A METHOD FOR CALCULATING POWER PLANT EMISSION RATES

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A B S T R A C T

Federal new source performance standards governing emission from stationary sources require that emissions from fossil-fuel-fired steam generating units of 250 X 10^6 Btu/hr heat input be expressed in terms of lb/10^6 Btu heat input. Many State and local regulations also require the same expression to be used. To express emissions in these terms requires that the following be determined: (1) pollutant concentration, (2) effluent volumetric flow rate, and (3) heat input rate (fuel rate X fuel heat content). An alternative method is presented in this paper for calculating emission rates in terms of 10^6 Btu heat input without determining (2) and (3) above. Constants for respective fossil fuels are presented that permit (1) the calculation of emission rates without the measurement of dry effluent volumetric flow rate and heat input rate, (2) the checking of sampling data accuracy for (1) when these quantities are measured, and (3) the checking of accuracy of proximate and ultimate analyses.

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Introduction

In the final State Implementation Plans submitted by the 50 States, the District of Columbia, Puerto Rico, American Samoa, Guam, and the Virgin Islands in response to the 1970 Clean Air Act, most of the regulations for the control of particulate, sulfur dioxide, and nitrogen oxide emissions from fuel burning sources are expressed in pounds of emissions per million Btu of heat input ($lb/10^6$ Btu)[1]. The Federal New Source Performance Standards[2] regulating the same pollutants from fossil fuel-fired steam generating units of more than 250 million Btu/hr heat input are expressed in the same terms. To arrive at this expression, the Federal performance standard regulations call for the determination of the pollutant concentration (C), the effluent volumetric flow rate (Q_s), and the heat input rate (Q_H). In addition, the heat input rate must be confirmed by a material balance over the steam generator system.

The purpose of this paper is to present an alternative method for arriving with improved accuracy at the expression of $lb/10^6$ Btu called for by the State and Federal regulations without having to determine effluent gas volumetric flow rate, fuel rate, or fuel heat content.

Derivation of the F-Factor Method

Standard Method

In the standard method of calculating emission rates as published in the Federal Register:[2]

$$E = \frac{C\,Q_s}{Q_H} \qquad (1)$$

where: E = pollutant emission, lb/10^6 Btu.

C = pollutant concentration, dry basis, lb/scfd.

Q_s = dry effluent volumetric flow rate, scfd/hr.

Q_H = heat input rate, 10^6 Btu/hr.

F-Factor Method

When the laws of conservation of mass and energy are applied, the following must hold true:

$$\frac{Q_s}{Q_H}\left(\frac{20.9 - \%\,O_2}{20.9}\right) = \frac{V_s}{HHV} \qquad (2)$$

where: V_s = theoretical dry combustion products per pound of fuel burned, scfd/lb.

HHV = high heating value, 10^6 Btu/lb.

$\frac{20.9 - \%\,O_2}{20.9}$ = excess air correction factor.

Solving Equation 2 for the ratio Q_s/Q_H and substituting into Equation 1 yields:

$$E = C\left(\frac{V_s}{HHV}\right)\left(\frac{20.9}{20.9 - \%\,O_2}\right) \qquad (3)$$

The amount of dry effluent gas (V_s) generated by combustion of a fossil fuel can easily be calculated from the ultimate analysis. The high heating value can be obtained from the proximate analysis. The ratio, F, between V_s and HHV can be calculated for various fossil fuels; F is the effluent gas generated per 10^4 Btu heat content:

$$F = \frac{V_s}{HHV\ (100)} \qquad (4)$$

Values for F calculated from data obtained from the literature are summarized in Table I. Of course, this ratio can be calculated for each specific case, but the dry effluent per 10^4 Btu varies no more than about $\pm$ 3 % within a fuel category. For this reason, these ratios will be considered as constants and will hereafter be called "F Factors." The use of these F Factors, as will be discussed later, eliminates the need for ultimate and proximate analyses. A list of average F Factors derived from Table I is shown in Table II.

Table I

F Factors for Fossil Fuels (Calculated from Data in Literature)

Fuel	Lit. Source	Samples, No.	Avg., scfd/10⁶ Btu[a]	Max. Dev. (+)	Max. Dev. (-)
Coal					
Anthracite	3	3	101.0	2.4	1.2
	4	1	102.8	-	-
Total or avg.		4	101.4	2.0	1.6
Bituminous	3	8	97.5	1.4	1.1
	5	44	97.5	2.1	2.4
	6	38	98.7	1.4	1.2
	7	13	98.9	1.5	1.1
	8	39	98.6	2.3	1.4
	9	26	98.2	2.1	1.2
	10	57	98.0	1.0	1.2
	4	1	99.3	-	-
Lignite	3	1	97.5	-	-
	5	2	99.4	1.0	1.0
Total or avg.		229	98.2	2.7	3.1
Oil					
Crude	11,12	6	91.9	1.9	2.6
	4	1	92.0	-	-
Residuum	12	4	93.1	1.9	2.1
Distillate	12	2	92.7	0.5	1.5
Fuel	11	3	91.5	1.9	1.3
Total or avg.		16	92.2	2.8	3.0
Gas					
Natural	[illegible]	1	[illegible]	-	-
	[illegible]	[illegible]	[illegible]	0.3	0.5
Commercial propane	3	2	[illegible]	0.1	0.1
Commercial butane	[illegible]	[illegible]	[illegible]	0.3	0.3
Total or avg.		9	87.4	2.2	1.2

[a] [illegible]

Table II. Average F Factors[a]

Fuel	F Factors scfd/10^4 Btu[b]
Coal-anthracite	101.4
Coal-bituminous, lignite	98.2
Oil-crude, residumm, distillate, fuel oil	92.2
Gas-natural, butane, propane	87.4

[a]Derived from Table I.

[b]Standard conditions are 70°F, 29.92 in. Hg, and 0 % excess air.

Use of F Factors

Emission Rate Calculation

When Q_S and Q_H are not measured or are unobtainable, F Factors can be used to calculate E. Substituting Equation 4 into Equation 3 we obtain:

$$E = C\ F\ \left(\frac{20.9}{20.9 - \%\ O_2}\right) \quad (5)$$

where: F = F Factor from Table II, in scfd/10^4 Btu.

Equation 5 shows that E can be obtained by simply measuring the pollutant concentration and percentage oxygen and by knowing the type of fuel being burned. Q_s and Q_H are no longer required.

Material Balance Check

If Q_s and Q_H are measured, F Factors can be used to check sampling data by comparing them with F_m, which is calculated as:

$$F_m = \frac{Q_s}{Q_H}\left(\frac{20.9}{20.9 - \%\ O_2}\right) \quad (6)$$

Fuel Analysis Check

If ultimate and proximate analyses are made, F Factors can be used to check the accuracy of such analyses by comparing them with V_s/HHV which is the calculated amount of dry effluent gas generated per 10^4 Btu heat content.

Discussion

In the present method for calculating power plant emission rates, four separate quantities must be determined, each of which requires at least two measurements, as shown in Table III.

Table III
Quantities and Measurements Required
For Calculation of Power Plant
Emission Rates (Regulation Method)

Quantity Used	Quantity Measured
1. Pollutant concentration, C	a. Pollutant mass b. Dry gas volume
2. Effluent volumetric flow rate, Q_s	a. Velocity head b. Stack temperature c. Stack pressure d. Dry gas composition (Orsat) % CO_2, % O_2, % N_2 e. Moisture content (determined [illegible] measurement of [illegible])
3. Heat input rate, Q_H	a. Coal feed rate b. Proximate analysis of coal
4. Material balance confirmation	a. Effluent volumetric flow rate (determined in 2(a-e)) b. Ultimate analysis of c. Excess air (calculated from 2(d))

From Table III, it is obvious that the use of F Factors in calculating E requires fewer measurements than are required by methodology in current use. Because there are fewer measurements, the inaccuracies attendant to measuring items 2 through 4 (except for 2d) are not included in the final results. Granted that those measurements in 2 must be made for isokinetic sampling, but the errors made do not contribute directly to the emission standard calculation.

Conclusion

It has been shown that, for a given type of fuel, a relationship exists between the fuel heat value and dry effluent that permits a constant (F Factor) to be calculated within $\pm$ 3 % deviation.

This implies that: (1) pollutant emissions in lb/10^6 Btu can be easily calculated when only pollutant concentration, O_2 concentration, and fuel type are known, thus eliminating the need for measuring effluent volumetric flow rate and heat input rate; (2) the inconsistencies that arise in measuring the heat input rate are eliminated while at most a maximum error of 3 % may be propagated from the F Factor to the pollutant emission rate; and (3) if effluent volumetric flow rate (Q_s) and heat input rate (Q_H) are measured, an F_m Factor can be calculated from these values and compared with the F Factor as a mass balance check.

In short, use of the F Factor provides a method less complex than the one now employed for calculating power plant emission rates and evaluating the sampling data.

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