279,160
8:45	1095	1148	1062	1152	1028	1145	1092	1151	355	435	64,000	200	2	
9:00	1073	1148	1046	1159	1024	1146	1114	1148	355	430	62,500	200	2	
9:10	M5 inlet and outlet started													
9:15	1063	1154	1102	1141	1042	1124	1084	1142	350	430	58,000	190	2	
9:30	1061	1150	1086	1153	1046	1147	1100	1156	350	430	60,000	195	3	
9:45	1071	1148	1052	1131	1114	1146	1080	1145	350	430	61,000	195	3	
10:00	1108	1150	1035	1141	1148	1143	1070	1159	350	430	62,000	195	3	
10:15	1097	1151	1054	1142	1148	1144	1072	1148	350	430	58,000	205	3	
10:30	1077	1148	999	1142	1066	1144	1089	1148	350	430	60,000	200	3	
10:45	1064	1147	1014	1143	1048	1148	1090	1146	350	430	58,000	200	2	
11:00	1033	1152	1084	1140	1030	1144	1108	1145	350	430	58,000	195	3	
11:15	1046	1148	1115	1150	1043	1143	1128	1155	350	430	57,000	200	3	
11:30	1032	1154	1023	1142	1082	1156	1102	1150	350	430	59,000	200	4	
11:45	Port change at 11:40 a.m.; cracked probe noted on inlet; sampling stopped													
	1076	1150	1086	1148	1052	1144	1101	1150	355	430	64,000	200	4	
p.m.														
12:08	Particle sizing outlet started													
12:30	1100	1148	980	1139	1017	1148	1040	1151	360	435	66,000	205	1	
12:38	Particle sizing inlet started													
12:45	1029	1159	960	1139	1020	1151	1027	1144	360	435	64,500	210	1	
12:54	M5 inlet started													
1:00	977	1145	932	1144	1013	1143	1058	1147	360	435	65,000	215	2	
1:15	977	1148	913	1141	1002	1143	1051	1163	360	435	66,500	215	2	
1:30	962	1150	892	1138	991	1142	1047	1179	360	435	67,500	215	1	
1:45	962	1161	903	1142	986	1149	1064	1152	360	435	67,500	215	1	
2:00	955	1150	929	1141	969	1142	1059	1146	360	435	66,500	215	1	
2:15	974	1140	927	1145	961	1143	1078	1146	355	435	65,500	215	2	
2:30	992	1150	932	1142	971	1147	1111	1146	355	435	62,500	220	2	
2:38	Particle sizing inlet ended													

(continued)



TABLE 5-4. (continued)

Time	Unit No. 1		Unit No. 2		Unit No. 3		Unit No. 4		Steam temp., °F	Steam pressure, psi	Steam flow, lb/h	I.D. fan, amps	Opacity, %	Steam total x10 lb/ h
	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C						
2:45	1023	1150	958	1146	1010	1145	1185	1145	355	435	63,500	210	3	
3:00	1069	1151	987	1150	1035	1144	1256	1140	355	435	63,500	205	3	
3:08	Particle sizing outlet ended													
3:15	1047	1150	1017	1143	1090	1146	1204	1147	355	435	61,000	200	3	
3:20	M5 outlet ended													
3:30	1043	1151	1018	1150	1065	1145	1037	1146	350	430	58,000	200	3	321,790
3:45	1025	1148	1029	1142	1020	1141	1114	1149	350	430	58,000	200	4	
4:00	1061	1152	1062	1134	1039	1143	1124	1144	350	430	58,000	195	3	
4:02	M5 inlet ended													

TABLE 5-5. PROCESS DATA FOR RUN 3--TUSCALOOSA ENERGY RECOVERY  
May 23, 1985

Time	Unit No. 1		Unit No. 2		Unit No. 3		Unit No. 4		Steam temp., °F	Steam pressure, psi	Steam flow, lb/h	I.D. fan, amps	Opacity, %	Steam total x10 lb/ h	
	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C							
a.m.															
8:00	1109	1146	1001	1136	1087	1144	1014	1152	435	355	65,000	215	1	419,700	
8:30	1078	1149	1037	1126	1031	1144	1051	1157	435	355	64,500	215	2		
8:40	M5 outlet started														
8:41	M5 inlet started														
8:45	1092	1147	1050	1143	1019	1144	1126	1155	435	355	64,500	215	1		
9:00	1105	1146	1063	1133	1009	1144	1090	1145	435	350	63,000	215	1		
9:30	1119	1150	1034	1143	1004	1143	1126	1150	435	350	62,000	215	1		
10:00	1066	1150	1064	1139	996	1148	1092	1142	435	355	65,000	215	1		
10:15	1052	1141	1054	1140	996	1146	1080	1148	435	355	65,000	215	1		
10:30	1036	1150	1038	1138	1003	1150	1063	1142	435	360	66,500	215	1		
10:40	Particle sizing outlet started														
10:45	1003	1151	1082	1137	987	1145	1034	1150	435	360	66,000	215	2		
11:00	1001	1150	1131	1139	982	1146	1025	1152	435	360	66,000	215	2		
11:15	993	1150	1163	1142	975	1145	1015	1155	435	360	66,500	215	2		
11:30	1043	1148	1117	1150	986	1143	1023	1142	435	360	65,000	215	3		
11:40	M5 outlet ended														
11:45	1068	1147	1110	1142	1003	1147	1022	1144	435	360	65,000	215	4		
11:58	Particle sizing inlet started														
p.m.															
12:00	1085	1153	1103	1139	1007	1147	991	1146	435	360	65,500	215	3		
12:15	1173	1147	1057	1142	1152	1145	1094	1144	435	350	62,000	215	7		
12:30	1192	1146	1088	1143	1122	1144	1081	1142	435	350	62,000	215	5		
12:45	1214	1146	1124	1142	1084	1142	1063	1142	435	350	62,000	215	2		
1:00	1169	1148	1085	1143	1043	1144	1018	1152	430	350	58,000	205	2		
1:15	1094	1150	1033	1140	998	1146	1006	1146	430	350	54,500	200	2		
1:30	1078	1148	1018	1143	995	1141	1036	1148	430	350	56,000	200	3		
1:40	Particle sizing outlet ended														
1:45	1054	1152	971	1139	983	1147	1015	1146	430	350	57,000	195	3		
2:00	1037	1149	1020	1125	1015	1135	1012	1148	430	350	58,500	195	3	457,450	
2:15	1006	1149	1011	1149	973	1148	1052	1146	430	350	60,500	195	7		
2:27	M5 inlet ended														

(continued)

TABLE 5-5. (continued)

Time	Unit No. 1		Unit No. 2		Unit No. 3		Unit No. 4		Steam temp., °F	Steam pressure, psi	Steam flow, lb/h	I.D. fan, amps	Opacity, %	Steam total x10 lb/ h
	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C	Lower chamber temp., °F	Upper chamber temp., °C						
2:30	1007	1148	1023	1146	989	1147	1050	1146	430	350	58,500	195	5	
2:45	1009	1147	1037	1142	1008	1148	1048	1145	430	350	57,000	195	4	
3:00	1025	1148	1005	1142	996	1149	1079	1148	430	350	56,500	205	5	
3:12	Particle sizing inlet started													
3:15	1035	1151	1013	1137	1025	1142	1064	1147	430	350	55,000	200	6	
3:30	1034	1147	1054	1139	1101	1143	1098	1147	430	350	58,000	195	5	
3:45	1019	1146	1034	1144	1082	1145	1077	1148	430	350	58,000	195	3	
4:00	996	1146	1018	1147	1066	1147	1059	1149	430	350	58,000	195	3	
4:15	1007	1150	1046	1145	1057	1142	1012	1145	430	350	58,000	195	3	
4:30	1029	1151	1030	1144	1067	1145	1020	1131	430	350	58,500	195	4	
4:42	Particle sizing inlet stopped													
5:00														474,873

The average ESP power level during Run 2 was estimated to be 2.0 kVA, representing 7 percent of the design power level. During Run 3, the outlet field tripped off from 11:00 to 11:30 a.m., and was restarted at 11:30 a.m. The average ESP power level during Run 3 was estimated to be 5.7 kVA, representing 21 percent of the design level. Tables J.3-1, J.3-2, and J.3-3 in Appendix J present the recorded values of the monitored ESP parameters during Runs 1, 2, and 3, respectively.

#### 5.4 SUMMARY OF PROCESS OPERATIONS DURING TESTING

The incinerator modules were operated under steady and normal conditions at approximately 90 percent of capacity throughout the tests. It is expected that the inlet sampling data are representative for uncontrolled emission levels. (Approximately 90 percent of all modular plants are uncontrolled.) The ESP operation was not steady and the ESP power levels represent only a small fraction of the design power level. (This ESP as well as the control devices on the modular plants with controls has a design removal efficiency of only approximately 50 percent.) Air inleakage at the ID fan flange occurred throughout most of the test period. It is expected that the outlet sampling results do not reflect representative conditions for controlled emission levels.

The inlet chromium emission levels will be used to represent the 90 percent of the modular facilities without controls. By applying a removal efficiency of 50 percent to the inlet chromium emission levels, typical chromium emissions for the uncontrolled facilities can be estimated; thus, the suspect outlet data from the Tuscaloosa facility will not have to be used to represent current controlled emission levels.

The temperature in the primary chamber of each incinerator is maintained between 540° and 760°C (1000° and 1400°F). Secondary chamber temperatures are typically 1150°C (2100°F). No auxiliary fuel is used during normal operation.

Approximately 99 percent of the refuse incinerated at the Tuscaloosa facility is supplied by residential sources in eight nearby municipalities. The remaining 1 percent [4.5 Mg/day (5 tons/day)] consists of scrap tires from the nearby tire plant. Large metal items are sorted from the refuse prior to incineration and sent to a landfill.

Exhaust from the incinerators is routed through a common ESP for particulate emission control prior to exiting through a single stack. The ESP was manufactured by the PPC Company of Longview, Texas. It has two fields with 14 plates in each field. The plates are spaced approximately 25 cm (10 in.) apart and are 7.6 m (25 ft) long and 2.4 m (8 ft) wide. The applied voltages to the first and second fields are 31 and 30 kV, respectively. The specific collection area is estimated to be 400 m<sup>2</sup>/1000 acmm (120 ft<sup>2</sup>/1000 acfm). The ESP has a design removal efficiency of 50 percent and collects approximately 320 kg (700 lb) of fly ash per day.

All tests were conducted while the incinerators were operating under normal conditions. However, the ESP experienced some operational difficulties at various times throughout the test program.