§ 89.422 Dilute sampling procedures—CVS calibration.

(a) The CVS is calibrated using an accurate flowmeter and restrictor valve.

(1) The flowmeter calibration must be traceable to NIST measurements, and will serve as the reference value (NIST "true" value) for the CVS calibration. (Note: In no case should an upstream screen or other restriction which can affect the flow be used ahead of the flowmeter unless calibrated throughout the flow range with such a device.)

(2) The CVS calibration procedures are designed for use of a "metering venturi" type flowmeter. Large radius or ASME flow nozzles are considered equivalent if traceable to NIST measurements. Other measurement systems may be used if shown to be equivalent under the test conditions in this section and traceable to NIST measurements.

(3) Measurements of the various flowmeter parameters are recorded and related to flow through the CVS.

(4) Procedures used by EPA for both PDP-CVS and CFV-CVS are outlined below. Other procedures yielding equivalent results may be used if approved in advance by the Administrator.

(b) After the calibration curve has been obtained, verification of the entire system may be performed by injecting a known mass of gas into the system and comparing the mass indicated by the system to the true mass injected. An indicated error does not necessarily mean that the calibration is wrong, since other factors can influence the accuracy of the system (for example, analyzer calibration, leaks, or HC hangup). A verification procedure is found in paragraph (e) of this section.

(c) PDP-CVS calibration. (1) The following calibration procedure outlines the equipment, the test configuration, and the various parameters which must be measured to establish the flow rate of the PDP-CVS pump.

(i) All the parameters related to the pump are simultaneously measured with the parameters related to a flowmeter which is connected in series with the pump.

(ii) The calculated flow rate, in (cm³/s), (at pump inlet absolute pressure and temperature) can then be plotted versus a correlation function which is the value of a specific combination of pump parameters.

(iii) The linear equation which relates the pump flow and the correlation function is then determined.

(iv) In the event that a CVS has a multiple speed drive, a calibration for each range used must be performed.

(2) This calibration procedure is based on the measurement of the absolute values of the pump and flowmeter parameters that relate the flow rate at each point. Two conditions must be maintained to assure the accuracy and integrity of the calibration curve:

(i) The temperature stability must be maintained during calibration. (Flowmeters are sensitive to inlet temperature oscillations; this can cause the data points to be scattered. Gradual changes in temperature are acceptable as long as they occur over a period of several minutes.)

(ii) All connections and ducting between the flowmeter and the CVS pump must be absolutely void of leakage.

(3) During an exhaust emission test the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

(4) Connect a system as shown in Figure 5 in appendix A to this subpart. Although particular types of equipment are shown, other configurations that yield equivalent results may be used if approved in advance by the Administrator. For the system indicated, the following measurements and accuracies are required:

<table>
<thead>
<tr>
<th>Calibration Data Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Barometric pressure (corrected)</td>
</tr>
<tr>
<td>Ambient temperature</td>
</tr>
<tr>
<td>Air temperature into metering venturi</td>
</tr>
</tbody>
</table>
Where:

- \( Q_o \) = meter air flow rate in standard cubic meters per minute, \( 0 \, ^\circ \text{C}, \, 101.3 \, \text{kPa} \)
- \( T_p \) = pump inlet temperature \( ^\circ \text{K} = P_in + 273 ^\circ \text{K} \)
- \( P_i \) = absolute inlet pressure, \( \text{kPa} \)
- \( P_v \) = absolute outlet pressure, \( \text{kPa} \)
- \( P_0 \) = barometric pressure, \( \text{kPa} \)
- \( P_r \) = pump inlet depression, \( \text{kPa} \)

### Calibration Data Measurements—Continued

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Units</th>
<th>Sensor-readout tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure drop between the inlet and throat of metering venturi.</td>
<td>( EDP )</td>
<td>kPa</td>
<td>±0.1 kPa</td>
</tr>
<tr>
<td>Air temperature at CVS pump inlet</td>
<td>( Q_o )</td>
<td>m³/min</td>
<td>±0.5% of NIST value.</td>
</tr>
<tr>
<td>Pressure depression at CVS pump inlet</td>
<td>( PTI )</td>
<td>°C</td>
<td>±1.1 °C</td>
</tr>
<tr>
<td>Pressure head at CVS pump outlet</td>
<td>( PPO )</td>
<td>kPa</td>
<td>±0.055 kPa</td>
</tr>
<tr>
<td>Air temperature at CVS pump outlet</td>
<td>( PTI )</td>
<td>°C</td>
<td>±1.1 °C</td>
</tr>
<tr>
<td>Pump revolutions during test period</td>
<td>( N )</td>
<td>Revs</td>
<td>±1 Rev.</td>
</tr>
<tr>
<td>Elapsed time for test period</td>
<td>( I )</td>
<td>s</td>
<td>±5 s</td>
</tr>
</tbody>
</table>

\[
X_0 = \frac{1}{n} \left( \frac{\Delta p}{P_0} \right)
\]

- \( X_0 \) = correlation function.
- \( \Delta p \) = the pressure differential from pump inlet to pump outlet, \( \text{kPa} \).
- \( P_0 \) = absolute pump outlet pressure, \( \text{kPa} \).

Where:

- \( P_{v0} \) = pressure head at pump outlet, \( \text{kPa} \).

(7) Data analysis:

(i) The air flow rate, \( Q_o \), at each test point is calculated in standard cubic meters per minute (\( 0 \, ^\circ \text{C}, \, 101.3 \, \text{kPa} \)) from the flowmeter data using the manufacturer's prescribed method.

(ii) The flow rate is then converted to pump flow, \( V_o \), in cubic meter per revolution at absolute pump inlet temperature and pressure:

\[
V_o = \frac{Q_o}{n} \times \frac{T_p}{273} \times \frac{101.3}{P_p}
\]

Where:

- \( V_o \) = Pump flow, \( \text{m}^3/\text{rev} \) at \( T_p, \, P_p \)
- \( Q_o \) = Meter air flow rate in standard cubic meters per minute, standard conditions are \( 0 \, ^\circ \text{C}, \, 101.3 \, \text{kPa} \).
- \( n \) = Pump speed in revolutions per minute.
- \( T_p \) = Pump inlet temperature \( ^\circ \text{K} = P\text{in} + 273 ^\circ \text{K} \)
- \( P_p \) = Absolute inlet pressure, \( \text{kPa} \)
- \( P_v \) = Absolute outlet pressure, \( \text{kPa} \)
- \( D_s \) = barometric pressure, \( \text{kPa} \).
- \( P_r \) = Pump inlet depression, \( \text{kPa} \).

(iii) The correlation function at each test point is then calculated from the calibration data.
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\[ Q_s = \frac{K_v P}{\sqrt{T}} \]

Where:

- \( Q_s \) = flow.
- \( K_v \) = calibration coefficient.
- \( P \) = absolute pressure.
- \( T \) = absolute temperature.

The calibration procedure described in paragraph (d)(3) of this section establishes the value of the calibration coefficient at measured values of pressure, temperature, and air flow.

(2) The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CPV.

(3) Measurements necessary for flow calibration are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Units</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barometric pressure (corrected)</td>
<td>( P_b )</td>
<td>kPa (Inches Hg)</td>
<td>0.034 (0.01).</td>
</tr>
<tr>
<td>Air temperature, flowmeter</td>
<td>( E_T )</td>
<td>deg.C (deg.F)</td>
<td>0.14 (0.25).</td>
</tr>
<tr>
<td>Pressure drop across LFE matrix</td>
<td>( E_D )</td>
<td>kPa (Inches H_2O)</td>
<td>0.001 (0.005).</td>
</tr>
<tr>
<td>Air flow</td>
<td>( Q_s )</td>
<td>m³/min. (Ft³/min)</td>
<td>0.5 pct.</td>
</tr>
<tr>
<td>CFV inlet depression</td>
<td>( P_{PI} )</td>
<td>kPa (Inches Hg)</td>
<td>0.055 (0.016).</td>
</tr>
<tr>
<td>CFV outlet pressure</td>
<td>( P_{PO} )</td>
<td>kPa (Inches Hg)</td>
<td>0.17 (0.05).</td>
</tr>
<tr>
<td>Temperature at venturi inlet</td>
<td>( T_v )</td>
<td>deg.C (deg.F)</td>
<td>0.28 (0.5).</td>
</tr>
<tr>
<td>Specific gravity of manometer fluid</td>
<td>Sp.Gr</td>
<td></td>
<td>(1.75 oil).</td>
</tr>
</tbody>
</table>

(4) Set up equipment as shown in Figure 6 in appendix A to subpart and eliminate leaks. (Leaks between the flow measuring devices and the critical flow venturi will seriously affect the accuracy of the calibration.)

(5) Set the variable flow restrictor to the open position, start the blower, and allow the system to stabilize. Record data from all instruments.

(6) Vary the flow restrictor and make at least eight readings across the critical flow range of the venturi.

(7) Data analysis. The data recorded during the calibration are to be used in the following calculations:

(i) The air flow rate (designated as \( Q_s \)) at each test point is calculated in standard cubic feet per minute from the flow meter data using the manufacturer's prescribed method.

(ii) Calculate values of the calibration coefficient for each test point:

\[ K_v = \frac{Q_s \sqrt{T_v}}{P_v} \]

Where:

- \( Q_s \) = Flow rate in standard cubic meter per minute, at the standard conditions of 0 °C, 101.3 kPa.
- \( T_v \) = Temperature at venturi inlet, °K.
- \( P_v \) = Barometric pressure, kPa.

\( P_{PI} \) = Venturi inlet pressure depression, (kPa).

(iii) Plot \( K_v \) as a function of venturi inlet pressure. For choked flow, \( K_v \) will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and \( K_v \) decreases. (See Figure 7 in appendix A to this subpart.)

(iv) For a minimum of eight points in the critical region calculate an average \( K_v \) and the standard deviation.

(v) If the standard deviation exceeds 0.3 percent of the average \( K_v \), take corrective action.

(e) CVS system verification. The following "gravimetric" technique can be used to verify that the CVS and analytical instruments can accurately measure a mass of gas that has been injected into the system. (Verification can also be accomplished by constant flow metering using critical flow orifice devices.)

(1) Obtain a small cylinder that has been charged with 99.5 percent or greater propane or carbon monoxide gas (Caution—carbon monoxide is poisonous).

(2) Determine a reference cylinder weight to the nearest 0.01 grams.

(3) Operate the CVS in the normal manner and release a quantity of pure propane into the system during the sampling period (approximately 5 minutes).
(4) The calculations are performed in the normal way except in the case of propane. The density of propane \((0.6109 \text{ kg/m}^3/\text{carbon atom})\) is used in place of the density of exhaust hydrocarbons.

(5) The gravimetric mass is subtracted from the CVS measured mass and then divided by the gravimetric mass to determine the percent accuracy of the system.

(6) Good engineering practice requires that the cause for any discrepancy greater than ±2 percent must be found and corrected.

\[\text{AWM} = \frac{\sum_{i=1}^{n} (g_i \times WF_i)}{\sum_{i=1}^{n} (P_i \times WF_i)}\]

Where:
\(A_{\text{WM}}\) = Weighted mass emission level (HC, CO, CO\(_2\), PM, or NO\(_X\)) in g/kW-hr.

\(g_i\) = Mass flow in grams per hour, = grams measured during the mode divided by the sample time for the mode.

\(WF_i\) = Effective weighing factor.

\(P_i\) = Power measured during each mode (Power set = zero for the idle mode).

(b) The mass of each pollutant for each mode for bag measurements and diesel heat exchanger system measurements is determined from the following equations:

(1) Hydrocarbon mass:

\[HC_{\text{mass}} = V_{\text{mix}} \times \text{Density}_{\text{HC}} \times (HC_{\text{conc}}/10^6)\]

(2) Oxides of nitrogen mass:

\[NOX_{\text{mass}} = V_{\text{mix}} \times \text{Density}_{\text{NO2}} \times KH \times (NOX_{\text{conc}}/10^6)\]

(3) Carbon monoxide mass:

\[CO_{\text{mass}} = V_{\text{mix}} \times \text{Density}_{\text{CO}} \times (CO_{\text{conc}}/10^6)\]

(4) Carbon dioxide mass:

\[CO2_{\text{mass}} = V_{\text{mix}} \times \text{Density}_{\text{CO2}} \times (CO2_{\text{conc}}/10^2)\]

(c) The mass of each pollutant for the mode for flow compensated sample systems is determined from the following equations:

\[HC_{\text{c}} = HC_{\text{d}} \left(1 - \frac{1}{DF}\right) \frac{10^6}{10^6}\]

\[HC_{\text{c}} = HC_{\text{d}} \left(1 - \frac{1}{DF}\right) \frac{10^6}{10^6}\]