SUMMARY SHEET 2

			Run #1	Run #2	Run #3	Avg
Client/Plant Name		FDS 2				
Job No.		FDS 2				
Sampling Location		FDS 2				
Run ID#		FDS 2				
Test Date		FDS 2				
Run Start Time		FDS 2				
Run Finish Time		FDS 2				
Net Traverse Points		FDS 1				
Traverse Matrix (Rectangular)		FDS 1				
Net Run Time, min	θ	FDS 2				
Barometric Pressure, in. Hg	P_b	FDS 2				
Stack Static Pressure, in. H_2O	P_g	FDS 2				
Abs Stack Pressure (P_b + P_g/13.6), in. Hg	P_s	SS 2				
Average Stack Temperature, °F	t_s	FDS 2				
Avg Abs Stack Temp (460 + t_s), R	T_s	SS 2				
Moisture Content, fraction	B_{ws}	FDS 4				
Carbon Dioxide, % dry	$\%CO_2$	FDS 3				
Oxygen, % dry	$\%O_2$	FDS 3				
Carbon Monoxide + Nitrogen, % dry	$\%(CO+N_2)$	FDS 3				
Dry Molecular Weight, lb/lb-mole	M_d	FDS 3				
Stack Area, ft^2	A	FDS 1				
Pitot Tube Coefficient	C_p	CDS 2a				
Average Velocity Pressure, in. H_2O	Δp	FDS 2				
Average $[(t_{si}+460)\ \Delta p]^{1/2}$	$[T_{si}\ \Delta p]^{1/2}$	FDS 2				
Average Velocity, ft/sec	v_s	SS 2				
Volumetric Flow Rate, dscfh	Q_{sd}	SS 2				
Volumetric Flow Rate, wscfh	Q_{sw}	SS 2				
Post-test Calibration Checks						
Temperature and Barometer		CDS 2d				
Differential Pressure Sensor		CDS 2d				

$$v_s = 85.49\, C_p \sqrt{\frac{(T_s \Delta p)_{avg}}{P_s M_s (1 - B_{ws})}}$$

$$Q_{sd} = 17.64\ (3600)\ (1 - B_{ws})\, v_s A \frac{P_s}{T_{s(avg)}}$$

$$Q_{sw} = \frac{Q_{sd}}{(1 - B_{ws})}$$

FIELD PROCEDURE 2
Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

A. ***Pretest Preparations***

1. Inspect or calibrate Type S pitot tube **(see CP 2 or CP 2a).**
2. Calibrate barometer **(see CP 2d).**

B. ***Procedure***

1. Set up the apparatus as shown in Figure F2-1. **Use FDS 2.**
2. ***Optional:*** Leak-check the setup (see FP 2a).
3. Level and zero the manometer.
4. Record all necessary data as shown in FDS 2.
5. Measure the velocity head and temperature at each traverse point.
6. Measure the static pressure in the stack.
7. Determine the atmospheric pressure.
8. Determine the stack gas dry molecular weight **(see FP 3).**
9. Obtain the moisture content from FP 4 (or equivalent) or from FP 5.
10. Determine the cross-sectional area of the stack or duct at the sampling location. Whenever possible, physically measure the stack dimensions rather than using blueprints.
11. ***Mandatory:*** Leak-check the pitot tube setup **(see FP 2a).**
12. Check pitot tube for damage.
13. If any $\Delta p \leq 0.05$ in. H_2O, check the necessity of using a more sensitive differential pressure gauge ($T \leq 1.05$). **See FDS 2.**

C. ***Post-test Calibrations***

After each test series **(use CDS 2d):**

1. Calibrate temperature gauges **(see CP 2e).**
2. Calibrate differential pressure gauges other than inclined manometers, e.g., magnehelic gauges **(see CP 2f).**

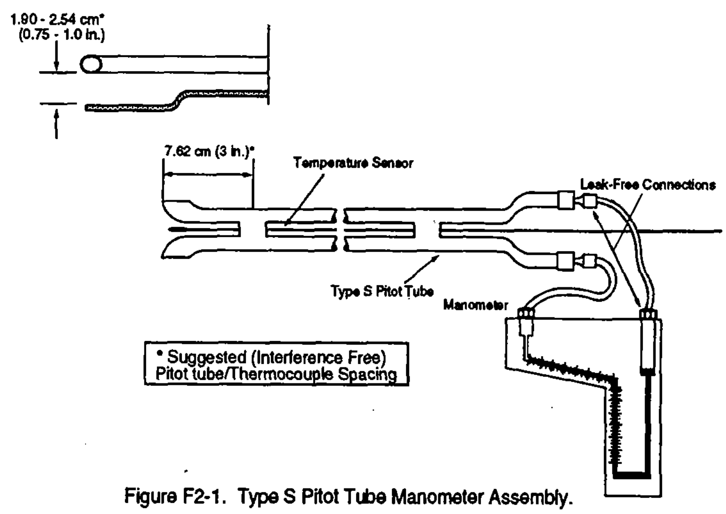


Figure F2-1. Type S Pitot Tube Manometer Assembly.

FIELD DATA SHEET 2
Velocity Head, Temperature, and Stack Pressure Measurements

Client/Plant Name ______________________ Job # ______________________

City/State ______________________ Date ______________________

Test Location/Run # ______________________ Personnel ______________________

Note: *Ensure that pitot tube is aligned parallel to the stack or duct axis.*

Pitot Tube ID #		
Pitot Tube Coefficient (C_p)		
Δp Gauge Sensitivity		
Barometric Pressure (P_b) (in. Hg)		
Test Location Elevation Difference from Bar., (positive if higher) (B) (ft)		
Corr $P_b = P_b - 0.001$ B (in. Hg)		
(✓) ____ Piezometer ____ Type S		
Static Pressure (P_g) (in. H_2O)		
Post-test Leak Check: Side	A	B
Pressure Tap Δp (in. H_2O)		
Stable for 15 seconds? (yes no)		
Pitot Tube Condition: Damaged? Post-test Intercomponent Spacing:		

Level/Zero Checks: Mark Pt. #'s with an asterisk (*)

Velocity Traverses Start Time: Finish Time:					
Pt. #	Δp in. H_2O	Temp. °F	Pt. #	Δp in. H_2O	Temp. °F
Average:					

QA/QC Check

Completeness _____ Legibility _____ Accuracy _____ Specifications _____ Reasonableness _____

Checked by: ______________________ ______________________

Personnel (Signature/Date) Team Leader (Signature/Date)

CHECKLIST

Velocity Differential Pressure Gauge

Pressure gauge sensitivity ________ in. H_2O.

____ Calculate T and ensure that $T \le 1.05$.

$$T = \frac{\sum_{i=1}^{n} \sqrt{\Delta p_i + 0.005}}{\sum_{i=1}^{n} \sqrt{\Delta p_i}}$$

where:
Δp_i = individual velocity head reading at traverse point i, in. H_2O.
n = total number of traverse points.

Temperature Gauge

____ Ensure that the temperature gauge (thermocouple) attached to the pitot tube is in an interference-free arrangement, i.e., at least 3/4 inch clearance.

____ Ensure that the sensor tip is not touching any metal.

Pressure Probe Manometer

____ Ensure readability of the manometer ≤0.1 in. Hg.

Barometric Pressure, FP 2a, Procedure 2 (if used)

Weather Station Value, A ____________ in. Hg

Weather Station Elevation, B ____________ ft

Test Location Elevation, C ____________ ft

Barometric Pressure, $P_b = A + 0.001 (B - C)$ ____________ in. Hg

FIELD PROCEDURE 2a
Leak-Check of Pitot Tube System

1. Blow into the pitot impact opening until at least 3 in. H_2O velocity pressure registers on the manometer, and close off the impact opening.

2. Observe the time (pressure must remain stable for at least 15 seconds).

3. Do the same for the static pressure side, except use suction to obtain -3 in. H_2O.

FIELD PROCEDURE 2b
Barometric Pressure

A. *Procedure 1*

1. Read and record the field barometer at the sampling location.
2. If the field barometer is read at ground level or at an elevation different from the sampling location, adjust the reading at a rate of 0.1 in. Hg per 100 ft (see step B3, except P_r would be the field barometer reading).

B. *Procedure 2*

1. Obtain the station pressure or absolute barometric pressure P_r from a nearby National Weather Service station and its elevation (A) in feet above sea level.
2. Determine the elevation (B) of sampling location in feet above sea level.
3. Calculate the site barometric pressure (P_b) as follows:

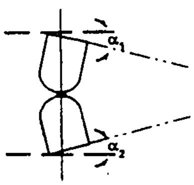
$$P_b = P_r + 0.001\ (A\text{-}B)$$

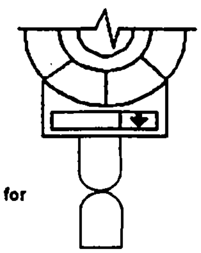
CALIBRATION PROCEDURE 2
Type S Pitot Tube Inspection

Note: Method 2 provides the criteria for an acceptably constructed Type S pitot tube. However, the procedure for making the necessary measurements is not specified. One approach is given below.

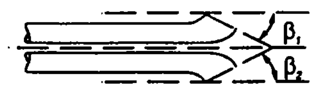
1. Use a vise with faces that are parallel and perpendicular. Use a carpenter's level (or similar) to make this check.
2. Place the pitot tube in the vise, and level the pitot tube horizontally using the degree indicating level or the carpenter's level.
3. Place a degree indicating level as shown on CDS 2.
4. Measure distance A, which is P_A plus P_B. Method 2 specifies that $P_A = P_B$, but does not give any tolerance for this measurement. Experience has shown that this measurement is very difficult; therefore, it is suggested that $P_A = P_B = A/2$.
5. Measure the external tube diameter (D_t) with a micrometer, machinist's rule, or internal caliper.
6. Record all data as shown on CDS 2.
7. Calculate dimensions w and z as shown on CDS 2.

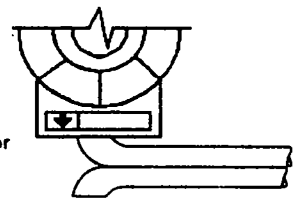
CALIBRATION DATA SHEET 2
Type S Pitot Tube Inspection



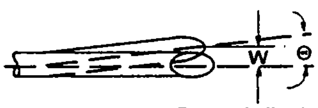


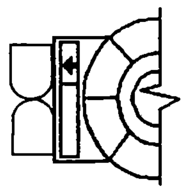
Degree indicating level position for determining α_1 and α_2.



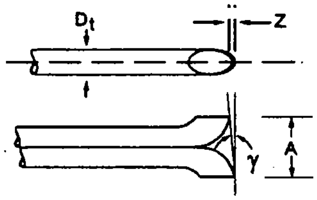


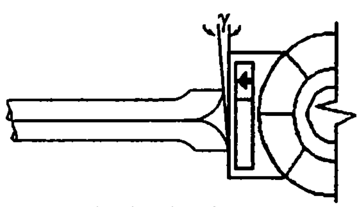
Degree indicating level position for determining β_1 and β_2.





Degree indicating level position for determining Θ.





Degree indicating level position for detemining γ then calculate Z.

Level and Perpendicular?	
Obstruction?	
Damaged?	
α_1 $(-10° \leq \alpha_1 \leq +10°)$	
α_2 $(-10° \leq \alpha_2 \leq +10°)$	
β_1 $(-5° \leq \beta_1 \leq +5°)$	
β_2 $(-5° \leq \beta_2 \leq +5°)$	
γ	
Θ	
$z = A \tan \gamma$ $(\leq 0.125")$	
$w = A \tan \Theta$ $(\leq 0.03125")$	
D_t $(3/16" \leq D_t \leq 3/8")$	
A	
$A/2D_t$ $(1.05 \leq P_A/D_t \leq 1.5)$	

QA/QC Check
Completeness ____ Legibility ____ Accuracy ____ Specifications ____ Reasonableness ____

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)

CALIBRATION PROCEDURE 2a
Type S Pitot Tube

A. Preliminaries

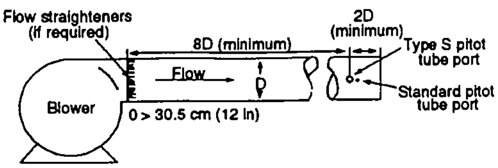
1. Check the Type S pitot tube construction specifications (see CP 2 and attach CDS 2). Do not use pitot tubes that do not meet the alignment specifications for the face openings.
2. Permanently mark ID# and mark one leg of the tube A and the other, B.
3. Check the standard type pitot tube specifications (see CP 2b)
4. Check the calibration flow system specifications (see CP 2c).
5. Consider the items in section C.

B. Procedure

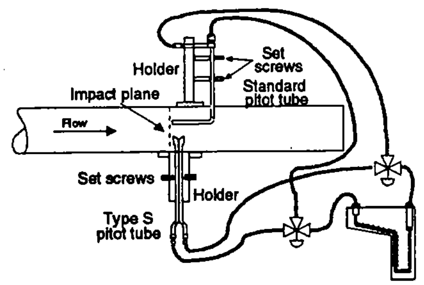
1. Fill the manometer with oil that is clean and of the proper density. Inspect and leak-check all pitot lines. A manometer setup using three-way valves as shown in Figure C2a-1 will facilitate the operation.
2. Turn on the fan, and allow the flow to stabilize.
3. Level and zero the manometer. Position and align the standard pitot tube at the calibration point. Seal the entry port surrounding the tube. Read and record Δp_{std} (see CDS 2a).
4. Remove the standard pitot tube from the duct, and disconnect it from the manometer. Seal the standard entry port.
5. Connect the Type S pitot tube to the manometer. Open the Type S entry port. Check the manometer level and zero. Insert and align the A side of the Type S pitot tube at the same measurement point as that of the standard pitot tube. Seal the entry port surrounding the tube. Read and record Δp_s.
6. If the B side is also being calibrated, align the B side. Read and record Δp_s.
7. Remove the Type S pitot tube from the duct, and disconnect it from the manometer.
8. Repeat steps B3 through B7 until three pairs of Δp readings have been obtained for A side and, if applicable, B side).
9. Calculate C_p as shown on the data sheet.

C. Special Considerations

1. Isolated Type S Pitot Tube. Must be used alone or, if used with other components (nozzle, thermocouple, sample probe), in an arrangement that is free from aerodynamic interference effects (see Figures C2a-2 through C2a-4)
2. Type S Pitot Tube-Thermocouple Combinations (without sample probe). Must be used in same configuration of pitot tube-thermocouple combination or with other components in an interference-free arrangement (Figures C2a-2 and C2a-4).
3. Assemblies with Sample Probes. Check for blockage effect before calibrating as shown in Figures 2a-5a and 2a-5b. If necessary, the calibration point may be a few inches off-center. If blockage is significant, adjust calibration coefficient as shown in CDS 2a-1.
4. Probe Assemblies in Non-Interference Free Arrangements. Perform separate calibrations with each of the commonly used nozzle sizes in place.
5. Probe Assemblies Always Used in Same Orientation. Calibration of only the side used is acceptable.
6. Unacceptable Assemblies. Impact pressure opening plane of the pitot tube below the entry plane of the nozzle (see Figure C2a-2).
7. Single Velocity Calibration at 3,000 fpm. Type S pitot tube coefficients are ±3% for the measurement of velocities above 1,000 fpm and to ±5% to ±6% for the measurement of velocities between 600 and 1,000 fpm.

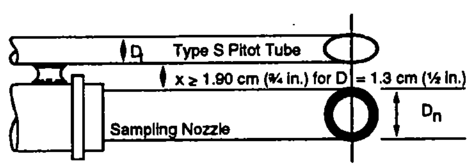


Pitot tube calibration system.

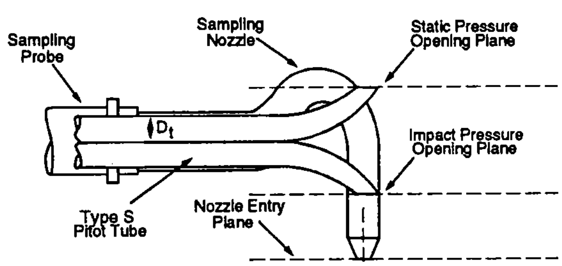


Pitot tube calibration set-up.

Figure C2a-1.



A. Bottom View; showing minimum pitot tube-nozzle separation.



B. Side View; to prevent pitot tube from interfering with gas flow streamlines approaching the nozzle, the impact pressure opening plane of the pitot tube shall be even with or above the nozzle entry plane.

Figure C2a-2. Proper Pitot Tube-Sampling Nozzle Configuration.

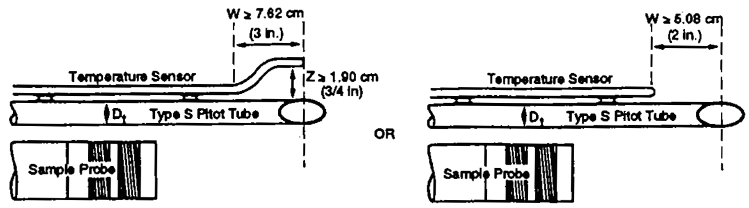


Figure C2a-3. Proper Thermocouple Placement to Prevent Interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

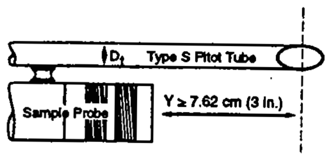


Figure C2a-4. Minimum Pitot-Sample Probe Seperation Needed to Prevent Interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

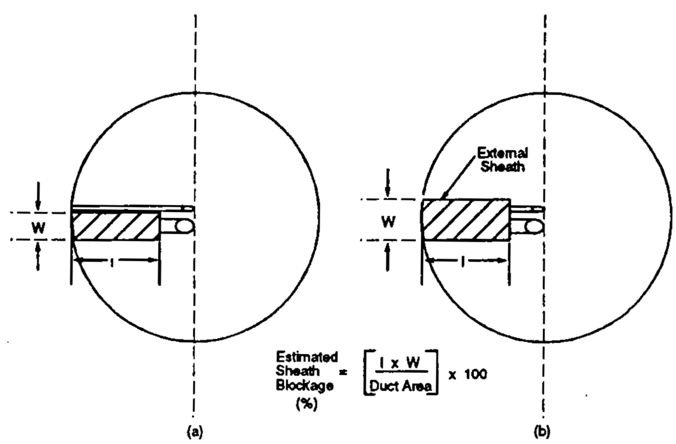


Figure C2a-5. Projected-Area Models for Typical Pitot Tube Assemblies.

CALIBRATION DATA SHEET 2a
Type S Pitot Tube

"A" Side Calibration				
Run No.	Δp_{std} in. H_2O	Δp_s in. H_2O	$C_{p(s)}$	Deviation
1				
2				
3				
		$\overline{C}_p$(Side A)		

"B" Side Calibration				
Run No.	Δp_{std} in. H_2O	Δp_s in. H_2O	$C_{p(s)}$	Deviation
1				
2				
3				
		$\overline{C}_p$(Side B)		

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

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

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

σ(A or B) must be ≤ 0.01

$|\overline{C}_p(\text{Side A}) - \overline{C}_p(\text{Side B})| \leq 0.01$

Average = $[\overline{C}_p(\text{Side A}) + \overline{C}_p(\text{Side B})]/2$ = ________

If the intent is to always use either Side A or Side B orientation, that side only need be calibrated. Otherwise use the average of Side A and Side B of the pitot tube that meets the specifications above for C_p.

QA/QC Check

Completeness ____ Legibility ____ Accuracy ____ Specifications ____ Reasonableness ____

Certification

I certify that the Type S pitot tube/probe ID# ________________, the standard type pitot tube, and the calibration setup meet or exceed all specifications, criteria and/or applicable design features and hereby assign a pitot tube calibration factor C_p of _____.

Certified by: ______________________________ ______________________________

Personnel (Signature/Date) Team Leader (Signature/Date)

CALIBRATION DATA SHEET 2b
Verification of Standard Pitot Tube Design Specifications

Shape of tip = (✓) Hemispherical ___ Ellipsoidal ___ Conical ___

Size of static pressure holes = about ***0.1 D_t?*** Yes ___ No ___

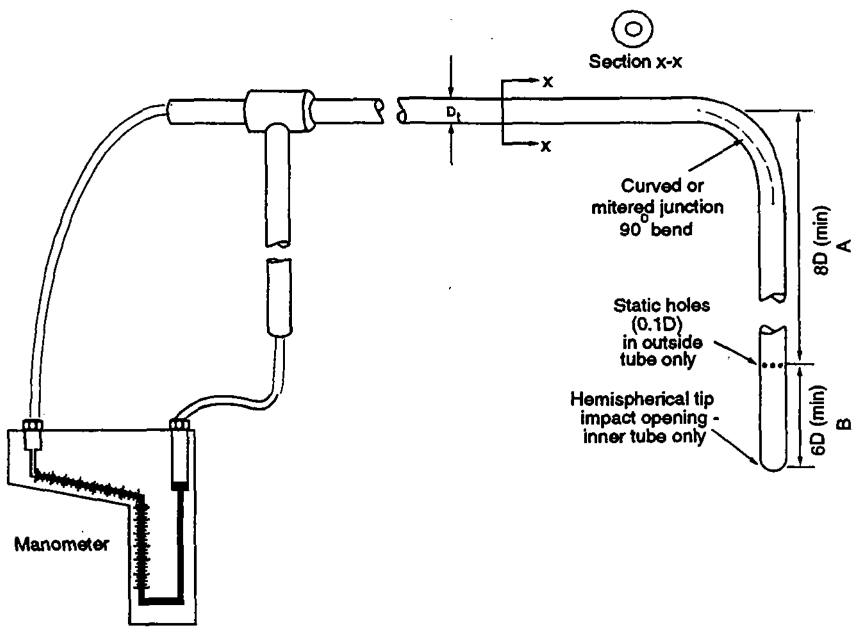
Static pressure holes equally spaced in a piezometer ring configuration? Yes ___ No ___

Tube diameter (D_t) = ____________ inch

Junction = ____________ ***90°?*** Yes ___ No ___

Distance A (D_A) = ____________ inch D_A/D_t = ____________ ≥ ***6?*** Yes ___ No ___

Distance B (D_B) = ____________ inch D_B/D_t = ____________ ≥ ***8?*** Yes ___ No ___



QA/QC Check
Completeness ____ Legibility ____ Accuracy ____ Specifications ____ Reasonableness ____

Certification
I certify that the Standard pitot tube/probe ID# ________________ meets or exceeds all specifications, criteria and/or applicable design features and is hereby assigned a pitot tube coefficient C_p of 0.99.

Certified by: ______________________________ ______________________________
Personnel (Signature/Date) Team Leader (Signature/Date)

CALIBRATION DATA SHEET 2c
Type S Calibration Setup

Duct Dimensions
Depth/Diameter ≥ *12 in. (?)* ________

Width (if rect.) ≥ *10 in. (?)* ________

Equiv. Dia. (if rect), D_e ________

Distances to disturbances
Upstream ≥ *8 D_e (?)** ________

Downstream ≥ *2 D_e (?)** ________

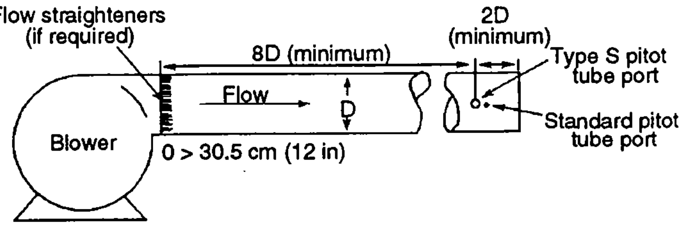
* If not, demonstrate acceptability
Yaw angle ≤ *2 degrees (?)* ________

Pitch angle ≤ *2 degrees (?)* ________

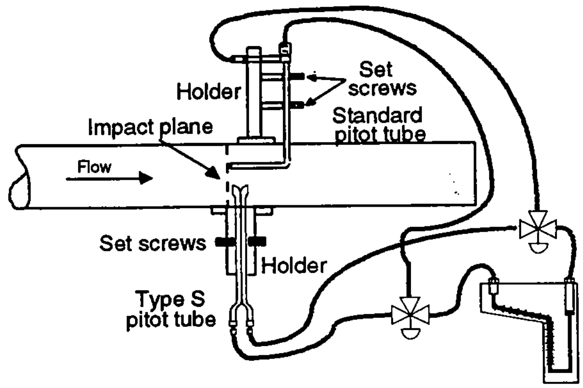
Flow Steadiness

	Δp	ΔΘ
3000 fpm		

ΔΘ is the lapse time before Δp changes by ±2% in minutes (time it takes to read Δp for standard pitot and Type-S pitot tubes).



Pitot tube calibration system.



Pitot tube calibration set-up.

QA/QC Check
Completeness ____ Legibility ____ Accuracy ____ Specifications ____ Reasonableness ____

Certification
I certify that the calibration setup for the Type S pitot tube meets or exceeds all specifications, criteria and/or applicable design features.

Certified by: ______________________ ______________________
Personnel (Signature/Date) Team Leader (Signature/Date)

CALIBRATION PROCEDURE 2d
Barometer

A. Procedure 1

1. Compare the field barometer reading against that of a mercury-in-glass barometer.
2. Adjust the field barometer reading to within ±0.1 in. Hg.

B. Procedure 2

1. Obtain the station value or absolute barometric pressure P_r from a nearby National Weather Service station and its elevation (A) in feet above sea level.
2. Determine the elevation (B) in feet above sea level of the site of the field barometer.
3. Calculate the site barometric pressure (P_b) as follows:

$$P_b = P_r + 0.001\ (A-B)$$

4. Compare the field barometer reading against P_b obtained in step 3.
5. Adjust the field barometer reading to within ±0.1 in. Hg.

CALIBRATION DATA SHEET 2d
Post-test Calibrations

Barometer			
Mercury (M)	Field (F)	F - M	*≤ ±0.1 in. Hg?*

Temperature				
Abs Average Stack Temperature.	S			
Reference Temperature	R		S/R =	*(0.90 to 1.10?)*
Temperature Reading	T		T/R =	*(Meet criterion?)*
Denote source of temperature: Oil bath _____ Other (Explain)				

Method 2: T/R = 0.985 to 1.015
Method 2A T/R = 0.98 to 1.02

Pressure Sensor (if other than inclined or mecury-in-glass)

Check (✓) Differential _____ U-Tube _____ Other _____

____ ***Low to high values span range of Δp's?*** _____ ***Low to high values span range of pressures***

Level	Gauge (A)	Reference (B)	A/B *(0.95 to 1.05?)*
Pressure Side			
Low			
Mid			
High			
Vacuum Side			
Low			
Mid			
High			

Reference: Inclined gauge-oil or mercury-in-glass.

QA/QC Check
Completeness _____ Legibility _____ Accuracy _____ Specifications _____ Reasonableness ____

Checked by: ______________________________ ______________________________
Personnel (Signature/Date) Team Leader (Signature/Date)

CALIBRATION PROCEDURE 2e
Temperature Sensors

A. References

Use as appropriate the following:

1. For ≤761°F, ASTM mercury-in-glass reference thermometers.
2. Reference thermocouple/potentiometer, NIST calibrated. Suitable for >761°F.
3. Thermometric fixed points, e.g., ice bath and boiling water (corrected for barometric pressure).

B. Measurement

1. Select the calibration temperature to within ±10% of the absolute average stack temperature. **(Use CDS 2d)**.
2. Select the appropriate references from section A.
3. Compare the field temperature sensors against the appropriate references (must be within ±1.5% of the absolute reference temperature, unless otherwise specified).

C. Notes

Although not stated in the Code of Federal Regulations, EPA has found the following to be acceptable as an alternative to calibrating thermocouples at ±10% of absolute stack temperature (see EMTIC GD-28, "Alternate Method for Thermocouple Calibration"):

1. Check the thermocouples against a reference thermometer at ambient conditions and at either an ice point or some elevated temperature other than ambient.
2. The temperatures of both sensors at both temperatures must agree within ±2°F for the thermocouple to be considered accurate.

CALIBRATION PROCEDURE 2f
Pressure Sensors

A. Differential Pressure Sensors

Calibrate or check the calibration of differential pressure sensors other than inclined manometers as follows:

1. Connect the differential pressure sensor to a gauge-oil manometer as shown in Figure C2f-1.
2. Vent the vacuum side to the atmosphere, and place a pressure on each system.
3. Compare Δp readings of both devices at three or greater levels that span the range.
4. Repeat steps A1 through A3 for the vacuum side; vent the pressure side and for the vacuum side and place a vacuum on the system.
5. The readings at the three levels must agree within ±5% of the reference sensor.

B. U-Tube Manometers

Calibrate or check the calibration of U-tube manometers or other pressure gauges other than mercury-in-glass manometers as follows: Use the same procedure as that in section A, except use a mercury-in-glass manometer as the reference.

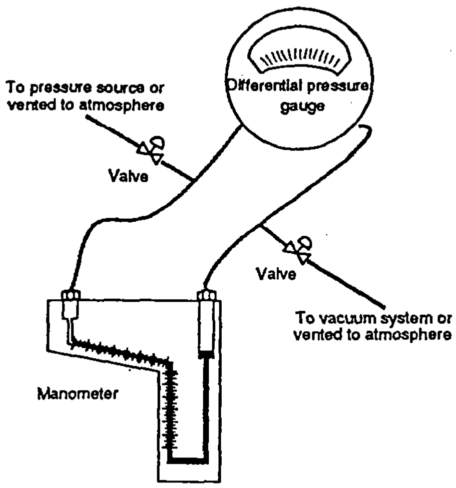


Figure C2f-1. Differential pressure sensor check.

SUMMARY SHEET 2A

			Run #1	Run #2	Run #3	Avg
Client/Plant Name		FDS 2A				
Job No.		FDS 2A				
Sampling Location		FDS 2A				
Run ID#		FDS 2A				
Test Date		FDS 2A				
Run Start Time		FDS 2A				
Run Finish Time		FDS 2A				
Net Run Time, min	θ	FDS 2A				
Barometric Pressure, mm Hg	P_b	FDS 2A				
Average Meter Gauge Pressure, mm Hg	P_g	FDS 2A				
Average Meter Temperature, K	T_s	FDS 2A				
Initial Meter Calibration Factor	Y_i	CDS 2A				
Final Meter Calibration Factor	Y_f	CDS 2A				
Average Meter Calibration Factor	Y_m	CDS 2A				
Initial Meter Reading, m^3	V_{mi}	FDS 2A				
Final Meter Reading, m^3	V_{mf}	FDS 2A				
Metered Volume, m^3	V_{ms}	SS 2A				
Volumetric Flow Rate, wscfh	Q_s	SS 2A				
Post-test Calibration Checks						
Temperature and Barometer		CDS 2d				
Metering Device		CDS 2A				

$$V_{ms} = 0.3853\ Y_m\ (V_{mf} - V_{mi})\ \frac{(P_b + P_g)}{T_m}$$

$$Q_s = \frac{V_{ms}}{\theta}$$

FIELD PROCEDURE 2A
Direct Measurement of Gas Volume Through Pipes and Small Ducts

Note: *This procedure applies to determining gas flow rates in pipes and small ducts, either in-line or at exhaust positions in range of 0 to 50°C.*

A. Preliminaries

1. Select an appropriate volume meter. Consider the manufacturer's recommended capacity (minimum and maximum) of the meter, temperature, pressure, corrosive characteristics, the type of pipe or duct, severe vibrations, and other factors that may affect the meter calibration.
2. Calibrate the volume meter to within ±2%. **See CP 2.**
3. Install the gas meter. Use flange fittings, wherever possible, and gaskets or other seal materials to ensure leak-tight connections.

B. Measurement

1. Leak-check the volume meter as follows:
   a. For a meter under positive pressure, apply a small amount of liquid leak detector solution containing a surfactant to the connections.
   b. For a meter under negative pressure, block the flow at the inlet of the line, if possible, and watch for meter movement. If this procedure is not possible, visually check all connections, and ensure leak-tight seals.
2. For sources with continuous, steady emission flow rates **(see FDS 2A).**
   a. Record the initial meter volume reading, meter temperature(s), meter pressure, and barometric pressure, and start the stopwatch.
   b. Throughout the test period, record the meter temperatures and pressure so that average values can be determined.
   c. At the end of the test, stop the timer, and record the elapsed time, the final volume reading, meter temperatures, pressure, and barometric pressure.
3. For sources with noncontinuous, non-steady emission flow rates, use step B2 with the addition of the following: Record all the meter parameters and the start and stop times corresponding to each process cyclical or noncontinuous event.

C. Post-test Calibrations

1. Calibrate the volume meter (must be ≤ ±5% from the initial). If >5%, either void the test series or use whichever meter coefficient value (i.e., before or after) that gives the greater value of pollutant emission rate. **(See CP 2A).**
2. Check the temperature gauge calibration at ambient temperature (must be < ±2% of absolute temperature). **(See CP 2e).**

FIELD DATA SHEET 2A
Volume Flow Rate - Direct

Client/Plant Name ______________________ Job # ____________

City/State ______________________ Date/Time ____________

Test Location/Run # ______________ Personnel ______________

Meter Type ____________ Meter ID# ____________ Meter Cal. Coeff, Y_i ____________

Date Meter Last Calibrated ____________ Start Time ____________ Finish Time ____________

Barometer ID# ________ Bar Pressure, mm Hg: Start ________ Finish ________ Avg, P_b ________

Time Run/Clock	Meter				
	Vol Rdg (V_m) (m^3)	Pressure, P_g (mm Hg)	Temperature		
			t_m (°C)	T_m (K)	
	Average				

Post-test Calibrations

Attach CDS 2d and CDS 2A temperature, barometer, meter calibrations.

____ Stopwatch accurate to ±1 sec?

____ For meter, Y_f/Y_i = ____________ **(0.95 to 1.05?)**

QA/QC Check

Completeness _____ Legibility _____ Accuracy _____ Specifications _____ Reasonableness _____

Checked by: ______________________ ______________________

Personnel (Signature/Date) Team Leader (Signature/Date)

CALIBRATION PROCEDURE 2A
Metering System

A. Preliminaries

1. Select a standard reference meter such as a spirometer or wet test meter that has a capacity consistent with that of the metering system.
2. Set up the metering system in a configuration similar to that used in the field installation, i.e., in relation to the flow moving device.
3. Connect the temperature and pressure gauges as they are to be used in the field.
4. Connect the reference meter to the inlet of the flow line, if appropriate for the meter.
5. Begin gas flow through the system, and check the system for leaks.

B. Measurements

1. Calibrate the system at three or more different flow rates at about 0.3, 0.6, and 0.9 times the maximum rated capacity of the metering system.
2. Run triplicates at each flow rate.
3. Obtain the necessary data (see CDS 2A).

C. Alternative

A standard pitot tube may be used for the reference measurement provided that:

1. A duct with $\geq$8 diameters upstream and $\geq$2 diameters downstream of the measurement point is used.
2. Use four traverse points according to Method 1.
3. Use FP 2 and FDS 2.

CALIBRATION DATA SHEET 2A
Metering System

Metering System ID# ______________________ Date ______________

Barometric Pressure, P_b ______________ mm Hg Personnel ______________________

Initial Calibration ___ Recalibration ____ Capacity of Ref Meter __________ ***>Max Cap of Metering Syst?***

Flow Rate of Max Cap	Run No.	Reading	Reference			Metering System			Time θ (min)	Y_m	Avg Y
			V_r (m^3)	t_r (°C)	P_r (mm Hg)	V_m (m^3)	t_m (°C)	P_m (mm Hg)			
0.3	1	Initial									
		Final									
	2	Initial									
		Final									
	3	Initial									
		Final									
0.6	1	Initial									
		Final									
	2	Initial									
		Final									
	3	Initial									
		Final									
0.9	1	Initial									
		Final									
	2	Initial									
		Final									
	3	Initial									
		Final									

Note: *If reference measurements are made with a standard pitot tube, attach FDS 2.*

____ ***For each run, difference of maximum and minimum Y_m ≤0.030?***

____ ***Y_{mf}/Y_{mi} 0.95 to 1.05?*** (For recalibration only; conduct the calibration at one flow rate (intermediate) and with the meter pressure set at the average value of previous field test.

$$Y_m = \frac{(V_{rf} - V_{ri})\,(t_{r(avg)} + 273)}{(V_{mf} - V_{mi})\,(t_{m(avg)} + 273)} \; \frac{P_b}{(P_b + P_{g(avg)})}$$

QA/QC Check

Completeness ____ Legibility ____ Accuracy ____ Specifications ____ Reasonableness ____

Checked by: ______________________________ ______________________________

Personnel (Signature/Date) Team Leader (Signature/Date)

SUMMARY SHEET 2B

			Run #1	Run #2	Run #3	Avg
Client/Plant Name		FDS 2B				
Job No.		FDS 2B				
Sampling Location		FDS 2B				
Run ID#		FDS 2B				
Test Date		FDS 2B				
Run Start Time		FDS 2B				
Run Finish Time		FDS 2B				
Net Run Time, min	θ	FDS 2B				
Barometric Pressure, mm Hg	P_b	FDS 2B				
Average Meter Gauge Pressure, mm Hg	P_g	FDS 2B				
Average Meter Temperature, K	T_s	FDS 2B				
Initial Meter Calibration Factor	Y_i	CDS 2A				
Final Meter Calibration Factor	Y_f	CDS 2A				
Average Meter Calibration Factor	Y_m	CDS 2A				
Initial Meter Reading, m^3	V_{mi}	FDS 2B				
Final Meter Reading, m^3	V_{mf}	FDS 2B				
Metered Volume, m^3	V_{ls}	SS 2B				
Calibration Gas Factor	K	FDS 25A				
Mean Inlet Organic Concentration, ppm	HC_i	FDS 25A				
Mean Outlet Organic Concentration, ppm	HC_e	FDS 25A				
Mean Outlet CO Concentration, ppm	CO_e	FDS 10				
Mean Outlet CO_2 Concentration, ppm	CO_{2e}	FDS 6C/SS 3A				
Exhaust Gas Volume, m^3	V_{es}	SS 2B				
Exhaust Gas Volume flow Rate, m^3/min	Q_{es}	SS 2B				
Post-test Calibration Checks						
Temperature and Barometer		CDS 2d				
Metering Device		CDS 2A				

$$V_{is} = 0.3853\ Y_m\ (V_{mf} - V_{mi})\ \frac{(P_b + P_g)}{T_m}$$

$$V_{es} = V_{is}\ \frac{K\ (HC_i)}{K\ (HC_e) + CO_{2e} + CO_e - 300}$$

where K is the calibration gas factor as follows:
ethane = 2; propane = 3, butane = 4;
other = appropriate response factor.

$$Q_{es} = \frac{V_{es}}{\theta}$$

FIELD PROCEDURE 2B
Exhaust Gas Volume Flow Rate From Gasoline Vapor Incinerators

Note: *This procedure applies to the measurement of exhaust volume flow rate from incinerators that process gasoline vapors consisting primarily of alkanes, alkenes, and/or arenes (aromatic hydrocarbons). It is assumed that the amount of auxiliary fuel is negligible. This procedure combines Methods 2A, 25A or 25B, and 10 (for CO and CO_2). Refer to respective FP's and attach respective FDS's to the test report.*

A. Preliminaries

1. Select and calibrate the volume meter as in Method 2A. **(See CP 2A)**.
2. Install the volume meter in the vapor line to incinerator inlet according to the procedure in Method 2A.
3. At the volume meter inlet, install a sample probe **(see Method 25A)**. Connect to the probe a leak-tight sample line (stainless steel or equivalent) and an organic analyzer system **(see Method 25A or 25B)**.
4. At the incinerator exhaust, install a sample probe **(see Method 25A)** and connect the CO_2, CO, and organic analyzers. A sample manifold may be used.
5. Heat samples lines, if necessary, to prevent condensation.
6. Connect data output recorders, and prepare and calibrate all equipment and analyzers. For the CO_2 analyzer, follow the procedures in Method 10, but substitute CO_2 calibration gas where the method calls for CO calibration gas. Use span value of 15% for the CO_2 analyzer.

B. Sampling

1. Inject all calibration gases at the connection between the probe and the sample line. If a manifold system is used for the exhaust analyzers, operate all the analyzers and sample pumps during the calibrations. *Do not use methane as a calibration gas.*
2. At the beginning of test run, record the initial parameters for the inlet volume meter **(see Method 2A)**, mark all of the recorder strip charts to indicate the start of the test.
3. Record the inlet organic and exhaust CO_2, CO, and organic concentrations throughout the test run.
4. During periods of process interruption and halting of gas flow, stop the timer and mark the recorder strip charts so that data from this interruption are not included in the calculations.
5. At the end of the test period, record the final parameters for the inlet volume meter and mark the end on all of the recorder strip charts.
6. At the conclusion of the sampling period, introduce the calibration gases for each analyzer.
7. If an analyzer output does not meet the specifications of the method, invalidate the test data for the period. Alternatively, calculate the volume results using initial calibration data and using final calibration data and report both resulting volumes. Then, for emissions calculations, use the volume measurement resulting in the greatest emission rate or concentration.
8. Attach FDS's from Method 2A, Method 25A or 25B, Method 10, and CO_2 analyzer.

FIELD DATA SHEET 2B
Volume Flow Rate - Indirect

Client/Plant Name ______________________ Job # ____________

City/State ______________________ Date/Time ____________

Test Location/Run # ______________ Personnel ______________

Meter ID# ____________ Meter Cal. Coeff, Y_i ________ Date Last Calibrated ____________

Barometer ID# ________ Bar Press, P_b Start ________ Finish ________ mm Hg Date Last Calibrated ______

Time Run/Clock	Volume Meter Rdg (m^3)	Pressure, P_g	Temperature		
		(mm Hg)	(°C)	T_s (K)	
	Average				

Post-test Calibrations

Attach FDS 2d and CDS 2A temperature, barometer, meter calibrations.

____ For meter, Y_f/Y_i = __________ ***(0.95 to 1.05?)***

QA/QC Check

Completeness _____ Legibility _____ Accuracy _____ Specifications _____ Reasonableness _____

Checked by: ______________________ ______________________

Personnel (Signature/Date) Team Leader (Signature/Date)

SUMMARY SHEET 2C

			Run #1	Run #2	Run #3	Avg
Client/Plant Name		FDS 2				
Job No.		FDS 2				
Sampling Location		FDS 2				
Run ID#		FDS 2				
Test Date		FDS 2				
Run Start Time		FDS 2				
Run Finish Time		FDS 2				
Net Traverse Points		FDS 1A				
Traverse Matrix (Rectangular)		FDS 1				
Net Run Time, min	θ	FDS 2				
Barometric Pressure, in. Hg	P_b	FDS 2				
Stack Static Pressure, in. H_2O	P_g	FDS 2				
Absolute Stack Pressure, in. Hg	P_s	SS 2				
Average Stack Temperature, °F	t_s	FDS 2				
Avg Absolute Stack Temperature, R	T_s	SS 2				
Moisture Content, fraction	B_{ws}	FDS 4				
Carbon Dioxide, % dry	$\%CO_2$	FDS 3				
Oxygen, % dry	$\%O_2$	FDS 3				
Carbon Monoxide + Nitrogen, % dry	$\%(CO+N_2)$	FDS 3				
Dry Molecular Weight, lb/lb-mole	M_d	FDS 3				
Stack Area, ft^2	A	FDS 1				
Pitot Tube Coefficient	C_p	CDS 2a				
Average Velocity Pressure, in. H_2O	Δp	FDS 2				
Average $[(t_{si}+460)\ \Delta p]^{1/2}$	$[T_{si}\ \Delta p]^{1/2}$	FDS 2				
Average Velocity, ft/sec	v_s	SS 2				
Volumetric Flow Rate, dscfh	Q_{sd}	SS 2				
Volumetric Flow Rate, wscfh	Q_{sw}	SS 2				
Post-test Calibration Checks						
Temperature and Barometer		CDS 2d				
Differential Pressure Sensor		CDS 2d				

FIELD PROCEDURE 2C
Velocity and Volumetric Flow Rate from Small Stacks or Ducts (Standard Pitot Tube)

***Note:** This procedure is used in conjunction with Method 1A. The procedure is the same as that in Method 2, except that a standard type pitot tube or the alternative pitot tube (see Figure F2C-1) is used instead of a Type S. **Use FDS 2.** Other variations are as follows:*

1. Conduct the measurements at the traverse points specified in Method 1A.
2. Take the velocity head (Δp) reading at the final traverse point. If the Δp at the final traverse point is unsuitably low, select another point.
3. Clean out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air.
4. Take another Δp reading (after the back-purge).
5. The ratio of the Δp readings (after divided by before) must be between 0.95 and 1.05 for the traverse to be acceptable.
6. If "back purging" at regular intervals is part of the procedure, then take comparative Δp readings, as above, for the last two back purges at which suitably high Δp readings are observed.

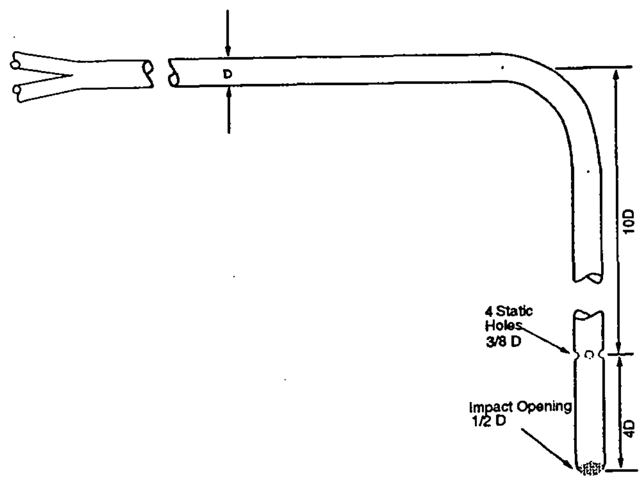


Figure F2C-1. Modified Hemispherical-Nosed Pitot Tube.

SUMMARY SHEET 2D

			Run #1	Run #2	Run #3	Avg
Client/Plant Name		FDS 2D				
Job No.		FDS 2D				
Sampling Location		FDS 2D				
Run ID#		FDS 2D				
Test Date		FDS 2D				
Run Start Time		FDS 2D				
Run Finish Time		FDS 2D				
Net Run Time, min	θ	FDS 2D				
Barometric Pressure, in. Hg	P_b	FDS 2D				
Average Meter Gauge Pressure, in. Hg	P_g	FDS 2D				
Average Meter Temperature, R	T_s	FDS 2D				
Initial Meter Calibration Factor	Y_i	CDS 2D				
Final Meter Calibration Factor	Y_f	CDS 2D				
Average Meter Calibration Factor	Y_m	CDS 2D				
Initial Meter Reading, cfm	Q_{mi}	FDS 2D				
Final Meter Reading, cfm	Q_{mf}	FDS 2D				
Volumetric Flow Rate, scfm	Q_s	SS 2D				
Post-test Calibration Checks						
Temperature and Barometer		CDS 2d				
Metering Device		CDS 2D				

$$Q_s = 17.64\ Y_m\ Q_m\ \frac{(P_b + P_g)}{T_m}$$

FIELD PROCEDURE 2D
Gas Volume Flow Rates in Small Pipes and Ducts

Note: *In applying this procedure, use particular caution for intermittent or variable gas flows. The apparatus, installation, and leak-check procedures are the same as that for Method 2A, except for the following:*

A. Preliminaries

1. Select a gas metering rate or flow element device, e.g., rotameter, orifice plate, or other volume rate or pressure drop measuring device, capable of measuring the stack flow rate to within ±5%. In selecting this metering device, consider the following:

   a. Capacity of the metering device (must be sufficient to handle the expected maximum and minimum flow rates at the stack gas conditions).

   b. Magnitude and variability of stack gas flow rate, molecular weight, temperature, pressure, dewpoint, and corrosive characteristics, and pipe or duct size.

2. Calibrate the metering system according to CP 2A; however, use CDS 2D.

B. Volume Rate Measurement

1. <u>*Continuous, Steady Flow*</u>

   a. Record the barometric pressure at the beginning of the test run.

   b. At least once an hour or at ≥12 equally spaced readings, measure the metering device flow rate or pressure drop reading, the metering device temperature and pressure, and other parameters during the test run. **(See FDS 2D).**

   c. Measure the barometric pressure at the end of the test run.

2. <u>*Noncontinuous and Nonsteady Flow*</u>

   a. Use volume rate devices with particular caution. Calibration will be affected by variation in stack gas temperature, pressure and molecular weight.

   b. Use the procedure in step B1 with the addition of the following: Measure all the metering device parameters on a time interval frequency sufficient to adequately profile each process cyclical or noncontinuous event. A multichannel continuous recorder may be used.

FIELD DATA SHEET 2D
Flow Rate Measurement

Client/Plant Name ________________ Job # ________

City/State ________________ Date/Time ________

Test Location/Run # ________________ Personnel ________

Meter ID# ________ Meter Cal. Coef, Y_{mi} ________ Date Last Calibrated ________

Barometer ID# ________ Bar Press, P_b Start ________ Finish ________ in. Hg Date Last Calibrated ______

Time Run/Clock	Flow Rate Rdg (cfm)	Pressure (in. Hg)	Temperature		
			°F	R	
Average					

Post-test Calibrations

Attach CDS 2d and CDS 2D temperature, barometer, meter calibrations.

____ For meter recalibration, Y_f/Y_{mi} = ________ ***(0.95 to 1.05?)***

QA/QC Check

Completeness ____ Legibility ____ Accuracy ____ Specifications ____ Reasonableness ____

Checked by: ________________ ________________

Personnel (Signature/Date) Team Leader (Signature/Date)

CALIBRATION DATA SHEET 2D
Metering System

Metering System ID# ______ ______________________ Date ______________

Barometric Pressure, P_b ____________ in. Hg Personnel ______________________

Initial Calibration ___ Recalibration ____ Capacity of Ref Meter __________ ***>Max Cap of Metering Syst?***

Flow Rate of Max Cap	Run No.	Reading	Reference			Metering System			Time θ (min)	Y_m	Avg Y
			V_r (cf)	t_r (°F)	P_r (in. Hg)	Q_m (cfm)	t_m (°F)	P_m (in. Hg)			
0.3	1	Initial									
		Final									
	2	Initial									
		Final									
	3	Initial									
		Final									
0.6	1	Initial									
		Final									
	2	Initial									
		Final									
	3	Initial									
		Final									
0.9	1	Initial									
		Final									
	2	Initial									
		Final									
	3	Initial									
		Final									

Note: *If reference measurements are made with a standard pitot tube, attach FDS 2.*

_____ ***For each run, difference of maximum and minimum Y_m ≤0.030?***

_____ ***Y_{mf}/Y_{mi} 0.95 to 1.05?*** (For recalibration only; conduct the calibration at one flow rate (intermediate) and with the meter pressure set at the average value of previous field test.

$$Y_m = \frac{(V_{rf} - V_{ri})\,(t_{r(avg)} + 460)}{(Q_{mf} - Q_{mi})\,(t_{m(avg)} + 460)}\;\frac{P_b}{(P_b + P_{g(avg)})}$$

QA/QC Check

Completeness___ Legibility ____ Accuracy ____ Specifications ____ Reasonableness ___

Checked by: ______________________________ ______________________________

Personnel (Signature/Date) Team Leader (Signature/Date)