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HI-VOL/SSI AUDIT

by

R. E. Brande

ManTech Environmental Technology, Inc.
Research Triangle Park, NC

CAUTION

Disclaimer: This Standard Operating Procedure has been developed for use by ManTech Environmental Technology, Inc. in support of the National Performance Audit Program (NPAP) under contract to the U.S. Environmental Protection Agency and may not be applicable to the activities of other organizations.

Approved by:

Kenneth J. Caviston, Manager — Date
ManTech Environmental Technology, Inc.

Joe Elkins — Date
EPA NPAP Coordinator

Effective: When approved

CONTENTS

Page

Page

FIGURE

Page

1.0 SCOPE AND APPLICATION

This procedure is intended for use in calibrating a reference flow (ReF) device that will be used by a National Performance Audit Program (NPAP) participant to conduct a flow audit of high volume samplers. It also describes the one point calibration check used as a quick check. The quick checks provide a fast turnaround time for ReF devices.

2.0 SUMMARY AND PRINCIPLE

A new ReF undergoes a five point calibration. This is repeated four times to provide a database for that Ref. After calibration, the one point check is compared to this database.

Upon return from an audit, the device is opened, inspected for obvious damage and completeness of parts. A one-point calibration check is performed. If it passes, the device is shipped to the next NPAP participant. If it fails, the cause is determined, corrected, and the device is checked again.

Each ReF device contains a fixed orifice and is packed with five interchangeable resistance plates each with a specific number of holes of equal size (See Figure 1). The fixed orifice is incorporated into the ReF and provides a flow measurement characteristic for that particular ReF. The pressure differential across an orifice is dependent upon the rate of air flow through the orifice. The air flows through the system for an accurately measured time of sampling, and the volume is measured with a Roots® Meter. This information is used to determine flow in m^3-min^{-1}. Pressure and temperature readings during the calibration are used to determine the flow rates at ambient temperature and pressure conditions (Q_A) . A graph of flow rate versus pressure drop across the orifice to the one-half (1/2) power provides a linear plot with a slope and intercept for a ReF. The slope and intercept are independent of the method used to vary the flow through the ReF.

3.0 DEFINITIONS

- RM: Roots® Meter
- Volume of Air: The volume of air in cubic meters (m^3) passing through Roots® Meter (RM)
  Volume = $RM_{Initial}$ - RM_{Final}

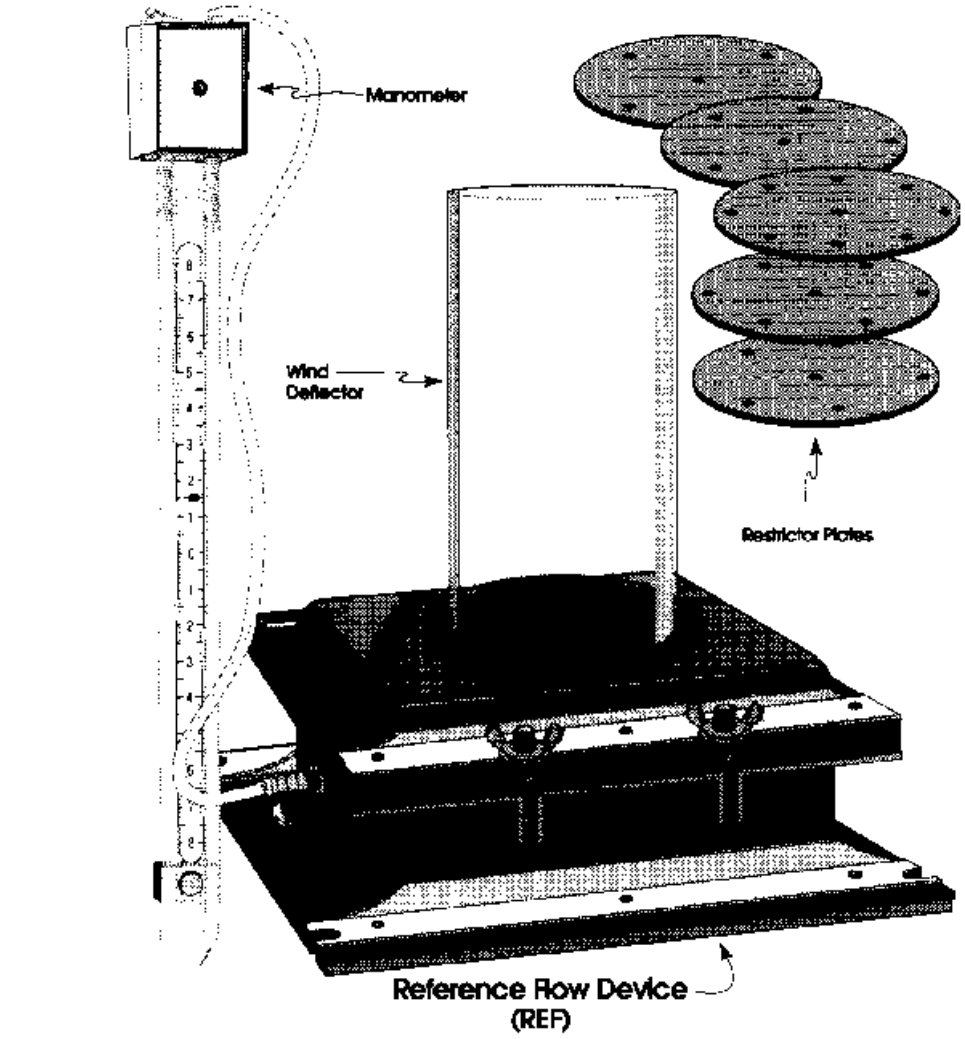

Figure 1. Reference Flow Device (ReF)

- Time of Sampling: The time over which sampling has taken place (usually two minutes)

- Ambient Temperature: Temperature of air going through the RM in ^{o}K ($^{o}C + 273.16$)
- Mercury Manometer Reading: Mercury manometer reading in millimeters of mercury (mm Hg)
- Water Manometer Reading: Water manometer reading in inches of water
- Atmospheric Pressure: Pressure reading in millimeters of mercury on a barometer
- LFE: Laminar Flow Element
- NIST: National Institute of Standards and Technology
- ReF: Reference Flow device
- SSI: Size Selective Inlet

4.0 SAFETY PRECAUTIONS

Observe standard safety precautions when using electrical equipment. Always have the ReF Device Adaptor Funnel in place before turning on the motor. This will prevent possible injury to the operator from the impeller blades.

5.0 FACILITY REQUIREMENTS

This procedure requires adequate bench space for the equipment and electrical connections.

6.0 INTERFERENCES

Leaks are the main interferences. Leaks may occur if the lower wing nuts are not tight or if the lid is not tightened down firmly.

7.0 APPARATUS

- High volume sampler filter head
- Roots® Meter, certified with an NIST-traceable flow standard
- Variable transformer, 140V
- Water manometer, graduated in tenths of an inch, filled with water containing a fluorescent dye
- Mercury manometer, graduated in millimeters
- Thermometer, measuring degrees Celsius
- Mercury barometer, graduated in millimeters
- Reference flow (ReF) device with a 13-hole restrictor plate
- Tubing, Tygon, ID 3/16", OD 5/16", wall thickness 1/16", 3' length
- Stopwatch

8.0 CALIBRATION/STANDARDIZATION

The Roots® Meter is certified annually against an NIST-traceable LFE. Manometers are zeroed prior to use.

9.0 PROCEDURE

9.1 System Connection

1. Attach the ReF device to the high volume sampler filter head being sure to firmly tighten the filter head wing nuts into the slots on the ReF base plate
2. Open the ReF lid and place a 13-hole resistance plate in the recessed area .

3. Firmly tighten down the lid using ReF lid wing nuts.

4. Attach the mercury manometer to the tube connector on the front of the RM.

9.2 Leak Check

1. Place a piece of Parafilm® over the holes in the lid of the ReF device; turn the RM motor on, and adjust the variable transformer to read 100.

2. Place your finger over the tube connector located on the left side of the ReF, and observe the flow recorder on the Roots® Meter. It should not indicate any flow going through the RM. Turn off the motor.

3. Any problems with leakage must be corrected before proceeding with the calibration. Often a leak can be corrected by tightening the ReF more securely to the Hi-Vol filter head.

9.3 Five Point Calibration

Record all data on an "ORIFICE DATA SHEET" form.

1. Record the atmospheric pressure in mm of Hg. Record the temperature in degrees Celsius.

2. Adjust both manometers to zero and make sure that both manometer outlets are in the open position.

3. Turn on the RM motor, and let it run for one minute. Adjust the variable transformer so the water manometer reads 3.0 inches of pressure drop.

4. Read the volume on the RM and start the stopwatch simultaneously. Record the reading as the initial reading (IR). Volume measurements are made during two minute runs.

5. Record the mercury manometer reading in mm of Hg.

6. Read the volume on the RM at the finish of the run and record it as the final reading (FR).

7. Subtract (IR) from (FR) and divide by time (t). This will give you flow in CFM.

8. Repeat **Steps 1 through 7** for water manometer pressure drops of 5.0, 7.0, 9.0, and 11.0 inches. This data is considered one data set.

9. For this data set, plot the flow rate (in m^3/min) versus pressure drop across the orifice (in inches of water) times the absolute temperature (in ^oK) divided by the barometric pressure (in mm Hg) to the one-half power to provide a linear relationship. Perform a linear regression analysis to determine a slope (m), y-intercept (b), and linearity (r^2) for the data set.

   Note: y = flow rate
   $x = [(\ )H_2O)(T_a)/(P_a)]^{1/2}$

10. Repeat **Steps 1 through 9** three more times so that slope, y-intercept, and linearity have been determined for each data set.

11. Compare the four slopes, y-intercepts, and linearities.

    A. Accept the calibration and proceed if

    - Range of slopes # 4% of their mean

      e.g. $m_1 = 0.6976$
      $m_2 = 0.6955$
      $m_3 = 0.7001$
      $m_4 = 0.6973$

      1. Mean = 0.6976
      2. $\frac{(m_{max} - m_{min})}{mean} \times 100$ # 4%

         $\frac{0.7001 - 0.6955}{0.6976} \times 100 = 0.6594\%$

      3. 0.6594% # 4.0000%

    - All r^2 $ 0.999
    - All intercepts # 0.09

    B. Reject the calibration if the acceptance criteria are not met. Take corrective action. A high y-intercept value may indicate a leak. Repeat the entire calibration procedure. If the criteria are not met on the second calibration, remove the ReF from the audit population.

12. Perform a linear regression analysis using all of the raw data points from the four runs. The resulting slope and intercept are the new calibration constants for the ReF device.

13. Enter the new constants in the NPAP Data system (see **Section 9.5**).

9.4 One Point Calibration Check

Record all data on a "DATA SHEET FOR ReF FLOW DEVICES" form.

1. Record the atmospheric pressure in mm of Hg. Record the temperature in degrees Celsius.

2. Adjust both manometers to zero and make sure that both manometer outlets are in the open position.

3. Turn on the RM motor, and let it run for one minute. Adjust the variable transformer so the water manometer reads 8.0 inches of pressure drop.

4. Read the volume on the RM and start the stopwatch simultaneously. Record the reading as the initial reading (IR). Volume measurements are made during two minute runs.

5. Record the mercury manometer reading in mm of Hg.

6. Read the volume on the RM at the finish of the run and record it as the final reading (FR).

7. Subtract (IR) from (FR) and divide by time (t). This will give you flow in CFM.

9.5 Data Entry

Enter new constants (**Section 9.3**) or the data recorded on the DATA SHEET FOR REF FLOW DEVICES (**Section 9.4**) n the **Standards Data Entry Section** for the SSI/Hi-Vol Audit under the ReF check menu selection.

1. Access the **Main Menu** for the NPAP Data System. Select the year for the audit.

2. Select "Enter Data."

3. Select "Enter Standards Data" from the next menu.

4. Select the "SSI/Hi-Vol" audit from the list displayed on the screen.

9.5.1 Data Entry for New Constants

1. Select "Enter/List ReF device constants."

2. Select "Enter ReF device constants."

3. Enter the ReF device number.

4. Enter the slope and intercept in the boxes as labeled on the screen.

5. Add any appropriate comments. Exit by holding the control (CTRL) key down and typing "W."

6. Exit the program by following the screen instructions.

9.5.2 Data Entry for One Point

1. Select "Check/List ReF device flows."

2. Select "Check ReF device flows."

3. Enter the data as requested by the data entry program.

4. The actual flow is compared to a flow computed from the ReF device's composite data, under the same conditions, and they must agree within ±2% for the device to pass the acceptance test.

   A. If the device passes, it is packed for shipment to another NPAP participant.
   B. If it fails, the device is checked for leaks or other problems. Any problems found are corrected and the device rechecked.
      (1) If the device passes, it is packed for shipment to another NPAP participant.
      (2) If the device fails again, it is removed from service pending total recalibration or repair.

5. Exit the program by following the screen instructions.

10.0 CALCULATIONS

The computer program will compute the flow at ambient conditions according to the following equation:

$$Q_{RM} = \frac{V(P_a - \Delta Hg)}{(t)(P_a)}$$

where Q_{RM} = RM flow (ambient)
V = volume in m^3, the difference between starting and ending volumes recorded by the RM
P_a = atmospheric pressure (barometer reading in mm Hg)
ΔHg = mercury manometer reading in mm
t = time of sampling, in minutes

Another flow is computed from a slope and intercept for the device based on 4-5 years of data or a new five-point calibration repeated four times. The following equation is used:

$$Q_{ReF} = K\sqrt{\frac{(\Delta H_2O)(T_a)}{(P_a)}} + B$$

where Q_{ReF} = ReF flow (ambient)
K = the slope based on cumulative calibration data
ΔH_2O = water manometer reading in inches of H_2O
T_a = atmospheric temperature in degrees Kelvin (273.16 +°C)
P_a = atmospheric pressure (barometer reading in mm Hg)
B = intercept based on cumulative calibration data

The two flows calculated by the formulas are compared and must agree within ±2% for the device

to pass the acceptance test.

11.0 SENSITIVITY, RANGE, PRECISION AND ACCURACY

The sensitivity of the ReF calibration can be defined as the slope, K, for the plot of Q_{RM} versus the square root of [() $H_2$0) (T_a)/(P_a)]. This slope has typically been found to be between 0.72 and 0.81 with an average of approximately 0.765. From a study in which three ReFs were calibrated with a Roots® Meter twice a day for three days, a pooled standard deviation for K of 0.008 was obtained. Any Roots® Meter used with this method must be certified against a NIST traceable flow standard such as a laminar flow element.

12.0 QUALITY ASSURANCE/QUALITY CONTROL

The Roots® Meter is certified annually against an NIST traceable LFE. Quality control on the system includes a record of percent differences for each device. Performance and systems audits are also conducted by the EPA.

Any data which exceeds acceptance criteria results in a careful and thorough inspection of the device. If a question remains on its reliability, it is not shipped to an audit participant until all questions are resolved.

13.0 CORRECTIVE ACTION

If the ReF fails the one-point check, the leak test is repeated, leaks or other problems are corrected, and the device is checked again. If the device fails again, it is taken out of service pending total recalibration or repair.

14.0 SHIPPING

1. Obtain a list of the quarterly participants from the NPAP system.
2. Prepare a data packet for each participant including:

    - Cover letter
    - Instructions for conducting the audit
    - Data sheets

- Return instructions with return address label
- Data return envelope
- Questionnaire

3. Check the audit kit for completeness of parts.
4. Record on the audit list, the ReF device number being sent to each participant.
5. Enclose the packet in the shipping box with the ReF device.
6. Apply the participant address label to the shipping box.
7. Ship, using the appropriate carrier, during the first week of the quarter.
6. Enter the shipment into the NPAP data base.

15.0 DATA REPORTING

Audit data is sent directly to the Data Entry personnel and handled according to **NPAP-SOP-005: Computer Data Entry, Report Printing, and System Maintenance for the NPAP**.

16.0 REFERENCES

(None)