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Chromium Screening Study Test Report

Harbison-Walker Refractories Baltimore, Maryland

EMISSION TEST REPORT

HARBISON-WALKER REFRACTORIES
BALTIMORE, MARYLAND

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CONTENTS

CONTENTS (Continued)

FIGURES

TABLES

1.0 INTRODUCTION

During the week of June 24, 1985, Entropy Environmentalists, Inc. conducted an emission measurement program at Harbison-Walker Refractories plant located in Baltimore, Maryland. The purpose of this program was to provide data for a screening study to determine the quantity and form of chromium emissions associated with the manufacture of refractories.

Comprehensive testing was conducted on a rotary dryer controlled by a cyclone and a fabric filter and an uncontrolled tunnel kiln.

The rotary dryer and the tunnel kiln at this plant were selected for source testing for the following reasons:

- The rotary dryer and tunnel kiln are typical process equipment for the refractories industry. Both the chromite ore processed and the chromium refractory bricks produced at this plant are typical for the industry. Thus, uncontrolled emissions measured at this plant are expected to be representative of those at other plants in the industry.

- The rotary dryer is operated and used to dry chromium-containing raw materials at least 8 to 12 hours per day. Dryers at other plants are operated far less often.

- The fabric filter used to control the dryer and the degree of control achieved are typical of those at other plants in the industry. Thus, the controlled emissions measured at this plant are expected to be representative of those at other plants in the industry.

- None of the tunnel kilns used in the industry are controlled.

Particulate concentrations and mass emission rates were measured at the rotary dryer exhaust duct, fabric filter outlet, and tunnel kiln stack using U. S. Environmental Protection Agency (EPA) Reference Method 5.* Total chromium

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

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 D. 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 emissions at the rotary dryer exhaust, the fabric filter outlet, and tunnel kiln stack 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.

Mr. Michael Maul [Midwest Research Institute (MRI)] monitored process operation throughout the test period. Mr. Dennis Holzschuh (EPA Task Manager) of the Emission Measurement Branch (EMB) observed the test program. Mr. A. H. Clark, Assistant Plant Manager - Engineering and Pat McDermott, Engineering, served as the plant contacts and Mr. Ralph Crawford, Manager of Engineering, served as the corporate contact for Harbison-Walker.

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); Visible Emissions Observation Data (Appendix C); Sampling and Analytical Procedures (Appendix D); Calibration Data (Appendix E); MRI Process Data (Appendix F); and Test Participants and Observers (Appendix G).

2.0 PROCESS OPERATION

2.1 PROCESS DESCRIPTION

Harbison-Walker Refractories is a diversified refractories producer with several plants throughout the country. The Baltimore, Maryland, plant produces basic refractory brick and unformed refractories (specialty refractories). Magnesite-chromium refractory brick is the predominant basic refractory brick produced at the plant. The Baltimore plant is listed by the U.S. Bureau of Mines as one of the major users of chromium in the refractory industry. This plant is among the larger suppliers of chromium-containing refractories. The chromite ore content in the magnesite-chromium refractory brick ranges between 0 and 80 percent. The process equipment used to produce basic brick at the Baltimore plant is typical of that used in the industry.

Figure 2-1 is a flow diagram for the manufacture of refractories that contain chromium at the plant. Chromite ore, which is imported, is stored outdoors in stockpiles adjacent to stockpiles of magnesite ore. Magnesite-chromium brick that are rejected for sale (called "bats") are also typically stored outdoors until they are reprocessed. A front-end loader is used to transfer magnesite ore and the bats to a vibrating grizzly, which feeds into a gyrating crusher. The crushed bats are transported by belt conveyor to the rotary dryer that was tested, which is used to dry raw materials containing chromium. The crushed magnesite ore is transported by belt conveyor to a rotary dryer used to dry only magnesite ore. The chromite ore, which does not require crushing, is placed directly into a hopper next to the chromium rotary dryer by a front-end loader.

The chromium rotary dryer is approximately 6 feet (ft) in diameter and 60 ft in length. The burner is located at the discharge end of the dryer and is fired by natural gas, although No. 2 fuel oil can be used. The dryer operates at temperatures between 500° and 600°F and has a rated production capacity of 25 tons/h. The actual production rate is about 14 to 20 tons/h, however, because of limitations in kiln production rate. Moisture content of the chromite ore is approximately 2 percent prior to drying and less than 0.5 percent after drying.

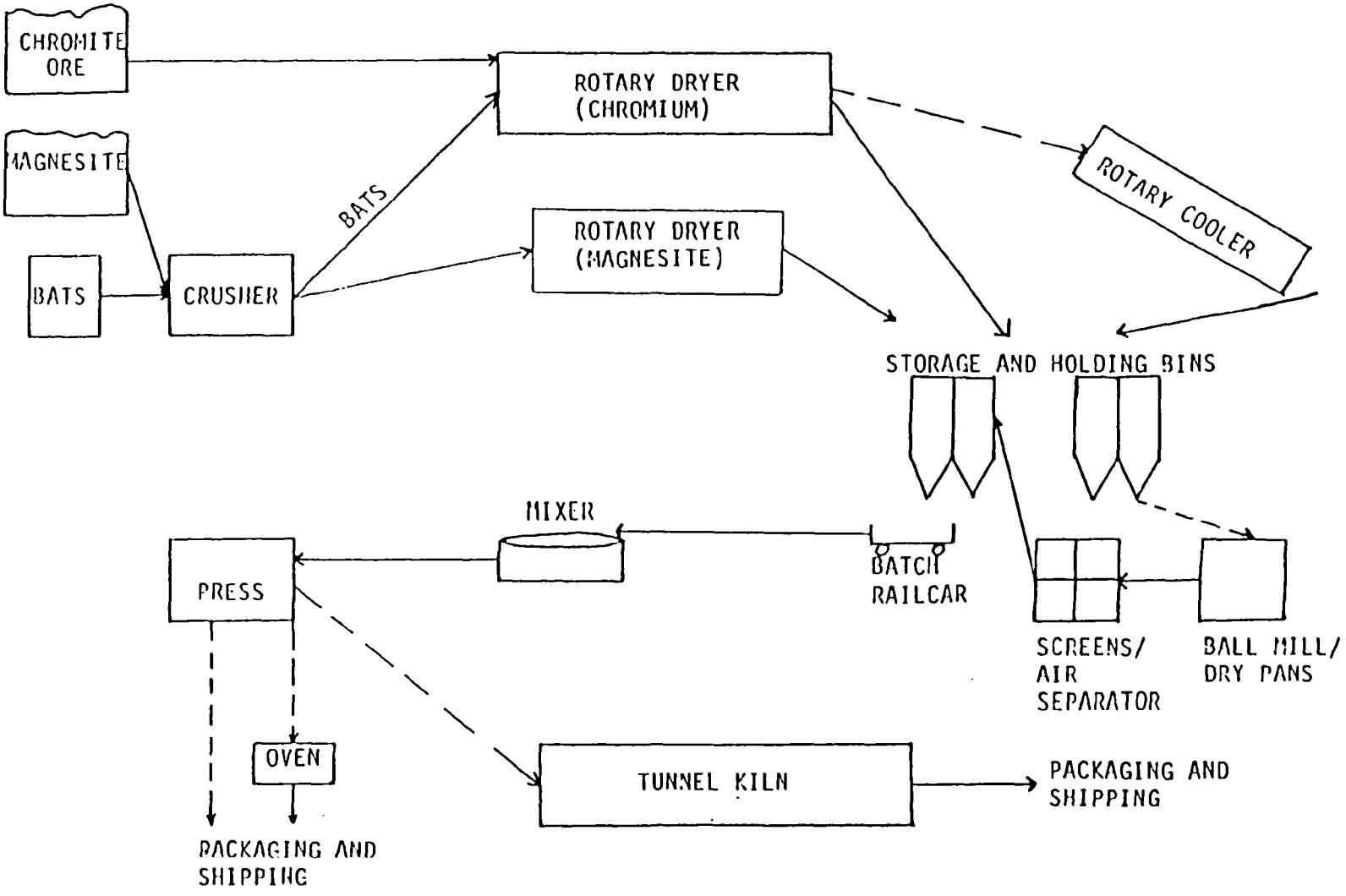

Figure 2-1. Flow diagram for the manufacture of chromium refractories.

The hot, dried materials, which are typically 350° to 400°F in temperature at the dryer discharge end, are sent through a rotary cooler located next to the rotary dryer. The rotary cooler consists of a horizontal, cyclindrical steel shell measuring approximately 6 ft in diameter and 40 ft in length. Cooling is achieved by the countercurrent flow of ambient air into the cooler, which reduces the temperature of the dried materials to 150°F. The rotary cooler is used only during summer months to hasten cooling so that binding agents added later in the production process will not evaporate.

After drying, the chromite ore and the other raw materials are ground to specified sizes. The different size raw materials are weighed out in various proportions and mixed with a liquid binder and other minor additives. The resultant mixture is then fed to a mechanical brick press where various refractory shapes are produced. Any scrap from the presses is recycled to the grinding, screening, and mixing stages of the process.

Although some of the pressed brick are dried, packaged, and shipped without further processing, most of the pressed brick are placed on a refractory-protected railcar and sent through either tunnel kiln No. 1 or No. 2 where they are fired at high temperatures. Each kiln measures approximately 320 ft in length, 12 ft in height, and 10 ft in width. The kilns are equipped with 18 burners mounted along the middle section of both sidewalls and are fired by natural gas.

Each kiln has three zones, a preheating zone at the entrance of the kiln, a firing zone in the middle section of the kiln, and a cooling zone. The hot combustion gases are drawn countercurrent to the flow of brick through the firing and preheating zones by an induced draft fan. The kiln exhaust gases, which total approximately 46,000 acfm at 660°F, are ducted out through a stack. The kiln firing temperature zone is typically kept at 3200°F. The entrances to the tunnel kilns are double sealed with sliding doors to prevent air from being drawn in and disrupting the countercurrent airflow. Approximately 48 hours are required for the brick to travel the entire length of a kiln. Brick exiting the kilns are cooled and subsequently packaged and shipped.

2.2 AIR POLLUTION CONTROL SYSTEM

Emission points in the production process are controlled by baghouses for raw material recovery and for air pollution control. The chromite ore dryer is equipped with a single compartment, negative-pressure baghouse preceded by a cyclone. The baghouse is located above the rotary dryer and inside the building that houses the dryer. The baghouse contains 456 woven glass bags that each measure 5 inches in diameter and 9 ft in length, resulting in a cloth area of 5,372 square feet. The baghouse is designed to handle 9,000 acfm of gas at an air-to-cloth ratio of 2.5:1 and a pressure drop of 6 inches w.c. The bags are cleaned once every 2 hours using vibration created by sonic horns. Prior to entering the baghouse, the temperature of the heated gas stream is about 350°F. The baghouse exhaust is discharged at a temperature of about 140°F through a rectangular stack that extends from the baghouse outlet up through the roof of the building. Tests were conducted at both inlet and outlet to the chromite ore dryer.

The rotary cooler is controlled by a negative-pressure, continuous-cleaning pulse jet baghouse. The baghouse has 1 compartment with 144 polyester felt bags. The bags measure 6 inches in diameter and 8.3 feet in length. The total cloth area is 1,887 square feet. The baghouse is designed to handle 10,000 acfm of gas at an air-to-cloth ratio of 5:1. The stack dimensions are the same as those of the rotary dryer baghouse stack. The cooler baghouse was not tested.

Neither tunnel kiln is equipped with a control device. Combustion gases and any entrained particulate matter are emitted directly to the atmosphere through a stack at an exhaust gas temperature of between 700° and 800°F. Tests were conducted at the exhaust stack of the No. 1 kiln.

2.3 PROCESS CONDITIONS DURING TESTING

The rotary dryer, the rotary dryer baghouse, and the No. 1 tunnel kiln were monitored to ensure normal operation throughout the test. The dryer process parameters monitored included type of chromium product dried, percent Cr_2O_3 in the product, production rates, and operating procedures. The kiln process parameters monitored included type of chromium product dried, percent Cr_2O_3 in the product, production rates,

operating procedures, draft pressure, temperatures in the firing zone, exhaust gas temperatures, and fuel flow to the kiln. Observations of fugitive emissions escaping the dryer were made about every 15 minutes of operation, and estimates of emission capture efficiency were recorded. In addition, system wide pressure drop for the baghouse was monitored, as were visible emissions from the baghouse stack.

Table 1 lists the material throughput and characteristics for the dryer and No. 1 tunnel kiln during testing. Process parameters and observations recorded during the test program are presented in Appendix F. Processes were operated within normal limits throughout the tests. Observations of the dryer operation during testing were made about every 15 minutes. No gauges were available to monitor the dryer firing temperature. The flame temperature is adjusted based on operator judgment. Because of the steady-state nature of the tunnel kiln, plant personnel only record the firing zone temperature every 2 hours, the draft pressure and exhaust temperature once every 4 hours, and the fuel flow once each shift.

During the first test on Tuesday, June 25, three different chromite ores were processed by the dryer. For the last 20 minutes of the run during which the second chromite ore was being processed, the dryer flame was turned off because there was sufficient heat in the dryer to dry the remaining material adequately. This flame shutdown is considered normal operation by the plant and was done during each test run. Twenty minutes into the run during which the third chromite ore was being processed, the chain on the rotary dryer slipped. The dryer was shut down, and the test was discontinued for the day. The baghouse was not cleaned during this test run.

On Wednesday, June 26, the second test covered processing of one type of chromite ore. Testing continued during the cleaning of the baghouse. Visible emissions ranging between 0 and 35 percent opacity were noted during cleaning and immediately after the baghouse came back on-line.

The third test on June 26 consisted entirely of recycled bats. Because the brick typically contains less moisture than the ore, the intensity of the burner flame was decreased from that used for ore

TABLE 2-1. FINAL OPERATING PARAMETERS FOR THE ROTARY DRYER AND TUNNEL KILN NO. 1

Test run No.	Chromite product	Process weight, tons[a]	Percent Cr_2O_3	Cr_2O_3 throughput
		Rotary dryer		
1	Hammond-10	35.00	32	11.20
1	T-chrome	3.56	56.5	2.01
2	BC-3	27.90	46.3	12.92
3	Nu-60 bats	37.20	14.5	5.39
4	T-chrome	12.30	56.5	6.95
4	Hammond-10	21.35	32.0	6.83
		Tunnel kiln No. 1		
1	0.65 Nu-60[b] 0.35 HW31-73	7.35	14.5 10.0[c]	0.95
2	0.70 Nu-60 0.30 other brick	8.59	14.5 10.0[c]	1.13
3	0.70 Nu-60 0.30 other brick	8.03	14.5 10.0[b]	1.06

[a]Process weight during inlet testing only. Process weight during outlet testing is similar since inlet and outlet testing were done as close together as possible.
[b]Type of chromite product averaged over test run.
[c]Approximate average of Cr_2O_3 in the variety of chromite products.

drying. More fugitive emissions escaped the dryer from the feed exit during some of this test than during the tests for chromite ore processing. Plant personnel indicated that a partial blockage in the ductwork leading to the baghouse might be decreasing the airflow, rendering the baghouse less effective for emission capture at the point of material transfer. The crushed brick had more fine lightweight material than the chromite ores and apparently overburdened the capture system at this point on occasion. Testing was not stopped because it was estimated that 98 percent of rotary dryer emissions were still being captured by the baghouse despite the increased fugitive emissions. Two-thirds of the way through the third test, the conveyor belt transporting the recycled brick to the dryer jammed. The dryer flame was turned down to low, and the rotation of the drum stopped for about 5 minutes. Testing was stopped temporarily until the operation was back to normal. Testing continued through the cleaning cycle of the baghouse. Visible emissions ranging between 0 and 5 percent opacity were noted during cleaning and immediately after the baghouse came back on-line.

The fourth dryer test on June 26 was done during the processing of two different chromite ores. The second chromite ore processed needed a higher temperature flame to ensure sufficient drying. The dryer was stopped rotating for about 3 minutes during testing because of a bottleneck downstream in the production process. Because the burner was firing and chromite ore was in the dryer, testing was continued during the short time the dryer was not rotating. The baghouse was not cleaned during this test run.

The rotary dryer baghouse and tunnel kiln operated continuously without interruption throughout the testing.

3.0 SUMMARY OF RESULTS

Particulate matter and particle size distribution tests were conducted at the rotary dryer exhaust (uncontrolled rotary dryer emissions), the fabric filter outlet (controlled emissions from rotary dryer and fugitive dust from materials handling), and the tunnel kiln outlet (uncontrolled tunnel kiln emissions). The fugitive dust from the five material handling pick up points entered the duct to the fabric filter downstream of the rotary dryer exhaust sampling location and was not quantified. The testing schedule for Harbison-Walker is shown in Table 3.1.

In brief, the uncontrolled emissions from the rotary dryer averaged 28.9 pounds per hour of particulate, 0.0003 pounds per hour of hexavalent chromium and 3.5 pounds per hour of total chromium. The controlled emissions from the fabric filter controlling the rotary dryer and five fugitive dust material transfer points averaged 5.3 pounds per hour of particulate, 0.0002 pounds per hour of hexavalent chromium, and 0.64 pounds per hour of total chromium. The overall collection efficiency of the fabric filter was greater than 80 percent by weight for particulate emissions, greater than 35 percent by weight for hexavalent chromium, and greater than 80 percent by weight for total chromium. The collection efficiency values for both hexavalent chromium and total chromium are not accurate representations of the actual collection efficiencies since more than half the emissions exiting the fabric filter are materials collected prior to the testing and held in the filter cake. For this test program, the material on the bags of the fabric filter which was collected prior to testing was higher in hexavalent chromium concentration, thereby making the hexavalent chromium collection efficiency appear lower.

TABLE 3.1. TESTING SCHEDULE FOR HARBISON-WALKER

Date (1985)	Sample Type	Rotary Dryer Exhaust		Fabric Filter Outlet		Tunnel Kiln Stack	
		Run No.	Test Time 24 h clock	Run No.	Test Time 24 h clock	Run No.	Test Time 24 h clock
6/25	Particulate	1	0815-1053	2	0820-1110		
	Particle size	S1	1117-1137	S4	0836-1101		
6/26	Particulate	3	0813-1016	4	0810-1033		
	Particulate	5	1124-1423	6	1107-1432		
	Particulate	7	1623-1852	8	1514-1829		
	Particle size	S5	1019-1026	S6	0823-1006		
	Particle size	S9	1508-1523	S8	1125-1418		
	Particle size	S11	1856-1911	S10	1519-1807		
6/27	Particulate					9	1050-1401
	Particulate					10	1525-1833
	Particle size					S12	0949-1150
	Particle size					S13	1254-1654
	Particle size					S14	1733-1933
6/28	Particulate					11	0732-1050
	Particle size					S15	0716-0916

The uncontrolled emissions from the tunnel kiln averaged 3.3 pounds per hour of particulate matter, 0.009 pounds per hour of hexavalent chromium, and 0.14 pounds per hour of total chromium.

The particle size distribution tests for the rotary dryer showed that about 24 percent of the uncontrolled particulate matter emissions were less than 10 μm and 52 percent of the controlled emissions were less than 10 μm in diameter. Further analysis of the combined particulate samples showed that about 64 percent of the hexavalent chromium emissions were less than 10 μm and 75 percent of the controlled hexavalent chromium emissions were less than 10 μm. The particle size distribution tests for the tunnel kiln showed that 84 percent, 84 percent, and 93 percent of the emissions by weight were less than 10 μm for the uncontrolled emissions of particulate, hexavalent chromium and total chromium, respectively.

In the following sections, the results addressed above and additional results are presented and discussed in detail according to the emission type and sampling 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 rates were conducted at the rotary dryer exhaust, fabric filter outlet, and tunnel kiln outlet. 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 used are given in Chapter 4.

3.1.1 Rotary Dryer Exhaust

The emission measurements made at the rotary dryer exhaust represent the uncontrolled emissions from the rotary dryer.

Flue Gas Conditions and Isokinetic Sampling Rate - A summary of the flue gas conditions at the rotary dryer exhaust is presented in Table 3.2. The volumetric flow rate for the four runs averaged 6,800 actual cubic meters per hour (238,000 actual cubic feet per hour) with a flue gas temperature of 151°C (304°F), and a moisture content of 12.6 percent and composition of 16.2 percent oxygen, and 2.7 percent carbon dioxide. The volumetric flow rate at standard conditions averaged 4,100 dry standard cubic meters per hour (145,000 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 within the allowable range for all runs.

Particulate Emissions - The particulate emissions from the rotary dryer (see Table 3.3) were variable. The variability is believed to be the normal variability related to the process operations. The particulate emissions averaged 3170 milligrams per dry standard cubic meter (1.39 grains per dry standard cubic foot) and 13.1 kilograms per hour (28.9 pounds per hour).

Hexavalent Chromium Emissions - The hexavalent chromium emissions were variable when compared to the corresponding particulate run and averaged 9, 11, 20, and 6 micrograms of hexavalent chromium per gram of particulate matter emissions. The hexavalent chromium emissions averaged 0.033 milligrams per dry standard cubic meter (15×10^{-6} grains per dry standard cubic foot) and 0.00014 kilograms per hour (0.00032 pounds per hour). The emission results were in the quanifiable range, therefore, the variability is probably due to the variability in the process and materials processed.

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 $\times 10^6$	acfh $\times 10^6$	dscmh $\times 10^6$	dscfh $\times 10^6$	°C	°F					
Rotary Dryer Exhaust													
1	6/25	0815-1053	0.0067	0.237	0.0036	0.127	176	349	18.2	15.8	3.2	0.0	109.9
3	6/26	0813-1016	0.0070	0.248	0.0038	0.135	188	371	13.7	14.6	3.4	0.0	100.3
5	6/26	1124-1423	0.0063	0.223	0.0049	0.171	84	184	5.6	19.6	0.8	0.0	92.5
7	6/26	1623-1852	0.0070	0.246	0.0041	0.146	156	313	12.8	15.0	3.4	0.0	100.2
Average			0.0068	0.238	0.0041	0.145	151	304	12.6	16.2	2.7	0.0	
Fabric Filter Outlet													
2	6/25	0820-1110	0.0156	0.550	0.0126	0.446	71	160	5.6	19.2	1.3	0.0	95.3
4	6/26	0810-1033	0.0146	0.514	0.0117	0.412	72	161	5.7	18.0	0.9	0.0	97.5
6	6/26	1107-1432	0.0153	0.540	0.0137	0.484	49	121	1.5	19.9	0.5	0.0	80.7
8	6/26	1514-1829	0.0157	0.556	0.0135	0.476	58	136	3.5	19.7	0.7	0.0	96.4
Average			0.0153[c]	0.540[c]	0.0129[c]	0.454[c]	62[c]	144[c]	4.1[c]	19.2[c]	0.85[c]	0.0	
Tunnel Kiln Stack													
9	6/27	1050-1401	0.0982	3.47	0.0394	1.39	416	781	5.5	16.5	2.3	0.0	93.1
10	6/27	1525-1833	0.0975	3.44	0.0389	1.38	416	781	5.9	16.7	2.3	0.0	102.4
11	6/28	0732-1050	0.0989	3.49	0.0404	1.43	409	768	4.8	17.0	2.5	0.0	93.0
Average			0.0982	3.47	0.0396	1.40	414	777	5.4	16.7	2.4	0.0	

[a]Volumetric flow rate in actual 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 (dsmh) and dry standard cubic feet per hour (dscfh).
[c]These values show that the ambient dilution air was approximately twice the inlet flue gas.

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	gr/dscf x 10^{-3}	kg/h	lb/h	mg/dscm	gr/dscf	kg/h	lb/h
Rotary Dryer Exhaust													
1	6/25	2191	0.957	7.87	17.35	0.0196	0.00858	0.000071	0.000156	366	0.160	1.31	2.90
3	6/26	2675	1.169	10.22	22.52	0.0298	0.01304	0.000114	0.000251	551	0.241	2.10	4.64
5	6/26	2804	1.225	13.61	30.00	0.0554	0.02421	0.000269	0.000593	258	0.113	1.25	2.76
7	6/26	5027	2.197	20.74	45.73	0.0288	0.01260	0.000119	0.000262	424	0.185	1.75	3.85
Average		3170	1.387	13.11	28.9	0.0334	0.01461	0.000143	0.000316	400	0.175	1.60	3.54
Fabric Filter Outlet													
2	6/25	163.6	0.0715	2.064	4.551	0.00460	0.00201	0.000058	0.000128	21.9	0.0096	0.276	0.609
4	6/26	241.9	0.1057	2.826	6.230	0.00642	0.00281	0.000075	0.000165	29.0	0.0127	0.339	0.747
6	6/26	186.7	0.0816	2.556	5.636	0.00644	0.00281	0.000088	0.000194	17.7	0.0077	0.242	0.533
8	6/26	157.1	0.0686	2.115	4.664	0.00717	0.00313	0.000097	0.000213	22.6	0.0099	0.304	0.670
Average		187[a]	0.0818[a]	2.39	5.27	0.00616[a]	0.00269[a]	0.000080	0.000175	22.8[a]	0.010[a]	0.29	0.64
Tunnel Kiln Stack													
9	6/27	46.94	0.0205	1.848	4.073	0.1034	0.0452	0.00407	0.00897	1.09	0.00048	0.043	0.095
10	6/27	42.70	0.0187	1.663	3.666	0.1179	0.0515	0.00459	0.01012	2.36	0.00103	0.092	0.203
11	6/28	24.37	0.0106	0.984	2.170	0.0903	0.0395	0.00365	0.00804	1.48	0.00065	0.060	0.132
Average		38.0	0.0166	1.50	3.30	0.1039	0.0454	0.00410	0.00904	1.64	0.00072	0.065	0.143

[a]The pollutant concentrations have been biased low by a factor of approximately three due to the fact that the dilution air was about twice the amount of the inlet flue gas.

Total Chromium Emissions - The total chromium emissions for each test run (see Table 3.3) were variable when compared to the corresponding particulate results, and averaged 17, 21, 9, and 8 percent by weight total chromium. As for the hexavalent chromium emissions, the variability is probably due to the variability in the process. The total chromium emissions averaged 400 milligrams per dry standard cubic meter (0.175 grains per dry standard cubic foot) and 1.60 kilograms per hour (3.54 pounds per hour).

3.1.2 Fabric Filter Outlet

The fabric filter outlet emissions represent the controlled emissions from (1) the rotary dryer and (2) five material handling pick up points (fugitive dust). Following the inlet sampling location were the insersections of an emergency bypass stack with damper and the five ducts used to control fugitive emissions from the material handling points. The volume of ambient air entering the system from the ducts and the damper was almost double the volume of flue gas from the rotary dryer. This resulted in a measured outlet volumetric flow (at standard conditions) of approximately three times that of the measured inlet flow. This did not cause any problems in sampling; the net result is, however, pollutant concentrations that are biased low by a factor of three, a volumetric flow rate biased high by a factor of three, and a true value for the mass emission rate.

Flue Gas Conditions and Isokinetic Sampling Rate - A summary of flue gas conditions at the fabric filter outlet is presented in Table 3.2. The volumetric flow rate (which includes the dilution air) was very consistent for all runs and averaged 15,300 actual cubic meters per hour (540,000 actual cubic feet per hour) with a flue gas temperature of 62°C (144°F) and a moisture content of 4.1 percent and composition of 19.2 percent oxygen and 0.85 percent

carbon dioxide. The volumetric flow rate (including dilution air) at standard conditions averaged 12,900 dry standard cubic meters per hour (454,000 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 three of the four sample runs. The other run (at 81 percent) was less than 90 percent of the isokinetic sampling rate. This would have very little effect on the total results since the flue gas parameter values for this run were close to the averages of the other runs.

Particulate Emissions - The particulate emissions from the fabric filter were fairly consistent (see Table 3.3) and averaged 187 milligrams per dry standard cubic meter (0.082 grains per dry standard cubic foot) uncorrected for dilution air and 586 milligrams per dry standard cubic meter (0.26 grains per dry standard cubic foot) corrected for dilution air. The emission rate corresponding to both the uncorrected and corrected concentrations was 2.4 kilograms per hour (5.3 pounds per hour).

Hexavalent Chromium Emissions - The hexavalent chromium concentrations in the particulate catch were much higher at the fabric filter outlet than at the rotary dryer exhaust and averaged 28, 27, 34, and 46 micrograms of hexavalent chromium per gram of particulate matter for Runs 2, 4, 6, and 8, respectively. This higher concentration is a result of the fact that the material previously collected on the bags which was released during the testing was several times greater in chromium concentration than the uncontrolled emissions. The hexavalent chromium emissions averaged 0.006 milligrams per dry standard cubic meter (2.7×10^{-6} grains per dry standard cubic foot) and 0.00008 kilograms per hour (0.00018 pounds per hour).

Total Chromium Emissions - The total chromium emissions for each test run (see Table 3.3) were fairly consistent when compared to the corresponding particulate results and averaged 13, 12, 9, and 14 percent by weight total chromium. The total chromium emissions averaged 22.8 milligrams per dry standard cubic meter (0.01 grains per dry standard cubic foot) and 0.29 kilograms per hour (0.64 pounds per hour).

3.1.3 Tunnel Kiln Stack

The tunnel kiln emissions represent the uncontrolled emisisons from the tunnel kiln. No air pollution control equipment is installed to collect these emissions, therefore, these emissions are discharged to the atmosphere.

Flue Gas Conditions and Isokinetic Sampling Rate - A summary of the flue gas conditions from the tunnel kiln is presented in Table 3.2. These were very consistent from run to run; the volumetric flow rate averaged 98,200 actual cubic meters per hour (3,470,000 actual cubic feet per hour), with an average flue gas temperature of 414°C (777°F), a moisture content of 5.4 percent, and a gas composition of 16.7 percent oxygen and 2.4 percent carbon dioxide. The volumetric flow rate at standard conditions averaged 39,600 cubic meters per hour (1,400,000 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 within the allowable range for all runs.

Particulate Emissions - The particulate emissions from the tunnel kiln were fairly consistent from run to run (see Table 3.3), and averaged 38 milligrams per dry standard cubic meter (0.017 grains per dry standard cubic foot) and 1.5 kilograms per hour (3.3 pounds per hour).

Hexavalent Chromium Emissions - The hexavalent chromium concentration in the particulate catch was variable from run to run, averaging 2200, 2800, and 3700 micrograms of hexavalent chromium per gram of particulate emissions. The

hexavalent chromium emissions averaged 0.10 milligrams per dry standard cubic meter (0.045×10^{-3} grains per dry standard cubic foot) and 0.004 kilograms per hour (0.009 pounds per hour).

Total Chromium Emissions - The total chromium emissions for each test run (see Table 3.3) were variable when compared to the corresponding particulate results, and averaged 2.3, 5.5, and 6.1 percent by weight total chromium. The total chromium emissions averaged 1.64 milligrams per dry standard cubic meter (0.00072 grains per dry standard cubic foot) and 0.065 kilograms per hour (0.143 pounds per hour).

3.2 PARTICLE SIZE DISTRIBUTION

Particle sizing runs were conducted at all locations tested for particulate emissions. The first of the four runs at each location was conducted at a point of average velocity. The other runs at the same location were conducted at a point with a velocity similar to the first run. This sampling procedure was followed to ensure that the particle cut-size for all four runs would be the same on corresponding impactor stages.

The total mass of particulate matter collected on each stage was determined using a gravimetric technique. Stages were then combined in such a manner as to obtain a quantifiable amount of hexavalent and total chromium and determine the particle size distribution of these chromium species. The particle size distribution results are presented in Table 3.4 and the corresponding calculations and graphs can be found in Appendix A. The particle size distribution for the uncontrolled rotary dryer emissions showed that approximately 24 percent of the particulate, 64 percent of the hexavalent chromium, and 19 percent of the total chromium, by weight, were less than 10 μm in diameter. The controlled emissions from the rotary dryer and fugitive dust sources showed that approximately 52 percent of the particulate, 75 percent of the hexavalent chromium, and 42 percent of total chromium, by weight, were less than 10 μm in diameter.

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	10 µm	1 µm	5 µm	10 µm
Rotary Dryer Exhaust											
S1	6/25	1117-1137	0.6	9	17						
S5	6/26	1019-1026	3	18	30						
S9	6/26	1508-1523	0.5	14	30						
S11	6/26	1856-1911	0.8	12	20						
Average			1.2	13	24	3.5*	39*	64*	0.8*	9*	19*
Fabric Filter Outlet											
S4	6/25	0836-1101	3.5	33	54						
S6	6/26	0823-1006	5.5	39	63						
S8	6/26	1125-1418	0.5	19	39						
S10	6/26	1519-1807	3.5	33	52						
Average			3.2	31	52	8*	52*	75*	1.7*	23*	42*
Tunnel Kiln Stack											
S12	6/27	0949-1150	72	79	87						
S13	6/27	1254-1654	71	78	85						
S14	6/27	1733-1933	72	80	85						
S15	6/28	0716-0916	70	74	81						
Average			71	78	84	71*	81*	84*	84*	91*	93*

*Values calculated from composites of all runs.

The particle size distributions for the tunnel kiln emissions are also presented in Table 3.4 and show that the majority of the particulate, hexavalent and total chromium emissions were less than 1 μm in diameter.

The particle size distribution samples contained a smaller amount of hexavalent and total chromium than the particulate samples and were therefore subject to a higher degree of analytical error. The results are, however, believed to be representative and show a hexavalent chromium particle size dependency toward the smaller particle sizes; results from two of the three locations sampled showed that the majority of the hexavalent chromium was present in the particles less than 5 μm in diameter, which is to be expected.

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

The emission rates in units of the process rate are expressed in terms of grams of pollutant emissions per tons of chromite product processed and are presented in Table 3.5

To determine the collection efficiency of the fabric filter, the uncontrolled and controlled emissions measured were used; no actual measurements were made on the mass removal rates from the collector.

Emissions from the rotary dryer are actually controlled by both a cyclone and a fabric filter; fugitive emissions from the material transfer pick up points are also controlled by the same fabric filter. However, during the test program, the open bottom cyclone showed no collected material. When the rotary dryer exhaust emissions were to calculate collection efficiency, that of the fabric filter (see Table 3.5) averaged about 80 percent by weight for particulate matter, 35 percent by weight for hexavalent chromium, and 80 percent by weight for total chromium. The actual efficiency would be somewhat higher depending upon the amount of the unquantified fugitive particulate emissions.

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

Run No.	Process Rate tons/h	Uncontrolled Emissions			Controlled Emissions			Collection Efficiency		
		particulate g/ton	hexavalent chromium g/ton x 10^{-3}	total chromium g/ton	particulate g/ton	hexavalent chromium g/ton x 10^{-3}	total chromium g/ton	particulate %	hexavalent chromium %	total chromium %
Rotary Dryer Fabric Filter (+ Cyclone)										
1,2	19.28	408	3.68	68.0	107	3.00	14.3	>73.8	>18.5	>79.0
3,4	13.95	732	8.18	151	203	5.38	24.3	>72.3	>34.2	>83.9
5,6	21.26	641	12.65	58.8	120	4.15	11.4	>81.3	>67.2	>80.6
7,8	16.83	1232	7.08	104	126	5.76	18.1	>89.8	>18.6	>82.6
Average		753	7.90	95.5	139	4.57	17.0	>79.3	>34.6	>81.5
Tunnel Kiln										
9	3.68	502	1108	11.7						
10	4.30	388	1068	21.4	N/A	N/A	N/A	N/A	N/A	N/A
11	4.02	246	910	14.9						
Average		379	1029	16.0						

As previously noted, an accurate collection efficiency cannot be determined for hexavalent chromium and total chromium for a fabric filter if the materials typically collected are variable with respect to concentration of these pollutants. Based on other studies, it appears that about 50 to 80 percent of the emissions from the fabric filter consist of materials previously collected on the bags. The collection efficiency for hexavalent chromium is apparently lower due to the fact that material previously collected by the fabric filter was much higher in hexavalent chromium content. The concentration of uncontrolled hexavalent chromium emissions averaged about 11 μg of Cr^{+6} per gram of particulate. The material collected by the fabric filter and then discharged through the hoppers averaged 76 μg of Cr^{+6} per gram of particulate. The emissions controlled by the fabric filter averaged 34 μg of Cr^{+6} per gram of particulate.

3.4 SUMMARY OF ANALYTICAL RESULTS FOR HEXAVALENT AND TOTAL CHROMIUM

The summary of analytical results for 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 and total chromium are the results obtained by the EPA tentative method for "Determination of Hexavalent Chromium Emissions from Stationary Sources" and the "EPA Protocol for Emissions Sampling for Both Hexavalent and Total Chromium" (see Appendix D). When, for total chromium analysis, the table indicates that the sample "residue" was analyzed, then the values presented for total chromium content are a sum of (1) the hexavalent chromium in the sample filtrate from the extraction of the sample and (2) the chromium in the residue from the extraction as measured by Neutron Activation Analysis. When the table indicates that the "total" sample was analyzed, then the values presented for

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
Rotary Dryer Exhaust								
1	Particulate Front Half	C-296	2989.1 mg	26.8	8.97	Residue	499	166.9
1	Impinger Contents	C-307	Total	< 0.2	negligible	175 ml	0	0
3	Particulate Front Half	C-297	3540.9 mg	39.5	11.2	Residue	729	205.9
5	Particulate Front Half	C-298	3806.8 mg	75.2	19.8	Residue	350	91.9
7	Particulate Front Half	C-299	7181.6 mg	41.2	5.74	Residue	605	84.2
S1,5,9,11	Particle Size, Large	C-326	678.4 mg	3.8	5.60	Residue	103	151.8
S1,5,9,11	Particle Size, Medium	C-327	257.9 mg	5.0	19.4	Residue	19.4	75.2
S1,5,9,11	Particle Size, Small	C-328	105.4 mg	3.7	35.1	Residue	9.12	86.5
Fabric Filter Outlet								
2	Particulate Front Half	C-300	598.2 mg	16.8	28.1	Residue	80	133.7
2	Impinger Contents	C-311	Total	< 0.2	negligible	175 ml	0	0
4	Particulate Front Half	C-301	1009.4 mg	26.8	26.6	Residue	121	119.9
6	Particulate Front Half	C-302	672.6 mg	23.2	34.5	Residue	63.6	94.6
8	Particulate Front Half	C-303	438.1 mg	20.0	45.7	Residue	62.9	143.6
S4,6,8,10	Particle Size, Large	C-329	191.6 mg	4.2	21.9	Residue	25.4	132.6
S4,6,8,10	Particle Size, Medium	C-330	191.0 mg	7.0	36.6	Residue	14.8	77.5
S4,6,8,10	Particle Size, Small	C-331	109.2 mg	8.1	74.2	Residue	8.38	76.7
Tunnel Kiln Stack								
9	Particulate Front Half	C-304	54.5 mg	120	2202	Residue	1.27	23.3
9	Impinger Contents	C-315	Total	< 0.2	negligible	175 ml	0	0
10	Particulate Front Half	C-305	53.9 mg	148.8	2761	Residue	2.98	55.3
11	Particulate Front Half	C-306	29.0 mg	107.5	3707	Residue	1.76	60.7
S12,13,14,15	Particle Size, Large	C-332	19.4 mg	1.7	87.6	Residue	0.27	13.9
S12,13,14,15	Particle Size, Medium	C-333	8.0 mg	1.7	212	Residue	0.49	61.3
S12,13,14,15	Particle Size, Small	C-334	75.2 mg	9.7	129	Residue	4.31	57.3
Grab Samples								
1	Ore Feed	C-319		--	4.4	112.8 g	33.9	300.5
2	Ore Feed	C-320	--	--	1.8	103.3 g	35.8	346.6
3	Ore Feed	C-321	--	--	19.2	119.6 g	14.0	117.1
4	Ore Feed	C-322	--	--	1.4	115.9 g	47.0	405.5
1	Fabric Filter Hopper	C-323	--	--	75.3	139.9 g	20.5	146.5
2	Fabric Filter Hopper	C-324	--	--	87.0	119.2 g	18.8	157.7
3	Fabric Filter Hopper	C-325	--	--	65.7	116.1 g	18.0	155.0
Blank Samples								
	Particle Size Filters	C-336	--	1.0	--	Residue	--	--
	Distilled H_2O Blank	C-318	--	<0.2	negligible	100 ml	0	0

total chromium content are from the direct analysis of the total sample for total chromium 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 somewhat variable for most sampling locations. The variability of results for the particle size distribution tests emissions may reflect some analytical imprecision due to the small amount of hexavalent chromium analyzed. The other samples had a sufficient quantity of particulate, hexavalent chromium and total chromium, and should therefore be representative of the sample analyzed. Overall, the goals of obtaining quantifiable emissions were obtained.

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

3.5 VISIBLE EMISSIONS OBSERVATION DATA

Visible emission observations were performed at the fabric filter stack exit by the EMB Task Manager (see Table 3.8 and Appendix C). Readings were made for two or three 6 to 7 minute sets for Runs 2, 4, and 6. Under normal operating conditions the opacity at the fabric filter stack was observed to be 0 percent; however, during the manual cleaning cycles used between product runs, the opacity levels increased to an average of 3 to 10 percent with a maximum range of 30 percent.

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-335	50 µg/ml Cr^{+6}	50.8	+1.6	----	----
--	Quality Assurance	QA-19	50 µg Cr	----	----	52.30	+4.6
--	Quality Assurance	QA-20	100 µg Cr	----	----	97.22	-2.8
--	Quality Assurance	QA-21	200 µg Cr	----	----	200.1	+0.05

TABLE 3.8. SUMMARY OF VISIBLE EMISSIONS DATA FOR FABRIC FILTER
HARBISON-WALKER

Date	Time	Range	Avg. % Opacity	Average Over All Sets
		Run Nos. 1 and 2		
6/25	0906-0913 1007-1014	0 0-15	0 5	2.50
		Run Nos. 3 and 4		
6/26	0847-0854 0952-0959 1024-1033	0 0 0-30	0 0 10.14	4.08
		Run Nos. 5 and 6		
6/26	1321-1328 1425-1434 1630-1640	0 0-5 0-10	0 0.9 3.2	1.60

4.0 SAMPLING LOCATIONS AND TEST METHODS

This section describes the sampling locations and test methods used to characterize emissions from the rotary dryer and tunnel kiln at Harbison-Walker Refractories in Baltimore, Maryland. A total of five sampling locations were used in the emission testing program. At three sampling locations, emissions testing was conducted for particulate matter, total chromium content, hexavalent chromium content, and particle size distribution and chromium distribution with respect to particle size. At the fourth and fifth sampling locations, grab samples of the dust collected by the fabric filter and the rotary dryer ore feed were taken for hexavalent and total chromium analysis. 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 ROTARY DRYER EXHAUST (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 rotary dryer exhaust duct. A schematic of this sampling location is shown in Figure 4-2. A 3.5 by 17 inch slot for sampling was cut in one side of the 17-inch square, vertical duct. This sampling slot was located 67 inches (3.9 equivalent duct diameters) downstream of a bend in the duct and 17 inches (1 equivalent duct diameter) upstream of another bend in the duct to the fabric filter.

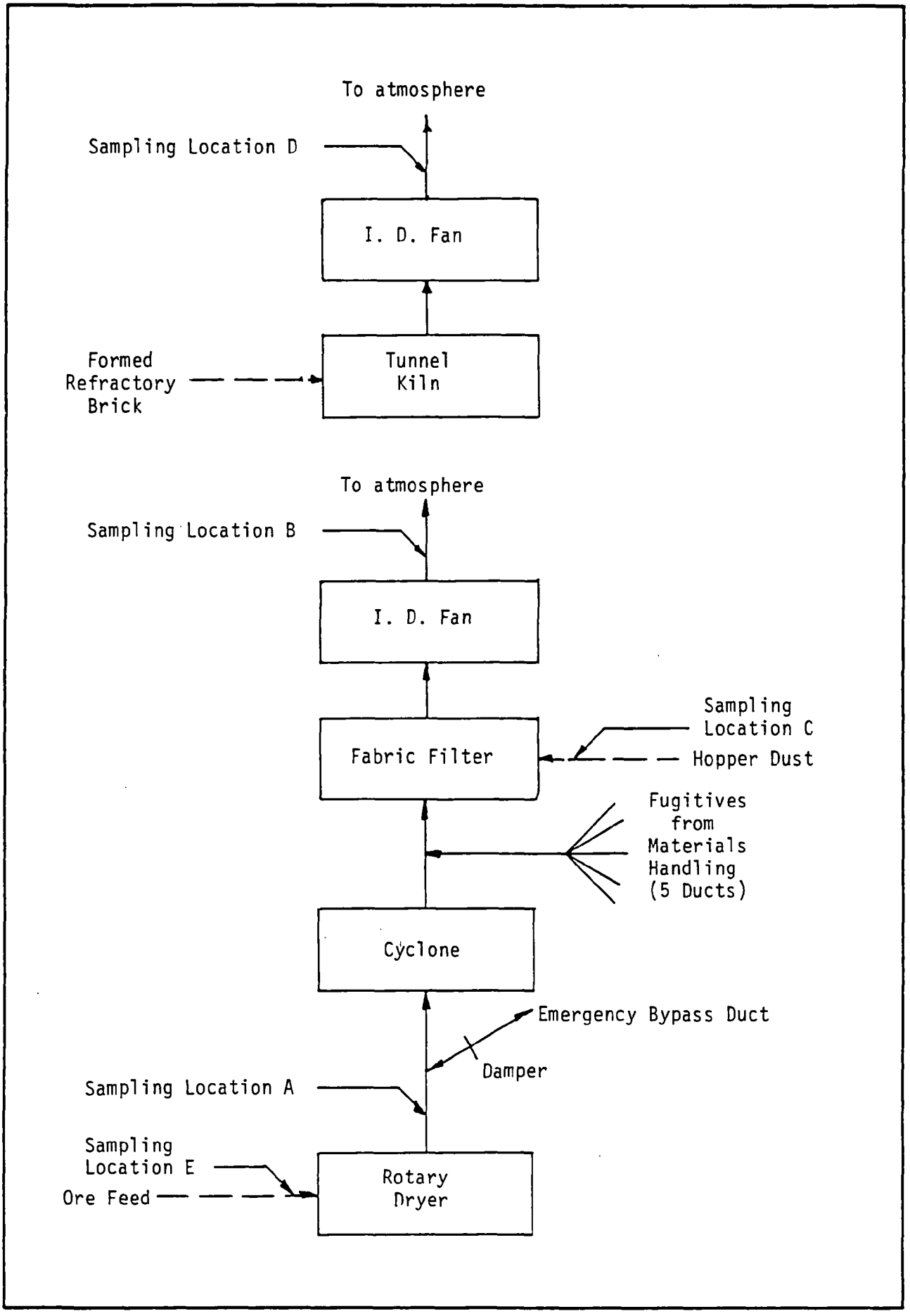

Figure 4-1. Process Air Flow Schematic of Rotary Dryer and Tunnel Kiln.

TABLE 4.1. SAMPLING PLAN FOR HARBISON-WALKER

Sample Type	Sampling Locations	Number of Samples	Methods
Particulate matter	A, B, D	4 at A & B 3 at D	EPA Method 5
Hexavalent chromium	A, B, D	4 at A & B 3 at D	EPA 5 using Tentative EPA Method for Hexavalent Chromium
Total chromium	A, B, D	4 at A & B 3 at D	EPA 5 using EPA Protocol for Total Chromium
Particle size distribution	A, B, D	4	Impactor (Andersen)
Hexavalent and total chromium distribution by particle size	A, B, D	4 at A & D 5 at B	Impactor using Tentative EPA Method for Hexavalent Chromium and EPA Protocol for Total Chromium
Hexavalent chromium, total chromium	C, E	3 grab at C 4 grab at E	Tentative EPA Method for Hexavalent Chromium, EPA Protocol for Total Chromium

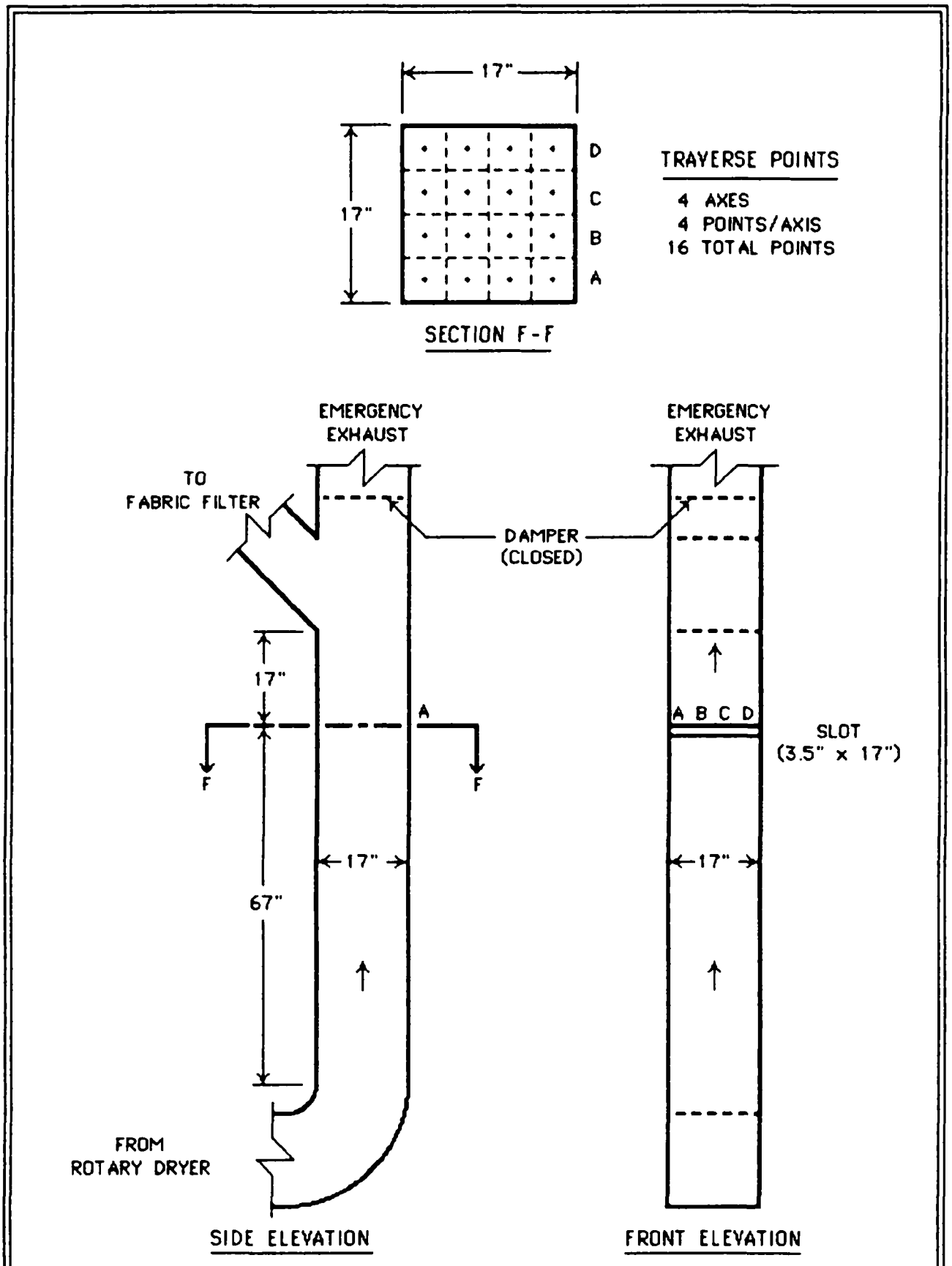

FIGURE 4-2. ROTARY DRYER EXHAUST DUCT (SAMPLING LOCATION A)

For the Method 5 testing (used for particulate matter, hexavalent chromium, and total chromium determinations), a total of 16 points (4 axes, 4 points per axis), as per Method 1, were sampled. Each point was sampled for 7.5 minutes for a total sampling time of 120 minutes per run (one exception was Run 5 where a process upset resulted in several points not being sampled and a shorter total sampling time of 105 minutes).

The particle size testing (including hexavalent and total chromium distribution by particle size), was conducted at a single point. Runs S1, S5, S9, and S11 were 20, 7.:52, 15, and 15 minutes in duration, respectively.

4.2 FABRIC FILTER OUTLET (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 at the fabric filter outlet. A schematic of this sampling location is shown in Figure 4-3. A 3.5 by 22 inch slot for sampling was cut in the long side of the 19 by 22 inch rectangular, vertical duct. This slot was located 110 inches (5.4 equivalent duct diamteters) downstream of the fabric filter I. D. fan and 100 inches (4.9 equivalent duct diameters) upstream of the fabric filter stack exit.

For the EPA Method 5 sampling (used for particulate matter, hexavalent chromium, and total chromium determinations), a total of 16 points (4 axes, 4 points per axis), as per Method 1, were sampled. For the first run each point was sampled for 15 minutes, however, a process upset prevented sampling all the points resulting in a total run time of 170 minutes. In addition, the heavy particulate catch from this run suggested a shorter sampling time, so for the remaining runs each point was sampled for 7.5 minutes. The total sampling

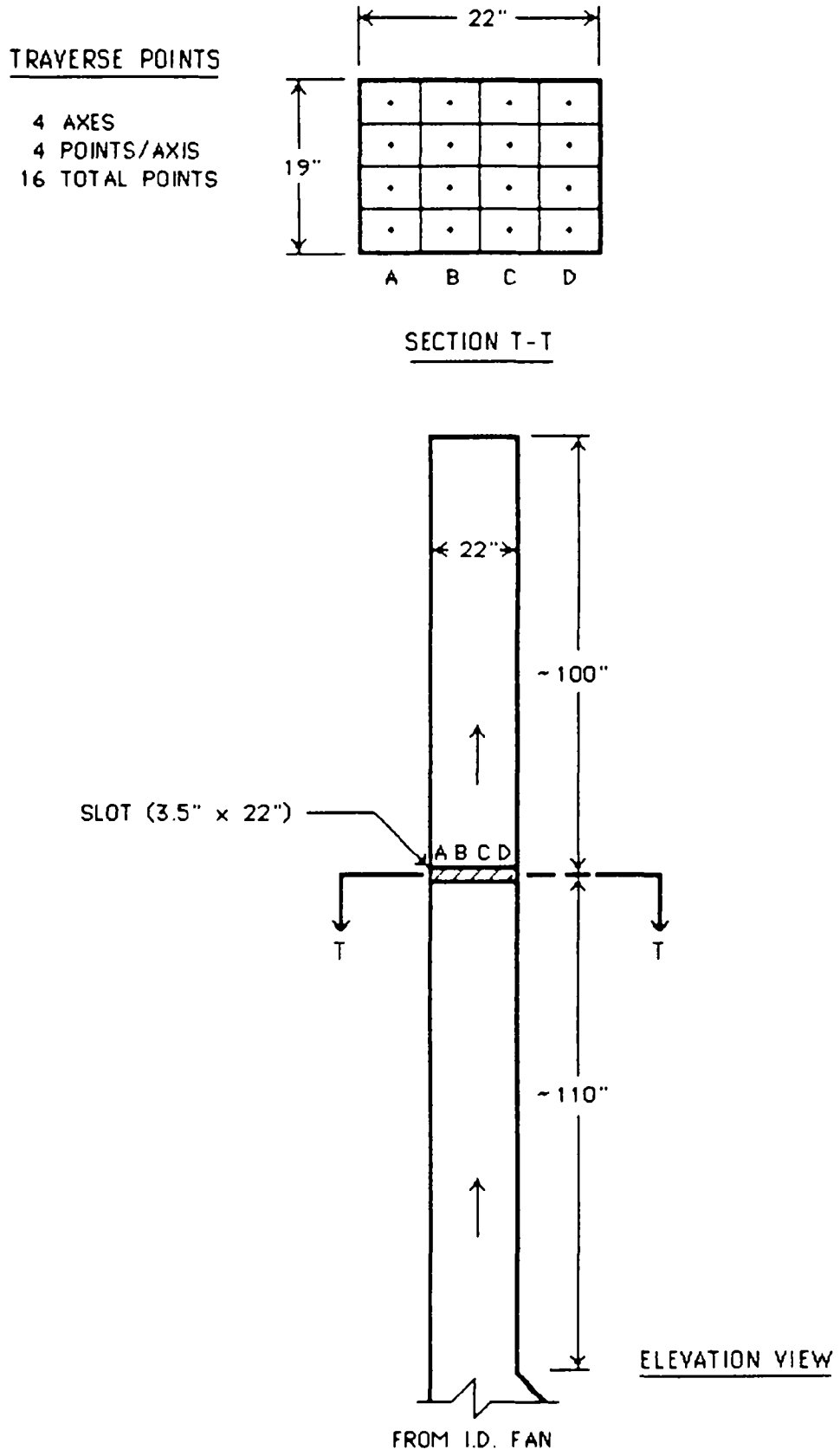

FIGURE 4-3. FABRIC FILTER OUTLET STACK (SAMPLING LOCATION B)

times for these runs were 136, 121, and 120 minutes. For the 136 minute run, the EPA Task Manager requested that sampling continue beyond the 120 minute mark.

The particle size testing (including hexavalent and total chromium distribution by particle size) was conducted at a single point. Runs S4, S6, S8, and S10 were 100 minutes in duration.

Visible emissions observations of the effluent from the fabric filter stack were conducted by the EMB Task Manager for several 6 (or 7) minute sets during Runs 2, 4, and 6.

4.3 FABRIC FILTER DUST HOPPER (SAMPLING LOCATION C)

Grab samples representative of the material collected by the fabric filter were taken from the fabric filter hopper during each set of test runs. Each grab sample was a composite of material from each of the three hopper sections of the filter and each was analyzed for hexavalent chromium and total chromium content.

4.4 TUNNEL KILN STACK (SAMPLING LOCATION D)

Particulate matter, hexavalent chromium, total chromium, particle size distribution, and hexavalent and total chromium distribution with respect to particle size were measured at the tunnel kiln stack.

A schematic of this sampling location is shown in Figure 4-4. Two sampling ports were installed at a 90° angle in the 42 inch diameter vertical stack. These ports were located 96 inches (2.3 duct diameters) downstream of the induced draft fan and 380 inches (9.0 duct diameters) upstream of the stack exit.

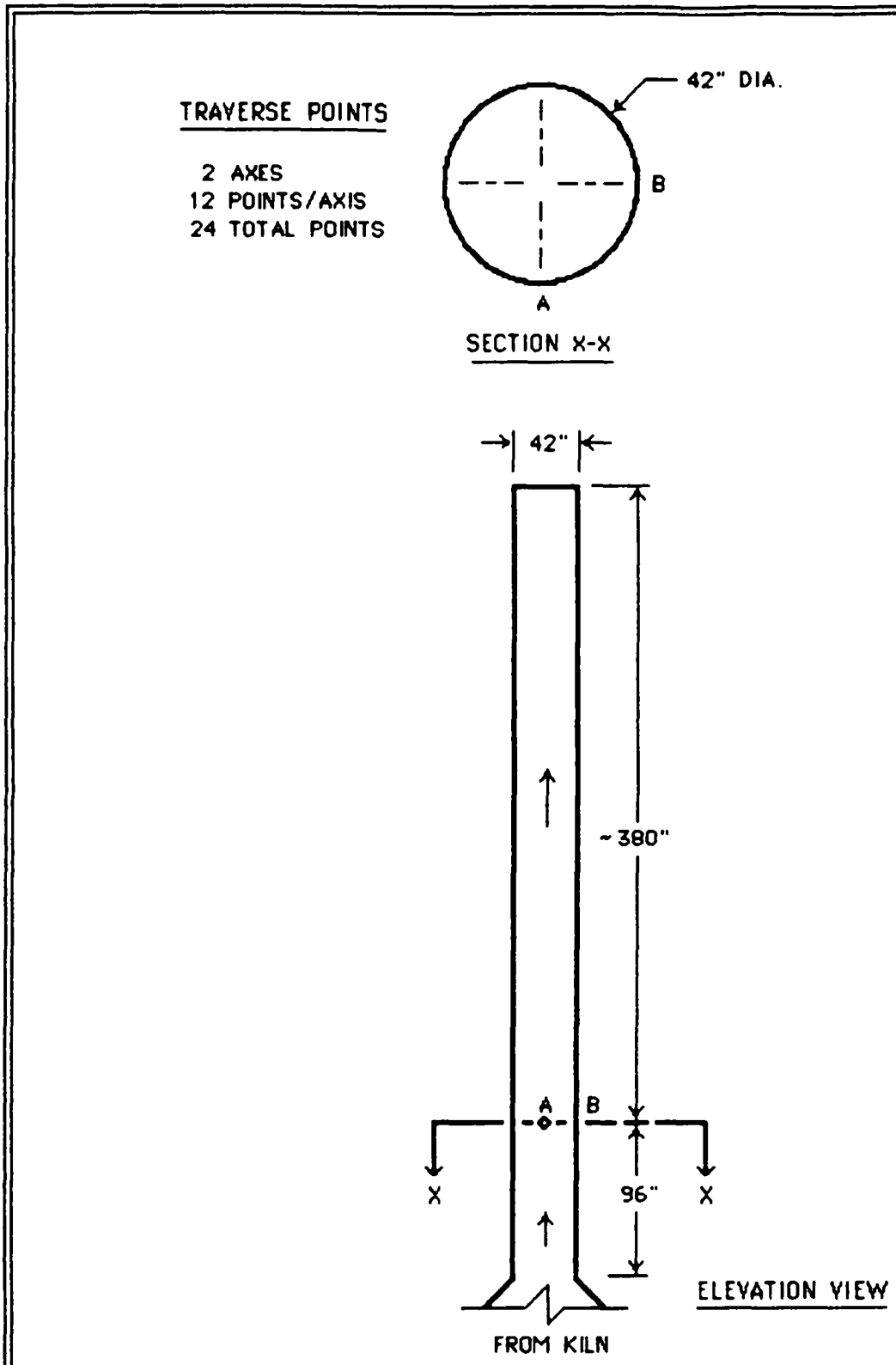

FIGURE 4-4. TUNNEL KILN STACK (SAMPLING LOCATION D)

For the Method 5 testing (used for particulate matter, hexavalent chromium, and total chromium determinations), a total of 24 points (2 axes, 12 points per axis), as per Method 1, were sampled. Each point was sampled for 5 minutes for a total sampling time of 120 minutes per run.

The particle size testing (including hexavalent and total chromium distribution by particle size) was conducted at a single point. Runs S12, S14, and S15 were 120 minutes in duration, Run S13 was 240 minutes in duration.

4.5 ROTARY DRYER FEED (SAMPLING LOCATION E)

Grab samples representative of the feed material (ore) entering the rotary dryer were taken from the feed belt as it went to the dryer. Samples were taken at the beginning, middle, and end (if possible because of process operations) of each particulate test series. The samples from each test series were combined into a single sample which was analyzed for hexavalent chromium and total chromium content.

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.

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.

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

4.8 PARTICULATE MATTER

Method 5, as described in the Federal Register,* was used to measure particulate grain loading at locations A, B, 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. See Appendix D for detailed sampling procedures.

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 and particle size cut-offs ranging 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 D for detailed sampling procedures.

Four impactor runs each were conducted at the rotary dryer exhaust, the fabric filter outlet and the tunnel kiln stack. At the locations sampled, a

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

single point 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 D). 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 of the fabric filter hopper dust and rotary dryer ore feed samples.

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 Appendix D). 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 hopper dust and the rotary dryer ore feed samples were also determined using these procedures using a representative portion of the sample.

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

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 E 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.

In addition to the pre- and post-test calibrations, 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.

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 5.1 summarizes these results.

TABLE 5.1. 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			
B472	166.68	166.69	0.01
A472	145.49	145.53	0.04
B473	166.12	166.22	0.10
A473	146.85	146.85	0.00
B474	164.70	164.71	0.01
A474	147.69	147.70	0.01
B475	164.46	164.49	0.03
A475	148.40	148.42	0.02
SF192	275.34	275.34	0.00
Particle size reactivity run filters			
B525	164.18	164.18	0.00
A525	146.00	146.02	0.02
B526	164.06	164.09	0.03
A526	147.62	147.66	0.04
B527	163.31	163.32	0.01
A527	146.17	146.17	0.00
B528	165.68	165.68	0.00
A528	145.91	145.92	0.01
SF205	274.34	274.30	-0.04

Audit solutions prepared by the EPA were used to check the analytical procedures of the laboratories conducting the hexavalent and total chromium analyses. Table 5.2 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. AUDIT REPORT CHROMIUM ANALYSIS

Plant: Harbison - Walker

Task No.: 3021

Date samples received: 7/22/85

Date analyzed: 7/26/85

Sample analyzed by: RTI / NCSU

Reviewed by: Peter Grohse

Date of review:

Sample Number	µg/ml Cr^{+6} or Cr	Source of Sample	Audit Value	Relative error, %
C-335	50 µg /ml Cr^{+6}	QAD	50.8	+1.6
QA-19	50 µg Cr	NBS	52.30	+4.6
QA-20	100 µg Cr	NBS	97.22	-2.8
QA-21	200 µg Cr	NBS	200.1	+0.05