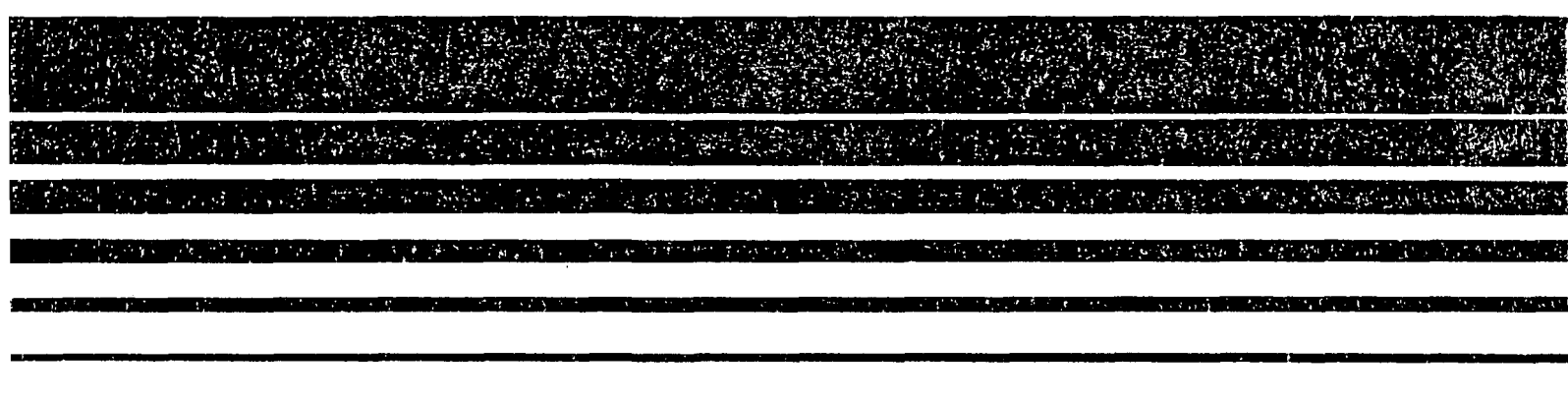


Air



Neshap Screening Study Chromium

Emission Test
Report
Carolina Plating
Company
Greenville,
South Carolina



EMISSION TEST REPORT

CAROLINA PLATING COMPANY
GREENVILLE, SOUTH CAROLINA

ESED 85/02

EMB 85-CHM-11

by

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1.0 INTRODUCTION

During the week of May 13-17, 1985, the Emission Measurement Branch of the U. S. Environmental Protection Agency conducted an emission measurement program at Carolina Plating Company's plating plant located in Greenville, South Carolina. The purpose of this program was to provide data for a screening study to determine the quantity and form of chromium emissions associated with hard chromium plating.

Comprehensive testing was conducted on a series of chromium plating tanks all of whose emissions are controlled by a single packed-bed wet scrubber. This fume scrubber controlling emissions from hard chromium plating tanks No. 1, 2, 3, and 7 at the plant was selected for source testing for the following reasons:

- o Carolina Plating applies hard chromium plate to large industrial rollers. Typically the rollers remain in the tanks for 12 to 36 hours, depending on the dimensions of the rollers and the chromium plate thickness required. Although there is no industry wide "typical" part that receives hard chromium plate, it is not unusual for job shops to plate industrial rollers. The advantages of performing a source test on a tank used for plating rollers instead of other types of metal parts are: a) the long plating time accommodates continuous testing, b) the amount of chromium deposited during the test can be easily determined, and c) the surface area plated can be easily determined.
- o The plating tanks appear to be typical of other hard chromium plating tanks in the electroplating industry, based on operating parameters such as current, voltage, plating time, and chromic acid concentration. The tanks are situated with the longest dimension in the vertical direction, which is common for tanks that are used to plate large industrial rollers. There are no demisting agents used in the plating tanks. The use of demisting agents is not common practice for hard chromium platers.

- o The emissions capture system is highly efficient in directing fumes from the plating tanks to the control device. The vertical orientation of the tanks minimizes the exposed surface area of plating solution from which fumes must be drawn. Each of the four tanks is equipped with hoods on three sides through which a common induction fan pulls a total of 20,000 standard cubic feet per minute (scfm).
- o The Napco wet packed-bed fume scrubber at this facility is typical of control devices in use at other hard chromium plating facilities. Most hard chromium plating facilities that control chromic acid emissions use impingement-type mist eliminators or packed-bed fume scrubbers. As a result, emission data obtained from testing at the outlet of the scrubber at this facility should be representative of emissions from control devices typically applied at hard chromium plating facilities.

Particulate concentrations and mass emission rates were measured at the scrubber inlet and outlet 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, "medium volume" (MV) particulate matter sampling was conducted at the same locations using a thimble filter and an experimental MV sampling train as described in Appendix C.

Ms. Barbara Duletsky [Midwest Research Institute (MRI)] monitored process operation throughout the test period. Mr. Dan Bivins (EPA Task Manager) of the Emission Measurement Branch (EMB) and Mr. Al Vervaert of the Industrial Studies Branch (ISB) observed the test program. Mr. J. F. Tucker, Vice-President served as the contact for Carolina Plating.

* 40 CFR 60, Appendix A, Reference Method 5, July 1, 1980.

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

The Carolina Plating Roll Division is a job shop specializing in precision finishing and refinishing of industrial rolls. Operations performed at this facility include hard chromium plating, sulfamate nickel plating, machining, grinding, and mirror finishing. The plant plates rolls that are used primarily in the paper manufacturing, roofing, laminating, and coating industries. Although some parts of the finishing processes performed at this plant are unique, the actual plating process is similar to that at most other hard chromium plating operations.

There are seven hard chromium plating tanks at this facility, arranged as shown in Figure 2-1. On the average, the tanks are charged for a total of 20 hours per day. Approximately 4 hours per day are required for the change-over of rolls. During a change-over, the roll that has been plated is raised out of the plating tank, rinsed with water from a hose, and transferred to the grinding area. Then, the roll to be plated is cleaned with an abrasive cleanser and lowered into the plating solution. Plating times range from 2 to 36 hours, depending on the surface area of the roll and the plate thickness required. Usually, rolls that require longer plating times are plated overnight, and rolls that require shorter plating times are plated during the day when personnel are available to perform the change-over.

Tank Nos. 1, 2, 3, and 7 were tested during this source test program. The tanks are situated below floor level and are oriented with the largest dimension in the vertical direction. This orientation is typical of tanks used to plate industrial rolls throughout the electroplating industry. Each tank is serviced by an electric hoist that lowers and raises the rolls into and out of the plating solution. In addition, each tank is equipped with a timer that automatically turns off the electrodes at the end of the specified plating time.

The plating tanks are typical of other hard chromium plating tanks in the electroplating industry, based on operating parameters such as current, voltage, plating time, and chromic acid concentration. Table 2-1 lists maximum operating conditions for the four tanks. Although the

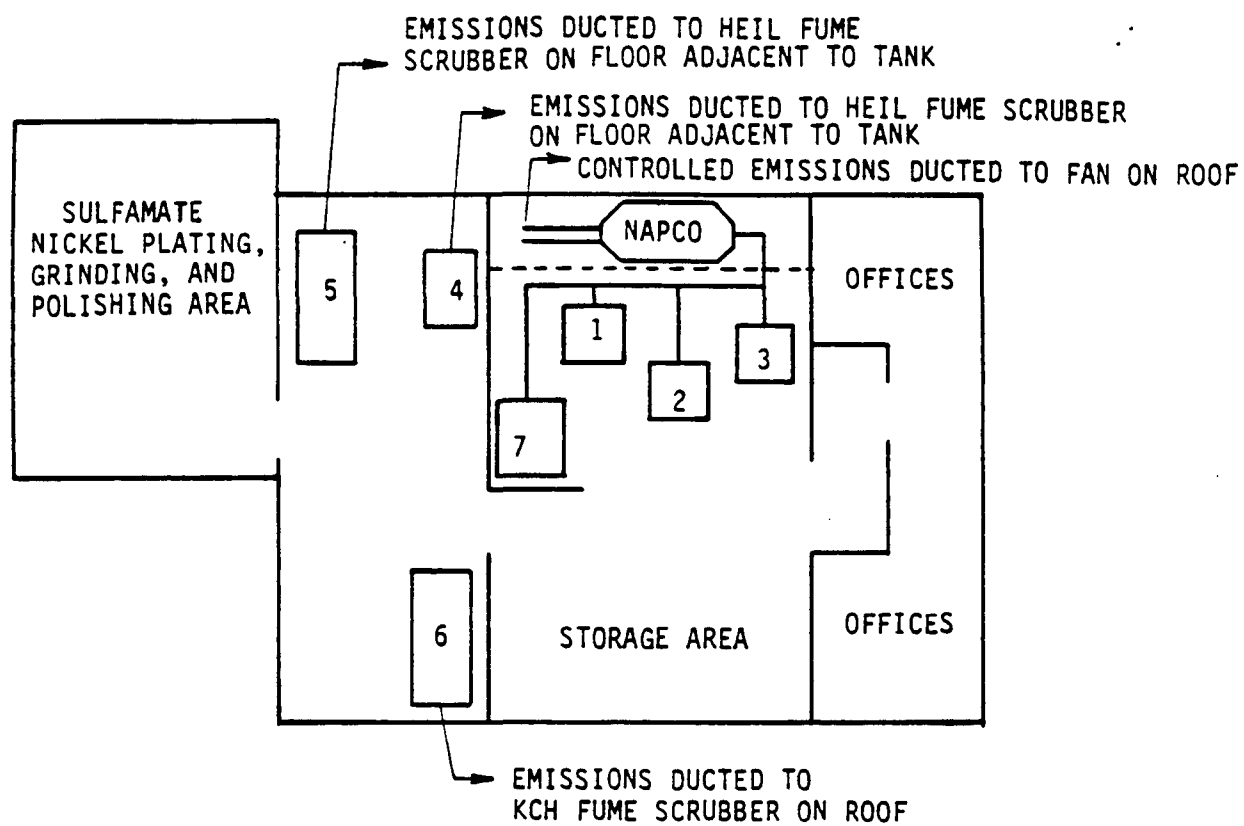


Figure 2-1. Plan view of Carolina Plating facility.

TABLE 2-1. SPECIFICATIONS OF HARD CHROMIUM PLATING TANKS AT CAROLINA PLATING

Tank No.	Capacity, ℓ (gal)	Surface, m ² (ft ²)	Voltage, volts ^a	Current, amperes ^a	Method of cooling	Constituents, g/ℓ (oz/gal)	
						CrO ₃	H ₂ SO ₄
1	3,800 (1,000)	1.3 (14)	12	7,000	Water	250 (33)	2.5 (0.33)
2	7,600 (2,000)	1.7 (18)	12	20,000	Water	250 (33)	2.5 (0.33)
3	11,400 (3,000)	3.3 (36)	10	30,000	Water	250 (33)	2.5 (0.33)
7	9,100 (2,400)	2.2 (24)	10	15,000	Water	250 (33)	2.5 (0.33)

^aValues represent maximum operating values.

composition of the plating solution remains constant, the operating voltage and current vary with each roll that is plated.

2.2 AIR POLLUTION CONTROL

All four tanks are equipped with hoods on three sides to capture the chromic acid mist generated during the plating process. A plan view of the exhaust system is shown in Figure 2-2. Emissions that are captured by the exhaust system are treated by a fume scrubber located on a mezzanine adjacent to the plating area. The scrubber is a double packed-bed type manufactured by Napco, Incorporated (Model No. MA-101). Each bed contains 30 cm (12-inches) of polypropylene packing. The beds are sprayed continuously with water, which drains into a holding tank and is recirculated through the scrubber. The holding tank is flushed and filled with clean water about 3 times a day. The spent liquid is either used as make-up solution for the plating tanks or is treated on site in a wastewater treatment system.

The scrubber also contains a mist elimination stage for the removal of water droplets entrained in the exhaust gas stream. This stage consists of a "Chevron-type" arrangement of baffles that changes the direction of gas flow four times at 30°-angles. The entire scrubbing unit has a design control efficiency of 96 to 99 percent for the removal of chromic acid.

The exhaust fan, which is located immediately downstream of the scrubber, is manufactured by Duall Industries, Incorporated (Model No. NH-66). The fan is rated at 9.4 cubic meters per second (m^3/s) (20,000 standard cubic feet per minute [scfm]) for air at 21°C (70°F); however, a gas flow of 4.7 m^3/s (10,000 scfm) was measured during the test series. Exhaust gases exit through a short stack located on the roof.

2.3 PROCESS CONDITIONS DURING TESTING

Process operating parameters such as plating solution temperature, operating voltage, and operating current were monitored and recorded during each test run. Copies of the actual data sheets are presented in Appendix E. Also recorded were descriptions (dimensions and surface area) and plating requirements (current and plating time) of each individual job or item being plated during each test run. This information was obtained

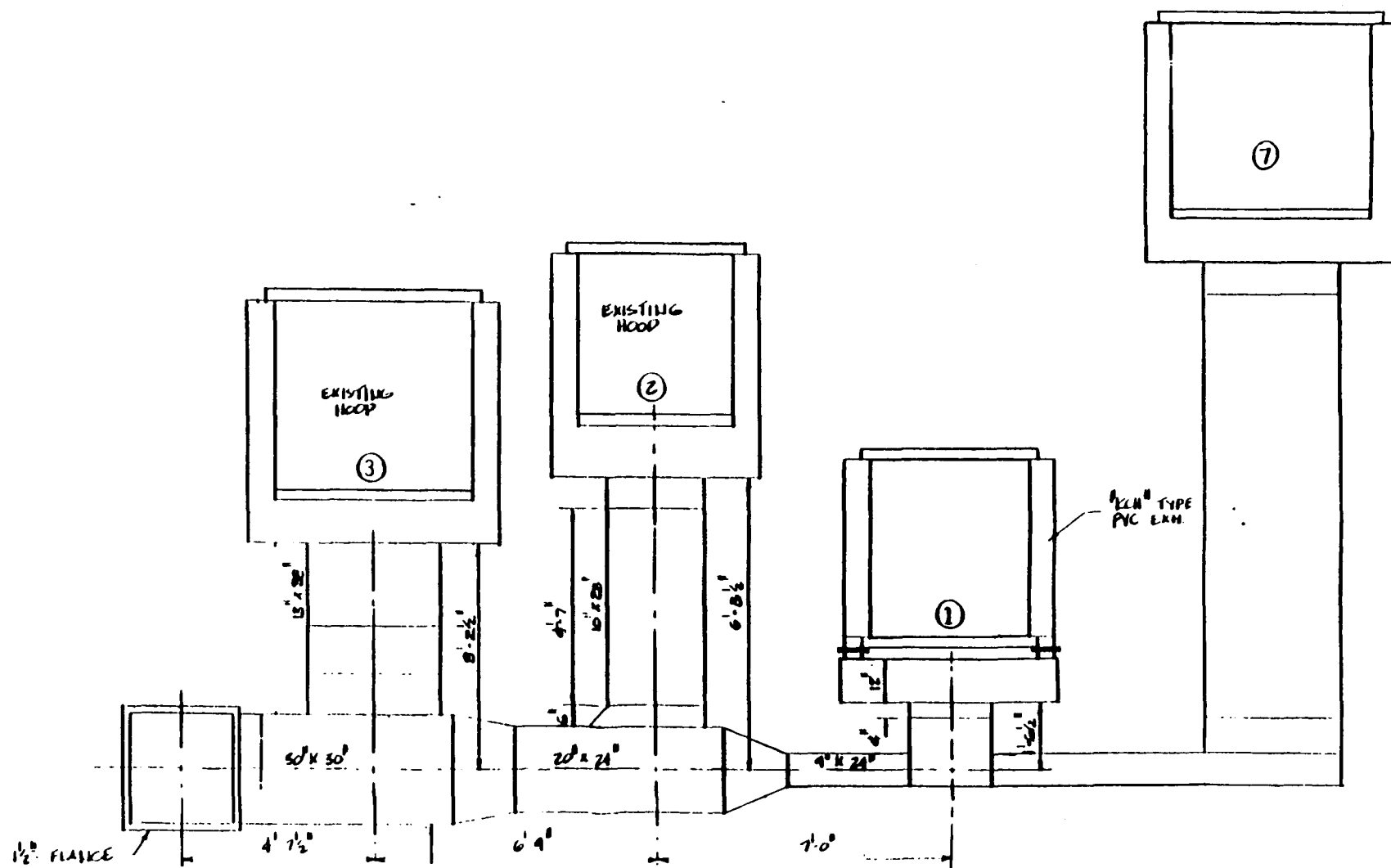


Figure 2-2. Plan view of exhaust system on Tank Nos. 1, 2, 3, and 7.

from log sheets maintained by plant personnel and is also presented in Appendix E. No operating parameters were monitored for the scrubber; however, there were no indications of any malfunction in the system during the testing period.

Test run Nos. 1 and 3 were performed without interruption. Test run No. 2 was suspended at one point because the production rate in the tanks was significantly lower than normal. Testing was resumed after 1 hour when the production rate was increased.

The total current supplied to the tanks during each test run is calculated in terms of ampere-hours and included in Appendix E. A summary of the total current values is presented in Table 2-2.

TABLE 2-2. TOTAL CURRENT SUPPLIED TO TANKS DURING
SOURCE TEST RUNS

Test No.	Total current, ampere-hours	
	Inlet	Outlet
1	41,300	42,200
2	50,300	45,900
3	72,400	70,600

3.0 SUMMARY OF RESULTS

Particulate matter and experimental "medium volume" tests were conducted at the inlet and the outlet of the packed-bed wet scrubber controlling chromium plating tanks No. 1, 2, 3, and 7. Table 3.1 summarizes the testing schedule.

In brief, from the results of the Method 5 testing, the uncontrolled emissions from the tanks averaged 0.22 pounds per hour of particulate matter, 0.025 pounds per hour of hexavalent chromium, and 0.052 pounds per hour of total chromium. The controlled emissions averaged 0.11 pounds per hour of particulate matter, 0.001 pounds per hour of hexavalent chromium, and 0.004 pounds per hour of total chromium. The resulting collection efficiency of the wet scrubber was 43.5% for particulate matter, 95.7% for hexavalent chromium, and 93.0% for total chromium. The "medium volume" testing results are not included in the summary of results since this is a screening technique. These results are discussed separately in Section 3.4.

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 are 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 both the scrubber inlet and outlet. The particulate matter samples were initally analyzed using gravimetric techniques to determine the mass of particulate matter. Then the

TABLE 3.1. TESTING SCHEDULE FOR CAROLINA PLATING

Date (1985)	Sample Type	Scrubber Inlet		Scrubber Outlet	
		Run No.	Test Time 24 h clock	Run No.	Test Time 24 h clock
5-14	Medium Volume	DIF1	1230-2130		
5-15	Particulate Medium Volume	I-1 DIF2	1235-1723 1915-0730	0-1	1230-1724
5-16	Particulate Particulate Medium Volume	I-2 I-3	0901-1442 1525-2013	0-2 0-3 DIF3	0838-1419 1517- 2015-0850

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 (and Appendix C).

3.1.1 Scrubber Inlet

The scrubber inlet represents the uncontrolled emissions from plating tanks No. 1, 2, 3, and 7. The circular horizontal inlet duct was only traversed in one direction during the particulate sampling. The single traverse was utilized because of the difficulty in gaining access to the duct and because the very fine acid mist particles present in the duct would be expected to behave like a gas resulting in a uniform cross-sectional particle distribution. Prior to the Method 5 testing at the scrubber inlet, a pitot traverse was conducted along two axes. Since the pitot traverse showed flow rates only slightly less (1%) than the Method 5 sampling, the Method 5 test data was used in the calculations and is presented in the summary tables.

Flue Gas Conditions and Isokinetic Sampling Rate - A summary of the flue gas conditions at the scrubber inlet and outlet is presented in Table 3.2. The volumetric flow rates were fairly consistent and averaged 16,500 actual cubic meters per hour (582,000 actual cubic feet per hour). The flow rate at the inlet was approximately 13% lower than the outlet flow rate; this was likely due to measurement error in the outlet flow rate measurements which were conducted in nonparallel flow.

The flue gas temperature averaged 28°C (82°F), with a moisture content of 1.5 percent. The oxygen, carbon dioxide, and carbon monoxide content was that of air at 20.9, 0.0, and 0.0 percent, respectively. The volumetric flow rate at standard conditions averaged 15,200 dry standard cubic meters per hour

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					
Scrubber Inlet													
1-1	5/15	1235-1723	0.0171	0.6029	0.0158	0.5589	29	84	1.6	20.9	0.0	0.0	97.1
1-2	5/16	0901-1442	0.0160	0.5645	0.0149	0.5264	26	79	1.5	20.9	0.0	0.0	100.1
1-3	5/16	1525-2013	0.0163	0.5772	0.0151	0.5333	29	84	1.4	20.9	0.0	0.0	98.9
Average			0.0165	0.582	0.0152	0.540	28	82	1.5	20.9	0.0	0.0	
Scrubber Outlet													
0-1	5/15	1230-1724	0.0190	0.6723	0.0177	0.6246	29	85	2.2	20.9	0.0	0.0	95.9
0-2	5/16	0838-1419	0.0190	0.6721	0.0178	0.6278	25	77	2.2	20.9	0.0	0.0	96.5
0-3	5/16	1517-	0.0186	0.6565	0.0173	0.6103	27	81	1.7	20.9	0.0	0.0	95.8
Average			0.0189	0.667	0.0176	0.621	27	81	2.0	20.9	0.0	0.0	

^aVolumetric flow rate in actual cubic meters per hour (acmh) and actual cubic feet per hour (acfh) at stack conditions.

^bVolumetric flow rate in dry standard cubic meters per hour (dscmh) and dry standard cubic feet per hour (dscfh).

(540,000 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 three sample runs.

Particulate Emissions - The particulate emissions from the plating tanks (see Table 3.3) were variable. The particulate emissions for the inlet runs averaged 6.37 milligrams per dry standard cubic meter (0.0028 grains per dry standard cubic foot) and 0.097 kilograms per hour (0.22 pounds per hour).

Hexavalent Chromium Emissions - The hexavalent chromium emissions for each test run (see Table 3.3) were consistent with the corresponding particulate run. They averaged 119, 95, and 127 milligrams of hexavalent chromium per gram of particulate emissions for runs I-1, I-2, and I-3, respectively. The hexavalent chromium emissions for the inlet tests averaged 0.736 milligrams per dry standard cubic meter (0.00032 grains per dry standard cubic foot) and 0.0113 kilograms per hour (0.025 pounds per hour).

Total Chromium Emissions - The total chromium emissions for each test run (see Table 3.3) were consistent with the corresponding particulate run and averaged 249, 207, and 260 milligrams of total chromium per gram of particulate emissions for runs I-1, I-2, and I-3 respectively. The total chromium emissions for the inlet tests averaged 1.54 milligrams per dry standard cubic meter (0.00067 grains per dry standard cubic foot) and 0.024 kilograms per hour (0.052 pounds per hour).

3.1.2 Scrubber Outlet

The scrubber outlet represents the controlled emissions from plating tanks No. 1, 2, 3, and 7. Some nonparallel (cyclonic or swirling) flow was present in the scrubber outlet stack. To estimate the effect of these flow conditions

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	kg/h	lb/h	mg/dscm	gr/dscf	kg/h	lb/h
Scrubber Inlet													
1-1	5/15	7.548	0.00330	0.119	0.263	0.898	0.00039	0.0142	0.0313	1.868	0.00082	0.0296	0.0652
1-2	5/16	4.962	0.00217	0.074	0.163	0.473	0.00021	0.0071	0.0155	1.027	0.00045	0.0153	0.0338
1-3	5/16	6.586	0.00288	0.099	0.219	0.837	0.00037	0.0126	0.0279	1.713	0.00075	0.0259	0.0570
Average		6.37	0.00278	0.097	0.215	0.736	0.00032	0.0113	0.0249	1.54	0.00067	0.024	0.052
Scrubber Outlet													
0-1	5/15	2.620	0.00114	0.046	0.102	0.0262	0.000011	0.00046	0.00102	0.1231	0.000054	0.00218	0.00480
0-2	5/16	3.411	0.00149	0.061	0.134	0.0202	0.000009	0.00036	0.00079	0.0510	0.000022	0.00091	0.00200
0-3	5/16	2.788	0.00122	0.048	0.106	0.0301	0.000013	0.00052	0.00115	0.1120	0.000049	0.00194	0.00427
Average		2.94	0.00128	0.052	0.114	0.0255	0.000011	0.00045	0.00099	0.095	0.000042	0.0017	0.0037

on the sampling data, the angle of misalignment was determined at each sampling point during a preliminary pitot traverse. Application of these angles to the pitot traverse data resulted in a flow rate about 10% lower than the measured inlet values. Thus, the flow rate data for each Method 5 test was used in the calculations and is presented in the summary tables.

Flue Gas Conditions and Isokinetic Sampling Rate - A summary of flue gas conditions at the scrubber outlet is presented in Table 3.2. The volumetric flow rates for the three outlet runs were very consistent. The outlet volumetric flow rate averaged 18,900 actual cubic meters per hour (667,000 actual cubic feet per hour) with a flue gas temperature of 27°C (81°F) and a moisture content of 2.0 percent. The oxygen, carbon dioxide, and carbon monoxide concentrations were that of ambient air at 20.9, 0.0, and 0.0 percent, respectively. The volumetric flow rate at standard conditions averaged 17,600 dry standard cubic meters per hour (621,000 dry standard cubic feet per hour). Standard conditions are 20°C (68°F), 760 mm Hg (29.92 in. Hg), and dry. These flow rate measurements are likely to be biased high due to the nonparallel flow conditions.

The isokinetic sampling rates were well within the allowable range for all runs.

Particulate Emissions - The particulate emissions from the control equipment to the atmosphere were variable (see Table 3.3) with all runs being within approximately 20% of the averages. Over all three runs, the particulate emissions averaged 2.94 milligrams per dry standard cubic meter (0.00128 grains per dry standard cubic foot) and 0.052 kilograms per hour (0.114 pounds per hour).

Hexavalent Chromium Emissions - The hexavalent chromium emissions for each test run were fairly consistent with their corresponding particulate run and averaged 10.0, 5.9, and 10.8 milligrams of hexavalent chromium per gram of

particulate emissions for runs 0-1, 0-2, and 0-3, respectively. The hexavalent chromium emissions averaged 0.0255 milligrams per dry standard cubic meter (0.000011 grains per dry standard cubic feet) and 0.00045 kilograms per hour (0.00099 pounds per hour).

Total Chromium Emissions - The total chromium emissions were variable (see Table 3.3) when compared to the corresponding particulate runs and averaged 47, 15, and 40 milligrams of total chromium per gram of particulate for runs 0-1, 0-2, and 0-3 respectively. The total chromium emissions averaged 0.095 milligrams per dry standard cubic meter (0.000042 grains per dry standard cubic foot) and 0.0017 kilograms per hour (0.0037 pounds per hour).

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

The emission rates in units of process rate are given in terms of grams of emissions per hour per square foot of tank surface area, and in units of milligrams of emissions per amperage input to the plating operation. To determine the collection efficiency of the scrubber, the milligrams per hour per square foot (uncontrolled emissions and controlled emissions) were used for the calculations.

3.2.1 Emissions in Units of Process Rate

Two process parameters were used to determine the emissions in terms of units of the process rate as shown in Table 3.4. The first was milligrams of emissions per amperage input into the plating operation. The second was grams of emissions per hour per square foot of tank surface area. The surface area of the tank was 92 ft² for all tests.

TABLE 3.4. SUMMARY OF EMISSION RATES IN UNITS OF PROCESS RATE AND EFFICIENCY

Run Nos.	Process Rate amps/hr	Uncontrolled Emissions						Controlled Emissions						Collection Efficiency**		
		particulate		hexavalent chromium		total chromium		particulate		hexavalent chromium		total chromium		particulate	hexavalent chromium	total chromium
		mg/amp	$\frac{g/hr}{ft^2*}$	mg/amp	$\frac{g/hr}{ft^2*}$	mg/amp	$\frac{g/hr}{ft^2*}$	mg/amp	$\frac{g/hr}{ft^2*}$	mg/amp	$\frac{g/hr}{ft^2*}$	mg/amp	$\frac{g/hr}{ft^2*}$	%	%	%
1-1	41,300	2.88	1.29	0.345	0.154	0.717	0.322	--	--	--	--	--	--			
0-1	42,300	--	--	--	--	--	--	1.09	0.50	0.011	0.005	0.052	0.024	61.2	96.8	92.5
1-2	50,300	1.47	0.80	0.141	0.077	0.304	0.166	--	--	--	--	--	--			
0-2	45,900	--	--	--	--	--	--	1.33	0.66	0.008	0.004	0.020	0.010	17.5	94.8	94.0
1-3	72,400	1.37	1.08	0.174	0.137	0.358	0.282	--	--	--	--	--	--			
0-3	70,600	--	--	--	--	--	--	0.68	0.52	0.007	0.006	0.027	0.021	51.9	95.6	92.6
Average		1.91	1.06	0.22	0.12	0.46	0.26	1.03	0.56	0.009	0.005	0.033	0.018	43.5	95.7	93.0

*Emission rate in units of grams per hour per square foot of tank surface ($g/hr/ft^2$) using tank surface of 92 ft^2 .

**Collection efficiency of control equipment is based on the uncontrolled and controlled emission rate in units of emissions per hour per ft^2 of tank surface.

3.2.2 Control Equipment Collection Efficiency

The collection efficiency of the packed-bed scrubber (see Table 3.4) averaged 43.5 percent by weight for particulate matter, 95.7 percent by weight for hexavalent chromium, and 93.0 percent by weight for total chromium.

The much greater collection efficiency for hexavalent chromium emissions as compared to particulate emissions is probably a result of one or a combination of two things: (1) the solubility of hexavalent chromium in water, and/or (2) the measured hexavalent chromium results at the outlet (which were extremely low) could be biased low.

3.3 SUMMARY OF ANALYTICAL RESULTS FOR HEXAVALENT AND TOTAL CHROMIUM

The summary of analytical results for the hexavalent chromium and total chromium analyses of samples collected is presented in Table 3.5. The analytical data sheets are contained in Appendix B. The results shown in Table 3.5 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 C). When, for total chromium analysis, the table indicates that the sample "residue" was analyzed, then the values presented for total chromium content are the 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 total chromium content are from the direct analysis 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.

TABLE 3.5. SUMMARY OF ANALYTICAL RESULTS FOR HEXAVALENT AND TOTAL CHROMIUM

Run No.	Sample Type	Sample No. Analyzed	Amount of Sample mg or ml	Hexavalent Chromium		Amount of Sample Analyzed	Total Chromium		Sample Prep Method ^a
				Results mg	Concentration mg/g		Results mg	Concentration mg/g	
Scrubber Inlet									
I-1	Particulate Front Half	C-227	60.5	7.200	119	Residue	14.977	247.6	1
I-1	Impinger Contents	C-233	Total	0.007	negligible	Total	0.011	negligible	2
I-2	Particulate Front Half	C-228	38.6	3.680	95.3	Residue	7.993	207.1	1
I-3	Particulate Front Half	C-229	51.3	6.520	127	Residue	13.345	260.1	1
I-3	Impinger Contents	C-234	Total	0.0004	negligible	Total	0.002	negligible	2
DIF1	Thimble Filter	C-237	100.0	23.099	231	Residue	31.883	318.8	1
DIF2	Thimble Filter	C-221	147.3	29.099	198	Residue	43.209	293.3	1
Scrubber Outlet									
0-1	Particulate Front Half	C-224	15.5	0.155	10.0	Residue	0.728	47.0	1
0-1	Impinger Contents	C-231	Total	0.0008	negligible	Total	0.002	negligible	2
0-2	Particulate Front Half	C-225	20.4	0.121	5.93	Residue	0.305	15.0	1
0-3	Particulate Front Half	C-226	16.1	0.174	10.8	Residue	0.647	40.2	1
0-3	Impinger Contents	C-232	Total	<0.0005	negligible	Total	0.001	negligible	2
DIF3	Thimble Filter	C-222	55.2	6.499	118	Residue	10.090	182.8	1
Blank Samples									
---	Filter & Acetone Blank	C-230		<0.0005		Residue	no value	---	
---	Thimble Blank	C-223		0.001		Residue	no value	---	

^aSample preparation methods are as follows:

1 = For the Method 5 and thimble filters: Hexavalent chromium was extracted from the filter, acetone rinse, (and water rinse for Method 5 filters) and the filtrate from this process was analyzed for Cr⁺⁶. The residue from the extraction was analyzed for total chromium. Total chromium results reported (mg) are the sum of both measurements (blank corrected).

2 = For Impinger contents: The liquid samples were concentrated; one measured aliquot was taken for hexavalent chromium analysis and one measured aliquot taken for total chromium analysis. Chromium concentrations are expressed as mg Cr per g of particulate matter catch.

For this testing program, there is some sample analysis variability due to the small amount of hexavalent chromium present. However, the average values for the runs are believed to be fairly accurate.

Quality assurance audit samples were analyzed for both the hexavalent and total chromium methods. As shown in Table 3.6 no bias was present and the results are considered acceptable.

3.4 SUMMARY OF RESULTS FOR THE MEDIUM VOLUME SAMPLING TRAIN

EPA employed the use of the "medium volume" sampling train during the test program. This technique is a screening method and was used prior to testing to obtain an estimate of uncontrolled emissions. The data collected is not intended for the purposes of source evaluation or emissions estimates. The method was additionally evaluated to determine its ability to collect samples over a wide variation in stack velocities and to collect samples over an extended period of time. Tables 3.7 and 3.8 present the data obtained. This data cannot be compared to the emission data from the Method 5 testing since was collected at different times and under different process operating conditions.

TABLE 3.6. 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-76	150 µg/ml Cr ⁺⁶	149	-0.7	---	---
--	Quality Assurance	C-239	10 µg Cr	---	---	10.88	+8.8
--	Quality Assurance	C-240	450 µg Cr	---	---	412.5	-8.3

TABLE 3.7. SUMMARY OF FLUE GAS CONDITIONS FOR RUNS
CONDUCTED USING "MEDIUM VOLUME" SAMPLING TRAIN

Run No.	Date (1985)	Test Time 24 h clock	Volumetric Flow Rate				Stack Temperature		Moisture %
			Actual ^a		Standard ^b				
			acmh x 10 ⁶	acfh x 10 ⁶	dscmh x 10 ⁶	dscfh x 10 ⁶	°C	°F	
Scrubber Inlet									
DIF1	5/14	1230-1440, 1535-2130	0.0163	0.5762	0.0149	0.5269	33	92	1.5
DIF2	5/15, 5/16	1915-0730	0.0167	0.5904	0.0155	0.5482	28	82	1.6
Average			0.0165	0.583	0.0152	0.538	31	87	1.6
Scrubber Outlet									
DIF3	5/16, 5/17	2015-0850	0.0184	0.650	0.0171	0.604	27	81	1.7

^aVolumetric flow rate in actual cubic meters per hour (acmh) and actual feet per hour (acfh) at stack conditions.

^bVolumetric flow rate in dry standard cubic meters per hour (dscmh) and dry standard cubic feet per hour (dscfh).

TABLE 3.8. SUMMARY OF PARTICULATE, HEXAVALENT CHROMIUM, AND TOTAL CHROMIUM EMISSIONS
FOR RUNS CONDUCTED USING "MEDIUM VOLUME" SAMPLING TRAIN

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	kg/h	lb/h	mg/dscm	gr/dscf	kg/h	lb/h
Scrubber Inlet													
DIF1	5/14	3.633	0.00159	0.054	0.119	0.839	0.000367	0.0125	0.0276	1.158	0.00051	0.0173	0.0381
DIF2	5/15-5/16	2.806	0.00123	0.044	0.096	0.554	0.000242	0.0086	0.0190	0.823	0.00036	0.0128	0.0282
Average		3.22	0.00141	0.049	0.108	0.696	0.00030	0.011	0.023	0.99	0.00044	0.015	0.033
Scrubber Outlet													
DIF3	5/16-5/17	0.310	0.00014	0.005	0.012	0.036	0.000016	0.00062	0.0014	0.057	0.00002	0.001	0.002

4.0 SAMPLING LOCATIONS AND TEST METHODS

This section describes the sampling locations and test methods used to characterize emissions from hard chromium plating tanks No. 1, 2, 3, and 7 at Carolina Plating Company in Greenville, South Carolina. Two sampling locations were used in the emission testing program. At each sampling location (one at the scrubber inlet and one at the scrubber outlet), emissions testing was conducted for particulate matter, total chromium content, and hexavalent chromium content. Particulate and chromium sampling was also conducted at both sampling locations using the "medium volume" train under development by John Brown (EMB). 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 SCRUBBER INLET (SAMPLING LOCATION A)

Particulate matter, hexavalent chromium, and total chromium were measured at the inlet to the packed-bed scrubber controlling emissions from chromium plating tanks No. 1, 2, 3, and 7 as shown in Figure 4-2. One sampling port was installed on the side of the horizontal circular duct (36 inches in diameter). This port was located 20 inches (0.55 duct diameters) upstream of a bend in the duct to the scrubber and 37 inches (1.03 duct diameters) downstream from another bend. Because of the close proximity of potential flow disturbances, this location did not meet EPA Method 1 sampling requirements; however, there was no other location available for inlet testing. For the particulate testing, a

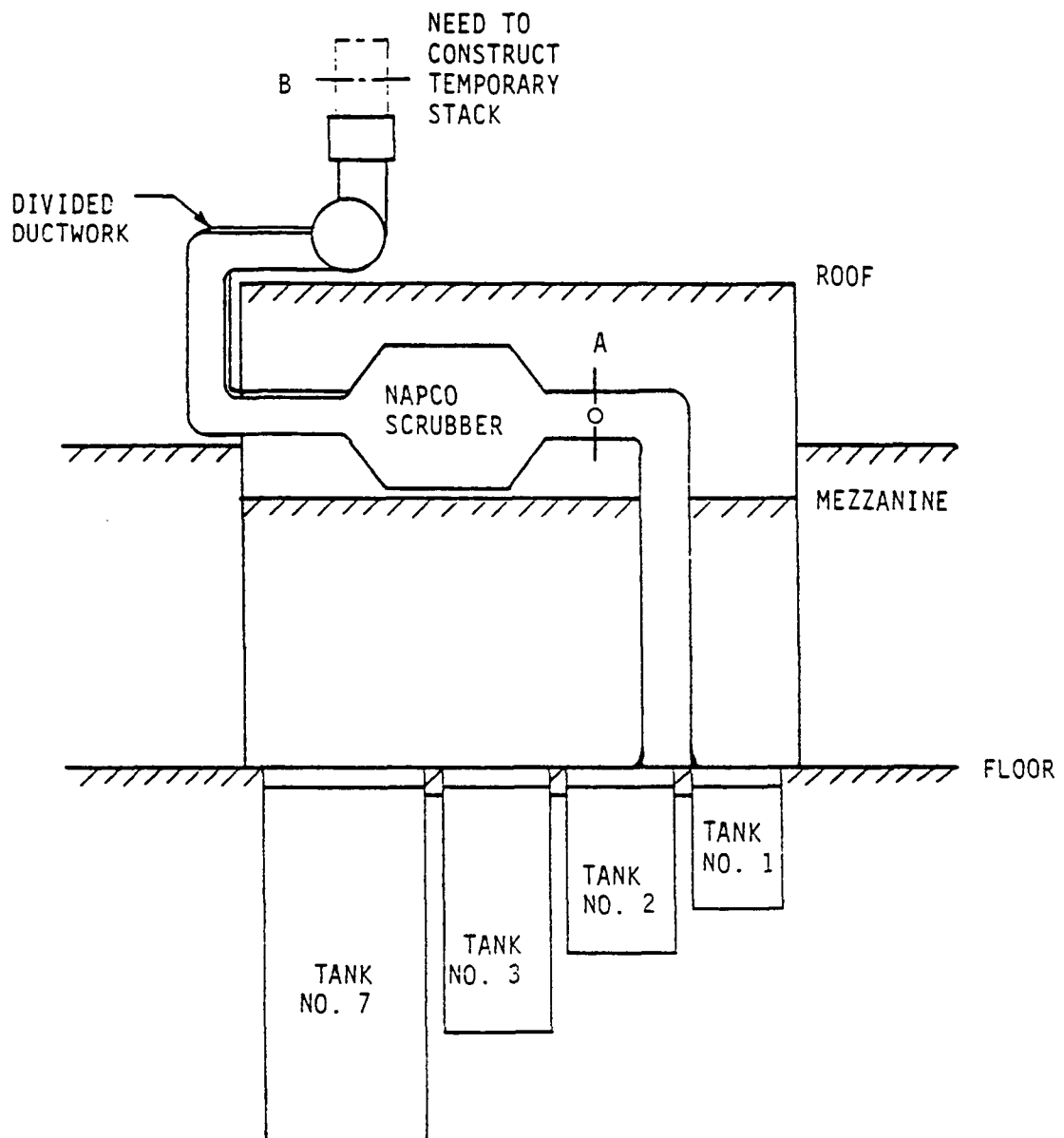


Figure 4-1. Simplified Process Air Flow Diagram of Chrome Plating Tanks and Emission Control Equipment at Carolina Plating.

TABLE 4.1. SAMPLING PLAN FOR CAROLINA PLATING

Sample Type	Sampling Locations	Number of Samples	Methods
Particulate matter	A, B	3 (M5) 2 (MV at A) 1 (MV at B)	EPA Method 5 or MV Train
Hexavalent chromium	A, B	3 (M5) 2 (MV at A) 1 (MV at B)	EPA 5 or MV Train using Tentative EPA Method for Hexavalent Chromium
Total chromium	A, B	3 (M5) 2 (MV at A) 1 (MV at B)	EPA 5 or MV Train using EPA Protocol for Total Chromium

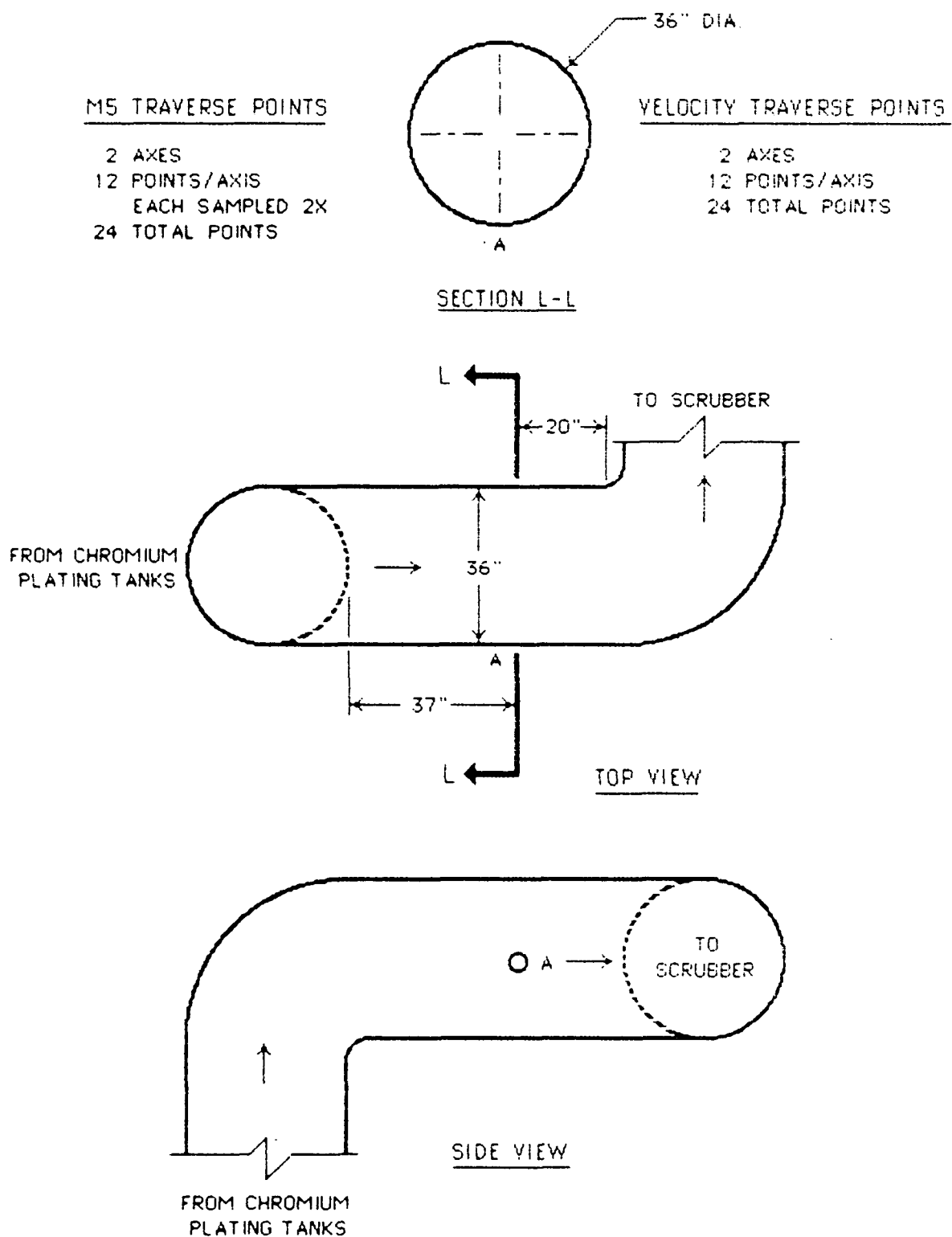


FIGURE 4-2. SCRUBBER INLET (SAMPLING LOCATION A)

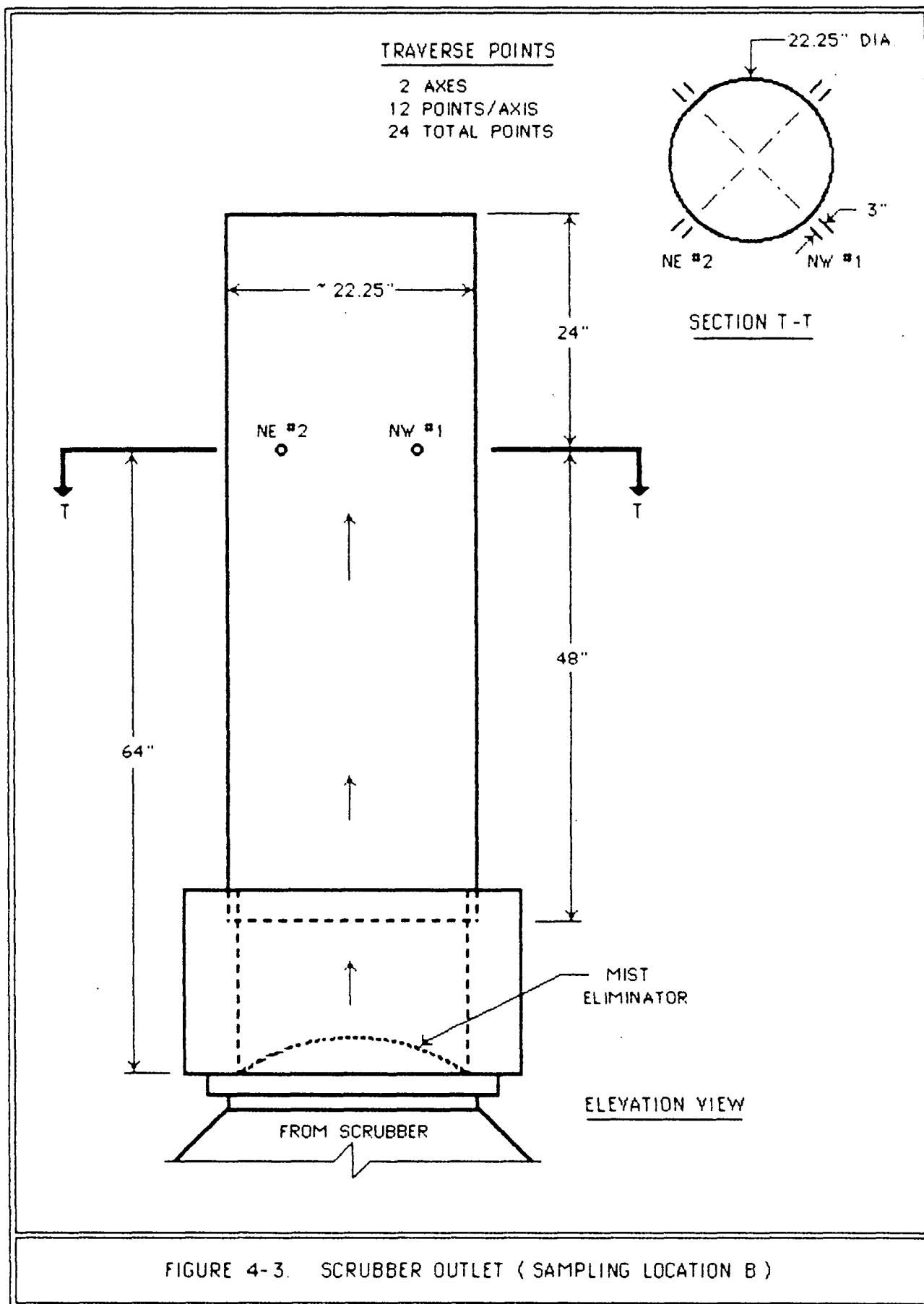
single traverse was chosen. This was because of the difficulty in gaining access to the duct and because the very fine acid mist particles in the duct would be expected to have the characteristics of a gas and thus, the cross-sectional distribution of the particles in the duct should be uniform. To check the cross-sectional flow distribution at this location, a pitot traverse was conducted along two axes through the single port. The axis perpendicular to the sampling axis was traversed by inserting the pitot tube through the available port at a predetermined angle for a predetermined distance, both of which were calculated geometrically.

For the Method 5 testing, (used for particulate matter, hexavalent chromium, and total chromium determinations), 24 points were sampled, 12 going into the port and 12 coming out of the port. Each of the 24 points was sampled for 12 minutes for a total of 288 minutes of sampling per run. Each of the three runs were conducted to coincide with the sampling at the scrubber outlet location.

"Medium volume" (MV) sampling, was also conducted at the scrubber inlet. The two runs were 485 and 735 minutes in duration and were each conducted at a single sampling point. To avoid interference between the two trains, the MV sampling was performed so as not to coincide with the Method 5 sampling.

4.2 SCRUBBER OUTLET (SAMPLING LOCATION B)

Particulate matter, hexavalent chromium, and total chromium were measured at the scrubber outlet as shown in Figure 4-3. Four sampling ports were installed 90° apart on the 22 3/16" diameter stack extension; however, only the NW and NE ports were used in this testing program. The ports were located about 24 inches (1.08 duct diameters) upstream from the stack exit and 64 inches (2.88 duct diameters) downstream from the mist eliminator.



For the EPA Method 5 sampling (used for particulate matter, hexavalent chromium, and total chromium determinations), a total of 24 points, as per Method 1, were sampled. Each point was sampled for 12 minutes for a total sampling time of 288 minutes. Because of the potential for cyclonic flow conditions (which are fairly common at scrubber outlet sampling locations), a preliminary traverse was conducted to determine the misalignment angles for each of the sampling points. The angles measured indicated that cyclonic flow was present; however, since the emissions were fumes and would be expected to behave like a gas, testing in the normal manner was considered to be less biased.

One sampling run was conducted at the outlet location using the MV sampling train. This run was 735 minutes in duration and was conducted at a single sampling point. As was done at the inlet location, the MV sampling was performed so as not to coincide with the Method 5 sampling.

4.3 VELOCITY AND GAS TEMPERATURE

A type S pitot tube and an inclined draft gauge manometer 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 calibrated Palmer bimetallic coil thermometer.

4.4 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.

4.5 PARTICULATE MATTER

Method 5, as described in the Federal Register,* was used to measure particulate grain loading at locations A and B. 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 79 mm (3 inch) diameter glass fiber filter (Reeve Angel), and a series of Greenburg-Smith impingers was employed for each test. An acetone rinse and a water rinse of the nozzle, probe, and filter holder portions of the sample train were made at the end of each test. The acetone rinse and the particulate caught on the filter media were dried at room temperature, the water rinse was taken to dryness in an oven; all three were then desiccated to a constant weight, and weighed on an analytical balance. Total filterable particulate matter was determined by adding these three values.

The "medium volume" (MV) sampling train was also used to measure particulate matter at locations A and B. MV sampling was conducted at a single sampling point. See Appendix C for detailed Method 5 and MV sampling procedures.

4.6 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. It was also used to determine the hexavalent chromium content of the MV sampling train filter catch and the impinger contents.

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

4.7 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 C). Samples collected during Method 5 runs and first submitted for analysis for hexavalent chromium were then analyzed for total chromium using this method. The total chromium content of the MV sampling train filter catch and the impinger contents were also determined using these procedures.

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. One such document used in this test program to ensure the collection of acceptable data and to provide a definition of unacceptable data was the EPA Quality Assurance Handbook Volume III, EPA-600/4-77-027.

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

- o Calibration of field sampling equipment (Appendix E).
- o Checks of train configuration and on calculations.
- o Use of designated analytical equipment and sampling reagents.

In addition, the analytical balance used for filter weighing by Entropy was audited with Class "S" weights.

Audit solutions prepared by the EPA were used to check the analytical procedures of the laboratories conducting the hexavalent and total chromium analyses. Table 5.1 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 5.1. AUDIT REPORT CHROMIUM ANALYSIS

Plant: Carolina Plating Task No.: 3018Date samples received: _____ Date analyzed: 6/14 - 6/17Sample analyzed by: RTI-DHReviewed by: Peter Grohse Date of review: _____

Sample Number	$\mu\text{g/ml}$ Cr^{+6} or Cr	Source of Sample	Audit Value	Relative Error, %
C-76	150 $\mu\text{g/ml}$ of Cr^{+6}	QAD	149 $\mu\text{g/ml}$	- 0.7 %
(GA-22) C-239	10 μg of Cr	QAD	10.88 μg	+ 8.8 %
(GA-23) C-240	450 μg of Cr	QAD	412.5 μg	- 8.3 %