

the throttle is placed in the mode and ends when the throttle is moved to the succeeding mode. The start of the first idle mode corresponds to the start of the test sequence.

(b) Analyze the smoke trace by means of the following procedure:

(1) Locate the highest reading, and integrate the highest 3-second average reading around it.

(2) Locate and integrate the highest 30-second average reading.

(3) The highest reading occurring more than two minutes after the notch change (excluding peaks lasting less than 5 seconds, caused by such random events as the cycling of an air compressor) is the "steady-state" value.

(c)(1) The values determined in paragraph (b) of this section shall be normalized by the following equation:

$$N_n = 100 \times \left[1 - \left[1 - \frac{N_m}{100} \right]^{1/L} \right]$$

Where:

N_n is the normalized percent opacity, N_m is the average measured percent opacity (peak or steady-state), and L is actual distance in meters from the point at which the light beam enters the exhaust plume to the point at which the light beam leaves the exhaust plume.

(2) The normalized opacity values determined in paragraph (c)(1) of this section are the values that are compared to the standards of subpart A of this part for determination of compliance.

(d) This smoke trace analysis may be performed by direct analysis of the recorder traces, or by computer analysis of data collected by automatic data collection equipment.

§ 92.132 Calculations.

(a) *Duty-cycle emissions.* This section describes the calculation of duty-cycle emissions, in terms of grams per brake

horsepower hour (g/bhp-hr). The calculation involves the weighted summing of the product of the throttle notch mass emission rates and dividing by the weighted sum of the brake horsepower. The final reported duty-cycle emission test results are calculated as follows:

$$(1) (i) E_{idc} = (\Sigma(M_{ij})(F_j)) / (\Sigma(BHP_j)(F_j))$$

Where:

E_{idc} =Duty-cycle weighted, brake-specific mass emission rate of pollutant i (i.e., HC, CO, NO_x or PM and, if appropriate, THCE or NMHC) in grams per brake horsepower-hour;

M_{ij} =the mass emission rate pollutant i for mode j ;

F_j =the applicable weighting factor listed in Table B132-1 for mode j ;

BHP_j =the measured brake horsepower for mode j .

(ii) Table B132-1 follows:

TABLE B132-1—WEIGHTING FACTORS FOR CALCULATING EMISSION RATES

Throttle notch setting	Test mode	Locomotive not equipped with multiple idle notches		Locomotive equipped with multiple idle notches	
		Line-haul	Switch	Line-haul	Switch
Low Idle	1a	NA	NA	0.190	0.299
Normal Idle	1	0.380	0.598	0.190	0.299
Dynamic Brake	2	0.125	0.000	0.125	0.000
Notch 1	3	0.065	0.124	0.065	0.124
Notch 2	4	0.065	0.123	0.065	0.123
Notch 3	5	0.052	0.058	0.052	0.058
Notch 4	6	0.044	0.036	0.044	0.036
Notch 5	7	0.038	0.036	0.038	0.036
Notch 6	8	0.039	0.015	0.039	0.015
Notch 7	9	0.030	0.002	0.030	0.002
Notch 8	10	0.162	0.008	0.162	0.008

§ 92.132

40 CFR Ch. I (7-1-04 Edition)

(2) Example: For the line-haul cycle, for locomotives equipped with normal and low idle, and with dynamic brake, the brake-specific emission rate for HC would be calculated as:

$$E_{HCdc} = [(M_{HC1a}) (0.190) + (M_{HC1}) (0.190) + (M_{HC2}) (0.125) + (M_{HC3}) (0.065) + (M_{HC4}) (0.065) + (M_{HC5}) (0.052) + (M_{HC6}) (0.044) + (M_{HC7}) (0.038) + (M_{HC8}) (0.039) + (M_{HC9}) (0.030) + (M_{HC10}) (0.162)] / [(BHP_{1a}) (0.190) + (BHP_1) (0.190) + (BHP_2) (0.125) + (BHP_3) (0.065) + (BHP_4) (0.065) + (BHP_5) (0.052) + (BHP_6) (0.044) + (BHP_7) (0.038) + (BHP_8) (0.039) + (BHP_9) (0.030) + (BHP_{10}) (0.162)]$$

(3) In each mode, brake horsepower output is the power that the engine delivers as output (normally at the flywheel), as defined in § 92.2.

(i) For locomotive testing (or engine testing using a locomotive alternator/generator instead of a dynamometer), brake horsepower is calculated as:

$$BHP = HP_{out} / A_{eff} + HP_{acc}$$

Where:

HP_{out}=Measured horsepower output of the alternator/generator.

A_{eff}=Efficiency of the alternator/generator.

HP_{acc}=Accessory horsepower.

(ii) For engine dynamometer testing, brake horsepower is determined from the engine speed and torque.

(4) For locomotive equipped with features that shut the engine off after prolonged periods of idle, the measured mass emission rate M_{ij} (and M_{ija} as applicable) shall be multiplied by a factor equal to one minus the estimated fraction reduction in idling time that will result in use from the shutdown feature. Application of this adjustment is subject to the Administrator's approval.

(b) *Throttle notch emissions.* This paragraph (b) describes the calculation of throttle notch emissions for all operating modes, including: idle (normal and low, as applicable); dynamic brake; and traction power points. The throttle notch (operating mode) emission test results, final reported values and values used in paragraph (a)(1) of this section are calculated as follows:

(1) Brake specific emissions (E_{ij}) in grams per brake horsepower-hour of each species i (i.e., HC, CO, NO_x or PM

and, if appropriate, THCE or NMHC) for each mode j:

(i) E_{HC mode}=HC grams/BHP-hr=M_{HC mode}/Measured BHP in mode.

Where:

M_{HC mode}=Mass HC emissions (grams per hour) for each test mode.

(ii) E_{THCE mode}=THCE grams/BHP-hr=M_{THCE mode}/Measured BHP in mode.

Where:

M_{THCE mode} (Total hydrocarbon equivalent mass emissions (grams per hour) for each test mode):

$$= M_{HCj} + \sum (M_{ij}) (MWC_p) / MWC_i$$

M_{ij}=the mass emission rate oxygenated pollutant i for mode j.

MWC_i=the molecular weight of pollutant i divided by the number of carbon atoms per molecule of pollutant i.

MWC_p=the molecular weight of a typical petroleum fuel component divided by the number of carbon atoms per molecule of a typical petroleum fuel component=13.8756.

(iii) E_{NMHC mode}=NMHC grams/BHP-hr=M_{NMHC mode}/Measured BHP in mode.

Where:

M_{NMHC mode}=Mass NMHC emissions (grams per hour) for each test mode.

(iv) E_{CO mode}=CO grams/BHP-hr=M_{CO mode}/Measured BHP in mode.

Where:

M_{CO mode}=Mass CO emissions (grams per hour) for each test mode.

(v) E_{NOx mode}=NO_x grams/BHP-hr=M_{NOx mode}/Measured BHP in mode.

Where:

M_{NOx mode}=Mass NO_x emissions (grams per hour) for each test mode.

(vi) E_{PM mode}=PM grams/BHP-hr=M_{PM mode}/Measured BHP in mode.

Where:

M_{PM mode}=Mass PM emissions (grams per hour) for each test mode.

(vii) E_{AL mode}=Aldehydes grams/BHP-hr=M_{AL mode}/Measured BHP in mode.

(viii) E_{AL mode}=Aldehydes grams/BHP-hr=M_{AL mode}/Measured BHP in mode.

Where:

M_{AL mode}=Total aldehyde mass emissions (grams per hour) for each test mode.

(2) Mass Emissions—Raw exhaust measurements. For raw exhaust measurements mass emissions (grams per hour) of each species for each mode:

(i) General equations. (A) The mass emission rate, M_{X mode} (g/hr), of each

Environmental Protection Agency

§ 92.132

pollutant (HC, NO_x, CO₂, CO, CH₄, CH₃OH, CH₃CH₂OH, CH₂O, CH₃CH₂O) for each operating mode for raw measurements is determined based on one of the following equations:

$$M_{X \text{ mode}} = (DX/10^6)(DVol)(MW_X/V_m)$$

$$M_{X \text{ mode}} = (WX/10^6)(WVol)(MW_X/V_m)$$

Where:

X designates the pollutant (e.g., HC), DX is the concentration of pollutant X (ppm or ppmC) on a dry basis, MW_X is the molecular weight of the pollutant (g/mol), DVol is the total exhaust flow rate (ft³/hr) on a dry basis, WX is the concentration of pollutant X (ppm or ppmC) on a wet basis, WVol is the total exhaust flow rate (ft³/hr) on a wet basis, V_m is the volume of one mole of gas at standard temperature and pressure (ft³/mol).

(B) All measured volumes and volumetric flow rates must be corrected to standard temperature and pressure prior to calculations.

(ii) The following abbreviations and equations apply to this paragraph (b)(2):

α=Atomic hydrogen/carbon ratio of the fuel.
β=Atomic oxygen/carbon ratio of the fuel.

CMW_f=Molecular weight of the fuel per carbon atom, or carbon molecular weight (g/moleC)=(12.011+1.008α+16.000β).

DCO=CO concentration in exhaust, ppm (dry).

DCO₂=CO₂ concentration in exhaust, percent (dry).

DHC=HC carbon concentration in exhaust, ppm C (dry).

DNO_x=NO_x concentration in exhaust, in ppm (dry).

DVol=Total exhaust flow rate (ft³/hr) on a dry basis; or
=(V_m)(W_f)/((CMW_f)(DHC/10⁶+DCO/10⁶+DCO₂/100)).

K=Water gas equilibrium constant=3.5.

K_w=Wet to dry correction factor.

M_f=Mass flow-rate of fuel used in the engine in lb/hr=W_f/453.59.

MW_C=Atomic weight of carbon=12.011.

MW_{CO}=Molecular weight of CO=28.011.

MW_H=Atomic weight of hydrogen=1.008.

MW_{NO₂}=Molecular weight of nitrogen dioxide (NO₂)=46.008.

MW_O=Molecular weight of atomic oxygen=16.000.

T=Temperature of inlet air (°F).

V_m=Volume of one mole of gas at standard temperature and pressure (ft³/mole).

W_f=Mass flow-rate of fuel used in the engine, in grams/hr=(453.59)×(M_f lbs/hr).

WCO₂=CO₂ concentration in exhaust, percent (wet).

WHC=HC concentration in exhaust, ppm C (wet).

WVol=Total exhaust flow rate (ft³/hr) on a wet basis; or
=(V_m)(W_f)/((CMW_f)(WHC/10⁶+WCO/10⁶+WCO₂/100)).

(iii) Calculation of individual pollutant masses. Calculations for mass emission are shown here in multiple forms. One set of equations is used when sample is analyzed dry (equations where the concentrations are expressed as DX), and the other set is used when the sample is analyzed wet (equations where the concentrations are expressed as WX). When samples are analyzed for some constituents dry and for some constituents wet, the wet concentrations must be converted to dry concentrations, and the equations for dry concentrations used. Also, the equations for HC, NMHC, CO, and NO_x have multiple forms that are algebraically equivalent: An explicit form that requires intermediate calculation of V_m and DVol or WVol; and an implicit form that uses only the concentrations (e.g., DCO) and the mass flow rate of the fuel. For these calculations, either form may be used.

(A) Hydrocarbons and nonmethane hydrocarbons.

(I) Hydrocarbons. (i) For petroleum-fueled engines:

$$M_{HC \text{ mode}} = (DHC)CMW_f(DVol)(10^6)/V_m$$

$$= ((DHC/10^6)(W_f)/((DCO/10^6)+(DCO_2/100)+(DHC/10^6)+(\Sigma DX/10^6)))$$

$$M_{HC \text{ mode}} = (WHC)CMW_f(WVol)(10^6)/V_m$$

$$= ((WHC/10^6)(W_f)/((WCO/10^6)+(WCO_2/100)+(WHC/10^6)+(\Sigma(WX/10^6))))$$

(ii) For alcohol-fueled engines:

DHC=FID HC - Σ(r_x)(DX)

WHC=FID HC - Σ(r_x)(WX)

Where:

FID HC=Concentration of "hydrocarbon" plus other organics such as methanol in exhaust as measured by the FID, ppm carbon equivalent.

r_x=FID response to oxygenated species×(methanol, ethanol, or acetaldehyde).

DX=Concentration of oxygenated species×(methanol, ethanol, or acetaldehyde) in exhaust as determined from the dry exhaust sample, ppm carbon (e.g., DCH3OH, 2(DCH3CH2OH)).

WX=Concentration of oxygenated species×(methanol, ethanol, or acetaldehyde) in exhaust as determined from the wet exhaust sample, ppm carbon.

§ 92.132

40 CFR Ch. I (7-1-04 Edition)

ΣDX=The sum of concentrations DX for all oxygenated species.

ΣWX=The sum of concentrations WX for all oxygenated species.

(2) Nonmethane hydrocarbons:

$$M_{\text{NMHC mode}} = (\text{DNMHC})\text{CMW}_i(\text{DVol}) (10^6) / V_m = ((\text{DNMHC}/10^6)(W_i)/((\text{DCO}/10^6) + (\text{DCO}_2/100) + (\text{DHC}/10^6)))$$

$$M_{\text{NMHC mode}} = (\text{WNMHC})\text{CMW}_i(\text{WVol}) (10^6) / V_m = ((\text{WNMHC}/10^6)(W_i)/((\text{WCO}/10^6) + (\text{WCO}_2/100) + (\text{WHC}/10^6)))$$

Where:

DNMHC=FID HC - (r_{CH4})(DCH4)

WNMHC=FID HC - (r_{CH4})(WCH4)

FID HC=Concentration of "hydrocarbon" plus other organics such as methane in exhaust as measured by the FID, ppm carbon equivalent.

r_{CH4}=FID response to methane.

DCH4=Concentration of methane in exhaust as determined from the dry exhaust sample, ppm.

WCH4=Concentration of methane in exhaust as determined from the wet exhaust sample, ppm.

(B) Carbon monoxide:

$$M_{\text{CO mode}} = (\text{DCO})\text{MW}_{\text{CO}}(\text{DVol})/10^6/V_m = ((\text{MW}_{\text{CO}}(\text{DCO}/10^6)(W_i)/((\text{CMW}_i)(\text{DCO}/10^6) + (\text{DCO}_2/100) + (\text{DHC}/10^6) + (\Sigma\text{DX}/10^6)))$$

$$M_{\text{CO mode}} = (\text{WCO})\text{MW}_{\text{CO}}(\text{DVol}) (10^6)/V_m + ((\text{MW}_{\text{CO}}(\text{WCO}/10^6)(W_i)/((\text{CMW}_i)(\text{WCO}/10^6) + (\text{WCO}_2/100) + (\text{WHC}/10^6) + (\Sigma\text{WX}/10^6)))$$

(C) Oxides of nitrogen:

$$M_{\text{NOx mode}} = (\text{DNOX})\text{MW}_{\text{NO}_2}(\text{DVol}) (10^6)/V_m = ((\text{MW}_{\text{NO}_2}(\text{DNOX}/10^6)(W_i)/((\text{CMW}_i)(\text{DCO}/10^6) + (\text{DCO}_2/100) + (\text{DHC}/10^6) + (\Sigma\text{DX}/10^6)))$$

$$M_{\text{NOx mode}} = (\text{WNOX})\text{MW}_{\text{NO}_2}(\text{DVol}) (10^6)/V_m = ((\text{MW}_{\text{NO}_2}(\text{WNOX}/10^6)(W_i)/((\text{CMW}_i)(\text{WCO}/10^6) + (\text{WCO}_2/100) + (\text{WHC}/10^6) + (\Sigma\text{WX}/10^6)))$$

(D) Methanol:

$$M_{\text{CH}_3\text{OH mode}} = (\text{DCH}_3\text{OH}/10^6)32.042(\text{DVol})/V_m$$

$$M_{\text{CH}_3\text{OH mode}} = (\text{WCH}_3\text{OH}/10^6)32.042(\text{WVol})/V_m$$

Where:

$$\text{DCH}_3\text{OH} = (V_m)(10^6)[(C_1 \times \text{AV}_1) + (C_2 \times \text{AV}_2)] / \text{DVol}_{\text{MS}}$$

$$\text{WCH}_3\text{OH} = (V_m)(10^6)[(C_1 \times \text{AV}_1) + (C_2 \times \text{AV}_2)] / \text{WVol}_{\text{MS}}$$

C_i=concentration of methanol in impinger i (1 or 2) in mol/ml.

AV_i=Volume of absorbing reagent in impinger i (1 or 2) in ml.

DVol_{MS}=Volume (standard ft³) of exhaust sample drawn through methanol impingers (dry).

WVol_{MS}=Volume (standard ft³) of exhaust sample drawn through methanol impingers (wet).

(E) Ethanol:

$$M_{\text{CH}_3\text{CH}_2\text{OH mode}} = (\text{DCH}_3\text{CH}_2\text{OH}/10^6)23.035(\text{DVol})/V_m$$

$$M_{\text{CH}_3\text{CH}_2\text{OH mode}} = (\text{WCH}_3\text{CH}_2\text{OH}/10^6)23.035(\text{WVol})/V_m$$

Where:

$$\text{DCH}_3\text{CH}_2\text{OH} = (V_m)(10^6)[(C_1 \times \text{AV}_1) + (C_2 \times \text{AV}_2)] / \text{DVol}_{\text{ES}}$$

$$\text{WCH}_3\text{CH}_2\text{OH} = (V_m)(10^6)[(C_1 \times \text{AV}_1) + (C_2 \times \text{AV}_2)] / \text{WVol}_{\text{ES}}$$

C_i=concentration of ethanol in impinger i (1 or 2) in mol/ml.

AV_i=Volume of absorbing reagent in impinger i (1 or 2) in ml.

DVol_{ES}=Volume (standard ft³) of exhaust sample drawn through ethanol impingers (dry).

WVol_{ES}=Volume (standard ft³) of exhaust sample drawn through ethanol impingers (wet).

(F) Formaldehyde:

$$M_{\text{CH}_2\text{O mode}} = (\text{DCH}_2\text{O}/10^6)30.026(\text{DVol})/V_m$$

$$M_{\text{CH}_2\text{O mode}} = (\text{WCH}_2\text{O}/10^6)30.026(\text{WVol})/V_m$$

(1) If aldehydes are measured using impingers:

$$\text{DCH}_2\text{O} = (V_m)(10^6)[(C_1 \times \text{AV}_1) + (C_2 \times \text{AV}_2)] / \text{DVol}_{\text{FS}}$$

$$\text{WCH}_2\text{O} = (V_m)(10^6)[(C_1 \times \text{AV}_1) + (C_2 \times \text{AV}_2)] / \text{WVol}_{\text{FS}}$$

(2) If aldehydes are measured using cartridges:

$$\text{DCH}_2\text{O} = (V_m)(10^6)(C_R \times \text{AV}_R) / \text{DVol}_{\text{FS}}$$

$$\text{WCH}_2\text{O} = (V_m)(10^6)(C_R \times \text{AV}_R) / \text{WVol}_{\text{FS}}$$

(3) The following definitions apply to this paragraph (b)(2)(iii)(F):

AV_i=Volume of absorbing reagent in impinger i (1 or 2) in ml.

AV_R=Volume of absorbing reagent use to rinse the cartridge in ml.

C_i=concentration of formaldehyde in impinger i (1 or 2) in mol/ml.

C_R=concentration of formaldehyde in solvent rinse in mol/ml.

DVol_{FS}=Volume (standard ft³) of exhaust sample drawn through formaldehyde sampling system (dry).

WVol_{FS}=Volume (standard ft³) of exhaust sample drawn through formaldehyde sampling system (wet).

(G) Acetaldehyde:

Environmental Protection Agency

§ 92.132

$$M_{\text{CH}_3\text{CHO}} = 10^6 \cdot 27.027 \cdot (\text{DVol}) / V_m \quad \text{mode} = (\text{DCH}_3\text{CHO} / 10^6)$$

$$M_{\text{CH}_3\text{CHO}} = 10^6 \cdot 27.027 \cdot (\text{WVol}) / V_m \quad \text{mode} = (\text{WCH}_3\text{CHO} / 10^6)$$

(1) If aldehydes are measured using impingers:

$$\text{DCH}_3\text{CHO} = (V_m) (10^6) [(C_1 \times \text{AV}_1) + (C_2 \times \text{AV}_2)] / \text{DVol}_{\text{AS}}$$

$$\text{WCH}_3\text{CHO} = (V_m) (10^6) [(C_1 \times \text{AV}_1) + (C_2 \times \text{AV}_2)] / \text{WVol}_{\text{AS}}$$

(2) If aldehydes are measured using cartridges:

$$\text{DCH}_3\text{CHO} = (V_m) (10^6) (C_R \times \text{AV}_R) / \text{DVol}_{\text{AS}}$$

$$\text{WCH}_3\text{CHO} = (V_m) (10^6) (C_R \times \text{AV}_R) / \text{WVol}_{\text{AS}}$$

(3) The following definitions apply to this paragraph (b)(2)(iii)(G):

AV_i = Volume of absorbing reagent in impinger i (1 or 2) in ml.

AV_R = Volume of absorbing reagent used to rinse the cartridge in ml.

C_i = concentration of acetaldehyde in impinger i (1 or 2) in mol/ml.

C_R = concentration of acetaldehyde in solvent rinse in mol/ml.

DVol_{AS} = Volume (standard ft³) of exhaust sample drawn through acetaldehyde sampling system (dry).

WVol_{AS} = Volume (standard ft³) of exhaust sample drawn through acetaldehyde sampling system (wet).

(iv) Conversion of wet concentrations to dry concentrations. Wet concentra-

tions are converted to dry concentrations using the following equation:

$$\text{DX} = K_w \text{WX}$$

Where:

WX is the concentration of species X on a wet basis.

DX is the concentration of species X on a dry basis.

K_w is a conversion factor = WVol / (DVol + DH₂O).

(A) Iterative calculation of conversion factor. The conversion factor K_w is calculated from the fractional volume of water in the exhaust on a dry basis (DH₂O = volume of water in exhaust / dry volume of exhaust). Precise calculation of the conversion factor K_w must be done by iteration, since it requires the dry concentration of HC, but HC emissions are measured wet.

(1) The conversion factor is calculated by first assuming DHC = WHC to calculate DVol:

$$\text{DVol} = (V_m) (W_i) / ((\text{CMW}_i) (\text{DHC} / 10^6 + \text{DCO} / 10^6 + \text{DCO}_2 / 100))$$

(2) This estimate is then used in the following equations to calculate DVol_{air}, then DH₂O, then K_w, which allows DHC to be determined more accurately from WHC:

$$\text{DH}_2\text{O} = \left[\frac{\alpha \left(\frac{\text{DCO}_2}{10^2} + \frac{\text{DCO}}{10^6} \right)}{2} + \frac{(Y)(\text{DVol}_{\text{air}})}{\text{DVol}} \right] \left[\frac{1}{1 + \frac{\text{DCO}}{(\text{DCO}_2)(K)(10^4)}} \right]$$

Where:

Y = Water volume concentration in intake air, volume fraction (dry).

DVol_{air} = Air intake flow rate (ft³/hr) on a dry basis, measured, or calculated as:

$$\text{DVol}_{\text{air}} = \text{DVol} \left[1 - \left(\frac{\text{DCO}_2}{10^2} \right) \left(\frac{\alpha}{4} \right) - \frac{\text{DCO}}{10^6} \left(\frac{\alpha}{4} + 0.5 \right) \right]$$

(3) The calculations are repeated using this estimate of DHC. If the new estimate for K_w is not within one percent of the previous estimate, the

iteration is repeated until the difference in K_w between iterations is less than one percent.

(B) Alternate calculation of DH2O (approximation). The following approximation may be used for DH2O instead of the calculation in paragraph (b)(2)(iv)(A) of this section:

$$DH2O = \left[\frac{\alpha \left(\frac{DCO2}{10^2} + \frac{DCO}{10^6} \right)}{2} + (Y)(DVol_{Ratio}) \right] \left[\frac{1}{1 + \frac{DCO}{(DCO2)(K)(10^4)}} \right]$$

Where:

$$DVol_{ratio} = \frac{DVol_{air}}{DVol} = \left[1 - \left(\frac{DCO2}{10^2} \right) \left(\frac{\alpha}{4} \right) - \frac{DCO}{10^6} \left(\frac{\alpha}{4} + 0.5 \right) \right]$$

Y=Water volume concentration in intake air, volume fraction (dry).

(3) *Mass Emissions—Dilute exhaust measurements.* For dilute exhaust measurements mass emissions (grams per hour) of each species for each mode:

(i) *General equations.* The mass emission rate, $M_{x mode}$ (g/hr) of each pollutant (HC, NO_x , CO_2 , CO, CH_4 , CH_3OH , CH_3CH_2OH , CH_2O , CH_3CH_2O) for each operating mode for bag measurements and diesel continuously heated sampling system measurements is determined from the following equation:

$$M_{x mode} = (V_{mix})(Density_x)(X_{conc})/(V_f)$$

Where:

x designates the pollutant (e.g., HC), V_{mix} is the total diluted exhaust volumetric flow rate (ft³/hr), $Density_x$ is the specified density of the pollutant in the gas phase (g/ft³), X_{conc} is the fractional concentration of pollutant x (i.e., ppm/10⁶, ppmC/10⁶, or %/100), and V_f is the fraction of the raw exhaust that is diluted for analysis.

(ii) The following abbreviations and equations apply to paragraphs (b)(3)(i) through (b)(3)(iii)(J) of this section:

(A) DF=Dilution factor, which is the volumetric ratio of the dilution air to the raw exhaust sample for total dilution, calculated as:

$$DF = \frac{WCO_2 - WCO_{2d}}{WCO_{2e} - WCO_{2d}} - 1$$

Where:

WCO_2 =Carbon dioxide concentration of the raw exhaust sample, in percent (wet).

WCO_{2e} =Carbon dioxide concentration of the dilute exhaust sample, in percent (wet).

WCO_{2d} =Carbon dioxide concentration of the dilution air, in percent (wet).

(B) V_{mix} =Diluted exhaust volumetric flow rate in cubic feet per hour corrected to standard conditions (528°R, and 760 mm Hg).

(C) V_f =Fraction of the total raw exhaust that is diluted for analysis.

$$= ((CO_{2conc}/10^2) + (CO_{conc}/10^6) + (HC_{conc}/10^6))(V_{mix})(CMW_f)/V_m/M_f$$

(iii) Calculation of individual pollutants.

(A) $M_{HC mode}$ =Hydrocarbon emissions, in grams per hour by mode, are calculated using the following equations:

$$M_{HC mode} = (V_{mix})(Density_{HC})(HC_{conc}/10^6)/V_f$$

$$HC_{conc} = HC_e - (HC_d)(1 - (1/DF))$$

$$HC_e = FID HC_e - \Xi(r_x)(X_e)$$

Where:

Density_{HC}=Density of hydrocarbons=16.42 g/ft³ (0.5800 kg/m³) for #1 petroleum diesel fuel, 16.27 g/ft³ (0.5746 kg/m³) for #2 diesel, and 16.33 g/ft³ (0.5767 kg/m³) for other fuels, assuming an average carbon to hydrogen ratio of 1:1.93 for #1 petroleum diesel fuel, 1:1.80 for #2 petroleum diesel fuel, and 1:1.85 for hydrocarbons in other fuels at standard conditions.

HC_{conc}=Hydrocarbon concentration of the dilute exhaust sample corrected for background, in ppm carbon equivalent (i.e., equivalent propane×3).

HC_e=Hydrocarbon concentration of the dilute exhaust bag sample, or for diesel continuous heated sampling systems, average hydrocarbon concentration of the dilute exhaust sample as determined from the integrated HC traces, in ppm carbon equivalent. For petroleum-fueled engines, HC_e is the FID measurement. For methanol-fueled and ethanol-fueled engines:

FID HC_e=Concentration of hydrocarbon plus methanol, ethanol and acetaldehyde in dilute exhaust as measured by the FID, ppm carbon equivalent.

r_x=FID response to oxygenated species x (methanol, ethanol or acetaldehyde).

X_e=Concentration of species x (methanol, ethanol or acetaldehyde) in dilute exhaust as determined from the dilute exhaust sample, ppm carbon.

HC_d=Hydrocarbon concentration of the dilution air as measured, in ppm carbon equivalent.

(B) M_{NOx mode} = Oxides of nitrogen emissions, in grams per hour by mode, are calculated using the following equations:

$$M_{NOx mode} = (V_{mix}) (Density_{NO2}) (NOx_{conc} / 10^6) / V_f$$

$$NOx_{conc} = (NOx_e - NOx_d (1 - (1/DF)))$$

Where:

Density_{NO2}=Density of oxides of nitrogen is 54.16 g/ft³ (1.913 kg/m³), assuming they are in the form of nitrogen dioxide, at standard conditions.

NOx_{conc}=Oxides of nitrogen concentration of the dilute exhaust sample corrected for background, in ppm.

NOx_e=Oxides of nitrogen concentration of the dilute exhaust bag sample as measured, in ppm.

NOx_d=Oxides of nitrogen concentration of the dilution air as measured, in ppm.

(C) M_{CO2 mode}=Carbon dioxide emissions, in grams per hour by mode, are calculated using the following equations:

$$M_{CO2 mode} = (V_{mix}) (Density_{CO2}) (CO_{2conc} / 10^2) / V_f$$

$$CO_{2conc} = CO_{2e} - CO_{2d} (1 - (1/DF))$$

Where:

Density CO₂=Density of carbon dioxide is 51.81 g/ft³ (1.830 kg/m³), at standard conditions.

CO_{2conc}=Carbon dioxide concentration of the dilute exhaust sample corrected for background, in percent.

CO_{2e}=Carbon dioxide concentration of the dilute exhaust bag sample, in percent.

CO_{2d}=Carbon dioxide concentration of the dilution air as measured, in percent.

(D)(1) M_{CO mode}=Carbon monoxide emissions, in grams per hour by mode, are calculated using the following equations:

$$M_{CO mode} = (V_{mix}) (Density_{CO}) (CO_{conc} / 10^6) / V_f$$

$$CO_{conc} = CO_e - CO_d (1 - (1/DF))$$

$$CO_d = (1 - 0.000323R) CO_{dm}$$

Where:

Density_{CO}=Density of carbon monoxide is 32.97 g/ft³ (1.164 kg/m³), at standard conditions.

CO_{conc}=Carbon monoxide concentration of the dilute exhaust sample corrected for background, water vapor, and CO₂ extraction, ppm.

CO_e=Carbon monoxide concentration of the dilute exhaust sample volume corrected for water vapor and carbon dioxide extraction, in ppm.

CO_e=(1 - (0.01+0.005/α))CO_{2e} - 0.000323RH)CO_{em}, where α is the hydrogen to carbon ratio as measured for the fuel used.

CO_{em}=Carbon monoxide concentration of the dilute exhaust sample as measured, in ppm.

RH = Relative humidity of the dilution air, percent.

CO_d=Carbon monoxide concentration of the dilution air corrected for water vapor extraction, in ppm.

CO_{dm}=Carbon monoxide concentration of the dilution air sample as measured, in ppm.

(2) If a CO instrument which meets the criteria specified in §86.1311 of this chapter is used and the conditioning column has been deleted, CO_{em} must be substituted directly for CO_e, and CO_{dm} must be substituted directly for CO_d.

(E) M_{CH4 mode}=Methane emissions corrected for background, in gram per hour by mode, are calculated using the following equations:

$$M_{CH4 mode} = (V_{mix}) (Density_{CH4}) (CH_{4conc} / 10^6) / V_f$$

$$CH_{4conc} = C_{CH4e} - C_{CH4d} (1 - (1/DF))$$

Where:

Density_{CH4}=Density of methane is 18.89 g/ft³ at 68 °F (20 °C) and 760 mm Hg (101.3kPa) pressure.

CH_{4conc} =Methane concentration of the dilute exhaust corrected for background, in ppm.

C_{CH_4e} =Methane concentration in the dilute exhaust, in ppm.

C_{CH_4d} =Methane concentration in the dilution air, in ppm.

(F) $M_{CH_3OH mode}$ =Methanol emissions corrected for background, in gram per hour by mode, are calculated using the following equations:

$$M_{CH_3OH mode} = (V_{mix}) (Density_{CH_3OH}) (CH_3OH_{conc}/10^6) / V_f$$

$$CH_3OH_{conc} = C_{CH_3OHe} - C_{CH_3OHd} (1 - (1/DF))$$

$$C_{CH_3OHe} = ((3.817) (10^{-2}) (T_{EM}) (((C_{S1}) (AV_{S1})) + (C_{S2}) (AV_{S2}))) / ((P_B) (V_{EM}))$$

$$C_{CH_3OHd} = ((3.817) (10^{-2}) (T_{DM}) (((C_{D1}) (AV_{D1})) + (C_{D2}) (AV_{D2}))) / ((P_B) (V_{DM}))$$

Where:

$Density_{CH_3OH}$ =Density of methanol is 37.71 g/ft³ (1.332 kg/m³), at 68 °F (20 °C) and 760 mm Hg (101.3kPa) pressure.

CH_3OH_{conc} =Methanol concentration of the dilute exhaust corrected for background, in ppm.

C_{CH_3OHe} =Methanol concentration in the dilute exhaust, in ppm.

C_{CH_3OHd} =Methanol concentration in the dilution air, in ppm.

T_{EM} =Temperature of methanol sample withdrawn from dilute exhaust, °R.

T_{DM} =Temperature of methanol sample withdrawn from dilution air, °R.

P_B =Barometric pressure during test, mm Hg.

V_{EM} =Volume of methanol sample withdrawn from dilute exhaust, ft³.

V_{DM} =Volume of methanol sample withdrawn from dilution air, ft³.

C_S =GC concentration of aqueous sample drawn from dilute exhaust, µg/ml.

C_D =GC concentration of aqueous sample drawn from dilution air, µg/ml.

AV_S =Volume of absorbing reagent (deionized water) in impinger through which methanol sample from dilute exhaust is drawn, ml.

AV_D =Volume of absorbing reagent (deionized water) in impinger through which methanol sample from dilution air is drawn, ml.

₁=first impinger.

₂=second impinger.

(G) $M_{C_2H_5OH mode}$ =Ethanol emissions corrected for background, in gram per hour by mode, are calculated using the following equations:

$$M_{CH_3CH_2OH mode} = (V_{mix}) (Density_{CH_3CH_2OH}) ((CH_3CH_2OH_{conc}/10^6) / V_f)$$

$$CH_3CH_2OH_{conc} = C_{CH_3CH_2OHe} - C_{CH_3CH_2OHd} (1 - (1/DF))$$

$$C_{CH_3CH_2OHe} = ((2.654) (10^{-2}) (T_{EM}) (((C_{S1}) (AV_{S1})) + (C_{S2}) (AV_{S2}))) / ((P_B) (V_{EM}))$$

$$C_{CH_3CH_2OHd} = ((2.654) (10^{-2}) (T_{DM}) (((C_{D1}) (AV_{D1})) + (C_{D2}) (AV_{D2}))) / ((P_B) (V_{DM}))$$

$$C_{CH_3CH_2OHe} = ((2.654) (10^{-2}) (T_{EM}) (((C_{S1}) (AV_{S1})) + (C_{S2}) (AV_{S2}))) / ((P_B) (V_{EM}))$$

Where:

$Density_{C_2H_5OH}$ =Density of ethanol is 54.23 g/ft³ (1.915 kg/m³), at 68 °F (20 °C) and 760 mm Hg (101.3kPa) pressure.

$CH_3CH_2OH_{conc}$ =Ethanol concentration of the dilute exhaust corrected for background, in ppm.

$C_{CH_3CH_2OHe}$ =Ethanol concentration in the dilute exhaust, in ppm.

$C_{CH_3CH_2OHd}$ =Ethanol concentration in the dilution air, in ppm.

T_{EM} =Temperature of ethanol sample withdrawn from dilute exhaust, °R.

T_{DM} =Temperature of ethanol sample withdrawn from dilution air, °R.

P_B =Barometric pressure during test, mm Hg.

V_{EM} =Volume of ethanol sample withdrawn from dilute exhaust, ft³.

V_{DM} =Volume of ethanol sample withdrawn from dilution air, ft³.

C_S =GC concentration of aqueous sample drawn from dilute exhaust, µg/ml.

C_D =GC concentration of aqueous sample drawn from dilution air, µg/ml.

AV_S =Volume of absorbing reagent (deionized water) in impinger through which ethanol sample from dilute exhaust is drawn, ml.

AV_D =Volume of absorbing reagent (deionized water) in impinger through which ethanol sample from dilution air is drawn, ml.

₁=first impinger.

₂=second impinger.

(H) $M_{CH_2O mode}$ =Formaldehyde emissions corrected for background, in gram per hour by mode, are calculated using the following equations:

$$M_{CH_2O mode} = (V_{mix}) (Density_{CH_2O}) ((CH_2O_{conc}/10^6) / V_f)$$

$$CH_2O_{conc} = C_{CH_2Oe} - C_{CH_2Od} (1 - (1/DF))$$

$$C_{CH_2Oe} = ((4.069) (10^{-2}) (C_{FDE}) (V_{AE}) (Q) (T_{EF})) / ((V_{SE}) (P_B))$$

$$C_{CH_2Od} = ((4.069) (10^{-2}) (C_{FDA}) (V_{AA}) (Q) (T_{DF})) / ((V_{SA}) (P_B))$$

Where:

$Density_{CH_2O}$ =Density of formaldehyde is 35.36 g/ft³ (1.249 kg/m³), at 68 °F (20 °C) and 760 mmHg (101.3 kPa) pressure.

CH_2O_{conc} =Formaldehyde concentration of the dilute exhaust corrected for background, ppm.

C_{CH_2Oe} =Formaldehyde concentration in dilute exhaust, ppm.

C_{CH_2Od} =Formaldehyde concentration in dilution air, ppm.

C_{FDE} =Concentration of DNPH derivative of formaldehyde from dilute exhaust sample in sampling solution, µg/ml.

V_{AE} =Volume of sampling solution for dilute exhaust formaldehyde sample, ml.

Q = Ratio of molecular weights of formaldehyde to its DNPH derivative = 0.1429.

Environmental Protection Agency

§ 92.132

T_{EF} =Temperature of formaldehyde sample withdrawn from dilute exhaust, °R.
 V_{SE} =Volume of formaldehyde sample withdrawn from dilute exhaust, ft³.
 P_B =Barometric pressure during test, mm Hg.
 C_{FDA} =Concentration of DNPH derivative of formaldehyde from dilution air sample in sampling solution, µg/ml.
 V_{AA} =Volume of sampling solution for dilution air formaldehyde sample, ml.
 T_{DF} =Temperature of formaldehyde sample withdrawn from dilution air, °R.
 V_{SA} =Volume of formaldehyde sample withdrawn from dilution air, ft³.

(I) $M_{CH_3CHO \text{ mode}}$ =Acetaldehyde emissions corrected for background, in grams per hour by mode, are calculated using the following equations:

$$M_{CH_3CHO \text{ mode}} = \frac{(V_{\text{mix}})(\text{Density}_{CH_3CHO})((CH_3CHO_{\text{conc}}/10^6)/V_f)}{(V_f)}$$

$$CH_3CHO_{\text{conc}} = C_{CH_3CHO_e} - C_{CH_3CHO_d}(1 - (1/DF))$$

$$C_{CH_3CHO_e} = ((2.774)(10^{-2})(C_{ADE})(V_{AE})(Q)(T_{EF}))/((V_{SE})(P_B))$$

$$C_{CH_3CHO_d} = ((2.774)(10^{-2})(C_{ADA})(V_{AA})(Q)(T_{DF}))/((V_{SA})(P_B))$$

Where:

Density_{CH_3CHO} =Density of acetaldehyde is 51.88 g/ft³ (1.833 kg/m³), at 68 °F (20 °C) and 760 mmHg (101.3 kPa) pressure.
 CH_3CHO_{conc} =Acetaldehyde concentration of the dilute exhaust corrected for background, ppm.
 $C_{CH_3CHO_e}$ =Acetaldehyde concentration in dilute exhaust, ppm.
 $C_{CH_3CHO_d}$ =Acetaldehyde concentration in dilution air, ppm.
 C_{ADE} =Concentration of DNPH derivative of acetaldehyde from dilute exhaust sample in sampling solution, µg/ml.
 V_{AE} =Volume of sampling solution for dilute exhaust acetaldehyde sample, ml.
 Q =Ratio of molecular weights of acetaldehyde to its DNPH derivative = 0.182
 T_{EF} =Temperature of acetaldehyde sample withdrawn from dilute exhaust, °R.
 V_{SE} =Volume of acetaldehyde sample withdrawn from dilute exhaust, ft³.
 P_B =Barometric pressure during test, mm Hg.
 C_{ADA} =Concentration of DNPH derivative of acetaldehyde from dilution air sample in sampling solution, µg/ml.
 V_{AA} =Volume of sampling solution for dilution air acetaldehyde sample, ml.
 T_{DF} =Temperature of acetaldehyde sample withdrawn from dilution air, °R.
 V_{SA} =Volume of acetaldehyde sample withdrawn from dilution air, ft³.

(J) $M_{NMHC \text{ mode}}$ =Nonmethane hydrocarbon emissions, in grams per hour by mode.

$$M_{NMHC \text{ mode}} = (V_{\text{mix}})(\text{Density}_{NMHC})(NMHC_{\text{conc}}/10^6)/V_f$$

$$NMHC_{\text{conc}} = NMHC_e - (NMHC_d)(1 - (1/DF))$$

$$NMHC_e = FID \text{ HC}_e - (r_m)(C_{CH_4e})$$

$$NMHC_d = FID \text{ HC}_d - (r_m)(C_{CH_4d})$$

Where:

Density_{NMHC} =Density of nonmethane hydrocarbons=16.42 g/ft³ (0.5800 kg/m³) for #1 petroleum diesel fuel, 16.27 g/ft³ (0.5746 kg/m³) for #2 diesel, and 16.33 for other fuels, assuming an average carbon to hydrogen ratio of 1:1.93 for #1 petroleum diesel fuel, 1:1.80 for #2 petroleum diesel fuel, and 1:1.85 for nonmethane hydrocarbons in other fuels at standard conditions.
 $NMHC_{\text{conc}}$ =Nonmethane hydrocarbon concentration of the dilute exhaust sample corrected for background, in ppm carbon equivalent (i.e., equivalent propane × 3).
 $NMHC_e$ =Nonmethane hydrocarbon concentration of the dilute exhaust bag sample:
 $FID \text{ HC}_e$ =Concentration of hydrocarbons in dilute exhaust as measured by the FID, ppm carbon equivalent.
 r_m =FID response to methane.
 C_{CH_4e} =Concentration of methane in dilute exhaust as determined from the dilute exhaust sample.
 $NMHC_d$ =Nonmethane hydrocarbon concentration of the dilution air:
 $FID \text{ HC}_d$ =Concentration of hydrocarbons in dilute exhaust as measured by the FID, ppm carbon equivalent.
 r_m =FID response to methane.
 C_{CH_4d} =Concentration of methane in dilute exhaust as determined from the dilute exhaust sample, ppm.

(4) *Particulate exhaust emissions.* The mass of particulate for a test mode determined from the following equations when a heat exchanger is used (i.e., no flow compensation), and when background filters are used to correct for background particulate levels:

$$M_{PM \text{ mode}} = \text{Particulate emissions, grams per hour by mode.}$$

$$M_{PM \text{ mode}} = (WVol)(PM_{\text{conc}})(1+DF) = (V_{\text{mix}})(PM_{\text{conc}})/V_f$$

$$PM_{\text{conc}} = PM_c - PM_d(1 - (1/DF))$$

$$PM_c = M_{PM_e}/V_{\text{sample}}/10^3$$

$$PM_d = M_{PM_d}/V_{\text{sampd}}/10^3$$

Where:

PM_{conc} =Particulate concentration of the diluted exhaust sample corrected for background, in g/ft³
 M_{PM_e} =Measured mass of particulate for the exhaust sample, in mg, which is the difference in filter mass before and after the test.

§ 92.133

40 CFR Ch. I (7-1-04 Edition)

M_{PMd} =Measured mass of particulate for the dilution air sample, in mg, which is the difference in filter mass before and after the test.

V_{sampe} =Total wet volume of sample removed from the dilution tunnel for the exhaust particulate measurement, cubic feet at standard conditions.

V_{sampd} =Total wet volume of sample removed from the dilution tunnel for the dilution air particulate measurement, cubic feet at standard conditions.

DF=Dilution factor, which is the volumetric ratio of the dilution air to the raw exhaust sample, calculated as:

$$DF = \frac{WCO_2 - WCO_{2d}}{WCO_{2e} - WCO_{2d}} - 1$$

(c) *Humidity calculations.* (1) The following abbreviations (and units) apply to paragraph (b) of this section:

BARO=barometric pressure (Pa).
 H=specific humidity, (g H₂O/g of dry air).
 K_H =conversion factor=0.6220 g H₂O/g dry air.
 M_{air} =Molecular weight of air=28.9645.
 M_{H_2O} =Molecular weight of water=18.01534.
 P_{DB} =Saturation vapor pressure of water at the dry bulb temperature (Pa).
 P_{DP} =Saturation vapor pressure of water at the dewpoint temperature (Pa).
 P_v =Partial pressure of water vapor (Pa).
 P_{WB} =Saturation vapor pressure of water at the wet bulb temperature (Pa).
 T_{DB} =Dry bulb temperature (Kelvin).
 T_{WB} =Wet bulb temperature (Kelvin).
 Y=Water-vapor volume concentration.

(2) The specific humidity on a dry basis of the intake air (H) is defined as:

$$H = ((K_H) (P_v) / (BARO - P_v))$$

(3) The partial pressure of water vapor may be determined using a dew point device. In that case:

$$P_v = P_{DP}$$

(4) The percent of relative humidity (RH) is defined as:

$$RH = (P_v / P_{DB}) 100$$

(5) The water-vapor volume concentration on a dry basis of the engine intake air (Y) is defined as:

$$Y = ((H) (M_{air}) / (M_{H_2O})) = P_v / (BARO - P_v)$$

(d) *NO_x correction factor.* (1) NO_x emission rates ($M_{NO_x, mode}$) shall be adjusted to account for the effects of humidity and temperature by multiplying each emission rate by K_{NO_x} , which is calculated from the following equations:

$$K_{NO_x} = (K) (1 + (0.25 (\log K)^2)^{1/2})$$

$$K = (K_H) (K_T)$$

$$K_H = [C_1 + C_2 (\exp((-0.0143) (10.714)))] / [C_1 + C_2 (\exp((-0.0143) (1000H)))]$$

$$C_1 = -8.7 + 164.5 \exp(-0.0218 (A/F)_{wet})$$

$$C_2 = 130.7 + 3941 \exp(-0.0248 (A/F)_{wet})$$

Where:

$(A/F)_{wet}$ =Mass of moist air intake divided by mass of fuel intake.

$K_T = 1 / [1 - 0.017 (T_{30} - T_A)]$ for tests conducted at ambient temperatures below 30 °C.

$K_T = 1.00$ for tests conducted at ambient temperatures at or above 30 °C.

T_{30} =The measured intake manifold air temperature in the locomotive when operated at 30 °C (or 100 °C, where intake manifold air temperature is not available).

T_A =The measured intake manifold air temperature in the locomotive as tested (or the ambient temperature (°C), where intake manifold air temperature is not available).

(e) *Other calculations.* Calculations other than those specified in this section may be used with the advance approval of the Administrator.

§ 92.133 Required information.

(a) The required test data shall be grouped into the following two general categories:

(1) *Pre-test data.* These data are general test data that must be recorded for each test. The data are of a more descriptive nature such as identification of the test engine, test site number, etc. As such, these data can be recorded at any time within 24 hours of the test.

(2) *Test data.* These data are physical test data that must be recorded at the time of testing.

(b) When requested, data shall be supplied in the format specified by the Administrator.

(c) *Pre-test data.* The following shall be recorded, and reported to the Administrator for each test conducted for