

Air



# Electric Arc Furnace — Revision Argon Oxygen Decarburization

Emission Test Report  
Carpenter Technology  
Corporation  
Reading, Pennsylvania

EMISSION TEST REPORT  
Carpenter Technology Corporation  
Reading, Pennsylvania  
ESED No. 79/9  
EMB No. 80-ELC-10

by

PEDCo Environmental, Inc.  
11499 Chester Road  
Cincinnati, Ohio 45246

Contract No. 68-02-3546  
Work Assignment No. 2  
PN 3530-2

Task Manager

Dennis Holzschuh  
Emission Measurement Branch, MD-13  
Emission Standards and Engineering Division

OFFICE OF AIR QUALITY PLANNING AND STANDARDS  
U.S. ENVIRONMENTAL PROTECTION AGENCY  
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

April 1981

## CONTENTS

	<u>Page</u>
Figures	iv
Tables	vi
Quality Assurance Element Finder	viii
Acknowledgment	xiv
 1. Introduction	 1-1
 2. Process Operation	 2-1
 3. Summary of Results	 3-1
Particulate matter	3-3
Particle size	3-22
Visible and fugitive emissions	3-31
Fabric filter dust samples	3-34
Supplemental analyses for fluoride, chromium, lead, and nickel	3-39
 4. Sampling Sites and Test Methods	 4-1
Site 1--Inlet AOD	4-1
Site 2--Fabric filter outlet	4-5
Site 3--Scavenger duct	4-8
Site 4--Continuous casting torch cutter	4-9
Velocity and gas temperature	4-9
Molecular weight	4-12
Particulate matter	4-12
Particle size distribution	4-13
Visible and fugitive emissions	4-15
Fabric filter dust samples	4-16
 5. Quality Assurance	 5-1
 6. Standard Sampling and Analytical Procedures	 6-1
Determination of particulate emissions	6-1
Determination of particle size distribution	6-8
 References	 R-1

## CONTENTS (continued)

	<u>Page</u>
Appendix A      Computer printouts and example calculations	A-1
Appendix B      Field data	B-1
Appendix C      Sample recovery and analytical data	C-1
Appendix D      MRI process summary	D-1
Appendix E      Calibration procedures and results	E-1
Appendix F      Quality assurance summary	F-1
Appendix G      Project participants and activity log	G-1

## FIGURES

<u>Number</u>		<u>Page</u>
2-1	Process and Control System Schematic at Cartech	2-4
3-1	Average Particle Size Results for Uncontrolled Emissions, Site 1	3-25
3-2	Average Particle Size Results for Controlled Emissions, Site 2	3-26
3-3	Average Particle Size Distribution of Fabric Filter Dust Samples	3-38
4-1	Sampling Sites for Uncontrolled Emissions	4-2
4-2	Sampling Location for Uncontrolled AOD Emissions, Site 1	4-3
4-3	Location of Sampling Points at Site 1	4-4
4-4	Fabric Filter, Site 2	4-6
4-5	Location of Sampling Points at the Fabric Filter Outlet, Site 2	4-7
4-6	Location of Velocity Traverse Points at Site 3	4-10
4-7	Location of Traverse Points at Site 4	4-11
5-1	Dry Gas Meter Audit	5-7
5-2	Dry Gas Meter Audit	5-8
5-3	Dry Gas Meter Audit	5-9
5-4	Dry Gas Meter Audit	5-10
5-5	Dry Gas Meter Audit	5-11
6-1	Particulate Sampling Train Used at Site 1	6-4

FIGURES (continued)

<u>Number</u>		<u>Page</u>
6-2	Particulate Sampling Train Used at Site 2	6-5
6-3	Particle Size Distribution Sampling Train Used at Site 1	6-10
6-4	Particle Size Distribution Sampling Train Used at Site 2	6-11

## TABLES

<u>Number</u>		<u>Page</u>
2-1	No. 2 AOD Production Summary	2-6
3-1	Samples Collected at Cartech	3-2
3-2	Summary of Gas Stream Characteristics at Sites 1 and 2	3-6
3-3	Summary of Gas Stream Characteristics at Sites 3 and 4	3-7
3-4	Summary of Filterable Particulate Emissions Data at the Inlet, Site No. 1	3-8
3-5	Summary of Particulate Emissions Data at the Outlet, Site No. 2	3-9
3-6	Filterable Particulate Collection Efficiency	3-13
3-7	Particulate Emission Factors Based on Furnace Capacity	3-14
3-8	Particulate Emission Factors Based on Production	3-15
3-9	Summary of Particle Size Distribution and Fractional Efficiency	3-27
3-10	Summary of Visible and Fugitive Emissions	3-33
3-11	Summary of Trace Element Analyses on Fabric Filter Dust Samples	3-35
3-12	Summary of Supplemental Analyses for Fluoride, Chromium, Lead, and Nickel	3-41
5-1	Field Equipment Calibration	5-3
5-2	Dry Gas Meter Audit Results	5-6
5-3	Filter Blank Analysis	5-12
5-4	Reagent Blank Analysis	5-14

TABLES (continued)

<u>Number</u>		<u>Page</u>
5-5	Trace Element Audit Results	5-15
5-6	Trace Element Audit Results	5-16



## QUALITY ASSURANCE ELEMENT FINDER

	Location	
	Section	Page
(1) Title page	-	-
(2) Table of contents	..	ii
(3) Project description	1	1-1
(4) Project organization and responsibilities	Appendix F	F-2
(5) QA objective for measurement data in terms of precision, accuracy, completeness, representativeness, and comparability	Appendix F	F-3
(6) Sampling procedures	Appendix D	D-1
(7) Sample custody	Appendix C	C-1
(8) Calibration procedures and frequency	Appendix E	E-1
(9) Analytical procedures	Appendix D	D-1
(10) Data reduction, validation, and reporting	Appendix F	F-4
(11) Internal quality control checks and frequency	Appendix F	F-5
(12) Performance and system audits and frequency	Appendix F	F-4
(13) Preventive maintenance procedures and schedules	Appendix F	F-6
(14) Specific routine procedures used to assess data precision, accuracy and completeness of specific measurement parameters involved	Appendix F	F-5
(15) Corrective action	Appendix F	F-6
(16) Quality assurance reports to management	Appendix F	F-7

## ACKNOWLEDGMENT

Mr. William Terry of Midwest Research Institute, the New Source Performance Standards contractor, monitored the process operation during the test series, assisted in the coordination of tests with process conditions, and provided the information contained in Section 2 and Appendix D of this report. Messrs. Larry Geiser and George Michael of Carpenter Technology Corporation helped to coordinate plant activities.

## SECTION 1

### INTRODUCTION

During the week of April 28, 1981, PEDCo Environmental personnel conducted an emission sampling program at the steel melt shop operated by Carpenter Technology Corporation (Cartech) in Reading, Pennsylvania. The purpose of this test program was to provide data for assessing the need for revising current New Source Performance Standards (NSPS) for electric arc furnaces (EAF) to include argon-oxygen decarburization (AOD) furnaces.

The No. 2 AOD at Cartech was selected for source testing for the following reasons:

- 1) It utilizes best available control technology.
- 2) The emissions capture and control equipment is representative of the industry.
- 3) Emissions from a single AOD are controlled separately from those of other furnaces.
- 4) Emission data could be obtained by standard sampling techniques at the desired locations.

Particulate matter concentrations and mass emission rates were measured at one inlet and one outlet site according to U.S. Environmental Protection Agency (EPA) Reference Method 5.\* Inlet and outlet tests for particulate matter were performed simultaneously so that control efficiency as well as values for

---

\* 40 CFR 60, Appendix A, July 1980.

controlled and uncontrolled emissions could be determined. Flue gas flow rates, temperature, and composition were measured in conjunction with these tests. In addition, particle size distribution samples were collected simultaneously at the inlet and outlet sites. Method 9\* procedures were used to evaluate visible emissions (VE) from the melt shop and fabric filter outlet throughout the test series. Fugitive emissions (FE) from the fabric filter dust handling system were determined visually according to the proposed Method 22.\*\* Samples of dust collected by the fabric filter were obtained for analysis of particle size distribution and trace element composition. Tests took place simultaneously at all sites, including visible and fugitive emission sites. A representative from the NSPS contractor assisted in coordinating the tests with process operations. Two filterable particulate samples taken at the outlet and two fabric filter dust samples were subsequently analyzed for concentrations of fluoride, chromium, lead, and nickel.

This report documents the activities and results of the test program. Section 2 describes the process that was tested and the operating conditions during the sampling period. Section 3 presents and discusses the results. Section 4 describes the sampling sites and general test procedures. Section 5 briefly outlines quality assurance measures and audit results. Section 6 gives details of the sampling and analytical procedures for

---

\* 40 CFR 60, Appendix A, July 1980.

\*\* Federal Register, Vol. 45, No. 224, November 19, 1980.

determining particulate matter concentrations and particle size distribution. The appendices contain computer output and example calculations (Appendix A), field data (Appendix B), sample recovery and analytical data (Appendix C), the Midwest Research Institute (MRI) process summary (Appendix D), calibration procedures and results (Appendix E), a quality assurance summary (Appendix F), and a list of project participants (Appendix G).

## SECTION 2

### PROCESS OPERATION

Cartech's Reading plant has five EAF's and two AOD's. The plant is capable of producing about 400 different grades of steel for use in numerous industries (e.g., electronics, automotive, appliance, aerospace, and industrial equipment). Each of the five EAF's has a rated capacity of 13.6 megagrams (Mg) (15 tons) and produces an average heat of 15.4 Mg (17 tons). The No. 1 AOD has a rated capacity of 15.4 Mg (17 tons). The No. 2 AOD has a rated capacity of 18.1 Mg (20 tons), but typically refines a 15.4-Mg (17-ton) charge of molten metal. During the test series the facility was operating at normal capacity (three shifts per day, 5 days per week).

The No. 2 AOD vessel normally operates continuously, with only a 5- to 10-minute delay between a tap and a subsequent charge of molten metal. The molten metal charge comes from one of two EAF's (designated as "C" and "E"). The time lapse between tap and charge is short because no refractory gunning is performed on the AOD. Longer delays occur periodically, when maintenance is performed on the AOD vessel or when vessel charging is delayed because a crane is not available. Delays

in tapping could occur if the continuous caster were still casting the metal from the No. 1 AOD or if the continuous caster were broken down.

Each heat in the No. 2 AOD vessel consists of three general stages. The first stage begins with the charging of molten metal from either of two EAF's (C or E), which is followed by the addition of the fluxing agent (lime). The vessel blow begins almost immediately after the charge, with an oxygen-to-argon ratio of 3:1 [930 normal cubic meters per hour ( $\text{Nm}^3/\text{h}$ ) of oxygen to 310  $\text{Nm}^3/\text{h}$  of argon, or 33,000 standard cubic feet per hour (scfh) to 11,000 scfh]. Some of the heats also use nitrogen in a ratio of 3:1:1 (oxygen:argon:nitrogen) for the first phase of the heat. After a gas blow of 15 to 30 minutes, the vessel is turned down for a temperature check. If the temperature is close to 1923 K (3182°F), alloys are added. The type and weight of the alloy additions depend on final product specifications.

During the next stage of the heat (approximately 1 hour), the orientation of the vessel alternates between an upright position (for blowing or stirring the molten metal with oxygen, argon, or nitrogen gas) and a turned-down position (for temperature measurement, sample acquisition, and alloy and flux addition). The oxygen-to-argon ratio for blowing during this stage is 1:3. The AOD vessel operators make the necessary alloy and flux additions, which are determined by mathematical calculations based on the gross weight of the heat. Near the end of the heat,

the slag is poured off into a slag pot to remove the lime and impurities that are chemically bound in the slag.

Final chemical additions are made at the end of the heat, after the final sample results are available. After the alloys are melted into the bath by stirring with argon or nitrogen gas, the molten metal is tapped into a ladle for transfer to the continuous caster area. The AOD shop and the continuous caster building are separated by a sheet metal wall suspended from the ceiling to a level of about 6.1 meters (m) [20 feet (ft)] above the floor. The molten metal ladle from the AOD must pass under this wall to the ladle-stirring area before it is delivered to the single-strand continuous caster.

Figure 2-1 is a schematic of the process and control system. The process emissions generated during the heat are captured by a canopy hood built into the roof trusses approximately 13 m (42.7 ft) above the mouth of the vessel. The fumes are directed to the canopy hood by a movable diverter hood located 1.5 m (5 ft) above the mouth of the AOD vessel. The diverter hood swings out of the way during charging and tapping operations. The shop roof above the No. 2 AOD is closed, and any fugitive emissions not captured by the canopy hood remain inside the building and are drawn into two openings in a scavenger duct located in the peak of the roof between the AOD canopy and the continuous caster area. The scavenger duct openings are not hooded.

The canopy hood and scavenger ducts are combined to form a main inlet duct, which is then split into two ducts. Each duct



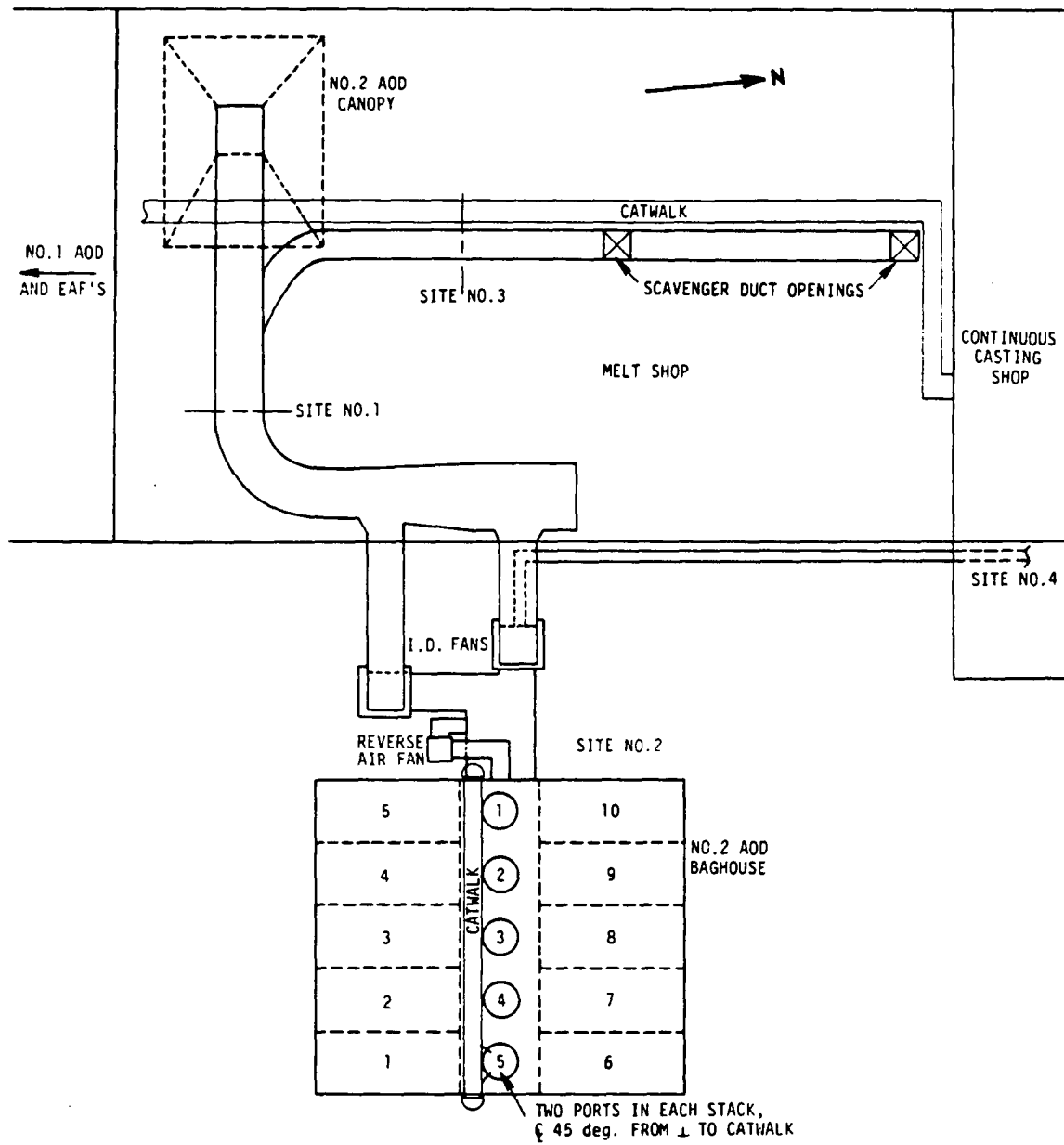


Figure 2-1. Process and control system schematic at Cartech.

has a 522-kilowatt (700-horsepower) fan that routes the emissions to the inlet plenum of the fabric filter. The emissions from the continuous-caster cutting torch are normally routed to the fabric filter by a small duct and booster fan. The EPA requested that this duct be closed off during the source test, however, to prevent emissions from the cutting torch and the AOD from mixing.

The AOD gases are treated in a positive-pressure Carborundum fabric filter to remove the particulate matter. The cleaned exhaust gases exit via five short stacks on the fabric filter. Table 2 in Appendix D presents technical data on the No. 2 AOD and the associated control device.

William Terry of MRI monitored the operation of the vessel and the fabric filter. The AOD vessel operated normally during the source tests, with only a few short delays. Table 2-1 presents a summary of production data for the test series. Tap-to-tap times ranged from 1.4 to 2.3 hours, and the weight of metal produced per heat ranged from 14.9 to 18.8 Mg (16.4 to 20.7 tons). The average production rate during the tests was 9.2 Mg per hour (10.1 tons per hour), not including process delay times. The average time between heats was less than 5 minutes, and testing continued during these periods unless maintenance was to be performed or the AOD operators indicated there would be a delay. The testing was stopped on April 28, 1981, when emissions from a fire at the No. 1 AOD drifted over to the No. 2 AOD.

TABLE 2-1. NO. 2 AOD PRODUCTION SUMMARY<sup>a</sup>

PEDCo Run No.	Date (1981)	Complete heats sampled, Heat No.	Tap-to- tap time, minutes	Metal produced <sup>b</sup>		Process weight <sup>c</sup> rate	
				Mg	tons	Mg/h	tons/h
1	4/28	1	86 <sup>d</sup>	16.4	18.1	11.4	12.6
		2	108	17.7	19.5	9.8	10.8
		3	100	15.7	17.3	9.4	10.4
		4	104 <sup>e</sup>	15.3	16.9	8.9	9.8
		5	105	15.1	16.6	8.6	9.5
		Average		16.1	17.7	9.5	10.5
2	4/29	1	121	15.5	17.1	7.7	8.5
		2	94 <sup>f</sup>	15.9	17.5	10.2	11.2
		3	137 <sup>f</sup>	16.1	17.7	7.1	7.8
		4	95	17.2	19.0	10.9	12.0
		Average		16.1	17.8	8.6	9.5
3	4/30	1	115	15.4	17.0	8.1	8.9
		2	115	18.8	20.7	9.8	10.8
		3	97	15.1	16.6	9.3	10.3
		4	102	16.1	17.8	9.5	10.5
		5	87 <sup>g</sup>	14.9	16.4	10.3	11.3
		Average		16.1	17.7	9.3	10.3

<sup>a</sup>Compiled from data in Appendix D (Table 4 and Attachment 1).

<sup>b</sup>Final billet weights, reported in megagrams and tons.

<sup>c</sup>Process weight rates were calculated by dividing the weight of metal produced by the tap-to-tap time. Averages are based on average metal produced and heat time to yield a weighted average.

<sup>d</sup>These are actually charge-to-charge times because one tap time was unavailable.

<sup>e</sup>Seven minutes was subtracted from the actual time to reflect a delay resulting from the unavailability of a crane.

<sup>f</sup>Thirteen minutes was subtracted from the actual time to reflect a delay caused by slag pot removal. The long heat time resulted from problems in attaining metal specifications.

<sup>g</sup>Five minutes was subtracted from the actual time to reflect a delay caused by pulling a collar.

The fabric filter was observed approximately once an hour and was found to be operating normally. Indicator dials in the fabric filter control room showed which compartment was closed for cleaning, the amperage on each of the two fans, the inlet gas temperature, and the amperage of the reverse-air fan. The amperage of the reverse-side fan was typically 100 to 105 when the fan was in the cleaning operation and 60 when it was not in the cleaning mode. The other indicator dial readings are included in Attachment 1 of Appendix D.

The test conditions were representative of normal operations and should provide useful data on controlled and uncontrolled emissions from an individually controlled AOD vessel. Emissions were most significant during the blowing operation, and the flow to the fabric filter appeared to be adequate to capture almost all of the emissions in the canopy hood. The emissions that were not captured by the canopy drifted northward toward the continuous caster area, where they were captured by the scavenger ducts. Charging and tapping emissions were minimal, and most were captured by the canopy hood.

### SECTION 3

#### SUMMARY OF RESULTS

Particulate matter and particle size distribution tests were conducted simultaneously at the inlet and outlet of the fabric filter. Visible emissions from the melt shop and fabric filter outlet were evaluated concurrently with particulate tests. Fugitive emissions from the fabric filter dust-handling system were evaluated periodically. Fabric filter dust samples were collected and analyzed for trace elements and particle size distribution. Table 3-1 summarizes the type and number of samples that were collected.

In brief, uncontrolled particulate matter concentrations averaged  $167 \text{ mg/dNm}^3$  ( $0.073 \text{ gr/dscf}$ ). At the fabric filter outlet, particulate concentrations averaged  $0.66 \text{ mg/dNm}^3$  ( $0.00029 \text{ gr/dscf}$ ) which indicates a 99.6 percent control efficiency. Both concentration levels were in the range of expected values based on reported data on EAF's.<sup>1,2</sup> Outlet emissions, however, were significantly lower than results of previous tests at this site.<sup>3</sup>

The opacity of melt shop visible emissions averaged zero percent over the test series; in fact, no emissions were visually detected at any time. These results attested to the efficient capture of emissions during charging, tapping, and other process

TABLE 3-1. SAMPLES COLLECTED AT CARTECH

Sampling site	Sample type	Sampling method	Number of samples <sup>a</sup>	Time for each sample	Additional analysis		
					Type	No.	Method
No. 1 - Inlet	Particulate Particle size	EPA 5	3	~7-1/2 h	Organic and inorganic condensibles	3	Back half E/C extract
		High capacity impactor	3	~5 h			
		Impactor	3	5-15 minutes			
No. 2 - Outlet	Particulate Particle size VE	EPA 5	3	~8 h			
		Impactor	3	7-1/2 - 9 h			
		EPA 9	3	~1-5 h			
No. 3 - Scavenger duct	Velocity	EPA 2 - Average point	3	~7-1/2 h			
No. 4 - Torch cutter	Velocity	EPA 2	1	10 minutes			
Melt shop	VE	EPA 9	3	~1-5 h	Trace metals, particle size	3	SSMS, <sup>c</sup> Coulter
Fabric filter dust handling system	FE Dust	EPA 22 Grab	3 <sup>b</sup>	20 minutes 1 per day			

<sup>a</sup>Does not include preliminary, blank, or duplicate runs.

<sup>b</sup>Two samples were analyzed later for fluoride (by EPA Method 13B) and for chromium, lead, and nickel (by Atomic Absorption Spectrophotometry).

<sup>c</sup>Spark source mass spectroscopy.

operations. The opacity of visible emissions from the fabric filter outlet averaged zero percent, which is indicative of efficient control of particulate matter in terms of opacity.

These and other results are presented and discussed in detail according to emission type.

### 3.1 PARTICULATE MATTER

The fabric filter inlet duct (Site 1) and the fabric filter outlet (Site 2) were tested simultaneously for particulate matter. Site 1 represented uncontrolled process and fugitive emissions from the No. 2 AOD; Site 2 represented controlled emissions from the same source.

The fugitive portion of uncontrolled emissions was represented by Site 3, the scavenger duct. The velocity in this duct was monitored for the duration of the particulate tests to detect any changes in flow rate and corresponding emission capture efficiency. Uncontrolled emissions from the torch cutter operation (represented by Site 4) were not sampled. After initial gas flow measurements had been made at Site 4, the torch cutter duct was blocked (at EPA's request) to prevent those emissions from entering the control system. This accomplished two things: 1) only emissions related to the AOD were tested, and 2) the gas flow measurements at Site 1 represented the total net gas flow to the fabric filter (not counting gas recirculated by the reverse-air cleaning system).

Particulate tests at Sites 1 and 2 were conducted over approximately five AOD heats. Because the large number of heats covered by the sampling period reduced the significance of testing for integral heats (i.e., charging through tapping), tests were commenced at any convenient time during a heat. Testing started at both sites simultaneously and continued until the respective traverses were completed, (about 7.5 to 8 hours). This procedure made possible the calculation of control efficiencies and average emission factors. Fabric filter cleaning cycles were sampled as they occurred.

The NSPS contractor representative, who was on site to monitor process operations, helped to coordinate the tests with process conditions. Based on his observations, tests were interrupted whenever the AOD experienced an operational delay or conditions were unrepresentative.

Particulate matter was sampled and analyzed according to procedures described in EPA Methods 1, 2, 3, and 5 of the Federal Register.<sup>\*</sup> Each outlet test consisted of traversing all five stacks. Site 1 did not meet minimum Method 1 criteria, but previous velocity profiles obtained by Cartech personnel indicated the site was acceptable. At Sites 3 and 4 velocity was measured according to procedures described in EPA Method 2. Three particulate tests were conducted at Sites 1 and 2. Three velocity determinations were made at Site 3, and one was made at

---

<sup>\*</sup> 40 CFR 60, Appendix A, July 1980.



Site 4. Integrated gas samples were collected once at Sites 1 and 2 (according to Method 3) to verify that the gas streams were essentially air. Additional molecular weight determinations were not made.

### 3.1.1. Gas Conditions and Particulate Emissions

Summaries of the measured stack gas and particulate emission data are presented in Tables 3-2 through 3-5. Volumetric flow rates are expressed in actual cubic meters per second ( $\text{m}^3/\text{s}$ ) and actual cubic feet per minute (acfm) at stack conditions. Flow rates corrected to zero percent moisture and standard conditions [20°C and 101 kPa (68°F and 29.92 in.Hg)] are expressed as dry normal cubic meters per second ( $\text{dNm}^3/\text{s}$ ) and dry standard cubic feet per minute (dscfm). Average stack gas velocities are expressed in actual meters per second (m/s) and actual feet per second (ft/s) at stack conditions. Particulate concentrations are reported in milligrams per dry normal cubic meter and grains per dry standard cubic foot. Emission rates are expressed in kilograms per hour and pounds per hour. The product of the concentration and the volumetric flow rate is the mass emission rate. The filterable particulate data represent material collected in the sample probe and on the filter, both of which were heated to approximately 121°C (250°F). The condensible organic and inorganic fractions represent material that passed through the filter and was collected by the impinger section of the sampling train at approximately 20°C (68°F). The isokinetic rate

TABLE 3-2. SUMMARY OF GAS STREAM CHARACTERISTICS  
AT SITES 1 AND 2<sup>a</sup>

Run No.	Date (1981)	Flow rate <sup>b</sup>		Temperature		Moisture, %	Velocity <sup>c</sup>		Flow rate <sup>d</sup>	
		dNm <sup>3</sup> /s	dscfm	°C	°F		m/s	ft/s	m <sup>3</sup> /s	acfm
C1P-1	4/28	130.6	276,800	57	135	1.1	21.5	70.5	150.0	317,800
C1P-2	4/29	138.7	293,800	51	124	1.7	22.7	74.3	158.1	335,000
C1P-3	4/30	133.3	282,400	50	122	0.9	21.5	70.5	149.9	317,600
Average		134.2	284,300	53	127	1.2	21.9	71.8	152.7	323,500
C2P-1	4/28	59.0	125,100	55	130	0.3	6.0	19.8	66.5	141,000
C2P-2	4/29	63.0	133,400	55	131	1.4	6.5	21.4	72.0	152,800
C2P-3	4/30	68.5	142,200	49	119	0.5	6.9	22.6	76.1	161,300
Average		63.5	134,600	53	127	0.7	6.5	21.3	71.5	151,700

<sup>a</sup>Average CO<sub>2</sub> ≤ 0.6%, O<sub>2</sub> = 19.4%. Sites 1 and 2 are the inlet and outlet, respectively.

<sup>b</sup>Dry normal cubic meters per second at 20°C and 101 kPa and dry standard cubic feet per minute at 68°F and 29.92 in.Hg.

<sup>c</sup>Velocity at stack conditions.

<sup>d</sup>Flow rate at stack conditions.

Note: Outlet flowrates are values measured in the five stack exhausts. The difference between reported inlet and outlet flowrates is the net gas flow that escapes by means other than the stacks; that is, through the partially open grating at the bottom level of the bags and through other small openings on the clean side of the exhaust. These losses are a result of the back pressure on the exhaust system caused by the small stack outlet area.

TABLE 3-3. SUMMARY OF GAS STREAM CHARACTERISTICS  
AT SITES 3 AND 4<sup>a</sup>

Run No.	Date (1981)	Flow rate <sup>b</sup>		Temperature		Moisture, % <sup>c</sup>	Velocity <sup>d</sup>		Flow rate <sup>e</sup>	
		dNm <sup>3</sup> /s	dscfm	°C	°F		m/s	ft/s	m <sup>3</sup> /s	acfm
C3-1	4/28	34.0	72,030	53.4	128	1.5	15.9	52.2	34.5	73,130
C3-2	4/29	34.0	72,060	52.8	127	1.5	15.9	52.2	34.5	73,160
C3-3	4/30	34.5	73,030	47.8	118	1.5	16.1	52.9	35.0	74,140
Average		34.2	72,370	51.3	124	1.5	16.0	52.4	34.7	73,480
C4V-1	4/27	6.5	13,830	33.4	92	1.5	32.7	107.3	6.6	14,040

<sup>a</sup> Average CO<sub>2</sub> and O<sub>2</sub> estimated at 0.6 percent and 19.4 percent, respectively. Site 3 is the scavenger duct, and Site 4 is the torch cutter.

<sup>b</sup> Dry normal cubic meters per second at 20°C and 101 kPa and dry standard cubic feet per minute at 68°F and 29.92 in.Hg.

<sup>c</sup> Estimated.

<sup>d</sup> Velocity at stack conditions.

<sup>e</sup> Flow rate at stack conditions.

Note: Scavenger duct flowrates are included in inlet values reported in Table 3-2. The flow through the torch cutter duct was blocked during the test series, but the reported data were obtained prior to testing.

TABLE 3-4. SUMMARY OF FILTERABLE PARTICULATE EMISSIONS DATA  
AT THE INLET, SITE NO. 1

Run No.	Date (1981)	Concentration <sup>a</sup>		Mass emission rate		Isokinetic rate, %
		mg/dNm <sup>3</sup>	gr/dscf	kg/h	lb/h	
C1P-1	4/28	149.9	0.0655	70.5	155.4	108
C1P-2	4/29	141.1	0.0617	70.5	155.3	107
C1P-3	4/30	210.9	0.0921	101.2	223.0	101
Average		167.3	0.0731	80.7	177.9	

<sup>a</sup> Milligrams per dry normal cubic meter at 20°C and 101 kPa and grains per dry standard cubic foot at 68°F and 29.92 in.Hg.

TABLE 3-5. SUMMARY OF PARTICULATE EMISSIONS DATA AT THE OUTLET, SITE NO. 2

Run No.	Date (1981)	Concentration <sup>a</sup>						Mass emission rate <sup>b</sup>						Iso-kinetic rate, %
		Filterable		Condensible				Filterable		Condensible				
		mg/dNm <sup>3</sup>	gr/dscf	Organic		Inorganic		kg/h	lb/h	Organic		Inorganic		
				mg/dNm <sup>3</sup>	gr/dscf	mg/dNm <sup>3</sup>	gr/dscf			kg/h	lb/h	kg/h	lb/h	
C2P-1	4/28	0.827	0.000365	0	0	0.372	0.000162	0.390	0.859	0	0	0.175	0.385	98.0
C2P-2	4/29	0.493	0.000217	0.069	0.000030	0.259	0.000113	0.246	0.542	0.035	0.077	0.130	0.286	98.7
C2P-3	4/30	0.650	0.000284	0.289	0.000126	0.449	0.000196	0.312	0.687	0.138	0.305	0.216	0.475	97.9
Average		0.657	0.000289	0.119	0.000052	0.360	0.000157	0.316	0.696	0.058	0.127	0.174	0.382	

<sup>a</sup> Milligrams per dry normal cubic meter at 20°C and 101 kPa and grains per dry standard cubic foot at 68°F and 29.92 in.Hg.

<sup>b</sup> Outlet mass emission rates are based on measured outlet concentrations and total inlet standard flow rates.

is the ratio of the velocity of the sample gas stream entering the nozzle to the local stack gas velocity, expressed as a percentage.

The volumetric flow rate at the combined inlet (Site 1) averaged  $134 \text{ dNm}^3/\text{s}$  (284,000 dscfm). The outlet flow rate averaged  $64 \text{ dNm}^3/\text{s}$  (135,000 dscfm), which was significantly lower than it should have been. This discrepancy is believed to be a result of the excessive back pressure on the exhaust system, which was caused by the small cross sectional area of the outlet stacks. Because of this back pressure, a large volume of cleaned exhaust gas exited the fabric filter through various openings in the structure as well as through the stacks. These flow measurements are discussed in more detail later in this section.

The actual flow rate at inlet Site 1 averaged  $153 \text{ m}^3/\text{s}$  (324,000 acfm) at  $53^\circ\text{C}$  ( $127^\circ\text{F}$ ) and approximately 1 percent moisture, and was equivalent to a gas velocity of  $22 \text{ m/s}$  (72 ft/s). The actual flow rate measured at outlet Site 2 averaged  $72 \text{ m}^3/\text{s}$  (152,000 acfm) at  $53^\circ\text{C}$  ( $127^\circ\text{F}$ ) and less than 1 percent moisture, which represented a gas velocity of  $6.5 \text{ m/s}$  (21 ft/s).

For calculation purposes, the stack gases were essentially air. During one run at each site, the carbon dioxide ( $\text{CO}_2$ ) concentration averaged less than 0.6 percent, and the oxygen concentration was 19.4 percent by volume.

Table 3-3 presents the results of velocity and flow measurements at the scavenger duct (Site 3) and the torch cutter duct (Site 4). For calculation purposes, gas composition data were

estimated from results of the particulate tests at Sites 1 and 2. The flow rate measured in the scavenger duct averaged  $34 \text{ dNm}^3/\text{s}$  (72,000 dscfm), which is included in the total flow reported for Site 1. At a stack temperature of  $51^\circ\text{C}$  ( $124^\circ\text{F}$ ), the actual flow rate averaged  $35 \text{ m}^3/\text{s}$  (73,000 acfm) and represented a gas velocity of  $16 \text{ m/s}$  (52 ft/s). Measurements of the normal flow rate in the torch cutter duct made before the duct was blocked off showed that the actual flow rate was  $6.6 \text{ m}^3/\text{s}$  (14,000 acfm) at  $33^\circ\text{C}$  ( $92^\circ\text{F}$ ), which represented a gas velocity of  $33 \text{ m/s}$  (107 ft/s). This flow was equivalent to  $6.5 \text{ dNm}^3/\text{s}$  (13,800 dscfm).

Tables 3-4 and 3-5 present particulate emission results. At Site 1 the average filterable particulate concentration was  $167 \text{ mg/dNm}^3$  (0.0731 gr/dscf), with a corresponding uncontrolled mass emission rate of  $80.7 \text{ kg/h}$  (178 lb/h). Condensible fractions were not determined at this site so as to avoid biases that could be caused by the long sample line used between the filter and first impinger.

At the outlet, the filterable particulate concentration averaged  $0.66 \text{ mg/dNm}^3$  (0.00029 gr/dscf). The organic and inorganic condensible concentrations averaged  $0.12 \text{ mg/dNm}^3$  (0.00005 gr/dscf) and  $0.36 \text{ mg/dNm}^3$  (0.00016 gr/dscf), respectively. The reported mass emission rates are based on the total flow rates measured at inlet Site 1 rather than on the flow rates measured at the outlet, which were biased low. Thus, they provide a realistic estimate of the total particulate matter exiting the fabric filter. The filterable, organic condensible, and

inorganic condensible emission rates averaged 0.32, 0.06, and 0.17 kg/h (0.70, 0.13, and 0.38 lb/h), respectively.

Isokinetic sampling rates ranged between 101 and 108 percent at the inlet and were either 98 or 99 percent at the outlet.

### 3.1.2 Control Efficiencies and Emission Factors

Control efficiencies were calculated by dividing the difference between the outlet and inlet particulate concentrations by the inlet value. Table 3-6 presents a summary of filterable particulate concentrations and indicates the fabric filter collection efficiency for each run. Control efficiencies were 99.4, 99.6, and 99.7 percent on the three test days.

Table 3-7 presents filterable particulate emission factors for uncontrolled and controlled emissions in terms of emission rate per unit of furnace metal capacity. Factors were calculated by dividing the appropriate hourly mass emission rate by the furnace capacity of 18.1 Mg (20 tons). Results are reported in kilograms per hour per megagram of furnace capacity (kg/h per Mg) and in pounds per hour per ton (lb/h per ton). The emission factor for uncontrolled emissions averaged 4.5 kg/h per Mg, or 8.9 lb/h per ton. The average controlled emission factor was 0.018 kg/h per Mg (0.035 lb/h per ton).

The emission factors shown in Table 3-8 are based on actual production data. Results were calculated by dividing the filterable mass emission rate by the corresponding average production rate. Emission factors are reported in kilograms per



TABLE 3-6. FILTERABLE PARTICULATE COLLECTION EFFICIENCY

Run	Inlet concentration		Outlet concentration		% efficiency <sup>c</sup>
	mg/dNm <sup>3a</sup>	gr/dscf <sup>b</sup>	mg/dNm <sup>3</sup>	gr/dscf	
1	150	0.0655	0.827	0.000365	99.4
2	141	0.0617	0.493	0.000217	99.6
3	211	0.0921	0.650	0.000284	99.7
Average	167	0.0731	0.657	0.000289	99.6

<sup>a</sup>Milligrams per dry normal cubic meter at 20°C and 191 kPa.

<sup>b</sup>Grains per dry standard cubic foot at 68°F and 29.92 in.Hg.

<sup>c</sup>Percent efficiency =  $\frac{C_{\text{inlet}} - C_{\text{outlet}}}{C_{\text{inlet}}} \times 100$ .

TABLE 3-7. PARTICULATE EMISSION FACTORS BASED ON FURNACE CAPACITY<sup>a</sup>

Run No.	Uncontrolled		Controlled	
	kg/h per Mg	lb/h per ton	kg/h per Mg	lb/h per ton
1	3.90	7.77	0.022	0.043
2	3.90	7.76	0.014	0.027
3	5.59	11.2	0.017	0.034
Average	4.46	8.91	0.018	0.035

<sup>a</sup>Factors are based on emissions per unit of furnace metal capacity in kilograms per hour per megagram (pounds per hour per ton). The furnace capacity is 18.1 Mg (20 tons).

TABLE 3-8. PARTICULATE EMISSION FACTORS BASED ON PRODUCTION<sup>a</sup>

Run No.	Metal production rate <sup>b</sup>		Emission factor <sup>c</sup>			
			Uncontrolled		Controlled	
	Mg/h	tons/h	kg/Mg	lb/ton	kg/Mg	lb/ton
1	9.5	10.5	7.42	14.8	0.041	0.082
2	8.6	9.5	8.20	16.3	0.029	0.057
3	9.3	10.3	10.9	21.6	0.034	0.067
Average	9.1	10.1	8.84	17.6	0.035	0.069

<sup>a</sup>Calculated by dividing the filterable mass emission rate by the corresponding average metal production rate.

<sup>b</sup>From Table 2-1.

<sup>c</sup>Kilograms per megagram (pounds per ton) of metal produced.

megagram (pounds per ton) of metal produced. The average uncontrolled emission factor was 8.8 kg/Mg (18 lb/ton), based on a production rate of 9.1 Mg/h (10.1 ton/h). At the same production rate, controlled emissions averaged 0.035 kg/Mg (0.069 lb/ton).

### 3.1.3 Discussion

In general, the particulate tests were conducted according to schedule. Only minor problems were encountered with the sampling equipment and the process operation. The report does not include the results of preliminary tests that were conducted at Sites 1 and 2 to compare particulate loadings with estimated sampling times and to eliminate any problems associated with test coordination or physical sampling maneuvers. This section discusses validity of results, the discrepancy between inlet and outlet flow rates, and effects of process operations.

The primary purpose of the long sampling time was twofold: (1) to collect approximately 25 to 50 mg in the front half of the outlet sampling train so as to minimize handling and weighing errors; and (2) to satisfy NSPS minimum requirements for sample time and volume. The actual filterable catch weights, which ranged between 5.7 and 8.9 mg, were considerably lower than desired. The actual minimum sampling time and volume were 8 hours and  $10.8 \text{ dNm}^3$  (380 dscf), which met the minimum criteria of 4 hours and  $4.5 \text{ dNm}^3$  (160 dscf) set forth for EAF's in Subpart AA of the Federal Register.\*

---

\* 40 CFR 60, Subpart AA, July 1980.

The analyses of filterable particulate matter should provide results within the expected limits of accuracy for Method 5. Several factors support this conclusion: 1) all repeat weighings of filters and acetone rinses were within 0.2 mg, which is closer than the 0.5 mg allowed by the method; 2) the acetone used was within method specifications (impurities were 0.006 mg/g versus a tolerance of 0.01 mg/g); 3) the analysis of the particulate filter blank agreed within 0.4 mg of the original tare weight (Method 5 gives no criterion for this); and 4) a glass-lined probe was used to minimize possible sample biases. The maximum possible margin for error associated with net acetone blank adjustments, filter blanks, and repeat weighings was estimated to be about 30 percent. Actual error was probably much lower on the average; therefore, results were considered to be acceptable.

Condensible concentrations measured at the outlet compared favorably with expected values based on previously reported tests at EAF's and AOD's. Test results indicated that a significant portion (30 to 50 percent) of total emissions was being collected in the impinger section of the sampling train.

Sampling equipment problems were minor. Although the probe heat failed during Run 1 at the inlet site, it was heating properly during about 30 percent of the test, and a comparison of Run 1 results with those of the other two runs indicated that particulate concentrations had not been significantly affected. Sampling at the outlet during Run 3 was delayed for a short period while the filter holder heating system was being repaired. This delay did not affect the results.

Inlet flow rates measured at Site 1 agreed very well with the system design flow rate of  $142 \text{ m}^3/\text{s}$  (300,000 acfm); all runs were within 12 percent of this value. This satisfactory agreement supported the decision to sample at Site 1 despite its failure to meet minimum Method 1 criteria.

All flow rates measured at the scavenger duct were within 2.5 percent of the design flow of  $35 \text{ m}^3/\text{s}$  (75,000 acfm). Comparison of the combined inlet and scavenger duct flow rates indicated that approximately 25 percent of the control system's capacity was used to capture fugitive emissions and 75 percent to capture primary process emissions.

Although the system for the capture of torch cutter emissions represented only 5 percent of the total volumetric capacity of the entire No. 2 AOD control system, the EPA requested that it be disconnected for the duration of the test series so that only AOD emissions could be determined. Based on visual observations, particulate loading at the torch cutter operation was much lower in magnitude than the AOD process emissions. Therefore, the impact of this source on total fabric filter emissions under normal operating conditions is probably insignificant.

Measured outlet flow rates were approximately half of those expected. Actual velocity measurements are considered to be representative of conditions at the time of the tests and accurate within the limits of EPA Method 2. This conclusion is supported by the following: 1) the site met minimum Method 1

criteria, 2) all procedures of Method 2 were followed properly, 3) checks for cyclonic flow were negative during both the test series and the pretest survey, 4) all five stacks were traversed during each test, 5) Cartech's previous measurements at this site indicated similar low flow rates,<sup>3</sup> and 6) inlet flow rates were validated.

The difference between measured inlet and outlet flow rates is believed to have resulted from an excessive back pressure on the exhaust system. Because the cross-sectional area provided by the five stacks is so small, some exhaust gases must exit through other available openings. Among the possible exit points were the interior walkway gratings at the bottom level of the bags. Even though Cartech personnel had covered these openings with Masonite panels prior to the test series, the low stack flow rates indicated that some gases still managed to escape. It was also evident that, contrary to conditions at similar installations, these gratings were not sources of air inleakage at this facility. Other possible gas exit points included the seams between the compartment walls, roof, and access doors. All possible exit points were considered to be on the clean side of the fabric filter because there was no visually detected leakage of particulate-laden gases. Because the measured stack flow rates were biased low and the measured outlet particulate concentrations were considered to be representative, the total inlet flow rate was used to calculate a more realistic estimate of the

outlet mass emission rate. The gas flow of the reverse-air cleaning system was not added to the inlet flow because the reverse-air system recirculated cleaned exhaust gas and did not represent an increase in net flow out of the fabric filter. Also, based on the agreement between the measured and design inlet flows, air inleakage at the induced draft (I.D.) fans was probably negligible. Although comparison of inlet and outlet moisture contents seemed to indicate some dilution, accuracy limitations of moisture determinations at the 1 to 2 percent level are probably greater than the reported differences. The close agreement between average inlet and outlet gas temperatures indicated that any entry of dilution air was less than 10 percent. There was an apparent discrepancy between the inlet and outlet gas temperatures measured during Run 2, but it was not significant because the difference was within the 1.5 percent criterion specified in Method 2. Because the flow rate measured at Site 1 was considered representative of the net system flow, the outlet mass emission rates reported in the text and tables reflect this flow rate. Calculations used to adjust the computer output are shown in Appendix A. These calculations did not affect any other parameters.

The concentration of particulate matter measured at the stack outlets was considered to be representative of the gases escaping through openings other than the stacks. Although the measured outlet particle size distributions indicated that the number of large particles present was greater than expected,



these distributions were thought to be biased by a combination of factors (which are discussed later in this section): 1) increased collection efficiency of upper impactor stages, 2) weighing errors, and 3) particle agglomeration. A similar type of particle size distribution (i.e., greater than expected number of large particles) also was shown by a separate test series at an EAF/AOD installation that did not show a loss of gas flow between inlet and outlet test sites. This comparison tends to support the conclusion that an apparent high number of large particles does not necessarily indicate a biased particulate concentration. In addition, observations of the fabric filter structure and stack outlets did not reveal any visually detectable differences in opacity of the gases exiting the stacks and the gases escaping via other means. Therefore, the particulate concentrations measured at the stack outlets are considered to be representative.

Evaluation of the process data furnished by MRI seemed to indicate that the No. 2 AOD system was operating normally during the test series. The several short process-related delays in testing did not seem to affect emission results. The increase in uncontrolled emissions indicated by Run 3 was substantiated by the results of the particle size test during the same period; however, the increase could not be related to specific process activities. Overall, process operations were relatively consistent. The average production rates for each test were within 10 percent of each other and compared favorably with normal

values. Emission results were therefore considered to be representative of normal operations.

### 3.2 PARTICLE SIZE

Tests for particle size distribution were conducted at Site 1 to represent uncontrolled emissions, and at Site 2 to represent controlled emissions. These tests were performed in conjunction with particulate matter tests.

Inlet particle size tests were conducted over three entire heat cycles to represent average emissions, and during shorter intervals to provide supplemental data. Tests during integral heats were initiated at the beginning of a charge, continued for three heats, and concluded at the end of tapping operations. This yielded a sampling time of approximately 5 hours, which was necessary to collect an adequate sample in the impactor that was used. The shorter particle size runs were performed at various times during the particulate test. The sampling times for these shorter tests were approximately 5 to 15 minutes, adjusted as necessary to obtain proper loadings.

Particle size distribution samples were collected at the outlet simultaneously with each particulate test, which yielded a sampling time of between 7.5 and 9 hours for each run. All five stacks were sampled during each run in a manner that minimized interferences with the coinciding particulate tests. Fabric filter cleaning cycles were sampled as they occurred.

The NSPS contractor's representative assisted in the coordination of the integral heat runs at the inlet with process operations. Tests were interrupted when he considered it necessary to avoid sampling during unrepresentative conditions.

Andersen Mark III Cascade Impactors were used to collect the shorter inlet samples and all of the outlet samples, and an Andersen Heavy Grain Loading Impactor was used to obtain integral heat samples. All inlet samples were collected at an average velocity point in the combined inlet duct (Site 1). Outlet samples were run in duplicate, with the impactors positioned at average velocity points in each of the five stacks. The sample time for each run was divided equally among the five stacks. Velocity data were obtained periodically during each run by the use of Method 2 equipment. The report presents the results of three runs for each type of sample.

#### 3.2.1 Particle Size Distributions and Fractional Efficiencies

Cumulative distribution curves represent the total weight percent of particulate matter smaller than the indicated aerodynamic particle diameter in micrometers. Each distribution curve represents the best-fit average curve through test data points. Each data point was plotted manually and indicates both the 50 percent effective cut-size of each impactor stage and the cumulative weight percent of material collected in subsequent stages.

The three cut-points for each Andersen Heavy Grain Loading Impactor test at Site 1 were determined graphically from information supplied by the manufacturer. 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>4</sup> All particle size results are based on a particle density of one gram per cubic centimeter. Data reduction and intermediate result calculations for both types of impactors were performed by the CIDRS programs with moisture contents obtained from simultaneous particulate tests. All calculations and results are included in Appendix A.

Figure 3-1 shows the average cumulative distribution curve for uncontrolled emissions. Results of the integral heat tests and shorter interval tests agreed very well with each other and were plotted on the same graph. The average distribution indicated that 50 percent by weight of uncontrolled particulate emissions consisted of particles with aerodynamic diameters of 1.2  $\mu\text{m}$  or less. Approximately 81 percent by weight had diameters of 10  $\mu\text{m}$  or less.

Figure 3-2 shows the average distribution curve for the outlet samples. Results indicated that approximately 50 percent of the mass emissions consisted of particles having aerodynamic diameters of 10  $\mu\text{m}$  or less. Only 20 percent by weight had diameters of 3.0  $\mu\text{m}$  or less.

Table 3-9 presents the fractional collection efficiencies for various size ranges. Weight percents in each size range were determined from the average inlet and outlet cumulative distribution curves plotted in Figures 3-1 and 3-2. Controlled and

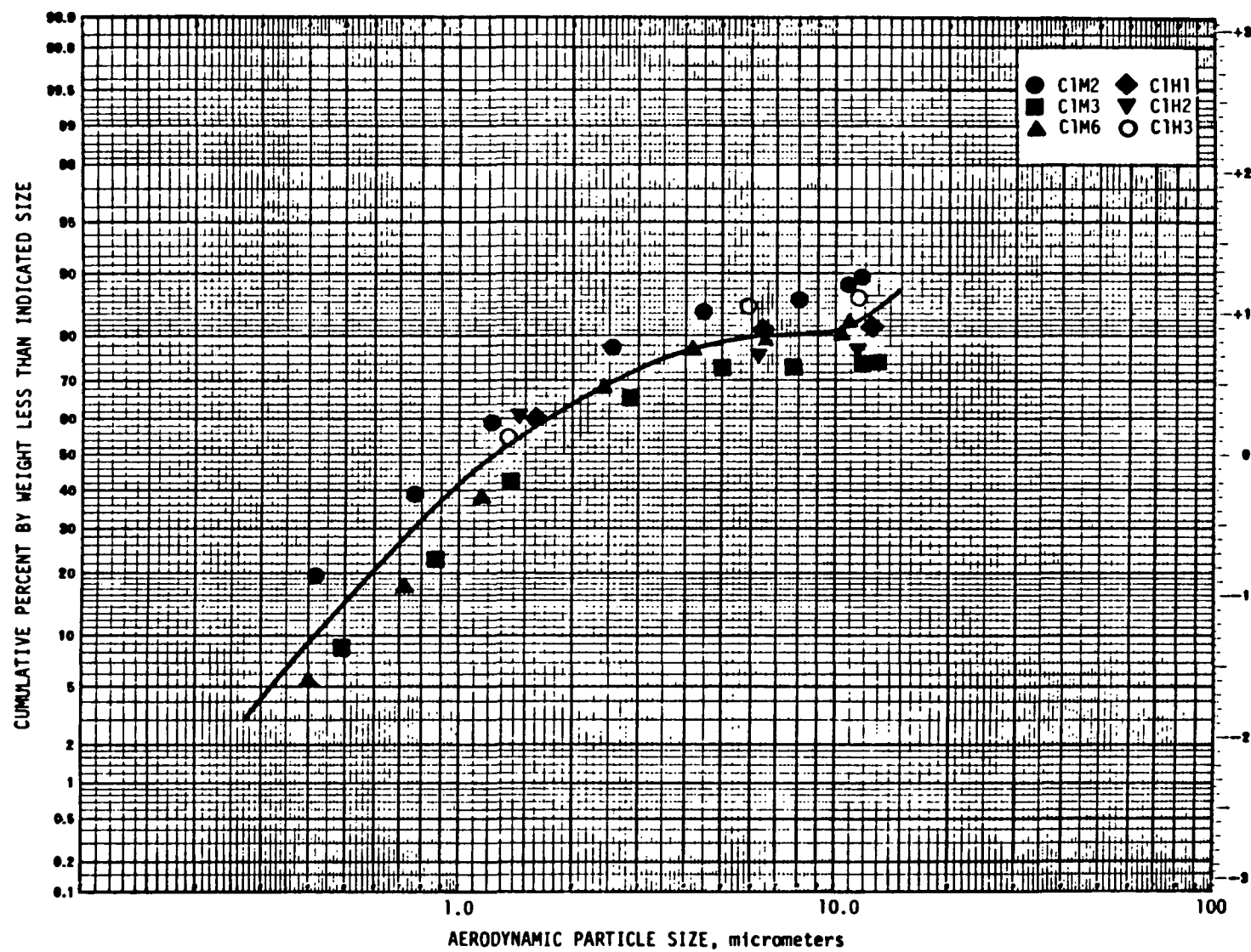


Figure 3-1. Average particle size results for uncontrolled emissions, Site 1.

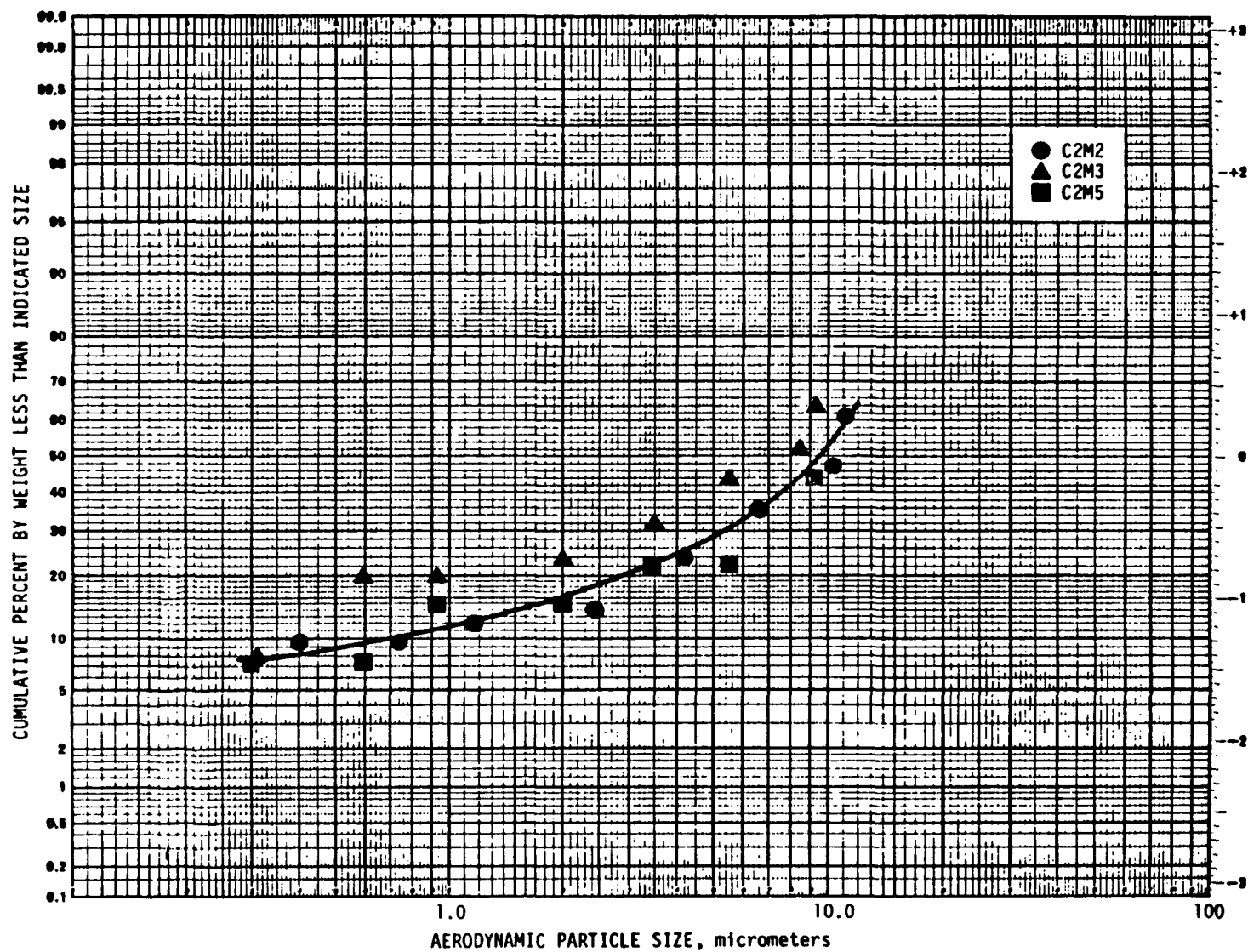


Figure 3-2. Average particle size results for controlled emissions, Site 2.

TABLE 3-9. SUMMARY OF PARTICLE SIZE DISTRIBUTION AND FRACTIONAL EFFICIENCY

		Aerodynamic particle size range, micrometers						
		D<0.5	0.5<D<1.0	1.0<D<2.5	2.5<D<5	5<D<10	D>10 $\mu$ m	Total
Cumulative weight percent less than larger stated size <sup>a</sup>	Inlet	15	15-42	42-70	70-78	78-82	-	100
	Outlet	9	9-12	12-18	18-28	28-53	-	100
Weight percent in stated size range	Inlet	15	27	28	8	4	18	100
	Outlet	9	3	6	10	25	47	100
Particulate concentration in stated size range, <sup>b</sup> mg/dNm <sup>3</sup>	Inlet	25.0	45.1	46.8	13.4	6.7	30.1	167
	Outlet	0.059	0.020	0.039	0.066	0.164	0.309	0.657
(gr/dscf)	Inlet	0.0110	0.0197	0.0205	0.0058	0.0029	0.0132	0.0731
	Outlet	0.000026	0.000009	0.000017	0.000029	0.000072	0.000135	0.000289
Fractional collection efficiency in stated size range <sup>c</sup>		99.8	>99.9	99.9	99.5	97.6	99.0	99.6

<sup>a</sup>Weight percents are taken from plots of average distributions.

<sup>b</sup>Filterable particulate concentration = total emissions x weight percent in stated size range; concentrations given in terms of milligrams per dry normal cubic meter at 20°C and 101 kPa and grains per dry standard cubic foot at 68°F and 29.92 in.Hg. Total concentrations were taken from Method 5 test results.

<sup>c</sup>Collection efficiency =  $\frac{\text{Inlet concentration} - \text{outlet concentration}}{\text{inlet concentration}} \times 100$ .

uncontrolled mass loadings in the respective size ranges were calculated by multiplying these weight percentages by the average inlet and outlet particulate concentrations shown in Table 3-6. Fractional efficiencies were calculated for each size range by dividing the difference between inlet and outlet concentrations by the inlet values. The overall efficiency was 99.6 percent; the range was from a high of 99.9+ percent for particles between 0.5 and 1.0  $\mu\text{m}$  in diameter to a minimum of 97.6 percent for particles between 5 and 10  $\mu\text{m}$  in diameter.

### 3.2.2 Discussion of Results

All test run results are not reported. Some runs were not included because of poor isokinetics, undesirable stage loadings, or problems related to impactor assembly.

When evaluating these results, one should keep in mind that particle sizes are in terms of aerodynamic diameters based on a particle density of 1  $\text{g}/\text{cm}^3$ . Cumulative distribution curves based on physical diameters and actual density would be shifted to the left toward smaller sizes if the actual density were greater, and vice versa. A quick approximation of the physical diameter can be obtained by dividing the reported aerodynamic diameter by the square root of the actual particle density. For example, the specific gravity of the fabric filter dust samples was about 3.8  $\text{g}/\text{cm}^3$ . Using this particle density would increase the amount of controlled emissions of particles smaller than 5  $\mu\text{m}$  from roughly 30 to 50 cumulative weight percent.



As expected, results of the Mark III blank run at the outlet indicated that stack gases did not react with the glass fiber filter media to create false weight changes.

Results representing average uncontrolled emissions over an entire heat cycle compared very well with results of the shorter tests conducted during the 3:1 oxygen-to-argon blow phase of operation. Because of this agreement, both sets of data were plotted on the same graph. The resultant distribution generally agreed with expected results based on previous EAF/AOD data. Except for the first set of runs, the particulate concentrations indicated by the integral heat and shorter particle size tests compared favorably with the results of particulate tests conducted over similar time frames. The differences between the first set of runs may be related to the variation in emissions over the short term.

The isokinetic sampling rates for five of the six reported inlet tests were between 91 and 101 percent. The isokinetic sampling rate for one of the shorter Mark III runs was 67 percent, but the distribution results agreed with the other runs. The sampling flow rates were all within limits suggested by the manufacturer, and results are believed to be within generally expected limits of accuracy.

Particle size distributions at the outlet showed a higher number of large particles than expected; 80 to 90 cumulative weight percent of the particles were expected to have aerodynamic diameters of about 2.5  $\mu\text{m}$  or less. One of several plausible

explanations for the apparent discrepancy is the possibility of bias as a result of increased efficiency in the upper impactor stages when glass fiber filters are used.<sup>5</sup> Although examination of analytical results indicated that this may have occurred, it could not be verified. Adjusting outlet results for this type of bias would not completely account for the difference between actual and expected results, however.

A partial explanation of the results could be related to the very low sample weights. Despite the long sampling times (7.5 to 9 hours) and large sample volumes [5.6 to 9.8 dNm<sup>3</sup> (198 to 347 dscf)], the total catch weights were low (between 2.5 and 4.2 mg). Approximately 30 to 55 percent of the catch weights were collected in the acetone rinse of the nozzle and inlet chamber. Because each total catch represents 10 separate analyses (9 filters and 1 rinse), weighing errors could have contributed to the discrepancy between actual and expected results, but would not completely account for the difference. The particle size distributions indicated by the three runs were in relative agreement, and the particulate concentrations indicated by two of the runs were within 65 to 90 percent of the results from simultaneous particulate tests (which is good agreement for the two different methods).

Another explanation could be related to particle agglomeration caused by electrostatic charge. Although the existence of such a charge was not verified at this site, it has occurred before at an EAF/AOD installation. This agglomeration could

account for the discrepancy between expected and actual distribution results.

Sampling procedures probably had no effect on results. All the isokinetic sampling rates averaged between 99 and 102 percent, and all sampling flow rates were within the limits suggested by the manufacturer.

The results probably were affected by a combination of the following: 1) increased collection efficiency of the upper stages, 2) weighing errors, and 3) particle agglomeration. Therefore, the reported distributions for outlet emissions are believed to be biased, and describing them by mean particle size and geometric standard deviation would be misleading.

### 3.3 VISIBLE AND FUGITIVE EMISSIONS

Evaluation of visible emissions from the melt shop roof and five fabric filter stacks took place simultaneously with particulate concentration tests. Emissions were observed in 6-minute sets, and individual opacity readings were recorded at 15-second intervals according to Method 9\* procedures. Fugitive emissions from the fabric filter dust-handling system were evaluated periodically according to procedures outlined in the proposed Method 22.\*\* Fugitive emissions were recorded as the cumulative minutes of any emissions visually detectable during 20-minute observation periods.

---

\* 40 CFR 60, Appendix A, July 1, 1980.

\*\* Federal Register, Vol. 45, No. 224, November 18, 1980.

### 3.3.1 Results

Table 3-10 summarizes the results of all visible and fugitive emission observations. No emissions were visually detectable at any time during normal operations. Most of the data were collected during Run 1 because adverse weather conditions prevented additional observations during Runs 2 and 3. A total of 69 six-minute observations were made at the melt shop during 13 hours of process operation covering all modes of furnace operation. A total of 68 six-minute sets of opacity data were collected at the fabric filter outlet. The fabric filter dust-handling system was observed for a total of 60 minutes.

### 3.3.2 Discussion

Capture of melt shop emissions during charging, tapping, and other process operations was efficient. It is important to note that only the area of the melt shop surrounding the No. 2 AOD was observed; the continuous casting shop and the No. 1 AOD were not. Several of the 6-minute set times did not coincide exactly with actual charging and tapping times. Because emission points were casually monitored during break periods, and readings were to be resumed if emissions greater than zero percent opacity were noticed, the average opacity for these charging and tapping periods was considered to be zero percent. During the 13 hours of operation, a total of seven charges and seven taps were observed. The emissions caused by a fire at the No. 1 AOD during Run 1 were recorded but not included in the summary.

TABLE 3-10. SUMMARY OF VISIBLE AND FUGITIVE EMISSIONS<sup>a</sup>

Melt shop <sup>b</sup>					
Date (1981)	Run No.	Point of emissions	Number of sets	Range of readings, % opacity	Range of set averages, % opacity
4/28	1	Roof	48	0	0
4/29	2	Roof	8	0	0
4/30	3	Roof	13	0	0
Fabric filter outlet					
Number of sets		Range of readings, % opacity		Range of set averages, % opacity	
68		0		0	
Fugitive emissions from fabric filter dust handling system					
Accumulated observation period, minutes		Accumulated emission time			
		minutes		% of observation period	
60		0		0	

<sup>a</sup>Data were collected during 9.5 hours of process operation on April 28, 1.5 hours on April 29, and 2 hours of April 30. Unfavorable weather conditions prevented additional readings on April 29 and 30.

<sup>b</sup>On April 28 an abnormal situation at the No. 1 AOD, which occurred between 4:38 and 4:43 p.m., caused visible emissions at the No. 2 AOD. The average opacity for that period was 6 percent.

The lack of visible emissions from the fabric filter outlet indicated efficient control of particulate matter in terms of opacity. No emissions were detected at any time, even after compartment cleaning cycles, and these results were supported by the low particulate concentration results.

Fugitive emission data for the fabric filter dust-handling system may be misleading in that the system probably was not in operation during most of the observation period.

### 3.4 FABRIC FILTER DUST SAMPLES

Samples of dust collected by the fabric filter were obtained daily from the waste container into which the hopper screw conveyors emptied. Samples were collected in a manner that did not interfere with other ongoing tests. The laboratory split each sample into two fractions for separate analyses of trace elements by spark source mass spectroscopy (SSMS) and for particle size distribution by Coulter Counter.

#### 3.4.1 Trace Elements

Table 3-11 summarizes the results of SSMS analyses on the three dust samples. Concentrations are given in micrograms of element per gram of sample. Less-than (<) and greater-than (>) marks are used to denote concentrations outside the quantification limits for the particular element and sample analysis. The minimum detection limit for most of the elements was 0.1 µg/g, although it was as high as 0.8 µg/g in some cases. Major constituents are listed as >1000 µg/g. Results for several elements

TABLE 3-11. SUMMARY OF TRACE ELEMENT ANALYSES ON  
FABRIC FILTER DUST SAMPLES

Element	Sample 1	Concentration, $\mu\text{g/g}$ (ppm weight)	
		Sample 2	Sample 3
Aluminum	> 90	> 130	> 96
Antimony	7	10	8
Arsenic	19	27	20
Barium	430	140	260
Beryllium	< 0.1	< 0.1	< 0.1
Bismuth	70	45	33
Boron	2	5	2
Bromine	8	11	8
Cadmium	27	10	7
Calcium	>1000	>1000	>1000
Carbon	NR <sup>a</sup>	NR	NR
Cerium	2	6	2
Cesium	1	2	1
Chlorine	510	740	540
Chromium	>1000	>1000	>1000
Cobalt	>1000	>1000	>1000
Copper	>1000	>1000	>1000
Dysprosium	< 0.1	< 0.1	< 0.1
Erbium	< 0.1	< 0.1	< 0.1
Europium	< 0.1	0.3	0.2
Fluorine	>1000	>1000	>1000
Gadolinium	< 0.1	< 0.1	< 0.1
Gallium	75	110	80
Germanium	9	13	10
Gold	< 0.1	< 0.1	< 0.1
Hafnium	< 0.1	$\leq$ 0.8	< 0.1
Holmium	< 0.1	< 0.1	< 0.1
Hydrogen	NR	NR	NR
Indium	STD <sup>b</sup>	STD	STD
Iodine	0.4	0.6	0.5
Iridium	< 0.1	< 0.1	< 0.1
Iron	>1000	>1000	>1000
Lanthanum	0.9	5	2
Lead	>1000	>1000	>1000
Lithium	3	8	6
Lutetium	< 0.1	< 0.1	< 0.1
Magnesium	>1000	>1000	>1000
Manganese	> 920	>1000	>1000
Mercury	NR	NR	NR
Molybdenum	>1000	>1000	>1000
Neodymium	$\leq$ 0.4	0.6	0.5

(continued)

TABLE 3-11 (continued)

Element	Sample 1	Concentration, $\mu\text{g/g}$ (ppm weight)	
		Sample 2	Sample 3
Nickel	>1000	>1000	>1000
Niobium	21	17	12
Nitrogen	NR	NR	NR
Osmium	< 0.1	< 0.1	< 0.1
Oxygen	NR	NR	NR
Palladium	< 0.1	< 0.1	< 0.1
Phosphorus	390	560	170
Platinum	< 0.1	< 0.1	< 0.1
Potassium	>1000	>1000	>1000
Praseodymium	0.2	0.9	0.4
Rhenium	< 0.1	< 0.1	< 0.1
Rhodium	< 0.1	< 0.1	< 0.1
Rubidium	16	51	21
Ruthenium	< 0.1	< 0.1	< 0.1
Samarium	< 0.1	1	0.5
Scandium	< 0.1	< 0.1	< 0.1
Selenium	280	640	290
Silicon	>1000	>1000	>1000
Silver	84	140	40
Sodium	> 230	> 330	< 250
Strontium	65	53	31
Sulfur	> 560	> 810	> 600
Tantalum	< 0.3	< 0.1	< 0.1
Tellurium	0.7	2	0.7
Terbium	< 0.1	< 0.1	< 0.1
Thallium	2	6	5
Thorium	< 0.8	2	< 0.8
Thulium	< 0.1	< 0.1	< 0.1
Tin	16	26	19
Titanium	>1000	680	150
Tungsten	89	73	85
Uranium	< 0.6	0.9	0.7
Vanadium	270	99	180
Ytterbium	< 0.1	< 0.1	< 0.1
Yttrium	0.7	1	0.7
Zinc	>1000	>1000	>1000
Zirconium	3	4	6

<sup>a</sup>Not reported.<sup>b</sup>Internal standard.



are not reported, and indium was added to each sample as an internal standard. Elements are listed alphabetically for convenience. The analytical results included in Appendix C are listed in order of decreasing atomic number.

#### 3.4.2 Particle Size Distribution

Figure 3-3 shows the best-fit cumulative distribution curve for the three dust samples. This curve represents the weight percent of particulate matter smaller than the indicated physical particle diameter (in micrometers). Each data point was plotted manually from differential distribution data reported by the laboratory. The average curve indicated that 50 percent by weight of collected dust consisted of particles with physical diameters of 1.6  $\mu\text{m}$  or less. Ninety-eight percent by weight had diameters of less than 10  $\mu\text{m}$ .

#### 3.4.3 Discussion

Concentrations of several trace elements seem to vary considerably. Such variation could be related to the different specifications of the metal in the furnaces. It should be remembered, however, that the SSMS analytical technique is more qualitative than quantitative. The results of the audit samples shown in Tables 5-5 and 5-6 bear this out in that they indicate that reported element concentrations are only accurate within a factor of  $\pm 3$ .

When evaluating the particle size results, one should note that the cumulative distribution curves are based on physical diameters rather than aerodynamic diameters as reported for

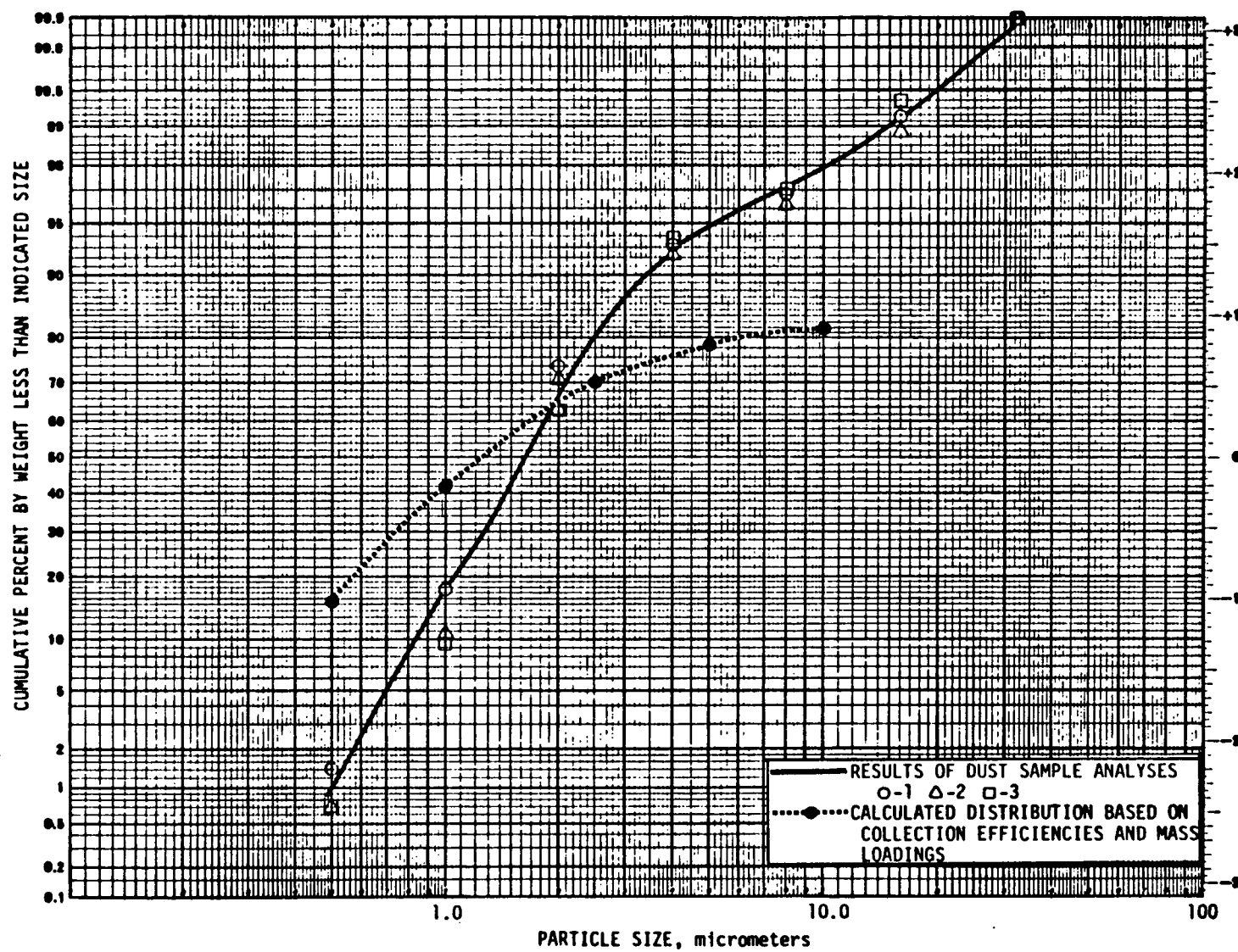


Figure 3-3. Average particle size distribution of fabric filter dust samples.

emission tests. An approximation of the aerodynamic diameters can be made by multiplying the reported physical diameters by the square root of the actual particle density. Using the specific gravity analysis results of  $3.8 \text{ g/cm}^3$  would decrease the amount of dust smaller than  $5 \text{ }\mu\text{m}$  from approximately 95 to 80 cumulative weight percent.

The reported cumulative weight distributions also assume that all particles have the same density. This assumption was necessary to convert particle volume data measured by the Coulter Counter to a weight basis.

The Coulter Counter results were compared with a theoretical size distribution based on emission test results at the inlet and outlet sites. This theoretical cumulative weight curve was estimated from the average size distributions, fractional efficiencies, and mass loadings listed in Table 3-9. The Coulter Counter and theoretical curves both indicated that 65 cumulative weight percent of the collected dust consisted of particles with aerodynamic diameters of approximately  $2.0 \text{ }\mu\text{m}$  or less. The curves differed considerably at other sizes, but this may be related to the different test methods.

### 3.5 SUPPLEMENTAL ANALYSES FOR FLUORIDE, CHROMIUM, LEAD, AND NICKEL

Several outlet samples and fabric filter dust samples were analyzed for particulate fluoride content by procedures described in EPA Method 13B\*, and for chromium, lead, and nickel content

---

\* 40 CFR 60, Appendix A, July 1980.

by Atomic Absorption Spectrophotometry. These analyses were performed subsequent to the completion of originally scheduled laboratory work for better quantification of emission levels that SSMA analyses on the fabric filter dust samples had indicated as being greater than 1000  $\mu\text{g/g}$ .

Separate fluoride analyses were performed on two acetone rinses and one filter from the outlet filterable particulate samples, two of the fabric filter dust samples, and appropriate blanks. Metal analyses were performed on two outlet filterable particulate samples (acetone rinse and filter combined), two dust samples, and appropriate blanks. The fourth outlet sample was obtained from the shorter preliminary test run.

Laboratory results of fluoride and metal analyses on the outlet samples were reported as milligrams of pollutant. The species concentration (in micrograms per gram) was calculated by dividing the mass of pollutant by the mass of particulate matter reported in earlier gravimetric analyses. The laboratory results for dust samples were reported in concentrations of milligrams per gram, which were easily converted to micrograms per gram. The two concentration results of each species and sample type were averaged. Average concentrations were multiplied by average filterable particulate emission results to determine pollutant gas stream concentrations, mass emission rates, and emission factors. For this purpose, results of dust sample analyses were assumed to be representative of uncontrolled emissions. Results are summarized in Table 3-12.

TABLE 3-12. SUMMARY OF SUPPLEMENTAL ANALYSES FOR  
FLUORIDE, CHROMIUM, LEAD, AND NICKEL

Uncontrolled emissions <sup>a</sup>									
Pollutant species	Concentration			Emission rate		Emission factors			
	µg/g of solid	mg/dNm <sup>3</sup>	gr/dscf	kg/h	lb/h	kg/h/Mg	lb/h/ton	kg/Mg	lb/ton
Fluoride	15,200	2.5	0.0011	1.2	2.7	0.068	0.14	0.13	0.27
Chromium	49,200	8.2	0.0036	4.0	8.8	0.22	0.44	0.43	0.87
Lead	2,200	0.37	0.0002	0.18	0.39	0.0098	0.020	0.019	0.039
Nickel	21,500	3.6	0.0016	1.7	3.8	0.096	0.19	0.19	0.38
Controlled emissions <sup>b</sup>									
Fluoride <sup>c</sup>	10,300	0.0068	0.000003	0.0033	0.0072	0.0002	0.0004	0.0004	0.0007
Chromium	7,600	0.0050	0.000002	0.0024	0.0053	0.0001	0.0003	0.0003	0.0005
Lead <sup>d</sup>	<2,300	<0.0015	<7 x 10 <sup>-7</sup>	<0.0007	<0.0016	<0.00004	<0.00008	<0.00008	<0.0002
Nickel	6,800	0.0045	0.000002	0.0021	0.0047	0.0001	0.0002	0.0002	0.0005

<sup>a</sup>Based on average uncontrolled particulate emissions and the average of analyses on two dust samples, assuming that the concentration in the uncontrolled gas stream is the same as in the collected dust.

<sup>b</sup>Based on average controlled particulate emissions and the average of analyses on two outlet samples.

<sup>c</sup>Based on analyses of acetone rinses only; the glass fiber filter analysis had a high blank weight of fluoride and was not used.

<sup>d</sup>Lead concentrations were below the analytical detection limits for these samples; numerical values for emissions are based on the minimum detectable mass of lead.

The outlet fluoride results are based on acetone rinse analyses only because the filter analysis had a high blank value of fluoride. This was caused by the filter material, which was glass fiber instead of paper as specified by Method 13B. The total filter blank value was two times larger than the net fluoride on the filter, which increased the possibility of error in the results. Because the amount of fluoride in the acetone rinse was much smaller than that indicated by the filter analysis, a small error in the filter results would have a significant impact on total fluoride. For these reasons, and because the filter result indicated a much higher concentration of fluoride than did the acetone rinse results, the filter analysis was disregarded. Should the filter result be correct, the outlet fluoride concentration would be 40,700  $\mu\text{g/g}$  instead of the 10,300  $\mu\text{g/g}$  indicated in the table. This would not compare favorably with the 15,200  $\mu\text{g/g}$  of fluoride measured in the dust samples because it would contradict the trend of the other results, which indicate lower pollutant concentrations in the outlet samples than in the dust samples.

The mass of lead in each outlet sample was less than the minimum detection limit. The concentration of lead (in micrograms per gram) was therefore calculated by dividing the minimum detectable mass of lead by the particulate sample weight. A less-than mark (<) is used in the table to indicate that emissions are based on the equivalent minimum detection limit.

## SECTION 4

### SAMPLING SITES AND TEST METHODS

This section describes the sampling sites and outlines the various test methods that were used to characterize particulate matter emissions, particle size distributions, visible and fugitive emissions, and fabric filter dust samples. An overall schematic of the No. 2 AOD process and control system was shown earlier in Figure 2-1.

#### 4.1 SITE 1--INLET

Uncontrolled process and fugitive emissions from the No. 2 AOD were sampled at Site 1 for particulate matter and particle size distribution. As shown in Figure 4-1, this site was in the 264-cm (104-in.) square main inlet duct downstream of the junction of the canopy and scavenger ducts, and upstream of the point where the duct is split by the two I.D. fans. Seven new sampling ports in the side of the duct were located 1.1 equivalent diameters downstream of the scavenger duct inlet and 0.4 diameter upstream of a 90-degree bend, as shown in Figure 4-2. Although the site did not meet minimum Method 1 criteria, analysis of velocity traverse data indicated an acceptable flow distribution without cyclonic characteristics. Figure 4-3 shows the location of the 49 sampling points used to traverse the duct cross-

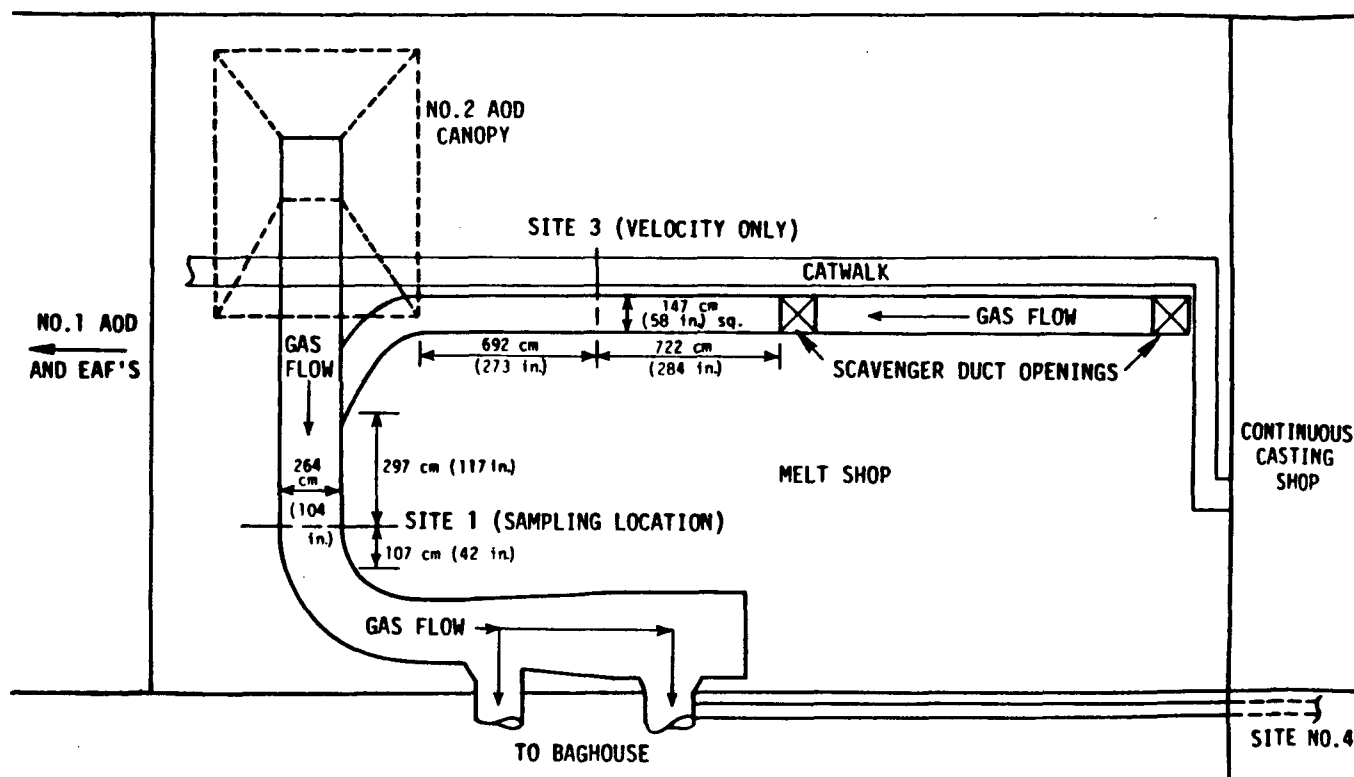


Figure 4-1. Sampling sites for uncontrolled emissions.



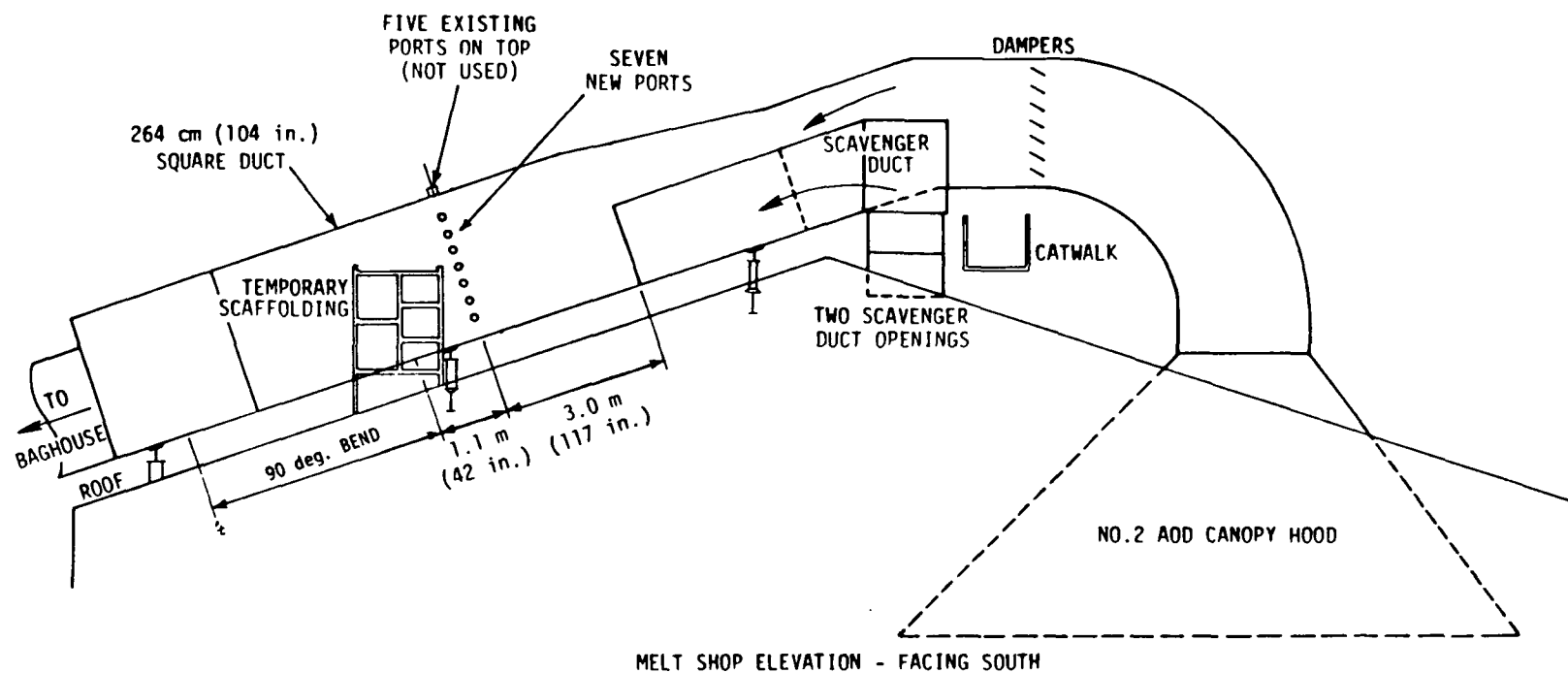
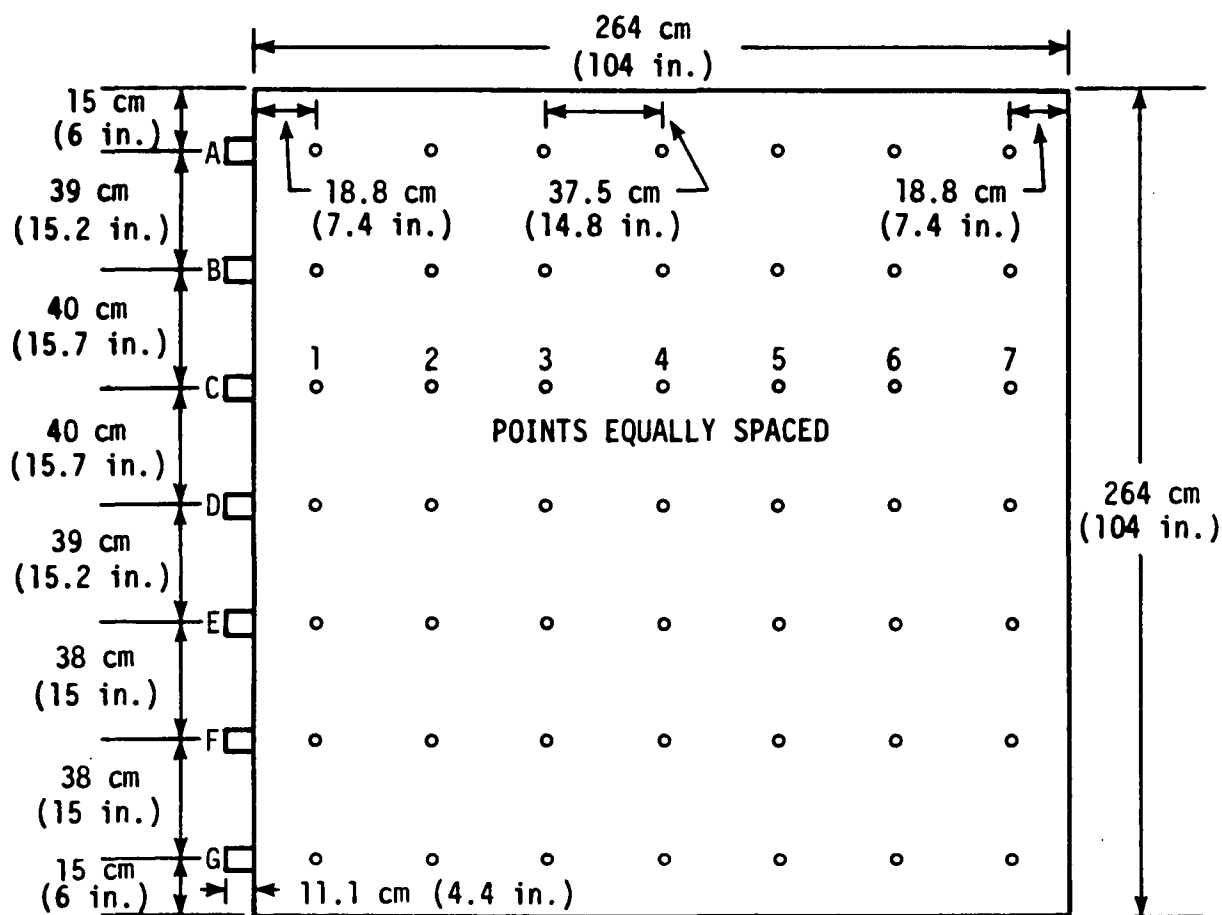


Figure 4-2. Sampling location for uncontrolled AOD emissions, Site 1.



PORTS B, C, AND D ARE 15.2 cm (6 in.) IN DIAMETER,  
OTHERS ARE 10.2 cm (4 in.)

INLET DUCT

Figure 4-3. Location of sampling points at Site 1.

sectional area for the particulate matter tests. During one complete traverse each point in the equal matrix was sampled for 9 minutes, which yielded a total sampling time of 441 minutes per run. Tests were initiated sometime during a heat and continued until the traverse was completed. Sampling was interrupted during process delays or unrepresentative operating conditions, but not for the short intervals (~5 minutes) between heats.

Particle size distribution samples were collected at a point of average velocity near the centroid of the duct. A separate port was used to minimize interferences with the particulate matter tests. Sampling times ranged from 5 minutes for the Andersen Mark III samples to 310 minutes for the Andersen Heavy Grain Loading Impactor samples, which covered three integral heats. These integral heat runs were initiated at the beginning of a charge and continued through the end of the third subsequent tap.

#### 4.2 SITE 2--FABRIC FILTER OUTLET

Controlled emissions from the No. 2 AOD fabric filter were sampled at Site 2 for particulate matter and particle size distribution. This site consisted of five 168-cm (66-in.) diameter stub stacks aligned down the center of the baghouse roof. As shown in Figures 4-4 and 4-5, each stack exhausted cleaned gases from 2 of the 10 compartments. Two sampling ports in each stack were located 2.0 duct diameters downstream of the gas entry point and 0.4 diameter upstream of the stack exit. At

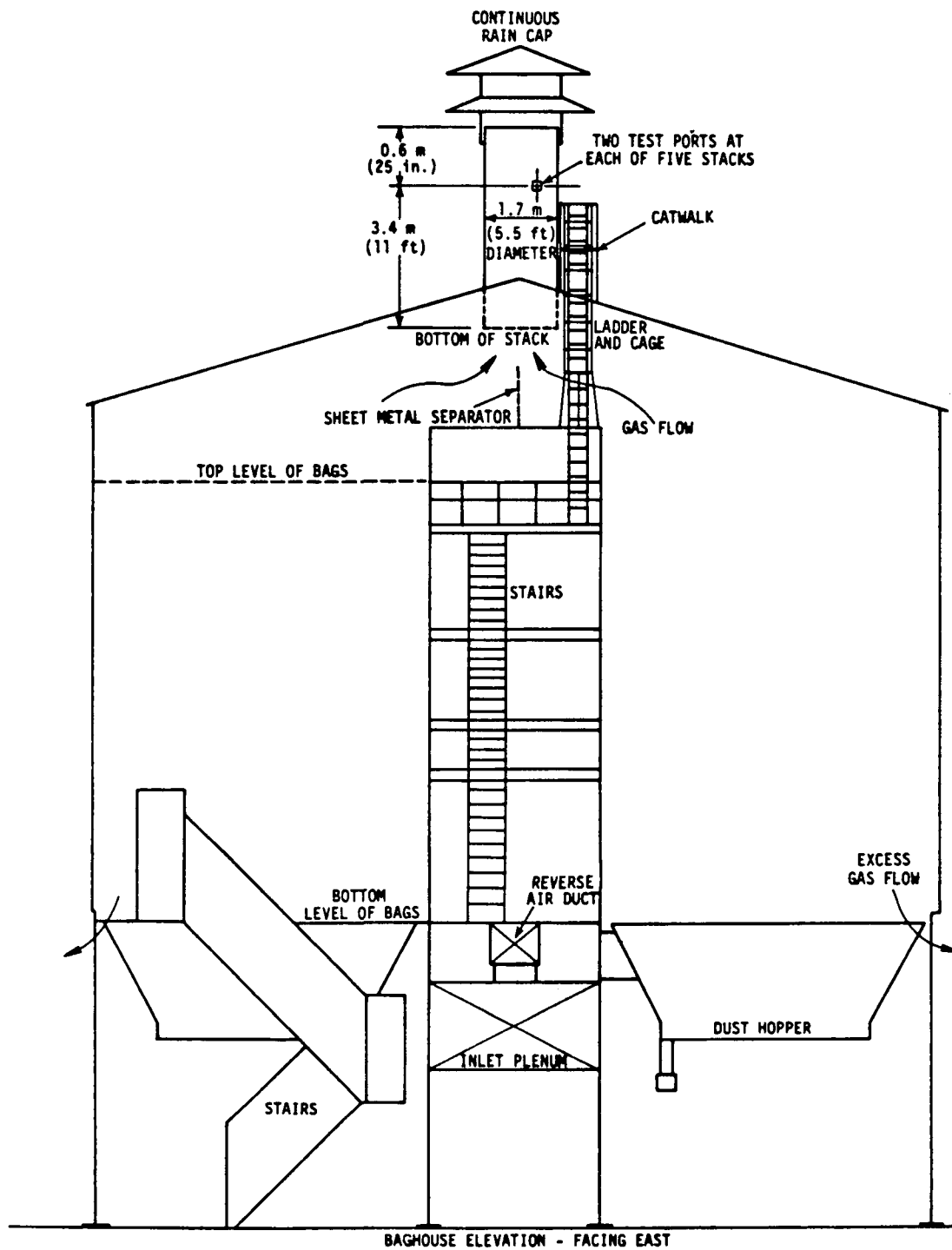


Figure 4-4. Fabric filter, Site 2.

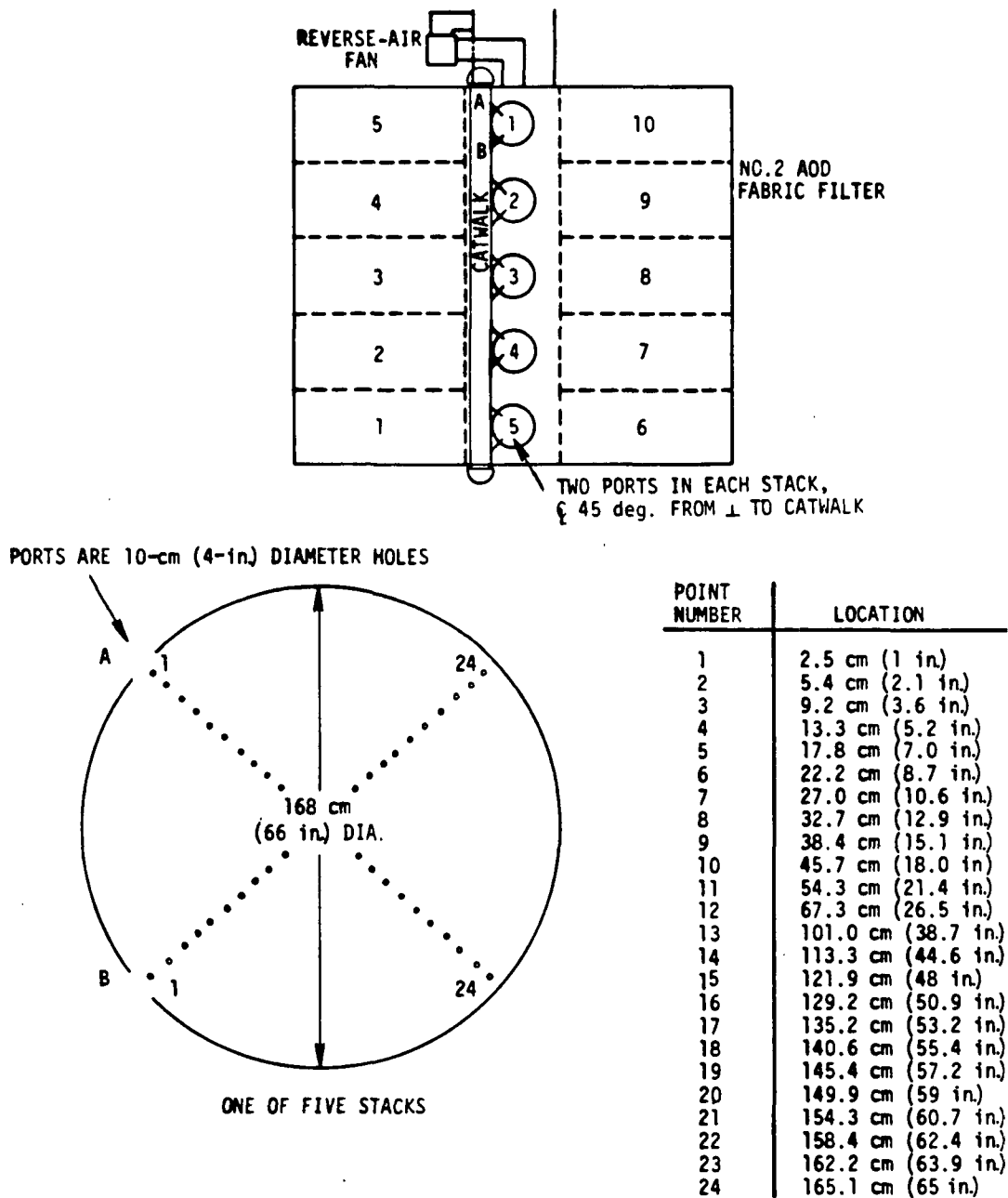


Figure 4-5. Location of sampling points at the fabric filter outlet, Site 2.

these distances Method 1 criteria required 48 particulate sampling points. Figure 4-5 shows the location of sampling points and the orientation of traverse diameters. Each particulate test consisted of traversing all five stacks. Each point was sampled for 2 minutes, which yielded a total sampling time of 480 minutes. The tests began at the same time as the inlet tests and continued until all stacks had been traversed. Cleaning cycles were sampled as they occurred, and tests were interrupted during process delays and unrepresentative operating conditions.

Each particle size distribution sample was collected for an equal amount of time at one sampling point in each of the five stacks. During Runs 1 and 2, each stack was sampled for 90 minutes, which yielded a total run time of 450 minutes. Because the sample catch weights for these runs were low, each stack was sampled for 108 minutes during Run 3, which yielded a total sampling time of 540 minutes. All particle size sampling occurred simultaneously with particulate matter tests, but all probes were not in the same stack at the same time.

Sometime before the test series, Cartech personnel had covered all of the gratings at the bottom level of the fabric filter with Masonite panels to minimize the loss of exhaust gas flow through these gratings.

#### 4.3 SITE 3--SCAVENGER DUCT

The velocity in the scavenger duct was monitored at Site 3 during each test. As shown in Figure 4-1, the site was located 4.9 equivalent duct diameters downstream of the last fugitive

emission capture point and 4.7 duct diameters upstream of a 60-degree bend. Figure 4-6 shows the 21 traverse points used to obtain initial velocity data. An average velocity point was selected and monitored for the duration of each test at Site 1.

#### 4.4 SITE 4--CONTINUOUS CASTING TORCH CUTTER

Emissions from this source are normally controlled by the fabric filter. The EPA requested that flow through this duct be prevented during the test series so that tests would be representative of AOD emissions only. The normal flow through the torch cutter duct was measured prior to the tests to determine its impact on the control system. (Figure 4-1 shows the approximate location of Site 4.) As shown in Figure 4-7, two sampling ports, 90 degrees apart, were located 1.5 duct diameters downstream and 0.5 duct diameter upstream of 45-degree bends. Twenty points were used to traverse the duct cross section.

#### 4.5 VELOCITY AND GAS TEMPERATURE

A type S pitot tube and an inclined draft gauge manometer were used to measure the gas velocity pressures at each site. Velocity pressures were measured at each sampling point across the duct to determine an average value. Measurements were taken in accordance with procedures outlined in Method 2 of the Federal Register.<sup>\*</sup> The temperature at each sampling point was measured with a thermocouple and digital readout.

---

<sup>\*</sup> 40 CFR 60, Appendix A, July 1980.

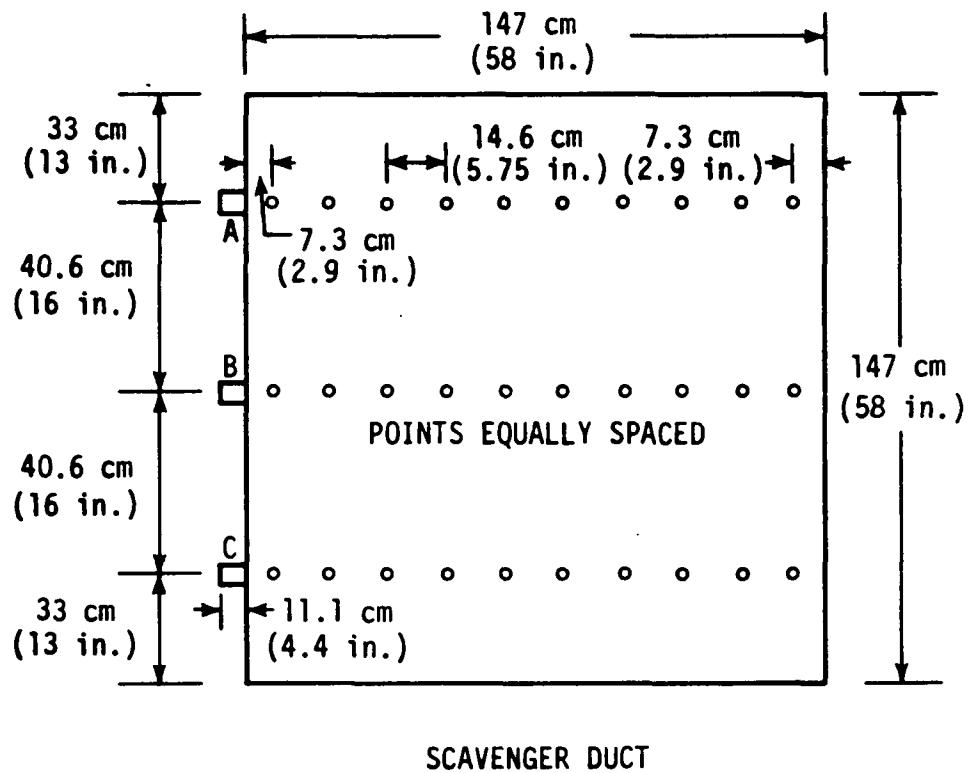


Figure 4-6. Location of velocity traverse points at Site 3.



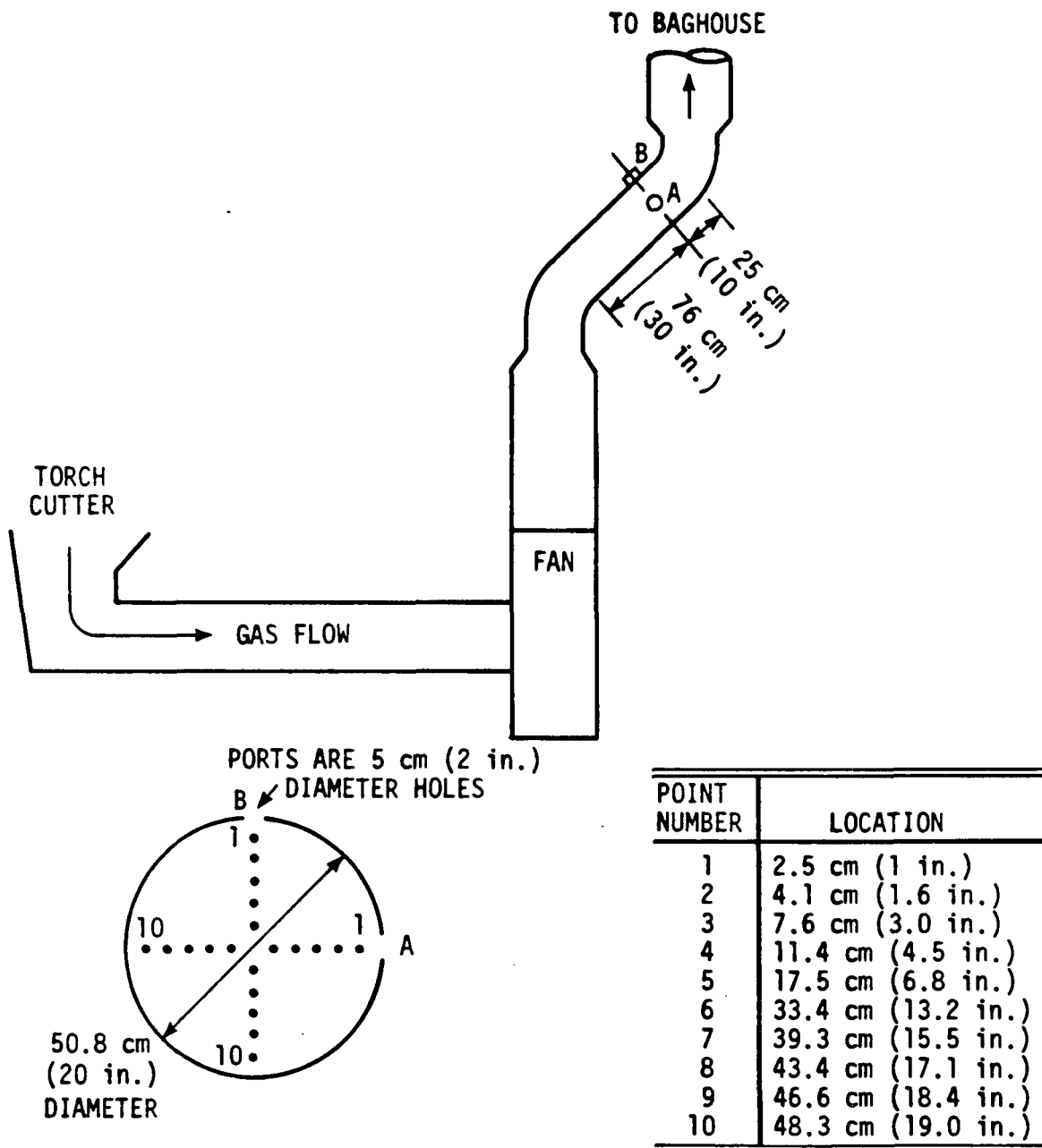


Figure 4-7. Location of traverse points at Site 4.

#### 4.6 MOLECULAR WEIGHT

Flue gas composition was determined in accordance with procedures described in Method 3.\* An integrated bag sample was collected at Sites 1 and 2 during the preliminary runs on Monday, and an Orsat Gas Analyzer was used to analyze the bag contents for oxygen and carbon dioxide. Since these results verified that the gas streams were essentially air, additional samples were not collected.

#### 4.7 PARTICULATE MATTER

Method 5\* was used to measure particulate concentrations at Sites 1 and 2. All tests were conducted isokinetically by traversing the cross sectional area of the stack and 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 probe. The outlet sampling train consisted of a heated, glass-lined probe, a heated 87-mm (3-in.) diameter glass fiber filter (Gelman Type AE), and a series of Greenburg-Smith impingers followed by an umbilical line and metering equipment. The inlet sampling train was similar except that the probe was lined with 316 stainless steel, and a Teflon sample line was used between the filter and first impinger. At the end of each test, the nozzle, probe, and filter holder portions of the sample train were acetone-rinsed. The acetone rinse and filter media were dried at room temperature, desiccated to a constant weight, and

---

\* 40 CFR 60, Appendix A, July 1980.

weighed on an analytical balance. Total filterable particulate matter was determined by adding the net weights of the two sample fractions. The amount of water collected in the impinger section of the sampling train was measured (any condensate in the sample line used at the inlet was first drained into the impingers). On the outlet train, the impinger contents were recovered and analyzed for organic and inorganic condensible matter by ether-chloroform extraction.

Sampling times and volumes for particulate tests at the outlet exceeded the respective minimum requirements of 4 hours and  $4.5 \text{ dNm}^3$  (160 dscf) specified for EAF's in Subpart AA of the Federal Register.\*

#### 4.8 PARTICLE SIZE DISTRIBUTION

Particle size samples at the inlet site were collected with an Andersen Mark III Cascade Impactor and an Andersen Heavy Grain Loading Impactor (HGLI). The Mark III is an in-stack, multistage cascade impactor that yields a total of eight particle cut-sizes ranging, nominally, from 0.5 to 15  $\mu\text{m}$ . Substrates for this impactor were 64-mm diameter glass fiber filters. The Mark III was used to collect samples over time intervals of approximately 5 to 15 minutes. The HGLI is an in-stack multistage impactor designed specifically to allow longer sampling times at high grain loadings. The three nominal cut-points are 2, 5, and 10  $\mu\text{m}$ . The only filter in the HGLI is a glass fiber thimble used as

---

\* 40 CFR 60, Subpart AA, July 1980.

the backup stage. This impactor was used to collect samples over an interval that included three entire AOD heats (approximately 5 hours).

A cyclone precutter was attached to the front of each type of impactor to remove larger particles and to avoid the need to use buttonhook nozzles. Because the sampling rate could not be adjusted to obtain the 15- $\mu$ m cut-point of the cyclone precutter, the weight of particulate collected by the cyclone was added to the weight in the first stage of the respective impactor.

All inlet samples were collected at a point of average velocity near the centroid of the duct. The isokinetic sampling rate was based on initial measurements of velocity pressure and temperature. Constant cut-point characteristics were maintained during sampling, but velocity pressures and temperatures were measured periodically at the sampling point to evaluate the actual variation in isokinetic rate. Nozzles were selected to keep sampling rates in the recommended range of 8.5 to 21 liters per minute (0.3 to 0.75 acfm). Each filter was recovered, desiccated, and weighed on an analytical balance. Acetone rinses of appropriate stages were evaporated, desiccated, and weighed.

Particle size samples at the outlet were collected by a Mark III impactor fitted with a straight nozzle. Each sample was collected for an equal amount of time at an average velocity point in each of the five stacks. The isokinetic sampling rate was based on initial measurements of velocity pressure and gas temperature. Constant cut-point characteristics were maintained

throughout each test, but gas temperatures and velocity pressures were measured periodically at the sampling points to evaluate the actual variation in isokinetic sampling rate. Each filter was recovered, desiccated, and weighed on an analytical balance. The inlet chamber and nozzle were brushed and rinsed with acetone, and the rinse was evaporated, desiccated, and weighed.

#### 4.9 VISIBLE AND FUGITIVE EMISSIONS

Certified observers recorded visible emissions from the melt shop roof and fabric filter stacks in accordance with procedures described in EPA Method 9.\* Data were taken in 6-minute sets (simultaneously with particulate tests), and individual readings were recorded in percent opacity at 15-second intervals. Intermittent rest periods were taken to prevent eye fatigue; however, as long as emissions were visually detectable, readings were continued until a break was absolutely necessary. The emission points were casually monitored during break periods, and readings were resumed immediately if any opacity was noted.

Fugitive emissions from the fabric filter dust-handling system were observed according to the proposed Method 22.\*\* Emissions were recorded as the cumulative amount of time that any fugitive emissions were visually detectable during a 20-minute observation period. Several observation periods were recorded during the test series.

---

\* 40 CFR 60, Appendix A, July 1980.

\*\* Federal Register, Vol. 45, No. 224, November 18, 1980.

Observers were positioned near the parking lots, approximately 60 meters (200 feet) southeast of the fabric filter. Adverse weather conditions reduced the amount of time available for visual emission observations during the second and third tests.

#### 4.10 FABRIC FILTER DUST SAMPLES

Samples from the dust-handling system were obtained from the waste container into which all the hoppers were emptied. Because the hoppers were emptied only once a day, a single grab sample was taken on each test day. For each sample, approximately 1 liter of dust was collected in a glass jar that had been rinsed with dilute nitric acid in the laboratory. Upon return to the laboratory, each sample was split into two fractions: one for analysis of trace elements and one for analysis of particle size distribution.

The Spark Source Mass Spectroscopy technique was used for qualitative examination of approximately 70 elements. A known concentration of indium was added to each sample before it was ionized. All elements were ionized with approximately equal sensitivity. A photographic plate used to record the mass spectra was examined, and the response of each element was related to that of indium. Relative sensitivity factors based on previous analyses of standards were used to compensate for the variation in response of the photoplate for different elements.

The Coulter Counter technique was used to determine particle size distributions. Particles in each sample were suspended in a

sodium chloride electrolytic solution, and electrical current passed from one immersed electrode to another electrode through a small aperture. As a particle passed through the aperture, it displaced a volume of electrolyte and changed the electrical current by an amount proportional to the size of the particle. The volume and number of particles were used to establish a differential distribution by volume. Assuming all particles were of equal density, the volume distribution also represented a weight distribution.

## SECTION 5

### QUALITY ASSURANCE

Quality assurance (QA) is one of the main facets of stack sampling because the end product of testing is to produce representative emission results. Quality assurance guidelines provide detailed procedures and actions necessary for defining and producing acceptable data. The four guideline documents used in this test program were a source-specific test plan prepared by PEDCo and reviewed by the Emissions Measurement Branch; the EPA Quality Assurance Handbook Volume III, EPA-600/4-77-027b; a draft of the PEDCo Environmental Emission Test Quality Assurance Plan; and the PEDCo Environmental Laboratory Quality Assurance Plan. The last two quality assurance plans are PEDCo's general guideline manuals, which define the standard operating procedures followed by the company's emission testing and laboratory groups.

Appendix F provides more detail on the Quality Assurance procedures, including the QA objective; data reduction; quality control checks; performance and system audits; preventive maintenance; precision, accuracy, and completeness; corrective action; and quality assurance reports to management.



With regard to this specific test program, the following were steps taken to ensure that quality data were obtained by the testing and analytical procedures.

- ° Calibration of field sampling equipment. (Calibration guidelines are described in more detail in Appendix E.)
- ° Train configuration and calculation checks.
- ° Onsite quality assurance checks, such as leak checks on the sample train, pitot tube, and Orsat line.
- ° Use of designated analytical equipment and sampling reagents.

Table 5-1 lists the sampling equipment used to conduct particulate loading and particle size tests, along with calibration guidelines and limits. In addition to the pre- and post-test calibration, a field audit was performed on the dry gas meters by the use of critical orifices calibrated and supplied by the EPA. The audit results in Table 5-2 show that all dry gas meters used for this test series were within limitations stipulated in EPA Method 5. Dry gas meter performance test procedures and field audit sheets are shown in Figures 5-1 through 5-5.

Between runs, onsite preliminary calculation checks were performed to verify isokinetic sampling rates and to compare moisture contents, flow rates, and other parameters with expected values. These checks were used to ensure that the tests were conducted properly.

As a check of the reliability of the method used to analyze the particulate matter and particle size filters, sets of blank filters that had been preweighed in the laboratory were resubmitted for replicate analysis. Table 5-3 summarizes the results

TABLE 5-1. FIELD EQUIPMENT CALIBRATION

Equipment	I.D. No.	Calibrated against	Allowable deviation	Actual deviation	Within allowable limits	Comments
Meter box	FB-2	Wet test meter	$\Delta Y_{pre}^a \pm 0.020$ $\Delta H_0 \pm 0.15$ $\Delta Y_{post}^b \pm 0.05$	+0.005	✓	$\bar{V}_{pre} = 1.007$
				-0.08	✓	
				-0.011	✓	$\bar{V}_{post} = 0.996$
Meter box	FB-3			-0.005	✓	$\bar{V}_{pre} = 1.008$
				-0.09	✓	
				+0.027	✓	$\bar{V}_{post} = 1.035$
Meter box	FB-4			+0.002	✓	$\bar{V}_{pre} = 1.050$
				-0.07	✓	
				-0.019	✓	$\bar{V}_{post} = 1.031$
Meter box	FB-6			+0.001	✓	$\bar{V}_{pre} = 0.973$
				-0.06	✓	
				-0.000	✓	$\bar{V}_{post} = 0.973$
Meter box	FB-8	Standard pitot tube	$\Delta C_p \pm 0.01$	-0.010	✓	$\bar{V}_{pre} = 0.982$
				+0.06	✓	
				+0.014	✓	$\bar{V}_{post} = 0.996$
Pitot tube	179			0.01	✓	$C_p = 0.82$
Pitot tube	180			0.00	✓	$C_p = 0.81$
Pitot tube	185			0.00	✓	$C_p = 0.84$
Pitot tube	187			0.00	✓	$C_p = 0.83$
Pitot tube	189			0.00	✓	$C_p = 0.82$
Pitot tube	192			0.00	✓	$C_p = 0.84$

TABLE 5-1 (continued)

Equipment	I.D. No.	Calibrated against	Allowable deviation	Actual deviation	Within allowable limits	Comments
Thermocouple	129	ASTM reference thermometer	$\pm 1.5\%$	+0.70	✓	OK in range of use
Thermocouple	164			-1.4	✓	
Thermocouple	256			-0.2	✓	
Thermocouple	259			-0.3	✓	
Digital indicator	124	Millivolt signals	0.5%	Avg. 0.13%	✓	O <sub>2</sub> and CO <sub>2</sub> are the higher deviation
	125			Avg. 0.22%	✓	
	219			Avg. -0.10%	✓	
Orsat analyzer	232	Standard gas	$\pm 0.5\%$	0.1%	✓	
Trip balance	198	Type S weights	$\pm 0.5$ g	0.0 g	✓	
Barometer	225	NBS traceable barometer	0.20 in. Hg post-test	0.02 in. Hg	✓	

(continued)

TABLE 5-1 (continued)

Equipment	I.D. No.	Calibrated against	Allowable deviation	Actual deviation	Within allowable limits	Comments
Dry gas thermometer	FB-2	Reference thermometer type ASTM 2F or 3F	$\pm 5^{\circ}\text{F}$	I 1.2°F O 1.4°F	✓ ✓	I = inlet thermometer O = outlet thermometer
	FB-3			I 1.1°F O 2.0°F	✓ ✓	
	FB-4			I 1.1°F O 1.0°F	✓ ✓	
	FB-6			I 0.8°F O 1.4°F	✓ ✓	
	FB-8			I 1.0°F O 2.1°F	✓ ✓	
Probe nozzle	CIM-3	Caliper	$D_n \pm 0.004 \text{ in.}$	0.002	✓	Nozzles for particle-size tests were labeled according to run numbers
	6XXX			0.000	✓	
	C2M-4			0.000	✓	
	C2M-2			0.001	✓	
	C2M-P			0.001	✓	
	2-103			0.002	✓	
	CIH-3			0.002	✓	

<sup>a</sup>Allowable deviation  $\Delta Y$  pretest =  $\pm 0.02 \bar{Y}$  pretest.

<sup>b</sup>Allowable deviation  $\Delta Y$  post-test =  $\pm 0.05 \bar{Y}$  pretest.

TABLE 5-2. DRY GAS METER AUDIT RESULTS

Meter box No.	Calibrated against	Deviation, % <sup>a</sup>
FB-2	Critical orifice No. 6	- 2.5
FB-3	Critical orifice No. 7	- 0.71
FB-4	Critical orifice No. 9	- 1.78
FB-6	Critical orifice No. 10	+ 0.99
FB-8	Critical orifice No. 8	- 1.72

<sup>a</sup>Expected deviation < +5%.

# AUDIT REPORT SAMPLE METER BOX

Date 4/27/81  
 Barometric pressure (  $P_{bar}$ , in Hg ) 29.825  
 Orifice number # 6  
 Orifice K factor  $4.995 \times 10^{-4}$

Client EPA  
 Meter box number FB-2  
 Pretest Y 1.007  
 Auditor R. Campbell

Orifice manometer reading AH in H <sub>2</sub> O	Dry gas meter reading $V_s/V_f$ ft <sup>3</sup>	Dry gas meter volume $V_m$ ft <sup>3</sup>	Temperatures					Sampling time $\theta$ min	$V_{std}$ ft <sup>3</sup>	$V_{act}$ ft <sup>3</sup>	Percent error
			Ambient $T_a/T_{af}$ $^{\circ}F$	Average $T_o$ $^{\circ}F$	Inlet $T_{mi}$ $^{\circ}F$	Outlet $T_{mo}$ $^{\circ}F$	Average $T_m$ $^{\circ}F$				
1.76	901.434	11.656	93	93	100	88	96.5	0	10.948	11.225	-2.47%
	913.090		93		107	91		15			

$$V_{std} = (17.647) (V_m) (Y) (P_{bar} + AH/13.6) / (T_m + 460) = 10.948$$

$$V_{act} = (1203) (\theta) (K) (P_{bar}) / (T_a + 460)^{1.5} = 12.704$$

$$V_{std} = (17.647) ( ) ( ) ( ) / ( ) = 10.948$$

$$V_{act} = (1203) (15) (4.995 \times 10^{-4}) (29.825) / (93 + 460)^{1.5} = 11.225$$

$$error = (V_{std} - V_{act}) (100) / (V_{act}) = (0.277) (100) / (11.225) = 2.47$$

Figure 5-1. Dry gas meter audit.

# AUDIT REPORT SAMPLE METER BOX

Date 4-27-81  
 Barometric pressure (  $P_{bar}$ , in Hg ) 29.74  
 Orifice number # 7  
 Orifice K factor  $5.036 \times 10^{-4}$

Client USEPA  
 Meter box number FB#3  
 Pretest Y 1008  
 Auditor DAN FITZGERALD

Orifice manometer reading AH in H <sub>2</sub> O	Dry gas meter reading $V_r/V_f$ ft <sup>3</sup>	Dry gas meter volume $V_m$ ft <sup>3</sup>	Temperatures					Sampling time $\theta$ min	$V_{std}$ ft <sup>3</sup>	$V_{act}$ ft <sup>3</sup>	Percent error
			Ambient $T_a/T_{af}$ $^{\circ}F$	Average $T_o/T_{of}$ $^{\circ}F$	Inlet $T_{mi}/T_{mf}$ $^{\circ}F$	Outlet $T_{mo}/T_{of}$ $^{\circ}F$	Average $T_m/T_{mf}$ $^{\circ}F$				
2.2	643.00	12.000	91	91	95	85	91	15.2	11.584	11.667	0.71%
	655.00		91		97	87					

$$V_{std} = ( 17.647 ) ( V_m ) ( Y ) ( P_{bar} + AH/13.6 ) / ( T_m + 460 )$$

$$V_{act} = ( 1203 ) ( \theta ) ( K ) ( P_{bar} ) / ( T_a + 460 )^{1/2}$$

$$V_{std} = ( 17.647 ) ( 12.00 ) ( 1.008 ) ( 29.74 ) / ( 91 + 460 ) = 11.584 \text{ ft}^3$$

$$V_{act} = ( 1203 ) ( 15.2 ) ( 5.036 \times 10^{-4} ) ( 29.74 ) / ( 91 + 460 )^{1/2} = 11.667 \text{ ft}^3$$

$$\text{error} = ( V_{std} - V_{act} ) ( 100 ) / ( V_{act} ) = ( 11.584 - 11.667 ) ( 100 ) / ( 11.667 ) = -0.7116 \%$$

Figure 5-2. Dry gas meter audit.

# AUDIT REPORT SAMPLE METER BOX

Date 4/27/81  
 Barometric pressure (  $P_{bar}$ , in Hg ) 29.825  
 Orifice number #9  
 Orifice K factor  $4.796 \times 10^{-4}$

Client EPA Carpenter Technology  
 Meter box number FB-4  
 Pretest Y 1.050  
 Auditor P. Campbell

Orifice manometer reading AH in H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ft <sup>3</sup>	Dry gas meter volume $V_m$ ft <sup>3</sup>	Temperatures					Sampling time $\phi$ min	$V_{std}$ ft <sup>3</sup>	$V_{act}$ ft <sup>3</sup>	Percent error
			Ambient $T_a/T_{af}$ °F	Average $T_{av}$ °F	Inlet $T_{in}$ °F	Outlet $T_{out}$ °F	Average $T_m$ °F				
1.79	558.114	10.876	91	91	101	92	99	0	10.800	10.996	1.78%
	568.990		90		102	95		15			

$$V_{std} = (17.647) (V_m) (Y) (P_{bar} + AH/13.6) / (T_m + 460)$$

$$V_{act} = (1203) (\phi) (K) (P_{bar}) / (T_m + 460)^{1/2}$$

$$V_{std} = (17.647) (10.876) (1.050) (29.825) / (99 + 460) = 10.800$$

$$V_{act} = (1203) (15.0) (4.796 \times 10^{-4}) (29.825) / (91 + 460)^{1/2} = 10.996$$

$$error = (V_{std} - V_{act}) (100) / (V_{act}) = (-0.196) (100) / (10.996)$$

Figure 5-3. Dry gas meter audit.



# AUDIT REPORT SAMPLE METER BOX

Date 04/30/81  
 Barometric pressure (  $P_{bar}$ , in Hg ) 29.70  
 Orifice number #10  
 Orifice K factor  $4.798 \times 10^{-4}$

Client (CARPENTER TECH) USIRPA  
 Meter box number EB-6  
 Pretest Y 973  
 Auditor R. ANTOSZAK

Orifice manometer reading AH in H <sub>2</sub> O	Dry gas meter reading $V_1/V$ ft <sup>3</sup>	Dry gas meter volume $V_m$ ft <sup>3</sup>	Temperatures					Sampling time $\theta$ min	$V_{std}$ ft <sup>3</sup>	$V_{act}$ ft <sup>3</sup>	Percent error
			Ambient $T_a / T_a$ $^{\circ}F$	Average $T_a$ $^{\circ}F$	Inlet $T_{in}$ $^{\circ}F$	Outlet $T_{out}$ $^{\circ}F$	Average $T_m$ $^{\circ}F$				
1.50	723.700	12.10	75	75	94	91	91.5	15.0	11.23	11.12	+0.99
	735.800		75		90	90					

$$V_{std} = ( 17.647 ) ( V_m ) ( Y ) ( P_{bar} + AH/13.6 ) / ( T_m + 460 )$$

$$V_{act} = ( 1203 ) ( \theta ) ( K ) ( P_{bar} ) / ( T_a + 460 )^{\frac{1}{2}}$$

$$V_{std} = ( 17.647 ) ( 12.10 ) ( .973 ) ( 29.81 ) / ( 531.5 ) = 11.23$$

$$V_{act} = ( 1203 ) ( 15.0 ) ( 4.798 \times 10^{-4} ) ( 29.70 ) / ( 535 )^{\frac{1}{2}} = 11.12$$

$$error = ( \frac{V_{std} - V_{act}}{V_{act}} ) ( 100 ) / ( V_{act} ) = ( .11 ) ( 100 ) / ( 11.12 ) = .99$$

Figure 5-4. Dry gas meter audit.

5-11

Client CARPENTER TRUCK READING, PA  
Meter box number FB-8  
Pretest Y 922  
Auditor ANTHONY EPICONE

Orifice manometer reading AH in H <sub>2</sub> O	Dry gas meter reading V <sub>i</sub> /V <sub>f</sub> ft <sup>3</sup>	Dry gas meter volume V <sub>m3</sub> ft <sup>3</sup>	Temperatures					Sampling time s min	V <sub>mstd</sub> ft <sup>3</sup>	V <sub>mact</sub> ft <sup>3</sup>	Percent error
			Ambient T <sub>a</sub> °F	Average T <sub>a</sub> °F	Inlet T <sub>mi</sub> °F	Outlet T <sub>mo</sub> °F	Average T <sub>m</sub> °F				
1.85	622.30	11.3	75	75	76	74	15.0 min		10.86	11.05	1.72
1.85	633.60		75		79	76					

$$V_{std} = (27.647) \left( \frac{11.3}{V_{std}} \right) \left( \frac{0.982}{Y} \right) \left( \frac{29.6}{P_{bar}} + \frac{1.85}{AH/13.6} \right) / \left( \frac{76.25}{T_{std}} + 460 \right)$$

$$V_{\text{act}} = (1203) (15) (4.784 \times 10^{-4})^{29.6} (75) / (T_a + 460)^{1.4}$$

$$V_{std} = (17.647)(11.3)(0.982)(\frac{29.736}{2136})(536.25)$$

$$V_{\text{act}} = (1203)(15)(29.6)(4.784 \times 10^{-4})(535)^{2.76} / (535)^{1.1}$$

$$\text{error} = (V_{\text{std}} - V_{\text{act}})(100)/(V_{\text{act}}) = (.19)(100)/(11.05)$$

Figure 5-5. Dry gas meter audit.

TABLE 5-3. FILTER BLANK ANALYSIS

Type of filter	Filter No.	Tare weight, mg	Blank weight, mg	Net weight, mg	Comments
Particulate: 87-mm Gelman A/E <sup>a</sup>	0002029	363.0	363.4	0.4	c
Andersen Mark III Impactor <sup>b</sup>	W-39	148.7	149.2	0.5	
	W-42	136.7	136.2	-0.3	
	X39	149.2	149.6	0.4	
	W38	136.6	136.8	0.2	
	W35	147.2	147.3	0.1	
	W34	137.8	138.0	0.2	
	W31	147.6	148.8	1.2	
	W32	135.8	136.0	0.2	
	B217	188.1	188.0	-0.1	
Andersen Mark III Impactor Blank test run <sup>b</sup>	W07	149.0	148.8	-0.2	
	W08	139.2	139.1	-0.1	
	W05	150.2	149.6	-0.6	
	W06	139.4	138.8	-0.6	
	W03	149.0	149.2	0.2	
	W04	138.6	138.8	0.2	
	W01	149.0	149.0	0.0	
	W02	138.0	137.8	-0.2	
	B407	198.3	198.8	0.5	
Andersen Heavy Grain Loading Impactor (HGLI) Thimble <sup>d</sup>	4-BU658	1878.1	1880.6	2.5	
	5-BU659	2120.2	2122.6	2.4	
	6-BU660	2329.2	2330.0	2.8	

<sup>a</sup>Expected deviation,  $\pm 0.5$  mg.

<sup>b</sup>Expected deviation,  $\pm 0.3$  mg.

<sup>c</sup>Both initial tare weighings agreed within  $\pm 0.2$  mg, as did both blank weighings.

<sup>d</sup>Expected deviation,  $\pm 5.0$  mg.

of these blank filter analyses. Except for one particle size filter, these results show good data reproducibility from an analytical standpoint.

A blank run was performed at the fabric filter outlet to determine whether stack gases reacted with the filter media to produce erroneous results. This was accomplished by placing a backup filter in front of a normally prepared impactor and then sampling in the usual manner. Table 5-3 lists results of the blank run. These results show that stack gases did not significantly affect filter media.

Blanks also were taken to check the quality of reagents used to recover and analyze particulate and particle size samples. Table 5-4 summarizes the results of these blank analyses. These results show that all reagents met designated specifications for quality.

A trace element audit sample was analyzed along with the fabric filter dust samples to check the accuracy of the SSMS analytical procedures. The audit sample was taken from Standard Reference Material (SRM) No. 1633, "Trace Elements in Coal Fly Ash," which was obtained from the National Bureau of Standards (NBS). The results (shown in Table 5-5) indicate that, except for manganese, the analyses were within a factor of three of true values, which is the expected limit of SSMS accuracy. The laboratory performed its own internal audit by analyzing a sample taken from SRM No. 1632, "Trace Elements in Coal," which was also obtained from the NBS. The results (shown in Table 5-6) indicate

TABLE 5-4. REAGENT BLANK ANALYSIS

Type of blank	Container No.	Volume of blank, ml	Weight after evaporation and desiccation, mg/g <sup>a</sup>	Comments
Particulate blanks:				
Acetone	1228A	537	+0.0061	
Water	1229A	500	+0.0052	
Particle size blanks:				
Acetone	3823A	221	+0.0074	
Analytical blanks:				
Ether/chloroform	BU630	150	0.004	

<sup>a</sup>Tolerance:  $\pm 0.01$  mg/g.

TABLE 5-5. TRACE ELEMENT AUDIT RESULTS

Element	Concentration, $\mu\text{g/g}$		Percent difference <sup>b</sup>
	NBS certified <sup>a</sup>	Measured	
Arsenic	61 $\pm$ 6	31	- 50
Cadmium	1.45 $\pm$ 0.06	0.5	- 70
Chromium	131 $\pm$ 2	170	+ 30
Copper	128 $\pm$ 5	49	- 60
Lead	70 $\pm$ 4	59	- 20
Manganese	493 $\pm$ 7	74	- 80
Nickel	98 $\pm$ 3	27	- 70
Selenium	9.4 $\pm$ 0.5	4	- 60
Uranium	11.6 $\pm$ 0.2	13	+ 10
Vanadium	214 $\pm$ 8	110	- 50
Zinc	210 $\pm$ 20	96	- 50

<sup>a</sup>SRM No. 1633, "Trace Elements in Coal Fly Ash."

<sup>b</sup>Percent difference =  $\frac{\text{measured} - \text{actual}}{\text{actual}} \times 100$ , to the nearest 10%. Expected deviation is +200%, -70% ( $\pm$  factor of 3).

TABLE 5-6. TRACE ELEMENT AUDIT RESULTS

Element	Concentration, $\mu\text{g/g}$		Percent difference <sup>b</sup>
	NBS certified <sup>a</sup>	Measured	
Arsenic	$5.9 \pm 0.6$	5	- 20
Cadmium	$0.19 \pm 0.03$	0.7	+270
Chromium	$20.2 \pm 0.5$	10	- 50
Copper	$18 \pm 2$	12	- 30
Lead	$30 \pm 9$	4	- 90
Manganese	$40 \pm 3$	46	+ 10
Nickel	$15 \pm 1$	9	- 40
Selenium	$2.9 \pm 0.3$	2	- 30
Thallium	$0.59 \pm 0.03$	<0.1	>- 80
Uranium	$1.4 \pm 0.01$	1	- 30
Vanadium	$35 \pm 3$	17	- 50
Zinc	$37 \pm 4$	15	- 60

<sup>a</sup>SRM No. 1632, "Trace Elements in Coal."

<sup>b</sup>Percent difference =  $\frac{\text{measured} - \text{actual}}{\text{actual}} \times 100$ , to the nearest 10%. Expected deviation is +200%, -70% ( $\pm$  factor of 3).

that, except for cadmium, lead, and thallium, the analyses were within the range of expected accuracy.

Sampling equipment, reagents, and analytical procedures for this test series followed and met all necessary guidelines set forth for accurate test results in Volume III of the Quality Assurance Handbook.<sup>6</sup> Therefore, test results reported in this document should be within the expected accuracies of the method used.



## SECTION 6

### STANDARD SAMPLING AND ANALYTICAL PROCEDURES

This section describes the test methods, sampling equipment, and analytical techniques that were used for determination of particulate matter and particle size distribution.

#### 6.1 DETERMINATION OF PARTICULATE EMISSIONS

The sampling and analytical procedures used to determine particulate emissions were those described in Method 5 of the Federal Register.\*

##### 6.1.1 Sampling Apparatus

The particulate sampling train used in these tests met design specifications established by the EPA. The sampling apparatus, which was assembled by PEDCo personnel, consisted of the following:

Nozzle - Stainless steel (316) with sharp, tapered leading edge and accurately measured round opening.

Probe - Stainless steel (316) with a heating system capable of maintaining a minimum gas temperature of 121°C (250°F) at the exit end during sampling. (A glass-lined probe was used at Site 2.)

Pitot Tube - A type S pitot tube that met all geometric standards was attached to a probe to monitor stack gas velocity pressure.

---

\* 40 CFR 60, Appendix A, July 1980.

Temperature Gauge - A Chromel/Alumel type-K thermocouple (or equivalent) was attached to the pitot tube, in an interference-free arrangement, to monitor stack gas temperature within 1.5°C (5°F) by the use of a digital readout.

Filter Holder - The filter holder was made of Pyrex glass and had a heating system capable of maintaining a filter temperature of approximately 121°C (250°F).

Filter - An 87-mm (3-in.) diameter, glass fiber filter (Gelman A/E) was used.

Draft Gauge - The draft was measured with an inclined Dwyer manometer with a readability of 0.25 mm (0.01 in.) H<sub>2</sub>O in the 0 to 25 mm (0 to 1 in.) H<sub>2</sub>O range.

Impingers - Four Greenburg-Smith design impingers were connected in series with glass ball joints. The first, third, and fourth impingers were modified by removing the tip and extending the tube to within 1.3 cm (0.5 in.) of the bottom of the flask.

Metering System - The metering system consisting of a vacuum gauge, a leak-free pump, thermometers capable of measuring temperature to within 1.5°C (5°F), a calibrated dry gas meter, and related equipment was used to maintain an isokinetic sampling rate and to determine sample volume. The dry gas meter was made by Rockwell, and the fiber vane pump was made by Gast.

Barometer - An aneroid type barometer was used to measure atmospheric pressures to 0.3 kPa (+0.1 in.Hg).

#### 6.1.2 Sampling Procedure

After the sampling site and minimum number of traverse points were selected, the stack pressure, temperature, moisture, and range of velocity head were measured according to procedures described in the Federal Register.\*

Approximately 400 grams of silica gel were weighed and placed in a sealed impinger prior to each test. Glass fiber filters were desiccated for at least 24 hours to a constant

---

\* 40 CFR 60, Appendix A, Methods 1, 2, 3, or 4, July 1980.

weight and weighed to the nearest 0.1 mg on an analytical balance. One hundred milliliters of distilled water was placed in each of the first two impingers, the third impinger was initially empty, and the impinger containing the silica gel was placed next in series. The train was set up as shown in Figure 6-1 or Figure 6-2. Before each test run the sampling train was leak-checked at the sampling site by plugging the inlet to the nozzle and pulling a 50-kPa (15-in.Hg) vacuum and at the conclusion of the test, by plugging the inlet to the nozzle and pulling a vacuum equal to the highest vacuum reached during the test run.

The pitot tube and lines were leak-checked at the test site before and after each test run. The check was made by blowing into the impact opening of the pitot tube until the manometer indicated 7.6 cm (3 in.) or more of water and then capping the impact opening and holding it for 15 seconds to assure it was leak-free. The same procedure was used to leak-check the static pressure side of the pitot tube, except suction was used to obtain the 7.6-cm (3-in.) H<sub>2</sub>O manometer reading. Crushed ice was placed around the impingers to keep the temperature of the gases leaving the last impinger at 20°C (68°F) or less.

During sampling, stack gas and sampling train data were recorded at each sampling point and whenever significant changes in stack flow conditions occurred. Isokinetic sampling rates were set throughout the sampling period with the aid of a nomograph or calculator. All sampling data were recorded on the Emission Testing Field Data Sheet.

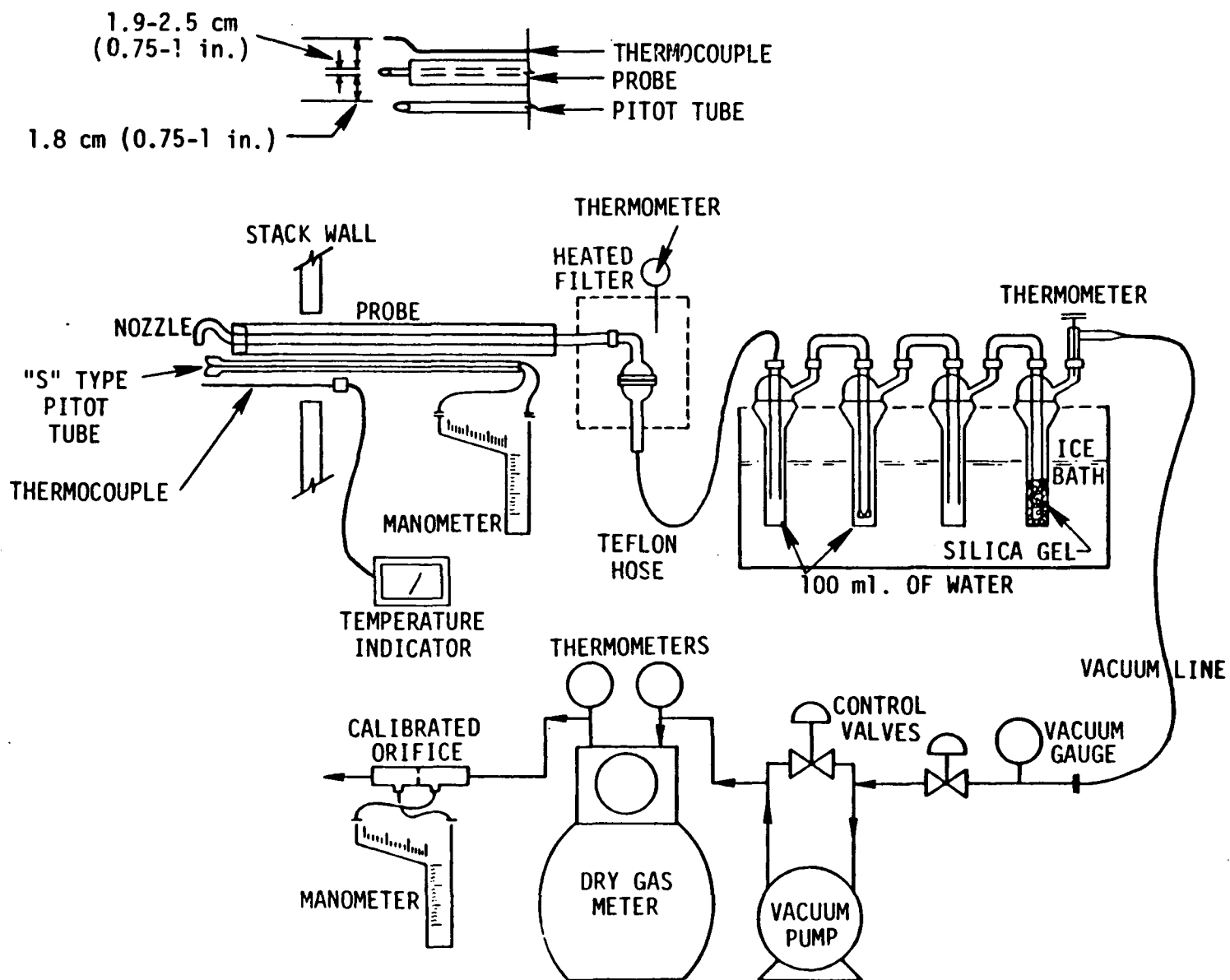


Figure 6-1. Particulate sampling train used at Site 1.

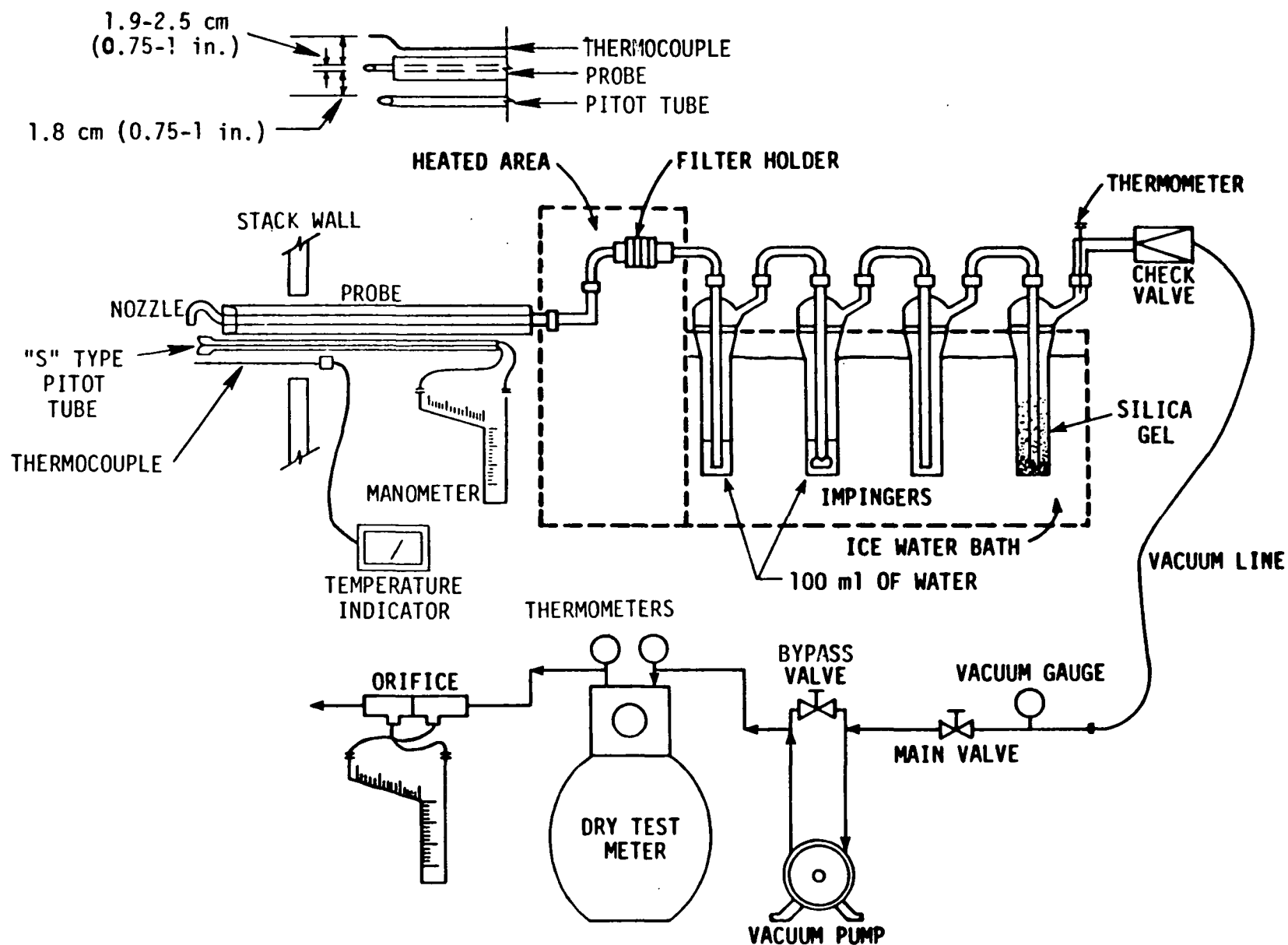


Figure 6-2. Particulate sampling train used at Site 2.

### 6.1.3 Sample Recovery Procedure

The sampling train was moved carefully from the test site to the cleanup area. The volume of water from the first three impingers was measured, and the silica gel from the fourth impinger was weighed to the nearest 0.1 gram. Sample fractions were recovered as follows:

Container No. 1 - The filter was removed from its holder, placed in a petri dish, and sealed.

Container No. 2 - Loose particulate and acetone washings from all sample-exposed surfaces prior to the filter were placed in a polyethylene jar, sealed, and labeled. Particulate was removed from the probe with the aid of a brush and acetone rinsing. The liquid level was marked after the container was sealed.

Container No. 3 - A minimum of 200 ml of acetone was taken for the blank analysis. The blank was obtained and treated in a similar manner as the acetone washing.

Container No. 4 - After being measured, distilled water in the impinger section of the sampling train was placed in a polyethylene container. The impingers and connecting glassware were rinsed with distilled H<sub>2</sub>O, and this rinse was added to the container for shipment to the laboratory.

Container No. 5 - A minimum of 200 ml of distilled water was taken for the blank analysis. The blank was obtained and treated in a similar manner as the water rinse.

Container No. 6 - An unused glass fiber filter was taken for blank analysis.

### 6.1.4 Analytical Procedures

The analytical procedures used were those described in the Federal Register.\*

Container No. 1 - The filter and any loose particulate matter were desiccated in the petri dish for 24 hours to a constant weight and then weighed to the nearest 0.1 mg.

---

\* 40 CFR 60, Appendix A, July 1980.

Container No. 2 - The volume of acetone washings was measured and transferred to a tared beaker. The sample was evaporated to dryness at ambient temperature and pressure, desiccated for 24 hours to a constant weight, and weighed to the nearest 0.1 mg.

Container No. 3 - The volume of acetone blank was measured and transferred to a tared beaker. The blank was evaporated to dryness at ambient temperature and pressure, desiccated for 24 hours to a constant weight, and weighed to the nearest 0.1 mg.

Container No. 4 - For tests at Site 1, the content of this container was stored for future reference. For tests at Site 2, the volume of distilled water and water rinse was measured and transferred to a separatory funnel. The sample was extracted three times with diethyl ether, and each time the water was drained back into the original sample container and the ether into a clean, tared beaker. The sample was then extracted three times with chloroform, and each time the chloroform was drained into the beaker with the ether. After the final extraction, the water portion was drained into a separate tared beaker, evaporated to dryness at 105°C, desiccated, and weighed to a constant weight to obtain the condensible inorganic content. The ether/chloroform portion was evaporated to dryness at ambient temperature, desiccated, and weighed to a constant weight to obtain the condensible organic content.

Container No. 5 - For tests at Site 1, the content of this container was stored for future reference. For tests at Site 2 the distilled water blank was treated in an identical manner as Container No. 4. The aqueous fraction was used as a water blank, and the organic fraction was used as an ether/chloroform blank.

Container No. 6 - The blank filter was treated in an identical manner as the filter in Container No. 1.

The term "constant weight" means a difference of no more than 0.5 mg or 1 percent of total weight less tare weight, whichever is greater between two consecutive readings, with no less than 6 hours of desiccation between weighings. All analytical data were recorded on the Analytical Particulate Data Sheet. Acetone and water blank data were recorded on respective blank data sheets.

## 6.2 DETERMINATION OF PARTICLE SIZE DISTRIBUTION

Three different configurations of in-stack cascade impactors were used to collect samples for particle size distribution measurements. The following sampling and analytical procedures were used.

### 6.2.1 Sampling Apparatus

The source sampling train used in these tests met design specifications established by the EPA. Assembled by PEDCo personnel, it consisted of the following:

Nozzle - Stainless steel (316) with sharp tapered leading edge and accurately measured round opening.

Temperature gauge - A Chromel/Alumel type-K thermocouple (or equivalent) was attached to the probe to monitor stack gas (impactor) temperature to within 1.5°C (5°F) by the use of a digital readout.

Metering system - The metering system consisting of a vacuum gauge, a leak-free pump, thermometers capable of measuring temperature to within 1.5°C (5°F), a dry gas meter with 2 percent accuracy, and related equipment was used to maintain an isokinetic sampling rate and to determine sample volume. The dry gas meter was made by Rockwell, and the fiber vane pump was made by Gast.

Condenser - The condenser consisted of a moisture-removal device capable of maintaining a temperature of less than 20°C (68°F), and an attached thermometer to monitor temperature.

Impactor - An Andersen Mark III with eight stages and a backup filter was used at Sites 1 and 2. An Andersen Heavy Grain Loading Impactor with three stages and a backup filter was used at Site 1. A cyclone precutter was attached to the front of each impactor used at Site 1.

Barometer - An aneroid type barometer was used to measure atmospheric pressures to 0.3 kPa (+0.1 in.Hg).



### 6.2.2 Sampling Procedure

The stack pressure, temperature, moisture, and velocity pressure of the selected sampling site were measured with Method 5 equipment in accordance with procedures described in the Federal Register.<sup>\*</sup> One or more points representing average velocity were selected as sampling points.

Each type of impactor was assembled appropriately. Assembly of the Andersen Mark III (Mark III) involved alternating the stage plates, collection media, flat crossbars, and Inconel spacer rings so as to provide eight cut-sizes. The collection substrates were Reeve Angel 934 AH glass fiber filters that had been heated in a 204°C (400°F) oven for 1 to 2 hours, desiccated for 24 hours to a constant weight, and weighed to the nearest 0.1 mg on an analytical balance.

Assembly of the Andersen Heavy Grain Loading Impactor (HGLI) involved inserting a glass fiber thimble in the backup stage and threading together the various parts of the third-stage cyclone and first- and second-stage jet-impaction chambers. The glass fiber thimble had been desiccated for 24 hours to a constant weight and weighed to the nearest 0.1 mg on an analytical balance.

It used, the cyclone precutter was threaded together and attached to the front of the impactor.

The sampling train was assembled as shown in Figure 6-3 or Figure 6-4. It was leak-checked at the sampling site prior to each test run by plugging the inlet to the impactor (or cyclone

---

<sup>\*</sup> 40 CFR 60, Appendix A, Methods 2, 3, or 4, July 1980.

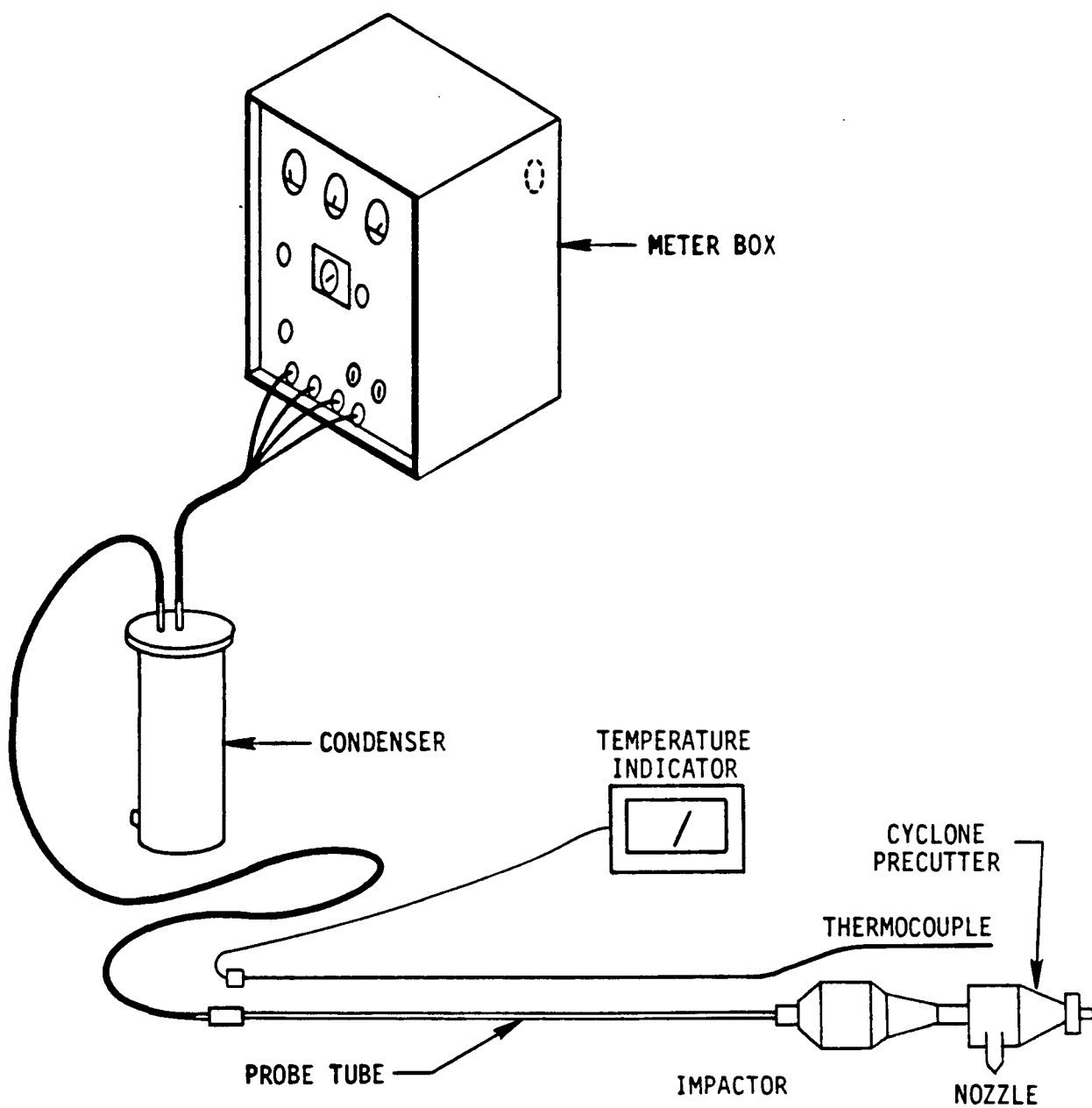


Figure 6-3. Particle size distribution sampling train used at Site 1.

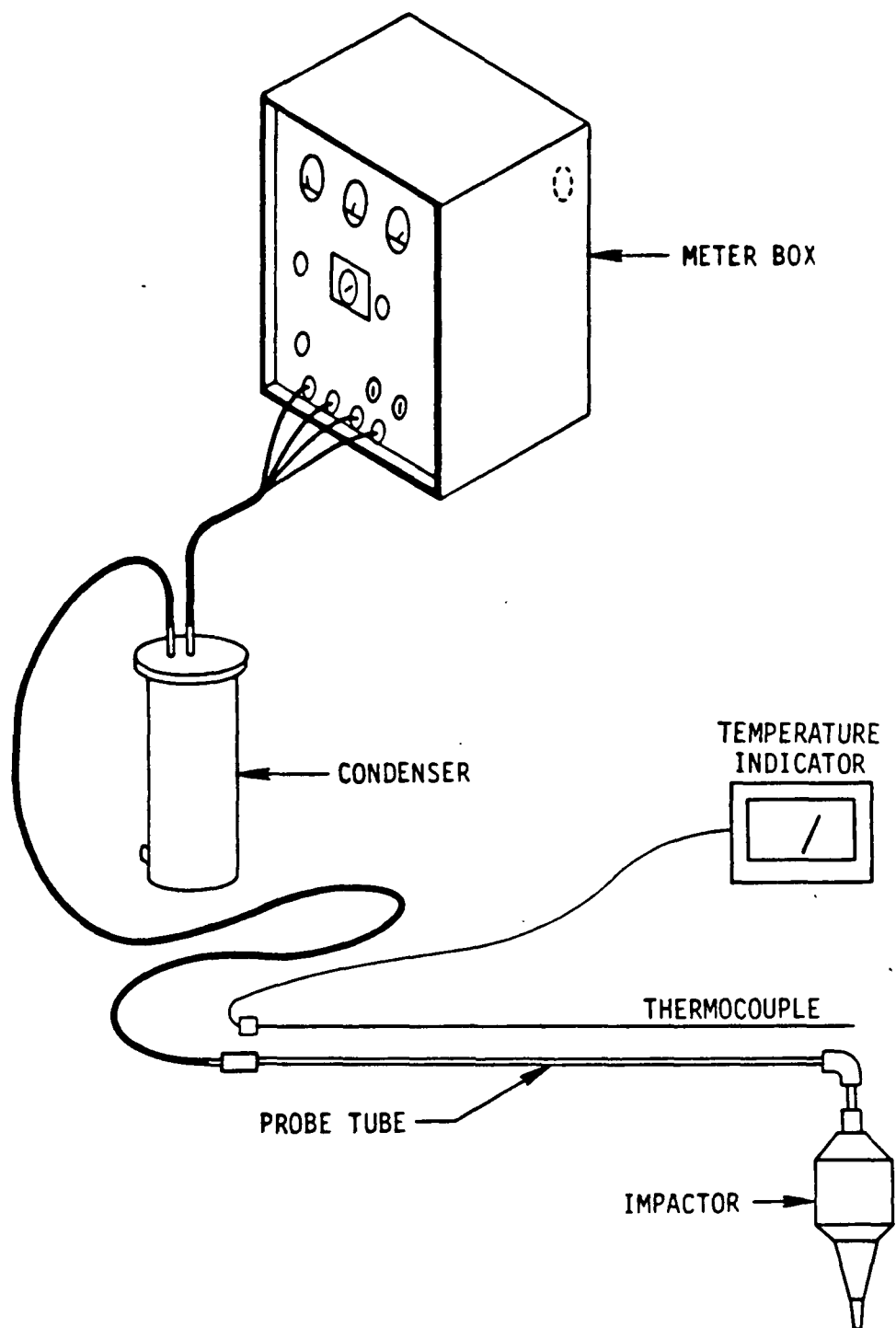


Figure 6-4. Particle size distribution sampling train used at Site 2.

precutter, if used) and pulling a 50-kPa (15-in.Hg) vacuum. Once the desired vacuum was reached, the leakage rate was checked at the dry gas meter for 1 minute. If the leak rate was less than 0.6 liter/min (0.02 cfm), the train was considered ready for sampling. Any excessive leaks were corrected before the train was used. The impactor was then placed at the selected sampling point and allowed to preheat for several minutes before sampling began. While the impactor was preheating, the nozzle was capped or pointed away from the gas flow. A leak-check was capped or pointed away from the gas flow. A leak-check was not performed after the test run so as to avoid the possibility of dislodging the particles on individual stages.

During sampling, stack gas and sampling train data were recorded at regular intervals based on the length of the run. Velocity pressure data were obtained periodically using separate Method 5 equipment. The isokinetic sampling rate was set initially, and constant cut-point characteristics were maintained throughout the sampling period. Preliminary impactor runs were made at each site to determine the Mark III sampling times required to allow uniform loading on the backup filter and to prevent loadings of greater than 10 mg on any one stage. All sampling data were recorded on the Impactor Testing Field Data Sheet.

#### 6.2.3 Sample Recovery Procedure

When the test was over, the impactor was removed from the probe and carefully moved to the designated cleanup area while

still in an upright position. The impactors were recovered as follows:

Mark III:

Container No. 1 - Particulate in the nozzle and inlet chamber was removed by brushing and rinsing with acetone into a polyethylene container, which was sealed and labeled.

Containers No. 2 through 10 - Each filter was removed from its stage and carefully placed in a petri dish. Loose particulate from the bottom side of the previous stage plates, the Inconel spacer, the flat crossbar, and the top side of the plate directly under the filter were brushed into the same petri dish as the respective filter. Each petri dish was sealed and labeled.

Container No. 11 - If the cyclone precutter was used, particulate from all sample-exposed surfaces except the interior of the cyclone exit tube was brushed and acetone-rinsed into a polyethylene container, which was sealed and labeled. Particulate from the interior of the cyclone exit tube was added to Container No. 1.

Heavy Grain Loading Impactor With Cyclone Precutter:

Containers No. 1 through 5 - Particulate from all sample-exposed surfaces after the cut-point of the preceding stage and prior to the cut-point of a given stage was brushed and rinsed with acetone into a polyethylene container. After the container was sealed and labeled, the liquid level was marked.

Container No. 6 - The glass fiber thimble was carefully removed from the holder and placed in a glass jar. The jar was then sealed and labeled.

All pertinent data were recorded on Sample Recovery and Integrity Data Sheets.

6.2.4 Analytical Procedures

Filters - Each glass fiber filter or thimble and any loose particulate matter were desiccated in respective sample containers for 24 hours to a constant weight and weighed to the nearest 0.1 mg on an analytical balance.

Acetone Rinses - The volume of each acetone washing was measured and transferred to a tared beaker. The sample was evaporated to dryness at ambient temperature and pressure,

desiccated for 24 hours to a constant weight, and weighed to the nearest 0.1 mg.

The term "constant weight" means a difference of no more than 0.5 mg or 1 percent of total weight less tare weight, whichever is greater between two consecutive weighings, with no less than 6 hours of desiccation between weighings. All analytical data were recorded on Andersen Impactor or HGLI Particulate Analytical Data Sheets.

#### 6.2.5 Blanks

Several unused glass fiber thimbles and a complete set of unused Mark III filters were returned to the laboratory in their respective containers. Approximately 200 ml of the acetone used for sample recovery was taken as a blank. In addition, a blank test run was conducted with the Mark III impactor to determine if stack gases had reacted with the filter media to cause false weight changes. In the blank run a backup filter was placed in front of a normally assembled impactor to filter out all particulate matter so that only the stack gases would contact the filter media.

All blanks were recovered and analyzed in the same manner as the actual samples. Data were recorded on the respective blank data sheets.

## REFERENCES

1. U.S. Environmental Protection Agency. A Review of Standards of Performance for Electric Arc Furnaces in the Steel Industry. EPA 450/3-70-033, October 1979.
2. U.S. Environmental Protection Agency. Background Information for Standards of Performance: Electric Arc Furnaces in the Steel Industry. EPA 450/2-74-017b, October 1974.
3. Carpenter Technology Corporation. Reports of Emissions Testing Performed August 22, 1978, on Carbonumundum Baghouse - No. 2 AOD. September 1978.
4. Southern Research Institute. A Computer-Based Cascade Impactor Data Reduction System. Prepared for U.S. Environmental Protection Agency under Contract No. 68022131, March 1978.
5. University of Florida. Use and Limitations of In-Stack Impactors. Prepared by the Department of Environmental Sciences for U.S. Environmental Protection Agency under Grant No. R803692-02, February 1980.
6. U.S. Environmental Protection Agency. Quality Assurance Handbook for Air Pollution Measurement Systems. Vol. III. EPA-600/4-77-027b, August 1977.