

WHEN YOU NEED TO BE SURE

SGS

## **CyFlex® Knowledge Article**

### **Gaseous Emissions**

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July 9, 2019



## Emissions Measurements

The burned gas composition calculation outlined in the [Burned Gas Composition](#) document is based on the assumption of complete combustion at low temperature. Real-world combustion is a much more complicated process that often leads to significant departures from the theoretical burned gas composition. Some of the resulting species are undesirable pollutants that are regulated by the government and must be measured to assure compliance with various standards. The most commonly measured species in the burned gas are CO<sub>2</sub>, CO, NO<sub>x</sub>, O<sub>2</sub> and unburned hydrocarbons (UHC). Concentrations are generally reported in % or ppm depending on the species being measured.

### Dry-to-wet Correction

To prevent equipment damage and interference on many of these measurements, the water vapor is removed and the measurements are made on a "dry" basis. The theoretical burned gas composition calculations are used to define a dry-to-wet correction factor that is used to convert dry burned gas composition measurements to a wet basis. The dry-to-wet conversion factor,  $K_{dry-to-wet,theor}$ , is given by

$$K_{dry-to-wet,theor} = \frac{\beta + \gamma + \delta + \eta + \lambda + \psi + \omega}{\alpha + \beta + \gamma + \delta + \eta + \lambda + \psi + \omega} = 1 - y_{H_2O,burned} \quad \text{ge.1}$$

The formula for converting a concentration measurement of species  $X$  made on a dry basis,  $y_{X,dry}$ , to a wet basis is simply

$$y_{X,wet} = K_{dry-to-wet,theor} \times y_{X,dry} \quad \text{ge.2}$$

*Note: The dry-to-wet conversion factor assumes water is completely removed from the sample. This is usually a good approximation when the equipment is functioning properly but can lead to low concentration measurements when water removal is incomplete.*

### Emissions Mass Flow Rate

The mass flow rate of species  $X$  in the exhaust based on the measured concentration is given by

$$\dot{m}_{X,burned} = y_{X,wet} \times \frac{M_X}{M_{burned\ gas}} \times \dot{m}_{burned\ gas} \quad \text{ge.3}$$

The burned gas molecular weight is determined using the theoretical calculations outlined in the [Burned Gas Composition](#) document.

Fuel is generally assumed to be the primary source of UHC, so the molecular weight of the unburned hydrocarbons is usually defined as

$$M_{UHC} = M_C + \kappa M_H \quad \text{ge.4}$$

where  $\kappa$  is the molar hydrogen to carbon ratio of the fuel given by

$$\kappa = \frac{\Theta_{fuel}}{\Pi_{fuel}} \quad \text{ge.5}$$

where  $\Pi_{fuel}$  and  $\Theta_{fuel}$  are computed by summing over *only* the streams containing fuel using equations bgc.3 and bgc.4 respectively from the *Burned Gas Composition* document.

The measured NOx is actually a mixture of NO and NO<sub>2</sub>. The molecular weight of NOx is assumed to be the same as the molecular weight of NO<sub>2</sub>, which is the worst-case scenario for emissions calculations. So

$$M_{NO_x} = M_{NO_2} \quad \text{ge.6}$$

## Brake Specific Emissions

Emissions regulations are generally expressed on a brake specific basis which can be calculated based on the measured engine brake horsepower, BHP, using

$$bsX_{burned\ gas} = \frac{\dot{m}_{X,burned\ gas}}{BHP} \quad \text{ge.7}$$

## Fuel Specific Emissions

Brake specific emissions tend to approach infinity at low load points. To help in understanding the underlying combustion processes that drive emissions, fuel specific emissions are often calculated based on the measured fuel rate,  $\dot{m}_{fuel}$ , using

$$fsX_{burned\ gas} = \frac{\dot{m}_{X,burned\ gas}}{\dot{m}_{fuel}} \quad \text{ge.8}$$

## NOx Humidity Correction

The humidity of the intake air affects the amount of NOx formed during combustion. It is common practice to use a correction factor,  $K_H$ , to correct NOx emissions back to a standard condition of 75 grains of water per lbm of dry air. The formula is

$$\dot{m}_{NO_x,burned,corrected} = K_H \times \dot{m}_{NO_x,burned} \quad \text{ge.9}$$

where  $K_H$  is defined to be a function of the absolute humidity, H, given by the empirical relationship

$$K_H = \frac{1}{1 - 0.0182(H - 10.71)} \quad \text{ge.10}$$

where

$$H = \text{Intake Air Absolute Humidity in g water / kg dryair}$$

$H$  may be determined from barometric and vapor pressure measurements using

$$H = \left( \frac{P_{vap}}{P_{bar} - P_{vap}} \right) \frac{M_{H_2O}}{M_{air,dry}} \times 1000 \quad \text{ge.11}$$

Note: The above correction is an approximation and only applies to diesel engines burning diesel fuel.