WHEN YOU NEED TO BE SURE

CyFlex® Knowledge Article

Component Balances

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The document *Burned Gas Composition* describes a method for calculating the theoretical burned gas stream composition given the mass flow rates and composition of the component streams. The *Gaseous Emissions* document describes a method for calculating emissions rates based on various concentration measurements. By comparing the measured emissions to the values calculated theoretically, it is often possible to detect errors in several critical measurement systems. It is important to note that an insignificant difference between the measured and theoretical values does not necessarily mean that a measurement error does not exist - it is possible for two errors to cancel each other. On the other hand, if a significant discrepancy does exist, there will always be at least one measurement error.

Another use for component balances is the determination of the flow rate of one component stream based on the measurement of some unique species in the exhaust. For example, lube oil consumption is sometimes determined by measuring the sulfur concentration in the exhaust. By burning fuel with virtually no sulfur content and sometimes doping the oil to a higher sulfur level, it becomes a good assumption that all of the sulfur appearing in the exhaust originated from the oil.

Atom Balances

We can no longer use the simplified reaction equation from the *Burned Gas Composition* document since minor species will undoubtedly exist in the real burned gas. So instead we write

$$a\left(y_{A,a}A + y_{B,a}B + y_{C,a}C + \ldots\right) + b\left(y_{A,b}A + y_{B,b}B + y_{C,b}C + \ldots\right) + \ldots \Rightarrow x_{burned}\left(y_{A,x}A + y_{B,x}B + y_{C,x}C + \ldots\right) \qquad \text{cb.1}$$

where

$a, b, \ldots = $ *mole flow rate of given component stream.*

$y_{V,z} = $ *mole fraction of component V in stream z.*

$x_{burned} = $ *mole flow rate of the burned gas stream.*

The molar flow rate of the burned gas stream can be calculated from

$$x_{burned} = \frac{\dot{m}_{burned}}{M_{burned}} \qquad \text{cb.2}$$

where

$\dot{m}_{burned} = $ *burned gas mass flow rate.*

$M_{burned} = $ *burned gas molecular weight.*

Both the burned gas mass flow rate and the burned gas molecular weight are calculated based on the equations and assumptions of the *Burned Gas Composition* document. The molar flow rate of *Z* atoms in the burned gas, x_Z, is given by

$$\begin{aligned} x_{Z,measured} &= x_{burned}\, w_{Z,A}\, y_{A,burned} + x_{burned}\, w_{Z,B}\, y_{B,burned} + x_{burned}\, w_{Z,C}\, y_{C,burned} + \ldots \\ &= x_{burned}\left(w_{Z,A}\, y_{A,burned} + w_{Z,B}\, y_{B,burned} + w_{Z,C}\, y_{C,burned} + \ldots\right) \end{aligned} \qquad \text{cb.3}$$

where:

$$w_{Z,V} = moles\ of\ Z\ atoms\ per\ mole\ of\ component\ V$$
$$(eg.\ 2\ moles\ of\ hydrogen\ atoms\ per\ mole\ of\ H_2O)$$

The mass flow rate of *Z* atoms in the burned gas, $\dot{m}_{Z,burned}$, is given by

$$\dot{m}_{Z,burned} = \dot{m}_{burned} \frac{M_Z}{M_{burned}} \left(w_{Z,A}\, y_{A,burned} + w_{Z,B}\, y_{B,burned} + w_{Z,C}\, y_{C,burned} + \ldots \right) \quad \text{cb.4}$$

In both the above equations the measured concentrations of the burned gas components, $y_{Z,V}$, should be converted to a wet basis if they were measured dry. The atom balance error, written as a percentage, is given by

$$\%\ atom\ balance\ error = \left(\frac{x_{Z,theoretical} - x_{Z,measured}}{x_{Z,theoretical}} \right) 100\% \quad \text{cb.5}$$

For the species we commonly measure, carbon is the only really viable atom to consider for such a balance calculation. A trace species such as sulfur might be a useful check if special emissions measurement equipment is available.