

**Environmental Protection Agency**

**§ 89.418**

the average concentration readings determined from the corresponding calibration data.

[59 FR 31335, June 17, 1994. Redesignated at 63 FR 56996, Oct. 23, 1998]

**§ 89.418 Raw emission sampling calculations.**

(a) The final test results shall be derived through the steps described in this section.

(b) The exhaust gas flow rate  $G_{EXHW}$  and  $V_{EXHW}$  shall be determined for each mode.

(1) For measurements using the mass flow method, see § 89.416(a).

(2) For measurements using the fuel consumption and exhaust gas concentrations method, use the following equations:

$$G_{EXHW} = G_{fuel} + G_{aird} \left( 1 + \left( \frac{H}{1000} \right) \right)$$

Where:

$$G_{aird} = \frac{G_{fuel}}{(fla)} = \frac{\text{Mass Fuel Measured}}{G_{airw} \times \left( 1 - \frac{H}{1000} \right)}$$

$$(fla) = \frac{4.77 (1 + \alpha/4) (fla)_{stoich}}{\frac{1}{X} - \left( \frac{DCO}{2X(10^6)} \right) - \left( \frac{DHC}{X(10^6)} \right) + \frac{\alpha}{4} \left( 1 - \frac{DHC}{X(10^6)} \right) - \frac{0.75 \alpha}{\left( \frac{K}{\left( \frac{DCO}{X(10^6)} \right)} \right) + \left( \frac{(1-K)}{\left( 1 - \frac{DHC}{X(10^6)} \right)} \right)}$$

$$(fla)_{stoich} = \frac{M_c + \alpha M_H}{138.18 (1 + \alpha/4)}$$

$$X = \frac{DCO_2}{10^2} + \frac{DCO}{10^6} + \frac{DHC}{10^6}$$

$K = 3.5$

(3) Humidity values may be calculated from either one of the following equations:

$$H = \frac{6.22 \times R_a \times p_d}{p_R - (p_d \times R_a \times 10^{-2})}$$

or

$$H = \frac{622 \times P_v}{(P_B - P_v)}$$

(c) When applying  $G_{EXHW}$ , the measured “dry” concentration shall be corrected to a wet basis, if not already measured on a wet basis. This section is applicable only for measurements made on raw exhaust gas. Correction to a wet basis shall be according to the following formula:

$$CONC_{WET} = K_w \times CONC_{DRY}$$

Where:

$K_w$  is determined according to the equations in paragraph (c)(1) or (c)(2) of this section.

(1) For measurements using the mass flow method (see § 89.416(a)):

$$K_w = \left[ 1 - F_{FH} \times \frac{G_{fuel}}{G_{aird}} \right] - K_{w1}$$

$$F_{FH} = ALF \times 0.1448 \times \frac{1}{1 + \left( \frac{G_{fuel}}{G_{aird}} \right)} \text{ for diesel fuel only}$$

$$ALF = \text{Hydrogen mass percentage of fuel} = \frac{1.008 \times \alpha}{12.01 + 1.008 \times \alpha} \times 100 = 13.12 \text{ for } CH_{1.8} \text{ fuel}$$

$\alpha$  = H/C mole ratio of the fuel.

(2) For measurements using the fuel consumption and exhaust gas concentrations method (see § 89.416(b)):

$$K_w = \frac{1}{1 + 1.8 \times 0.005 \times \left[ \frac{DCO}{10^4} = DCO_2 \right]} - K_{w1}$$

Where:

$$K_{w1} = \frac{1.608 \times H}{1000 + 1.608 \times H}$$

(d) As the  $NO_x$  emission depends on intake air conditions, the  $NO_x$  concentration shall be corrected for intake air temperature and humidity with the factor  $K_h$  given in the following for-

mula. For engines operating on alternative combustion cycles, other correction formulas may be used if they can be justified or validated. The formula follows:

$$K_H = \frac{1}{1 - 0.0182(H - 10.71)}$$

(e) The pollutant mass flow for each mode shall be calculated as follows:

$$\text{Gas mass} = u \times \text{Gas conc.} \times G_{\text{EXHW}}$$

$$\text{Gas mass} = v \times \text{Gas conc.} \times V_{\text{EXHD}}$$

Gas mass =  $w \times \text{Gas conc.} \times V_{\text{EXHW}}$   
 The coefficients  $u$  (wet),  $v$  (dry), and  $w$  (wet) are to be used according to the following table:

Gas	$u$	$v$	$w$	conc.
NO <sub>x</sub> .....	0.001587	0.00205	0.00205	ppm.
CO .....	0.000966	0.00125	0.00125	ppm.
HC .....	0.000478		0.000618	ppm.
CO <sub>2</sub> .....	15.19	19.64	19.64	percent.

NOTE: The given coefficients  $u$ ,  $v$ , and  $w$  are calculated for 273.15 °K (0 °C) and 101.3 kPa. In cases where the reference conditions vary from those stated, an error may occur in the calculations.

(f) The following equations may be used to calculate the coefficients  $u$ ,  $v$ , and  $w$  in paragraph (e) of this section for other conditions of temperature and pressure:

(1) For the calculation of  $u$ ,  $v$ , and  $w$  for NO<sub>x</sub> (as NO<sub>2</sub>), CO, HC (in paragraph (e) of this section as CH<sub>1.80</sub>), CO<sub>2</sub>, and O<sub>2</sub>:

Where:

- $w = 4.4615 \cdot 10^{-5} \times M$  if conc. in ppm
- $w = 4.4615 \cdot 10^{-1} \times M$  if conc. in percent
- $v = w$
- $u = w/\rho_{\text{Air}}$
- $M$  = Molecular weight

$\rho_{\text{Air}}$  = Density of dry air at 273.15 °K (0 °C), 101.3 kPa = 1.293 kg/m<sup>3</sup>

(2) For real gases at 273.15 °K (0 °C) and 101.3 kPa: For the calculation of  $u$ ,  $v$ , and  $w$

- $w = \text{gas} \times 10^{-6}$  if conc. in ppm
- $v = w$
- $u = w/\rho_{\text{Air}}$
- $\rho_{\text{Gas}}$  = Density of measured gas at 0 °C, 101.3 kPas in g/m<sup>3</sup>

(3) General formulas for the calculation of concentrations at temperature (designated as  $T$ ) and pressure (designated as  $p$ ):

—for ideal gases

$$\text{conc} \frac{\text{g}}{\text{m}_3} = \frac{M}{M_v} \times \frac{T_0}{T_0 + T} \times \frac{P}{P_0} \frac{\text{Conc(ppm)}}{10^6}$$

—for real gases

$$\text{conc} \frac{\text{g}}{\text{m}_3} = \rho_{\text{Gas}} \times \frac{T_0}{T_0 + T} \times \frac{P}{P_0} \frac{\text{Conc(ppm)}}{10^6}$$

with:

- 1% = 10<sup>4</sup> ppm
- $M$  = Molecular weight in g/Mol
- $M_v$  = Molecular Volume = 22.414 × 10<sup>-3</sup> m<sup>3</sup>/Mol for ideal gases
- $T$  = reference temperature 273.15 K
- $p$  = reference pressure 101.3 kPa
- $T$  = Temperature in °C

- $p$  = pressure in kPa
- $\rho_{\text{Gas}}$  = Density of the measured gas at 0 °C, 101.3 kPa
- $\text{Conc.}$  = Gas concentration

(g)(1) The emission shall be calculated for all individual components

in the following way where power at idle is equal to zero:

$$\text{individual gas} = \frac{\sum_{i=1}^{i=n} (g_i \times WF_i)}{\sum_{i=1}^{i=n} (P_i \times WF_i)}$$

(2) The weighting factors and the number of modes (n) used in the calculation in paragraph (g)(1) of this section are according to § 89.410.

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**§ 89.419 Dilute gaseous exhaust sampling and analytical system description.**

(a) *General.* The exhaust gas sampling system described in this section is designed to measure the true mass of gaseous emissions in the exhaust of petroleum-fueled nonroad compression-ignition engines. This system utilizes the CVS concept (described in 40 CFR part 1065, subparts A and B) of measuring mass emissions of HC, CO, and CO<sub>2</sub>. A continuously integrated system is required for HC and NO<sub>x</sub> measurement and is allowed for all CO and CO<sub>2</sub> measurements. The mass of gaseous emissions is determined from the sample concentration and total flow over the test period. As an option, the measurement of total fuel mass consumed over a cycle may be substituted for the exhaust measurement of CO<sub>2</sub>. General requirements are as follows:

(1) This sampling system requires the use of a PDP-CVS and a heat exchanger or a CFV-CVS with either a heat exchanger or electronic flow compensation. Figure 2 in appendix A to this subpart is a schematic drawing of the PDP-CVS system. Figure 3 in appendix A to this subpart is a schematic drawing of the CFV-CVS system.

(2) The HC analytical system for petroleum-fueled compression-ignition engines requires a heated flame ionization detector (HFID) and heated sample system (191 ± 11 °C).

(i) The HFID sample must be taken directly from the diluted exhaust

stream through a heated probe and integrated continuously over the test cycle. Unless compensation for varying flow is made, the HFID must be used with a constant flow system to ensure a representative sample.

(ii) The heated probe shall be located in the primary dilution tunnel and far enough downstream of the mixing chamber to ensure a uniform sample distribution across the CVS duct at the point of sampling.

(3) The CO and CO<sub>2</sub> analytical system requires:

(i) Bag sampling (see 40 CFR part 1065) and analytical capabilities (see 40 CFR part 1065), as shown in Figure 2 and Figure 3 in appendix A to this subpart; or

(ii) Continuously integrated measurement of diluted CO and CO<sub>2</sub> meeting the minimum requirements and technical specifications contained in paragraph (b)(4) of this section. Unless compensation for varying flow is made, a constant flow system must be used to ensure a representative sample.

(4) The NO<sub>x</sub> analytical system requires a continuously integrated measurement of diluted NO<sub>x</sub> meeting the minimum requirements and technical specifications contained in paragraph (b)(4) of this section. Unless compensation for varying flow is made, a constant flow system must be used to ensure a representative sample.

(5) Since various configurations can produce equivalent results, exact conformance with these drawings is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components, such as snubbers, which are not needed to maintain