HOW TO FIGURE BITUMINOUS-COAL COMBUSTION QUICKLY

1. Kind of fuel	Bituminous coal
2. Heating value as fired	13,800 Btu per lb
3. Room temperature	80 F
4. Flue-gas temperature	530 F
5. Flue-gas analysis:	
a. CO_2	10.2%
b. CO	0.6%
c. O_2	9.2%
6. Boiler efficiency (from test)	76.4%
COMPUTATIONS:	
7. Theoretical air, from scale 1	10.2 lb per lb fuel
8. Water produced by burning available hydrogen (scale 2)	0.35 lb per lb fuel
9. Total water from burning of coal = 0.35 + 0.05	= 0.40 lb per lb fuel
10. Actual air = 175% of theoretical = 1.75 × 10.2	= 17.9 lb per lb fuel
11. Total flue gas = air + coal − ashes = 17.9 + 1 − 0.2	= 18.7 lb per lb fuel
12. Dry flue gas = total flue gas − water produced = 18.7 − 0.40	= 18.3 lb per lb fuel
13. Sensible heat loss in dry gas = Dry gas weight × temperature rise × specific heat = 18.3 × (530−90) × 0.24	= 1930 Btu per lb fuel
14. Moisture heat loss per lb water = 1000 + ½ flue gas temperature − 1000 + 265	= 1265 Btu
15. Moisture heat loss = loss per lb water × lb water per lb coal = 1265 × 0.4	= 500 Btu per lb fuel
16. Incomplete-combustion loss, from chart 4	2.5%
17. Heat balance	Btu per lb fuel
a. Dry-gas loss	1,930
b. Moisture loss	500
c. Incomplete-combustion loss	440
d. Unaccounted-for losses	660
e. Total losses	3,530
f. Useful heat	10,270
g. Heating value, Btu per lb fuel	13,800
18. Calculation of heat balance items:	
a. Dry-gas loss = 1930/13,800	= 14.0%
b. Moisture loss = 500/13,800	= 3.6%
c. Incomplete combustion loss = 13,800 × 0.032	= 440 Btu per lb fuel
d. Unaccounted losses = 2530 − 440 − 500 − 1930	= 660 Btu per lb fuel
e. Useful heat = 13,800 × 0.744	= 10,270 Btu per lb

Short-cut Combustion Calculations

Every textbook on steam power plants has a complete demonstration *on the calculation of fuel combustion.* Such an exhibit usually assumes that complete fuel, flue-gas and refuse analyses are available. But many plants, especially in the smaller capacities, do not have such complete information and cannot justify the *money needed to determine it. Nevertheless,* to operate economically these plants should closely follow their combustion performance because it is at this point that efficiency can be made or broken.

Assuming that such a plant has instruments for analyzing flue-gas composition and measuring flue-gas temperature the method described here suffices to tell the operator whether his combustion conditions are proceeding satisfactorily or not. While the method is approximate, numerous checks have shown the results to be within 2% of those found by using the longer, complete methods. The operator must know his fuel type and its heating value in Btu per pound *as fired.* The *fuel supplier can normally give this* information with satisfactory accuracy.

Scales and charts forming the basis of this computing method are given on the facing page. Their use is demonstrated in the table above for a given set of data using bituminous coal as the fuel. Let's follow through on this table, item by item, to find out how the calculations are made.

Items 1 to 6 are the data that must be known as mentioned above. The boiler efficiency should preferably be known by test, but a guaranteed efficiency using the same fuel will do if test results are not available.

Item 7. Scale 1 under the appropriate fuel classification on the facing page gives the theoretical air requirement *when the fuel heating value is known.* In this computation method, note that all weights are given in pounds per pound of fuel as fired.

Item 8. Water in the flue gas originates from three sources: (1) water originally in the coal (2) water produced *by the burning of available hy*drogen in the fuel (3) moisture in the air supplied for combustion. Of these we shall figure only (2), which is five to ten times as much as the amount appearing in (1). We do not attempt to figure the value of (3) because it is very small and its variation unimportant from the angle of everyday operation. *Item 8* is found by using Scale 2 for the appropriate fuel.

Item 9. Since original moisture in coal is unknown we assume it to be 0.05 lb per lb of fuel. Any error in this assumption will be of little practical importance in figuring moisture heat loss later, except with lignite, wood and very wet coals.

Item 10. First add CO_2 and ½CO to find $10.2+\frac{1}{2}(0.6)=10.5$. *Use this value* with Scale 3 for bituminous coal and read 75% excess air. On the lower scale it will be found that 9.0% O_2 corresponds to 75% excess air. This figure should be close to the O_2 value found by flue-gas analysis, which in this case was 9.2%. This is close enough to indicate a consistent gas analysis. If the CO_2 only should be known and the CO believed to be zero or negligible, enter Scale 3 with the CO_2 value to get the excess air magnitude.

Item 11. Practically speaking, everything fed to the furnace ultimately goes up the stack or into the ashpit. Then, to get the total weight of flue gas (per lb of coal fired) add 1 lb (of coal) to the air supplied and subtract the refuse produced *per lb of coal. The refuse* generally contains the original ash in the coal and perhaps some unburned carbon. Hence the amount of refuse is always greater or at least equal to the original ash weight in the coal, unless some ash is lost up the stack. Fortunately *the refuse correction for the flue* gas is not important. An error of 50% in the refuse allowance usually affects the total flue gas less than 1%. For practical purposes it is close enough (for any bituminous or anthracite coal) to assume 0.2 lb refuse *for this calculation.*

Item 12. Dry gas and water vapor in the flue gas must be separated to calculate the amount of heat energy *carried off by each.*

Item 13. Largest loss in boiler furnaces is the heat energy carried off by the dry gas. It is proportional to the amount of dry gas and the number of degrees above room temperature to which it is heated. These Btu loss figures are rounded off to the nearest 10 Btu. The method does not warrant closer figuring.

Item 14. Water in the coal as fired and the water produced by burning the fuel's available hydrogen must be heated to the boiling point, evaporated and then superheated to the flue-gas temperature. The formula given calculates the heat approximately needed to put 1 lb of water through these heating steps, starting with room temperature of 80 F. The formula is also suitable for room temperature ranging from 60 to 100 F.

Item 15. The previous step calculated the heat energy per lb of water this formula corrects this figure to heat

SCALES AND CHART FOR COMBUSTION PERFORMANCE ESTIMATE

