Unit Definitions

$rev := 2 \cdot \pi \cdot rad$ $ppm_{Methane} := 1$ $ppm_{NOx} := 1$ $ppm_{C1} := 1$

Molecular Weights of Gases

$M_{CO} := 28.01 \cdot \frac{gm}{mol}$ $M_{CO2} := 44.01 \cdot \frac{gm}{mol}$ $M_{NO2} := 46.01 \cdot \frac{gm}{mol}$

Calculating Correction Factor

$H_{specific} := 3.0343 \cdot \frac{gm}{kg}$ Specific humidity of intake air in grams of moisture per kilogram of dry air

$K_H := \frac{1}{1 - 0.0329 \cdot (H_{specific} - 10.71)}$ Correction factor for effects of humidity on NO_2 formation $K_H = 0.74$

Fuel Properties (must be changed for each fuel)

$HC_{ratio} := 1.75$ Ratio of hydrogen atoms to carbon atoms

$MW_{fuel} := (12.01 + 1.008 \cdot HC_{ratio}) \cdot \frac{gm}{mol}$ $MW_{fuel} = 13.774 \frac{gm}{mol}$

Measured Engine Data (must be changed for each data point)

$RPM_{measured} := 2750 \cdot \frac{rev}{min}$ Engine RPM at point

$Torque_{measured} := 42.23 \cdot ft \cdot lbf$ Engine torque measured on dynamometer

$G_{fuel} := 10.128 \cdot \frac{lb}{hr}$ Fuel mass flow rate at point

Measured Emissions Data - Dry Measurement (must be changed for each data point)

$CO2_{dry} := 5.0\%$ CO_2 reading on analyzer

$CO_{dry} := .45\%$ CO reading on analyzer

$HC_{dry} := 3 \cdot 6 \cdot ppm_{Methane}$ HC reading on analyzer

$NOx_{dry} := 519 \cdot ppm_{NOx}$ NO_x reading on analyzer

$O2_{.dry} := 12.06\%$ O_2 reading on analyzer

Calculated Data

$$Power_{measured} := Torque_{measured} \cdot RPM_{measured} \qquad Power_{measured} = 16.489\,kW$$

Must calculate the percent dry H_2 in the exhaust in order to find the correction factor K
K is used to convert between dry and wet measurements

$$H2_{dry} := \frac{0.5 \cdot HC_{ratio} \cdot CO_{dry} \cdot \left(CO_{dry} + CO2_{dry}\right)}{CO_{dry} + 3 \cdot CO2_{dry}} \qquad H2_{dry} = 0.139\,\%$$

$$K_{factor} := \frac{1}{1 + \left[.005 \cdot \left(CO_{dry} + CO2_{dry}\right) \cdot HC_{ratio} - 0.01 \cdot H2_{dry}\right] \cdot 10^{0}} \qquad K_{factor} = 0.956$$

$$HC_{wet} := HC_{dry} \cdot K_{factor} \qquad HC_{wet} = 17.204\,ppm_{C1}$$

$$CO_{wet} := CO_{dry} \cdot K_{factor} \qquad CO_{wet} = 0.43\,\%$$

$$CO2_{wet} := CO2_{dry} \cdot K_{factor} \qquad CO2_{wet} = 4.779\,\%$$

$$NOx_{wet} := NOx_{dry} \cdot K_{factor} \qquad NOx_{wet} = 496.034\,ppm_{NOx}$$

$$O2_{wet} := O2_{dry} \cdot K_{factor} \qquad O2_{wet} = 11.526\,\%$$

Calculated Mass Emissions

Must calculate the total carbon percent (TC). This ratio helps calculate the mass flow of emissions based on the mass flow of the fuel.

$$TC := \left(CO_{wet} + CO2_{wet} + \frac{HC_{wet}}{10^{6}}\right) \cdot 100 \qquad TC = 5.211 \text{ \% Carbon}$$

$$HC := \frac{G_{fuel}}{\frac{TC}{100}} \cdot \frac{HC_{wet}}{10^{6}} \qquad \boxed{HC = 1.517\,\frac{gm}{hr}}$$

$$CO := \frac{M_{CO}}{MW_{fuel}} \cdot \frac{G_{fuel}}{\frac{TC}{100}} \cdot CO_{wet} \qquad \boxed{CO = 771.108\,\frac{gm}{hr}}$$

$$CO2 := \frac{M_{CO2}}{MW_{fuel}} \cdot \frac{G_{fuel}}{\frac{TC}{100}} \cdot CO2_{wet} \qquad \boxed{CO2 = 1.346 \times 10^{4}\,\frac{gm}{hr}}$$

$$NOx := \frac{M_{NO2}}{MW_{fuel}} \cdot \frac{G_{fuel}}{\frac{TC}{100}} \cdot \frac{NOx_{wet}}{10^{6}} \cdot K_{H} \qquad \boxed{NOx = 108.031\,\frac{gm}{hr}}$$

Comparing carbon flow in and carbon flow out

This section is a comparison of the mass flow of carbon out the exhaust compared to the fuel used. The two final values should match one another. If they do not, this indicates a source of error.

Mass flow of carbon from each emission source

$$m_{dot\_carbon\_HC} := \frac{HC}{(12.01 + 1.008)\cdot\frac{gm}{mol}}\cdot 12.01\cdot\frac{gm}{mol} \qquad m_{dot\_carbon\_HC} = 1.399\,\frac{gm}{hr}$$

$$m_{dot\_carbon\_CO} := \frac{CO}{M_{CO}}\cdot 12.01\cdot\frac{gm}{mol} \qquad m_{dot\_carbon\_CO} = 330.632\,\frac{gm}{hr}$$

$$m_{dot\_carbon\_CO2} := \frac{CO2}{M_{CO2}}\cdot 12.01\cdot\frac{gm}{mol} \qquad m_{dot\_carbon\_CO2} = 3.674\times 10^{3}\,\frac{gm}{hr}$$

$$m_{dot\_carbon\_exh} := m_{dot\_carbon\_HC} + m_{dot\_carbon\_CO} + m_{dot\_carbon\_CO2}$$

$$\boxed{m_{dot\_carbon\_exh} = 4.006\times 10^{3}\,\frac{gm}{hr}}$$ Mass flow out exhaust

$$m_{dot\_carbon\_fuel} := \frac{G_{fuel}}{MW_{fuel}}\cdot 12.01\cdot\frac{gm}{mol}$$

$$\boxed{m_{dot\_carbon\_fuel} = 4.006\times 10^{3}\,\frac{gm}{hr}}$$ Mass flow in to engine