



FIGURE N84-8— SONIC FLOW CHOKING

(iv) For a minimum of 8 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 pure propane.

(2) Determine the weight of the reference propane cylinder to an accuracy of  $\pm 0.2$  percent or less of the actual amount of propane discharged into the system.

(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 of § 86.1342 are performed in the normal way except in the case of propane. The density of propane (17.30 g/ft<sup>3</sup>/carbon atom (0.6109 kg/m<sup>3</sup>/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  $\pm 2$  percent must be found and corrected.

[48 FR 52210, Nov. 16, 1983, as amended at 49 FR 48144, Dec. 10, 1984; 52 FR 47871, Dec. 16, 1987; 63 FR 24449, May 4, 1998]

#### § 86.1319-90 CVS calibration.

(a) The CVS is calibrated using an accurate flowmeter and restrictor valve. The flowmeter calibration shall be traceable to the NBS, and will serve as the reference value (NBS "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.) 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 NBS measurements. Other measurement systems may be used if shown to be equivalent under the test conditions in this section and traceable to NBS measurements. Measurements of the various flowmeter parameters are recorded and related to flow through the CVS. 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 (e.g., analyzer calibration, leaks, or HC hangup). A verification procedure is found in paragraph (e) of this section.

(c) *PDP 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 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, ft<sup>3</sup>/min, (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 N84-6. 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:

CALIBRATION DATA MEASUREMENTS

Parameter	Symbol	Units	Sensor-read-out tolerances
Barometric pressure (corrected) .....	P <sub>B</sub>	in. Hg (kPa) .....	±0.10 in. Hg (±0.340 kPa).
Ambient temperature .....	T <sub>A</sub>	°F (°C) .....	±0.5 °F (±0.28 °C).
Air temperature into metering venturi .....	ETI	°F (°C) .....	±2.0 °F (±1.1 °C).
Pressure drop between the inlet and throat of metering venturi .....	EDP	in. H <sub>2</sub> O (kPa) .....	±0.05 in H <sub>2</sub> O (±0.012 kPa).
Air flow .....	Q <sub>S</sub>	ft <sup>3</sup> /min (m <sup>3</sup> /min) ...	±0.5% of NBS "true" value.

CALIBRATION DATA MEASUREMENTS—Continued

Parameter	Symbol	Units	Sensor-read-out tolerances
Air temperature at CVS pump inlet .....	PTI	°F ( °C) .....	±2.0 °F (±1.1 °C).
Pressure depression at CVS pump inlet .....	PPI	in. Fluid (kPa) .....	±0.13 in. Fluid (±0.055 kPa).
Specific gravity of manometer fluid (1.75 oil) .....	Sp.Gr.	.....	.
Pressure head at CVS pump outlet .....	PPO	in. Fluid (kPa) .....	±0.13 in. Fluid (±0.055 kPa).
Air temperature at CVS pump outlet (optional) .....	PTO	°F ( °C) .....	±2.0 °F (±1.1 °C).
Pump revolutions during test period .....	N	Revs .....	± 1 Rev..
Elapsed time for test period .....	t	sec. ....	±0.5 sec.

(5) After the system has been connected as shown in Figure N84-6, set the variable restrictor in the wide open position and run the CVS pump for 20 minutes. Record the calibration data.

(6) Reset the restrictor valve to a more restricted condition in an increment of pump inlet depression that will yield a minimum of six data points for the total calibration. Allow the system to stabilize for 3 minutes and repeat the data acquisition.

(7) *Data analysis:*

(i) The air flow rate,  $Q_s$ , at each test point is calculated in standard cubic feet per minute (68°, 29.92 in. Hg.) from the flowmeter data using the manufacturer's prescribed method.

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

$$V_o = (Q_s/n) \times (T_p/528) \times (29.92/P_p)$$

Where:

(A)  $V_o$  = Pump flow, ft<sup>3</sup>/rev (m<sup>3</sup>/rev) at  $T_p$ ,  $P_p$ .

(B)  $Q_s$  = Meter air flow rate in standard cubic feet per minute, standard conditions are 68 °F, 29.92 in. Hg (20 °C, 101.3 kPa).

(C)  $n$  = Pump speed in revolutions per minute.

(D)  $T_p$  = Pump inlet temperature °R(°K) = PTI + 460 (°R), or = PTI + 273 (°K).

(E)  $P_p$  = Absolute pump inlet pressure, in. Hg. (kPa)  
 =  $P_B - PPI$  (Sp.Gr./13.5955) and  
 =  $P_B - PPI$  for SI units.

Where:

(F)  $P_B$  = barometric pressure, in. Hg. (kPa).

(G) PPI = Pump inlet depression, in. fluid (kPa).

(H) Sp.Gr. = Specific gravity of manometer fluid.

(iii) The correlation function at each test point is then calculated from the calibration data:

$$X_o = \frac{1}{n} \sqrt{\frac{\Delta P}{P_e}}$$

Where:

(A)  $X_o$  = correlation function.

(B)  $D_p$  = The pressure differential from pump inlet to pump outlet, in. Hg. (kPa).

=  $P_e - P_p$ .

(C)  $P_e$  = Absolute pump outlet pressure, in. Hg. (kPa)

=  $P_B + PPO$  (Sp.Gr./13.5955) and

=  $P_B + PPO$  for SI units.

Where:

(D) PPO = Pressure head at pump outlet, in. fluid (kPa).

(iv) A linear least squares fit is performed to generate the calibration equation which has the form:

$$V_o = D_o - M(X_o)$$

$D_o$  and  $M$  are the intercept and slope constants, respectively, describing the regression line.

(8) A CVS system that has multiple speeds should be calibrated on each speed used. The calibration curves generated for the ranges will be approximately parallel and the intercept values,  $D_o$ , will increase as the pump flow range decreases.

(9) If the calibration has been performed carefully, the calculated values from the equation will be within ±0.50 percent of the measured value of  $V_o$ .

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Values of M will vary from one pump to another, but values of  $D_o$  for pumps of the same make, model and range should agree within  $\pm 3$  percent of each other. Particulate influx over time will cause the pump slip to decrease, as reflected by lower values for M. Calibrations should be performed at pump start-up and after major maintenance to assure the stability of the pump slip rate. Analysis of mass injection data will also reflect pump slip stability.

(d) *CFV calibration.* (1) Calibration of the CFV is based upon the flow equation for a critical venturi. Gas flow is a function of inlet pressure and temperature:

$$Q_s = \frac{K_v P}{\sqrt{T}}$$

Where:

- (i)  $Q_s$  = flow.
- (ii)  $K_v$  = calibration coefficient.
- (iii) P = absolute pressure.
- (iv) 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 CFV.

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

CALIBRATION DATA MEASUREMENTS

Parameter	Symbol	Units	Sensor-readout tolerances
Barometric pressure (corrected) .....	P <sub>b</sub>	in Hg (kPa)	±0.01 in Hg (±0.034 kPa).
Air temperature, into flowmeter .....	ETI	°F (°C)	±0.5 °F (±0.28 °C).
Pressure drop between the inlet and throat of metering venturi .....	EDP	Inches H <sub>2</sub> O (kPa)	±0.05 in H <sub>2</sub> O (±0.012 kPa).
Air flow .....	Q <sub>a</sub>	ft <sup>3</sup> /min, (m <sup>3</sup> /min)	±5 % of NBS "true" value.
CFV inlet depression .....	PPI	Inches fluid (kPa)	±.13 in fluid (±0.055 kPa).
CFV outlet pressure .....	PPO	Inches Hg (kPa)	±.05 in Hg (±1.7 kPa) <sup>1</sup> .
Temperature at venturi inlet .....	T <sub>v</sub>	°F (°C)	±4.0 °F (±2.22 °C).
Specific gravity of manometer fluid (1.75 oil) .....	Sp. Gr		

<sup>1</sup> Requirement begins August 20, 2001.

(4) Set up equipment as shown in Figure N84-7 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,  $Q_s$ , 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:

(A)  $Q_s$  = Flow rate in standard cubic feet per minute, at the standard conditions of 68 °F, 29.92 in Hg (20 °C, 101.3 kPa).

(B)  $T_v$  = Temperature at venturi inlet, °R(°K).

(C)  $P_v$  = Pressure at venturi inlet, in. Hg. (kPA)  
 =  $P_B - PPI$  (Sp.GR./13.5955), and  
 =  $P_B - PPI$  for SI units.

Where:

(D) PPI = Venturi inlet pressure depression, in. fluid (kPa).

(E) Sp.Gr. = Specific gravity of manometer fluid.

(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 N84-8.)

(iv) For a minimum of 8 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.

(8) Calculation of a parameter for monitoring sonic flow in the CFV during exhaust emissions tests:

(i) *Option 1.* (A) CFV pressure ratio. Based upon the calibration data selected to meet the criteria for paragraphs (d)(7)(iv) and (v) of this section, in which  $K_v$  is constant, select the data values associated with the calibration point with the lowest absolute venturi inlet pressure. With this set of calibration data, calculated the following CFV pressure ratio limit,  $Pr_{ratio-lim}$ :

$$Pr_{ratio-lim} = \frac{P_{out-cal}}{P_{in-cal}}$$

Where:

$P_{in-cal}$  = Venturi inlet pressure (PPI in absolute pressure units), and

$P_{out-cal}$  = Venturi outlet pressure (PPO in absolute pressure units), measured at the exit of the venturi diffuser outlet.

(B) The venturi pressure ratio ( $Pr_{ratio-i}$ ) during all emissions tests must be less than, or equal to, the calibration pressure ratio limit ( $Pr_{ratio-lim}$ ) derived from the CFV calibration data, such that:

$$\frac{P_{out-i}}{P_{in-i}} = Pr_{ratio-i} \leq Pr_{ratio-lim}$$

Where:

$P_{in-i}$  and  $P_{out-i}$  are the venturi inlet and outlet pressures, in absolute pressure units, at each i-th interval during the emissions test.

(ii) *Option 2.* Other methods: With prior Administrator approval, any other method may be used that assure that the venturi operates at sonic conditions during emissions tests, provided the method is based upon sound engineering principles.

(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 pure 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) Following completion of step (3) above (if methanol injection is required), continue to operate the CVS in the normal manner and release a known quantity of pure methanol (in gaseous form) into the system during the sampling period (approximately five minutes). This step does not need to be performed with each verification, provided that it is performed at least twice annually.

(5) The calculations of §86.1342 are performed in the normal way except in the case of propane. The density of propane (17.30 g/ft<sup>3</sup>/carbon atom (0.6109 kg/m<sup>3</sup>/carbon atom)) is used in place of the density of exhaust hydrocarbons. In the case of methanol, the density of 37.71 g/ft<sup>3</sup> (1.332 kg/m<sup>3</sup>) is used.

(6) 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.

(7) The cause for any discrepancy greater than ±2 percent must be found and corrected. (For 1991-1995 calendar years, discrepancies greater than ±2 percent are allowed for the methanol test, provided that they do not exceed ±6 percent.)

(8) The Administrator, upon request, may waive the requirement to comply with ±2 percent methanol recovery tolerance, and instead require compliance with a higher tolerance (not to exceed ±6 percent), provided that:

(i) The Administrator determines that compliance with these specified tolerances is not practically feasible; and

(ii) The manufacturer makes information available to the Administrator which indicates that the calibration tests and their results are consistent with good laboratory practice, and that the results are consistent with the results of calibration testing conducted by the Administrator.

[54 FR 14591, Apr. 11, 1989, as amended at 60 FR 34371, June 30, 1995; 63 FR 24449, May 4, 1998; 65 FR 8279, Feb. 18, 2000]

**§ 86.1320-90 Gas meter or flow instrumentation calibration; particulate, methanol, and formaldehyde measurement.**

(a) Sampling for particulate, methanol and formaldehyde emissions requires the use of gas meters or flow instrumentation to determine flow through the particulate filters, methanol impingers and formaldehyde impingers. These instruments shall receive initial and periodic calibrations as follows:

(1)(i) Install a calibration device in series with the instrument. A critical flow orifice, a bellmouth nozzle, or a laminar flow element or an NBS traceable flow calibration device is required as the standard device.

(ii) The flow system should be checked for leaks between the calibration and sampling meters, including any pumps that may be part of the system, using good engineering practice.

(2) Flow air through the calibration system at the sample flow rate used for particulate, methanol, and formaldehyde testing and at the backpressure which occurs during the sample test.

(3) When the temperature and pressure in the system have stabilized, measure the indicated gas volume over a time period of at least five minutes or until a gas volume of at least ±1 percent accuracy can be determined by the standard device. Record the stabilized air temperature and pressure upstream of the instrument and as required for the standard device.

(4) Calculate air flow at standard conditions as measured by both the standard device and the instrument(s). (Standard conditions are defined as 68 °F (20 °C) and 29.92 in Hg (101.3 kPa).)

(5) Repeat the procedures of paragraphs (a) (2) through (4) of this section using at least two flow rates which bracket the typical operating range.

(6) If the air flow at standard conditions measured by the instrument differs by ±1.0 percent of the maximum operating range or ±2.0 percent of the point (whichever is smaller), then a correction shall be made by either of the following two methods:

(i) Mechanically adjust the instrument so that it agrees with the calibration measurement at the specified flow