

Ohio EPA

Division of Air Pollution Control

Engineering Guide #27

Questions:

- 1) Can the F-factor be used to calculate the boiler heat inputs during stack tests?
- 2) Is the F-factor calculation preferable to the heat balance method for determining the boiler heat inputs during stack tests?

These questions were submitted by Dennis Bush of the Northeast District Office on April 22, 1980.

Answers:

- 1) Yes. It is preferable to determine actual heat input with actual coal (or other solid fuel) flow measurements demonstrating an accuracy of + or - 1%; however, if fuel flow measurements and accuracy cannot be verified, use of the F-factor or heat balance methods are suitable alternatives for the determination of boiler heat inputs.
- 2) Yes. The F-factor calculation has demonstrated more reliable accuracy than the heat balance method, although both rely on assumptions.

Background information and discussion:

F-factor:

The following F-factor equations can be used in the determination of boiler heat inputs during stack tests. Each equation has inherent assumptions which may bias results. The F-factor must be determined prior to calculation of actual heat input. If determination is required during an actual stack test, assumptions must be made regarding fuel heat content during the stack test.

Equation 1(A) - determination of F-factor:

$$F = \frac{10^6 [3.64 (\%H) + 1.53 (\%C) + 0.57 (\%S) + 0.14 (\%N) - 0.46 (\%O)]}{GCV}$$

Where,

%H, %C, %S, %N, and %O = weight percent (dry basis) of each element as obtained from the ultimate fuel analysis

GCV = gross calorific value of fuel (Btu/lb, dry basis), and

F = F-factor (dscf/mmBtu)

Once the F-factor value has been determined, it can be used to determine heat input using the following equation:

Equation 1(B) - heat input:

$$\text{Heat input (mmBtu/hr)} = \frac{Q_s}{F \times \left(1 + \frac{[\%O_2 - 0.5 (\%CO)]}{[0.264 (\%N_2) - (\%O_2) + 0.5 (\%CO)]} \right)}$$

Where,

Q_s = stack volumetric flow rate from actual measurements (dscf/hr), and

%O₂, %N₂, and %CO = volume % of each (dry basis) measured at the same location that the velocity measurements for the calculation of Q_s were made

Equation 1(A) is a stoichiometric representation of the products of combustion in terms of dscf/mmBtu. There is an assumption made that the measured stack gas volume and the theoretical stack gas volume are identical because all fuel constituents are ideally combusted and excess air volume is accounted for. In actuality, a portion of the carbon remains in the ash, especially in stoker-fired boilers. Therefore the F-factor term overestimates the gaseous volume produced, based on theoretical complete combustion.

In addition, if the Q_s term of equation 1(B) is measured accurately, the result will be a low bias of the heat input value due to the assumptions made about complete combustion in equation 1(A). In reality the methodology used in determining Q_s inherently biases flow rates high due to the aerodynamic design and nature of the tool used to determine volumetric flow in the stack, the pitot tube. A higher Q_s term will result in an overestimation of boiler heat inputs using equation 1(B).

An overestimate of flow rate coupled with an overestimate of F-factor results in a slight overestimate of boiler heat input using these equations.

Heat balance:

Equation 2 – heat input:

Heat input (Btu input /hour) = Qms x Mms

Where,

$$Qms = \frac{(Hms - Hfw)}{e} \times 100$$

- Hfw = feedwater enthalpy at Tfw and Pfw, Btu/lb
- Tfw = feedwater temperature, °F
- Pfw = feedwater pressure, psig
- Hms = main steam enthalpy at Tms and Pms, Btu/lb
- Tms = main steam temperature, °F
- Pms = main steam pressure, psig
- Mms = main steam flow, lbs/hr , and
- e = boiler design efficiency, %

The heat balance determination of heat input involves the incorporation of some estimates and assumptions. The estimates include boiler efficiency, steam temperature, feedwater temperature, and pressure measurements, in addition to steam flow rate. The boiler efficiency rate may be outdated or unsupported. An average efficiency based on fuel acquisition records and steam flow rate may be estimated. In addition, the manufacturer's rated efficiency may be used. Calculation of heat input by heat balance provides an additional cross check of the F-factor calculated value.

If a discrepancy greater than 10% exists between the F-factor calculation vs. the heat balance method, check for errors in the terms. If no errors are detected, the higher of the heat input values should be used or the actual heat input should be calculated using fuel flow rate. Accurate fuel flow rate measurement is preferable to the F-factor or heat balance means of heat input determination. Alternatively, F-factor and accurate stack gas flow rate determinations yield more accurate heat input determinations than those made from estimates or possible unknown values used in the heat balance methods. (It should be noted that State of Ohio permit terms often specify emission limits in terms of actual heat input.)

Emission calculations based on F-factor determinations:

Emission rate determinations can be performed using F-factor data. The F-factor calculation can vary depending on test conditions and other real-time test data. The following is one available version of the F-factor derived emission rate calculation:

Equation 3 – emission rate:

$$E = (C) (F) \times \frac{20.9}{(20.9 - \%O_2)}$$

Where,

E = emission rate, lbs/mmBtu
C = concentration, lbs/dscf (dry basis)
F = F-factor, dscf/mmBtu (dry basis), and
%O₂ = volume percent O₂, dry basis, measured where C was determined

Alternative F-factor equations are available in US EPA Method 19. These equations vary in terms such as wet vs. dry concentration determinations and O₂ vs. CO₂ F-factor determination. These equations are not dependent upon fuel flow rates or stack volumetric flow rate measurements. Determining which equation to use will depend on some test-specific parameters. These equations may slightly overestimate actual emissions as explained earlier regarding equation 1(A). It is possible to adjust the F-factor to account for the carbon losses. A carbon loss of 0-5% has been determined to result in biasing emissions by only 0-3%. F-factor adjustment based on carbon loss is generally not practiced due to the minimal bias effect.

In summary, basing heat input rates upon accurate fuel mass flow rate data is preferable to heat input calculated from F-factor or boiler heat balance methods. If confidence can be placed in the stack gas volumetric flow rate data, the heat input calculated from the F-factor and the stack gas flow rate will likely be more accurate than a heat input calculated from the heat balance method utilizing an unsupported or outdated boiler efficiency. It will be necessary in certain cases to calculate heat input by several methods. Only after a careful evaluation of heat input values and the variables involved, will the “best” estimate of heat input be obtained.

JH/JO/JC

Reference: Summary of F-Factor Methods for Determining Emissions from Combustion Sources, R. T. Shigehara and R. M. Neulicht, OAQPS, USEPA, July 1976.

(June 9, 1981; reviewed and revised December 26, 2008)