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Environmental Protection
Agency

Air Quality Planning and Standards
Education and Outreach Group
Air Pollution Training Institute
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EPA APTI Course #450/#468 Laboratory Manual

Monitoring Compliance Test And Source Test Observation

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Notice

This is not an official policy and standards document. The opinions and selections are those of the author and not necessarily those of the Environmental Protection Agency. Every attempt has been made to represent the present state of the art as well as subject areas still under evaluation. Any mention of products or organizations does not constitute endorsement by the United States Environmental Protection Agency (USEPA).

Usage of This Manual

The Central States Air Resource Agencies Association (CenSARA) is one of several multi-jurisdictional organizations (MJOs) operating for the U.S. Environmental Protection Agency (USEPA), through the Air Pollution Training Institute (APTI), to update more of the frequently used APTI courses. The primary objectives of the MJOs are to:

- Promote the exchange of information between the States;
- Serve as a forum to discuss regional air quality issues of common concern;
- Share resources for the common benefit of the member states; and
- Provide training services to their member air pollution control agencies.

APTI provides courses on air pollution control technology, ambient air and source monitoring, and air quality management. Historically, APTI designed courses that meet the job training needs of governmental agency personnel and others in the field of air pollution. This requires a thorough examination of both the materials for instruction and the characteristics of the student audience. Based on studies conducted by APTI of those who have participated in the various training courses, courses were developed and revised to provide training that enables every student to achieve specific course objectives. A basic goal of APTI was to provide training that will enable a student to do specific jobs in his or her home environmental agency. However, recently APTI has taken a new direction and has given money to the various MJOs, of which CenSARA is one, to update needed training course for their member states.

CenSARA meets these training needs of its member states by identifying, designing, developing and delivering needed, cost-effective, responsive, and focused educational opportunities for state and local air agency staff. Agenda and course materials are obtained from a variety of sources including EPA, colleges and universities, regional training consortia, and individual instructors. Yet, due to changes in environmental regulations, the implementation of new policies, and the advancement of technologies, agendas and course materials become out-of-date. When this happens, staffs' ability to enhance skills, knowledge and abilities are constrained, limiting their ability to excel in the dynamic field of air pollution control. So by providing up-to-date, high quality educational opportunities for staff, their chances to greatly enhance their skills, knowledge and abilities is significantly improved.

Consequently, CenSARA announced a Request for Proposals (RFP) to the environmental training community to solicit technical proposals and cost bids to review current compliance test and observation programs within the USEPA and to **update** as necessary the content title, agenda topics, course length, instructor and student manuals, lectures involving presentation slides, classroom and homework exercises, and other handouts and materials for EPA's APTI Course 468 entitled: *"Monitoring Compliance Test and Source Test Observation."* In response to CenSARA's RFP, EnviroTech Solutions, William T. "Jerry" Winberry, Jr., 1502 Laughridge Drive, Cary, North Carolina 27511, jwinberry@mindspring.com, 919-467-2785, was awarded the contract to update EPA's APTI Course #450. Mr. Winberry is the author of this Laboratory Manual and every attempt has been made to represent the most recent advances in sampling and analytical methodology

This material has been developed and assembled to provide training associated with EPA's APTI Course #450/#468 entitled: *""Monitoring Compliance Test and Source Test Observation."* It is not intended to be used for regulatory purposes, or to be a substitute for, nor interpreted as official Agency policy. Every attempt was made to reflect the technical state of art and regulatory information as of the date of publication.

Table of Contents

Appendices

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Introduction

To The User of This Manual and Description of Laboratory Stations

EPA's APTI Course #450/#468 laboratory manual (LM) has been prepared to guide the students through a series of laboratory exercises developed to provide the students a hands-on experience related to stack testing issues and concepts discussed in the lecture portion of this course. The primary objective of these exercises is for the students to gain a practical understanding of common procedures outlined in the Federal Register necessary to monitor compliance test and source test observation for determining compliance with the applicable emission regulations. This LM provides guidance and materials for completing ten (10) laboratory stations utilizing a source simulator to reinforce lecture objectives. Each station has specific objectives to be accomplished. The ten laboratory stations are:

- **Laboratory Station 1: Calibration of Nozzle for FRM 5 Train**
- **Laboratory Station 2: Dry Gas Meter "Gamma" Calibration**
- **Laboratory Station 3: Orifice Meter Calibration Involving ΔH@ of FRM 5 Train**
- **Laboratory Station 4: Stack Gas Velocity and Volumetric Flow Rate**
- **Laboratory Station 5: Source Simulator/Pitot Tube Calibration**
- **Laboratory Station 6: Source Simulator/Stack Gas Moisture**
- **Laboratory Station 7: Type S Pitot Tube Inspection**
- **Laboratory Station 8: Federal Reference Method 5 Sampling Train**
- **Laboratory Station 9: IsoCal Electronic Spreadsheet/Isokinetic Rate Equation**
- **Laboratory Station 10: FRM 1 Traverse Point Determination**

The 10 laboratory simulator stations focus on source testing activities and lecture objectives presented in the classroom involving stack gas velocity, sampling site location, determination of stack gas molecular weight, determining stack gas moisture etc. This LM contains step-by-step instructions to the participant on how to accomplish the objectives of each station exercise. Instrumentation used during each Laboratory Station exercise can be obtained from the Inspector's Tool Kit (see Appendix C). A brief explanation for each laboratory station follows.

Laboratory Station 1: Nozzle Diameter (D_n)

The objective of Laboratory Station 1 is to demonstrate to the participant the difficulty in measuring a proper nozzle diameter. The participant will be given data to satisfy the estimated probe nozzle diameter equation for an upcoming stack test. Based upon the calculation, the participant will measure several nozzles using a micrometer acquired from the Inspector's Tool Kit (see Appendix C), document the findings on standardized forms, and select the correct nozzle for the upcoming test. Probe nozzles should be inspected and calibrated in the field immediately before each use to verify that they were not damaged in transport or shipment to the test site.

Laboratory Station 2: DGM "γ" Determination

Test results from a stack emission test are meaningless without calibration of the equipment and it's components. The dry gas meter (DGM) serves to record the volume of gas sampled during the test and the orifice tube on the outlet of the DGM serves to provide flow rate determination during testing. Both of these components must be calibrated. The DGM "γ " value is a calibration factor that relates volume from a primary standard (i.e., wet test meter) to the recorded dry gas meter volume. The objective of Laboratory Station 2 is to use a set of calibrated orifices obtained from the Inspector's Tool Kit (see Appendix C) to determine the "γ" of a meter box assembly containing DGM. Once again, standardized forms are used to complete the assignment.

Laboratory Station 3: Orifice Meter "ΔH@" Determination

Test results from a stack emission test are meaningless without calibration of the equipment and it's components. The dry gas meter (DGM) serves to record the volume of gas sampled during the test and the orifice tube on the outlet of the DGM serves to provide flow rate determination during testing. Both of these components must be calibrated. The orifice tube calibration factor "ΔH@" is the pressure drop across the orifice for a typical sampling flow rate of 0.75 which is the standard sampling rate for solving the isokinetic equation and setting up the nomographs (sets of equations) for testing. The objective of Laboratory Station 3 is to use a set of NIST calibrated orifices to determine the orifice tube calibration factor "ΔH@". The set of NIST calibrated orifices can be obtained from the Inspector's Tool Kit (see Appendix C). Once again, standardized forms are used to complete the assignment.

Laboratory Station 4: Source Simulator/Stack Gas Velocity (v_s) and Volumetric Flow Rate (Q_s)

Laboratory Station 4 involves the participant to use an "S-type" pitot tube to determine simulated stack gas flow rate. In determining the stack gas flow rate, the pitot tube must be constructed to specifications identified in Federal Reference Method 2 (FRM 2), have a known pitot tube coefficient factor (C_p), and positioned in the source using proper orientation. Laboratory Station 4 will require the participant to verify that the pitot tube meets geometric specifications using a micrometer and standardized data sheet in order to assign a known C_p. In addition, Laboratory Station 4 requires the participant to divide the stack into equal area identified in Federal Reference Method 1 (FRM 1), mark the pitot tube/probe for each sample point, and determine the stack gas velocity at each of the sampling points in the centroid of the equal areas. A Type S pitot tube along with measurement tape can be acquired from the Inspector's Tool Kit (see Appendix C). Once again, a standardized field test data sheet (FTDS) will be available to complete the assignment.

Laboratory Station 5: Source Simulator/Calibration of Type S Pitot Tube

As identified in Federal Reference Method 2, a Type S pitot tube can be calibrated using a standard type pitot tube. The objective of Laboratory Station 6 is to follow standardized procedures provided in order to calibrate a Type S pitot tube using a standard pitot tube. Entry points will be provided for inserting the Type S and standard pitot tube into the source simulator. The Type S and Standard pitot tube along with a digital manometer can be acquired from the Inspector's Too0l Kit (see Appendix C). Once again, standardized calibration forms are provided to complete this assignment.

Laboratory Station 6: Source Simulator/Stack Gas Moisture

One of the most important parameters to estimate correctly when selecting your nozzle diameter and setting up your isokinetic rate equation is the stack gas moisture (B_{ws}). For every % stack gas moisture you estimate incorrectly will cause your % isokinetics to be off the same %. The objective of Laboratory Station 6 is to determine the stack gas moisture content of the source simulator using the wet bulb/dry bulb technique. Obtain a Type K thermocouple along with the digital readout instrument from the Inspector's Tool Kit (see Appendix C). Once again, standardized forms are provided to assist in the calculations. In addition, other techniques for determining stack gas moisture will be reviewed.

Laboratory Station 7: Pitot Tube Inspection

In order to assign a known pitot tube coefficient factor, C_p, the pitot tube must meet certain design and construction requirements as identified in Federal Reference Method 2 (FRM 2) in order to assign a value of 0.84. To complete this exercise, you will be given a Type S pitot tube along with a "bulls eye" and level indicator out of the Inspector's Tool Kit (see Appendix C). Using the standardized data form, inspect the Type S pitot tube and see if it meets specifications by evaluating α, β, z, w and A characteristics so a C_p of 0.84 can be assigned to the Type S pitot tube.

Laboratory Station 8: Federal Reference Method 5 (FRM 5) Sampling Train

Laboratory Station 5 contains a complete Federal Reference Method 5 (FRM 5) sampling train, however unassembled. The task of Laboratory Station 5 is for the participant to completely assemble the FRM 5 train, including attaching a nozzle, adding silica gel and water to the impingers, and inserting a filter to the assembly. Once completed, the participant is to turn on the pump and leak check the complete FRM 5 sampling train to a leak rate <0.02 cfm. After leak check, the participant positions the FRM 5 sampling train at the sampling port of the "closed-looped source simulator) and commence sampling. Sampling of the source simulator gas stream should begin while traversing the source simulator diameter until at least 21 standard cubic feet have been extracted from the source through the assembled FRM 5 sampling train.

Laboratory Station 9: Isokinetic Rate Equation and Calculations

One of the major activities associated with FRM 5 is the setting and maintaining isokinetic rate conditions during a test. One call use either a nomograph to assist with this or use of applicable software. The objective of Laboratory Station 9 is to demonstrate the use of the IsoCal software spreadsheet in completing the necessary equations for proper operation of the FRM 5 sample train during sampling. The participant will be given source test data that should be entered into the lap top computer containing the IsoCal software. Based upon the data input, the participant will determine point-by-point isokinetics and average isokinetics. In addition, the participant will be able to see the variability in isokinetics as one changes the various input parameters (i.e., nozzle diameter, moisture content of stack gas etc.).

Laboratory Station 10: FRM 1 Traverse Point Determination

Federal Reference Method 1 requires that the number of traverse points for a given test be based upon the sampling port locations with reference to upstream and downstream flow disturbances. The objective of Laboratory Station 10 is to determine the number and the location of traverse points at your assigned sampling site. A measurement tape can be obtained from the Inspector's Tool Kit (see Appendix C). Once again, you will be provided with standardized procedures to assist with this task.

Source Simulator

Many of the laboratory stations outlined above require the use of a "source simulator" to complete laboratory objectives. APTI Course #450/#468 utilizes a **"closed-loop source simulator"** to re-enforce lecture objectives involving Federal Reference Methods (FRMs) 1, 2, 3, 4, and 5. The source simulator is constructed of 12" diameter galvanized air conditioning duct material configured in a closed-loop containing a 360 watt 12" blower. Ambient air is circulated within the closed-loop by the blower system. Port holes are positioned throughout the duct work to provide access to the sample gas stream. Figure 1 documents the closed-loop source simulator.

Figure 1. APTI Course #450/#468 Closed-Loop Source Simulator

The use of the closed-loop source simulator allows each participant to acquire "field experience" associated with many of EPA's FRMs and how to observe their use to quantify emissions from stationary sources.

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Laboratory
Station
1

Nozzle Diameter (D_n)

The objective of Laboratory Station 1 is to demonstrate to the participant the difficulty in measuring a proper nozzle diameter. Three (3) different Federal Reference Method 5 (FRM 5) probe nozzles are provided as part of this laboratory station. The objective is to measure the nozzle diameters (Dn) of the three nozzles using a micrometer, document the findings on the standardized calibration data sheet, and determine if the nozzles meet the requirements specified in FRM 5. The micrometer can be obtained from the Inspector's Tool Kit (see Appendix C). Probe nozzles should be inspected and calibrated in the field immediately before each use to verify that they were not damaged in transport or shipment.

Laboratory Station 1: Calibration of Sampling Nozzles

☐ Obtain three (3) different probe nozzles for this laboratory exercise. You are to calibrate three (3) nozzles.

☐ Before starting the calibration check, obtain the Probe Nozzle Diameter Calibration Data Sheet, Laboratory Station 1 Worksheet.

☐ Inspect the nozzle for nicks, dents and corrosion. If these are found, they should be corrected before calibration. Record the individual nozzle identification number for each nozzle on the Probe Nozzle Diameter Calibration Data Sheet.

☐ Place a reference mark on the nozzle. Place the nozzle at the center of the figure, as illustrated in Figure 1-1 (see also Calibration Data Sheet) and aligned reference mark with point Pl. Mark P1 position on outside of the nozzle aligned with the diameter line for P1.

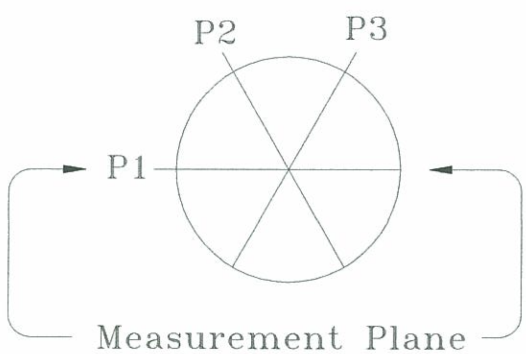


Figure 1-1. Measurement Plane for Measuring Inside Diameter of Nozzle

☐ Using a vernier or dial calipers obtained from the Inspector's Tool Kit (see Appendix C) with at least 0.025 mm (0.001 inch) tolerance, measure the inside diameter (Dn) of the nozzle from the reference mark to P1, as illustrated in Figure 1-2.

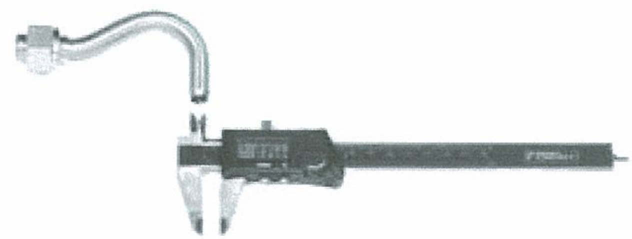


Figure 1-2. Illustration of Using Dial Caliper for Measuring Inside Diameter of Nozzle

[**NOTE:** Remember, the caliper must be zeroed and measurement should be just touching the inside of the nozzle.]

- ☐ Record your reading on the Probe Nozzle Diameter Calibration Data Sheet.
- ☐ Now place the same nozzle at the center of the figure once again, but this time rotate the reference point until it is at P2. Mark P2 on opposite outside of nozzle aligned with the diameter line for P2.
- ☐ Once again, using a vernier or dial caliper with at least 0.025 mm (0.001 inch) tolerance, measure the inside diameter of the nozzle. Remember, the calipers should just touch the inside of the nozzle.
- ☐ Record your reading on the Prober Nozzle Diameter Calibration Data Sheet.
- ☐ Now place the same nozzle at the center of the figure once again, but this time rotate the reference point until it is at P3. Mark P3 on opposite outside of nozzle aligned with the diameter line for P3.
- ☐ Once again, using vernier or dial caliper with at least 0.025 mm (0.001 inch) tolerance, measure the inside diameter of the nozzle. Remember, the calipers should just touch the inside of the nozzle.
- ☐ Record your three readings on the Probe Nozzle Diameter Calibration Data Sheet.
- ☐ Calculate the average (D_{avg}) of the three readings and the ΔD of the nozzle and record on the Probe Nozzle Diameter Calibration Data Sheet.
- ☐ Repeat the above procedure using two additional nozzles.
- ☐ If the individual readings for each nozzle do not fall within 0.1 mm (0.004 inches) of one another, the nozzle must be reshaped, re-sharpened and recalibrated.
- ☐ Sign and date the Probe Nozzle Diameter Calibration Data Sheet, Laboratory Station 1 Worksheet.

Laboratory Station 1 Worksheet

Probe Nozzle Diameter
Calibration Data Sheet

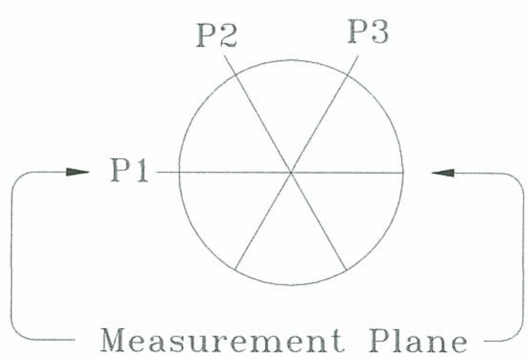
Date	Calibrated By	Nozzle ID #	Nozzle Diameter (Inches)			Hi-Lo ΔD	D_{avg}
			D1	D2	D3		

Where:

D1, D2, D3 = Three different nozzle diameters at 60 degrees to each other, each measured to the nearest 0.001 inches

Hi – Lo ΔD = Maximum diameter between any two diameters, must be ≤ 0.004 inches

$D_{avg} = (D1 + D2 + D3)/3$



Group #: ______________________________ **Date** ______________________

Laboratory Stations

2 & 3

Dry Gas Meter (DGM) "γ" and "ΔH@" Determination

Test results from a stack emission test are meaningless without calibration of the components of the Federal Reference Method 5 (FRM 5) equipment and it's components. The dry gas meter (DGM) serves to record the volume of gas sampled during the test and the orifice tube on the outlet of the DGM serves to provide flow rate determination during testing. Both of these components must be calibrated. The DGM "γ " value is a calibration factor that relates volume from a primary standard (i.e., NIST traceable critical orifices) to the recorded dry gas meter volume. The objective of Laboratory Station 2 is to use a set of calibrated orifices from the Inspector's Tool Kit (see Appendix C) to determine the "γ" of a meter box assembly containing the DGM. Once again, standardized forms are used to complete the assignment. The orifice tube calibration factor "ΔH@" is the pressure drop across the orifice for a sampling flow rate of 0.75 which is the standard sampling rate for solving the isokinetic equation and setting up the nomographs (sets of equations) for testing. The objective of Laboratory Station 3 is to use the same set of calibrated orifices to determine the orifice tube calibration factor "ΔH@". The Laboratory Station 2 and 3 Worksheet is provided at the end of this section.

Laboratory Station 2 & 3: Dry Gas Meter (DGM) "γ" Determination and "ΔH@" Determination

- ☐ Position your self in front of the Federal Reference Method 5 (FRM 5) meter console. Insure that the orange oil manometer (ΔH manometer) has been leveled and zeroed.
- ☐ Using the power toggle switch, turn on the meter box pump and adjust the ΔH using the coarse and fine adjust knobs to read~ 1.5 inches of water as illustrated by the orange oil manometer. Allow the meter box to operate for - 5 minutes to allow the system to warm up.
- ☐ Obtain Method 5 Dry Gas Meter Calibration Using Critical Orifices Form (see attached Calibration sheet) and record on the form the date, meter console number, DGM serial number, critical orifice set serial number, barometric pressure, and ambient temperature.
- ☐ Obtain from the Inspector's Tool Kit (see Appendix C) the NIST traceable Calibration Orifice Set (which contains five NIST-traceable orifices) along with the manufacturer's certification sheet (see Manufacturer Supplied Orifice Calibration Spreadsheet Example) for the five NIST-traceable orifices, as illustrated in Figure 2-1.

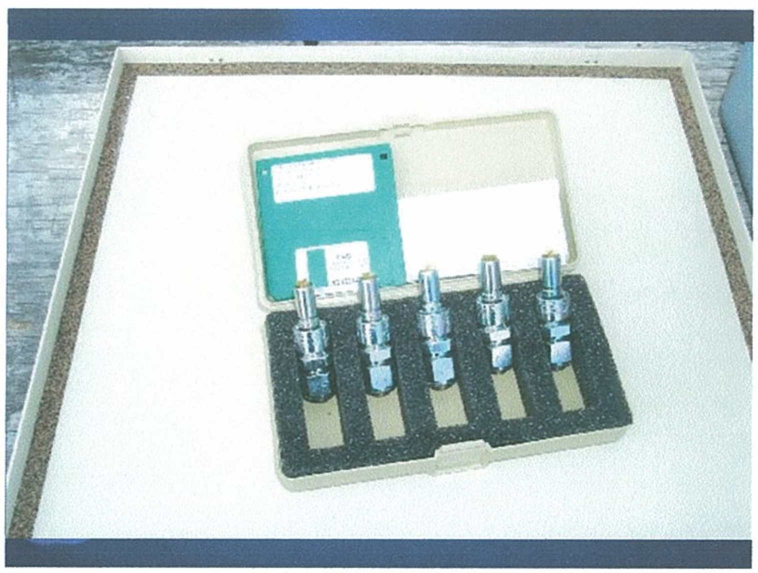


Figure 2-1. NIST-Traceable Calibration Orifice Set

Select one of the NIST-traceable orifices from the set to be used in the calibration of the DGM. Under the "Orifice #" column on the Laboratory Station 2 and 3 Worksheet, Method 5 Dry Gas

Meter Calibration Form, record the assigned orifice number as indicated from the manufacturer's certification sheet.

- ☐ From the manufacturer's certification sheet obtain for the selected NIST-traceable critical orifice the "Average K Factor Value" and record under the "K' Factor (Avg)" column on the Laboratory Station 2 & 3 Worksheet, Method 5 Dry Gas Meter Calibration Form.
- ☐ After ~5 minutes, turn off the pump.
- ☐ Insert the selected NIST-traceable critical orifice male quick connect into the inlet (SAMPLE) of the Method 5 meter console, as illustrated in Figure 2-2.

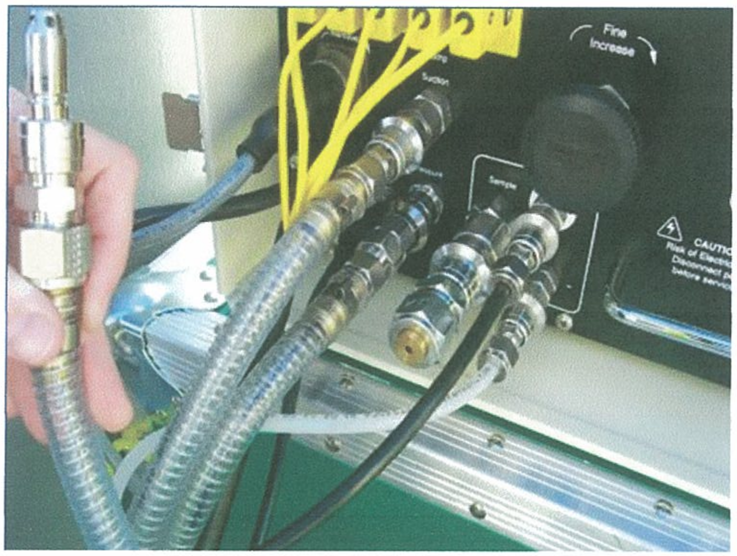


Figure 2-2. NIST-Traceable Critical Orifice Inserted Into Inlet of Method 5 Meter Console

- ☐ Record the Dry Gas Meter (DGM) initial reading on the Laboratory Station 2 & 3 Worksheet, Method 5 Dry Gas Meter Calibration Form, under the column "DGM Readings: Initial" along the row for Run # 1. Also record ambient temperature along the row for Run #1. Set the Method 5 meter console elapsed timer to zero.
- ☐ Turn on the pump and elapsed timer at the same time. Adjust the coarse and fine valves on the Method 5 meter console until a vacuum of -18 inch of mercury is indicated on the Method 5 meter box vacuum gauge. Recorded the vacuum on the Laboratory Station 2 and 3 Worksheet, Method 5 Dry Gas Meter Calibration Form under the column labeled "Test Vacuum (in. Hg)."
- ☐ Continue operating the meter console for a period of 5 minutes so you achieve a minimum total volume of 2 cubic feet through the DGM for Run #1. Record ambient temperature, DGM inlet and outlet temperatures, and "ΔH" on the Laboratory Station 2 & 3 Worksheet, Method 5 Dry Gas Meter Calibration Form during the 5-minute run.
- ☐ At the end of the elapsed time, stop the pump.
- ☐ Record the final DGM reading on the Laboratory Station 2 & 3 Worksheet, Method 5 Dry Gas Meter Calibration Form.

- ☐ Remove the first NIST-traceable orifice from the meter console and select a second NIST-traceable critical orifice and repeat the above steps.
- ☐ If time permits, select your third critical orifice and once again repeat the above steps.
- ☐ Using the equations found on bottom of the Laboratory Station 2 & 3 Worksheet, Method 5 Dry Gas Meter Calibration Form, calculate the Vm(std), Vcr(std), γ, and $\Delta H@$ associated with this Method 5 meter box.

ORIFICE CALIBRATION SPREADSHEET - APEX INSTRUMENTS
ENGLISH REFERENCE METER UNITS

DATE:	3/2/00	CALIBRATION METER S/N:	707179	LEAK CHECK:	OK
MODEL:	JC40-73	METER CONSTANT, Yc:	1.0008	FILENAME:	F:\DATAFILE\CALIBRAT\CAL_MENU.DSK\ORIFI
OPERATOR:	VHJ	BAROMETRIC PRESSURE:	29.6 (in. Hg)	REVISED:	6/8/95

RUN NUMBER	ORIFICE IDENT.	AMBIENT TEMP. (deg. F)	ACTUAL VACUUM (in. Hg)	THEORETICAL CRITICAL VACUUM (in. Hg)	DRY GAS METER READINGS INITIAL (cu. ft.)	FINAL (cu. ft.)	NET (cu. ft.)	DRY GAS METER AVG. INITIAL (deg. F)	FINAL (deg. F)	TEMP. AVG. (deg. F)	METER DELTA H (in. H2O)	TEST DURATION (minutes)	ENGLISH K FACTOR VALUE	K FACTOR VARIATION (percent)
1	40	80	26.0	14.0	455.950	464.194	8.244	77	77	77	0.30	26.0	0.2424	0.2
2	40	80	26.0	14.0	464.194	471.780	7.586	77	77	77	0.30	24.0	0.2417	-0.1
3	40	80	26.0	14.0	471.780	478.740	6.960	77	77	77	0.30	22.0	0.2419	0.0
AVG.												AVG.	0.2420	
1	48	80	25.0	14.0	478.740	491.131	12.391	77	77	77	0.65	27.0	0.3512	0.0
2	48	80	25.0	14.0	491.131	508.556	17.425	77	77	77	0.65	38.0	0.3509	-0.1
3	48	80	25.0	14.0	508.556	528.069	19.513	77	77	77	0.65	42.5	0.3513	0.1
AVG.												AVG.	0.3511	
1	55	80	24.0	14.0	528.069	538.656	10.587	77	77	77	1.10	17.5	0.4634	-0.2
2	55	77	24.0	14.0	538.656	545.944	7.288	74	74	74	1.10	12.0	0.4666	0.5
3	55	77	24.0	14.0	545.944	574.533	28.589	74	72	73	1.10	47.5	0.4632	-0.3
AVG.												AVG	0.4644	
1	63	77	22.0	14.0	574.533	600.238	25.705	72	73	73	1.80	33.5	0.5921	-0.3
2	63	77	22.0	14.0	600.238	611.428	11.190	73	73	73	1.80	14.5	0.5950	0.2
3	63	77	22.0	14.0	611.428	638.417	26.989	73	74	74	1.80	35.0	0.5940	0.0
AVG.												AVG	0.5937	
1	73	77	20.0	14.0	638.417	758.379	119.962	74	77	76	3.30	112.5	0.8213	0.1
2	73	77	20.0	14.0	758.379	790.951	32.572	77	77	77	3.30	30.5	0.8203	0.0
3	73	77	20.0	14.0	790.951	808.574	17.623	77	77	77	3.30	16.5	0.8204	0.0
AVG.												AVG	0.8206	

I certify that orifice set number JC40-73 was tested in accordance with the US EPA Method 5 standards.
See the Code of Federal Regulations, title 40, part 60, Appendix A, Method 5, Item 7.2.

Signature

Date 3-2-00

Federal Reference Method 5 Dry Gas Meter and Orifice Calibration Using Critical Orifices

Date: ______________ **Barometric Pressure (" Hg): Initial**_________**Final**___________
Group Number: ___________ **Ambient Temperature (°F): Initial**_________**Final**_________
Meter Box Number: _______________

Orifice #	Run #	K' Factor (Average From Manuf. Data Sheet)	DGM Readings (ft^3) (V_m)		DGM Temperature. (°F) (T_m)		Elapsed Time (θ)	Avg. Orifice Meter Reading (ΔH)
			Initial	Final	Initial	Final		
	1							
	2							
	3							
	1							
	2							
	3							

Calculations for γ and ΔH@

(1) $$V_{m(std)} = \frac{[(K_1)(V_m)][(P_{bar}) + (\Delta H/13.6)]]}{T_m}$$

Where:

$V_{m(std)}$ = Volume of gas sample passed through DGM (V_m) corrected to standard conditions
V_m = Volume of gas (ft^3) sampled through DGM for test run (Final – Initial)
K_1 = 17.64 °R/inches of Hg
P_{bar} = Average barometric pressure during test run ("Hg)
ΔH = Average ΔH reading during test run (in. of water)
T_m = Absolute DGM average temperature during run (°R)

(2) $V_{cr(std)} = \dfrac{[(K')(P_{bar})(\theta)]}{(T_{amb})^{1/2}}$

Where:

$V_{cr(std)}$ = Volume of gas sample passed through critical orifice corrected to standard conditions

K' = Average K' obtained from Critical Orifice Calibration Sheet for test run orifice

P_{bar} = Average barometric pressure during test run ("Hg)

Θ = Total sample time during test run (minutes)

T_{amb} = Absolute average ambient temperature (^{o}R)

(3) $\gamma = \dfrac{V_{cr(std)}}{V_{m(std)}}$

Where:

$V_{m(std)}$ = Volume of gas sample passed through DGM (V_m) corrected to standard conditions

$V_{cr(std)}$ = Volume of gas sample passed through critical orifice (V_{cr}) corrected to standard conditions

γ = Dry gas meter calibration factor (no units)

(4) $\Delta H@ = [(0.75)(\theta)/V_{cr(std)}]^2 (\Delta H) (V_{m(std)}/V_m)$

Where:

ΔH@ = Orifice pressure differential (" H_2O) that equated to 0.75 cfm of air @ 68 ^{o}F and 29.92 inches of mercury through the FRM 5 sampling train

Θ = Total sample time during test run (minutes)

$V_{cr(std)}$ = Volume of gas sample passed through critical orifice corrected to standard conditions

ΔH = Average ΔH reading during test run (in. of water)

$V_{m(std)}$ = Volume of gas sample passed through DGM (V_m) corrected to standard conditions

V_m = Volume of gas (ft^3) sampled through DGM for test run (Final – Initial)

Laboratory Results

γ = ______________________

ΔH@= ____________________

Laboratory Station

4

Determination of Flue Gas Velocity (v_s) and Volumetric Flow Rate (Q_s)

The objective of Laboratory Station 4 requires the participant to divide the stack into equal areas as instructed in Federal Reference Method 1(FRM1), mark the Type S pitot tube/probe for each sample point, and determine the stack gas velocity and volumetric flow rate at each of the sampling points in the centroid of the equal areas. The port associated with the source simulator for velocity and volumetric flow rate determination will be used. Obtain the measurement tape, Type S pitot tube, digital or water manometer, and marking liquid from the Inspector's Tool Kit (see Appendix C).

Laboratory Station #4: Determination of Flue Gas Velocity (v_s) and Volumetric Flow Rate (Q_s)

☐ Obtain a Type-S pitot tube with a known Cp and a Method 5 meter box console containing a water manometer or a digital manometer from the Inspector's Tool Kit. Examine the Type S pitot tube top, side and end views to verify that the face openings of the tube are aligned within specifications identified in Federal Reference Method 2 (FRM 2).

☐ Level and zero the Method 5 meter box water manometer identified for use in determining stack gas velocity and volumetric flow rate or zero the digital manometer.

☐ Using the standard Method 5 umbilical cable, connect the Type-S pitot tube to the umbilical cable using the quick disconnects. Connect the other end of the umbilical cable to the pitot quick connects on the Method 5 meter box console, as illustrated in Figure 4-1.

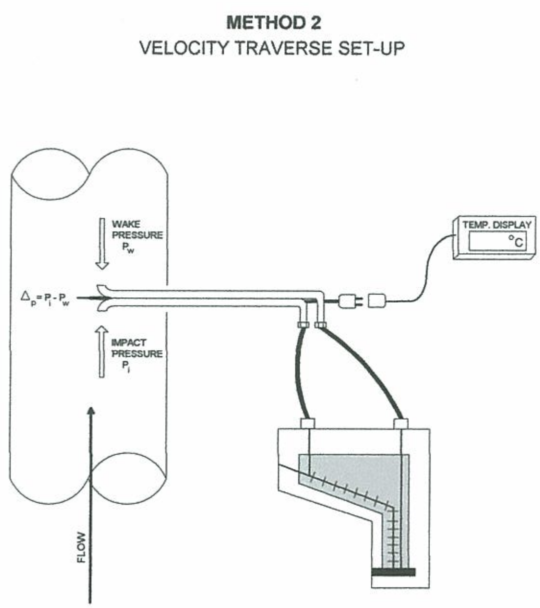


Figure 4-1. Type-S Pitot Tube Connected to FRM 5 Meter Console Containing Manometer

[Note: One should hear a "snap" when connecting quick connects to have a leak-free connection.] If not using a Method 5 umbilical cable, then connect ¼" Teflon lines to the Type-S pitot tube and opposite end to an independent digital manometer or the Method 5 meter box console using the pitot tube quick connects.

☐ Mark the impact side of the Type-S pitot tube as P_A and the other face opening as P_B.

☐ Leak-check the P_A side of the Type-S pitot tube. Attach a small piece of rubber tubing to cover the opening of the P_A side (i.e., impact side) of the Type-S pitot tube. Blow into the rubber tubing until at least 3 inches of water velocity head registers on the manometer; then, close off the impact opening. The pressure shall remain stable for at least 15 seconds. Do the same for the static pressure side, except using suction to obtain the minimum of 3 inches water.

- ☐ Retrieve the data for determination of traverse point locations for the source simulator as outlined in Laboratory Station 10. Using a measurement tape and marker, mark the determined traverse point distances on the Type S pitot tube.
- ☐ Position the Type-S pitot tube impact side (i.e., P_A side) facing the impact of the gas stream in the source simulator at Traverse Point #1 (i.e., traverse point closest to the source simulator wall). Be sure to cover the port hole with material to prevent air entering the source simulator and affecting data.
- ☐ Observe the pitot tube manometer reading (i.e., Δp) on the Method 5 box console or digital manometer and record value on the Laboratory Station 4 Worksheet, Flue Gas Velocity Data Sheet.
- ☐ Move the pitot tube to the next point, obtain a manometer reading (i.e., Δp), and record the results on the Laboratory Station 4 Worksheet, Flue Gas Velocity Data Sheet.
- ☐ Repeat the above steps for all of the traverse point for a diameter. [**Note:** Due to the source simulator construction, only one diameter will be utilized during this laboratory exercise.]
- ☐ At the last traverse point, move the pitot tube to traverse point #3 and record static pressure. Then remove pitot tube from the source simulator and cover the port hole.
- ☐ Complete the Laboratory Station 4 Worksheet, Flue Gas Velocity Data Sheet by taking the square root of each individual Δps and average the individual square root Δps.
- ☐ Calculate the source simulator flue gas velocity (v_s) and volumetric flow rate (Q_s) utilizing the equations provided. Finally, complete the Laboratory Station 4 Worksheet found at the end of this laboratory.

Laboratory Station 4 Worksheet
Flue Gas Velocity Data Sheet

FRM 2 Flue Gas Velocity Data Sheet		
Traverse Point	**Δp**	**$\sqrt{\Delta p}$**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
	$(\sqrt{\Delta p})_{avg}$	

Calculations

Flue Gas Velocity Equation

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

Where: v_s = average velocity of the gas stream, ft/sec
T_s = absolute temperature, °R (°F + 460).
(Use dry bulb temperature from Laboratory Station 6.)
P_s = absolute pressure, in. Hg (Assume P_{bar} for sampling location)
Δp = velocity pressure, in. H_2O
K_p = constant: 85.49, in units of [(ft^2)(in. Hg)(lbs/lbs-mole)/(sec^2)(in. H_2O)(°R)]
C_p = pitot tube coefficient, dimensionless
M_s = stack gas molecular weight
= $M_d(1-B_{ws}) + 18 \ B_{ws}$
(Since the source simulator uses ambient air, assume M_d = 29.0)
B_{ws} = the average moisture fraction by volume of the gas stream. Use the value determined in Station #6 (~ 2 % moisture).

$$v_s = K_p \ x \ (\qquad) \ x \ (\qquad) \ x \ \sqrt{\frac{(\qquad)}{(\qquad) x (\qquad)}}$$

Volumetric Flow Rate Equation

There are two equations used for calculating the volumetric flow rate of a flow gas. One determines the flow rate at actual stack temperature and pressure conditions. The other determines the volumetric flow rate corrected to standard conditions of 68 °F and 29.92 in. Hg. Both are important.

Actual Stack Gas Volumetric Flow Rate

$$Q_a = 3600 \ x \ v_s \ x \ A_s$$

Where: A_s = area of stack = 3.14(Diameter/2)^2

$$Q_a = 3600 \ x \ (\qquad) \ x \ (\qquad)$$

Stack Gas Volumetric Flow Rate Corrected to Standard Conditions

$$Q_{sd} = 3600\ x\ (1 - B_{ws})\ x\ v_s\ x\ A_s\ x\ \frac{T_{std}}{T_s}\ x\ \frac{P_s}{P_{std}}$$

Where: Q_s = the volumetric flow rate of the gas stream on a dry basis at standard conditions (scfh)

3600 = conversion factor (3600 sec/hr)

B_{ws} = the average moisture fraction by volume of the gas stream (dimensionless). Use the value determined in Station #6 (~ 1-2 %).

T_s = absolute temperature, ^oR ($^oF + 460$)

P_s = absolute pressure, in. Hg (Assume P_{bar})

T_{std} = the absolute temperature at standard conditions, (528 ^{o} R)

P_s = the absolute pressure at standard conditions, (29.92 in. Hg)

$$Q_{sd} = 3600\ x\ (1 - (\qquad))\ x\ (\qquad)\ x\ (\qquad)\ x\ \frac{T_{std}}{(\qquad)}\ x\ \frac{(\qquad)}{P_{std}}$$

Calculation Summary for Laboratory Station 4 Worksheet

1. No of traverse points ______________________
2. $(\sqrt{\Delta p})_{avg}$ ______________________
3. C_p ______________________
4. $T_{s(avg)}$ ______________________
5. P_s ______________________
6. M_s ______________________
7. $v_{s(avg)}$ ______________________
8. A ______________________
9. Q_s ______________________
10. Q_a ______________________

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Laboratory Station

5

Type S Pitot Tube Calibration (C_p)

As identified in Federal Reference Method 2 (FRM 2), a Stausscheibe type (i.e., Type S) pitot tube, if used for compliance determination, must be calibrated using a standard type pitot tube. The objective of Laboratory Station #5 is to follow standardized procedures as outlined in FRM 2 to calibrate a Type S pitot tube using a standard pitot tube in developing the Type-S pitot tube C_p factor. Depending upon the equipment available, you may be using either a bare Type S pitot tube or a pitot tube attached to a Method 5 sampling probe. In either case, determine the C_p for both the A and B sides of the Type S pitot tube. Entry points will be provided for inserting the Type S and standard pitot tube into the source simulator. Once again, a Laboratory Station 5 Worksheet is provided to summarize your laboratory findings.

APTI #468: MONITORING COMPLIANCE TEST AND SOURCE TEST OBSERVATION

Laboratory Station 5: Calibration of Type S Pitot Tube

☐ Locate the pitot tube calibration ports on the source simulator.
☐ At the test station, note two holes in the ductwork, as illustrated in Figure 5-1.

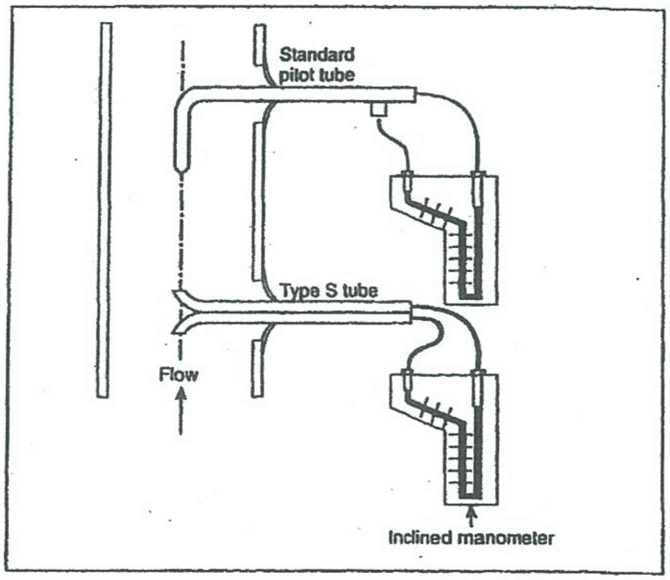

Figure 5-1. Two Sampling Ports for Insertion of Type S and Standard Pitot Tubes

[Note: The sampling port for the standard pitot tube is downstream of the port for the Type S pitot tube. The port for the standard pitot tube should be located in such a manner that the tip of the standard pitot tube will be measuring the gas pressure at the same location in the stack gas as the impact side of the Type S pitot tube.]

☐ If using incline manometers for documenting pressure drops across the Type S and standard pitot tubes, then set-up, level, and zero the inclined manometer. Make sure that any valves on the manometer are in the "open" position. If you are using an electronic manometer, then zero the electronic manometer without tubes attached.
☐ Label one leg of the Type S pitot tube as "A" and the other leg as "B."
☐ Determine the distance from the center of the duct to the outside wall of the duct. Insert the Type S pitot tube so that the center of the impact tube is located at the center of the duct. Place a mark on the tube such that when the mark is placed at the outside edge of the duct, the tip of the Type S pitot tube is at the center of the duct.
☐ Repeat the same steps for the standard pitot tube.
☐ Connect the Type S pitot tube to the manometer on the Method 5 meter console or to the electronic manometer by way of umbilical cord or Teflon tubing. Leak check the Type S pitot tube as performed in Laboratory Station 4.

☐ Insert the Type S pitot tube into the duct until the mark is at the outside edge of the duct wall, as illustrated in Figure 5-2.

☐ Align the Type S pitot tube so that the "A" leg faces directly into the flow stream. Tape the port hole with duct tape to minimize air leakage into the duct.

☐ On the Laboratory Station 5 Worksheet, Calibration of Type S Pitot Tube, record the Δp, in inches of H_20, indicated by either the water manometer or the electronic manometer.

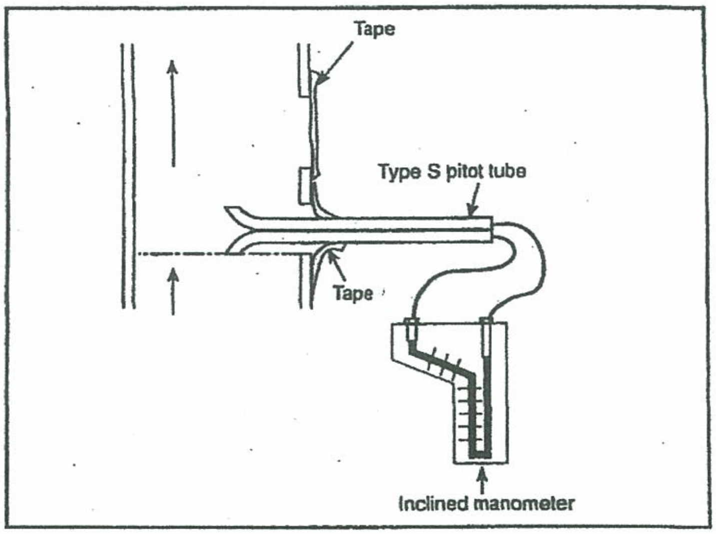

Figure 5-2. Insertion of Type S Pitot Tube Into Source Simulator

☐ Disconnect the umbilical cord or Teflon lines from the Type S pitot tube and attach them to the standard pitot tube.

☐ Insert the standard pitot tube into the duct until the mark is at the outside edge of the duct wall.

☐ Align the tube so that it faces directly into the flow stream and the center of the tube is in exactly the same location in the duct as the Type S pitot tube was, as illustrated in Figure 5-3.

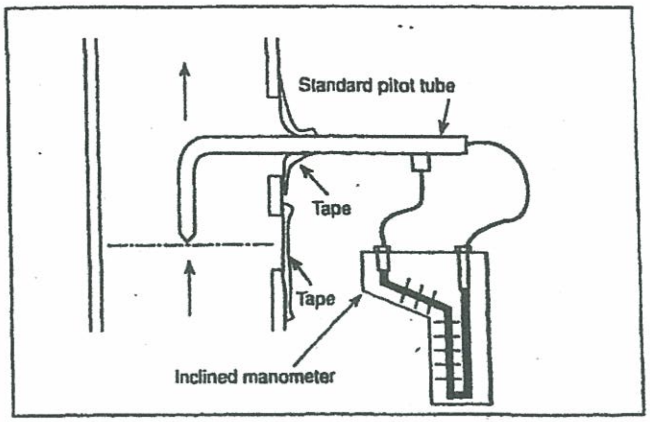

Figure 5-3. Insertion of Standard Pitot Tube Into Source Simulator

- ☐ On the Laboratory Station 5 Worksheet, Calibration of Type S Pitot Tube, record the Δp, in inches of H_20, indicated by either the water manometer or the electronic manometer for the standard pitot tube.
- ☐ Repeat the above steps for "B" side of Type S pitot tube. [**Note:** This means that you must also obtain another measurement with the standard tube.]
- ☐ Perform a second calibration run by repeating the above steps for calibration of the Type S pitot tube against a standard pitot tube.
- ☐ Perform a third calibration run by repeating the above steps for calibration of the Type S pitot tube against a standard pitot tube.
- ☐ After three (3) runs, determine the Cp for both the "A" and "B" side of the Type S pitot tube utilizing the following equation:

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

Assume $C_{p(std)} = 0.99$

- ☐ Obtain the average C_p for leg A and leg B of the Type S pitot tube and record the result on the Laboratory Station 5 Worksheet, Type S Pitot Tube Coefficient Data Form.

Laboratory Station 5 Worksheet
Calibration of Type S Pitot Tube Form

Date: ______________________________

Time: ______________________________

Tester: ______________________________

Location: ______________________________

Type S Pitot Tube Identification Number: ______________________________

NIST Traceable Standard Pitot Tube Identification Number: ____________________

NIST Traceable Standard Pitot Tube C_p Value: 0.99

Type S Pitot Tube Calibration Form					
	Leg A, B of Type S Pitot Tube	Standard Pitot Tube Δp (in. H_2O)	Type S Pitot Tube Δp (in. H_2O)	$C_p(s)$ Leg A	$C_p(s)$ Leg B
Test 1	A				
	B				
Test 2	A				
	B				
Test 3	A				
	B				
			$C_{p(s)}$ Average		

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

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Laboratory Station

6

Stack Gas Moisture

One of the most important parameters to estimate correctly when selecting your nozzle diameter and setting up your isokinetic rate equation is the stack gas moisture (B_{ws}). For every % stack gas moisture you estimate incorrectly will cause your % isokinetics to be off the same %. The objective of Laboratory Station 6 is to determine the stack gas moisture content of the source simulator using three (3) estimation techniques. They are:

- **Wet bulb/dry bulb technique;**
- **Nomograph technique; and**
- **Psychometric chart technique.**

Complete the laboratory exercises and record your results on the Laboratory Station 6 Worksheet.

APTI #468: MONITORING COMPLIANCE TEST AND SOURCE TEST OBSERVATION

Moisture Determination Using Wet Bulb/dry Bulb Technique

☐ The determination of a stack gas wet and dry bulb temperatures can be accomplished with either thermocouples or in-glass mercury thermometers, as illustrated in Figure 6-1. This experiment involves recording both the dry bulb and wet temperatures of the stack gas in order to calculate percent (%) moisture of the stack gas.

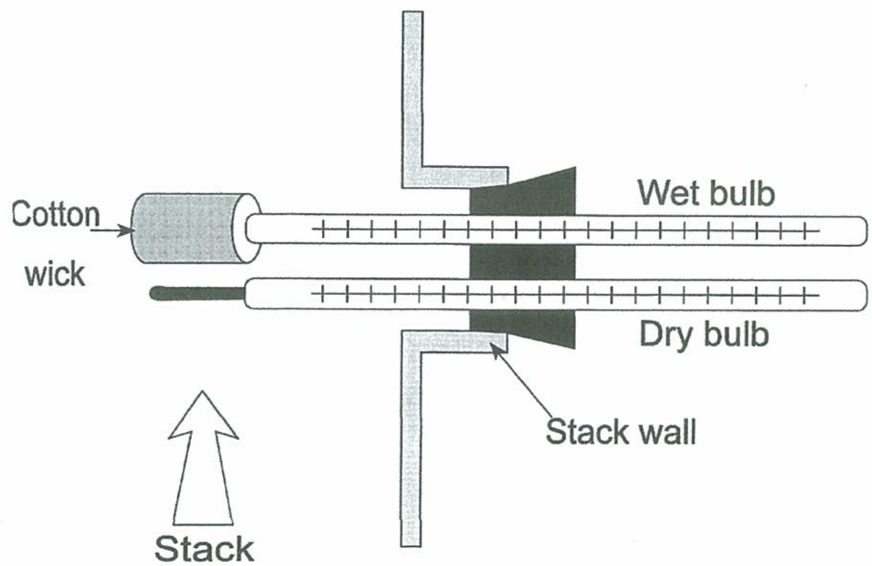

Figure 6-1. Test Arrangement For Wet Bulb-Dry Bulb Technique Using In-Glass Mercury Thermometers For Moisture Determination

During this exercise, we will use a Type K thermocouple attached to a hand held digital temperature display.

☐ Obtain the Type K thermocouple with the hand held digital temperature display along with a cotton sleeve and a 50-mL beaker containing distilled-deionized (DI) water from the Inspector's Tool Kit (see Appendix C).

☐ Attach the Type K thermocouple with standard plug to the hand held digital temperature instrument. Turn on the hand held digital temperature instrument and verify that the measurement scale records in ° F.

☐ Using any port on the source simulator, insert the Type K thermocouple into the gas stream at the center of the stack. Cover the port hole with duct tape or a rag so that air does not leak in. Allow the thermocouple to come into equilibrium with the flue gas temperature. Read the temperature indicated by the hand held digital temperature instrument.

☐ Record the dry bulb/flue gas temperature.

Dry bulb temperature: ________________ ° F

☐ Once equilibrium has been reached and the dry bulb temperature recorded, remove the Type K thermocouple from the stack gas and cover the thermocouple with a cotton sleeve. Secure the sleeve over the thermocouple with some tape.
☐ Dip the end of the thermocouple with the cotton sleeve into water to saturate the wick.
☐ Insert the sleeve covered thermocouple into the duct and allow the thermocouple to come into equilibrium with the flue gas temperature. The temperature reading (as a function of time elapsed) should change in a manner indicated by Figure 6-2.

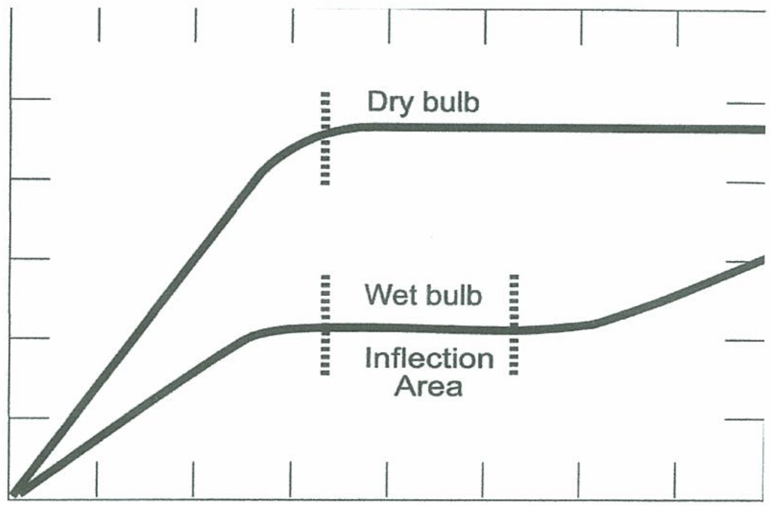

Figure 6-2. Equilibrium and Inflection Points of Dry Bulb and Wet Bulb Thermocouples

☐ The temperature of the wet bulb thermocouple will rise to an equilibrium value, and then drying out, will reach the temperature of the dry bulb temperature (i.e., flue gas) if allowed to remain for a period of time.
☐ Read the wet bulb temperature at the first equilibrium value (the inflection point) and record this temperature as the wet bulb temperature.

Wet Bulb Temperature ______________________________ °F

☐ Obtain a value for the current barometric pressure, P_{bar}, by either asking the instructor or obtaining the local barometric pressure from the National Weather Service using the computer or phoning the local weather station.
☐ Obtain a value for p_s, the stack static pressure, by inserting a standard pitot tube into the center of the duct and measuring the pressure on the static tap of the tube. If the stack pressure is positive, attach the tube to the left-hand side of the manometer. If the stack pressure is negative, attach the tube to the right-hand side of the manometer.
☐ Moisture content can be calculated (using the wet bulb-dry bulb technique) from the following equations:

$$B_{ws} = \frac{v.p.}{P_s}$$

Where: v.p. = vapor pressure of H_2O
Ps = absolute pressure of stack gas

☐ First solve for v.p.:

$$\mathbf{v.p .= s.v.p. - (3.67 \times 10^{-4})(P_s)(t_d\text{-}t_w)\left(1 + \frac{T_w - 32}{1571}\right)}$$

Where: s.v.p. = saturated H_2O vapor pressure at wet bulb temperatures taken from Table 6-1.
t_d = temperature of dry bulb measurement, ^oF
t_w = temperature of wet bulb measurement, ^oF
P_s = absolute pressure of stack gas = $P_{bar} + p_s$

v.p. = (_______in. Hg) – (3.67x10^{-4})(_______in. Hg)(_______-_______)(1 + ____ - 32/1571)
=(__________in. Hg) – (___________in. Hg)
= ____________in. Hg

☐ Determine P_s:

P_s = ________in. Hg + ________in. H_2O/in. Hg

P_s =________in. Hg

☐ Supplying all unknown into the $\mathbf{B_{ws}} = \frac{v.p.}{P_s}$ equation:

B_{ws} = ________ in. Hg /________ in. Hg = __________ X 100 = ________%

Table 6-1. Saturated Water Vapor Pressure (Inches of Mercury)

Wet Bulb Temp. Degree F	Saturated Water Vapor Pressure (Inches of Mercury)									
	0	1	2	3	4	5	6	7	8	9
-20	.0129	.0119	.0112	.0106	.0100	.0095	.0089	.0084	.0080	.0075
-10	.0222	.0209	.0199	.0187	.0178	.0168	.0156	.0150	.0142	.0134
0	.0376	.0398	.0417	.0463	.0441	.0489	.0517	.0541	.0571	.0598
10	.0631	.0660	.0696	.0728	.0768	.0810	.0846	.0892	.0932	.0982
20	.1025	.1080	.1127	.1186	.1248	.1302	.1370	.1429	.1502	.1567
30	.1647	.1716	.1803	.1878	.1955	.2035	.2118	.2203	.2292	.2382
40	.2478	.2576	.2677	.2782	.2891	.3004	.3120	.3240	.3364	.3493
50	.3626	.3764	.3906	.4052	.4203	.4359	.4520	.4586	.4858	.5035
60	.5218	.5407	.5601	.5802	.6009	.6222	.6442	.6669	.6903	.7144
70	.7392	.7648	.7912	.8183	.8462	.8750	.9048	.9352	.9666	.9989
80	1.032	1.066	1.102	1.138	1.175	1.213	1.253	1.293	1.335	1.378
90	1.422	1.467	1.513	1.561	1.610	1.660	1.712	1.765	1.819	1.875

☐ Record your results below and on the Laboratory Station 6 Worksheet located at the end of this laboratory instructions.

% Moisture = ____________________ %

Moisture Determination Using Nomograph Technique

☐ Another technique for determining approximate moisture in the flue gas is by the use of a nomograph. Nomographs are mathematically constructed to solve various equations when known process information is supplied. While nomographs may not be as accurate as an actual analysis, they do provide a useful approximate moisture determination. To properly use the nomograph, obtain the wet bulb and dry bulb temperatures from the previous exercise and determine the wet bulb/dry bulb depression.

$$\text{Depression} = t_d - t_w$$

$$= \_\_\_\_\_\_ {}^{o}F - \_\_\_\_\_\_ {}^{o}F$$

$$= \_\_\_\_\_\_\_\_\_\_ {}^{o}F$$

☐ On the line from absolute stack gas pressure to wet bulb depression temperature, mark the pivot point on line 1, using Figure 6-3.

[NOTE: Because we are testing ambient air in the "enclosed-loop source simulator," one will have to extrapolate the nomograph down in order to determine % moisture.]

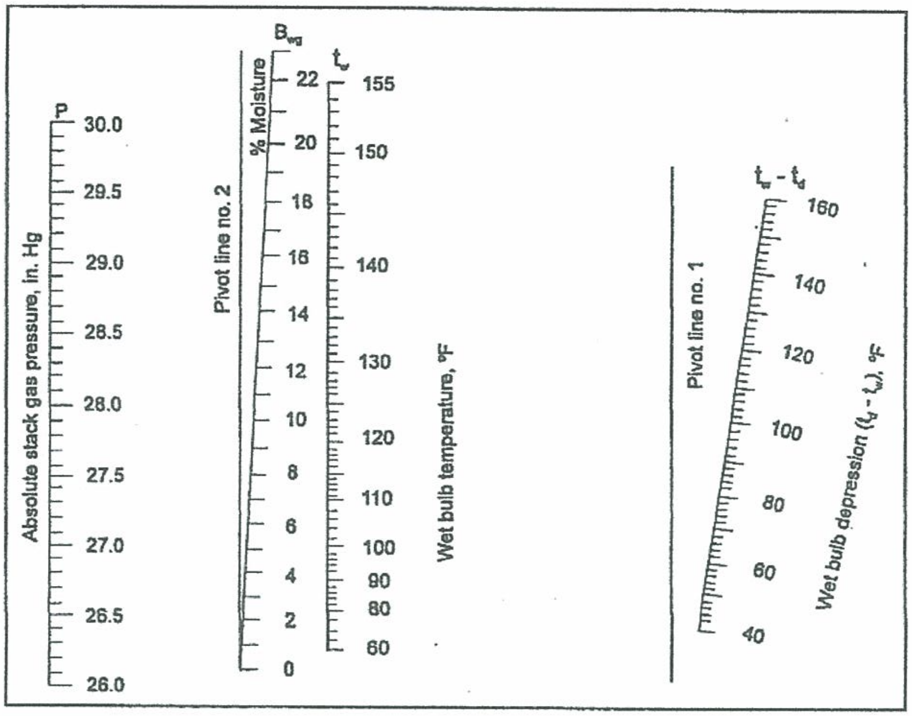

Figure 6-3. Determination of % Moisture Using Nomograph Technique

- ☐ From the pivot point online 1 to the t_w, mark the pivot point on line 2.
- ☐ From the absolute stack gas pressure through the mark on pivot point on line 2, read % H_20 on scale $B_{ws.}$ Record your results below and on the Laboratory Station 6 Worksheet located at the end of this laboratory instructions.

% Moisture = ____________________ %

Moisture Determination Using Psychrometric Chart Technique

- ☐ Moisture concentration of a stack gas can also be determining using the psychrometric chart technique if one knows the wet bulb and dry bulb temperatures. Figure 6-4 illustrates how to use a psychrometric chart utilizing the wet bulb and dry bulb temperatures.
- ☐ Using Figure 6-5, find the dry bulb temperature on the X-axis.
- ☐ Now find the wet bulb temperature on the saturation line (wet bulb temperature line).
- ☐ Draw a line "up" from the dry bulb temperature.
- ☐ Draw a line sideways from the wet bulb temperature.

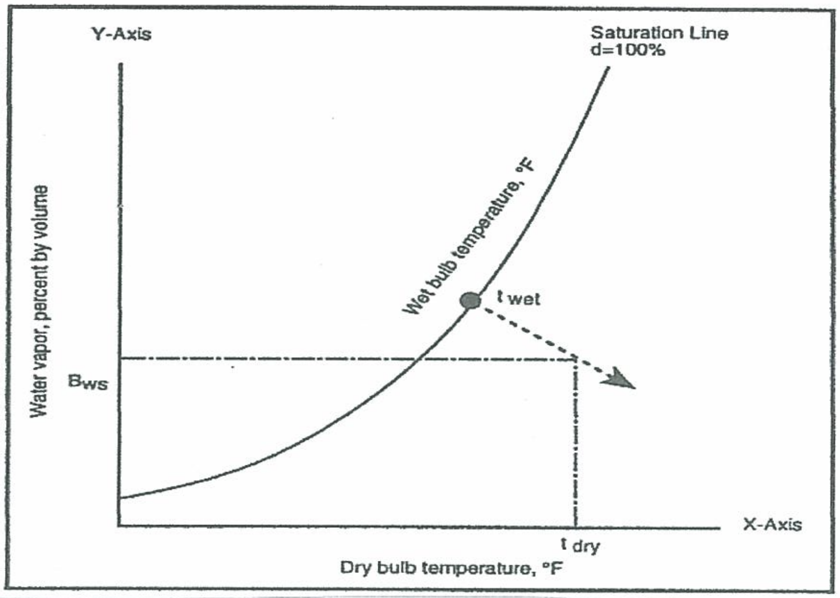

Figure 6-4. Using A Psychrometric Chart

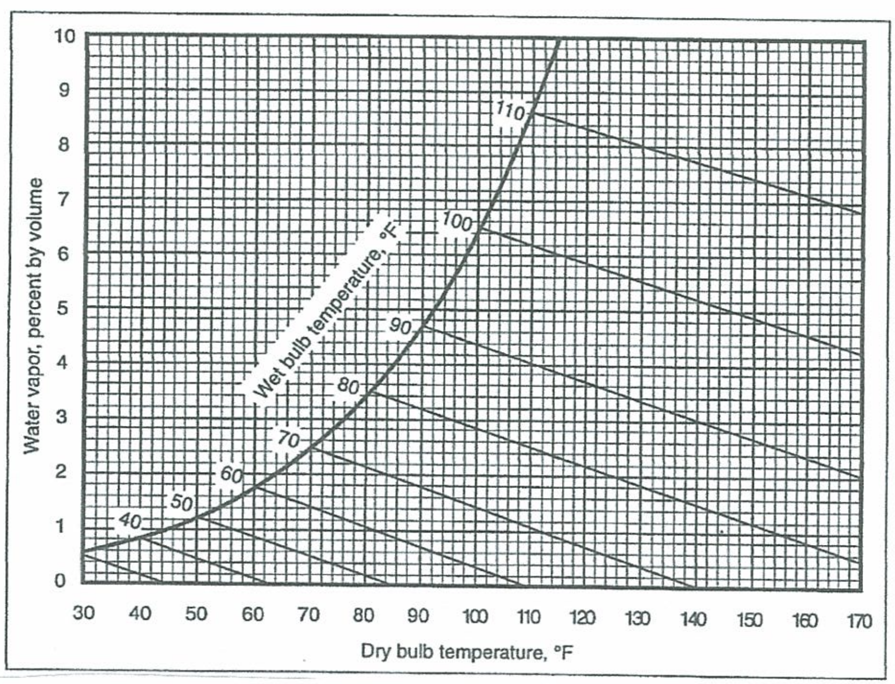

Figure 6-5. Psychrometric Chart Expressing Volume of Water Vapor by Percent

☐ The point of intersection on the two lines is read as the percent water vapor on the Y-axis. Record your results below and on the Laboratory Station 6 Worksheet located at the end of this laboratory instructions.

% Moisture = ________________ %

Laboratory Station 6 Worksheet
Moisture Determination Using Wet Bulb/dry Bulb Technique

- ☐ Retrieve the results from the various methods for determination of moisture in a stack gas.
- ☐ Record the results below.

1. **B_{ws} ____________________ % Calculation Method**
2. **B_{ws} ____________________ % Nomograph Method**
3. **B_{ws} ____________________ % Psychrometric Chart Method**

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Laboratory Station

7

Pitot Tube Inspection

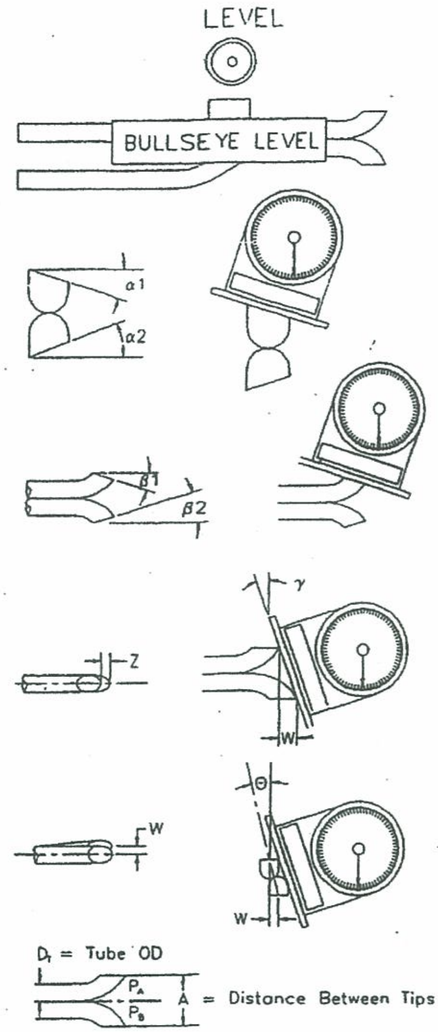
In order to assign a known pitot tube coefficient factor, C_p, the pitot tube must meet certain design and construction requirements as identified in Federal Reference Method 2 (FRM 2) inorder to assign a value of 0.84. To complete this exercise, you will be given a Type S pitot tube along with a "bulls eye" and level indicator from the Inspector's Tool Kit (see Appendix C). Using the Laboratory Station 7 Worksheet, inspect the Type S pitot tube and see if it meets specifications as defined by Federal Reference Method 2 (FRM 2) by evaluating the pitot tubes α, β, z, w and A characteristics so a C_p of 0.84 can be assigned to the Type S pitot tube.

APTI #468: MONITORING COMPLIANCE TEST AND SOURCE TEST OBSERVATION

Pitot Tube Inspection

- ☐ Obtain a traditional Type S pitot tube to be used in this laboratory exercise. Also obtain a dial caliper, bull's eye level, and a level indicator from the Inspector's Tool Kit (see Appendix C)..
- ☐ Before starting the inspection check, obtain the Laboratory Station 7 Worksheet (i.e., Type S Pitot Tube Inspection Data Sheet).
- ☐ Clamp the Type S pitot tube so that it is level, verify and record on Inspection Data Sheet.
- ☐ Verify that the Type S pitot openings are not damaged or obstructed and record on the Laboratory Station 7 Worksheet.
- ☐ Using an angle indicator, measure the angles (α1 and α2) between the pitot tube opening plane and the horizontal plane when viewed from the end, and record on the Laboratory Station 7 Worksheet.
- ☐ Measure the angles (β1 and β2) between the pitot tube opening plane and the horizontal plane when viewed from the side, and record on the Laboratory Station 7 Worksheet.
- ☐ Calculate the difference in length between the two pitot tube legs (Z) by measuring the angle ☐ and record on the Laboratory Station 7 Worksheet.
- ☐ Calculate the distance that the Type S pitot tube legs are rotated (W) by measuring the angle ☐ and record on the Laboratory Station 7 Worksheet.
- ☐ Measure and record the vertical distances (P_A and P_B) between each pitot tube opening plane and the center line of the Type S pitot tube and record on the Laboratory Station 7 Worksheet.
- ☐ Measure and record the tube external diameter (D_T) and calculate the minimum and maximum values of P_A and P_B and record on the Laboratory Station 7 Worksheet.
- ☐ If the Type S pitot meets the construction specifications, then sign and date the Laboratory Station 7 Worksheet (i.e., Type S Pitot Tube Inspection Data Sheet).

Laboratory Station 7 Worksheet
Type S Pitot Tube Inspection Data Sheet



Parameter	Value	Allowable Range
Assembly Level?		Yes
Holes Damaged?		No
Obstructed?		No
$\alpha 1$		$-10° < \alpha 1 < +10°$
$\alpha 2$		$-10° < \alpha 2 < +10°$
$\beta 1$		$-5° < \beta 1 < +5°$
$\beta 2$		$-5° < \beta 2 < +5°$
γ		
θ		
A		for 1/4" OD, 0.526 to 0.750 for 3/8" OD, 0.788 to 1.125
$Z = A \sin \gamma$		$Z = \leq 0.125"$
$W = A \sin \theta$		$W = \leq 0.031"$
P_A		for 1/4" OD, 0.263 to 0.375 for 3/8" OD, 0.394 to 0.563
P_B		for 1/4" OD, 0.263 to 0.375 for 3/8" OD, 0.394 to 0.563
$P_A - P_B$		-0.063 to 0.063"
D_T		0.188 to 0.375"

Certification

I certify that the Type S pitot tube/probe ID # ______________ meets or exceeds all specifications, criteria and/or applicable design features and is hereby assigned a pitot tube calibration factor C_p of 0.84

Certified By:

______________________ Personnel (Signature/Date)

______________________ Team Leader (Signature/Date)

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Laboratory Station

8

Federal Reference Method 5 (FRM 5) Sampling Train

Federal Reference Method 5 (FRM 5) is the principal method used for sampling particulate matter from industrial sources. However, other particulate sampling methods can also be used and may be applied for specific source categories. These methods include the FRM 8 and 17, given in 40CFR60, Appendix A and the PM-10 sampling methods given in 40CFR51, Appendix M. Equivalent methods for special purposes, or when emissions from a given facility are not capable of being measured by FRM 5, are also used. However, their use is generally subject to the approval of the agency administrator.

The objective of Laboratory Station 5 is to assemble the FRM 5 sampling train, charging the filter holder with a filter, and charging the impingers with water and silica gel. Once assembled, your objective is to "leak check" the train to see if you indeed assembled the system properly. Once the "leak check" has been completed, it is your task to use data from the other laboratory stations and determine a correct D_n and "K" factor in order to set-up the isokinetic rate equation. Once the isokinetic rate equation has been established, complete all data entry to the Laboratory Station 8 Worksheet [i.e., FRM 5 Field Test Data Sheet (FTDS)] and prepare to sample the source simulator gas stream. We will only sample 4 traverse points on a single diagonal at the source simulator. Sample the 4 points for 5 minutes each maintaining isokinetic conditions. After sampling is complete, remove the sampling train from the monorail and recover the filter, water and silica gel. Use the equations in the procedure to complete the emission calculations.

APTI #468: MONITORING COMPLIANCE TEST AND SOURCE TEST OBSERVATION

Federal Reference Method 5 (FRM 5) Sampling Train

- ☐ **Pre-Test Preparation**
- ☐ Obtain a filter from the laboratory equipment supply and check the filter visually against light for irregularities and flaws or pinhole leaks. Label the filter on the back side near the edge using numbering machine ink.
- ☐ The filters have been desiccated at 20° ± 5.6°C and ambient pressure for ≥ 24 hr, and weighted at intervals of ≥ 6 hr to a constant weight (≤ 0.5 mg change from previous weighing). Record weight on your Laboratory Station 8 Worksheet/Field Test Data Sheet (FTDS).
- ☐ The probe liners and probe nozzles have been internally brushed, first with tap water, then distilled/deionized water, followed by reagent-grade acetone. The probe liner and probe nozzle have been rinsed with acetone and allow to air-dry. Inspect visually for cleanliness and repeat the procedure if necessary. Cover the probe liner openings to avoid contamination. Nozzles should be kept in a case to avoid contamination or damage to the knife-edge. ***Note:*** Special cleaning procedures may be required for other test methods (for example, metals or dioxin).
- ☐ The glassware (filter assemblies, impingers and connecting glassware) have been cleaned internally by wiping the joints, washing with glass cleaning detergent, rinsing with distilled/de-ionized water, followed by reagent-grade acetone, and then allow to air-dry. All exposed openings have been covered with parafilm, plastic caps, serum caps, ground-glass stoppers or aluminum foil (not for metals!) to avoid contamination. ***Note:*** Special cleaning procedures may be required for other test method (for example, metals or dioxin).
- ☐ **Preliminary Determinations**
- ☐ Select the sampling site, measure the stack or duct dimensions, and determine the number of traverse points (Use Federal Reference Method 1 Laboratory Station 10 results).
- ☐ Determine the stack gas pressure, range of velocity pressure heads, and temperature (Use Federal Reference Method 2 Laboratory Station 4 results)
- ☐ Determine or estimate the dry molecular weight (Use Federal Reference Method 3 Laboratory Station 6 results).
- ☐ Determine the moisture content of the stack gas (Use Federal Reference Method 4 Laboratory Station 6 results).
- ☐ Select a suitable probe assembly length such that all traverse points can be sampled.
- ☐ Using the following equation, calculate an estimated nozzle diameter (D_n) using the values from other laboratory stations.

$$D_{n(est)} = \sqrt{\frac{K_5 Q_m P_m}{T_m C_p (1 - B_{ws})} \sqrt{\frac{T_s M_s}{P_s \Delta p_{avg}}}}$$

[NOTE: Assume the following values to complete the selection of the nozzle:

K_5 = 0.03850
Q_m = 0.75 cfm
P_m = Barometric pressure at laboratory site (inches of mercury)

T_m = 68 °F + 25 °F+ 460 = 553 °R
C_p = 0.84
B_{ws} = 2.0%
T_s = 68 °F + 25 °F+ 460 = 553 °R
M_s = 29 lb/lb-mole
P_s = Barometric pressure at laboratory site (inches of mercury)
$\Delta p_{(avg)}$ = Source simulator $\Delta p_{(avg)}$ value (inches of water).]

- ☐ Select a nozzle from the FRM 5 nozzle set that closest measures the same diameter as the calculated value. Refer to Appendix A for definition of abbreviations and terminology.
- ☐ After selecting the appropriate nozzle, determine the K-factor for the isokinetic sampling rate using the following equation **(K-factor should be <10).**

[NOTE: Use the same values for the various terms illustrated above for estimating K-factor.]

$$K = \frac{\Delta H}{\Delta p} = K_6 \, D_n^4 \, \Delta H_@ \, C_p^2 (1 - B_{ws})^2 \, \frac{M_d \, T_m \, P_s}{M_s \, T_s \, P_m}$$

Where:

D_n = Actual nozzle diameter selected **(NOT ESTIMATED NOZZLE DIAMETER),** inches
K_6 = 846.72 (English units)
$\Delta H@$ = 1.84

- ☐ Select the total sampling time (we will use 20 minutes) and standard gas sample volume specified in the test procedures for the specific industry. Select equal sampling times of 5 minutes per traverse point.

C. Preparation of Sampling Train

- ☐ Mark the probe assembly with heat-resistant tape or "White-Out" to denote the proper distance into the stack or duct for each sampling point.
- ☐ Insert the probe nozzle into the probe sheath union, and finger tight the union fitting. Avoid over tightening to prevent cracking the glass probe liner. Keep the nozzle tip and the ball joint on the probe liner covered until the assembly of the train is complete and sampling is about to begin. Secure the probe assembly to the sample case by tightening the probe clamp.
- ☐ Prepare each set of impingers for a sampling run
    - ☐ Impingers 1 & 2: 100 mL water in each
    - ☐ Impinger 3: Empty
    - ☐ Impinger 4: 200 to 300 g of silica gel
- ☐ Weigh each impinger to the nearest ± 0.5 g using a top-loading electronic balance, as illustrated in Figure 8-1. Record initial weights on the Laboratory Station 8 field test data sheet (FTDS).

Figure 8-1. Top-Loading Electronic Balance for Weighting

☐ Assemble the impingers in the cold box with U-tubes, double "L" adapter, and the sample case/umbilical adapter, using ball joint clamps or clips, as illustrated in Figure 8-2.

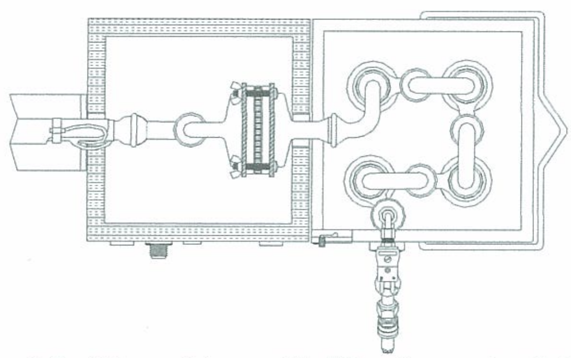

Figure 8-2. View of Assembled Impingers in Cold Box

☐ Using tweezers or clean disposable surgical gloves, place the tared filter on the grooved side of the TFE filter support in the filter holder, as illustrated in Figure 8-3. Check the filter for tears after placement, and center on the filter support. Assemble the filter holder and tighten the clamps around the filter holder to prevent leakage around the O-ring. Record filter number on the Laboratory Station 8 FTDS.

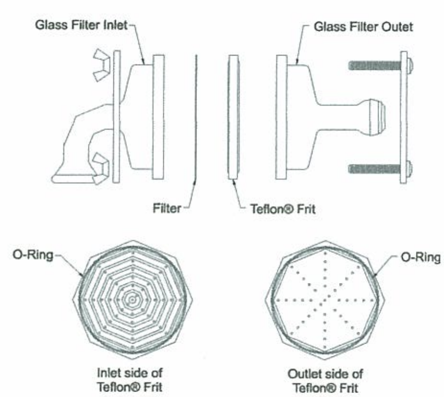

Figure 8-3. Exploded View of Filter Assembly

- ☐ Connect the filter holder and cyclone bypass (if applicable) in the hot box to the probe liner ball joint and to the "L" adapter using ball joint clamps. Close the hot box doors and fasten shut.
- ☐ Connect the umbilical cable electrical and pitot tube line connections to the assembled sampling train and to the source sampler console, as illustrated in Figure 8-4.

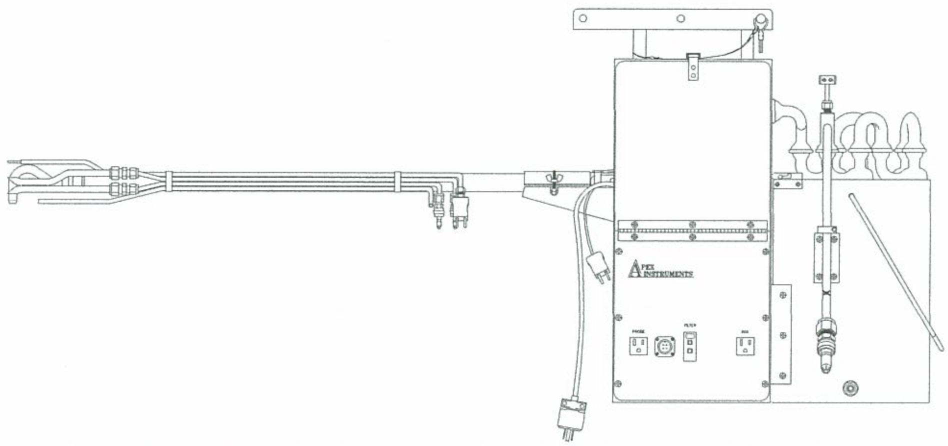

Figure 8-4. Assembled Sampling Train Before Umbilical Hookup

- ☐ Place the assembled sampling train near the sampling port, either on the monorail or other support.
- ☐ Turn on and set probe and hot box heaters. Allow the hot box and probe to heat for at least 15 minutes before starting the test, and make periodic checks and adjustments to ensure the desired temperatures. Check all thermocouple connections by dialing through each selection and noting ambient or heated temperatures. Place crushed ice and a little water around the impingers.
- ☐ Leak-check the sampling train (see Leak-Check Procedure for Isokinetic Sampling Trains in Method 4 and Pitot Tube and Line Leak-Check in Method 2) by putting your finger over the opening of the nozzle and start the pump by pushing down on the toggle switch. Now adjust the vacuum in the sampling train to – 15 ' Hg using both the coarse and fine adjust knobs. The dry gas meter should not rotate more than 0.02 ft^3 for one minute to have a successful leak check. If passed, then slowly remove the finger until the vacuum gauge is below 5 " Hg vacuum, then remove the finger totally and cut off the pump. Record leak rate on Laboratory Station 8 FTDS.

D. Sampling Run Procedure

- ☐ Open and clean the portholes of dust and debris
- ☐ Level and zero the Δp and ΔH manometers on the meter box.
- ☐ Record the initial dry gas meter (DGM) reading on the Laboratory Station 8 FTDS.
- ☐ Remove the nozzle cap, verify that the hot box/filter and probe heating systems are up to temperature, and check pitot tube, temperature gauge, and probe alignments and clearances.
- ☐ Close the coarse valve and fully open the fine valve. Position the nozzle at the first traverse point. Record the clock time, read Δp on the manometer and determine ΔH from your calculations using the calculated "K" factor. Immediately start the pump, and adjust the flow to set the ΔH, first by adjusting the coarse valve and then the fine adjust valve. [*Note:* If necessary

to overcome high negative stack pressure, turn on the pump while positioning the nozzle at the first traverse point.]

- ☐ When the probe is in position, block off the openings around the probe and porthole using duct tape, rags, gloves or towels (or flameproof materials for hot stacks), as illustrated in Figure 8-5.

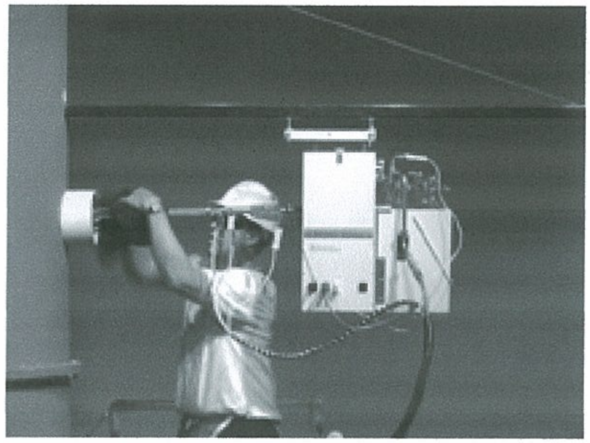

Figure 8-5. Blocking off the Porthole During Sampling

- ☐ Record the ΔH, pump vacuum and temperatures for stack gas, DGM, filter box, probe, and impinger exit on the Laboratory Station 8 FTDS for Point #1. Record the ID numbers for DGM, thermocouples, pitot tube, and sample box.
- ☐ Traverse the stack cross-section for the same time (~ 5 minutes) period at each sampling point (4 sampling points) without turning off the pump except when changing ports. *Do not bump the probe nozzle into the stack walls.*
  - ☐ Maintain the temperature of the hot box (probe outlet or filter outlet) at the proper level.
  - ☐ Monitor the Δp during each point, and if the Δp changes by more than 20%, another set of readings should be recorded.
  - ☐ Periodically check the level and zero of the manometers, and re-adjust if necessary.
  - ☐ Record DGM readings at the beginning and end of each sampling time increment, before and after each leak-check, and when sampling is halted.
  - ☐ Take other readings (ΔH, temps, vacuum) at least once each sample point during each time increment, maintaining the ΔH/Δp isokinetic ratio.
  - ☐ Add more ice and, if necessary, salt to maintain a temperature <20°C (68°F) at the silica gel impinger exit.
- ☐ At the end of the sample run, turn off the coarse valve, remove the probe and nozzle from the stack, turn off the pump and heaters, and record the final DGM reading on the Laboratory Station 8 FTDS.
- ☐ ***[Mandatory:*** Leak-Check the sampling train at the maximum vacuum achieved during the sample run. Record leak-check results on the Laboratory Station 8 FTDS.]
- ☐ ***[Mandatory:*** Leak-Check the pitot lines. Record on the Laboratory Station 8 FTDS.]

- ☐ Allow the probe to cool. Wipe off all external particulate material near the tip of the probe nozzle, and cap the nozzle to prevent contamination or loss of sample. *Hint:* Open the hot box doors to allow the filter holder to cool.
- ☐ Before moving the sampling train to the cleanup site, disconnect the probe from the inlet and cover both ends. Do not lose any condensate that might be present. Disconnect the filter holder from the "L" Adapter and cap off the filter holder.
- ☐ Disconnect the umbilical cable from the sample box and cover the last impinger outlet and first impinger inlet. Disconnect the cold box from the hot box. The probe/nozzle assembly, filter holder, and impinger case are ready for sample recovery.
- ☐ Transfer the probe and filter-impinger assembly to a cleanup area that is clean and protected from the wind.

E. Sample Recovery

[Note: Sample Recovery is extremely important because that is where sample loss can occur (bias results low due to sampler errors or blunders) or contamination can be introduced (bias results high).]

- ☐ Place 200 ml of acetone from the wash bottle being used for cleanup in a glass sample container labeled "Acetone Blank".
- ☐ Inspect the train prior to and during disassembly, and note any abnormal conditions on the Laboratory Station 8 FTDS.
- ☐ **Container No. 1 – Filter**
    - ☐ Using a pair of tweezers and/or clean disposable surgical gloves, carefully remove filter from the Filter Holder, and place it in its identified petri dish container. If necessary, fold the filter such that the particulate matter cake is inside the fold.
    - ☐ Using a nylon bristle brush and/or a sharp-edged blade, carefully transfer to the petri dish any PM and/or remaining pieces of filter or filter fibers that adhere to the filter support or gasket.
- ☐ **Container No. 2 – Acetone Rinses** – Recover any particulate matter from the internal surfaces of the probe nozzle, swaged union fitting, probe liner (use a glass funnel to aid in transferring liquid washed to the container), front half of the Filter Holder, and (if applicable) the cyclone. Recover all rinses in a single glass container, as illustrated in Figure 8-6, 8-7, 8-8 and 8-9. Perform the following steps in sample recovery:
    - ☐ Before cleaning the front half of the filter holder, wipe clean all joints.
    - ☐ Rinse with acetone, brush with small nylon bristle brush, and rinse with acetone until there are no visible particles. Make a final acetone rinse.
    - ☐ For probe liner, repeat rinse, brush, rinse sequence at least three times for glass liners, and six times for metal liners.

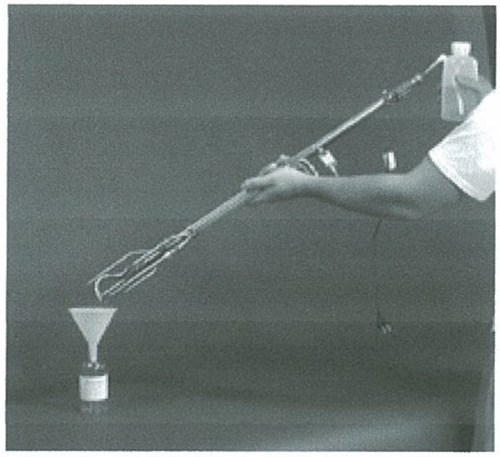

Figure 8-6. Acetone Rinse of Sampling Probe Liner

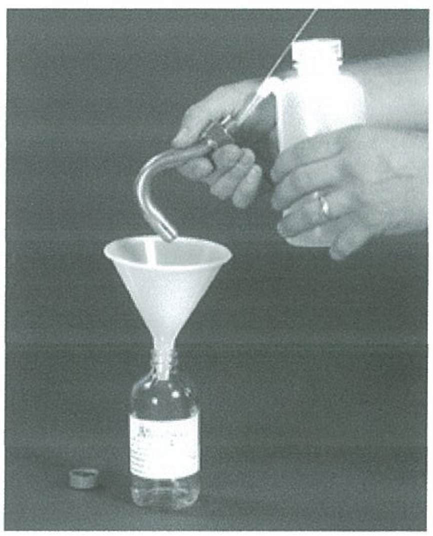

Figure 8-7. Rinsing Probe Nozzle

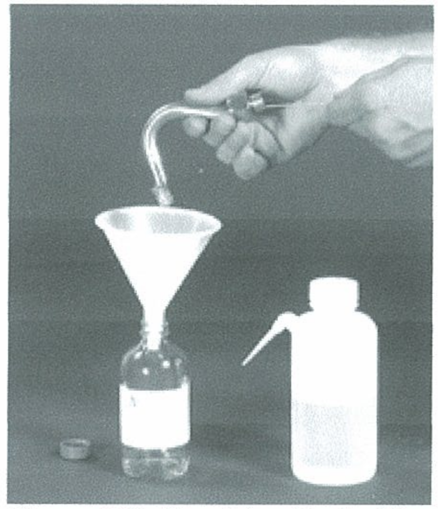

Figure 8-8. Brushing Probe Nozzle

Figure 8-9. Front Half Acetone Rinse Samples

- ☐ Make a final rinse of the probe brush with acetone.
- ☐ For Probe Nozzle, use the nylon nozzle brush and follow the same sequence of rinse, brush, rinse as for the probe linger.
- ☐ After completing the rinse, tighten the lid on the sample container. Mark the height of the fluid level. Label the container.

☐ **Container No. 3 – Silica Gel**

- ☐ Determine whether silica gel has been completely spent, and note on the FTDS its condition and color.
- ☐ Recover the silica gel into a pre-weighted Nalgene bottle, as illustrated in Figure 8-10.

Figure 8-10. Recovering Silica Gel Into Pre-weighted Nalgene Bottle

- ☐ Weigh the silica gel for moisture determination. Either re-use in the next run, using the final weight as the initial weight for the new sampling run, or discard.

☐ **Container No. 4 - Impinger Water**

- ☐ Note on the Laboratory Station 8 FTDS any color or film in the liquid catch.
- ☐ Measure the volume in the impingers as illustrated in Figure 8-11 or weigh to the nearest gram for calculating stack gas moisture determination.

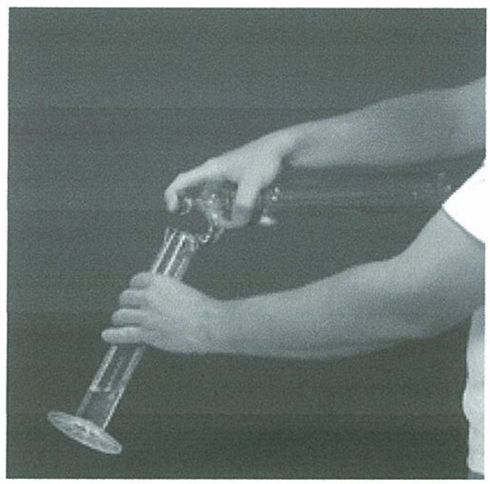

Figure 8-11. Measuring the Impinger Water Using Graduated Cylinder

F. Calculations

☐ At the conclusion of each sampling run, it is prudent to calculate the stack gas moisture (for the next sampling run) as well as the average isokinetic rate. To calculate the stack gas moisture content (B_{ws}), the following equations are used to compute the sample gas volume ($V_{m(std)}$) and gas moisture volume ($V_{wc(std)}$):

$$V_{m(std)} = K_3 Y \frac{V_m \left(P_{bar} + \frac{\Delta H}{13.6} \right)}{T_m}$$

Where: ΔH = Average orifice tube pressure during sampling, in. H_2O

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

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

	Y	= Dry gas mater calibration factor
	K_3	= 0.3858 °dK/mm Hg (metric units)
		= 17.64 °R/in. Hg (English units)

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

Where:	W_f	= Final weight of water collected, g
	W_i	= Initial weight of water collected, g
	K_2	= 0.001335 m^3/g (metric units)
		= 0.04715 ft^3/g (English units)

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

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

Next, the average stack gas velocity is calculated. The equation for average gas velocity in a stack or duct is:

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

Where:	V_s	= Average stack gas velocity, m/sec (ft/sec)
	C_p	= Pitot tube coefficient, dimensionless
	$(\sqrt{\Delta p})_{avg}$	= Average of the square roots of each stack gas velocity T_s = Absolute average stack gas temperature, °K (°R)
	P_s	= Absolute stack gas pressure, mmHg (in. Hg)
		= $P_{bar} + P_g/13.6$
	P_{bar}	= Barometric pressure at measurement site, mm Hg (in. Hg)
	P_g	= Stack static pressure, mm H_2O (in. H_2O)
	M_s	= Molecular weight of stack on wet basis, g/g-mole (lb/lb-mole)
		= $M_d (1-B_{ws}) + 18.0\, B_{ws}$
	M_d	= Molecular weight of stack on dry basis, g/g-mole (lb/lb-mole)
	K_p	= Constant, 34.97 for metric system (85.49 for English system)

- Calculate the average percent isokinetic sampling rate using the following equation:

$$I = \frac{100 T_s \left[K_4 V_{lc} + \frac{(V_m Y)}{T_m}\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right]}{60 \theta v_s P_s A_n}$$

where	A_n	= Cross-sectional area of the nozzle, m^2 (ft^2)
	θ	= Sampling time, minutes
	K4	= 0.003454 (Metric units)
		= 0.002269 (English units)

G. Variations and Alternatives To Operation of FRM 5 Sampling Train

- ☐ Acceptable alternatives to glass probe liners are metal liners, for example, 316 stainless steel, Inconel or other corrosion resistant metals made of seamless tubing. These can be useful for cross-sections over 3 m (10 ft.) in diameter. Whenever practical, make every effort to use borosilicate glass or quartz probe liners. Metal liners will bias particulate matter results high.
- ☐ For large stacks, consider sampling from opposite sides of the stack to reduce the length of probe.
- ☐ Use either borosilicate or quartz glass probe liners for stack temperatures up to 480° to 900°C (900 – 1,650°F). The softening temperature for borosilicate glass is 820°C (1,508°F), and for quartz it is 1,500°C (2,732°F).
- ☐ Rather than labeling filters, label the shipping containers (glass or plastic petri dishes), and keep the filters in these containers at all times except during sampling and weighing.
- ☐ Use more silica gel in impinger 4, if necessary, but ensure that there is no entrainment or loss during sampling. Hint: Loosely place cotton balls or glass wool in the neck of the silica gel impinger outlet stem.
- ☐ If a different type of condenser (other than impingers) is used, measure the amount of moisture condensed either volumetrically or gravimetrically.
- ☐ For moisture content, measure the impinger contents volumetrically before and after a sampling run. Use a pre-weighed amount of silica gel in a shipping container, then empty the silica gel after the run back into the container for weighing at another time.
- ☐ If the total particulate catch is expected to exceed 100 mg or more or when water droplets are present in the stack gas use a glass cyclone between the probe and filter holder.
- ☐ If high pressure drops across the filter (high vacuum on the gauge) causing difficulty in maintaining isokinetic sampling, replace the filter. Suggestion: Use another filter assembly rather than changing the filter itself. Before installing a new filter, conduct a leak-check. Add the filter assembly catches for the total particulate matter weight.
- ☐ Use a single train for the entire sampling run, except when 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 in trains. In all other situations, obtain approval from the regulatory agency before using two or more trains.
- ☐ When two or more trains are used, analyze separately the front-half and (if applicable) impinger catches from each train unless identical nozzle sizes were used on all trains. In this case, the front-half catches 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 regulatory agency for details concerning the calculation of results when two or more trains are used.
- ☐ 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.
- ☐ Do not cap off the probe tip too tightly while the sampling train is cooling down, as this would create a vacuum in the filter holder, which may draw water from the impingers into the filter holder.

Laboratory Station 8 Worksheet
FRM 5 Field Test Data Sheet (FTDS)

FRM 5 Particulate Field Test Data Sheet (FTDS)

Plant ______ C_p ______ Δp_{est}, in. H2O ______
Run No. ______ $\Delta H_@$ ______ Test Start Time ______
Location ______ P_m, in. Hg ______ Test Stop Time ______
Date ______ Ps, in. Hg ______ D_n, Calculated (in.) ______
Operator ______ B_{ws} (assumed) ______ D_n, Used (in.) ______
Sample Box No. ______ M_d ______ Ambient Temp. °F ______
Meter Box No. ______ M_s ______ Bar. Pressure, in. Hg ______
Filter No. ______ T_m, °F ______ Average ΔH, in. H2O ______
Silica Gel No. ______ T_s, °F ______ K Factor ______
Pre-Test Leak Rate @ 15 in. Hg ______ DGM "y" Factor ______
Post Test Leak Rate @ 15 in. Hg ______

Expert Stack Testers
1502 Stack Testing Lane
Cary, NC 27511
919-467-2785
Email: jwinberry@mindspring.com

Trav. Point	Clock	DGM	Pitot (Δp)	Orifice Δ H (In. H_2O)		DGM Temp. (°F)		Box Temp.	Impinger Temp.	Stack Temp.	Pump Vacuum	Stack O_2	Other
No.	Min	Ft^3	In. H_2O	Desired	Actual	Inlet	Outlet	°F	°F	°F	In. Hg	%	

Final Volume (mL) Impingers: ______ Final Weight (mg) of Silica Gel: ______ Final Weight (mg) of Filter: ______
Initial Volume (mL) Impingers: ______ Initial Weight (mg) of Silica Gel: ______ Initial Weight (mg) of Filter: ______
Total Volume (mL) Gained: ______ Total Weight (mg) Gained: ______ Total Weight (mg) Gained: ______

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Laboratory
Station

9

Isokinetic Rate Equation and The IsoCal Spreadsheet

One of the major activities associated with Federal Reference Method 5 is the setting and maintaining isokinetic rate conditions during the test. One call use a nomograph to assist with this or applicable software. The objective of Laboratory Station 9 is to demonstrate the use of the IsoCal software spreadsheet in completing the necessary equations for proper operation of the Federal Reference Method 5 (FRM 5) sample train during sampling.
The participant will be given source test data that should be entered into the lap top computer containing the IsoCal software. Based upon the data input, the participant will determine point-by-point isokinetics and average isokinetics. In addition, the participant will be able to see the variability in isokinetics as one changes the various input parameters (i.e., stack gas moisture and nozzle diameter).

Isokinetic Rate Equation and The IsoCal Spreadsheet

- ☐ The package before you contains a brief discussion of the IsoCal software program. Read the instructions and become familiar with the program.
- ☐ You have just completed a Federal Reference Method 5(FRM 5) stack test at a brick manufacturing facility (Plant A).
- ☐ You have been provided with the field data from that Method 5 test on the exhaust of the process. The first several screens of the IsoCal program you have been provided with contain traditional background information and stack characterization information needed to be acquired about the facility before the actual testing begins. This information helps you to determine the proper nozzle diameter needed tor the test, acquiring estimated water vapor concentration of the source to be tested, and determining average stack gas velocity, temperature and pressure. The screens which have been provided include:

    - Source Sampling Title Page Information;
    - Method 1: Sample and Velocity Traverses for Circular Sources;
    - Method 2: Determination of Stack Gas Velocity and Volumetric Flow Rate;
    - Method 3: Gas Analysis For 'The Determination of Dry Molecular Weight;
    - Method 4: Determination of Moisture Content In Stack Gases;
    - Method 5: Sample Recovery and Integrity Data Sheet; and
    - Method 5: Sample Analytical Data Sheet.

- ☐ In addition, you have been provided the actual Field Test Data Sheet (FTDS) for the Method 5 test.
- ☐ Your task is to use the computer and enter the FTDS from the stack test information into the Method 5-Run 1 data screen. Only concern yourself with Run 1 from the data given to you for this exercise.
- ☐ Complete entering the test data. In order for the software to generate "% Isokinetics," you must complete entry of all test data.

[NOTE: You will have to take the average values for DGM temperature, average stack temperature, average Δp, stack gas moisture (Bws), barometric pressure and static pressure values recorded at the bottom of the tab and transfer this information to the top of the spreadsheet in order for "% isokinetics" to be calculated at each sampling point as illustrated on the right hand side of M5, Run 1 tab.]

- ☐ Did the test team meet overall isokinetics of 90-110 % ?
- ☐ Record your answer.

Yes______________

No______________

SOURCE SAMPLING TITLE PAGE

ALARMS exist and have been acknowledged.

Source Information				
Plant Name	Plant A			
Sampling Location	Outlet of Scrubber (Stack)			
Fuel or Source Type	Natural Gas			
Fuel F-Factor	8710	8710	8710	

Test Information			
Starting Test Date		12/16/03	
Project #		ENCERTEC 1	
Operator		WTW	
Standard Temperature		68	°F
Standard Pressure		29.92	in Hg
Minimum required sample vol.		30	scf
Run Duration		60	Minutes
Base Run Number		1	
# of Ports Available		2	
# of Ports Used		2	
Port Inside Diameter		4.00	in
Circular Stack?		☑	
Rectangular Stack?		☐	

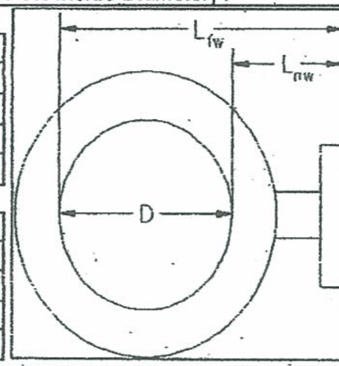
Test Equipment Information			
Meter Box Number		1	
Meter Calibration Factor	(Y)	0.991	
Orifice Meter Coefficient	($\Delta H_{@}$)	1.851	in H_2O
Pitot Identification		1	
Pitot Tube Coefficient	(C_p)	0.840	
Orsat Identification		1	
Nozzle Number		1	
Nozzle Diameter	(D_n)	0.3713	in
Probe Number		1	
Probe Length		70.00	in
(SS, Glass ....) Liner Material		Glass	
Sample Case / Oven Number		1	
Impinger Case Number		1	
Acetone Lot Number		1	

Testing Company Information	
Company Name	EnviroTech Solutions
Address	1502 Laughridge Drive
City, State Country Zip	Cary, North Carolina 27511
Project Manager	Jerry Winberry
Phone Number	919-467-2785
Fax Number	919-460-9932

METHOD 1 - SAMPLE AND VELOCITY TRAVERSES FOR CIRCULAR SOURCES

Plant Name	Plant A	Date	12/16/03
Sampling Location	Outlet of Scrubber (Stack)	Project #	ENCERTEC 1
Operator	WTW	# of Ports Available	2
Stack Type	Circular	# of Ports Used	2
Stack Size	Large	Port Inside Diameter	4

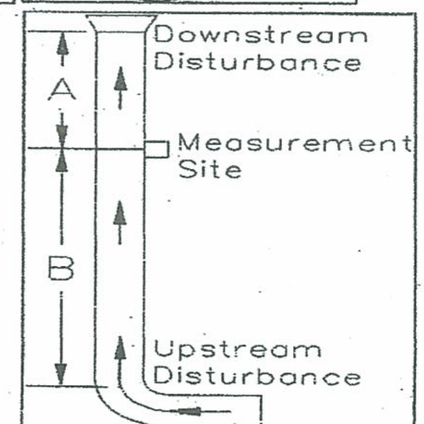
Circular Stack or Duct Diameter			
Distance to Far Wall of Stack	(L_{fw})	69.50	in
Distance to Near Wall of Stack	(L_{nw})	5.50	in
(=Lfw - Lnw) Diameter of Stack	(D)	64.00	in
(=3.14(D/2/Cunits)2) Area of Stack	(A_s)	22.34	ft^2



Distance from Port to Disturbances			
Distance Upstream	(B)	676.00	in
(=B/D) Diameters Upstream	(B_D)	10.56	diameters
Distance Downstream	(A)	164.00	in
(=A/D) Diameters Downstream	(A_D)	2.56	diameters

Number of Traverse Points Required			
Diameters to Flow Disturbance		Minimum Number of[1] Traverse Points	
Up Stream	Down Stream	Particulate Points	Velocity Points
2.00-4.99	0.50-1.24	24	16
5.00-5.99	1.25-1.49	20	16
6.00-6.99	1.50-1.74	16	12
7.00-7.99	1.75-1.99	12	12
>= 8.00	>=2.00	8 or 12[2]	8 or 12[2]
Upstream Spec		#NAME?	#NAME?
Downstream Spec		#NAME?	#NAME?
averse Pts Required		#NAME?	#NAME?

[1] Check Minimum Number of Points for the Upstream and Downstream conditions, then use the largest.
[2] 8 for Circular Stacks 12 to 24 inches
12 for Circular Stacks over 24 inches



Number of Traverse Points Used			
2	Ports by	6	Across
2	Pts Used	6	Required
☑	Particulate	☐	Velocity

Location of Traverse Points in Circular Stacks
(Fraction of Stack Diameter from Inside Wall to Traverse Point)

Traverse Point Number	2	4	6	8	10	12
	Number of Traverse Points on a Diameter					
1	.146	.067	.044	.032	.026	.021
2	.854	.250	.146	.105	.082	.067
3		.750	.296	.194	.146	.118
4		.933	.704	.323	.226	.177
5			.854	.677	.342	.250
6			.956	.806	.658	.356
7				.895	.774	.644
8				.968	.854	.750
9					.918	.823
10					.974	.882
11						.933
12						.979

Traverse Point Locations			
Traverse Point Number	Fraction of Stack Diameter	Distance from Inside Wall	Distance Including Nipple Length
		in	in
1	0.044	2 7/8	8 3/8
2	0.146	9 3/8	14 7/8
3	0.296	19	24 4/8
4	0.704	45	50 4/8
5	0.854	54 5/8	60 1/8
6	0.956	61 1/8	66 5/8
7			
8			
9			
10			
11			
12			

ETHOD 2 - DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RAT

Plant Name	Plant A		Date	12/16/03
Sampling Location	Outlet of Scrubber (Stack)		Project #	ENCERTEC 1
Operator	WTW		# of Ports Used	2
Stack Type	Circular		Pitot Identification	1
Pitot Leak Check	☑ PreTest	☑ PostTest	Pitot Coefficient (C_p)	0.84

Stack Dimensions			
Diameter or Length of Stack	(D)	64.00	in
Width of Stack	(W)		in
Area of Stack	(A_s)	22.34	ft^2

Pressures			
Barometric Pressure	(P_b)	29.92	in Hg
Static Pressure	(P_{static})	0.20	in H_2O
Absolute Stack Pressure	(P_s)	29.93	in Hg

Stack Gas Composition			
Composition Data:	Actual ☑	Estimated ☐	
Carbon Dioxide Concentration	(%CO_2)	3.7	%
Oxygen Concentration	(%O_2)	14.8	%
ırbon Monoxide Concentration	(%CO)	0.0	%
Nitrogen Concentration	(%N_2)	81.5	%
Stack Moisture Content	(B_{ws})	11.800	
Stack Dry Molecular Weight	(M_d)	29.18	lb/lb-mole
Stack Wet Molecular Weight	(M_s)	27.86	lb/lb-mole

Results			
Avg Stack Gas Velocity	(v_s)	32.1	ft/sec
Avg Stack Dry Std Flow Rate	(Q_{sd})	1324134	dscf/hr
Avg Stack Dry Std Flow Rate	(Q_{sd})	22069	dscf/min
Avg Stack Wet Flow Rate	(Q_{aw})	43028	ascf/min

Stack Cross Section Schematic

Velocity Traverse Data			
Run Number	1-V1		
Run Time			
Traverse Point	Velocity Head (Δp)	Stack Temp (t_s)	Local Velocity (v_s)$_i$
	in H_2O	°F	ft/sec
1.00	0.15	446	29.0
2.00	0.19	448	32.7
3.00	0.19	451	32.7
4.00	0.20	451	33.6
5.00	0.19	450	32.7
6.00	0.24	449	36.7
7.00	0.17	444	30.8
8.00	0.19	446	32.6
9.00	0.19	449	32.7
10.00	0.17	449	30.9
11.00	0.18	449	31.8
12.00	0.15	449	29.0
Average[1]	0.43	448	

[1] Please report the average of the square roots o Δp, or, $(\Delta p)^{1/2}_{avg} = {}^1/_n\Sigma(\Delta p^{1/2})$

Formulas Used

$A_s = DW/K_u$ for Rectangular Stacks

$A_s = (\pi(D/2)^2)/K_u$ for Circular Stacks

where $K_u = 1$ for metric units

where $K_u = 144$ (in^2/ft^2) for English units

$P_s = P_{bar} + P_{static}/13.6$

$\%N_2 = 100 - \%CO_2 - \%O_2 - \%CO$

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

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

$(\Delta p)^{1/2}_{avg} = {}^1/_n\Sigma(\Delta p^{1/2})$

$T_{s(avg)} = {}^1/_n\Sigma t_s + T_u$

where $T_u = 273$ °K for metric units

where $T_u = 460$ °R for English units

$v_s = K_pC_p(\Delta p)^{1/2}_{avg}(T_{s(avg)}/(P_sM_s))^{1/2}$

where $K_p = 34.97$ for metric units

where $K_p = 85.49$ for English units

$Q_{sd} = 3600(1 - B_{ws})v_sA_s(T_{std}/T_{s(avg)})(P_s/P_{std})$

where $T_{std} = 293$ °K, $P_{std} = 760$ mm Hg, for metric unit

where $T_{std} = 528$ °R, $P_{std} = 29.92$ in Hg, for English un

ETHOD 3 - GAS ANALYSIS FOR THE DETERMINATION OF DRY MOLECULAR WEIGH

Plant Name	Plant A	Date	12/16/03
Sampling Location	Outlet of Scrubber (Stack)	Project #	ENCERTEC 1
Operator	WTW	# of Ports Used	2
Fuel Type	N/A Minimum Fuel Factor	Maximum Fuel Factor	
Orsat Leak Check	☑ PreTest ☑ PostTest	Orsat Identification	1

Gas Analysis Data

Run Number	1			Run Start Time	10:40			Run Stop Time	12:05
Sample Analysis Time	Carbon Dioxide Volume (V_{CO2})	Oxygen Volume (V_{O2})	Carbon Monoxide Volume (V_{CO})	Carbon Dioxide Conc. (%CO_2)	Oxygen Conc. (%O_2)	Carbon Monoxide Conc. (%CO)	Nitrogen Conc. (%N_2)	Dry Molecular Weight (M_d)	Molecular Weight Deviation (ΔM_d)
hh:mm	ml	ml	ml	percent	percent	percent	percent	lb/lb-mole	lb/lb-mole
12:05	3.7	18.5	20.0	3.7	14.8	1.5	80.0	29.18	0.00
12:05	3.7	18.5	20.0	3.7	14.8	1.5	80.0	29.18	0.00
	3.7	18.5	20.0	3.7	14.8	1.5	80.0	29.18	0.00
	Results		Averages	3.7	14.8	1.5	80.0	29.18	
Average Calculated Fuel Factor			$(F_o)_{avg}$	1.029		Molecular Wt Deviation < 0.3?			☐
Average Excess Air			$(\%EA)_{avg}$	198.7	percent	uel Factor in Handbook Range?			☐

Gas Analysis Data

Run Number	2			Run Start Time	1:25			Run Stop Time	2:40
Sample Analysis Time	Carbon Dioxide Volume (V_{CO2})	Oxygen Volume (V_{O2})	Carbon Monoxide Volume (V_{CO})	Carbon Dioxide Conc. (%CO_2)	Oxygen Conc. (%O_2)	Carbon Monoxide Conc. (%CO)	Nitrogen Conc. (%N_2)	Dry Molecular Weight (M_d)	Molecular Weight Deviation (ΔM_d)
hh:mm	ml	ml	ml	percent	percent	percent	percent	lb/lb-mole	lb/lb-mole
2:45	3.6	18.5	20.0	3.6	14.9	1.5	80.0	29.17	0.00
	3.6	18.5	20.0	3.6	14.9	1.5	80.0	29.17	0.00
	3.6	18.5	20.0	3.6	14.9	1.5	80.0	29.17	0.00
	Results		Averages	3.6	14.9	1.5	80.0	29.17	
Average Calculated Fuel Factor			$(F_o)_{avg}$	1.029		Molecular Wt Deviation < 0.3?			☐
Average Excess Air			$(\%EA)_{avg}$	203.0	percent	uel Factor in Handbook Range?			☐

Gas Analysis Data

Run Number	3			Run Start Time	4:00			Run Stop Time	5:15
Sample Analysis Time	Carbon Dioxide Volume (V_{CO2})	Oxygen Volume (V_{O2})	Carbon Monoxide Volume (V_{CO})	Carbon Dioxide Conc. (%CO_2)	Oxygen Conc. (%O_2)	Carbon Monoxide Conc. (%CO)	Nitrogen Conc. (%N_2)	Dry Molecular Weight (M_d)	Molecular Weight Deviation (ΔM_d)
hh:mm	ml	ml	ml	percent	percent	percent	percent	lb/lb-mole	lb/lb-mole
5:20	3.8	18.4	20.0	3.8	14.6	1.6	80.0	29.19	0.00
	3.8	18.4	20.0	3.8	14.6	1.6	80.0	29.19	0.00
	3.8	18.4	20.0	3.8	14.6	1.6	80.0	29.19	0.00
	Results		Averages	3.8	14.6	1.6	80.0	29.19	
Average Calculated Fuel Factor			$(F_o)_{avg}$	1.019		Molecular Wt Deviation < 0.3?			☐
Average Excess Air			$(\%EA)_{avg}$	188.5	percent	uel Factor in Handbook Range?			☐

Fuel Factor Fo

Fuel Type	Minimum	Maximum
Coal, Anthracite	1.016	1.130
Coal, Lignite	1.016	1.130
Coal, Bituminous	1.083	1.230
Oil, Distillate	1.260	1.413
Oil, Residual	1.210	1.370
Gas, Natural	1.600	1.836
Gas, Propane	1.434	1.586
Gas, Butane	1.405	1.553
Wood	1.000	1.120
Wood Bark	1.003	1.130

Formulas Used

$\%CO_2 = V_{CO2}$

$\%O_2 = V_{O2} - V_{CO2}$

$\%CO = V_{CO} - V_{O2}$

$\%N_2 = 100 - \%CO_2 - \%O_2 - \%CO$

$M_d = .44(\%CO_2) + .32(\%O_2) + .28(\%N_2 + \%C$

$\Delta M_d = M_d - M_{davg}$

$F_o = (20.9 - \%O_2 - .5\%CO)/(\%CO_2 + \%CO)$

$\%EA = 100(\%O_2 - .5\%CO)/(.264\%NO_2 - (\%O_2 - .5\%C$

ENCERTECPlantAOutlet - M3 - Orsat Page 1 Printed 1/23/2004 V1.15

METHOD 4 - DETERMINATION OF MOISTURE CONTENT IN STACK GASES

Plant Name	Plant A	Date	12/16/03
Sampling Location	Outlet of Scrubber (Stack)	Project #	ENCERTEC 1
Operator	WTW	# of Ports Used	2
Stack Type	Circular	Meter Box Number	1
Train Leak Check	☑ PreTest ☑ PostTest	Meter Cal Factor (Y)	0.9905

Moisture Content Data								
Run Number	1		Run Start Time		10:40	Run Stop Time		12:05
Total Meter Volume	(V_m)	40.676	dcf	Barometric Press.		(P_b)	29.92	in Hg
Avg Meter Temp	$(t_m)_{avg}$	61	°F	Stack Static Press.		(P_{static})	0.20	in H_2O
Avg Stack Temp	$(t_s)_{avg}$	448	°F	Avg Orifice Press.		$(\Delta H)_{avg}$	1.70	in H_2O
		Impinger 1	Impinger 2	Impinger 3	Impinger 4	Impinger 5	Impinger 6	Impinger 7
		ml	ml	ml	g	ml	ml	ml
Contents		DI	DI		Sil Gel			
Final Value	$(V_f),(W_f)$	150.00	148.00	0.00	219.70			
Initial Value	$(V_i),(W_i)$	100.00	100.00	0.00	201.00			
Net Value	$(V_n),(W_n)$	50.0	48.0	0.0	18.7			
Results								
Total Volume	(V_t)	98.00	ml	ater Vol Condensed		$(V_{wc(std)})$	4.613	scf
Total Weight	(W_t)	18.70	g	Water Vol Weighed		$(V_{wsg(std)})$	0.882	scf
Std Meter Volume	$(V_{m(std)})$	41.017	dscf	at. Moisture Content		$(B_{ws(svp)})$	100.0	%
lc Moisture Content	$(B_{ws(calc)})$	11.8	%	al Moisture Content		(B_{ws})	11.8	%

Moisture Content Data								
Run Number	2		Run Start Time		1:25	Run Stop Time		2:40
Total Meter Volume	(V_m)	37.698	dcf	Barometric Press.		(P_b)	29.92	in Hg
Avg Meter Temp	$(t_m)_{avg}$	74	°F	Stack Static Press.		(P_{static})	0.20	in H_2O
Avg Stack Temp	$(t_s)_{avg}$	451	°F	Avg Orifice Press.		$(\Delta H)_{avg}$	1.37	in H_2O
		Impinger 1	Impinger 2	Impinger 3	Impinger 4	Impinger 5	Impinger 6	Impinger 7
		ml	ml	ml	g	ml	ml	ml
Contents		DI	DI		Sil Gel			
Final Value	$(V_f),(W_f)$	150.00	150.00	0.00	219.21			
Initial Value	$(V_i),(W_i)$	100.00	100.00	0.00	202.90			
Net Value	$(V_n),(W_n)$	50.0	50.0	0.0	16.3			
Results								
Total Volume	(V_t)	100.00	ml	ater Vol Condensed		$(V_{wc(std)})$	4.707	scf
Total Weight	(W_t)	16.31	g	Water Vol Weighed		$(V_{wsg(std)})$	0.769	scf
Std Meter Volume	$(V_{m(std)})$	37.068	dscf	at. Moisture Content		$(B_{ws(svp)})$	100.0	%
lc Moisture Content	(B_{ws})	12.9	%	al Moisture Content		(B_{ws})	12.9	%

Moisture Content Data								
Run Number	3		Run Start Time		4:00	Run Stop Time		5:15
Total Meter Volume	(V_m)	39.877	dcf	Barometric Press.		(P_b)	29.92	in Hg
Avg Meter Temp	$(t_m)_{avg}$	73	°F	Stack Static Press.		(P_{static})	0.20	in H_2O
Avg Stack Temp	$(t_s)_{avg}$	447	°F	Avg Orifice Press.		$(\Delta H)_{avg}$	1.54	in H_2O
		Impinger 1	Impinger 2	Impinger 3	Impinger 4	Impinger 5	Impinger 6	Impinger 7
		ml	ml	ml	g	ml	ml	ml
Contents		DI	DI		Sil Gel			
Final Value	$(V_f),(W_f)$	190.00	110.00	0.00	213.28			
Initial Value	$(V_i),(W_i)$	100.00	100.00	0.00	201.80			
Net Value	$(V_n),(W_n)$	90.0	10.0	0.0	11.5			
Results								
Total Volume	(V_t)	100.00	ml	ater Vol Condensed		$(V_{wc(std)})$	4.707	scf
Total Weight	(W_t)	11.48	g	Water Vol Weighed		$(V_{wsg(std)})$	0.541	scf
Std Meter Volume	$(V_{m(std)})$	39.297	dscf	at. Moisture Content		$(B_{ws(svp)})$	100.0	%
lc Moisture Content	(B_{ws})	11.8	%	al Moisture Content		(B_{ws})	11.8	%

METHOD 5 - SAMPLE RECOVERY AND INTEGRITY DATA SHEET

Plant Name	Plant A	**Date**	12/16/03
Sampling Location	Outlet of Scrubber (Stack)	**Project #**	ENCERTEC 1
Operator	WTW	**Acetone Lot Number**	1

Run History Data				
Run Number	1	2	3	
Run Start Time	10:40	1:25	4:00	(hh:mm)
Run Stop Time	12:00	2:40	5:15	(hh:mm)
Train Prepared By	WTW	WTW	WTW	
Train Recovered By	WTW	WTW	WTW	
Recovery Date	########	########	########	(mm/dd/yy)
Relinquished By	WTW	WTW	WTW	
Received By	FS	FS	FS	
Relinquished Date	########	########	########	(mm/dd/yy)
Relinquished Time	10:00	10:00	10:00	(hh:mm)

Equipment Identification Numbers			
Filter	1	2	3
Acetone Wash	1	2	3
Silica Gel	1	2	3
Impinger Case	1	1	1
Sample Box	1	1	1
Oven			

Moisture Content Data					
Impingers 1, 2, and 3 - Water Volume					
Final Volume	(V_f)	298.0	300.0	300.0	ml
Initial Volume	(V_i)	200.0	200.0	200.0	ml
Net Volume	(V_n)	98.0	100.0	100.0	ml
Comments					
Impinger 4 - Silica Gel Weight					
Final Weight	(W_f)	219.7	219.2	213.3	g
Initial Weight	(W_i)	201.0	202.9	201.8	g
Net Weight	(W_n)	18.7	16.3	11.5	g
Comments					
Total Water Collected					
Total Volume	(V_{lc})	116.7	116.3	111.5	g

Formulas Used

$V_n = V_f - V_i$ $W_n = W_f - W_i$ $V_{lc} = V_n + W_n/\rho_w$ where $\rho_w = .9982$ g/ml

METHOD 5 - SAMPLE ANALYTICAL DATA SHEET

Plant Name	Plant A	Date	12/16/03
Sampling Location	Outlet of Scrubber (Stack)	Project #	ENCERTEC 1
Operator	WTW	Acetone Lot Number	1

Analytical Data

Placed in Desiccator	Number	Date	Time
Filter	1	01/20/04	8:00
Acetone Wash Beaker	1	01/20/04	8:00

Run Number	1
Run Start Time	10:40
Leakage Evident?	☐
Estimated Volume	

		Filter	Acetone	Date	Time	Humidity	Temp	Cal Audit
		g	g	mm/dd/yy	hh:mm	%RH	°F	g
Measurement 1	$(m_{1f}),(m_{1a})$	0.2664	30.0837					
Measurement 2	$(m_{2f}),(m_{2a})$	0.2664	30.0837					
Measurement 3	$(m_{3f}),(m_{3a})$	0.2664	30.0837					
Measurement 4	$(m_{4f}),(m_{4a})$	0.2664	30.0837					

Results					Acetone Wash			
Final Weight	$(m_{ff}),(m_{fa}')$	0.2664	30.0837	g	Bottle Wt with Wash	(m_{bw})	30.0663	g
Tare Weight	$(m_{tf}),(m_{ta}')$	0.2568	30.0663	g	Additional Rinse Wt	(m_{ar})	0.0000	g
Weight Gain	$(m_f),(m_a')$	9.6	17.4	mg	Bottle Tare Weight	(m_{tb})	30.0663	g
Blank Adjustment	(W_a)		0.0	mg	Net Wash Weight	(m_{nw})	0.0000	g
Total Particulates	(m_n)		27.0	mg	Blank Concentration	(C_a)	0.0000	mg/g

Analytical Data

Placed in Desiccator	Number	Date	Time
Filter	2	01/20/04	8:00
Acetone Wash Beaker	2	01/20/04	8:00

Run Number	2
Run Start Time	1:25
Leakage Evident?	☐
Estimated Volume	

		Filter	Acetone	Date	Time	Humidity	Temp	Cal Audit
		g	g	mm/dd/yy	hh:mm	%RH	°F	g
Measurement 1	$(m_{1f}),(m_{1a})$	0.2644	30.3884					
Measurement 2	$(m_{2f}),(m_{2a})$	0.2644	30.3884					
Measurement 3	$(m_{3f}),(m_{3a})$	0.2644	30.3884					
Measurement 4	$(m_{4f}),(m_{4a})$	0.2644	30.3884					

Results					Acetone Wash			
Final Weight	$(m_{ff}),(m_{fa}')$	0.2644	30.3884	g	Bottle Wt with Wash	(m_{bw})	30.3692	g
Tare Weight	$(m_{tf}),(m_{ta}')$	0.2542	30.3692	g	Additional Rinse Wt	(m_{ar})	0.0000	g
Weight Gain	$(m_f),(m_a')$	10.2	19.2	mg	Bottle Tare Weight	(m_{tb})	30.3692	g
Blank Adjustment	(W_a)		0.0	mg	Net Wash Weight	(m_{nw})	0.0000	g
Total Particulates	(m_n)		29.4	mg	Blank Concentration	(C_a)	0.0000	mg/g

Analytical Data

Placed in Desiccator	Number	Date	Time
Filter	3	01/20/04	8:00
Acetone Wash Beaker	3	01/20/04	8:00

Run Number	3
Run Start Time	4:00
Leakage Evident?	☐
Estimated Volume	

		Filter	Acetone	Date	Time	Humidity	Temp	Cal Audit
		g	g	mm/dd/yy	hh:mm	%RH	°F	g
Measurement 1	$(m_{1f}),(m_{1a})$	0.2565	29.3968					
Measurement 2	$(m_{2f}),(m_{2a})$	0.2565	29.3968					
Measurement 3	$(m_{3f}),(m_{3a})$	0.2565	29.3968					
Measurement 4	$(m_{4f}),(m_{4a})$	0.2565	29.3968					

Results					Acetone Wash			
Final Weight	$(m_{ff}),(m_{fa}')$	0.2565	29.3968	g	Bottle Wt with Wash	(m_{bw})	29.3926	g
Tare Weight	$(m_{tf}),(m_{ta}')$	0.2516	29.3926	g	Additional Rinse Wt	(m_{ar})	0.0000	g
Weight Gain	$(m_f),(m_a')$	4.9	4.2	mg	Bottle Tare Weight	(m_{tb})	29.3926	g
Blank Adjustment	(W_a)		0.0	mg	Net Wash Weight	(m_{nw})	0.0000	g
Total Particulates	(m_n)		9.1	mg	Blank Concentration	(C_a)	0.0000	mg/g

Formulas Used

m_{ff} = average of last two filter measurements

m_{fa}' = average of last two acetone measurements

$m_f = m_{ff} - m_{tf}$

$m_a' = m_{fa}' - m_{ta}'$

$W_a = C_a m_{nw}$

$m_{nw} = m_{bw} + m_{ar} - m_{tb}$

$m_n = m_f + m_a' - W_a$

C-10

Particulate Field Data Sheet

Very important - Fill in all blanks

Plant: BRICK PLANT #A
Run no.: #1
Location: COLUMBIA, S.C.
Date: 12/16/03
Operator: WTW
Sample box no.: #1
Meter box no.: #1
Nomograph ID no.: #1
Filter no.: #1 (0.2568g)
Orsat no.: NA Date rebuilt: NA

Fyrite no.: NA Date rebuilt: NA
C_p = 0.84
$\Delta H_@$: 1.8513
P_m, in. Hg:
p_s, in. Hg:
B_{ws} (assumed): 12%
M_d = 30.00
M_s: 28.56
T_m, °R:
T_s, °R: 893

Δp_{avg}, in. H_2O: 0.65
Test start time: 10:40
Stop time: 12:05
D_n calculated (in.): 0.3526
D_n used (in.): 0.3713
Ambient temp., °F: 53
Bar. pressure, in. Hg: 29.92
Heater box setting, °F: 250
Probe heater setting, °F: 250
Average ΔH: 1.70

Leak rate @ 15 in. Hg Pre-test: ✓ <0.02 cfm
K: 9.3003
Post-test: <0.02 cfm @ 15 in Hg

Point	Clock time (min)	Dry gas meter C(ft³)	Pitot Δp (in. H_2O)	Orifice ΔH (in. H_2O) Desired	Orifice ΔH (in. H_2O) Actual	Dry gas temp. (°F) Inlet	Dry gas temp. (°F) Outlet	Pump vacuum gauge (in. Hg)	Box temp. (°F)	Impinger temp. (°F)	Stack pressure (in. Hg)	Stack Temp. (°F)	Fyrite %CO_2
1	10:40	189.354	0.15	1.39	1.39	56	54	−4.0	248	51		446	
2	10:45	192.840	0.19		1.76	57	54	−4.0	247	49		448	
3	10:50	195.650	0.19		1.76	58	55	−4.5	249	49		451	
4	10:55	199.050	0.20		1.86	56	61	−5.0	248	55		451	
5	11:00	202.590	0.19		1.76	63	56	−5.5	248	63		450	
6	11:05	206.400	0.24		2.16	64	57	−6.0	248	74		449	
7	11:35	209.931	0.17		1.58	62	59	−5.0	248	57		444	
8	11:40	213.230	0.19		1.76	64	60	−5.0	248	55		446	
9	11:45	216.655	0.19		1.26	66	60	−5.0	249	58		449	
10	11:50	220.150	0.17		1.58	68	61	−5.0	249	64		449	
11	11:55	223.450	0.18		1.67	71	62	−5.0	247	60		449	
12	12:00	226.850	0.15		1.39	73	62	−5.0	249	69		449	
		230.030											

Comments: Initial wt. of Filter: 0.2568 grams
Initial silica gel weight: 201.0 g

Test Observers:

Figure C-4. Particulate field data sheet form

Impinger Recoveries! 1st Impinger: 150 mL 2nd Impinger: 148 mL

3.0-09-95

Laboratory
Station

10

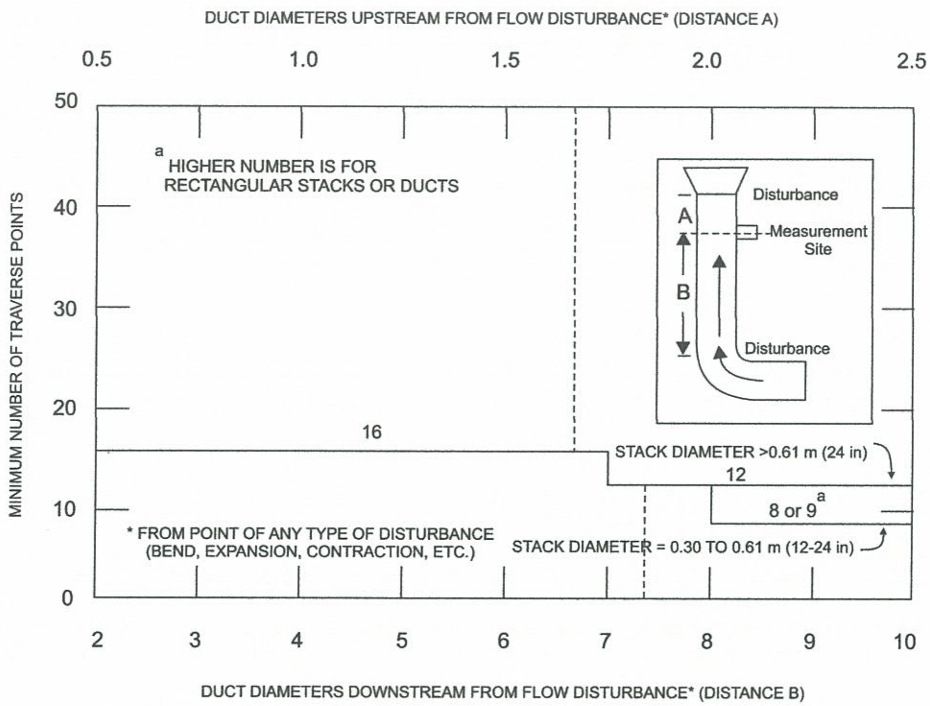
FRM 1 Traverse Point Determination

Federal Reference Method 1 (FRM 1) requires that the number of traverse points for a given test be based upon the sampling port locations with reference to upstream and downstream flow disturbances. The objective of Laboratory Station 10 is to determine the number and the location of traverse points at your assigned sampling port on the source simulator. Record you finds on the Laboratory Station 10 Worksheet, FRM 1 Field Test Data Sheet (FTDS).

FRM 1 TRAVERSE POINT DETERMINATION

Determination of the Minimum Number of Traverse Points

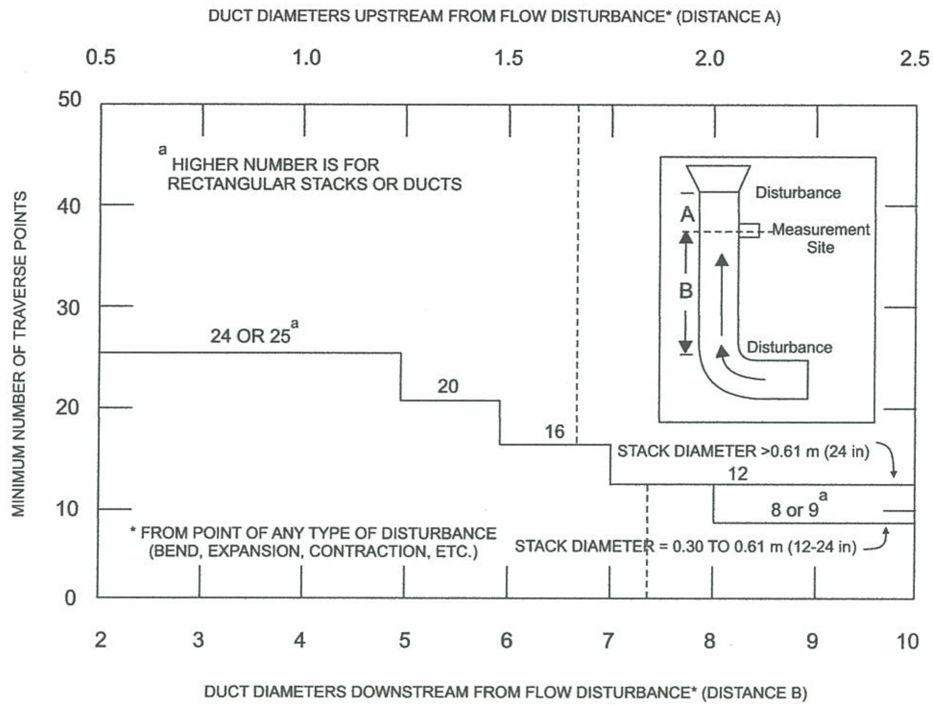
- ☐ Obtain a tape measure from the Inspector's Tool Kit and identify the sampling port location on the source simulator.
- ☐ Measure the inside dimensions of the duct at the sampling site. Sampling ports have been installed in the source simulator; Use the port assigned to your laboratory group. For Laboratory Station 10 we will use only one (1) diameter. Record the information on the Laboratory Station 10 FRM 1 Field Test Data Sheet (FTDS).
- ☐ Determine the duct diameter distances of the sampling port from upstream and downstream flow disturbances. Keep in mind the direction of the flow of gas in the source simulator. **[NOTE:** Elbows and fans are considered flow disturbances in the source simulator.] Record the information on the Laboratory Station 10 FRM 1 FTDS.
- ☐ Determine the number of traverse points for a velocity determination using Figure 10-1.
- ☐ Record the information on the Laboratory Station 10 FRM 1 FTDS.



(Minimum number of traverse points for non-particulate traverses.)

Figure 10-1. Minimum Number of Traverse Points for Non-Particulate Traverses

- ☐ Determine the number of traverse points for a particulate traverse determination using Figure 10-2.



(Minimum number of traverse points for particulate traverses.)

Figure 10-2. Minimum Number of Traverse Points for Particulate Traverses

- ☐ Record the information on the Laboratory Station 10 FRM 1 FTDS.
- ☐ Using Table 10-1, determine the locations for the particulate measurement traverse points and record your calculations on the Laboratory Station 10 FRM 1 FTDS.
- ☐ For circular stacks with diameters greater than 60 cm (24 inches), the minimum number of traverse points required is twelve (12), or six (6) in each of two directions 90° apart, when the duct diameters from disturbances are eight (8) or more upstream and two (2) or more downstream. For circular stacks with diameters between 30 and 60 cm (12 and 24 inches), the minimum number of sample points required is eight (8), or four (4) in each of two directions 90° apart. For stacks less than 30 cm (12 inches) in diameter, refer to Method 1A for calculating traverse points.
- ☐ After completing Laboratory Station 10 FRM 1 FTDS, obtain a FRM 5 sampling probe and mark the traverse point distances on the sampling probe with heat-resistant fiber tape or whiteout correction fluid, as illustrated in Figure 10-3.

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												99.9

Table 10-1. Location of Traverse Points in Circular Stacks

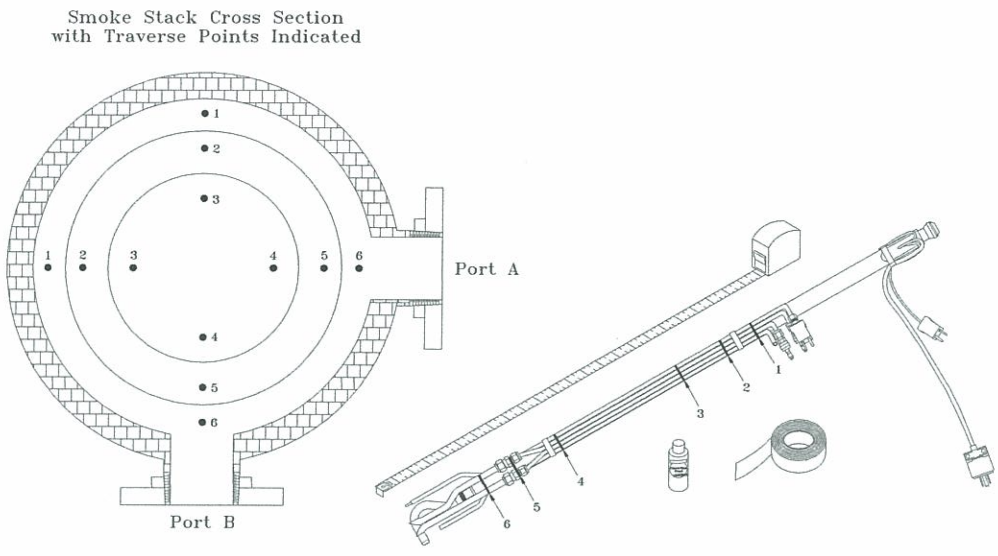


Figure 10-3. Marking of Probe For Traverse Point Determination

APTI #468: MONITORING COMPLIANCE TEST AND SOURCE TEST OBSERVATION

Laboratory Station 10 Worksheet
FRM 1 Field Test Data Sheet (FTDS)

1. Number of Traverse Points
   Port Number: ______________________________
   Port Location: ______________________________
   Duct Diameter (inches): ______________________________
   Number of Duct Diameters From Upstream Disturbance: ______________
   Number of Duct Diameters From Downstream Disturbance: ______________
   Number of Traverse Points on a Diameter For Velocity Traverse
   (From Table 10-1): ______________________________
   Number of Traverse Points on a Diameter For Particulate Traverse
   (From Table 10-2): ______________________________

2. Traverse Point Locations [**NOTE:** Use number of traverse points on a diameter for particulate traverse.]

Traverse Point Number	Percent of Duct Diameter From Inside Wall to Traverse Point	Location of Traverse Point (Inches)	Adjusted Traverse Point Location (Inches)

APTI #468: MONITORING COMPLIANCE TEST AND SOURCE TEST OBSERVATION

Appendix A

Abbreviations and Terminology

%CO	Percent CO by volume, dry basis
%CO2	Percent CO2 by volume, dry basis
%N2	Percent N2 by volume, dry basis
%O2	Percent O2 by volume, dry basis
0.280	Molecular weight of N2 or CO, divided by 100
0.320	Molecular weight of O2 divided by 100
0.440	Molecular weight of CO2 divided by 100
100	Conversion to percent.
13.6	Specific gravity of mercury.
18.0	Molecular weight of water, g/g mole (lb/lb mole).
3600	Conversion Factor, sec/hr.
60	Sec/min.
A	Cross sectional area of stack, m^2 (ft^2).
A	Absorbance of sample.
A	Analytical detection limit, μg/ml.
A1	Absorbance of the 100 μg NO_2 standard.
A2	Absorbance of the 200 μg NO_2 standard.
A3	Absorbance of the 300 μg NO_2 standard.
A4	Absorbance of the 400 μg NO_2 standard.
An	Cross-sectional area of nozzle, m^2 (ft^2).
B	Liquid volume of digested sample prior to aliquotting for analysis, ml.

Bws	Water vapor in the gas stream [from Method 4 (reference method) or Method 5], proportion by volume.
C	Corrected to standard conditions, mg/dscm(lb/dscf).
C	TGNMO concentration of the effluent, ppm C equivalent.
Ca	Acetone blank residue concentration, mg/mg.
Ca	Actual concentration of SO2 in audit sample, mg/dscm.
Ca	Actual audit sample concentration, mg/dscm.
Ca1	Concentration of metal in Analytical Fraction 1A as read from the standard curve, µg/mL.
Ca2	Concentration of metal in Analytical Fraction 2A as read from the standard curve, (µg/mL).
Cc	Calculated condensible organic (condensate trap) concentration of the effluent, ppm C equivalent.
Ccm	Measured concentration (NMO analyzer) for the condensate trap ICV, ppm CO_2.
Cd	Determined concentration of SO_2 in audit sample, mg/dscm.
Cd	Determined audit sample concentration, mg/dscm.
CH_2S	Concentration of H_2S at standard conditions,mg/dscm.
Cp	Pitot tube coefficient, dimensionless.
Cp(s)	Type S pitot tube coefficient, dimensionless.
Cp(std)	Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 6.7.1 to 6.7.5 of FRM 2.
cs	Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/dscm (gr/dscf).
Cs	Concentration of a metal in the stack gas, mg/dscm.
CSO_2	Concentration of SO_2, dry basis, corrected to standard conditions, mg/dscm (lb/dscf).
Ct	Calculated noncondensible organic concentration (sample tank) of the effluent, ppm C equivalent.
Ctm	Measured concentration (NMO analyzer) for the sample tank, ppm NMO.
D	Diameter of stack, in.
De	Equivalent diameter.
F	Dilution factor. Required only if sample dilution was needed to reduce the absorbance into the range of the calibration).

F	Sampling flow rate, cc/min.
Fa	Aliquot factor, volume of Sample Fraction 2 divided by volume of Sample Fraction 2A
Fd	Dilution factor (Fd = the inverse of the fractional portion of the concentrated sample in the solution actually used in the instrument to produce the reading Ca1. For example, if a 2 mL aliquot of Analytical Fraction 1A is diluted to 10 mL to place it in the calibration range, Fd = 5).
ΔH	Average pressure differential across the orifice meter, mm H20 (in. H_20).
Hgbh	Total mass of Hg collected in the back
Hgbh2	Total mass of Hg collected in Sample Fraction 2, μg.
Hgbh3(A,B,C)	Total mass of Hg collected separately in Fraction 3A, 3B, or 3C, μg.
Hgbhb	Blank correction value for mass of Hg detected in back
Hgfh	Total mass of Hg collected in the front
Hgfhb	Blank correction value for mass of Hg detected in front
Hgt	Total mass of Hg collected in the sampling train, μg.
I	Percent of isokinetic sampling.
K	0.127 mm H20 (metric units); 0.005 in. H_20 (English units).
K4	103 mg/μg.
Kc	Spectrophotometer calibration factor.
Kp	Velocity equation constant.
L	Length.
L	Volume of liquid injected, μl.
L1	Individual leakage rate observed during the leak-check conducted prior to the first component change, m3/min (ft3/min)
La	pretest leak-check or for a leak-check following a component change; equal to 0.00057 m3/min (0.020 cfm) or 4 percent of the average sampling rate, whichever is less.
LI	Individual leakage rate observed during the leak-check conducted prior to the "ith" component change (i = 1, 2, 3...n), m^3/min or cfm).
Lp	Leakage rate observed during the post-test leak-check, m^3/min (cfm).
m	Mass of NOx as NO_2 in gas sample, μg.

M	Molecular weight of the liquid injected, g/g mole.
ma	Mass of residue of acetone after evaporation,mg.
Mbh	Total mass of each metal (except Hg) collected in the back
Mbhb	Blank correction value for mass of metal detected in back
Mc	TGNMO mass concentration of the effluent, mg C/dscm.
Md	Dry molecular weight, g/g mole (lb/lb mole)
Md	Molecular weight of stack gas, dry basis, g/g mole (lb/lb mole).
Mfh	Total mass of each metal (except Hg) collected in the front half of the sampling train (Sample Fraction 1), µg.
Mfhb	Blank correction value for mass of metal detected in front
mn	Total amount of particulate matter collected, mg.
Ms	Molecular weight of stack gas, wet basis, g/g mole (lb/lb mole).
Mt	Total mass of each metal (separately stated for each metal) collected in the sampling train, µg.
Mw	Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).
N	Total number of traverse points.
n	total number of traverse points.
N	Normality of barium standard titrant, meq/ml.
N	Carbon number of the liquid compound injected (N = 12 for decane, N = 6 for hexane).
NA	Normality of standard C_6H_5AsO solution, g eq/liter.
NI	Normality of standard I2 solution, g eq/liter.
NS	Normality of standard (0.1 N) $Na_2S_2O_3$ solution, g eq/liter.
NT	Normality of standard (0.01 N) $Na_2S_2O_3$ solution, assumed to be 0.1 NS, g eq/liter.
p	Velocity head of stack gas, mm H_20 (in. H_20).
P	Allowable pressure change, cm Hg.
Pb	Barometric pressure, cm Hg.
Pbar	Barometric pressure at measurement site, mm Hg (in. Hg).
Pf	Final pressure of the intermediate collection vessel, mm Hg absolute.

Pg	Stack static pressure, mm Hg (in. Hg).
pi	Individual velocity head reading at traverse point "i", mm (in.) H20.
Pi	pitch angle at traverse point i, degree.
PI	Initial absolute pressure of flask, mm Hg (in. Hg).
Ps	Absolute stack pressure (Pbar + Pg), mm Hg (in. Hg),
Δps	Velocity head measured by the Type S pitot tube, cm (in.) H20.
Pstd	Standard absolute pressure, 760 mm Hg (29.92 in. Hg).
Δpstd	Velocity head measured by the standard pitot tube, cm (in.) H_20.
Pt	Gas sample tank pressure after sampling, but before pressurizing, mm Hg absolute.
Ptf	Final gas sample tank pressure after pressurizing, mm Hg absolute.
Pti	Gas sample tank pressure before sampling, mm Hg absolute.
q	Total number of analyzer injections of intermediate collection vessel during analysis (where k = injection number, 1 ... q).
Qbh2	Quantity of Hg, µg, TOTAL in the ALIQUOT of Analytical Fraction 2B selected for digestion and analysis . NOTE: For example, if a 10 mL aliquot of Analytical Fraction 2B is taken and digested and analyzed (according to Section 11.1.3 and its NOTES Nos. 1 and 2), then calculate and use the total amount of Hg in the 10 mL aliquot for Qbh2.
Qbh3(A,B,C)	Quantity of Hg, µg, TOTAL, separately, in the ALIQUOT of Analytical Fraction 3A, 3B, or 3C selected for digestion and analysis (see NOTES in Sections 12.7.1 and 12.7.2 describing the quantity "Q" and calculate similarly).
Qfh	Quantity of Hg, µg, TOTAL in the ALIQUOT of Analytical Fraction 1B selected for digestion and analysis . NOTE: For example, if a 10 mL aliquot of Analytical Fraction 1B is taken and digested and analyzed (according to Section 11.1.3 and its NOTES Nos. 1 and 2), then calculate and use the total amount of Hg in the 10 mL aliquot for Qfh.
Qsd	Dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr).
R	[(mm Hg)(m3)]/[(K)(g-mole)] {21.85 [(in. Hg)(ft3)]/[(R)(lb-mole)]}.
r	Total number of analyzer injections of sample tank during analysis (where j = injection number, 1 ... r).
Ravg	average resultant angle, degree.

RE	Relative error for QA audit samples, percent.
Ri	resultant angle at traverse point i, degree.
Sd	standard deviation, degree.
T	Sensitivity factor for differential pressure gauges.
Tf	Final absolute temperature of flask, K (R).
Tf	Final temperature of intermediate collection vessel, K.
Ti	Initial absolute temperature of flask, K (R).
Tm	Absolute DGM temperature
Ts	Stack temperature, C (F).
Ts(abs)	Absolute stack temperature, K (R).=273 + Ts for metric units, =460 + Ts for English units.
Tstd	Standard absolute temperature, 293 K (528 R).
Tt	Sample tank temperature at completion of sampling, K.
Ttf	Sample tank temperature after pressurizing, K.
Tti	Sample tank temperature before sampling, K.
V	Sample tank volume, m3.
Va	Volume of acetone blank, ml.
Va	Volume of sample aliquot titrated, ml.
Va	Volume of absorbing solution, 25 mL.
VA	Volume of C6H5AsO solution used for standardization, ml.
Va	Total volume of digested sample solution (Analytical Fraction 2A), mL
VAI	Volume of standard C6H5AsO solution used for titration analysis, mL.
Vaw	Volume of acetone used in wash, ml.
Vf	Volume of flask and valve, ml.
Vf1B	Volume of aliquot of Analytical Fraction 1B analyzed, ml. NOTE: For example, if a 1 mL aliquot of Analytical Fraction 1B was diluted to 50 mL with 0.15 percent HNO3 as described in Section 11.1.3 to bring it into the proper analytical range, and then 1 mL of that 50
Vf2B	Volume of Analytical Fraction 2B analyzed, ml. NOTE: For example, if 1 mL of Analytical Fraction 2B was diluted to 10 mL with 0.15 percent HNO3 as described in Section 11.1.3 to bring it into the proper analytical range, and then 5 mL of that 10 mL was analyzed, Vf2B would be 0.5 ml.

Vf3(A,B,C)	Volume, separately, of Analytical Fraction 3A, 3B, or 3C analyzed, mL (see previous notes in Sections 12.7.1 and 12.7.2, describing the quantity "V" and calculate similarly).
VI	Volume of standard I2 solution used for standardization, ml.
VIT	Volume of standard I2 solution used for titration analysis, normally 50 ml.
Vlc	Total volume of liquid collected in impingers and silica gel (see Figure 5-6), ml.
Vm	Volume of gas sample as measured by dry gas meter, dcm (dcf).
Vm	Dry gas volume as measured by the DGM, dcm (dcf).
Vm	Volume of gas sample at meter conditions, liters.
Vm(std)	Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm(dscf).
vs	Stack gas velocity, calculated by Method 2,
vs	Average stack gas velocity, m/sec (ft/sec).
Vs	Gas volume sampled, dsm3.
Vsc	Sample volume(dry basis), ml. at standard conditions
VSI	Volume of 0.1 N Na2S2O3 solution used for standardization, ml.
Vsoln	Total volume of solution in which the SO2 sample is contained, 100 ml.
Vsoln,1	Total volume of digested sample solution (Analytical Fraction 1), ml.
Vsoln,2	Total volume of Sample Fraction 2, ml.
Vsoln,3(A,B,C)	Total volume, separately, of Analytical Fraction 3A, 3B, or 3C, ml.
Vt	Volume of barium standard titrant used for the sample (average of replicate titration), ml.
VT	Volume of standard (0.01 N) Na2S2O3 solution used in standardizing iodine solution (see Section 10.2.1), ml.
Vt	Sample train volume, cc.
Vtb	Volume of barium standard titrant used for the blank, ml.
VTT	Volume of standard (0.01 N) Na2S2O3 solution used for titration analysis, ml.
Vv	Intermediate collection vessel volume, m3.

Vw(std)	Volume of gas,corrected to standard conditions, scm (scf).
W	width.
W	Weight of $K_2Cr_2O_7$ used to standardize $Na_2s_2O_3$ or C_6H_5AsO solutions, as applicable (see Sections 10.2.2 and 10.2.3), g.
Wa	Weight of residue in acetone wash, mg.
xi	Individual measurements.
Y	Dry gas meter calibration factor.
Yi	yaw angle at traverse point i, degree.

APTI #468: MONITORING COMPLIANCE TEST AND SOURCE TEST OBSERVATION

Appendix B

Equations

General

$$\Delta H = K(\Delta p)$$

$$\overline{pmr}_s = c_s Q_s$$

$$A_s = \pi\left(\frac{D_s}{2}\right)^2$$

$$A_s = LW$$

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

$$\%EA = \frac{(\%O_2) + 0.5(\%CO)}{0.0264(\%N_2) - (\%O_2) + 0.5(\%CO)}$$

$$\%N_2 = 100 - \%CO_2 - \%O_2 - \%CO$$

Federal Reference Method 1

Equation 1-1

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

Equation 1-2

$$R_i = \text{arccosine}[(\text{cosine}Y_i)(\text{cosine}P_i)]$$

Equation 1-3

$$\overline{R} = \frac{\sum R_i}{n}$$

Equation 1-4

$$S_d = \sqrt{\frac{\sum_{i=1}^{n}(R_i - \overline{R})^2}{(n-1)}}$$

Federal Reference Method 2

Equation 2-1

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

Equation 2-2

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

Equation 2-3

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

Equation 2-4

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

Equation 2-5

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

Equation 2-6

$$= P_{bar} + P_g$$

Equation 2-7

$= 273 + t_s$ for metric.

Equation 2-8

$= 460 + t_s$ for English.

Equation 2-9

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

Equation 2-10

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

Federal Reference Method 2F

Equation 2F-1

$$F_1 = \frac{(P_4 - P_5)}{(P_1 - P_2)}$$

Equation 2F-2

$$F_2 = C_p \sqrt{\frac{\Delta p_{std}}{(P_1 - P_2)}}$$

Equation 2F-3

$$\%Diff = \frac{F_2^{max} - F_2^{min}}{F_2^{min}} \text{ x } 100\%$$

Equation 2F-4

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

Equation 2F-5

$$P_s = P_{bar} + \frac{P_g}{13.6}$$

Equation 2F-6

$$T_{s(i)} = 273 + t_{s(i)}$$

Equation 2F-7

$$T_{s(i)} = 460 + t_{s(i)}$$

Equation 2F-8

$$v_{a(i)} = K_p F_{2(i)} \sqrt{\frac{(P_1 - P_2)_i T_{s(i)}}{P_s M_s}} (\cos\theta_{y(i)})(\cos\theta_{p(i)})$$

Equation 2F-9

$$v_{a(avg)} = \frac{\sum_{i=1}^{n} v_{a(i)}}{n}$$

Equation 2F-10

$$Q_{sw} = 3{,}600 (v_{a(avg)})(A) \left(\frac{T_{std}}{T_{s(avg)}} \right) \left(\frac{P_s}{P_{std}} \right)$$

Equation 2F-11

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

Federal Reference Method 3

Equation 3-1

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

Federal Reference Method 3A

Equation 3A-1

$$C_{gas} = \frac{C_{ma} - C_{oa}}{C_m - C_o}(\overline{C} - C_m) + C_{ma}$$

Federal Reference Method 4

Equation 4-1

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

$$= K_1 (V_f - V_i)$$

Equation 4-2

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

$$= K_2 (W_f - W_i)$$

Equation 4-3

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

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

Equation 4-4

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

Equation 4-5

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

$$= K_1 (V_f - V_i)$$

Equation 4-6

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

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

Equation 4-7

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

Method 5

Equation 5-9

$$\Delta H_{@} = 0.0319\, \Delta H \frac{T_m}{P_{bar}} \frac{\theta^2}{Y^2 V^2{}_m}$$

Equation 5-1

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

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

Equation 5-1a

$$\left[V_m - (L_p - L_a)\right]$$

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

Equation 5-2

$$V_{w(std)} = \frac{V_{lc}\, \rho_w R T_{std}}{M_w P_{std}}$$

$$= K_2\, V_{lc}$$

Equation 5-3

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

Equation 5-4

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

Equation 5-5

$$W_a = C_a V_{aw} \rho_a$$

Equation 5-6

$$c_s = (0.001\ g/mg)\left(\frac{m_n}{V_{m(std)}}\right)$$

Equation 5-7

$$I = \frac{100 T_s \left[K_3 V_{lc} + \left(\frac{V_m Y}{T_m}\right)\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right]}{60 \theta V_s P_s A_n}$$

Equation 5-8

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

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

Equation 5-8a

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

Equation 5-9

$$K' = \frac{K_1 V_m Y \left(P_{bar} + \frac{\Delta H}{13.6}\right)\sqrt{T_{amb}}}{P_{bar} T_m \theta}$$

Equation 5-10

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

Equation 5-11

$$V_{cr}(std) = K' \frac{P_{bar} \theta}{T_{amb}}$$

Equation 5-12

$$Y = \frac{V_{cr(std)}}{V_{m(std)}}$$

Method 6

Equation 6-1

$$V_{m(std)} = V_m\, Y \left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar}}{P_{std}}\right)$$
$$= K_1\, Y \left(\frac{V_m\, P_{bar}}{T_m}\right)$$

Equation 6-2

$$C_{SO_2} = K_3 \frac{(V_t - V_{tb})N\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 6-3

$$RE = \frac{C_d - C_a}{C_a}(100)$$

Equation 6-4

$$V_{sb(std)} = V_{sb}\left(\frac{T_{std}}{T_{amb}}\right)\left(\frac{P_{bar}}{P_{std}}\right)$$

Equation 6-5

$$Q_{std} = \frac{V_{sb(std)}}{\theta}$$

Equation 6-6

$$V_{m(std)} = \overline{Q}_{std}\, \theta_s\, (1 - B_{wa})\left(\frac{P_{bar} + P_{sr}}{P_{bar} + P_c}\right)$$

Equation 6-7

$$V_{m(std)} = \overline{Q}_{std}\, \theta_s\, (1 - B_{wa})\sqrt{\frac{M_a}{M_s}}\left(\frac{P_{bar} + P_{sr}}{P_{bar} + P_c}\right)$$

Method 6A

Equation 6A-1

$$V_{CO2(std)} = 5.467 \times 10^{-4} (m_{af} - m_{ai})$$

Equation 6A-2

$$V_{w(std)} = 1.336 \times 10^{-3} (m_{wf} - m_{wi})$$

Equation 6A-3

$$C_{SO_2} = 32.03 \frac{(V_t - V_{tb}) N \left(\frac{V_{soln}}{V_a} \right)}{V_{m(std)} + V_{CO_2(std)}}$$

Equation 6A-4

$$C_{CO_2} = \frac{V_{CO_2(std)}}{V_{m(std)} + V_{CO_2(std)}} \times 100$$

Equation 6A-5

$$C_w = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)} + V_{CO2(std)}}$$

Equation 6A-7

$$m_{SO_2} = 32.03 (V_t - V_{tb}) N \left(\frac{V_{soln}}{V_s} \right)$$

Equation 6A-8

$$E_{SO_2} = F_c (1.829 \times 10^{9}) \frac{m_{SO_2}}{(m_{af} - m_{ai})}$$

Method 6C

Equation 6C-1

$$C_{gas} = (\overline{C} - C_o) \frac{C_{ma}}{C_m - C_o}$$

Method 7

Equation 7-1

$$K_c = 100\frac{A_1 + 2A_2 + 3A_3 + 4A_4}{A_1^2 + A_2^2 + A_3^2 + A_4^2}$$

Equation 7-2

$$V_{sc} = \left(\frac{T_{std}}{P_{std}}\right)(V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= K_1 (V_f - 25\,ml)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

Equation 7-3

$$m = 2K_c\,A\,F$$

Equation 7-4

$$C = K_2\frac{m}{V_{sc}}$$

Equation 7-5

$$RE = \frac{C_d - C_a}{C_a}(100)$$

Method 8

Equation 8-1

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

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

Equation 8-2

$$C_{H_2SO_4} = K_2\frac{N(V_t - V_{tb})\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 8-3

$$C_{SO_2} = K_3 \frac{N\left(V_t - V_{tb}\right)\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 8-4

$$I = \frac{100T_s\left[K_3\, V_{lc} + \left(\frac{V_m Y}{T_m}\right)\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right]}{60\,\theta\, V_s P_s A_n}$$

Equation 8-5

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

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

Method 11

Equation 11-1

$$N_s = 2.039 \frac{W}{V_s}$$

Equation 11-2

$$N_A = 0.2039 \frac{W}{V_s}$$

Equation 11-3

$$N_I = N_T \frac{V_T}{V_I}$$

Equation 11-4

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

Equation 11-5

$$C_{H2S} = \frac{K[(V_{IT} N_I - V_{TT} N_T)\text{sample} - (V_{IT} N_I - V_{TT} N_T)]}{V_{m(std)}}$$

Method 15

Equation 15-1

$$C = \frac{(K)(P_r)}{ML}$$

Equation 15-2

$$SO_2 \text{ equivalent} = \sum (H_2S, COS, 2CS_2)d$$

Equation 15-3

$$\text{Average } SO_2 \text{ equivalent} = \frac{\sum_{i=1}^{N} SO_2 \text{ equiv}_i}{N}$$

Method 15A

Equation 15A-1

$$V_{ms(std)} = \frac{V_{ms}\, Y\, (T_{std})(P_{bar})}{(T_m)(P_{std})} = \frac{K_1\, Y\, (V_m)(P_{bar})}{T_m}$$

Equation 15A-2

$$V_{mc(std)} = \frac{k_1\, Y_c\, (V_{mc})(P_{bar})}{T_m}$$

Equation 15A-3

$$C_{TRS} = \frac{K_2 (V_t - V_{tb}) N \left(\frac{V_{soln}}{V_a}\right)}{V_{ms(std)} - V_{mc(std)}}$$

Equation 15A-4

$$C_{RG} = \frac{(C_{COS})(Q_{COS})}{Q_{COS} + Q_{N2}}$$

Equation 15A-5

$$R = \frac{C_{TRS}}{C_{RG}} \text{ x } 100$$

Method 16

Equation 16-1

$$C = K\frac{P_r}{ML}$$

Equation 16-2

$$TRS = \sum(H_2S, MeSH, DMS, 2DMDS)\, d$$

Equation 16-3

$$AverageTRS = \frac{\sum_{i=1}^{N} TRS_i}{N(1 - B_{WO})}$$

Equation 16-4

$$C = \frac{\sum_{i=1}^{N} S_i}{N}$$

Method 16A

Equation 16A-1

$$V_{m(std)} = V_m\, Y \frac{T_{std}}{T_m}\frac{P_{bar}}{P_{std}} = K_1\, Y \frac{V_m - P_{bar}}{T_m}$$

Equation 16A-2

$$C_{TRS(ppm)} = \frac{K_2\,(V_t - V_{tb})\,N\left(\frac{V_{soln}}{V_a}\right)}{V_{m(std)}}$$

Equation 16A-3

$$C_{RG} = \frac{(Q_{H2S})(C_{H2S})}{Q_{H2S} + Q_{CG}}$$

Equation 16A-4

$$R = \frac{C_{TRS}}{C_{RG}} \times 100$$

Equation 16A-5

$$N_T = \frac{1}{ml\ Na_2\,S_2\,O_3\ Consumed}$$

Equation 16A-6

$$N_I = \frac{N_T V_T}{V_I}$$

Equation 16A-7

$$V_{m(std)} = (\overline{Q}_{std})(\theta_s)(1 - B_{wa})\frac{M_a}{M_b}$$

Equation 16A-8

$$C_{H2S} = \frac{K N_T (V_{TB} - V_T)}{V_{m(std)}}$$

Method 16B

Equation 16B-1

$$C_{TRS} = (C_{SO2})(d)$$

Equation 16B-2

$$C_{TRS} = \frac{\sum_{i=1}^{n} C_{TRS}}{N}$$

Method 18

Equation 18-1

$$C_s = \frac{10^6 (\overline{x} q_c)}{q_c + q_d}$$

Equation 18-2

$$C_s = 106 \overline{x} \left(\frac{q_{c1}}{q_{c1} + q_{d1}} \right) \left(\frac{q_{c2}}{q_{c2} + q_{d2}} \right)$$

Equation 18-3

$$C_s = \frac{G_V \, x \, 10^6 \, \frac{293}{T_s} \frac{P_s}{760}}{V_m \, Y \frac{293}{T_m} \frac{P_m}{760} 1000}$$

$$= \frac{G_V \, x \, 10^3 \, \frac{P_s}{T_s} \frac{T_m}{P_m}}{V_m \, Y}$$

Equation 18-4

$$C_s = \frac{\frac{L_V}{M}\rho(24.055 \times 10^6)}{V_m Y \frac{293}{T_m}\frac{P_m}{760}1000} = 6.24 \times 10^4 \frac{L_V \rho T_m}{M V_m Y P_m}$$

Equation 18-5

$$C_c = \frac{C_s P_r T_i F_r}{P_i T_r (1 - B_{ws})}$$

Method 20

Equation 20-1

$$C_d = \frac{C_w}{1 - B_{ws}}$$

Equation 20-2

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

Equation 20-3

$$X_{CO2} = \frac{5.9}{F_o}$$

Equation 20-4

$$C_{adj} = C_d \frac{5.9}{20.0 - \%O_2}$$

Equation 20-5

$$C_{adj} = C_d \frac{X_{CO2}}{\%CO_2}$$

Equation 20-6

$$E = C_d F_d \frac{20.9}{20.9 - \%O_2}$$

Equation 20-7

$$E = C_d F_c \frac{100}{\%CO_2}$$

Equation 20-8

$$E = C_w F_c \frac{100}{\%CO_{2w}}$$

Method 23

Equation 23-1

$$RRF_i = \frac{1}{n}\sum_{j=1}^{n}\frac{A_{cij}\, m^*_{ci}}{A^*_{cij}\, m_{ci}}$$

Equation 23-2

$$C_i = \frac{m_i * A_i}{A_i * RRF_i\, V_{mstd}}$$

Equation 23-3

$$RRF_{rs} = \frac{A_{ci} * m_{rs}}{A_{rs}\, m_{ci} *}$$

Equation 23-4

$$R* = \frac{A_i * m_{rs}}{A_{rs}\, RF_{rs}\, m_i *} x100\%$$

Equation 23-5

$$RRF_s = \frac{A_{ci} * m_s}{A_{cis}\, m_{ci} *}$$

Equation 23-6

$$R_s = \frac{A_s\, m_i *}{A_i * RRF_s\, m_s} x100\%$$

Equation 23-7

$$MDL = \frac{2.5\, A_{ai}\, m_i *}{A_{ci} * RRF_i}$$

Equation 23-8

$$C_{Tr} = \sum_{i=1}^{n} C_i$$

Method 25

Equation 25-1

$$\Delta P = 0.01\frac{FP_b\, \theta}{V_t}$$

Equation 25-2

$$V_s = 0.3857\, V\left[\frac{P_t}{T_t} - \frac{P_{ti}}{T_{ti}}\right]$$

Equation 25-3

$$C_t = \left[\frac{\frac{P_{tf}}{T_{tf}}}{\frac{P_t}{T_t} - \frac{P_{ti}}{T_{ti}}} \right] \left[\frac{1}{r} \sum_{j=1}^{r} C_{tm_j} \right]$$

Equation 25-4

$$C_c = 0.3857 \frac{V_v P_f}{V_s T_f} \left[\frac{1}{q} \sum_{k=1}^{q} C_{cm_k} \right]$$

Equation 25-5

$$C = C_t + C_c$$

Equation 25-6

$$m_c = 0.4993\,C$$

Equation 25-7

$$\text{Percent recovery} = 1.604 \frac{M}{L} \frac{V_v}{P} \frac{P_t}{T_f} \frac{C_{cm}}{N}$$

Equation 25-8

$$RSD = \frac{100}{\bar{x}} \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

Method 25A

Equation 25A-1

$$C_c = K\,C_{meas}$$

Method 26

Equation 26-1

$$\mu g \frac{Cl^-}{ml} = g \text{ of NaCl x } 10^3 \text{ x } \frac{35.453}{58.44}$$

Equation 26-2

$$\mu g \frac{Br^-}{ml} = g \text{ of NaBr x } 10^3 \text{ x } \frac{79.904}{102.90}$$

Equation 26-3

$$\mu g \frac{F^-}{ml} = g \text{ of NaF x } 10^3 \text{ x } \frac{18.998}{41.99}$$

Equation 26-4

$$m_{HX} = K V_s (S_X^- - B_X^-)$$

Equation 26-5

$$m_{X2} = V_s (S_X^- - B_X^-)$$

Equation 26-6

$$C = K \frac{m_{HX,X2}}{V_{m(std)}}$$

Method 26A

Equation 26A-1

$$\mu g \frac{Cl^-}{ml} = g \text{ of NaCl x } 10^3 \text{ x } \frac{35.453}{58.44}$$

Equation 26A-2

$$\mu g \frac{Br^-}{ml} = g \text{ of NaBr x } 10^3 \text{ x } \frac{79.904}{102.90}$$

Equation 26A-3

$$\mu g \frac{F^-}{ml} = g \text{ of NaF x } 10^3 \text{ x } \frac{18.998}{41.99}$$

Equation 26A-4

$$m_{HX} = K V_s (S_{X-} - B_{X-})$$

Equation 26A-5

$$m_{X2} = V_s (S_{X-} - B_{X-})$$

Equation 26A-6

$$C = K \frac{m_{HX,X2}}{V_{m(std)}}$$

Method 29

Equation 29-1

$$M_{fh} = C_{a1} F_d V_{soln,1}$$

Equation 29-2

$$M_{bh} = C_{a2} F_a V_a$$

Equation 29-3

$$M_t = (M_{fh} - M_{fhb}) + (M_{bh} - M_{bhb})$$

Equation 29-4

$$Hg_{fh} = \frac{Q_{fh}}{V_{f1B}}\left(V_{soln,1}\right)$$

Equation 29-5

$$Hg_{bh2} = \frac{Q_{bh2}}{V_{f2B}}\left(V_{soln,2}\right)$$

Equation 29-6

$$Hg_{bh3(A,B,C)} = \frac{Q_{bh3(A,B,C)}}{V_{f3(A,B,C)}}\left(V_{soln,3(A,B,C)}\right)$$

Equation 29-7

$$Hg_{bh} = Hg_{bh2} + Hg_{bh3A} + Hg_{bh3B} + Hg_{bh3C}$$

Equation 29-8

$$Hg_{t} = (Hg_{fh} - Hg_{fhb}) + (Hg_{bh} - Hg_{bhb})$$

Equation 29-9

$$C_s = \frac{K_4 M_t}{V_{m(std)}}$$

Method 0010

$$\frac{\text{Max POHC}_i \text{ Mass}}{DV_{eff(std)}} = \text{Max POHC}_i \text{ conc}$$

$$\frac{LDL_{POHC} \times 10}{POHC_{i\ conc}} = V_{TBC}$$

$$C_{POHC}\ (\mu g/ml) \times \text{sample volume}\ (ml) = \text{amount}\ (\mu g) \text{ of POHC in sample}$$

Method 0030

$$C_g = \frac{\text{Total weight of CPD in sample, } \mu g \text{ (i.e. VOST tubes \& condensator)}}{\text{Volume of sample at standard conditions, dscm}}$$

Method 0050

Equation 0050-4

$$m_{HCl} = S \times V_s \times \frac{36.46}{35.45}$$

Equation 0050-5

$$m_{Cl2} = S \times V_2$$

Equation 0050-6

$$C = K \times \frac{m}{V_{m(std)}}$$

Method 0051

$$m_{HCl} = S \times V_s \times \frac{36.46}{35.45}$$

$$m_{Cl2} = S \times V_2$$

$$C = K \times \frac{m}{V_{m(std)}}$$

Method 0060

$$M_{fh} = C_{a1} F_d V_{soln,1}$$

$$M_{bh} = C_{a2} F_a V_a$$

$$M_t = (M_{fh} - M_{fhb}) + (M_{bh} - M_{bhb})$$

Method 0061

$$m = (S - B) \times V_{ls} \times d$$

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Appendix C

The Inspector's Tool Kit

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The Inspector's Tool Kit Items

1. **Dial Caliper-** Used for measuring nozzle diameter and inspection of pitot tubes. The dial caliper should have graduation units of 0.001 inches. Price: $38.

2. **Level Indicator-** Used for verification of proper construction dimensions and spacing requirements for Type S pitot tube. Also used in measuring yaw angle of Type S pitot tube during verification of absence of cyclonic flow at a sampling location. Price: $28.

3. **Thermocouple Simulator Source-** Used with the Method 5 meter box for checking accuracy of temperature displays and controllers. The thermocouple simulator source should be designed for Type K thermocouples with 22 precise test points. The temperature range should be from 0 to 2100 F. Price: $225.

4. **Calibration Orifice Set-** The Calibration Orifice Set is used for calibrating and auditing Method 5 metering system. The set should include 5 calibrated orifices with ½ inch quick connects. In addition, a disk with appropriate software/spreadsheet for performing calculations should also be part of the Calibration Orifice Set. Price: $395.

5. **IsoCal Software-** IsoCal Software should be a MicroSoft Excel workbook/3.5" disk designed for integrated isokinetic source sampling calculations. The IsoCal Software should provide all the worksheets necessary to perform US EPA's Federal Reference Methods 1 through 5 test setup, data entry, and data reduction. Price: $195.

6. **Isokinetic Slide Rule or Calculator-** The Isokinetic Slide Rule or Calculator performs isokinetic stack sampling calculations to calculate a proper Delta H based upon a Delta P reading, once all the various constants/source parameters have been entered properly into the calculator or performed correctly with the slide ruler. Price: $195.

7. **Pocket Barometer-** Used to determine atmospheric pressure, readable to within 0.02 inches Hg divisions. Price: $30.

8. **Modular Pitot Tube-** A Modular Pitot Tube, capable of extension to 1 meter, used to measure stack gas velocity, static pressure, and cyclonic flow. The pitot tube would be used in conjunction with a hand-held digital manometer (0-19.99 inches). Price: $80.

9. **Hand-Held Manometer-** Used in conjunction with the Modular Pitot Tube. The hand-held digital manometer (readable to 0.01 inches of water) is a useful alternative to the standard size manometer or magnehelic gauge; and is especially ideal for field monitoring and troubleshooting. Measures positive, negative, or differential air pressure. Price: $55.

10. **Hand-held Digital Thermometers-** Used to measure stack temperature and various temperatures associated with the Method 5 sampling train. Should be a Type K thermocouple coupled to a hand-held control unit with capability of readings in the range of –58 to 1999.9 F. Price: $155.

11. **Bull's Eye Level-** Used for indicating level of pitot tube during evaluation with Level Indicator. The Bull's Eye Level may also be placed on the pitot tube (has thumb screw clamps) during sampling to indicate proper orientation. Price: $25.

12. **Tape Measure-** Used to document stack geometry and sampling port location from upstream and downstream disturbances. Material should be stainless steel and length of 100 feet. Price: $75

13. **Agency Checklist-** Various Agency checklist for observing Federal Reference Methods 1 through 5 and specific SW-846 methods (Methods 0010, 0030, 0050, 0051, 0060, 0061).

14. **Stack Sampling Nomographs for Field Estimations-** Field nomographs used in estimating or checking data used in stack sampling. Four basic groups of nomographs are helpful to the Agency inspector. They are:

    - Moisture nomographs (Wet bulb/dry bulb, combustion calculation, FRM 4 etc.);
    - Excess air nomographs (Temperature versus excess air, excess air versus composition etc.);
    - Velocity and volumetric flow rate nomographs (Coal-fired equipment, volume versus heat input, pitot tube velocity readings etc.); and
    - Concentration and mass emission rate nomographs (ppm emissions, pounds per million BTU, pounds per hour etc.).