2.3.2.2 CALIBRATION OF ORIFICE FLOW DEVICE

This section describes the calibration of the orifice flow devices (Top Hat) using the Rootsmeter. This Top Hat is used in the calibration/audit of the flow control devices on Hi-Vol samplers. This procedure separates TSP with mass flow units from PM-10 and those TSP with volumetric flow units. Top Hats are calibrated with both procedures and have two certification equations.

2.3.2.2.1 SET-UP

The following equipment must be available to accomplish the calibration:

Digital manometer set to read in. Hg	Digital manometer set to in. H_2O
Orifice and restriction plates(5,5a,6,7,8,10,13)	Scientific calculator
Hardware fitting to adapt the rootsmeter	Digital stopwatch
Manual event counter	TSP motor and PM-10 motor
Vari-ac	Multi meter (volts, ac)
Barometer, Thermometer CE	

Set up is as depicted in the diagram depicted on Figure 2.3.2.2.1.

2.3.2.2.2 CALIBRATION PROCEDURE

Clean the orifice and restrictor plates with a clean cloth. Inspect these parts for nicks, excessive wear, or need of painting. If painting is needed, paint and allow to dry before proceeding. Note in the specific device logbook if any parts are damaged. Severely damaged parts must be replaced. Assemble / set-up the apparatus as depicted in the figure 2.3.2.2.1.

1. Insure both manometers are zeroed.

2. Check the level of the Rootsmeter, adjust if required.

3. Install the TSP motor. Load the orifice with the #5 holed plate, turn the Vari-ac dial to below 40 % and switch on. Turn the Vari-ac clockwise until desired voltage [115v > voltage <116v] is achieved. Stabilize (run) for 5 minutes. While warm up progresses, continue with the next few documentation items.

4. Complete all the applicable data in the orifice calibration logbook.

5. After warm up, leak check the system by clamping both manometer properly installed. After a satisfactory leak check, unclamp both manometers.

6. Allow the flow to stabilize and read the digital manometer at the orifice port ()H, in.H_20) and record in the calibration logbook.

7. Record in the calibration log the digital manometer reading at the Rootsmeter tap () P,in.Hg).

8. Using the uncompensated dial on the Rootsmeter, see figure 2.3.2.2.2 p 5 , time and record 11 revolutions (110 ft^3). Time is to be minutes and hundredth's of minutes.

9. Turn off the motor by turning the dial of the Vari-ac counter clockwise,

9. Repeat the TSP procedure with the 7,8,10,13 holed plates. Mount the PM-10 motor. Repeat the procedure for the PM-10 equation using 5, 5a, 6, 7, 8 holed plates.

2.3.2.2.3 CALCULATIONS

2.3.2.2.3.1 TSP MASS FLOW (OLD TSP) EQUATION DEVELOPMENT

1. Convert the 110 ft^3 Rootsmeter volume to Standard Temperature

$$V_{STD} = V_{AMB} \frac{(P_1 -)P)\, T_{STD}}{(P_{STD})\, T_1}$$

or

$$V_{STD} = (110) \frac{(P_1 -)P)\, (298)}{(29.92)\, T_1}$$

where:

V_{STD} = standard volume @ 298EK and 29.92 in. Hg
V_{AMB} = volume measured by Rootsmeter, 110 ft^3
P_1 = ambient barometric pressure, in. Hg
)P = pressure at the Rootsmeter tap, in. Hg
P_{STD} = 29.92 in. Hg
T_{STD} = 298EK T_1 = ambient temperature, EK

2. Calculate the rate, Q_{STD}, using the volume corrected to standard

$$Q_{STD} = \frac{V_{STD}}{t}$$

3. For each flow(restrictor plate) compute:

Note: $(x)^{½}$ = square root of x = οx

$$9 \frac{)H)(P_1)(T_{STD})}{(P_{STD})(T_1)} A^{½} \qquad \text{Note: } 9 \frac{(P_1)(T_{STD})}{(P_{STD})(T_1)} A^{½} = C \text{ from table 2.3.2.3}$$

4. Given: $9 \frac{)H)(P_1)(T_{STD})}{(P_{STD})(T_1)} A^{½} = 9\,)H)^{½} \frac{(P_1)(T_{STD}}{(P_{STD})(T_1)} A^{½} = m\ Q_{STD} + b$

$$)H)^{½} \times C = m\ Q_{STD} + b \qquad \text{Values for C in Table 1}$$

or

$$y = m x + b$$

Use the scientific calculator using linear regression or plot points

$x = (Q_{STD})$, and $y =)H)^{½} \times C$

for each experimental point(restrictor plate). Determine the slope,

5. TSP Certification Equation:

$$)H)^{½} \times C = m\ Q_{STD} + b \quad \textbf{or} \quad)H)^{½} = \frac{m}{C}\ Q_{STD} + \frac{b}{C}$$

then: $\mathbf{)H)^{½} = m'\ Q_{STD} + b'}$ where $m' = \frac{m}{C}$ and $b' = \frac{b}{C}$

6. Reinsert the value of y into the scientific calculator curve, looking for

$$\frac{Q_{STD} - Q_{CURVE}}{Q_{CURVE}} \times 100 = \%\ \text{difference}$$

If the % difference for any point > 2 %, rerun that point in the procedure. If the % difference for all points is # 2%, sign the certification equation form.

7. As an continuity check:
Take m' and b' from the certification equation (f) and the previous certification equation (i) and insert into these equations.

a. $Q_{STD(i)} = \frac{(2.5 - b'_i)}{m'_i}$

b. $Q_{STD(f)} = \frac{(2.5 - b'_f)}{m'_f}$

$Q_{STD(i)} = Q_{STD(f)}$ ∀ 1.0 cfm

$Q_{STD(i)} = Q_{STD}$ (cfm) resulting from initial equation(last year)
$Q_{STD(f)} = Q_{STD}$ (cfm) resulting from initial equation(today)
2.5 = given constant for check purposes only
b'_i = intercept prime from last year's equation
m'_i = slope prime from last year's equation
b'_f = intercept prime from this year's equation
m'_f = slope prime from this year's equation
cfm = cubic feet per minute for Q_{STD}

2.3.2.2.3.2 PM-10, TSP(VFC) EQUATION DEVELOPMENT

1. The Rootsmeter by definition measures volume (V_{amb},10 ft^3) at ambient conditions (temperature, barometer) per revolution. The flow rate at ambient conditions, Q_{amb} is controlled by the restrictor plates.

$$Q_{amb} = \frac{V_{amb}}{t} \times \frac{(P_1 -)P)}{P_1}$$

Calculate to the nearest 0.01acfm or 0.01m^3/min.

2. For each flow, (restrictor plates 5,5a,6,7,8), determine values

$$9 \; \frac{( )H)(T_1)}{(P_1)} \; A^{1/2}$$

where:
)H = pressure at the orifice, in. H_2O;
P_1 = ambient pressure during certification, in. Hg
)P = pressure at the Rootsmeter tap, in. Hg
T_1 = ambient temperature during certification, EK
t = time(min and tenths of a minute)

3. Use the scientific calculator using linear regression or plot points

$$y = m \; x + b \text{ ,or}$$

$$\frac{()H)(T_1)}{}^{1/2} = m \; Q_{amb} + b \quad \text{(Certification Equation)}$$

9 (P_1) A

determine: m = slope
b = y intercept

4. Reinsert each value of y into the scientific calculator, looking for the corresponding value of x... $Q_{curve,}$ or using the graph, find the corresponding value of x ... Q_{curve}. Then compute and compare:

$$\frac{Q_{amb} - Q_{curve}}{Q_{curve}} \times 100 = \% \text{ difference}$$

If the % difference for any point > 2 %, rerun that point in the

5. As an continuity check: current T_1 / P_1 are inserted into the PM-10

$$y = m\ x + b \text{ ,or}$$

$$\underline{)H)(T_1)}^{\frac{1}{2}} = m\ Q_{amb} + b \quad \text{(Certification Equation)}$$

9 (P_1) A

is reexpressed as:

$$)H^{\frac{1}{2}} = \frac{m}{(T_1/P_1)^{\frac{1}{2}}} Q_{amb} + \frac{b}{(T_1/P_1)^{\frac{1}{2}}}$$

$$)H^{\frac{1}{2}} = m^* \ Q_{amb} + b^*$$

where:

$$m^* = \frac{m}{(T_1/P_1)^{\frac{1}{2}}} \text{ and } b^* = \frac{b}{(T_1/P_1)^{\frac{1}{2}}}$$

a. $Q_{amb(i)} = \dfrac{(2.5 - b^*_i)}{m^*_i}$

b. $Q_{amb(f)} = \dfrac{(2.5 - b^*_i)}{m^*_i}$

c. $Q_{amb(i)} = Q_{amb(f)}$ (∀ 1.0 cfm)

See definitions of terms in the TSP section 2.3.2.2.3.1(7)

It is the responsibility of the Supervisor of the Electronics and Calibration Branch to check the data and verify the data calculations. This duty may be assigned to a Technician III knowledgable in the task (not the individual performing the task).

ORIFICE CALIBRATION SET-UP

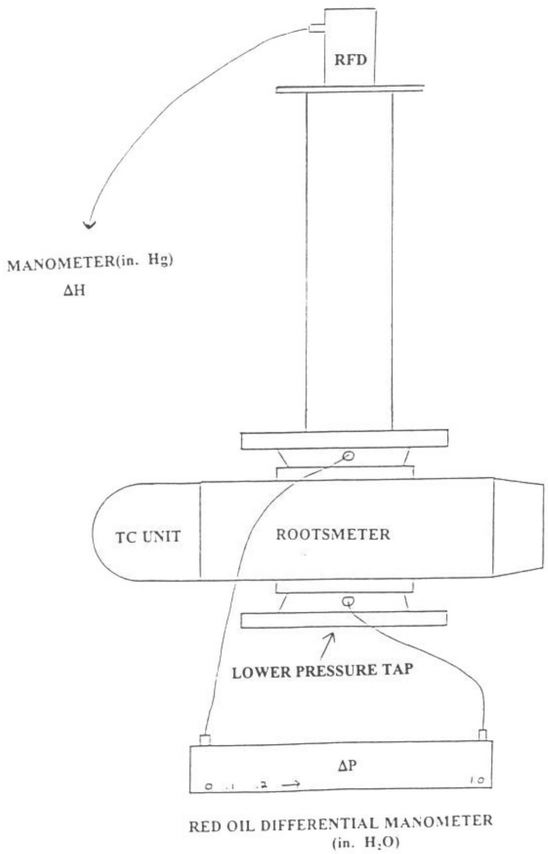

Figure 2.3.2.2.1

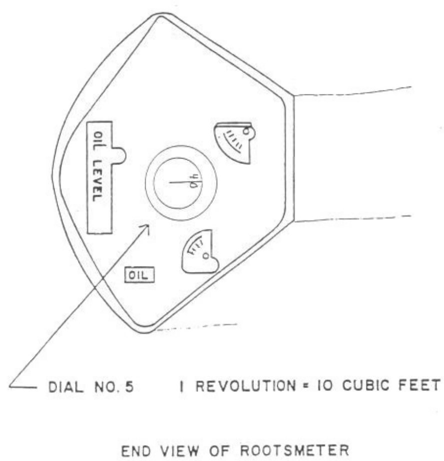

Figure 2.3.2.2.2

ORIFICE CERTIFICATION FOR MASS FLOW & VOLUMETRIC FLOW CONTROLLERS

Region Unit Assigned:	**Date:**	**Certified By:**
Rootsmeter # **8918139**	**Time:**	**Reviewed By:**
Barometric Pressure (P_1) **in. Hg**	**Temperature (T_1)** **°C =** **°K =**	
Unit #:		

MFC (OLD TSP) CERTIFICATION					**C Factor:**			
Plate #	**) P**	**) H**	**V_{amb}**	**t**	**$(\,)\ H)^{½}$ x C**	**Q_{STD}**	**Q_{CURVE}**	**%d**
13			**110**					
10			**110**					
08			**110**					
07			**110**					
05			**110**					

linear regression: **corr. =** **m = ____________ m ' =** **b = ____________ b ' =**	**data from :** **m ' = ________b ' =** **C Factor =**	**Continuity check** **i = (2.5 -________) / (______) =** **f = (2.5 -________) / (______) =** **d =**

() H)^{½} (C) = m Q_{std} + b or
() H)^{½} = m' Q_{std} + b'
where m' = $\frac{m}{C}$ = ( ) and b ' = $\frac{b}{C}$ = ( )

MFC (OLD TSP) Certification Equation:	**() H)^{½} = ( ) ' Q_{std} + ( )'**

VFC CERTIFICATION				**Date:**	**Time:**			
Barometric Pressure (P_1)			**in. Hg**		**Temperature (T_1)**	**°C =**	**°K =**	
Plate #	**) P**	**) H**	**V_{AMB}**	**t**	**() H x $T_1/P_1)^{½}$**	**Q_{AMB}**	**Q_{CURVE}**	**%d**
08			**110**					
07			**110**					
06			**110**					
05 A			**110**					
05			**110**					

linear regression: **corr. =** **m = ________ m* =** **b = ________ b* =**	**data from :** **m* = ________ b* =**	**Continuity check** **i = (2.5 -________) / (______) =** **f = (2.5 -________) / (______) =** **d =**

() H x $T_1/P_1)^{½}$ = mQ_{AMB} + b

VFC Certification Equation:	**() H x $T_1/P_1)^{½}$ = ( )Q_{AMB} + ( )**