TABLE 9. APPROXIMATE MAXIMUM THEORETICAL CO_2 VALUES, AND CO_2 VALUES FOR VARIOUS FUELS WITH DIFFERENT PERCENTAGES OF EXCESS AIR

TYPE OF FUEL	MAXIMUM THEORETICAL OR ULTIMATE PERCENT CO_2	PERCENT CO_2 AT GIVEN EXCESS AIR VALUES		
		20%	40%	60%
Coke	21.0	17.5	15.0	13.0
Anthracite	20.2	16.8	14.4	12.6
Bituminous Coal	18.2	15.1	12.9	11.3
No. 1 and 2 Fuel Oil	15.0	12.3	10.5	9.1
No. 6 Fuel Oil	16.5	13.6	11.6	10.1
Natural Gas	12.1	9.9	8.4	7.3
Carburetted Water Gas	17.2	14.2	12.1	10.6
Coke Oven Gas	11.2	9.2	7.8	6.8
Mixed Gas (Natural and Carburetted Water Gas)	15.3	12.5	10.5	9.1
Propane Gas (Commercial)	13.9	11.4	9.6	8.4
Butane Gas (Commercial)	14.1	11.6	9.8	8.5

a *heat balance*. Various components of this balance are generally expressed in terms of Btu per pound of fuel burned, or as a percentage of its calorific value. Components of special interest are listed as items 1 to 7 inclusive.

1. Useful heat transferred to heating medium, usually computed by determining the rate of flow of the heating fluid through the heating device, and the change in enthalpy of the fluid (heat added) between the inlet and outlet.

2. Heat loss in the dry chimney gases.

$$h_1 = w_g c_p (t_g - t_a) \tag{12}$$

3. Heat loss in water vapor formed by the combustion of hydrogen.

$$h_2 = \frac{9H_2}{100}(1089 - t_a + 0.455\, t_g) \tag{13}$$

4. Heat loss in water vapor in the air supplied for combustion.

$$h_3 = 0.455\, M\, w_a (t_g - t_a) \tag{14}$$

5. Heat loss from incomplete combustion.

$$h_4 = 10143\, C\left(\frac{CO}{CO_2 + CO}\right) \tag{15}$$

6. Heat loss from unburned carbon in the ash or refuse.

$$h_5 = 14600^*\left(\frac{C_u}{100} - C\right) \tag{16}$$

7. Radiation and all other unaccounted for losses.

Radiation and convection losses from a heating appliance are not usually determined by direct measurement. For this reason they, together with any other losses not measured, are determined by subtracting the total of items 1 to 6 from the heat of combustion of the fuel. If the heating appliance is located within the heated space, however, radiation and convection losses may be considered as useful heat rather than lost heat. They may, therefore, be omitted from calculations of heat losses, or added to item 1. If there is CO in the flue gases, small amounts of unburned hydrogen and hydrocarbons will probably also be present. The small loses due to incomplete combustion of these latter gases would also be included in item 7.

* A value of 14600 applies in calculating ash pit loss; in calculating heat of formation of carbon compounds use 14093 Btu per lb.

Symbols used in Equations 12 to 16 inclusive are:

h_1 = heat loss in the dry chimney gases, Btu per pound of fuel.
h_2 = heat loss in water vapor from combustion of hydrogen, Btu per pound of fuel.
h_3 = heat loss in water vapor in combustion air, Btu per pound of fuel.
h_4 = heat loss from incomplete combustion of carbon, Btu per pound of fuel.
h_5 = heat loss from unburned carbon in the ash, Btu per pound of fuel.
w_g = weight of dry flue gas per pound of fuel (from Equation 10), pounds.
c_p = mean specific heat of flue gases at constant pressure (c_p ranges from 0.242 to 0.254 for flue gas temperatures from 300 F to 1000 F)[2], Btu per pound.
t_g = temperature of flue gases at exit of heating device, Fahrenheit.
t_a = temperature of combustion air, Fahrenheit.
H_2 = percentage of hydrogen in fuel by weight from ultimate analysis of fuel burned.
1091.8 = enthalpy of saturated water vapor at a temperature of 70 F, Btu per pound.
M = humidity ratio of combustion air, pounds of water vapor per pound of dry air.
w_a = weight of combustion air per pound of fuel used, pounds, from Equations 2, 4, 5, 6, 7 and 8.
CO, CO_2 = percentages of CO, CO_2 in flue gases by volume.
C = weight of carbon burned per pound of fuel corrected for carbon in ash, pounds.

$$C = \frac{WC_u - W_a C_a}{100W} \tag{17}$$

where

C_u = percentage of carbon in the fuel by weight from the ultimate analysis.
W_a = weight of ash and refuse, pounds.
C_a = percent of combustible in ash by weight (combustible in ash is usually considered to be carbon).
W = weight of fuel used, pounds.

Flue gas losses for solid and liquid fuels, listed as items 2, 3 and 4 of the heat balance, may be determined with sufficient precision for most purposes from curves shown in Fig. 6[2], if CO_2 content and temperature of flue gases are known. Values of the losses plotted for fuel oil were computed from the ultimate analysis of a typical fuel oil used in domestic burners, while those presented for the several ranks of coal were computed from the typical ultimate analyses shown in Table 1. The curves for medium volatile bituminous coal may be used for high volatile bituminous coal with negligible error.

Utilization of gaseous fuels, for numerous reasons, is generally a more simple process than is the case with either solid or liquid fuels. Accordingly, the determination of a practical heat balance is also a more simple procedure in that items 5 and 6 do not generally apply to gas installations. A series of typical alignment charts has been combined in Fig. 7 for use in determining flue losses of items 2, 3 and 4 from common types of gas burning appliances. To determine flue losses place a straight edge extending from the corrected temperature reading to the percent CO_2 recorded. Percent flue loss is indicated where the straight edge interesects the flue loss column.