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FLOW RATE CALIBRATION OF HIGH VOLUME SAMPLERS

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FLOW RATE CALIBRATION OF HIGH VOLUME SAMPLERS

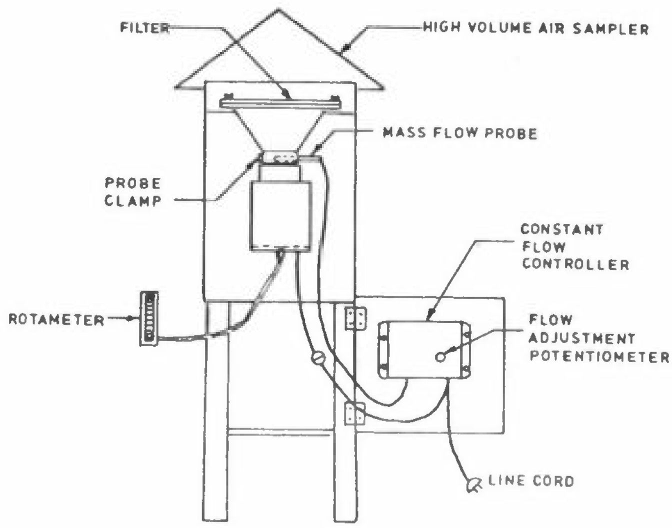
1 THE HIGH VOLUME SAMPLER

The US EPA-type "high-volume" suspended particulate sampler (1) is a device that pumps a sample of ambient air through a filter within a measured time interval. To determine the gravimetric, chemical, or other characteristics (e.g., concentrations) of the particulates on the filter, three independent determination must be made:

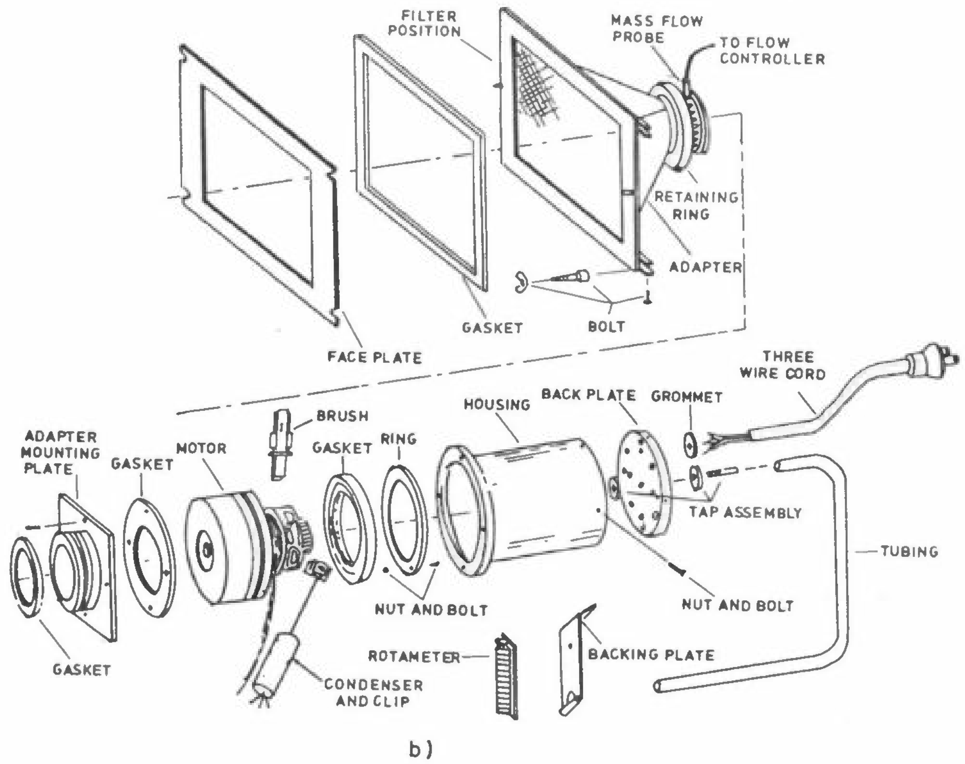
- mass (e.g., of particles, chemical constituents)
- volume flow rate of air
- sampling time.

All three must be measured with sufficient accuracy to give an accurate calculated result.

The high volume sampler is normally placed in a standardized shelter, with the filter facing upward, as illustrated in Figure 1(a). The components of the sampler are shown in Figure 1(b) in an exploded view. In the sampler, the air is pulled through the filter by a centrifugal blower, passes along the windings of the blower motor, and finally into a plenum within the sampler housing just downstream of the motor unit. The air in this chamber is then exhausted to the atmosphere through perforations in the base plate of the motor housing. The base plate in essence, functions as an orifice and allows a flow rate determination directly through the measurement of overpressure in the plenum, by means of some sort of pressure transducer.



a)



b)

Figure 1: (a) typical US EPA-type high volume sampler in standard shelter,

(b) exploded view of typical high volume sampler.

In principle, a downstream location for flow measurement is **undesirable**, and careful and frequent calibrations are required. The small rotameter, used in an indirect manner for flow indication with high volume samplers, draws only a small fraction of the total air flow through the sampler and is particularly susceptible to the slightest of changes in air flow patterns through the sampler (e.g., after brush changes, insects) that may alter the portion of flow passing through the meter, and to mis-adjustments. Rotameter indication are also affected by changes in ambient temperature and pressure. Fortunately the more recently developed mass flow controllers (cf. Figure 1(a)) are always mounted ahead of the blower (in the "neck" of the filter holder adapter), away from any downstream disterbances. The desired flowrates, however, still must be set by means of a calibration unit. Such secondary calibration standards (e.g., the orifice calibration unit) for use in the field must be themselves calibrated against a primary standard.

2 THE ROOTSMETER

Positive displacement primary standards, such as the Rootsmeter, are recommended (1) for secondary standard calibration. The Rootsmeter is a positive displacement rotary-type device. Actual volume measurement (displaced volume) is completely independent of gas density, temperature or pressure. Correction of displaced volume indication to volume at standard conditions of temperature and pressure is easily accomplished by application of the common gas laws. Volumetric accuracy of any rotary positive type meter is permanent and non-adjustable, because its measuring characteristics are established by the dimensions and machined contours of non-wearing fixed and rotating parts.

As shown by diagram in Figure 2, a rotary type meter consists principally of two contra-rotating impellers of two-lobe or "figure 8" contour, operating within a rigid casing having inlet and outlet gas connection on opposite sides. Impeller contours are mathematically developed and accurately produced, and are of such form that a continuous line seal within contact can be obtained between the two impellers at all positions during rotation. To accomplish this the correct relative impeller positions are established, and maintained, by precision grade timing gears. Similar line seals also exist between the impeller lobe tips and the two semicircular parts of the meter casing, and minimum clearances are provided between the ends of the impellers and the headplates. Thus, the inlet side of the meter is always effectively isolated from the outlet by the impellers.

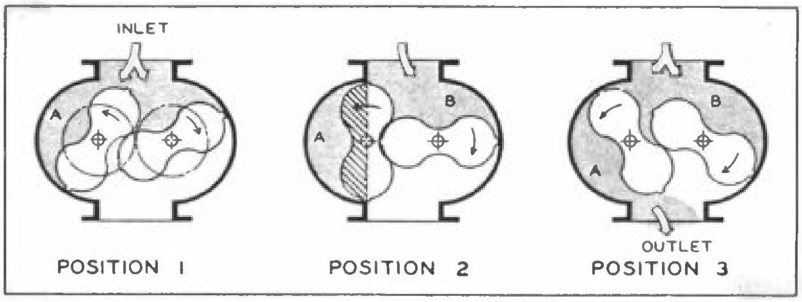


Figure 2: Principle of gas flow through a rotary meter.

When flowing air is brought to the meter inlet, it fills all of the space above the impellers as shown in POSITION 1 of Figure 2. A differential air pressure develops across the impellers, causing them to rotate in the directions indicated by the small arrows. At POSITION 2 a specific volume of air is trapped and sealed off in pocket A, formed between the left impeller and its semicircular portion of the meter casing (cylinder), while similar pocket B is being formed by the other impeller and is filling with air. Continued rotation opens pocket A, allowing its trapped volume of air to pass to the meter outlet as indicated in POSITION 3, and further rotation successively closes pocket B and then delivers its air to the outlet. At the same time, pocket A is again being formed on the second side of the left impeller, etc. Therefore, one complete revolution of the meter impellers will measure and pass 4 gas volumes equal to that contained in pocket A in POSITION 2. This total volume - the displacement of the meter per revolution - has been precisely determined for each meter model, both by calculation and by accurate laboratory tests. When the meter is in use, the rotating impellers drive a counter (through a planetary gear system) in order to provide an indication of the displaced volume of air passing through the meter.

3 THE ORIFICE CALIBRATION UNIT

The orifice calibration unit, illustrated in Figure 3, is a specially adapted orifice meter, that can be mounted on top of the high volume sampler filter holder, ahead of the filter. This orifice meter of standardized dimensions, has simple tubular construction with a central orifice (round hole) at one end, a pressure tap, and a mounting plate at the other end. A water manometer, with one leg connected to the pressure tap, measures the differential pressure across the orifice (i.e., the pressure drop from barometric to that downstream of the orifice).

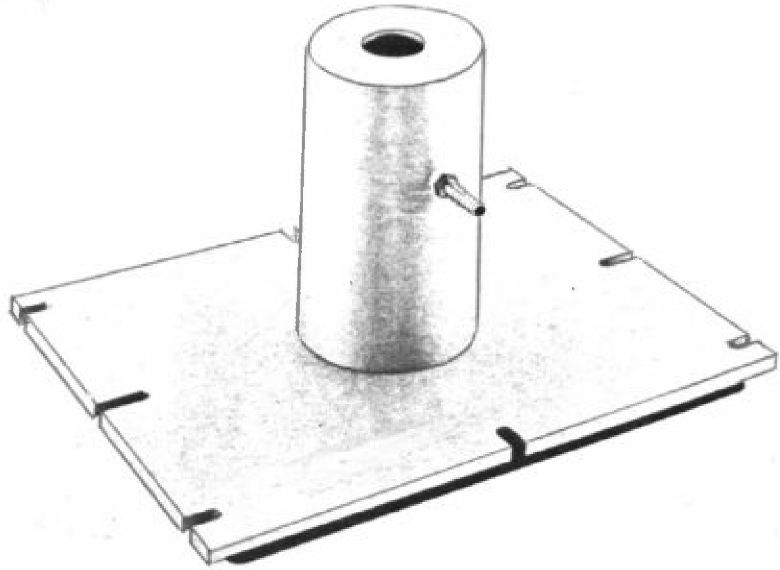


Figure 3: Top-loading orifice calibration unit.

The orifice calibration unit should be calibrated against the primary standard immediately after receipt from the manufacturer. Recalibrations should be performed at least once a year, and every time some damage (particularly to the orifice hole) is noted.

For both the orifice unit calibration and the setting of the mass flow controller in the field, on-site barometric pressure and ambient temperature measurements are required.

4 PRIMARY CALIBRATION OF THE SECONDARY STANDARD

With the primary standard a Rootsmeter, a typical calibration arrangement is shown in Figure 4. The calibration consists of passing ambient air through the orifice calibration unit (secondary standard) and the Rootsmeter at different, but constant air flows, and recording the pertinent variables.

Because the Rootsmeter measures the actual volume of air (at the conditions it passes through the meter), the air flow rate through the Rootsmeter, Q_m, at meter pressure, P_m, and temperature, T_m, is:

$$Q_m = \frac{V_m}{t}$$

where V_m is the volume of air passing through the Rootsmeter over a time period t. The flow rate, Q_a, through the orifice and the Rootsmeter at barometric pressure, P_b, and ambient temperature, T_a, is:

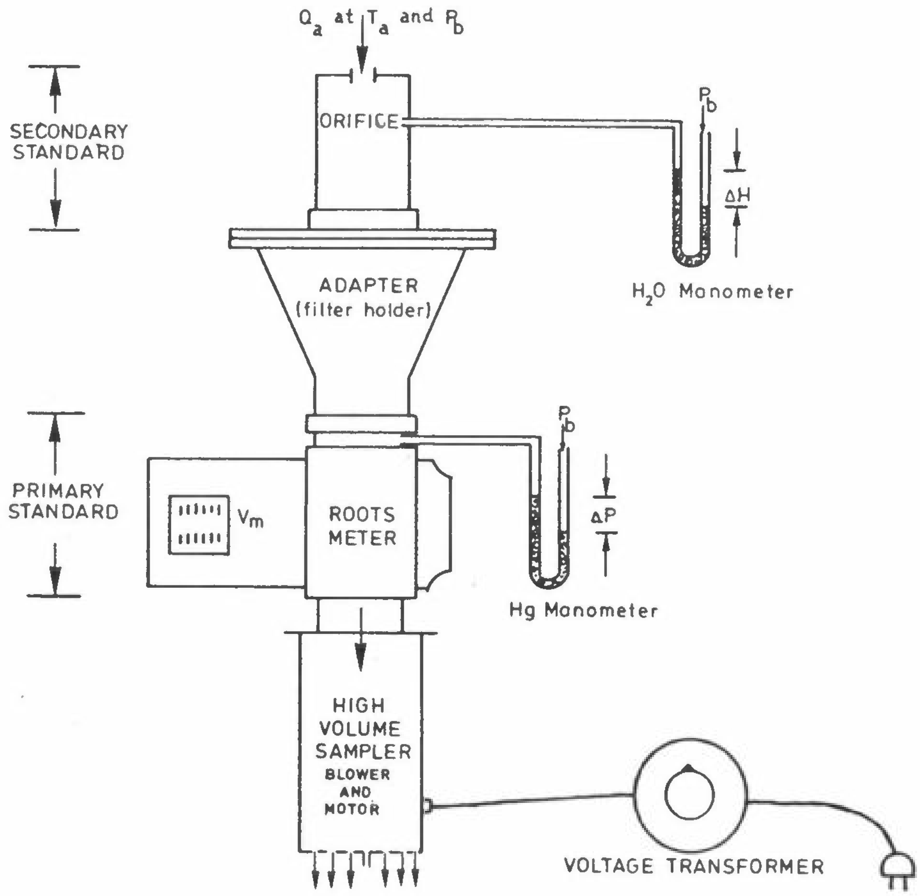


Figure 4: Typical set-up for primary calibration of secondary standard (orifice calibration unit).

$$Q_a = \frac{V_m}{t} \left(\frac{P_m}{P_b} \cdot \frac{T_a}{T_m}\right), \text{ or, if } T_m \simeq T_a,$$

$$Q_a = \frac{V_m}{t} \left(\frac{P_m}{P_b}\right) = \frac{V_m}{t} \left(\frac{P_b - \Delta P}{P_b}\right) \qquad (1)$$

where $P_m = P_b - \Delta P$ = pressure at Rootsmeter inlet.

$\Delta P = P_b - P_m$ = differential pressure drop from ambient to Rootsmeter inlet (measured by the Hg manometer in Figure 4).

T_a = ambient air temperature

T_m = air temperature in Rootsmeter (usually assumed equal to T_a)

The flow rate of air through the orifice meter, based on standard volume, Q_{std}, at the standard conditions of pressure, P_{std}, and temperature, T_{std}, is:

$$Q_{std} = \frac{V_m}{t} \left(\frac{P_b - \Delta P}{P_b}\right) \left(\frac{P_b}{P_{std}} \cdot \frac{T_{std}}{T_a}\right), \text{ or}$$

$$Q_{std} = \frac{V_m}{t} \left(\frac{P_b - \Delta P}{P_{std}}\right) \left(\frac{T_{std}}{T_a}\right) \qquad (2)$$

NB: All pressures and temperatures in the above must be in consistent absolute units. Thus, although the barometer already measures absolute pressures, the necessary absolute temperatures, T, (in K degrees) are obtained sufficiently accurately from the observed ^{o}C: $T = {}^{o}C + 273$.

For each of the different air flows, Q_a, through the orifice the corresponding differential pressures, ΔH, of the orifice meter (measured by the water manometer in Figure 4) are recorded.

5 ORIFICE UNIT CALIBRATION CURVE

By measuring during the calibration runs V_m, t, P_b, ΔP, and T_a, either the ambient flowrates, Q_a, or the standard, Q_{std}, (in m^3/min) through the orifice can be calculated from Equations (1) or (2), respectively. Either of these, together with the corresponding orifice pressure drops, ΔH, (in mm) are then used to construct the orifice unit calibration curve. When the mass flow controller is used with the high volume sampler, the controller is set to maintain a constant flowrate at standard conditions, and a calibration curve in terms of Q_{std} is preferable.

In constructing the calibration curve, the main objective is to fit the experimental data points with a smooth curve. Plotting on linear graph paper, of, e.g., "Q_{std} vs. ΔH", has the advantage of simplicity and ease of reading the calibration curve. If a straight-line plot is preferred, log-log graph paper, or "Q_{std} vs. $\sqrt{\Delta H}$" graph can be used. The smallest division on the ordinate of the curve (i.e., Q_{std} axis) should be at least 0.01 m^3/min and on the abscissa (i.e., ΔH axis) 1 mm. Actual data points should be shown in the graph, along with the values of P_{std} and T_{std}, and date of calibration.

An acceptable primary calibration should consist of at least 5 points, having no data points deviating more than ± 0.04 m^3/min from the curve for the same value of ΔH (2).
Detailed instructions for the calibration procedure are given in the Appendix.

6 SETTING THE FLOW CONTROLLER

The constant flow controller (3) uses a constant temperature thermal anemometer to measure the mass flow of the sampled air. A block diagram of the components of the flow controller is shown in Figure 5. An integral temperature sensor corrects for changes in ambient temperature. A feed-back control system, using a triac motor speed regulator, maintains the mass flow rate constant over a selectable range of 0.57 to 1.70 standard cubic metres per minute. Since the controller responds to mass flow, it automatically corrects the flow rate to the desired standard conditions.

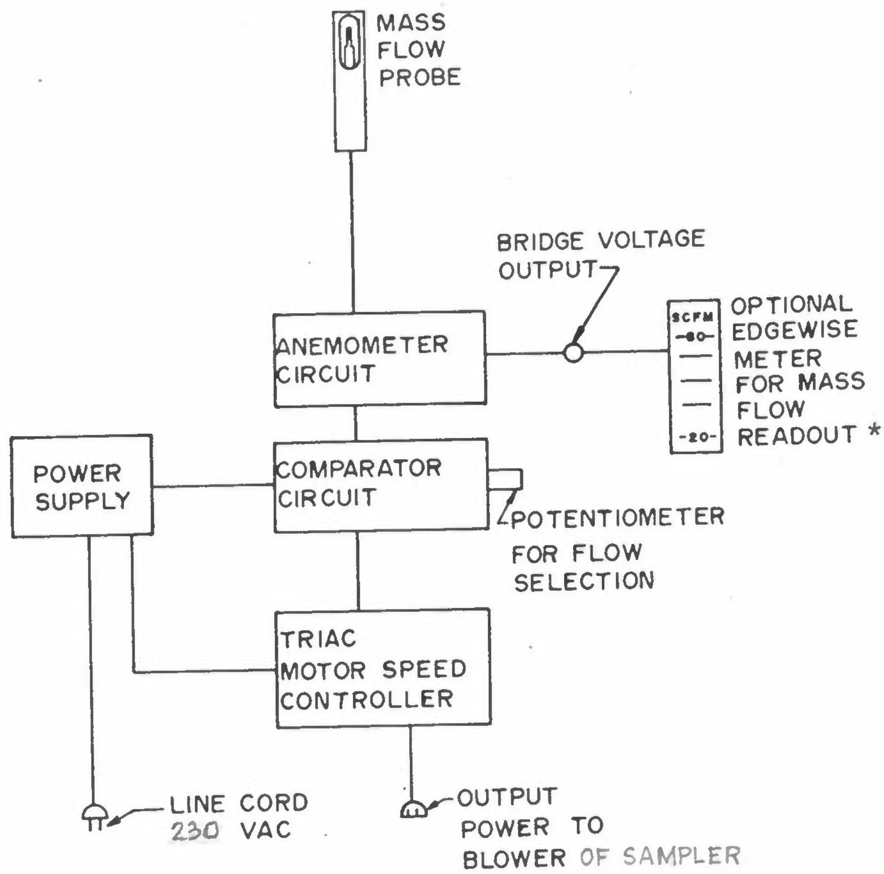


Figure 5: Block diagram of constant flow controller.
** not on NILU's high volume samplers.*

In order to establish a chosen standard flow rate for the high volume sampler equipped with a constant mass flow controller, the controller has to be set at the sampling site by means of the orifice calibration unit.

From conservation of energy considerations (i.e., Bernoulli's equation), it can be shown (cf, e.g., (2)) that for an orifice meter, such as the orifice calibration unit, using a water manometer as the differential pressure indicator, the ambient air flow rate, Q_a, is:

$$Q_a = C\sqrt{\frac{\Delta H}{\rho_a}} \qquad (3)$$

where ΔH = differential pressure across the orifice (as measured by the water manometer);

C = a constant (incorporates velocity and contraction coefficients and area of orifice, and appropriate conversion factors);

ρ_a = density of ambient air.

As can be seen from Equation (3), the flowrate, Q_a, through the orifice at a fixed ΔH is a function of the density of the flowing air.

In most cases, conditions of pressure and temperature at the sampling site are likely to be different from standard conditions. The flow rate, measured with the high volume sampler orifice calibration unit at the site, must therefore be corrected for field conditions of barometric pressure and ambient temperature*, and the flow controller set according to:

$$Q_f = Q_{std}\sqrt{\frac{P_{std}}{P_b} \cdot \frac{T_a}{T_{std}}} \qquad (4)$$

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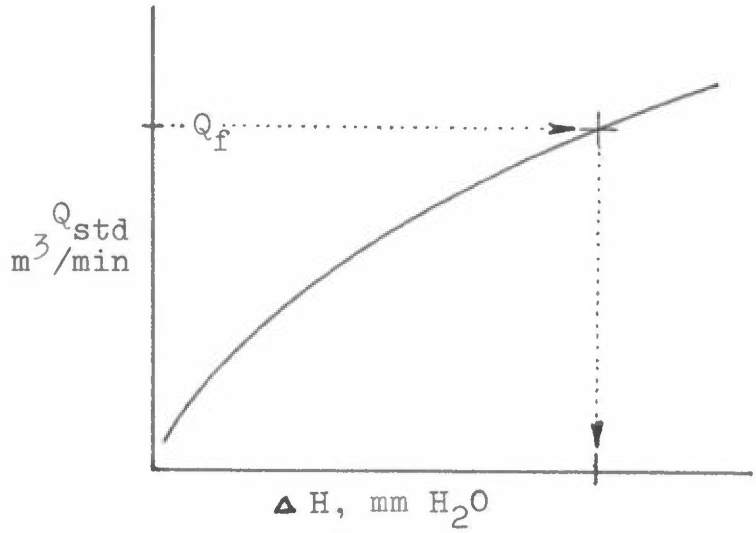
* Assuming that ρ_a is a function of air pressure and temperature only. It has been estimated (2) that air moisture content effects can for all practical purposes be neglected, since the error in flow rate measurement at relatively extreme combination of pressure and temperature would be < 2%.

Here Q_f is the flowrate, at the site conditions P_b and T_a, which corresponds to the desired flowrate at standard conditions*
Using on-site measurements of P_b and T_a, Q_f is computed, and the corresponding ΔH obtained from the orifice unit calibration curve, as shown below.



With the orifice calibration unit mounted on top of the high volume sampler, the potentiometer of the flow controller (cf. Figures 1(a) and 5) is adjusted until the water manometer shows the ΔH obtained above.

Once the selected standard flow rate has been set in this manner, the flow controller is expected to maintain** it independent of changes in barometric pressure, ambient temperature, line voltage, and filter loading.

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* The standard conditions for primary calibration of the orifice unit and for the field sampling rate should be the same.

** within ± 0.03 m^3/min over the temperature range of -20 °C to + 55 °C, according to the manufacturer.

The high volume sampler rotameter can also be adjusted at this time to indicate the selected flowrate. The rotameter can then be used for subsequent quire-reference checks of the flow rate (e.g., at each filter change). It must be remembered, however, that without corrections rotameter indications may be inaccurate, when pressure and temperature conditions at the site change significantly from those existing during the original adjustment. Thus, the orifice calibration unit should be always used to re-measure the flowrate at the close of any high volume sampling program, or when the rotameter indicates a substantial change in a flow controller-regulated flow rate in the absence of obvious reasons (e.g., very heavy particulate matter loading of the filter). Detailed instructions for the controller setting procedure are given in the Appendix.

7 REFERENCES

(1) Reference method for the determination of suspended particulates in the atmosphere (high volume method). National Primary and Secondary Ambient Air Standards, Appendix B, *Federal Register*, 36, No. 84, Part II, Washington, D.C. April 30, 1971.

(2) Smith, F., Wohlschlegel, P.S., Rogers, R.S.C., Mulligan, D.G. Investigation of flow rate calibration procedures associated with the High Volume Method for determination of suspeded particulates. PB 291386, EPA-600/4-78-047, US EPA, Research Triangle Park, N.C. Aug. 1978.

(3) Kurz, J.L., Olin, J.G. A new flow controller for high volume air samplers. Paper 85-65.6, presented at the 68th annual meeting of APCA, Boston, MA, June 15-20, 1975.

APPENDIX

INSTRUCTIONS FOR CALIBRATION OF HIGH VOLUME SAMPLERS

The calibration of high volume samplers, equipped with constant flow regulators, can be divided into two phases.

Phase 1: Primary calibration of the orifice calibration unit (secondary standard) with a Rootsmeter (primary standard) in the laboratory;

Phase 2: Setting the constant flow controller to operate the high volume sampler at a selected, standard volume flow rate at the sampling site.

Phase 1: Calibration of the orifice calibration unit

Calibration of orifice calibration units is accomplished using a Rootsmeter as a primary standard. A typical laboratory calibration set-up is shown in Figure A1. In addition to the equipment illustrated, a barometer, thermometer, and a stopwatch are also required. Least scale divisions of 1 mm Hg, 1 ^{o}C, and 1/10 second, respectively, for these are adequate.

(a) Use and maintenance of the Rootsmeter.
The Rootsmeter must be installed, operated and maintained in the strict accordance with the instructions given in the manual of the instrument*. Be sure to read it carefully and consult when necessary.
It is essential, that the Rootsmeter be properly leveled and lubricated before every operation. Lubrication oil of the manufacturer's specification only must be used and the oil maintained at the proper levels in the oil sumps. In use, the meter must be level to within 5 mm/m in all directions.

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* Rotary positive displacement Roots Meters. Installation, operation, maintenance. Dresser Measurement Division, Dresser Industries, Inc. Houston, TX.

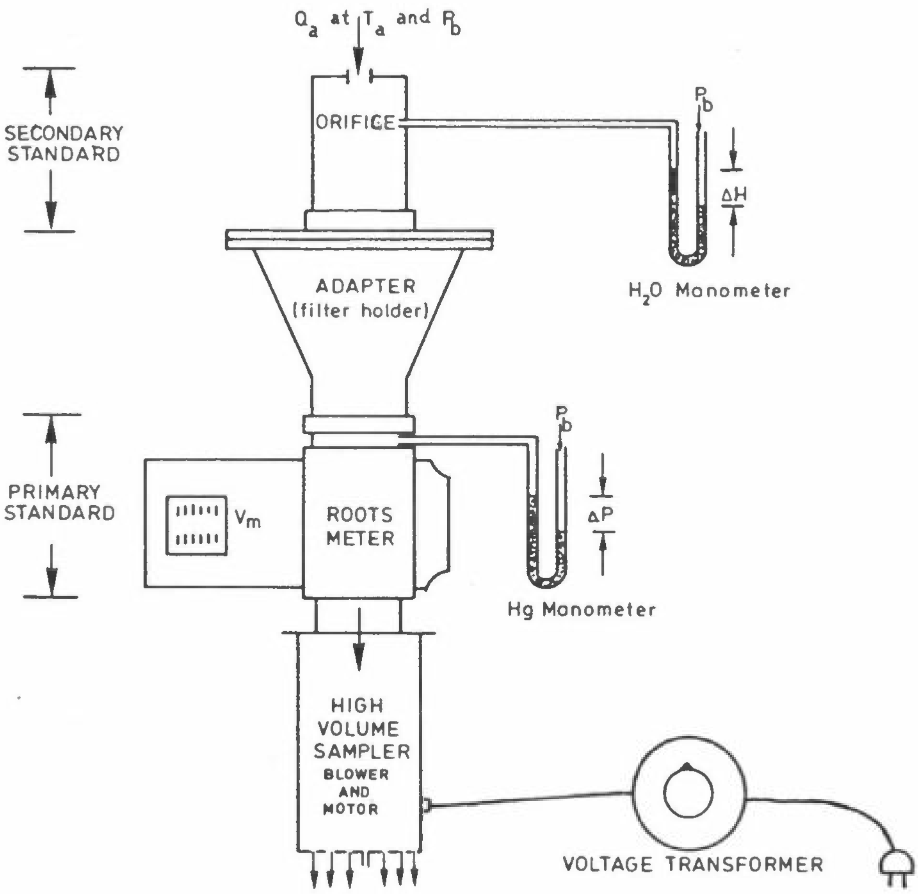


Figure A1: Laboratory set-up for primary calibration of orifice calibration unit.

(b) Procedure for orifice unit calibration.

(i) Mount the filter holder of the high volume sampler (labelled "ADAPTER" in Figure A1) on the inlet (top) of the Rootsmeter; connect a high volume sampler blower to the outlet of the Rootsmeter;

(ii) With the voltage transformer turned off (on "0"), connect the power cord of the blower through the voltage transformer to the mains supply;

(iii) Place a 20 cm x 25 cm glass fiber filter on the filter holder, and clamp the orifice calibration unit on top;

(iv) Connect, with flexible tubing, one leg of the H_2O manometer to the pressure tap of the orifice calibration unit, and leave the other leg open to the atmosphere;

the H_2O manometer will now measure ΔH, the pressure drop across the orifice;

be certain not to obstruct the orifice opening at any time during the calibration runs (as this would cause the water from the H_2O manometer to be sucked into the orifice unit);

(v) Connect, with flexible tubing, one leg of the Hg manometer to the Rootsmeter inlet (top) pressure tap, and leave the other leg open to the atmosphere (the Rootsmeter outlet tap must be closed); the Hg manometer will now measure ΔP, the pressure drop from the barometric to that at the Rootsmeter inlet;

(vi) Select at least 5 different, but "well-spaced", flowrates in the normal operating range of high volume samplers (i.e., between ca 0.6 and 1.7 m^3/min), and estimate the corresponding ΔHs (i.e., H_2O manometer readings) from the calibration curve supplied by the manufacturer of the orifice calibration unit;

(vii) By turning the voltage transformer dial slowly, adjust the ΔH appropriate for one of the Rootsmeter flowrates selected;

allow the Rootsmeter to run for several minutes before taking readings;

(viii) Using a data sheet (such as the "Primary calibration worksheet" in Figure A2, or similar), record the observed barometric pressure (P_b) and air temperature (T_a) in the calibration room;

(ix) Using a stopwatch, time the interval for a given volume of air to pass through the Rootsmeter (V_m); either a fixed time interval (e.g., at least 5 minutes) or a fixed air volume (e.g., at least 6 m^3) may be used;

the Rootsmeter volume is determined by either reading the meter counter or counting the resolutions on the end dial (1 in Figure A3).

PRIMARY CALIBRATION WORKSHEET

Run No.	Rootsmeter reading		Elapsed time, t		Rootsmeter volume	Differential pressure	Orifice pressure drop	Standard volume flow rate
	start	end	min:sec	min.	$V_m = (2)-(1)$ m^3	ΔP mm Hg	ΔH mm H_2O	Q_{std} m^3/min
	(1)	(2)		(3)	(4)	(5)	(6)	(7)

RECORD CALIBRATION DATA

Rootsmeter: Model 5M125 CTR Hi-Vol calibration meter Serial No. 798954

Calibrator: Model 330, Sierra Top-Loading Orifice calibrator. Serial (or NILU) No.

(8) P_b: mm Hg (10) P_{std}: 760.0 mm Hg

(9) T_a: $^oC+273 =$ K (11) T_{std}: K

Calibration performed by:

Date of calibration:

CALCULATION EQUATIONS

$V_m = (2)-(1)$

$$Q_{std} = \frac{V_m}{t} \cdot \frac{P_b - \Delta P}{T_a} \cdot \frac{T_{std}}{P_{std}}$$

$$(7) = \frac{(4)}{(3)} \cdot \frac{(8)-(5)}{(9)} \cdot \frac{(11)}{(10)}$$

Figure A2: Example of orifice calibration unit calibration worksheet.

the Rootsmeter must not be stopped and started for this, but the volume (or revolution) readings taken "on the run";

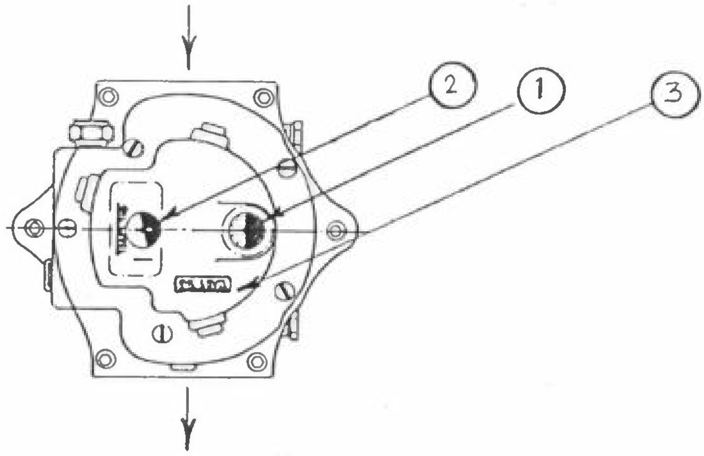


Figure A3: Dial and gauge information:

(1) 1 revolution = 0.1 m^3

(2) 1 revolution = 1 impeller shaft revolution

(3) oil level mark of counter housing

(x) Record the start and end Rootsmeter counter readings (or revolution count), the elapsed time (minutes, seconds and 1/10 sec.), and ΔH and ΔP on the data sheet;

(xi) Repeat steps (vii) through (x) for the other calibration flowrates selected in step (vi);

(xii) After all calibration runs have been performed, shut off the blower by turning the voltage transformer back to "0";

(xiii) Observe and record again P_b and T_a in the calibration room.

(xiv) Perform the necessary calculations (as shown in Figure A2) to obtain Q_{std} for each of the calibration runs;

(xv) Plot the calibration curve of "Q_{std} vs. ΔH", as illustrated in Figure A4; The smallest division should be 0.01 m^3/min on the Q_{std} axis and 1.0 mm H_2O on the ΔH axis;

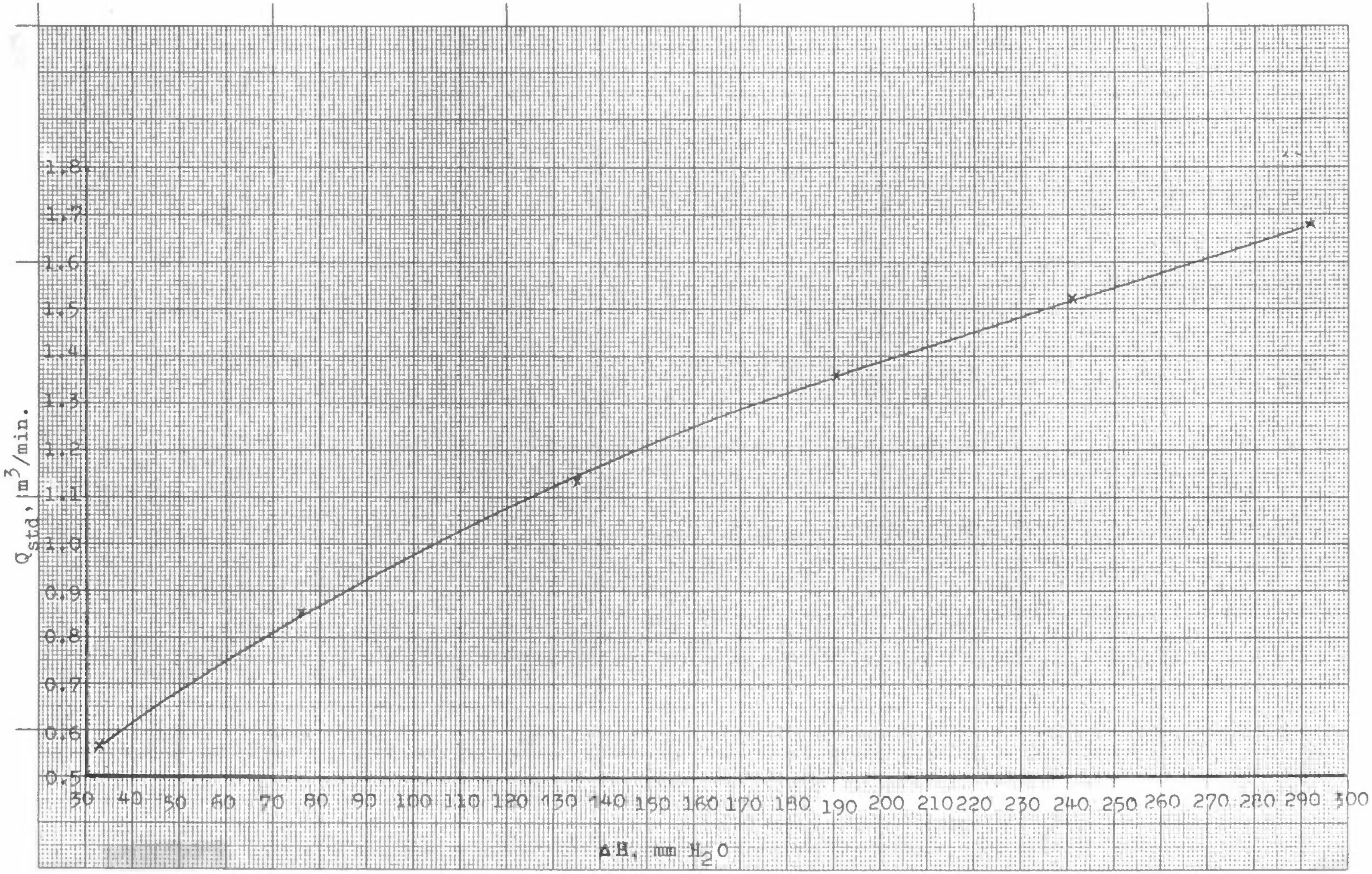


Figure A4: Example of orifice calibration unit calibration curve.

show the standard conditions of pressure and temperature, orifice calibration unit identification (e.g., NILU number), name of the person(s) performing the calibration, and the date of calibration on the graph.

It is advisable to make a rough plot of the calibration points immediately after the completion of the calibration runs. Any grossly "out of line" data points (deviating by more than 0.04 m^3/min from a smooth curve) can then be spotted and the questionable run(s) repeated before the calibration set-up has been taken down.

Phase 2: Setting the constant flow controller

Settting of the constant flow controller of the high volume sampler is accomplished at the sampling site by means of the orifice calibration unit(including its H_2O manometer). In addition, a barometer, a thermometer, the calibration curve of the orifice unit (from Phase 1) and an extra 20 cm x 25 cm glass fibre filter, are required.

(a) Procedure for setting the flow controller

With the high volume sampler in place at the sampling site, and its shelter roof open:

(i) Place the glass fibre filter on the filter holder screen and clamp the orifice calibration unit on top;

(ii) start the high volume sampler, and carefully (so as not to suck out the water from the manometer). Connect with flexible tubing, one leg of the H_2O manometer to the pressure tap of the orifice calibration unit, and leave the other leg open to the atmosphere;

be certain not to obstruct the orifice opening at any time while the H_2O manometer is connected and the sampler is running;

Let the sampler run for at least 5 minutes, before taking any ΔH readings and making adjustments;

(iii) Using a data sheet (such as the "Flow controller sork-sheet" in Figure A5, or similar) record the observed barometric pressure (P_b) and air temperature (T_a) at the sampling site;

FLOW CONTROLLER WORKSHEET

RECORDED ON-SITE DATA

Calibrator: Model 330, Sierra Top-Loading
Orifice calibrator
Serial (or NILU) No.

Flow controller: Series 350, Sierra Constant
Flow Controller
Serial (or NILU) No.

(1) P_b: mm Hg

(2) T_a: $^oC+273 =$ K

(3) P_{std}: 760.0 mm Hg

(4) T_{std}: K

(5) Q_{std}: m^3/min

(6) ΔH: mm H_2O (from (e))

Sampling site location:

Controller set by:

Date of setting:

CALCULATIONS AND INSTRUCTIONS

(a) Calculate:

$$Q_f = Q_{std} \sqrt{\frac{P_{std}}{P_b} \cdot \frac{T_a}{T_{std}}}$$

$$Q_f = (5) \cdot \sqrt{\frac{(3)}{(4)} \cdot \frac{(2)}{(4)}}$$

(b) Enter the Model 330 Top Loading Orifice unit calibration graph Q_{std} axis at the Q_f value found in (a);

(c) Proceed horizontally across, until the calibration curve is intersected;

(d) Proceed vertically down until the ΔH axis of the calibration graph is intersected;

(e) Enter the value of ΔH at the intersection as item (6) under "RECORDED ON-SITE DATA";

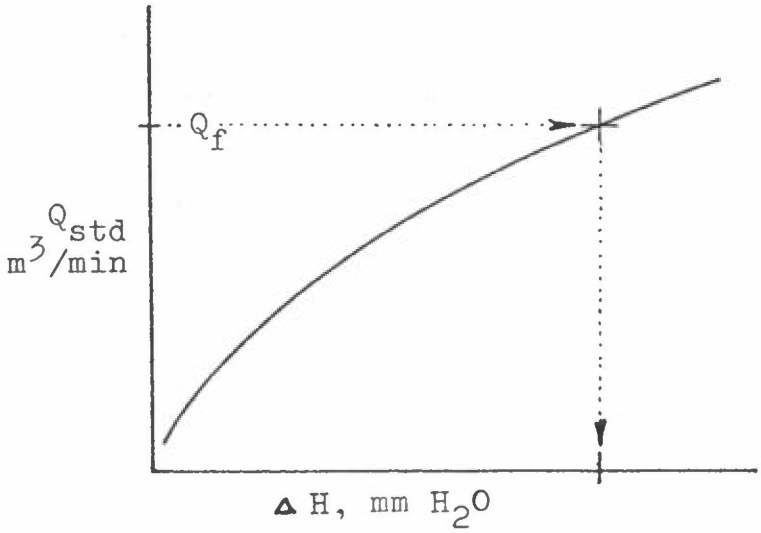
(f) Adjust the potentiometer of the Series 350 Constant Flow Controller until the H_2O manometer of Model 330 Top Loading Orifice unit reads (6).

Figure A5: Example of flow controller setting worksheet.

(iv) Perform the calculation of Q_f (as shown in Figure A5) using the selected standard volume flowrate for the high volume sampler, and the measured P_b and T_a at the site;

NB: P_{std} and T_{std} for the sample volume should be the same as for the orifice unit calibration curve.

(v) Using the Q_f value calculated in (iv) above, obtain ΔH from the orifice unit calibration curve, as illustrated below:



(vi) Open the cover of the flow controller unit and, using a fine screwdriver, adjust the flow controller potentiometer screw, until the differential pressure indicated by the H_2O manometer equals the ΔH found in step (v) above;

NB: After the initial adjustment, wait for about 5 minutes for the flow through the sampler to stabilize, i.e., for the H_2O manometer deflection to remain at the proper ΔH. If necessary, readjust the controller potentiometer until the manometer reading remains within at least ± 2 mm H_2O of the ΔH found in step (v).

(vii) Shut off the high volume sampler, close the cover of the controller unit, and remove the calibration unit from the filterholder;

the high volume sampler is now ready for steady operation at the selected standard flow rate (provided glass fibre filters are used and particle loading are not excessive);

The high volume sampler standard flowrate should be rechecked with the orifice calibration unit against the inital calibration value at least at the end of each sampling program, by re-measuring ΔH, P_b and T_a at the site. Periodic checks during an extended program (e.g., every 3 months) are preferable, particularly after change of the season. ,

For rough, more frequent checks of the sampler flow rate (e.g., at each filter change), the small rotameter of the high volume sampler can be used. If large differences in rotameter readings are observed, and no obvious causes (e.g., excessive particle loadings) can be spotted, the entire system should be checked and possibly recalibrated.

When used for this purpose, the rotameter should be adjusted at the same time the constant flow controller is set.

(b) Procedure for adjusting sampler rotameter

(i) After step (vi) in the controller setting procedure (Phase 2, Section (a)) is completed, connect with flexible tubing the rotameter inlet (bottom) to the pressure tap in the multi-hole base plate of the high volume sampler housing;

(ii) hold the rotameter vertically;

if the centre of the rotameter ball reads a flowrate that is within ± 0.04 m^3/min (ca 1.5 ft^3/min) of Q_f (obtained in step (iv) of flow controller setting procedure), no readjustment is necessary;

(iii) If the condition in step (ii) above is not met, loosen the rotameter tube locking nut (top) by turning it counterclockwise;

(iv) Holding the rotameter vertically, turn the adjusting screw (above the locking not) clockwise to lower the ball, or counterclockwise to raise the ball, until the centre of the ball indicates Q_f;

(v) Re-tighten the locking nut, but be certain that the rotameter ball still reads the proper flowrate afterwards;

(vi) Seal the adjustment screw and the locking nut with some non-permanent sealant (e.g., silicon rubber adhesive/ sealant), to assure that the setting is not easily tampered with;

(vii) Use the adjusted rotameter only together with the same high volume sampler as during the adjustments;
Use the same piece of flexible tubing to connect the rotameter to the sampler's pressure tap for subsequent flow rate measurements as used for the rotameter adjustments.

NB: If the ambient temperature and barometric pressure at the sampling site are substantially different from those during the adjustment of the rotameter (e.g., after change of the season) flow rates indicated by the rotameter may have to be corrected to account for differences in ambient temperature and barometric pressure by:

$$Q_2 = Q_1 \sqrt{\frac{P_1 T_2}{P_2 T_1}}$$

where: Q_2 = corrected flow rate, m^3/min, at conditions P_2 and T_2;

Q_1 = indicated flow rate, m^3/min;

T_1 = absolute temperature, K, when rotameter was adjusted;

P_1 = barometric pressure, mm Hg, when rotameter was adjusted;

T_2 = absolute temperature, K, when rotameter is read;

P_2 = barometric pressure, mm Hg, when rotameter is read.

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ABSTRACT (max. 300 characters, 5-10 lines)
Primary (using a Rootsmeter) and secondary (using an orifice calibration unit) calibration methods for the US EPA-type "high-volume" suspended particulate sampler are described.

**Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
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