§ 91.417 Fuel flow measurement specifications.

(a) Fuel flow measurement is required only for raw testing but is allowed for dilute testing.

(b) The fuel flow rate measurement instrument must have a minimum accuracy of ±2 percent of full-scale flow rate for each measurement range used.

§ 91.418 Data evaluation for gaseous emissions.

For the evaluation of the gaseous emissions recording, record the last two minutes of each mode and determine the average values for HC, CO, CO₂, and NOₓ during each mode from the average concentration readings determined from the corresponding calibration data.

§ 91.419 Raw emission sampling calculations.

(a) Derive the final test results through the steps described in this section.

(b) Air and fuel flow method. If both air and fuel flow mass rates are measured, the following equations are used to determine the weighted emission values for the test engine:

\[
W_{NO_x} = (G_{AIRD} + G_{FUEL}) \times \frac{M_{NO_x}}{M_{exh}} \times W_{NO_x} \times K_H \times \frac{1}{10^6}
\]

\[
W_{HC} = (G_{AIRD} + G_{FUEL}) \times \frac{M_{HC_{exh}}}{M_{exh}} \times WHC \times \frac{1}{10^6}
\]

\[
W_{CO} = (G_{AIRD} + G_{FUEL}) \times \frac{M_{CO}}{M_{exh}} \times WCO \times \frac{1}{10^2}
\]

Where:

- \(W_{HC}\) = Mass rate of HC in exhaust [g/hr].
- \(G_{AIRD}\) = Intake air mass flow rate on dry basis [g/hr].
- \(G_{FUEL}\) = Fuel mass flow rate [g/hr].
- \(M_{HC_{exh}}\) = Molecular weight of hydrocarbons in the exhaust; see the following equation:

\[
M_{exh} = M_{HC_{exh}} \times WHC \times \frac{10^6}{10^6} + 28.01 \times WCO \times \frac{10^2}{10^2} + 44.1 \times WCO_2 \times \frac{10^2}{10^6} + 46.01 \times WNO_x \times \frac{10^6}{10^6} + 2.016 \times WH_2 \times \frac{10^2}{10^2} + 18.01 \times (1 - K) + 28.01 \times \left[ \frac{100 - WHC \times 10^4 - WCO - WCO_2 - WNO_x \times 10^2 - WH_2 - 100 \times (1 - K)}{10^2} \right]
\]

Where:

- \(WHC\) = HC volume concentration in exhaust, ppmC wet.
- \(WCO\) = CO percent concentration in the exhaust, wet.
- \(WCO_2\) = CO₂ percent concentration in the exhaust, wet.
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DCO = CO₂ percent concentration in the exhaust, dry
WNOₓ = NO volume concentration in exhaust, ppm wet
WH₂ = H₂ percent concentration in exhaust, wet

K = correction factor to be used when converting dry measurements to a wet basis. Therefore, wet concentration = dry concentration \times K, where K is:

\[
K = \frac{1}{1 + 0.005 \times (DCO + DCO₂) \times \alpha - 0.01 \times DH₂}
\]

DH₂ = H₂ percent concentration in exhaust, dry, calculated from the following equation:

\[
DH₂ = \frac{0.5 \times \alpha \times DCO \times (DCO + DCO₂)}{DCO + (3 \times DCO₂)}
\]

Where:
- WCO = Mass rate of CO in exhaust, [g/hr]
- M₉₈ = Molecular weight of CO = 28.01
- WNOₓ = Mass rate of NOₓ in exhaust, [g/hr]
- MNO₂ = Molecular weight of NO₂ = 46.01
- K₉₈ = Factor for correcting the effects of humidity on NO₂ formation for four-stroke gasoline engines; see the equation below:

\[
K₉₈ = \frac{1}{1 - 0.0329 \times (H - 10.71)}
\]

Where:
- H = specific humidity of the intake air in grams of moisture per kilogram of dry air.

For two-stroke gasoline engines, K₉₈ should be set to 1.

(c) Fuel flow method. The following equations are to be used when fuel flow is selected as the basis for mass emission calculations using the raw gas method.

\[
W_{HC} = \frac{G_{FUEL}}{TC} \times \frac{WHC}{10^4}
\]

\[
W_{CO} = \frac{M_{CO}}{M_F} \times \frac{G_{FUEL}}{TC} \times WCO
\]

\[
W_{NO_X} = \frac{M_{NO_X}}{M_F} \times \frac{G_{FUEL}}{TC} \times \frac{WNO_X}{10^4} \times K_H
\]

Where:
- WHC = Mass rate of HC in exhaust, [g/hr]
- MF = Molecular weight of test fuel; see following equation:
  \[
  M_F = 12.01 + 1.008 \times \alpha
  \]
- G_FUEL = Fuel mass flow rate, [g/hr]
- TC = Total carbon; see following equation:
  \[
  TC = WCO + WCO₂ + \frac{WHC}{10^4}
  \]
- WHC = HC volume concentration in exhaust, ppmC wet

WCO = CO percent concentration in the exhaust, wet
DCO = CO percent concentration in the exhaust, dry
WCO₂ = CO₂ percent concentration in the exhaust, wet
DCO₂ = CO₂ percent concentration in the exhaust, dry
WNOₓ = NO volume concentration in exhaust, ppm wet
WH₂ = H₂ percent concentration in exhaust, wet

K = correction factor to be used when converting dry measurements to a wet basis. Therefore, wet concentration = dry concentration \times K, where K is:
\[ K = \frac{1}{1 + 0.005 \times (DCO + DCO_2) \times \alpha - 0.01 \times DH_2} \]

\( DH_2 = H_2 \) percent concentration in exhaust, dry, calculated from the following equation:

\[ DH_2 = \frac{0.5 \times \alpha \times DCO \times (DCO + DCO_2)}{DCO + (3 \times DCO_2)} \]

\( W_{CO} = \) Mass rate of CO in exhaust, \([g/hr]\)
\( M_{CO} = \) Molecular weight of CO = 28.01
\( W_{NOx} = \) Mass rate of NO\(_X\) in exhaust, \([g/hr]\)
\( M_{NO2} = \) Molecular weight of NO\(_2\) = 46.01
\( K_H = \) Factor for correcting the effects of humidity on NO\(_2\) formation for four-stroke gasoline engines; see the equation below:

\[ K_H = \frac{1}{1 - 0.0329 \times (H - 10.71)} \]

Where:

\( H = \) specific humidity of the intake air in grams of moisture per kilogram of dry air.

For two-stroke gasoline engines, \( K_H \) should be set to 1.

(d) The final reported emission test results must be computed by using the following formula for each individual gas component:

\[ Y_{wm} = \frac{\sum (W_i \times f_i)}{\sum (P_i \times f_i)} \]

Where:

\( Y_{wm} = \) Weighted mass emission level (HC, CO, NO\(_X\)) for a test \([g/kW-hr]\),
\( W_i = \) Average mass flow rate \((W_{HC}, W_{CO}, W_{NOx})\) of an emission from the test engine during mode \(i\), \([g/hr]\),
\( f_i = \) Weighting factors for each mode according to §91.410(a),
\( P_i = \) Average power measured during mode \(i\), \([kW]\), calculated according to the formula given in §91.423(b). Power for the idle mode should always be zero for this calculation.

(e) The final reported weighted brake-specific fuel consumption (WBSFC) shall be computed by use of the following formula:

\[ \text{WBSFC} = \frac{\sum (F_i \times f_i)}{\sum (P_i \times f_i)} \]

Where:

\( F_i = \) Fuel mass flow rate of the engine during mode \(i\), \([g/hr]\),
\( P_i = \) Average power measured during mode \(i\), \([kW]\), calculated according to the formula given in §91.423(b). Power for the idle mode should always be zero for this calculation.