TECHNICAL ASSISTANCE MONOGRAPH
EVALUATION PROCEDURE FOR MULTI-HOLE SAMPLE PROBES

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INTRODUCTION

The installation requirements of the revised Continuous Monitoring Perfomance Specification 2[1] allow the use of a multi-hole stack gas sampling probe. The provisions for this probe include that the sample flow rate through each hole is within $\pm$ 10 percent of the average through all the holes at the design flow rate for the probe. This paper describes a method for determining whether this provision is met.

TEST METHOD

1. Apparatus

1.1 Sample Probe. Probe with sample holes located according to the criteria in revised Performance Specification 2.

1.2 Reference Method 5 Meter Box. Meter box equipped with properly sized pump, calibrated[2] dry-gas meter, water manometer, and meter temperature gauges.

1.3 Partial-flow Dry-Gas Meter. Dry-gas meter calibrated[2] in the range of flowrates through a single hole of the multihole probe. This dry-gas meter should have a back pressure of less than 0.2 in H_2O at these flowrates.

1.4 Tubings and Connectors. Diameters of all tubings and connectors between the sample probe and the total flow dry-gas meter must be larger than the inside diameter of the probe, and all tubings and fittings between the partial flow dry-gas meter and sample holes must have diameters larger than that of the holes. All tubings should be as short as practical.

1.5 Stopwatch.

2. Procedure. This procedure should be completed under laboratory conditions where ambient temperatures and moisture conditions are well controlled.

2.1 Connect the probe and the measurement equipment as shown in Figure 1. Connect the partial flow dry-gas meter to any hole of the probe making certain that the connection is leak-tight and does not block any part of the sample hole. Leave the other sample holes open and clear.

2.2 Record the initial volume readings on both dry-gas meters, the ambient temperature, barometric pressure, and the total flow dry-gas meter temperature.

2.3 Start the pump and the stopwatch simultaneously and set the total probe flow rate to equal the design flow rate of the sample probe. (A trial run before the test is helpful in setting this rate).

2.4 Record the manometer reading and continue sampling at a constant flow rate until a sample volume equivalent to approximately 1.0 ft^3 x number of sample holes is measured by the total flow dry-gas meter. At the end of the run, stop the pump and the stopwatch; record the final volume readings of both dry-gas meters and the final temperature(s) of the total flow dry-gas meter.

2.5 Repeat steps 2.1 through 2.4 for the other sample holes maintaining the same manometer pressure as for the first run.

3. Calculations

3.1 Determine the total flow rate, Q_i, and each partial flow rate, q_i, from the test data for each hole, as follows:

$$Q_i = 17.65\ V_i\ \frac{P_b}{T_m \theta_i}$$

$$q_i = 17.65\ v_i\ \frac{P_b}{T_a\ \theta_i}$$

Where:

v = Volume recorded on the total flow gas meter, corrected by the meter calibration factor, scf.
P_b = Barometric pressure, in. Hg.
T_m = Temperature of the total flow-gas meter, ˚R.
2_i = Elapsed sampling time, min.
v_i = Volume recorded on partial flow-gas meter, corrected by the meter calibration factor, scf.
T_a = Room temperature, ˚R.
17.65= Standard temperature and pressure correction factor, viz.

$$\frac{528°R}{29.92\ in.\ Hg}$$

Calculate the mean total flow rate, $\overline{Q}$, and the mean of the partial flow rate, $\overline{q}$:

$$\overline{Q} = \frac{\sum_{i=1}^{n} Q_i}{n}$$

$$\overline{q} = \frac{\sum_{i=1}^{n} q_i}{n}$$

Where:

n = Number of sampling holes.

3.2 Determine the percent deviation,)Q, from the mean total flow rate:

$$\Delta Q = \frac{\overline{Q} - \sum_{i=1}^{n} q_i}{\overline{Q}} \; x \; 100$$

If a)Q greater than 10 percent is found, indicating the total flow rate is too low for the probe design or the sample holes are too large, repeat the test with a redesigned probe or a revised flow rate.

3.3 Determine the percent deviation,)q_i, from the mean partial flow rate for each hole:

All)q_i must be within $\pm$ 10 percent for an acceptable probe design

$$\Delta q_1 = \frac{q_1 - \overline{q}}{\overline{q}} \; x \; 100$$

at the design flow rate.

SUMMARY AND DISCUSSION OF TEST RESULTS

Method validation tests were performed in the laboratory using three different multi-hole probes. All three probes had similar internal diameters of 0.375 inches and each had three sample equal-sized sample holes: 0.078 in. for probe 1, 0.125 in. for probe 2, and 0.203 in. for probe 3. The results of the test are summarized in Table 1.

These test results demonstrate the importance of properly setting the total flow rate for the probe. For example, at similar flow rates of about 48 scfh, probe 1 (I.D. = 0.078 in.) showed that the sum of partial flow rates totaled within 10 percent of the measured total flow rate while probe 2 (I.D. = 0.125 in.) showed almost 25 percent difference between these two figures. This indicates that the slight pressure drop associated with the partial flow dry-gas meter greatly affected the partial flow rates of probe 2, because of the larger sample holes, and was a limiting factor in the partial flow measurements. The result is a false indication of the operation of the probe.

The second criterion set by the method is that the partial flow rates all be within 10 percent of the average partial flow rate. These results indicate that this criterion can be met if the total flow rate is sufficient to cause a probe pressure of about -10 in. water. Of course, the pressure drop at each sample hole includes the pressure drop associated with the dry-gas meter and the tubing connectors during the measurements. This makes it of prime importance that the dry-gas meter be of high quality (i.e., low pressure drop), and the tubing and connectors be of larae diameter and as short as practical.

One limitation in the use of multi-hole probes brought out by these results and by the work of others[3] is that very small sample holes are required to maintain adequate pressure drop to assure approximately equal flow. The results of this study indicate a hole diameter of 0.125 in. is about the upper limit for a 1.0 cfm probe. This restriction limits the applicability of multihole probes to stack gases with low particulate concentrations to avoid probe plugging problems.

TABLE 1, SUMMARY OF RESULTS OF THE FLOW-RATE EVALUATIONS OF MULTI-POINT SAMPLING PROBES

Hole Diameter (in.)	Probe Pressure (in. H_2O)	Average Total Flow-rate (SCFH)	Average Partial Flow-rate (SCFH)	Percent Deviation From Total ()Q, %)	Percent Deviation Per Hole)q_a (%)	)q_b (%)	)q_c (%)
0.078	-1.2	19.4	5.7	11.7	0.9	-1.2	0.4
	-3.1	31.8	9.5	10.7	7.1	-6.2	-0.8
	-6.4	47.4	14.3	9.1	5.2	-2.6	-2.6
	-10.1	60.1	18.2	9.2	6.9	-6.5	-0.3
	-16.4	74.6	23.5	5.3	4.3	-0.4	-3.9
	-35.3	108.8	33.3	8.2	3.4	-3.3	-0.1

0.125	-1.1	47.9	12.3	23.0	6.5	-5.8	-0.9
	-3.4	83.7	25.6	8.3	10.8	0.7	-10.1
	-7.0	124.7	36.9	11.3	10.8	-8.7	-2.0
	-10.9	148.3	46.7	5.6	5.5	-0.8	-4.8
	-14.5	170.0	51.3	9.4	11.2	-3.9	-7.4
0.203	-1.1	75.5	14.8	41.3	42.2	-2.4	-39.9
	-3.2	131.9	34.5	21.5	23.3	2.1	-25.3
	-5.4	173.7	46.3	20.0	23.3	-1.4	-21.9

REFERENCES

1. Performance Specification 2 - Specifications and Test Procedures for SO_2 and NO_x Continuous Monitoring Systems in Stationary Sources, Environmental Protection Agency, Emission Measurement Branch revision, May 1979.

2. Westlin, P. R. and R. T. Shigehara, Procedure for Calibrating and Using Dry Gas Volume Meters as Calibration Standards, Source Evaluation Society Newsletter, Vol. 3, No. 1, February 1978.

3. Technical Manual for Process Stream Volumetric Flow Measurement and Gas Sample Extraction Methodology, prepared for EPA, IERL, PMB, by TRW Systems Group, Contract No. 68-02-1412, November 1975.