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AFOEHL REPORT 89-048EQ0094FEF

Compliance Testing of the Phosphoric Acid Anodizing Line Wet Scrubber, Metal Bonding Facility, Building 375, Kelly AFB TX

JAMES A. GARRISON, Maj, USAF, BSC

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Final Report

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19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

At the request of HQ SA-ALC/EM, personnel of the AFOEHL Air Quality Function conducted source emission testing of the exhaust from the phosphoric acid anodizing tank line, metal bonding facility, Bldg 375, Kelly AFB TX. The survey was conducted to satisfy special conditions of Texas Air Control Board (TACB) Permit Exemption X-16361 which required determination of phosphoric acid, sulfuric acid, total chromium and hexavalent chromium emissions from the wet scrubber control device on the anodizing line exhaust system. TACB will analyze the emission results and make the final determination as to whether additional control is needed on the anodizing line exhaust. Keywords: air pollution; pollution abatement; (KT)

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Illustration

I. INTRODUCTION

On 5-6 Jan 89 and 9-10 Jan 89 source emission testing was accomplished on the exhaust from the phosphoric acid anodizing tank line, a system within the metal bonding facility located in Building 375, Kelly AFB TX. Testing was performed by the Air Quality Function, Consultant Services Division, the Air Force Occupational and Environmental Health Laboratory (AFOEHL/ECQ). The survey was conducted to satisfy Special Conditions of Texas Air Control Board (TACB) Permit Exemption X-16361 which required determination of phosphoric acid (H_3PO_4), sulfuric acid (H_2SO_4), total chromium (Cr) and hexavalent chromium (Cr^{+6}) emissions from the wet scrubber control device on the anodizing line exhaust system. Personnel involved with on-site testing are listed in Appendix A.

II. DISCUSSION

A. Background

On 19 Sep 1988, HQ SA-ALC/EM, Kelly AFB TX requested source emissions testing of the exhaust from the phosphoric acid anodizing tank line. The requirement for testing was generated by a Notice of Violation (NOV) received from TACB for not demonstrating compliance with TACB Rule 116.4 of Texas Air Control Board Regulation VI (31 Texas Administrative Code, Chapter 116), Control of Air Pollution by Permits for New Construction or Modification (Appendix B) and Special Condition #1 of Permit Exemption X-16361 (Appendix C). Rule 116.4 requires that holders of permits and/or exemptions shall comply with any and all special conditions contained therein. Special Condition #1 requires stack sampling and other testing as needed to establish the actual pattern and quantities of air contaminants being emitted into the atmosphere from the exhaust system.

B. Site Description

The phosphoric anodizing line is used to prepare aluminum skins for bonding operations. The line consists of a series of eight (8) tanks through which the aluminum skins are sequentially processed (one part is processed through the entire line before the next one is started). A process diagram of the line is shown in Figure 1. A description of the line follows (times are approximate):

1. Tank #1, Degreaser Tank: Contains 110 gallons of perchloroethylene maintained at 240°F. Skins remain in the tank for 15 minutes.

2. Tank #2, Alkaline Cleaning Tank: Contains 1,778 gal of Isoprep #44, a mildly alkaline cleaning solution which acts as a pre-cleaner prior to the anodizing process. The solution is maintained at 135°F and parts remain in the tank for 15 minutes. Isoprep contains: (1) sodium salts of borates, phosphates, silicates, carbonates and sulfates and (2) soap and synthetic detergents.

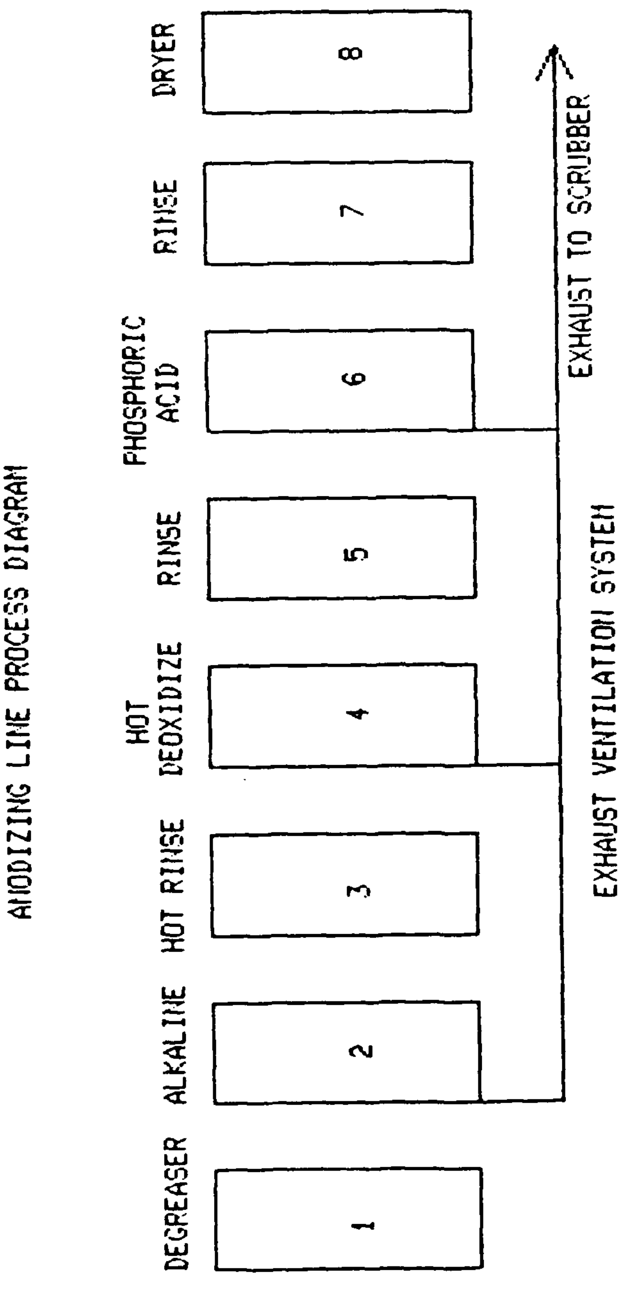

ANODIZING LINE PROCESS DIAGRAM
DEGREASER
1
ALKALINE
2
HOT RINSE
3
HOT DEOXIDIZE
4
RINSE
5
PHOSPHORIC ACID
6
RINSE
7
DRYER
8
EXHAUST VENTILATION SYSTEM
EXHAUST TO SCRUBBER

Figure 1

3. Tank #3, Hot Rinse Tank: Parts are washed with water at room temperature (approximately 74°F) for 15 minutes.

4. Tank #4, Hot Deoxidize Tank: Contains 1,778 gal of a mixture of sulfuric acid, sodium dichromate and deionized water which acts as another pre-cleaner prior to the anodizing process. This solution actually etches the surfaces of the aluminum parts. The mixture is maintained at 150 ± 10°F and parts remain in the tank for 25 minutes.

5. Tank #4, Rinse Tank: Parts are washed with water at room temperature for 15 minutes.

6. Tank #6, Phosphoric Acid Anodize Tank: Contains 1,778 gallons of phosphoric acid and water. The solution is maintained at 77°F and parts remain in the tank for 25 minutes. An electrical potential of 15 volts dc is impressed across the part; amperage varies according to the size of the part.

7. Tank #7, Final Rinse Tank: Parts are washed with water at room temperature for 15 minutes.

8. Tank #8, Dryer tank: Parts are dried with 160°F air until completely dry.

Figure 2 provides a view of the anodizing line showing the various tanks which make up the system. Figure 3 shows an aluminum skin similar to the ones processed during emissions testing. The part measures approximately 3x6 feet on edge and 0.02 inches thick.

Emissions control equipment consists of a wet scrubber and the associated exhaust stack and support structure located outside Building 375. The main component of the scrubber system is the COLAG (Contact of Liquid And Gas) Mist, Vapor and Fume Collector, Size 252, manufactured by American Air Filter. A diagram of the COLAG showing its main components is presented in Figure 4. Figures 5 and 6 provide an overall view of the scrubber system and a closeup of the COLAG unit, respectively.

The COLAG uses a set of scrubbing pads to clean the contaminated air stream. Air enters the unit at a high velocity and is distributed over the inlet to the scrubber section by a perforated plate. Water is supplied to the plate through nine metering valves and is entrained in the air stream and carried up to the reaction pad. The reaction pad becomes completely flooded with water, thus providing a liquid-gas contact surface which scrubs the exhaust gases. Water droplets passing through the reaction pad impinge on the sloped eliminator pads. Contaminated water from the eliminator pads is channeled to internal drains and out of the unit to a storage tank. Figure 7 shows the reaction and eliminator pads through a transparent acrylic observation window in the COLAG. The COLAG is equipped with a fiberglass reinforced plastic stack which contains an inline centrifugal blower rated at 20,000 cubic feet per minute (CFM) at a pressure drop across the blower of 9 inches of water pressure. The motor which drives the blower is rated at 50 horsepower (hp) and 1750 revolutions per minute (RPM). This blower provides the exhaust capacity for the anodizing tank line exhaust system.

FIGURE 2. VIEW OF ANODIZING LINE

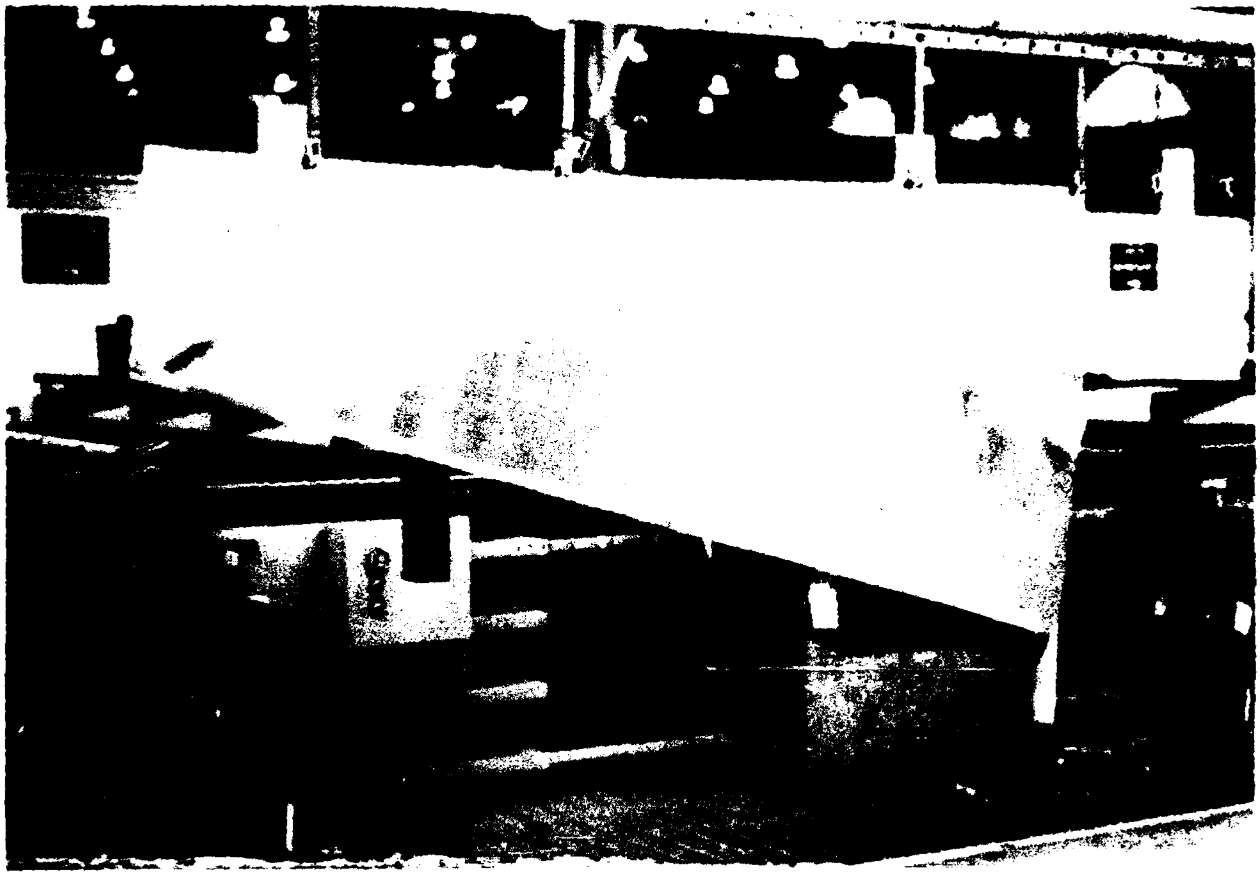


FIGURE 3. TYPICAL ALUMINUM SKIN

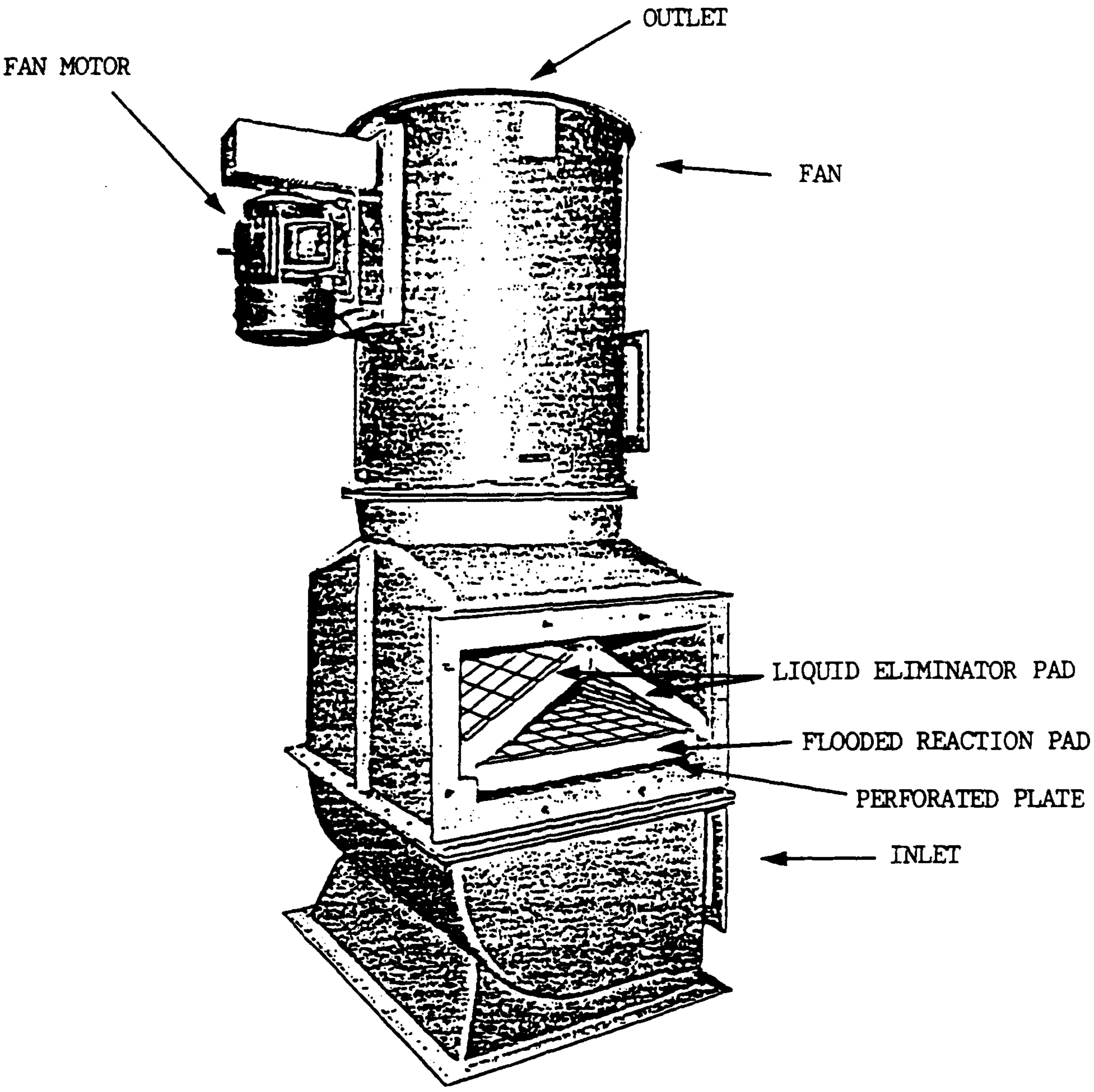


FIGURE 4. COLAG MIST, VAPOR AND FUME COLLECTOR

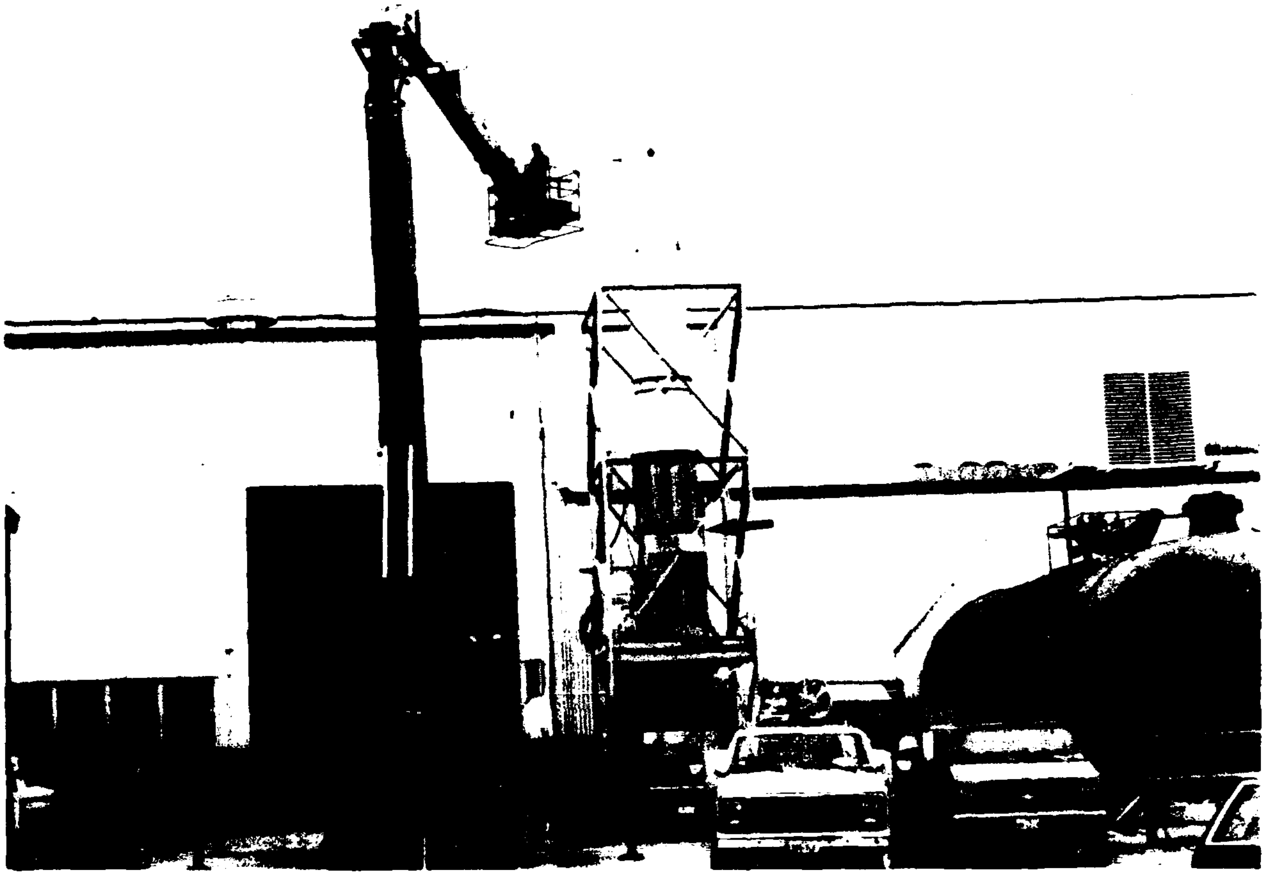


FIGURE 5. VIEW OF COLAG

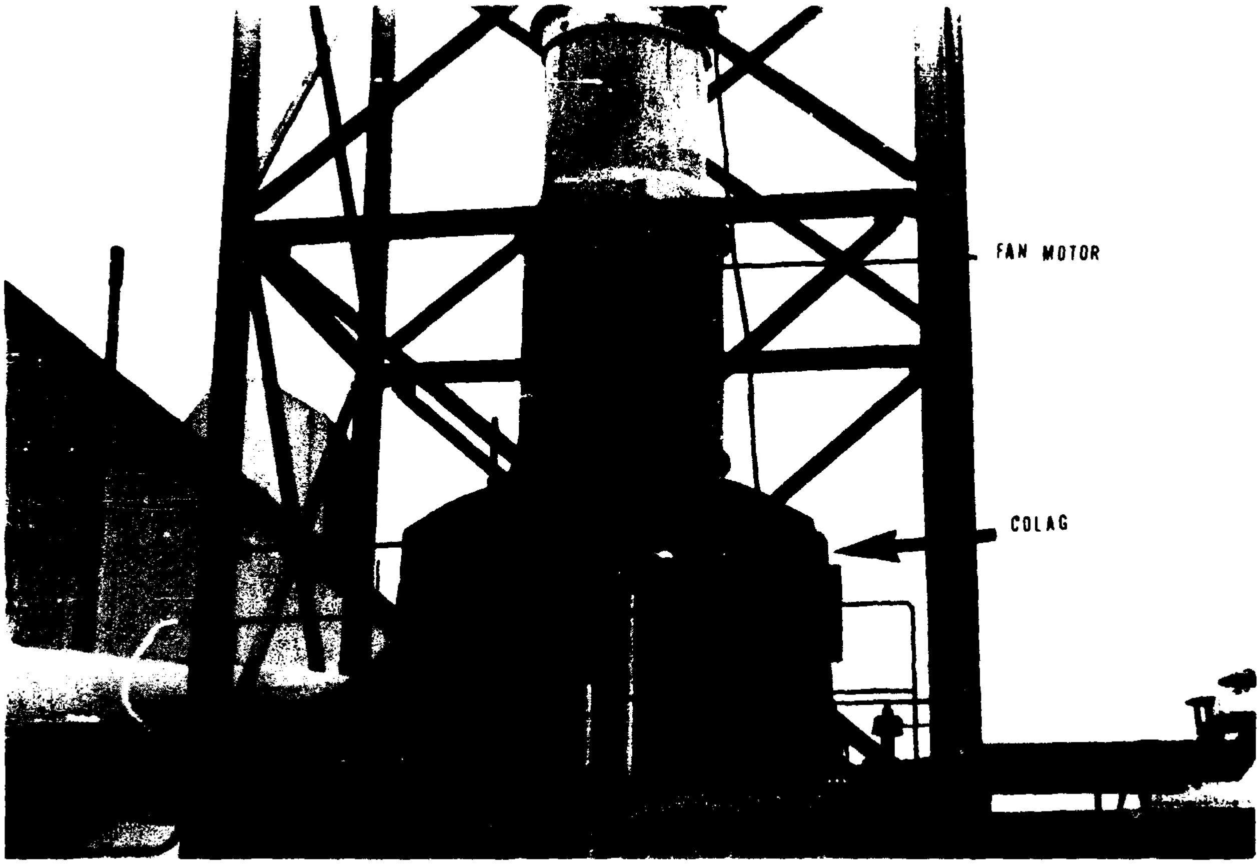


FIGURE 6. VIEW OF SCRUBBER DURING TESTING
(ARROW INDICATES COLAG)

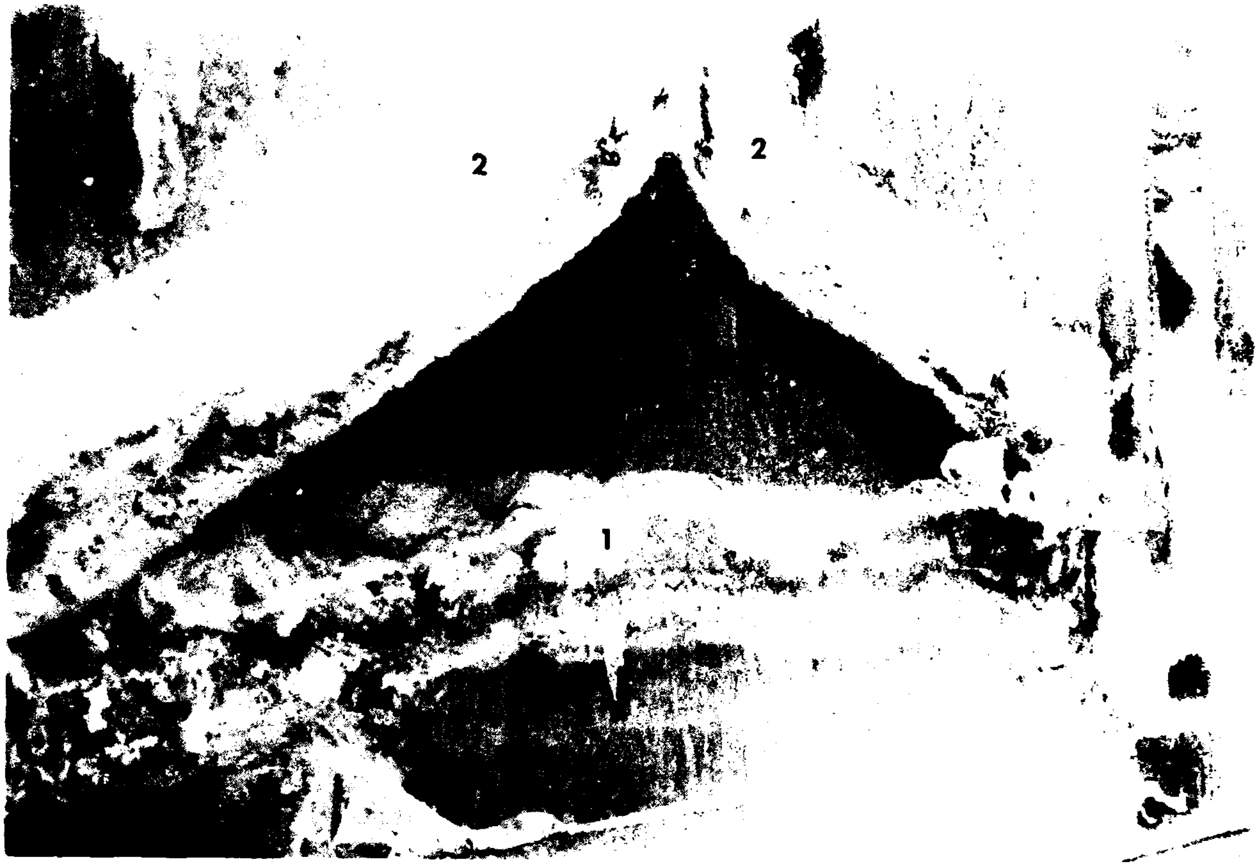


FIGURE 7. VIEW OF REACTION (1) AND ELIMINATOR (2) PADS THROUGH TRANSPARENT OBSERVATION WINDOW

C. Applicable Standards

Regulations governing allowable emissions of sulfuric acid are defined under Texas Regulation II (31 TAC Chapter 112) - Control of Air Pollution from Sulfur Compounds, Paragraph 112.41 (Appendix D). Regulations state that emissions of sulfuric acid from a source will not exceed: (1) a net ground level concentration of 15 micrograms per cubic meter ($\mu g/m^3$) of air averaged over any 24-hour period, (2) a net ground level concentration of 50 $\mu g/m^3$ of air averaged over a 1-hour period of time more than once during any consecutive 24-hour period or 100 $\mu g/m^3$ of air maximum at any time. The TACB uses a dispersion model to determine ambient concentrations based on the pollutant emission rate from the source.

There are no published standards for ambient concentrations of phosphoric acid, total chromium and hexavalent chromium. To determine an acceptable ambient concentration for these pollutants, the assigned TACB permit engineer determines the ground level concentration and provides this data to a health effects group. The health effects group then provides feedback as to the associated health risk. Based on the risk assessment, a determination is made as to what, if any, additional controls are needed on the emission source.

D. Test Methods and Procedures

Test methods, equipment, sample train preparations, sampling and recovery, calibration requirements and quality assurance were done in accordance with the applicable methods and procedures outlined in 40 CFR 60, Appendix A. A performance test consisted of three test runs of 96 minutes each (test 1 on 5 Jan was 120 min) for each of the pollutants of concern. The results of the three runs were averaged for a final emission value.

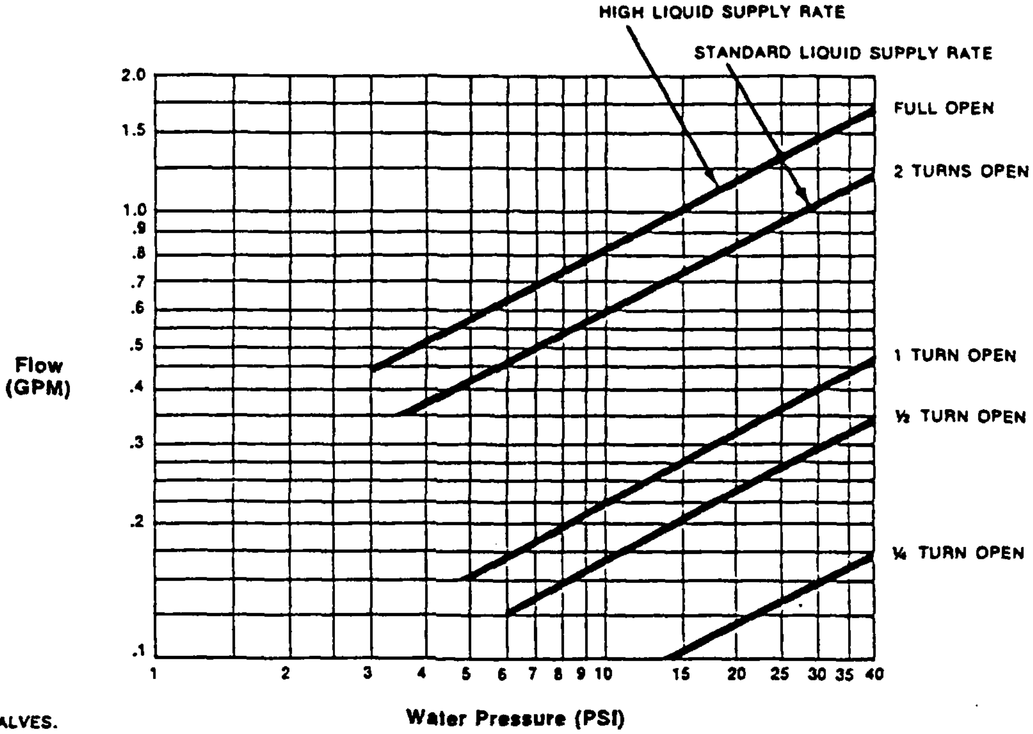
1. Anodizing Line/Scrubber Operation

a. The line was operated in a normal day-to-day mode with one part sequenced through the process at any one time. The time required to process one part was initially assumed to be approximately 120 minutes (min) which is the summation of times required for the subprocesses described in Paragraph B. However, after the first aluminum skin was processed through the anodizing line for emissions testing on 5 Jan, we determined that 96 minutes was the actual process time. Therefore, except for the first test run on 5 Jan, all test runs were 96 minutes long.

b. All tank temperatures were maintained at the levels described in Paragraph B.

c. Water supply rate to the COLAG is controlled by the water supply pressure and the positioning of the nine metering valves controlling water to the perforated plate. During testing, the water pressure was 20.5 pounds per square inch (psi) and the metering valves were opened greater than two turns. Based on the Liquid Flow Rate Curve supplied by the manufacturer (Figure 8), water supply rate to the unit was determined to be approximately 11 gallons per minute (gpm).

COLAG Size	21	42	84	168	252	336	504
Number of Valves	1	1	3	6	9	8	12



NOTES:

1. FOR IMPERIAL VALVES.
2. ON UNITS WITH MULTIPLE VALVES, ALL VALVES MUST BE OPENED AN EQUAL NUMBER OF TURNS UNTIL DESIRED PRESSURE/FLOW IS ATTAINED.

FIGURE 8. LIQUID FLOW RATE CURVE

d. Pressure drop across the scrubber was measured at pressure taps located on the inlet and outlet sides of the scrubber portion of the COLAG. These points are indicated by the arrows in Figure 9. The inlet and outlet pressures were -1.8 inches of water ("H_2O) and -8.8 "H_2O, respectively. The pressure drop across the scrubber during testing was 7.0 "H_2O.

2. Preliminary Procedures

Sampling ports had to be installed on the scrubber stack prior to testing and were located 0.6 stack diameters upstream from the stack exit and greater than 4.0 stack diameters downstream from any disturbance (straightener vanes downstream from blower). Based on a 48 inch inside stack diameter, port location and type of sampling (particulate), a total of 24 traverse points were determined for emission evaluation. The sampling time for the first test run on 5 Jan was 120 minutes; therefore, the sampling time for each point in the scrubber stack was 5 minutes. The sampling time for all subsequent test runs was 96 minutes with the sampling time for each point being 4 minutes. An illustration showing port locations and sampling points is provided in Appendix E.

Prior to the initial sample run on the stack, cyclonic flow was determined. For acceptable flow conditions to exist in a stack, the average of the absolute value of the flow angle taken at each traverse point must be less than or equal to 20 degrees. The flow angle in the scrubber stack averaged 39 degrees which indicated an unacceptable flow condition. Straightening vanes were constructed and installed directly above the blower which brought the average flow angle to 6 degrees. Cyclonic flow results are provided in Appendix E. Prior to each test, a preliminary velocity pressure and temperature traverse was accomplished in order to size the sampling nozzle and ensure isokinetic sampling.

3. Sampling Equipment

Particulate samples were collected using variations of the EPA Method 5 sampling train shown in Figure 10. The standard train consists of a buttonhook probe nozzle, heated glass probe, heated glass filter, impingers and a pumping and metering device. The nozzle is sized prior to each sample run so that the gas stream can be sampled isokinetically; in other words, the velocity at the nozzle tip is the same as the stack gas velocity at each point sampled (if the percent of isokinetic sampling is greater than 90% and less than 100% results are acceptable). Flue gas velocity pressure is measured at the nozzle tip using a Type-S pitot tube connected to a 10 inch inclined-vertical manometer. Type K thermocouples are used to measure flue gas as well as sampling train temperatures. The probe is heated to minimize moisture condensation. The heated filter is used to collect particulate materials. The impinger train (first, third and fourth impingers: modified Greenburg-Smith type, second impinger: standard Greenburg-Smith design) is used as a condenser to collect stack gas moisture as well as hold pollutant collection media. The pumping and metering system is used to control and monitor the sample gas flow rate.

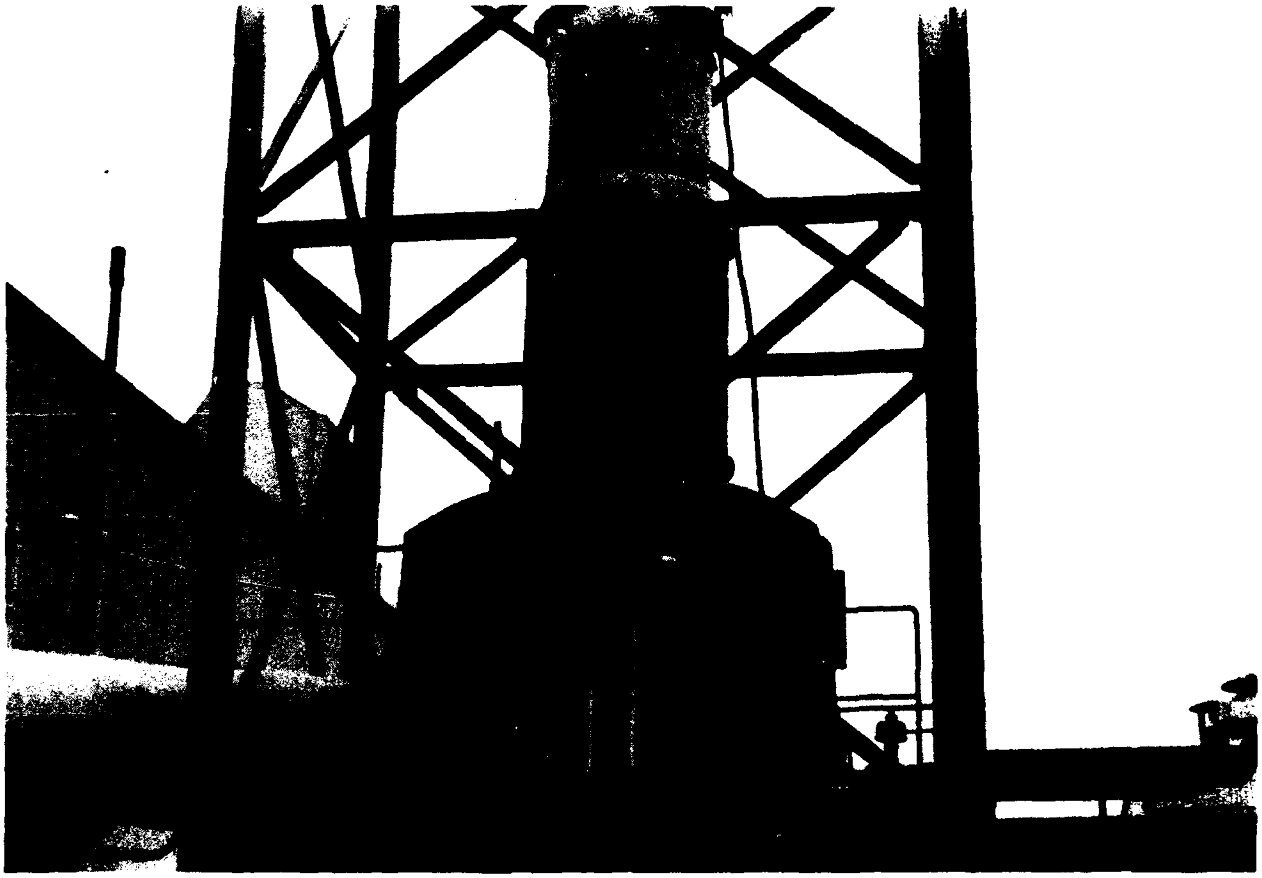


FIGURE 9. VIEW OF COLAG SHOWING LOCATION OF STATIC PRESSURE TAPS

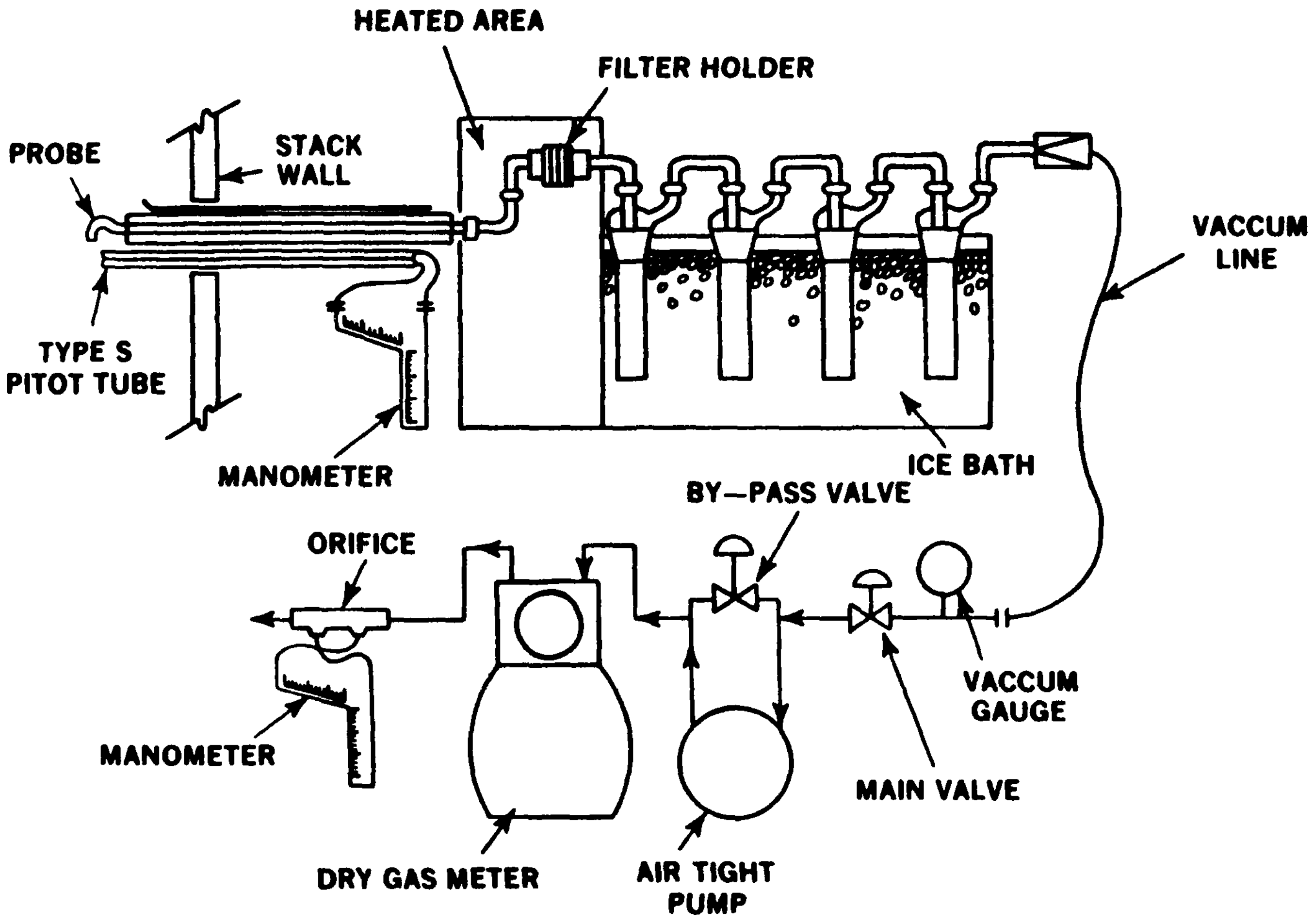


FIGURE 10. EPA METHOD 5 SAMPLING TRAIN

Since exhaust gas was essentially conditioned air from inside Building 375, molecular weight was assumed to be 29. No ORSAT apparatus was used to determined stack gas molecular weight.

4. Test Procedure

Since emissions were considered to be particulate or aerosol in nature, our sampling strategy utilized EPA Method 5 sampling procedures and equipment except when modified for the particular pollutant of concern. Any modifications that were made are discussed under the test procedures discussed below. A complete test for each of the pollutants comprised three complete sample runs. The final emission value for each pollutant was the average of the results of emissions obtained for each of the three sample runs.

a. Phosphoric acid

The Method 5 sampling train was modified by removing the particulate filter between the probe and the first impinger. The modified train is shown in Figure 11. The distilled water used in the first two impingers of the Method 5 train was used as the collection media for phosphates as well as for collecting stack gas moisture. The nozzle, probe liner and glassware before the first impinger and between impingers was washed with the distilled water. The impinger media and wash were combined and analyzed for phosphates by ion chromatography. A blank sample of distilled water used as the collection media was also analyzed for phosphates.

b. Sulfuric Acid (H_2SO_4)

EPA Method 8, "Determination of Sulfuric Acid Mist and Sulfur Dioxide Emissions from Stationary Sources," was used for determining H_2SO_4 emissions. This test method is found in Appendix A to Title 40, Code of Federal Regulations, Part 60 (40 CFR 60). The first impinger contained 100 ml of 80 percent isopropanol solution (isopropanol and distilled water), the collection media for H_2SO_4. Since sulfur dioxide (SO_2) was not of concern, we modified the train by replacing impingers 2 and 3 which contained the SO_2 collection media (hydrogen peroxide) with the following:

(1) impinger 2: Modified type impinger containing 100 milliliters (ml) of distilled water.

(2) impinger 3: Modified type impinger, empty.

The Method 8 sampling train is shown in Figure 12.

We used an average stack gas moisture content based on moisture determinations from the nine test runs for the other three pollutants. The percent moisture content did not differ significantly during any of the test runs (moisture percent ranged from 1.4 - 2.8% with an average of 1.6%). All other Method 8 test methods and procedures were followed. Samples were analyzed using the barium perchlorate titration method described in Method 8.

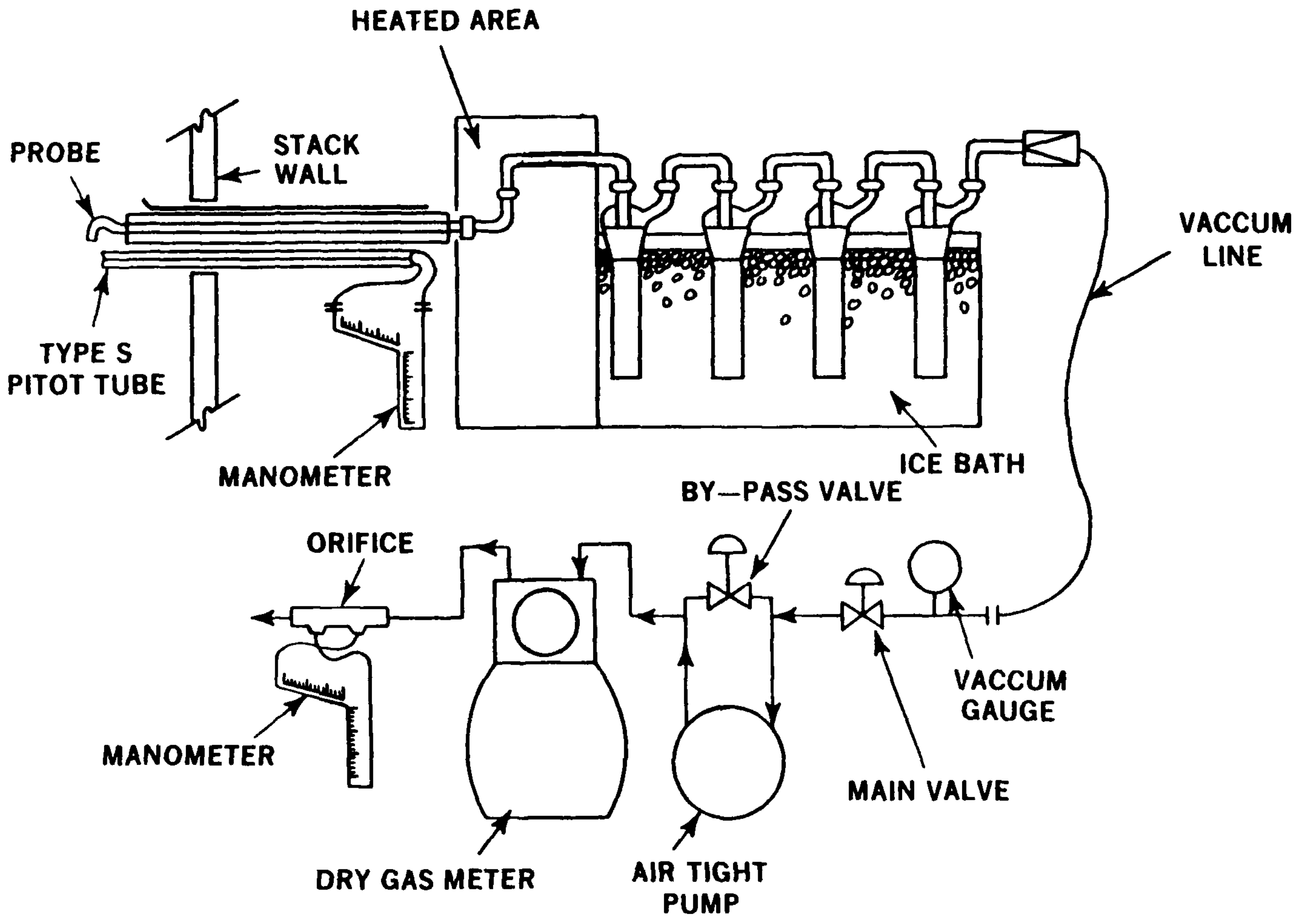


FIGURE 11. PHOSPHORIC ACID SAMPLING TRAIN

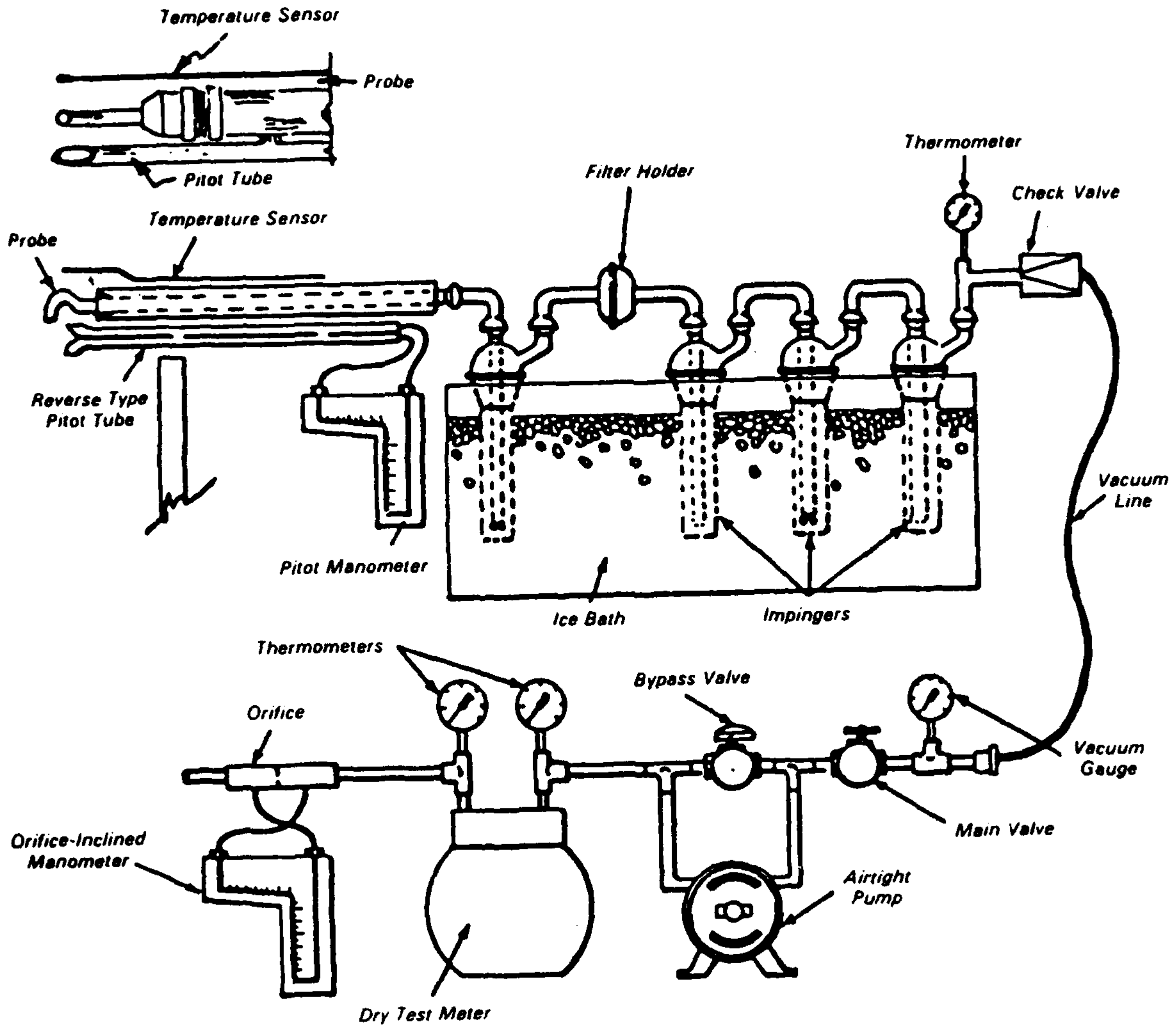


FIGURE 12. SULFURIC ACID (METHOD 8) SAMPLING TRAIN

c. Total Chromium

Sampling for total chromium was accomplished according to the procedures provided in Appendix F with respect to "very low chromium levels" using the "impinger sampling train" which is the Method 5 train modified by removing the heated glass filter (Figure 11). Prior to testing, the nozzle, probe and impingers were rinsed with 0.1 N nitric acid (HNO_3) followed by distilled water to remove any residual chromium. The collection media in the first two impingers was 0.1 N HNO_3. A collection media blank was subjected to the same preparation and analysis as the sample. Probe and glassware rinses were done with the same solution as in the impingers. The impinger collection media was combined with the probe and glassware rinse for final analysis. Graphite furnace atomic absorption was used for determining total chromium.

d. Hexavalent Chromium

Sampling for hexavalent chromium was accomplished according to the procedures provided in Appendix F with respect to "very low hexavalent chromium levels" using the "impinger sampling train" which is the Method 5 train modified by removing the heated glass filter (Figure 11). Prior to testing, the nozzle, probe and impingers were rinsed with 0.1 N HNO_3 followed by distilled water to remove any residual chromium. The collection media in the first two impingers was 0.1 N sodium hydroxide (NaOH). A collection media blank was subjected to the same preparation and analysis as the sample. Probe and glassware rinses were done with the same solution as in the impingers. The impinger collection media was combined with the probe and glassware rinse for final analysis. Graphite furnace atomic absorption was used for determining hexavalent chromium.

III. CONCLUSION

Field survey data are presented in Appendixes G-J. Laboratory results and isokinetic and emissions calculations for each sample run are presented in Appendixes K and L, respectively. Emissions calculations were done using "Source Test Calculation and Check Programs for Hewlett-Packard 41 Calculators" (EPA-340/1-85-018) developed by the EPA Office of Air Quality Planning and Standards, Research Triangle Park NC. This is our standard method for calculating emissions data. Equipment calibration data is presented in Appendix M.

Neither phosphoric acid nor sulfuric acid was detected in any of the three runs. Total chromium emission rates averaged .002 lb/hr. Hexavalent chromium was being emitted at an average rate of 0.001 lb/hr.

Table 1 provides operating and testing parameters for the scrubber stack during testing along with the resultant pollutant emission rates determined from these tests. TACB will use the emission results provided in Table 1 to make the final determination as to whether additional control is needed on the anodizing line exhaust.

IV. RECOMMENDATION

The AFOEHL Air Quality Function will continue to provide consultant services regarding this project as requested by HQ SA-ALC/EM.

TABLE 1
STACK EMISSIONS TEST RESULTS

PHOSPHORIC ACID

DATE	RUN #	STACK TEMP (deg F)	STACK FLOWRATE (dscfm)*	% ISOKINETIC	TOTAL CATCH (ug)**	EMISSION RATE (lb/hr)
5 JAN 89	1	73	17644	96.9	ND	-
5 JAN 89	2	74	17706	96.4	ND	-
6 JAN 89	3	64	18031	94.0	ND	-

SULFURIC ACID

DATE	RUN #	STACK TEMP (deg F)	STACK FLOWRATE (dscfm)*	% ISOKINETIC	TOTAL CATCH (ug)**	EMISSION RATE (lb/hr)
6 JAN 89	1	70	18418	92.9	ND	-
6 JAN 89	2	72	18092	93.2	ND	-
6 JAN 89	3	73	17871	94.8	ND	-

TOTAL CHROMIUM

DATE	RUN #	STACK TEMP (deg F)	STACK FLOWRATE (dscfm)*	% ISOKINETIC	TOTAL CATCH (ug)**	EMISSION RATE (lb/hr)
9 JAN 89	1	60	19004	93.3	5.18	0.002
9 JAN 89	2	61	18895	93.9	2.12	0.001
9 JAN 89	3	60	18401	93.1	11.94	0.004
						AVG = 0.002

HEXAVALENT CHROMIUM

DATE	RUN #	STACK TEMP (deg F)	STACK FLOWRATE (dscfm)*	% ISOKINETIC	TOTAL CATCH (ug)**	EMISSION RATE (lb/hr)
10 JAN 89	1	60	17569	94.2	1.92	0.001
10 JAN 89	2	62	17228	92.3	3.61	0.001
10 JAN 89	3	62	18015	94.1	1.49	0.001
						AVG = 0.001

* dscfm = dry standard cubic feet per minute

** ug = micrograms
ND = none detected

REFERENCES

1. "Standards of Performance for New Stationary Sources", Title 40, Part 60, Code of Federal Regulations, July 1, 1987.

2. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume III, Stationary Source Specific Methods, U.S. Environmental Protection Agency, EPA-600/4-77-027-b, Research Triangle Park, North Carolina, December 1984.

3. Source Test Calculation and Check Programs for Hewlett-Packard 41 Calculators. U.S. Environmental Protection Agency, EPA-340/1-85-018, Research Triangle Park, North Carolina, May 1987.

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APPENDIX A
Personnel Information

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1. AFOEHL Test Team

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Capt Ronald Vaughn, Consultant, Air Quality Engineer
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Mr Jerry Bingham, HQ SA-ALC/EM
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Mr Miguel Juarez, HQ SA-ALC/MABPSP
Mr David Mann, HQ SA-ALC/MABPSP
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Ms Valerie Haris, Texas Air Control Board
San Antonio TX

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APPENDIX B
Texas Air Control Board Rule 116.4

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TEXAS REGULATION VI: CONTROL OF AIR POLLUTION BY PERMITS FOR NEW CONSTRUCTION OR MODIFICATION

(Texas Administrative Code, Title 31, Natural Resources and Conservation, Part III, Air Control Board, Chapter 116 — Control of Air Pollution by Permits for New Construction or Modification; Adopted April 21, 1971, effective June 18, 1971; Amended effective March 5, 1972; August 21, 1972; April 27, 1975; February 12, 1978; September 30, 1978; May 6, 1979; November 25, 1979; August 22, 1980; April 16, 1981; January 1, 1983; July 14, 1983; March 15, 1985; Corrected August 23, 1985; Amended effective August 28, 1985; October 21, 1985; November 25, 1985; October 2, 1986; November 5, 1986; August 20, 1987; September 24, 1987; January 27, 1988; May 4, 1988; August 30, 1988)

§116.1. Permit.

(a) Any person who plans to construct any new facility or to engage in the modification of any existing facility which may emit air contaminants into the air of this state must obtain a permit to construct pursuant to §116.3(a) of this title (relating to Consideration for Granting Permits to Construct and Operate) or pursuant to §116.7 of this title (relating to Special Permits) or satisfy the conditions for exempt facilities pursuant to §116.6 of this title (relating to Exempted Facilities) before any actual work is begun on the facility. If a permit to construct is issued by the board, the person in charge of the facility must apply for an operating permit pursuant to §116.3(b) of this title (relating to Consideration for Granting Permits to Consideration for Granting Permits to Construct and Operate) within 60 days after the facility has begun operation, unless this 60-day period has been extended by the executive director.

(b) The new owner of a facility which previously has received a permit or special permit from the Texas Air Control Board (TACB) shall not be required to apply for a new permit or special permit and the change of ownership shall not be subject to the public notification requirements of this chapter, provided that within 30 days after the change of ownership the new owner notifies the TACB of the change. The notification shall include a certification of the following:

(1) the ownership change has occurred and the new owner will comply with all conditions and provisions of the permit or special permit and all representations made in the application for permit or special permit and any amendments thereto;

(2) there will be no change in the type of pollutants emitted; and

(3) there will be no increase in the quantity of pollutants emitted.

§116.2 Responsibility for Obtaining Permit or Exemption. The owner of the facility or operator of the facility authorized to act for the owner is responsible for complying with §116.1 of this title (relating to Permit Requirements).

§116.3. Consideration for Granting Permits to Construct and Operate.

(a) Permit to construct. In order to be granted a permit to construct, the owner or operator of the proposed facility shall submit information to the Texas Air Control Board, which will demonstrate that all of the following are met:

(1) The emissions from the proposed facility will comply with all rules and regulations of the Texas Air Control Board and with the intent of the Texas Clean Air Act, including protection of the health and physical property of the people. In considering the issuance of a permit for construction or modification of any facility within 3,000 feet or less of an elementary, junior high, or senior high school, the TACB shall consider any possible adverse short-term or long-term side effects that an air contaminant or nuisance odor from the facility may have on the individuals attending these school facilities.

(2) the proposed facility will have provisions for measuring the emission of significant air contaminants as determined by the Executive Director.

(3) The proposed facility will utilize the best available control technology, with consideration given to the technical practicability and economic reasonableness of reducing or eliminating the emissions from the facility.

(4) The emissions from the proposed facility will meet at least the requirements of any applicable new source performance standards promulgated by the Environmental Protection Agency pursuant to authority granted under section 111 of the Federal Clean Air Act, as amended.

(5) The emissions from the proposed facility will meet, at least, the requirements of any applicable emission standard for hazardous air pollutants promulgated by the Environmental Protection Agency pursuant to authority granted under Section 112 of the Federal Clean Air Act as amended.

(6) The proposed facility will achieve the performance specified in the application for a permit to construct. The applicant may be required to submit additional engineering data after a permit to construct has been issued in order to demonstrate further that the proposed facility will achieve the performance specified in the application for a permit to construct.

(7) All requirements of Section 129(a)(1) of the Clean Air Act Amendments of 1977

(Public Law 95-95). This provision shall not apply to new or modified facilities for which construction permits are issued after June 30, 1979.

(8) After June 30, 1979, the owner or operator of a proposed new facility which is a major stationary source of volatile organic compound emissions or which is a facility that will undergo a major modification with respect to VOC emissions and which is to be located in any area designated as nonattainment for ozone in accordance with Section 107 of the Federal Clean Air Act shall demonstrate that the following additional requirements are met:

(A) The proposed facility will comply with the lowest achievable emissions rate (LAER) as defined in the General Rules.

(B) All major stationary sources owned or operated by the applicant (or by any person controlling, controlled by, or under common control with the applicant) in the state are in compliance or on a schedule for compliance with all applicable state and federal emission limitations and standards.

(9) After June 30, 1979, the owner or operator of a proposed new facility which is a major stationary source of volatile organic compounds (VOC) or which is a facility that will undergo a major modification with respect to VOC emissions, and which is to be located in Dallas, El Paso, Harris, Nueces, or Tarrant County will provide information concerning his expected emissions to enable the executive director to determine that by the time the facility is to commence operation, total allowable emissions from existing facilities, from the proposed facility, and from new or modified facilities which are not major sources in the area will be sufficiently less than the total emissions from existing sources allowed in the area under the applicable State Implementation Plan (SIP) as promulgated by the administrator of the U.S. Environmental Protection Agency in 40 Code of Federal Regulations, Part 52, Subpart SS, prior to the application for the construction permit so as to represent reasonable further progress as defined in Chapter 101 of this title (relating to General Rules).

(10) The owner or operator of the proposed facility which is a major stationary source of VOC emissions or will undergo a major modification and is to be located in any area designated as nonattainment for ozone in accordance with Section 107 of the Federal Clean Air Act for which regulations and a control strategy providing for attainment of the standard have not been adopted by the U.S. Environmental Protection Agency shall demonstrate that at the time that the facility is to commence operation, a net decrease in total allowable VOC emissions in the area has been provided, taking into account any increases in emissions resulting from operation of the proposed new facility or modification.

(11) After June 30, 1979, the owner or operator of a proposed new facility to be located anywhere within the state that is a major stationary source of emissions of any air contaminant (other than volatile organic compounds-VOC) for which a national ambient air quality standard has been issued, or is a facility that will undergo a major modification with respect to emissions of any air contaminant (other than VOC), must meet the following additional requirements if the source's emissions would exceed a de minimis impact level as defined in §101.1 of the general rules (relating to definitions) in any area where the standard is exceeded or predicted to be exceeded.

(A) The proposed facility will comply with the lowest achievable emissions rate (LAER) as defined in the General Rules.

(B) All major stationary sources owned or operated by the applicant (or by any person controlling, controlled by, or under common control with the applicant) in the state are to be in compliance or on a schedule for compliance with all applicable state and federal emission limitations and standards.

(C) By the time the facility is to commence operation, total allowable emissions from existing facilities which have more than a de minimis impact on air quality in the same area as the proposed faciity, from the proposed facility, and from new or modified facilities which are not major sources but which will significantly contribute to a predicted or existing exceedance of the standard in the same area as the proposed facility will not cause the national ambient air quality standard for that contaminant to be exceeded at any location and will not significantly contribute to any existing exceedance at any location.

(12) The owner or operator of a new facility in a designated nonattainment area which will be a major stationary source or a major modification of an existing facility for any air contaminant other than volatile organic compounds for which a national ambient standard has been issued must meet the following additional requirements regardless of the degree of impact of its emissions on ambient air quality if the facility is located in a designated nonattainment area:

(A) The proposed facility will comply with the lowest achievable emissions rate (LAER) as defined in the §101.1 of this title (relating to definitions) for the nonattaining pollutants.

(B) All major stationary sources owned or operated by the applicant (or by any person controlling, controlled by, or under common control with the applicant) in the state are to be in compliance or on a schedule for compliance with all applicable state and federal emission limitations and standards.

(C) At the time the facility commences operation, a net decrease in total allowable emissions in the area has been provided notwithstanding any increases in emissions resulting from operation of the proposed facility or modification.

(13) The proposed facility shall comply with the prevention of significant deterioration (PSD) of air quality regulations promulgated by the Environmental Protection Agency (EPA) in the Code of Federal Regulations at 40 Code of Federal Regulations, §52.21 as amended August 1, 1987, and the definitions for protection of visibility promulgated at 40 Code of Federal Regulations, §51.301, hereby incorporated by reference, except for the following paragraphs: 40 Code of Federal Regulations, §52.21(j), concerning control technology review; 40 Code of Federal Regulations, §52.21(l), concerning air quality models; 40 Code of Federal Regulations, §52.21(q), concerning public notification (provided, however, that a determination to issue or not issue a permit shall be made within one year after receipt of a complete permit application so long as a contested case hearing has not been called on the application); 40 Code of Federal Regulations, §52.21(r)(2), concerning source obligation; 40 Code of Federal Regulations, §51.21(s), concerning environmental impact statements; 40 Code of Federal Regulations, §52.21(u), concerning delegation of authority; 40 Code of Federal Regulations, §52.21(w), concerning permit rescission. The term "executive director" shall replace the word "administrator" except in 40 Code

of Federal Regulations, §52.21(b)(17), f(1)(*v*),(f)(3),(f)(4)(*i*),(g), and (t). "Administrator or executive director" shall replace "administrator" in 40 Code of Federal Regulations, §52.21(b)(3)(*iii*) and "administrator and executive director" shall replace "administrator" in 40 Code of Federal Regulations, §52.21(p)(2). All estimates of ambient concentrations required under this paragraph shall be based on the applicable air quality models and modeling procedures specified in the *EPA Guideline on Air Quality Models*, as amended, or models and modeling procedures currently approved by EPA for use in the state program, and other specific provisions made in the state PSD state implementation plan. If the air quality impact model approved by EPA or specified in the guideline is inappropriate, the model may be modified or another model substituted on a case-by-case basis, or a generic basis for the state program, where appropriate. Such a change shall be subject to notice and opportunity for public hearing and written approval of the administrator of the EPA. Copies of 40 Code of Federal Regulations, §52.21 and 40 Code of Federal Regulations, §51,301 are available upon request from the Texas Air Control Board, 6330 U.S. Highway 290 East, Austin, Texas 78723.

(14) In evaluating air quality impacts under paragraphs (11) or (13) of this subsection, the owner or operator of a proposed new facility or modification of an existing facility shall not take credit for reductions in impact due to dispersion techniques as defined in the Code of Federal Regulations. The relevant federal regulations are incorporated herein by reference, as follows: 40 Code of Federal Regulations, §51.100(hh)-(kk) promulgated November 7, 1986; the definitions of "owner or operator," "emission limitation and emission standards," "stack," "a stack in existence" and "reconstruction," as given under 40 Code of Federal Regulations, §51.100(f), (z), (ff), (gg), and 40 Code of Federal Regulations, §60, respectively; 40 Code of Federal Regulations, §51.118(a), (b), and (c); and 40 Code of Federal Regulations, §51.164. Copies of these sections of the Code of Federal Regulations are available upon request from the Texas Air Control Board, 6330 U.S. Highway 290 East, Austin, Texas 78723.

(b) Permit to operate. In order to be granted a permit to operate, the owner of the facility shall demonstrate that:

(1) The facility is complying with the rules and regulations of the Texas Air Control Board and the intent of the Texas Clean Air Act.

(2) The facility has been constructed and is being operated in accordance with the requirements for and conditions contained in the permit to construct.

(3) The facility is being operated in accordance with any applicable new source performance standards promulgated by the Environmental Protection Agency pursuant to authority granted under Section 111 of the Federal Clean Air Act as amended.

(4) The facility is being operated in accordance with any applicable National Emissions Standard for Hazardous Air Pollution promulgated by the Environmental Protection Agency pursuant to authority granted under Section 112 of the Federal Clean Air Act as amended.

(c) Emission reductions: offset. At the time of application for a construction permit in accordance with this chapter, any applicant who has effected air contaminant emission reductions may also apply to the executive director to use such emission reductions to offset emissions expected from the source(s) for which the permit is sought provided the following conditions are met:

(1) The emission reductions are not required by any provision of the Texas State Implementation Plan as promulgated by the administrator of the U.S. Environmental Protection Agency in Code of Federal Regulations, Title 40, Part 52, Subpart SS, nor by any other federal regulation under the Federal Clean Air Act, as amended, such as new source performance standards.

(2) The applicant furnished documentation at the time of his permit application to substantiate his claim of emission reductions previously effected. The following information must be included in the documentation.

(A) location and identity of the source(s) where emissions are reduced.

(B) chemical composition of emissions reduced;

(C) date(s) when emission reductions occurred;

(D) amount of emission reductions expressed in rates of tons per year and in pounds per hour;

(E) a complete description of the reduction method (i.e., source shutdown, process or operational change, type of control device, etc.):

(F) a certification by the applicant that the emission reductions have in fact been achieved and that the same reductions have not been used previously and will not be used subsequently to offset another source.

(G) any other pertinent detailed description information that may be requested by the executive director.

(d) Determination by Executive Director. The executive director may grant authority to a permit applicant to use prior emission reductions and emission reductions granted to the applicant by another entity (either public or private) in accordance with Rule .003(c) if he determines that the prior emission reductions have, in fact, occurred and, when considered with other emission reductions that may be required by the permit as well as contaminants that will be emitted by the new source, will result in compliance with Rule .002(a)(12), (13), and/or (14)(C) (whichever is applicable) in the area where the new source is to be located. Prior as well as future emission reductions to be used as offset will be made conditions for granting authority to construct the proposed new source and will be enforced.

(e) Records. The executive director will maintain no records of emission offset credits claimed by an applicant in accordance with Rule .003(c) other than those contained in permit application and permit files. The applicant shall maintain all records necessary to substantiate claims of emission reductions and shall make such records available for inspection upon request of the executive director.

(f) Effective date. This amended rule (Rule .003) shall be effective 30 days after the filing of certified copies in the Office of the Secretary of State.

§116.4. Special Conditions.

Permits to construct and operate special permits, and exemptions may contain general and special conditions. The holders of exemptions, construction and operating permits, and special permits shall comply with any and all such conditions or satisfy the conditions for a standard exemption as published by the executive director.

§116.5. Representations in Application for Permit or Exemption.

All representations with regard to construction plans and operation procedures in an application for a special permit, a permit to construct, or a permit to operate,

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APPENDIX C
Special Condition No. 1 of Permit Exemption X-16361

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SPECIAL CONDITION

X-16361

1. The holder of this exemption shall perform stack sampling and other testing as required to establish the actual pattern and quantities of air contaminants being emitted into the atmosphere from the tank ventilation system. The holder of this exemption is responsible for providing sampling and testing facilities and conducting the sampling and testing operation at his expense.

   A. The Texas Air Control Board (TACB) regional office in the region where the source is located shall be contacted as soon as testing is scheduled but not less than 45 days prior to sampling to schedule a pretest meeting.

      The notice shall include:

      1. Date for pretest meeting.
      2. Date sampling will occur.
      3. Name of firm conducting sampling.
      4. Type of sampling equipment to be used.
      5. Method or procedure to be used in sampling.

      The purpose of the pretest meeting is to review the necessary sampling and testing procedures, to provide the proper data forms for recording pertinent data and to review the format procedures for submitting the test reports.

      A written proposed description of any deviation from sampling procedures specified in permit provision or TACB or EPA sampling procedures shall be made available to the TACB at or prior to the pretest meeting. The regional director or the director of the Quality Assurance Division shall approve or disapprove of any deviation from specified sampling procedures. Requests to waive testing for any pollutant specified in B of this provision shall be submitted to the TACB Permits Division. Test waivers and alternate/equivalent procedure proposals for NSPS testing which must have EPA approval shall be submitted to the TACB Quality Assurance Division in Austin.

   B. Air contaminants emitted from the tank ventilation system to be tested for include (but are not limited to) sodium dichromate, phosphoric acid and sulfuric acid.

   C. Sampling shall occur within 60 days after the facilities achieve maximum production, but not later than 180 days after initial start-up of the facilities and at such other times as may be required by the Executive Director of the TACB. Requests for additional time to perform sampling shall be submitted to the regional office. Additional time to comply with the requirements of 40 CFR 60 and 40 CFR 61 cannot be granted.

D. Three copies of the final sampling report shall be forwarded to the TACB within 30 days after sampling is completed. Sampling reports shall comply with the provisions of Chapter 14 of the TACB Sampling Procedures Manual. The reports shall be distributed as follows:

One copy to the appropriate Texas Air Control Board regional office.
One copy to each appropriate local air pollution control program.
One copy to the Quality Assurance Division, TACB, Austin Office.

APPENDIX D
Texas Regulation II (31 TAC, Chapter 112)- Control of Air Pollution From Sulfur Compounds

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(B) Example 2. (Temperature of stack gas greater than 125°F.) How many lbs/hr of H_2S can be discharged from a 200 ft. stack having a 4 ft. exit diameter (ID) and a 30 ft/sec. exit gas velocity? The temperature of the exit gases is 400°F. Emissions under §112.31 of this title (relating to Allowable Emissions—Residential, Business, or Commercial). Solution:

(i) enter ordinate of Graph III with 400; go horizontally to intersection of a 4 ft. diameter, read on the abscissa on the scale set forth in §112.31 of this title (relating to Allowable Emissions—Residential, Business, or Commercial) 36 lb/hr emission. This is permitted value for 100 ft. stack and exit velocity of 20 ft/sec;

(ii) correct for stack height of 200 ft. This is direct ratio and becomes $\frac{200'}{100'} = 2$;

The emission now becomes 36 x 2 = 72 lbs/hr.

(iii) correct for stack exit velocity of 30 ft/sec. This is a direct ratio and becomes $\frac{30}{20} = 1.5$;

The allowed emission now becomes
72 x 1.5 = 108 lbs/hr.

(iv) Note: less than 30 stack heights to property line — *no* credit.

§112.34. Effective Date.

Sections 112.31-112.34 of this title (relating to Control of Hydrogen Sulfide) shall be in force immediately and shall supersede the previous Regulation III of the Texas Air Control Board which became effective on February 22, 1968, with regard to hydrogen sulfide.

CONTROL OF SULFURIC ACID

§112.41. Allowable Emissions.

No person may cause, suffer, allow, or permit emissions of sulfuric acid from a source or sources operated on a property or multiple sources operated on contiguous properties to exceed:

(1) a net ground level concentration of 15 ug per cubic meter of air averaged over any 24-hour period;

(2) a net ground level concentration of 50 ug per cubic meter of air averaged over a one-hour period of time more than once during any consecutive 24-hour period; or

(3) One hundred ug per cubic meter of air maximum at any time.

§112.42. Calculation Methods.

(a) Application. Determination of the net ground level concentration shall be performed in accordance with the procedures outlined in §112.33 of this title (relating to Calculation Methods) for hydrogen sulfide and this section for sulfuric acid.

(b) Determination of compliance with emission limits. In most cases downwind samples will suffice; however, if the sampled properties are suspected of being influenced by an upwind source of H_2SO_4, then both upwind and downwind samples shall be used in determining whether the emissions from the property comply with requirements of §112.41 of this title (relating to Allowable Emissions). Calculated maximum allowable emission rates or ground level concentrations which are obtained by the method in subsection (c) of this section below may be used in determining whether a property is in compliance with the emission limits specified.

(c) Calculations of H_2SO_4 concentrations from stack samples and measurements. The maximum allowable H_2SO_4 emission rate which may be made from a stack on a property to comply with the emission limit set forth in §112.41 of this title (relating to Allowable Emissions) may be calculated by Sutton's equation which has been modified to consider the critical wind speed and to correspond to one-hour sample. Additional credit on stack emissions can be obtained if the distance from the stack to the property line is greater than 30 stack heights. Those properties with greater than 30 stack heights to the property line should contact the executive director to obtain the proper correction factor.

(1) For exit stack gas for temperatures of less than 125°F. The following calculations shall be used for exit stack gas for temperatures of less than 125°F:

(A) the H_2SO_4, ambient air level of 80 ug/M³ for one hour is used;

$$Q_s = 5.56 \times 10^{-4} V_s d_s^2 \frac{1}{\left[\frac{d_s}{h_s}\right]^{1.29}} \qquad \text{(Equation 1)}$$

Where:

Q_s = emission rate, lbs/hr.
V_s = stack exit velocity, ft/sec.
d_s = exit stack diameter, ft.
h_s = physical stack height, ft.

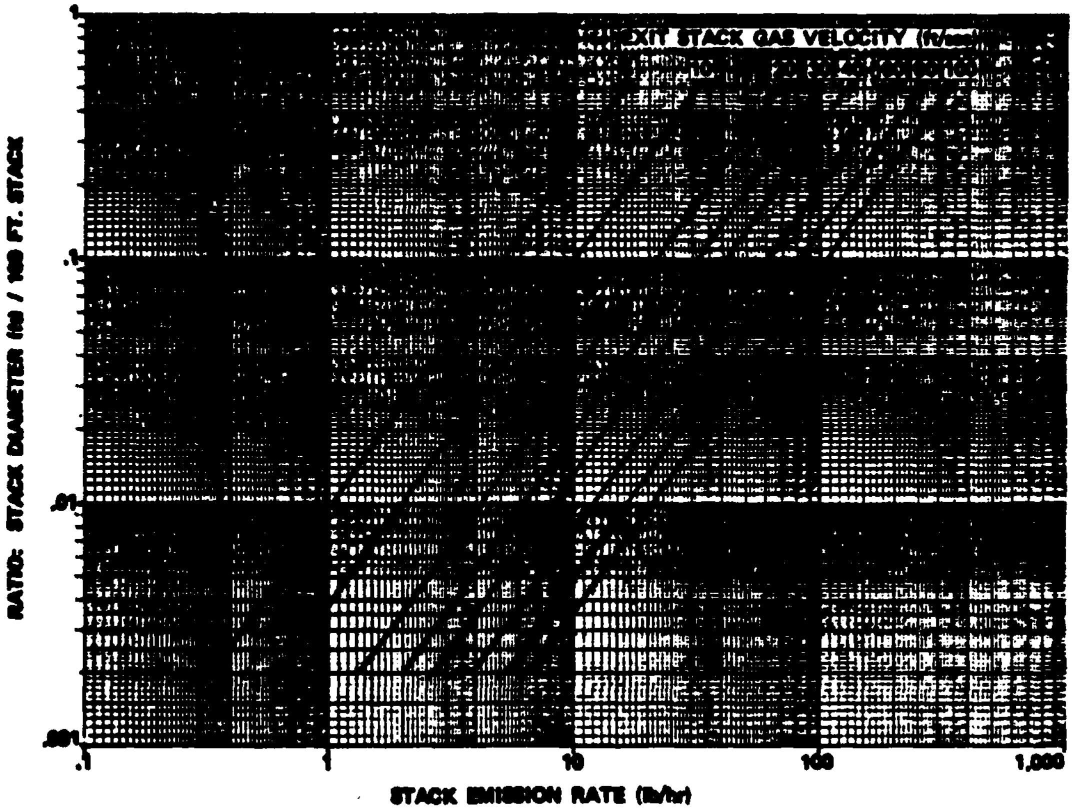
(B) to plot Graph IV assume a basic stack height of 100 ft. and plot

$$\left[\frac{d_s}{100}\right]^{1.29}$$

for various stack diameters versus stack velocity.

GRAPH IV

SULFURIC ACID MIST
EXIT STACK GAS TEMPERATURE LESS THAT 125°F



(2) For exit stack gas for temperature greater than 125°F. The following calculations shall be used for exit stack gas for temperatures greater than 125°F:

(A) the H_2SO_4 ambient air level of 80 ug/M^3 for one hour is used;

$$Q_s = 12.32 \times 10^{-4} V_s d_s \left[1.5 + 0.82 \left(\frac{\Delta T}{T_s} \right) d_s \right] h_s$$

(Equation 2)

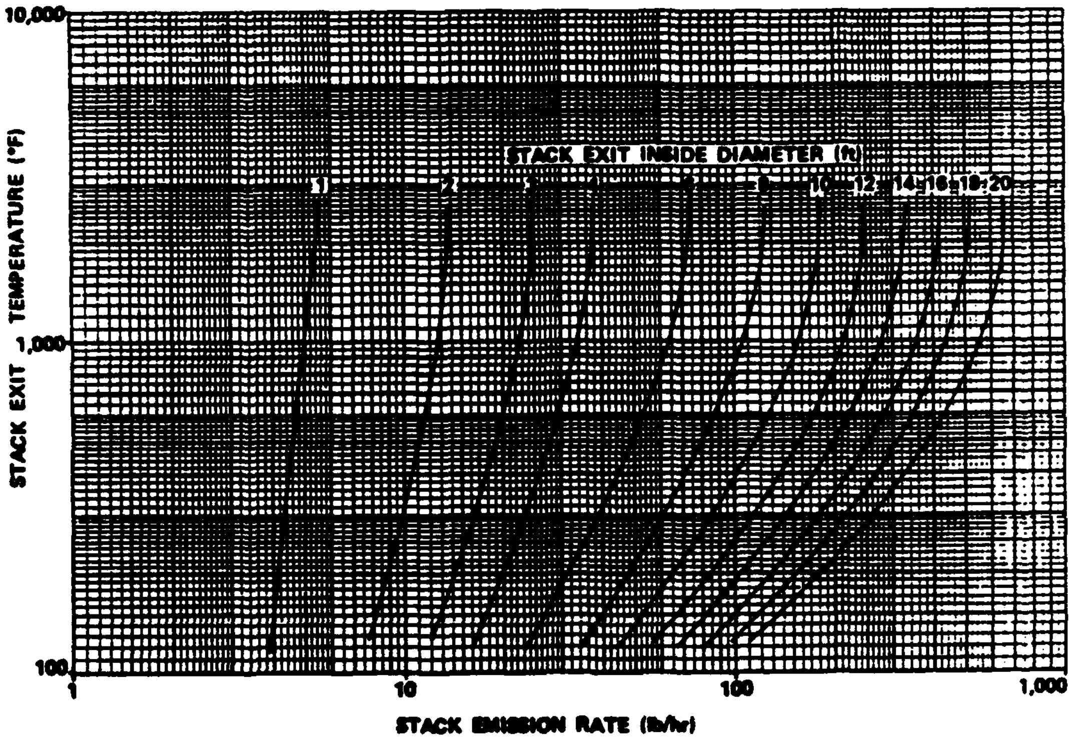
Where:

Q_s = emission rate, lbs/hr.
V_s = stack exit velocity, ft/sec.
d_s = exit stack diameter, ft.
h_s = physical stack height, ft.
ΔT = temperature difference between stack gas and the outdoor atmosphere in °Rankine. An outdoor temperature of 90°F (550°R) is assumed in preparing dispersion graphs.
T_s = stack exit temperature in °Rankine.

(B) to plot Graph V, assume a basic stack height of 100 feet and an exit velocity of 20 ft/sec. Let stack gas temperature vary with stack diameter.

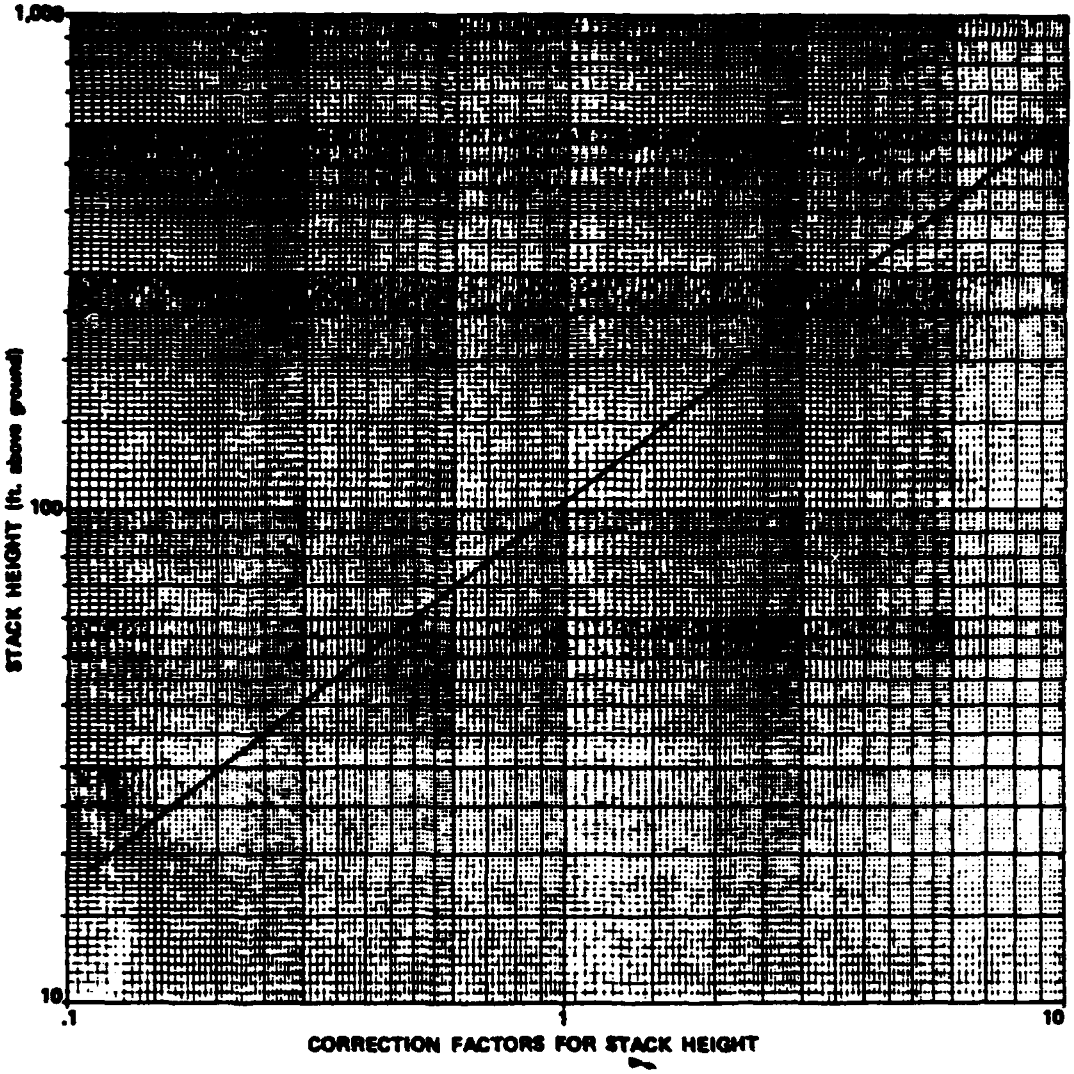
GRAPH V

SULFURIC ACID MIST
EXIT TEMPERATURE GREATER THAN 125°F



GRAPH I

CORRECTION FACTORS
STACK GAS TEMPERATURE EQUAL OR LESS THAN 125°F



(3) Examples. The following are examples of stack emission calculations:

(A) Example 1. (Temperature of stack gas less than 125°F.) How many lbs/hr of H_2SO_4 can be discharged from a 200 foot stack having a 4 foot exit diameter (ID) and a 30 ft/sec exit gas velocity? The temperature of the exit gases is 100°F. Solution:

(i) the ratio of stack diameter to 100 ft. is 4/100 = 0.04;

(ii) enter ordinate of Graph IV with 0.04; go horizontally to intersection of 30 ft/sec. velocity curve. At this intersection read on the abscissa 17 lbs/hr. This is the permitted value for a 100 foot stack;

(iii) correct emissions for a 200 foot stack. Enter Graph I at 200 feet and obtain correction factor of 2.3. Thus the emissions become 17 × 2.3 = 39 lbs/hr.

(B) Example 2. (Temperature of stack gas greater than 125°F.) How many lbs/hr of H_2SO_4 can be discharged from a 200 foot stack having a 4 foot exit diameter (ID) and a 30 ft/sec exit gas velocity? The temperature of the exit gases is 400°F. Solution:

(i) Enter ordinate of Graph V with 400; go horizontally to intersection of 4 foot diameter and read on abscissa 26 lbs/hr emission. This is permitted value for 100 foot stack and exit velocity of 20 ft/sec.

(ii) Correct for stack height. Thus, 200/100 = 2. We now have 26 × 2 = 52 lbs/hr.

(iii) Correct for stack exit velocity of 30 ft/sec. This is a direct ratio and becomes 30/20 = 1.5. The emission now is 52 × 1.5 = 78 lbs/hr.

§112.43. Effective Date.

Sections 112.41-112.43 of this title (relating to Control of Sulfuric Acid) shall be in force immediately and shall supersede the previous Regulation III of the Texas Air Control Board which became effective on February 22, 1968, with regard to sulfuric acid emissions.

APPENDIX E
Preliminary Field Data

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DETERMINATION OF MINIMUM NUMBER OF TRAVERSE POINTS

Stack ID: 4 Stack diameter at ports: 4 (ft)

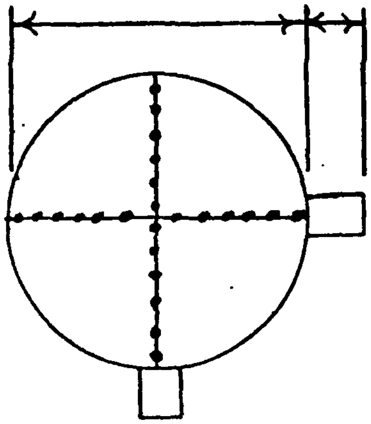
Distance A (ft) 2.4 (duct diameters) 0.6

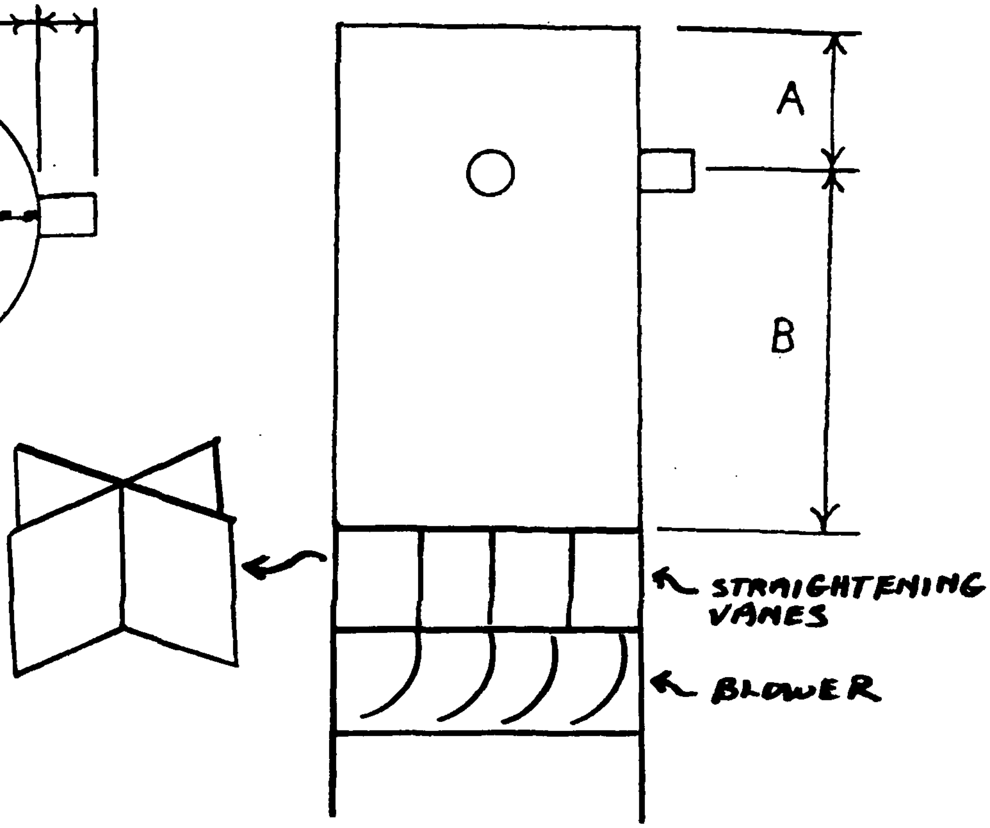
Recommended number of traverse points as determined by distance A: 24

Distance B (ft) 18.5 (duct diameters) 4.6

Recommended number of traverse points as determined by distance B: 24

Number of traverse points used: 24





PRELIMINARY SURVEY DATA SHEET NO. 1

(Stack Geometry)

BASE: Kelly AFB

PLANT: Anodizing Unit

DATE: 4 Jan 89

SAMPLING TEAM: OEHL

SOURCE TYPE AND MAKE: Wet Scrubber

SOURCE NUMBER:

INSIDE STACK DIAMETER: 48 in Inches

RELATED CAPACITY:

TYPE FUEL: N/A

DISTANCE FROM OUTSIDE OF NIPPLE TO INSIDE DIAMETER: 8.75 in Inches

NUMBER OF TRAVERSES: 2

NUMBER OF POINTS/TRAVERSE: 12

LOCATION OF SAMPLING POINTS ALONG TRAVERSE

POINT	PERCENT OF DIAMETER	DISTANCE FROM INSIDE WALL *(Inches)*	TOTAL DISTANCE FROM OUTSIDE OF NIPPLE TO SAMPLING POINT *(Inches)*
1			9.8
2			12.0
3			14.4
4			17.3
5			20.8
6			25.8
7			39.7
8			44.8
9			48.2
10			51.1
11			53.5
12			55.7

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PRELIMINARY SURVEY DATA SHEET NO. 2
(Velocity and Temperature Traverse)

BASE KELLY AFB

DATE 4 JAN 88

BOILER NUMBER ANODIZING WET SCRUBBER UNIT

INSIDE STACK DIAMETER 48 Inches

STATION PRESSURE 29.575 In Hg

STACK STATIC PRESSURE In H20

SAMPLING TEAM OEHL

TRAVERSE POINT NUMBER	VELOCITY HEAD, V_p IN H20	α ~~$\sqrt{V_p}$~~	STACK TEMPERATURE (°F)
1	.31	50 49	60
2	.33	30 32	60
3	.34	25 25	60
4	.33	20 19	60
5	.31	25 20	60
6	.28	35 32	60
7	.19	30 30	60
8	.20	50 45	60
9	.24	50 48	60
10	.42	55 50	60
11	.47	50 47	60
12	.43	50 47	60
		AVG = 39°	
AVERAGE			

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PRELIMINARY SURVEY DATA SHEET NO. 2

(Velocity and Temperature Traverse)

BASE KELLY AFB	**DATE** 5 JAN 84

BOILER NUMBER
ANODIZING WET SCRUBBER UNIT

INSIDE STACK DIAMETER
48 Inches

STATION PRESSURE
29.245 In Hg

STACK STATIC PRESSURE
.14 In H20

SAMPLING TEAM
OEHL

TRAVERSE POINT NUMBER	VELOCITY HEAD, Vp IN H20	$\sqrt{V_p}$		STACK TEMPERATURE (°F)
1	.13	15	16	71
2	.15	3	5	72
3	.15	4	4	72
4	.21	3	4	72
5	.23	0	0	72
6	.23	0	0	72
7	.21	0	0	72
8	.2	5	3	72
9	.18	4	3	72
10	.18	10	7	72
11	.17	9	12	73
12	.15	14	16	73
		AVG = 6°		
	assume % H_2O =	7		
	FPS = 19			
	$\overline{T_s}$ = 72			
	NDZ = 0.3179			
AVERAGE				

APPENDIX F
Hexavalent and Total Chromium Sampling Methods

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87-70.4

METHOD DEVELOPMENT AND TESTING FOR MEASUREMENT OF SOURCE LEVELS OF HEXAVALENT AND TOTAL CHROMIUM

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and

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For Presentation at the 80th Annual
Air Pollution Control Association Meeting

June 1987

INTRODUCTION

In 1985, a comprehensive screening study and testing program were initiated by the U.S. Environmental Protection Agency (EPA) to evaluate the levels of chromium emissions from stationary sources to determine whether chromium emissions should be regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAP). This evaluation involved the determination of the emissions of total chromium and hexavalent (Cr^{+6}) chromium from stationary source categories with significant potential air emissions of chromium. Total chromium and hexavalent chromium were both measured.

At the beginning of the study, a reference method had not been proposed or promulgated for chromium. However, the Quality Assurance Division (QAD) of EPA had developed and evaluated a tentative field sampling and laboratory analytical procedure for chromium.[1] This tentative method was designed to measure emissions that could be collected by EPA Method 5 type filters. It was determined during the screening study that the QAD train was unable to effectively collect chromium effectively from some source categories that emitted significant amounts of chromium. An impinger type train was then developed and evaluated.

Because of the need to provide accurate data on sources with low levels of chromium emissions, several sample preparation and analytical techniques were employed and evaluated. It was anticipated that distilled water in the impinger solution might not prevent conversion of the hexavalent chromium to other valence states; therefore, other solutions and different analytical techniques were investigated.

The following discussions will provide the specific information needed to develop a source specific hexavalent chromium emission measurement method. They describe: 1) the types and levels of hexavalent chromium emissions encountered, 2) selecting a sample collection technique, 3) selecting sample preparation and analytical techniques, and 4) selecting a method for specific sources.

DEFINING THE TYPES AND LEVELS OF CHROMIUM EMISSIONS

Chromium emission sources can be characterized by type and concentration level of their emissions. Both characteristics greatly influence the selection or development of a chromium method. The types and levels of chromium emissions are described below and shown in Table I.

Types of Chromium Emissions

There are two types of hexavalent chromium emissions that result from two broad processes: (1) processes that use raw materials containing naturally occurring chromium and (2) processes that use hexavalent chromium.

Processes With Naturally Occurring Chromium. Naturally occurring chromium (trivalent chromium) may be contained in process raw materials (e.g. chromite ore) or in the fuel in certain combustion sources (e.g. coal-fired boilers and incinerators). Generally the chromium emissions from the processes are particulate in nature. The trivalent chromium is converted to hexavalent chromium by:

Table I. Summary Table For Methods Selection.

Emission Types & Levels	Filterable Particulate High (>100 ug Cr per sample)	Filterable Particulate Low (10-100 ug Cr per sample)	Filterable Particulate Very Low (=1 ug Cr per sample)	Mist/Droplet High (>100 ug Cr per sample)	Mist/Droplet Low (10-100 ug Cr per sample)	Mist/Droplet Very Low (=1 ug Cr per sample)
Example Sources	Refractory Plants Electric Arc Furnaces Chromium Chemical Plants	Boilers Incinerators	Boilers Incinerators	Hard Chromium Plating Plants	Decorative Chromium Plating Plants Industrial Cooling Towers	Industrial Cooling Towers
	GENERALLY, NATURALLY OCCURING IN RAW MATERIALS.			GENERALLY, PROCESSES UTILIZING HEXAVALENT CHROMIUM.		
Sample Collec-tion	M5 Train w/Glass Fiber Filter. D.I. H_2O in Impingers. Acetone Rinse.	M5 Train w/Teflon Filter(<300° F), or Low Blank Value Glass Fiber Filter for >300° F. D.I. H_2O in Impingers. Acetone Rinse.	M5 Train w/Teflon Filter(<300° F), or Low Blank Value Glass Fiber Filter for >300° F. D.I. H_2O in Impingers. Acetone Rinse.	Impinger Train. 0.1 N NaOH in Impingers. 0.1 N NaOH Rinse.	Impinger Train w/Teflon Backup Filter. 0.1N NaOH in Impingers(Cr^{+6}). 0.1 N HNO_3 in Impingers (Total Cr). 0.1 N NaOH Rinse (Cr^{+6}). 0.1 N NHO_3 Rinse (Total Cr).	Impinger Train w/Teflon Backup Filter. 0.1N NaOH in Impingers(Cr^{+6}). 0.1 N HNO_3 in Impingers (Total Cr). 0.1 N NaOH Rinse (Cr^{+6}). 0.1 N NHO_3 Rinse (Total Cr).
Sample Prepar-ation	Filter Digestion in NaOH-Na_2CO_3. Collection of Filtrate for Cr^{+6} Analysis.	Filter Digestion using 1/10 concentration of NaOH-Na_2CO_3. Concentrate Filtrate to 1/10 Volume (10 ml) at High pH (8-10).	Filter Digestion using 1/10 concentration of NaOH-Na_2CO_3. Concentrate Filtrate to 1/10 Volume (10 ml) at High pH (8-10).	None.	Concen.(pH 8-10) using Heat(Cr^{+6}). Concentrate, if necessary, (pH<2) using Heat (Total Cr).	Separate and Concen. Cr^{+6} sample using, Coprecipitation, Chelation/Extrac., Chela./Solid Phase Concentration or Ion Exchange Concen.(Cr^{+6}). Concen.(pH<2) using Heat(Total Cr).
Sample Analysis	Diphenylcarbazide Colorimetric Method (Cr^{+6}).	Diphenylcarbazide Colorimetric Method(Cr^{+6}).	NAA(Cr^{+6}). GFAA(Cr^{+6}). ICAP(Cr^{+6}).	Diphenylcarbazide Colorimetric Method(Cr^{+6}).	Diphenylcarbazide Color. Method(Cr^{+6}) NAA,GFAA, or ICAP(Total Cr).	AA (Cr^{+6}). NAA,GFAA, or ICAP(Total Cr).

1) high temperature, 2) long residence time, and 3) an alkaline media. Processes such as boilers and incinerators have sufficiently high temperatures; but short residence time. Based on 38 test runs at five different boiler and incinerator sources, typically less than 3 percent of the trivalent chromium converts to hexavalent chromium. Therefore, if the amount of total chromium in the fuel or raw material is known, the maximum hexavalent chromium emissions can be closely estimated. Emissions from this process contain 20 to 100 times more trivalent chromium than hexavalent chromium in the sample. In separating the hexavalent chromium from the trivalent chromium, there is a large potential for error during the sample preparation.

Processes With Hexavalent Chromium. Two major processes that use hexavalent chromium are chromium plating plants, where chromic acid is used for plating metals, and cooling tower facilities, where sodium dichromate is used as a corrosion inhibitor. The hexavalent chromium emissions from these sources are generally in the form of liquid droplets or a mist and are not readily collected by a Method 5 type filter.

Levels of Chromium

The level of the chromium emissions concentration is important in the selection of the sampling and analytical procedures. The total hexavalent chromium sample catch can be defined and categorized into three levels: 1) high - greater than 100 ug of hexavalent chromium, 2) low - between 10 ug and 100 ug hexavalent chromium and, 3) very low - approximately 1 ug of hexavalent chromium.

As will be discussed in much greater detail later, when the total sample catch of hexavalent chromium is greater than 100 ug, the sample can be easily prepared and analyzed directly for hexavalent chromium using the diphenylcarbazide colorimetric method.[2] When the sample catch is between 10 ug and 100 ug, the sample may need to be concentrated before analysis by the same colorimetric method. When the sample catch is about 1 ug, then the sample preparation and analytical techniques must be modified significantly.

SELECTING A SAMPLE COLLECTION TECHNIQUE

The chromium screening study and methods development program revealed that two sample trains are required: 1) filter sample trains and 2) impinger sample trains. Modifications are made to each type of train to account for the chromium catch levels. The application of each of these trains to chromium emission types and levels is described in this section. Specific details for filter and impinger sample trains are presented in a later section, "Description of Sampling Techniques, Sample Preparation, and Analytical Methods."

Filter Sample Trains

Front half filter trains are found to be acceptable at sources where the emissions are in the form of dry solid particulates, not droplets or mists. Two types of filters are used, one for sources with high hexavalent chromium levels and the other for sources with low and very low chromium levels.

High Level Hexavalent Chromium. The tentative field sampling procedure,2 works well for the sources with high chromium levels, filterable emissions. These included refractory plants, electric arc furnaces, and chrome chemical plants. A standard 3-inch fiberglass front filter was used for tests at these sources. The small hexavalent chromium filter blank values gave insignificant errors, when compared to the large total hexavalent sample catches at these plants. Results from 13 sample runs at 11 different process streams show that less than 1 percent of the hexavalent sample catch was in the impingers. Therefore, the impinger catches are considered negligible and should not be used in calculating emission rates.

Low and Very Low Level Hexavalent Chromium. The tentative field sampling procedure[2] also works well for low hexavalent chromium concentration filterable sources, except that glass fiber filters are not recommended. Blank values of about 0.3 ug hexavalent chromium cause significant errors when the total front-half catches are as low as 1 ug. Most boilers and incinerators have low to very low filterable chromium emission levels. At sources where the stack temperatures are less than 300°F, Teflon filters are recommended because they do not contain chromium. If the stack temperatures exceed 300°F, glass fiber filters may be used if 10 filters from the same lot are extracted and analyzed for hexavalent chromium, and the average filter blank value is less than 10 percent of the expected hexavalent chromium catch.

Impinger Sample Trains

Filter trains are unsuitable for sampling emissions of hexavalent chromium in the form of a mist or droplets. In these cases, better results are obtained using an impinger train. Different impinger reagents and/or sample preparation techniques are required for sources with different chromium levels, corresponding to the analytical techniques.

High Level Hexavalent Chromium. The results from one of the first tests conducted at a hard chromium plater,[3] where sample catches exceeded 100 mg, showed that hexavalent chromium was not recovered completely from the filter and frit assembly. Also, the results from 12 paired test runs performed on 2 different locations in another chrome plating facility showed that about 10-25 percent of the hexavalent chromium was not recovered when filter train results were compared with results for an impinger train. This prompted the decision to use an impinger train to sample all such sources, no matter what the level of hexavalent emissions concentration. In addition, 6 paired impinger train runs were conducted to compare using 0.1 N sodium hydroxide (NaOH) and distilled water as impinger reagents. The results show that significant amounts of hexavalent chromium are unaccounted for when only distilled water is used in the impingers during testing. Therefore, 0.1 N NaOH is used as the impinger reagent to prevent potential hexavalent chromium conversion to another valence state.

Low and Very Low Level Hexavalent Chromium. Impinger trains are also employed at sources where the hexavalent chromium sample catch is low (10 to 100 ug) or very low (around 1 ug), such as industrial cooling towers.

A method development and evaluation test was performed at the beginning of the NESHAP study for industrial cooling towers.[4] This test shows that approximately half the quantity of each ion present (Li, Br, Ca, and Mg) passes through the front-half filter. Although chromium was not measured at this test, it was assumed to behave like the other ions. Following this, impinger trains were included refractory plants, electric arc furnaces, and chrome chemical plants. A standard 3-inch fiberglass front filter was used for tests at these sources. The small hexavalent chromium filter blank values gave insignificant errors, when compared to the large total hexavalent sample catches at these plants. Results from 13 sample runs at 11 different process streams show that less than 1 percent of the hexavalent sample catch was in the impingers. Therefore, the impinger catches are considered negligible and should not be used in calculating emission rates.

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All cooling tower testing has used deionized or distilled water as the impinger reagent. Measurements of total chromium, in conjunction with the total-to-hexavalent chromium ratio measured for cooling water samples, are used to calculate hexavalent chromium emissions. The impinger reagent used depends on whether methods specific for hexavalent chromium or total chromium are selected for sample preparation and analysis. Thus, 0.1 N NaOH is used when the sample will be analyzed for hexavalent chromium and 0.1 N nitric acid (HNO_3) is used when the sample will be analyzed for total chromium. Sample preparation and analysis options are discussed in detail in the next section. Rinses are done with the same solution as is in the impingers. Approximately 500 ml of the distilled water used to make the impinger reagent should be set aside as a sample blank, and then subjected to the same preparation and analysis techniques as the sample. The reagent blank should contain less than 0.5 ug/liter of hexavalent chromium.

SELECTING A SAMPLE PREPARATION AND ANALYTICAL TECHNIQUE

The choice of a sample preparation and analysis technique also depends on the types and levels of chromium emissions. The subsections which follow describe which preparation and analytical techniques are used for filterable or nonfilterable sources (requiring impinger trains) at each of the three chromium levels. Detailed explanations of each sample preparation and each analytical technique are offered in the section "Description of Sampling Techniques, Sample Preparation, and Analytical Methods."

Filterable Sample Preparation and Analysis

High Hexavalent Chromium Levels. Sample preparation for sources with high chromium levels requires no modification to procedures in the EPA Draft Method for hexavalent chromium.[2] The diphenylcarbazide colorimetric method is used for analysis.

Low Hexavalent Chromium Levels. Sample prepration for sources with low chromium levels requires a modification to the extraction technique in the draft method. One tenth the concentration of digestion solution is used in the extraction of the hexavalent chromium; then the extraction filtrate is concentrated to 10 ml. The diphenylcarbazide colorimetric method is used for analysis.

Very Low Hexavalent Chromium Levels. Sources with very low chromium levels require the same extraction technique modification as the low level sources, but the filtrate is analyzed by a technique other than the diphenylcarbazide colorimetric method. Other techniques include neutron activation analysis (NAA), graphite furnace atomic absorption (GFAA) or inductively coupled argon plasmography (ICAP). These have not been used for very low filterable sources, but they have been used for the higher sample concentration sources and the results compare favorably with the colorimetric technique.

Impinger Train Sample Preparation and Analysis

High Chromium Levels. Impinger samples containing higher levels of hexavalent chromium may be analyzed directly by the diphenylcarbazide colorimetric method without concentrating the impinger liquid.

Low Concentration Levels. Impinger samples may be analyzed directly for low levels of hexavalent chromium using the diphenylcarbazide colorimetric method provided they are first concentrated. The 0.1 N NaOH used as the impinger reagent in this situation provides the high pH (8-10) needed during heating to prevent conversion of the hexavalent chromium to another state. Alternatively, samples may be analyzed for total chromium using NAA, GFAA, or ICAP. The impinger reagent is 0.1 N HNO_3 and the samples are concentrated, if necessary, at a low pH (<2) using heat.

Very Low Chromium Levels. Very low level chromium impinger samples cannot be analyzed directly for hexavalent chromium using the colorimetric method even after concentration. Therefore, alternative procedures are used to separate the hexavalent chromium from the sample matrix, concentrate it, and convert it to trivalent chromium so it can be analyzed using sensitive atomic absorption (AA) techniques. Four recommended alternative procedures are coprecipitation, chelation with extraction, chelation with solid phase concentration, and ion exchange concentration. Impinger samples at the very low chromium levels can also be analyzed for total chromium using NAA, GFAA, or ICAP. This requires concentrating the samples by heating at a low pH (<2) which is provided by HNO_3 in the impinger solution.

SELECTION OF METHODS FOR SPECIFIC SOURCE CATEGORIES

Chromium Chemical Plants, Electric Arc Furnaces, and Refractory Plants

The emissions from chromium chemical plants, electric arc furnaces, and refractory plants are dry particulate matter with high levels of hexavalent chromium. Therefore, a filter train with glass fiber filters is used for sample collection. The EPA Draft Method[2] is used for sample preparation and the diphenylcarbazide colorimetric method is used for analysis.

Boilers and Incinerators

Boiler and incinerator emissions are dry particulate matter with low levels of hexavalent chromium. A filter train is suggested for sampling. Teflon filters should be used low temperature sources (<300°F); low blank value glass fiber filters should be used at high temperature sources (>300°F). For sample preparation, the draft method is modified to use one tenth the concentration of digestion solution in the extraction and to concentrate the sample filtrate to one tenth of original volume. The diphenylcarbazide colorimetric method is used for analysis.

Hard Chromium Plating Facilities

Emissions from chromium platers are characteristically a mist or droplets containing high levels of hexavalent chromium. An impinger train with 0.1 N NaOH in the impingers is recommended for sample collection. The diphenylcarbazide colorimetric method is used for analysis.

Industrial Cooling Towers

Emissions from cooling towers are typically in the form of a mist or droplets containing very low to low chromium levels. An impinger train with a backup filter is used to sample these emissions. If direct measurement of hexavalent chromium is required, the impingers should contain 0.1 N NaOH. Four techniques, discussed in the section "Analysis of Impinger Train Samples with Very Low Levels of Hexavalent Chromium," can be used to separate hexavalent chromium from the sample matrix so it can be measured using AA.

For an inferred hexavalent chromium measurement, 0.1 N HNO_3 is used in the impingers and the total chromium content of the sample is measured using NAA, GFAA, or ICAP, following concentration. This value is used with the hexavalent-to-total chromium ratio in the cooling water to calculate the hexavalent chromium emission rate.

Other Source Categories

There may be sources with unique emissions and chromium levels, but generally the method selection process, described above may be followed to develop a sampling technique or method suitable for the particular source.

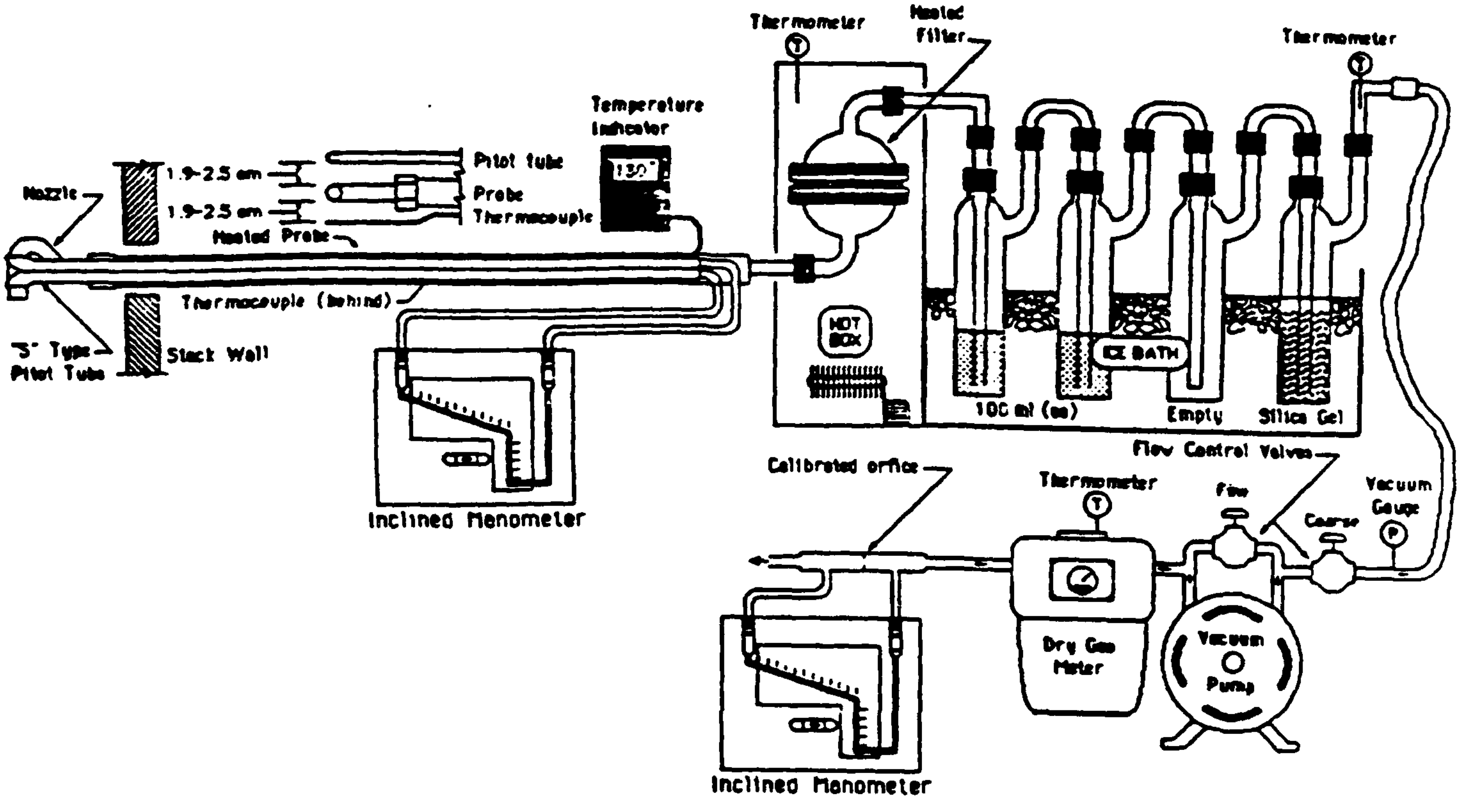
DESCRIPTION OF SAMPLING TECHNIQUES, SAMPLE PREPARATION, AND ANALYTICAL METHODS

The following sections describe the sampling techniques, sample preparation, and analytical methods used to sample at chromium sources. Alternative analytical techniques are described, potential sampling problems are noted, and special field sampling problems are described.

Sampling Techniques

EPA Method 5. Figure 1 shows the EPA Method 5 sampling apparatus, as described in the Federal Register.[5] It is the particulate matter sampling system for the dry filterable emissions. Testing is conducted by traversing the cross-sectional area of the stack or duct 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 glass fiber filter (or Teflon filter when necessary), and a series of Greenburg-Smith impingers is employed. Prior to testing, the nozzle, probe, and filter holder halves should be thoroughly rinsed with 0.1 N HNO_3 followed by distilled water to remove any residual chromium. Distilled water is used in the impingers and an acetone rinse of the nozzle, probe, and filter holder is made at the end of each test. The collected sample is digested and analyzed colorimetrically or by another appropriate technique.

Figure 1. EPA Method 5 Sampling Train.



Glass, Teflon, or other nonchromium containing probe liners are used. Stainless steel and other chromium containing probe liners must not be used. Any hexavalent chromium contamination from the small surface area of the stainless steel nozzle is negligible, based on six test runs at two municipal incinerators.[6,7] The total amount of hexavalent chromium in each sample was less than the detectable limit of the colorimetric technique.

Impinger Sampling Train Method. Figure 2 shows the impinger train that is used on wet nonfilterable emissions. The filter and filter holder portions are removed, and the testing is conducted as described in the previous section. The impinger reagent is chosen according to the analytical technique, as described in the section "Selecting a Sample Collection Technique." The rinse for the impingers, nozzle, and probe following sampling should correspond to the impinger reagent. Prior to each test, the nozzle, probe, and impingers should be rinsed with 0.1 N HNO_3 followed by distilled water to remove any residual chromium.

Impinger Sampling Train Method With Backup Filter. Figure 3 shows an impinger sampling train similar to Figure 2, except it includes a Teflon backup filter placed between the third and fourth impingers. With the exception of cooling towers, where a propeller anemometer is used in place of the pitot tube to

Figure 2. Impinger Train.

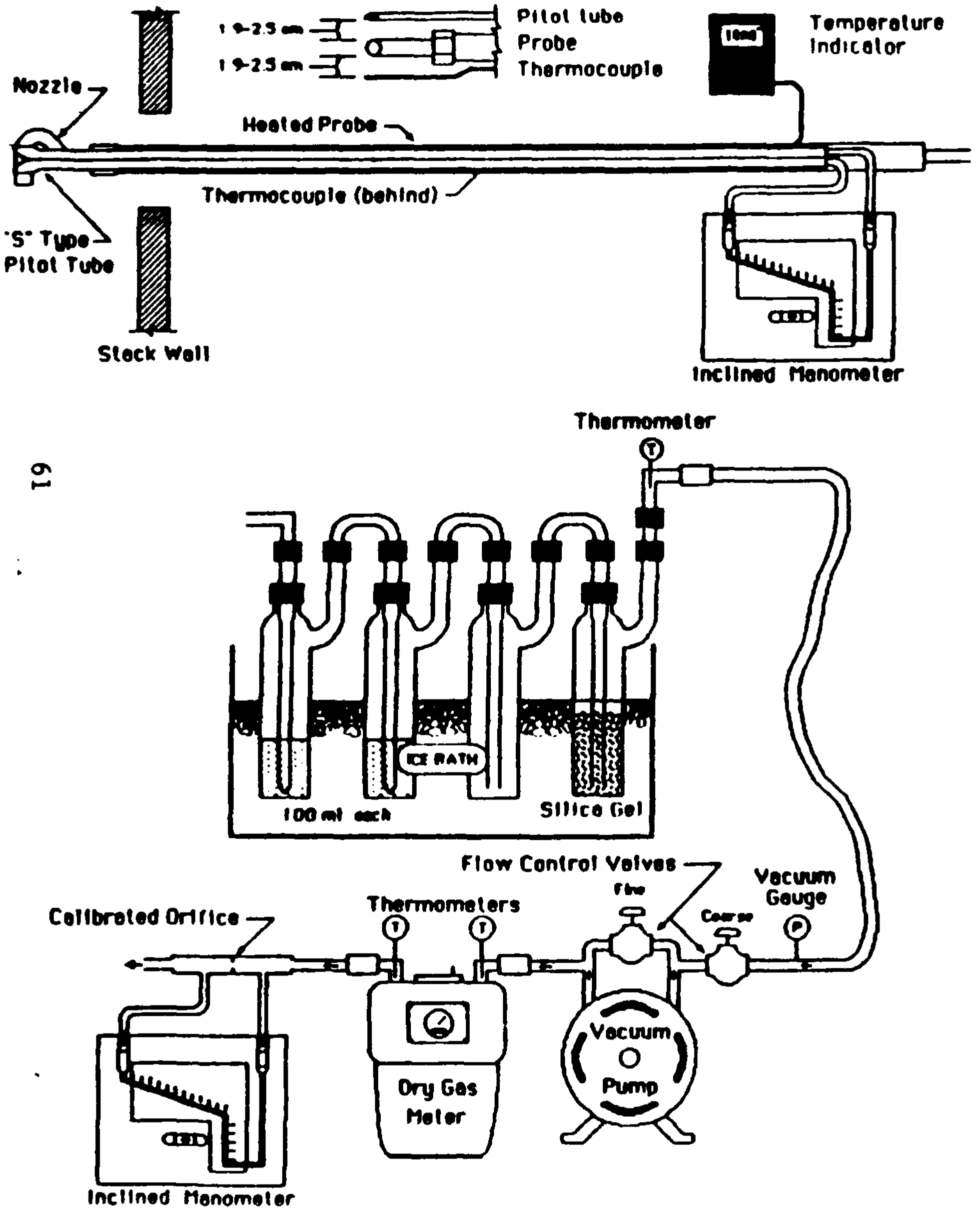
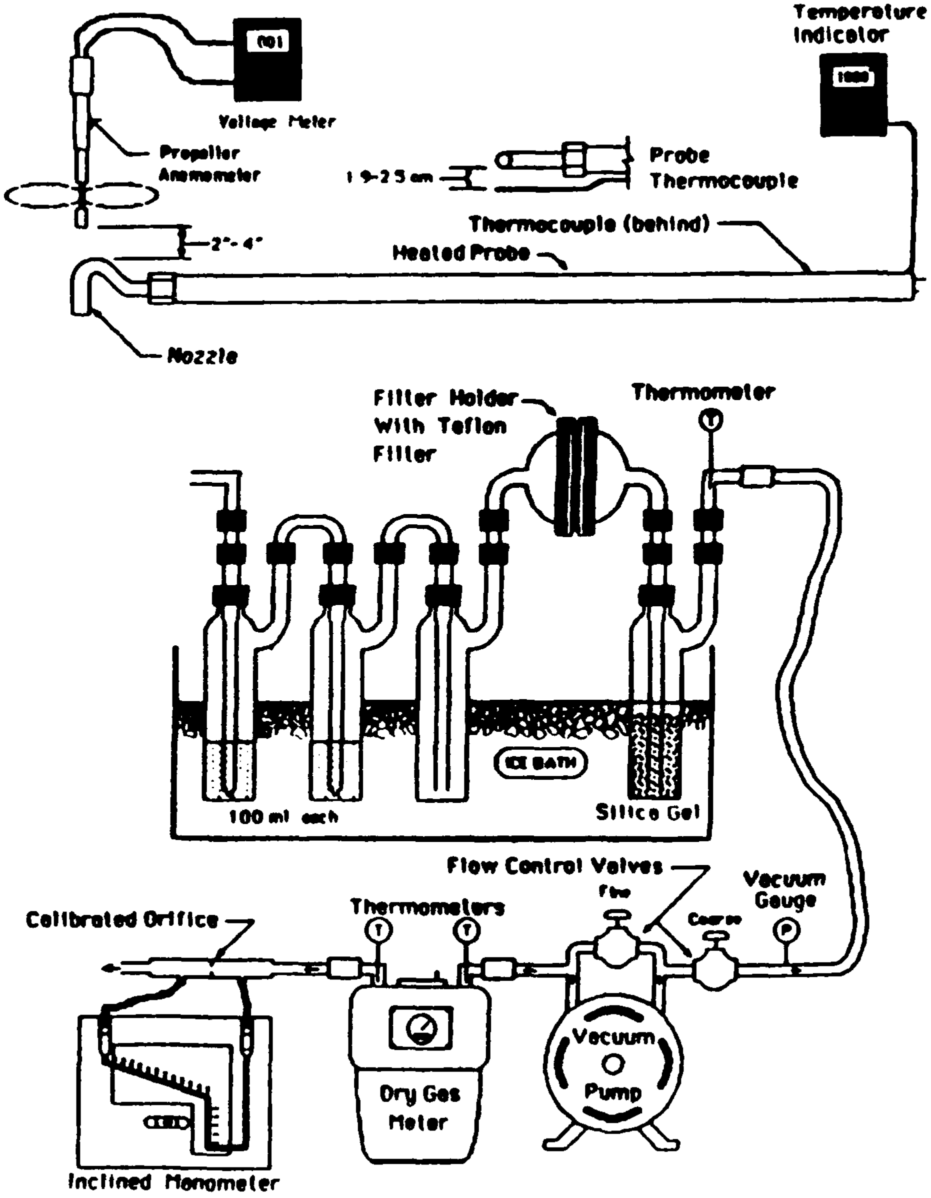


Figure 3. Impinger Train with Backup Filter.



measure the stack gas velocity, sampling is conducted as described in section "EPA Method 5."[8] The nozzle, probe, and impingers are rinsed prior to each test with 0.1 N HNO_3 followed by distilled water to remove any residual chromium. When impinger samples will be analyzed for total chromium, the impinger reagent should be 0.1 N HNO_3 with a corresponding final rinse of impingers, nozzle, and probe. When impinger samples will be analyzed for hexavalent chromium, the impinger reagent should be 0.1 N NaOH with a corresponding final rinse. This may be followed by a separate 0.1 N HNO_3 rinse to recover trivalent chromium, if a total chromium analysis is desired in addition to the hexavalent chromium analysis.

Sample Preparation

Sample Preparation for Direct Analysis of Particulate Filter Samples with High Levels of Hexavalent Chromium Using Colorimetric Method. Particulate samples collected using the EPA Method 5 sampling train are analyzed for hexavalent chromium using the "EPA Draft Method - Determination of Hexavalent Chromium Emissions from Stationary Sources" by digesting in an alkaline solution and analyzed with the diphenylcarbazide colorimetric method. The minimum quantifiable level is 10 ug per sample. To prevent the possibility of sample deterioration, all samples should be protected from extreme heat, kept dry, and analyzed within one month of collection. Sample preparation involves digestion and filtration. The acetone probe rinse is evaporated to dryness in a beaker, the filter is cut into small pieces and added to the dry probe rinse, and 40 ml of the digestion solution (20 g of NaOH and 30 g of anhydrous Na_2CO_3 in 1 liter of water) is added. Using a hot plate, this solution is heated to near boiling with constant stirring for 30 minutes, but not taken to dryness. The sample is then filtered with water through a vacuum filter unit which accomodates a 47-mm diameter, 3.0-um pore size Teflon filter. The filtrate, which contains the hexavalent chromium, is transferred to a 100-ml volumetric flask and brought to volume. The residue on the filter contains the trivalent chromium. Trivalent chromium can be soluble, although none was found in any of the particulate sample filtrates.

Sample Preparation for Direct Analysis of Particulate Filter Samples with Low Levels of Hexavalent Chromium Using Colorimetric Method. The particulate matter samples are prepared in a manner similar to that described above. The major difference is that the filtrate is concentrated using heat to a final volume of 10 ml. The minimum quantifiable limit using this preparation technique and the colorimetric analytical technique is 1 ug of hexavalent chromium. In proportion to the change in final volume, the digestion solution used should be 10 times less concentrated. The filtrate is concentrated on a hot plate to less than 10 ml and then diluted to 10 ml. If the sample contains just less than 1 ug of hexavalent chromium, the volume of the filtrate may be reduced to less than 10 ml and then accurately determined.

Sample Preparation for Analysis of Particulate Filter Samples with Very Low Levels of Hexavalent Chromium Using a Total Chromium Method. The particulate samples are prepared in the same manner as those with low levels of hexavalent chromium. The minimum quantifiable limit is determined by both the final volume of the filtrate and the detection limit of the total chromium analytical method selected. In using this approach, it is assumed that all chromium in the filtrate is in the hexavalent state. If any soluble trivalent chromium is present in the filtrate, then the results will be biased high by that amount.

Sample Preparation for Analysis of Impinger Train Samples with High Levels of Hexavalent Chromium Using Colorimetric Method. When the sample concentration is expected to exceed 0.3 ug of hexavalent chromium per ml of sample, then the sample may be analyzed using the diphenycarbazide colorimetric method with no sample preparation other than determining the exact sample volume.

Sample Preparation for Analysis of Impinger Train Samples with Low Levels of Hexavalent Chromium Using Colorimetric Method. When the sample concentration is expected to be less than 0.3 ug of hexavalent chromium per ml of sample, then the sample must be concentrated to a volume such that this expected level is exceeded. To insure that there is no conversion of the hexavalent chromium, the concentration step is performed at a high pH (8-10). The 0.1 N NaOH in the impinger reagent will generally provide this pH. The exact final volume of the sample must be determined prior to analysis by the colorimetric method.

Sample Preparation for Analysis of Impinger Train Samples with Very Low Levels of Hexavalent Chromium Using Total Chromium Methods. If the sample concentration is expected to be less than 0.3 ug of hexavalent chromium per ml of sample, even after the sample is concentrated to 10 ml, then a total chromium method must be used for analysis to provide a quantifiable value. Sample preparation procedures are specific to the analytical method and are described below.

Sample Analyses

Direct Analysis of Hexavalent Chromium Using Colorimetric Method. Preparation of samples containing different levels of chromium for the diphenylcarbazide colorimetric method has been previously described. The diphenylcarbazide analysis for hexavalent chromium involves four elements: (1) color development and measurement, (2) a check for matrix effects on the Cr^{+6} results, (3) calibration of the spectrophotometer, and (4) calculation of the results. For color development and measurement, the sample or an aliquot is transferred to appropriately sized volumetric glassware and the pH is adjusted to 2 with 10 percent sulfuric acid (H_2SO_4). Diphenylcarbazide solution (250 mg of 1, 5 diphenylcarbazide in 50 ml of acetone) is added at 0.02 ml per ml of final volume and the solution is diluted to an appropriate final volume. Ten minutes is allowed for color development. The sample absorbance is read at the optimum wavelength (540 nm) and the reagent blank absorbance reading is subtracted. At least one sample should be checked for matrix effects using the method of additions.

To calibrate the spectrophotometer, it is first confirmed that 540 nm is the optimum wavelength. A calibration factor (K_c) is calculated from the absorbance measurements made on the calibration standards: 0.0, 1.0, 2.0, 5.0, 10.0, 15.0, and 20 mls of potassium dichromate standard solution (5 mg/liter Cr^{+6}) is diluted to 100 ml. The absorbance value obtained for each standard is multiplied by K_c (least squares slope) to determine the distance each calibration point lies from the calibration line. To maintain quality control, they should not deviate by more than 7 percent for five of the six standards. The hexavalent chromium concentration of the sample is calculated by multiplying the absorbance of the sample by K_c and any dilution factor.

Analysis of Chromium Using Total Chromium Methods. Neutron activation analysis, graphite furnace atomic absorption, and inductively coupled argon plasmography are the three methods that have been found to have sufficiently low detection limits and suitable sample preparation requirements for the purposes of analyzing for total chromium emission samples from low level sources for total chromium (approximately 1 ug chromium or less per sample). NAA is performed commercially by two or three laboratories across the nation. For NAA, the sample, either a filter, a filter in impinger liquid, or impinger liquid alone must be less than 30 ml (and preferably approximately 2 ml) in volume and be accurately weighed before submission to the NAA facility. NAA involves irradiation of the sample by neutrons followed by measurement of the x or gamma-rays given off later by the sample. Results are expressed in total micrograms of chromium per sample. In GFAA, a liquid sample in a microliter quantity is injected into a graphite tube inside a minifurnace, where it is thermally atomized at a high temperature. A detector measures the absorbance of radiation from a special source made from the element of interest which is directed at the atomized sample. GFAA measurements are expressed as a concentration (i.e. ug of the element per ml of sample). For ICAP, a liquid sample is introduced into a quartz tube where argon plasma acts as an excitation source. Excitation of the elements in the sample results in emission spectra which are detected with photomultiplier tubes set at wavelengths for specific elements. ICAP results are also expressed as a concentration (i.e. ug per ml).

Alternative Sample Preparation and Analytical Techniques for Direct Measurement of Very Low Levels of Hexavalent Chromium in Impinger Train Samples. Analysis of very low levels of hexavalent chromium (less than 1 ug per sample) in impinger train samples cannot be accomplished using the colorimetric method because the chromium concentration of these samples is below the method's detection limit, even after concentration to remove excess water. Several alternative procedures are available for determining very low levels of hexavalent chromium. These procedures specifically separate the hexavalent chromium from the sample matrix, concentrate the hexavalent chromium, and quantitate it after conversion to trivalent chromium using sensitive atomic absorption techniques. Four of the procedures, coprecipitation, chelation with extraction, chelation with solid phase concentration, and ion exchange concentration are discussed below.

The coprecipitation method separates hexavalent chromium from the impinger sample by coprecipitation of lead chromate with lead sulfate in an acetic acid solution. After separating of the precipitate by centrifuging, the supernatant, containing trivalent chromium, is removed. The precipitate is washed to remove any occluded trivalent chromium, and then solubilized in nitric acid. The nitric acid solution, now containing the hexavalent chromium in the trivalent state, is analyzed by flame or furnace atomic absorption. This coprecipitation method can be used for impinger samples containing more than 2.5 ug of hexavalent chromium.

The chelation with extraction procedure and the chelation with solid phase concentration procedure are both based on chelation of hexavalent chromium with ammonium pyrrolidine dithiocarbamate (APDC). In the extraction procedure the hexavalent chromium-APDC complex is extracted from the aqueous sample using methyl isobutyl ketone. The extract is analyzed directly by flame atomic absorption. The chelation with extration procedure can be used for impinger samples containing 0.5 to 12 ug of hexavalent chromium.

In the solid phase extraction procedure the aqueous solution containing the hexavalent chromium-APDC complex is filtered through a cartridge containing C-18 bonded silica gel. The hexavalent chromium-APDC complex is retained on the cartridge and later eluted off the cartridge with acetone. The acetone is then evaporated and the chromium complex is solubilized with nitric acid prior to quantitation by furnace atomic absorption. The chelation with solid phase concentration procedure can be used on impinger samples containing more than 0.1 ug of hexavalent chromium.

The ion exchange concentration procedure involves passing the impinger sample through an anion-exchange resin bed. The hexavalent chromium is retained on the resin along with other anions present in the impinger sample. Soluble trivalent chromium is cationic and not retained on the anion-exchange resin. The hexavalent chromium is reduced in-situ to trivalent chromium with an acidic ferrous solution and eluted from the resin with the same solution. The chromium containing solution is analyzed directly by flame atomic absorption. The ion exchange concentration procedure can be used on impinger samples containing more than 0.5 ug of hexavalent chromium.

SUMMARY

In brief, the development or selection of a source specific method for chromium involves several considerations. First, it should be determined whether the source category is one of those previously studied by EPA which should have a documented sampling and analytical technique that would provide a sound basis for method selection. Source categories previously tested for chromium emissions include refractory plants, electric arc furnaces, chromium chemical plants, boilers, incinerators, hard and decorative chromium plating plants, and industrial cooling towers. If the source to be tested does not fit into one of these categories, it can be categorized for method selection purposes by determining the type and concentration level(s) of the chromium emissions. Specifically, it is necessary to know if the emissions are in the form of a filterable particulate or a mist/droplets, and the approximate range of the chromium levels which will be caught in the emission sample(s): high (>100 g Cr), low (10-100 g Cr), and very low (1 g Cr). Finally, it is important to determine whether the end use of the data will require measurements of total and/or hexavalent chromium. Then, by using Table I of this paper in conjunction with the details in the text, a suitable combination of a sample collection technique and sample preparation and analytical techniques can be selected.

REFERENCES

1. Cox, X. B., R. L. Linton, and F. E. Butler, "Determination of Chromium Specialization in Environmental Particles; Multitechnique Study of Ferrochrome Smelter Dust," ES&T, April 1985.

2. EPA Draft Method - Determination of Hexavalent Chromium Emissions from Stationary Sources, Dec. 13, 1984.

3. Test Report, U.S. EPA, Office of Air Quality Planning and Standards, EMB Report 86-CEP-1, March 1986, p. 3-23.

4. Drift Methods Study, Method Development and Evaluation Report, Munters Corporation, Fort Myers, Florida, U.S. EPA, Office of Air Quality and Planning and Standards, EMB Report 85-CCT-1, October 1986, p. 3-8.

5. 40 CFR 60, Appendix A, Reference Methods 2,3, and 5, March 23, 1978.

6. Test Report, U.S. EPA, Office of Air Quality Planning and Standards, EMB Report 85-CHM-8, p. 2-6.

7. Test report, U.S. EPA, Office of Air Qualtiy Planning and Standards, EMB Report 85-CHM-9, p. 2-6.

8. EPA Draft Method - Determination of Chromium Emissions from Cooling Towers, Jan. 23, 1987.

Method __ - Determination of Hexavalent Chromium Emissions from Decorative and Hard Chrome Electroplating

1. Applicability and Principle

1.1 Applicability. This method applies to the determination of hexavalent chromium (Cr^{+6}) in emissions from decorative and hard chrome electroplating operations.

1.2 Principle. Emissions are collected from the source by use of Method 5 (Appendix A, 40 CFR Part 60), with the filter omitted. The first and second impingers are charged with 0.1N sodium hydroxide. The collected samples remain in an alkaline solution until analysis, and are analyzed for Cr^{+6} by the diphenylcarbazide colorimetric method.

2. Range, Sensitivity, Precision, and Interferences

2.1 Range. A straight line response curve can be obtained in the range 5 μg Cr^{+6}/100 ml to 100 μg Cr^{+6}/100 ml. For a minimum analytical accuracy of ±10 percent, the lower limit of the range is 10 μg/100 ml. The upper limit can be extended by appropriate dilution.

2.2 Sensitivity. A minimum detection limit of 1 μg Cr^{+6}/100 ml has been observed.

2.3 Precision. To be determined.

2.4 Interference. Molybdenum, mercury and vanadium react with diphenylcarbazide to form a color; however, approximately 20 mg of these elements can be present in a sample without creating a problem. Iron produces a yellow color, but this effect is not measured photometrically at 540 nm.

3. Apparatus

3.1 Sampling Train. Same as Method 5, Section 2.1, but omit filter.

3.2 Sample Recovery. Same as Method 5, Section 2.2, but use 0.1N NaOH in place of acetone.

3.3 Analysis. The following equipment is needed.

3.3.1 Beakers. Borosilicate, 250-ml, with watchglass covers.

3.3.2 Volumetric Flasks. 100-ml and other appropriate volumes.

3.3.3 Pipettes. Assorted sizes, as needed.

3.3.4 Spectrophotometer. To measure absorbance at 540 nm.

4. Reagents

Unless otherwise indicated, all reagents shall conform to the specifications established by the Committee on Analytical Reagents of the American Chemical Society. Where such specifications are not available, use the best available grade.

4.1 Sampling.

4.1.1 0.1N NaOH.

4.2 Sample Recovery.

4.2.2 0.1N NaOH.

4.3 Analysis. The following reagents are required.

4.3.1 Water. Deionized distilled, meeting American Society for Testing and Materials (ASTM) specifications for type 2 reagent - ASTM Test Method D 1193-77 (incorporated by reference - see § 61.18).

4.3.2 Potassium Dichromate Stock Solution. Dissolve 141.4 mg of analytical reagent grade $K_2Cr_2O_7$ in water, and dilute to 1 liter (1 ml = 50 µg Cr^{+6}).

4.3.3 Potassium Dichromate Standard Solution. Dilute 10.00 ml $K_2Cr_2O_7$ stock solution to 100 ml (1 ml = 5 µg Cr^{+6}) with water.

4.3.5 Sulfuric Acid, 10 Percent (v/v). Dilute 10 ml H_2SO_4 to 100 ml in water.

4.3.6 Diphenylcarbazide Solution. Dissolve 250 mg of 1, 5-diphenylcarbizide in 50 ml acetone. Store in a brown bottle. Discard when the solution becomes discolored.

5. Procedure

5.1 Sampling. Same as Method 5, Section 4.1, except omit the filter and filter holder, and place 100 ml of 0.1N NaOH in each of the first two impingers.

5.2 Sample Recovery. Measure the volume and place all liquid in the first, second, and third impingers in a labelled sample container (Container Number 1). Use 200 ml of 0.1N NaOH to rinse the probe, three impingers, and connecting glassware. Place this wash in the same container. Place the silica gel from the fourth impinger in Container Number 3.

5.3 Preservation. Analyze all samples within ______________ of collection.

5.4 Reagent Blank Preparation. Place 400 ml of 0.1N NaOH in a labelled sample container (Container Number 2).

5.5 Silica Gel Weighing. Weigh the spent silica gel (Container Number 3) or silica gel plus impinger to the nearest 0.5 g using a balance. This step may be conducted in the field.

5.6 Analysis.

5.6.1 Color Development and Measurement. After stirring the sample in Container Number 1, transfer a 50-ml or smaller measured aliquot to a 100 ml volumetric flask and add sufficient water to bring the volume to approximately 80 ml. Adjust the pH to 2 ± 0.5 with 10 percent H_2SO_4, add 2.0 ml of diphenylcarbazide solution, and dilute to volume with water. Allow the solution to stand about 10 minutes for color development. For each set of samples analyzed, treat an identical aliquot of reagent blank solution from Container Number 2 in the same way. Transfer a portion of the sample to a 1-cm absorption cell, and measure the absorbance at the optimum wavelength (Section 6.2.1). Measure and subtract the reagent blank absorbance reading, if any, to obtain a net reading. If the absorbance of the sample exceeds the absorbance of the 100 μg Cr^{+6} standard as determined in Section 6.2.2, dilute the sample and the reagent blank with equal volumes of water.

5.6.2 Check for Matrix Effects on the Cr^{+6} Results. Since the analysis for Cr^{+6} by colorimetry is sensitive to the chemical composition of the sample (matrix effects), the analyst shall check at least one sample from each source using the method of additions as follows:

Obtain two equal volume aliquots of the same sample solution. The aliquots should each contain between 30 and 50 μg of Cr^{+6} (less is acceptable if not possible). Spike one of the aliquots with an aliquot of standard solution that contains between 30 and 50 μg of Cr^{+6}. Now treat both the spiked and unspiked sample aliquots as described in Section 5.6.1.

Next, calculate the Cr^{+6} mass C_s, in µg in the aliquot of the unspiked sample solution by using the following equation:

$$C_s = C_a \frac{A_s}{A_t - A_s} \qquad \text{Eq. — -1}$$

where:

C_a = Cr^{+6} in the standard solution, µg.

A_s = Absorbance of the unspiked sample solution.

A_t = Absorbance of the spiked sample solution.

Volume corrections will not be required since the solutions as analyzed have been made to the same final volume. If the results of the method of additions procedure used on the single source sample do not agree to within 10 percent of the value obtained by the routine spectrophotometric analysis, then reanalyze all samples from the source using this method of additions procedure.

6. Calibration

6.1 Sampling Train. Perform all of the calibrations described in Method 5, Section 5.

6.2 Spectrophotometer Calibration.

6.2.1 Optimum Wavelength Determination. Calibrate the wavelength scale of the spectrophotometer every 6 months. The calibration may be accomplished by using an energy source with an intense line emission such as a mercury lamp, or by using a series of glass filters spanning the measuring range of the spectrophotometer. Calibration materials are available commercially and from the National Bureau of Standards. Specific details on the use of such materials are normally supplied by the vendor; general information about calibration techniques can be obtained from general reference books on analytical chemistry. The wavelength scale of the spectrophotometer shall read correctly within ±5 nm at all calibration points; otherwise, repair and recalibrate the spectrophotometer. Once the wavelength scale of the spectrophotometer is in proper calibration, use 540 nm as the optimum wavelength for the measurement of the absorbance of the standards and samples.

Alternatively, a scanning procedure may be employed to determine the proper measuring wavelength. If the instrument is a double-beam spectrophotometer, scan the spectrum between 530 and 550 nm using the 50 µg Cr^{+6} standard solution (Section 4.3.4) in the sample cell and a blank solution in the reference cell. If a peak does not occur, the spectrophotometer is malfunctioning. When a peak is obtained within the 530 to 550 nm range, record and use the wavelength at which this peak occurs as the optimum wavelength for the measurement of absorbance of both the standards and the samples. For a single-beam spectrophotometer, follow the scanning procedure described above, except scan the blank and standard solutions separately. For this instrument, the optimum wavelength is the wavelength at which the maximum difference in absorbance between the standard and the blank occurs.

6.2.2 Spectrophotometer Calibration. Alternative calibration procedures are allowed, provided acceptable accuracy and precision can be demonstrated. Add 0.0 ml, 1 ml, 2 ml, 5 ml, 10ml, 15 ml, and 20 ml of the working standard solution (1 ml = 5 µg Cr^{+6}) to a series of seven 100-ml volumetric flasks. Dilute each to mark with water. Analyze these calibration standards as in Section 5.6.1. Repeat this calibration procedure on each day that samples are analyzed. Calculate the spectrophotometer calibration factor K_c as follows:

$$K_c = 5 \frac{A_1 + 2A_2 + 5A_3 + 10A_4 + 15A_5 + 20A_6}{A_1^2 + A_2^2 + A_3^2 + A_4^2 + A_5^2 + A_6^2} \qquad \text{Eq. \_\_ -2}$$

where:

K_c = Calibration factor.

A_1 = Absorbance of the 5 µg Cr^{+6}/100 ml standard.

A_2 = Absorbance of the 10 µg Cr^{+6}/100 ml standard.

A_3 = Absorbance of the 25 µg Cr^{+6}/100 ml standard.

A_4 = Absorbance of the 50 µg Cr^{+6}/100 ml standard.

A_5 = Absorbance of the 75 µg Cr^{+6}/100 ml standard.

A_6 = Absorbance of the 100 µg Cr^{+6}/100 ml standard.

6.2.2.1 Spectrophotometer Calibration Quality Control. Multiply the absorbance value obtained for each standard by the K_c factor (least squares slope) to determine the distance each calibration point lies from the theoretical calibration line. These calculated concentration values shall not differ from the actual concentrations (i.e., 5, 10, 25, 50, 75, and 100 µg Cr^{+6}/100 ml) by more than __ percent (to be determined) for five of the six standards.

7. Emission Calculations

Carry out the calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculations.

7.1 Total Cr^{+6} in Sample. Calculate m, the total μg Cr^{+6} in each sample, as follows:

$$m = \frac{V_{ml} \; K_c \; A F}{v_a} \qquad \text{Eq. — -3}$$

where:

V_{ml} = Volume in ml of total sample.

A = Absorbance of sample.

F = Dilution factor (required only if sample dilution was needed to reduce the absorbance into the range of calibration).

v_a = Volume in ml of aliquot analyzed.

7.2 Average Dry Gas Meter Temperature and Average Orifice Pressure Drop. Same as Method 5, Section 6.2.

7.3 Dry Gas Volume, Volume of Water Vapor, Moisture Content. Same as Method 5, Sections 6.3, 6.4, and 6.5, respectively.

7.4 Cr^{+6} Emission Concentration. Calculate c_s (g/dscm), the Cr^{+6} concentration in the stack gas, dry basis, corrected to standard conditions, as follows:

$$c_s = (10^{-6} g/\mu g)(m/V_{m(std)}) \qquad \text{Eq. — -4}$$

7.5 Isokinetic Variation, Acceptable Results. Same as Method 5, Sections 6.11 and 6.12, respectively.

8. Bibliography

1. Test Methods for Evaluating Solid Waste. U.S. Environmental Protection Agency. SW-846, 2nd Edition. July 1982.

2. Cox, X.B., R.W. Linton, and F.E. Butler. Determination of Chromium Speciation in Environmental Particles - A Multitechnique Study of Ferrochrome Smelter Dust. Accepted for publication in Environmental Science and Technology.

3. Same as in Bibliography of Method 5, Citations 2 to 5 and 7.

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APPENDIX G
Phosphoric Acid Field Sampling Data

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Part 1 of 2

PARTICULATE SAMPLING DATA SHEET

[redacted] ΔH@ = 1.91

RUN NUMBER: ONE - Phosp

DATE: 5 July 99

PLANT: Anodizing - Wet Scrub

BASE: Kelley

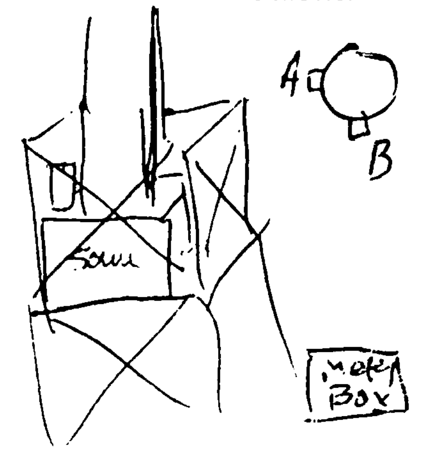
SAMPLE BOX NUMBER: Nutech #2

METER BOX NUMBER: Nutech #2

Qw/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$^oR = ^oF + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Assumed CO_2 = .5%

Assumed O_2 = 20%

Assumed H_2O = 7.%

static .14

Pre leak check at 15 in Hg good

START TIME 1043 L

AMBIENT TEMP: 69 °F

STATION PRESS: 29.245 in Hg

HEATER BOX TEMP: 145 °F

PROBE HEATER SETTING: 190 F

PROBE LENGTH: 72 in

NOZZLE ~~AREA (A)~~ ~~.52~~: .318 sq ft

Cp: .84

DRY GAS FRACTION (Fd):

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	vac ~~STATIC PRESSURE~~ (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1043 A 1	0	2.0	70		.13	1.40	start 111.905	71		71	262	64
2	5	2.2	73		.15	1.68		76		72	254	53
3	10	3.0	74		.19	2.13		81		72	253	58
4	15	5.0	73		.21	2.38		85		74	255	65
5	20	5.5	73		.22	2.50		87		75	256	67
6	25	6.0	74		.23	2.64		89		76	242	68
7	30	6.0	74		.22	2.51		96		78	236	68
8	35	5.5	74		.20	2.28	139.400	90		79	230	67
9	40	5.0	73		.18	2.06	143.080	91		79	242	67
10	45	5.0	74		.18	2.06	147.350	92		80	256	66
11	50	5.4	73		.18	2.66	151.100	92		80	234	66
1143 12	55	4.5	73		.17	1.93	155.2	93		81	245	66
							stop 158.664					

Part 2 of 2

PARTICULATE SAMPLING DATA SHEET

2.07

RUN NUMBER: CNE Phosp

DATE: 5 July

PLANT: Anodizing

BASE: Kelly

SAMPLE BOX NUMBER:

METER BOX NUMBER:

Qw/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION

2 of 2

EQUATIONS

$^{o}R = {}^{o}F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Post leak check at 12 in Hg good

STOP TIME: 1251

AMBIENT TEMP: °F

STATION PRESS: in Hg

HEATER BOX TEMP: °F

PROBE HEATER SETTING:

PROBE LENGTH: in

NOZZLE AREA (A): sq ft

Cp:

DRY GAS FRACTION (Fd):

	TRAVERSE POINT NUMBER	SAMPLING TIME (min)	VAC ~~STATIC~~ PRESSURE (~~in H2O~~) in Hg	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1151	B 1	0	2.00	75		.08	0.91	158.664	84		81	255	57
	2	5	3.0	74		.12	1.37		87		82	257	54
	3	10	3.5	73		.15	1.77		89		82	251	55
	4	15	3.5	73		.15	1.77	161.250	91		82	255	57
(1223)	5	20	4.0	73		.16	1.89	171.180	92		83	255	57
	6	25	4.0	73		.18	2.07	174.860	92		83	251	58
[illegible]	7	30	6.0	73		.25	2.87	178.650	92		83	254	58
	8	35	8.0	73		.28	3.24	183.122	92		83	253	60
	9	40	8.0	73		.27	3.10	188.115	92		84	256	61
	10	45	7.5	73		.25	2.87	[illegible]	93		84	258	61
	11	50	6.5	73		.23	2.63	197.200	94		84	257	61
1251	12	55	6.0	73		.21	2.42	201.751	94		84	257	61
		60						205.853					

~~Tm = 8~~ ~~Ts = 78~~ ~~ΔH = 2.09~~ ~~9.57~~

Tot Cu ft = 93.948

VSTS = 10.0126

Ts = 73°F

Tm = ~~2.23~~ 82°F

ΔH = 2.23

OEHL FORM MAY 78 18

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY AFB	DATE 5 JAN 89	RUN NUMBER 1

BUILDING NUMBER 375	SOURCE NUMBER P04 WET SCRUBBER - ANODIZING LINE

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* H_2O	221	200	21
IMPINGER 2 *(H20)* H_2O	210	200	10
IMPINGER 3 *(Dry)*	3	0	3
IMPINGER 4 *(Silica Gel)*	224.0	200	24
	Total Weight of Water Collected		58 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

OEHL FORM MAY 78 20

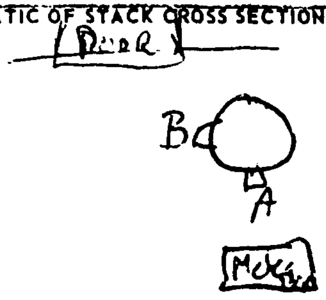
Page 1 of 2

PARTICULATE SAMPLING DATA SHEET

ΔH@ [illegible] = 1.91

RUN NUMBER: TWO PO4
DATE: 5 Jan 88
PLANT: Anodizing Unit
BASE: Kelly
SAMPLE BOX NUMBER: Nutech
METER BOX NUMBER: Nutech
Qw/Qm:
Co:

SCHEMATIC OF STACK CROSS SECTION



Readjusted Run time to accomodate 1:40 for anodizing Process instead of 2:00 hr.

EQUATIONS

$^{o}R = ^{o}F + 460$

$$H = \left[\frac{.5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Pre Leak check at 15 in Hg

STATIC P .14

START TIME ~~[illegible]~~ 1346 L

AMBIENT TEMP: 82 °F
STATION PRESS: 29.245 in Hg
HEATER BOX TEMP: 245 °F
PROBE HEATER SETTING: 190
PROBE LENGTH: 72 in
NOZZLE AREA (A): .318 sq ft
Cp: .84
DRY GAS FRACTION (Fd):

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	~~STATIC~~ PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1	0	0	78		.100	1.14	206.428	88		87	254	66
2	4	0	74		.130	1.49	209.230	89		87	256	54
3	8		74		.140	1.61	211.655	93		88	253	55
4	12		73		.150	1.74	214.336	95		88	253	59
5	16		73		.16	1.85	217.150	95		88	248	62
6	20	0	73		.19	2.20	220.150	96		88	250	66
7	24	0	72		.25	2.90	223.195	97		88	247	67
8	28	1.6	72		.26	3.02	226.770	98		88	250	67
9	32	2.0	73		.27	3.14	230.480	99		89	252	68
10	36	2.0	73		.25	2.91	234.215	100		90	254	68
11	40	2.0	73		.24	2.79	238.200	99		90	250	66
1436 12	44	1.0	73		.21	2.45	241.745	100		90	250	67
	48						245.[illegible]90					

PARTICULATE SAMPLING DATA SHEET

Continuation

RUN NUMBER TWO PO4

DATE 5 Jan 88

PLANT Anodizing Unit

BASE Kelly

SAMPLE BOX NUMBER

METER BOX NUMBER

Qw/Qm

Co

SCHEMATIC OF STACK CROSS SECTION 2 ft²

EQUATIONS

$^{o}R = {}^{o}F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Post leak check at 5 in Hg good

second half 1440

AMBIENT TEMP 82 °F

STATION PRESS Cont in Hg

HEATER BOX TEMP Cont °F

PROBE HEATER SETTING cont

PROBE LENGTH Cont in

NOZZLE AREA (A) Cont sq ft

Cp cont

DRY GAS FRACTION (Fd)

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
B 1	0	0	74		.11	1.26	245.190	90		88	249	68
2	4	0	72		.15	1.72	247.550	92		88	247	67
3	8	0	77		.18	2.07	250.300	94		88	260	68
4	12	0	74		.20	2.31	253.000	95		88	256	68
5	16	.5	73		.21	2.44	256.100	97		87	254	68
6	20	.5	74		.23	2.66	259.642	97		88	254	69
7	24	1.0	73		.23	2.67	262.810	98		88	245	68
8	28	1.0	73		.22	2.55	266.440	98		88	251	66
9	32	1.0	72		.19	2.21	270.010	98		88	249	65
10	36	1.0	73		.18	2.09	273.200	98		88	250	66
11	40	0.5	73		.17	1.77	276.025	97		88	252	67
12	44	0.5	73		.16	1.85	279.575	97		88	251	68
	48						282.765					

$\bar{T}_m = 92$

$\bar{T}_s = 74$

$\overline{\Delta H} = 2.21$

$\sqrt{\overline{P_s T_s}} = 10.0106$

CU FT = 76.28

IEHL FORM 18 MAY 78

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY AFB	DATE 5 JAN 89	RUN NUMBER 2

BUILDING NUMBER 375	SOURCE NUMBER PO4 WET SCRUBBER - AN. DIZING LINE

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* H_2O	194	200	-6
IMPINGER 2 *(H20)* H_2O	214	200	14
IMPINGER 3 *(Dry)*	6	0	6
IMPINGER 4 *(Silica Gel)*	221.4	200	21.4
	Total Weight of Water Collected		35.4 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

OEHL FORM MAY 78 20

Page 1 of 2

PARTICULATE SAMPLING DATA SHEET

$\Delta H@ = 1.91$

RUN NUMBER THREE PO4

DATE 6 Jan 89

PLANT Anodizing - Wet Scrub

BASE Kelly

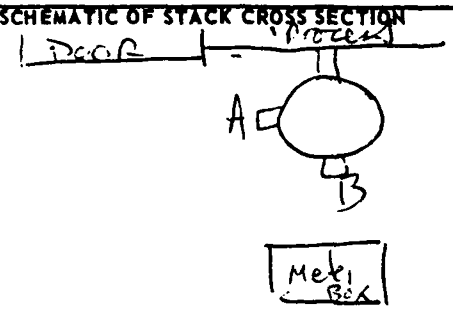
SAMPLE BOX NUMBER Nutech #2

METER BOX NUMBER Nutech # 2

Qw/Qm

Co

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Pitot good

Assumed H_2O - 4

static P: .14

Pre leakcheck at 15 in Hg

AMBIENT TEMP 54 °F

STATION PRESS 29.190 in Hg

HEATER BOX TEMP ~~NA~~ 804 °F

PROBE HEATER SETTING 190

PROBE LENGTH 72 in

NOZZLE AREA (A) .318 sq ft

Cp .84

DRY GAS FRACTION (Fd)

TIME 0827

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	VAC ~~STATIC~~ PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
A 1	0	3.0	59		.11	1.19	283.070	56		55	207	53
2	4	3.4	63		.14	1.51	285.316	60		56	203	46
3	8	3.0	66		.17	1.83	287.766	64		56	203	46
4	12	4.0	63		.18	1.96	290.460	68		58	202	50
5	16	5.0	64		.20	2.18	293.510	72		59	204	54
6	20	5.5	63		.22	2.41	296.410	74		60	205	56
7	24	6.0	63		.23	2.53	296.690	77		62	208	58
8	28	6.0	63		.21	2.32	302.930	80		64	209	60
9	32	5.5	64		.19	2.19	306.260	81		65	208	61
10	36	4.5	63		.17	1.89	309.410	81		67	206	61
11	40	4.5	64		.17	1.84	312.425	81		68	207	62
12	44	4.4	63		.16	1.78	315.330	82		69	207	62
	stop 48						318.272					

0913

OEHL FORM MAY 78 18

Page 2 of 2 P04

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER: THREE Continued

DATE: 6 Jan 98

PLANT: Anod Tz

BASE: Kelly

SAMPLE BOX NUMBER:

METER BOX NUMBER:

Qw/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION

EQUATIONS

$$^{\circ}R = {}^{\circ}F + 460$$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Page 2 of 2

Post leak check at 8" Hg good.

AMBIENT TEMP: °F

STATION PRESS.: Cont in Hg

HEATER BOX TEMP: Cont °F

PROBE HEATER SETTING: Cont

PROBE LENGTH: in

NOZZLE AREA (A): sq ft

Cp:

DRY GAS FRACTION (Fd):

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	~~STATIC~~ VAC PRESSURE (~~in~~ H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
B 1	0	3.0	67		.12	1.32	318.272	74		71	204	63
2	4	3.5	68		.14	1.54	320.660	80		71	207	54
3	8	4.0	64		.15	1.67	323.390	83		72	207	54
4	12	4.0	63		.16	1.79	325.960	84		73	204	55
5	16	4.0	63		.17	1.90	328.920	86		74	205	56
6	20	5.0	63		.20	2.25	331.490	87		76	207	57
7	24	7.0	64		.27	3.04	334.750	89		77	203	58
8	28	8.0	64		.29	3.28	338.280	92		79	204	59
9	32	7.5	64		.27	3.06	341.890	94		80	204	62
10	36	7.0	64		.25	2.89	345.930	93		81	204	63
11	40	6.5	65		.23	2.61	349.240	95		82	202	60
12	44	6.0	64		.21	2.40	353.120	96		84	206	63
	48											
							356.670					

$\overline{T_m} = 75$

$\overline{T_s} = 64$

$\overline{\Delta H} = 2.14$

$\overline{\sqrt{\Delta P_s T_s}} = 9.9561$

Cu FT = 73.6000

OEHL FORM MAY 78 18

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY	**DATE** 6 JAN 89.	**RUN NUMBER** 3
BUILDING NUMBER 375	**SOURCE NUMBER** P04 WET SCRUBBER ANODIZING LINE	

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* H_2O	198.0	200	-2.0
IMPINGER 2 *(H20)* H_2O	206.0	200	6.0
IMPINGER 3 *(Dry)*	1.8	0	1.8
IMPINGER 4 *(Silica Gel)*	218.6	200	18.6
	Total Weight of Water Collected		24.4 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

AMD FORM FEB 84 651 REPLACES OEHL 20, MAY 78, WHICH IS OBSOLETE.

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APPENDIX H
Sulfuric Acid Field Sampling Data

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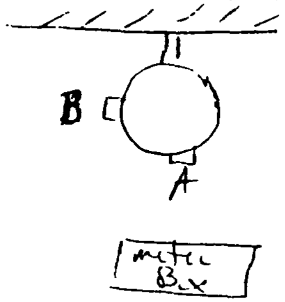
Day 1 of 2

PARTICULATE SAMPLING DATA SHEET

$\Delta H_{@} = 1.91$

RUN NUMBER ONE H_2SO_4	SCHEMATIC OF STACK CROSS SECTION	EQUATIONS	AMBIENT TEMP 74 °F
DATE 6 JAN 89			STATION PRESS 29.190 in Hg
PLANT Anodizing Wet Scrubber			HEATER BOX TEMP °F
BASE Kelly			PROBE HEATER SETTING 190
SAMPLE BOX NUMBER NuTech #1			PROBE LENGTH 72 in
METER BOX NUMBER NuTech #2			NOZZLE AREA (A) .318 sq ft
Qw/Qm			Cp .84
Co			DRY GAS FRACTION (Fd)

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Assumed H_2O = 4 %

Static P = .14

Preleak Check @ 15" Hg – good

Pitot check – good

Time	TRAVERSE POINT NUMBER	SAMPLING TIME (min)	VAC STAT~~IC~~ ~~PRESSURE~~ (~~in~~ H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1101	A 1	0	3.0	87		.14	1.53	357.010	92		90	187	68
	2	4	3.0	84		.15	1.65	359.344	93		90	188	58
	3	8	3.2	69		.16	1.82	362.091	97		91	187	60
	4	12	3.2	67		.16	1.84	364.885	100		92	189	66
	5	16	4.0	67		.18	2.07	367.795	101		93	195	70
	6	20	5.0	67		.22	2.90	370.740	102		94	180	74
	7	24	5.5	67		.27	3.12	374.150	104		95	197	80
	8	28	5.8	67		.28	3.24	377.895	107		95	180	87
	9	32	~~6.0~~ 5.9	67		.275	3.19	381.711	108		97	192	92
	10	36	5.2	67		.25	2.91	385.590	110		98	184	95
	11	40	5.0	68		.23	2.67	389.841	109		98	183	95
1149	12	44	4.5	67		.21	2.44	392.951	109		99	191	93
		48 stop						396.408					

OEHL FORM MAY 78 18

Page 2 of 2

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER: ONE H_2SO_4

DATE: 6 JAN 81

PLANT: Anodizing Wet Scrubber

BASE: Kelly

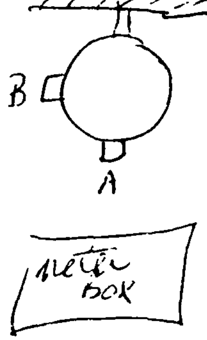
SAMPLE BOX NUMBER:

METER BOX NUMBER:

Qw/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Page 2 of 2

Post leak Check @ 9" Hg — good

AMBIENT TEMP: °F

STATION PRESS: cont. in Hg

HEATER BOX TEMP: cont. °F

PROBE HEATER SETTING: cont.

PROBE LENGTH: in

NOZZLE AREA (A): sq ft

Cp:

DRY GAS FRACTION (Fd):

JAC

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H2O)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
B 1	0	2.9	79		.14	1.59	396.408	104		100	190	83
2	4	3.1	82		.165	1.86	398.845	106		100	192	78
3	8	3.2	80		.17	1.93	401.695	107		101	192	80
4	12	4.1	67		.21	2.44	404.676	107		101	188	81
5	16	4.1	[illegible]		.22	2.57	407.767	108		101	184	77
6	20	4.5	67		.23	2.69	411.288	110		102	188	76
7	24	5.0	66		.25	2.93	414.785	111		102	183	76
8	28	5.6	66		.24	2.82	418.308	112		103	193	76
9	32	4.1	67		.21	[illegible]	422.018	113		104	192	76
10	36	4.0	67		.19	2.23	425.514	113		104	189	76
11	40	3.2	67		.17	2.00	428.815	113		105	188	76
12	44	3.0	68		.16	1.87	431.955	112		104	189	75
	48 (stop)						434.942					

$\sqrt{PsTs} = 10.2834$

Ts: 70°F

Tm = 102°F

$\Delta H = 2.36$

TOTAL CU FT = 77.932

time 1053

1241

OEHL FORM 18 MAY 78

Page 1 of 2

PARTICULATE SAMPLING DATA SHEET

ΔH@ = 1.91

RUN NUMBER: TWO H_2SO_4

DATE: 6 Jan 88

PLANT: Anodizing Unit

BASE: Kelly AFB

SAMPLE BOX NUMBER: Nutech 2

METER BOX NUMBER: Nutech 2

Qw/Qm:

Co: ~~STACK~~ TIME 1325

SCHEMATIC OF STACK CROSS SECTION

EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

assumed H_2O = 4

MW ≈ 29

Preleak at 15 in Hg good

AMBIENT TEMP: Hot 86 °F

STATION PRESS: 29.190 in Hg

HEATER BOX TEMP: 130 °F

PROBE HEATER SETTING: 130

PROBE LENGTH: 72 in

NOZZLE AREA (A): .318 sq ft

Cp: .84

DRY GAS FRACTION (Fd):

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP		VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP			SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
			(°F)	(Ts) (°R)				IN (°F)	AVG (Tm) (°R)	OUT (°F)		
A 1	0	3.0	85		.10	1.17	442.930	104		103	190	70
2	4	3.5	89		.14	1.56		103		102	187	63
3	8	4.5	76		.19	2.17		106		102	188	67
4	12	5.0	69		.20	2.32		108		102	185	74
5	16	5.5	69		.21	2.49		108		102	181	77
6	20	6.0	69		.24	2.79		109		102	163	80
7	24	8.0	69		.26	3.03		110		103	160	81
8	28	6.5	70		.22	2.56		110		103	151	80
9	32	6.0	69		.20	2.32		108		102	131	79
10	36	5.5	68		.19	2.20		105		100	125	76
11	40	5.0	68		.17	1.97		105		100	126	75
14B 12	44	5.0	68		.17	1.96		103		98	122	74
							480.995					

$\sqrt{PsTs}$ = 10.1440 TOTAL ft^3 = 76.380

Ts = 72°F

Tm = 99°F

ΔH = 2.26

Page 2 of 2

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER TWO H2SO4	SCHEMATIC OF STACK CROSS SECTION	EQUATIONS	AMBIENT TEMP Cont °F
DATE 6 July 82			STATION PRESS Cont in Hg
PLANT Anodizing			HEATER BOX TEMP Cont °F
BASE Kelly			PROBE HEATER SETTING Cont
SAMPLE BOX NUMBER			PROBE LENGTH Cont in
METER BOX NUMBER			NOZZLE AREA (A) sq ft
Qw/Qm			Cp
Co			DRY GAS FRACTION (Fd)

$$^{\circ}R = ^{\circ}F + 460$$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Post leak at 9 in Hg good

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1418 B 1	0	3.0	77		.11	1.24	480.995	97		96	130	76
2	4	3.9	78		.13	1.46		96		95	130	63
3	8	4.0	76		.15	1.69		96		94	132	65
4	12	4.5	69		.16	1.83		97		93	132	67
5	16	5.0	68		.18	2.06		97		92	131	68
6	20	5.0	68		.20	2.29		98		97	131	68
7	24	5.0	69		[illegible]	3.04		97		91	129	68
8	28	6.0	69		.28	3.19		98		96	134	68
9	32	5.0	68		.27	3.08		98		90	130	67
10	36	5.0	69		.26	2.96		98		90	128	67
11	40	5.0	69		.23	2.62		99		90	125	66
1506 12	44	5.0	69		.20	2.28		99		90	130	66
	48						519.310					

TOTAL CU FT - 76.38

FORM 18
MAY 78

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PARTICULATE SAMPLING DATA SHEET

ΔH@ = 1.91

RUN NUMBER: THREE H₂SO₄

DATE: 6 ~~Feb~~ JAN 89

PLANT: Anodizing Wet Scrubber

BASE: Kelly

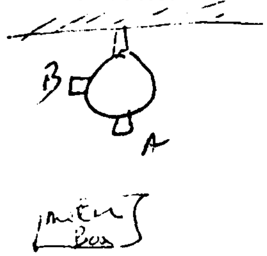
SAMPLE BOX NUMBER: Nutech #1

METER BOX NUMBER: Nutech #2

Qs/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Pitot good

Assumed H_2O = 4%

Static P = .14

Pre leak check @ 15" Hg – good

AMBIENT TEMP: 78 °F

STATION PRESS: 29.190 in Hg

HEATER BOX TEMP: 130 °F

PROBE HEATER SETTING: 130

PROBE LENGTH: 72 in

NOZZLE AREA (A): .318 sq ft

Cp: .84

DRY GAS FRACTION (Fd):

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
A 1	0	2.0	79		.115	1.26	524.542	85		83	132	73
2	4	2.0	77		.13	1.43	528.615	85		83	124	60
3	8	2.0	76		.14	1.55		88		84	125	60
4	12	2.7	72		.16	1.79		89		83	117	63
5	16	2.9	71		.18	2.01		89		83	127	68
6	20	3.0	72		.195	2.18		91		84	114	74
7	24	3.7	71		.24	2.69		92		84	119	78
8	28	4.0	71		.25	2.81		94		84	125	82
9	32	4.0	71		.24	2.70	549.555	95		84	121	87
10	36	3.7	71		.225	2.53		95		85	145	89
11	40	3.5	71		.21	2.36		94		84	135	91
12	44	3.5	71		.18	2.03		95		85	134	90
	48 (stop)						563.211					

time 447

435

OEHL FORM 18 MAY 78

Page 2 of 2

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER: three H_2SO_4

DATE: 6 JAN 89

PLANT: Kelly Anodizing wet scrubber

BASE:

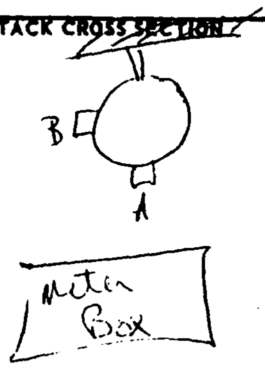
SAMPLE BOX NUMBER: Nutech #1

METER BOX NUMBER: Nutech #2

Qw/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Page 2 of 2

post leak check @ ~~15~~ 15" Hg — good.

AMBIENT TEMP: °F

STATION PRESS: in Hg

HEATER BOX TEMP: °F

PROBE HEATER SETTING:

PROBE LENGTH: in

NOZZLE AREA (A): sq ft

Cp:

DRY GAS FRACTION (Fd):

Time 441

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H2O)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1	0	2.5	81		.14	1.53	563.211	85		84	134	77
2	4	2.9	82		.14	1.53		88		83	136	72
3	8	2.9	~~80~~ 78		.15	1.62		90		84	121	73
4	12	3.2	73		.20	2.23		90		83	121	74
5	16	3.5	71		.22	2.47		91		84	135	74
6	20	3.5	71		.235	2.64		93		84	124	75
7	24	3.5	71		.24	2.70		93		84	134	74
8	28	3.5	71		.23	2.59		95		85	131	73
9	32	3.1	71		.20	2.24		92		84	146	73
10	36	3.1	71		.20	2.24		92		83	133	73
11	40	3.0	72		.19	2.13		92		84	105	72
12	44	3.0			.18	2.01		91		84	106	72
	48 (stop)						601.745					
										(84)		

529

$\sqrt{P_sT_s}$ = 10.0390

Ts = 73°F

Tm = 87°F

ΔH = 2.13

TOTAL CU FT = 75.203

OEHL FORM 18 MAY 78

APPENDIX I
Total Chromium Field Sampling Data

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PARTICULATE SAMPLING DATA SHEET

$\Delta H_@ = 1.91$

RUN NUMBER
Total Chromium # 1

DATE
9 JAN 89

PLANT
Kelly Anodizing Unit Wet Scrubber

BASE
Nutech #2

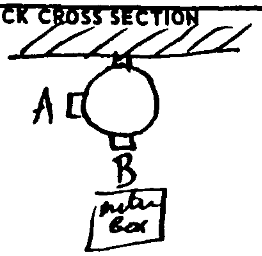
SAMPLE BOX NUMBER
Nutech #2

METER BOX NUMBER

Qw/Qm

Co

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$^{o}R = {}^{o}F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

pitot tube good

[illegible] Pressure leak test @ 15" Hg — good

assume $H_2O = 4$

Static Pressure = .14

MW = 29.0

AMBIENT TEMP
47 °F

STATION PRESS
29.535 in Hg

HEATER BOX TEMP
190 °F

PROBE HEATER SETTING
190

PROBE LENGTH
72" in

NOZZLE ~~AREA (A)~~ Diameter
.318 sq ft

Cp
.84

DRY GAS FRACTION (Fd)

Time	TRAVERSE POINT NUMBER	SAMPLING TIME (min)	~~STATIC PRESSURE (in H2O)~~ VAC	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1032 99	A 1	0	3.0	52		.14	1.57	609.062	71		69	248	47
	2	4	4.0	58		.18	2.02		77		70	250	42
	3	8	4.6	59		.205	2.30		82		71	255	44
	4	12	5.1	60		.22	2.48		87		73	253	47
	5	16	5.7	60		.23	2.61		90		74	253	50
	6	20	6.0	60		.25	2.84		92		76	254	53
	4	24	6.3	61		.26	2.97	627.625	95		78	248	56
	8	28	5.5	61		.22	2.51		96		79	246	58
	9	32	5.5	61		.21	2.41		98		80	246	59
	10	36	5.0	61		.20	2.30		98		82	246	60
	11	40	5.0	61		.20	2.30		99		83	247	60
1120	12	44	4.0	61		.17	1.96		100		85	245	60
		48 (tot)						647.641					

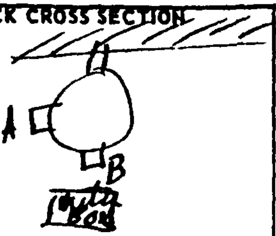
OEHL FORM MAY 78 18

Total Chromium #1 (cont)

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER: 9 JAN 89
DATE: Kelly
PLANT: ANODIZING Wet Scrubber
BASE: Nutech #2
SAMPLE BOX NUMBER: Nutech #2
METER BOX NUMBER:
Qw/Qm:
Co:

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$^{\circ}R = ^{\circ}F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

post leak check @ 10" Hg - good

AMBIENT TEMP: cont °F
STATION PRESS: cont in Hg
HEATER BOX TEMP: cont °F
PROBE HEATER SETTING: cont
PROBE LENGTH: cont in
NOZZLE AREA (A): cont sq ft
Cp: cont
DRY GAS FRACTION (Fd):

time 1129

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	~~STATIC PRESSURE (in H2O)~~ VAC	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
B 1	0	3.0	55		.13	1.50	647.641	88		85	248	53
2	4	3.0	59		.14	1.62		96		87	245	52
3	8	3.5	61		.16	1.85		98		87	245	52
4	12	3.5	61		.16	1.85		100		88	246	53
5	16	3.5	60		.18	2.09		100		89	243	53
6	20	5.0	61		.21	2.43		101		89	246	53
7	24	6.7	61		.27	3.13		102		90	245	54
8	28	7.4	61		.29	3.37		104		90	246	55
9	32	7.0	61		.28	3.26		105		91	244	57
10	36	6.0	61		.25	2.91		105		91	244	58
11	40	5.2	61		.23	2.68		105		92	245	58
12	44	5.0	61		.21	2.45		105		93	244	57
	48 (stop)						687.104					

1217

$\overline{T_m} = 89.0$

$\overline{T_s} = 60$

$\Delta H = 2.39$

$\sqrt{PSTS} = 10.3439$

Total Cu ft = 78.042

OEHL FORM 18
MAY 78

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY	DATE 9 JAN 89	RUN NUMBER 1
BUILDING NUMBER 375	SOURCE NUMBER TOTAL CHROMIUM WET SCRUBBER	

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* HNO3	94.0	100	-6.0
IMPINGER 2 *(H20)* HNO3	107.5	100	7.5
IMPINGER 3 *(Dry)*	3.3	0	3.3
IMPINGER 4 *(Silica Gel)*	219.1	200	19.1
	Total Weight of Water Collected		23.9 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

AMD FORM FEB 84 651 REPLACES OEHL 20, MAY 78, WHICH IS OBSOLETE.

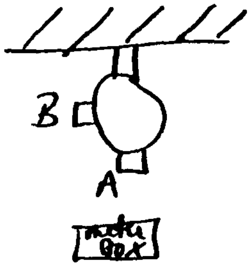
Total Chromium #2

PARTICULATE SAMPLING DATA SHEET

ΔH@ = 1.91

RUN NUMBER 9 JAN 89
DATE Kelly
PLANT ANODIZING WETSCRUBBER
BASE Nutech #2
SAMPLE BOX NUMBER Nutech #2
METER BOX NUMBER
Qw/Qm
Co

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$^{\circ}R = {}^{\circ}F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Pitot tube - good
Preleak check @ 15" Hg - good
assume $H_2O = 4$
Static P = .14
MW = 29

AMBIENT TEMP 49 °F
STATION PRESS 29.535 in Hg
HEATER BOX TEMP 190 °F
PROBE HEATER SETTING 190
PROBE LENGTH 72 in
NOZZLE AREA (A) .318 sq ft
Cp .84
DRY GAS FRACTION (Fd)

Time	TRAVERSE POINT NUMBER	SAMPLING TIME (min)	VAC STATIC PRESSURE (in H2O)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1:00	A 1	0	0	54		.12	1.39	687.9[illegible]	89		88	225	46
	2	4		58		.14	1.61		91		88	237	42
	3	8		60		.15	1.73		95		89	233	44
	4	12		61		.17	1.96		98		89	244	46
	5	16		62		.18	2.08		100		90	244	48
	6	20		61		.21	2.43		101		90	234	50
	7	24		62		.27	3.13		102		90	233	51
	8	28		62		.28	3.25		104		91	240	53
	9	32		61		.28	3.26		105		92	238	54
	10	36		62		.26	3.02		105		92	234	55
	11	40		62		.24	2.80		106		93	237	57
1:48	12	44		61		.21	2.45		106		93	241	57
		48 (Stop)						727.345					

OEHL FORM MAY 78 18

Total Chromium #2 (cont)

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER: 9 JAN 89

DATE: Anodizing Wet Scrubber

PLANT: Kelly

BASE: Nutech #2

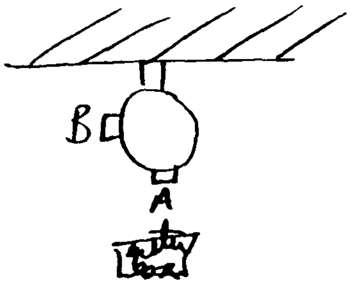
SAMPLE BOX NUMBER: Nutech #2

METER BOX NUMBER:

Qw/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$^{\circ}R = {}^{\circ}F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

~~pitot tube check~~

~~[illegible]~~ post check @ ~~[illegible]~~ 10" Hg -good

AMBIENT TEMP: cont °F

STATION PRESS: cont in Hg

HEATER BOX TEMP: cont °F

PROBE HEATER SETTING: cont

PROBE LENGTH: cont in

NOZZLE AREA (A): cont sq ft

Cp:

DRY GAS FRACTION (Fd):

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	VAC STATIC PRESSURE (in H2O)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1	B 0	0	54		.14	1.64	727.345	96		93	205	52
2	4		59		.17	1.98		101		93	255	53
3	8		61		.19	2.21		101		93	245	55
4	12		62		.20	2.33		104		93	242	56
5	16		62		.23	2.68		104		94	236	56
6	20		62		.23	2.68		106		94	233	58
7	24		62		.25	2.92		106		94	243	59
8	28		62		.24	2.80		106		95	241	60
9	32		62		.21	2.45		106		95	229	61
10	36		62		.20	2.34		106		95	246	62
11	40		62		.19	2.22		105		95	237	62
12	44		62		.18	2.10		105		95	237	62
	48 (stop)						767.157					

$\overline{T_M} = 97$

$\overline{T_s} = 61$

$\overline{\Delta H} = 2.40$

$\overline{\sqrt{P_s T_s}} = 10.2926$

Total Cuft = 79.196

OEHL FORM MAY 78 18

1/53

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY	DATE 9 JAN 89	RUN NUMBER 2

BUILDING NUMBER 375	SOURCE NUMBER TOTAL CHROMIUM WET SCRUBBER

I. ARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* HNO_3	92.5	100	-7.5
IMPINGER 2 *(H20)* HNO_3	109.5	100	9.5
IMPINGER 3 *(Dry)*	2.8	0	2.8
IMPINGER 4 *(Silica Gel)*	216.8	200	16.8
	Total Weight of Water Collected		21.6 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

AMD FORM FEB 84 651 REPLACES OEHL 20, MAY 78, WHICH IS OBSOLETE.

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PARTICULATE SAMPLING DATA SHEET

$\Delta H_@ = 1.91$

RUN NUMBER: THREE TOTAL CHROMIUM

DATE: 9 Jan 89

PLANT: Anodizing - Wet Scrubber

BASE: Kelly

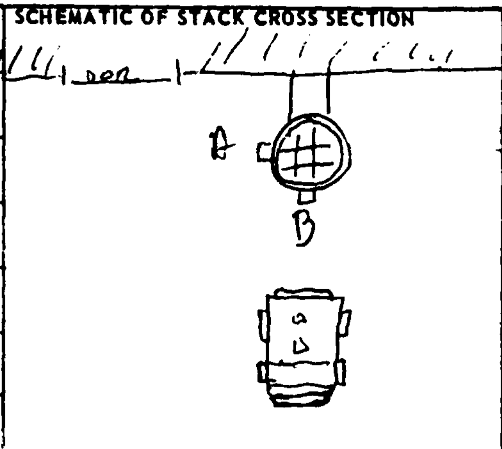
SAMPLE BOX NUMBER: Nutech #2

METER BOX NUMBER: Nutech #2

Qw/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Pre leak at 15 in Hg good
Pitot good
Static P = ,14
MW = 29

AMBIENT TEMP: 50 °F

STATION PRESS: 29.535 in Hg

HEATER BOX TEMP: 245 °F

PROBE HEATER SETTING: 190

PROBE LENGTH: 72 in

NOZZLE ~~AREA (A)~~ Dia: ,318 sq ft

Cp: ,84

DRY GAS FRACTION (Fd):

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (~~in H20~~) in Hg	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1525 A 1	0	1.0	53		,14	1.63	768.040	89		89	247	50
2	4	2.0	58		,16	1.85		92		89	247	43
3	8	2.5	60		,19	2.20		96		89	246	44
4	12	2.5	61		,21	2.43		100		90	249	43
5	16	3.0	61		,22	2.56		102		91	247	50
6	20	3.0	61		,23	2.68		104		91	245	57
7	24	3.0	62		,24	2.79		105		92	245	55
8	28	3.0	62		,23	2.68		106		92	247	56
9	32	3.0	61		,21	2.45		106		93	245	57
10	36	2.5	62		,19	2.22		107		93	248	58
11	40	2.0	62		,18	2.10		106		93	248	58
1623 12	44	2.0	61		,18	2.10	~~8~~	106		94	246	59
	48						807.310					

OEHL FORM 18 MAY 78

Page 2 of 2

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER THREE TOTAL CHROME

DATE 9 Jan 89

PLANT Anodizing

BASE Kelly

SAMPLE BOX NUMBER Cont

METER BOX NUMBER Cont

Qw/Qm Cont

Co

SCHEMATIC OF STACK CROSS SECTION

EQUATIONS

$^{o}R = {^{o}F} + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Post leak check at 3.5 in Hg good

AMBIENT TEMP Cont °F

STATION PRESS Cont in Hg

HEATER BOX TEMP Cont °F

PROBE HEATER SETTING Cont

PROBE LENGTH 77 in

NOZZLE AREA (A) .310 sq ft

Cp .84

DRY GAS FRACTION (Fd)

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
617 B 1	0	1.0	54		.12	1.41	807.310	99		94	260	52
2	4	2.0	58		.13	1.52		102		95	246	55
3	8	2.0	60		.13	1.52		104		95	246	52
4	12	2.0	60		.14	1.64		105		96	247	52
5	16	2.0	61		.16	1.87		105		95	244	52
6	20	2.0	61		.19	2.22		105		95	242	53
7	24	3.5	61		.25	2.93		106		96	248	55
8	28	3.5	61		.27	3.16		107		96	246	55
9	32	3.5	61		.25	2.94		108		97	242	55
10	36	3.0	61		.23	2.70		108		97	245	55
11	40	3.0	61		.22	2.58		108		97	243	55
1705 12	44	3.0	61		.21	2.47		108		97	244	56
	48						844.790					

$\overline{T_m} = 99$

$\overline{T_s} = 60$

$\overline{\Delta H} = 2.28$

$\overline{\sqrt{P_s T_s}} = 10.011$

TOTAL CU FT = 76.75

106

OEHL FORM MAY 78 18

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY	**DATE** 9 JAN 89	**RUN NUMBER** 3

BUILDING NUMBER 375	**SOURCE NUMBER** TOTAL CHROMIUM WET SCRUBBER

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* HNO_3	93.5	100	-6.5
IMPINGER 2 *(H20)* HNO_3	107.5	100	7.5
IMPINGER 3 *(Dry)*	5.2	0	5.2
IMPINGER 4 *(Silica Gel)*	216.2	200	16.2
	Total Weight of Water Collected		22.2 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

AMD FORM FEB 84 651 REPLACES OEHL 20, MAY 78, WHICH IS OBSOLETE.

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APPENDIX J
Hexavalent Chromium Field Sampling Data

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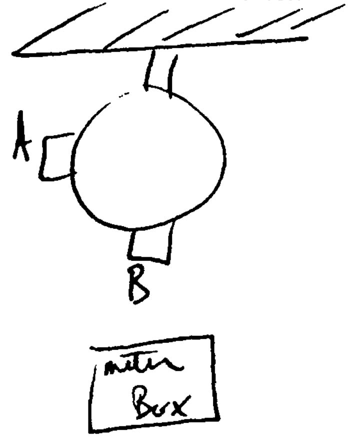
PARTICULATE SAMPLING DATA SHEET

ΔH@ = 1.91

RUN NUMBER Cr^{+6} Run#3
DATE 10 Jan 89
PLANT Anodizing-Wet Scrubber
BASE Kelly AFB
SAMPLE BOX NUMBER Nutech #2
METER BOX NUMBER Nutech #1
Qw/Qm
Co

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Mw ≈ 29
$\%H_2O \approx 4$
P_{ST} ≈ .14
pitot tube - good
preleak check @ 15" Hg - good.

AMBIENT TEMP 61 °F
STATION PRESS 29.530 in Hg
HEATER BOX TEMP 240 °F
PROBE HEATER SETTING 190
PROBE LENGTH 72 in
NOZZLE AREA (A) .318 sq ft
Cp .84
DRY GAS FRACTION (Fd)

TIME	TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
103	A 1	0	0	61		.09	1.03	989.100	85		87	231	48
	2	4	0	63		.14	1.59		87		87	233	46
	3	8	0	62		.17	1.94		90		86	239	48
	4	12	1.1	62		.19	2.17		92		86	233	51
	5	16	1.5	62		.20	2.29		93		86	233	53
	6	20	1.5	62		.21	2.40		93		85	236	54
	7	24	1.8	62		.24	2.76		98		85	234	56
	8	28	1.6	62		.22	2.52		94		85	232	57
	9	32	1.3	62		.19	2.17		93		85	237	58
	10	36	1.5	62		.19	2.17		92		85	235	57
	11	40	1.5	62		.18	2.05		92		84	233	58
1:57	12	44	1.0	62		.16	1.83		92		84	234	57
		48 (stop)						025.844					

OEHL FORM MAY 78 18

Cr^{+6} Run #3 Page 2 of 2

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER

DATE
10 JAN 89

PLANT
Anodizing Wet Scrubber

BASE
Kelly

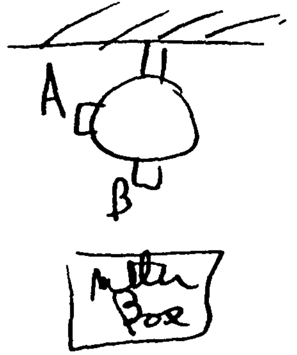
SAMPLE BOX NUMBER
Nutech #2

METER BOX NUMBER
Nutech #1 1

Qw/Qm

Co

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$$°R = °F + 460$$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

post leak check at 4 in Hg good

AMBIENT TEMP Cont °F

STATION PRESS cont in Hg

HEATER BOX TEMP cont °F

PROBE HEATER SETTING cont

PROBE LENGTH cont in

NOZZLE AREA (A) cont sq ft

Cp cont

DRY GAS FRACTION (Fd)

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
B1	0	0	59		.12	1.37	025.844	84		83	236	56
2	4	0	62		.13	1.47		87		83	234	53
3	8	0	62		.14	1.59		88		82	237	53
4	12	0	61		.15	1.71		88		82	233	53
5	16	1.0	62		.17	1.93		88		81	235	53
6	20	1.0	61		.19	2.16		89		81	236	53
7	24	1.9	61		.24	2.73		89		81	235	54
8	28	2.0	61		.26	2.96		90		81	238	55
9	32	2.0	62		.26	2.96		91		81	235	56
10	36	2.0	61		.25	2.85		91		81	235	56
11	40	1.8	61		.23	2.62		91		81	235	57
12	44	1.0	62		.20	2.27		91		81	234	57
	48 (stop)						063.580					
$\overline{T_m}$ =	87					Total Cu ft = 74.43						
T_s =	62											
ΔH =	2.15											
$\overline{\sqrt{P_s T_s}}$	9.8364											

Time 1:55

243

OEHL FORM MAY 78 18

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY	DATE 10 JAN 89.	RUN NUMBER 3

BUILDING NUMBER 375	SOURCE NUMBER Cr^6 WET SCRUBBER

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(if needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* NAOH	95.0	100	-5.0
IMPINGER 2 *(H20)* NAOH	10.2	100	10.2
IMPINGER 3 *(Dry)*	0.0	0	0
IMPINGER 4 *(Silica Gel)*	216.2	200	16.2
	Total Weight of Water Collected		21.4 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

AMD FORM FEB 84 651 REPLACES OEHL 20, MAY 78, WHICH IS OBSOLETE.

Page 1 of 2

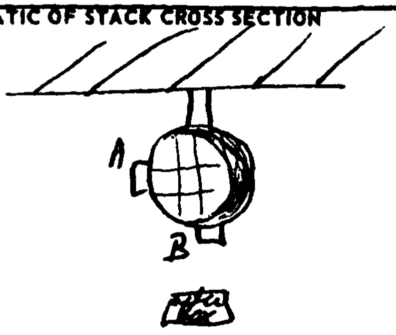
PARTICULATE SAMPLING DATA SHEET

Hexavalent Chromium #2

$\Delta H@ = 1.91$

RUN NUMBER
10 JAN 89
DATE
ANODIZING Wet Scrubber
PLANT
Kelly
BASE
Nutech #1
SAMPLE BOX NUMBER
Nutech #2
METER BOX NUMBER
Qw/Qm
Co

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$^{o}R = ^{o}F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

pitot tube -
pre leak check @ 15" Hg good

assume $H_2O = 4$
Static P = .14
MW = 29.

AMBIENT TEMP
52 °F
STATION PRESS
29.530 in Hg
HEATER BOX TEMP
~~190~~ 225 °F
PROBE HEATER SETTING
190
PROBE LENGTH
72 in
NOZZLE AREA (A)
.318 sq ft
Cp
.84
DRY GAS FRACTION (Fd)

time 1051

1145

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	VAC STATIC PRESSURE (in H2O) In Hg	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1	0	0	60		.10	1.14	917.580	84		84	262	51
2	4	0	63		.11	1.25		86		84	262	44
3	8	0	61		.12	1.37		88		84	261	45
4	12	0	61		.13	1.49		92		85	265	48
5	16	0	61		.14	1.61		95		86	223	50
6	20	0	62		.17	1.95		97		87	237	53
7	24	0.3	62		.23	2.65		95		87	244	54
8	28	0.3	62		.24	2.77		100		88	247	56
9	32	0.3	62		.24	2.77		101		89	238	57
10	36	0.1	67		.22	2.55		102		87	235	58
11	40	0	62		.21	2.43		103		90	233	60
12	44	0	61		.19	2.21		104		90	234	60
	48 (stop)	0					952.790					

Page 2 of 2

Hexavalent Chromium #2 (cont)

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER
10 JAN 89

DATE
Anodizing Wet Scrubber

PLANT
Kelly

BASE
Nutech #2

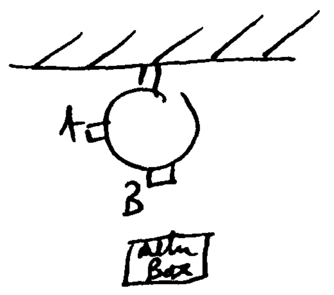
SAMPLE BOX NUMBER
Nutech #2

METER BOX NUMBER

Qw/Qm

Co

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$$°R = °F + 460$$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

post leak check @ "Hg

AMBIENT TEMP Cont °F

STATION PRESS Cont in Hg

HEATER BOX TEMP Cont °F

PROBE HEATER SETTING Cont

PROBE LENGTH Cont in

NOZZLE AREA (A) Cont sq ft

Cp Cont

DRY GAS FRACTION (Fd)

Time 1153

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1	0	0	61		.11	1.28	952.790	100		97	240	56
2	4	0	63		.13	1.50		100		92	236	53
3	8	0	62		.16	1.85		100		92	236	55
4	12	0	61		.18	2.09		100		92	235	56
5	16	0	61		.19	2.21		101		92	239	58
6	20	0	61		.20	2.32		101		92	231	59
7	24	.1	62		.22	2.55		102		92	241	61
8	28	0	62		.19	2.26		102		92	238	64
9	32	0	62		.18	2.09		102		92	230	64
10	36	0	62		.17	1.97		101		97	247	65
11	40	0	62		.16	1.86		101		93	236	65
12	44	0	62		.15	1.74		101		93	232	66
	48 (stop)						988.291					

1241

$\overline{T_M}$ = 94

TOTAL CU FT = 70.711

$\overline{T_S}$ = 62

$\overline{\Delta H}$ = 1.99

$\overline{\sqrt{P_S T_S}}$ = 9.414

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY	**DATE** 10 JAN 89	**RUN NUMBER** 2

BUILDING NUMBER 375	**SOURCE NUMBER** Cr^6 WET SCRUBBER

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* NAOH	100.0	100	0
IMPINGER 2 *(H20)* NAOH	102.2	100	2.2
IMPINGER 3 *(Dry)*	2.5	0	2.5
IMPINGER 4 *(Silica Gel)*	216.7	200	16.7
	Total Weight of Water Collected		21.4 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

AMD FORM FEB 84 651 REPLACES OEHL 20, MAY 78, WHICH IS OBSOLETE.

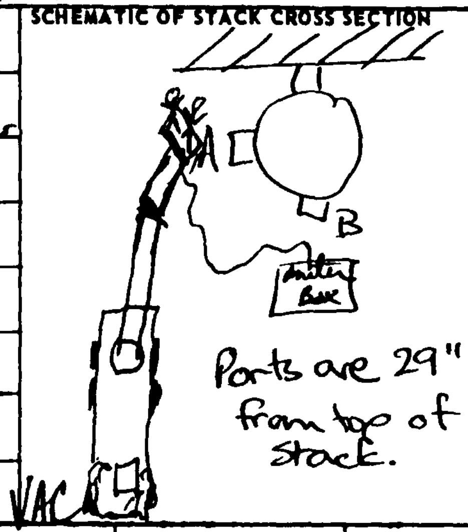
Hexavalent Chromium #1

PARTICULATE SAMPLING DATA SHEET

$\Delta H_{@} = 1.91$

RUN NUMBER
10 JAN 89
DATE
ANODIZING Wet Scrubber
PLANT
Kelly
BASE
Nutech #2
SAMPLE BOX NUMBER
Nutech #2
METER BOX NUMBER
Qw/Qm
Cn

SCHEMATIC OF STACK CROSS SECTION



Ports are 29" from top of stack.

EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

pitot tube – good.
preleak check @ 15" Hg – good.

assume H_2O = 4
Static P = .14
MW = 29.0

AMBIENT TEMP 52 °F
STATION PRESS 29.530 in Hg
HEATER BOX TEMP 225 °F
PROBE HEATER SETTING 190
PROBE LENGTH 72 in
NOZZLE AREA (A) .318 sq ft
Cp .84
DRY GAS FRACTION (Fd)

Time 0822

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	~~STATIC PRESSURE (in H2O)~~ VAC	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
A 1	0	3.0	50		.13	1.45	845.198	63		61	255	46
2	4	3.0	53		.14	1.56		70		62	247	45
3	8	4.0	59		.17	1.89		75		64	247	45
4	12	4.0	61		.18	2.00		80		66	248	48
5	16	5.0	62		.20	2.23		83		67	248	51
6	20	5.0	61		.21	2.35		85		69	248	52
7	24	5.0	61		.23	2.58		86		70	246	54
8	28	5.0	61		.21	2.37		88		72	247	56
9	32	4.5	61		.19	2.14		88		73	246	56
10	36	4.0	61		.17	1.92		88		74	246	57
11	40	4.0	61		.17	1.92		89		75	248	57
12	44	3.0	61		.14	1.59		90		76	248	57
	48 (stop)						880.795					

0910

OEHL FORM MAY 78 18

Hexavalent Chromium #1 (cont)

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER

~~Ac~~ 10 JAN 87

DATE

Kelly

PLANT

Anodizing Wet Scrubber

BASE

Natick #2

SAMPLE BOX NUMBER

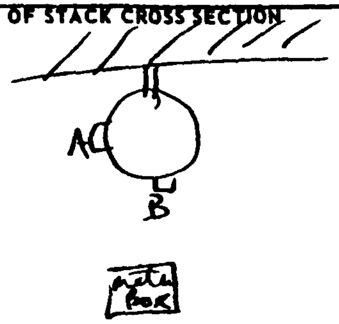
Nutech #2

METER BOX NUMBER

Qw/Qm

Co

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$^{o}R = {}^{o}F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

post leak check @ 7" Hg
-good

AMBIENT TEMP cont oF

STATION PRESS cont in Hg

HEATER BOX TEMP cont oF

PROBE HEATER SETTING cont

PROBE LENGTH cont in

NOZZLE AREA (A) cont sq ft

Cp cont

DRY GAS FRACTION (Fd)

VAC

time 0915

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	~~STATIC PRESSURE (in H2O)~~	STACK TEMP (oF)	STACK TEMP (Ts) (oR)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (oF)	GAS METER TEMP AVG (Tm) (oR)	GAS METER TEMP OUT (oF)	SAMPLE BOX TEMP (oF)	IMPINGER OUTLET TEMP (oF)
1	3 0	2.0	51		.09	1.03	880.795	80		77	253	53
2	4	2.0	57		.11	1.26		87		78	247	52
3	8	2.5	61		.12	1.36		89		79	247	52
4	12	2.8	63		.13	1.47		91		80	249	53
5	16	3.3	61		.15	1.71		93		81	249	53
6	20	3.5	62		.16	1.83		94		82	247	53
7	24	6.0	61		.24	2.75		95		83	247	54
8	28	6.5	62		.26	2.98		97		84	246	55
9	32	6.2	61		.25	2.88		99		85	247	56
10	36	5.8	61		.23	2.65		100		85	247	58
11	40	5.8	61		.23	2.65		100		86	246	59
12	44	4.5	61		.19	2.20		101		87	246	59
	48 (stop)						917.136					

108

$\bar{T}_m = 82.$

$\bar{T}_s = 60.$

$\overline{\Delta H} = 2.03$

$\overline{\sqrt{P_s T_s}} = 9.5680$

Total Cuft = 71.938

OEHL FORM MAY 78 18

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE KELLY	**DATE** 10 JAN 89	**RUN NUMBER** 1
BUILDING NUMBER 375	**SOURCE NUMBER** Cr^{6} WET SCRUBBER	

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER			
ACETONE WASHINGS *(Probe, Front Half Filter)*			
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)* NAOH	95.0	100	-5.0
IMPINGER 2 *(H20)* NAOH	109.0	100	9.0
IMPINGER 3 *(Dry)*	2.9	0	2.9
IMPINGER 4 *(Silica Gel)*	216.2	200	16.2
	Total Weight of Water Collected		23.1 gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2					
VOL % O_2					
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

AMD FORM FEB 84 651 REPLACES OEHL 20, MAY 78, WHICH IS OBSOLETE.

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APPENDIX K
Laboratory Results

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LABORATORY ANALYSIS REPORT AND RECORD *(General)*

DATE 1 3 JAN 1989

TO: Kelly AFB

FROM: USAFOEHL/SA
BROOKS AFB, TX 78235-5501

SAMPLE IDENTITY

DATE RECEIVED

SAMPLE FROM
Bldg #

LAB CONTROL NR
2202 - 205

TEST FOR
Phosphoric Acid

	run 1	run 2	run 3	control
OEHL NUMBER	2202	2203	2204	2205
BASE NUMBER	SY890001	SY890002	SY890003	SY890004 ← 4
RESULTS ~~(mg/m^3~~) mg/Sample	<0.5	<0.5	<0.5	<0.3

Comments:
sample volume 540ml 505ml 520ml 310ml

OEHL NUMBER				
BASE NUMBER				
RESULTS (mg/m^3)				

Comments:

OEHL NUMBER				
BASE NUMBER				
RESULTS (mg/m^3)				

Comments:

Mark J Dibben
MARK J. DIBBEN, 1Lt, USAF
Occupational Chemist

Andrew Richardson, III
ANDREW RICHARDSON, III, GS-12
Chief, IH Analysis Section

REQUESTING AGENCY *(Mailing Address)*
Capt Scott
USAFOEHL/ECQ
Brooks AFB, TX 78235

REVIEWED BY	DATE
Andrew Richardson, III	30 JAN 89

AFSC Form 3511, DEC 85 REPLACES AMD FORM 641, SEP 82, WHICH IS OBSOLETE

✓

LABORATORY ANALYSIS REPORT AND RECORD *(General)*

DATE 17 JAN 1989

TO: Kelly AFB

FROM: USAFOEHL/SA
BROOKS AFB, TX 78235-5501

SAMPLE IDENTITY

DATE RECEIVED

SAMPLE FROM
Bldg #

LAB CONTROL NR 2206 - 209

TEST FOR Sulfuric Acid

8/4

	Control	run 1	run 2	run 3
OEHL NUMBER	2206	2207	2208	2209
BASE NUMBER	SY890007	SY890004 ↑	SY890005	SY890006
RESULTS ~~(mg/m³)~~ mg/sample	<0.1	<0.4	<0.4	<0.4
Comments: sample Volume	100ml	355ml	390ml	460ml

OEHL NUMBER				
BASE NUMBER				
RESULTS (mg/m^3)				

Comments:

OEHL NUMBER				
BASE NUMBER				
RESULTS (mg/m^3)				

Comments:

Andrew Richardson, III
ANDREW RICHARDSON, III, GS-12
Chief, IH Analysis Section

Mark J. Dibben
MARK J. DIBBEN, 1Lt, USAF
Occupational Chemist

REQUESTING AGENCY *(Mailing Address)*

USAFOEHL /ECQ
Brooks AFB, TX 78235

Attn: Capt Scott

REVIEWED BY	DATE
Andrew Richardson, III	17 JAN 89

AFSC Form 3511, DEC 85 REPLACES AMD FORM 641, SEP 82, WHICH IS OBSOLETE

LABORATORY ANALYSIS REPORT AND RECORD *(General)*

DATE 19 Jan 89

TO:

FROM: USAFOEHL/SA
Brooks AFB TX 78235-5501

SAMPLE IDENTITY Anodizing Unit (Kelly AFB TX)

DATE RECEIVED 17 Jan 89

SAMPLE FROM

LAB CONTROL NR

TEST FOR Total Chromium and Hexavalent Chromium

TOTAL CHROMIUM

OEHL NO:	BASE NO:	Other	ug/ml	Volume	ug/sample	-BLANK (µg)
2491	GU890009	run one	0.0220	258 mls	5.68	5.18
2492	GU890010	run two	0.0096	276 mls	2.65	2.12
2493	GU890011	run three	0.0425	294 mls	12.5	11.94
2494	GU890012	blank	0.0019	330 mls	0.63	
HEXAVALENT CHROMIUM						
2495	GU890013	run one	0.0070	294 mls	2.06	1.92
2496	GU890014	run two	0.0123	306 mls	3.76	3.61
2497	GU890015	run three	0.0050	330 mls	1.65	1.49
2498	GU890016	blank	0.0005	229 mls	0.11	

Leo J Jehl
LEO J. JEHL, JR.
Chief, Metals Analysis Section

REQUESTING AGENCY *(Mailing Address)*

USAFOEHL/ECQ (Maj Garrison)

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APPENDIX L
Isokinetic and Emissions Calculations

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```
           XROM "METH 5"
RUN NUMBER
PHOS ACID R1
                        RUN
METER BOX Y?
           1.0020       RUN
DELTA H?
           2.2300       RUN
BAR PRESS ?
          29.2450       RUN
METER VOL ?
          93.9400       RUN
MTR TEMP F?
          82.0000       RUN
STATIC HOH IN ?
            .1400       RUN
STACK TEMP.
          73.0000       RUN
ML. WATER ?
          58.0000       RUN


SAT % = 2.8


IMP. % HOH = 2.9

% HOH=2.8


% CO2?
            .0300       RUN
% OXYGEN?
          21.0000       RUN
% CO ?
           0.0000       RUN

MWd =28.84
MW WET=28.54


SQRT PSTS ?
          10.0126       RUN
TIME MIN ?
         120.0000       RUN
NOZZLE DIA ?
            .3180       RUN
STK DIA INCH ?
          48.0000       RUN

* VOL MTR STD = 90.130
  STK PRES ABS = 29.26
  VOL HOH GAS = 2.73
  % MOISTURE = 2.80
  MOL DRY GAS = 0.972
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.54
  VELOCITY FPS = 24.88
  STACK AREA = 12.57
  STACK ACFM = 18,761.
* STACK DSCFM = 17,664.
  % ISOKINETIC =  96.93
```

```
           XROM "METH 5"
RUN NUMBER
PHOS ACID R2
                        RUN
METER BOX Y?
           1.0020       RUN
DELTA H?
           2.2100       RUN
BAR PRESS ?
          29.2450       RUN
METER VOL ?
          76.2800       RUN
MTR TEMP F?
          92.0000       RUN
STATIC HOH IN ?
            .1400       RUN
STACK TEMP.
          74.0000       RUN
ML. WATER ?
          35.4000       RUN


SAT % = 2.9


IMP. % HOH = 2.3

% HOH=2.3


% CO2?
            .0300       RUN
% OXYGEN?
          21.0000       RUN
% CO ?
           0.0000       RUN

MWd =28.84
MW WET=28.60


SQRT PSTS ?
          10.0106       RUN
TIME MIN ?
          96.0000       RUN
NOZZLE DIA ?
            .3180       RUN
STK DIA INCH ?
          48.0000       RUN

* VOL MTR STD = 71.857
  STK PRES ABS = 29.26
  VOL HOH GAS = 1.67
  % MOISTURE = 2.27
  MOL DRY GAS = 0.977
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.60
  VELOCITY FPS = 24.85
  STACK AREA = 12.57
  STACK ACFM = 18,739.
* STACK DSCFM = 17,706.
  % ISOKINETIC =  96.37
```

```
           XROM "METH 5"
RUN NUMBER
PHOS ACID R3
                        RUN
METER BOX Y?
           1.0020       RUN
DELTA H?
           2.1400       RUN
BAR PRESS ?
          29.1900       RUN
METER VOL ?
          73.6000       RUN
MTR TEMP F?
          75.0000       RUN
STATIC HOH IN ?
            .1400       RUN
STACK TEMP.
          64.0000       RUN
ML. WATER ?
          24.4000       RUN


SAT % = 2.1


IMP. % HOH = 1.6

% HOH=1.6


% CO2?
            .0300       RUN
% OXYGEN?
          21.0000       RUN
% CO ?
           0.0000       RUN

MWd =28.84
MW WET=28.67


SQRT PSTS ?
           9.9561       RUN
TIME MIN ?
          96.0000       RUN
NOZZLE DIA ?
            .3180       RUN
STK DIA INCH ?
          48.0000       RUN

* VOL MTR STD = 71.389
  STK PRES ABS = 29.20
  VOL HOH GAS = 1.15
  % MOISTURE = 1.58
  MOL DRY GAS = 0.984
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.67
  VELOCITY FPS = 24.71
  STACK AREA = 12.57
  STACK ACFM = 18,630.
* STACK DSCFM = 18,031.
  % ISOKINETIC =  94.02
```

```
           XROM "METH 5"
RUN NUMBER
SULF ACID R1
                       RUN
METER BOX Y?
           1.0020      RUN
DELTA H?
           2.3600      RUN
BAR PRESS ?
          29.1900      RUN
METER VOL ?
          77.9320      RUN
MTR TEMP F?
         102.0000      RUN
STATIC HOH IN ?
            .1400      RUN
STACK TEMP.
          70.0000      RUN
ML. WATER ?
                       RUN
% MOISTURE ?
           1.6000      RUN


SAT % = 2.5


IMP. % HOH = 0.0

% HOH=1.6


% CO2?
            .0300      RUN
% OXYGEN?
          21.0000      RUN
% CO ?
           0.0000      RUN

MWd =28.84
MW WET=28.67


SQRT PSTS ?
          10.2834      RUN
TIME MIN ?
          96.0000      RUN
NOZZLE DIA ?
            .3180      RUN
STK DIA INCH ?
          48.0000      RUN

* VOL MTR STD = 71.999
  STK PRES ABS = 29.20
  VOL HOH GAS = 0.00
  % MOISTURE = 1.60
  MOL DRY GAS = 0.984
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.67
  VELOCITY FPS = 25.52
  STACK AREA = 12.57
  STACK ACFM = 19,243.
* STACK DSCFM = 18,410.
  % ISOKINETIC =  92.87
```

```
           XROM "METH 5"
RUN NUMBER
SULF ACID R2
                       RUN
METER BOX Y?
           1.0020      RUN
DELTA H?
           2.2600      RUN
BAR PRESS ?
          29.1900      RUN
METER VOL ?
          76.3800      RUN
MTR TEMP F?
          99.0000      RUN
STATIC HOH IN ?
            .1400      RUN
STACK TEMP.
          72.0000      RUN
ML. WATER ?
                       RUN
% MOISTURE ?
           1.6000      RUN


SAT % = 2.7


IMP. % HOH = 0.0

% HOH=1.6


% CO2?
            .0300      RUN
% OXYGEN?
          21.0000      RUN
% CO ?
           0.0000      RUN

MWd =28.84
MW WET=28.67


SQRT PSTS ?
          10.1440      RUN
TIME MIN ?
          96.0000      RUN
NOZZLE DIA ?
            .3180      RUN
STK DIA INCH ?
          48.0000      RUN

* VOL MTR STD = 70.926
  STK PRES ABS = 29.20
  VOL HOH GAS = 0.00
  % MOISTURE = 1.60
  MOL DRY GAS = 0.984
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.67
  VELOCITY FPS = 25.10
  STACK AREA = 12.57
  STACK ACFM = 18,982.
* STACK DSCFM = 18,092.
  % ISOKINETIC =  93.10
```

```
           XROM "METH 5"
RUN NUMBER
SULF CR R3
                       RUN
METER BOX Y?
           1.0020      RUN
DELTA H?
           2.1300      RUN
BAR PRESS ?
          29.1900      RUN
METER VOL ?
          75.2030      RUN
MTR TEMP F?
          87.0000      RUN
STATIC HOH IN ?
            .1400      RUN
STACK TEMP.
          73.0000      RUN
ML. WATER ?
                       RUN
% MOISTURE ?
           1.6000      RUN


SAT % = 2.8


IMP. % HOH = 0.0

% HOH=1.6


% CO2?
            .0300      RUN
% OXYGEN?
          21.0000      RUN
% CO ?
           0.0000      RUN

MWd =28.84
MW WET=28.67


SQRT PSTS ?
          10.0390      RUN
TIME MIN ?
          96.0000      RUN
NOZZLE DIA ?
            .3180      RUN
STK DIA INCH ?
          48.0000      RUN

* VOL MTR STD = 71.342
  STK PRES ABS = 29.20
  VOL HOH GAS = 0.00
  % MOISTURE = 1.60
  MOL DRY GAS = 0.984
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.67
  VELOCITY FPS = 24.92
  STACK AREA = 12.57
  STACK ACFM = 18,786.
* STACK DSCFM = 17,871.
  % ISOKINETIC =  94.80
```

```
        XROM "METH 5"
RUN NUMBER
TOT CR R1
                    RUN
METER BOX Y?
          1.0020    RUN
DELTA H?
          2.3900    RUN
BAR PRESS ?
         29.5350    RUN
METER VOL ?
         78.0420    RUN
MTR TEMP F?
         89.0000    RUN
STATIC HOH IN ?
           .1400    RUN
STACK TEMP.
         60.0000    RUN
ML. WATER ?
         23.9000    RUN


SAT % = 1.8


IMP. % HOH = 1.5

% HOH=1.5


% CO2?
           .0300    RUN
% OXYGEN?
         21.0000    RUN
% CO ?
          0.0000    RUN

MWd =28.84
MW WET=28.68


SQRT PSTS ?
         10.3439    RUN
TIME MIN ?
         96.0000    RUN
NOZZLE DIA ?
           .3180    RUN
STK DIA INCH ?
         48.0000    RUN

* VOL MTR STD = 74.681
  STK PRES ABS = 29.55
  VOL HOH GAS = 1.12
  % MOISTURE = 1.48
  MOL DRY GAS = 0.985
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.68
  VELOCITY FPS = 25.52
  STACK AREA = 12.57
  STACK ACFM = 19,239.
* STACK DSCFM = 19,004.
  % ISOKINETIC =  93.32
```

```
        XROM "METH 5"
RUN NUMBER
TOT CR R2
                    RUN
METER BOX Y?
          1.0020    RUN
DELTA H?
          2.4000    RUN
BAR PRESS ?
         29.5350    RUN
METER VOL ?
         79.1960    RUN
MTR TEMP F?
         97.0000    RUN
STATIC HOH IN ?
           .1400    RUN
STACK TEMP.
         61.0000    RUN
ML. WATER ?
         21.6000    RUN


SAT % = 1.8


IMP. % HOH = 1.3

% HOH=1.3


% CO2?
           .0300    RUN
% OXYGEN?
         21.0000    RUN
% CO ?
          0.0000    RUN

MWd =28.84
MW WET=28.70


SQRT PSTS ?
         10.2926    RUN
TIME MIN ?
         96.0000    RUN
NOZZLE DIA ?
           .3180    RUN
STK DIA INCH ?
         48.0000    RUN

* VOL MTR STD = 74.698
  STK PRES ABS = 29.55
  VOL HOH GAS = 1.02
  % MOISTURE = 1.34
  MOL DRY GAS = 0.987
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.70
  VELOCITY FPS = 25.38
  STACK AREA = 12.57
  STACK ACFM = 19,138.
* STACK DSCFM = 18,895.
  % ISOKINETIC =  93.88
```

```
        XROM "METH 5"
RUN NUMBER
TOT CR R3
                    RUN
METER BOX Y?
          1.0020    RUN
DELTA H?
          2.2800    RUN
BAR PRESS ?
         29.5350    RUN
METER VOL ?
         76.7500    RUN
MTR TEMP F?
         99.0000    RUN
STATIC HOH IN ?
           .1400    RUN
STACK TEMP.
         60.0000    RUN
ML. WATER ?
         22.2000    RUN


SAT % = 1.8


IMP. % HOH = 1.4

% HOH=1.4


% CO2?
           .0300    RUN
% OXYGEN?
         21.0000    RUN
% CO ?
          0.0000    RUN

MWd =28.84
MW WET=28.69


SQRT PSTS ?
         10.0110    RUN
TIME MIN ?
         96.0000    RUN
NOZZLE DIA ?
           .3180    RUN
STK DIA INCH ?
         48.0000    RUN

* VOL MTR STD = 72.111
  STK PRES ABS = 29.55
  VOL HOH GAS = 1.04
  % MOISTURE = 1.43
  MOL DRY GAS = 0.986
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.69
  VELOCITY FPS = 24.69
  STACK AREA = 12.57
  STACK ACFM = 18,618.
* STACK DSCFM = 18,401.
  % ISOKINETIC =  93.06
```

```
        XROM "MASSFLO"

RUN NUMBER
TOT CR R1
                     RUN

VOL MTR STD ?
         74.6810    RUN
STACK DSCFM ?
      19,004.0000    RUN
FRONT 1/2 MG ?
          .00518    RUN
BACK 1/2 MG ?
          0.0000    RUN


F  GR/DSCF = 1.0704E-6
F  MG/MMM = 0.0024
F  LB/HR = 0.0002
F  KG/HR = 0.0001
        XROM "MASSFLO"

RUN NUMBER
TOT CR R2
                     RUN

VOL MTR STD ?
         74.6980    RUN
STACK DSCFM ?
      18,895.0000    RUN
FRONT 1/2 MG ?
          .00212    RUN
BACK 1/2 MG ?
          0.0000    RUN


F  GR/DSCF = 4.3798E-7
F  MG/MMM = 0.0010
F  LB/HR = 0.0001
F  KG/HR = 3.2175E-5



        XROM "MASSFLO"

RUN NUMBER
TOT CR R3
                     RUN

VOL MTR STD ?
         72.1110    RUN
STACK DSCFM ?
      18,481.0000    RUN
FRONT 1/2 MG ?
          .01194    RUN
BACK 1/2 MG ?
          0.0000    RUN


F  GR/DSCF = 2.5552E-6
F  MG/MMM = 0.0058
F  LB/HR = 0.0004
F  KG/HR = 0.0002
```

```
          XROM "METH 5"
RUN NUMBER
HEX CR R1
                  RUN
METER BOX Y?
          1.0020   RUN
DELTA H?
          2.0300   RUN
BAR PRESS ?
         29.5300   RUN
METER VOL ?
         71.9380   RUN
MTR TEMP F?
         82.0000   RUN
STATIC HOH IN ?
           .1400   RUN
STACK TEMP.
         60.0000   RUN
ML. WATER ?
         23.1000   RUN


SAT % = 1.8


IMP. % HOH = 1.5

% HOH=1.5


% CO2?
           .0300   RUN
% OXYGEN?
         21.0000   RUN
% CO ?
          0.0000   RUN

MWd =28.84
MW WET=28.68


SQRT PSTS ?
          9.5680   RUN
TIME MIN ?
         96.0000   RUN
NOZZLE DIA ?
           .3180   RUN
STK DIA INCH ?
         48.0000   RUN

* VOL MTR STD = 69.655
  STK PRES ABS = 29.54
  VOL HOH GAS = 1.09
  % MOISTURE = 1.54
  MOL DRY GAS = 0.985
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.68
  VELOCITY FPS = 23.61
  STACK AREA = 12.57
  STACK ACFM = 17,799.
* STACK DSCFM = 17,569.
  % ISOKINETIC =  94.15
```

```
          XROM "METH 5"
RUN NUMBER
HEX CR R2
                  RUN
METER BOX Y?
          1.0020   RUN
DELTA H?
          1.9900   RUN
BAR PRESS ?
         29.5300   RUN
METER VOL ?
         70.7110   RUN
MTR TEMP F?
         94.0000   RUN
STATIC HOH IN ?
           .1400   RUN
STACK TEMP.
         62.0000   RUN
ML. WATER ?
         21.4000   RUN


SAT % = 1.9


IMP. % HOH = 1.5

% HOH=1.5


% CO2?
           .0300   RUN
% OXYGEN?
         21.0000   RUN
% CO ?
          0.0000   RUN

MWd =28.84
MW WET=28.68


SQRT PSTS ?
          9.4140   RUN
TIME MIN ?
         96.0000   RUN
NOZZLE DIA ?
           .3180   RUN
STK DIA INCH ?
         48.0000   RUN

* VOL MTR STD = 66.977
  STK PRES ABS = 29.54
  VOL HOH GAS = 1.01
  % MOISTURE = 1.48
  MOL DRY GAS = 0.985
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.68
  VELOCITY FPS = 23.22
  STACK AREA = 12.57
  STACK ACFM = 17,511.
* STACK DSCFM = 17,228.
  % ISOKINETIC =  92.32
```

```
          XROM "METH 5"
RUN NUMBER
HEX CR R3
                  RUN
METER BOX Y?
          1.0020   RUN
DELTA H?
          2.1500   RUN
BAR PRESS ?
         29.5300   RUN
METER VOL ?
         74.4300   RUN
MTR TEMP F?
         87.0000   RUN
STATIC HOH IN ?
           .1400   RUN
STACK TEMP.
         62.0000   RUN
ML. WATER ?
         21.4000   RUN


SAT % = 1.9


IMP. % HOH = 1.4

% HOH=1.4


% CO2?
           .0300   RUN
% OXYGEN?
         21.0000   RUN
% CO ?
          0.0000   RUN

MWd =28.84
MW WET=28.69


SQRT PSTS ?
          9.8364   RUN
TIME MIN ?
         96.0000   RUN
NOZZLE DIA ?
           .3180   RUN
STK DIA INCH ?
         48.0000   RUN

* VOL MTR STD = 71.430
  STK PRES ABS = 29.54
  VOL HOH GAS = 1.01
  % MOISTURE = 1.39
  MOL DRY GAS = 0.986
  % NITROGEN = 78.97
  MOL WT DRY = 28.84
  MOL WT WET = 28.69
  VELOCITY FPS = 24.26
  STACK AREA = 12.57
  STACK ACFM = 18,293.
* STACK DSCFM = 18,015.
  % ISOKINETIC =  94.16
```

```
          XROM "MASSFLO"

RUN NUMBER
HEX CR R1
                     RUN

VOL MTR STD ?
          69.6550    RUN
STACK DSCFM ?
      17,569.0000    RUN
FRONT 1/2 MG ?
           .00192    RUN
BACK 1/2 MG ?
           0.0000    RUN


F  GR/DSCF = 4.2538E-7
F  MG/MMM = 0.0010
F  LB/HR = 0.0001
F  KG/HR = 2.9057E-5

          XROM "MASSFLO"

RUN NUMBER
HEX CR R2
                     RUN

VOL MTR STD ?
          66.9770    RUN
STACK DSCFM ?
      17,228.0000    RUN
FRONT 1/2 MG ?
           .00361    RUN
BACK 1/2 MG ?
           0.0000    RUN


F  GR/DSCF = 8.3178E-7
F  MG/MMM = 0.0019
F  LB/HR = 0.0001
F  KG/HR = 0.0001

          XROM "MASSFLO"

RUN NUMBER
HEX CR R3
                     RUN

VOL MTR STD ?
          71.4300    RUN
STACK DSCFM ?
      18,015.0000    RUN
FRONT 1/2 MG ?
           .00149    RUN
BACK 1/2 MG ?
           0.0000    RUN


F  GR/DSCF = 3.2191E-7
F  MG/MMM = 0.0007
F  LB/HR = 4.9707E-5
F  KG/HR = 2.2547E-5
```

APPENDIX M
Calibration Data

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NOZZLE CALIBRATION DATA FORM

Date ____________________ Calibrated by ____________________

Nozzle identification number	Nozzle Diameter[a]			ΔD,[b] mm (in.)	D_{avg}[c]
	D_1, mm (in.)	D_2, mm (in.)	D_3, mm (in.)		
#9	.318	.318	.317	.001	.318

where:

[a] $D_{1,2,3,}$ = three different nozzles diameters, mm (in.); each diameter must be within (0.025 mm) 0.001 in.

[b] ΔD = maximum difference between any two diameters, mm (in.), $\Delta D \leq$ (0.10 mm) 0.004 in.

[c] D_{avg} = average of D_1, D_2, and D_3.

METER BOX CALIBRATION DATA AND CALCULATION FORM

(English units)

Date 21 Nov 88 **Meter box number** Nutch #2

Barometric pressure, P_b = 30.02 **in. Hg** **Calibrated by** Scott & Vaughn

		Gas volume		Temperature						
					Dry gas meter					
VAC	Orifice manometer setting (ΔH), in. H_2O	Wet test meter (V_w), ft^3	Dry gas meter (V_d), ft^3	Wet test meter (t_w), °F	Inlet (t_{d_i}), °F	Outlet (t_{d_o}), °F	Avg[a] (t_d), °F	Time (θ), min	Y_i	$\Delta H@_i$ in. H_2O
4.0	0.5	5	5.057	75 75 535	77 82	75 77	537.75	12.40	0.9926	1.73
4.0	1.0	5	5.031	76 76 536	84 89	77 80	542.5	9.14	1.0034	1.87
4.0	1.5	10	10.101	77 77 537	90 96	81 84	547.75	15.35	1.0061	1.97
4.0	2.0	10	10.230	78 78 538	97 99	85 87	552.0	13.45	0.9981	2.00
4.0	3.0	10	10.170	78 78 538	100 103	87 89	554.75	10.92	1.0065	1.97
4.0	4.0	10	10.191	78 78 538	103 105	87 91	557.0	9.35	1.0061	1.92
								Avg	1.002	1.91

ΔH, in. H_2O	$\frac{\Delta H}{13.6}$	$Y_i = \frac{V_w P_b (t_d + 460)}{V_d (P_b + \frac{\Delta H}{13.6}) (t + 460)}$	$\Delta H@_i = \frac{0.0317 \Delta H}{P_b (t_d + 460)} \left[\frac{(t_w + 460)\theta}{V_w}\right]^2$
0.5	0.0368	$\frac{(5)(30.02)(537.75)}{(5.057)(30.02+\frac{.5}{13.6})(535)}$	$\frac{(.0317)(.5)}{(30.02)(537.75)}\left(\frac{(535)(12.4)}{(5)}\right)^2$
1.0	0.0737	$\frac{(5)(30.02)(542.5)}{(5.031)(30.02+\frac{1}{13.6})(536)}$	$\frac{(.0317)(1.0)}{(30.02)(542.5)}\left[\frac{(536)(9.14)}{5}\right]^2$
1.5	0.110	$\frac{(10)(30.02)(547.75)}{(10.101)(30.02+\frac{1.5}{13.6})(537)}$	$\frac{(.0317)(1.5)}{(30.02)(547.75)}\left[\frac{(538)(15.35)}{10}\right]^2$
2.0	0.147	$\frac{(10)(30.02)(552)}{(10.23)(30.02+\frac{2.0}{13.6})(538)}$	$\frac{(.0317)(2.0)}{(30.02)(552)}\left[\frac{(538)(13.45)}{10}\right]^2$
3.0	0.221	$\frac{(10)(30.02)(554.75)}{(10.17)(30.02+\frac{3}{13.6})(538)}$	$\frac{(.0317)(3.0)}{(30.02)(554.75)}\left[\frac{(538)(10.92)}{10}\right]^2$
4.0	0.294	$\frac{(10)(30.02)(557)}{(10.191)(30.02+\frac{4}{13.6})(538)}$	$\frac{(.0317)(4.0)}{(30.02)(557)}\left[\frac{(538)(9.35)}{10}\right]^2$

---

[a] If there is only one thermometer on the dry gas meter, record the temperature under t_d.

POSTTEST DRY GAS METER CALIBRATION DATA FORM (English units)

Test number KELLY AFB POST TEST Date 13 JAN 89 Meter box number NUTECH #2 Plant POST KELLY AFB PRE OFFUTT AFB

Barometric pressure, P_b = 29.560 in. Hg Dry gas meter number ______ Pretest Y 1.002

Orifice manometer setting, (ΔH), in. H_2O	Gas volume		Temperature				Time (θ), min	Vacuum setting, in. Hg	Y_i	Y_i
	Wet test meter (V_w), ft^3	Dry gas meter (V_d), ft^3	Wet test meter (t_w), °F	Dry gas meter						$\frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$
				Inlet (t_{d_i}), °F	Outlet (t_{d_o}), °F	Average^a (t_d), ~~°F~~/K				
2.0	10	88.015 77.932 10.083	76 76 536°K	83 93	76 80	543	13.40	5.0	0.999	$\frac{(10)(29.56)(543)}{(10.08)(29.71)(536)}$
2.0	10	99.764 89.634 10.130	76 76 536°K	93 95	80 83	547.8	13.40	5.0	1.004	$\frac{(10)(29.56)(547.8)}{(10.13)(29.71)(536)}$
2.0	10	111.160 100.980 10.180	76 76 536°K	95 96	83 85	549.8	13.40	5.0	1.003	$\frac{(10)(29.56)(549.8)}{(10.18)(29.71)(536)}$
									Y = 1.002	

[a] If there is only one thermometer on the dry gas meter, record the temperature under t_d

where

V_w = Gas volume passing through the wet test meter, ft^3.

V_d = Gas volume passing through the dry gas meter, ft^3.

t_w = Temperature of the gas in the wet test meter, °F.

t_{d_i} = Temperature of the inlet gas of the dry gas meter, °F.

t_{d_o} = Temperature of the outlet gas of the dry gas meter, °F.

t_d = Average temperature of the gas in the dry gas meter, obtained by the average of t_{d_i} and t_{d_o}, °F.

ΔH = Pressure differential across orifice, in. H_2O.

Y_i = Ratio of accuracy of wet test meter to dry gas meter for each run.

Y = Average ratio of accuracy of wet test meter to dry gas meter for all three runs; tolerance = pretest Y ±0.05Y.

P_b = Barometric pressure, in. Hg.

θ = Time of calibration run, min.

YRANGE = 0.952 - 1.052

TYPE S PITOT TUBE INSPECTION DATA FORM

#6A

Pitot tube assembly level? ✓ yes ______ no

Pitot tube openings damaged? ______ yes (explain below) ✓ no

α_1 = 1 ° (<10°), α_2 = 2 ° (<10°), β_1 = 2 ° (<5°),

β_2 = 3 ° (<5°)

(1.1875)

γ = 4 °, θ = 0 °, A = 13/16 ~~cm~~ (in.)

0.125

z = A sin γ = 0.0828 ~~cm~~ (in.); <0.32 cm (<1/8 in.),

w = A sin θ = 0.0 ~~cm~~ (in.); <.08 cm (<1/32 in.)

0.0313

P_A 19/32 (0.5938) ~~cm~~ (in.) P_b 19/32 (0.5938) ~~cm~~ (in.)

D_t = 0.375 cm (in.)

Comments: CONSTRUCTED IAW 40 CFR 60, APP A, METH 2, FIG 2.2. ASSIGNED BASELINE COEFFICIENT = 0.84

Calibration required? ______ yes ✓ no

STACK TEMPERATURE SENSOR CALIBRATION DATA FORM

NUTECH #2

Date 3 JAN 89 Thermocouple number INLET/OUTLET

Ambient temperature 26 °C Barometric pressure ______ in. Hg

Calibrator GARRISON SCOTT Reference: mercury-in-glass ASTM 63F

other ______

Reference point number	Source[a] (specify)	Reference thermometer temperature, °C	Thermocouple potentiometer temperature, °C	Temperature difference,[b] ~~%~~ °C *
INLET				
–	HOT WATER BATH	43.5	43	.5
–	ROOM TEMP	26	26	0
OUTLET				
–	HOT WATER BATH	43.5	42	1
–	ROOM TEMP	26	26.5	.5

[a] Type of calibration system used.

[b] $\left[\frac{(\text{ref temp, °C} + 273) - (\text{test thermom temp, °C} + 273)}{\text{ref temp, °C} + 273}\right] 100 \le 1.5\%$.

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* MUST BE WITHIN 3°C OF REFERENCE

STACK SENSOR CALIBRATION: 19-20 Oct 88

```
        REFERENCE    TEST
SENSOR TEMPERATURE TEMPERATURE
  #      (deg K)     (deg K)
          X axis      Y axis
---------------------------------

  P1       273.30      273.60                 Regression Output:
           371.90      373.60       Constant                             -4.30
           447.00      450.20       Std Err of Y Est                      0.20
                                    R Squared                             1.00
                                    No. of Observations                   3.00
                                    Degrees of Freedom                    1.00

                                    X Coefficient(s)       1.02
                                    Std Err of Coef.       0.00

                                    % Deviation @ 2000 F(1093.3 K) = 1.29%


  P2       273.30      273.60                 Regression Output:
           371.80      373.60       Constant                             -4.27
           447.60      450.80       Std Err of Y Est                      0.11
                                    R Squared                             1.00
                                    No. of Observations                   3.00
                                    Degrees of Freedom                    1.00

                                    X Coefficient(s)       1.02
                                    Std Err of Coef.       0.00

                                    % Deviation @ 2000 F(1093.3 K) = 1.25%


  P3       273.30      274.10                 Regression Output:
           371.90      374.10       Constant                             -2.96
           447.60      450.80       Std Err of Y Est                      0.03
                                    R Squared                             1.00
                                    No. of Observations                   3.00
                                    Degrees of Freedom                    1.00

                                    X Coefficient(s)       1.01
                                    Std Err of Coef.       0.00

                                    % Deviation @ 2000 F(1093.3 K) = 1.11%


  P4       273.30      273.60                 Regression Output:
           371.80      373.60       Constant                             -4.27
           447.60      450.80       Std Err of Y Est                      0.11
                                    R Squared                             1.00
                                    No. of Observations                   3.00
                                    Degrees of Freedom                    1.00

                                    X Coefficient(s)       1.02
                                    Std Err of Coef.       0.00

                                    % Deviation @ 2000 F(1093.3 K) = 1.27%
```

```
P5        273.30      274.10               Regression Output:
          371.90      373.60       Constant                          -3.03
          447.60      450.80       Std Err of Y Est                   0.37
                                   R Squared                          1.00
                                   No. of Observations                3.00
                                   Degrees of Freedom                 1.00

                                   X Coefficient(s)       1.01
                                   Std Err of Coef.       0.00

                                   % Deviation @ 2000 F(1093.3 K) = 1.08%

P6        273.30      273.30               Regression Output:
          371.90      373.60       Constant                          -5.03
          447.60      450.80       Std Err of Y Est                   0.09
                                   R Squared                          1.00
                                   No. of Observations                3.00
                                   Degrees of Freedom                 1.00

                                   X Coefficient(s)       1.02
                                   Std Err of Coef.       0.00

                                   % Deviation @ 2000 F(1093.3 K) = 1.37%

P7        273.30      273.30               Regression Output:
          371.90      373.60       Constant                          -5.03
          447.60      450.80       Std Err of Y Est                   0.09
                                   R Squared                          1.00
                                   No. of Observations                3.00
                                   Degrees of Freedom                 1.00

                                   X Coefficient(s)       1.02
                                   Std Err of Coef.       0.00

                                   % Deviation @ 2000 F(1093.3 K) = 1.37%

P8        273.60      273.60               Regression Output:
          371.80      373.00       Constant                          -4.75
          449.40      452.40       Std Err of Y Est                   0.39
                                   R Squared                          1.00
                                   No. of Observations                3.00
                                   Degrees of Freedom                 1.00

                                   X Coefficient(s)       1.02
                                   Std Err of Coef.       0.00

                                   % Deviation @ 2000 F(1093.3 K) = 1.25%
```

STACK TEMPERATURE SENSOR CALIBRATION DATA FORM

Date 19/20 OCT 88 Thermocouple number IMPINGER D1

Ambient temperature 26 °C Barometric pressure 29 232/ 29.175 in. Hg

Calibrator GARRISON/ SCOTT Reference: mercury-in-glass NBS

other

Reference point number[a]	Source[b] (specify)	Reference thermometer temperature, °C	Thermocouple potentiometer temperature, °C	Temperature difference,[c] ~~%~~ °C *
0	ICE BATH	0	0	—
—	ROOM TEMP	25.5	26.1	0.6

[a] Every 30°C (50°F) for each reference point.

[b] Type of calibration system used.

[c] $\left[\frac{(\text{ref temp, °C} + 273) - (\text{test thermom temp, °C} + 273)}{\text{ref temp, °C} + 273}\right] 100 \leq 1.5\%$.

* MUST BE WITHIN 1°C OF REF

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STACK TEMPERATURE SENSOR CALIBRATION DATA FORM

Date 19/20 OCT 88 Thermocouple number IMPINGER D2

Ambient temperature 26° °C Barometric pressure 29.232/ 29.175 in. Hg

Calibrator GARRISON / SCOTT Reference: mercury-in-glass NBS

other

Reference point number[a]	Source[b] (specify)	Reference thermometer temperature, °C	Thermocouple potentiometer temperature, °C	Temperature difference,[c] ~~%~~ °C *
0	ICE BATH	0	0	—
—	ROOM TEMP	26.0	26.6	0.6

[a] Every 30°C (50°F) for each reference point.

[b] Type of calibration system used.

[c] $\left[\frac{(\text{ref temp, °C} + 273) - (\text{test thermom temp, °C} + 273)}{\text{ref temp, °C} + 273}\right] 100 \leq 1.5\%.$

* MUST BE WITHIN 1°C OF REF

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STACK TEMPERATURE SENSOR CALIBRATION DATA FORM

IMPINGER

Date 19/20 OCT 88 Thermocouple number D3

Ambient temperature 26 °C Barometric pressure 29.232/ 29.175 in. Hg

Calibrator GARRISON/ SCOTT Reference: mercury-in-glass NBS

other

Reference point number[a]	Source[b] (specify)	Reference thermometer temperature, °C	Thermocouple potentiometer temperature, °C	Temperature difference,[c] ~~%~~ °C *
C	ICE BATH	0	0.6	0.6
—	ROOM TEMP	25.8	25.6	0.2

[a] Every 30°C (50°F) for each reference point.

[b] Type of calibration system used.

[c] $$\left[\frac{(\text{ref temp, °C} + 273) - (\text{test thermom temp, °C} + 273)}{\text{ref temp, °C} + 273}\right] 100 \leq 1.5\%.$$

* MUST BE WITHIN 1°C OF REF

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STACK TEMPERATURE SENSOR CALIBRATION DATA FORM

Date 19/20 OCT 88 Thermocouple number IMPINGER DY

Ambient temperature 26 °C Barometric pressure 29.232 29.175 in. Hg

Calibrator GARRISON/ SCOTT Reference: mercury-in-glass NBS

other

Reference point number[a]	Source[b] (specify)	Reference thermometer temperature, °C	Thermocouple potentiometer temperature, °C	Temperature difference,[c] ~~%~~ °C *
0	ICE BATH	0	0.6	0.6
–	ROOM TEMP	25.5	25.6	0.1

[a] Every 30°C (50°F) for each reference point.

[b] Type of calibration system used.

[c] $$\left[\frac{(\text{ref temp, }^\circ\text{C} + 273) - (\text{test thermom temp, }^\circ\text{C} + 273)}{\text{ref temp, }^\circ\text{C} + 273}\right] 100 \leq 1.5\%.$$

* MUST BE WITHIN 1°C OF REF

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STACK TEMPERATURE SENSOR CALIBRATION DATA FORM

IMPINGER

Date 19 Oct 88 Thermocouple number D5

Ambient temperature 26 °C Barometric pressure 29.175 29.232 in. Hg

Calibrator GARRISON/ SCOTT Reference: mercury-in-glass NBS

other ______

Reference point number[a]	Source[b] (specify)	Reference thermometer temperature, °C	Thermocouple potentiometer temperature, °C	Temperature difference,[c] ~~%~~ °C *
0	ICE BATH	0	0.6	0.6
—	ROOM TEMP	26	25.5	0.5

---

[a] Every 30°C (50°F) for each reference point.

[b] Type of calibration system used.

[c] $$\left[\frac{(\text{ref temp, °C} + 273) - (\text{test thermom temp, °C} + 273)}{\text{ref temp, °C} + 273}\right] 100 \leq 1.5\%.$$

* MUST BE WITHIN 1°C OF REF

STACK TEMPERATURE SENSOR CALIBRATION DATA FORM

Date 19/20 Oct 88 Thermocouple number IMPINGER D6

Ambient temperature 26 °C Barometric pressure 29.232/ 29.175 in. Hg

Calibrator GARRISON/ SCOTT Reference: mercury-in-glass NBS

other

Reference point number[a]	Source[b] (specify)	Reference thermometer temperature, °C	Thermocouple potentiometer temperature, °C	Temperature difference,[c] ~~%~~ °C *
0	ICE BATH	0	0.6	0.6
—	ROOM TEMP	26	25.5	0.5

[a] Every 30°C (50°F) for each reference point.

[b] Type of calibration system used.

[c] $\left[\frac{(\text{ref temp, °C} + 273) - (\text{test thermom temp, °C} + 273)}{\text{ref temp, °C} + 273}\right] 100 \leq 1.5\%$.

* MUST BE WITHIN 1°C OF REF

STACK TEMPERATURE SENSOR CALIBRATION DATA FORM

Date 19/20 Oct 88 Thermocouple number IMPINGER D7

Ambient temperature 26 °C Barometric pressure 29.232 29.175 in. Hg

Calibrator GARRISON/ SCOTT Reference: mercury-in-glass NBS

other

Reference point number[a]	Source[b] (specify)	Reference thermometer temperature, °C	Thermocouple potentiometer temperature, °C	Temperature difference,[c] ~~%~~ °C*
0	ICE BATH	0	0.6	0.6
—	ROOM TEMP	26	25.5	0.5

---

[a] Every 30°C (50°F) for each reference point.

[b] Type of calibration system used.

[c] $$\left[\frac{(\text{ref temp, °C} + 273) - (\text{test thermom temp, °C} + 273)}{\text{ref temp, °C} + 273}\right] 100 \leq 1.5\%.$$

* MUST BE WITHIN 1°C OF REF

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