The operating efficiency of a gas appliance can then be computed with sufficient precision by application of Equation 18.

$$\text{Percent Combustion Efficiency} = \frac{\left(\begin{matrix}\text{Gross Btu of fuel}\\ \text{gas per cubic foot}\end{matrix}\right) - \left(\begin{matrix}\text{total flue losses per}\\ \text{cubic foot fuel gas)}\end{matrix}\right)}{\text{Gross Btu of fuel gas per cubic foot}} \times 100 \quad (18)$$

Reference to Table 9 will show that ultimate CO_2 percentage values of fuel gases vary. While personal errors involved in CO_2, temperature, and chart determinations, would doubtless more than offset any inaccuracies due to universal use of the alignment charts shown, precise laboratory work may require a more exact method. For more complete information the reader is referred to *Combustion*, 3rd Edition, and *Gaseous Fuels*, (published by *American Gas Association*) and particularly to tables covering various properties of different commercial gases included in these publications.

CONDENSATION AND CORROSION

Sulfur dioxide or sulfur trioxide, formed by the combustion of sulfur in fuels, are the principal corroding substances in flue gases. They become active whenever sufficient moisture is present for the formation of sulfurous or sulfuric acid,[22] and they lower the dew points of flue gases appreciably. Therefore, unless heating equipment is designed for operation at flue gas temperatures below the dewpoint, which is seldom the case, it is always advisable to maintain temperatures above this value in all parts of the appliance. Excessive spot temperatures in the combustion chamber or elsewhere, on the other hand, are also destructive in that they may result in rapid oxidation of ordinary heating surfaces. *American Standard Requirements* for gas furnaces, floor furnaces, and recessed heaters, for example, specify that minimum spot heating surface temperatures during normal operation must neither fall below 178 F (50 F above average dewpoint) nor exceed 875 F on any portion of the heating surface. In any event, it is usually desirable to maintain flue temperatures within the limits indicated not only throughout the appliance, but in its connecting vent, flue, or chimney as well. Otherwise, excessive condensation and corrosion problems, with resultant customer dissatisfaction, will in all probability be the result. Average dewpoint temperatures of flue gases resulting from the combustion of various fuels, when burned with the amount of excess air normally supplied to insure complete combustion, are shown in Table 10.

SOOT

The deposit of soot on the flue surfaces of a boiler or heater acts as an insulating layer over the surface, and reduces the heat transmission to the water or air. The *Bureau of Mines Report of Investigations* No. 3272[23] shows that the loss of seasonal efficiency is not so great as has been believed, and usually is not over 6 percent because the greater part of the heat is transmitted through the combustion chamber surfaces. The *Bureau of Standards Report* BMS 54[24] points out that, although the decrease in efficiency of an oil fired boiler, due to soot deposits, is relatively small, the attendant increase in stack temperature may be considerable.

The soot accumulation clogs the flues, reduces the draft, and may prevent proper combustion. Soot can probably be most effectively removed by a jet of compressed air, by means of a brush, or a vacuum cleaner. However, it has been found that copper chloride, lead chloride, tin chloride, zinc chloride, common salt and some other salts are partially effective in

TABLE 10. AVERAGE FLUE GAS DEW-POINT FOR VARIOUS FUELS[6]

TYPE OF FUEL	AVERAGE DEW-POINT TEMPERATURE, F
Anthracite	68
Semi-Bituminous Coal	84
Bituminous Coal	93
Oil	111
Natural Gas	127
Manufactured Gas	137
Propane Gas (2500 Btu/cu ft)	119
Butane Gas (3200 Btu/cu ft)	124
Butane-Air Gas Mixture (535 Btu/cu ft	121

removing soot from furnaces and boilers when properly used.[25] A discussion of instruments and methods of evaluating smoke will be found in Chapter 52.

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