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BAY COUNTY, FLORIDA WASTE-TO-ENERGY FACILITY

EMISSION COMPLIANCE TEST

SUBMITTED TO THE FLORIDA
DEPARTMENT OF ENVIRONMENTAL RESOURCES

JUNE 1987

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Prepared by: David S. Beachler
Manager, Environmental and Quality Engineering

Signature: David S Beachler

Jill Weldon
Senior Engineer

Signature: Jill Weldon

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

BAY COUNTY, FLORIDA WASTE-TO-ENERGY FACILITY
EMISSION COMPLIANCE TEST REPORT

1.0 INTRODUCTION

In April 1987, Westinghouse contracted ETS, Inc. of Roanoke, Virginia to conduct stack sampling of the Bay County Resource Recovery Facility. These tests were conducted over a 1-1/2 month period during the start-up and equipment fine-tuning stages, the plant 72-hour acceptance test, and the Florida DER emission compliance tests. The DER offices were notified that tests were being conducted during the time periods of May 12-14, May 18-21, and June 4-5, 1987.

Westinghouse submits this test report to the Florida Department of Environmental Regulations as part of the Certificate of Completion of Construction.

2.0 FACILITY DESCRIPTION

The Bay County Resource Recovery Facility is located on Highway 231, 10 miles Northeast of Panama City, Florida. The facility processes 510 tons per day of municipal solid wastes (MSW) and waste wood. Heat generated by the combustion of waste in the combustor produces steam to drive a turbine generator. A process flow diagram of the Bay County facility is shown in Figure 1.

The plant consists of two combustor/boiler units, a turbine-generator, a truck scale, tipping floor, front end loaders, conveyors, air emission control equipment, a stack, ash handling equipment, a central control room, and all required ancillary equipment. The facility also includes administration offices, change rooms, parking areas, roadways, and security fencing.

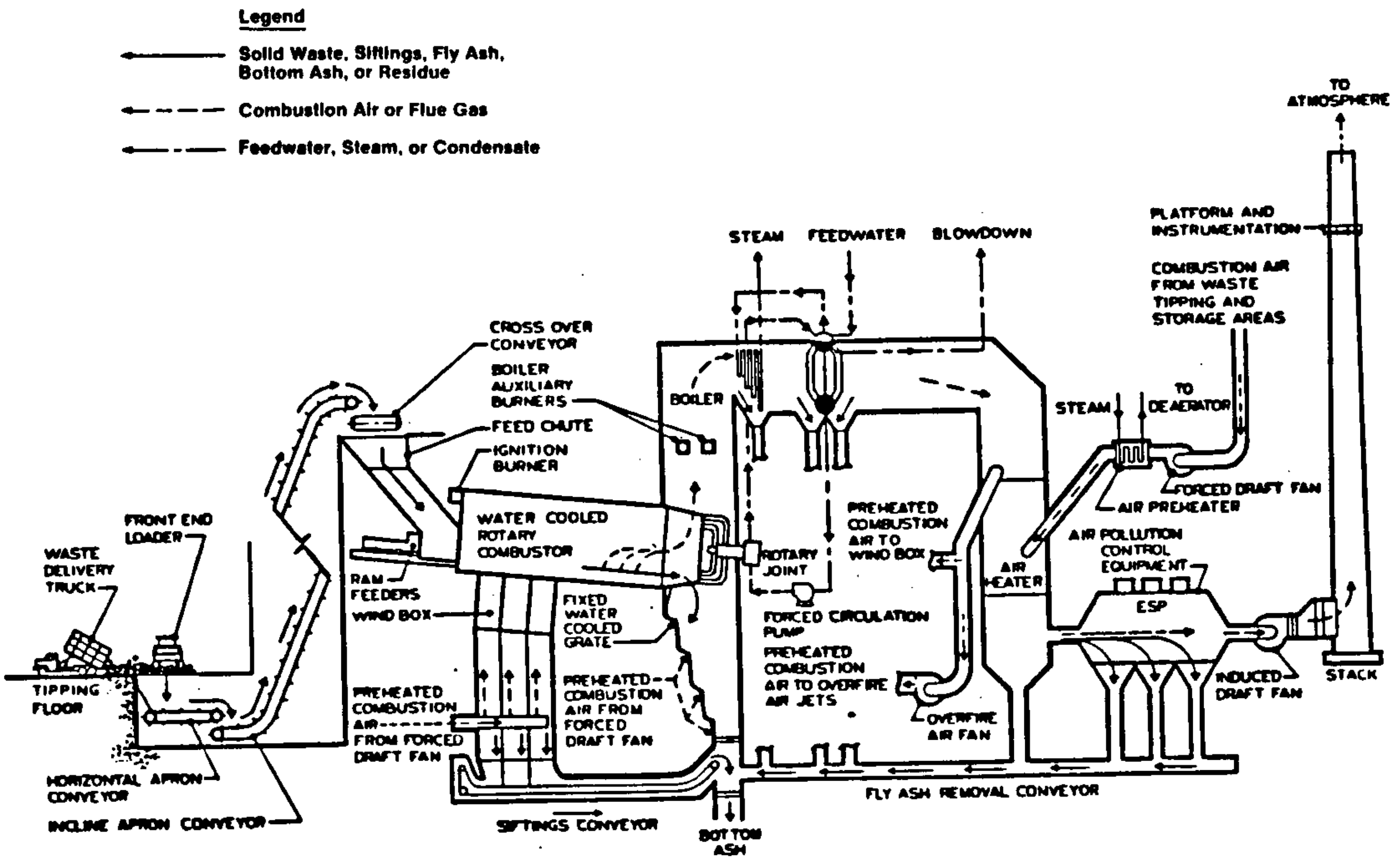


Figure 1 Simplified Process Flow Diagram, Gas Cycle

767306-1A

All municipal waste received at the plant enters through an automatic gate system and is unloaded on the tipping floor. Solid waste collection vehicles hauling the material to be processed are weighed at the scale prior to entering the plant and are then directed to a specific bay on the tipping floor. The weight is automatically entered into a computer system that records and files all pertinent data for each transaction. The vehicles enter the designated bay and discharge their load on the floor. The tipping floor accommodates approximately 1500 tons of waste while allowing room for maneuvering the incoming trucks and front end loaders.

A man-operated front-end loader disperses MSW on the tipping floor to separate large and unprocessible objects. Large items are separated from MSW; the combustible ones are processed through a shear shredder; the noncombustible items are removed and stored temporarily for landfill disposal. After sorting, the MSW is pushed onto the horizontal apron conveyor by the front-end loader. The horizontal apron conveyor transfers the MSW to the inclined apron conveyor and then into the combustor charging chute. The incline apron conveyor contains a weigh scale that continuously measures the weight of MSW sent for processing. When one line of apron feed conveyors is down for maintenance, a transfer conveyor at the charging hopper level feeds both combustors by changing the moving direction of the conveyor apron belt.

From the combustor charging chute, the MSW is pushed into the combustor by the hydraulic ram feeders (see Figure 2). The speed of the ram feeders and, consequently, the amount of solid waste fed to the combustor are controlled by the level of the solid waste in the chute. The feed throat of the combustor chute is provided with a water-cooled isolation door to prevent the flames in the rotary combustor barrel from reaching the solid waste in the charging chute. The combustion process begins when the MSW is pushed into the combustor. The slightly inclined combustor barrel rotates slowly, causing the waste to tumble and advance as combustion proceeds. A forced draft fan supplies air to the combustor. The air is preheated before entering the multiple zone windbox located beneath each combustor barrel.

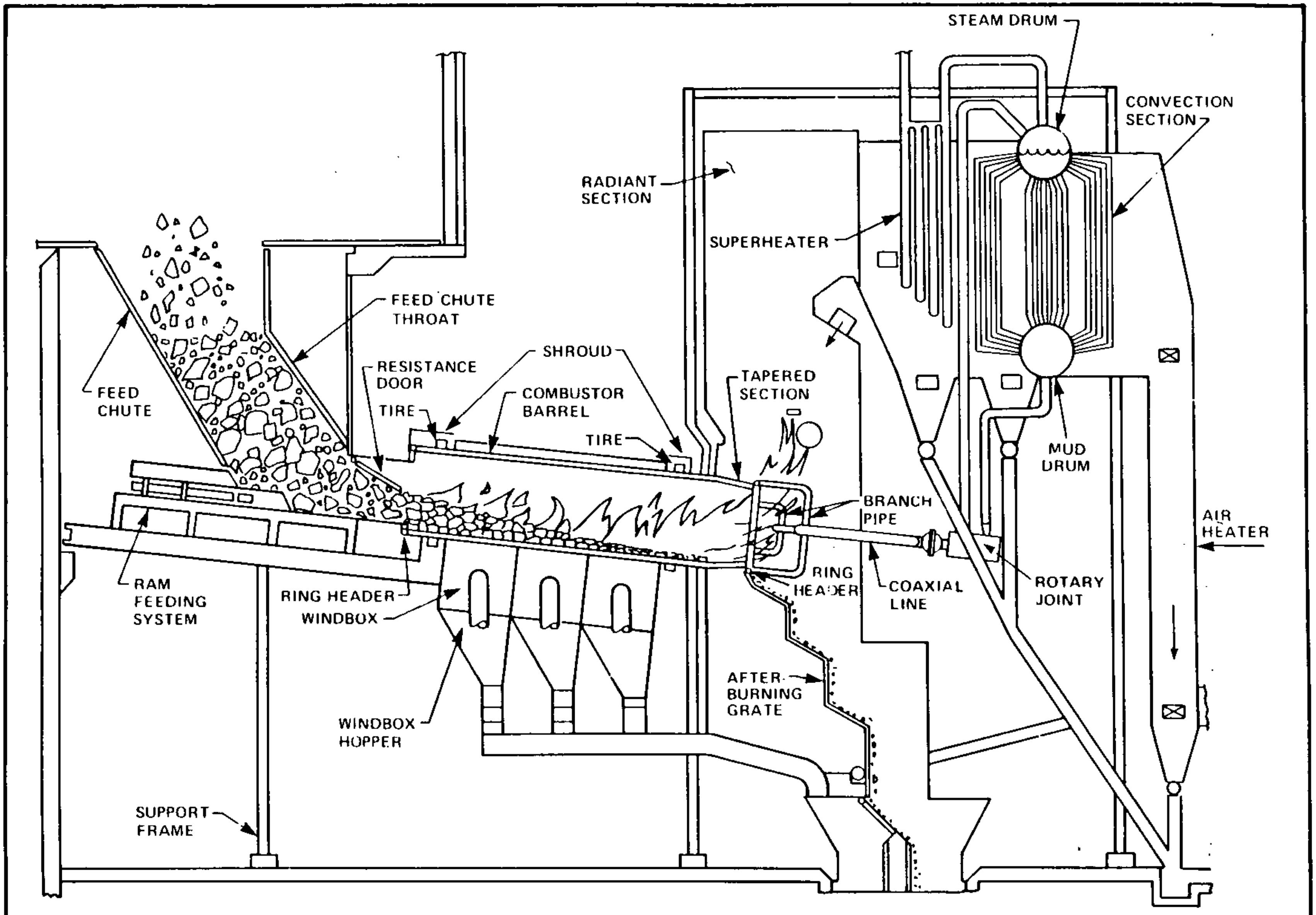


Figure 2 Westinghouse O'Connor Water-Cooled Rotary Combustor/Boiler

767327-10A

The heat released from the combustion process is recovered through the rotary combustor walls, boiler water walls and tubes, primary and secondary superheater, and the air preheater. Hot gases, produced during the combustion process, flow from the combustor barrel through the boiler's radiant, superheater, and convection sections. To maximize energy recovery and expedite combustion of high-moisture waste, the combustion gases exiting the convection section pass through a heat exchanger which preheats the incoming combustion air. To prevent corrosion problems in the lower part of the boiler air heater, a steam preheater is located at the air heater inlet to increase the air temperature from ambient to 150°F.

The flue gases from the air heater enter the electrostatic precipitator (ESP). The ESP's were manufactured by Environmental Elements Corporation. They are arranged into three mechanical fields, each with its own electrical field and ash removal hopper. They are designed to remove 99.33% of the particulate matter in the flue gas at a gas flow rate of 56,000 ACFM (400°F) and at a particulate inlet loading of 3 gr/dscf.

The flue gas is drawn from the ESP by an induced draft fan which maintains a slightly negative pressure through the entire system. The flue gas from each unit discharges to the atmosphere through a separate flue in the common stack. The stack is made of precast concrete with two 4-ft, 6-in. diameter flues that are constructed of 4-in. thick acid resistant bricks. The stack is 125 feet tall and has air emissions monitoring ports located 60 feet from the stack base.

Three types of ash by-products are produced by the process: fly ash, siftings, and bottom ash. Fly ash is collected in hoppers under the convection, superheater, boiler/air heater, and ESP sections of each unit and is conveyed pneumatically to the bottom ash conveyor. Siftings are collected underneath the combustor by the siftings conveyor and are transferred by an ash drag system to the bottom ash conveyor. Bottom ash is collected on the ash burnout grate and is directed by a bifurcated chute into a water quench basin. The fly ash, siftings, and bottom ash mixture are water quenched, dewatered, and removed by the bottom ash drag conveyor into trucks that are disposed of at a landfill.

Heat from the combustion of MSW is absorbed in the combustor barrel, boiler, and superheater to produce steam to drive the turbine-generator. Boiler feedwater moves through the boiler tubes by natural circulation as it is transformed into a mixture of saturated steam and water. Pumps circulate water through the rotary combustor by drawing water from the lower drum of the boiler through the rotary joint and into one of the combustor barrel's ring headers. The water passes through the combustor tubes and returns to the boiler steam drum as a mixture of saturated water and steam. Steam leaves the drum and passes through the primary and secondary tubes of the superheater section where the steam is heated to the design steam condition for the turbine (750°F).

The steam flows from the superheater to the turbine-generator where a portion of its energy is converted to electricity. The generator produces 3-phase, 60 Hz electrical power. Transformers provide power at reduced voltage for in-plant use, and at increased voltage for distribution to the utility grid.

3.0 PLANT CAPACITY

Plant capacity is based on the boiler steam flow rate. The facility is designed to process 510 tons per day of 4500 Btu/lb MSW in two units to produce a total of 136,000 lb/hr of steam at 600 psig and 750°F. The steam flow rate per ton of MSW is proportional to the heating value of the garbage. As the heating value fluctuates, the feed rate of MSW is adjusted to maintain a constant steam rate to the turbine. Because one cannot continuously predict the heating value of MSW, the measured steam flow rate is used to determine the capacity of each unit. During compliance testing, plant operators maintained the steam rate of each unit as close to the design condition of 68,000 lb/hr as practical.

4.0 TEST PROGRAM

In May and June 1987, Westinghouse conducted emissions testing of the Bay County Facility in accordance with Permit Numbers AC-03-84703 and AC-03-84704. Environmental testing consultants from ETS, Inc. performed particulate emissions testing in accordance with EPA Methods 1,2,3 and 5, and visible emissions testing in accordance with FAC Rule 17-2.700(6)(a)9., DER Method 9.

All stack sampling was performed through the sampling ports at the 60-ft elevation of the stack. Two sampling ports, positioned 90 degrees from each other, are located on each flue. Visible emissions were measured simultaneously with the stack sampling for particulate emissions.

Although the majority of the testing was conducted by ETS, a number of others also participated. A certified observer from Westinghouse measured visible emissions during the June testing program and environmental specialists from Roy F. Weston, Inc., employed by the Bay County Authority, witnessed at least three compliance test runs at each stack. Westinghouse provided individuals to monitor the plant operating conditions and to coordinate the test runs.

5.0 TEST DATES

Emission tests for determining particulate matter concentration were conducted from April 22 through June 5, 1987. The Florida DER was notified and invited to attend the DER emission compliance and plant acceptance tests as listed in the table below. Mr. Bert Lent of the Panama CIty Office of the Florida DER observed at least one day of testing on May 13, 1987. Mr. Lent indicated that he would try to attend testing during June 4-5, 1987.

Date	Test
5/12 - 5/14	DER Emission Compliance Test
5/18 - 5/21	Facility 72-hr Acceptance Test
6/4 - 6/5	DER Emission Compliance Test

Officials from Roy F. Weston observed various tests during these three testing periods. Roy F. Weston acted as an independent third-party engineer to observe the stack test for the Bay County Resource Recovery Authority.

6.0 TESTING PERSONNEL

Individuals from Westinghouse (RESD), ETS, Inc., and Roy F. Weston, Inc. participated during various phases of the 1-1/2-month test program. The following is a list of the participating individuals and their responsibility during the test program.

Company	Name	Responsibility
Westinghouse	David Beachler	Test Coordinator
	Jill Weldon	Test Coordinator
	Spencer Brady	Visual Emissions Observer, 6/4-6/5
ETS, Inc.	Jeff Smith	Stack Sampling Test Team Leader
	Jim Eckenrode	Stack Sampling
	Tony Underwood	Stack Sampling
	John Richardson	Visual Emissions Observer, 5/12-14
Roy F. Weston, Inc.	Denise Alston	Test Observer. 5/12-14
	Norman Getz	Test Observer, 5/20-21
	John Mills	Test Observer, 6/5

7.0 RESULTS

Westinghouse has collected a considerable amount of test data on the operation of Units 1 and 2 at the Bay County Resource Recovery Facility. Testing begin in April to evaluate the performance of the ESP and associated equipment during the start-up and break-in phases of the facility. Since initial compliance testing (May 12-14) was conducted at extremely high firing rates, additional testing was required in late May and June to evaluate the units at the more typical design conditions of the facility.

Scheduled compliance testing was conducted on May 12, 13, 14, and June 4 and 5. The testing was originally to be conducted entirely during the week of May 12. During the original testing period, however, there were a number of problems that disrupted the normal operation of Unit 1. Major leaks were discovered in the valve seals between the fly ash collection hoppers and the pneumatic conveying system. In addition, the water seal at the bottom of the combustor/boiler was not complete, allowing air to leak into a stagnant region where it could possibly re-entrain dust and increase the particulate loading to the ESP.

Compliance efforts were resumed in June to complete the test program. During the week of June 1, Unit 1 was shutdown and, after extensive troubleshooting efforts, major leaks in the fly ash removal system were repaired. The bifurcated chute flap door seal was also secured to provide the water seal at the bottom of the furnace. Plant operation was resumed and Unit 1 compliance testing was rescheduled for June 5. Unit 2 was retested on June 4 to confirm earlier results.

Table 1 contains the emission compliance test results for Units 1 and 2 conducted on June 4-5, 1987. The average outlet particulate emissions for Units 1 and 2 are 0.0193 gr/dscf and 0.0243 gr/dscf corrected to 12% CO_2, respectively. The average emissions for both units comply with the particulate limit of 0.03 gr/dscf corrected to 12% CO_2 set by the Florida DER. The complete testing report prepared by ETS, Inc. containing test results, sample calculations, raw data sheets, and test procedures is given as Appendix A to this report.

Particulate measurements made during the scheduled compliance tests on May 12-14 and May 20-21 are included in Table 2. An environmental specialist

TABLE 1 EMISSION COMLIANCE TEST RESULTS FROM BAY COUNTY ENERGY RESOURCES

BAY COUNTY COMPLIANCE TEST RESULTS UNIT 1

DATE	TIME	FLUE GAS FLOW KDSCFM	FLUE GAS FLOW KACFM	STACK TEMP DEG F	STEAM FLOW KLB/HR	PERCENT OF RATED CAPACITY	PARTICULATE GR/DSCF @12%CO2
6/5	959	25.8	52.4	425.0	71.1	104.5	0.0140
6/5	1140	27.9	55.1	429.0	66.5	97.8	0.0240
6/5	1307	25.8	52.8	427.0	65.0	95.6	0.0200
AVERAGE					67.5	99.3	0.0193

BAY COUNTY COMPLIANCE TEST RESULTS UNIT 2

6/4	945	27.7	52.6	429.0	69.7	102.5	0.0250
6/4	1310	28.4	58.1	449.0	62.7	92.2	0.0190
6/4	1525	29.2	59.0	451.0	62.3	91.6	0.0290
AVERAGE					64.9	95.4	0.0243

TABLE 2 ADDITIONAL TEST RESULTS FROM BAY COUNTY ENERGY RESOURCES

BAY COUNTY ADDITIONAL TEST RESULTS UNIT 1

DATE	TIME	FLUE GAS FLOW KDSCFM	FLUE GAS FLOW KACFM	STACK TEMP DEG F	STEAM FLOW KLB/HR	PERCENT OF CAPACITY	PARTICULATE GR/DSCF @12% CO2
4/22	1436	25.0	45.5	373.0	58.6	86.2	0.0176
4/22 (1)	1652	25.9	50.3	387.0	70.4	103.5	0.0279
4/27	1505	24.9	48.1	441.0	68.9	101.3	0.0265
4/29	1214	19.9	39.0	441.0	61.1	89.9	0.0252
5/20 (2)	1542	29.8	49.8	426.0	70.4	104	0.0256
6/1	1903	25.5	51.2	426.0	64.0	94.1	0.0177
6/1	2029	23.7	52.3	436.0	57.2	84.0	0.0195
AVERAGE					64.4	94.7	0.0229

BAY COUNTY ADDITIONAL TEST RESULTS UNIT 2

4/23	925	28.9	56.8	422.0	64.0	94.1	0.0161
4/23	1148	24.3	48.2	422.0	65.6	96.5	0.0215
4/23	1356	23.4	45.4	405.0	62.6	92.1	0.0192
4/30	957	27.4	51.7	427.0	NO DATA	NO DATA	0.0167
5/12 (3)	1350	25.7	54.2	437.0	76.0	112	0.0246
5/13 (3,4)	1635	23.7	48.2	408.0	72.0	106	0.0355
5/14 (3)	826	25.3	51.3	421.0	80.0	118	0.0157
5/21	1016	34.1	57.3	431.0	72.6	107	0.0172
5/21 (5)	1705	30.6	50.2	411.0	69.9	103	0.0184
6/1	927	25.9	54.5	436.0	64.5	94.8	0.0164
6/1	1045	24.3	52.3	428.0	60.8	89.4	0.0173
6/1	1215	25.2	55.4	426.0	57.8	85.0	0.0177
6/3	1023	25.8	52.0	438.0	59.8	87.9	0.0191
AVERAGE					67.1	98.7	0.0196

(1) TEST DISCONTINUED AFTER 1/2 HOUR DUE TO PLANT SHUTDOWN
(2) WITNESSED BY CONSULTANT FROM ROY F. WESTON
(3) DER EMISSION COMPLIANCE TEST WITNESSED BY WESTON CONSULTANT
(4) FURNACE WENT POSITIVE FOR A FEW MINUTES WHILE CONDUCTING THIS TEST WHEN AN AIR ACTUATOR VALVE WAS BEING REPAIRED.
(5) INCINERATOR WAS FIRED WITH MUNICIPAL WASTE AND WOOD CHIP MIXTURE.

from Weston witnessed these tests for Bay County. Additional Method 5 particulate testing was conducted before and between compliance runs to evaluate whether the ESP was meeting its performance guarantees and to assist in plant troubleshooting. Table 2 contains the results from some of those tests which show an average particulate emission level of 0.0229 gr/dscf at 12% CO_2 for Unit 1 and 0.0196 gr/dscf at 12% CO_2 for Unit 2. Appendix C of this report contains the computer calculation sheets for each of the test runs listed in Table 2. This data is supplied to reinforce the compliance data and demonstrate overall reliability of the particulate removal system.

The results of Method 9 opacity measurements which were conducted during the June 4-5 compliance tests are contained in the report in Appendix A. Additional opacity measurements for the May compliance tests are contained in Appendix B. Visual measurements of opacity were continuously between 5 and 10% and confirm the low particulate levels measured by Method 5. The measurements meet, in all cases, the Florida DER requirements of less than 10% opacity and no more than 20% opacity for up to three minutes.

8.0 CONCLUSION

The results of scheduled testing indicate that Units 1 and 2 of the Bay County Resource Recovery Facility are in compliance with the particulate and visual emission levels required by the State of Florida Department of Environmental Regulations. The Method 5 particulate measurements conducted on June 4-5 at the design capacity of 255 ton per day per unit averaged 0.0193 gr/dscf at 12% CO_2 for Unit 1 and 0.0243 gr/dscf at 12% CO_2 for Unit 2. Method 9 opacity measurements were consistently at or less than 10% for both units during the test runs. Additional testing, conducted at the plant for verification and troubleshooting purposes, confirmed the low emission levels measured during the compliance test runs with average Unit 1 emissions of 0.0229 gr/dscf at 12% CO_2 and Unit 2 emissions of 0.0196 gr/dscf at 12% CO_2. The performance of the plant from an air quality standpoint is clearly within the acceptable range of less than 0.03 gr/dscf particulate and less than 10% opacity required by the State of Florida Department of Environmental Regulations. Westinghouse (RESD) submits this report for the Bay County Resource Recovery Facility to the FLorida DER and to request the issuance of an operating permit to burn MSW at the maximum plant design capacity rate of 190 x 10^6 Btu/hr or an equivalent of 510 TPD MSW with a heating value of 4500 Btu/lb.

APPENDIX A

EMISSION COMPLIANCE REPORT FOR JUNE 4 AND 5 COMPILED BY ETS, INC.

STATIONARY SOURCE SAMPLING

FOR

WESTINGHOUSE ELECTRIC CORP.

BAY COUNTY RESOURCE RECOVERY FACILITY - PANAMA CITY, FL

JUNE, 1987

ETS, inc.

3140 Chaparral Dr., SW

Suite C-103

Roanoke, VA 24018

ETS CONTRACT NO: 87-718-T

CLIENT P.O. NO: RN-15467-H

Pollution Control Consultants
Specializing In
Fabric Filtration and Sulfur Dioxide Removal

REPORT CERTIFICATION

The sampling and analysis performed for this report were carried out under my direction and supervision.

DATE: 6/16/87

SIGNATURE: James P. Eckenrode
James Eckenrode

I have reviewed all testing details and results in this report and hereby certify that the test report is authentic and accurate.

DATE: 6/16/87

SIGNATURE: Gary P Greiner
Gary P. Greiner
Vice President

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Source sampling was performed on the outlet stack of Units 1 and 2 serving the Bay County Energy Resources MSW incinerators located in Panama City, FL. The purpose of these formal tests was to determine the particulate emissions of the waste incinerators. The test series consisted of EPA Methods 1-5. The tests were performed by Jim Eckenrode, Jeff Smith, and Tony Underwood of ETS, Inc. on June 4 and 5, 1987.

The following people took part or observed this test series:

PERSONNEL	COMPANY AFFILIATE
Jim Eckenrode	ETS, Inc.
Jeff Smith	ETS, Inc.
Tony Underwood	ETS, Inc.
Jill Welden	Westinghouse
Spencer Brady	Westinghouse
John Mills	Weston

SUMMARY

Particulate results are summarized in Table I. The State of Florida requires the incinerator emission concentrations be .03 gr/SCF corrected to 12% CO_2. The average emission rate for the three runs conducted on Unit #1 was 0.0190 gr/SCF corrected to 12% CO_2. The average emission rate for the three runs of Unit #2 was 0.0241 gr/SCF corrected to 12% CO_2. The average of each unit, as well as each test run, were well under the State of Florida standard. These tests were conducted while the system was operating

TABLE I

BAY COUNTY ENERGY RESOURCES EMISSION COMPLIANCE TESTS SUMMARY - JUNE 4-5, 1987

UNIT NO.	TEST REFERENCE NO.	1987 DATE	TIME	Q_S KDSCFM	Q_A KACFM	°F TEMP.	% MOISTURE	STEAM FLOW KLB/HR	% RATED CAPACITY	PARTICULATE CORRECTED 12% gr/SCF
1	1	6/5	0952	25.8	52.4	424.6	17.7	71.1	105	.0140
	2	6/5	1140	27.9	55.1	429.2	14.9	66.5	98	.0236
	3	6/5	1305	25.8	51.8	426.9	16.6	65.0	96	.0195
									AVERAGE	=0.0190
2	1	6/4	0945	26.7	52.6	428.8	14.6	69.7	103	.0248
	2	6/4	1311	28.4	58.1	448.8	16.0	62.7	92	.0188
	3	6/4	1527	29.2	59.0	451.3	14.7	62.3	92	.0288
									AVERAGE	=0.0241

between 92% and 105% of rated capacity. Inlet feed conditions and operating data was monitored by Westinghouse personnel. John Mills of Weston observed the tests run on 6/5/87.

FACILITY DESCRIPTION

The facility uses two Westinghouse/O'Connor combustors to process 510 tons per day of municipal solid waste (MSW) and waste wood. Heat generated by the combustion of waste in the combustor produces steam to drive a turbine generator.

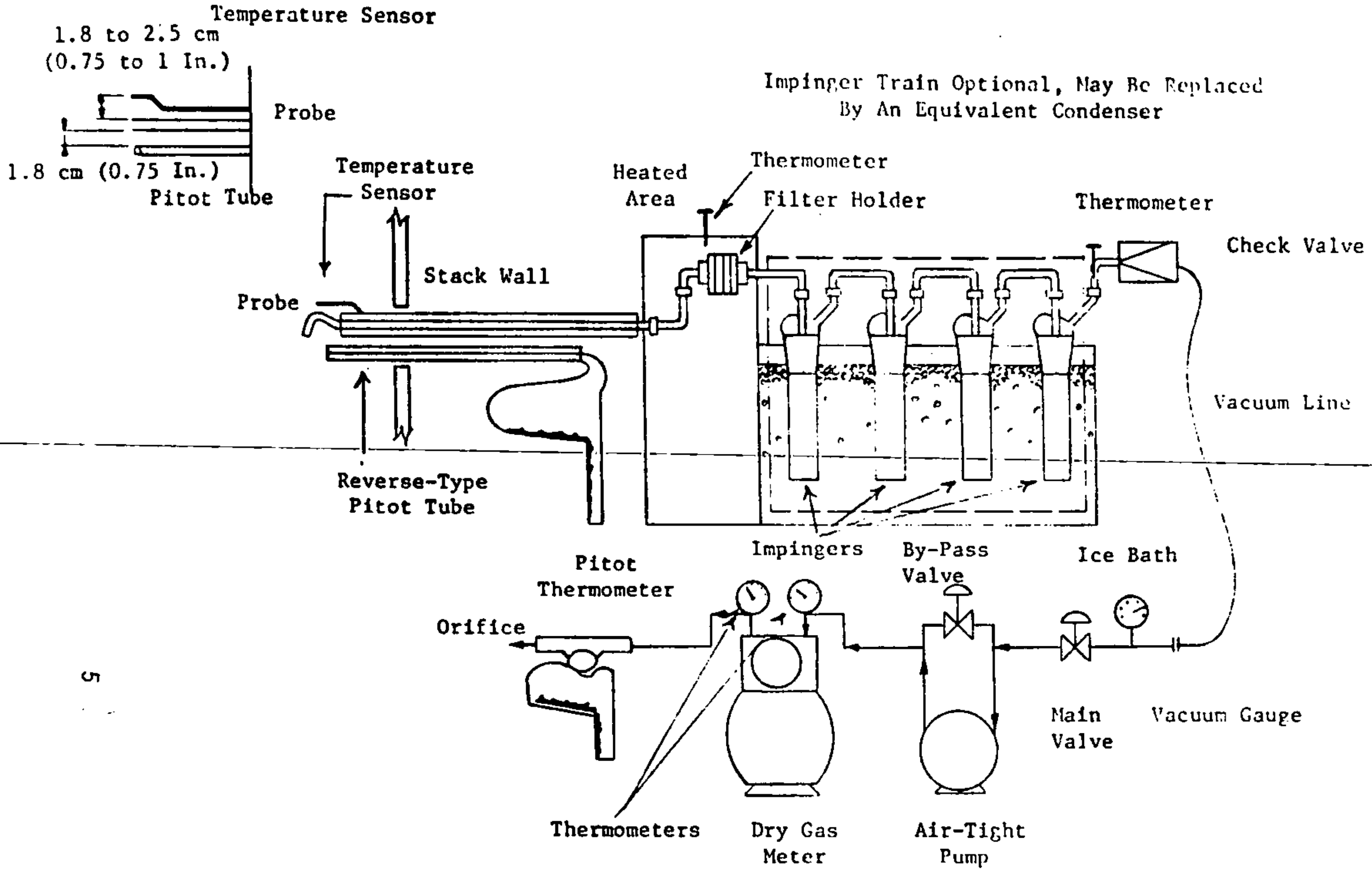
The flue gases leaving the boiler air heater pass through the pollution control equipment. The air pollution control equipment consists of an Electrostatic Precipitator (ESP), in which the small suspended particles (fly ash) contained in the flue gas, are collected on the collection plates. Periodic rapping of the plates causes fly ash to fall into hoppers located at the bottom of the Electrostatic Precipitator. From there the fly ash is then transferred by a pneumatic conveying system to the boiler bottom ash conveyor (submerged drag conveyor) where it is mixed with bottom ash. The flue gas is drawn from the ESP by the induced draft fan which maintains a controlled slightly negative pressure through the entire system. Using an induced draft fan for each combustion train, the flue gases from each unit discharge to the atmosphere through a separate flue in the common stack.

FIELD TESTING

Field testing was conducted on 6/4 and 6/5/87. All sampling and analytical procedures used were those recommended by the United States Environmental Protection Agency. EPA Methods 1-5 were used in performing all of the compliance particulate tests.

Each test run was conducted to determine particulate mass emissions at the outlet. The sampling point number and locations were determined according to EPA Method 1 located in the Appendix. The round stack measured 53" I.D. and was traversed on two axes located 90° apart, with 6 traverse points per port. Each point was sampled for 5 minutes, resulting in a 60 minute particulate test excluding the time required to change ports. All tests used a .254" I.D. nozzle.

Testing was conducted utilizing a Method 5 sampling train and a Teflon lined stainless steel probe (see Figure 1). From the nozzle, the sample gas was pulled through the heated probe and then through a heated glass fiber filter which was maintained at a temperature sufficiently high to prevent the condensation of water (248° ± 25°). Sample gas was subsequently passed through an impinger train consisting of four glass impingers immersed in an ice bath. The first and second impingers contained approximately 100 mls of water. The third impinger was initially dry and the fourth initially contained 200 gms of silica gel. Pre and post test impinger weights for the tests were taken on-site using a Mettler top loading balance. The heated stainless steel probe measured 84 inches in length.



Method 5 Sampling Train

FIGURE 1

Leak checks were performed on the sampling train before and after the tests were run. Post test leak checks were recorded on the field data sheets. All of the field data sheets can be found in Appendix C.

Velocity measurements were made according to Method 2, flue gas composition determinations and molecular weights according to Method 3, moisture determinations according to Method 4, and particulate emission determinations according to Method 5.

Spencer Brady of Westinghouse monitored the visible opacity readings on 6/4 and 6/5 according to EPA Method 9.

DISCUSSION

The tests on Unit #1 were conducted on 6/5 and the tests on Unit #2 were conducted on 6/4. The flows for Unit #1 were slightly less than the flows for Unit #2. In the first unit, gas flows averaged 53,100 ACFM whereas the gas flows for Unit #2 averaged 56,600 ACFM. Unit #1 also had a lower gas temperature. These results may be viewed on Table I. A complete list of calculated values can be seen in Appendix A.

The initial test period on 6/5/87 Unit #1 was aborted at 0839. Jill Welden informed the test team to void the test after sampling for 30 minutes. The test was interrupted because the system was not running at full capacity. The filter and probe wash was discarded and testing re-started when the system was back to full capacity. Three complete tests were run following the aborted test period.

Weston personnel observed the stack testing and control room operations during the tests on 6/5. Westinghouse personnel were responsible for collecting operational data in the control room.

Lab Activity

Particulate weighings were performed at the ETS lab. Report sheets for each run are included with the computer printouts located in Appendix A.

Post test equipment calibrations were performed and data sheets are included in Appendix D.

Data Analysis

Particulate test calculations such as flue gas volume, flue gas velocity, mass emissions and percent isokinetics were performed by computer. Sample calculations and computer printouts of each run can be found in Appendix A.

APPENDIX A-1

SAMPLE CALCULATIONS

AND

COMPUTER CALCULATION SHEET

ETS

GENERAL

Name of firm	BAY RESOURCES
Location of plant	PANAMA CITY, FLA.
Type of unit	MSW INCINERATOR
Control equipment	ESP
Sampling location	OUTLET UNIT #1
Pollutants sampled	
Date test started	JUNE 5, 1987

REFERENCE METHOD #1

Area of stack, ft²	A_s =	15.32
No. of equivalent dia. upstream	=	NA
No. of equivalent dia. downstream	=	NA
No. of traverse points	=	12
Total test time per run	θ =	60

SPECIFIC
RUN No. 1
DATA AND CALCULATIONS

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

REFERENCE METHOD #2

Standard temperature

Degrees Fahrenheit t_{std} = 68

Degrees Rankine

$T_{std} = t_{std} + 459.67$

$T_{std} = 68 + 459.67$ T_{std} = 528

Average stack temperature

Degrees Fahrenheit t_s = 425

Degrees Rankine

$T_s = t_s + 459.67$

$T_s = 425 + 459.67$ T_s = 884

Barometric pressure, in. Hg P_b = 30.02

Static pressure, in. H_2O P_{static} = -.55

Stack absolute pressure, in. Hg

$P_s = P_b + (P_{static} / 13.6)$

$P_s = 30.02 + (-.55 / 13.6)$ P_s = 29.98

Average delta p, in. H_2O Δp = 0.608

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

REFERENCE METHOD #3

Gas analysis, % average

sample gas	1	2	3	avg
$\%CO_2$	11.5	11.5	11.5	11.5
$\%O_2$	7.3	7.2	7.2	7.2
%CO	0.0	0.0	0.0	0.0

$\%N_2$ determination, % average

$\%N_2 = 100 - (\%CO_2 + \%O_2 + \%CO)$

$\%N_2 = 100 - (11.5 + 7.2 + 0.0)$ $\%N_2 =$ 81.3

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

REFERENCE METHOD #4

Water vapor volume collected, SCF

Constants

K_1 = ft^3/ml (english/metric units) @ 68 t_{std} K_1 = 0.04707

K_2 = ft^3/ml (english/metric units) @ 68 t_{std} K_2 = 0.04715

Impingers

Volume initial, ml V_i = 1147.0

Volume final, ml V_f = 1303.0

$V_{wc(std)} = K_1 (V_f - V_i)$

$V_{wc(std)}$ = 0.04707 * (1303.0 - 1147.0) $V_{wc(std)}$ = 7.34

Silica gel

Weight initial, g W_i = 633.0

Weight final, g W_f = 643.0

$V_{wsg(std)} = K_2 (W_f - W_i)$

$V_{wsg(std)}$ = 0.04715 * (643.0 - 633.0) $V_{wsg(std)}$ = 0.47

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

REFERENCE METHOD #5

Meter calibration factor Y_m = 1.001

Delta H, in. H_2O average ΔH = 1.537

Nozzel diameter, in. D_n = 0.254

$$A_n = \frac{\pi\ (D_n\ /\ 2)^2}{144}$$

$$A_n = \frac{3.1416 * (0.254\ /\ 2)^2}{144}$$

A_n = 0.000352

Meter temp., average

Degrees fahrenheit t_m = 94

Degrees rankine

$T_m = t_m + 459.67$

$T_m = 94 + 459.67$

T_m = 554

Volume metered, cf V_m = 37.846

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

CALCULATIONS

Dry gas volume corrected to standard conditions

$P_m = P_b + \Delta H / 13.6$

$P_m = 30.02 + 1.54 / 13.6$ $P_m = 30.13$

SCF calculation

$V_{m(std)} = V_m \; Y_m \; \frac{T_{std}}{T_m} \; \frac{P_m}{P_{std}}$

$V_{m(std)} = 37.85 * 1.001 * \frac{528}{554} * \frac{30.13}{29.92}$ $V_{m(std)} = 36.367$

Moisture content of stack gas

$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$

$B_{ws} = \frac{7.34 + 0.47}{7.34 + 0.47 + 36.367}$ $B_{ws} = 0.177$

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

CALCULATIONS

Molecular weight of stack gas, lb/lb-mole

Dry molecular weight

$M_d = .44\ \%CO_2 + .32\ \%O_2 + .28\ \%CO + .28\ \%N_2$

$M_d = .44 * 11.5 + .32 * 7.2 + .28 * 0.0 +$

$.28 * 81.3$ $M_d =$ 30.13

Wet molecular weight

$M_s = M_d\ (1 - B_{ws}) + 18\ B_{ws}$

$M_s = 30.13 * (1 - .177) + 18 * .177$ $M_s =$ 27.98

Excess air, %

$$\%EA = \frac{\%O_2 - .5\ \%CO}{.264\ \%N_2 - (\%O_2 - .5\ \%CO)}\ 100$$

$$\%EA = \frac{7.2 - .5 * 0.0}{.264 * 81.3 - (\ 7.2 - .5 * 0.0)}\ 100$$ $\%EA =$ 50.9

Average stack gas velocity, ft/sec

Constant

K_p = ft/sec (english units) $K_p =$ 85.49

$$v_s = K_p\ C_p\ (\sqrt{\Delta p})avg\ \sqrt{\frac{T_s}{P_s\ M_s}}$$

$$v_s = 85.49 * 0.84 * 0.774 * \sqrt{\frac{884}{29.98 * 27.98}}$$ $v_s =$ 57.04

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

CALCULATIONS

Average stack volumetric flow rate, ACFM

$Q_s = 60\ v_s\ A_s$

$Q_s = 60 * 57.04 * 15.3$ $Q_s =$ 52430

Average stack volumetric flow rate @ standard conditions, SCFM

$$Q_s = 60\ v_s\ A_s\ (1 - B_{ws})\ \frac{T_{std}\ P_s}{P_{std}\ T_s}$$

$$Q_s = 60 * 57.04 * 15.3 * (1 - .177) * \frac{528 * 29.98}{29.92 * 884}$$

$Q_s =$ 25805

Isokinetic, %

$$\%I = \frac{T_s\ V_{m(std)}\ P_{std}}{A_n\ \theta\ v_s\ P_s\ T_{std}\ 60\ (1 - B_{ws})}\ 100$$

$$\%I = \frac{884 * 36.367 * 29.92}{.000352 * 60 * 57.04 * 29.98 * 528 * 60 * (1 - .177)} * 100$$

$\%I =$ 102.3

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

EMISSION CALCULATIONS

Pollutant mass rate, lb/hr

Constant

K_c = gm/lb-hr (english metric units) K_c = 0.132159

Dry - (Particulate catch before and including the filter.)

$$pmr_d = \frac{m_d}{V_{m(std)}} Q_s K_c$$

$pmr_d = \frac{0.0315}{36.37} * 25805 * 0.132159$ pmr_d = 2.96

Wet - (Particulate catch including dry catch and solids condenced beyond the filter in glassware and impingers.)

$$pmr_w = \frac{m_w}{V_{m(std)}} Q_s K_c$$

$pmr_w = \frac{0.0315}{36.37} * 25805 * 0.132159$ pmr_w = 2.96

Concentration, gr./SCF

Dry - (Particulate catch before and including the filter.)

$$C_{sd} = 15.43 \frac{m_d}{V_{m(std)}}$$

$C_{sd} = 15.43 * \frac{0.0315}{36.367}$ C_{sd} = 0.0134

Wet - (Particulate catch including dry catch and solids condenced beyond the filter in glassware and impingers.)

$$C_{sw} = 15.43 \frac{m_w}{V_{m(std)}}$$

$C_{sw} = 15.43 * \frac{0.0315}{36.367}$ C_{sw} = 0.0134

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

EMISSION CALCULATIONS

Concentration @ 50% EA, gr./SCF

Dry - (Particulate catch before and including the filter.)

$$C_{sd50} = \frac{C_{sd}\ (100 + \%EA)}{150}$$

$$C_{sd50} = \frac{0.0134 * (100 + 50.9)}{150}$$

C_{sd50} = 0.0135

Wet - (Particulate catch including dry catch and solids condenced beyond the filter in glassware and impingers.)

$$C_{sw50} = \frac{C_{sw}\ (100 + \%EA)}{150}$$

$$C_{sw50} = \frac{0.0134 * (100 + 50.9)}{150}$$

C_{sw50} = 0.0135

Concentration @ 12% CO_2, gr./SCF

Dry - (Particulate catch before and including the filter.)

$$C_{sd12CO2} = C_{sd}\ \frac{12}{\%CO_2}$$

$$C_{sd12CO2} = 0.0134 * \frac{12}{11.5}$$

$C_{sd12CO2}$ = 0.0140

Wet - (Particulate catch including dry catch and solids condenced beyond the filter in glassware and impingers.)

$$C_{sw12CO2} = C_{sw}\ \frac{12}{\%CO_2}$$

$$C_{sw12CO2} = 0.0134 * \frac{12}{11.5}$$

$C_{sw12CO2}$ = 0.0140

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

EMISSION CALCULATIONS

Concentration @ 7% O_2, gr./SCF

Dry - (Particulate catch before and including the filter.)

$$C_{sd7O2} = C_{sd}\,\frac{20.9 - 7}{20.9 - \%O_2}$$

$$C_{sd7O2} = 0.0134 * \frac{20.9 - 7}{20.9 - 7.2} \qquad C_{sd7O2} = 0.0136$$

Wet - (Particulate catch including dry catch and solids condenced beyond the filter in glassware and impingers.)

$$C_{sw7O2} = C_{sw}\,\frac{20.9 - 7}{20.9 - \%O_2}$$

$$C_{sw7O2} = 0.0134 * \frac{20.9 - 7}{20.9 - 7.2} \qquad C_{sw7O2} = 0.0136$$

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

SAMPLE RECOVERY SUMMARY

	Con 1	Con 2	Con 3	Con 4	Con 5
Tare	1.3361	79.1541		633.0	
Gross	1.3489	79.1729		643.0	
m_1	0.0128	m_3	NA		

	Con 2		Con 5
C_a	0.000	C_a	
V_{aw}	100.000	V_{aw}	
ρ_a	0.7850	ρ_a	
W_a	0.00	W_a	0.00
m_2	0.0187	m_5	NA

Tare and gross weights are in grams. Tare weight is the container without sample, gross weight is the container with sample. Containers 1 thru 5 used in weighing recovered sample are :

Container 1 - filter. (includes weight of filter)
Filter identification : 87-304

Container 2 - washings from probe, cyclone, and front of filter holder.

Container 3 - solids trapped in impingers

Container 4 - silica gel. (method #4)

Container 5 - washings from fluid filled impingers and connecting glassware.

m_1 & m_3 = Gross$_{con.}$ - Tare$_{con.}$

Additional inputs for containers 2 and 5 are required if container is used. The inputs are :

V_{aw} - volume of the acetone wash in milliliters.

C_a - acetone blank residue concentration in milligrams per gram.

ρ_a - density of acetone in grams per milliliter.

$W_a = C_a \; V_{aw} \; \rho a$

ETS
Test of
BAY RESOURCES
Date : 6/5/87 Run No. 1

SAMPLE RECOVERY SUMMARY

Dry* particulate mass, g

$m_d = m_1 + m_2$

$m_d = 0.0128 + 0.0187$ $m_d =$ 0.0315

Wet* particulate mass, g

$m_w = m_3 + m_5 + m_d$

$m_w =$ NA + NA + 0.0315 $m_w =$ 0.0315

Fluid volumes for impingers in milliliters :

V_i - initial
V_f - final

	Imp 1	Imp 2	Imp 3	total
V_i	581.0	566.0	0.0	1147.0
V_f	712.0	591.0	0.0	1303.0

- Dry - (Particulate catch before and including the filter.)
- Wet - (Particulate catch including the dry catch and solids condenced beyond the filter in glassware and impingers.)

ETS
RAY RESOURCES
TEST #

FIELD DATA SUMMARY

Location:PANAMA CITY, FLA.
Operator:JIM ECKENRODE
Date:6/5/87
Run number: 1
Stack diameter,in: 53.00

Sample box I.D.:NUTECH
Meter box I.D.:NUTECH #3

Meter calibration (Y_m):1.001
Pitot tube (C_p):0.84
Probe heater setting:250
Ambient temperature: 80
Bar. press.(P_b),in Hg:30.02
Assumed moisture,%:15.0
Static prs.(P_s),in H_2O: -.55
Reference(Δp): 0.650

Sheet :1 of 1
Nozzle I.D.:.254
Nozzle diameter,in.:0.254
Thermometer I.D.:NONE
Final leak rate,cfm:0.000
Vac. @ leak check,in Hg: 6.0
Filter I.D.:87-304
Meter (ΔH@):2.052

Point No.	Time(24h)	Stack temp. t °F	Velocity head Δp, in. H_2O	Pressure differential across orifice ΔH, in. H_2O	Gas sample volume V ft³	Temp. tm, dry gas meter °F		FLt	EXt	Pvc	LKc
						In	Out				
A 1	09:52:00	428	0.740	1.890	121.757	93	92	236	0	4.0	
A 2	09:57:00	428	0.790	2.000	125.200	91	92	246		4.0	
A 3	10:02:00	428	0.730	1.870	128.800	93	92	250		4.0	
A 4	10:07:00	429	0.680	1.720	132.300	92	92	252		4.0	
A 5	10:12:00	429	0.600	1.500	135.600	93	93	247		3.0	
A 6	10:17:00	396	0.400	1.000	138.600	93	93	252	0	2.0	
A	10:22:00	port	end		141.300						
B 1	10:24:00	428	0.610	1.550	141.300	95	94	249	0	3.0	
B 2	10:29:00	434	0.680	1.720	144.400	95	95	256		4.0	
B 3	10:34:00	435	0.690	1.750	147.700	96	95	257		4.0	
B 4	10:39:00	434	0.560	1.420	151.200	95	95	257		4.0	
B 5	10:44:00	433	0.500	1.250	154.400	96	96	263		3.0	
B 6	10:49:00	393	0.310	0.770	157.300	97	96	260	0	2.0	
B	10:54:00	port	end		159.603						
run	end							max	max		
		avg	avg	avg	sum	avg	avg	263	0	max	
		425	0.608	1.537	37.846	94	94	min	min	4.0	
								236	0		

FLt - Filter temp., °F
EXt - Gas temp. from train exit, °F
Pvc - Pump vacuum, in. Hg
LKc - Leak check leak rate, cfm

UNIT #1

```
FLA1                 run  1              15:37:11     06-15-1987                     Page   1
     ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

[illegible]02 avg.     11.5                        pmrd               2.956468948082777
[illegible]2 avg.      7.233333333333333           pmrw               2.956468948082777
%CO avg.               0                           csd                1.337677366069144D-02
As stack area          15.32071832265625           csw                1.337677366069144D-02
[illegible] avg. DGM   37.846                      csd50%             1.345378000791836D-02
[illegible] avg. delta p  .6075                    csw50%             1.345378000791836D-02
ts avg. temp           424.5833333333333           csd12              1.395837251550412D-02
[illegible] avg. delta H  1.534666666666667        csw12              1.395837251550412D-02
[illegible]i avg. temp 94.08333333333333           csd7               1.360515760761458D-02
tmo avg. temp          93.75                       csw7               1.360515760761458D-02
%N2 avg.               81.26666666666667           saturation flag -1
[illegible] mole wt. dry  30.12933335105578        Bws saturated      .1748698385098112
[illegible] mole wt.   27.98402012002288           Vm corrected       37.846
[illegible]n area nozzle  3.518801934156250D-04    total # points.    12
[illegible] temp meter 93.91666666666667           Vf impingers       1303
[illegible] abs temp   553.5866666666667           Vi impingers       1147
Ts abs temp            884.2533333333333           sqr(Dp) avg.       .7736374035997174
Pm abs pre             30.13299019290914           Bws kick flag      0
[illegible] abs pre    29.97955882466376           Vm C kick flag     0
[illegible]m(std)      36.36733572409156           not in use        NA
Vwc(std)               7.34292                     Wa2                .0019625
[illegible]sg(std)     .4715                       Wa5                0
[illegible]s           .1748698385098112           K1 constant        .04707
vs velocity            57.03648374168055           K2 constant        .04715
[illegible] vol rate   25804.82891193186           Tstd abs temp      527.67
[illegible] time min.  60                          container 1        .01279
%I isokinetic          102.2688935470582           container 2        .01873803749990061
Qa vol rate            52430.35409126303           container 3       NA
[illegible] mass dry   3.152803749990609D-02       container 4        10
[illegible] mass wet   3.152803749990609D-02       container 5       NA
%EA                    50.8635080757911            not in use        NA
```

* Variables defined in sample calculations.

UNIT #1

```
FLA1           run  2            15:37:33    06-15-1987                       Page    1
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%CO2 avg.          11.06666666666667       pmrd              5.204822979421487
%O2 avg.           9.333333333333333       pmrw              5.204822979421487
%CO avg.           0                       csd               2.179562086823446D-02
As stack area      15.32071832265625       csw               2.179562086823446D-02
Vm avg. DGM        40.201                  csd50%            2.614065496509841D-02
Dp avg. delta p    .6725                   csw50%            2.614065496509841D-02
ts avg. temp       429.25                  csd12             2.363402262820604D-02
DH avg. delta H    1.710833333333333       csw12             2.363402262820604D-02
tmi avg. temp      99.75                   csd7              2.619267248522116D-02
tmo avg. temp      98.58333333333333       csw7              2.619267248522116D-02
%N2 avg.           79.6                    saturation flag -1
Md mole wt. dry    30.1440000017484        Bws saturated     .1486586607112696
Ms mole wt.        28.33868922581083       Vm corrected      40.201
An area nozzle     3.51880193415625D-04    total # points    12
tm temp meter      99.16666666666667       Vf impingers      1257
Tm abs temp        558.8366666666667       Vi impingers      1128
Ts abs temp        888.92                  sqr(Dp) avg.      .8154478297451962
Pm abs prs         30.14579656509895       Bws kick flag     0
Ps abs prs         29.97882353056673       Vm C kick flag    0
Vm(std)            38.28367482317118       not in use       NA
Vwc(std)           6.07203                 Wa2               .0019625
Vwsg(std)          .61295                  Wa5               0
Bws                .1486586607112696       K1 constant       .04707
vs velocity        59.99974189443064       K2 constant       .04715
Qs vol rate        27881.22005939102       Tstd abs temp     527.67
   time min.       60                      container 1       2.918999999999999D-02
%i isokinetic      99.64027100939907       container 2       2.488903749990775D-02
Qa vol rate        55062.42438986302       container 3      NA
md mass dry        5.407803749990775D-02   container 4       13
mw mass wet        5.407803749990775D-02   container 5      NA
%EA                79.90137964839974       not in use       NA
```

```
                  UNIT #1
FLA1              run  3              15:37:54     06-15-1987                        Page    1
     ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units


 O2 avg.             11.4                          pmrd                  4.08731404274903
 O2 avg.             8.733333333333333             pmrw                  4.08731404274903
%CO avg.             0                             csd                   1.852943309371419D-02
As stack area        15.32071832265625             csw                   1.852943309371419D-02
 m avg. DGM          37.669                        csd50%                2.108734144345626D-02
 p avg. delta p      .5933333333333333             csw50%                2.108734144345626D-02
ts avg. temp         426.9166666666667             csd12                 1.950466641443599D-02
 H avg. delta H      1.505833333333333             csw12                 1.950466641443599D-02
 mi avg. temp        99.25                         csd7                  .02116924282227097
tmo avg. temp        97.75                         csw7                  .02116924282227097
%N2 avg.             79.86666666666667             saturation flag -1
 d mole wt. dry      30.17333333889643             Bws saturated         .166209396381665
 s mole wt.          28.15001095268566             Vm corrected          37.669
An area nozzle       3.518801934156250D-04         total # points        12
 m temp meter        98.5                          Vf impingers          1298
 m abs temp          558.17                        Vi impingers          1161
Ts abs temp          886.5866666666667             sqr(Dp) avg.          .765534402716032
Pm abs prs           30.13072303610999             Bws kick flag         0
 s abs prs           29.97882353056673             Vm C kick flag        0
 m(std)              35.89732158881965             not in use           NA
Vwc(std)             6.44859                       Wa2                   .0019625
 wsg(std)            .70725                        Wa5                   0
 ws                  .166209396381665              K1 constant           .04707
vs velocity          56.34732929108269             K2 constant           .04715
 s vol rate          25754.60632677361             Tstd abs temp         527.67
   time min.         60                            container 1           3.023000000000001D-02
%  isokinetic        101.1440140969227             container 2           1.287803749990768D-02
Qs vol rate          51796.89361815814             container 3          NA
 d mass dry          4.310803749990768D-02         container 4           15
 w mass wet          4.310803749990768D-02         container 5          NA
%EA                  70.70685328152157             not in use           NA
```

unit #2

```
FLA2            run  1            15:27:22    06-15-1987                    Page   1
     ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%CO2 avg.          11.36666666666667           pmrd              5.371203480508901
%O2 avg.           7.733333333333333           pmrw              5.371203480508901
%CO avg.           0                           csd               2.347715933698708D-02
As stack area      15.32071832265625           csw               2.347715933898708D-02
Vm avg. DGM        38.48700000000001           csd50%            2.453542599677754D-02
Dp avg. delta p    .6225                       csw50%            2.453542599677754D-02
ts avg. temp       428.8333333333333           csd12             2.478527085640865D-02
DH avg. delta H    1.5825                      csw12             2.478527085640865D-02
tmi avg. temp      104.5                       csd7              2.478474799828298D-02
tmo avg. temp      103.4166666666667           csw7              2.478474799828298D-02
%N2 avg.           80.9                        saturation flag -1
Md mole wt. dry    30.12800001402696           Bws saturated     .1461575121652505
Ms mole wt.        28.35540170443666           Vm corrected      38.48700000000001
An area nozzle     3.51880193415625D-04        total # points    12
tm temp meter      103.9583333333333           Vf impingers      1249
Tm abs temp        563.6283333333333           Vi impingers      1132
Ts abs temp        888.5033333333333           sqr(Dp) avg.      .7792771210528337
Pm abs prs         30.11636029085383           Bws kick flag     0
Ps abs prs         29.95808823646971           Vm C kick flag    0
Vm(std)            36.30434612283541           not in use       NA
Vwc(std)           5.50719                     Wa2               .0019625
Vwsg(std)          .70725                      Wa5               0
Bws                .1461575121652505           K1 constant       .04707
vs velocity        57.23228821468709           K2 constant       .04715
Qs vol rate        26711.91958358461           Tstd abs temp     527.67
run time min.      60                          container 1       3.038999999999997D-02
%I isokinetic      98.62490004518748           container 2       2.484803749990571D-02
Qa vol rate        52610.38600189799           container 3      NA
md mass dry        5.523803749990569D-02       container 4       15
mw mass wet        5.523803749990569D-02       container 5      NA
%EA                56.76146531939914           not in use       NA
```

unit #2

```
 A2              run  2            15:27:59    06-15-1987                    Page   1
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

 02 avg.         10.4                         pmrd              3.955833269966886
%02 avg.         8.833333333333333            pmrw              3.955833269966886
%  O avg.        0                            csd               1.625206685830415D-02
   stack area    15.32071832265625            csw               1.625206685830415D-02
Vm avg. DGM      41.792                       csd50%            .0184979433588628
   avg. delta p  .7333333333333333            csw50%            .0184979433588628
   avg. temp     448.8333333333333            csd12             1.875238483650479D-02
   avg. delta H  1.851666666666667            csw12             1.875238483650479D-02
tmi avg. temp    101.8333333333333            csd7              1.872130361373205D-02
  o avg. temp    99.91666666666667            csw7              1.872130361373205D-02
  2 avg.         80.76666666666667            saturation flag -1
Md mole wt. dry  30.01733334163825            Bws saturated     .1595899111659054
Ms mole wt.      28.09948818119513            Vm corrected      41.792
   area nozzle   3.512801934156250D-04        total # points    12
   temp meter    100.875                      Vf impingers      1262
Tm abs temp      560.545                      Vi impingers      1114
   abs temp      908.5033333333333            sqr(Dp) avg.      .8478833877467027
   abs pre       30.13615195696535            Bws kick flag     0
Ps abs pre       29.95955882466376            Vm C kick flag    0
  (std)          39.66480843599196            not in use       NA
  c(std)         6.96636                      Wa2               .0019625
  sg(std)        .5658                        Wa5               0
Bws              .1595899111659054            K1 constant       .04707
   velocity      63.25241044705001            K2 constant       .04715
   vol rate      28418.97560553189            Tstd abs temp     527.67
run time min.    60                           container 1       .03128
   isokinetic    101.2814703368752            container 2       1.049803749990718D-02
   vol rate      58144.34182129756            container 3      NA
   mass dry      4.177803749990719D-02        container 4       12
mw mass wet      4.177803749990719D-02        container 5      NA
  A              70.72853120904214            not in use       NA
```

UNIT #2

```
FLA2                 run  3            15:33:06    06-15-1987                              Page    1
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units


%CO2 avg.          11.6333333333333           pmrd               6.970056641344015
%O2 avg.           8.53333333333333           pmrw               6.970056641344015
%CO avg.           0                          csd                2.789144751735134D-02
As stack area      15.32071832265625          csw                2.789144751735134D-02
Vm avg. DGM        41.904                     csd50%             3.124482566401509D-02
Dp avg. delta p    .7616666666666667          csw50%             3.124482566401508D-02
ts avg. temp       451.333333333333           csd12              2.877054758236815D-02
DH avg. delta H    1.916666666666667          csw12              2.877054758236815D-02
tmi avg. temp      90                         csd7               3.134968639976257D-02
tmo avg. temp      89.5                       csw7               3.134968639976257D-02
%N2 avg.           79.8333333333333           saturation flag -1
Md mole wt. dry    30.20266667306423          Bws saturated       .147369669678075
Ms mole wt.        28.4043637162631           Vm corrected       41.904
An area nozzle     3.51880193415625D-04       total # points     12
tm temp meter      89.75                      Vf impingers       1283
Tm abs temp        549.42                     Vi impingers       1146
Ts abs temp        911.003333333333           sqr(Dp) avg.        .863974970105123
Pm abs pre         30.140931368596            Bws kick flag      0
Ps abs pre         29.95147058959651          Vm C kick flag     0
Vm(std)            40.58285314591153          not in use        NA
Vwc(std)           6.44859                    Wa2                .0019625
Vweg(std)          .5658                      Wa5                0
Bws                .147369669678075           K1 constant        .04707
vs velocity        64.20282517269598          K2 constant        .04715
Qs vol rate        29177.2458076676           Tstd abs temp      527.67
r  time min.       60                         container 1        4.991000000000001D-02
%I isokinetic      100.9325714585557          container 2        .0234480374999072
Qa vol rate        59018.00399937716          container 3       NA
md mass dry        7.335803749990721D-02      container 4        12
mw mass wet        7.335803749990721D-02      container 5       NA
%EA                68.03444305594532          not in use        NA
```

APPENDIX B-1

EPA METHODS 1-5

Method 1—Sample and Velocity Traverses for Stationary Sources

1. *Principle and Applicability*

1.1 Principle. To aid in the representative measurement of pollutant emissions and/or total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas.

1.2 Applicability. This method is applicable to flowing gas streams in ducts, stacks, and flues. The method cannot be used when: (1) flow is cyclonic or swirling (see Section 2.4), (2) a stack is smaller than about 0.30 meter (12 in.) in diameter, or 0.071 m^2 (113 $in.^2$) cross-sectional area, or (3) the measurement site is less than two stack or duct diameters downstream or less than a half diameter upstream from a flow disturbance.

The requirements of this method must be considered before construction of a new facility from which emissions will be measured; failure to do so may require subsequent alterations to the stack or deviation from the standard procedure. Cases involving variants are subject to approval by the Administrator, U.S. Environmental Protection Agency.

2. *Procedure*

2.1 Selection of Measurement Site. Sampling or velocity measurement is performed at a site located at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, or contraction in the stack, or from a visible flame. If necessary, an alternative location may be selected, at a position at least two stack or duct diameters downstream and a half diameter upstream from any flow disturbance. For a rectangular cross section, an equivalent diameter (D_e) shall be calculated from the following equation, to determine the upstream and downstream distances:

$$D_e = \frac{2LW}{(L+W)}$$

where L=length and W=width.

2.2 Determining the Number of Traverse Points.

2.2.1 Particulate Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.); (2) eight, for circular stacks with diameters between 0.30 and 0.61 meter (12-24 in.); (3) nine, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12-24 in.).

When the eight- and two-diameter criterion cannot be met, the minimum number of traverse points is determined from Figure 1-1. Before referring to the figure, however, determine the distances from the chosen measurement site to the nearest upstream and downstream disturbances, and divide each distance by the stack diameter or equivalent diameter, to determine the distance in terms of the number of duct diameters. Then, determine from Figure 1-1 the minimum number of traverse points that corresponds: (1) to the number of duct diameters upstream; and (2) to the number of diameters downstream. Select the higher of the two minimum numbers of traverse points, or a greater value, so that for circular stacks the number is a multiple of 4, and for rectangular stacks, the number is one of those shown in Table 1-1.

TABLE 1-1 CROSS-SECTION LAYOUT FOR RECTANGULAR STACKS

Number of traverse points	Matrix layout
9	3x3
12	4x3
16	4x4
20	5x4
25	5x5
30	6x5
36	6x6
42	7x6
49	7x7

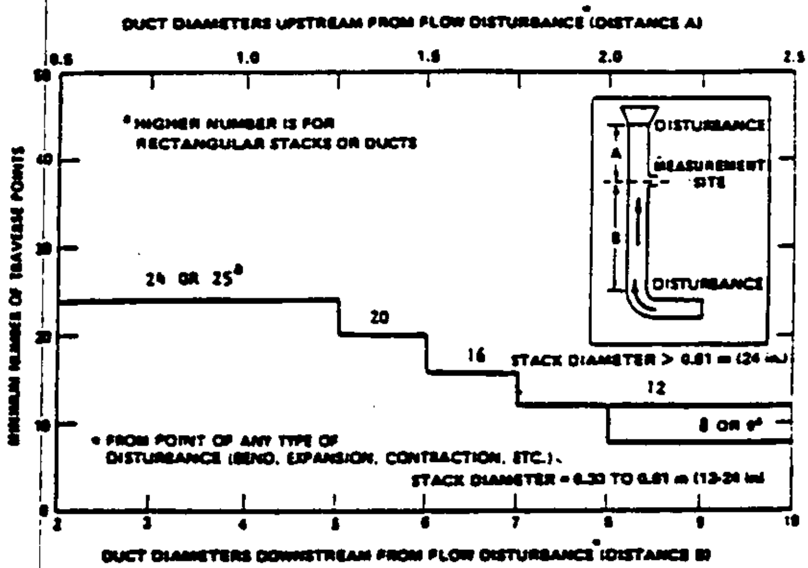


Figure 1-1. Minimum number of traverse points for particulate traverses.

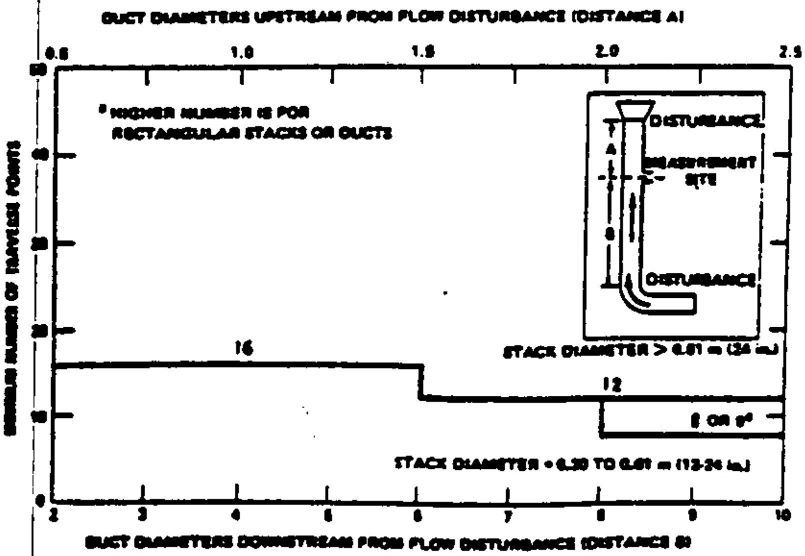


Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

2.2.2 Velocity (Non-Particulate) Traverses. When velocity or volumetric flow rate is to be determined (but not particulate matter), the same procedure as that for particulate traverses (Section 2.2.1) is followed, except that Figure 1-2 may be used instead of Figure 1-1.

2.3 Cross-sectional Layout and Location of Traverse Points.

2.3.1 Circular Stacks. Locate the traverse points on two perpendicular diameters according to Table 1-2 and the example shown in Figure 1-3. Any equation (for examples, see Citations 2 and 3 in the Bibliography) that gives the same values as those in Table 1-2 may be used in lieu of Table 1-2.

For particulate traverses, one of the diameters must be in a plane containing the greatest expected concentration variation, e.g., after bends, one diameter shall be in the plane of the bend. This requirement becomes less critical as the distance from the disturbance increases; therefore, other diameter locations may be used, subject to approval of the Administrator.

In addition, for stacks having diameters greater than 0.61 m (24 in.) no traverse points shall be located within 2.5 centimeters (1.00 in.) of the stack walls; and for stack diameters equal to or less than 0.61 m (24 in.), no traverse points shall be located within 1.3 cm (0.50 in.) of the stack walls. To meet these criteria, observe the procedures given below.

2.3.1.1 Stacks With Diameters Greater Than 0.61 m (24 in.). When any of the traverse points as located in Section 2.3.1 fall within 2.5 cm (1.00 in.) of the stack walls, relocate them away from the stack walls to: (1) a distance of 2.5 cm (1.00 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger. These relocated traverse points (on each end of a diameter) shall be the "adjusted" traverse points.

Whenever two successive traverse points are combined to form a single adjusted traverse point, treat the adjusted point as two separate traverse points, both in the sampling (or velocity measurement) procedure, and in recording the data.

TRAVERSE POINT	DISTANCE, % of diameter
1	4.4
2	14.7
3	29.5
4	70.5
5	85.3
6	95.6

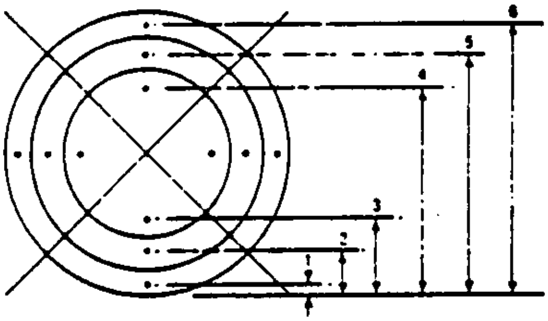


Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

TABLE 1-2. LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

[Percent of stack diameter from inside wall to traverse point]

Traverse point number on a diameter	Number of traverse points on a diameter—											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8				96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10					97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.8	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

2.3.1.2 Stacks With Diameters Equal to or Less Than 0.61 m (24 in.). Follow the procedure in Section 2.3.1.1, noting only that any "adjusted" points should be relocated away from the stack walls to: (1) a distance of 1.3 cm (0.50 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger.

2.3.2 Rectangular Stacks. Determine the number of traverse points as explained in Sections 2.1 and 2.2 of this method. From Table 1-1, determine the grid configuration. Divide the stack cross-section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point at the centroid of each equal area according to the example in Figure 1-4.

If the tester desires to use more than the minimum number of traverse points, expand the "minimum number of traverse points" matrix (see Table 1-1) by adding the extra traverse points along one or the other or both legs of the matrix; the final matrix need not be balanced. For example, if a 4x3 "minimum number of points" matrix were expanded to 36 points, the final matrix could be 9x4 or 12x3, and would not necessarily have to be 6x6. After constructing the final matrix, divide the stack cross-section into as many equal rectangular, elemental areas as traverse points, and locate a traverse point at the centroid of each equal area.

The situation of traverse points being too close to the stack walls is not expected to arise with rectangular stacks. If this problem should ever arise, the Administrator must be contacted for resolution of the matter.

2.4 Verification of Absence of Cyclonic Flow. In most stationary sources, the direction of stack gas flow is essentially parallel to the stack walls. However, cyclonic flow may exist (1) after such devices as cyclones and inertial demisters following venturi scrubbers, or (2) in stacks having tangential inlets or other duct configurations which tend to induce swirling; in these instances, the presence or absence of cyclonic flow at the sampling location must be determined. The following techniques are acceptable for this determination.

Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at each traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0° reference." Note the differential pressure (Δp) reading at each traverse point. If a null (zero) pitot reading is obtained at 0° reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at 0° reference, rotate the pitot tube (up to ±90° yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (α) to the nearest degree. After the null technique has been applied at each traverse point, calculate the average of the absolute values of α; assign α values of 0° to those points for which no rotation was required, and include these in the overall average. If the average value of α is greater than 10°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

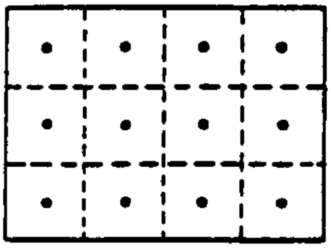


Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

3. *Bibliography*

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● SEE PROPOSED AMENDMENT NEXT PAGE

METHOD 2—DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE (TYPE S PITOT TUBE)

1. *Principle and Applicability*

1.1 Principle. The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube.

1.2 Applicability. This method is applicable for measurement of the average velocity of a gas stream and for quantifying gas flow.

This procedure is not applicable at measurement sites which fail to meet the criteria of Method 1, Section 2.1. Also, the method cannot be used for direct measurement in cyclonic or swirling gas streams: Section 2.4 of Method 1 shows how to determine cyclonic or swirling flow conditions. When unacceptable conditions exist, alternative procedures, subject to the approval of the Administrator, U.S. Environmental Protection Agency, must be employed to make accurate flow rate determinations; examples of such alternative procedures are: (1) to install straightening vanes; (2) to calculate the total volumetric flow rate stoichiometrically, or (3) to move to another measurement site at which the flow is acceptable.

2. *Apparatus*

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

2.1 Type S Pitot Tube. The Type S pitot tube (Figure 2-1) shall be made of metal tubing (e.g. stainless steel). It is recommended that the external tubing diameter (dimension D_t, Figure 2-2b) be between 0.48 and 0.95 centimeters (3/16 and 3/8 inch). There shall be an equal distance from the base of each leg of the pitot tube to its face-opening plane (dimensions P_A and P_B, Figure 2-2b); it is recommended that this distance be between 1.05 and 1.50 times the external tubing diameter. The face openings of the pitot tube shall, preferably, be aligned as shown in Figure 2-2; however, slight misalignments of the openings are permissible (see Figure 2-3).

The Type S pitot tube shall have a known coefficient, determined as outlined in Section 4. an identification number shall be assigned to the pitot tube; this number shall be permanently marked or engraved on the body of the tube.

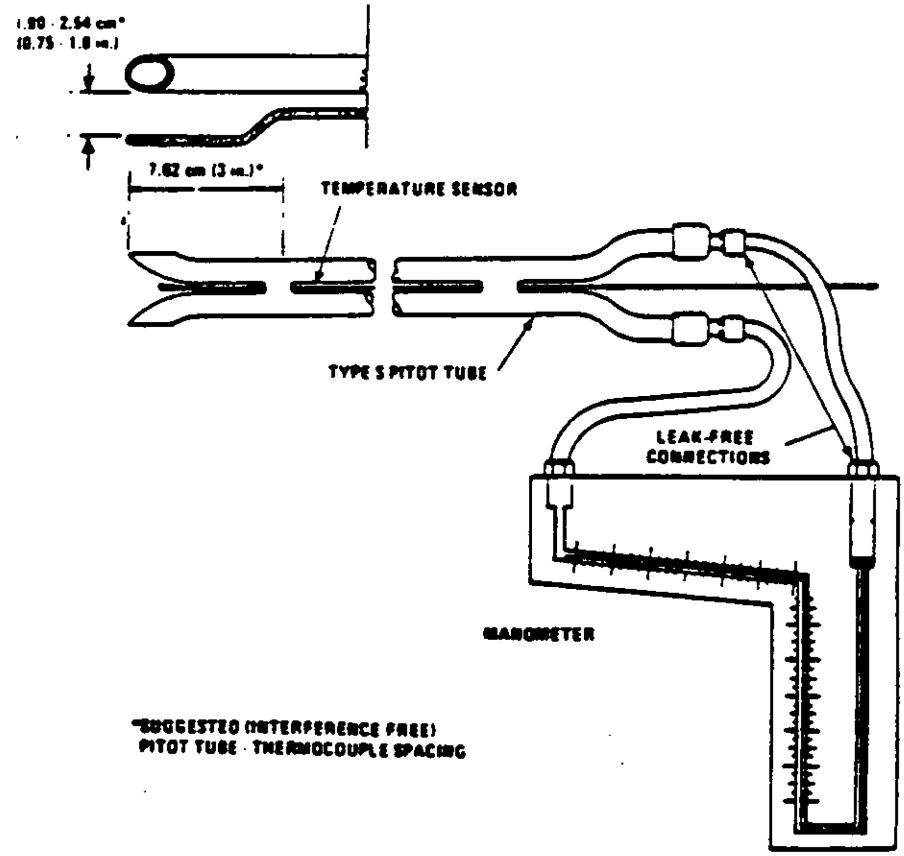


Figure 2-1. Type S pitot tube manometer assembly.

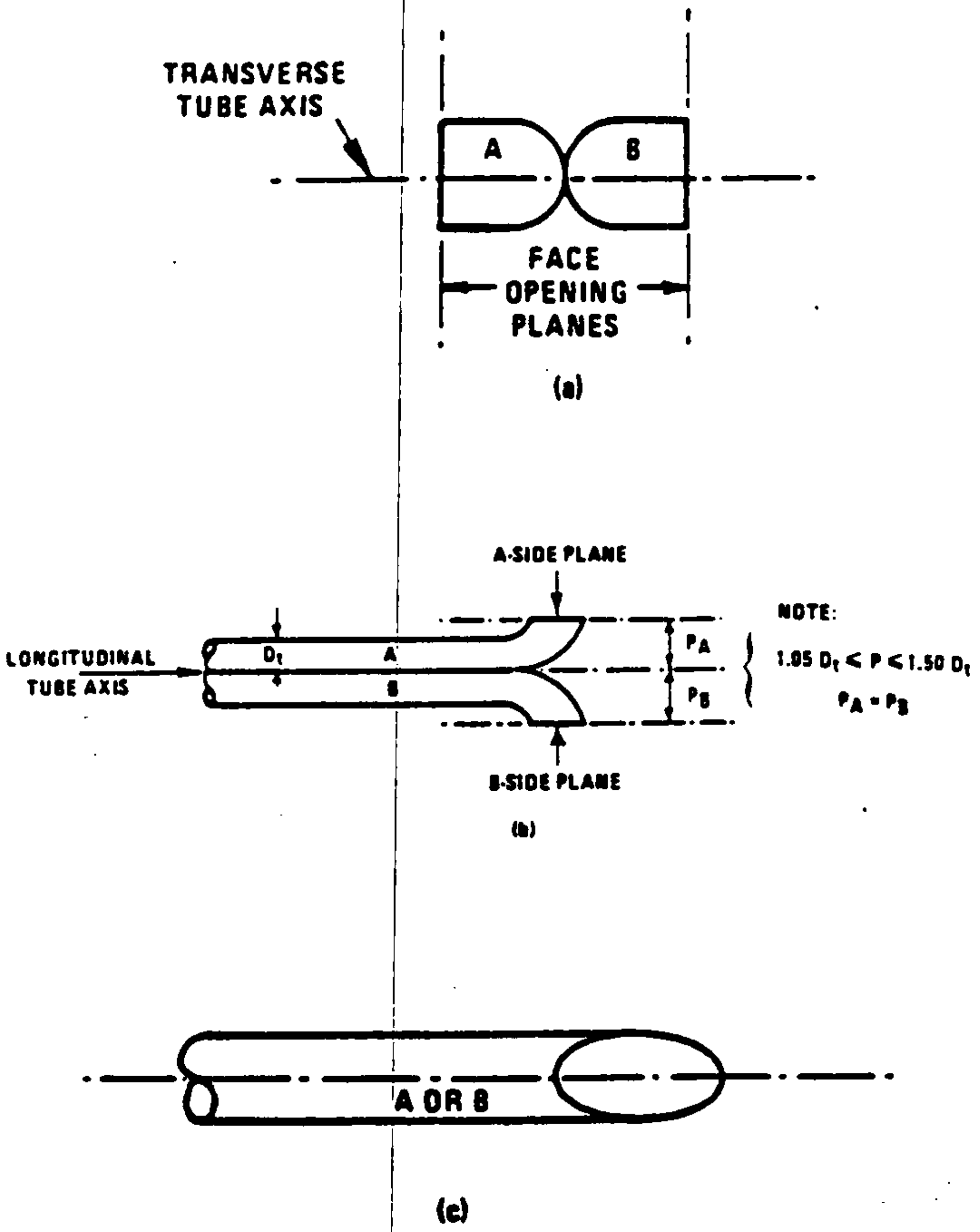


Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline coefficient values of 0.84 may be assigned to pitot tubes constructed this way.

taken, as above, for the last two back purges at which suitably high Δp readings are observed.

2.2 Differential Pressure Gauge. An inclined manometer or equivalent device is used. Most sampling trains are equipped with a 10-in. (water column) inclined-vertical manometer, having 0.01-in. H_2O divisions on the 0-to 1-in. inclined scale, and 0.1-in. H_2O divisions on the 1- to 10-in. vertical scale. This type of manometer (or other gauge of equivalent sensitivity) is satisfactory for the measurement of Δp values as low as 1.3 mm (0.05 in.) H_2O. However, a differential pressure gauge of greater sensitivity shall be used (subject to the approval of the Administrator), if any of the following is found to be true: (1) the arithmetic average of all Δp readings at the traverse points in the stack is less than 1.3 mm (0.05 in.) H_2O; (2) for traverses of 12 or more points, more than 10 percent of the individual Δp readings are below 1.3 mm (0.05 in.) H_2O; (3) for traverses of fewer than 12 points, more than one Δp reading is below 1.3 mm (0.05 in.) H_2O. Citation 18 in Section 6 describes commercially available instrumentation for the measurement of low-range gas velocities.

As an alternative to criteria (1) through (3) above, the following calculation may be performed to determine the necessity of using a more sensitive differential pressure gauge:

$$T=\frac{\sum_{i=1}^{n}\sqrt{\Delta p_i+K}}{\sum_{i=1}^{n}\sqrt{\Delta p_i}}$$

where:

Δp_i = Individual velocity head reading at a traverse point, mm H_2O (in. H_2O).
= Total number of traverse points.
K = 0.13 mm H_2O when metric units are used and 0.005 in H_2O when English units are used.

If T is greater than 1.05, the velocity head data are unacceptable and a more sensitive differential pressure gauge must be used.

Note: If differential pressure gauges other than inclined manometers are used (e.g., magnehelic gauges), their calibration must be checked after each test series. To check the calibration of a differential pressure gauge, compare Δp readings of the gauge with those of a gauge-oil manometer at a minimum of three points, approximately representing the range of Δp values in the stack. If, at each point, the values of Δp as read by the differential pressure gauge and gauge-oil manometer agree to within 5 percent, the differential pressure gauge shall be considered to be in proper calibration. Otherwise, the test series shall either be voided, or procedures to adjust the measured Δp values and final results shall be used subject to the approval of the Administrator.

2.3 Temperature Gauge. A thermocouple, liquid-filled bulb thermometer, bimetallic thermometer, mercury-in-glass thermometer, or other gauge, capable of measuring temperature to within 1.5 percent of the minimum absolute stack temperature shall be used. The temperature gauge shall be attached to the pitot tube such that the sensor tip does not touch any metal; the gauge shall be in an interference-free arrangement with respect to the pitot tube face openings (see Figure 2-1 and also Figure 2-7 in Section 4). Alternate positions may be used if the pitot tube-temperature gauge system is calibrated according to the procedure of Section 4. Provided that a difference of not more than 1 percent in the average velocity measurement is introduced, the temperature gauge need not be attached to the pitot tube; this alternative is subject to the approval of the *Administrator*.

2.4 Pressure Probe and Gauge. A piezometer tube and mercury- or water-filled U-tube manometer capable of measuring stack pressure to within 2.5 mm (0.1 in.) Hg is used. The static tap of a standard type pitot tube or one leg of a Type S pitot tube with the face opening planes positioned parallel to the gas flow may also be used as the pressure probe.

2.5 Barometer. A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm (0.1 in.) Hg per 30-meter (100 foot) elevation increase or vice-versa for elevation decrease.

2.6 Gas Density Determination Equipment. Method 3 equipment, if needed (see Section 3.6), to determine the stack gas dry molecular weight, and Reference Method 4 or Method 5 equipment for moisture content determination; other methods may be used subject to approval of the Administrator.

2.7 Calibration Pitot Tube. When calibration of the Type S pitot tube is necessary (see Section 4), a standard pitot tube is used as a reference. The standard pitot tube shall, preferably, have a known coefficient, obtained either (1) directly from the National Bureau of Standards, Route 270, Quince Orchard Road, Gaithersburg, Maryland, or (2) by calibration against another standard pitot tube with an NBS-traceable coefficient. Alternatively, a standard pitot tube designed according to the criteria given in 2.7.1 through 2.7.5 below and illustrated in Figure 2-4 (see also Citations 7, 8, and 17 in Section 6) may be used. Pitot tubes designed according to these specifications will have baseline coefficients of about 0.99±0.01.

2.7.1 Hemispherical (shown in *Figure* 2-4), ellipsoidal, or conical tip.

2.7.2 A minimum of six diameters straight run (based upon *D*, the external diameter of the tube) between the tip and the static pressure holes.

2.7.3 A minimum of eight diameters straight run between the static pressure holes and the centerline of the external tube, following the 90 degree bend.

2.7.4 Static pressure holes of equal size (approximately 0.1 *D*), equally spaced in a piezometer ring configuration.

2.7.5 Ninety degree bend, with curved or mitered junction.

2.8 Differential Pressure Gauge for Type S Pitot Tube Calibration. An inclined manometer or equivalent is used. If the single-velocity calibration technique is employed (see Section 4.1.2.3), the calibration differential pressure gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in. H_2O). For multivelocity calibrations, the gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in H_2O) for Δp values between 1.3 and 25 mm H_2O (0.05 and 1.0 in. H_2O), and to the nearest 1.3 mm H_2O (0.05 in. H_2O) for Δp values above 25 mm H_2O (1.0 in. H_2O). A special, more sensitive gauge will be required to read Δp values below 1.3 mm H_2O (0.05 in. H_2O) (see Citation 18 in Section 6).

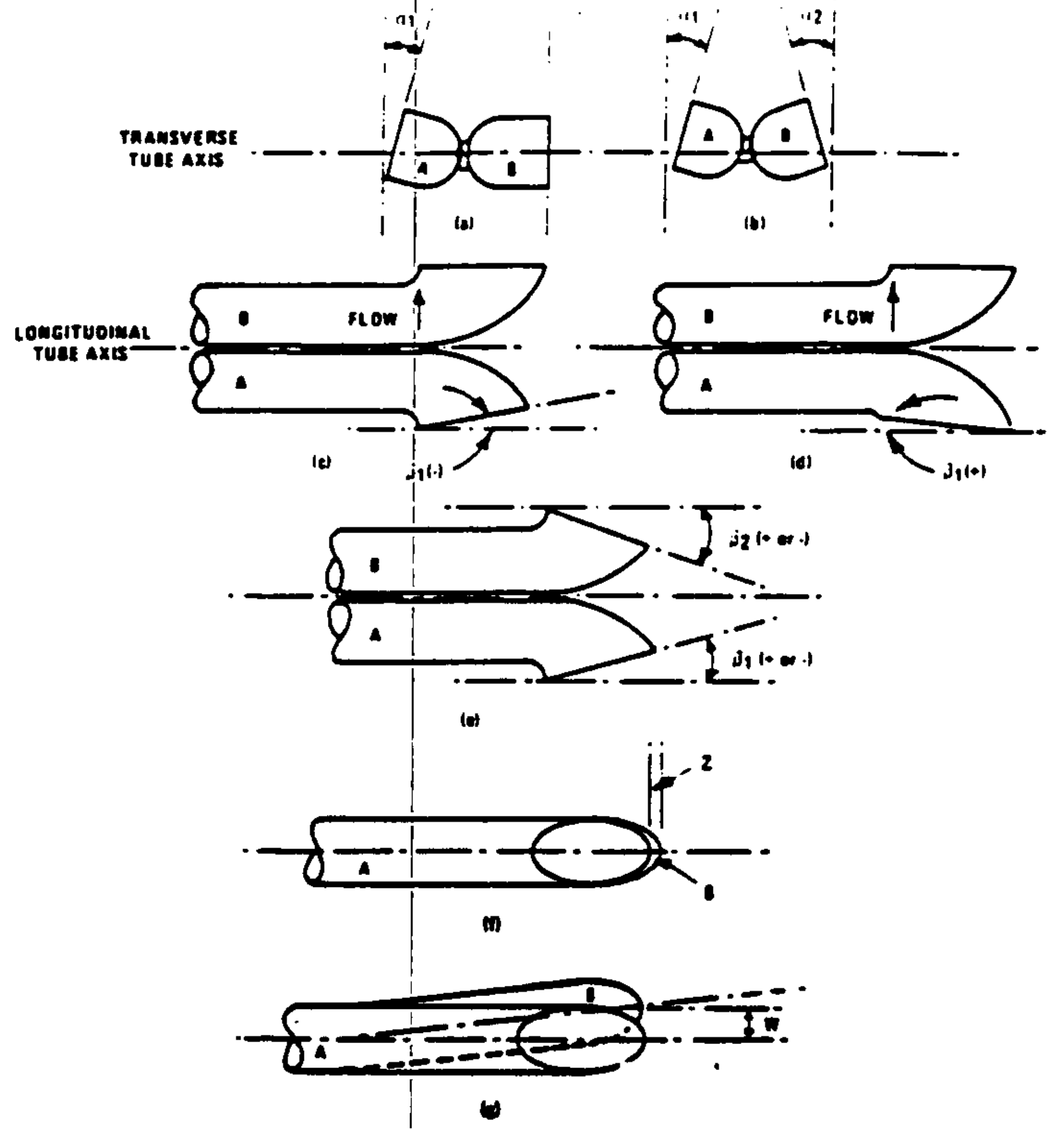


Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of Cp(s) so long as α_1 and α_2 10°, β_1 and β_2 5°, z 0.32 cm (1/8 in.) and w 0.08 cm (1/32 in.) (citation 11 in Section 6).

A standard pitot tube may be used instead of a Type S, provided that it meets the specifications of Sections 2.7 and 4.2; note, however, that the static and impact pressure holes of standard pitot tubes are susceptible to plugging in particulate-laden gas streams. Therefore, whenever a standard pitot tube is used to perform a traverse, adequate proof must be furnished that the openings of the pitot tube have not plugged up during the traverse period; this can be done by taking a velocity head (Δp) reading at the final traverse point, cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and then taking another Δp reading. If the Δp readings made before and after the air purge are the same ($\pm$5 percent), the traverse is acceptable. Otherwise, reject the run. Note that if Δp at the final traverse point is unsuitably low, another point may be selected. If "back-purging" at regular intervals is part of the procedure, then comparative Δp readings shall be

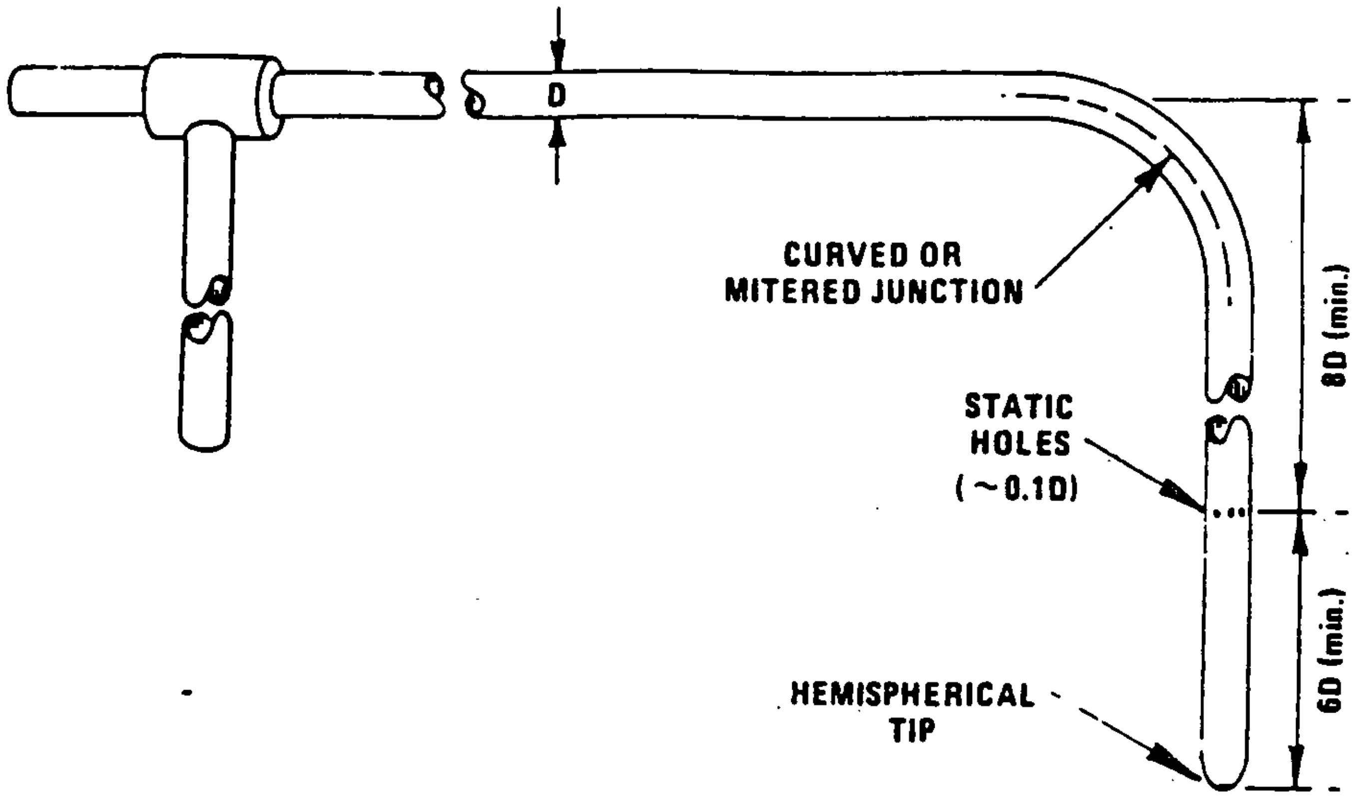


Figure 2-4. Standard pitot tube design specifications.

3. *Procedure*

3.1 Set up the apparatus as shown in Figure 2-1. Capillary tubing or surge tanks installed between the manometer and pitot tube may be used to dampen Δp fluctuations. It is recommended, but not required, that a pretest leak-check be conducted, as follows: (1) blow through the pitot impact opening until at least 7.6 cm (3 in.) H_2O velocity pressure registers on the manometer; then, close off the impact opening. The pressure shall remain stable for at least 15 seconds; (2) do the same for the static pressure side, except using suction to obtain the minimum of 7.6 cm (3 in.) H_2O. Other leak-check procedures, subject to the approval of the Administrator may be used.

3.2 Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse. Record all necessary data as shown in the example data sheet (Figure 2-5).

3.3 Measure the velocity head and temperature at the traverse points specified by Method 1. Ensure that the proper differential pressure gauge is being used for the range of Δp values encountered (see Section 2.2). If it is necessary to change to a more sensitive gauge, do so, and remeasure the Δp and temperature readings at each traverse point. Conduct a post-test leak-check (mandatory), as described in Section 3.1 above, to validate the traverse run.

3.4 Measure the static pressure in the stack. One reading is usually adequate.

3.5 Determine the atmospheric pressure.

PLANT ____________________
DATE ____________ RUN NO. ________
STACK DIAMETER OR DIMENSIONS, m(in.) ________
BAROMETRIC PRESSURE, mm Hg (in. Hg) ________
CROSS SECTIONAL AREA, $m^2(ft^2)$ ________
OPERATORS ____________
PITOT TUBE I.D. NO. ____________
AVG. COEFFICIENT, C_p = ________
LAST DATE CALIBRATED ________

SCHEMATIC OF STACK CROSS SECTION

Traverse Pt. No.	Vel. Hd., Δp mm (in.) H_2O	Stack Temperature		P_g mm Hg (in.Hg)	$\sqrt{\Delta p}$
		t_s, °C (°F)	T_s, °K (°R)		
		Average			

Figure 2-5. Velocity traverse data.

3.6 Determine the stack gas dry molecular weight. For combustion processes or processes that emit essentially CO_2, O_2, CO, and N_2, use Method 3. For processes emitting essentially air, an analysis need not be conducted; use a dry molecular weight of 29.0. For other processes, other methods, subject to the approval of the Administrator, must be used.

3.7 Obtain the moisture content from Reference Method 4 (or equivalent) or from Method 5.

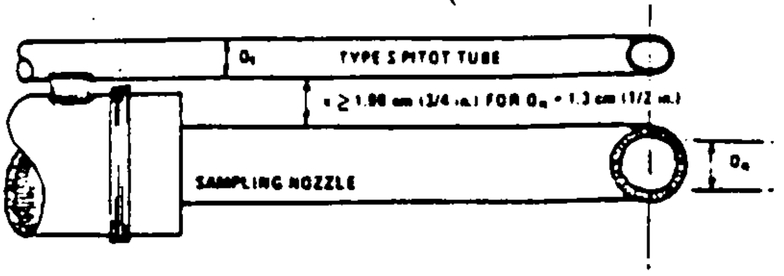
3.8 Determine the cross-sectional area of the stack or duct at the sampling location. Whenever possible, physically measure the stack dimensions rather than using blueprints.

4. *Calibration*

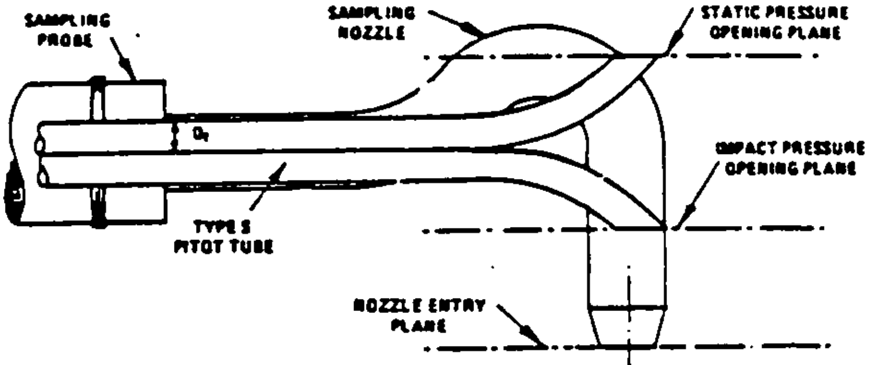
4.1 Type S Pitot Tube. Before its initial use, carefully examine the Type S pitot tube in top, side, and end views to verify that the face openings of the tube are aligned within the specifications illustrated in Figure 2-2 or 2-3. The pitot tube shall not be used if it fails to meet these alignment specifications.

After verifying the face opening alignment, measure and record the following dimensions of the pitot tube: (a) the external tubing diameter (dimension D_t, Figure 2-2b); and (b) the base-to-opening plane distances (dimensions P_A and P_B, Figure 2-2b). If D_t is between 0.48 and 0.95 cm (3/16 and 3/8 in.) and if P_A and P_B are equal and between 1.05 and 1.50 D_t, there are two possible options: (1) the pitot tube may be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, or (2) a baseline (isolated tube) coefficient value of 0.84 may be assigned to the pitot tube. Note, however, that if the pitot tube is part of an assembly, calibration may still be required, despite knowledge of the baseline coefficient value (see Section 4.1.1).

If D_t, P_A, and P_B are outside the specif limits, the pitot tube must be calibrated outlined in 4.1.2 through 4.1.5 below.



A. BOTTOM VIEW: SHOWING MINIMUM PITOT-NOZZLE SEPARATION.



B. SIDE VIEW: TO PREVENT PITOT TUBE FROM INTERFERING WITH GAS FLOW STREAMLINES APPROACHING THE NOZZLE. THE IMPACT PRESSURE OPENING PLANE OF THE PITOT TUBE SHALL BE EVEN WITH OR ABOVE THE NOZZLE ENTRY PLANE.

4.1.1 Type S Pitot Tube Assemblies. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of other sampling components can sometimes affect the baseline value of the Type S pitot tube coefficient (Citation 9 in Section 6); therefore an assigned (or otherwise known) baseline coefficient value may or may not be valid for a given assembly. The baseline and assembly coefficient values will be identical only when the relative placement of the components in the assembly is such that aerodynamic interference effects are eliminated. Figures 2-6 through 2-8 illustrate interference-free component arrangements for Type S pitot tubes having external tubing diameters between 0.48 and 0.95 cm (3/16 and 3/8 in.). Type S pitot tube assemblies that fail to meet any or all of the specifications of Figures 2-6 through 2-8 shall be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, and prior to calibration, the values of the intercomponent spacings (pitot-nozzle, pitot-thermocouple, pitot-probe sheath) shall be measured and recorded.

NOTE: Do not use any Type S pitot tube assembly which is constructed such that the impact pressure opening plane of the pitot tube is below the entry plane of the nozzle (see Figure 2-6b).

4.1.2 Calibration Setup. If the Type S pitot tube is to be calibrated, one leg of the tube shall be permanently marked A, and the other, B. Calibration shall be done in a flow system having the following essential design features:

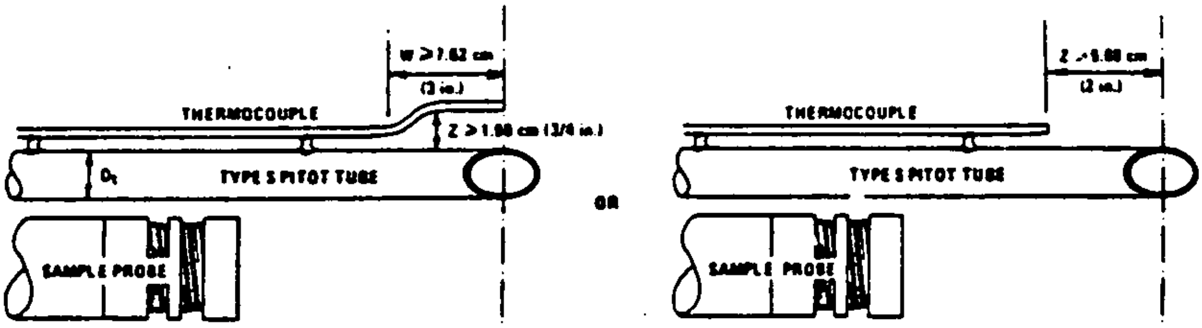


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

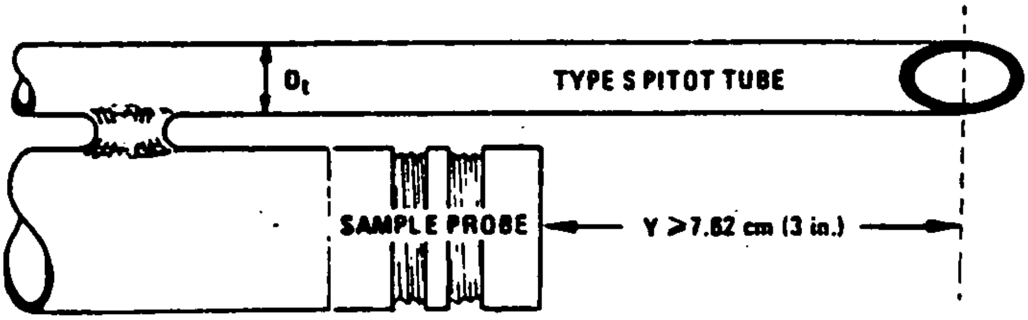


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

4.1.2.1 The flowing gas stream must be confined to a duct of definite cross-sectional area, either circular or rectangular. For circular cross-sections, the minimum duct diameter shall be 30.5 cm (12 in.); for rectangular cross-sections, the width (shorter side) shall be at least 25.4 cm (10 in.).

4.1.2.2 The cross-sectional area of the calibration duct must be constant over a distance of 10 or more duct diameters. For a rectangular cross-section, use an equivalent diameter, calculated from the following equation, to determine the number of duct diameters:

$$D = \frac{2LW}{(L+W)}$$

Equation 2-1

where:

D_e = Equivalent diameter

L = Length

W = Width

To ensure the presence of stable, fully developed flow patterns at the calibration site, or "test section," the site must be located at least eight diameters downstream and two diameters upstream from the nearest disturbances.

NOTE: The eight- and two-diameter criteria are not absolute; other test section locations may be used (subject to approval of the Administrator), provided that the flow at the test site is stable and demonstrably parallel to the duct axis.

4.1.2.3 The flow system shall have the capacity to generate a test-section velocity around 915 m/min (3,000 ft/min). This velocity must be constant with time to guarantee steady flow during calibration. Note that Type S pitot tube coefficients obtained by single-velocity calibration at 915 m/min (3,000 ft/min) will generally be valid to within ±3 percent for the measurement of velocities above 305 m/min (1,000 ft/min) and to within ±5 to 6 percent for the measurement of velocities between 180 and 305 m/min (600 and 1,000 ft/min). If a more precise correlation between C_p and velocity is desired, the flow system shall have the capacity to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 1,525 m/min (600 to 5,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see Citations 9 and 14 in Section 6 for details).

4.1.2.4 Two entry ports, one each for the standard and Type S pitot tubes, shall be cut in the test section; the standard pitot entry port shall be located slightly downstream of the Type S port, so that the standard and Type S impact openings will lie in the same cross-sectional plane during calibration. To facilitate alignment of the pitot tubes during calibration, it is advisable that the test section be constructed of plexiglas or some other transparent material.

4.1.3 Calibration Procedure. Note that this procedure is a general one and must not be used without first referring to the special considerations presented in Section 4.1.5. Note also that this procedure applies only to single-velocity calibration. To obtain calibration data for the A and B sides of the Type S pitot tube, proceed as follows:

4.1.3.1 Make sure that the manometer is properly filled and that the oil is free from contamination and is of the proper density. Inspect and leak-check all pitot lines; repair or replace if necessary.

PITOT TUBE IDENTIFICATION NUMBER: ______________ DATE: __________

CALIBRATED BY: ______________________________

"A" SIDE CALIBRATION

RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(A)$
1				
2				
3				
		$\bar{C}_p$ (SIDE A)		

"B" SIDE CALIBRATION

RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(B)$
1				
2				
3				
		$\bar{C}_p$ (SIDE B)		

$$\text{AVERAGE DEVIATION} = \sigma(\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_p(s) - \bar{C}_p(\text{A OR B}) \right|}{3} \longleftarrow \text{MUST BE} < 0.01$$

$$\left| \bar{C}_p(\text{SIDE A}) - \bar{C}_p(\text{SIDE B}) \right| \longleftarrow \text{MUST BE} < 0.01$$

Figure 2-9. Pitot tube calibration data.

4.1.3.2 Level and zero the manometer. Turn on the fan and allow the flow to stabilize. Seal the Type S entry port.

4.1.3.3 Ensure that the manometer is level and zeroed. Position the standard pitot tube at the calibration point (determined as outlined in Section 4.1.5.1), and align the tube so that its tip is pointed directly into the flow. Particular car should be taken in aligning the tube to avoid yaw and pitch angles. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.4 Read Δp_{std} and record its value in a data table similar to the one shown in Figure 2-9. Remove the standard pitot tube from the duct and disconnect it from the manometer. Seal the standard entry port.

4.1.3.5 Connect the Type S pitot tube to the manometer. Open the Type S entry port. Check the manometer level and zero. Insert and align the Type S pitot tube so that its A side impact opening is at the same point as was the standard pitot tube and is pointed directly into the flow. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.6 Read Δp_s and enter its value in the data table. Remove the Type S pitot tube from the duct and disconnect it from the manometer.

4.1.3.7 Repeat steps 4.1.3.3 through 4.1.3.6 above until three pairs of Δp readings have been obtained.

4.1.3.8 Repeat steps 4.1.3.3 through 4.1.3.7 above for the B side of the Type S pitot tube.

4.1.3.9 Perform calculations, as described in Section 4.1.4 below.

4.1.4 Calculations.

4.1.4.1 For each of the six pairs of Δp readings (i.e., three from side A and three from side B) obtained in Section 4.1.3 above calculate the value of the Type S pitot tub coefficient as follows:

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_s}}$$

Equation 2-2

where:

$C_{p(s)}$ = Type S pitot tube coefficient

$C_{p(std)}$ = Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.

Δp_{std} = Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)

Δp_s = Velocity head measured by the Type S pitot tube, cm H_2O (in H_2O)

4.1.4.2 Calculate $\overline{C}_p$ (side A), the mean A-side coefficient, and $\overline{C}_p$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\overline{C}_p$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\overline{C}_p$ $\overline{C}_p$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \overline{C}_p(\text{A or B})$$

Equation 2-3

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B sides of the pitot tube. Use the following equation:

$$\sigma\,(\text{side A or B}) = \frac{\sum_{1}^{3} |C_{p(s)} - \overline{C}_p(A \text{ or } B)|}{3}$$

Equation 2-4

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\overline{C}_p$ (A) and $\overline{C}_p$ (B) is 0.01 or less.

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

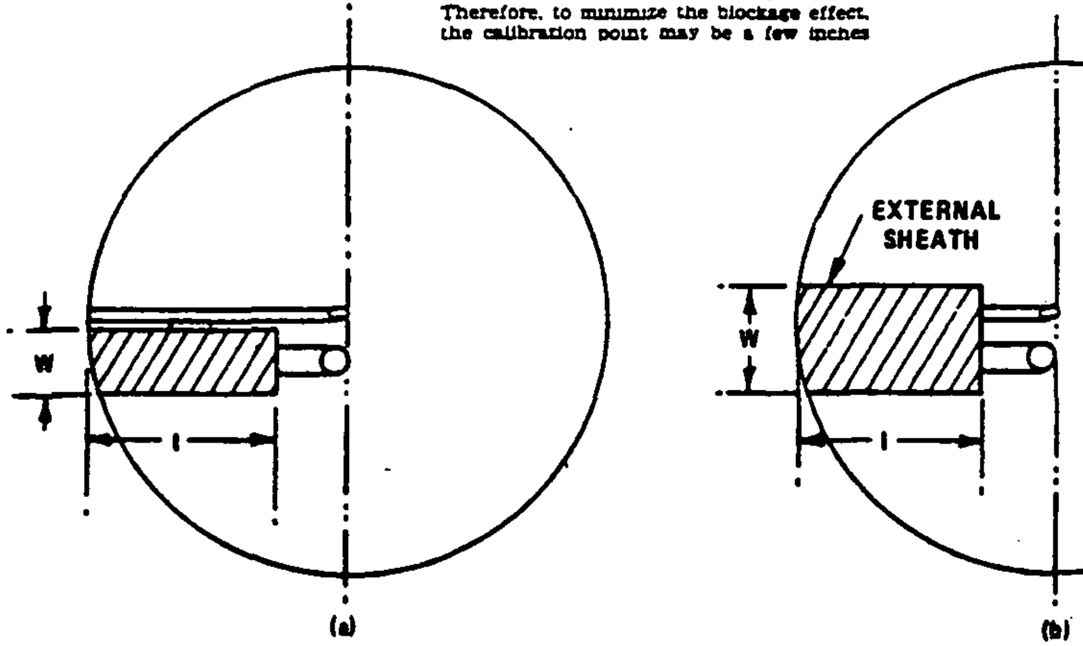
4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\overline{C}_p$ (side A) and $\overline{C}_p$ (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2-6 through 2-8).

4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2-6, and 2-8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Section 6). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2-10a), and 3 percent or less for assemblies with external sheaths (Figure 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzle separation distance fails to meet the specification illustrated in Figure 2-6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-2 or 2-3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).



$$\text{ESTIMATED SHEATH BLOCKAGE (\%)} = \left[\frac{l \times W}{\text{DUCT AREA}}\right] \times 100$$

Figure 2-10. Projected-area models for typical pitot tube assemblies.

Figure 2-10. Projected-area models for typical pitot tube assemblies.

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

4.1.6.1.1 When a Type S pitot tube (isolated tube or assembly) is used in the field, the appropriate coefficient value (whether assigned or obtained by calibration) shall be used to perform velocity calculations. For calibrated Type S pitot tubes, the A side coefficient shall be used when the A side of the tube faces the flow, and the B side coefficient shall be used when the B side faces the flow; alternatively, the arithmetic average of the A and B side coefficient values may be used, irrespective of which side faces the flow.

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 36 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of $C_{p(s)}$. Consult Citation 9 in Section 6 for details. Conventional pitot-sampling probe assemblies are not recommended for use in ducts having inside diameters smaller than 12 inches (Citation 16 in Section 6).

4.1.6.2 Recalibration.

4.1.6.2.1 Isolated Pitot Tubes. After each field use, the pitot tube shall be carefully reexamined in top, side, and end views. If the pitot face openings are still aligned within the specifications illustrated in Figure 2-2 or 2-3, it can be assumed that the baseline coefficient of the pitot tube has not changed. If, however, the tube has been damanged to the extent that it no longer meets the specifications of Figure 2-2 or 2-3, the damage shall either be repaired to restore proper alignment of the face openings or the tube shall be discarded.

4.1.6.2.2 Pitot Tube Assemblies. After each field use, check the face opening alignment of the pitot tube, as in Section 1.6.2.1; also, remeasure the intercomponent spacings of the assembly. If the intercomponent spacings have not changed and the face opening alignment is acceptable, it can be assumed that the coefficient of the assembly has not changed. If the face opening alignment is no longer within the specifications of Figures 2-2 or 2-3, either repair the damage or replace the pitot tube (calibrating the new assembly, if necessary). If the intercomponent spacings have changed, restore the original spacings or recalibrate the assembly.

4.2 Standard pitot tube (if applicable). If a standard pitot tube is used for the velocity traverse, the tube shall be constructed according to the criteria of Section 2.7 and shall be assigned a baseline coefficient value of 0.99. If the standard pitot tube is used as part of an assembly, the tube shall be in an interference-free arrangement (subject to the approval of the Administrator).

4.3 Temperature Gauges. After each field use, calibrate dial thermometers, liquid-filled bulb thermometers, thermocouple-potentiometer systems, and other gauges at a temperature within 10 percent of the average absolute stack temperature. For temperatures up to 405° C (761° F), use an ASTM mercury-in-glass reference thermometer, or equivalent, as a reference; alternatively, either a reference thermocouple and potentiometer (calibrated by NBS) or thermometric fixed points, e.g., ice bath and boiling water (corrected for barometric pressure) may be used. For temperatures above 405° C (761° F), use an NBS-calibrated reference thermocouple-potentiometer system or an alternate reference, subject to the approval of the Administrator.

If, during calibration, the absolute temperatures measured with the gauge being calibrated and the reference gauge agree within 1.5 percent, the temperature data taken in the field shall be considered valid. Otherwise, the pollutant emission test shall either be considered invalid or adjustments (if appropriate) of the test results shall be made, subject to the approval of the Administrator.

4.4 Barometer. Calibrate the barometer used against a mercury barometer.

5. *Calculations*

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

5.1 Nomenclature.

A = Cross-sectional area of stack, m² (ft²).

B_{ws} = Water vapor in the gas stream (from Method 5 or Reference Method 4), proportion by volume.

C_p = Pitot tube coefficient, dimensionless.

K_p = Pitot tube constant.

$$34.97\ \frac{\text{m}}{\text{sec}}\left[\frac{(\text{g/g-mole})(\text{mm Hg})}{(°\text{K})(\text{mm H}_2\text{O})}\right]^{1/2}$$

for the metric system and

$$85.49\ \frac{\text{ft}}{\text{sec}}\left[\frac{(\text{lb/lb-mole})(\text{in. Hg})}{(°\text{R})(\text{in. H}_2\text{O})}\right]^{1/2}$$

for the English system.

M_d = Molecular weight of stack gas, dry basis (see Section 3.6) g/g-mole (lb/lb-mole).

M_s = Molecular weight of stack gas, wet basis, g/g-mole (lb/lb-mole).

$= M_d\,(1 - B_{ws}) + 18.0\ B_{ws}$

Equation 2-5

P_{bar} = Barometric pressure at measurement site, mm Hg (in. Hg).

P_g = Stack static pressure, mm Hg (in. Hg).

P_s = Absolute stack gas pressure, mm Hg (in. Hg).

$= P_{bar} + P_g$

Equation 2-6

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

Q_{sd} = Dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr).

t_s = Stack temperature, °C (°F).

T_s = Absolute stack temperature, °K, (°R).

$= 273 + t_s$ for metric

Equation 2-7

$= 460 + t_s$ for English

Equation 2-8

T_{std} = Standard absolute temperature, 293 °K (528° R)

v_s = Average stack gas velocity, m/sec (ft/sec).

Δp = Velocity head of stack gas, mm H₂O (in. H₂O).

3,600 = Conversion factor, sec/hr.

18.0 = Molecular weight of water, g/g-mole (lb/lb-mole).

5.2 Average stack gas velocity.

$$v_s = K_p C_p (\sqrt{\Delta p})_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}}$$

Equation 2-9

5.3 Average stack gas dry volumetric flow rate.

$$Q_{sd} = 3{,}600(1 - B_{ws})v_s A \left(\frac{T_{std}}{T_{s(avg)}}\right)\left(\frac{P_s}{P_{std}}\right)$$

Equation 2-10

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METHOD 3—GAS ANALYSIS FOR CARBON DIOXIDE, OXYGEN, EXCESS AIR, AND DRY MOLECULAR WEIGHT

1. *Principle and Applicability*

1.1 Principle. A gas sample is extracted from a stack, by one of the following methods: (1) single-point, grab sampling; (2) single-point, integrated sampling; or (3) multi-point, integrated sampling. The gas sample is analyzed for percent carbon dioxide (CO_2), percent oxygen (O_2), and, if necessary, percent carbon monoxide (CO). If a dry molecular weight determination is to be made, either an Orsat or a Pyrite [1] analyzer may be used for the analysis; for excess air or emission rate correction factor determination, an Orsat analyzer must be used.

1.2 Applicability. This method is applicable for determining CO_2 and O_2 concentrations, excess air, and dry molecular weight of a sample from a gas stream of a fossil-fuel combustion process. The method may also be applicable to other processes where it has been determined that compounds other than CO_2, O_2, CO, and nitrogen (N_2) are not present in concentrations sufficient to affect the results.

Other methods, as well as modifications to the procedure described herein, are also applicable for some or all of the above determinations. Examples of specific methods and modifications include: (1) a multi-point sampling method using an Orsat analyzer to analyze individual grab samples obtained at each point; (2) a method using CO_2 or O_2 and stoichiometric calculations to determine dry molecular weight and excess air; (3) assigning a value of 30.0 for dry molecular weight, in lieu of actual measurements, for processes burning natural gas, coal, or oil. These methods and modifications may be used, but are subject to the approval of the Administrator, U.S. Environmental Protection Agency.

2. *Apparatus*

As an alternative to the sampling apparatus and systems described herein, other sampling systems (e.g., liquid displacement) may be used provided such systems are capable of obtaining a representative sample and maintaining a constant sampling rate, and are otherwise capable of yielding acceptable results. Use of such systems is subject to the approval of the Administrator.

2.1 Grab Sampling (Figure 3–1).

2.1.1 Probe. The probe should be made of stainless steel or borosilicate glass tubing and should be equipped with an in-stack or out-stack filter to remove particulate matter (a plug of glass wool is satisfactory for this purpose). Any other materials inert to O_2, CO_2, CO, and N_2 and resistant to temperature at sampling conditions may be used for the probe; examples of such material are aluminum, copper, quartz glass and Teflon.

2.1.2 Pump. A one-way squeeze bulb, or equivalent, is used to transport the gas sample to the analyzer.

2.2 Integrated Sampling (Figure 3–2).

2.2.1 Probe. A probe such as that described in Section 2.1.1 is suitable.

2.2.2 Condenser. An air-cooled or water-cooled condenser, or other condenser that will not remove O_2, CO_2, CO, and N_2, may be used to remove excess moisture which would interfere with the operation of the pump and flow meter.

2.2.3 Valve. A needle valve is used to adjust sample gas flow rate.

2.2.4 Pump. A leak-free, diaphragm-type pump, or equivalent, is used to transport sample gas to the flexible bag. Install a small surge tank between the pump and rate meter to eliminate the pulsation effect of the diaphragm pump on the rotameter.

2.2.5 Rate Meter. The rotameter, or equivalent rate meter, used should be capable of measuring flow rate to within ±2 percent of the selected flow rate. A flow rate range of 500 to 1000 cm^3/min is suggested.

2.2.6 Flexible Bag. Any leak-free plastic (e.g., Tedlar, Mylar, Teflon) or plastic-coated aluminum (e.g., aluminized Mylar) bag, or equivalent, having a capacity consistent with the selected flow rate and time length of the test run, may be used. A capacity in the range of 55 to 90 liters is suggested.

To leak-check the bag, connect it to a water manometer and pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O). Allow to stand for 10 minutes. Any displacement in the water manometer indicates a leak. An alternative leak-check method is to pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O) and allow to stand overnight. A deflated bag indicates a leak.

2.2.7 Pressure Gauge. A water-filled U-tube manometer, or equivalent, of about 28 cm (12 in.) is used for the flexible bag leak-check.

2.2.8 Vacuum Gauge. A mercury manometer, or equivalent, of at least 760 mm Hg (30 in. Hg) is used for the sampling train leak-check.

2.3 Analysis. For Orsat and Pyrite analyzer maintenance and operation procedures, follow the instructions recommended by the manufacturer, unless otherwise specified herein.

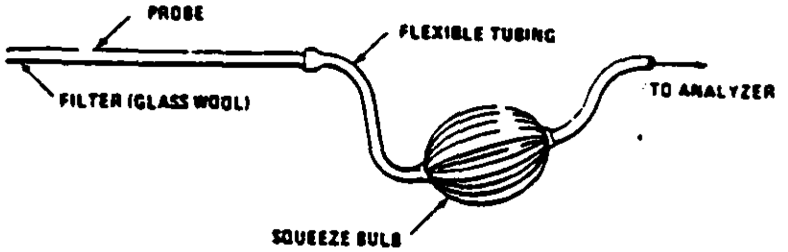

Figure 3-1. Grab-sampling train.

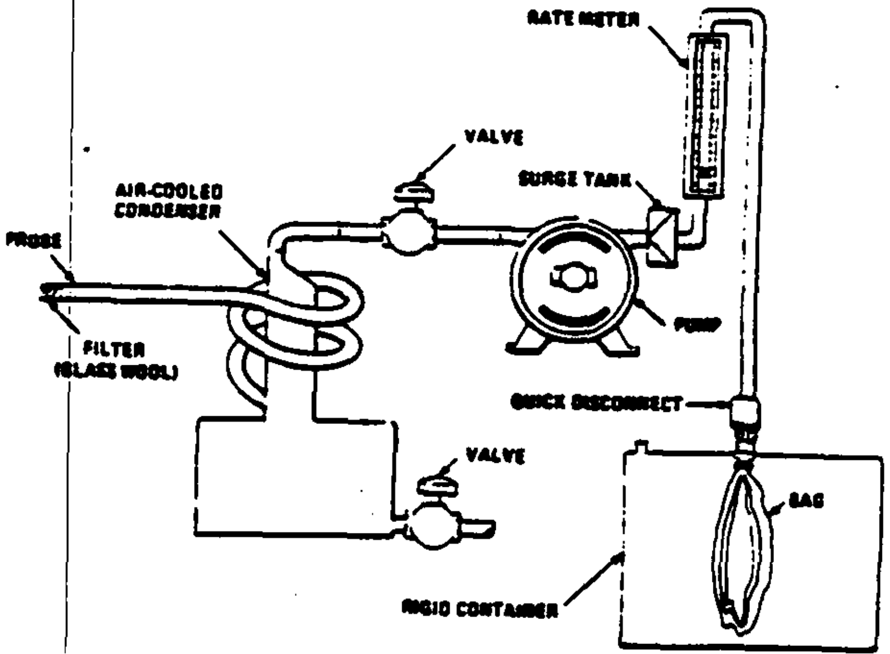

Figure 3-2. Integrated gas-sampling train.

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[1] Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

2.3.1 Dry Molecular Weight Determination. An Orsat analyzer or Fyrite type combustion gas analyzer may be used.

2.3.2 Emission Rate Correction Factor or Excess Air Determination. An Orsat analyzer must be used. For low CO_2 (less than 4.0 percent) or high O_2 (greater that 15.0 percent) concentrations, the measuring burette of the Orsat must have at least 0.1 percent subdivisions.

3. *Dry Molecular Weight Determination*

Any of the three sampling and analytical procedures described below may be used for determining the dry molecular weight.

3.1 Single-Point, Grab Sampling and Analytical Procedure.

3.1.1 The sampling point in the duct shall either be at the centroid of the cross section or at a point no closer to the walls than 1.00 m (3.3 ft), unless otherwise specified by the Administrator.

3.1.2 Set up the equipment as shown in Figure 3-1, making sure all connections ahead of the analyzer are tight and leak-free. If and Orsat analyzer is used, it is recommended that the analyzer be leaked-checked by following the procedure in Section 5; however, the leak-check is optional.

3.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Draw a sample into the analyzer and immediately analyze it for percent CO_2 and percent O_2. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.3.

3.1.4 Repeat the sampling, analysis, and calculation procedures, until the dry molecular weights of any three grab samples differ from their mean by no more than 0.3 g/g-mole (0.3 lb/lb-mole). Average these three molecular weights, and report the results to the nearest 0.1 g/g-mole (lb/lb-mole).

3.2 Single-Point, Integrated Sampling and Analytical Procedure.

3.2.1 The sampling point in the duct shall be located as specified in Section 3.1.1.

3.2.2 Leak-check (optional) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3-2. Just prior to sampling, leak-check (optional) the train by placing a vacuum gauge at the condenser inlet, pulling a vacuum of at least 250 mm Hg (10 in. Hg), plugging the outlet at the quick disconnect, and then turning off the pump. The vacuum should remain stable for at least 0.5 minute. Evacuate the flexible bag. Connect the probe and place it in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Next, connect the bag and make sure that all connections are tight and leak free.

3.2.3 Sample at a constant rate. The sampling run should be simultaneous with, and for the same total length of time as, the pollutant emission rate determination. Collection of at least 30 liters (1.00 ft³) of sample gas is recommended; however, smaller volumes may be collected, if desired.

3.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. Within 8 hours after the sample is taken, analyze it for percent CO_2 and percent O_2 using either an Orsat analyzer or a Fyrite-type combustion gas analyzer. If an Orsat analyzer is used, it is recommended that the Orsat leak-check described in Section 5 be performed before this determination; however, the check is optional. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 6.3.

3.2.5 Repeat the analysis and calculation procedures until the individual dry molecular weights for any three analyses differ from their mean by no more than 0.3 g/g-mole (0.3 lb/lb-mole). Average these three molecular weights, and report the results to the nearest 0.1 g/g-mole (0.1 lb/lb-mole).

3.3 Multi-Point, Integrated Sampling and Analytical Procedure.

3.3.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less than 0.61 m (24 in.), a minimum of nine shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of twelve traverse points shall be used for all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to approval of the Administrator.

3.3.2 Follow the procedures outlined in sections 3.2.2 through 3.2.5, except for the following: traverse all sampling points and sample at each point for an equal length of time. Record sampling data as shown in Figure 3-3.

4. *Emission Rate Correction Factor or Excess Air Determination*

NOTE: A Fyrite-type combustion gas analyzer is not acceptable for excess air or emission rate correction factor determination, unless approved by the Administrator. If both percent CO_2 and percent O_2 are measured, the analytical results of any of the three procedures given below may also be used for calculating the dry molecular weight.

Each of the three procedures below shall be used only when specified in an applicable subpart of the standards. The use of these procedures for other purposes must have specific prior approval of the Administrator.

4.1 Single-Point, Grab Sampling and Analytical Procedure.

4.1.1 The sampling point in the duct shall either be at the centroid of the cross-section or at a point no closer to the walls than 1.00 m (3.3 ft), unless otherwise specified by the Administrator.

4.1.2 Set up the equipment as shown in Figure 3-1, making sure all connections ahead of the analyzer are tight and leak-free. Leak-check the Orsat analyzer according to the procedure described in Section 5. This leak-check is mandatory.

FIGURE 3-3—SAMPLING RATE DATA

Time	Traverse pt.	Q lpm	% dev.*
Average			

$*\% \text{ Dev.} = (Q - Q_{avg})/Q_{avg} \times 100$ (Must be ≤10%)

4.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Draw a sample into the analyzer. For emission rate correction factor determination, immediately analyze the sample, as outlined in Sections 4.1.4 and 4.1.5, for percent CO_2 or percent O_2. If excess air is desired, proceed as follows: (1) immediately analyze the sample, as in Sections 4.1.4 and 4.1.5, for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; and (3) calculate percent excess air as outlined in Section 6.2.

4.1.4 To insure complete absorption of the CO_2, O_2, or if applicable, CO, make repeated passes through each absorbing solution until two consecutive readings are the same. Several passes (three or four) should be made between readings. (If constant readings cannot be obtained after three consecutive readings, replace the absorbing solution.)

4.1.5 After the analysis is completed, leak-check (mandatory) the Orsat analyzer once again, as described in Section 5. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis.

NOTE: Since this single-point, grab sampling and analytical procedure in normally conducted in conjunction with a single-point, grab sampling and analytical procedure for a pollutant, only one analysis is ordinarily conducted. Therefore, great care must be taken to obtain a valid sample and analysis. Although in most cases only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Section 4.4 be used to validate the analytical data.

4.2 Single-Point, Integrated Sampling and Analytical Procedure.

4.2.1 The sampling point in the duct shall be located as specified in Section 4.1.1.

4.2.2 Leak-check (mandatory) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3-2. Just prior to sampling, leak-check (mandatory) the train by placing a vacuum gauge at the condenser inlet, pulling a vacuum of a least 250 mm Hg (10 in. Hg), plugging the outlet at the quick disconnect, and then turning off the pump. The vacuum shall remain stable for at least 0.5 minute. Evacuate the flexible bag. Connect the probe and place it in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Next, connect the bag and make sure that all connections are tight and leak free.

4.2.3 Sample at a constant rate, or as specified by the Administrator. The sampling run must be simultaneous with, and for the same total length of time as, the pollutant emission rate determination. Collect at least 30 liters (1.00 ft³) of sample gas. Smaller volumes may be collected, subject to approval of the Administrator.

4.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. For emission rate correction factor determination, analyze the sample within 4 hours after it is taken for percent CO_2 or percent O_2 (as outlined in Sections 4.2.5 through 4.2.7). The Orsat analyzer must be leak-checked (see Section 5) before the analysis. If excess air is desired, proceed as follows: (1) within 4 hours after the sample is taken, analyze it (as in Sections 4.2.5 through 4.2.7) for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; (3) calculate percent excess air, as outlined in Section 6.2.

4.2.5 To insure complete absorption of the CO_2, O_2, or if applicable, CO, make repeated passes through each absorbing solution until two consecutive readings are the same. Several passes (three of four) should be make between readings. (If constant readings cannot be obtained after three consecutive readings, replace the absorbing solution.)

4.2.6 Repeat the analysis until the following criteria are met:

4.2.6.1 For percent CO_2, repeat the analytical procedure until the results of any three analyses differ by no more that (a) 0.3 percent by volume when CO_2 is greater than 4.0 percent or (b) 0.2 percent by volume when CO_2 is less than or equal to 4.0 percent. Average the three acceptable values of percent CO_2 and report the results to the nearest 0.1 percent.

4.2.6.2 For percent O_2, repeat the analytical procedure until the results of any three analyses differ by no more than (a) 0.3 percent by volume when O_2 is less than 15.0 percent or (b) 0.2 percent by volume when O_2 is greater than or equal to 15.0 percent. Average the three acceptable values of percent O_2 and report the results to the nearest 0.1 percent.

4.2.6.3 For percent CO, repeat the analytical procedure until the results of any three analyses differ by no more than 0.3 percent. Average the three acceptable values of percent CO and report the results to the nearest 0.1 percent.

4.2.7 After the analysis is completed, leak-check (mandatory) the Orsat analyzer once again, as described in Section 5. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before an after the analysis.

NOTE: Although in most instances only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Citation 5 in the Bibliography be used to validate the analytical data.

4.3 Multi-Point, Integrated Sampling and Analytical Procedure.

4.3.1 Both the minimum number of sampling points and the sampling point location shall be as specified in Section 3.3.1 of this method. The use of fewer points than specified is subject to the approval of the Administrator.

4.3.2 Follow the procedures outlined in Sections 4.2.2 through 4.2.7, except for the following: Traverse all sampling points and sample at each point for an equal length of time. Record sampling data as shown in Figure 3-3.

4.4 Quality Control Procedures.

4.4.1 Data Validation When Both CO_2 and O_2 Are Measured. Although in most instances, only CO_2 or O_2 measurement is required, it is recommended that both CO_2 and O_2 be measured to provide a check on the quality of the data. The following quality control procedure is suggested.

NOTE: Since the method for validating the CO_2 and O_2 analyses is based on combustion of organic and fossil fuels and dilution of the gas stream with air, this method does not apply to sources that (1) remove CO_2 or O_2 through processes other than combustion, (2) add O_2 (e.g., oxygen enrichment) and N_2 in proportions different from that of air, (3) add CO_2 (e.g., cement or lime kilns), or (4) have no fuel factor, F_o, values obtainable (e.g., extremely variable waste mixtures). This method validates the measured proportions of CO_2 and O_2 for the fuel type, but the method does not detect sample dilution resulting from leaks during or after sample collection. The method is applicable for samples collected downstream of most lime or limestone flue-gas desulfurization units as the CO_2 added or removed from the gas stream is not significant in relation to the total CO_2 concentration. The CO_2 concentrations from other types of scrubbers using only water or basic slurry can be significantly affected and would render the F_o check minimally useful.

4.4.1.1 Calculate a fuel factor, F_o, using the following equation:

$$F_o = \frac{20.9 - \%O_2}{\%CO_2}$$

Eq. 3-3

Where:

$\%O_2$ = Percent O_2 by volume (dry basis).
$\%CO_2$ = Percent CO_2 by volume (dry basis).
20.9 = Percent O_2 by volume in ambient air.

If CO is present in quantities measurable by this method, adjust the O_2 and CO_2 values before performing the calculation for F_o as follows:

$$\%CO_2(adj) = \%CO_2 + \%CO$$

$$\%O_2(adj) = \%O_2 - 0.5\ \%CO$$

Where: %CO = Percent CO by volume (dry basis).

4.4.1.2 Compare the calculated F_o factor with the expected F_o values. The following table may be used in establishing acceptable ranges for the expected F_o if the fuel being burned is known. When fuels are burned in combination, calculate the combined fuel F_d and F_c factors (as defined in Method 19) according to the procedure in Method 19 Section 5.2.3. Then calculate the F_o factor as follows:

$$F_o = \frac{0.209\ F_d}{F_c}$$

Eq. 3-4

Fuel type	F_o range
Coal:	
Anthracite and lignite	1.016–1.130
Bituminous	1.083–1.230
Oil:	
Distillate	1.260–1.413
Residual	1.210–1.370
Gas:	
Natural	1.600–1.836
Propane	1.434–1.586
Butane	1.405–1.553
Wood	1.000–1.120
Wood bark	1.003–1.130

Calculated F_o values beyond the acceptable ranges shown in this table should be investigated before accepting the test results. For example, the strength of the solutions in the gas analyzer and the analyzing technique should be checked by sampling and analyzing a known concentration, such as air; the fuel factor should be reviewed and verified. An acceptability range of ±12 percent is appropriate for the F_o factor of mixed fuels with variable fuel ratios. The level of the emission rate relative to the compliance level should be considered in determining if a retest is appropriate, i.e., if the measured emissions are much lower or much greater than the compliance limit, repetition of the test would not significantly change the compliance status of the source and would be unnecessarily time-consuming and costly.

5. *Leak-Check Procedure for Orsat Analyzers*

Moving an Orsat analyzer frequently causes it to leak. Therefore, an Orsat analyzer should be throughly leak-checked on site before the flue gas sample is introduced into it. The procedure for leak-checking an Orsat analyzer is:

5.1.1 Bring the liquid level in each pipette up to the reference mark on the capillary tubing and then close the pipette stopcock.

5.1.2 Raise the leveling bulb sufficiently to bring the confining liquid meniscus onto the graduated portion of the burette and then close the manifold stopcock.

5.1.3 Record the meniscus position.

5.1.4 Observe the menicus in the burette and the liquid level in the pipette for movement over the next 4 minutes.

5.1.5 For the Orsat analyzer to pass the leak-check, two conditions must be met.

5.1.5.1 The liquid level in each pipette must not fall below the bottom of the capillary tubing during this 4-minute interval.

5.1.5.2 The meniscus in the burette must not change by more than 0.2 ml during this 4-minute interval.

5.1.6 If the analyzer fails the leak-check procedure, all rubber connections and stopcocks should be checked until the cause of the leak is identified. Leaking stopcocks must be disassembled, cleaned, and regreased. Leaking rubber connections must be replaced. After the analyzer is reassembled, the leak-check procedure must be repeated.

6. *Calculations*

6.1 Nomenclature.

M_d = Dry molecular weight, g/g-mole (lb/lb-mole).
%EA = Percent excess air.
$\%CO_2$ = Percent CO_2 by volume (dry basis).
$\%O_2$ = Percent O_2 by volume (dry basis).
%CO = Percent CO by volume (dry basis).
$\%N_2$ = Percent N_2 by volume (dry basis).
0.264 = Ratio of O_2 to N_2 in air, v/v.
0.280 = Molecular weight of N_2 or CO, divided by 100.
0.320 = Molecular weight of O_2 divided by 100.
0.440 = Molecular weight of CO_2 divided by 100.

6.2 Percent Excess Air. Calculate the percent excess air (if applicable), by substituting the appropriate values of percent O_2, CO, and N_2 (obtained from Section 4.1.3 or 4.2.4) into Equation 3-1.

$$\%EA = \frac{\%O_2 - 0.5\%\ CO}{0.264\%\ N_2 - (\%O_2 - 0.5\ \%\ CO)} \times 100$$

Equation 3-1

NOTE: The equation above assumes that ambient air is used as the source of O_2 and that the fuel does not contain appreciable amounts of N_2 (as do coke oven or blast furnace gases). For those cases when appreciable amounts of N_2 are present (coal, oil, and natural gas do not contain appreciable amounts of N_2) or when oxygen enrichment is used, alternate methods, subject to approval of the Administrator, are required.

6.3 Dry Molecular Weight. Use Equation 3-2 to calculate the dry molecular weight of the stack gas

$$M_d = 0.440(\%CO_2) + 0.320(\%O_2) + 0.280(\%N_2 + \%CO)$$

Equation 3-2

NOTE: The above equation does not consider argon in air (about 0.9 percent, moleculars weight of 37.7). A negative error of about 0.4 percent is introduced. The tester may opt to include argon in the analysis using procedures subject to approval of the Administrator.

7. *Bibliography*

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METHOD 4—DETERMINATION OF MOISTURE CONTENT IN STACK GASES

1. *Principle and Applicability*

1.1 Principle. A gas sample is extracted at a constant rate from the source: moisture is removed from the sample stream and determined either volumetrically or gravimetrically.

1.2 Applicability. This method is applicable for determining the moisture content of stack gas.

Two procedures are given. The first is a reference method, for accurate determinations of moisture content (such as are needed to calculate emission data). The second is an approximation method, which provides estimates of percent moisture to aid in setting isokinetic sampling rates prior to a pollutant emission measurement run. The approximation method described herein is only a suggested approach; alternative means for approximating the moisture content, e.g., drying tubes, wet bulb-dry bulb techniques, condensation techniques, stoichiometric calculations, previous experience, etc., are also acceptable.

The reference method is often conducted simultaneously with a pollutant emission measurement run; when it is, calculation of percent isokinetic, pollutant emission rate, etc., for the run shall be based upon the results of the reference method or its equivalent; these calculations shall not be based upon the results of the approximation method, unless the approximation method is shown, to the satisfaction of the Administrator, U.S. Environmental Protection Agency, to be capable of yielding results within 1 percent H_2O of the reference method.

NOTE: The reference method may yield questionable results when applied to saturated gas streams or to streams that contain water droplets. Therefore, when these conditions exist or are suspected, a second determination of the moisture content shall be made simultaneously with the reference method, as follows: Assume that the gas stream is saturated. Attach a temperature sensor (capable of measuring to ±1° C (2° F)) to the reference method probe. Measure the stack gas temperature at each traverse point (see Section 2.2.1) during the reference method traverse; calculate the average stack gas temperature. Next, determine the moisture percentage, either by: (1) using a psychrometric chart and making appropriate corrections if stack pressure is different from that of the chart, or (2) using saturation vapor pressure tables. In cases where the psychrometric chart or the saturation vapor pressure tables are not applicable (based on evaluation of the process), alternate methods, subject to the approval of the Administrator, shall be used.

2. *Reference Method*

The procedure described in Method 5 for determining moisture content is acceptable as a reference method.

2.1 Apparatus. A schematic of the sampling train used in this reference method is shown in Figure 4-1. All components shall be maintained and calibrated according to the procedure outlined in Method 5.

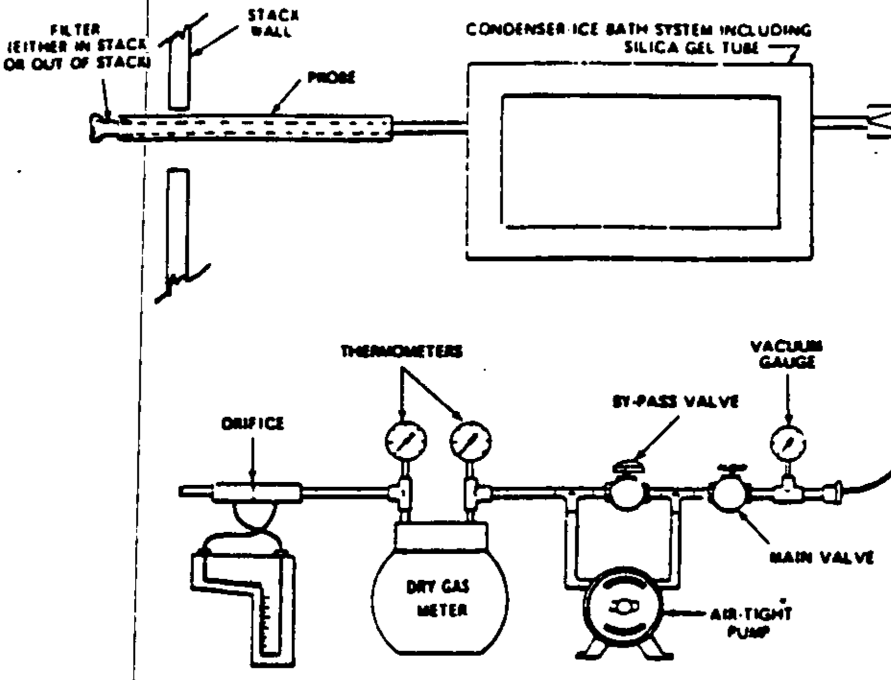

Figure 4-1. Moisture sampling train-reference method.

2.1.1 Probe. The probe is constructed of stainless steel or glass tubing, sufficiently heated to prevent water condensation, and is equipped with a filter, either in-stack (e.g., a plug of glass wool inserted into the end of the probe) or heated out-stack (e.g., as described in Method 5), to remove particular matter.

When stack conditions permit, other metals or plastic tubing may be used for the probe, subject to the approval of the Administrator.

2.1.2 Condenser. The condenser consists of four impingers connected in series with ground glass, leak-free fittings or any similarly leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with a 1.3 centimeter (½ inch) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the condenser) may be used, subject to the approval of the Administrator.

The first two impingers shall contain known volumes of water, the third shall be empty, and the fourth shall contain a known weight of 6- to 16-mesh indicating type silica gel, or equivalent desiccant. If the silica gel has been previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. A thermometer, capable of measuring temperature to within 1° C (2° F), shall be placed at the outlet of the fourth impinger, for monitoring purposes.

Alternatively, any system may be used (subject to the approval of the Administrator) that cools the sample gas stream and allows measurement of both the water that has been condensed and the moisture leaving the condenser, each to within 1 ml or 1 g. Acceptable means are to measure the condensed water, either gravimetrically or volumetrically, and to measure the moisture leaving the condenser by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures, or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap, with exit gases kept below 20° C (68° F), and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump, to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

2.1.3 **Cooling System.** An ice bath container and crushed ice (or equivalent) are used to aid in condensing moisture.

2.1.4 **Metering System.** This system includes a vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment as shown in Figure 4-1. Other metering systems, capable of maintaining a constant sampling rate and determining sample gas volume, may be used, subject to the approval of the Administrator.

2.1.5 **Barometer.** Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.6 **Graduated Cylinder and/or Balance.** These items are used to measure condensed water and moisture caught in the silica gel to within 1 ml or 0.5 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. These balances are suitable for use here.

2.2 **Procedure.** The following procedure is written for a condenser system (such as the impinger system described in Section 2.1.2) incorporating volumetric analysis to measure the condensed moisture, and silica gel and gravimetric analysis to measure the moisture leaving the condenser.

2.2.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less than 0.61 m (24 in.), a minimum of nine points shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of twelve traverse points shall be used in all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to the approval of the Administrator. Select a suitable probe and probe length such that all traverse points can be sampled. Consider sampling from opposite sides of the stack (four total sampling ports) for large stacks, to permit use of shorter probe lengths. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point. Place known volumes of water in the first two impingers. Weigh and record the weight of the silica gel to the nearest 0.5 g, and transfer the silica gel to the fourth impinger; alternatively, the silica gel may first be transferred to the impinger, and the weight of the silica gel plus impinger recorded.

2.2.2 Select a total sampling time such that a minimum total gas volume of 0.60 scm (21 scf) will be collected, at a rate no greater than 0.021 m³/min (0.75 cfm). When both moisture content and pollutant emission rate are to be determined, the moisture determination shall be simultaneous with, and for the same total length of time as, the pollutant emission rate run, unless otherwise specified in an applicable subpart of the standards.

2.2.3 Set up the sampling train as shown in Figure 4-1. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120° C (248° F), to prevent water condensation ahead of the condenser; allow time for the temperatures to stabilize. Place crushed ice in the ice bath container. It is recommended, but not required, that a leak check be done, as follows: Disconnect the probe from the first impinger or (if applicable) from the filter holder. Plug the inlet to the first impinger (or filter holder) and pull a 380 mm (15 in.) Hg vacuum; a lower vacuum may be used, provided that it is not exceeded during the test. A leakage rate in excess of 4 percent of the average sampling rate or 0.00057 m³/min (0.02 cfm), whichever is less, is unacceptable. Following the leak check, reconnect the probe to the sampling train.

2.2.4 During the sampling run, maintain a sampling rate within 10 percent of constant rate, or as specified by the Administrator. For each run, record the data re-

FIGURE 4-2—FIELD MOISTURE DETERMINATION REFERENCE METHOD

Plant ....

Location ....

Operator ....

Date ....

Run No. ....

Ambient temperature ....

Barometric pressure ....

Probe length m (ft) ....

SCHEMATIC OF STACK CROSS SECTION

Traverse point number	Sampling time (θ), min.	Stack temperature °C (°F)	Pressure differential across orifice meter ΔH mm (in.) H_2O	Meter reading gas sample volume m³ (ft³)	ΔV_m m³ (ft³)	Gas Sample temperature at dry gas meter		Temperature of gas leaving condenser or last impinger °C (°F)
						Inlet ($T_{m_{in}}$), °C (°F)	Outlet ($T_{m_{out}}$), °C (°F)	
Total .... Average					Avg.	Avg.	Avg.	

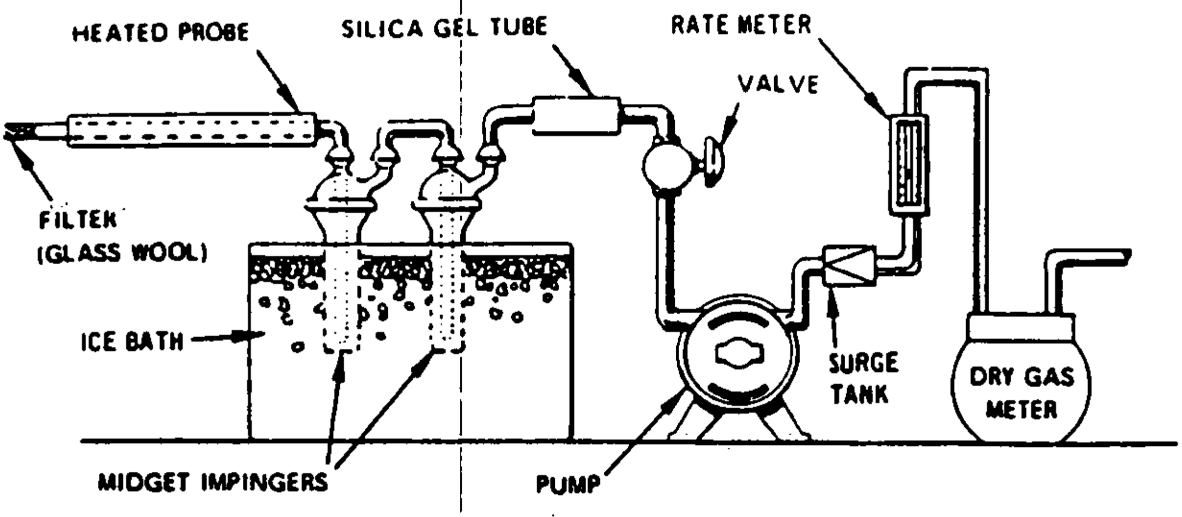

Figure 4-4. Moisture-sampling train - approximation method.

FIGURE 4-5—FIELD MOISTURE DETERMINATION—APPROXIMATION METHOD

Location ____________ Comments:
Test ____________
Date ____________
Operator ____________
Barometric pressure ____________

Clock time	Gas volume through meter, (Vm), m³ (ft³)	Rate meter setting m³/min. (ft³/min.)	Meter temperature, °C (°F)

3.2.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 lpm (0.071 cfm). Continue sampling until the dry gas meter registers about 30 liters (1.1 ft³) or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4-5.

3.2.3 After collecting the sample, combine the contents of the two impingers and measure the volume to the nearest 0.5 ml.

3.3 Calculations. The calculation method presented is designed to estimate the moisture in the stack gas; therefore, other data, which are only necessary for accurate moisture determinations, are not collected. The following equations adequately estimate the moisture content, for the purpose of determining isokinetic sampling rate settings.

3.3.1 Nomenclature.

B_{wm} = Approximate proportion, by volume, of water vapor in the gas stream leaving the second impinger, 0.025.

B_{ws} = Water vapor in the gas stream, proportion by volume.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter.

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/lb-mole) (°R) for English units.

T_m = Absolute temperature at meter, °K (°R).

T_{std} = Standard absolute temperature, 293° K (528° R).

V_f = Final volume of impinger contents, ml.

V_i = Initial volume of impinger contents, ml.

V_m = Dry gas volume measured by dry gas meter, dcm (dcf).

$V_{m(std)}$ = Dry gas volume measured by dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$ = Volume of water vapor condensed, corrected to standard conditions, scm (scf).

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

Y = Dry gas meter calibration factor.

3.3.2 Volume of water vapor collected.

$$V_{wc} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w}$$

$$= K_1 (V_f - V_i)$$

Equation 4-5

where:

K_1 = 0.001333 m³/ml for metric units
= 0.04707 ft³/ml for English units.

3.3.3 Gas volume.

$$V_{m(std)} = V_m\left(\frac{P_m}{P_{std}}\right)\left(\frac{T_{std}}{T_m}\right)$$

$$= K_2 \frac{V_m P_m}{T_m}$$

Equation 4-6

where:

K_2 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

3.3.4 Approximate moisture content.

$$B_{ws} = \frac{V_{wc}}{V_{wc} + V_{m(std)}} + B_{wm}$$

$$= \frac{V_{wc}}{V_{wc} + V_{m(std)}} + (0.025)$$

Equation 4-7

4. *Calibration*

4.1 For the reference method, calibrate equipment as specified in the following sections of Method 5: Section 5.3 (metering system); Section 5.5 (temperature gauges); and Section 5.7 (barometer). The recommended leak check of the metering system (Section 5.6 of Method 5) also applies to the reference method. For the approximation method, use the procedures outlined in Section 5.1.1 of Method 6 to calibrate the metering system, and the procedure of Method 5, Section 5.7 to calibrate the barometer.

5. *Bibliography*

1. Air Pollution Engineering Manual (Second Edition). Danielson, J. A. (ed.). U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, N.C. Publication No. AP-40. 1973.

2. Devorkin, Howard, et al. Air Pollution Source Testing Manual. Air Pollution Control District. Los Angeles, Calif. November, 1963.

3. Methods for Determination of Velocity, Volume Dust and Mist Content of Gases. Western Precipitation Division of Joy Manufacturing Co., *Los Angeles*, Calif. Bulletin WP-50. 1968.

quired on the example data sheet shown in Figure 4-2. Be sure to record the dry gas meter reading at the beginning and end of each sampling time increment and whenever sampling is halted. Take other appropriate readings at each sample point, at least once during each time increment.

2.2.5 To begin sampling, position the probe tip at the first traverse point. Immediately start the pump and adjust the flow to the desired rate. Traverse the cross section, sampling at each traverse point for an equal length of time. Add more ice and, if necessary, salt to maintain a temperature of less 20° C (68° F) at the silica gel outlet.

2.2.6 After collecting the sample, disconnect the probe from the filter holder (or from the first impinger) and conduct a leak check (mandatory) as described in Section 2.2.3. Record the leak rate. If the leakage rate exceeds the allowable rate, the tester shall either reject the test results or shall correct the sample volume as in Section 6.3 of Method 5. Next, measure the volume of the moisture condensed to the nearest ml. Determine the increase in weight of the silica gel (or silica gel plus impinger) to the nearest 0.5 g. Record this information (see example data sheet, Figure 4-3) and calculate the moisture percentage, as described in 2.3 below.

2.2.7 A quality control check of the volume metering system at the field site is suggested before collecting the sample following the procedure in Method 5, Section 4.4

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

FIGURE 4-3—ANALYTICAL DATA—REFERENCE METHOD

	Impinger volume, ml	Silica gel weight, g
Final ________		
Initial ________		
Difference ________		

2.3.1 Nomenclature.

B_{ws} = Proportion of water vapor, by volume, in the gas stream.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter, mm Hg (in. Hg).

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/(lb-mole) (°R) for English units.

T_m = Absolute temperature .at meter, °K (°R).

T_{std} = Standard absolute temperature, 293° K (528°R).

V_m = Dry gas volume measured by dry gas meter, dcm (dcf).

ΔV_m = Incremental dry gas volume measured by dry gas meter at each traverse point, dcm (dcf).

$V_{m(std)}$ = Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$ = Volume of water vapor condensed corrected to standard conditions, scm (scf).

$V_{wsg(std)}$ = Volume of water vapor collected in silica gel corrected to standard conditions, scm (scf).

V_f = Final volume of condenser water, ml.

V_i = Initial volume, if any, of condenser water, ml.

W_f = Final weight of silica gel or silica gel plus impinger, g.

W_i = Initial weight of silica gel or silica gel plus impinger, g.

Y = Dry gas meter calibration factor.

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

2.3.2 Volume of water vapor condensed.

$$V_{wc(std)} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w}$$

$$= K_1 (V_f - V_i)$$

Equation 4-1

where:

K_1 = 0.001333 m³/ml for metric units
= 0.04707 ft³/ml for English units

2.3.3 Volume of water vapor collected in silica gel.

$$V_{wsg(std)} = \frac{(W_f - W_i) R T_{std}}{P_{std} M_w}$$

$$= K_2 (W_f - W_i)$$

Equation 4-2

where:

K_2 = 0.001335 m³/g for metric units
= 0.04715 ft³/g for English units

2.3.4 Sample gas volume.

$$V_{m(std)} = V_m Y \frac{(P_m)(T_{std})}{(P_{std})(T_m)}$$

$$= K_3 Y \frac{V_m P_m}{T_m}$$

Equation 4-3

where:

K_3 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

NOTE: If the post-test lead rate (Section 2.2.6) exceeds the allowable rate, correct the value of V_m in Equation 4-3, as described in Section 6.3 of Method 5.

2.3.5 Moisture Content.

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$$

Equation 4-4

NOTE: In saturated or moisture droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one using a value based upon the saturated conditions (see Section 1.2), and another based upon the results of the impinger analysis. The lower of these two values of B_{ws} shall be considered correct.

2.3.6 Verification of constant sampling rate. For each time increment, determine the ΔV_m. Calculate the average. If the value for any time increment differs from the average by more than 10 percent, reject the results and repeat the run.

3. *Approximation Method*

The approximation method described below is presented only as a suggested method (see Section 1.2).

3.1 Apparatus.

3.1.1 Probe. Stainless steel glass tubing, sufficiently heated to prevent water condensation and equipped with a filter (either in-stack or heated out-stack) to remove particulate matter. A plug of glass wool, inserted into the end of the probe, is a satisfactory filter.

3.1.2 Impingers. Two midget impingers, each with 30 ml capacity, or equivalent.

3.1.3 Ice Bath. Container and ice, to aid in condensing moisture in impingers.

3.1.4 Drying Tube. Tube packed with new or regenerated 6- to 16-mesh indicating-type silica gel (or equivalent desiccant), to dry the sample gas and to protect the meter and pump.

3.1.5 Valve. Needle valve, to regulate the sample gas flow rate.

3.1.6 Pump. Leak-free, diaphragm type, or equivalent, to pull the gas sample through the train.

3.1.7 Volume Meter. Dry gas meter, sufficiently accurate to measure the sample volume within 2%, and calibrated over the range of flow rates and conditions actually encountered during sampling.

3.1.8 Rate Meter. Rotameter, to measure the flow range from 0 to 3 lpm (0 to 0.11 cfm).

3.1.9 Graduated Cylinder. 25 ml.

3.1.10 Barometer. Mercury, aneroid, or other barometer, as described in Section 2.1.5 above.

3.1.11 Vacuum Gauge. At least 760 mm Hg (30 in. Hg) gauge, to be used for the sampling leak check.

3.2 Procedure.

3.2.1 Place exactly 5 ml distilled water in each impinger.

Leak check the sampling train as follows: Temporarily insert a vacuum gauge at or near the probe inlet; then, plug the probe inlet and pull a vacuum of at least 250 mm Hg (10 in. Hg). Note, the time rate of change of the dry gas meter dial; alternatively, a rotameter (0–40 cc/min) may be temporarily attached to the dry gas meter outlet to determine the leakage rate. A leak rate not in excess of 2 percent of the average sampling rate is acceptable.

NOTE: Carefully release the probe inlet plug before turning off the pump.

LOCATION ______________________________ COMMENTS

TEST ______________________________

DATE ______________________________

OPERATOR ______________________________

BAROMETRIC PRESSURE ______________________________

CLOCK TIME	GAS VOLUME THROUGH METER, (Vm), m^3 (ft^3)	RATE METER SETTING m^3/min. (ft^3/min.)	METER TEMPERATURE, °C (°F)

Figure 4-5. Field moisture determination - approximation method.

3.2.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 lpm (0.071 cfm). Continue sampling until the dry gas meter registers about 30 liters (1.1 ft^3) or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4-5.

3.2.3 After collecting the sample, combine the contents of the two impingers and measure the volume to the nearest 0.5 ml.

3.3 Calculations. The calculation method presented is designed to estimate the moisture in the stack gas therefore, other data, which are only necessary for accurate moisture determinations, are not collected. The following equations adequately estimate the moisture content, for the purpose of determining isokinetic sampling rate settings.

3.3.1 Nomenclature.

B_{wm} = Approximate proportion, by volume, of water vapor in the gas stream leaving the second impinger, 0.025.

B_{ws} = Water vapor in the gas stream, proportion by volume.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter.

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 (mm Hg) (m^3)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft^3/lb-mole) (°R) for English units.

T_m = Absolute temperature at meter, °K (°R).

T_{std} = Standard absolute temperature, 293° K (528° R).

V_f = Final volume of impinger contents, ml.

V_i = Initial volume of impinger contents, ml.

V_m = Dry gas volume measured by dry gas meter, dcm (dcf).

$V_{m(std)}$ = Dry gas volume measured by dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$ = Volume of water vapor condensed, corrected to standard conditions, scm (scf).

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

Y = Dry gas meter calibration factor.

3.3.2 Volume of water vapor collected.

$$V_{wc(std)} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w}$$

$$= K_1 (V_f - V_i)$$

Equation 4–5

where:

K_1 = 0.001333 m^3/ml for metric units
= 0.04707 ft^3/ml for English units.

3.3.3 Gas volume.

$$V_{m(std)} = V_m \left(\frac{P_m}{P_{std}}\right) \left(\frac{T_{std}}{T_m}\right)$$

$$= K_2 \frac{V_m P_m}{T_m}$$

Equation 4–6

where:

K_2 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

3.3.4 Approximate moisture content.

$$B_{ws} = \frac{V_{wc(std)}}{V_{wc(std)} + V_{m(std)}} + B_{wm}$$

$$= \frac{V_{wc(std)}}{V_{wc(std)} + V_{m(std)}} + (0.02$$

Equation 4–.

4. Calibration

4.1 For the reference method, calibrate equipment as specified in the following sections of Method 5: Section 5.3 (metering system); Section 5.5 (temperature gauges); and Section 5.7 (barometer). The recommended leak check of the metering system (Section 5.6 of Method 5) also applies to the reference method. For the approximation method, use the procedures outlined in Section 5.1.1 of Method 6 to calibrate the metering system, and the procedure of Method 5, Section 5.7 to calibrate the barometer.

5. Bibliography

1. Air Pollution Engineering Manual (Second Edition). Danielson, J. A. (ed.). U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, N.C. Publication No. AP-40. 1973.

2. Devorkin, Howard, et al. Air Pollution Source Testing Manual. Air Pollution Control District, Los Angeles, Calif. November, 1963.

3. Methods for Determination of Velocity, Volume Dust and Mist Content of Gases. Western Precipitation Division of Joy Manufacturing Co., Los Angeles, Calif. Bulletin WP-50. 1968.

48 FR 55670 12/14/83

METHOD 5—DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 120±14° C (248±25° F) or such other temperature as specified by an applicable subpart of the standards or approved by Administrator.

U.S. Environmental Protection Agency, for a particular application. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method is applicable for the determination of particulate emissions from stationary sources.

2. *Apparatus*

2.1 Sampling Train. A schematic of the sampling train used in this method is shown in Figure 5-1. Complete construction details are given in APTD-0581 (Citation 2 in Bibliography); commercial models of this train are also available. For changes from APTD-0581 and for allowable modifications of the train shown in Figure 5-1, see the following subsections.

The operating and maintenance procedures for the sampling train are described in APTD-0576 (Citation 3 in Bibliography). Since correct usage is important in obtaining valid results, all users should read APTD-0576 and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

2.1.1 Probe Nozzle. Stainless steel (316) or glass with sharp, tapered leading edge. The angle of taper shall be 30° and the taper shall be on the outside to preserve a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing; other materials of construction may be used, subject to the approval of the Administrator.

A range of nozzle sizes suitable for isokinetic sampling should be available, e.g., 0.32 to 1.27 cm (⅛ to ½ in.)—or larger if higher volume sampling trains are used—inside diameter (ID) nozzles in increments of 0.16 cm (1/16 in.). Each nozzle shall be calibrated according to the procedures outlined in Section 5.

2.1.2 Probe Liner. Borosilicate or quartz glass tubing with a heating system capable of maintaining a gas temperature at the exit end during sampling of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. (The tester may opt to operate the equipment at a temperature lower than that specified.) Since the actual temperature at the outlet of the probe is not usually monitored during sampling, probes constructed according to APTD-0581 and utilizing the calibration curves of APTD-0576 (or calibrated according to the procedure outlined in APTD-0576) will be considered acceptable.

Either borosilicate or quartz glass probe liners may be used for stack temperatures up to about 480° C (900° F); quartz liners shall be used for temperatures between 48 and 900° C (900 and 1,650° F). Both types of liners may be used at higher temperatures than specified for short periods of time, subject to the approval of the Administrator. The softening temperature for borosilicate is 820° C (1,508° F), and for quartz it is 1,500° C (2,732° F).

Whenever practical, every effort should be made to use borosilicate or quartz glass probe liners. Alternatively, metal liners (e.g., 316 stainless steel, Incoloy 825,[1] or other corrosion resistant metals) made of seamless tubing may be used, subject to the approval of the Administrator.

2.1.3 Pitot Tube. Type S, as described in Section 2.1 of Method 2, or other device approved by the Administrator. The pitot tube shall be attached to the probe (as shown in Figure 5-1) to allow constant monitoring of the stack gas velocity. The impact (high pressure) opening plane of the pitot tube shall be even with or above the nozzle entry plane (see Method 2, Figure 2-6b) during sampling. The Type S pitot tube assembly shall have a known coefficient, determined as outlined in Section 4 of Method 2.

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[1] Mention of trade names or specific product does not constitute endorsement by the Environmental Protection Agency.

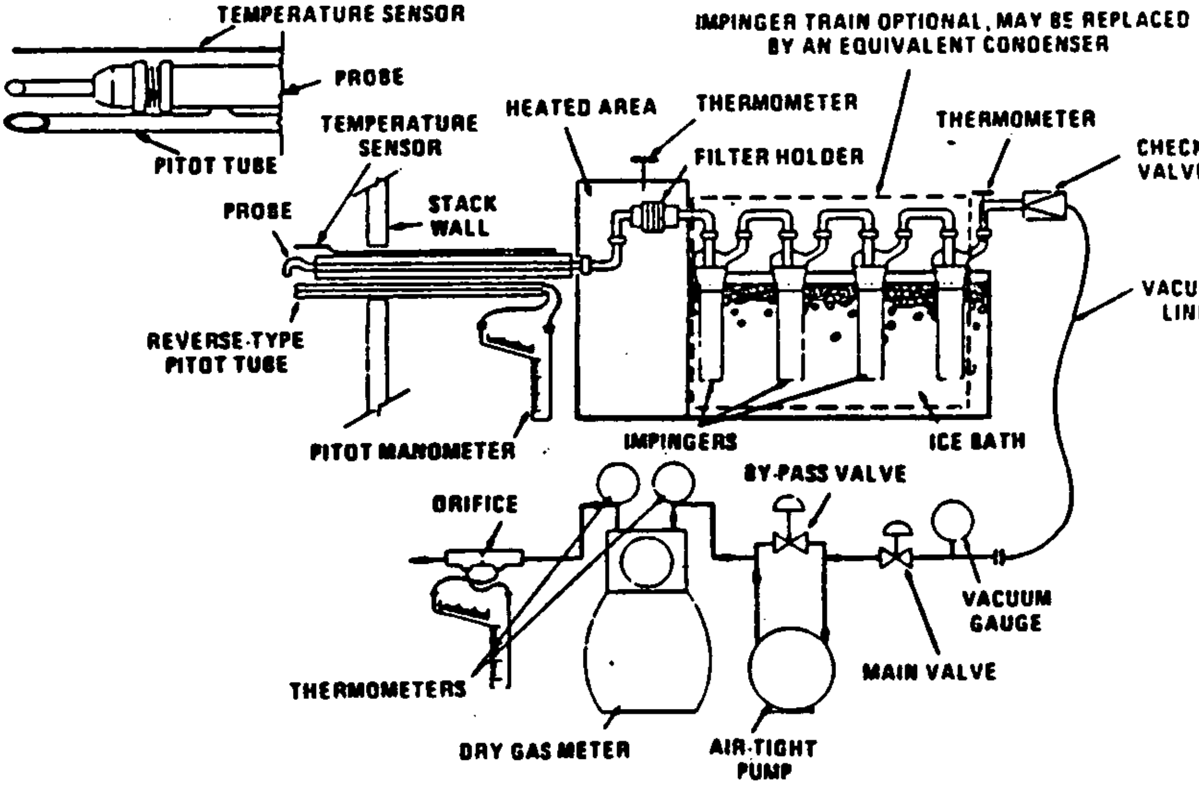

Figure 5-1. Particulate-sampling train.

2.1.4 Differential Pressure Gauge. Inclined manometer or equivalent device (two), as described in Section 2.2 of Method 2. One manometer shall be used for velocity head (Δp) readings, and the other, for orifice differential pressure readings.

2.1.5 Filter Holder. Borosilicate glass, with a glass frit filter support and a silicone rubber gasket. Other materials of construction (e.g., stainless steel, Teflon, Viton) may be used, subject to approval of the Administrator. The holder design shall provide a positive seal against leakage from the outside or around the filter. The holder shall be attached immediately at the outlet of the probe (or cyclone, if used).

2.1.6 Filter Heating System. Any heating system capable of maintaining a temperature around the filter holder during sampling of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator for a particular application. Alternatively, the tester may opt to operate the equipment at a temperature lower than that specified. A temperature gauge capable of measuring temperature to within 3° C (5.4° F) shall be installed so that the temperature around the filter holder can be regulated and monitored during sampling. Heating systems other than the one shown in APTD-0581 may be used.

2.1.7 Condenser. The following system shall be used to determine the stack gas moisture content: Four impingers connected in series with leak-free ground glass fittings or any similar leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with 1.3 cm (½ in.) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the condenser) may be used, subject to the approval of the Administrator. The first and second impingers shall contain known quantities of water (Section 4.1.3), the third shall be empty, and the fourth shall contain a known weight of silica gel, or equivalent desiccant. A thermometer, capable of measuring temperture to within 1° C (2° F) shall be placed at the outlet of the fourth impinger for monitoring purposes.

Alternatively, any system that cools the sample gas stream and allows measurement of the water condensed and moisture leaving the condenser, each to within 1 ml or 1 g may be used, subject to the approval of the Administrator. Acceptable means are to measure the condensed water either gravimetrically or volumetrically and to measure the moisture leaving the condenser by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures; or (2) passing the sample has stream through a tared silica gel (or equivalent desiccant) trap with exit gases kept below 20° C (68° F) and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

NOTE: If a determination of the particulate matter collected in the impingers is desired in addition to moisture content, the impinger system described above shall be used, without modification. Individual States or control agencies requiring this information shall be contacted as to the sample recovery and analysis of the impinger contents.

2.1.8 Metering System. Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 5-1. Other metering systems capable of maintaining sampling rates within 10 percent of isokinetic and of determining sample volumes to within 2 percent may be used, subject to the approval of the Administrator. When the metering system is used in conjunction with a pitot tube, the system shall enable checks of isokinetic rates.

Sampling trains utilizing metering systems designed for higher flow rates than that decribed in APTD-0581 or APDT-0576 may be used provided that the specifications of this method are met.

2.1.9 Barometer. Mercury aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg). In many cases the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.10 Gas Density Determination Equipment. Temperature sensor and pressure gauge, as described in Sections 2.3 and 2.4 of Method 2, and gas analyzer, if necessary, as described in Method 3. The temperature sensor shall, preferably, be permanently attached to the pitot tube or sampling probe in a fixed configuration, such that the tip of the sensor extends beyond the leading edge of the probe sheath and does not touch any metal. Alternatively, the sensor may be attached just prior to use in the field. Note, however, that if the temperature sensor is attached in the field, the sensor must be placed in an interference-free arrangement with respect to the Type S pitot tube openings (see Method 2, Figure 2-7). As a second alternative, if a difference of not more than 1 percent in the average velocity measurement is to be introduced, the temperature gauge need not be attached to the probe or pitot tube. (This alternative is subject to the approval of the Administrator.)

2.2 Sample Recovery. The following items are needed.

2.2.1 Probe-Liner and Probe-Nozzle Brushes. Nylon bristle brushes with stainless steel wire handles. The probe brush shall have extensions (at least as long as the probe) of stainless steel, Nylon, Teflon, or similarly inert material. The brushes shall be properly sized and shaped to brush out the probe liner and nozzle.

2.2.2 Wash Bottles—Two. Glass wash bottles are recommended; polyethylene wash bottles may be used at the option of the tester. It is recommended that acetone not be stored in polyethylene bottles for longer than a month.

2.2.3 Glass Sample Storage Containers. Chemically resistant, borosilicate glass bottles, for acetone washes, 500 ml or 1000 ml. Screw cap liners shall either be rubber-backed Teflon or shall be constructed so as to be leak-free and resistant to chemical attack by acetone. (Narrow mouth glass bottles have been found to be less prone to leakage.) Alternatively, polyethylene bottles may be used.

2.2.4 Petri Dishes. For filter samples, glass or polyethylene, unless otherwise specified by the Administrator.

2.2.5 Graduated Cylinder and/or Balance. To measure condensed water to within 1 ml or 1 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. Any of these balances is suitable or use here and in Section 2.3.4.

2.2.6 Plastic Storage Containers. Air-tight containers to store silica gel.

2.2.7 Funnel and Rubber Policeman. To aid in transfer of silica gel to container; not

2.2.8 Funnel. Glass or polyethylene, to aid in sample recovery.

2.2 Analysis. For analysis, the following equipment is needed.

2.3.1 Glass Weighing Dishes.

2.3.2 Desiccator.

2.3.3 Analytical Balance. To measure to within 0.1 mg.

2.3.4 Balance. To measure to within 0.5 g.

2.3.5 Beakers. 250 ml.

2.3.6 Hygrometer. To measure the relative humidity of the laboratory environment.

2.3.7 Temperature Gauge. To measure the temperature of the laboratory environment.

3. *Reagents*

3.1 Sampling. The reagents used in sampling are as follows:

3.1.1 Filters. Glass fiber filters, without organic binder, exhibiting at least 99.95 percent efficiency (<0.05 percent penetration) on 0.3-micron dioctyl phthalate smoke particles. The filter efficiency test shall be conducted in accordance with ASTM standard method D2986-71 (Reapproved 1978) (incorporated by reference—see § 60.17). Test data from the supplier's quality control program are sufficient for this purpose. In sources containing SO_2 or SO_3, the filter material must be of a type that is unreactive to SO_2 or SO_3. Citation 10 in *Section 7* Bibliography, may be used to select the appropriate filter.

3.1.2 Silica Gel. Indicating type, 6 to 16 mesh. If previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. Alternatively, other types of desiccants (equivalent or better) may be used, subject to the approval of the Administrator.

3.1.3 Water. When analysis of the material caught in the impingers is required, distilled water shall be used. Run blanks prior to field use to eliminate a high blank on test samples.

3.1.4 Crushed Ice.

3.1.5 Stopcock Grease. Acetone-insoluble, heat-stable silicone grease. This is not necessary if screw-on connectors with Teflon sleeves, or similar, are used. Alternatively, other types of stopcock grease may be used, subject to the approval of the Administrator.

3.2 Sample Recovery. Acetone-reagent grade, <0.001 percent residue, in glass bottles—is required. Acetone from metal containers generally has a high residue blank and should not be used. Sometimes, suppliers transfer acetone to glass bottles from metal containers; thus, acetone blanks shall be run prior to field use and only acetone with low blank values (<0.001 percent) shall be used. In no case shall a blank value of greater than 0.001 percent of the weight of acetone used be subtracted from the sample weight.

3.3 Analysis. Two reagents are required for the analysis:

3.3.1 Acetone. Same as 3.2.

3.3.2 Desiccant. Anhydrous calcium sulfate, indicating type. Alternatively, other types of desiccants may be used, subject to the approval of the Administrator.

4. *Procedure*

4.1 Sampling. The complexity of this method is such that, in order to obtain reliable results, testers should be trained and experienced with the test procedures.

4.1.1 Pretest Preparation. It is suggested that sampling equipment be maintained according to the procedures described in APTD-0576.

Weigh several 200 to 300 g portions of silica gel in air-tight containers to the nearest 0.5 g. Record the total weight of the silica gel plus container, on each container. As an alternative, the silica gel need not be preweighed, but may be weighed directly in the impinger or sampling holder just prior to train assembly.

Check filters visually against light for irregularities and flaws or pinhole leaks. Label filters of the proper diameter on the back side near the edge using numbering machine ink. As an alternative, label the shipping containers (glass or plastic petri dishes) and keep the filters in these containers at all times except during sampling and weighing.

Desiccate the filters at 20±5.6° C (68±10° F) and ambient pressure for at least 24 hours and weigh at intervals of at least 6 hours to a constant weight, i.e., 0.5 mg change from previous weighing; record results to the nearest 0.1 mg. During each weighing the filter must not be exposed to the laboratory atmosphere for a period greater than 2 minutes and a relative humidity above 50 percent. Alternatively (unless otherwise specified by the Administrator), the filters may be oven dried at 105° C (220° F) for 2 to 3 hours, desiccated for 2 hours, and weighed. Procedures other than those described, which account for relative humidity effects, may be used, subject to the approval of the Administrator.

4.1.2 Preliminary Determinations. Select the sampling site and the minimum number of sampling points according to Method 1 or as specified by the Administrator. Determine the stack pressure, temperature, and the range of velocity heads using Method 2; it is recommended that a leak-check of the pitot lines (see Method 2, Section 3.1) be performed. Determine the moisture content using Approximation Method 4 or its alternatives for the purpose of making isokinetic sampling rate settings. Determine the stack gas dry molecular weight, as described in Method 2, Section 3.6; if integrated Method 3 sampling is used for molecular weight determination, the integrated bag sample shall be taken simultaneously with, and for the same total length of time as, the particulate sample run.

Select a nozzle size based on the range of velocity heads, such that it is not necessary to change the nozzle size in order to maintain isokinetic sampling rates. During the run, do not change the nozzle size. Ensure that the proper differential pressure gauge is chosen for the range of velocity heads encountered (see Section 2.2 of Method 2).

Select a suitable probe liner and probe length such that all traverse points can be sampled. For large stacks, consider sampling from opposite sides of the stack to reduce the length of probes.

Select a total sampling time greater than or equal to the minimum total sampling time specified in the test procedures for the specific industry such that (1) the sampling time per point is not less than 2 min (or some greater time interval as specified by the Administrator), and (2) the sample volume taken (corrected to standard conditions) will exceed the required minimum total gas sample volume. The latter is based on an approximate average sampling rate.

It is recommended that the number of minutes sampled at each point be an integer or an integer plus one-half minute, in order to avoid timekeeping errors. The sampling time at each point shall be the same.

In some circumstances, e.g., batch cycles, it may be necessary to sample for shorter times at the traverse points and to obtain smaller gas sample volumes. In these cases, the Administrator's approval must first be obtained.

4.1.3 Preparation of Collection Train. During preparation and assembly of the sampling train, keep all openings where contamination can occur covered until just prior to assembly or until sampling is about to begin.

Place 100 ml of water in each of the first two impingers, leave the third impinger empty, and transfer approximately 200 to 300 g of preweighed silica gel from its container to the fourth impinger. More silica gel may be used, but care should be taken to ensure that it is not entrained and carried out from the impinger during sampling. Place the container in a clean place for later use in the sample recovery. Alternatively, the weight of the silica gel plus impinger may be determined to the nearest 0.5 g and recorded.

Using a tweezer or clean disposable surgical gloves, place a labeled (identified) and weighed filter in the filter holder. Be sure that the filter is properly centered and the gasket properly placed so as to prevent the sample gas stream from circumventing the filter. Check the filter for tears after assembly is completed.

When glass liners are used, install the selected nozzle using a Viton A O-ring when stack temperatures are less than 260° C (500° F) and an asbestos string gasket when temperatures are higher. See APTD-0576 for details. Other connecting systems using either 316 stainless steel or Teflon ferrules may be used. When metal liners are used, install the nozzle as above or by a leak-free direct mechanical connection. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

Set up the train as in Figure 5-1, using (if necessary) a very light coat of silicone grease on all ground glass joints, greasing only the outer portion (see APTD-0576) to avoid possibility of contamination by the silicone grease. Subject to the approval of the Administrator, a glass cyclone may be used between the probe and filter holder when the total particulate catch is expected to exceed 100 mg or when water droplets are present in the stack gas.

Place crushed ice around the impingers.

4.1.4 Leak-Check Procedures.

4.1.4.1 Pretest Leak-Check. A pretest leak-check is recommended, but not required. If the tester opts to conduct the pretest leak-check, the following procedure shall be used.

After the sampling train has been assembled, turn on and set the filter and probe heating systems at the desired operating temperatures. Allow time for the temperatures to stabilize. If a Viton A O-ring or other leak-free connection is used in assembling the probe nozzle to the probe liner, leak-check the train at the sampling site by plugging the nozzle and pulling a 380 mm Hg (15 in. Hg) vacuum.

NOTE: A lower vacuum may be used, provided that it is not exceeded during the test.

If an asbestos string is used, do not connect the probe to the train during the leak-check. Instead, leak-check the train by first plugging the inlet to the filter holder (cycone, if applicable) and pulling a 380 mm Hg (15 in. Hg) vacuum (see Note immediately above). Then connect the probe to the train and leak-check at about 25 mm Hg (1 in. Hg) vacuum; alternatively, the probe may be leak-checked with the rest of the sampling train, in one step, at 380 mm Hg (15 in. Hg) vacuum. Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, are unacceptable.

The following leak-check instructions for the sampling train described in APTD-0576 and APTD-0581 may be helpful. Start the pump with bypass valve fully open and coarse adjust valve, completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of bypass value; this will cause water to back up into the filter holder. If the desired vacuum is exceeded, either leak-check at this higher vacuum or end the leak-check as shown below and start over.

When the leak-check is completed, first slowly remove the plug from the inlet to the probe, filter holder, or cyclone (if applicable) and immediately turn off the vacuum pump. This prevents the water in the impingers from being forced backward into the filter holder and silica gel from being entrained backward into the third impinger.

4.1.4.2 Leak-Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) change becomes necessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. If the leakage rate is found to be no greater than 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction will need to be applied to the total volume of dry gas metered;

If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and plan to correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

Immediately after component changes, leak-checks are optional; if such leak-checks are done, the procedure outlined in Section 4.1.4.1 above shall be used.

4.1.4.3 Post-test Leak-Check. A leak-check is mandatory at the conclusion of each sampling run. The leakcheck shall be done in accordance with the procedures outlined in Section 4.1.4.1, except that it shall be conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be no greater than 0.00057 m³/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction need be applied to the total volume of dry gas metered.

If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

4.1.5 Particulate Train Operation. During the sampling run, maintain an isokinetic sampling rate (within 10 percent of true isokinetic unless otherwise specified by the Administrator) and a temperature around the filter of 120±14° C (248±25° F), or such other temperature as specified by an applicable subpart of the standards or approved by the Administrator.

For each run, record the data required on a data sheet such as the one shown in Figure 5-2. Be sure to record the initial dry gas meter reading. Record the dry gas meter readings at the beginning and end of each sampling time increment, when changes in flow rates are made, before and after each leak-check, and when sampling is halted. Take other readings required by Figure 5-2 at least once at each sample point during each time increment and additional readings when significant changes (20 percent variation in velocity head readings) necessitate additional adjustments in flow rate. Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse.

Clean the portholes prior to the test run to minimize the chance of sampling deposited material. To begin sampling, remove the nozzle cap, verify that the filter and probe heating systems are up to temperature, and that the pitot tube and probe are properly positioned. Position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. Nomographs are available, which aid in the rapid adjustment of the isokinetic sampling rate without excessive computations. These nomographs are designed for use when the Type S pitot tube coefficient is 0.85±0.02, and the stack gas equivalent density (dry molecular weight) is equal to 29±4. APTD-0576 details the procedure for using the nomographs. If C_p and M_d are outside the above stated ranges do not use the nomographs unless appropriate steps (see Citation 7 in Bibliography) are taken to compensate for the deviations.

When the stack is under significant negative pressure (height of impinger stem), take care to close the coarse adjust valve before inserting the probe into the stack to prevent water from backing into the filter holder. If necessary, the pump may be turned on with the coarse adjust valve closed.

When the probe is in position, block off the openings around the probe and porthole to prevent unrepresentative dilution of the gas stream.

Traverse the stack cross-section, as required by Method 1 or as specified by the Administrator, being careful not to bump the probe nozzle into the stack walls when sampling near the walls or when removing or inserting the probe through the portholes; this minimizes the chance of extracting deposited material.

During the test run, make periodic adjustments to keep the temperature around the filter holder at the proper level; add more ice and, if necessary, salt to maintain a temperature of less than 20° C (68° F) at the condenser/silica gel outlet. Also, periodically check the level and zero of the manometer.

If the pressure drop across the filter becomes too high, making isokinetic sampling difficult to maintain, the filter may be replaced in the midst of a sample run. It is recommended that another complete filter assembly be used rather than attempting to change the filter itself. Before a new filter assembly is installed, conduct a leak-check (see Section 4.1.4.2). The total particulate weight shall include the summation of all filter assembly catches.

A single train shall be used for the entire sample run, except in cases where simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct, or, in cases where equipment failure necessitates a change of trains. In all other situations, the use of two or more trains will be subject to the approval of the Administrator.

FIGURE 5-2—PARTICULATE FIELD DATA

Plant ____
Location ____
Operator ____
Date ____
Run No. ____
Sample box No. ____
Meter box No. ____
Meter ΔH@ ____
C factor ____
Pitot tube coefficient, Cp ____

SCHEMATIC OF STACK CROSS SECTION

Ambient temperature ____
Barometric pressure ____
Assumed moisture, % ____
Probe length, m (ft.) ____
Nozzle identification No. ____
Average calibrated nozzle diameter, cm (in.) ____
Probe heater setting ____
Leak rate, m³/min. (cfm) ____
Probe liner material ____
Static pressure, mm Hg (in. Hg) ____
Filter No. ____

Traverse point number	Sampling time	Vacuum	Stack temperature	Velocity head	Pressure differential across orifice meter	Gas sample volume	Gas sample temperature at dry gas meter		Filter holder temperature	Temperature of gas leaving condenser or last impinger
							Inlet	Outlet		
	(θ), min.	mm Hg (in. Hg)	(T_s), °C (°F)	(ΔP_s), mm (in.) H_2O	mm H_2O (in. H_2O)	m³ (ft³)	°C (°F)	°C (°F)	°C (°F)	°C (°F)
Total							Avg.	Avg.		
Average							Avg.			

Note that when two or more trains are used, separate analyses of the front-half and (if applicable) impinger catches from each train shall be performed, unless identical nozzle sizes were used on all trains, in which case, the front-half catches from the individual trains may be combined (as may the impinger catches) and one analysis of front-half catch and one analysis of impinger catch may be performed. Consult with the Administrator for details concerning the calculation of results when two or more trains are used.

At the end of the sample run, turn off the coarse adjust valve, remove the probe and nozzle from the stack, turn off the pump, record the final dry gas meter reading, and conduct a post-test leak-check, as outlined in Section 4.1.4.3. Also, leak-check the pitot lines as described in Method 2, Section 3.1; the lines must pass this leak-check, in order to validate the velocity head data.

4.1.6 Calculation of Percent Isokinetic. Calculate percent isokinetic (see Calculations, Section 6) to determine whether the run was valid or another test run should be made. If there was difficulty in maintaining isokinetic rates due to source conditions, consult with the Administrator for possible variance on the isokinetic rates.

4.2 Sample Recovery. Proper cleanup procedure begins as soon as the probe is removed from the stack at the end of the sampling period. Allow the probe to cool.

When the probe can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent losing or gaining particulate matter. Do not cap off the probe tip tightly while the sampling train is cooling down as this would create a vacuum in the filter holder, thus drawing water from the impingers into the filter holder.

Before moving the sample train to the cleanup site, remove the probe from the sample train, wipe off the silicone grease, and cap the open outlet of the probe. Be careful not to lose any condensate that might be present. Wipe off the silicone grease from the filter inlet where the probe was fastened and cap it. Remove the umbilical cord from the last impinger and cap the impinger. If a flexible line is used between the first impinger or condenser and the filter holder, disconnect the line at the filter holder and let any condensed water or liquid drain into the impingers or condenser. After wiping off the silicone grease, cap off the filter holder outlet and impinger inlet. Either ground-glass stoppers, plastic caps, or serum caps may be used to close these openings.

Transfer the probe and filter-impinger assembly to the cleanup area. This area should be clean and protected from the wind so that the chances of contaminating or losing the sample will be minimized.

Save a portion of the acetone used for cleanup as a blank. Take 200 ml of this acetone directly from the wash bottle being used and place it in a glass sample container labeled "acetone blank."

Inspect the train prior to and during disassembly and note any abnormal conditions. Treat the samples as follows:

Container No. 1. Carefully remove the filter from the filter holder and place it in its identified petri dish container. Use a pair of tweezers and/or clean disposable surgical gloves to handle the filter. If it is necessary to fold the filter, do so such that the particulate cake is inside the fold. Carefully transfer to the petri dish any particulate matter and/or filter fibers which adhere to the filter holder gasket, by using a dry Nylon bristle brush and/or a sharp-edged blade. Seal the container.

Container No. 2. Taking care to see that dust on the outside of the probe or other exterior surfaces does not get into the sample, quantitatively recover particulate matter or any condensate from the probe nozzle, probe fitting, probe liner, and front half of the filter holder by washing these components with acetone and placing the wash in a glass container. Distilled water may be used instead of acetone when approved by the Administrator and shall be used when specified by the Administrator; in these cases, save a water blank and follow the Administrator's directions on analysis. Perform the acetone rinses as follows:

Carefully remove the probe nozzle and clean the inside surface by rinsing with acetone from a wash bottle and brushing with a Nylon bristle brush. Brush until the acetone rinse shows no visible particles, after which make a final rinse of the inside surface with acetone.

Brush and rinse the inside parts of the Swagelok fitting with acetone in a similar way until no visible particles remain.

Rinse the probe liner with acetone by tilting and rotating the probe while squirting acetone into its upper end so that all inside surfaces will be wetted with acetone. Let the acetone drain from the lower end into the sample container. A funnel (glass or polyethylene) may be used to aid on transferring liquid washes to the container. Follow the acetone rinse with a probe brush. Hold the probe in an inclined position, squirt acetone into the upper end as the probe brush is being pushed with a twisting action through the probe; hold a sample container underneath the lower end of the probe, and catch any acetone and particulate matter which is brushed from the probe. Run the brush through the probe three times or more until no visible particulate matter is carried out with the acetone or until none remains in the probe liner on visual inspection. With stainless steel or other metal probes, run the brush through in the above prescribed manner at least six times since metal probes have small crevices in which particulate matter can be entrapped. Rinse the brush with acetone, and quantitatively collect these washings in the sample container. After the brushing, make a final acetone rinse of the probe as described above.

It is recommended that two people be used to clean the probe to minimize sample losses. Between sampling runs, keep brushes clean and protected from contaminations.

After ensuring that all joints have been wiped clean of silicone grease, clean the inside of the front half of the filter holder by rubbing the surfaces with a Nylon bristle brush and rinsing with acetone. Rinse each surface three times or more if needed to remove visible particulate. Make a final rinse of the brush and filter holder. Carefully rinse out the glass cyclone, also (if applicable). After all acetone washings and particulate matter have been collected in the sample container, tighten the lid on the sample container so that acetone will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not leakage occured during transport. Label the container to clearly identify its contents.

Container No. 3. Note the color of the indicating silica gel to determine if it has been completely spent and make a notation of its condition. Transfer the silica gel from the fourth impinger to its original container and seal. A funnel may make it easier to pour the silica gel without spilling. A rubber policeman may be used as an aid in removing the silica gel from the impinger. It is not necessary to remove the small amount of dust particles that may adhere to the impinger wall and are difficult to remove. Since the gain in weight is to be used for moisture calculations, do not use any water or other liquids to transfer the silica gel. If a balance is available in the field, follow the procedure for container No. 3 in Section 4.3.

Impinger Water. Treat the impingers as follows: Make a notation of any color or film in the liquid catch. Measure the liquid which is in the first three impingers to within ±1 ml by using a graduated cylinder or by weighing it to within ±0.5 g by using a balance (if one is available). Record the volume or weight of liquid present. This information is required to calculate the moisture content of the effluent gas.

Discard the liquid after measuring and recording the volume or weight, unless analysis of the impinger catch is required (see Note, Section 2.1.7).

If a different type of condenser is used, measure the amount of moisture condensed either volumetrically or gravimetrically.

Whenever possible, containers should be shipped in such a way that they remain upright at all times.

4.3 Analysis. Record the data required on a sheet such as the one shown in Figure 5-3. Handle each sample container as follows:

FIGURE 5-3—ANALYTICAL DATA

Plant ______
Date ______
Run No. ______
Filter No. ______
Amount liquid lost during transport ______
Acetone blank volume, ml ______
Acetone wash volume, ml ______
Acetone blank concentration, mg/mg (equation 5-4) ______
Acetone wash blank, mg (equation 5-5) ______

Container number	Weight of particulate collected, mg		
	Final weight	Tare weight	Weight gain
1			
2			
Total			
Less acetone blank			
Weight of particulate matter			

	Volume of liquid water collected	
	Impinger volume, ml	Silica gel weight, g
Final		
Initial		
Liquid collected		
Total volume collected		g* ml

*Convert weight of water to volume by dividing total weight increase by density of water (1 g/ml).

$$\frac{\text{Increase, g}}{(1\ \text{g/ml})} = \text{Volume water, ml}$$

Container No. 1. Leave the contents in the shipping container or transfer the filter and any loose particulate from the sample container to a tared glass weighing dish. Desiccate for 24 hours in a desiccator containing anhydrous calcium sulfate. Weigh to a constant weight and report the results to the nearest 0.1 mg. For purposes of this Section, 4.3, the term "constant weight" means a difference of no more than 0.5 mg or 1 percent of total weight less tare weight, whichever is greater, between two consecutive weighings, with no less than 6 hours of desiccation time between weighings.

Alternatively, the sample may be oven dried at 105° C (220° F) for 2 to 3 hours, cooled in the desiccator, and weighed to a constant weight, unless otherwise specified by the Administrator. The tester may also opt to oven dry the sample at 105° C (220° F) for 2 to 3 hours, weigh the sample, and use this weight as a final weight.

Container No. 2. Note the level of liquid in the container and confirm on the analysis sheet whether or not leakage occurred during transport. If a noticeable amount of leakage has occurred, either void the sample or use methods, subject to the approval of the Administrator, to correct the final results. Measure the liquid in this container either volumetrically to ±1 ml or gravimetrically to ±0.5 g. Transfer the contents to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

Container No. 3. Weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g using a balance. This step may be conducted in the field.

"Acetone Blank" Container. Measure acetone in this container either volumentrically or gravimetrically. Transfer the acetone to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

NOTE: At the option of the tester, the contents of Container No. 2 as well as the acetone blank container may be evaporated at temperatures higher than ambient. If evaporation is done at an elevated temperature, the temperature must be below the boiling point of the solvent; also, to prevent "bumping," the evaporation process must be closely supervised, and the contents of the beaker must be swirled occasionally to maintain an even temperature. Use extreme care, as acetone is highly flammable and has a low flash point.

4.4 Quality Control Procedures. The following quality control procedures are suggested to check the volume metering system calibration values at the field test site prior to sample collection. These procedures are optional for the tester.

4.4.1 Meter Orifice Check. Using the calibration data obtained during the calibration procedure described in Section 5.3, determine the $\Delta H_@$ for the metering system orifice. The $\Delta H_@$ is the orifice pressure differential in units of in. H_2O that correlates to 0.75 cfm of air at 528°R and 29.92 in. Hg. The $\Delta H_@$ is calculated as follows:

$$\Delta H_@ = 0.0319\ \Delta H\ \frac{T_m}{P_{bar}}\ \frac{\Theta^2}{Y^2 V_m^2}$$

Eq. 5-9

Where:

ΔH = Average pressure differential across the orifice meter, in. H_2O.

T_m = Absolute average dry gas meter temperature, °R.

P_{bar} = Barometric pressure, in. Hg.

Θ = Total sampling time, min.

Y = Dry gas meter calibration factor, dimensionless.

V_m = Volume of gas sample as measured by dry gas meter, dcf.

0.0319 = (0.0567 in. Hg/°R) x (0.75 cfm)^2

Before beginning the field test (a set of three runs usually constitutes a field test), operate the metering system (i.e., pump, volume meter, and orifice) at the $\Delta H_@$ pressure differential for 10 minutes. Record the volume collected, the dry gas meter temperature, and the barometric pressure. Calculate a dry gas meter calibration check value, Y_c as follows:

$$Y_c = \frac{10}{V_m}\left[\frac{0.0319\ T_m}{P_{bar}}\right]^{1/2}$$

Eq. 5-10

Where:

Y_c = Dry gas meter calibration check value, dimensionless.

10 = 10 minutes of run time.

Compare the Y_c value with the dry gas meter calibration factor Y to determine that:

$0.97Y < Y_c < 1.03Y$

If the Y_c value is not within this range, the volume metering system should be investigated before beginning the test.

4.4.2 Calibrated Critical Orifice. A calibrated critical orifice, calibrated against a wet test meter or spirometer and designed to be inserted at the inlet of the sampling meter box, may be used as a quality control check, such procedure being subject to approval by the Administrator.

5. *Calibration*

Maintain a laboratory log of all calibrations.

5.1 Probe Nozzle. Probe nozzles shall be calibrated before their initial use in the field. Using a micrometer, measure the inside diameter of the nozzle to the nearest 01.025 mm (0.001 in.). Make three separate measurements using different diameters each time, and obtain the average of the measurements. The difference between the high and low numbers shall not exceed 0.1 mm (0.004 in.). When nozzles become nicked, dented, or corroded, they shall be reshaped, sharpened, and recalibrated before use. Each nozzle shall be permanently and uniquely identified.

5.2 Pitot Tube. The Type S pitot tube assembly shall be calibrated according to the procedure outlined in Section 4 of Method 2.

5.3 Metering System. Before its initial use in the field, the metering system shall be calibrated according to the procedure outlined in APTD-0576. Instead of physically adjusting the dry gas meter dial readings to correspond to the wet test meter readings, calibration factors may be used to mathematically correct the gas meter dial readings to the proper values. Before calibrating the metering system, it is suggested that a leak-check be conducted. For metering systems having diaphragm pumps, the normal leak-check procedure will not detect leakages within the pump. for these cases the following leak-check procedure is suggested: make a 10-minute calibration run a 0.0057 m ³/min (0.02 cfm); at the end of th run, take the difference of the measure wet test meter and dry gas meter volumes divide the difference by 10, to get the lea rate. The leak rate should not excee 0.00057 m ³/min (0.02 cfm).

After each field use, the calibration of th metering system shall be checked by performing three calibration runs at a single intermediate orifice setting (based on th previous field test). With the vacuum set a the maximum value reached during the tes series. To adjust the vacuum, insert a valve between the wet test meter and the inlet o the metering system. Calculate the averag value of the calibration factor. If the calibration has changed by more than 5 percent, recalibrate the meter over the ful range of orifice settings, as outlined i APTD-0576.

Alternative procedures, e.g., using the orifice meter coefficients, maybe used, subjec to the approval of the Administrator.

NOTE: If the dry gas meter coefficien values obtained before and after a tes series differ by more than 5 percent, the test series shall either be voided, or calculations for test series shall be performed usin whichever meter coefficient value (i.e. before or after) gives the lower value o total sample volume.

5.3.1 Calibration Prior to Use. Before its initial use in the field, the metering system shall be calibrated as follows: Connect the metering system inlet to the outlet of a wet test meter that is accurate to within 1 percent. Refer to Figure 5.5. The wet test meter should have a capacity of 30 liters/rev (1 ft³/rev). A spirometer of 400 liters (14 ft³) or more capacity, or equivalent, may be used for this calibration, although a wet test meter is usually more practical. The wet test meter should be periodically calibrated with a spirometer or a liquid displacement meter to ensure the accuracy of the wet test meter. Spirometers or wet test meters of other sizes may be used, provided that the specified accuracies of the procedure are maintained. Run the metering system pump for about 15 minutes with the orifice manometer indicating a median reading as expected in field use to allow the pump to warm up and to permit the interior surface of the wet test meter to be thoroughly wetted. Then, at each of a minimum of three orifice manometer settings, pass an exact quantity of gas through the wet test meter and note the gas volume indicated by the dry gas meter. Also note the barometric pressure, and the temperatures of the wet test meter, the inlet of the dry gas meter, and the outlet of the dry gas meter. Select the highest and lowest orifice settings to bracket the expected field operating range of the orifice. Use a minimum volume of 0.15 m³ (5 cf) at all orifice settings. Record all the data on a form similar to Figure 5.6, and calculate Y, the dry gas meter calibration factor, and $\Delta H_@$, the orifice calibration factor, at each orifice setting as shown on Figure 5.6. Allowable tolerances for individual Y and $\Delta H_@$ values are given in Figure 5.6. Use the average of the Y values in the calculations in Section 6.

ing procedure is suggested (see Figure 5-4): Close the main valve on the meter box. Insert a one-hole rubber stopper with rubber tubing stached into the orifice exhaust pipe. Disconnect and vent the low side of the orifice manometer. Close off the low side orifice tap. Pressurize the system to 13 to 18 cm (5 to 7 in.) water column by blowing into the rubber tubing. Pinch off the tubing and observe the manometer for one minute. A loss of pressure on the manometer indicates a leak in the meter box; leaks, if present, must be corrected.

5.7 **Barometer.** Calibrate against a mercury barometer.

6. *Calculations*

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after the final calculation. Other forms of the equations may be used as long as they give equivalent results.

6.1 Nomenclature

A_n = Cross-sectional area of nozzle, m^2 (ft^2).

B_{ws} = Water vapor in the gas stream, proportion by volume.

C_a = Acetone blank residue concentration, mg/g.

c_s = Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/dscm (g/dscf).

I = Percent of isokinetic sampling.

L_a = Maximum acceptable leakage rate for either a pretest leak check or for a leak check following a component change; equal to 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.

L_i = Individual leakage rate observed during the leak check conducted prior to the "i^{th}" component change (i=1, 2, 3....n), m^3/min (cfm).

L_p = Leakage rate observed during the post-test leak check, m^3/min (cfm).

m_n = Total amount of particulate matter collected, mg.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0lb/lb-mole).

m_a = Mass of residue of acteone after evaporation, mg.

P_{bar} = Barometric pressure at the sampling site, mm Hg (in. Hg).

P_s = Absolute stack gas pressure, mm Hg (in. Hg).

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 mm Hg-m^3/°K-g-mole (21.85 in. Hg-ft^3/°R-lb-mole).

T_m = Absolute average dry gas meter temperature (see Figure 5-2), °K (°R).

T_s = Absolute average stack gas temperature (see Figure 5-2), °K (°R).

T_{std} = Standard absolute temperature, 293° K (528° R).

V_a = Volume of acetone blank, ml.

V_{aw} = Volume of acetone used in wash, ml.

V_{lc} = Total volume of liquid collected in impingers and silica gel (see Figure 5-3), ml.

V_m = Volume of gas sample as measured by dry gas meter, dcm (dscf).

$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{w(std)}$ = Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).

v_s = Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 5, m/sec (ft/sec).

W_a = Weight of residue in acetone wash, mg.

Y = Dry gas meter calibration factor.

ΔH = Average pressure differential across the orifice meter (see Figure 5-2), mm H_2O (in. H_2O).

ρ_a = Density of acetone, mg/ml (see label on bottle).

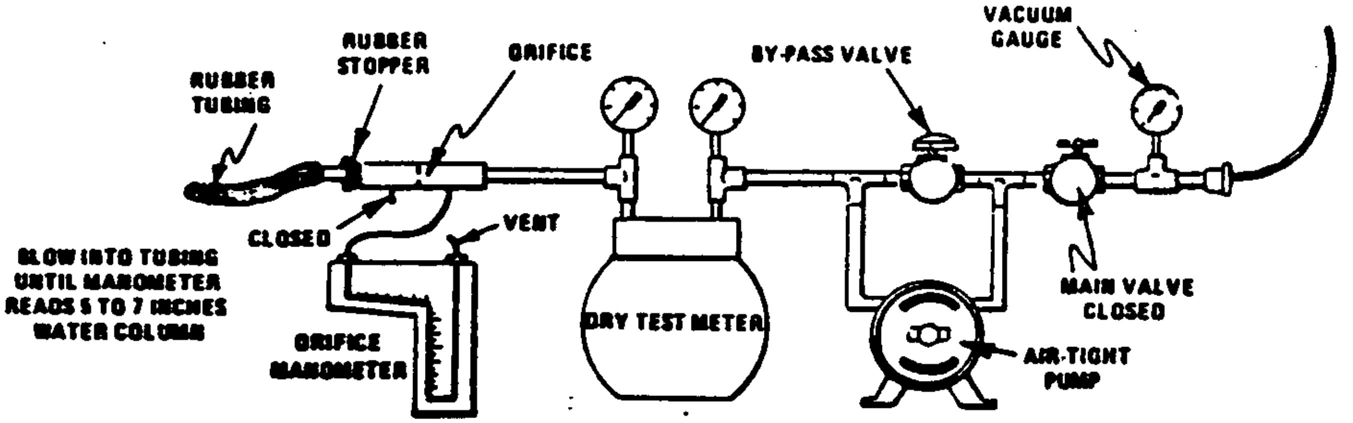

Figure 5-4. Leak check of meter box.

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).
θ = Total sampling time, min.
θ_1 = Sampling time interval, from the beginning of a run until the first component change, min.
θ_i = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.
θ_p = Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.
13.6 = Specific gravity of mercury.
60 = Sec/min.
100 = Conversion to percent.

6.2 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Figure 5-2).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20° C, 760 mm Hg or 68° F, 29.92 in. Hg) by using Equation 5-1.

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right)\left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}}\right]$$

$$= K_1 V_m Y \frac{P_{bar} + (\Delta H/13.6)}{T_m}$$

Equation 5-1

where:
K_1 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

NOTE: Equation 5-1 can be used as written unless the leakage rate observed during any of the mandatory leak checks (i.e., the post-test leak check or leak checks conducted prior to component changes) exceeds L_a. If L_p or , exceeds L_a, Equation 5-1 must be modified as follows:

(a) Case I. No component changes made during sampling run. In this case, replace V_m in Equation 5-1 with the expression:

$$V_m - (L_p - L_a)\theta]$$

(b) Case II. One or more component changes made during the sampling run. In this case, replace V_m in Equation 5-1 by the expression:

$$\left[V_m - (L_1 - L_a)\theta_1 - \sum_{i=2}^{n} (L_i - L_a)\theta_i - (L_p - L_a)\theta_p\right]$$

and substitute only for those leakage rates (L_i or L_p) which exceed L_a.

6.4 Volume of water vapor.

Equation 5-2

$$V_{w(std)} = V_{1c}\left(\frac{\rho_w}{M_w}\right)\left(\frac{RT_{std}}{P_{std}}\right) = K_2 V_{1c}$$

where:
K_2 = 0.001333 m³/ml for metric units
= 0.04707 ft³/ml for English units.

6.5 Moisture Content.

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$$

Equation 5-3

NOTE: In saturated or water droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one from the impinger analysis (Equation 5-3), and a second from the assumption of saturated conditions. The lower of the two values of B_{ws} shall be considered correct. The procedure for determining the moisture content based upon assumption of saturated conditions is given in the Note of Section 1.2 of Method 4. For the purposes of this method, the average stack gas temperature from Figure 5-2 may be used to make this determination, provided that the accuracy of the in-stack temperature sensor is ±1° C (2° F).

6.6 Acetone Blank Concentration.

Equation 5-4

$$C_a = \frac{m_a}{V_a \rho_a}$$

6.7 Acetone Wash Blank.

$W_a = C_a V_{aw} \rho_a$ Equation 5-5

6.8 Total Particulate Weight. Determine the total particulate catch from the sum of the weights obtained from containers 1 and 2 less the acetone blank (see Figure 5-3).

NOTE: Refer to Section 4.1.5 to assist in calculation of results involving two or more filter assemblies or two or more sampling trains.

6.9 Particulate Concentration.

$C_s = (0.001\ g/mg)\ (m_n/V_{m(std)})$ Equation 5-6

6.10 Conversion Factors:

From	To	Multiply by
ft³	m³	0.02832.
g/ft³	gr/ft³	15.43.
g/ft³	lb/ft³	2.205×10^{-3}.
g/ft³	g/m³	35.31.

6.11 Isokinetic Variation.

6.11.1 Calculation From Raw Data.

$$I = \frac{100\ T_s[K_3 V_{1c} + (V_m/T_m)(P_{bar} + \Delta H/13.6)]}{60\theta v_s P_s A_n}$$

Equation 5-7

where:

K_3 = 0.003454 mm Hg-m³/ml-°K for metric units.
= 0.002669 in. Hg-ft³/ml-°R for English units.

6.11.2 Calculation From Intermediate Values.

$$I = \frac{T_s V_{m(std)} P_{std} 100}{T_{std} v_s \theta A_n P_s 60 (1 - B_{ws})}$$

$$= K_4 \frac{T_s V_{m(std)}}{P_s v_s A_n \theta (1 - B_{ws})}$$

Equation 5-8

where:
K_4 = 4.320 for metric units
= 0.09450 for English units.

6.12 Acceptable Results. If 90 percent < I < 110 percent, the results are acceptable. If the particulate results are low in comparison to the standard, and I is over 110 percent or less than 90 percent, the Administrator may accept the results. Citation 4 in the bibliography section can be used to make acceptability judgments. If I is judged to be unacceptable, reject the particulate results and repeat the test.

7. Alternative Procedures

7.1 Dry Gas Meter as a Calibration Standard. A dry gas meter may be used as a calibration standard for volume measurements in place of the wet test meter specified in Section 5.3, provided that it is calibrated initially and recalibrated periodically as follows:

7.1.1 Standard Dry Gas Meter Calibration.

7.1.1.1 The dry gas meter to be calibrated and used as a secondary reference meter should be of high quality and have an appropriately sized capacity, e.g., 3 liters/rev (0.1 ft³/rev). A spirometer (400 liters or more capacity), or equivalent, may be used for this calibration, although a wet test meter is usually more practical. The wet test meter should have a capacity of 30 liters/rev (1 ft³/rev) and capable of measuring volume to within ±1.0 percent; wet test meters should be checked against a spirometer or a liquid displacement meter to ensure the accuracy of the wet test meter. Spirometers or wet test meters of other sizes may be used, provided that the specified accuracies of the procedure are maintained.

7.1.1.2 Set up the components as shown in Figure 5.7. A spirometer, or equivalent, may be used in place of the wet test meter in the system. Run the pump for at least 5 minutes at a flow rate of about 10 liters/min (0.35 cfm) to condition the interior surface of the wet test meter. The pressure drop indicated by the manometer at the inlet side of the dry gas meter should be minimized [no greater than 100 mm H₂O (4 in. H₂O) at a flow rate of 30 liters/min (1 cfm)]. This can be accomplished by using large diameter tubing connections and straight pipe fittings.

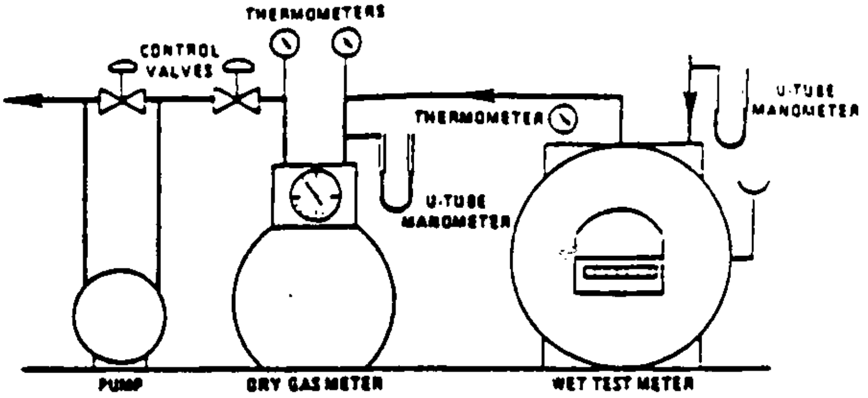

Figure 5.7 . Equipment arrangement for dry-gas meter calibration.

7.1.1.3 Collect the data as shown in the example data sheet (see Figure 5-8). Make triplicate runs at each of the flow rates and at no less than five different flow rates. The range of flow rates should be between 10 and 34 liters/min (0.35 and 1.2 cfm) or over the expected operating range.

DATE:____________________________

DRY GAS METER IDENTIFICATION:________________

BAROMETRIC PRESSURE (P_b):________________ in. Hg

APPROXIMATE FLOW RATE ($\bar{Q}$) cfm	SPIROMETER (WET METER) GAS VOLUME (V_s) ft³	DRY GAS METER VOLUME (V_{ds}) ft³	TEMPERATURES				DRY GAS METER PRESSURE (Δp) in. H₂O	TIME (Θ) min.	FLOW RATE (Q) cfm	METER METER COEFFICIENT (Y_{ds})	AVERAGE METER COEFFICIENT ($\bar{Y}_{ds}$)
				DRY GAS METER							
			SPIROMETER (WET METER) (t_s) °F	INLET (t_i) °F	OUTLET (t_o) °F	AVERAGE ($\bar{t}_d$) °F					
0.40											
0.60											
0.80											
1.00											
1.20											

$$Q = 17.64 \cdot \frac{V_s}{\Theta} \cdot \frac{P_b}{(t_s + 460)}$$

$$Y_{ds} = \frac{V_s}{V_{ds}} \cdot \frac{\bar{t}_d + 460}{t_s + 460} \cdot \frac{P_b}{(P_b + \frac{\Delta p}{13.6})}$$

Figure 5.8. Example data sheet for calibration of a standard dry gas meter for method 5 sampling equipment (English units).

7.1.1.4 Calculate flow rate, Q, for each run using the wet test meter gas volume, V_w, and the run time, θ. Calculate the dry gas meter coefficient, Y_{ds}, for each run. These calculations are as follows:

$$Q = K_1 \frac{P_{bar}}{t_w + t_{std}} \frac{V_w}{\theta}$$

$$Y_{ds} = \frac{V_w}{V_{ds}} \frac{(t_{ds} + t_{std})}{(t_w + t_{std})} \frac{P_{bar}}{\left(P_{bar} + \frac{\Delta p}{13.6}\right)}$$

Where:

K_1 = 0.3858 for international system of units (SI); 17.64 for English units.

V_w = Wet test meter volume, liters (ft³).

V_{ds} = Dry gas meter volume, liters (ft³).

t_{ds} = Average dry gas meter temperature, °C (°F).

t_{std} = 273° C for SI units; 460° F for English units.

t_w = Average wet test meter temperature, °C (°F).

P_{bar} = Barometric pressure, mm Hg (in. Hg).

Δp = Dry gas meter inlet differential pressure, mm H_2O (in. H_2O).

θ = Run time, min.

7.1.1.5 Compare the three Y_{ds} values at each of the flow rates and determine the maximum and minimum values. The difference between the maximum and minimum values at each flow rate should be no greater than 0.030. Extra sets of triplicate runs may be made in order to complete this requirement. In addition, the meter coefficients should be between 0.95 and 1.05. If these specifications cannot be met in three sets of successive triplicate runs, the meter is not suitable as a calibration standard and should not be used as such. If these specifications are met, average the three Y_{ds} values at each flow rate resulting in five average meter coefficients, $\overline{Y}_{ds}$.

7.1.1.6 Prepare a curve of meter coefficient, $\overline{Y}_{ds}$, versus flow rate, Q, for the dry gas meter. This curve shall be used as a reference when the meter is used to calibrate other dry gas meters and to determine whether recalibration is required.

7.1.2 Standard Dry Gas Meter Recalibration.

7.1.2.1 Recalibrate the standard dry gas meter against a wet test meter or spirometer annually or after every 200 hours of operation, whichever comes first. This requirement is valid provided the standard dry gas meter is kept in a laboratory and, if transported, cared for as any other laboratory instrument. Abuse to the standard meter may cause a change in the calibration and will require more frequent recalibrations.

7.1.2.2 As an alternative to full recalibration, a two-point calibration check may be made. Follow the same procedure and equipment arrangement as for a full recalibration, but run the meter at only two flow rates [suggested rates are 14 and 28 liters/min (0.5 and 1.0 cfm)]. Calculate the meter coefficients for these two points, and compare the values with the meter calibration curve. If the two coefficients are within ±1.5 percent of the calibration curve values at the same flow rates, the meter need not be recalibrated until the next date for a recalibration check.

8. *Bibliography*

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APPENDIX C-1

CLEAN-UP/FIELD DATA

METHOD 5 OR 17 FIELD DATA SHEET

ETS, INC.

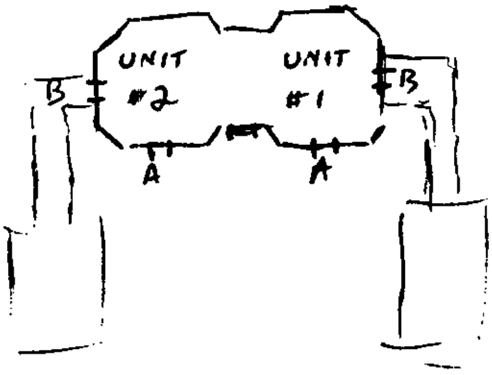
PROJECT Westinghouse BAY RESOURCES
LOCATION Panama City, Fla.
PROCESS MSW
CONTROL EQUIPMENT ESP
SAMPLING POINT OUTLET
POLLUTANTS

	P_b
6/1	30.04
6/2	30.03
6/3	30.10
6/4	30.00
6/5	30.02

DATE 6/4- 6/5/87 STD TEMP 68 °F
RUN # 1-6 METER BOX 3
OPERATOR Jim Eckenrode GAS METER 2.052 ΔH@
AMBIENT TEMP 80-90 GAS METER Y 1.001

Cp .84 PITOT TUBE COEFFICIENT
P BAR "HG" LOCAL BAROMETRIC PRESSURE
DN .254 "NOZZLE" DIAMETER
AS 15.32072 ft² STACK AREA
ASSUMED Bws 15% % MOISTURE

STACK SCHEMATIC
UPSTREAM DISTURBANCE >8
DOWNSTREAM DISTURBANCE >2



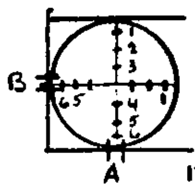
TRAVERSE POINTS

13" ports

NUMBER	INCHES	NUMBER	INCHES
A1	50.67		63.67
2	45.26		58.26
3	37.31		50.31
4	15.69		28.69
5	7.74		20.74
6	2.33		15.33
B1	50.67		
2	45.26		
3	37.31		
4	15.69		
5	7.74		
6	2.33		

ORSAT MEASUREMENT

	CO₂	O₂	CO	N₂
AVG				



13" ports

cmthd5

FLA2

Run 1 unit #2

PLANT Westinghouse DATE June 4, 1987 RUN # unit #2

START TIME: 0945

P	SAMPLE TIME θ	CLOCK TIME	STATIC PRESS.	Ts °F	STACK △ P	METER △h	Vm ft³	Tm INLET	Tm OUTLET	OVEN TEMP.	TEXIT	VAC in Hg
1	0			430	.64	1.56	981.064	100	101	250	<70	2
2	5			433	.71	1.90	984.2	101	102	245	<70	3
3	10		-.58	437	.79	1.99	987.7	102	102	255	<70	3
4	15			437	.75	1.90	991.3	104	103	254	<70	3
5	20			439	.65	1.65	994.9	105	103	255	<70	3
6	25			424	.46	1.15	998.4	106	104	256	<70	2
							1001.2					
1	30		-.57	434	.66	1.69	1001.2	106	106	250	<70	3
2	35			439	.77	1.98	1004.5	103	103	260	<70	3
3	110			441	.83	2.10	1008.1	103	102	259	<70	3
4	45			437	.50	1.28	1011.8	106	104	255	<70	3
5	50			435	.51	1.29	1014.8	108	105	261	<70	3
	55			360	.20	.50	1017.6	105	106	265	<70	2
	60						1019.551					
AVG												

TIME: 1048 LEAK CHECK C @ 4 " Hg

FLA 2

Run 2 unit #2

(

PLANT Westinghouse DATE June 4, 1957 RUN # unit #2

START TIME: 1311

P #	SAMPLE TIME θ	CLOCK TIME	STATIC PRESS.	Ts °F	STACK ΔP	METER Δh	Vm ft³	Tm INLET	Tm OUTLET	OVEN TEMP.	TEXIT	VAC in Hg
1	0			438	.49	1.24	19.656	101	99	250	<70	3
2	5		-.47	437	.46	1.15	22.6	99	99	270	<70	3
3	10			437	.45	1.12	25.4	99	99	251	<70	3
4	15			444	.71	1.80	28.2	100	99	254	<70	4
5	20			448	.72	1.82	31.7	102	100	253	<70	4
6	25			431	.57	1.44	35.2	103	100	251	<70	3
							38.3					
1	30			447	.90	2.29	38.3	102	100	251	<70	5
2	35			459	1.00	2.50	42.2	103	101	257	<70	5
3	40		-.69	462	1.05	2.65	46.3	104	101	257	<70	6
4	45			463	.87	2.20	50.4	102	100	253	<70	5
5	50			465	.90	2.30	54.3	103	100	256	<70	5
6	55			455	.68	1.71	58.1	104	101	256	<70	4
	60						61.448					
AVG												

(J TIME: 1413

LEAK CHECK .01 @ 10 " Hg

cmthd5

PLA2

Run 3 unit #2

(

PLANT Westinghouse DATE June 4 /1987 RUN # unit # 2

START TIME: 1527

P #	SAMPLE TIME θ	CLOCK TIME	STATIC PRESS.	Ts °F	STACK △P	METER △h	Vm ft³	Tm INLET	Tm OUTLET	OVEN TEMP.	TEXIT	VAC. in Hg
1	0			446	.97	2.47	61.606	92	92	251	<70	5
2	5		-.73	462	.93	2.30	65.6	93	93	254	<70	5
3	10			465	.99	2.50	69.6	94	93	257	<70	5
4	15			465	.98	2.48	73.6	94	92	244	<70	5
5	20			465	.85	2.12	77.7	92	91	241	<70	5
6	25			440	.31	.78	81.4	90	91	254	<70	2
							83.7					
1	30		-.60	444	.68	1.68	83.7	88	88	246	<70	4
2	35			451	.73	1.85	86.9	88	88	242	<70	4
3	40			451	.77	2.00	90.3	87	87	262	<70	4
4	45			453	.79	1.98	93.9	88	87	256	<70	4
5	50			456	.60	1.50	97.4	87	86	244	<70	3
	55			418	.54	1.34	100.5	87	86	240	<70	3
	60						103.510					
AVG:												

TIME: 1630

LEAK CHECK .01 @ 6 " Hg

cmthd5

VOIDED

PLANT Westinghouse DATE June 5 1987 RUN # unit #1

START TIME: 0809

P #	SAMPLE TIME θ	CLOCK TIME	STATIC PRESS.	Ts °F	STACK △ P	METER △ h	Vm ft³ 103.819	Tm INLET	Tm OUTLET	OVEN TEMP.	Texit	VAC in H
A 1	0			423	.53	1.31	~~103.689~~	85	85	250	<70	3
2	5			423	.53	1.31	106.7	85	85	255	<70	3
3	10		-.52	422	.56	1.42	109.6	86	85	255	<70	3
4	15			420	.57	1.45	112.6	86	86	255	<70	3
5	20			422	.50	1.27	115.7	86	86	256	<70	3
6	25			345	.35	.90	118.6	88	87	258	<70	2
		0839					121.1					
B 1	30											
2	35											
3	40											
4	45											
5	50											
6	55											
	60											
AVG:												

ND TIME: LEAK CHECK @ " Hg

cmthd5

VOIDED @ 0839

FLA1

RUN 1 unit #1

PLANT Westinghouse DATE June 5, 1987 RUN # unit #1

START TIME: 0952

P #	SAMPLE TIME θ	CLOCK TIME	STATIC PRESS.	Ts °F	STACK ΔP	METER Δh	Vm ft³	Tm INLET	Tm OUTLET	OVEN TEMP.	TEXIT	VAC in Hg
1	0			428	.74	1.89	121.757	93	92	236	<70	4
2	5			428	.79	2.00	125.2	91	92	248	<70	4
3	10			428	.73	1.87	128.8	93	92	250	<70	4
4	15		-.55	429	.68	1.72	132.3	92	92	252	<70	4
5	20			429	.60	1.50	135.6	93	93	247	<70	3
6	25			396	.40	1.00	138.6	93	93	252	<70	2
							141.3					
1	30			428	.61	1.55	141.3	95	94	249	<70	3
2	35			434	.68	1.72	144.4	95	95	256	<70	4
3	40			435	.69	1.75	147.7	96	95	257	<70	4
4	45			434	.56	1.42	151.2	95	95	257	<70	4
5	50			433	.50	1.25	154.4	96	96	263	<70	3
[illegible]	55			393	.31	.77	157.3	97	96	260	<70	2
	60						159.603					
AVG:												

.D TIME: 1054 LEAK CHECK 004 @ 6 " Hg

cmthd5

FLA!

Run 2 unit #1

PLANT Westinghouse DATE June 5, 1987 RUN # unit #1

START TIME: 1140

P #	SAMPLE TIME θ	CLOCK TIME	STATIC PRESS.	Ts °F	STACK △ P	METER △ h	Vm ft³	Tm INLET	Tm OUTLET	OVEN TEMP.	T_EXIT	VAC in H
1	0			433	.66	1.70	159.753	97	96	251	<70	3
2	5			433	.70	1.79	162.8	97	97	254	<70	4
3	10		-.56	433	.77	1.96	166.2	97	97	251	<70	4
4	15			434	.65	1.70	169.7	98	96	256	<70	4
5	20			434	.66	1.70	173.1	99	98	256	<70	4
6	25			399	.38	0.95	176.5	101	99	255	<70	2.5
					~~.81~~	~~20~~	179.0					
1	30			434	.81	2.0	179.0	101	99	255	<70	4.5
2	35			435	.83	2.10	182.7	102	100	256	<70	5.0
3	40			435	.82	2.09	186.3	102	100	254	<70	5.0
4	45			434	.71	1.82	190.0	101	101	253	<70	5.
5	50			435	.63	1.59	193.5	101	100	253	<70	4.0
6	55			412	.45	1.13	196.8	101	100	256	<70	3
	60						199.954					
AVG:												

D TIME: 1244

LEAK CHECK .008 @ 7 " Hg

cmthd5

FLA1

Run 3 unit #1

(

PLANT Westinghouse DATE June 5, 1987 RUN # unit #1

TART TIME: 1305

P #	SAMPLE TIME θ	CLOCK TIME	STATIC PRESS.	Ts °F	STACK ΔP	METER Δh	Vm ft³	Tm INLET	Tm OUTLET	OVEN TEMP.	T EXIT	VAC in Hg
1	0			431	.67	1.70	200.051	100	99	246	<70	5
2	5			434	.70	1.80	203.3	98	97	260	<70	5
3	10		-.56	435	.70	1.80	206.6	98	97	257	<70	5
4	15			435	.66	1.68	210.1	101	97	257	<70	5
5	20			435	.58	1.48	213.4	100	98	262	<70	5
6	25			370	.31	.78	216.4	101	98	267	<70	3
							219.1					
1	30			429	.66	1.68	219.1	100	99	257	<70	5
2	35			431	.67	1.70	222.3	99	98	261	<70	5
3	40			434	.65	1.65	225.6	98	97	262	<70	5
4	45			435	.61	1.52	228.9	98	97	262	<70	5
	50			434	.52	1.30	232.1	99	98	263	<70	4
	55			420	.39	.98	235.1	99	98	262	<70	4
	60						237.720					
AVG												

E. / TIME: LEAK CHECK .001 @ 5 " Hg

cmthd5

METHOD 5 LAB ANALYSIS

CLIENT Westinghouse

DATE OF TEST June 5, 1987 DATE OF ANALYSIS June 5, 1987 / June 8, 198

SAMPLE BOX # Nutech #3 ΔH @ 2.052 Y 1.001

BAROMETRIC PRESSURE 30.02 inches Hg

		* ~~RUN 1 unit #1~~	Run 1 ~~RUN 2~~ unit #1	Run 2 ~~RUN 3~~ unit #1	Run 3 ~~RUN 4~~ unit #1
PROBE WASH					
BEAKER	TARE	___ mg	TARE 79.15413	TARE 81.31562	TARE 77.18925
	FINAL	___ mg	FINAL 79.17287	FINAL 81.34051	FINAL 77.202
FILTER	#	~~87-305~~	# 87-304	# 86-262	# 86-263
	TARE	___ mg	TARE 1.33607	TARE 1.14115	TARE 1.22594
	FINAL	___ mg	FINAL 1.34886	FINAL 1.17034	FINAL 1.25617
IMPINGER	#1	~~544/~~ ml	#1 581/712	#1 575/678	#1 591/702
	#2	~~551/~~ ml	#2 566/591	#2 553/579	#2 570/596
	#3	___ ml	#3 —	#3 —	#3 —
SILICA GEL	TARE	~~623~~ mg	TARE 633	TARE 616	TARE 639
	FINAL	___ mg	FINAL 643	FINAL 629	FINAL 654
ORSAT	CO_2	___ %	CO_2 11.5 11.5 %	CO_2 11.0 11.1 11.1 %	CO_2 11.4 11.4
	O_2	___ %	O_2 7.3 7.2 7.2 %	O_2 9.4 9.3 9.3 %	O_2 8.6 8.8 8.8 %

* VOIDED - STEAM FLOW ONLY ABOUT 60% OF MAX.

METHOD 5 LAB ANALYSIS

CLIENT Westinghouse

DATE OF TEST June 4, 1987 DATE OF ANALYSIS June 4, 1987 / June 8, 1987

SAMPLE BOX # Nutech #3 ΔH @ 2.052 Y 1.001

BAROMETRIC PRESSURE 30.0 inches Hg

	RUN 1 Unit #2	RUN 2 unit #2	RUN 3 unit #2	RUN 4
PROBE WASH				BLANK
BEAKER	TARE 77.38123 mg FINAL 77.40608 mg	TARE 78.94502 FINAL 78.9552	TARE 77.88238 FINAL 77.90583	TARE 82.13472 FINAL 82.136657
FILTER	# 86-275 TARE 1.18793 mg FINAL 1.21832 mg	# 86-261 TARE 1.20971 FINAL 1.24099	# 86-274 TARE 1.14692 FINAL 1.19683	# 86-233 TARE 1.34697 FINAL 1.34698
IMPINGER	#1 567/637 ml #2 565/612 ml #3 — ml	#1 555/673 #2 559/589 #3 —	#1 574/683 #2 572/600 #3 —	#1 — #2 — #3 —
SILICA GEL	TARE 617 mg FINAL 632 mg	TARE 612 FINAL 624	TARE 635 FINAL 647	TARE — FINAL —
ORSAT	CO_2 11.3 11.4 11.4 % O_2 7.6 7.8 7.8 %	CO_2 10.4 10.4 % O_2 8.9 8.8 8.8 %	CO_2 11.5 11.7 11.7 % O_2 8.6 8.5 8.5 %	

Acetone Blank

$$C_a = \frac{m_a}{V_a \cdot \rho_a}$$

$m_a = 82.13472 - 82.136657$
$= .001937$
$V_a = 100$ ml
$\rho_a = .785$

$$\boxed{C_a = .000025}$$

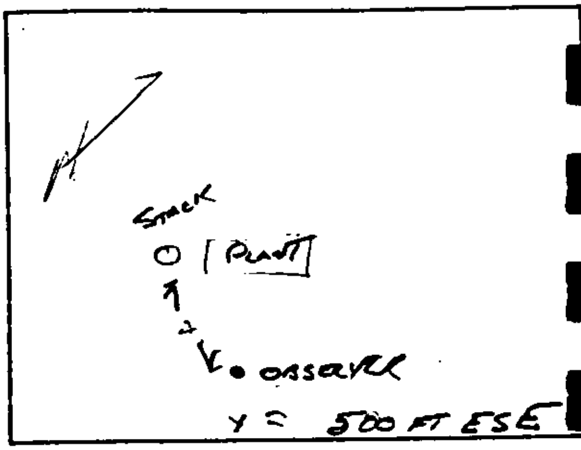
USEPA METHOD 9
OPACITY OBSERVATION

BAY COUNTY
RESOURCE RECOVERY FACILITY
PANAMA CITY, FLORIDA

Run #1 on Unit #

UNIT: 1
DATE: ~~9:53~~ 6/5/87
TIME STARTED: 9'53
TIME ENDED: 10:53
OBSERVER: S.J. Beach
WIND SPEED/DIRECTION: 3-5 E
SKY CONDITIONS: Clear

OBSERVER POSITION



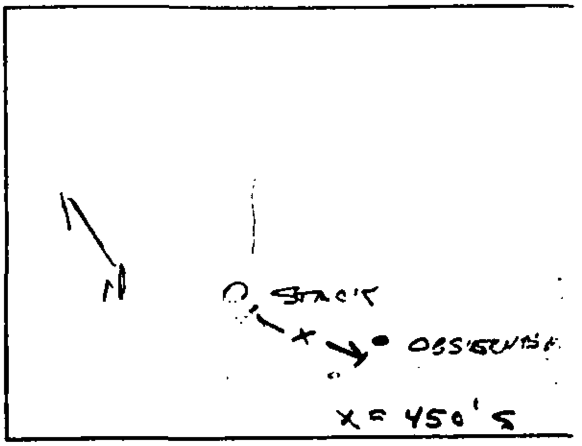
MIN / SEC	15	30	45	60
1	10	5	5	10
2	5	5	5	5
3	5	5	5	5
4	5	5	5	5
5	5	5	5	5
6	5	5	5	5
7	5	5	5	5
8	5	5	5	5
9	5	5	5	5
10	5	5	5	5
11	5	5	5	5
12	5	5	5	5
13	5	5	5	5
14	5	5	5	5
15	5	5	5	5
16	5	5	5	5
17	5	5	5	5
18	5	5	5	5
19	5	5	5	5
20	5	5	5	5
21	5	5	5	5
22	5	5	5	5
23	5	10	10	10
24	10	10	5	5
25	5	5	5	5
26	5	5	5	5
27	10	10	10	5
28	10	5	5	5
29	5	5	5	5
30	5	5	5	5
31	10	10	10	10
32	5	5	5	5
33	5	5	5	5
34	5	5	5	10
35	5	5	5	5
36	5	5	5	5
37	5	5	5	10
38	5	5	10	10
39	5	5	10	10
40	10	10	10	15
41	10	10	10	10
42	10	10	10	10
43	10	5	10	10
44	5	5	5	5
45	5	5	5	5
46	5	5	5	5
47	5	5	5	5
48	5	5	5	5
49	5	5	5	5
50	5	5	5	5
51	5	5	5	5
52	5	5	5	5
53	5	5	5	5
54	5	5	5	5
55	5	5	5	5
56	5	5	5	5
57	5	5	5	5
58	5	5	10	5
59	5	5	5	5
60	10	10	10	10

USEPA METHOD 9
OPACITY OBSERVATION

BAY COUNTY
RESOURCE RECOVERY FACILITY
PANAMA CITY, FLORIDA

UNIT: 1
DATE: 6/5/87
TIME STARTED: 11:40
TIME ENDED: 12:40
OBSERVER: S.J. Beasy
WIND SPEED/DIRECTION: 2-3 N
SKY CONDITIONS: Ptly cloudy

OBSERVER POSITION



MIN / SEC	15	30	45	60		15	30	45	60
1	5	5	5	5	31	5	5	5	5
2	5	5	5	5	32	5	5	5	5
3	5	5	5	5	33	5	5	5	5
4	5	5	5	5	34	5	5	5	5
5	5	5	10	5	35	5	5	5	5
6	5	5	5	5	36	5	5	5	5
7	5	5	5	5	37	5	5	5	5
8	5	5	5	5	38	5	5	5	5
9	5	5	5	5	39	5	5	5	5
10	5	5	5	5	40	5	5	5	5
11	5	5	5	5	41	5	5	5	5
12	5	5	5	5	42	5	5	5	5
13	5	5	5	5	43	5	5	5	5
14	5	5	5	5	44	5	5	5	5
15	5	5	5	5	45	5	5	5	5
16	5	5	5	5	46	5	5	5	5
17	5	5	5	5	47	5	5	5	5
18	5	5	5	5	48	5	5	5	5
19	5	5	5	5	49	5	5	5	5
20	5	5	5	5	50	5	5	5	5
21	5	5	5	5	51	5	5	5	5
22	5	5	5	5	52	10	5	5	5
23	5	5	5	5	53	5	5	5	5
24	5	5	5	5	54	5	5	5	5
25	5	5	5	5	55	5	5	5	5
26	5	5	5	5	56	5	5	5	5
27	5	5	5	5	57	5	5	5	5
28	5	5	5	5	58	5	10	10	10
29	10	5	5	5	59	5	5	5	5
30	10	5	5	5	60	5	5	5	5

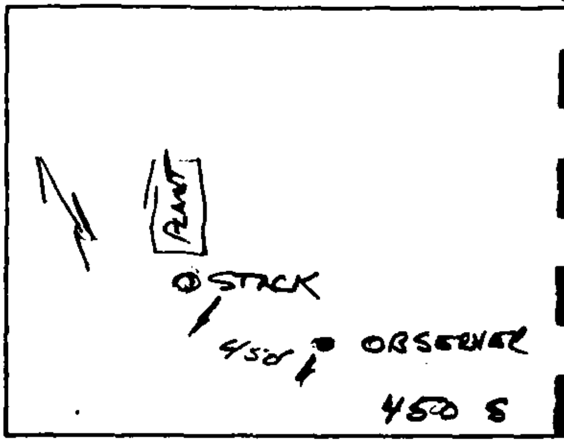
Rc on Unit #1

USEPA METHOD 9
OPACITY OBSERVATION

BAY COUNTY
RESOURCE RECOVERY FACILITY
PANAMA CITY, FLORIDA

UNIT: 1
DATE: 6/5/87
TIME STARTED: 1:10
TIME ENDED: 2:10
OBSERVER: S.J. Brady
WIND SPEED/DIRECTION: 2 - W
SKY CONDITIONS: CLEAR.

OBSERVER POSITION



SEC MIN	15	30	45	60		15	30	45	60
1	5	5	5	5	31	5	5	5	5
2	5	5	5	5	32	5	5	5	5
3	5	5	5	5	33	5	5	5	5
4	5	5	5	5	34	5	5	5	5
5	5	5	5	5	35	5	5	5	5
6	5	5	5	5	36	5	5	5	5
7	5	5	5	5	37	5	5	5	5
8	5	5	5	5	38	5	5	5	5
9	5	5	5	5	39	5	5	5	5
10	5	5	5	5	40	5	5	5	5
11	5	5	5	5	41	5	5	5	5
12	5	5	5	5	42	5	5	5	5
13	5	5	5	5	43	5	5	5	5
14	5	5	5	5	44	5	5	8	5
15	5	5	5	5	45	5	5	5	5
16	5	5	5	5	46	5	5	5	5
17	5	5	5	5	47	5	5	5	5
18	5	5	5	5	48	5	5	5	5
19	5	5	5	5	49	5	5	5	5
20	5	5	5	5	50	5	5	5	5
21	5	5	5	5	51	5	5	5	5
22	5	5	5	5	52	5	5	5	5
23	5	5	5	5	53	5	5	5	5
24	5	5	5	5	54	5	5	5	5
25	5	5	5	5	55	5	5	5	5
26	5	5	5	5	56	5	5	5	5
27	5	5	5	5	57	5	5	5	5
28	5	5	5	5	58	5	5	5	5
29	5	5	5	5	59	5	5	5	5
30	5	5	5	5	60	5	5	5	5

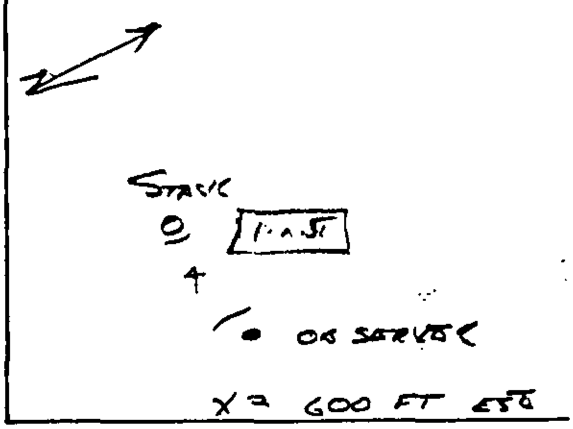
Run # 3 on Unit #1

USEPA METHOD 9
OPACITY OBSERVATION

BAY COUNTY
RESOURCE RECOVERY FACILITY
PANAMA CITY, FLORIDA

UNIT: 2
DATE: 2/14/87
TIME STARTED: 10:10 AM
TIME ENDED: 10:47
OBSERVER: S. J. Brady
WIND SPEED/DIRECTION: <2 S
SKY CONDITIONS: Scattered clouds

OBSERVER POSITION



MIN \ SEC	15	30	45	60		15	30	45	60
1	5	5	5	5	31	10	10	5	5
2	5	5	5	5	32	10	10	10	10
3	5	5	5	5	33	10	10	5	5
4	5	5	5	5	34	5	5	10	5
5	5	5	5	5	35	5	5	5	5
6	5	5	5	5	36	5	5	5	5
7	5	5	5	5	37	5	5	5	5
8	5	5	5	5	38		END	OF	TEST
9	5	5	5	5	39				
10	5	5	5	5	40				
11	5	5	5	5	41				
12	5	5	5	5	42				
13	5	5	5	5	43				
14	5	5	5	5	44				
15	5	5	5	5	45				
16	5	5	5	5	46				
17	5	5	5	5	47				
18	5	5	5	5	48				
19	5	5	5	5	49				
20	5	5	5	5	50				
21	5	5	5	5	51				
22	5	5	5	5	52				
23	5	5	5	5	53				
24	5	5	5	5	54				
25	5	5	5	5	55				
26	5	5	5	5	56				
27	5	5	5	5	57				
28	5	5	5	5	58				
29	5	5	5	5	59				
30	5	5	5	10	60				

RECD

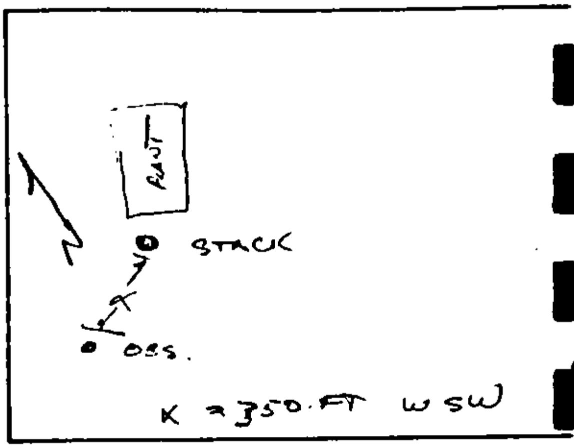
USEPA METHOD 9
OPACITY OBSERVATION

BAY COUNTY
RESOURCE RECOVERY FACILITY
PANAMA CITY, FLORIDA

UNIT: 2
DATE: 6/4/87
TIME STARTED: 1:10 pm
TIME ENDED: 2:10 pm
OBSERVER: S. J. Beasy
WIND SPEED/DIRECTION: 2-4 S
SKY CONDITIONS: Partly Cloudy

Run #1 w Unit #2

OBSERVER POSITION



MIN \ SEC	15	30	45	60
1	5	5	5	5
2	5	5	5	5
3	5	5	5	5
4	5	5	5	5
5	5	5	5	5
6	5	5	5	5
7	5	5	5	5
8	5	5	5	5
9	5	5	5	5
10	5	5	5	5
11	5	5	5	5
12	5	5	5	10
13	10	10	10	10
14	10	10	10	5
15	10	5	5	10
16	5	5	5	5
17	5	5	5	5
18	5	5	5	5
19	5	5	5	5
20	5	5	5	5
21	5	5	5	5
22	5	5	5	5
23	5	5	5	5
24	5	5	5	5
25	10	10	10	10
26	10	5	10	5
27	5	5	5	5
28	5	5	5	5
29	5	5	5	5
30	5	5	5	5

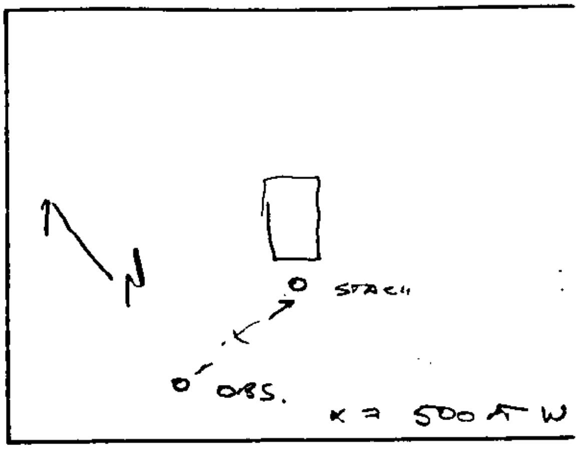
	15	30	45	60
31	5	5	5	5
32	5	5	5	5
33	5	5	5	5
34	5	5	5	5
35	5	5	5	5
36	5	5	5	5
37	5	5	5	5
38	5	5	5	5
39	5	5	5	5
40	5	5	5	5
41	5	3	5	5
42	5	5	5	5
43	5	5	5	5
44	5	5	5	5
45	5	5	5	5
46	5	10	10	10
47	5	10	5	5
48	5	5	5	5
49	5	5	5	5
50	5	5	5	5
51	5	5	5	5
52	5	5	5	5
53	5	5	5	5
54	5	5	5	5
55	5	5	5	5
56	5	5	5	5
57	5	5	5	5
58	5	5	5	5
59	5	5	5	5
60	5	5	5	5

USEPA METHOD 9
OPACITY OBSERVATION

BAY COUNTY
RESOURCE RECOVERY FACILITY
PANAMA CITY, FLORIDA

UNIT: 2
DATE: 6/4/87
TIME STARTED: 3:25
TIME ENDED: 4:25
OBSERVER: S. J. Bartlett
WIND SPEED/DIRECTION: 3-4 SW
SKY CONDITIONS: P. cloudy

OBSERVER POSITION



MIN	SEC 15	30	45	60
1	5	5	5	5
2	5	5	5	5
3	5	5	5	5
4	5	5	5	5
5	5	5	5	5
6	5	5	5	5
7	5	5	5	5
8	5	5	5	5
9	5	5	5	5
10	5	5	5	5
11	10	10	5	5
12	10	10	10	5
13	5	5	5	5
14	5	5	5	5
Clouds * Wind 5-7 mph 15	10	10	10	5
16	5	5	5	10
17	5	5	5	5
18	5	5	5	5
wind 8-12 mph 19	5	5	5	5
20	5	5	5	5
wind 12-15 21	5	5	5	5
22	5	5	5	5
23	5	5	5	5
24	5	5	5	6
25	5	5	5	5
26	5	5	5	5
27	5	5	5	6
28	5	5	5	5
29	5	5	5	5
30	5	5	5	5

MIN	15	30	45	60
31	5	5	5	5
32	5	5	5	5
x calm 2-4 33	5	5	5	5
34	5	10	5	5
35	5	5	5	5
36	5	5	5	5
37	5	5	5	5
38	5	5	5	5
39	10	10	10	10
40	10	10	10	10
41	10	10	10	5
42	10	10	5	5
43	5	5	10	5
44	5	5	5	5
45	5	5	5	5
46	5	5	5	5
47	5	5	5	5
48	5	5	5	5
49	10	5	5	5
50	5	5	5	5
51	10	5	5	5
52	5	10	10	5
53	10	10	5	5
54	10	5	5	5
55	10	10	5	10
56	5	5	5	5
57	5	5	5	5
58	5	5	10	5
59	10	5	5	5
60	20	20	10	10

APPENDIX D-1

CALIBRATIONS

ETS, INC.

Pitot tube assembly level? ✓ yes ______ no

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

a_1 = 2.5 ° (< 10°), a_2 = 1.5 ° (< 10°), B_1 = 1° ° (< 5°),
B_2 = 1 ° (< 5 °)

γ = 4.0 θ = 0.0

$Z = A \sin \gamma$ = 0.67 cm (in.); < 0.32 cm (< 1/8 in.),
$W = A \sin \theta$ = 0.0 cm (in.); < 0.08 cm (< 1/32 in.)

P_A .58 cm (in.) P_b .58 cm (in.)

D_t = .313 cm (in.)

Comments: Pitot tube meets all baseline criteria ∴ a C_p of .84 may be assumed

Calibration required? No

THERMOCOUPLE CALIBRATION DATA SHEET

Date: 1-12-87 Thermocouple No.: NUTECH 3

Ambient Temperature: 69°F °F Barometric pressure: 30.00 "Hg

Calibrator: J. SMITH Reference: Mercury-in-glass: ✓

Other: ____

Reference point No.[a]	Source* (specify)	Reference thermometer temperature, °F	Thermocouple potentiometer temperature, °F	Difference,[b] %
32°	ICE BATH	32	32	0.0
100	HOT OIL	100	98	2.0
200	↓	200	199	1.0
300		300	300	0.0
400		400	400	0.0
			Average % difference	0.60

[a] Every 100°F for each reference point when using furnace up to 500°F.

* Source: 1) Ice bath
2) Furnace

[b] Percent difference ≤ 1.5%

$$\frac{\text{Ref. temp. °F} - \text{thermocouple temp. °F}}{\text{Ref. temp. °F}} \times 100$$

NOZZLE CALIBRATION

Date 6/4/87 Calibrated by Jim Eckenrode

Nozzle identification number	D_1, in.	D_2, in.	D_3, in.	ΔD, in.	D_{avg}
(1/4")	.255	.254	.254	.001	.254

where:

$D_{1,2,3,}$ = nozzle diameter measured of a different diameter, in. Tolerance = measure within 0.001 in.

ΔD = maximum difference in any two measurements, in. Tolerance = 0.004 in.

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

DRY GAS METER AND ORIFICE POST TEST CALIBRATION

Date 6/16/87 Box No. #3

Barometric pressure, P_b = 29.95 in. Hg Dry gas meter No. 710917

ΔH = 1.67 in. H_2O Vac. = 10" Hg

Orifice manometer setting, ΔH, in. H_2O	Gas volume wet test meter V_w, ft^3	Gas volume dry gas meter V_d, ft^3	Temperature: Wet test: Meter t_w, °F	Temperature: Dry gas meter: Inlet t_{di}, °F	Temperature: Dry gas meter: Outlet t_{do}, °F	Temperature: Dry gas meter: Average t_d, °F	Time θ, min	γ	ΔH@
1.67	13.553	14.376	70	92	94	93	21	1.002	2.054
1.67	12.619	13.086	70	93	94	93.5	19	1.003	2.034
1.67	12.624	13.090	70	94	95	94.5	19	1.005	2.028
						Average		1.003	2.039

Calculations

ΔH	$\frac{\Delta H}{13.6}$	γ: $\frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$	ΔH@: $\frac{0.0317 \Delta H}{P_b (t_d + 460)} \left[\frac{(t_w + 460)\,\theta}{V_w}\right]^2$
1.67	.1228	1.002	2.054
1.67	.1228	1.003	2.034
1.67	.1228	1.005	2.028

γ = Ratio of accuracy of wet test meter to dry test meter. Tolerance = ± 0.01

ΔH@ = Orifice pressure differential that gives 0.75 cfm of air at 70 F and 29.92 inches of mercury, in. H_2O. Tolerance = ± 0.15

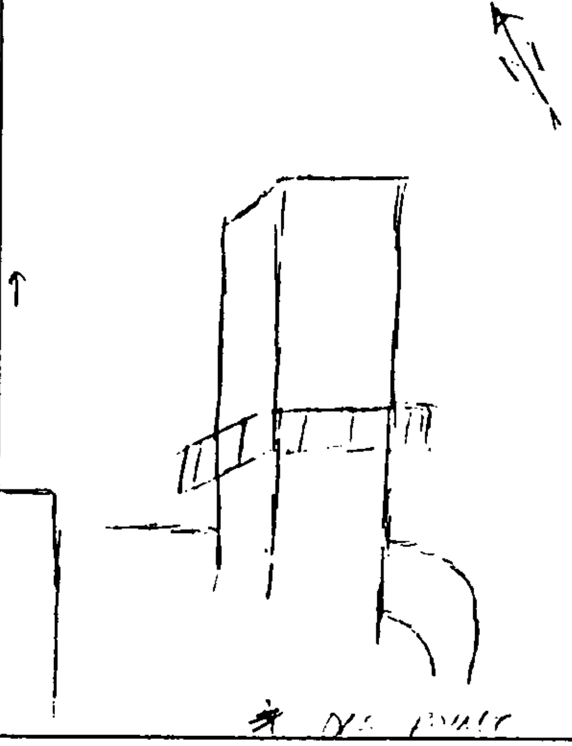
JE.

APPENDIX B

OPACITY MEASUREMENTS FOR MAY 12, 13, AND 14, 1987 COMPLIANCE TESTS

	INITIAL	FINAL
OB RVER LOCATION		
.TANCE TO DISCHARGE	350'	
RECTION TO DISCHARGE	N-NE	
IGHT OF OBSERVATION POINT	[illegible]	
BACKGROUND DESCRIPTION	LIGHT BLUE	
WE HER CONDITIONS		
WIND DIRECTION	S-SE	
ND SPEED	0-5 MPH	
AMBIENT TEMPERATURE	75 °F	
SK CONDITIONS	PARTLY CLOUDY	
P E DESCRIPTION		
LOR	LIGHT GRAY	W/ SOME
STANCE VISIBLE	BROWN	

DIAGRAM OF OBSERVER AND EMISSION POINT



COMMENTS

PARTLY CLOUDY - PLUME NOW APPEARS LIGHT GRAY W/ SOME BROWN.

OBSERVER SIGNATURE John Richardson

ETS, INC.

: 5/12/87

COMPANY Bay County Resourse REGISTRATION NO.

LOCATION Panama City, Fla.

EMISSION POINT NAME HEIGHT TO DISCHARGE POINT ≃ 150'

OBSERVER John Richardson CERTIFICATION EXPIRATION DATE 10/87

CLOCK TIME: INITIAL 2 : 15 A.M. [✓ P.M.] FINAL 2 : 35 A.M. [✓ P.M.]

Run 1, Unit 2

VISIBLE EMISSION READINGS

HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
2	15	5	5	5	5			
	16	5	5	5	5			
	17	5	5	5	5			
	18	5	5	5	5			
	19	5	5	5	5			
	20	5	5	5	5			
	21	5	5	5	5			
	22	5	5	5	5			
	23	5	5	5	5			
	24	5	5	5	5			
	25	5	5	5	5			
	26	5	5	5	5			
	27	5	5	5	5			
	28	5	5	5	5			
	29	5	5	5	5			

HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT
	30	5	5	5	5			
	31	5	5	5	5			
	32	5	5	5	5			
	33	5	5	5	5			
	34	5	5	5	5			
	35	5	5	5	5			
	36							
	37							
	38							
	39							
	40							
	41							
	42							
	43							
	44							
	45							
	46							
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	48							
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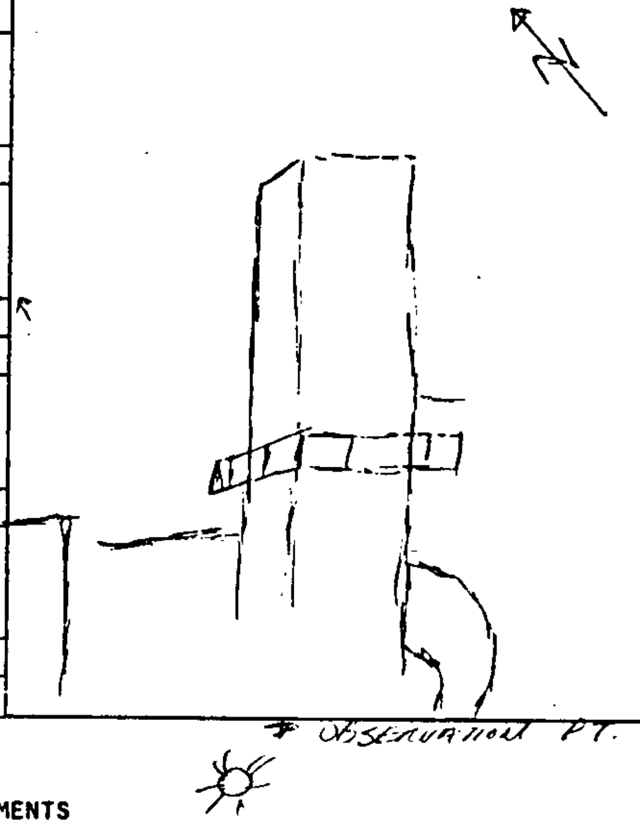
	51							
	52							
	53							
	54							
	55							
	56							
	57							
	58							
	59							

SAPCB Form 13
(5/1/75)

	INITIAL	FINAL
O ERVER LOCATION		
STANCE TO DISCHARGE	350'	
IRECTION TO DISCHARGE	N NE	
EIGHT OF OBSERVATION POINT	GROUND	
BACKGROUND DESCRIPTION	GRAY/WHITE CLOUDS	
W THER CONDITIONS		
WIND DIRECTION	SOUTH	
ND SPEED	0-5 MPH	
AMBIENT TEMPERATURE	85°F	
SK CONDITIONS	CLOUDY	
E DESCRIPTION		
LOR	FAINT GRAY	
STANCE VISIBLE	5-10'	

DIAGRAM OF OBSERVER AND EMISSION POINT



COMMENTS

HAS BECOME COMPLETELY CLOUDY NOW. BACKGROUND IS STILL SOMEWHAT LIGHT.

OBSERVER SIGNATURE John Richardson

ETS, INC.

5/13/87

MPANY Bay Co. Resources REGISTRATION NO.

CATION Panama City Fl.

ISSION POINT NAME HEIGHT TO DISCHARGE POINT ≈ 150'

SERVER John Richardson CERTIFICATION EXPIRATION DATE 10/87

CLOCK TIME: INITIAL 5 : 10 A.M./[✓ P.M.] FINAL 5 : 35 A.M./[✓ P.M.]

VISIBLE EMISSION READINGS

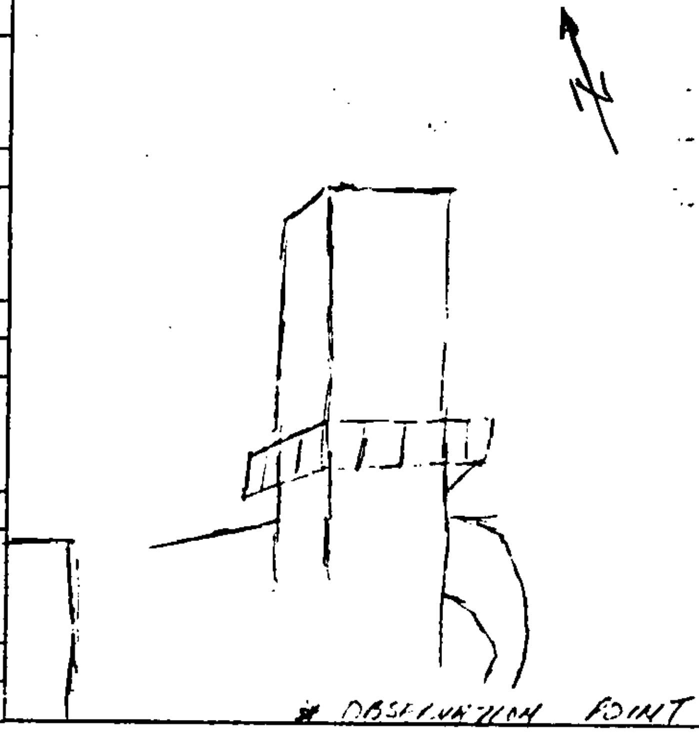
Run 2 Boiler 2

HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE			HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT			0	15	30	45	DET.	ATT.	COMMENT
	0									30	5	5	5	5			
	1									31	5	5	5	5			
	2									32	5	5	5	5			
	3									33	5	5	5	5			
	4									34	5	5	5	5			
	5									35	5	5	5	5			
	6									36							
	7									37							
	8									38							
	9									39							
5	10	5	10	5	10					40							
	11	5	5	5	5					41							
	12	5	5	5	5					42							
	13	5	5	5	5					43							
	14	5	5	5	5					44							
	15	5	5	5	5					45							
	16	5	5	5	5					46							
	17	5	5	5	5					47							
	18	5	5	5	5					48							
	19	5	5	5	5					49							
	20	5	5	5	5					50							
	21	5	5	5	5					51							
	22	5	5	5	5					52							
	23	5	5	5	5					53							
	24	5	5	5	5					54							
	25	5	5	5	5					55							
	26	5	5	5	5					56							
	27	5	5	5	5					57							
	28	5	5	5	5					58							
	29	5	5	5	5					59							

APCB Form 13
5/1/75)

	INITIAL	FINAL
ERVER LOCATION		
STANCE TO DISCHARGE	350'	
IRECTION TO DISCHARGE	N-NE	
EIGHT OF OBSERVATION POINT	GROUND	
BACKGROUND DESCRIPTION	BLUE-GRAY SKY	
THER CONDITIONS		
WIND DIRECTION	SOUTH	
ND SPEED	0-5 MPH	
AMBIENT TEMPERATURE	75°F	
S CONDITIONS	MOSTLY CLOUDY	
E DESCRIPTION		
LOR	LIGHT GRAY	
STANCE VISIBLE		

DIAGRAM OF OBSERVER AND EMISSION POINT



COMMENTS

READINGS AGAIN VERY LOW W/ EXCEPTION OF ≈ 7:29 PM WHEN OPACITY ROSE TO ≈ 10%. BACKGROUND IMPROVED OVER RUN 2 @ 1:50 PM.

Run 3 ↑, Boiler 1 @ 9:10

OBSERVER SIGNATURE John Richardson

ETS, INC.

. 5/13/87

OMPANY Bay County Resources REGISTRATION NO.

OCATION Panama City, Fl.

MISSION POINT NAME HEIGHT TO DISCHARGE POINT ≈ 150'

BSERVER John Richardson CERTIFICATION EXPIRATION DATE 10/87

CLOCK TIME: INITIAL 7 : 10 A.M./[✓ P.M.] FINAL 7 : 30 A.M./[✓ P.M.]

Run 3 Boiler 2

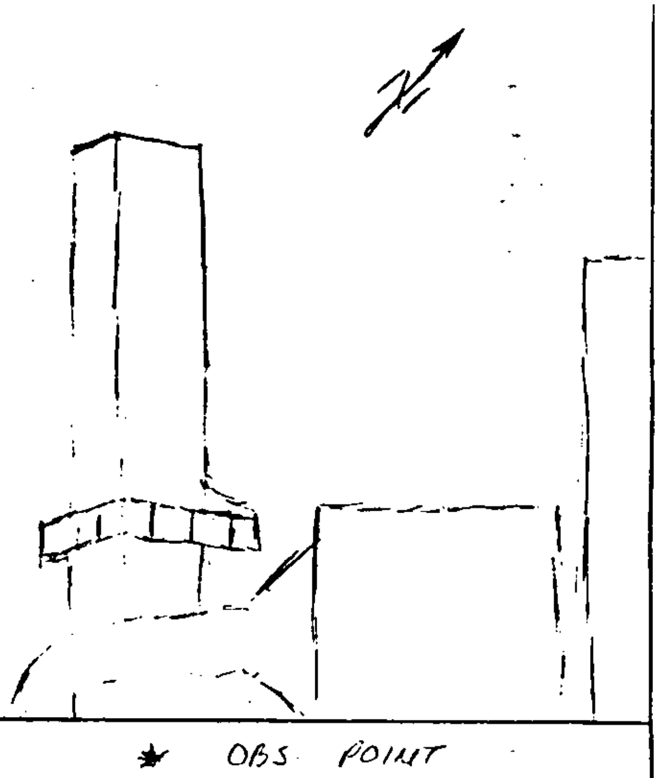
VISIBLE EMISSION READINGS

HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE			HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT			0	15	30	45	DET.	ATT.	COMMENT
	0									30							
	1									31							
	2									32							
	3									33							
	4									34							
	5									35							
	6									36							
	7									37							
	8									38							
	9									39							
7	10	5	5	5	5					40							
	11	5	5	5	5					41							
	12	5	5	5	5					42							
	13	5	5	5	5					43							
	14	5	5	5	5					44							
	15	5	5	5	5					45							
	16	5	5	5	5					46							
	17	5	5	5	5					47							
	18	5	5	5	5					48							
	19	5	5	5	5					49							
	20	5	5	5	5					50							
	21	5	5	5	5					51							
	22	5	5	5	5					52							
	23	5	5	5	5					53							
	24	5	5	5	5					54							
	25	5	5	5	5					55							
	26	5	5	5	5					56							
	27	5	5	5	5					57							
	28	3	5	5	10					58							
	29	10	10	10	5					59							

SAPCB Form 13
(5/1/75)

	INITIAL	FINAL
BS VER LOCATION		
STANCE TO DISCHARGE	500'	
ECTION TO DISCHARGE	N-NW	
HE GHT OF OBSERVATION POINT	GROUND	
ACK ROUND DESCRIPTION	BLUE SKY W/ SOME CLOUDS	
EAT ER CONDITIONS		
W ND DIRECTION	EAST	
W SPEED	0-5 MPH	
BIENT TEMPERATURE	75°F	
Y NDITIONS	PARTLY CLOUDY	
DESCRIPTION		
CO R	FAINT WHITE	
DI ANCE VISIBLE	15-20'	

DIAGRAM OF OBSERVER AND EMISSION POINT



COMMENTS

MOSTLY SUNNY TODAY. PLUME IS LIGHTER COLOR NOW - MORE WHITE BUT STILL VERY LIGHT NOT EXCEEDING 5%.

OBSERVER SIGNATURE John Richardson

ETS, INC.

: 5/14/87

COMPANY Bay County Resources REGISTRATION NO.

LOCATION Panama City, FL.

EMISSION POINT NAME HEIGHT TO DISCHARGE POINT ≈ 150'

OBSERVER John Richardson CERTIFICATION EXPIRATION DATE 10/87

CLOCK TIME: INITIAL 8 : 35 [✓ A.M.]/P.M. FINAL 9 : 00 [✓ A.M.]/P.M.

VISIBLE EMISSION READINGS

Run 4 Boiler 2

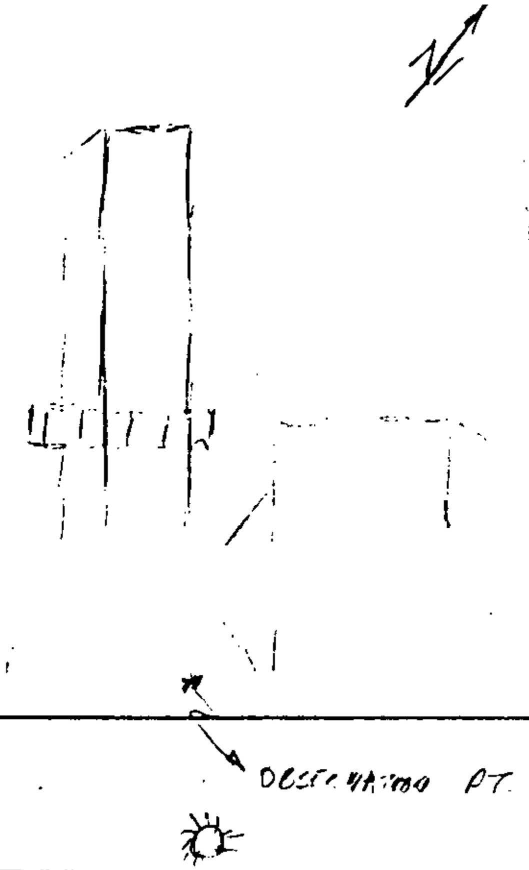
HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
	18							
	19							
	20							
	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							

HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT
	30							
	31							
	32							
	33							
	34							
8	35	5	5	5	5			
	36	5	5	5	5			
	37	5	5	5	5			
	38	5	5	5	5			
	39	5	5	5	5			
	40	5	5	5	5			
	41	5	5	5	5			
	42	5	6	5	5			
	43	5	5	5	5			
	44	5	5	5	5			
	45	5	5	5	5			
	46	5	5	5	5			
	47	5	5	5	5			
	48	5	5	5	5			
	49	5	5	5	5			
	50	5	5	5	5			
	51	5	5	5	5			
	52	5	5	5	5			
	53	5	5	5	5			
	54	5	5	5	5			
	55	5	5	5	5			
	56	5	5	5	5			
	57	5	5	5	5			
	58	5	5	5	5			
	59	5	5	5	5			

SAPCB Form 13
(5/1/75)

	INITIAL	FINAL
OBS RVER LOCATION		
STANCE TO DISCHARGE	500'	
ECTION TO DISCHARGE	N-NW	
GHT OF OBSERVATION POINT	GROUND	
ACKGROUND DESCRIPTION	BLUE SKY	
EA ER CONDITIONS		
WIND DIRECTION	S-SE	
D SPEED	5-10 MPH	
BIENT TEMPERATURE	75°F	
SKY ONDITIONS	Partly Cloudy	
E DESCRIPTION		
C OR	GRAY	
D TANCE VISIBLE	5-10'	

DIAGRAM OF OBSERVER AND EMISSION POINT



COMMENTS

EMISSIONS ARE QUITE LOW.

BACKGROUND PRETTY GOOD, MOSTLY CLEAR SKY.

OBSERVER SIGNATURE John Richardson

ETS, INC.

DATE 5/13/87

COMPANY Bay County Resources REGISTRATION NO.

LOCATION Panama City, FL.

EMISSION POINT NAME HEIGHT TO DISCHARGE POINT ≈125'

OBSERVER John Richardson CERTIFICATION EXPIRATION DATE 10/87

CLOCK TIME: INITIAL 9 : 35 [✓ A.M.]/P.M. FINAL 10 : 00 [✓ A.M.]/P.M.

Run 1 Boiler 1

VISIBLE EMISSION READINGS

HR.	MIN.	SECONDS 0	15	30	45	STEAM PLUME CHECK IF APPLICABLE DET.	ATT.	COMMENT
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
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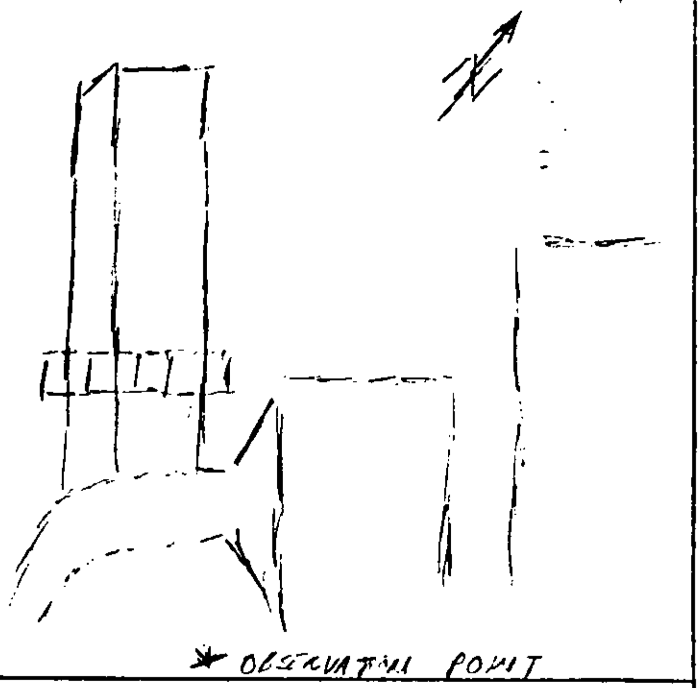
	17							
	18							
	19							
	20							
	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							

HR.	MIN.	SECONDS 0	15	30	45	STEAM PLUME CHECK IF APPLICABLE DET.	ATT.	COMMENT
	30							
	31							
	32							
	33							
	34							
9	35	5	5	5	5			
	36	5	5	5	5			
	37	5	5	5	5			
	38	5	5	5	5			
	39	5	5	5	5			
	40	5	5	5	5			
	41	5	5	5	5			
	42	5	5	5	5			
	43	5	5	5	5			
	44	5	5	5	5			
	45	5	5	5	5			
	46	5	5	5	5			
	47	5	5	5	5			
	48	5	5	5	5			
	49	5	5	5	5			
	50	5	5	5	5			
	51	5	5	5	5			
	52	5	5	5	5			
	53	5	5	5	5			
	54	5	5	5	5			
	55	5	5	5	5			
	56	5	5	5	5			
	57	5	5	5	5			
	58	5	5	5	5			
	59	5	5	5	5			

SAPCB Form 13
(5/1/75)

	INITIAL	FINAL
OBS RVER LOCATION		
STANCE TO DISCHARGE	500'	
RECTION TO DISCHARGE	N-NW	
GHT OF OBSERVATION POINT	GROUND	
BACKGROUND DESCRIPTION	WHITE CLOUDS	
EA ER CONDITIONS		
WIND DIRECTION	SE	
W D SPEED	0-5 MPH	
A IENT TEMPERATURE	80°F	
KY ONDITIONS	MOSTLY CLOUDY	
DESCRIPTION		
C OR	FAINT GRAY	
D TANCE VISIBLE	5-10'	

DIAGRAM OF OBSERVER AND EMISSION POINT



COMMENTS

HAS BECOME MORE CLOUDY THAN RUN 1, IS NOW MOSTLY CLOUDY. EMISSIONS AGAIN VERY LOW & NEARLY NONDETECTABLE.

OBSERVER SIGNATURE John Richardson

ETS, INC.

TE 5/13/87

COMPANY Bay County Resources REGISTRATION NO.

LOCATION Panama City, Fl.

EMISSION POINT NAME HEIGHT TO DISCHARGE POINT 150'

OBSERVER John Richardson CERTIFICATION EXPIRATION DATE 10/87

CLOCK TIME: INITIAL 11 : 45 [✓ A.M.]/P.M. FINAL 12 : 10 A.M./[✓ P.M.]

Run 2 Boiler 1

VISIBLE EMISSION READINGS

HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT
12	0	5	5	5	5			
	1	5	5	5	5			
	2	5	5	5	5			
	3	5	5	5	5			
	4	5	5	5	5			
	5	5	5	5	5			
	6	5	5	5	5			
	7	5	5	5	5			
	8	5	5	5	5			
	9	5	5	5	5			
	10	5	5	5	5			
	11							
	12							
	13							
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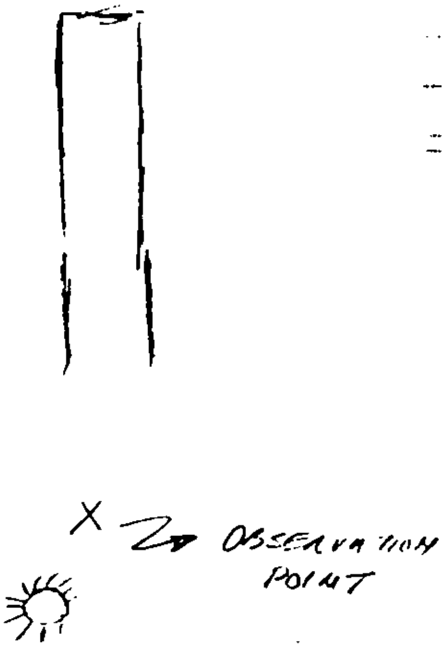
	19							
	20							
	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							

HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT
	30							
	31							
	32							
	33							
	34							
	35							
	36							
	37							
	38							
	39							
	40							
	41							
	42							
	43							
	44							
11	45	5	5	5	5			
	46	5	5	5	5			
	47	5	5	5	5			
	48	5	5	5	5			
	49	5	5	5	5			
	50	5	5	5	5			
	51	5	5	5	5			
	52	5	5	5	5			
	53	5	5	5	5			
	54	5	5	5	5			
	55	5	5	5	5			
	56	5	5	5	5			
	57	5	5	5	5			
	58	5	10	5	5			
	59	5	5	5	5			

SAPCB Form 13
(5/1/75)

	INITIAL	FINAL
O ERVER LOCATION		
ISTANCE TO DISCHARGE	400'	
RECTION TO DISCHARGE		
EIGHT OF OBSERVATION POINT	GROUND	
BACKGROUND DESCRIPTION		
	WHITE	
	CLOUDS	
WE THER CONDITIONS		
WIND DIRECTION		
ND SPEED	10-15 MPH	
BIENT TEMPERATURE	85°	
SK CONDITIONS		
	Mostly Cloudy	CLOUDLY
E DESCRIPTION		
LOR	HARDLY	
STANCE VISIBLE	DISCERNABLE	

DIAGRAM OF OBSERVER AND EMISSION POINT



COMMENTS

EMISSIONS ARE VERY LOW, JUST BARELY DETECTABLE BACKGROUND WAS FAIRLY GOOD AT ONSET OF READING BUT CHANGED TO MEDIUM GRAY CLOUDS. FAINT GRAY EMISSIONS OBSERVED THROUGHOUT READINGS.

OBSERVER SIGNATURE John Richardson

ETS, INC.

D . 5/13/87

COMPANY Bay County Resources REGISTRATION NO.

LOCATION Panama City, FL.

EMISSION POINT NAME HEIGHT TO DISCHARGE POINT ≈ 150'

OBSERVER John Richardson CERTIFICATION EXPIRATION DATE 10/87

CLOCK TIME: INITIAL 1 : 50 A.M./[✓ P.M.] FINAL 2 : 20 A.M./[✓ P.M.]

Run 3 Boiler 1

VISIBLE EMISSION READINGS

HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE			HR.	MIN.	SECONDS				STEAM PLUME CHECK IF APPLICABLE		
		0	15	30	45	DET.	ATT.	COMMENT			0	15	30	45	DET.	ATT.	COMMENT
2	0	5	5	5	5					30							
	1	5	5	5	5					31							
	2	5	5	5	5					32							
	3	5	5	5	5					33							
	4	5	5	5	5					34							
	5	5	5	5	5					35							
	6	5	5	5	5					36							
	7	5	5	5	5					37							
	8	5	5	5	5					38							
	9	5	5	5	5					39							
	10	5	5	5	5					40							
	11	5	5	5	5					41							
	12	5	5	5	5					42							
	13	5	5	5	5					43							
	14	5	5	5	5					44							
	15	5	5	5	5					45							
	16	5	5	5	5					46							
	17	5	5	5	5					47							
	18	5	5	5	5					48							
	19	5	5	5	5					49							
	20	5	5	5	5				1	50	5	5	5	5			
	21									51	5	5	5	5			
	22									52	5	5	5	5			
	23									53	5	5	5	5			
	24									54	5	5	5	5			
	25									55	5	5	5	5			
	26									56	5	5	5	5			
	27									57	5	5	5	5			
	28									58	5	5	5	5			
	29									59	5	5	5	5			

SAPCB Form 13
(5/1/75)

APPENDIX C

COMPUTER CALCULATION SHEETS FOR ADDITIONAL TEST RESULTS REPORTED IN TABLE 2

4/22 1436 *1

```
WEST1                                    08:57:49     04-29-1987                      Page
   ENVIRO-PRO processor direct variable dump   V1.0   English/Metric units

%CO2 avg.           13                    pmrd                 4.075032751833441
%O2 avg.            [illegible]           pmrw                 4.075032751833441
%CO avg.            0                     csd                  1.906570629048159D-02
As stack area       15.32071832265625     csw                  1.906570629048159D-02
Vm avg. DGM         47.149                csd50%               1.766775282446131D-02
Dp avg. delta p     .4908333333333333     csw50%               1.766775282446131D-02
ts avg. temp        373.75                csd12                1.759911349890608D-02
DH avg. delta H     2.389166666666667     csw12                1.759911349890608D-02
tmi avg. temp       92.41666666666667     csd7                 1.778612865433382D-02
tmo avg. temp       91.08333333333333     csw7                 1.778612865433382D-02
%N2 avg.            81                    saturation flag -1
Md mole wt. dry     30.32000002264977     Bws saturated        .1329112443417778
Ms mole wt.         28.68253348934865     Vm corrected         47.149
   area nozzle      4.974406528656250D-04 total # points       12
tm temp meter       91.75                 Vf impingers         326
Tm abs temp         551.42                Vi impingers         200
Ts abs temp         833.42                sqr(Dp) avg.         .6988695723679337
Pm abs prs          30.11567401468032     Bws kick flag        0
Ps abs prs          29.9105882361191      Vm C kick flag       0
Vm(std)             45.45874602257414     not in use          NA
Vwc(std)            5.93082               Wa2                  0
Vwsg(std)           1.0373                Wa5                  0
Bws                 .1329112443417778     K1 constant          .04707
vs velocity         49.46539289227205     K2 constant          .04715
   vol rate         24954.98114192209     Tstd abs temp        527.67
run time min.       60                    container 1          1.140000000000002D-02
%I isokinetic       93.50757805391747     container 2          4.476999999999975D-02
Qa vol rate         43470.72107332136     container 3         NA
md mass dry         5.616999999999978D-02 container 4          22
mw mass wet         5.616999999999978D-02 container 5         NA
                    39.00156035616007     not in use          NA
```

* Definitions + units of the variables are given in the sample calculations

```
ENVIRO-PR 4/22 1652 ~1 ct variable sums  V1.0  English/Metric units

  2 avg.          13                        cmrd               6.683764211788342
    avg.          6                         cmrw               6.683764211788342
    avg.          0                         csd                3.020726680940678D-02
  stack area      15.3207183226562 5        csw                3.020726680940678D-02
Vm avg. DGM       25.3830000000001          csd50%             2.799238147068258D-02
Dp avg. delta p   .58                       csw50%             2.799238147068258D-02
ts avg. temp      387.333333333333          csd12              2.788363090099086D-02
DH avg. delta H   2.77833333333333          csw12              2.788363090099086D-02
tmi avg. temp     89.3333333333333          csd7               .0281799334145898
t   avg. temp     87                        csw7               .0281799334145898
%N  avg.          81                        saturation flag  -1
Md mole wt. dry   30.3200000226497 7        Bws saturated      .1748840164916596
Ms mole wt.       28.16542893551144         Vm corrected       25.3830000000001
Ar area nozzle    4.974406528656250D-04     total # points     6
tm temp meter     88.1666666666667          Vf impingers       296
T  abs temp       547.8366666666667         Vi impingers       200
   abs temp       847.0033333333333         sqr(Dp) avg.       .7595053951150426
   bs prs         30.14428920995612         Bws kick flag      0
   s prs          29.91132353021612         Vm C kick flag     0
  std)            24.65652072063845         not in use        NA
   (std)          4.51872                   Wa2                0
   g(std)         .70725                    Wa5                0
Bws               .1748840164916596         K1 constant        .04707
vs velocity       54.68799812415877         K2 constant        .04715
Qs vol rate       25833.82598045883         Tstd abs temp      527.67
run time min.     30                        container 1        1.071999999999992D-02
%I isokinetic     97.98501469721418         container 2        3.754999999999953D-02
Q  vol rate       50271.56489341139         container 3       NA
md mass dry       4.826999999999951D-02     container 4        15
mw mass wet       4.826999999999951D-02     container 5       NA
/a                39.00156035616007         not in use        NA
```

```
WEST1   4/27 1505 #1        08:58:31    04-29-1987                    Page
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%CO2 avg.           13                          pmrd                6.123921122589678
%O2 avg.            6                           pmrw                6.123921122589878
%CO avg.            0                           csd                 2.867596632509704D-02
As stack area       15.32071832265625           csw                 2.867596632509704D-02
Vm avg. DGM         47.399                      csd50%              2.657336042606127D-02
Dp avg. delta p     .5158333333333333           csw50%              2.657336042606127D-02
ts avg. temp        440.6666666666667           csd12               2.647012276162804D-02
DH avg. delta H     2.324166666666667           csw12               2.647012276162604D-02
tmi avg. temp       85.5                        csd7                2.675140477749577D-02
tmo avg. temp       82.91666666666667           csw7                2.675140477749577D-02
%N2 avg.            81                          saturation flag -1
Md mole wt. dry     30.32000002264977           Bws saturated       .1234471419635653
Ms mole wt.         28.79913123086259           Vm corrected        47.399
An area nozzle      4.974406528656250D-04       total # points      12
tm temp meter       84.20833333333333           Vf impingers        393
   abs temp         543.8783333333333           Vi impingers        300
   abs temp         900.3366666666667           sqr(Dp) avg.        .7157758413700033
Pm abs prs          30.43089460304967           Bws kick flag       0
Ps abs prs          30.21367647188758           Vm C kick flag      0
Vm(std)             46.81845015367414           not in use          NA
Vwc(std)            4.37751                     Wa2                 0
Vwsg(std)           2.21605                     Wa5                 0
Bws                 .1234471419635653           K1 constant         .04707
v= velocity         52.28566395485316           K2 constant         .04715
   vol rate         24933.92032259212           Tstd abs temp       527.67
run time min.       60                          container 1         3.852999999999998D-02
%I isokinetic       96.38580271252002           container 2         4.847999999999963D-02
Q  vol rate         48063.23578592198           container 3         NA
   mass dry         8.700999999999962D-02       container 4         47
mw mass wet         8.700999999999962D-02       container 5         NA
%EA                 39.00156035616007           not in use          NA
```

4/29 1214 #1

```
WESTS                                07:32:56    05-04-1987                    Page
  ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%C[illegible]2 avg.        13                      pmrd                4.670828915775861
%[illegible] avg.          6                       pmrw                4.670828915775661
%C[illegible] avg.         0                       csd                 2.729277513196588D-02
As stack area      15.32071832265625       csw                 2.729277513196588D-02
Vm[illegible]avg. DGM      36.99799999999999       csd50%              2.529158886528706D-02
Dp[illegible]avg. delta p  .3533333333333333       csw50%              2.529158886528706D-02
ts avg. temp       418.25                  csd12               2.519333089104542D-02
D[illegible]avg. delta H   1.628333333333333       csw12               2.519333089104542D-02
tm[illegible] avg. temp    94.5                    csd7                2.546104521044135D-02
tmo avg. temp      91.75                   csw7                2.546104521044135D-02
%N2 avg.           81                      saturation flag -1
Md[illegible]mole wt. dry  30.32000002264977       Bws saturated       .1462431164718465
Ms[illegible]mole wt.      28.51828482440424       Vm corrected        36.99799999999999
A[illegible] area nozzle   4.974406528656250D-04   total # points      12
tm[illegible]temp meter    93.125                  Vf impingers        383
T[illegible]abs temp       552.795                 Vi impingers        300
[illegible] abs temp       877.92                  sqr(Dp) avg.        .5819842002140952
P[illegible]abs prs        30.01973038879852       Bws kick flag       0
Ps[illegible]abs prs       29.87352941250719       Vm C kick flag      0
V[illegible](std)          35.46956164476588       not in use         NA
Vwc(std)           3.90681                 Wa2                 0
V[illegible]g(std)         2.1689                  Wa5                 0
Bw[illegible]              .1462431164718465       K1 constant         .04707
vs velocity        42.42563001861055       K2 constant         .04715
Qs[illegible]vol rate      19981.37193655277       Tstd abs temp       527.67
r[illegible] time min.     60                      container 1         3.245000000000001D-02
%I isokinetic      91.1207152800595        container 2         3.028899999999979D-02
Qa vol rate        38999.4676305817        container 3        NA
md[illegible]mass dry      6.273899999999979D-02   container 4         46
mw mass wet        6.273899999999979D-02   container 5        NA
%EA                39.0015603561600?       not in use         NA
```

5/20 1542 #1

```
wb1                                      07:12:47     05-27-1987                    Page
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%CO2 avg.            12.4                         pmrd              5.785084460056904
%O2 avg.             8                            pmrw              5.785084460056904
%CO avg.             0                            csd               2.642635204349229D-02
As stack area        15.32071832265625            csw               2.642635204349229D-02
Vm avg. DGM          35.47800000000001            csd50%            2.844715260099988D-02
Dp avg. delta p      .5533333333333333            csw50%            2.844715260099988D-02
ts avg. temp         425.6666666666667            csd12             2.557388907357319D-02
DH avg. delta H      1.341666666666667            csw12             2.557388907357319D-02
tmi avg. temp        93.33333333333333            csd7              2.847490652518484D-02
tmo avg. temp        92.25                        csw7              2.847490652518484D-02
%N2 avg.             79.6                         saturation flag -1
Md mole wt. dry      30.30400000810623            Bws saturated      .1400125550570485
Ms mole wt.          28.58128558475201            Vm corrected       35.47800000000001
An area nozzle       3.743949407406250D-04        total # points     12
tm temp meter        92.79166666666667            Vf impingers       304
Tm abs temp          552.4616666666667            Vi impingers       200
Ts abs temp          885.3366666666667            sqr(Dp) avg.       .7417701993334804
   abs prs           30.09865195801172            Bws kick flag      0
    bs prs           29.97058823611191            Vm C kick flag     0
     td)             34.12234872763515            not in use        NA
vmc(std)             4.89528                      Wa2                0
Vwsg(std)            .6601                        Wa5                0
Bws                  .1400125550570485            K1 constant        .04707
vs velocity          54.15535493600144            K2 constant        .04715
 s vol rate          25559.45142488106            Tstd abs temp      527.67
run time min.        60                           container 1        5.843999999999999D-02
%I isokinetic        91.05112052753139            container 2       NA
Qa vol rate          49781.93631827699            container 3       NA
md mass dry          5.843999999999999D-02        container 4        14
mw mass wet          5.843999999999999D-02        container 5       NA
%EA                  61.47037181887387            not in use        NA
```

6/1 1903 #1

```
                            10:10:25    06-16-1987                      Page  1
   ENVIRO[illegible] processor direct variable dump  V1.0  English/Metric units

[illegible]O2 avg.         11.7                   pmrd             4.160724421385723
%O2 avg.                8.2                    pmrw             4.160724421385723
[illegible]O avg.          0                      csd              1.903243669895595D-02
A[illegible] stack area    15.32071832265625      csw              1.903243669895595D-02
Vm avg. DGM             37.97799999999999      csd50%           2.072481002660821D-02
D[illegible] avg. delta p  .6008333333333333      csw50%           2.072481002660821D-02
t[illegible] avg. temp     436.1666666666667      csd12            1.952044789639585D-02
DH avg. delta H         1.463333333333333      csw12            1.952044789639585D-02
[illegible]mi avg. temp    83.08333333333333      csd7             2.083077722849742D-02
t[illegible]p avg. temp    82.25                  csw7             2.083077722849742D-02
%[illegible]2 avg.         80.1                   saturation flag -1
Md mole wt. dry         30.200000089407        Bws saturated     .1734456583746612
M[illegible] mole wt.      28.08396297521911      Vm corrected      37.97799999999999
A[illegible] area nozzle   3.518801934156250D-04  total # points    12
[illegible]m temp meter    82.66666666666667      Vf impingers      1276
T[illegible] abs temp      542.3366666666667      Vi impingers      1133
[illegible] abs temp       895.8366666666667      sqr(Dp) avg.      .7683717843300268
[illegible] abs prs        30.12759803619764      Bws kick flag     0
[illegible] abs prs        29.98176470695482      Vm C kick flag    0
V[illegible](std)          37.24453212224598      not in use       NA
[illegible]c(std)          6.73101                Wa2               0
Vwsg(std)               1.08445                Wa5               0
B[illegible]s              .1734456583746612      K1 constant       .04707
V[illegible] velocity      56.91446229232026      K2 constant       .04715
Qs vol rate             25524.28579381761      Tstd abs temp     527.67
[illegible]n time min.     60                     container 1       2.462999999999999D-02
[illegible] isokinetic     105.8868380398462      container 2       2.130999999999972D-02
Qa vol rate             52318.22671596475      container 3      NA
md mass dry             .0459399999999997      container 4       23
m[illegible] mass wet      .0459399999999997      container 5      NA
[illegible]a               63.33807137563551      not in use       NA
```

611 2029 #1

```
FLA                                          10:10:41    06-16-1987                    Page  :
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%CO2 avg.           10.3                          pmrd                 4.31352340952869
%O2 avg.            9.6                           pmrw                 4.31352340952869
%CO avg.            0                             csd                  2.1241921970323377D-02
As stack area       15.32071832265625            csw                  2.1241921970323377D-02
Vm avg. DGM         35.37100000000001             csd50%               2.5935366912453910D-02
Dp avg. delta p     .5291666666666667             csw50%               2.5935366912453910D-02
ts avg. temp        442.5                         csd12                2.474787025668789D-02
DH avg. delta H     1.274166666666667             csw12                2.474787025668789D-02
tmi avg. temp       85                            csd7                 2.612944400459664D-02
tmo avg. temp       82.41666666666667             csw7                 2.612944400459664D-02
%N2 avg.            80.1                          saturation flag -1
Md mole wt. dry     30.03200000226498             Bws saturated        .1722794200530634
Ms mole wt.         27.95913401979631             Vm corrected         35.37100000000001
An area nozzle      3.518801934156250D-04         total # points       12
tm temp meter       83.70933333333333             Vf impingers         1222
   abs temp         543.3783333333333             Vi impingers         1081
   abs temp         902.17                        sqr(Dp) avg.         .7136150783847175
Pm abs prs          30.1136887228623              Bws kick flag        0
Ps abs prs          29.98470588334291             Vm C kick flag       0
Vm(std)             34.40539969155991             not in use          NA
Vwc(std)            6.63687                       Wa2                  0
Vwsg(std)           .5658                         Wa5                  0
Bws                 .1722794200530634             K1 constant          .04707
vs velocity         53.16074185230925             K2 constant          .04715
Qs vol rate         23709.22679019665             Tstd abs temp        527.67
run time min.       60                            container 1          2.579000000000001D-02
( isokinetic        105.9155033195273             container 2          2.184999999999881D-02
Qa vol rate         48867.6451045604              container 3         NA
md mass dry         4.763999999999882D-02         container 4          12
mw mass wet         4.763999999999882D-02         container 5         NA
 TA                 83.14279858023556             not in use          NA
```

(

4/23 0925 #2

```
W ST1                             08:57:57    04-29-1987                    Page
    ENVIRO--PRO processor direct variable dump  V1.0  English/Metric units

 CO2 avg.          13                     pmrd                4.303796045924327
%02 avg.           6                      pmrw                4.303796045924327
%CO avg.           0                      csd                 1.740908012526307D-02
   stack area      15.3207183226562 5     csw                 1.740908012526307D-02
 m avg. DGM        53.721                 csd50%              1.613259534517987D-02
Dp avg. delta p    .725                   csw50%              1.613259534517987D-02
   avg. temp       422.333333333333       csd12               1.606992011562744D-02
 H avg. delta H    3.325833333333333      csw12               1.606992011562744D-02
tmi avg. temp      90.25                  csd7                1.624068545607043D-02
 mo avg. temp      85                     csw7                1.624068545607043D-02
 N2 avg.           81                     saturation flag -1
Md mole wt. dry    30.32000002264977      Bws saturated       .1515834990417485
Ms mole wt.        28.45249131102209      Vm corrected        53.721
   area nozzle     4.974406528656 25D-04  total # points      12
   temp meter      87.625                 Vf impingers        362
Tm abs temp        547.295                Vi impingers        200
   abs temp        882.0033333333333      sqr(Dp) avg.        .8455823430303823
   abs prs         30.2645465617681       Bws kick flag       0
Ps abs prs         29.97220588369353      Vm C kick flag      0
Vm(std)            52.44350037054014      not in use         NA
   (std)           7.62534                Wa2                 0
  sg(std)          1.74455                Wa5                 0
Bws                .1515834990417485      K1 constant         .04707
   velocity        61.75414579682566      K2 constant         .04715
   vol rate        28863.89253254145      Tstd abs temp       527.67
run time min.      60                     container 1         2.523999999999998D-02
   isokinetic      93.26600518257677      container 2         3.392999999999979D-02
   vol rate        56767.07238056474      container 3        NA
md mass dry        5.916999999999978D-02  container 4         37
mw mass wet        5.916999999999978D-02  container 5        NA
  EA               39.00156035616007      not in use         NA
```

4/23 1148 #2

```
WEST1                                08:58:05     04-29-1987                  Page
 - ENVIRO-PRO processor direct variable dump   V1.0   English/Metric units

%CO2 avg.              13                       pmrd              4.86175939570683
%O2 avg.               6                        pmrw              4.86175939570683
%CO avg.     .         0                        csd               .023326809465375
As stack area          15.3207183226562         csw               .023326809465375
Vm avg. DGM            46.967                   csd50%            2.16164194254538D-0
Dp avg. delta p        .520833333333333         csw50%            2.16164194254538D-0
ts avg. temp           422.333333333333         csd12             2.15324395065007D-0
DH avg. delta H        2.395                    csw12             2.15324395065007D-0
tmi  avg. temp         90.0909090909090         csd7              2.17612517430544D-0
tmo  avg. temp         90.5454545454545         csw7            . 2.17612517430544D-0
%N2 avg.               81                       saturation flag -1
Md mole wt. dry        30.3200000226497         Bws saturated     .157689962961204
Ms mole wt.            28.3772596753960         Vm corrected      46.967
   area nozzle         4.97440652865625D-04     total # points    12
   temp meter          90.3181818181818         Vf  impingers     348
Tm abs temp            549.988181818181         Vi  impingers     200
Ts abs temp            882.003333333333         sqr(Dp)  avg.     .716881276344037
Pm abs prs             30.1961029362369         Bws kick flag     0
Ps abs prs             29.990588236119          Vm C kick flag    0
Vm(std)                45.5224106655549         not in use       NA
Vwc(std)               6.96636                  Wa2               0
Vwsg(std)              1.55595                  Wa5               0
Bws                    .157689962961204         K1 constant       .04707
   velocity            52.4061989014767         K2 constant       .04715
   vol rate            24334.204918762          Tstd abs temp     527.67
run time min.          60                       container 1       .02165
%I isokinetic          96.0272947609030         container 2       4.71699999999949D-02
Qa vol rate            48175.875190036          container 3      NA
md mass dry            6.88199999999949D-02     container 4       33
mw mass wet            6.88199999999949D-02     container 5      NA
                       39.0015603561600         not in use       NA
```

INLET

4/23 1356 #2

```
NE  T1                          02:58:12    04-29-1987                     Page
 ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%C 2 avg.         13                         pmrd             4.18334111210145Z
%O2 avg.          6                          pmrw             4.18334111210145Z
%CO avg.          0                          csd              2.08469815142992ZD-02
As stack area     15.3207163Z265625          csw              2.08469815142992ZD-02
Vm avg. DGM       45.07599999999999          csd50%           1.93184197280241ZD-02
Dp avg. delta p   .4708333333333333          csw50%           1.93184197280241ZD-02
ts avg. temp      405.25                     csd12            1.92433675516608 4D-02
DH avg. delta H   2.205                      csw12            1.92433675516608 4D-02
tmi avg. temp     90                         csd7             1.94478552023513 6D-02
tm  avg. temp     87.66666666666667          csw7             1.94478552023513 6D-02
%N  avg.          81                         saturation flag -1
Md mole wt. dry   30.32000002264977          Bws saturated    .155309863080446
Ms mole wt.       28.40658250598094          Vm corrected     45.07599999999999
   area nozzle    4.974406528656Z5D-04       total # points   12
   temp meter     88.83333333333333          Vf impingers     345
    bs temp       548.5033333333333          Vi impingers     200
   abs temp       864.92                     sqr(Dp) avg.     .6819317163956953
P  abs prs        30.18213234839349          Bws kick flag    0
P  abs prs        29.9905882361191           Vm C kick flag   0
Vm(std)           43.78757660306248          not in use      NA
Vw (std)          6.82515                    Wa2              0
Vw g(std)         1.2259                     Wa5              0
Bws               .155309863080446           K1 constant      .04707
V  velocity       49.34253726153965          K2 constant      .04715
   vol rate       23429.2905497124           Tstd abs temp    527.67
run time min.     60                         container 1      1.313999999999999D-02
%I isokinetic     95.93528605455597          container 2      4.602000000000039D-02
Q  vol rate       45357.78688255315          container 3     NA
    ass dry       5.916000000000038D-02      container 4      26
    ass wet       5.916000000000038D-02      container 5     NA
                  39.00156035616007          not in use      NA
```

4/30 0957 #2

```
WEST5                                    07:33:25   05-04-1987                    Page
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%CO2 avg.            13                         pmrd               4.240091853977272
%O2 avg.             6                          pmrw               4.240091853977272
%CO avg.             0                          csd                1.809104990973947D-01
As stack area        15.3207183226625           csw                1.809104990973947D-01
Vm avg. DGM          49.375                     csd50%             1.676456110623303D-02
Dp avg. delta p      .6008333333333333          csw50%             1.676456110623303D-02
ts avg. temp         426.8333333333333          csd12              1.669943068591336D-02
DH avg. delta H      2.746666666666667          csw12              1.669943068591336D-01
tmi  avg. temp       92.08333333333333          csd7               1.687688545518199D-02
tmo avg. temp        88.08333333333333          csw7               1.687688545518197D-02
%N2 avg.             81                         saturation flag -1
Md mole wt. dry      30.32000002264977          Bws saturated       .1090675305335957
Ms mole wt.          28.97628804400551          Vm corrected        49.375
An area nozzle       4.974406528656250D-04      total # points      12
Tm temp meter        90.08333333333333          Vf impingers        372
Tm abs temp          549.7533333333333          Vi impingers        300
Ts abs temp          886.5033333333333          sqr(Dp) avg.        .7738064284392416
Pm abs prs           30.09196077864888          Bws kick flag       0
Ps abs prs           29.8605882361191           Vm C kick flag      0
Vm(std)              47.71166982051774          not in use         NA
Vwc(std)             3.38904                    Wa2                 0
Vwsg(std)            2.4518                     Wa5                 0
Bws                  .1090675305335957          K1 constant         .04707
   velocity          56.2466379644777           K2 constant         .04715
   vol rate          27364.69008279531          Tstd abs temp       527.67
    time min.        60                         container 1         .03489
%I isokinetic        89.49951570796815          container 2         2.104999999999979D-02
Qa vol rate          51704.33381101117          container 3        NA
md mass dry          .0559399999999998          container 4         52
mw mass wet          .0559399999999998          container 5        NA
%EA                  39.00156035616007          not in use         NA
```

5/12 1353 UNIT #2

```
A[illegible]STOU1          run  1            14:22:59     05-17-1987                          Page   1
 ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

[illegible]02 avg.          10.2333333333333          pmrd               4.61530728436140l
%[illegible]2 avg.          9.7                       pmrw               4.61530728436140l
%CO avg.                    0                         csd                2.096669303877474D-02
A[illegible] stack area     15.32071832265625          csw                2.096669303877474D-02
V[illegible] avg. DGM       48.067                    csd50%             2.583208440074983D-02
Dp avg. delta p             .6566666666666667         csw50%             2.583208440074983D-02
[illegible]s avg. temp      436.8333333333333         csd12              2.458635014318862D-02
D[illegible] avg. delta H   2.669166666666667         csw12              2.458635014318862D-02
t[illegible]i avg. temp     90.16666666666667         csd7               2.602116385420505D-02
tmo avg. temp               90.75                     csw7               2.602116385420505D-02
%[illegible]2 avg.          80.06666666666667         saturation flag -1
M[illegible] mole wt. dry   30.02533333500226         Bws saturated      .1958879733752114
[illegible]s mole wt.       27.6697151588473          Vm corrected       48.067
[illegible] area nozzle     4.974406528656250D-04     total # points     12
[illegible] temp meter      90.45833333333333          Vf impingers       408
T[illegible] abs temp       550.1283333333333         Vi impingers       200
Ts abs temp                 896.5033333333333         sqr(Dp) avg.       .790002785072928
F[illegible] abs prs        30.19626224939695         Bws kick flag      0
[illegible] abs prs         29.95808823646971         Vm C kick flag     0
Vm(std)                     46.57695413358648         not in use        NA
V[illegible]c(std)          9.79056                   Wa2                0
V[illegible]sg(std)         1.55595                   Wa5                0
Bws                         .1958879733752114         K1 constant        .04707
vs velocity                 58.99833938977261         K2 constant        .04715
[illegible] vol rate        25700.98245786192         Tstd abs temp      527.67
[illegible] time min.       60                        container 1        3.518000000000002D-02
[illegible] isokinetic      93.02677438327585         container 2        2.810999999999986D-02
[illegible] vol rate        54233.81635771087         container 3       NA
m[illegible] mass dry       6.328999999999987D-02     container 4        33
mw mass wet                 6.328999999999987D-02     container 5       NA
%EA                         84.80800252794236         not in use        NA
```

5/13 1632 UNIT #2

```
WESTOU1          run  2            14:23:36    05-17-1987                          Page   1
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%CO2 avg.          10.4                          pmrd                  6.25807082178 6027
%O2 avg.           9.6                           pmrw                  6.25807082178 6027
%CO avg.           .15                           csd                   3.080595149363257D-02
As stack area      15.3207183226562 5            csw                   3.080595149363257D-02
Vm avg. DGM        47.911                        csd50%                3.746599181721248D-02
Dp avg. delta p    .525833333333333              csw50%                3.746599181721248D-02
ts avg. temp       408.833333333333              csd12                 3.554532864649912D-02
DH avg. delta H    2.45583333333333              csw12                 3.554532864649912D-02
tmi avg. temp      100.583333333333              csd7                  3.789404676684836D-02
tmo avg. temp      98.0833333333333              csw7                  3.789404676684836D-02
%N2 avg.           79.85                         saturation flag -1
Md mole wt. dry    30.0480000019073 5            Bws saturated         .191680426888 1441
Ms mole wt.        27.7386342183933 9            Vm corrected          47.911
An area nozzle     4.974406528656 25D-04         total # points        12
tm temp meter      99.3333333333333              Vf impingers          397
Tm abs temp        559.003333333333              Vi impingers          200
Ts abs temp        868.503333333333              sqr(Dp) avg.          .714703505575787
Pm abs prs         30.1805759753271 4            Bws kick flag         0
Ps abs prs         29.9610294128578              Vm C kick flag        0
Vm(std)            45.6649780900539              not in use           NA
Vwc(std)           9.27279                       Wa2                   0
Vwsg(std)          1.55595                       Wa5                   0
Bws                .191680426888 1441            K1 constant           .04707
vs velocity        52.4668943473253 1            K2 constant           .04715
Qs vol rate        23718.3725984936 7            Tstd abs temp         527.67
 n time min.       60                            container 1           .01693
%I isokinetic      98.8291293231339              container 2           7.4239999999 9964D-02
  vol rate         48229.8305735961 9            container 3          NA
  mass dry         9.116999999999 964D-02        container 4           33
mw mass wet        9.116999999999 964D-02        container 5          NA
%EA                82.4289950512801 4            not in use           NA
```

5/14 0825 UNIT #2

```
WESTOU1          run: 4             14:24:33     05-17-1987                   Page    1
  ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units


%O2 avg.          10.2                         pmrd                2.892550182725949
% 2 avg.          9.7                          pmrw                2.892550182725949
%CO avg.          0                            csd                 1.334679936634712D-02
As stack area     15.32071832265625            csw                 1.334679936634712D-02
V  avg. DGM       49.185                       csd50%              1.643816742478097D-02
Dp avg. delta p   .5875                        csw50%              1.643816742478097D-02
ts avg. temp      421.1666666666667            csd12               1.570211690158485D-02
D  avg. delta H   2.456666666666667            csw12               1.570211690158485D-02
t i avg. temp     97.66666666666667            csd7                1.656433146603715D-02
tmo avg. temp     91.16666666666667            csw7                1.656433146603715D-02
% 2 avg.          80.1                         saturation flag -1
M  mole wt. dry   30.02000000178814            Bws saturated       .1783223462470211
Ms mole wt.       27.87656539958008            Vm corrected        49.185
An area nozzle    4.97440652865625D-04         total # points      12
t  temp meter     94.41666666666667            Vf impingers        382
T  abs temp       554.0866666666667            Vi impingers        200
Ts abs temp       880.8366666666667            sqr(Dp) avg.        .7571383251240413
P  abs pre        30.18063724983522            Bws kick flag       0
P  abs pre        29.9705882361191             Vm C kick flag      0
Vm(std)           47.29533146288439            not in use         NA
V c(std)          8.56674                      Wa2                 0
V sg(std)         1.6974                       Wa5                 0
Bws               .1783223462470211            K1 constant         .04707
vs velocity       55.82776733136092            K2 constant         .04715
   vol rate       25303.62897807033            Tstd abs temp       527.67
   time min.      60                           container 1         2.467999999999998D-02
   isokinetic     95.94493775269678            container 2         1.623000000000019D-02
Q  vol rate       51319.28987199428            container 3        NA
m  mass dry       4.091000000000017D-02        container 4         36
mw mass wet       4.091000000000017D-02        container 5        NA
%EA               84.74280207839728            not in use         NA
```

5/21 1016 #2

```
 n2         ~~Run 1~~          08:27:43    05-28-1987                                Page   1
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units


%CO2 avg.           10.9                         pmrd               3.63014849707071
%O2 avg.            8.7                          pmrw               3.63014849707071
%CO avg.            0                            csd                1.670321943539691D-02
As stack area       15.32071832265625            csw                1.670321943539691D-02
Vm avg. DGM         30.06                        csd50%             1.886993335155235D-02
Dp avg. delta p     .5666666666666667            csw50%             1.886993335155235D-02
ts avg. temp        411.5                        csd12              1.838886547346449D-02
D   avg. delta H    1.1175                       csw12              1.838886547346449D-02
     avg. temp      111.25                       csd7               .0190307172983514
     avg. temp      111.25                       csw7               .0190307172983514
%N2 avg.            80.4                         saturation flag -1
Md mole wt. dry     30.09200000762939            Bws saturated      .1684282017538337
Ms mole wt.         28.05536619073703            Vm corrected       30.06
An area nozzle      3.743949407406250D-04        total # points     12
tm temp meter       111.25                       Vf impingers       317
Tm abs temp         570.92                       Vi impingers       200
Ts abs temp         871.17                       sqr(Dp) avg.       .7477479030408388
Pm abs prs          30.14216911534228            Bws kick flag      0
Ps abs prs          30.0305882361191             Vm C kick flag     0
Vm(std)             29.05269261874298            not in use        NA
Vwc(std)            5.50719                      Wa2                0
Vwsg(std)           .3772                        Wa5                0
B                   .1684282017538337            K1 constant        .04707
v   velocity        54.60235474606763            K2 constant        .04715
Qs vol rate         25374.83606135349            Tstd abs temp      527.67
run time min.       48                           container 1        3.145000000000001D-02
%I isokinetic       97.60926967189145            container 2       NA
Qa vol rate         50192.83780909529            container 3       NA
md mass dry         3.145000000000001D-02        container 4        8
mw mass wet         3.145000000000001D-02        container 5       NA
%EA                 69.45775116469892            not in use        NA
```

5/21 1705 #2

```
wn2                                 [illegible]8:27:58    05-28-1987                 Page    1
    ENVIRO-PRO processor direct variable dump  V1.0  English/Metric units

%CO2 avg.           11.5                      pmrd                4.330703635654533
[illegible]2 avg.   9                         pmrw                4.330703635654533
[illegible]O avg.   0                         csd                 1.641596898375574D-02
As stack area       15.32071832265625         csw                 1.641596598375574D-02
Vm avg. DGM         40.885                    csd50%              1.916018009301828D-02
[illegible] avg. delta p  .7441666666666667   csw50%              1.916018009301828D-02
[illegible] avg. temp     431                 csd12               1.712970676565816D-02
DH avg. delta H     2.650833333333333         csw12               1.712970676565816D-02
[illegible]i avg. temp    106.25              csd7                1.917495545602307D-02
[illegible]o avg. temp    106.25              csw7                1.917495545602307D-02
%N2 avg.            79.5                      saturation flag -1
[illegible] mole wt. dry  30.20000000298023   Bws saturated       9.481966548862889D-02
[illegible] mole wt.      29.04320008373638   Vm corrected        40.885
An area nozzle      4.974406528656250D-04     total # points      12
[illegible]m temp meter   106.25              Vf impingers        261
[illegible] abs temp      565.92              Vi impingers        200
[illegible] abs temp      890.67              sqr(Dp) avg.        .8578449567575251
Pm abs pre          30.25491421021908         Bws kick flag       0
[illegible] abs pre       30.03058823611191   Vm C kick flag      0
[illegible](std)    40.01317867071964         not in use         NA
Vwc(std)            2.87127                   Wa2                 0
[illegible]wsg(std) 1.3202                    Wa5                 0
[illegible]ws       9.481966548862889D-02     K1 constant         .04707
Vs velocity         62.25262439380102         K2 constant         .04715
Qs vol rate         30801.43728733193         Tstd abs temp       527.67
[illegible]n time min.    48                  container 1         1.846999999999999D-02
[illegible] isokinetic    83.35443015154688   container 2         2.410000000000068D-02
Qa vol rate         57225.29539101268         container 3        NA
[illegible] mass dry      4.257000000000066D-02   container 4      28
[illegible] mass wet      4.257000000000066D-02   container 5     NA
%EA                 75.07507578728418         not in use         NA
```

```
PLA         611 0927 #2         10:09:39    04-16-1987                      Page
   ENVIRO-PRO program  direct variable dump  V1.0  English/Metric units

 %CO2 avg.          10.6                        pmrd                3.20413662002774
 %O2 avg.           8.8                         pmrw                3.20413662002774
 %CO avg.           0                           csd                 1.444900750619912D-0
 As stack area      15.32071832265625           csw                 1.444900750619912D-0
 Vm avg. DGM        35.675                      csd50%              1.642467432227205D-0
 Dp avg. delta p    .6383333333333333           csw50%              1.642467432227205D-0
 ts avg. temp       436.5833333333333           csd12               1.635623491267719D-02
 DH avg. delta H    1.605833333333333           csw12               1.635623491267719D-02
 tmi avg. temp      88.41666666666667           csd7                1.659729794678049D-02
 tmo avg. temp      87.66666666666667           csw7                1.659729794678049D-02
 %N2 avg.           80.6                        saturation flag -1
 Md mole wt. dry    30.04800000786781           Bws saturated       .1946681097293766
 Ms mole wt.        27.70263862031667           Vm corrected        35.675
 An area nozzle     3.518801934156250D-04       total # points      12
 tm temp meter      88.04166666666667           Vf impingers        1345
 Tm abs temp        547.7116666666667           Vi impingers        1182
 Ts abs temp        896.2533333333333           sqr(Dp) avg.        .7946435024367213
 Pm abs prs         30.14807597708021           Bws kick flag       0
 Ps abs prs         29.98955882466374           Vm C kick flag      0
 Vm(std)            34.66219531317728           not in use          NA
 Vwc(std)           7.67241                     Wa2                 0
 Vwsg(std)          .70725                      Wa5                 0
 Bws                .1946681097293766           K1 constant         .04707
 vs velocity        59.27024533877442           K2 constant         .04715
 Qs vol rate        25892.98428569535           Tstd abs temp       527.67
 run time min.      60                          container 1         1.835999999999999D-02
 %I isokinetic      97.15327179850558           container 2         1.409999999999911D-02
 Wa vol rate        54483.76402500555           container 3         NA
 md mass dry        .0324599999999991           container 4         15
 mw mass wet        .0324599999999991           container 5         NA
 %EA                70.52186242876619           not in use          NA
```

```
A      |611 1047 #2|          10:09:55     06-16-1987                          Page   1
 ENVIRO-PRO processor direct variable dump   V1.0   English/Metric units

 O2 avg.           11.2                          pmrd               3.370052009806408
 O2 avg.           7.7                           pmrw               3.370052009806408
  D avg.           0                             csd                1.617701744012152D-02
A  stack area      15.32071832265625             csw                1.617701744012152D-02
Vm avg. DGM        36.765                        csd50%             1.684154195617942D-02
D  avg. delta p    .5483333333333333             csw50%             1.684154195617942D-02
t  avg. temp       428.4166666666667             csd12              1.733251868584448D-02
DH avg. delta H    1.3475                        csw12              1.733251868584448D-02
 mi avg. temp      92.83333333333333             csd7               1.703488960188949D-02
t o avg. temp      91.25                         csw7               1.703488960188949D-02
 N2 avg.           81.1                          saturation flag -1
Md mole wt. dry    30.10000001490116             Bws saturated       .1850815321982904
M  mole wt.        27.86051347254392             Vm corrected        36.765
A  area nozzle     3.518801934156250D-04         total # points      12
 m temp meter      92.04166666666667             Vf impingers        1324
   abs temp        551.7116666666667             Vi impingers        1165
   abs temp        888.0866666666667             sqr(Dp) avg.        .7363830463136791
Pm abs prs         30.1290808795738               Bws kick flag       0
Ps abs prs         29.9910294128578               Vm C kick flag      0
V (std)            35.44403670963133             not in use         NA
 wc(std)           7.48413                       Wa2                 0
Vwsg(std)          .5658                         Wa5                 0
B s                .1850815321982904             K1 constant         .04707
V  velocity        54.51748525187301             K2 constant         .04715
Qs vol rate        24323.00283671308             Tstd abs temp       527.67
r n time min.      60                            container 1         1.466000000000001D-02
   isokinetic      105.7448055184965             container 2         2.250000000000085D-02
Qa vol rate        50114.82211221077             container 3        NA
 d mass dry        3.716000000000086D-02         container 4          12
   mass wet        3.716000000000086D-02         container 5        NA
 A                 56.16174630321331             not in use         NA
```

611 1213 #2

```
FLA                                    10:10:09      06-16-1987                         Page
    ENVIRO-PRO processor direct variable dump   V1.0   English/Metric units


 02 avg.          10.8                           pmrd              3.431285032015641
%02 avg.          8.3                            pmrw              3.431285032015641
%CO avg.          0                              csd               1.588539761925769D-0
As stack area     15.32071832265625              csw               1.588539761925769D-02
Vm avg. DGM       35.629                         csd50%            1.732191568443525D-02
Dp avg. delta p   .5725                          csw50%            1.732191568443525D-02
ts avg. temp      426.25                         csd12             1.765044179917521D-02
DH avg. delta H   1.41                           csw12             1.765044179917521D-02
tmi avg. temp     92.33333333333333              csd7              1.752436726451591D-02
tmo avg. temp     92                             csw7              1.752436726451581D-02
%N2 avg.          80.9                           saturation flag -1
Md mole wt. dry   30.06000001132488              Bws saturated      .1742827906230467
Ms mole wt.       27.95814955443721              Vm corrected       35.629
An area nozzle    3.518801934156250D-04          total # points     12
tm temp meter     92.16666666666667              Vf impingers       1250
Tm abs temp       551.8366666666667              Vi impingers       1104
Ts abs temp       885.92                         sqr(Dp) avg.       .7539208355672653
 m abs prs        30.13367646768019              Bws kick flag      0
   abs prs        29.99250000105185              Vm C kick flag     0
vm(std)           34.34631055999344              not in use        NA
Vwc(std)          6.87222                        Wa2                0
Vwsg(std)         .3772                          Wa5                0
Bws               .1742827906230467              K1 constant        .04707
vs velocity       55.64896050896046              K2 constant        .04715
Qs vol rate       25219.57401876082              Tstd abs temp      527.67
run time min.     60                             container 1        .01538
% isokinetic      98.82695205734169              container 2        1.998000000000033D-02
ua vol rate       51154.92293438428              container 3       NA
md mass dry       3.536000000000034D-02          container 4        8
 w mass wet       3.536000000000034D-02          container 5       NA
 EA               63.56451471604416              not in use        NA
```

6/3 1023 **

```
A                                    10:12:29     04-16-1987                              Page    1
   ENVIRO     processor direct variable dump   V1.0   English/Metric units

 02 avg.            12                          pmrd                4.23278376386771
 2 avg.             7.8                         pmrw                4.23278376326771
 O avg.             0                           csd                 1.911786248478093D-02
  stack area        15.32071832265625           csw                 1.911786248478093D-02
Vm avg. DGM         37.265                      csd50%              2.017920356230977D-02
  avg. delta p      .5966666666666667           csw50%              2.017920356230577D-02
  avg. temp         438.5                       csd12               1.911786248478093D-02
DH avg. delta H     1.4575                      csw12               1.911786248478093D-02
 i avg. temp        96                          csd7                2.028536557128412D-02
 o avg. temp        95.25                       csw7                2.028536557128412D-02
 N2 avg.            80.2                        saturation flag -1
Md mole wt. dry     30.23200001120567           Bws saturated       .1573904022281733
  mole wt.          28.30680060873185           Vm corrected        37.265
  area nozzle       3.518801934156250D-04       total # points      12
tm temp meter       95.625                      Vf impingers        1263
  abs temp          555.295                     Vi impingers        1129
  abs temp          898.17                      sqr(Dp) avg.        .7663568122153158
Pm abs prs          30.20716911464105           Bws kick flag       0
Ps abs prs          30.06176470695482           Vm C kick flag      0
 (std)              35.78675181624649           not in use         NA
 c(std)             6.30738                     Wa2                 0
Vwsg(std)           .3772                       Wa5                 0
 s                  .1573904022281733           K1 constant         .04707
  velocity          56.53953981358393           K2 constant         .04715
Qs vol rate         25850.31205268073           Tstd abs temp       527.67
 n time min.        60                          container 1         .02653
   isokinetic       100.459161047966            container 2         1.780999999999899D-02
 a vol rate         51973.58181459167           container 3        NA
md mass dry         4.433999999999899D-02       container 4         8
   mass wet         4.433999999999899D-02       container 5        NA
 A                  58.32735154131695           not in use         NA
```