SBCAPCD ENGINEERING DIVISION

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APPLICATION PROCESSING AND CALCULATIONS

PROCESSED BY **Mike Goldman**

Gaseous Fuel SO_x Emission Factor:

Applicability: External Combustion units such as boilers and process heaters for gaseous fuels (e.g., natural gas, oil field produced gas and propane).

Equations: Two equations are presented. The first is the fundamental equation showing how the emission factor is generated. The second is a reduced form of the basic equation for streamlined use. Finally, a check on the units is shown.

$$EF = [ppmvd\ \mathrm{S}] \times \left[\frac{1}{HHV}\right] \times \left[\frac{1}{mol\ vol}\right] \times [mol\ ratio] \times [MW_{SO_2}]$$

$$EF = [0.169] \times \left[\frac{ppmvd\ \mathrm{S}}{HHV}\right]$$

$$\frac{lb}{MMBtu} = \left[\frac{ft^3\ \mathrm{S}}{MM\ ft^3\ \mathrm{Fuel}}\right] \times \left[\frac{ft^3\ \mathrm{Fuel}}{Btu}\right] \times \left[\frac{lb-mole\ \mathrm{S}}{379\ ft^3\ \mathrm{S}}\right] \times \left[\frac{lb-mole\ \mathrm{SO_2}}{lb-mole\ \mathrm{S}}\right] \times \left[\frac{64\ lb\ \mathrm{SO_2}}{lb-mole\ \mathrm{SO_2}}\right]$$

where:

EF	=	SO_x emission factor in units of lb/MMBtu (HHV based, as SO_2)
ppmvd S	=	total sulfur concentration in fuel (as S)
HHV	=	higher heating value of the fuel (Btu/scf)
mol vol	=	molar volume of the fuel at standard conditions (1 atm & 60 °F, equals 379 std ft^3/lb-mole)
mol ratio	=	stoichiometric molar ratio for the combustion of sulfur (1 S + 1 $O_2 \Rightarrow$ 1 SO_2)
MM	=	million

Defaults: Default emission factors can be arrived at by using standard default values for the heating value and sulfur concentrations for each fuel.

Fuel	ppmvd (as S)	ppmvd (as H_2S)	HHV (Btu/scf)	SO_x Emission Factor (lb/MMBtu)
PUC Natural Gas	85	80	1,050	0.0137
GPA Commercial Propane	254	239	2,522	0.0170
GPA HD-5 Propane	169	159	2,522	0.0113
Produced Gas - South Zone	254	239	1,050	0.0409
Produced Gas - North Zone	846	796	1,050	0.1362

where:

(a) PUC Natural Gas: Sulfur concentration based on maximum allowed total sulfur content of 5 gr/100 scf (as S) per General Order 58-A. The calculations below show how the equivalent concentrations are derived (depending on the "basis"):

{ppmvd as S = (5 gr S/100 scf)*(10^6 scf fuel/MM scf fuel)*(lb S/7000 gr S)*(379 scf S/lb-mole S)/(32 lb S/lb-mole S) = 85 ppmvd as S}

{ppmvd as H_2S = (5 gr H_2S/100 scf)*(10^6 scf fuel/MM scf fuel)*(lb H_2S/7000 gr H_2S)*(379 scf H_2S/lb-mole H_2S)/(34 lb H_2S/lb-mole H_2S) = 80 ppmvd as H_2S}.

Heating value based on USEPA AP-42, Appendix A (*Thermal Equivalents of Various Fuels*)

(b) Propane: Sulfur concentration based on Gas Processors Association Engineering Data Book (Ninth Edition, 1972), Figure 15-50 (GPA Liquefied Petroleum Gas Specifications, rev. 1979), Commercial Propane = 15 gr/100 scf, HD-5 Propane = 10 gr/100 scf (both as S). Same equation as listed in (a) above for the ppmvd "as S" calculation. Heating value based on Perry's Chemical Engineers Handbook, Chapter 9, 5th Edition, Table 9-16.

(c) Produced Gas: Sulfur concentration based on APCD Rule 311 - Southern Zone limit of 15 gr/100 scf (as H_2S) and Northern Zone limit of 50 gr/100 scf (as H_2S). To use in the calculations (which are based on an "as S" basis), these limits are adjusted to an as sulfur (as S) basis by use of the equation in note (a) above. This has the same affect as taking the ratio of the molecular weights (MW_S/MW_{H2S}) such that the respective Zone limits are 14.12 gr/100 scf and 47.06 gr/100 scf (as S). Heating value based on USEPA AP-42, Appendix A (*Thermal Equivalents of Various Fuels*)

(d) Reporting References: Reporting "as H_2S" means the total sulfur values are converted to an H_2S basis by taking the ratio of the molecular weights (MW_S/MW_{H2S}). This is needed to determine compliance with Rule 311 and permit conditions that require reporting "as H_2S". For PUC and GPA standards and the emission calculations, sulfur content "as S" is used. "S" in this case is mono-atomic sulfur (MW = 32 lb/lb-mole). When reviewing fuel analyses with di-atomic sulfur species, such as CS_2, the amount of sulfur from the compound in question must be doubled to account for the extra mole of sulfur.

(e) Permit Condition Limits and Reporting: Since permits require sulfur content of fuels to be reported "as H_2S", the associated limits for non-Rule 311 sulfur concentrations need to be also stated in an "as H_2S" basis so as to minimize the confusion of reporting in two ways. As such, for PUC natural gas the standard of 85 ppmvd "as S" is listed in the permit condition as 80 ppmv "as H_2S". For GPA propane/LPG, the standard of 254 ppmvd "as S" is listed in the permit condition as 239 ppmvd "as H_2S".

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