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EPA

Chromium Screening Study Test Report

Electric Arc & A.O.D. Furnace Carpenter Technology, Inc. Reading, Pennsylvania

EMISSION TEST REPORT

CARPENTER TECHNOLOGY
READING, PENNSYLVANIA

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1.0 INTRODUCTION

During the week of March 4, 1985, Entropy Environmentalists, Inc. conducted an emission measurement program at Carpenter Technology's (CarTech) Specialty Steel Plant located in Reading, Pennsylvania. The purpose of this program was to determine the quantity and form of chromium emissions associated with the production of stainless steels.

Comprehensive testing was conducted on an electric arc furnace (EAF) and an oxygen-argon decarburization (AOD) vessel and a fabric filter which controls both of these.

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

- The emission capture systems at the plant are considered to be the most effective technology to capture emissions from EAF's and AOD vessels. A total furnace enclosure captures emissions from the EAF. A diverter stack directs AOD vessel emissions to a canopy hood for capture. Any emissions escaping the canopy hood are captured by two scavenger ducts above the canopy hood. Based on observation of fugitive dust flows during a pretest plant visit, nearly 100 percent capture occurs. This efficient capture permits an accurate estimate of uncontrolled emissions as determined by testing the inlet to the control device.

- The uncontrolled emissions should be representative of the industry. The plant manufacturers steel products having chromium contents typical of those used industry wide (17 to 19 percent chromium).

- Inlet testing ports were already available for the EAF and AOD vessel.

- The fabric filter is of positive-pressure design, which is typical of the industry.

- The New Source Performance Standards (NSPS) for EAF's and AOD vessels are based on the use of fabric filters as "best demonstrated control technology." Emissions from the fabric filter at CarTech are in compliance with the NSPS (the plant achieved a 0.016 gr/dscf with no visible emissions in a 1982 test).

Particulate concentrations and mass emission rates were measured at the EAF and AOD vessel exhausts and at the fabric filter stacks using U. S. Environmental Protection Agency (EPA) Reference Method 5.* Total chromium concentrations and hexavalent chromium concentrations were measured at the same locations by further analysis of the Method 5 samples using the alternate sample preparation and analytical procedures as described in Appendix C. Flue gas flow rates, temperature, moisture content, and composition [oxygen (O_2), carbon dioxide (CO_2), and carbon monoxide (CO)] were measured in conjunction with the particulate tests. In addition, the particle size distribution of particulate matter in the EAF and AOD vessel exhaust gases was determined along with hexavalent and total chromium distribution by particle size.

Representative samples of the dust collected by the fabric filter were collected during the particulate tests for determination of the hexavalent and total chromium content of the material entering the fabric filter.

Messrs. Michael Maul and William Maxwell [Midwest Research Institute (MRI)] monitored process operation throughout the test period. Mr. Dennis Holzschuh (EPA Task Manager) of the Emission Measurement Branch (EMB) and Mr. Al Vervaert of the Industrial Studies Branch (ISB) observed the test program. Mr. Larry Geiser, Senior Air Quality Control Engineer, served as the contact for Carpenter Technology.

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* 40 CFR 60, Appendix A, Reference Method 5, July 1, 1981.

This report is organized into several sections addressing various aspects of the testing program. Immediately following this introduction is the "Process Operation" section which includes a description of the process and control device tested. Following this is the "Summary of Results" section which presents table summaries of the test data and discusses these results. The next section, "Sampling Locations and Test Methods" describes and illustrates the sampling locations for emissions testing and grab sampling and then explains the sampling strategies used. The final section, "Quality Assurance," notes the procedures used to ensure the integrity of the sampling program. The Appendices present the complete Test Results and Example Calculations (Appendix A); Field and Analytical Data (Appendix B); Sampling and Analytical Procedures (Appendix C); Calibration Data (Appendix D); MRI Process Data (Appendix E); and Test Participants and Observers (Appendix F).

2.0 PROCESS OPERATION

2.1 Process Description

CarTech is a stainless and specialty steel producer. The Reading plant produces over 400 grades of steel that are grouped in several general categories including stainless steel, tool steel, electronic alloys, alloy steel, high temperature steel, and valve steel. The major steel products at the Reading plant include billets, bars, and wire. CarTech is unique compared to other stainless steel producers because of the size and shape of its products. The formulation of its stainless steel, though, is typical of other producers. This CarTech plant has six EAF's and two AOD vessels. (At present, two of the six EAF's are not operating.) Figure 2-1 illustrates the plant layout, including EAF and AOD vessel locations, and the emissions capture system. The ultra-high powered (UHP) EAF (EAF "F") and the No. 2 AOD vessel were both tested during this test program.

The UHP EAF was installed in 1982 and has a rated capacity of 32 tons per cycle. Refractory has been added to the bottom of the UHP EAF, allowing, at present, a maximum production of 26 tons of steel production per heat cycle. Typical production in the UHP EAF is between 20 and 22 tons per heat cycle. The furnace is equipped with a total furnace enclosure (TFE) to contain and capture emissions. The No. 2 AOD vessel has a rated capacity of 30 tons per heat cycle. However, the size of the outer shell limits its production to a maximum of 25 tons per heat cycle. Typical production in the No. 2 AOD vessel is between 20 and 22 tons per heat cycle. Design specifications for the UHP EAF and No. 2 AOD vessel are listed in Table 2-1.

Figure 2-2 presents a simplified process flow diagram. Normal operation of the UHP EAF at the Reading plant consists of charging, initial melting, and backcharging with cold scrap, alloys, and fluxes; further melting of the charge and backcharge; and tapping the molten metal into a ladle. Normal No. 2 AOD vessel operations include charging the vessel with molten metal produced by the UHP EAF and with fluxes and alloys; refining the molten charge; and tapping the refined metal into a ladle. The refined metal is then transferred to a continuous caster where metal billets are produced.

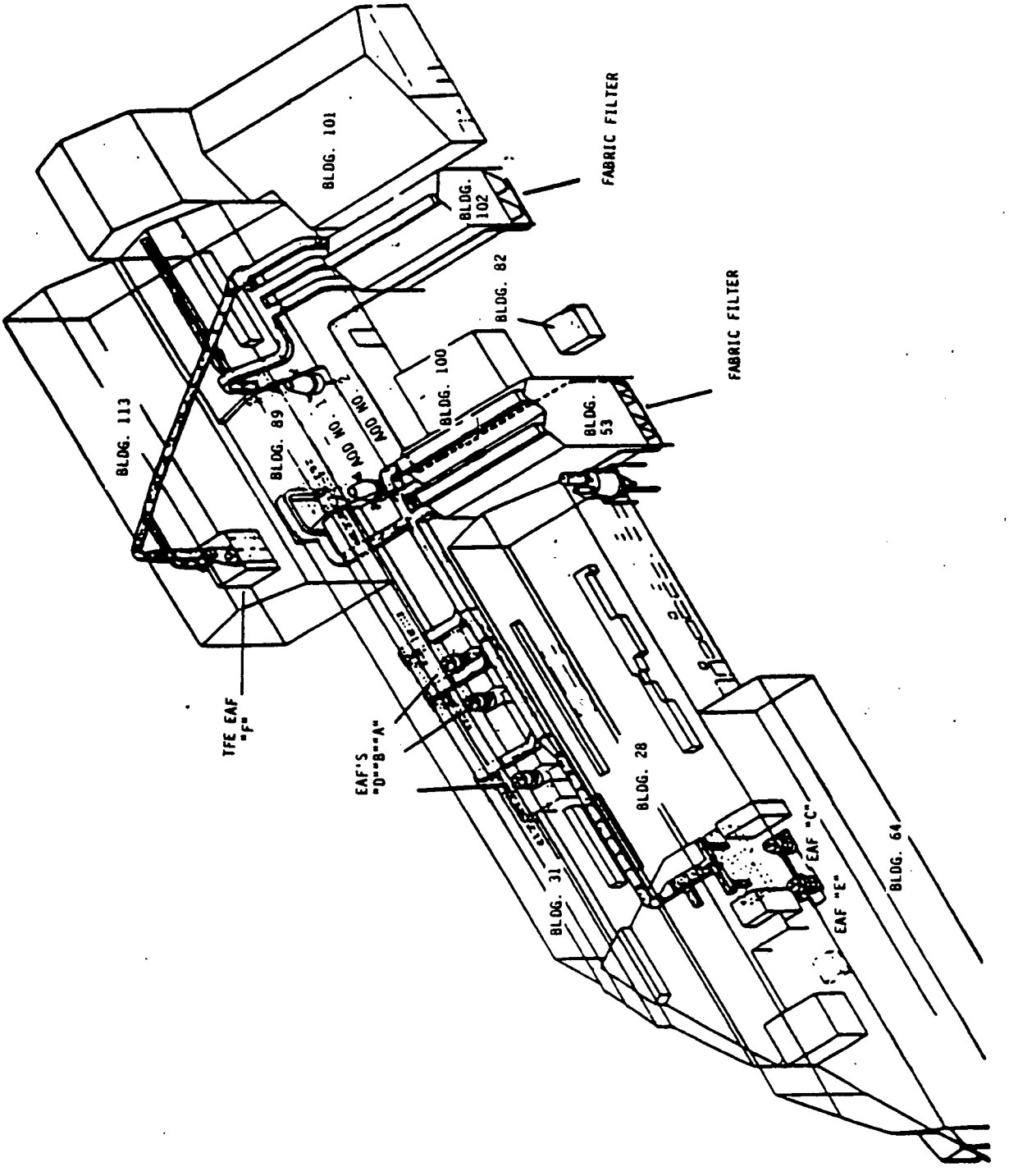


Figure 2-1. CarTech-Reading Plant Layout.

TABLE 2-1. UHP EAF AND NO. 2 AOD VESSEL SPECIFICATIONS

UHP Electric Arc Furnace	
Furnace manufacturer	Lectromelt NT
Roof ring diameter, ft	13.2
Transformer rating, kva	15,000/16,800
Type refractory	Basic
Meltdown time for initial charge, min	45
Meltdown rate, tons/h	30
Backcharge	One
Heat cycles, number/wk	60
Type of steel produced	Staninless steel/specialty
Material charged per heat, tons	22 in two charges
Metal tapped, tons	20
Type slag	Basic
Tapping temperature, °F	2900
Furnace cooling mechanism	Water cooled panels that begin 4.5 ft below the furnace top.
Tapping method	Tapping pit for accommodation of ladle
Doors	Slag door; fluxes and oxygen lancing door.
No. 2 argon-oxygen decarburization vessel	
Average charge size, tons	22
Metal tapped, tons	20
Vessel dimensions:	
Diameter, ft	9.2
Height, ft	14.5
Tapping temperature, °F	(2700-3020)
Refining time (average), h	1.6

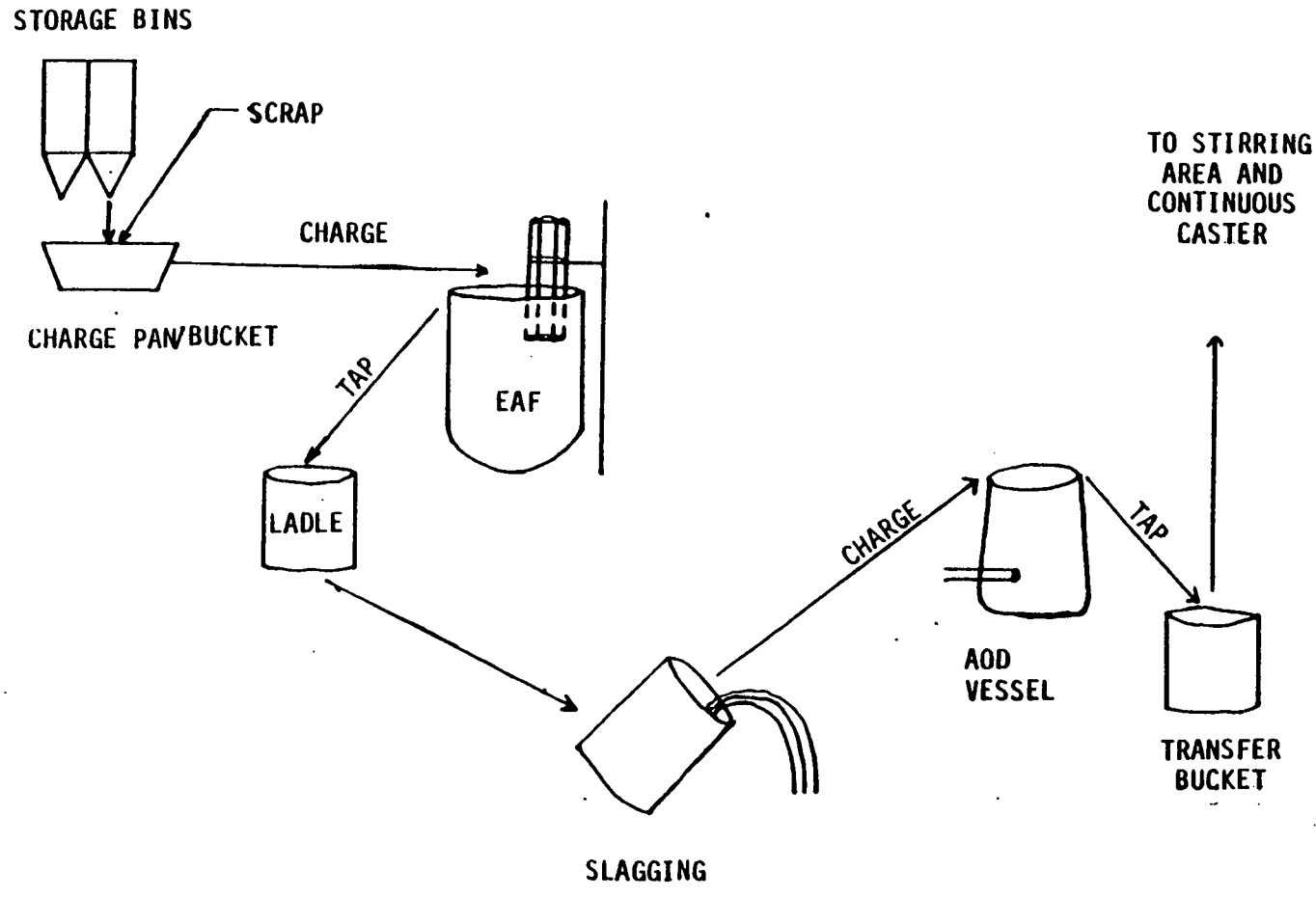


Figure 2-2. Flow Diagram For The Manufacture Of Specialty Steel At CarTech.

The charge material to the UHP EAF is typically 80 percent clean scrap (often composed of "18-8 scrap" that contains 18 percent chromium and 8 percent nickel) and 20 percent additives (such as lime, charge chrome [ferrochrome], ferronickel, and iron ore). The composition of the additives varies and is dependent on final product specifications. Steel to which chrome has been added has an average chrome content of 17 to 19 percent, which is typical in the industry. Most additives are discharged directly into charge buckets from enclosed storage bins. Scrap and additives are charged and backcharged to the UHP EAF in a preweighed charge bucket carried by an overhead crane. Pneumatic cylinders open the bi-parting front-end doors and the roof doors of the total furnace enclosure (TFE) to permit entry of the charge bucket and crane cable.

After charging is completed, the TFE doors are closed. The charge is melted for approximately 45 minutes by three 16-inch diameter electrodes, which have a maximum electrical rating of 16,800 kva and are powered by a transformer operating from a primary, 3 phase, 60 hertz (Hz) voltage supply of 13,800 volts. After the initial 45-minute melting period, the TFE doors are opened to allow one back charge, which brings the UHP EAF up to full melting capacity, and are then closed again to allow the melt to continue. Complete melting can take from 1 to 1.5 hours. Oxygen lancing is used during the melting phase, when needed, to speed up melting or bring molten metal back up to temperature for tapping. At the end of the melt, a sample of molten metal is taken for analysis.

After completion of the melting phase, the TFE doors are opened again, the UHP EAF is tipped at a 42° angle, and the molten metal is discharged or tapped into a ladle located in a pit next to and below the EAF. After tapping, the ladle is removed from the pit by the overhead crane and is transported to a slagging station where slag floating on the surface of the molten steel is skimmed. Following slag skimming, the crane takes the molten metal in the ladle to the No. 2 AOD vessel for refining. The molten metal is then poured directly into the AOD vessel. Decarburization begins almost immediately after charging. An oxygen and argon gas mixture (used in a ratio of 3:1) is blown through the molten bath. The oxygen decreases carbon in the molten metal by converting it to carbon monoxide (CO) gas. The argon both reduces the partial pressure of and dilutes the CO gas,

thereby allowing chromium to oxidize more slowly than the carbon to increase the amount of chromium retained. Sometimes nitrogen is used in the blowing gas as a replacement for argon. After blowing has occurred for 15 to 30 minutes, the vessel is tilted at a 90° angle for a temperature check. If the temperature is close to 3182°F, and if additional additives are required, additions of alloys and fluxing agents are made to meet final product specifications. During the next hour, the vessel is alternated between two positions: an upright position for blowing or stirring the molten bath with an argon and oxygen mixture (one part argon to three parts oxygen) and a tilted position, 90° from upright, for temperature measurement, sample acquisition, and alloy and flux addition. Near the end of the heat, slag is poured off into a slag pot to remove the lime and impurities. At the end of the heat, after a final sample of the molten metal is analyzed, final additions are made and melted into the bath by stirring with argon or nitrogen.

Between each EAF heat, unformed refractory material is sprayed onto the EAF refractory lining to seal any weak spots in the lining. The AOD vessel does not require refractory coating between heats and is used nearly continuously.

After being refined in the No. 2 AOD vessel, the molten metal is transferred to a teeming ladle which discharges from the bottom. The ladle is transported to the stirring station where the temperature is lowered by the addition of argon gas. The molten metal is discharged from the ladle into a tundish; a refractory-lined trough with holes in the bottom. Refractory plugs regulate the flow of the molten metal from the tundish to the water-cooled continuous caster that forms the metal into a continuous billet. As the metal cools in the caster, the billet is pulled through the caster by a chain. The billet continues to cool as it passes through the caster. At the end of the caster, torches are used to cut the billet into the desired size.

2.2 AIR POLLUTION CONTROL SYSTEM

Table 2-2 presents specifications for the TFE. The TFE has a 10,000 acfm air-curtain fan that continuously blows air across the roof opening during the entire heat cycle. Emissions are contained and directed

TABLE 2-2. TOTAL FURNACE ENCLOSURE SPECIFICATIONS

UHP EAF Total Furnace Enclosure--Building 113	
Airflow:	
Main exhaust volume, acfm	150,000
Air curtain supply, acfm	10,000
Air curtain exit velocity, ft/s	125
Structure:	
Dimensions, ft	42 x 51 x 35
Material, gauge	Hi-rib aluminized sheeting, 18
Doors:	
Dimensions, (ft)	2 horizontal roof doors--16 x 7 2 vertical front doors--10.5 x 35.3
Dampers:	Exhaust--two position Melt/charge or tap Air curtain--two position Melt/charge or tap
Controls for the pneumatic cylinders:	Tapping station--buttons 1. Damper mode--melt/charge or tap 2. Vertical doors--open or closed 3. Tap side roof door--open or closed 4. Melt/charge roof door--open or closed Main control room--buttons 1. All doors open or all doors closed
Other features:	Removable roof panels Emergency compressed air supply (tank)

by the airflow to one of two exhaust hoods located immediately beneath the TFE roof. The exhaust hood capture system has a ventilation rate of 150,000 acfm and is able to collect the emissions effectively even when the doors of the TFE are open. Using dampers, the air curtain can be positioned to direct emissions from either melting/charging or tapping to the exhaust hood located above the furnace and tapping areas. Dampers also determine which exhaust hood is operating. At present, the tapping air curtain position and its respective exhaust hood are not used since the melting/charging position does an adequate job in collecting tapping emissions. The captured emissions are ducted to a positive-pressure baghouse.

The process emissions generated during the refining process in the No. 2 AOD vessel are captured by a canopy hood built into the building roof trusses about 43 ft above the mouth of the vessel. The fumes are directed to the canopy hood by a diverter stack located 5 ft above the mouth of the AOD vessel. The diverter stack is movable and swings out of the way when the vessel is charged or tapped. The shop roof above the No. 2 AOD is closed, and any emissions not captured by the canopy hood remain inside the building. These uncaptured emissions are drawn into two scavenger ducts located in the peak of the roof between the canopy hood and the continuous caster area. The scavenger ducts are not equipped with hoods and consist only of an open piece of ductwork. Total ventilation applied to the No. 2 AOD vessel capture system is 300,000 acfm. The canopy hood and scavenger ducts join to form a main circular duct that connects with the UHP EAF ductwork upstream of the positive-pressure baghouse.

Table 2-3 presents specifications of the positive-pressure baghouse that is used to control emissions from the UHP EAF and No. 2 AOD vessel. Although the baghouse has a design capacity of 676,000 acfm, it currently treats only 450,000 acfm (150,000 acfm from the UHP EAF and 300,000 acfm from the No. 2 AOD vessel). The actual air-to-cloth ratio is 2.08 to 1. About two-thirds of the clean exhaust gas is discharged through 10 stub stacks, while the other third leaks out of the baghouse after passing through the fabric bags. Baghouse inspection and maintenance are performed once per day.

TABLE 2-3. BAGHOUSE DESIGN SPECIFICATIONS

Baghouse	
Type	Custom, pressurized, ventilated
No. of compartments	20
Total number of bags	2,400
Bag size, ft	1 x 31.5
Bag material	Dacron--seamless
Bag arrangement	6 rows x 20
Gross air-to-cloth ratio	3.18:1
Net air-to-cloth ratio (19 compartments)[a]	3.02:1
Inlet gas temperature °F	150
Total air capacity, acfm	676,000
Reverse air fan, hp	125
Reverse air fan capacity, acfm	23,000
Standard pressure at 70°F, in. Hg	15
Compartment pressure, (in w. c.)	4-6
Siding, gauge	CORTEN, 20
Exhaust fans	
Number of fans	3
Type	Double inlet, centrifugal with back stops
Wheel	Radial tip, blade liners
Individual capacity, acfm	225,333
Drive	Direct coupled
Motor hp	700
Voltage	2,300
Revolutions per minute	705
Brake horsepower at 70°F	672
Standard pressure at 70°F, in. Hg	12.8

[a]One compartment at a time is isolated in order to be cleaned.

The pressure drop across each compartment of the baghouse ranges from 4 to 6 inches water column. Each Dacron bag contains seven anti-collapsing rings that are attached to the inside of the bag and are spaced at even intervals along the length of the bag. The dust collected on the inside of the bags is dislodged by reverse air cleaning. One compartment at a time is removed from service and subjected to a reverse air stream. The dust from the compartment being cleaned falls into a hopper below the compartment and is conveyed pneumatically to a storage bin.

2.3 PROCESS CONDITIONS DURING TESTING

The EAF, AOD vessel, their associated capture equipment, and the baghouse were all monitored to ensure normal operation throughout the test. The process parameters monitored were production rates, percent chromium in the product, time and order for all process steps, secondary voltage to the EAF electrodes, and type and quantity of gases used in the AOD vessel. Observations of the emission capture equipment were made about every 15 minutes and estimates of capture efficiency recorded. Baghouse operating parameters monitored included inlet flue gas temperature, main duct pressure drop, compartment being cleaned, and individual compartment pressure drops. Typical operating values for the EAF, AOD vessel, and baghouse are listed in Table 2-4.

Process parameters and observations recorded during the test program are presented in Appendix E. Also presented for each sample run is a time chart which summarizes the process events (e.g., charges, blowing periods, taps, etc.) which occurred during each test run. All processes operated within normal limits throughout the test. Inlet and outlet testing were not performed simultaneously. The outlet test runs spanned an average of 2.5 heats per test run while the inlet test runs covered one full heat per test run for both the EAF and AOD vessel.

During the first heat of the first test run on Wednesday, March 6, the EAF encountered a series of minor delays because of the occurrence of power shortages which required that the power supply to the EAF be temporarily turned off. Plant personnel consider this to be within the limits of normal operation during certain times of the month. The interruptions caused a 15 to 20 minute increase in the actual melting time typically

TABLE 2-4. TYPICAL OPERATING VALUES

Electric Arc Furnace	
Duration, min:	
Charging	5 to 10
Tapping	3 to 5
O_2 lancing	3 to 5
Melting	60 to 90
Secondary voltage, volts	200 to 300
Process weight	20 to 22 tons
Percent chromium	17 to 19
kWh/heat	9,000
O_2/heat, scf	2,642
AOD Vessel	
Duration, min:	
Charging	1
Blowing	75 to 90
Slagging	5 to 10
Tapping	1 to 3
Rate of gas use, scfh:	
Initial blow (15 to 30 min. duration)	33,000 O_2, 11,000 Ar and/or N_2
Further refining (60 min. duration)	11,000 O_2, 33,000 Ar and/or N_2
Stirring	28,000 Ar
Total gas usage, scf	55,000 to 66,000
Baghouse	
Inlet flue gas temp., °F	120 to 130
Average compartment ΔP, in. w.c.	4 to 6
Main duct ΔP, in. w.c.	10 to 11

eeded to produce the steel. Because of minor emissions that were still oming from the furnace when melting was suspended, and the lengthened melt ime, emissions per ton of steel produced should be higher than if the ower interruptions had not occurred. The test results appear to support his.

On Thursday, March 7, the first EAF heat of the second test run had a hortened melting time because no backcharge was needed. When the charge aterial is not composed of as much bulky scrap, all raw materials can be harged in one step. The decreased melting time needed should slightly ecrease emissions per ton of steel produced. The reduced melting time, hough, was offset by increased oxygen lancing time used (~5 minutes) to aise the melt temperature. Emissions from oxygen lancing appeared heavier han melting. The data suggest that the added oxygen lancing emissions ept emissions per ton of steel produced at a typical level.

Because of communication problems, the samples taken during the ackcharge and tap of the first test EAF heat were gathered at times when elting, rather than charging or tapping, was occurring. However, because he mistaken sampling period accounted for only a small portion of the otal test run (~8 minutes out of the 106-minute sampling period and 2 out f 17 charges, backcharges, and taps included in the test run) and the fact hat emissions observed during the mistaken sampling periods were elatively light, the correctness of the charge/tap test run is not onsidered unduly compromised.

Based on the visual observations performed, the TFE generally captured 3 to 100 percent of the emissions from EAF charging and melting. pproximately 97 percent capture efficiency was achieved during tapping. missions from oxygen lancing were the heaviest for all EAF process teps. Capture efficiency by the TFE during oxygen lancing was estimated o be 95 percent. The AOD vessel diverter stack and canopy hood generally aptured nearly 100 percent of the emissions during blowing and stirring of ie AOD vessel. Approximately 90 percent of emissions were usually aptured during charging, slagging, and tapping of the AOD vessel. Any missions not captured by the hood were captured by the scavenger duct ystem.

TABLE 2-5. EAF FINAL OPERATING PARAMETERS

Heat No.	Process weight, lb	Percent chromium	O_2 use, ft^3	kWh/ heat, 10^2	Tap temp., °F
62002	43,780	18	2,500	107	2948
62003	43,340	18	2,000	93	2966
62024	42,700	18.5	4,500	78	2930
62027	44,320	18	7,000	86	2912
62028	45,400	17	2,000	96	2948
62031	33,600	19	3,000	68	2948
62032	34,160	21	5,500	79	2948
62035	43,920	18	2,500	90	2948

TABLE 2-6. AOD VESSEL FINAL OPERATING PARAMETERS

Heat No.	Process weight, lb	Percent chromium	O_2 use, ft^3	Ar use, ft^3	N_2 use, ft^3	Tap temp., °F
61999	63,350	18	32,960	29,650	1,650	2876
62002	64,930	18	31,200	26,000	1,610	2867
62023	58,445	19	29,720	29,380	2,170	2930
62024	57,895	18	20,560	11,970	3,570	2867
62027	62,560	18.5	25,590	14,280	5,720	2894
62028	58,300	17	21,630	22,170		2885
62031	43,640	19	22,680	18,250	6,340	2885
62032	50,005	20	28,880	13,170	5,800	2912

3.0 SUMMARY OF RESULTS

Particulate matter and particle size distribution tests were conducted at the electric arc furnace (EAF) outlet and the argon-oxygen decarburization (AOD) vessel outlet. A particulate matter test was also run at the EAF outlet exclusively during charging, recharging, and tapping of the EAF. Particulate matter tests were run at the outlet of the fabric filter which controlled the emissions from both the EAF and AOD vessel. No particle size distribution tests were run at the fabric filter outlet due to the extremely low concentration of emissions discharged. Also as a result of the low concentration of pollutants at the fabric filter discharge, two particulate trains were run simultaneously in an effort to obtain a quantifiable amount of hexavalent chromium. One train collected samples in discharge stacks No. 1 through 5 and the other in stacks No. 6 through 10. Table 3.1 summarizes the testing schedule.

In brief, the uncontrolled emissions from the EAF averaged 117 pounds per hour of particulate, 0.01 pounds per hour of hexavalent chromium and 9.9 pounds per hour of total chromium. The uncontrolled EAF emissions during charging, recharging, and tapping averaged 50 pounds per hour of particulate, 0.002 pounds per hour of hexavalent chromium, and 3 pounds per hour of total chromium. The uncontrolled emissions from the AOD vessel averaged 202 pounds per hour of particulate, 0.76 pounds per hour of hexavalent chromium, and 21 pounds per hour of total chromium. The controlled emissions from the fabric filter controlling both the EAF and AOD vessel averaged 5.6 pounds per hour of par- ticulate matter, 0.0005 pounds per hour of hexavalent chromium, and 0.14 pounds per hour of total chromium.

TABLE 3.1. TESTING SCHEDULE FOR CARPENTER TECHNOLOGY

Date (1985)	Sample Type	Electric Arc Furnace Exhaust		Argon-Oxygen Decarburization Vessel Exhaust		Fabric Filter Discharge Stacks Nos. 1-5		Fabric Filter Discharge Stacks Nos. 6-10	
		Run No.	Test Time 24 h clock	Run No.	Test Time 24 h clock	Run No.	Test Time 24 h clock	Run No.	Test Time 24 h clock
3/6	Particulate	A1	1233-1513	B1	1218-1446	C1	1234-1806	D1	1237-1806
	Particulate	CTA	1235-1755						
	Particle Size	S1A	1712-1727	S1B	1533-1543				
3/7	Particulate	A2	0930-1055	B2	0905-1119	C2	0929-1353	D2	0933-1355
	Particulate	CTA	0931-1724						
	Particle size	S2A	1152-1212	S2B	1150-1205				
	Reactivity			R1	1215-1230				
	Particulate	A3	1519-1632	B3	1513-1652	C3	1512-1932	D3	1516-1935
	Particle size	S3A	1727-1742	S3B	1659-1711				

The particle size distribution tests showed that almost all of the particulate matter emissions from both the EAF and AOD vessel were less than 10 μm in diameter. The overall collection efficiency of the fabric filter was 98.966 percent by weight for particulate emissions, 99.963 percent by weight for hexavalent chromium emissions, and 99.726 percent by weight for total chromium emissions.

In the following sections, the results addressed above and additional results are presented and discussed in detail according to the emission type and sample location. The computer printouts of the emission calculations can be found in Appendix A. The original field data sheets and the analytical data are located in Appendix B.

3.1 PARTICULATE MATTER, HEXAVALENT CHROMIUM, AND TOTAL CHROMIUM

Particulate matter tests (EPA Method 5) along with the determination of the associated flue gas flow rate were conducted at the EAF outlet, AOD vessel outlet, and fabric filter discharge stacks. The particulate matter samples were initally analyzed using gravimetric techniques to determine the mass of particulate matter. Then the samples were further analyzed for hexavalent and total chromium. Complete descriptions of each sampling location and the sampling and analytical procedures are given in Chapter 4.

3.1.1 Electric Arc Furnace Exhaust

The electric arc furnace (EAF) exhaust measurements represent the uncontrolled emissions from the EAF over one complete cycle. A separate particulate test was conducted during the charging, recharging, and tapping portion of the EAF cycles and represents the uncontrolled emissions for those portions of a cycle.

Flue Gas Conditions and Isokinetic Sampling Rate - A summary of the flue gas conditions at the EAF exhaust is presented in Table 3.2. The volumetric flow rate for the three runs conducted over the entire cycle and for the run conducted only during the charging, recharging, and tapping portion of the cycle were very consistent. The volumetric flow rate averaged 295,000 actual cubic meters per hour (10,420,000 actual cubic feet per hour) with a flue gas temperature of 26°C (78°F), and the moisture content and composition of ambient air. The volumetric flow rate at standard conditions averaged 289,000 dry standard cubic meters per hour (10,210,000 dry standard cubic feet per hour). Standard conditions are 20°C (68°F), 760 mm Hg (29.92 in. Hg) and dry. The flue gas conditions for the charging, recharging, and tapping were similar.

The isokinetic sampling rate was within the allowable range for all runs.

Particulate Emissions - The particulate mass rates from the EAF over three sample runs (see Table 3.3) were variable. This variability is primarily due to the variability in the duration of the heat sampled. The particulate emissions averaged 184 milligrams per dry standard cubic meter (0.0805 grains per dry standard cubic foot), and 53.2 kilograms per hour (117 pounds per hour).

The EAF emissions during charging, recharging and tapping averaged 75.3 milligrams per dry standard cubic meter (0.033 grains per dry standard cubic foot) and 22.8 kilograms per hour (50 pounds per hour). In an effort to obtain a quantifiable amount of hexavalent chromium, only a single test was run over the entire test program for the charging, recharging, and tapping portions of the cycle.

TABLE 3.2. SUMMARY OF FLUE GAS CONDITIONS

Run No.	Date (1985)	Test Time 24 h clock	Volumetric Flow Rate				Stack Temperature		Moisture %	O_2 %	CO_2 %	CO %	Isokinetic %
			Actual[a]		Standard[b]								
			acmh x 10^6	acfh x 10^6	dscmh x 10^6	dscfh x 10^6	°C	°F					
Electric Arc Furnace Exhaust													
A1	3/6	1233-1513	0.295	10.43	0.291	10.27	23	73	0.0	20.9	0.0	0.0	95.5
A2	3/7	0930-1055	0.292	10.30	0.286	10.12	26	78	0.0	20.9	0.0	0.0	96.6
A3	3/7	1519-1632	0.298	10.52	0.290	10.25	28	82	0.0	20.9	0.0	0.0	97.0
Average			0.295	10.42	0.289	10.21	26	78	0.0	20.9	0.0	0.0	97.0
Electric Arc Furnace Exhaust, Charging and Tapping													
CTA	3/6	1235-1724	0.311	10.98	0.303	10.71	24	76	0.4	20.9	0.0	0.0	99.7
Argon-Oxygen Decarburization Vessel Exhaust													
B1	3/6	1218-1446	0.670	23.67	0.645	22.79	29	85	0.1	20.9	0.0	0.0	97.5
B2	3/7	0905-1119	0.675	23.83	0.662	23.37	26	78	0.1	20.9	0.0	0.0	95.2
B3	3/7	1513-1652	0.697	24.61	0.679	23.96	28	82	0.1	20.9	0.0	0.0	97.5
Average			0.681	24.04	0.662	23.37	28	82	0.1	20.9	0.0	0.0	97.5
Fabric Filter Discharge Stacks													
C1	3/6	1234-1806	0.209	7.39	0.203	7.18	29	85	0.0	20.9	0.0	0.0	95.6
D1		1237-1806	0.180	6.36	0.175	6.18	29	85	0.0	20.9	0.0	0.0	99.2
C2	3/7	0929-1353	0.208	7.35	0.204	7.22	28	82	0.0	20.9	0.0	0.0	97.7
D2		0933-1355	0.192	6.77	0.188	6.65	28	82	0.0	20.9	0.0	0.0	99.1
C3	3/7	1512-1932	0.208	7.34	0.203	7.15	31	87	0.0	20.9	0.0	0.0	97.2
D3		1516-1935	0.197	6.97	0.192	6.79	31	87	0.0	20.9	0.0	0.0	98.9
Average			0.398	14.06	0.388	13.72	29	85	0.0	20.9	0.0	0.0	97.9

[a]Volumetric flow rate in actual cubic meters per hour (acmh) and actual cubic feet per hour (acfh) at stack conditions.
[b]Volumetric flow rate in dry standard cubic meters per hour (dscmh) and dry standard cubic feet per hour (dscfh)..
[c]The average represents the combination of C and D.

TABLE 3.3. SUMMARY OF PARTICULATE, HEXAVALENT CHROMIUM, AND TOTAL CHROMIUM EMISSIONS

Run No.	Date (1985)	Particulate				Hexavalent Chromium				Total Chromium			
		concentration		mass emissions		concentration		mass emissions		concentration		mass emissions	
		mg/dscm	gr/dscf	kg/h	lb/h	mg/dscm $\times 10^{-3}$	gr/dscf $\times 10^{-3}$	kg/h $\times 10^{-3}$	lb/h $\times 10^{-3}$	mg/dscm	gr/dscf $\times 10^{-3}$	kg/h	lb/h
Electric Arc Furnace Exhaust													
A1	3/6	112.79	0.0493	32.80	72.31	31.96	0.0140	9.29	20.49	9.28	4.06	2.70	5.95
A2	3/7	255.83	0.1118	73.29	161.58	6.44	0.0028	1.84	4.07	18.94	8.28	5.43	11.96
A3	3/7	183.79	0.0803	53.37	117.66	8.47	0.0037	2.46	5.42	18.25	7.98	5.30	11.69
Average		184	0.0805	53.2	117	15.6	0.0068	4.5	10.0	15.5	6.8	4.5	9.9
Electric Arc Furnace Exhaust, Charging and Tapping													
CTA	3/6	75.3	0.0329	22.8	50.4	3.26	0.0014	0.99	2.2	4.54	2.0	1.4	3.0
Argon-Oxygen Decarburization Vessel Exhaust													
B1	3/6	164.17	0.0717	105.83	233.54	406.7	0.178	262.4	578.6	14.00	6.12	9.03	19.91
B2	3/7	130.45	0.0570	86.33	190.32	616.6	0.269	408.0	899.6	13.61	5.95	9.00	19.85
B3	3/7	121.43	0.0531	82.40	181.66	536.5	0.234	364.1	802.6	14.87	6.50	10.09	22.25
Average		139	0.0606	91.6	202	520	0.23	345	760	14.2	6.2	9.4	20.7
Fabric Filter Discharge Stacks[a]													
C1, D1	3/6	3.45	0.0015	3.231	7.122	0.169	0.00007	0.158	0.309	0.0605	0.0265	0.0567	0.125
C2, D2	3/7	3.12	0.0014	2.957	6.516	0.161	0.00007	0.154	0.337	0.0552	0.0241	0.0533	0.115
C3, D3	3/7	1.50	0.0007	1.452	3.267	0.322	0.00014	0.312	0.688	0.0823	0.0360	0.0797	0.176
Average		2.69	0.0012	2.55	5.64	0.22	0.00009	0.21	0.45	0.066	0.021	0.063	0.139

[a]Numbers are composites of C and D runs and the mass emission rates were calculated based on the sum of the dry standard volumetric flow rate from the AOD and EAF.

Hexavalent Chromium Emissions - The hexavalent chromium emissions were variable when compared to the corresponding particulate run and averaged 283, 25, and 46 micrograms of hexavalent chromium per gram of particulate matter emissions. The reason for the high concentration of hexavalent chromium during the first run is unknown. The charging, recharging, and tapping run emissions were 43 micrograms of hexavalent chromium per gram of particulate matter. The hexavalent chromium emissions from the EAF averaged 0.016 milligrams per dry standard cubic meter (6.8×10^{-6} grains per dry standard cubic foot) and 0.0045 kilograms per hour (0.01 pounds per hour). The mass emissions from the charging, recharging and tapping run were about one fourth those at the EAF exhaust.

Total Chromium Emissions - The total chromium emissions were fairly consistent when compared to the corresponding particulate runs, and averaged 82, 74, and 99 milligrams of total chromium per gram of particulate matter emis- sions. The charging, recharging, and tapping run emissions were 60 milligrams of total chromium per gram of particulate matter emissions. The total chromium emissions from the EAF exhaust averaged 15.5 milligrams per dry standard cubic meter (0.0068 grains per dry standard cubic foot) and 4.5 kilograms per hour (9.9 pounds per hour). The charging, recharging, and tapping emissions were slightly less than one third of the EAF exhaust emissions. The total chromium content of the emissions measured at the EAF exhaust was about one thousand times that of the hexavalent chromium content.

3.1.2 Argon-Oxygen Decarburization Vessel

The argon-oxygen decarburization (AOD) vessel measurements represent the uncontrolled emissions from the AOD vessel over one complete cycle. A scavenger duct entered the AOD vessel exhaust duct after the AOD vessel discharge and prior to the sampling location. Although the canopy hood usually collects the emissions coming off the AOD vessel, the scavenger duct system ensures nearly 100% capture of emissions, and on some occasions can be a significant source of

emissions. The effects of the dilution air from the scavenger duct on the measured emissions from the AOD vessel would result in lower pollutant concentrations, but have no effect on mass emission rates.

Flue Gas Conditions and Isokinetic Sampling Rate - A summary of flue gas conditions at the AOD vessel exhaust is presented in Table 3.2. The volumetric flow rate (which includes the flow rate from the scavenger duct) was very consistent for all runs and averaged 681,000 actual cubic meters per hour (24,040,000 actual cubic feet per hour) with a flue gas temperature of 28°C (82°F) and the moisture content and composition of ambient air. The volumetric flow rate at standard conditions averaged 662,000 dry standard cubic meters per hour (23,370,000 dry standard cubic feet per hour). Standard conditions are 20°C (68°F), 760 mm Hg (29.92 in. Hg) and dry.

The isokinetic sampling rate was well within the allowable range for all sample runs.

Particulate Emissions - The particulate emissions from the AOD vessel were fairly consistent (see Table 3.3) and averaged 139 milligrams per dry standard cubic meter (0.061 grains per dry standard cubic foot) and 92 kilograms per hour (202 pounds per hour).

Hexavalent Chromium Emissions - The hexavalent chromium concentrations were much higher for the AOD vessel than the EAF and averaged 2480, 4730, and 4420 micrograms of hexavalent chromium per gram of particulate matter for runs 1B, 2B, and 3B, respectively. The hexavalent chromium emissions averaged 0.5 milligrams per dry standard cubic meter (0.00023 grains per dry standard cubic foot) and 0.35 kilograms per hour (0.76 pounds per hour).

Total Chromium Emissions - The values for total chromium content of the emissions for the AOD vessel exhaust were variable when compared to their corresponding particulate run values, and were slightly higher when compared to

the EAF exhaust emissions. The total chromium contents of the emissions measured were 85, 104, and 123 milligrams of total chromium per gram of particulate emissions. The total chromium emissions averaged 14 milligrams per dry standard cubic foot (0.0062 grains per dry standard cubic foot) and 9.4 kilograms per hour (20.7 pounds per hour).

3.1.3 Fabric Filter Discharge Stacks

The fabric filter discharge emissions represent the combined controlled emissions from the EAF and AOD vessel. Both the EAF and AOD vessel emissions are ducted to a common plenum prior to entering the fabric filter. The emissions are controlled by the pressurized fabric filter which has 10 stub stacks and is open at the bottom. The original design was probably intended to allow dilution air to be brought in from the bottom by natural draft. However, the design of the 10 stub stacks was too small and a back pressure is created by the stacks. As a result, during the test program only about 40 percent of the total volumetric flow actually was discharged through the stacks; the remainder exited through the bottom and other openings in the fabric filter. The concentration of particulate discharged through the bottom and other openings of the fabric filter housing was assumed to be the same as that measured in the stacks and the mass emissions were calculated based on the volumetric flow rate to the fabric filter. As previously stated, two sample trains were operated simultaneously in an effort to collect a quantifiable amount of hexavalent chromium for each sample run.

Flue Gas Conditions and Isokinetic Sampling Rate - A summary of the flue gas conditions at the ten stub stacks of the fabric filter discharge is presented in Table 3.2. Runs C1, C2, and C3 represent the flue gas conditions from stacks No. 1 through 5 and runs D1, D2 and D3 represent the flue gas conditions from stacks No. 6 through 10. The composites of runs C1 and D1, C2 and D2, and C3 and D3 represent the flow from all ten stacks for each run. The

volumetric flow rate was very consistent, similar to the two ducts entering the fabric filter housing, and averaged 398,000 actual cubic meters per hour (14,060,000 actual cubic feet per hour) with a flue gas temperature of 29°C (85°F) and the moisture content and composition of ambient air. The volumetric flow rate at standard conditions averaged 388,000 cubic meters per hour (13,720,000 dry standard cubic feet per hour). Standard conditions are 20°C (68°F), 760 mm Hg (29.92 in. Hg), and dry. The volumetric flow rate from the stacks represent only 40 percent of the total flow to the fabric filter.

The isokinetic sampling rate was within the allowable range for all runs.

Particulate Emissions - The particulate emissions from the fabric filter were very low and fairly consistent from run to run (see Table 3.3). Some of the variability in measured results is likely due to the levels measured which were just in the quantifiable range and subject to a greater degree of sampling and analytical error.

The concentration values represent the emissions measured in the stack discharge. The mass emissions represent the measured concentration times the total flow rate to the fabric filter. The pollutant concentration for the emissions discharged out the bottom of the housing was assumed to be the same as that measured in the stacks. The particulate emissions averaged 2.7 milligrams per dry standard cubic meter (0.0012 grains per dry standard cubic foot) and 2.6 kilograms per hour (5.6 pounds per hour).

Hexavalent Chromium Emissions - The hexavalent chromium concentration was variable averaging 49, 52, and 215 micrograms of hexavalent chromium per gram of particulate emissions. The hexavalent chromium emissions averaged 0.22×10^{-3} milligrams per dry standard cubic meter (0.09×10^{-6} grains per dry standard cubic foot) and 0.00021 kilograms per hour (0.00045 pounds per

hour). These results were just in the quantifiable limit and are subject to a greater degree of analytical error.

Total Chromium Emissions - The total chromium emissions at the fabric filter exhaust and the total chromium content of the hopper dust both reflect the fact that a large volume of previously collected material is present in the fabric filter. The exhaust emissions show a greater impact because this material is retained on the bags. The total chromium concentration at the outlet increased with each run from 17 milligrams per gram for the first run, through 18 milligrams per gram for the second run, to 55 milligrams per gram for the last run. The outlet value for the first run reflects less than 20 percent of the inlet total chromium content while the value for the last run was about one-half the inlet total chromium content. The total chromium concentration of the hopper dust collected was 74, 75, and 82 milligrams for the three runs, respectively. The total chromium emissions at the outlet averaged 0.066 milligrams per dry standard cubic meter (0.021×10^{-3} grains per dry standard cubic meter) and 0.063 kilograms per hour (0.14 pounds hour). These emission values are likely to be biased low by a factor of about three, because a fabric filter retains particulate on the bags and then releases it over a period of time.

3.2 PARTICLE SIZE DISTRIBUTION

Particle size runs were conducted in the EAF and AOD vessel exhaust ducts. The first of the three runs at each location was conducted at a point of average velocity. The second and third runs at the same location were conducted at a point with the same velocity as the first run. This sampling procedure was followed to ensure that the particle cut-size for all three runs would be the same on similar stages.

The total mass of particulate matter collected on each stage was determined using a gravimetric technique. Stages were then combined in a manner to obtain a quantifiable amount of hexavalent chromium and determine the

particle size distribution of chromium. The particle size distribution results are presented in Table 3.4 and the corresponding calculations and plots can be found in Appendix B. The particle size distribution for both the EAF and AOD vessel showed that about 95 percent of all the particles, by weight, were less than 10 μm in diameter. No particle size distribution runs were made at the fabric filter outlet due to the extremely low concentration of pollutant.

The particle size distribution for the hexavalent chromium emissions are also presented in Table 3.4. The particle size distribution from the AOD vessel showed that the majority of hexavalent chromium emissions were less than 1 μm in diameter. A large amount of hexavalent chromium was present in the AOD samples and the results of these analyses are considered to be representative.

The particle size distribution samples for the EAF contained only a small amount of hexavalent chromium and are therefore subject to a much higher degree of analytical error. The particle size distributions for both the EAF and the AOD vessel exhaust emissions were similar to the corresponding particulate emission particle size distribution.

3.3 EMISSIONS IN UNITS OF PROCESS RATE AND CONTROL EQUIPMENT COLLECTION EFFICIENCY

The emission testing was conducted at the EAF and the AOD vessel exhausts to correspond to one heat. The testing was conducted from the initial charging and ran until the final tapping. The process rate represented the total weight charged divided by the length of the heat. The tables in Appendix E give the process weight and duration of heats. The process rate calculation table at the end of the Appendix A summarizes the calculations for the process rate on an hourly basis.

The fabric filter discharge stack tests were conducted during approximately two and one-half heats for both the EAF and the AOD vessels. The process rates presented in the process rate calculation table represent the total weight charged for all heats tested during a particular run divided by the

TABLE 3.4. SUMMARY OF PARTICLE SIZE DISTRIBUTION

Run No.	Date (1985)	Test Time 24 h clock	Particulate wt. less than size, %			Hexavalent Chromium wt. less than size, %			Total Chromium wt. less than size, %		
			1 µm	5 µm	10 µm	1 µm	5 µm	10µ m	1 µ m	5 µm	10 µm
Electric Arc Furnace Exhaust											
S1A	3/6	1712-1727	29	86	96						
S2A	3/7	1152-1212	37	87	95						
S3A	3/7	1727-1742	28	82	94						
Average			31	85	95	45*	68*	74*	44*	76*	87*
Argon-Oxygen Decarburization Vessel Exhaust											
S1B	3/6	1533-1543	50	90	95						
S2B	3/7	1150-1205	40	89	96						
S3B	3/7	1659-1711	38	80	92						
Average			43	86	94	65*	91*	97*	55*	80*	87*

*Composite.

total time from the start of the first heat to the completion of tapping for the last heat.

3.3.1 Emissions in Units of the Process Rate

The emissions in units of the process rate are shown in Table 3.5. The values for emissions in units of process rate for particulate and total chromium from the EAF were consistent. The first run value for the hexavalent chromium emissions in units of process rate at the EAF exhaust was much higher than those for the other two runs. The reason for these higher results are not known.

The AOD vessel emissions measurements in units of process rate were fairly consistent for particulate, hexavalent, chromium, and total chromium.

The fabric filter discharge stack emissions in units of process rate were variable. All of the test results seem reasonable, since only a small amount of emissions could be collected during the emission tests.

3.3.2 Control Equipment Collection Efficiency

The EAF and AOD vessel exhaust emissions are ducted together in a common plenum prior to their entrance into the fabric filter housing. It is not possible to separate the collection efficiency for the different locations based on the emission results and particle size distribution. The overall collection efficiency is assumed to be the same for both processes. The collection efficiency of the fabric filter for both the EAF and AOD vessel averaged 98.966 percent by weight for particulate matter, 99.963 percent by weight for hexavalent chromium, and 99.726 percent by weight for total chromium (see Table 3.5).

The greater collection efficiency shown for hexavalent chromium and total chromium was due in part to the fact that the fabric filter collects particulate and then releases material collected previously over a subsequent time period. The actual collection efficiency for hexavalent and total chromium,

TABLE 3.5. SUMMARY OF EMISSION RATES IN UNITS OF PROCESS RATE AND EFFICIENCY

Date (1985)	Run Nos.	Process Rate tons/h	Uncontrolled Emissions			Controlled Emissions			Collection Efficiency		
			particulate lb/ton	hexavalent chromium lb/ton $\times 10^{-3}$	total chromium lb/ton	particulate lb/ton $\times 10^{-3}$	hexavalent chromium lb/ton $\times 10^{-6}$	total chromium lb/ton $\times 10^{-3}$	particulate %	hexavalent chromium %	total chromium %
EAF Exhaust											
3/6	1A	8.31	8.70	2.47	0.72						
3/7	2A	14.90	10.84	0.27	0.80						
3/7	3A	14.61	8.05	0.37	0.80						
Average		12.6	9.2	1.04	0.77						
AOD Exhaust											
3/6	1B	12.67	18.43	45.67	1.57						
3/7	2B	12.89	14.76	69.79	1.54						
3/7	3B	16.05	11.32	50.01	1.39						
Average		13.9	14.8	55.2	1.50						
Fabric Filter Discharge Stacks											
3/6	1C/1D	18.78				380	16.5	6.7	98.599	99.966	99.707
3/7	2C, 2D	26.09				250	12.9	4.4	99.023	99.982	99.812
3/7	3C, 3D	23.61				140	29.1	7.5	99.277	99.942	99.658
Average		22.8				260	19.5	6.2	98.966	99.963	99.726

although not greatly different, would probably be similar to the collection efficiency for the particulate emissions.

3.4 SUMMARY OF ANALYTICAL RESULTS FOR HEXAVALENT AND TOTAL CHROMIUM

The summary of analytical results of hexavalent chromium and total chromium for all samples collected is presented in Table 3.6. The analytical data sheets are contained in Appendix B. The results shown in Table 3.6 for hexavalent chromium are the results obtained by the EPA tentative method for hexavalent chromium. The values presented for total chromium content are based on the results obtained by Neutron Activation Analysis (NAA). In some cases, the results reported for total chromium are the sum of the hexavalent chromium content in the sample filtrate (from an extraction for Cr^{+6}) and the chromium in the extraction residue as measured by Neutron Activation Analysis. A table showing the total chromium calculations for each sample can be found at the end of Appendix A of this report.

The hexavalent chromium concentration was variable for most sampling locations. The variability of results for the particle size distribution tests and the fabric filter discharge emissions may reflect some analytical imprecision due to the small amount of hexavalent chromium analyzed. Some of the variability in the results for the fabric filter hopper material analyzed may be due to the fact that the sample had to be taken from the screw conveyors instead of the hoppers themselves. Sampling at both the EAF and AOD vessel sampling locations resulted in collection of sufficient material for accurate analyses. Overall, the goals of obtaining quantifiable emissions were obtained.

One set of impinger contents (or back half particulate catch) was analyzed for each sampling location. The purpose of this analysis was to reconfirm the

TABLE 3.6. SUMMARY OF ANALYTICAL RESULTS FOR HEXAVALENT AND TOTAL CHROMIUM

Run No.	Sample Type	Sample No. Analyzed	Amount of Sample Analyzed	Hexavalent Chromium		Amount of Sample Analyzed	Total Chromium	
				Results µg	Concentration µg/g		Results mg	Concentration mg/g
Electric Arc Furnace Exhaust								
1A	Particulate Front Half	C-193	324 mg	91.8	283	Residue	26.66	82
1A	Impinger Contents	C-204		----	----	4 ml of 25	0.008	Negligible
2A	Particulate Front Half	C-194	493 mg	12.4	24.8	Residue	36.49	74
3A	Particulate Front Half	C-195	321 mg	14.8	46.3	Residue	31.90	99
CTA	Particulate Front Half	C-196	233 mg	10.1	43.3	Residue	14.09	60
S1A,S2A,S3A	Particle Size, Large	C-190	32 mg	1.0	31.2	Residue	1.60	50
S1A,S2A,S3A	Particle Size, Medium	C-191	103 mg	0.8	7.8	Residue	5.66	55
S1A,S2A,S3A	Particle Size, Small	C-192	87 mg	1.3	14.9	Residue	4.31	50
Argon-Oxygen Decarburization Vessel Exhaust								
1B	Particulate Front Half	C-197	399 mg	989	2473	Residue	34.04	85
1B	Impinger Contents	C-208		---	----	4 ml of 25	0.002	Negligible
2B	Particulate Front Half	C-198	364 mg	1720	4914	Residue	37.96	104
3B	Particulate Front Half	C-199	213 mg	942	4710	Residue	26.11	123
S1B,S2B,S3B	Particle Size, Large	C-187	18 mg	25.3	1406	Residue	1.14	63
S1B,S2B,S3B	Particle Size, Medium	C-188	43 mg	118	2744	Residue	3.59	83
S1B,S2B,S3B	Particle Size, Small	C-189	55 mg	194	3527	Residue	4.13	75
Fabric Filter Discharge Stacks								
1C,1D	Particulate Front Half	C-200	39 mg	1.9	47.5	Residue	0.68	17
1C,1D	Impinger Contents	C-211		---	----	4 ml of 81	0.001	Negligible
2C,2D	Particulate Front Half	C-201	31 mg	1.6	53.3	Residue	0.55	18
3C,3D	Particulate Front Half	C-202	15 mg	3.2	213.3	Residue	0.82	55
Fabric Filter Hopper Materials								
1E	Hopper Material	C-214	----	----	1205	162.7 mg	11.97	74
2E	Hopper Material	C-215	----	----	657	151.2 mg	11.29	75
3E	Hopper Material	C-216	----	----	1210	154.8 mg	12.65	82

(continued)

TABLE 3.6. SUMMARY OF ANALYTICAL RESULTS FOR HEXAVALENT AND TOTAL CHROMIUM (continued)

Run No.	Sample Type	Sample No. Analyzed	Amount of Sample Analyzed	Hexavalent Chromium		Amount of Sample Analyzed	Total Chromium	
				Results µg	Concentration µg/g		Results mg	Concentration mg/g
				Blank Samples				
	Blank (Particle Size)	C-218	Total	0.6	N/A	Residue	46	N/A
	Filter Blank & Acetone	C-203	Total	<0.2	N/A	Residue	1.8	N/A

fact, established by the method development and evaluation study, that a significant amount of hexavalent chromium and/or total chromium does not pass through the front half. The analytical results for the impinger contents for runs 1A, 1B, and 1C/1D show that the amount of hexavalent chromium passing through the filter was negligible (see Table 3.6). Runs 2 and 3 show that the amount of total chromium passing through the filter is also negligible.

Quality assurance audit samples were analyzed for both methods. As shown in Table 3.7, no bias was present and the results are considered acceptable.

TABLE 3.7. SUMMARY OF ANALYTICAL RESULTS FOR HEXAVALENT AND TOTAL CHROMIUM QUALITY ASSURANCE SAMPLES

Run No.	Sample Type	Sample No.	True Value	Hexavalent Chromium		Total Chromium	
				Results µg/ml	% Dev.	Results µg	% Dev.
Quality Assurance Samples							
--	Quality Assurance	C-217	100 µg/ml Cr^{+6}	99.2	-0.8	---	---
--	Quality Assurance	QA12	66.3 µg Cr	---	---	75.2	+ 13.4
--	Quality Assurance	QA13	132.6 µg Cr	---	---	152.4	+ 14.9
--	Quality Assurance	QA14	331.6 µg Cr	---	---	307.5	- 7.3
--	Quality Assurance	QA15	1326 µg Cr	---	---	[a]	[a]

[a]Sample lost during NAA.

4.0 SAMPLING LOCATIONS AND TEST METHODS

This section describes the sampling locations and test methods used to characterize emissions from an electric arc furnace and an argon-oxygen decarburization vessel at Carpenter Technology's Speciality Steel Plant in Reading, Pennsylvania. A total of six sampling locations were used in the emission testing program. At four sampling locations, emissions testing was conducted for particulate matter, total chromium content, and hexavalent chromium content. At two of these four locations additional testing included determination of particle size distribution and chromium distribution with respect to particle size. At another sampling location grab samples of the dust collected by the fabric filter were taken for hexavalent and total chromium analysis. At the last sampling location only a velocity traverse was conducted to characterize the gas flow at that location. The relative positions and the type of testing conducted at each location are shown in the simplified process flow diagram (see Figure 4-1) and accompanying Table 4.1. The subsections which follow further describe each sampling location and applicable test methods.

4.1 ELECTRIC ARC FURNACE EXHAUST DUCT (SAMPLING LOCATION A)

Particulate matter, hexavalent chromium, total chromium, particle size distribution, and chromium distribution with respect to particle size distribution were measured in the duct which carries exhaust gases from the electric arc furnace (EAF) to the fabric filter inlet. A schematic of this sampling location is shown in Figure 4-2. Two sampling ports spaced 90^{o}

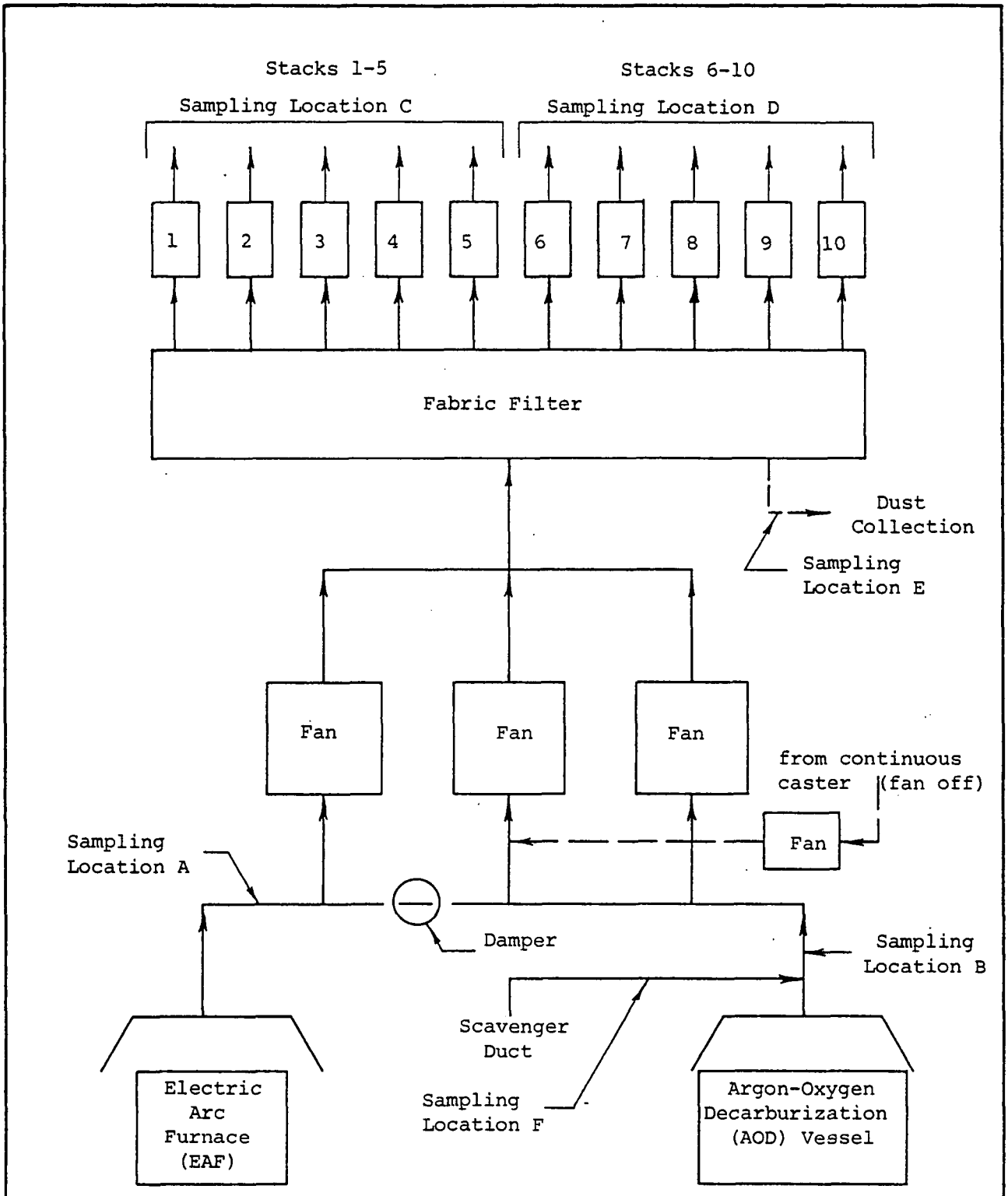
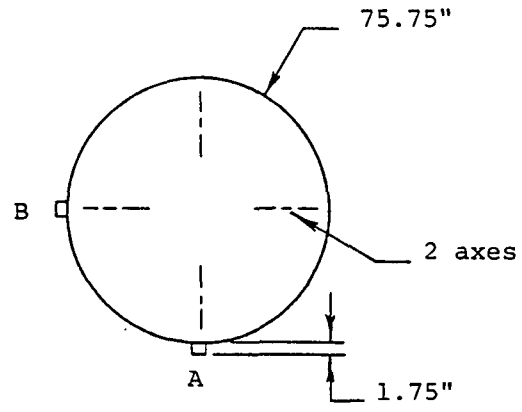


Figure 4.1. Process Air Flow Schematic of Electric Arc Furnace, Argon-Oxygen Decarburization Vessel, and Control Equipment.

TABLE 4.1. SAMPLING PLAN FOR CARPENTER TECHNOLOGY

Sample Type	Sampling Locations	Number of Samples	Methods
Particulate matter	A, B, C, D	3	EPA Method 5
Hexavalent chromium	A, B, C, D	3	EPA 5 using Tentative EPA Method for Hexavalent Chromium
Total chromium	A, B, C, D	3	EPA 5 using EPA Protocol for Total Chromium
Particle size distribution	A, B	3	Impactor (Andersen, Flow Sensor)
Hexavalent and total chromium distribution by particle size	A, B	3	Impactor using Tentative EPA Method for Hexavalent Chromium and EPA Protocol for Total Chromium
Hexavalent chromium, total chromium	E	3 grab	Gravimetric, Tentative EPA Method for Hexavalent Chromium, EPA Protocol for Total Chromium



Section M-M

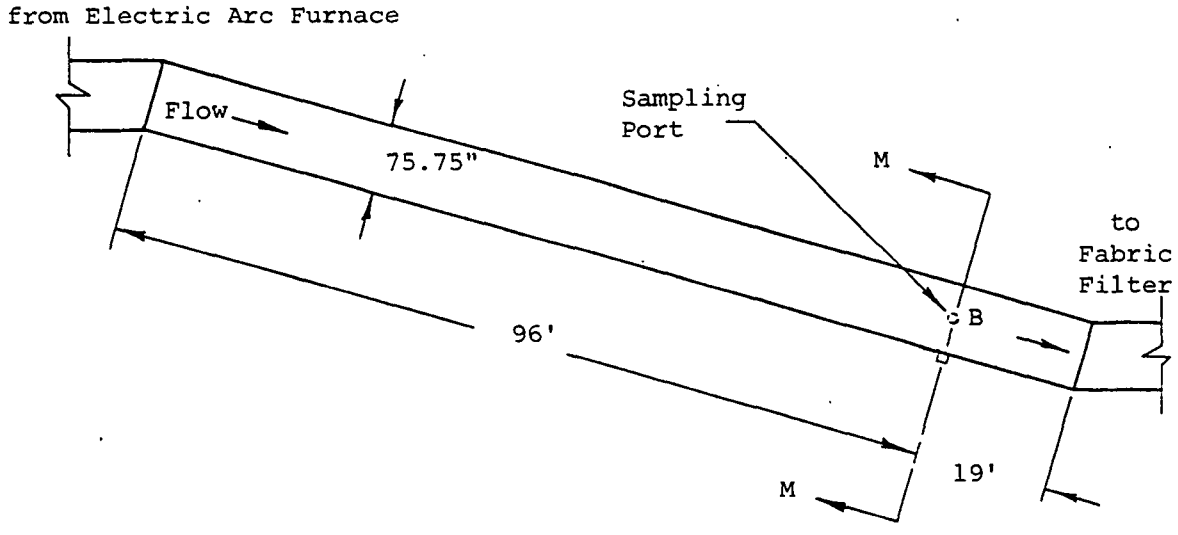


Figure 4.2. Electric Arc Furnace Exhaust Duct (Sampling Location A).

apart in the 77.5 inch diameter slanted round duct. These ports were located 96 feet (15.2 duct diameters) downstream of a bend in the duct and 19 feet (3.0 duct diameters) upstream of another bend in the duct.

For the Method 5 testing (used for particulate matter, hexavalent chromium, and total chromium determinations), a total of 12 points (2 axes, 6 points per axis), as per Method 1, were sampled during each EAF heat. Since the exact time for each heat was not known until the heat was complete, the sampling time per point was established to ensure a complete run at a minimal heat time. When the heat continued beyond the time it took to conduct a complete run, the sampling train continued to traverse the duct until the heat was completed. Total sampling times for the three runs conducted were 154, 80, and 70 minutes.

For particle size testing (including hexavalent and total chromium distribution by particle size), the first test run was conducted at a point of average velocity. To ensure consistent cut-sizes on the impactor plates, the second and third runs were conducted at points having the same velocity as the first run.

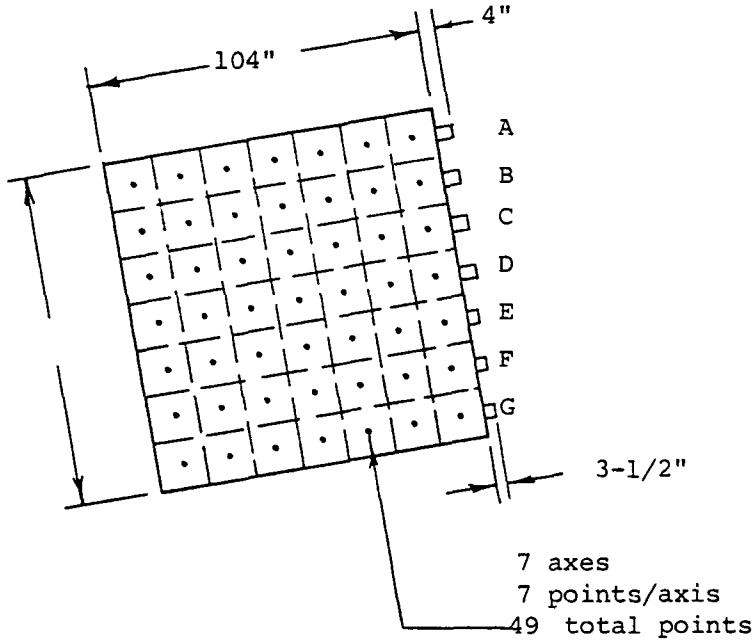
An additional sampling train was run throughout the entire test program at the EAF exhaust sampling location, but only during periods of charging, tapping, and recharging of the EAF. The sample was collected using single point sampling, and the total sampling time over the two-day period was 102 minutes. The sample was taken to represent the charging, recharging, and tapping emissions, and was analyzed for total particulate matter, hexavalent chromium content, and total chromium content.

4.2 ARGON-OXYGEN DECARBURIZATION VESSEL EXHAUST DUCT (SAMPLING LOCATION B)

Particulate matter, hexavalent chromium, total chromium, particle size distribution, and hexavalent and total chromium distribution with respect to particle size were measured in the duct which carries exhaust gases from the argon-oxygen decarburization (AOD) vessel to the fabric filter inlet. Schematics of this sampling location are shown in Figures 4-3 and 4-4. Seven ports were installed on the side of the slightly inclined square duct (104" x 104"). These ports were located 122 inches (1.17 duct diamteters) downstream of the intersection of a duct from the scavenger duct and 47 inches (0.45 duct diameters) upstream of a bend in the duct to the fabric filter. Because of the close proximity of 2 potential flow disturbances, this location did not meet EPA Method 1 sampling requirements. To check for the degree of flow disturbance at this location, the angle of flow misalignment was measured at each sampling point using a three-dimensional directional probe (see Appendix C). The average of the angles measured was less than 10 degrees.

For the EPA Method 5 sampling (used for particulate matter, hexavalent chromium, and total chromium determinations), a total of 49 points (7 x 7 matrix), as per Method 1, were sampled. As for the EAF heats, the exact time for the AOD cycles was not known before the cycle itself was completed. Thus, the sampling time per point was established to ensure a complete run at the predicted minimum heat time. When the cycle(s) continued beyond the time it took to conduct a complete run, the sampling train continued to traverse the duct until the cycle was completed. Total sampling times for the three runs conducted were 131, 118, and 88 minutes.

For the particle size tests (including hexavalent and total chromium distribution by particle size), the first test run was conducted at a point of



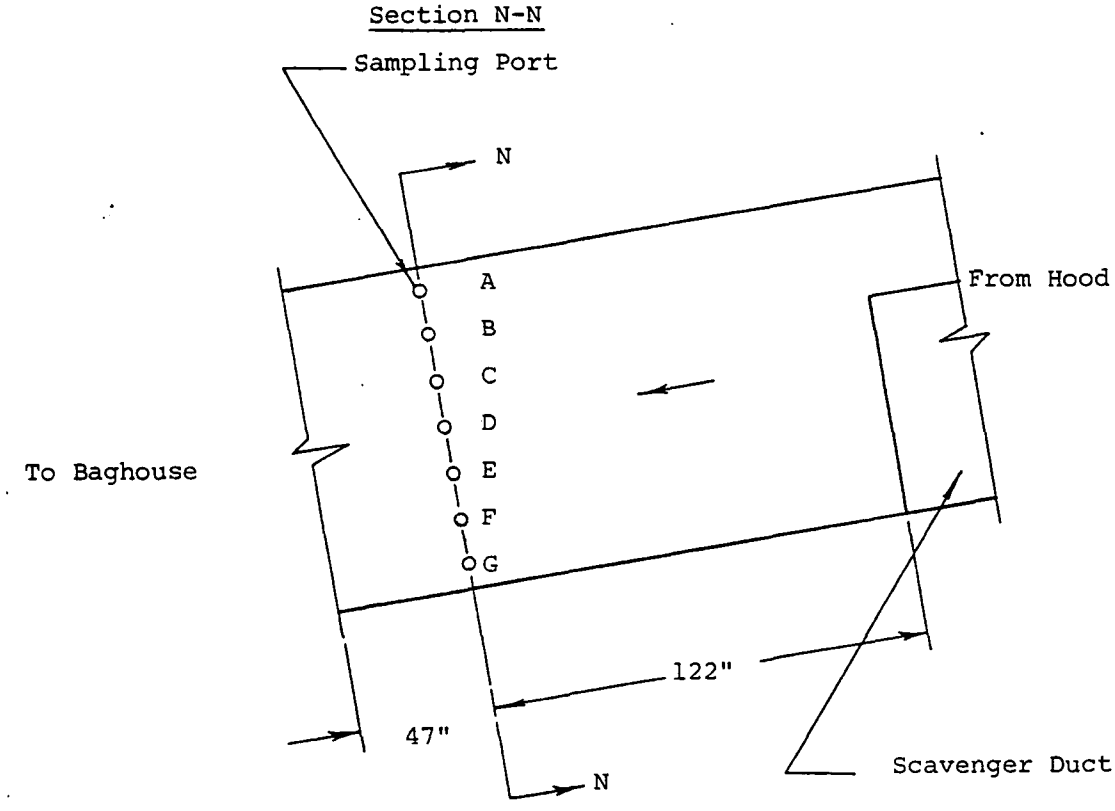


Figure 4.3. Argon-Oxygen Decarburization Vessel Exhaust Duct (Sampling Location B).

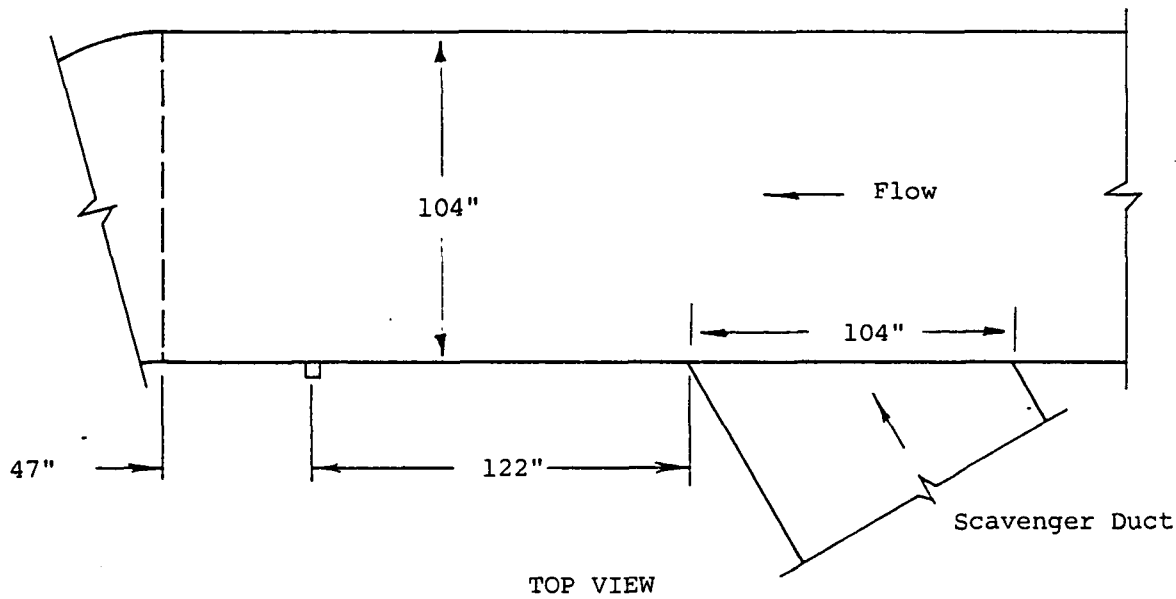


Figure 4.4. Argon-Oxygen Decarburization Vessel Exhaust Duct, Top View Showing Scavenger Duct.

average velocity. To ensure consistent cut-sizes on the impactor plates, the second and third runs were conducted at points having the same velocity as the first run.

4.3 FABRIC FILTER (BAGHOUSE) DISCHARGE STACKS (SAMPLING LOCATIONS C AND D)

Ten identical stacks are used to exhaust the fabric filter. Particulate matter, hexavalent chromium, and total chromium were measured at these discharge stacks. Two EPA Method 5 trains were run simultaneously for each run; the first train sampled in stacks No. 1 through 5, the second train sampled in stacks No. 6 through 10. In each 66 inch diameter stack, two sampling ports spaced 90° apart were located 132 inches (2.0 stack diameters) downstream from the inlet to the stack and 26 inches (0.39 stack diameters) upstream of the stack exit. A schematic of the sampling location is shown in Figure 4-5.

For the EPA Method 5 sampling (used for particulate matter, hexavalent chromium, and total chromium determinations), at least 6 points (1 axis of the stack) were sampled in each stack (Method 5D). Each point was sampled for 8 minutes. Sampling at the discharge stacks started and ended with cycles at the EAF. Total times for the three sets of runs conducted were 288, 240, 240, 285, 240, and 240 for runs C1, C2, C3, D1, D2, and D3, respectively.

No particle size testing was conducted at the discharge stacks due to the extremely low concentration of emissions.

4.4 FABRIC FILTER DUST HOPPER SCREW CONVEYORS (SAMPLING LOCATION E)

Grab samples representative of the material collected by the fabric filter were taken once during each test run from each of the two hopper screw conveyors. The samples were taken towards the end of the test run series to

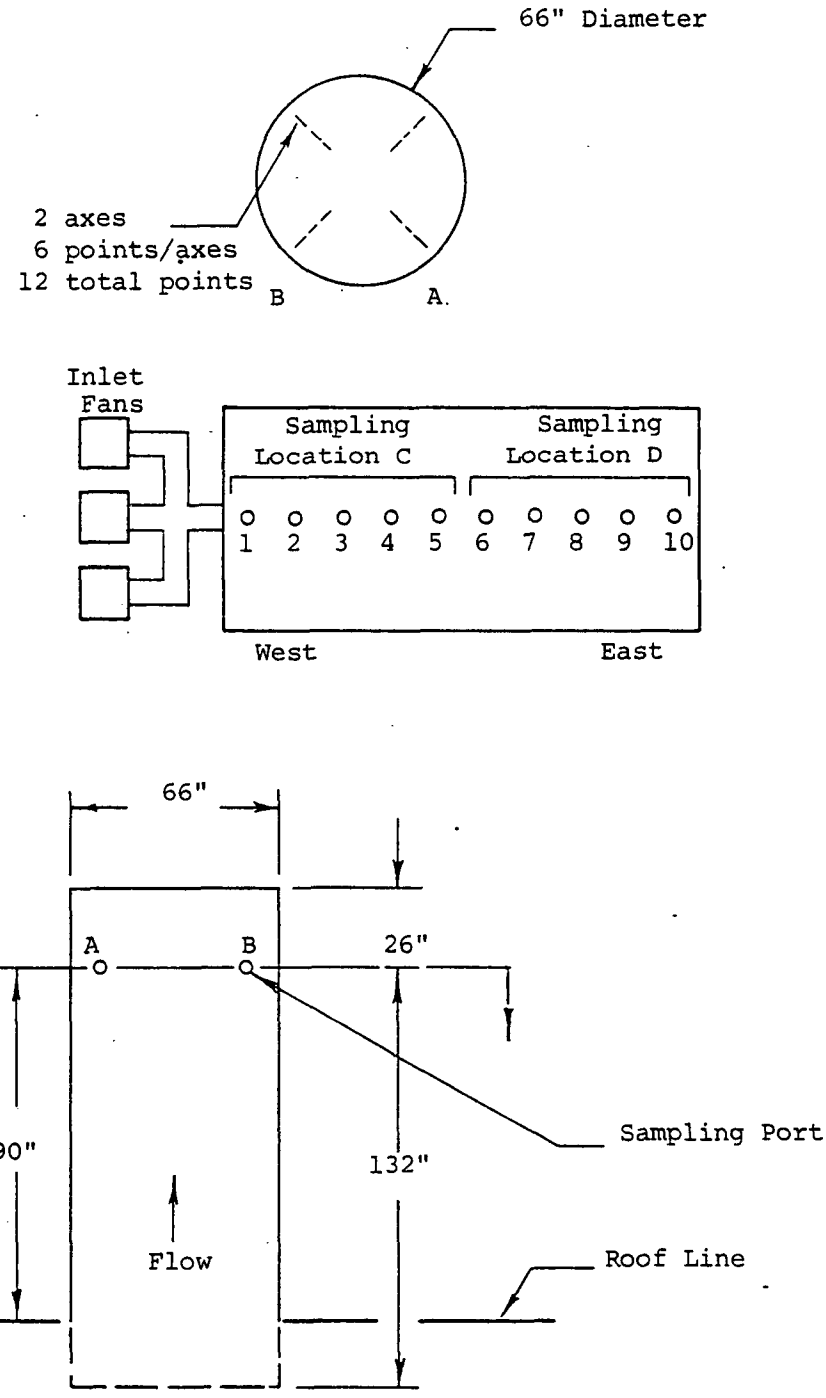


Figure 4.5. Fabric Filter Stacks (Sampling Locations C and D).

allow time for dust representative of the run to be discharged from the hoppers and to move through the screw conveyors. The samples from each of the two screw conveyors were combined into a single sample for that test run series and were analyzed for hexavalent chromium and total chromium content.

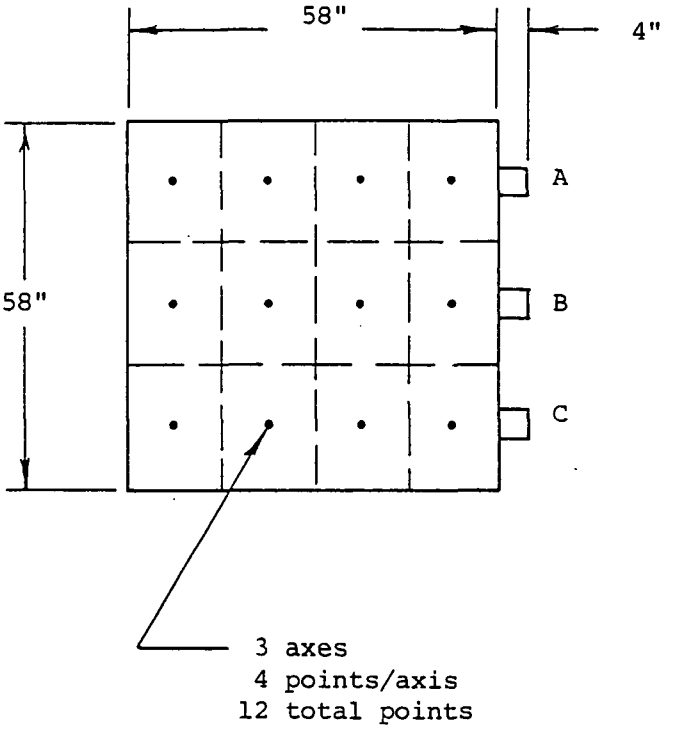
4.5 SCAVENGER DUCT (SAMPLING LOCATION F)

A scavenger duct is located in the peak of the roof between the AOD vessel canopy hood and the continuous caster area. Any emissions escaping the canopy hood are contained by the closed roof and drawn into either one of the two openings in the scavenger duct. This scavenger duct is joined with the canopy hood duct prior to the AOD vessel exhaust sampling location. To determine its contibution to the total flow, a velocity traverse was conducted in the scavenger duct prior to its entry into the main AOD vessel exhaust duct.

Three sampling ports were located along one side of the 58 inch square horizontal duct. These ports were 72 inches (1.24 duct diameters) downstream of a flow disturbance in the duct and 277 inches (4.78 duct diameters) upstream of the intersection with the main AOD vessel exhaust duct. A schematic of the sampling location is shown in Figure 4-6. For the traverse, a total of 12 points (3 x 4 matrix) were tested.

4.6 VELOCITY AND GAS TEMPERATURE

A type S pitot tube and an inclined draft gauge manometer or two differential pressure gauges in-paralled were used to measure the gas velocity pressure (Δp). Velocity pressures were measured at each sampling point across the duct to determine an average value according to the procedures outlined in Method 2 of the Federal Register.* The temperature at each sampling point was measured using a thermocouple and digital readout. The sampling points at the fabric filter outlet were selected according to Method 5D.



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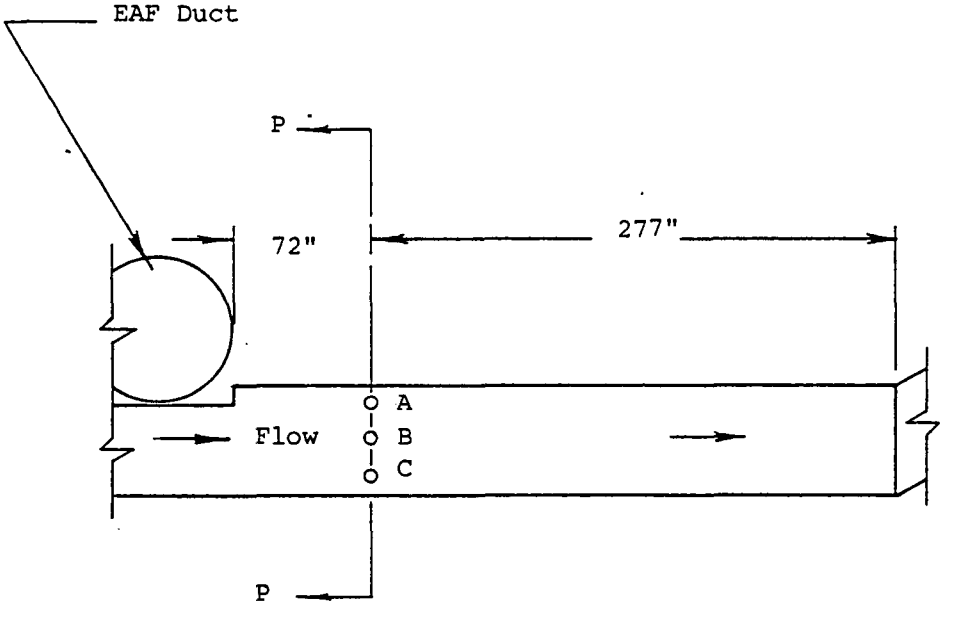

SIDE VIEW

Figure 4.6. Scavenger Duct (Sampling Location F).

4.7 MOLECULAR WEIGHT

Flue gas composition was determined utilizing procedures described in Method 3 of the Federal Register.* A bag sample was collected during each particulate test run. The bag contents were analyzed using an Orsat Gas Analyzer.

4.8 PARTICULATE MATTER

Method 5, as described in the Federal Register,* was used to measure particulate grain loading at locations A, B, C, and D. All tests were conducted isokinetically by traversing the cross-sectional area of the stack and regulating the sample flow rate relative to the flue gas flow rate as measured by the pitot tube attached to the sample probe. A sampling train consisting of a heated, glass-lined probe, a heated 87 mm (3.4 inches) diameter glass fiber filter (Gelman A/E), and a series of Greenburg-Smith impingers was employed for each test. An acetone rinse of the nozzle, probe, and filter holder portions of the sample train was made at the end of each test. The acetone rinse and the particulate caught on the filter media were dried at room temperature, desiccated to a constant weight, and weighed on an analytical balance. Total filterable particulate matter was determined by adding these two values.

4.9 PARTICLE SIZE DISTRIBUTION

Particle size samples were obtained using Andersen Mark III Cascade Impactors. These in-stack, multistage cascade impactors have a total of eight stages, followed by a back-up filter stage. Their particle cut-off sizes

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* 40 CFR 60, Appendix A, Reference Methods 2, 3, and 5, July 1, 1980.

range nominally from 0.5 to 15 microns. Substrates were 64 mm diameter glass fiber filters. A constant sampling rate was maintained through the test period. Sampling rates were set for isokinetic sampling as long as the sampling rate did not exceed the recommended flow rate for the impactor. See Appendix C for detailed sampling procedures.

Three impactor runs each were conducted at the EAF and AOD vessel exhaust ducts. None were conducted at the fabric filter discharge stacks due to the extremely low concentration of emissions present. At the locations sampled, a point of average velocity was sampled. With the exception of selection of the sampling point locations, the procedures used followed those recommended in the "Procedures Manual for Inhalable Particulate Sampler Operation" developed for EPA by the Southern Research Institute.*

4.10 HEXAVALENT CHROMIUM CONTENT

Hexavalent chromium content was determined utilizing procedures described in the tentative EPA Method "Determination of Hexavalent Chromium Emissions from Stationary Sources" (see Appendix C). The Method 5 filter catch collected and weighed for each Method 5 run was taken and analyzed for hexavalent chromium content using this method. If was also used to determine the hexavalent chromium content of representative portions the fabric filter dust samples collected.

4.11 TOTAL CHROMIUM CONTENT

Total chromium content was determined using procedures described in the "EMB Prototcol for Sample Preparation and Emission Calculation of Field Samples for Total Chromium" in combination with Neutron Activation Analysis (NAA) (see

*Prepared for EPA under Contract No. 68-02-3118, November 1979.

Appendix C). Samples collected during Method 5 runs and first submitted to analysis for hexavalent chromium were then analyzed for total chromium using this method. The total chromium content of the fabric filter dust samples were also determined using these procedures using a representative portion of the sample.

5.0 QUALITY ASSURANCE

Because the end product of testing is to produce representative emission results, quality assurance is one of the main facets of stack sampling. Quality assurance guidelines provide the detailed procedures and actions necessary for defining and producing acceptable data. Two such documents were used in this test program to ensure the collection of acceptable data and to provide a definition of unacceptable data. These documents are: the EPA Quality Assurance Handbook Volume III, EPA-600/4-77-027 and Entropy's "Quality Assurance Program Plan" which has been approved by the U. S. EPA, EMB.

Relative to this test program, the following steps were taken to ensure that the testing and analytical procedures produce quality data.

- Calibration of field sampling equipment. (Appendix D describes calibration guidelines in more detail.)
- Checks of train configuration and on calculations.
- On-site quality assurance checks such as sampling train, pitot tube, and Orsat line leak checks, and quality assurance checks of all test equipment prior to use.
- Use of designated analytical equipment and sampling reagents.

Table 5.1 summarizes the on-site audit data sheets for the sampling equipment used for particulate testing at each sampling location, including deviation limits. In addition to the pre- and post-test calibration audits, a field audit was performed on the meter boxes used for sampling. Entropy used the procedures described in the December 14, 1983 Federal Register (48FR55670). In addition, the analytical balance used for filter weighing was audited with Class "S" weights. Appendix D includes the audit run data sheets for each dry gas meter used for particulate testing and audit data sheets for the other sampling equipment.

TABLE 5.1. FIELD EQUIPMENT CALIBRATION

Equipment	Reference	Allowable Error	Actual Error	Within Allowable Limits
Electric Arc Furnace Exhaust Duct				
Meter box (N-8)	Wet test meter	Y ± 0.03Y	0.009	✓
Meter box thermometer	ASTM-3F at ambient temperature	5°F	0°F	✓
Impinger thermometer	ASTM-3F at ambient temperature	2°F	0°F	✓
Stack thermometer	ASTM-3F at stack temperature	7°F	4°F	✓
Stack thermocouple	ASTM-3F at stack temperature	7°F	1°F	✓
Trip balance	IOLM standard weight	0.5 grams	OK	✓
Analytical balance	Class "S" standard weight	0.1 mg	0.07 mg	✓
Argon-Oxygen Decarburization Vessel Exhaust Duct				
Meter box (N-7)	Wet test meter	Y ± 0.03Y	-0.005	✓
Meter box thermometer	ASTM-3F at ambient temperature	5°F	3°F	✓
Impinger thermometer	ASTM-3F at ambient temperature	2°F	1°F	✓
Stack thermometer	ASTM-3F at ambient temperature	7°F	3°F	✓
Stack thermocouple	ASTM-3F at stack temperature	7°F	1°F	✓
Trip balance	IOLM standard weight	0.5 grams	OK	✓
Analytical balance	Class "S" standard weight	0.1 mg	0.07 mg	✓
Electric Arc Furnace Exhaust Duct, Charging and Tapping				
Meter box (N-12)	Wet test meter	Y ± 0.03Y	0.019	✓
Meter box thermometer	ASTM-3F at ambient temperature	5°F	3°F	✓
Impinger thermometer	ASTM-3F at ambient temperature	2°F	1°F	✓
Stack thermometer	ASTM-3F at ambient temperature	7°F	4°F	✓
Stack thermocouple	ASTM-3F at stack temperature	7°F	2°F	✓
Trip balance	IOLM standard weight	0.5 grams	OK	✓
Analytical balance	Class "S" standard weight	0.1 mg	0.07 mg	✓

(continued on next page)

TABLE 5.1. FIELD EQUIPMENT CALIBRATION (continued)

Equipment	Reference	Allowable Error	Actual Error	Within Allowable Limits
Fabric Filter Discharge Stacks Nos.1-5				
Meter box (N-6)	Wet test meter	Y ± 0.03Y	0.001	✓
Meter box thermometer	ASTM-3F at ambient temperature	5°F	2°F	✓
Impinger thermometer	ASTM-3F at ambient temperature	2°F	0°F	✓
Stack thermometer	ASTM-3F at stack temperature	7°F	1°F	✓
Stack thermocouple	ASTM-3F at stack temperature	7°F	1°F	✓
Trip balance	IOLM standard weight	0.5 grams	OK	✓
Analytical balance	Class "S" standard weight	0.1 mg	0.07 mg	✓
Fabric Filter Discharge Stacks Nos. 6-10				
Meter box (N-3)	Wet test meter	Y ± 0.03Y	0.001	✓
Meter box thermometer	ASTM-3F at ambient temperature	5°F	2°F	✓
Impinger thermometer	ASTM-3F at ambient temperature	2°F	1°F	✓
Stack thermometer	ASTM-3F at ambient temperature	7°F	1°F	✓
Stack thermocouple	ASTM-3F at stack temperature	7°F	1°F	✓
Trip balance	IOLM standard weight	0.5 grams	OK	✓
Analytical balance	Class "S" standard weight	0.1 mg	0.07 mg	✓

As a check on the reliability of the method used to analyze the filters for particle size tests, sets of filters that had been preweighed in the lab were resubmitted for replicate analysis. Table 5.2 summarizes these results.

Audit solutions prepared by the EPA were used to check the analytical procedures of the laboratories conducting the hexavalent and total chromium analyses. Table 5.3 presents the results of these analytical audits. The audit tests show that the analytical techniques were good.

The sampling equipment, reagents, and analytical procedures for this test series were in compliance with all necessary guidelines set forth for accurate test results as described in Volume III of the Quality Assurance Handbook.

TABLE 5.2. PARTICLE SIZE BLANK FILTER AND REACTIVITY FILTER ANALYSIS

Sample type	Original tare weight, mg	Blank weight, mg	Net weight, mg
Particle size blank run filters			
B260	161.12	161.10	-0.02
A260	146.48	146.51	+0.03
B261	161.50	161.49	+0.01
A261	147.12	147.12	0.00
B262	163.12	163.19	+0.07
A262	147.05	147.00	-0.05
B263	161.59	161.63	+0.04
A263	146.81	146.80	+0.01
SF139	268.17	268.10	+0.07
Particle size reactivity run filters			
B276	163.30	163.29	-0.01
A276	146.35	146.36	+0.01
B277	165.03	165.13	+0.10
A277	148.19	148.20	+0.01
B278	164.30	164.25	-0.05
A278	147.24	147.24	0.00
B279	164.00	164.01	+0.01
A279	146.56	146.59	+0.03
SF143	269.11	269.11	0.00

TABLE 5.3. AUDIT REPORT CHROMIUM ANALYSIS

Plant: Curtech Task No.: 3018

Date samples received: 4/1/85 Date analyzed: 4/7/85

Sample analyzed by: RTI

Reviewed by: Peter Grosse Date of review: 4/12/85

Sample Number	μg/ml Cr^{+6} or Cr	Source of Sample	Audit Value	Relative error, %
C-217	100 µg/ml Cr^{+6}	QAD	99.2	−0.8
QA-12	66.3 µg Cr	NBS	75.2	+13.4
QA-13	132.6 µg Cr	NBS	152.4	+14.9
QA-14	331.6 µg Cr	NBS	307.5	− 7.3
QA-15	1326 µg Cr	NBS	a	a

For Cr^{+6} analysis

For Cr analysis

a Sample lost during NAA.