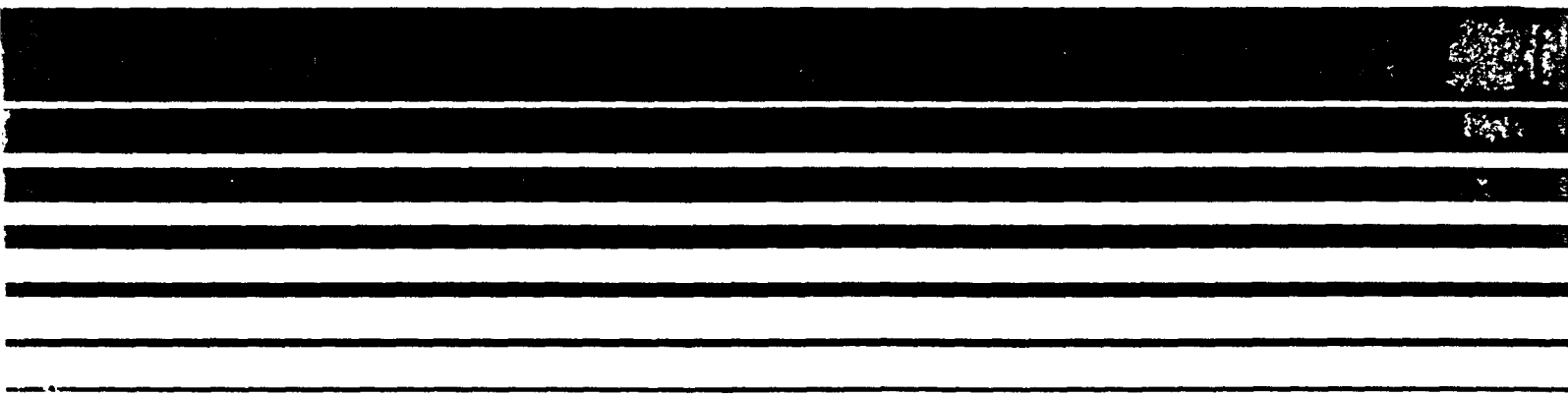

Air



Electric Arc Furnace - Revision Argon Oxygen Decarburization

Emission Test Report
Altech Specialty Steel
Corporation
Albany, New York

(let)



EMISSION TEST REPORT
AL TECH SPECIALTY STEEL CORPORATION
WATERVLIET, NEW YORK
ESED NO. 79/9
EMB NO. 80-ELC-7

by

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

Contract No. 68-02-3546
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ACKNOWLEDGMENT

Messrs. William Terry and Lalit Banker of Midwest Research Institute, the New Source Performance Standards contractor, monitored the process operation during the test series, assisted in the coordination of tests to process conditions, and provided most of the information contained in Section 2 of this report. Mr. Art Stienstra, Sr., of Al Tech Specialty Steel Corporation was available to coordinate plant activities, and Mr. Dennis Holzschuh, Task Manager for the U.S. Environmental Protection Agency, was on site to monitor the test series.

SECTION 1

INTRODUCTION

During the week of April 6, 1981, PEDCo Environmental personnel conducted an emission sampling program at the steel melt shop operated by Al Tech Specialty Steel Corporation (Al Tech) in Watervliet, New York. The purpose of this test program was to provide data for assessing the need for revising present New Source Performance Standards (NSPS) for electric arc furnaces (EAF) to include argon-oxygen decarburization (AOD) furnaces.

This plant was selected for source testing for the following reasons:

- 1) It exhibits best available control technology.
- 2) The emissions capture and control equipment is representative of the industry.
- 3) Both AOD and EAF furnaces are controlled by the same device.
- 4) Emission data could be obtained by nonstandard sampling techniques on the typical positive-pressure fabric filter.

Particulate matter concentrations and mass emission rates were measured at two inlet sites and one outlet site. Tests at the two inlet sites were conducted according to U.S. Environmental Protection Agency (EPA) Reference Method 5.* The sampling

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

train used for outlet tests was as described in Method 5, but procedures were adapted to the large exhaust area and corresponding low gas velocity.

Inlet and outlet tests for particulate matter were performed simultaneously to enable determination of control efficiency as well as values for controlled and uncontrolled emissions. Flue gas flow rates, temperature, and composition were measured in conjunction with these tests. In addition, particle size distribution samples were collected simultaneously at one inlet site and at the fabric filter outlet. Method 9* procedures were used to evaluate visible emissions (VE) from the melt shop and fabric filter outlet throughout the test. Visual determinations of fugitive emissions (FE) from the fabric filter dust handling system were recorded according to the proposed Method 22.** Samples of dust collected by the fabric filter were obtained for analysis of particle size distribution and elemental 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. Subsequent analyses were performed on two outlet particle size samples and two fabric filter dust samples to determine the concentration of fluoride, chromium, lead, and nickel.

This report documents the activities and results of the test program. Section 2 describes the processes that were tested and the operating conditions during the sampling period. Section 3

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

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

presents the results and discusses them, whereas Section 4 describes the sampling sites and general test procedures used. Section 5 briefly outlines quality assurance measures and audit results. Section 6 details the particulate matter and particle size distribution sampling and analytical procedures. The appendices contain computer output and example calculations (Appendix A), field data (Appendix B), sample recovery and analytical data (Appendix C), 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

Al Tech operates a total of two EAF's and two AOD's in the production of many different grades of steel, including stainless steel and high-temperature alloys. Each EAF and AOD has a rated capacity of 27.3 Mg (30 tons) and produces an average heat of 29 Mg (32 tons). The facility was operating 24 hours per day, 5 days per week, during the test series, but this schedule normally fluctuates between 3 and 5 days per week, depending on product demand.

The north AOD vessel and EAF No. 89 are located in the north end of the melt shop, and EAF No. 90 and the south AOD vessel are located in the south end of the shop. Typically, EAF No. 89 feeds the north AOD, and EAF No. 90 feeds the south AOD. If necessary, however, the north EAF can feed the south AOD vessel, and vice versa. Normal melt shop operation consists of charging and backcharging the EAF with cold scrap and fluxes; meltdown; tapping the EAF; charging molten metal, fluxes, and alloys into the AOD vessel; refining in the AOD vessel; and tapping the refined metal into a ladle, which is then transferred to the teeming aisle.

The EAF charge materials consists of 80 percent scrap and 20 percent additives. The scrap used at this plant is relatively clean, contains a high percentage of stainless steel, and is not pretreated. The initial additives are generally lime, charge chrome, ferronickel, and iron ore. Other materials may be added during the melting phase. A minimum amount of oxygen, if any, is blown into the molten metal while it is in the EAF, because refining is accomplished primarily in the AOD. Hot metal is tapped into a ladle, weighed, and transferred to the AOD vessel. The average EAF heat time (tap to tap) is 3.7 hours.

Hot metal from the EAF is charged into the AOD vessel, where major alloy additions are made. The additions include high-carbon magnesium, high-carbon chrome, nickel, silicon, molybdenum, and aluminum. The argon-oxygen-nitrogen gas mixture is blown into the molten bath through tuyeres located in the bottom of the vessel until the carbon in the metal has been oxidized to specification. Reduction mixes are added to remove sulfur and other impurities. The refined molten metal is tapped from the AOD into a ladle and transferred to the teeming area where the hot metal is poured into ingot molds. After it is tapped, the AOD remains idle until another hot metal charge from the EAF is ready. The AOD heat (charge through tap) takes about 1.5 to 2 hours, but can last longer if more refining is needed.

In the emission capture system, two hoods are provided above each electric furnace and each AOD vessel. The electric furnace hoods are situated so that one hood captures most of the

emissions from charging and melting, whereas the other captures most of the tapping emissions. The AOD hoods are situated so that each one captures half the refining emissions. A diverter stack directs the AOD refining emissions toward the hoods to avoid excessive drift of the emissions as a result of cross drafts. Each hood has a set of automatic dampers, which can be closed to direct more suction to another hood. The dampers on the hoods on the charging side of each EAF are always open. The dampers on the tapping side open automatically during tapping and remain closed the rest of the time. The dampers on the hood of the AOD vessels are always open because the automatic mechanism no longer functions.

Combined exhaust gases from all four furnaces are ducted to a Wheelabrator-Frye, positive-pressure fabric filter to remove particulate matter. The gas flows through the fabric filter at a rate of approximately $280 \text{ m}^3/\text{s}$ (600,000 acfm) and exits via a monovent type of exhaust. Mechanical shakers clean the bags in each compartment at periodic intervals. Al Tech has assigned two people to the regular maintenance of the fabric filter. A periodic visual inspection is made, and broken bags are changed when needed.

Technical data on the process and control system are included in Table 1 of Appendix D.

The operations of the four furnaces and the fabric filter were monitored by Lalit Banker and William Terry of Midwest Research Institute (MRI). Table 2-1 presents a summary of

TABLE 2-1. EAF AND AOD PRODUCTION SUMMARY^a

PEDCo run No., date	Furnace	Partial or completed heats tested				Tested production rate ^d	
		Heat No.	Heat time, ^b minutes	Metal produced ^c			
				Mg	tons	Mg/h	tons/h
1 4/7/81	North AOD	98033	85	28.0	30.9	8.7	9.6
		08440	100	27.9	30.8		
	89 EAF	98047	190	27.7	30.5	8.5	9.4
		98068	225	28.1	31.0		
	90 EAF	08440	440	25.4	28.0	6.5	7.2
		08444	240	30.2	33.2		
	South AOD	08445	235	27.2	30.0	5.2	5.7
		98047	110	28.9	31.8		
		08444	155	33.9	37.4		
		Total				28.9	31.9
2 4/8/81	North AOD	98045	90	27.9	30.8	8.5	9.4
		98064	65	30.8	34.0		
	89 EAF	98064	210	29.9	33.0	7.1	7.8
		98039	299	29.9	33.0		
	90 EAF	08464	185	28.6	31.5	7.7	8.5
		08446	225	29.5	32.5		
	South AOD	08447	300	28.8	31.8	6.9	7.6
		08464	150	32.7	36.1		
		08446	230	32.2	35.5		
		Total				30.2	33.3
3 4/9/81	North AOD	98090	225	29.1	32.1	4.9	5.4
		98091	225	30.4	33.5		
	89 EAF	98091	340	28.1	31.0	7.8	8.6
		98044	280	24.9	27.5		
	90 EAF	08451	350	30.4	33.5	9.8	10.8
		08465	225	32.5	35.8		
	South AOD	08452	e	-	-	5.7	6.3
		08451	160	35.0	38.6		
		Total				28.2	31.1

^aCompiled from process data in Appendix D and field data (test times) in Appendix B.

^bCharge-to-tap time for AOD's; tap-to-tap time for EAF's.

^cEAF production is the weight of metal transferred to an AOD; AOD production is the final tap weight.

^dTested production rates were determined by dividing the total weight of metal produced during a test by the sampling time. The weight of metal produced by a given furnace during a test was calculated by first dividing the minutes of normal operation actually sampled (from charging through tapping, not including delays or patching) by the total minutes of normal operation in the heat, and then multiplying by the weight of metal produced during the entire heat.

^eThe only normal operation of this heat sampled was the tap.

production data for the test series. The EAF heat times varied from 3.1 to 7.3 hours (tap to tap), and the weight of metal produced per heat ranged from 24.9 to 32.5 Mg (27.5 to 35.8 tons). The AOD heat times varied between 1.1 and 3.8 hours (charge through tap), and the weight of metal produced per heat varied between 27.9 and 35.0 Mg (30.8 and 38.6 tons). The variations in heat times were related in part to delays caused by one or more cranes that did not operate properly.

Production rates were calculated to determine if the tests were conducted during representative operating conditions. The tested production rate for each furnace was determined by dividing the total weight of metal produced during a test by the sampling time. The metal produced by a given furnace during a test was calculated by first dividing the minutes of normal operation actually sampled (from charging through tapping, not including delays or patching) by the total minutes of normal operation in the heat, and then multiplying by the weight of metal produced during the entire heat. For comparison, the normal production rate for all four furnaces operating at once was calculated at 31.4 Mg/h (34.6 tons/h), based on an average heat time of 3.7 hours and an average metal production of 29 Mg (32 tons) per furnace. The same heat time was used for the EAF's and AOD's, because one AOD heat normally occurs for each EAF heat. The tested production rate and the normal production rate both include the effects of delays and intervals between heats and should therefore be comparable. The average equivalent

production rate for the test series was 29.1 Mg/h (32.1 tons/h), which indicated that the tests were conducted while the process was operating at 93 percent of normal production rate.

Tests were delayed at various times during the series to avoid sampling when emissions were not representative of normal operation. On April 7, the test was stopped for 10 minutes because EAF No. 89 was idle for 33 minutes waiting for the pit crane to clean the tap runner. At 3:00 p.m. on April 8, the test was stopped for approximately 15 minutes because two of the furnaces were not operating. On April 8, the test was stopped before the end of the heat in EAF No. 89 because the furnace bay crane lost power. On April 9, the start of the test was delayed for about 30 minutes because the furnace bay crane temporarily lost power again.

The fabric filter was operating normally during the test period. The fabric filter control panels were monitored hourly for the duration of the tests. Test personnel periodically closed off a baghouse compartment for a short period to move their sampling equipment. Because one compartment is always in the cleaning mode, this meant two compartments were not in operation during that short period of time. The pressure drop in each compartment, the inlet gas temperature, the fan amperage for each of the three fans, and the number of compartments cleaning or closed off were observed to assure normal fabric filter operation. The pressure drop varied between 1.0 and 1.5 kilopascals (4 and 6 in. H₂O) throughout the tests. All three fans were

operating at full power during the tests. The flue gas inlet temperature fluctuated from 43° to 54°C (100° to 130°F) during the test period.

The test conditions were representative of normal plant operation, and the data should be useful.

During the tests, emissions periodically filled the melt shop. Some of the emissions were deflected when cranes passed above the furnaces and vessels and when the cranes were in position for a charge or tap. The cross drafts that developed from open doors in the scrap bay and tapping pit also sometimes deflected emissions from the hood. The inoperable automatic dampers on the AOD hoods were always open and prevented their optimal use. Although these dampers could be operated manually, they were left open throughout the tests in line with normal operating procedure. Although the emissions were not always completely captured, the shop always cleared in 5 to 10 minutes. Plant workers indicated that emission capture was better when the capture and control system was new and the automatic AOD dampers were operating properly.

Emissions generated by the EAF's were greatest during meltdown, but emissions were also significant during tapping. Emissions from the AOD were greatest during the initial stages of the heat when the oxygen concentration in the blowing gases was the highest. Emissions from the AOD during blowing appeared to be equal to or greater than EAF meltdown emissions. For long periods of time, however, the AOD vessel is in a nonblowing position

while operators wait for sample results to determine what alloys are needed and how much more blowing is necessary to meet final specifications.

SECTION 3

SUMMARY OF RESULTS

This section details results obtained from the emission test program. Particulate matter tests were run simultaneously at two inlet sites and the fabric filter outlet, and particle size distribution tests were run at one inlet site and at the outlet. Visible emissions from the melt shop and fabric filter outlet were evaluated concurrently with particulate test runs, as were fugitive emissions from the fabric filter. 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 245 milligrams per dry normal cubic meter (mg/dNm^3) at 20°C and 101 kilopascals (kPa), or 0.1076 grains per dry standard cubic foot (gr/dscf) at 68°F and 29.92 in.Hg. At the outlet, particulate concentration averaged 3.46 mg/dNm^3 (0.0015 gr/dscf), to yield a 98.6 percent control efficiency. Both levels of concentration were in the range of expected values, which were based on previously reported data on EAF's.^{1,2}

Individual 6-minute set averages of visible emissions from the melt shop ranged from 0 to 15 percent opacity during charging

TABLE 3-1. SAMPLES COLLECTED AT AL TECH SPECIALTY STEEL

Sampling site	Sample type	Sampling method	Number ^a of samples	Time for each sample	Additional analysis		
					Type	No.	Method
No. 1 - North	Particulate Particle size	EPA 5 High-capacity impactor	3	~ 6 h	Condensibles b	3	Gravimetric
			3	~ 3 h			
			3	~20 min			
No. 2 - South	Particulate	EPA 5	3	~ 6 h	Condensibles	3	Gravimetric
No. 3 - Fabric filter outlet	Particulate Particle size VE	Modified EPA 5 Impactor	3	~ 5-1/2 h	Organic and inorganic condensibles	3	Back-half E/C extract
			3	~ 5 h			
			2 ^c	~ 7 h			
Shop exit	VE	EPA 9	2 ^c	~ 7 h			
Fabric filter dust handling system	FE Dust	EPA 22 Grab	2 ^c	~ 5 h 1 per day	Trace metals, particle size ^b	3	SSMS, ^d Coulter
			3				

^aDoes not include preliminary, blank, or duplicate runs.

^bTwo samples were analyzed later for fluoride by EPA Method 13B and for chromium, lead, and nickel by atomic absorption.

^cThe third run could not be performed because of unfavorable weather conditions.

^dSpark source mass spectroscopy.

and tapping operations. Average opacities of individual sets ranged from 0 to 22 percent during refining and other process operations. Visible emissions from the fabric filter outlet were zero percent opacity, even after compartment cleaning cycles.

These and other results are presented and discussed in detail in the following sections. Results are grouped by emission type. The sections in each group describe the sampling scheme used at each site, summarize data and results, and discuss the results.

3.1 PARTICULATE MATTER

Two inlet sites and the fabric filter outlet were tested simultaneously. Site 1 represented emissions from the north EAF (designated by the plant as No. 89) and the north AOD; Site 2 represented emissions from the south pair of furnaces (including EAF No. 90); and Site 3 represented fabric filter outlet emissions.

3.1.1 Sampling Scheme

Tests at all sites commenced simultaneously and ran for approximately the same time until respective traverses were completed, about 5 to 6 hours. This procedure enabled calculation of control efficiencies and emission factors. Each test run at Site 1 was to have included two integral EAF heats (from initial charge through the final tap) of approximately 3 to 3.5 hours each and two complete AOD heats of approximately 1.5 to 2 hours each. Because a malfunctioning crane caused shifts in the

normal sequence of operation, the second and third tests were stopped prior to completion of the second EAF heat, and the third test included only portions of the AOD heats. Nevertheless, the actual tests were generally representative of integral EAF heats. So that tests at Site 2 could be conducted simultaneously with other tests, the sample times were not coordinated to include an integral number of heats, as the operating schedule of the south furnaces was staggered from that of the north furnaces. Outlet tests at Site 3 also could not be coordinated to represent an integral number of heats (because of the different furnace schedules), but they were conducted in conjunction with tests at other sites. Fabric filter cleaning cycles were sampled in the normal fashion as they occurred.

The NSPS contractor representative, who was on site to monitor process operations, assisted in the coordination of tests with process conditions. Based on his observations, tests were interrupted if one of the EAF's experienced an operational delay of longer than 20 minutes. Delays from 1 to 1.5 hours could be tolerated for the AOD's without interrupting tests, because that amount of AOD downtime would normally occur within the time frame of an EAF heat.

Particulate matter sampling and analytical procedures at both inlet sites followed those described in EPA Methods 1, 2, 3, and 5 of the Federal Register.^{*} A Method 5 sampling train and

^{*} 40 CFR 60, Appendix A, July 1, 1980.

analytical procedures were used on the outlet tests, but the sampling procedures were modified by sampling at a constant rate, at a site that did not meet minimum Method 1 criteria, and at fewer points than specified by Method 1. The sampling rate was based on the estimated average velocity of the gas stream at the sampling location, which was calculated by dividing the total inlet flow rate measured by Method 2 by the total exhaust area represented by the sampling cross section. Three tests were run at each site. Integrated gas samples were collected once at each site (according to Method 3) to verify that the gas streams were essentially air. Additional molecular weight determinations were not made.

3.1.2 Gas Conditions and Particulate Emissions

Summaries of the measured stack gas and particulate emission data are presented in Tables 3-2 and 3-3. Volumetric flow rates are expressed in actual cubic meters per second (m^3/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 (dNm^3/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 in Table 3-3 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

TABLE 3-2. SUMMARY OF GAS STREAM CHARACTERISTICS^a

Run No.	Date (1981)	Flow rate ^b		Temperature		Moisture, %	Velocity ^c		Flow rate ^d	
		dNm ³ /s	dscfm	°C	°F		m/s	ft/s	m ³ /s	acfm
AIP-1	4/7	130.0	275,500	43	110	0.81	19.1	62.8	139.6	295,800
AIP-2	4/8	121.8	258,200	47	117	0.89	18.2	59.8	133.0	281,900
AIP-3	4/9	127.2	269,600	42	107	1.25	19.0	62.2	138.4	293,300
Average		126.3	267,800	44	111	0.98	18.8	61.6	137.0	290,300
A2P-1	4/7	129.9	275,200	46	116	0.65	19.3	63.3	140.7	298,100
A2P-2	4/8	129.3	273,900	48	118	0.69	19.3	63.4	141.1	298,900
A2P-3	4/9	130.4	276,300	45	114	1.29	19.7	64.7	143.9	304,800
Average		129.9	275,100	46	116	0.88	19.4	63.8	141.9	306,600
A3P-1	4/7	259.9	550,700 ^e	42	108	0.41	2.4	3.0 ^f	275.7	584,100 ^f
A3P-2	4/8	251.1	532,100	48	119	0.68	2.4	7.9	273.0	578,600
A3P-3	4/9	257.6	545,900	46	114	1.17	2.5	8.2	282.0	597,600
Average		256.2	542,900	45	114	0.75	2.4	8.0	276.9	586,800

^a Average CO₂ ≤ 0.2%, O₂ = 20.3%.

^b 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.

^c Velocity at stack conditions.

^d Flow rate at stack conditions.

^e The outlet standard flow rates were determined by summing flows at both inlet sites.

^f Outlet gas velocities and actual flow rates are based on measured inlet flow rates converted to outlet conditions.

TABLE 3-3. SUMMARY OF FILTERABLE PARTICULATE EMISSIONS

Site	Run No.	Concentration ^a		Mass emission rate		Isokinetic rate, %
		mg/dNm ³	gr/dscf	kg/h	lb/h	
Inlet No. 1 north furnaces	A1P-1	217	0.0948	102	224	108
	A1P-2	182	0.0794	80	176	102
	A1P-3	523	0.2288	240	529	102
Average		307	0.1343	140	309	
Inlet No. 2 south furnaces	A2P-1	198	0.0867	93	205	104
	A2P-2	240	0.1047	111	246	104
	A2P-3	111	0.0485	52	115	105
Average		183	0.0800	86	188	
Combined inlets ^b	1	208	0.0908	194	428	
	2	212	0.0924	191	421	
	3	315	0.1397	292	643	
Average		245	0.1076	226	498	
Outlet No. 3 ^c	A3P-1	3.27	0.00143	3.06	6.75	107 ^d
	A3P-2	2.88	0.00126	2.61	5.75	106
	A3P-3	4.24	0.00185	3.94	8.68	102
Average		3.46	0.00151	3.20	7.06	

^a 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.

^b Combined inlet mass emission rates represent the sum of results for Sites 1 and 2; concentrations are weighted averages based on standard flow rates.

^c Outlet mass emission rates are based on measured outlet concentrations and total inlet standard flow rates.

^d Isokinetic sampling rates for outlet runs were calculated by using average gas velocities that are based on inlet flow rates converted to outlet conditions.

concentration and the volumetric flow rate is the mass emission rate. The particulate data represent filterable material collected in the sample probe and on the filter, both of which were heated to approximately 121°C (250°F). The isokinetic rate 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 rates at inlet Sites 1 and 2 averaged 126 dNm³/s (268,000 dscfm) and 130 dNm³/s (275,000 dscfm). The outlet flow rate averaged 256 dNm³/s (543,000 dscfm). The flow for each outlet run represents the sum of the standard flow rates measured at the two inlet sites.

The actual flow rate at inlet Site 1 averaged 137 m³/s (290,000 acfm) at 44°C (111°F) and less than 1 percent moisture, and was equivalent to a gas velocity of 19 m/s (62 ft/s). The actual flow rate at inlet Site 2 averaged 142 m³/s (301,000 acfm) at 46°C (116°F) and less than 1 percent moisture, which equalled a gas velocity of 19 m/s (64 ft/s). The outlet flow rate averaged 277 m³/s (587,000 acfm) at 45°C (114°F) and less than 1 percent moisture, which represented an average gas velocity of 2.4 m/s (8.0 ft/s) at the sampling cross section. Outlet velocities and flow rates are based on inlet standard flows and measured outlet stack conditions of temperature, pressure, and moisture.

For calculation purposes the stack gases were essentially air. For one run at each site, the carbon dioxide (CO₂)

concentration averaged less than 0.2 percent, and the oxygen concentration was 20.3 percent by volume.

The combined inlet concentration of filterable particulate matter averaged 245 mg/dNm^3 (0.1076 gr/dscf). This is the average of concentrations measured at both inlet sites, weighted according to measured standard flow rates. At inlet Site 1 the average particulate concentration was 307 mg/dNm^3 (0.1343 gr/dscf), and at Site 2 the average particulate concentration was 183 mg/dNm^3 (0.0800 gr/dscf). These concentrations correspond to mass emission rates of 140 kg/h (309 lb/h) at Site 1, 86 kg/h (188 lb/h) at Site 2, and 226 kg/h (498 lb/h) total uncontrolled emissions.

The outlet particulate concentration averaged 3.46 mg/dNm^3 (0.00151 gr/dscf), with a corresponding mass emission rate of 3.20 kg/h (7.06 lb/h). The concentration results for each run are actually representative of the exhaust stream from four of the eight fabric filter compartments, but emission rates are based on the total system flow.

All isokinetic sampling rates were between 102 and 108 percent. The outlet values are based on average gas velocities at the sampling cross section, which were calculated from measured inlet flow rates and outlet stack conditions.

3.1.3 Control Efficiencies and Emission Factors

Control efficiencies were calculated by dividing the difference between the outlet and weighted inlet particulate concentrations by the weighted inlet value. Table 3-4 presents a

TABLE 3-4. FILTERABLE PARTICULATE COLLECTION EFFICIENCY

Run	Inlet concentration ^{a,b}		Outlet concentration ^b		% efficiency ^c
	mg/dNm ³	gr/dscf	mg/dNm ³	gr/dscf	
1	208	0.0908	3.27	0.00143	98.4
2	212	0.0924	2.88	0.00126	98.6
3	315	0.1397	4.24	0.00185	98.7
Average	245	0.1076	3.46	0.00151	98.6

^aWeighted average from Sites 1 and 2.

^bMilligrams 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.

^cPercent efficiency = $\frac{C_{inlet} - C_{outlet}}{C_{inlet}} \times 100$.

summary of filterable particulate concentrations and indicates the fabric filter collection efficiency for each run. Control efficiencies were 98.4, 98.6, and 98.7 percent on the three test days.

Table 3-5 presents particulate emission factors for uncontrolled and controlled emissions, which were calculated by dividing the appropriate hourly mass emission rate by the corresponding furnace metal capacity. 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). Based on a total capacity of 109 Mg (120 tons) for the four furnaces, the emission factor for uncontrolled emissions averaged 2.1 kg/h per Mg, or 4.2 lb/h per ton. It was possible for two runs at Site 1 to be conducted over an integral number of heats. Each run consisted of two EAF heats and two AOD heats. Emission factors for these tests should be more representative of uncontrolled emissions on a per-heat basis. Results for the two runs averaged 1.67 kg/h per Mg (3.33 lb/h per ton) based on a metal capacity of 54.5 Mg (60 tons). The average controlled emission factor for all four furnaces was 0.03 kg/h per Mg (0.06 lb/h per ton).

Emission factors shown in Table 3-6 are based on actual production data. Results were calculated by dividing the filterable mass emission rate by the corresponding equivalent tested production rate. Emission factors are reported in kilograms per megagram (pounds per ton) of metal produced. The average uncontrolled emission factor was 7.8 kg/Mg (15.6 lb/ton),

TABLE 3-5. PARTICULATE EMISSION FACTORS^a

Run No.	Uncontrolled		Run No.	Controlled	
	kg/h per Mg	lb/h per ton		kg/h per Mg	lb/h per ton
A1P-1 ^b 1	1.88 1.78	3.73 3.57	1	0.028	0.056
A1P-2 ^b 2	1.47 1.75	2.93 3.51	2	0.024	0.048
3	2.08	5.36	3	0.036	0.072
Average ^c	2.07 (1.67)	4.15 (3.33)	Average	0.029	0.059

^aFactors are based on emissions per unit of furnace metal capacity in kilograms per hour per megagram (pounds per hour per ton).

^bTests were conducted for an integral number of heats and represent emissions from the north furnaces at a metal capacity of 54.4 Mg (60 tons). All other runs represent total emissions from the four furnaces at a metal capacity of 109 Mg (120 tons).

^cValues in parentheses () are for the integral heat tests on the north furnaces.

TABLE 3-6. PARTICULATE EMISSION FACTORS BASED ON PRODUCTION^a

Run No.	Metal production rate ^b		Emission factor ^c			
			Uncontrolled		Controlled	
	Mg/h	tons/h	kg/Mg	lb/ton	kg/Mg	lb/ton
1	28.9	31.9	6.7	13.4	0.11	0.21
2	30.2	33.3	6.3	12.6	0.09	0.17
3	28.2	31.1	10.4	20.7	0.14	0.28
Average	29.1	32.1	7.8	15.6	0.11	0.22

^aCalculated by dividing the filterable mass emission rate by the corresponding average metal production rate.

^bFrom Table 2-1.

^cKilograms per megagram (pounds per ton) of metal produced.

based on a production rate of 29.1 Mg/h (32.1 ton/h). At the same production rate, controlled emissions averaged 0.11 kg/Mg (0.22 lb/ton).

3.1.4 Discussion

In general, the particulate tests were conducted according to schedule. No problems were encountered with the sampling equipment, and the few problems associated with the process operation were considered minor. The report does not include the results of preliminary tests that were conducted at each site 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, deviations in test methods and calculations caused by the fabric filter site configuration, 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 catch weights were between 17 and 25 mg, which were considered satisfactory. The actual minimum sampling time and volume were 5.3 hours and 5.9 dNm^3 (208 dscf). These met the minimum criteria of 4 hours and 4.5 dNm^3 (160 dscf) set forth in Subpart AA of the Federal Register.*

* 40 CFR 60, Subpart AA, July 1, 1980.

The back-halves of each inlet and outlet run were analyzed for condensible matter. These results are included in the computer printouts in Appendix A, but are not summarized here because they are considered to be biased. The results do not agree well with expected values based on previously reported tests at similar installations. Probable cause of the biases is believed to be the long sample line used between the heated filter and first impinger, even though it was Teflon-lined.

The inlet flow rates measured at Sites 1 and 2 were within 6 percent of each other, which indicated that the three induced-draft (I.D.) fans were operating effectively to promote the equal capture of emissions from each half of the melt shop. The sum of the inlet flows compared very well with the system design flow rate of $280 \text{ m}^3/\text{s}$ (600,000 acfm), as all runs were within 4 percent of this value.

The outlet volumetric flow rates, dry and at standard conditions, were assumed to be equal to the sums of the inlet standard flow rates. This assumption was necessary because the site configuration made it impossible to obtain accurate velocity data at the outlet. Flows at stack conditions were calculated from the standard flow rates by use of measured values of temperature, pressure, and moisture at the outlet.

The procedure just described is typical for tests at positive-pressure fabric filters without stacks, and assumes no air leakage. Air inleakage at the I.D. fans was probably no more than 10 percent, as evidenced by the agreement between measured

and design flows. In addition, air leakage through the open grating at the bottom level of the fabric filter was minimized by covering the openings during the test period. At Al Tech these open gratings represented sources of dilution air. Comparison of inlet and outlet moisture contents seemed to indicate some dilution, but the limits of accuracy for the moisture determinations at the 1 to 2 percent level are probably greater than the reported differences. The close agreement between inlet and outlet gas temperatures indicated that any entry of dilution air was negligible. A significant inflow of ambient air would have caused a temperature decrease, which was not evident. For these reasons, the amount of dilution air that entered the system was considered to be minimal, and results reported for the outlet flow rates should be representative of actual conditions.

The fabric filter site configuration required that several modifications be made to EPA reference methods for their use in the outlet tests. Although they could not be analyzed precisely, the effects of these deviations on outlet particulate concentration results were considered to be relatively minimal. The two deviations from Method 1 were the use of a sampling location less than two equivalent duct diameters downstream from the nearest disturbance and sampling at fewer than the minimum number of points. The three deviations from Method 5 were the lack of velocity monitoring at individual sampling points, use of a constant sampling rate at all points during a given test, and traversing only half of the large exhaust area for each test.

These deviations, which generally would apply when testing positive-pressure fabric filters without stacks, are discussed in the following paragraphs.

The outlet site configuration did not provide any sampling location capable of meeting minimum Method 1 criteria. The throat of the monovent was selected as the sampling location, primarily because it was the smallest cross-sectional area available. This location would be less prone to concentration biases caused by faulty bags, and would provide the highest gas velocities.

The reason for sampling four rather than eight points per compartment was to lessen the possibility of biasing results. Because moving from one traverse point to another during sampling required test personnel to enter a compartment while the fabric filter was operating, extraneous dust could have been stirred up by bumping the probe against nearby beams or by personnel activity, and results could have been biased if any such dust had entered the nozzle during sampling. By sampling only four compartments and using extreme care during point changes, we were able to avoid these potential problems in all of the tests.

It should be noted that a better sampling approach for this type of fabric filter configuration would be to sample from outside on the baghouse roof and to use ports located in the monovent throat. This would reduce the possibility of sampling extraneous dust and shorten the time required to change traverse locations. More points and compartments per run could then be

sampled. Because safe access to the roof was not readily available, ports were not installed at this plant.

A constant sampling rate was used for the outlet tests because individual point velocities could not be accurately measured to make isokinetic sampling rate adjustments. The preliminary traverse of three compartments verified the inaccuracy of velocity measurement attempts. Most of the very low velocity heads were readable on an expanded scale manometer; however, turbulence at the low flows caused fluctuations and frequent negative readings. Thus, an average gas velocity at the outlet sampling location was calculated from previous data obtained at the two inlet sites and used to set a constant sampling rate. The two inlet flow rates were calculated and totaled; then the sum was converted from standard conditions of temperature and pressure to outlet conditions. This flow was then divided by the total cross-sectional area of all eight compartments represented by the sampling plane. The resultant average gas velocity was assumed to represent each traverse point. For each outlet test, inlet data obtained from the previous day's activities were used to estimate the average velocity. The constant isokinetic sampling rate to be used that day was then calculated from this estimated velocity. For data recording and computer calculation purposes, an equivalent velocity head was calculated and entered on the field data sheets for each traverse point as if it had actually been measured.

Other parameters entered on the data sheets were measured according to normal procedures.

All outlet computer calculations in Appendix A for flow rate, emission rate, velocity, and isokinetics are based on these estimated velocities; however, results reported in tables and text have been adjusted to reflect measured rather than estimated values. This was accomplished by dividing the measured total inlet flow rate by the flow rate used initially to estimate the outlet velocity. Results were adjusted by applying this ratio, either directly or inversely as appropriate, to computer outputs that were based on estimated values. These calculations are shown in Appendix A.

The average isokinetics indicated for the outlet tests were all within the acceptable range (100 ± 10 percent). These isokinetic calculations included the assumption that the average velocity for the four compartments tested per run was approximately equal to the average velocity for all eight compartments. We believe this is a reasonable assumption (± 10 percent), although the middle compartments may have had slightly higher velocities than the end ones. Another factor affecting isokinetic and velocity results was the fabric filter cleaning cycle time. Reported results do not account for the time when only seven compartments were operating instead of eight, but the greatest effect would occur if one compartment were always off line. This would reduce reported outlet isokinetics by a factor of 0.875 and increase gas velocities by the inverse of this

factor. Isokinetics would be between 89 and 94 percent; therefore, emission results should not be affected significantly by this consideration.

Although average outlet isokinetics were acceptable, values at individual traverse points could be much different, depending on the local gas velocities. The range of actual isokinetic variation was difficult to gauge without valid point velocity data, but an estimate of plus or minus 50 percent seems realistic. The overall isokinetic rates, however, were within specified limits, and any point-specific biases should tend to be averaged. Even so, it is expected that the precision of the method used (constant sampling rate) is less than that of Method 5, which requires isokinetic sampling at each point. Results should be viewed in this light, even though they were fairly consistent and appear to be representative.

Evaluation of the process data furnished by MRI and actual sampling times indicated that operation conditions were representative during the tests. The equivalent tested production rate averaged 93 percent of the maximum production rate of the four furnaces. Although the metal production of individual furnaces varied considerably, the overall production rates for each test were within 10 percent of each other. A periodically malfunctioning crane caused a shift in the normal sequence of furnace operations and several extended furnace delays. Tests were interrupted when the emissions were considered to be significantly affected. The results of Tests 1 and 2 did not seem

to be affected by the delays or variation in furnace operations, but Test 3 results may have been. The concentration at Site 1 increased and the concentration at Site 2 decreased, but these changes could not be related to specific process activities. Indeed, the equivalent production rates for Test 3 showed the reverse: a decrease for Site 1 furnaces and an increase for Site 2 furnaces. The overall increase in uncontrolled emissions was verified by the corresponding increase in outlet emissions, but the overall production rate for Test 3 was slightly lower than the previous tests. The increase in Test 3 emissions caused a 12 percent increase in the average outlet concentration, which was considered relatively insignificant. Overall results were therefore taken as being representative of normal operating conditions.

3.2 PARTICLE SIZE

Tests for particle size distribution were conducted at Site 1 (the north furnaces) to represent uncontrolled emissions, and at Site 3 to represent controlled emissions. These tests were performed in conjunction with particulate matter tests.

3.2.1 Sampling Scheme

Inlet particle size tests were conducted over an entire heat cycle to represent average emissions, and during shorter intervals, to represent different process modes. Tests during integral heats were initiated at the beginning of a charge for either the North AOD or EAF No. 89, whichever occurred first.

Tests continued for one heat and concluded at the end of tapping operations at EAF No. 89, which yielded a sampling time of approximately 3 to 3.5 hours. This time should have included an entire AOD heat of between 1.5 and 2 hours. Because a malfunctioning crane caused a shift in the sequence of normal operations, the first test included almost two AOD heats, and the third test included portions of two different AOD heats. The shorter particle size runs were performed at various times during the second half of each particulate test. The sampling times for these shorter tests were approximately 20 minutes, adjusted as necessary to obtain proper loadings.

Outlet particle size distribution samples were collected simultaneously with each particulate test, which yielded a 5-hour sampling time for each run. Each test was conducted in the same four fabric filter compartments as the coinciding particulate tests, but at different times to minimize interferences. Because of the overlapping schedules between north and south furnaces, no attempt was made to represent integral heats. Fabric filter cleaning cycles were sampled as they occurred.

The integral heat runs at the inlet were coordinated with process operations with the assistance of the NSPS contractor representative. Based on his observations, tests were interrupted as 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 north furnace duct. Velocity data were obtained periodically during each run by the use of Method 2 equipment. Outlet samples were run in duplicate, with each impactor positioned at one of the four sampling points per compartment. The sample time for each run was divided equally among the same four compartments in which the particulate tests were being conducted. Because accurate velocity data could not be obtained at the outlet site, estimated velocities calculated from previous inlet data were used to set approximate isokinetic sampling rates. The results of three runs for each type of sample are included in the report.

3.2.2 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 was plotted manually and represents the best-fit curve through individual and average 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).³ 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 over an entire heat cycle. Actual results were limited to three cut-points between 1.6 and 13 μm , but the curve was extrapolated down to a diameter of 0.5 μm for comparison purposes. The average distribution indicated that 50 percent by weight of uncontrolled particulate emissions consisted of particles with aerodynamic diameters of 0.55 μm or less. Eighty percent by weight had diameters less than or equal to 10 μm .

Figure 3-2 shows the results of three runs conducted at Site 1 during various times of process operation. The three cumulative distribution curves distinctly indicate a short-term variation of emissions. Run 1 represented EAF charging emissions, Run 2 represented emissions during the EAF melting phase, and Run 3 represented emissions from both an AOD and an EAF. The percent by weight of emissions that had diameters equal to or smaller than 10 μm varied among the three runs from 54 to 29 to 74 percent, respectively. Only the run representing AOD and EAF emissions was similar to average integral heat results.

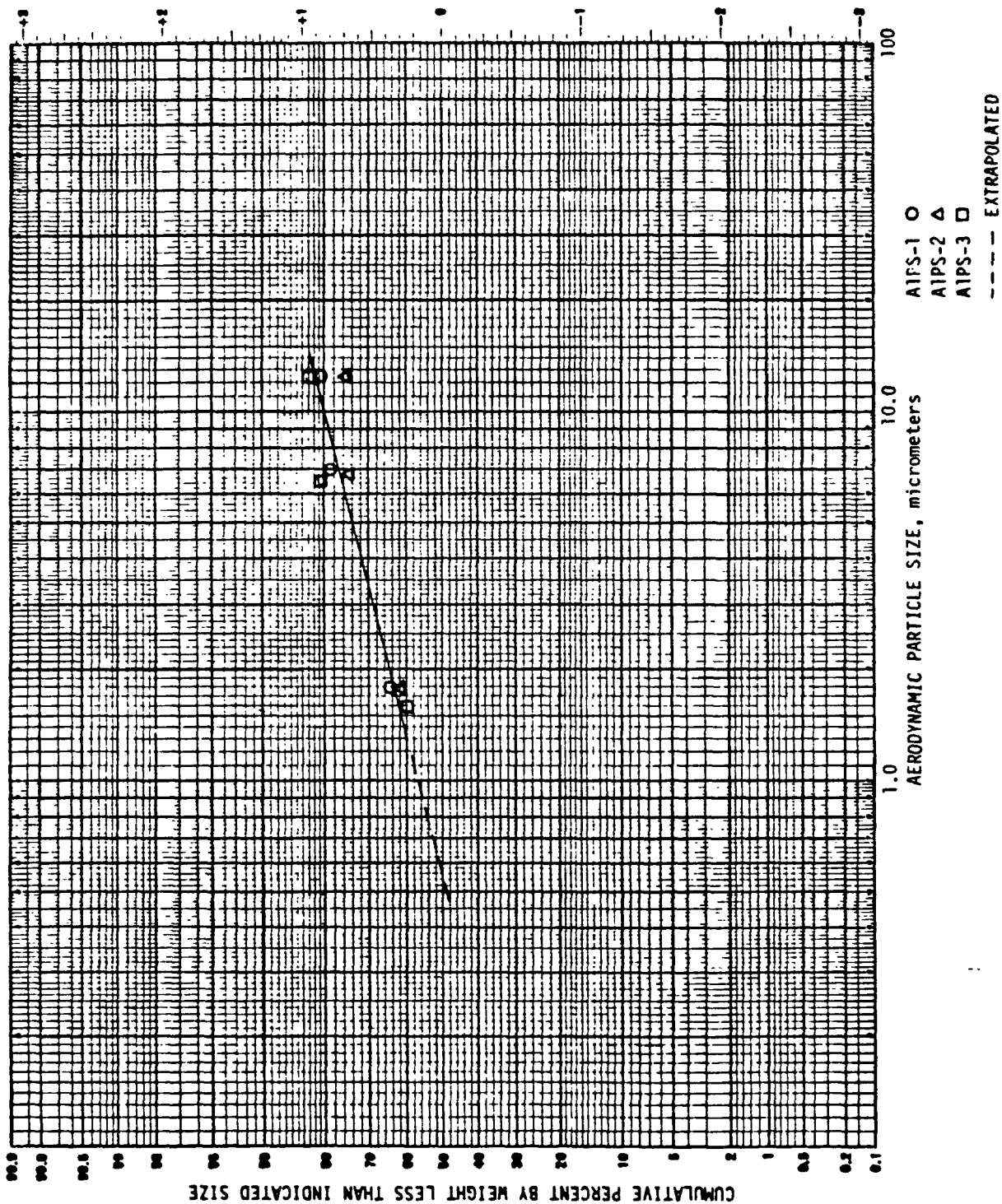


Figure 3-1. Average particle size results for uncontrolled emissions, Site No. 1.

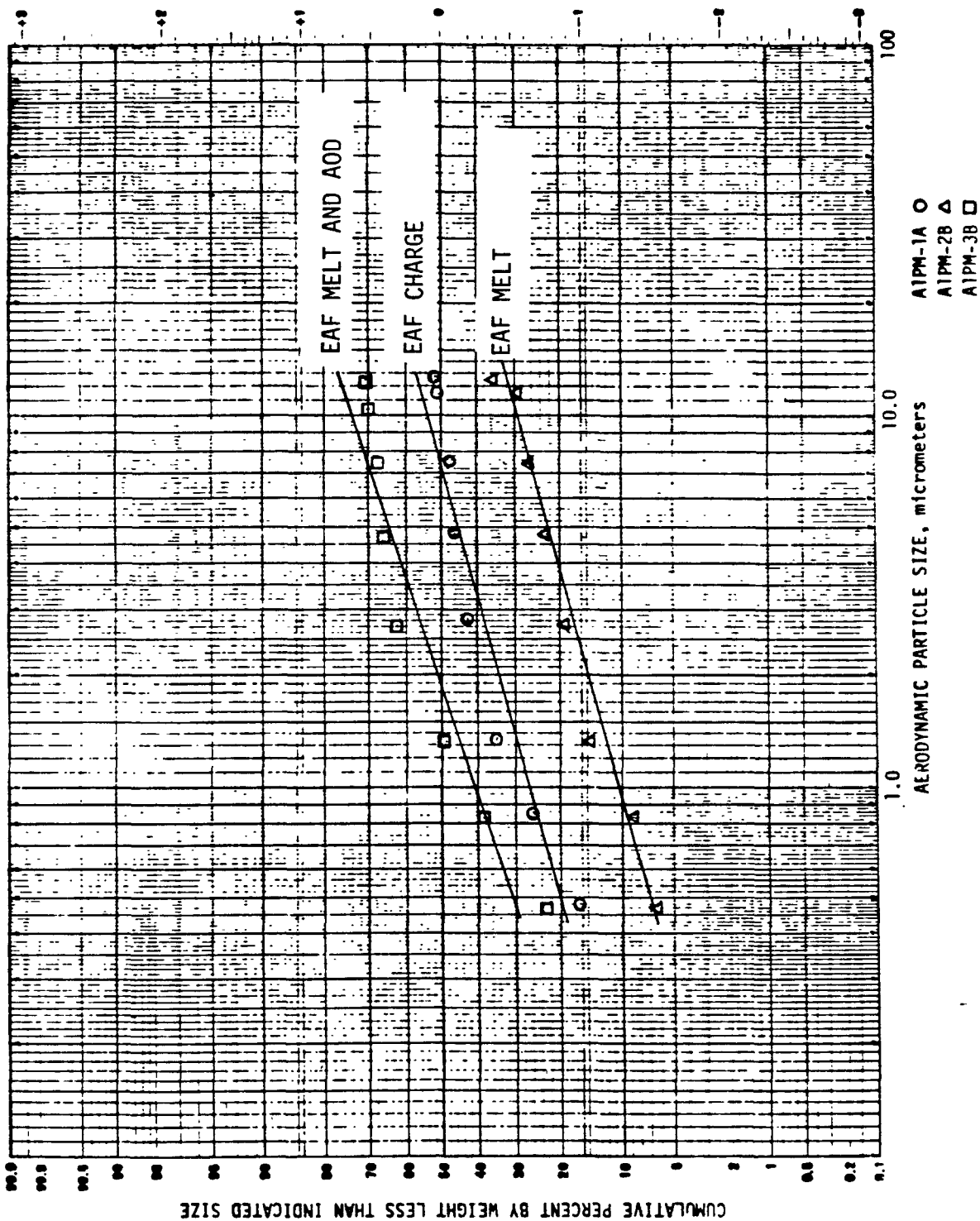


Figure 3-2. Particle size results for uncontrolled emissions during various furnace operations, Site No. 1.

Figure 3-3 shows the average distribution curve for the outlet samples. Results indicated that 50 percent of the mass emissions consisted of particles having aerodynamic diameters of 5 μm or less. Sixty-six percent by weight had diameters smaller than or equal to 10 μm .

Table 3-7 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 3-3. These percentages were multiplied by the average inlet and outlet particulate concentrations shown in Table 3-3 to calculate controlled and uncontrolled mass loadings in the respective size ranges. Fractional efficiencies were calculated for each size range by dividing the difference between inlet and outlet concentrations by the inlet values. Efficiency ranged from a high of 99.7 percent for particles smaller than 0.5 μm in diameter to a minimum of 96.2 percent for particles between 5 and 10 μm in diameter; the overall efficiency was 98.6 percent.

3.2.3 Discussion of Results

Results of all the tests 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 remember that particle sizes are in terms of aerodynamic diameters based on a particle density of 1 g/cm^3 . Cumulative distribution curves based on physical diameters and actual density would be shifted

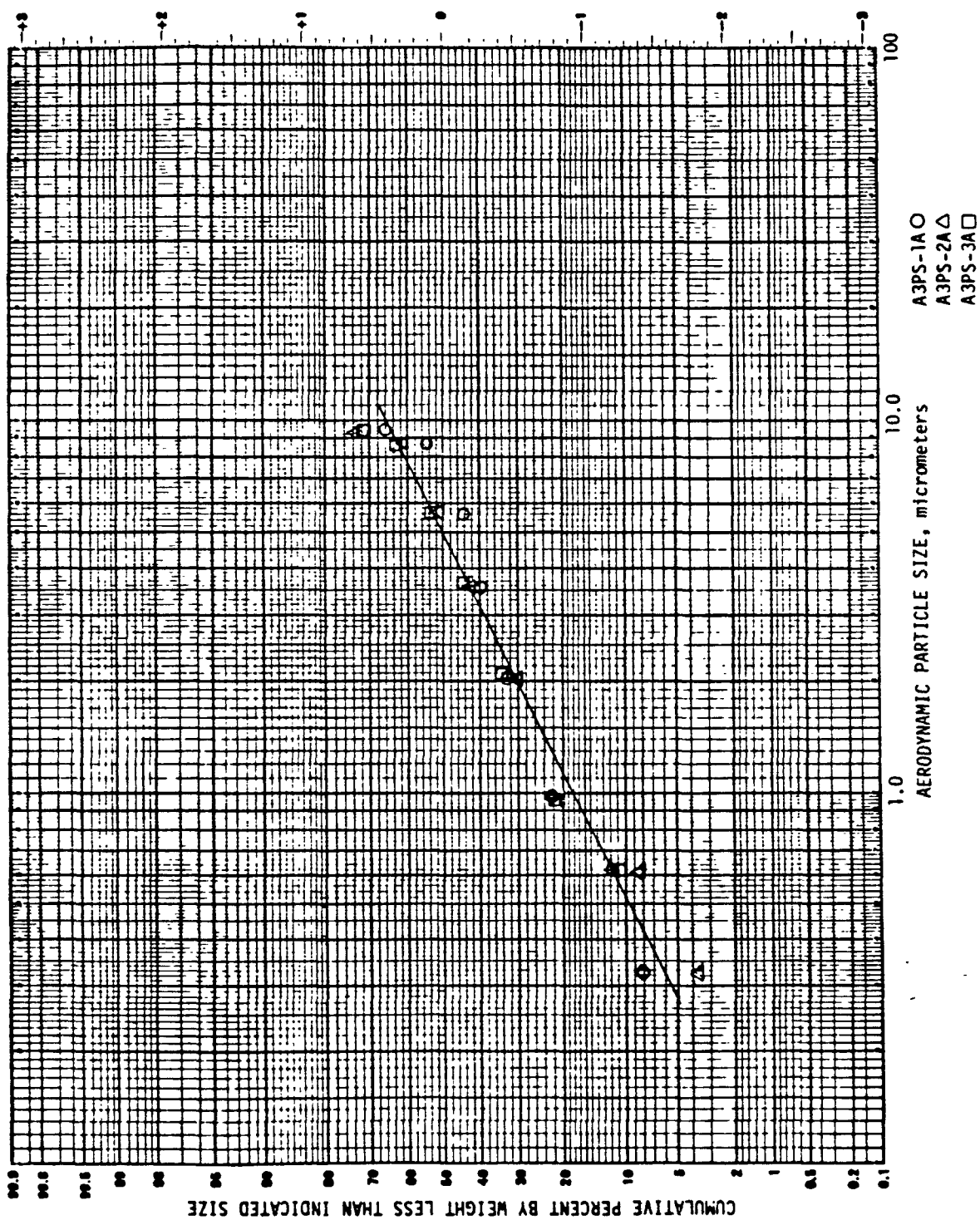


Figure 3-3. Average particle size results for controlled emissions, Site No. 3.

TABLE 3-7. 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 μ m	Total
Cumulative weight percent ^a less than larger stated size	Inlet 49 10 Outlet	49-57 10-18	57-67 18-35	67-74 35-50	74-80 50-66	- -	100 100
Weight percent in stated size range	Inlet 49 10 Outlet	8 8	10 17	7 15	6 16	20 34	100 100
Particulate concentration ^b in stated size range, mg/dNm ³	Inlet 120 0.346 Outlet	19.6 0.277	24.5 0.588	17.2 0.519	14.7 0.554	49.0 1.18	245 3.46
gr/dscf	Inlet 0.0527 0.0002 Outlet	0.0086 0.0001	0.0108 0.0003	0.0075 0.0002	0.0065 0.0002	0.0215 0.0005	0.1076 0.0015
Fractional collection efficiency ^c in stated size range		99.7	98.6	97.6	97.0	96.2	97.6
							98.6

^a Weight percents are taken from plots of average distributions.

^b Particulate concentration = total emissions x weight % in stated size range; concentrations given in terms of milligrams per dry standard 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.

^c Collection efficiency = $\frac{\text{Inlet concentration} - \text{outlet concentration}}{\text{inlet concentration}} \times 100$

to the left toward smaller sizes if the actual density were greater than 1 g/cm^3 , 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 3.3 g/cm^3 . Using this particle density would increase the amount of controlled emissions smaller than $1 \text{ }\mu\text{m}$ from roughly 20 to 30 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 generally agreed with expected distributions based on previous EAF data. Particulate concentrations indicated by the first two distribution tests compared favorably with the results of particulate tests conducted over similar time frames. Results of the third distribution test did not agree with the third particulate test, but this lack of agreement was believed to be representative of the short-term variation in emissions. The isokinetic sampling rates for the three runs (104, 100, and 112 percent, respectively) were considered acceptable. The Heavy Grain Loading Impactor sampling rates were all within the limits suggested by the manufacturer, and results are believed to be within generally expected limits of accuracy.

The particle size tests performed during various times of process operation show that uncontrolled emissions are not

consistent over the short term. Although these results generally can be related to process operations, one should remember that the actual sampling times do not precisely coincide with only one specific process mode. For example, Run 1 was conducted during an EAF charge, but the time required to obtain an adequate sample was longer than the charging operation. As a result, Run 1 overlapped into the melting phase of EAF operation. Also, the mode of AOD operation (and relative emission generation) during Run 3 was not clear. Evaluation of the appropriate heat sheet indicated that the AOD may not have been generating any emissions during the actual sampling period.

Comparison of particulate concentrations among the Mark III runs showed disagreement with the relative observation that emissions during EAF meltdown were greater than emissions during an EAF charge. For this reason, and because of the dilution effects when only one furnace was operating, particulate concentrations were not reported. The average isokinetic sampling rates (107, 110, and 106 percent) were all considered acceptable, and impactor sampling rates were within suggested operating limits. In addition, the distributions are not considered to be biased toward larger sizes by the use of glass fiber collection media. This possibility⁴ was discounted, as the filter material did not seem to increase the collection efficiencies of upper impactor stages because most of the captured material was either in the cyclone precutter or on the lower stages. Results,

therefore, are taken to be representative of the variation in uncontrolled emissions.

Outlet particle size distributions showed a higher number of large particles than expected. It was expected that 80 to 90 cumulative weight percent of emissions would be of particles with aerodynamic diameters of approximately 2.5 μm or less. One of the several plausible explanations for the apparent discrepancy is the possible bias caused by increased efficiency of the upper impactor stages when glass fiber filters are used.⁴ Examination of analytical results indicated that this may have occurred, but it could not be verified. The adjustment to outlet results for this type of bias would reduce the aerodynamic diameter from 5 to 3.5 μm at a cumulative weight of 50 percent; however, this adjustment would not completely account for the difference between actual and expected results.

A second explanation could be related to inaccuracies of the method at very low sample weights; however, results are considered to be acceptable, based on several observations. The particulate concentrations indicated by the particle size runs were between 65 and 85 percent of results from simultaneous particulate tests, which is good agreement for the two different methods. The increase in emissions indicated by the third particulate test is verified by a corresponding increase in particle size emission results. The close agreement among the three cumulative distribution curves is further evidence that particle size results are representative. If the stage sample weights had

been too low for accurate determinations, the three curves probably would have shown more variability and flatter slopes. All of these observations suggest that results were within expected limits of accuracy for particle size distributions tests.

The most likely explanation for the higher than expected number of large particles is related to electrostatic charge. Small charged particles could have agglomerated to form particles of larger diameter. Evidence of a high electrostatic charge inside the fabric filter was discovered while the open gratings at the bottom level of the filter were being covered. For this reason, results of particle size tests are considered to be representative of actual conditions during the tests and reflect possible particle agglomeration due to electrostatic charges.

The fractional efficiencies reported in Table 3-7 also could be affected by the possible particle agglomeration just described. Particle agglomeration would explain the relatively low control efficiencies indicated for the larger particle sizes compared with the abnormally higher efficiencies for smaller sizes. Large particles formed after filtration would indicate false filtering efficiencies for the different size classifications; however, the overall efficiency would be unaffected.

3.3 VISIBLE AND FUGITIVE EMISSIONS

Visible emissions from the melt shop and fabric filter monovalent were evaluated simultaneously with particulate matter

tests. In accordance with Method 9* procedures, emissions were observed in 6-minute sets, and individual opacity readings were recorded at 15-second intervals. Fugitive emissions from the fabric filter were evaluated periodically throughout the test series 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.

3.3.1 Results

Table 3-8 summarizes the visible emissions detected during charging, tapping, and other furnace operations. The melt shop was divided into a north and a south segment for evaluation purposes. Visible emissions from the north segment were attributed to the north furnaces, and vice versa. When one of the north furnaces was charging, only the emissions from the north segment of the melt shop were considered. Tabulated emission data for each furnace type and process mode include the total number of data sets for both melt shop segments; for example, the five data sets during Run 1 for EAF charging represented three sets from the north furnaces and two from the south. During Run 1, individual 6-minute set averages ranged from 0 to 4 percent opacity for charging and tapping operations. Average opacities of individual sets ranged from 0 to 13 percent for refining and other operations. During Run 2, individual set averages during

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

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

TABLE 3-8. SUMMARY OF VISIBLE AND FUGITIVE EMISSIONS^aMelt shop^b

Date (1981)	Run No.	Furnace type	Process mode	Number of sets	Range of readings, % opacity	Range of set averages, % opacity
4/7	1	EAF	Charge	5	0	0
			Tap	5	0	0
		AOD	Charge	4	0-5	0-3
			Tap	2	0	0
		EAF/AOD	Tap/Charge	1	0-10	4
			Charge/Tap	1	0	0
		EAF/AOD	Refining and other	60	0-25	0-13
4/8	2	EAF	Charge	8	0-20	0-12
			Tap	5	0-25	0-15
		AOD	Charge	4	0-20	0-8
			Tap	3	0-10	0-5
		EAF/AOD	Refining and other	74	0-25	0-22
		EAF/AOD	Charging and tapping	38	0-25	0-15
			Refining and other	134	0-25	0-22

Fabric filter outlet

Number of sets	Range of readings, % opacity	Range of set averages, % opacity
73	0	0

Fugitive emissions from fabric filter

Accumulated observation period, minutes	Minutes	Accumulated emission time, % of observation period
595	0	0

^a Data were collected during 7 hours of process operation on April 7, 7 hours on April 8, and 20 minutes on April 9. Unfavorable weather conditions prevented additional readings on April 9.

^b Each set of readings represents emissions from either the north or south segment of the melt shop. Data for Run No. 3 could not be obtained because of unfavorable weather conditions on April 9.

charging and tapping ranged from 0 to 15 percent opacity. Average opacities of individual sets ranged from 0 to 22 percent during refining and other operations. No data were obtained during Run 3 because of adverse weather conditions.

Table 3-9 lists the time and average opacity for each 6-minute set of visible emissions data obtained at the melt shop. The heat sheets in Appendix D were used to determine the times of various process operations for comparison to emissions. None of the emissions seemed to be caused by abnormal operations.

No visible emissions from the fabric filter monovent exhaust were detected at any time during the test series, even after compartment cleaning cycles. A total of 73 six-minute sets of data were collected.

The fabric filter structure was observed for a total of 595 minutes. No fugitive emissions were detected at any time.

3.3.2 Discussion

The higher periods of melt shop emissions could be related to daily activities that normally occur during the first part of the day shift. No significant emissions were detected after 1130 hours on April 7 or 1230 hours on April 8, 1981. Examination of the available process information did not yield support for this hypothesis, however.

The low opacity data for the fabric filter outlet were supported by the low particulate concentration results.

TABLE 3-9. COMPARISON OF MELT SHOP VISIBLE EMISSIONS TO PROCESS OPERATION

Process mode ^a		Run number, date, set time	Average opacity, %	
EAF	AOD		North	South
		Run No. 1, 4/7/81		
N-T	N-C	10:15 - 10:20 a.m.	0	0
	N-C	10:27 - 10:32	4	4
N-C	N-C	10:33 - 10:38	3	3
	N-C	10:43 - 10:48	0	12
		10:49 - 10:54	0	11
		10:55 - 11:00	13	13
		11:01 - 11:06	9	0
		11:07 - 11:12	0	2
		11:13 - 11:18	1	1
		11:25 - 11:30	0	0
		11:37 - 11:42	0	0
		11:49 - 11:54	0	0
NC, ST ₁	N-T ^b	12:01 - 12:06 p.m.	0	0
S-CTL		12:13 - 12:18	0	0
S-T ₂ ^b	N-C	12:25 - 12:30	0	0
		12:37 - 12:42	0	0
S-C ^b		12:49 - 12:54	0	0
		1:01 - 1:06	0	0
		1:13 - 1:18	0	0
		1:25 - 1:30	0	0
N-T		1:37 - 1:42	0	0
	S-C ^b	1:49 - 1:54	0	0
N-AE	N-T	2:01 - 2:06	0	0
N-C		2:13 - 2:18	0	0
		2:25 - 2:30	0	0
		2:37 - 2:42	0	0
		2:49 - 2:54	0	0
N-RT		3:01 - 3:06	0	0
N-RT		3:13 - 3:18	0	0
N-RT		3:25 - 3:30	0	0
	S-T ^b	3:37 - 3:42	0	0
		3:49 - 3:54	0	0
		4:01 - 4:06	0	0
NC, ST ₁ ^b , SBB		4:13 - 4:18	0	0
S-T ₂ ^b		4:25 - 4:30	0	0
	S-C	4:37 - 4:42	0	0
		4:49 - 4:54	0	0
S-C ^b		5:01 - 5:06	0	0
		5:13 - 5:18	0	0

(continued)

TABLE 3-9 (continued)

Process mode ^a		Run number, date, set time	Average opacity, %	
EAF	AOD		North	South
		Run No. 2, 4/8/81		
	N-C ^b	9:45 - 9:50 a.m.	8	0
N-C		9:51 - 9:56	10	10
N-C		9:57 - 10:02	5	5
		10:03 - 10:08	12	12
		10:09 - 10:14	22	22
N-AE, S-T ₁		10:15 - 10:20	15	15
N-AE, S-BB		10:21 - 10:26	5	5
S-BB		10:27 - 10:32	8	8
S-BB		10:33 - 10:38	10	10
S-T ₂		10:39 - 10:44	6	6
		10:45 - 10:50	2	2
	S-C	10:51 - 10:56	1	0
		10:57 - 11:02	2	0
	N-T	11:09 - 11:14	5	0
		11:15 - 11:20	4	0
N-RWP		11:20 - 11:26	6	0
N-RWP, S-C		11:27 - 11:32	10	10
N-RWP, S-C		11:33 - 11:38	12	12
N-C		11:39 - 11:44	8	8
		11:45 - 11:50	0	8
		11:51 - 11:56	13	13
		11:57 - 12:02 p.m.	20	20
		12:03 - 12:08	12	12
		12:09 - 12:14	8	8
		12:19 - 12:24	12	12
		12:25 - 12:30	2	2
		12:37 - 12:42	0	0
		12:49 - 12:54	0	0
N-T		1:01 - 1:06	0	0
	N-C	1:13 - 1:18	0	0
N-C	S-T	1:25 - 1:30	0	0
		1:37 - 1:42	0	0
		1:49 - 1:54	0	0
S-T ₁		2:01 - 2:06	0	0
S-BB		2:13 - 2:18	0	0
S-BB	N-T ^b	2:25 - 2:30	0	0
S-T ₂		2:37 - 2:42	0	0
	S-C	2:49 - 2:54	0	0
		3:01 - 3:06	0	0
		3:15 - 3:20	0	2
S-C ^b		3:27 - 3:32	0	0
S-AE		3:39 - 3:44	0	0

(continued)

TABLE 3-9 (continued)

Process mode ^a		Run number, date, set time	Average opacity, %	
EAF	AOD		North	South
N-C ^b		Run No. 2, 4/8/81		
	S-PS	3:51 - 3:56 p.m.	0	0
	S-PS	4:03 - 4:08	0	0
		4:15 - 4:20	0	0
		4:27 - 4:32	0	0
		4:39 - 4:44	0	0

^aN = North furnace, S = South furnace, C = Charge, T = Tap, CTL = Clean tap ladle, AE = Add or adjust electrode, RT = Repair tap spout, BB = Burn bottom, RWP = Repair water pipe, PS = Patch seam.

^bProcess mode actually began 3 to 6 minutes prior to indicated set time.

3.4 FABRIC FILTER DUST SAMPLES

Samples of dust collected by the fabric filter were obtained daily from the dust-handling system just below the central junction of the screw conveyors. 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 3-10 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 limits for the majority of elements ranged from 0.1 to 0.4 $\mu\text{g/g}$; major constituents are listed as $>1000 \mu\text{g/g}$. Results for several elements 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 3-4 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

TABLE 3-10. SUMMARY OF TRACE ELEMENT ANALYSES ON
FABRIC FILTER DUST SAMPLES

Element	Concentration, $\mu\text{g/g}$ (ppm weight)		
	Sample 1	Sample 2	Sample 3
Aluminum	>1000	>1000	>1000
Antimony	160	190	44
Arsenic	420	410	120
Barium	>1000	>1000	>1000
Beryllium	0.3	0.1	0.2
Bismuth	350	420	44
Boron	42	23	53
Bromine	170	94	43
Cadmium	150	180	132
Calcium	>1000	>1000	>1000
Carbon	NR ^a	NR	NR
Cerium	21	19	6
Cesium	7	14	3
Chlorine	>1000	>1000	>1000
Chromium	>1000	>1000	>1000
Cobalt	340	190	430
Copper	>1000	>1000	>1000
Dysprosium	<0.4	<0.1	<0.2
Erbium	<0.4	<0.1	<0.2
Europium	<0.4	0.4	<0.2
Fluorine	>1000	>1000	>1000
Gadolinium	<0.4	<0.1	<0.2
Gallium	660	810	330
Germanium	100	55	41
Gold	<0.4	<0.1	<0.2
Hafnium	3	1	1
Holmium	<0.4	<0.1	<0.2
Hydrogen	NR	NR	NR
Indium	STD ^b	STD	STD
Iodine	2	3	3
Iridium	<0.4	<0.1	<0.2
Iron	>1000	>1000	>1000
Lanthanum	21	25	6
Lead	>1000	>1000	>1000
Lithium	160	9	79
Lutetium	<0.4	<0.1	<0.2
Magnesium	>1000	>1000	>1000
Manganese	>1000	>1000	>1000
Mercury	NR	NR	NR
Molybdenum	>1000	>1000	>1000
Neodymium	5	3	1

(continued)

TABLE 3-10 (continued)

Element	Concentration, $\mu\text{g/g}$ (ppm weight)		
	Sample 1	Sample 2	Sample 3
Nickel	>1000	>1000	>1000
Niobium	190	56	52
Nitrogen	NR	NR	NR
Osmium	<0.4	<0.1	<0.2
Oxygen	NR	NR	NR
Palladium	<0.4	<0.1	<0.2
Phosphorus	>1000	840	970
Platinum	<0.4	<0.1	<0.2
Potassium	>1000	>1000	>1000
Praseodymium	2	1	1
Rhenium	<0.4	<0.1	<0.2
Rhodium	<0.4	<0.1	<0.2
Rubidium	170	530	200
Ruthenium	<0.4	<0.1	<0.2
Samarium	4	2	2
Scandium	1	0.1	0.5
Selenium	120	66	28
Silicon	>1000	>1000	>1000
Silver	<4	66	220
Sodium	>1000	>1000	>1000
Strontium	>1000	>1000	800
Sulfur	>1000	>1000	>1000
Tantalum	3	<0.9	1
Tellurium	3	5	2
Terbium	<0.4	<0.1	<0.2
Thallium	12	<0.1	2
Thorium	8	5	2
Thulium	<0.4	<0.1	<0.2
Tin	410	220	82
Titanium	>1000	710	660
Tungsten	100	54	50
Uranium	6	3	2
Vanadium	850	>1000	>1000
Ytterbium	<0.4	<0.1	<0.2
Yttrium	15	8	16
Zinc	>1000	>1000	>1000
Zirconium	130	39	36

^aNot reported.^bInternal standard.

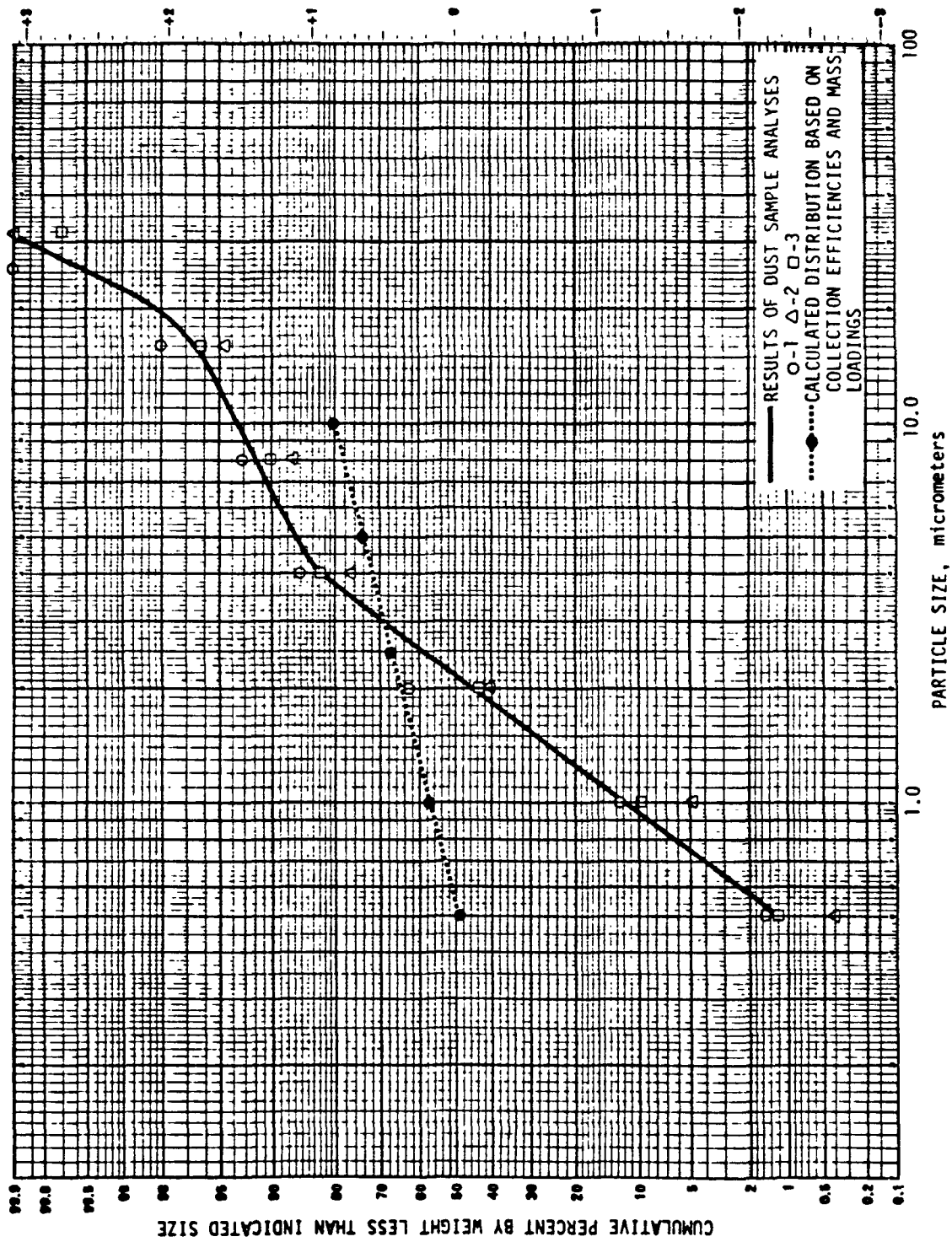


Figure 3-4. Average particle size distribution of fabric filter dust samples.

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 2.2 μm or less. Ninety-three percent by weight had diameters of less than 10 μm .

3.4.3 Discussion

The concentrations of several trace elements seem to vary considerably, and this could be related to different specifications of the metal in the furnaces. It should be noted, however, that SSMS is more of a qualitative than quantitative analytical technique. [The results of an audit sample (Section 5) bear this out; they indicate that reported element concentrations are only accurate within a factor of ± 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 emission tests. If desired, 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 3.3 g/cm^3 would decrease the amount of dust smaller than 3 μm from approximately 70 to 35 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 3-7. The Coulter Counter and theoretical curves both indicated that 75 cumulative weight percent of the collected dust consisted of particles with aerodynamic diameters of approximately 6 μm or less. The curves differed considerably at smaller sizes, but this may have resulted from the agglomeration of particles in the outlet gas stream.

The particle size distribution samples were originally subjected to Bahco analysis, but agglomeration of the particles during analysis prevented an accurate determination.

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

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

Separate fluoride analyses were performed on two acetone rinses and one set of filters from the outlet particle size samples, two of the fabric filter dust samples, and appropriate blanks. Metal analyses were performed on two sets of outlet particle size samples (acetone rinse and filters combined), two dust samples, and appropriate blanks. The fourth outlet sample was obtained from a duplicate 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 3-11.

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 2.3 times larger than the net

TABLE 3-11. SUMMARY OF SUPPLEMENTAL ANALYSES FOR
FLUORIDE, CHROMIUM, LEAD, AND NICKEL

Pollutant species	Uncontrolled emissions ^a						
	Concentration ³ µg/g of solid	gr/dscf	Emission rate		Emission factors		
			kg/h	lb/h	kg/h/Mg	lb/h/ton	lb/ton
Fluoride	47,200	0.0051	11	24	0.098	0.20	0.37
Chromium	39,200	0.0042	8.9	20	0.081	0.16	0.31
Lead	8,400	0.0009	1.9	4.2	0.017	0.035	0.066
Nickel	16,300	0.0018	3.7	8.1	0.034	0.068	0.13
Controlled emissions ^b							
Fluoride ^c	31,600	0.00005	0.10	0.22	0.0009	0.0019	0.0035
Chromium	17,400	0.00003	0.056	0.12	0.0005	0.0010	0.0019
Lead	5,800	0.000009	0.019	0.041	0.0002	0.0003	0.0006
Nickel	7,600	0.00001	0.024	0.054	0.0002	0.0004	0.0008

^aBased on average uncontrolled particulate emissions and average of analyses on two dust samples, assuming that the concentration in the uncontrolled gas stream is the same as in the collected dust.

^bBased on average controlled particulate emissions and an average of analyses on two outlet samples.

^cBased on analyses of acetone rinses only; the glass fiber filter analysis had a high blank weight of fluoride and was not used.

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. If the filter result is correct, the outlet fluoride concentration would be 56,700 $\mu\text{g/g}$ instead of the 31,600 $\mu\text{g/g}$ indicated in the table. This would not compare favorably with the 47,200 $\mu\text{g/g}$ 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.

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. The schematics of the air pollution control system presented in Figures 4-1 and 4-2 identify the relative locations of each sampling site. Figure 4-3 presents several photographs of the control system configuration and sampling sites.

4.1 SITE 1--UNCONTROLLED NORTH EAF AND NORTH AOD

Uncontrolled emissions from the north furnaces were sampled for particulate matter and particle size distribution. Site 1 was located in the 3.0-m (10-ft) diameter duct between the point where the north EAF and AOD ducts meet and the junction of north and south ducts. Two sampling ports, 90 degrees apart, were located 2.9 diameters downstream and 1.3 diameters upstream of 45-degree bends, as shown in Figure 4-4. Forty-four traverse points were used to sample the cross-sectional area of the duct for particulate matter, with 22 points on each traverse diameter. Each particulate run covered two consecutive EAF heats. Tests were started at the beginning of charging operations and

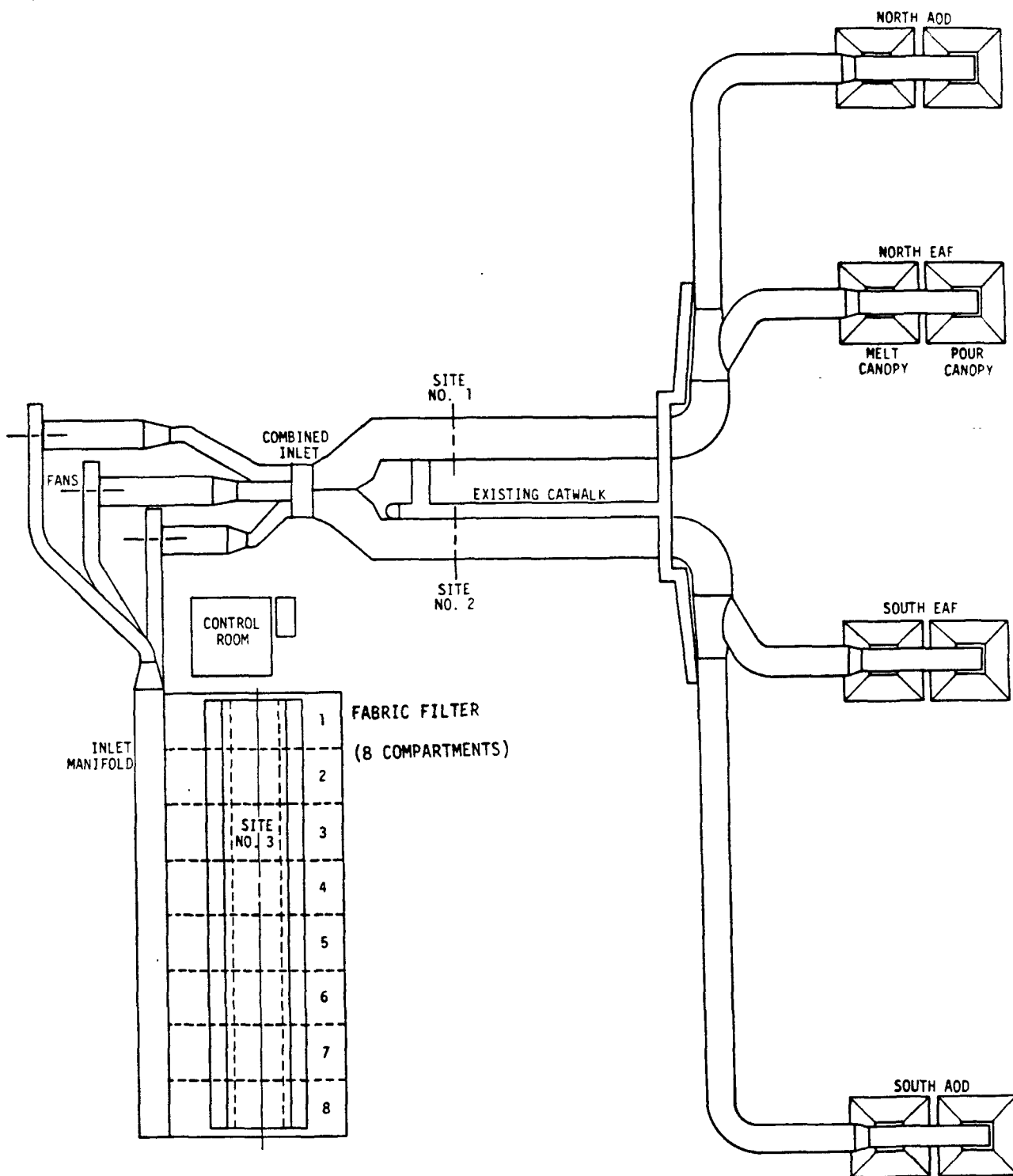


Figure 4-1. Control system schematic, top view.

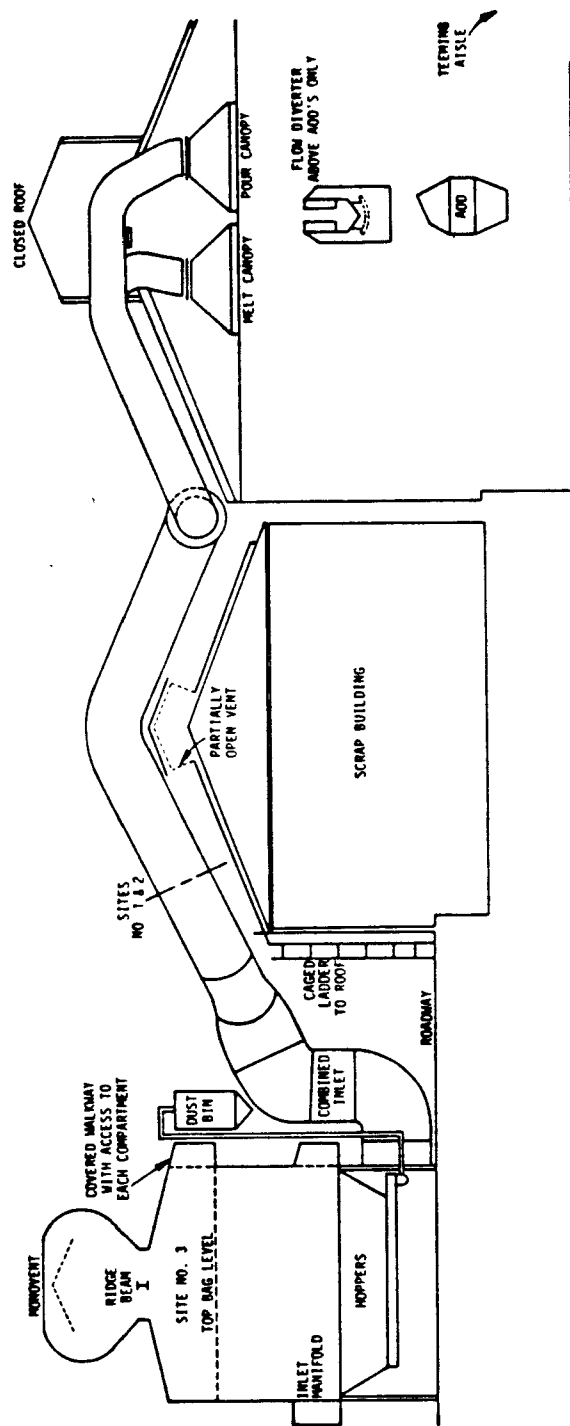
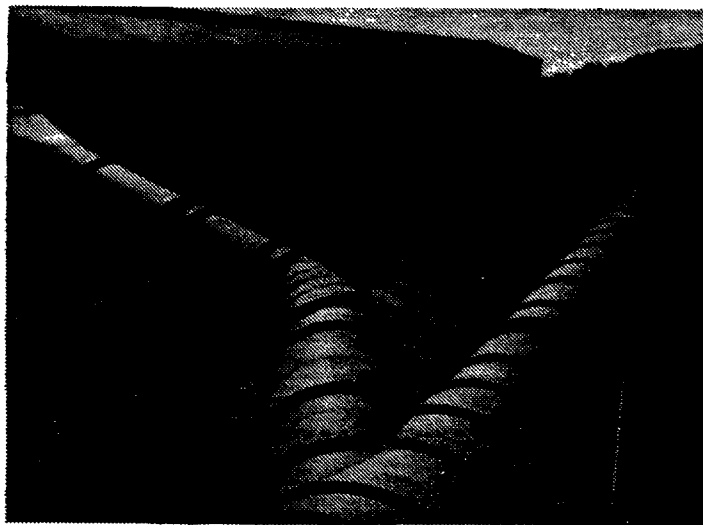


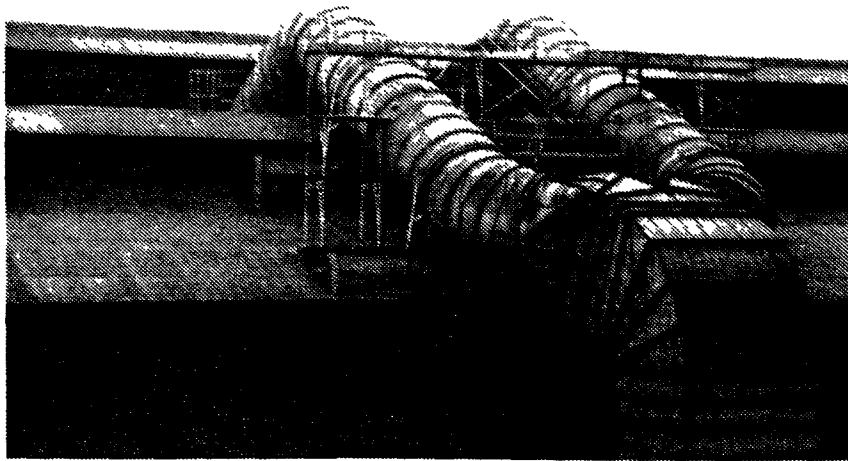
Figure 4-2. Control system schematic and location of sampling sites, elevation view.



NORTH AOD (LEFT) AND
NORTH EAF HOOD DUCTS



SOUTH EAF (LEFT) AND SOUTH
AOD HOOD DUCTS



SAMPLING LOCATIONS AT THE NORTH EAF/AOD DUCT
(LEFT, SITE NO. 1) AND THE SOUTH EAF/AOD DUCT
(SITE NO. 2)

Figure 4-3. Control system configuration and location of sampling sites.



FABRIC FILTER AND MONOVENT. SAMPLING LOCATIONS ARE INSIDE EACH COMPARTMENT NEAR THE BASE OF THE MONOVENT.



FANS AND COMBINED INLET DUCT

Figure 4-3. Control system configuration and location of sampling sites (continued).

TRAVERSE POINT NO.	DISTANCES	
	cm	(in.)
1	15.0	(5.9)
2	22.4	(8.8)
3	30.0	(11.8)
4	38.1	(15.0)
5	46.7	(18.4)
6	55.9	(22.0)
7	66.3	(26.1)
8	77.7	(30.6)
9	91.4	(36.0)
10	107.6	(42.3)
11	131.1	(51.6)
12	196.6	(77.4)
13	220.5	(86.8)
14	236.2	(93.0)
15	249.9	(98.4)
16	261.4	(102.9)
17	271.8	(107.0)
18	280.9	(110.6)
19	289.6	(114.0)
20	297.9	(117.3)
21	305.6	(120.3)
22	312.7	(123.1)

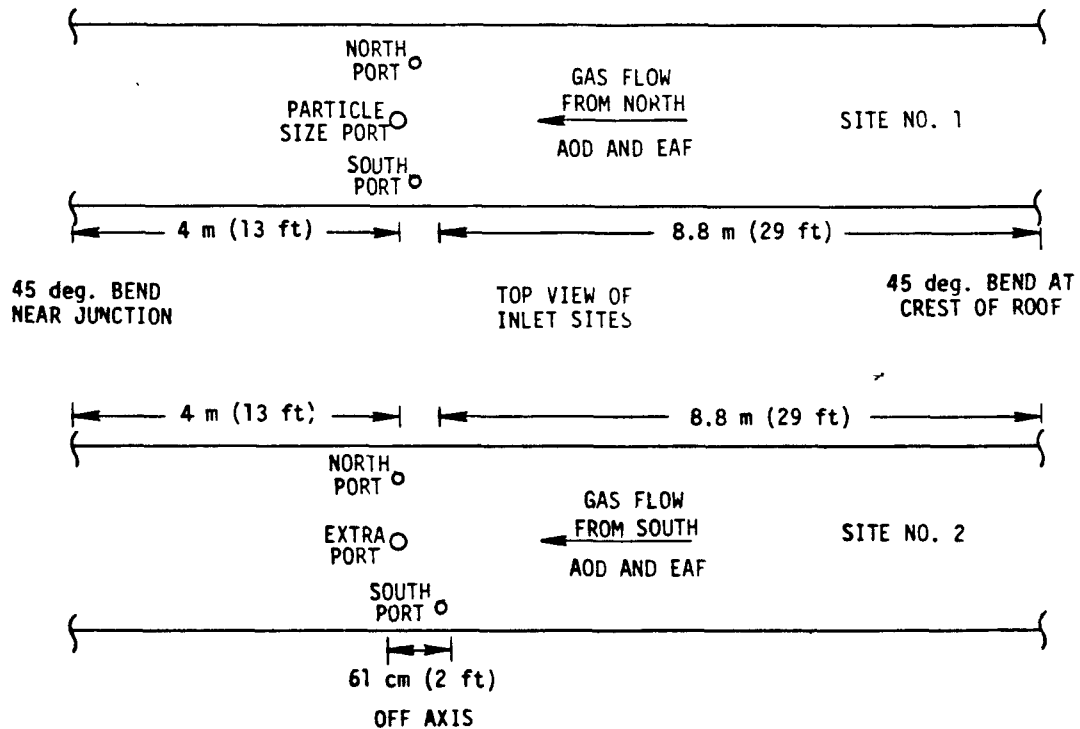
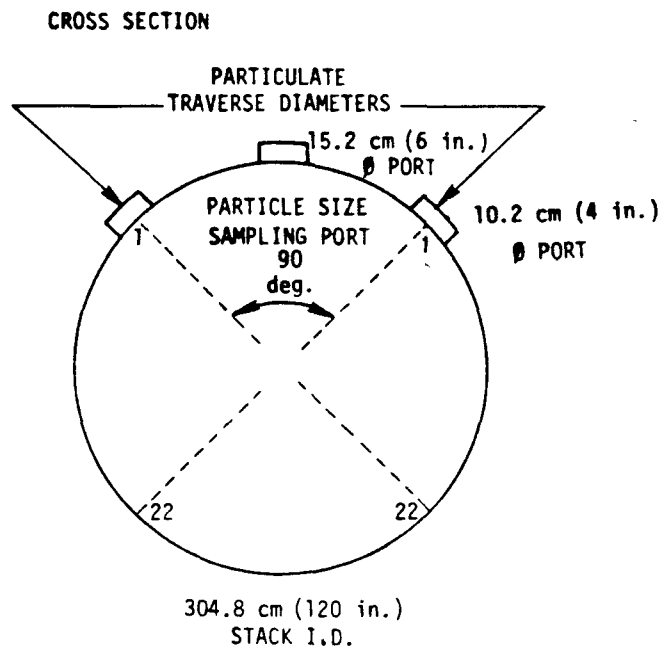


Figure 4-4. Inlet sampling locations.

continued through tapping. Initial sampling of each traverse point lasted 4 minutes. At the completion of a full traverse, the nozzle was positioned at a point of average velocity and sampling continued until the end of the first heat. A new traverse was then initiated for the second heat, and each point was sampled for 4 minutes. By the end of the second EAF heat, a minimum of two complete traverses had been conducted. Actual sampling time, which depended on heat times, ranged from 352 to 399 minutes.

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 17.5 minutes for the Andersen Mark III samples to 207 minutes for the Andersen Heavy Grain Loading Impactor samples, which covered an integral heat.

4.2 SITE 2--UNCONTROLLED SOUTH EAF AND SOUTH AOD

Site 2 was similar to Site 1, but only particulate matter tests were conducted at this site. Forty-four traverse points were sampled for 8 minutes each, to yield a total sampling time of 352 minutes per run. These tests were coordinated with tests at Site 1, not with process conditions of the south furnaces.

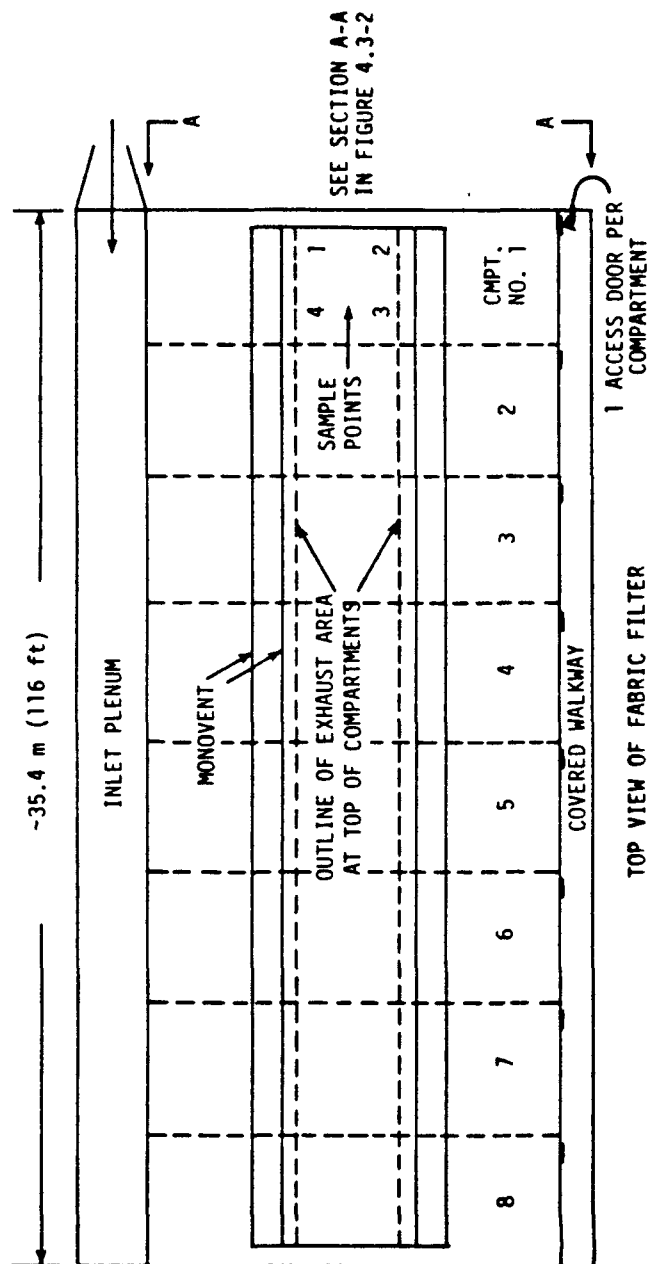
4.3 SITE 3--FABRIC FILTER OUTLET

Controlled emissions from the fabric filter serving all four furnaces were sampled for particulate matter and particle size distribution. The cleaned gases from each compartment exit

through the common monovalent located atop the fabric filter in a configuration typical of positive-pressure fabric filters. Method 1* criteria could not be met at this site; therefore, the throat of the monovalent was chosen as an optimum sampling location because it represented the smallest cross-sectional area. This small area would not only provide the highest gas velocities, but also offer less chance for bias due to faulty bags.

Figure 4-5, a top view of the fabric filter arrangement, shows the general location of sampling points. Figure 4-6, an end view of the fabric filter, shows the location of the sampling plane used in each compartment with respect to the site configuration. Figure 4-7 gives specific dimensions for the sampling plane cross-sectional area and the location of sampling points in a typical compartment. It should be noted that the dimensions of the sampling plane were slightly different from those of the actual monovalent throat because the tests were conducted just below the throat. Other dimensions are given for the compartment widths and panel offsets created by structural I beams. As the figure indicates, dimensions for the sampling cross section and the exhaust opening in the two end compartments were different from those in the six middle compartments. Based on these measurements, the total cross-sectional area of the sampling plane in all eight compartments was calculated to be 113.2 m^2 (1218.8 ft^2).

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



RUN 1 - COMPARTMENT NOS. 1 THROUGH 4
 RUN 2 - COMPARTMENT NOS. 3 THROUGH 6
 RUN 3 - COMPARTMENT NOS. 5 THROUGH 8

Figure 4-5. Sampling Site No. 3, the fabric filter outlet.

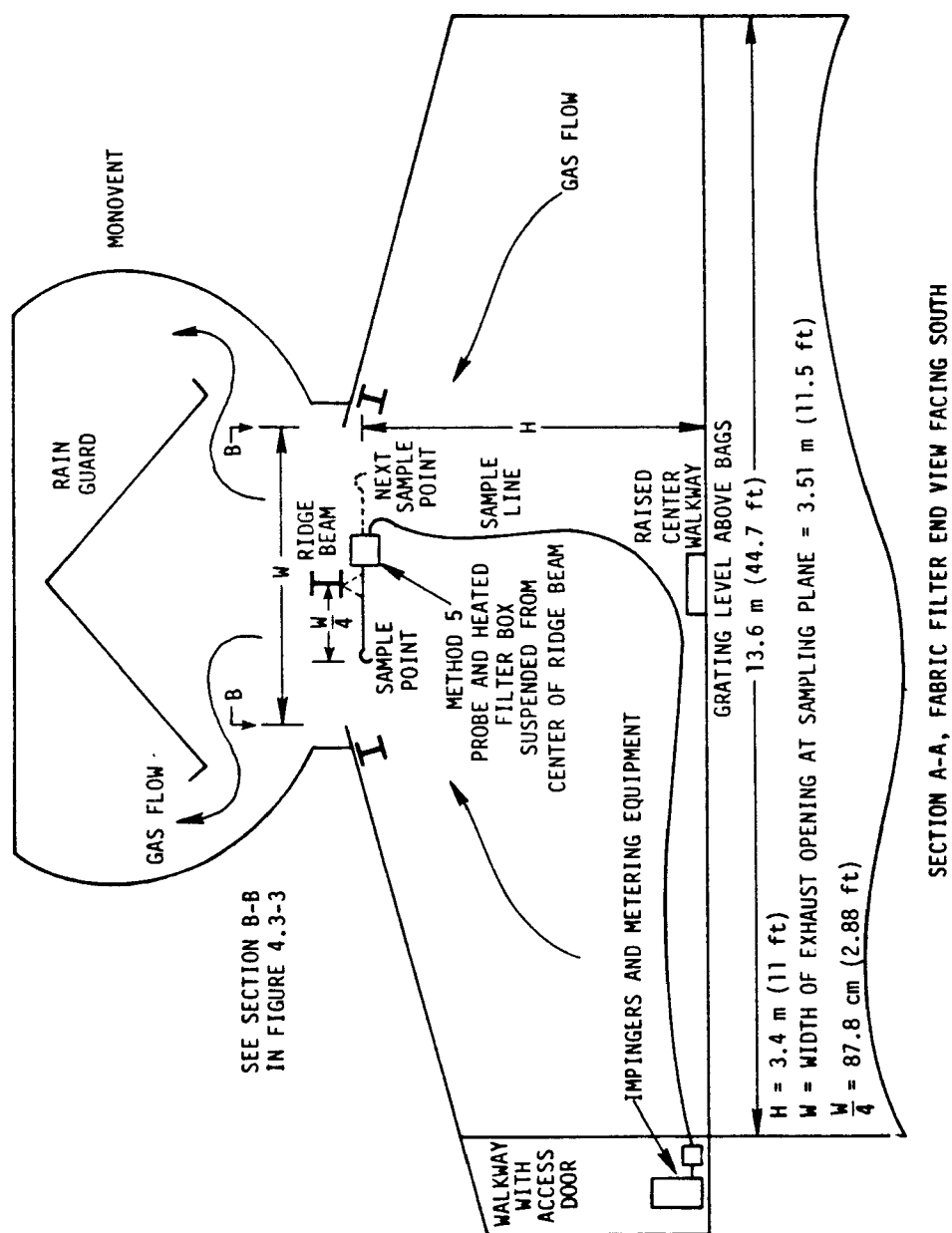
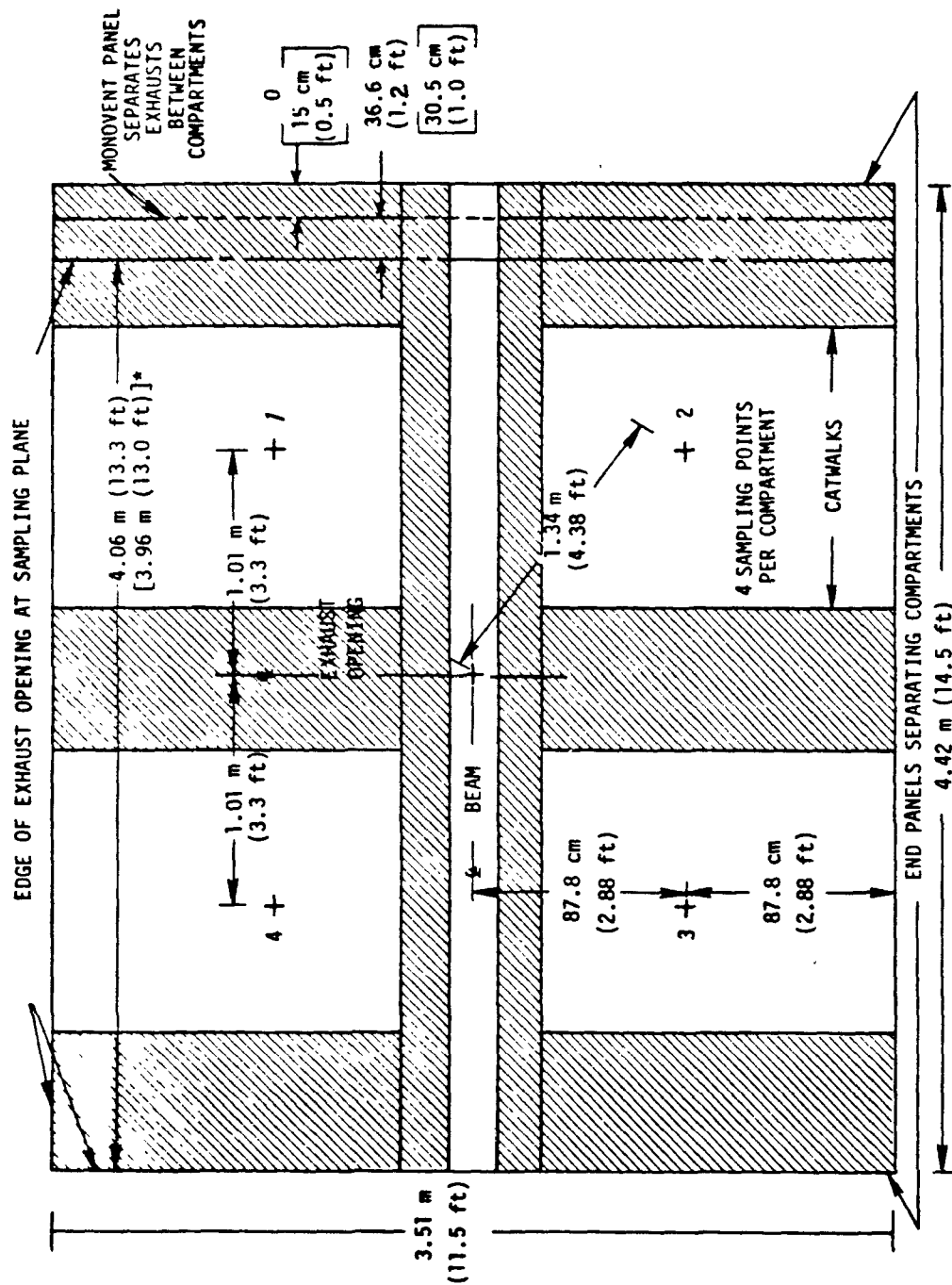


Figure 4-6. Sampling location at Site No. 3, the fabric filter outlet.



*DIMENSIONS IN BRACKET [] ARE FOR THE TWO END COMPARTMENTS, IF DIFFERENT.

NOTE: BAG ROWS ARE IN OPEN AREAS BETWEEN CATWALKS.

TOP VIEW OF FABRIC FILTER EXHAUST AREA WITH MONOVENT NOT SHOWN. ONLY ONE OF EIGHT COMPARTMENTS IS SHOWN.

Figure 4-7. Location of sampling points at Site No. 3, the fabric filter outlet.

Each particulate test consisted of sampling four points in each of four compartments (for a total of 16 points); at 20 minutes per point, this yielded 320 minutes of sampling time. The tests began at the same time as the inlet tests and concluded at the end of the 16-point traverse. Figure 4-5 shows the specific compartments tested during each run. At the end of three runs, each compartment had been tested at least once.

Each particle size distribution sample was collected at one sampling point in each of four compartments, which yielded a total sampling time of 300 minutes. These samples were collected simultaneously with particulate matter tests and in the same compartments; however, both probes were not in the same compartment at the same time.

During each test, the entry of dilution air through the open grating at the bottom level of the fabric filter was minimized by covering the gratings with kraft paper and boards. The gratings in all four compartments to be tested on a given day were covered during the preceding day to allow fabric filter conditions to equilibrate.

4.4 VELOCITY AND GAS TEMPERATURE

A type S pitot tube and an inclined draft gauge manometer were used to measure the gas velocity pressures at the two inlets. 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.^{*} Velocities at the outlet site were calculated from inlet flow rates and the size of the outlet area. The temperature at each sampling point was measured by using a thermocouple and potentiometer.

4.5 MOLECULAR WEIGHT

Flue gas composition was determined in accordance with procedures described in Method 3.* An integrated bag sample was collected at each site 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.

4.6 PARTICULATE MATTER

Method 5* was used to measure particulate concentrations at the two inlet sites. 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. Each sampling train consisted of a heated, 316 stainless steel-lined probe, a heated 87-mm (3-in.) diameter glass fiber filter (Gelman Type AE), a Teflon sample line, and a series of Greenburg-Smith impingers followed by an umbilical line and metering equipment. At the end of each test, the nozzle, probe, and filter holder portions of the sample train were

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

acetone-rinsed. The acetone rinse and filter media were dried at room temperature, desiccated to a constant weight, and weighed on an analytical balance. Total filterable particulate matter was determined by adding the net weights of the two sample fractions. Any condensate in the sample line was drained into the impinger section of the sampling train. After the amount of water collected in the impingers was measured, the contents were recovered and gravimetrically analyzed for condensible matter by evaporating the solutions in an oven at 105°C.

Method 5 equipment and modified sampling procedures were used for particulate tests at the fabric filter outlet. The sampling train was similar to those used at the inlet sites except for the lack of a pitot tube and the use of a glass-lined probe. Tests were conducted at a constant sampling rate based on the estimated average velocity of the entire sampling area. This average velocity was calculated by first converting the total flow rate measured at the two inlet sites to outlet conditions of temperature, pressure, and moisture, and then dividing by the total outlet sampling area. The resultant average velocity was assumed to represent each sampling point and was used to calculate an average isokinetic sampling rate. The heated probe and filter assembly was suspended from the center of the ridge beam in a fabric filter compartment, as shown in Figure 4-6. The nozzle was positioned at each of the four sampling points in a compartment by rotating the probe and filter assembly. When the sampling points were changed, care was taken to avoid stirring up

any dust or bumping the probe against any structural members. Compartment cleaning cycles were sampled as they occurred. Compartment gas flows were interrupted while test equipment was moved from one compartment to another, but conditions were allowed to equilibrate for several minutes before sampling resumed. Outlet samples were recovered and analyzed in a manner similar to inlet particulate samples, except that the impinger solutions were analyzed for organic and inorganic matter by ether-chloroform extraction.

Sampling times and volumes for the outlet particulate tests exceeded the respective minimum requirements of 4 hours and 4.5 dNm³ (160 dscf) specified in Subpart AA of the Federal Register.*

4.7 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 μ 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 20 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 μ m. The only filter in the HGLI is a glass fiber thimble used as the backup stage. This impactor was used to collect samples over an

* 40 CFR 60, Subpart AA, July 1, 1980.

entire EAF heat, which was approximately 3.5 hours. A cyclone precutter was attached to the front of each type of impactor to remove larger particles and to avoid the use of buttonhook nozzles. Because the sampling rate could not be adjusted to obtain the 15- μ 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 isokinetics. 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 using a Mark III impactor fitted with a straight nozzle. The impactor and probe were suspended in a fabric filter compartment from the center of the ridge beam, in a manner similar to that used on particulate matter testing equipment. Each sample was collected for an equal amount of time at one point in four different compartments. The initial isokinetic sampling rate was based on the calculated average velocity of the entire sampling area.

Constant cut-point characteristics were maintained throughout each test, and gas temperatures were measured with a thermocouple attached to the impactor probe. 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.

4.8 VISIBLE AND FUGITIVE EMISSIONS

Certified observers recorded visible emissions from the melt shop and fabric filter monovalent according to 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 if emissions greater than zero opacity were noticed.

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.

Observers were positioned on the side of a hill, approximately 75 meters (250 feet) southwest of the baghouse.

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

** Federal Register, Vol. 45, No. 224, November 14, 1980.

Adverse weather conditions prevented visual emission observations during the third test.

4.9 FABRIC FILTER DUST SAMPLES

Samples from the dust-handling system were obtained just below the central junction of the screw conveyors that connect individual hoppers. 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 trace element analysis, and one for particle size distribution analysis.

Spark Source Mass Spectroscopy was the analytical technique used for qualitative examination of the presence of approximately 70 elements. A known concentration of indium was added to each sample prior to ionization. All elements were ionized with approximately equal sensitivity. A photographic plate was used to record the mass spectra. The plate 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 after problems associated with particle agglomeration prevented the initial attempts by Bacho analysis. For the Coulter analysis, particles in each sample were suspended

in a sodium chloride electrolytic solution. Electrical current passed from one immersed electrode through a small aperture to another electrode. 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 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. Four documents were used in this test program to provide the required guidance to help ensure the collection of acceptable data and determine when data quality is unacceptable. These documents are the 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; the draft 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 the laboratory groups.

Appendix F provides more detail on the Quality Assurance procedures, including 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.

Relative to this specific test program, the following are the steps that were 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 sample train, pitot tube, and Orsat line leak checks.
- ° Use of designated analytical equipment and sampling reagents.

Table 5-1 lists the sampling equipment used to conduct particulate and particle sizing 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 5-6.

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 indicated that the tests were being 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-3	Wet test meter	ΔY pre ^a \pm 0.020 $\Delta H\theta$ \pm 0.15 ΔY post ^b \pm 0.05	-0.003 -0.09 +0.012	✓ ✓ ✓	\bar{Y} pre = 1.008 \bar{Y} post = 1.020
Meter box	FB-5			-0.008 -0.05 +0.019	✓ ✓ ✓	\bar{Y} pre = 1.056 \bar{Y} post = 1.075
Meter box	FB-2			-0.007 -0.08 -0.02	✓ ✓ ✓	\bar{Y} pre = 1.007 \bar{Y} post = 0.987
Meter box	FB-7			-0.009 -0.06 +0.009	✓ ✓ ✓	\bar{Y} pre = 1.004 \bar{Y} post = 1.013
Meter box	FB-6			+0.001 -0.06 +0.002	✓ ✓ ✓	\bar{Y} pre = 0.973 \bar{Y} post = 0.975
Meter box	FB-8			-0.010 +0.06 +0.018	✓ ✓ ✓	\bar{Y} pre = 0.982 \bar{Y} post = 0.999
Pitot tube	251	Standard pitot tube	$\Delta C_p \pm 0.01$	0.003	✓	$C_p = 0.81$
Pitot tube	252			0.003	✓	$C_p = 0.81$
Pitot tube	253			0.001	✓	$C_p = 0.80$

(continued)

^a Allowable deviation ΔY pretest = $\pm 0.02 \bar{Y}$ pretest.

^b Allowable deviation ΔY post-test = $\pm 0.05 \bar{Y}$ pretest.

TABLE 5-1 (continued)

Equipment	I.D. No.	Calibrated against	Allowable deviation	Actual deviation	Within allowable limits	Comments
Thermocouple	149	ASTM reference thermometer	$\pm 1.5\%$	-0.68	✓	
Thermocouple	138			-0.54	✓	
Thermocouple	129			+0.69	✓	
Thermocouple	128			-0.35	✓	
Thermocouple	254			-0.61	✓	
Digital indicator	219 222 208 207	Millivolt signals	0.5%	Avg. 0.1% Avg. 0.16% Avg. -0.10% 2.5°F	✓ ✓ ✓ ✓	Actual deviation is an average of eight temperature points; No. 207 tested and calibrated by manufacturer
Orsat analyzer	142	Standard gas	$\pm 0.5\%$	-0.2%	✓	CO is highest deviation
Trip balance	198	Type S weights	± 0.5 g	0.0 g	✓	
Barometer	227	NBS-traceable barometer	0.20 in. Hg post-test	0.00 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	+5°F	I 1.5°F O 1.7°F	✓	I = inlet thermometer O = outlet thermometer
	FB-3			I 1.2°F O 1.9°F	✓	
	FB-5			I 2.7°F O 1.6°F	✓	
	FB-6			I 0.6°F O 1.6°F	✓	
	FB-7			I 3.5°F O 1.4°F	✓	
	FB-8			I 1.0°F O 2.3°F	✓	
	3-111			0.001	✓	
	2-101			0.002	✓	
Probe nozzle	A2PS-P	Caliper	Dn ± 0.004 in.	0.001	✓	Nozzles for particle-size tests were labeled according to run numbers
	A1PS-2			0.001	✓	
	A1PM-2B			0.003	✓	
	A1PM-1B			0.003	✓	
	A1PM-2A			0.002	✓	
	A3PS-P			0.001	✓	
	A3PS-1B			0.001	✓	
					✓	

TABLE 5-2. DRY GAS METER AUDIT RESULTS

Meter box No.	Calibrated against	Deviation, %
FB-2	Critical orifice No. 2	+ 3.3
FB-3	Critical orifice No. 2	+ 2.0
FB-5	Critical orifice No. 2	+ 0.4
FB-6	Critical orifice No. 1	- 0.3
FB-7	Critical orifice No. 1	+ 2.7
FB-8	Critical orifice No. 1	- 0.2

AUDIT REPORT SAMPLE METER BOX

Date 4-7-81 Client US EPA
 Barometric pressure (P_{bar} , in Hg) 30.46 Meter box number FBZ
 Crifice number 2 Pretest Y 1.007
 Crifice K factor 5.36×10^{-4} Auditor D. FERGUSON

Crifice manometer reading AH in H ₂ O	Dry Gas meter reading V_1/V_f ft ³	Dry Gas meter volume V_{m3} ft ³	Temperatures				Sampling time ϕ min	V_{mstd} ft ³	V_{mact} ft ³	Percent error
			Average T_a °F	Inlet T_{in} °F	Outlet T_{mo} °F	Average T_m °F				
2.4	068.000	14.000	54	64	54	59.25	16.4	14.68	14.21	+3.3%
	082.000		54	64	55					

$$V_{mstd} = (17.647) (V_m) (Y) (P_{bar} + \Delta H / 13.6) / (T_m + 460)$$

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

$$V_{mstd} = (17.647) (14.000) (1.007) (30.46 + \frac{2.4}{13.6}) / (59.25 + 460)^{\frac{1}{2}} = 14.679$$

$$V_{mact} = (1203) (14.21) (5.36 \times 10^{-4}) (30.46) / (54 + 460)^{\frac{1}{2}}$$

$$error = (V_{mstd} - V_{mact}) (100) / (V_{mact}) = (0.47) (100) / (14.21)$$

Figure 5-1. Audit report sample meter box.

AUDIT REPORT SAMPLE METER BOX

Date 4-7-81 Client U.S. EPA 3530-2
 Barometric pressure (P_{bar} , in Hg) 30.46 Meter box number FB 3
 Orifice number 2 Pretest Y 1.008
 Orifice K factor 5.361 x 10⁻⁴ Auditor D. Fitzgerald

Orifice manometer reading ΔH in H ₂ O	Dry Gas meter reading V_1/V_f ft ³	Dry Gas meter volume V_{m3} ft ³	Temperatures				Sampling time ϕ min	V_{mstd} ft ³	V_{mact} ft ³	Percent error
			Average T_a °F	Inlet T_{in} °F	Outlet T_{no} °F	Average T_m °F				
2.65	247.00	17.000	54	71	56	63.5	20.033	17.706	17.358	+2.00%
	264.00		54	69	58					

$$V_{mstd} = (17.647) (V_m) (Y) (P_{bar} + \Delta H / 13.6) / (T_m + 460)$$

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

$$V_{mstd} = (17.647) (17.000) (1.008) (30.46 + \frac{2.6}{32}) (63.5) = 17.706$$

$$V_{mact} = (1203) (20.033) (5.361 \times 10^{-4}) (30.46) (54 + 460)^{\frac{1}{2}} = 17.358$$

$$error = (V_{mstd} - V_{mact}) (100) / (V_{mact}) = (\quad) (100) / (17.358)$$

Figure 5-2. Audit report sample meter box.

AUDIT REPORT SAMPLE METER BOX

Date 4-8-81 Client DSEPA 3530-2
 Barometric pressure (P_{bar} , in Hg) 30.39 Meter box number FB 5
 Orifice number 2 Pretest V 10.56
 Orifice K factor 5.361 x 10⁻⁴ Auditor P. Reinermann

Orifice manometer reading in H ₂ O	Dry gas meter reading V_1/V_2 ft ³	Dry gas meter volume V_{m3} ft ³	Temperatures			Sampling time ϕ min	V_{mstd} ft ³	V_{mact} ft ³	Percent error
			Ambient T_a of	Average T_a of	Inlet T_{in} of				
2.6	758.00	12.000	60	60	68	15.033	12.976	12.921	0.43%
	770.00		60		69				

$$V_{mstd} = (17.647) (V_m) (Y) (P_{bar} + \Delta H / 13.6) / (T_m + 460)$$

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

$$V_{mstd} = (17.647) (12.000) (1.036) (30.39) / (60 + 460) = 12.976$$

$$V_{mact} = (1203) (15.033) (5.361 \times 10^{-4}) (30.39) / (60 + 460)^{\frac{1}{2}} = 12.921$$

$$error = (V_{mstd} - V_{mact}) (100) / (V_{mact}) = (\quad) (100) / (\quad)$$

Figure 5-3. Audit report sample meter box.

EPA METHOD 5 DRY GAS METER PERFORMANCE TEST DATA SHEET

Date 4/7/81 Pollutant Code _____
 Barometric Pressure, P_{bar} 30.76 "Hg 773 Survey Number _____
 Meter Box No. FB 6 Participants ID _____
 Protocol 0.973 Office No. PE010 1 5206x10-4

Test No.	Orifice manometer reading Δh , in. H_2O	Gas volume dry gas meter V_i/V_f , ft ³	Gas volume dry gas meter V_a , ft ³	Temperature			Average In of	Sampling time 0, min.	Vacuum setting in Hg	Corrected gas volume V_{std} , m ³
				Ambient T_a , °C	Inlet T_{in} of	Dry gas meter Outlet T_{out} of				
1	1.9	73.000	14.9	60°F 15.5	88	78	82	17.32	20	0.4090
2		73.902			84	78				0.4102
3										$\Rightarrow -0.325$

V_i = initial reading of dry gas meter.
 V_f = final reading of dry gas meter.
 $V_a = V_f - V_i$ = volume of gas passing through dry gas meter

$$V_{std} = (0.4997)(V_i)(\frac{P_{bar}}{P_{std}} + \frac{\Delta h}{13.6})$$

The value of 0.4997 is obtained from $P_{std} = 0.020317$

where: 0.0207 is the conversion factor from ft³ to m³
 $T_{std} = 520^\circ R$
 $P_{std} = 29.92$ in. Hg

P. Schwanz
 Signature

Figure 5-4. EPA Method 5 dry gas meter performance test data sheet.

EPA METHOD 5 DRY GAS METER PERFORMANCE TEST DATA SHEET

Date 4/7/81 Pollutant Code _____
 Barometric Pressure, P_{bar} 30.46 "Hg 773 Survey Number _____
 Meter Box No. FB7 Participants ID _____
 Protocol V 1.004 Office No. PEOC 2 K-5,206X10⁻⁴

Test No.	Orifice manometer reading Δh , in. H ₂ O	Gas volume dry gas meter V_i/V_f , ft ³	Gas volume dry gas meter V_m , ft ³	Temperature			Sampling time t_s , min.	Vacuum setting in Hg	Corrected gas volume $V_{g,std}$, ft ³
				Ambient T_a , °F	Dry gas meter Inlet T_{in} , °F	Average Inlet T_m , °F			
1	1.9	767.700	12.5	55.5	63	61.5	15.25	2.1	3726 (.3629)
2		780.300			64	61			$\Rightarrow + 2.7\%$
3									

V_i = initial reading of dry gas meter.
 V_f = final reading of dry gas meter.
 $V_m = V_f - V_i$ = volume of gas passing through dry gas meter

$$V_{g,std} = \frac{(0.4997)(V_m)(V)(P_{bar} + 13.6)}{(T_m + 460)}$$

The value of 0.4997 is obtained from $\frac{14.7}{P_{std}} = 0.020317$

where: 0.0207 is the conversion factor from ft³ to m³
 $T_{std} = 520^\circ R$
 $P_{std} = 29.92$ in.Hg

P. Schuler
 Signature

Figure 5-5. EPA Method 5 dry gas meter performance test data sheet.

EPA METHOD 5 DRY GAS METER PERFORMANCE TEST DATA SHEET

Date 4/7/81
 Barometric Pressure, P_{bar} 30.46 "Hg 773
 Meter Box No. FB 8
 Pretest V .982
 Pollutant Code _____
 Survey Number _____
 Participants ID _____
 Orifice No. FDK 1

Test No.	Orifice manometer reading in. H_2O	Gas volume dry gas meter		Temperature		Average T_m of	Sampling time D. min.	Vacuum setting in. Hg	Corrected gas volume $V_{g(std)}$ m^3
		V_i/V_f ft^3	V_m ft^3	Ambient T_a $^{\circ}C$	Dry gas meter Inlet T_{mi} of	Outlet T_{mo} of			
1	2.3	630.400	130	60°F 15.5	78	75	15 $\frac{27}{60}$ 15.5	19	0.3652 .366
2		633.400			76	74			$\Rightarrow -0.270$
3									

V_i = Initial reading of dry gas meter.
 V_f = final reading of dry gas meter.
 $V_m = V_f - V_i$ = volume of gas passing through dry gas meter

$$V_{g(std)} = \frac{(0.4997)(V_m)(P_{bar} + 13.6)}{(T_m + 273)} \quad T_{std} = 0.028317$$

The value of 0.4997 is obtained from P_{std}

where: 0.0287 is the conversion factor from ft^3 to m^3
 $T_{std} = 528^{\circ}R$
 $P_{std} = 29.92$ in. Hg

P. Schuster
 signature

Figure 5-6. EPA Method 5 dry gas meter performance test data sheet.

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 ^a	2165	362.3	362.6	+ 0.3	
Andersen Mark III Impactor ^b	Y94	127.8	127.8	0.0	
	Z51	136.0	136.3	+ 0.3	
	Y66	126.8	126.8	0.0	
	Y75	134.9	135.0	+ 0.1	
	Y88	127.2	127.4	+ 0.2	
	Z39	136.0	136.3	+ 0.3	
	Y76	127.4	127.4	0.0	
	Z53	136.6	136.8	+ 0.2	
	B179	180.5	180.6	+ 0.1	
Andersen Mark III Impactor Blank test run ^b	X31	148.9	149.1	+ 0.2	
	X32	137.6	137.8	+ 0.2	
	X33	145.6	146.0	+ 0.4	
	X34	138.6	139.0	+ 0.4	
	X35	151.1	151.3	+ 0.2	
	X36	138.9	139.2	+ 0.3	
	X37	150.2	150.4	+ 0.2	
	W60	135.2	135.4	+ 0.2	
	B222	188.0	188.7	+ 0.7	c
Andersen Heavy Grain Loading Impactor ^d (HGLI) Thimble	39	2470.6	2480.4	+ 9.8	
	61	2176.6	2178.6	+ 2.0	

^aExpected deviation, ± 0.5 mg.

^bExpected deviation, ± 0.3 mg.

^cThe high net weight is probably a result of very small particles leaking around the prefilter.

^dExpected deviation, ± 0.5 mg.

of the blank filter analyses. 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, which shows that stack gases did not significantly affect filter media.

In addition, blanks 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, which show that most 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 No. 1633, "Trace Elements in Coal Fly Ash," which was obtained from the National Bureau of Standards. The results (shown in Table 5-5) indicate that the analyses were within a factor of three of true values, which is the expected limit of SSMS 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

TABLE 5-4. REAGENT BLANK ANALYSIS

Type of blank	Container No.	Volume of blank, ml	Weight after evaporation and desiccation, ^a mg/g	Comments
Particulate blanks:				
Acetone	3982A	237	+ 0.01	
Acetone	3989A	227	+ 0.007	
Water	3983A	378	+ 0.004	
Particle size blanks:				
Acetone	2526A	382	+ 0.004	
Acetone	2531A	190	+ 0.02	
Acetone	2549A	518	+ 0.005	0.01 used in calculations
Analytical blanks:				
Ether/chloroform	BT459 (org)	150	+ 0.005	
Water	BT459 (aq)	250	+ 0.002	

^aTolerance: ± 0.01 mg/g.

TABLE 5-5. TRACE ELEMENT AUDIT RESULTS

Element	Concentration, $\mu\text{g/g}$		Percent difference ^b
	NBS-certified ^a	Measured	
Arsenic	61 \pm 6	120	+100
Cadmium	1.45 \pm 0.06	1	- 30
Chromium	131 \pm 2	150	+ 10
Copper	128 \pm 5	71	- 40
Lead	70 \pm 4	110	+ 60
Manganese	493 \pm 7	170	- 70
Nickel	98 \pm 3	54	- 40
Selenium	9.4 \pm 0.5	16	+ 70
Uranium	11.6 \pm 0.2	18	+ 60
Vanadium	214 \pm 8	99	- 50
Zinc	210 \pm 20	220	0

^aSRM No. 1633, "Trace Elements in Coal Fly Ash".

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

Assurance Handbook.⁵ 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 in this test program for determination of particulate matter and particle size distribution.

6.1 DETERMINATION OF PARTICULATE EMISSIONS

In this test program, the sampling and analytical procedures used to determine particulate emissions at Sites 1 and 2 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.

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 1, 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) using a digital readout.

Filter Holder - The filter holder was made of Pyrex glass, with 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 manometer (made by Dwyer) with a readability of 0.25 mm (0.01 in.) H₂O in the 0 to 25 mm (0 to 1 in.) H₂O 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 consisted 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, 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 200 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 1, 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. The sampling train was leak-checked at the sampling site prior to each test run 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 prior to each test run and at the conclusion of each test run. The check was made by blowing into the impact opening of the pitot tube until 7.6 cm (3 in.) or more of water were recorded on the manometer 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.) H₂O 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.

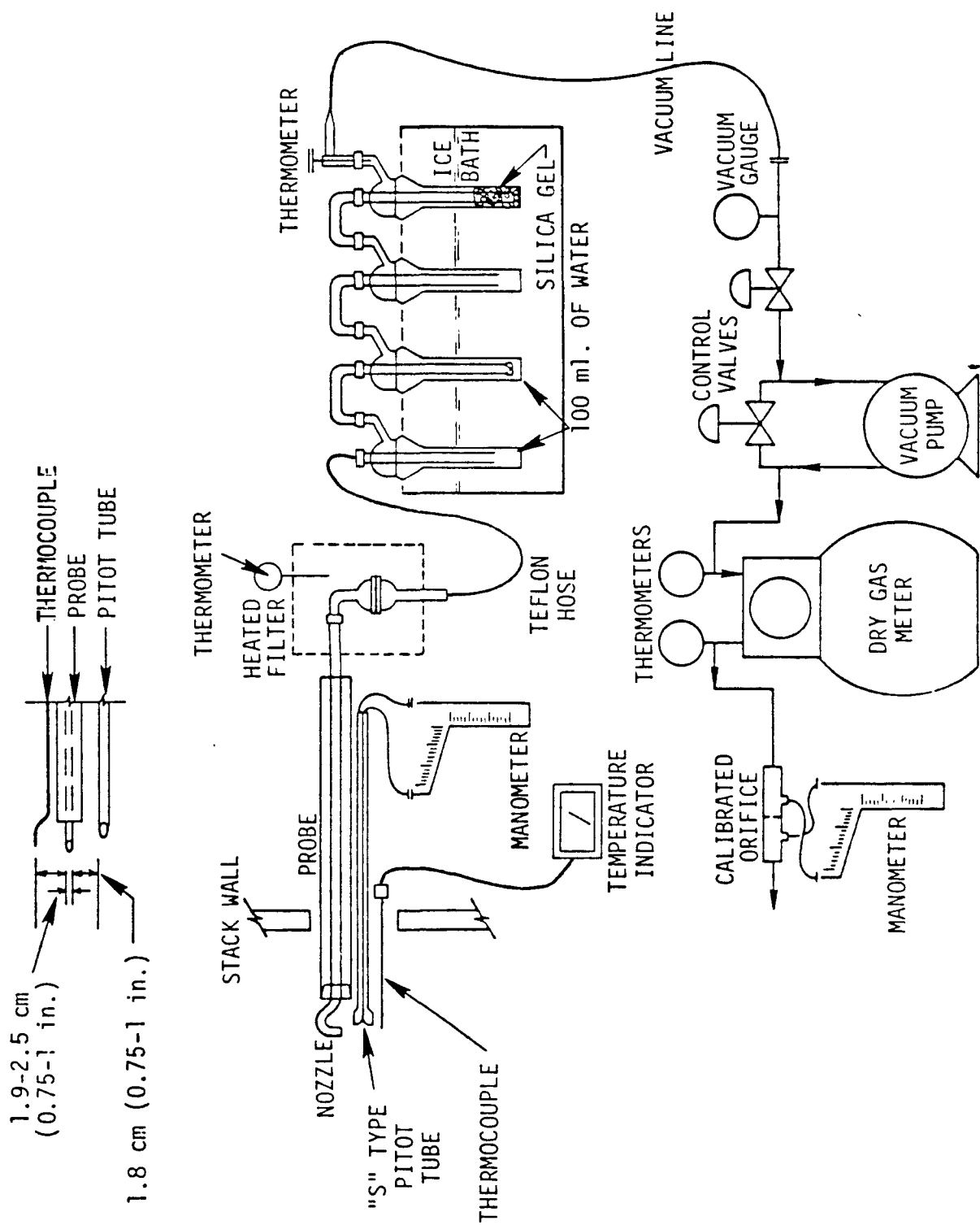


Figure 6-1. Schematic of particulate sampling train.

6.1.3 Sample Recovery Procedure

The sampling train was carefully moved 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 H₂O, 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.

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

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 1, 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 - The volume of the impinger contents and distilled water rinse was measured and transferred to a tared beaker. The sample was evaporated to dryness at 105°C, desiccated to a constant weight, and weighed to the nearest 0.1 mg.

Container No. 5 - The volume of distilled water blank was measured and transferred to a tared beaker. The blank was evaporated to dryness at 105°C, desiccated 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 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.

6.1.5 Modifications to Standard Procedures for Site 3 Tests

Several modifications were made to the standard sampling and analytical procedures to conduct particulate matter tests at Site 3. Some sampling equipment and analytical procedures were also different, but were not method deviations. These modifications and differences are as follows:

Sampling Apparatus--

Probe - The probe was of borosilicate glass with a heating system capable of maintaining a minimum gas temperature of 121°C (250°F) at the exit end during sampling.

Pitot Tube - A pitot tube was not used.

Sampling Procedure--

The sampling site and number of sampling points did not meet minimum Method 1* criteria, but were selected according to practical considerations. The stack pressure, temperature, and moisture at this site were measured according to standard procedures, but accurate velocity pressures could not be determined at each point.

The sampling train was prepared, assembled, and leak-checked according to standard procedures, except that a pitot tube was not used.

During sampling, stack gas temperature and sampling train data were recorded at each sampling point. An average isokinetic sampling rate was set initially, based on the estimated average velocity for the entire sampling cross-sectional area. This estimated velocity was calculated from data that had been obtained at Sites 1 and 2 and adjusted for the differences in cross-sectional area, temperature, pressure, and moisture. The resultant value was assumed to represent the average velocity at each Site 3 sampling point. The average isokinetic sampling rate was held constant throughout the sampling period. All sampling

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

data, including the estimated average velocity pressure, were recorded on the Emission Testing Field Data Sheet.

Initial calculations of emission results were based on estimated velocities and later adjusted to reflect actual velocities measured at Sites 1 and 2 during simultaneous tests.

Sample Recovery Procedure--

The sample recovery procedures were the same as those for Sites 1 and 2.

Analytical Procedures--

Container No. 4 - 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 - 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.

All other procedures for the determination of particulate emissions were as used in tests at Sites 1 and 2.

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:

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) using a digital readout.

Metering System - The metering system consisted 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 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 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 3. 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 according to procedures described in the Federal

Register.^{*} 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.

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

The sampling train was assembled as shown in Figure 6-2 or 6-3. It was leak-checked at the sampling site prior to each test run by plugging the inlet to the impactor (or cyclone 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

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

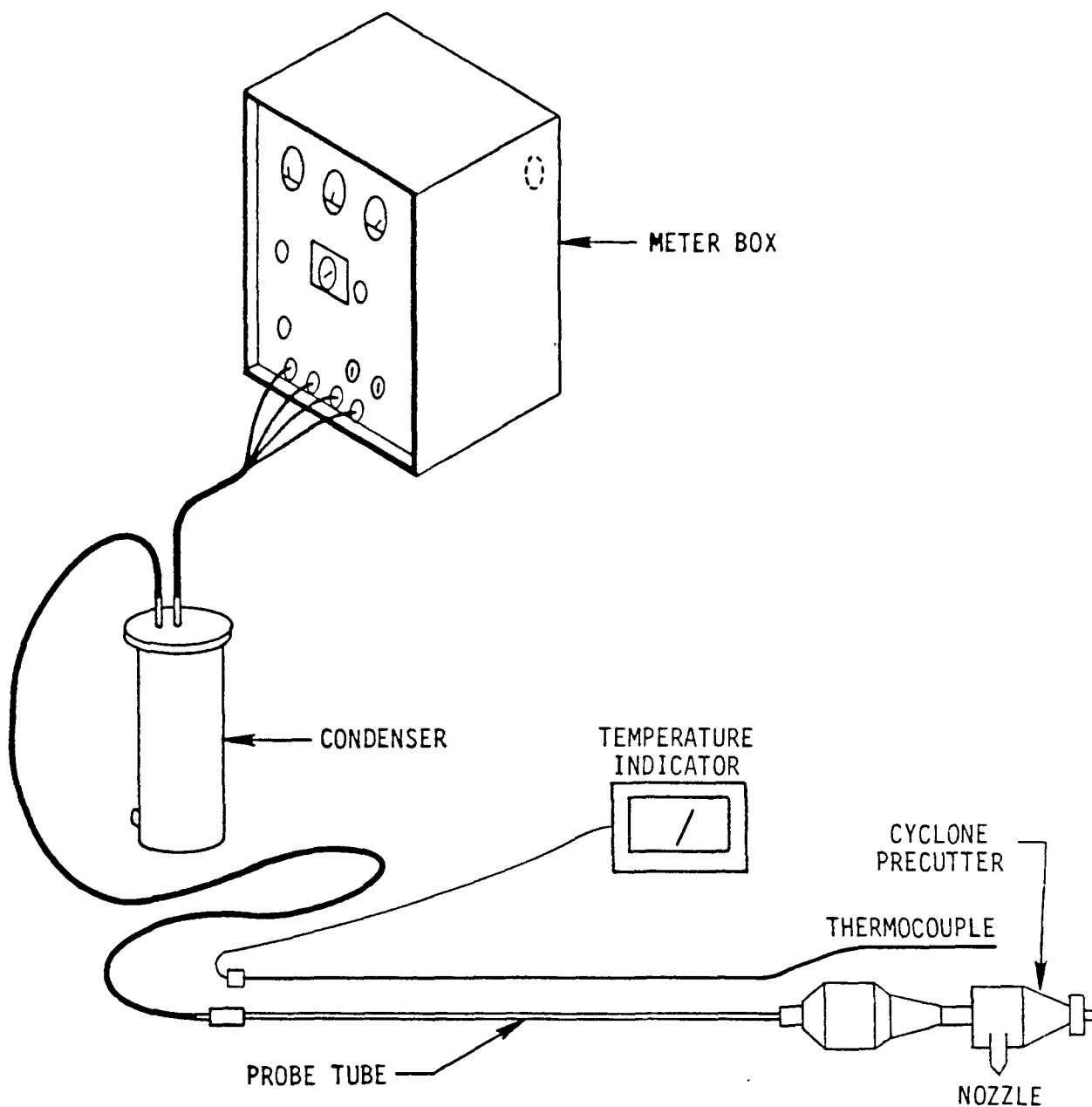


Figure 6-2. Particle size distribution sampling train at Site 1.

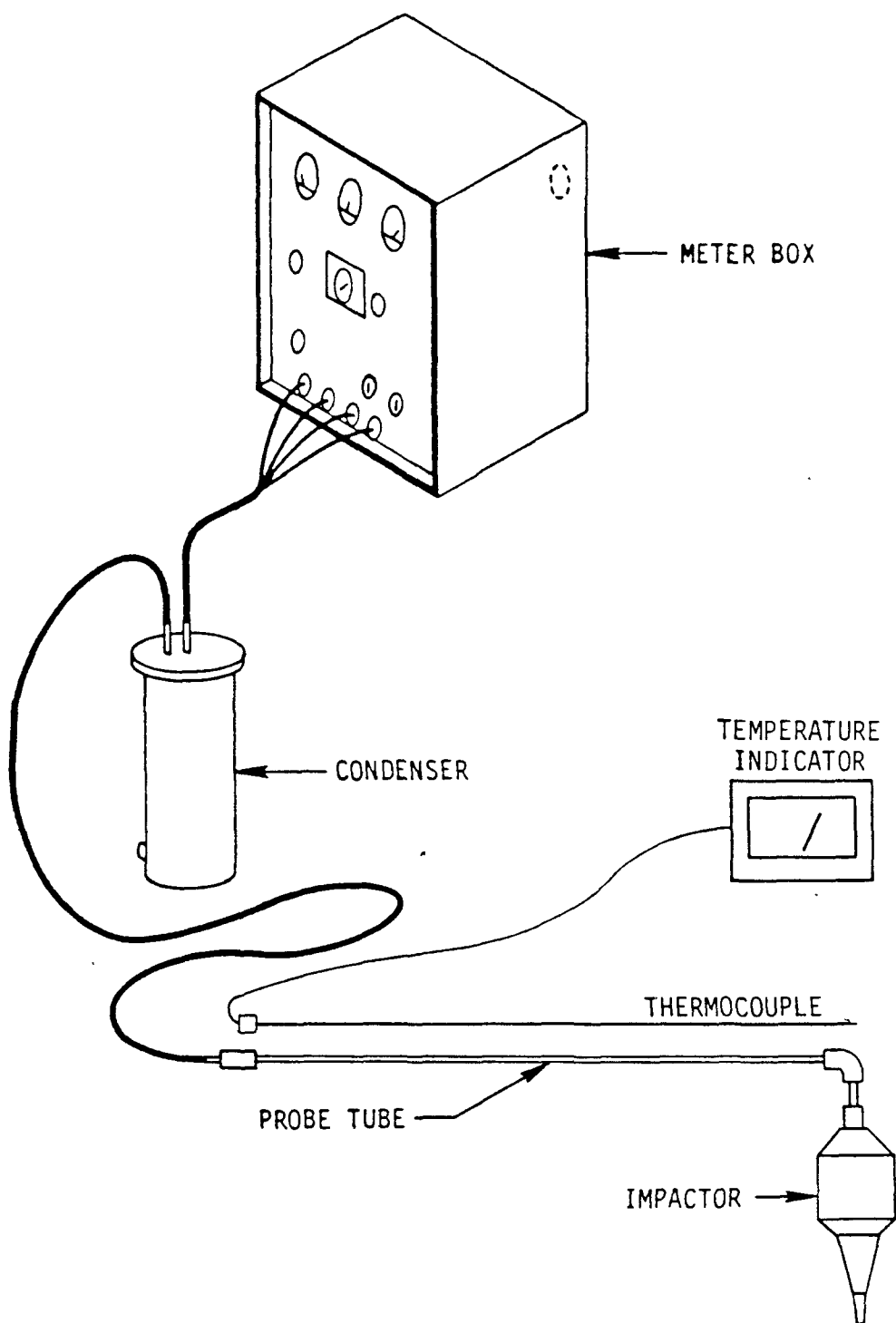


Figure 6-3. Particle size distribution sampling train at Site 3.

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 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 at Site 1 were obtained periodically using separate Method 5 equipment. Average velocities at Site 3 were estimated from previous data measured at Sites 1 and 2. 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

After the test was completed, the impactor was removed from the probe and carefully moved to a 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 plate, the Inconel spacer, 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.

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