

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

Percent Combustion Efficiency =

$$\frac{\left(\frac{\text{Gross Btu of fuel}}{\text{gas per cubic foot}} \right) - \left(\frac{\text{total flue losses per}}{\text{cubic foot fuel gas}} \right)}{\text{Gross Btu of fuel gas per cubic foot}} \times 100 \quad (18)$$

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. 3272²³ 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 54²⁴ 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 FUELS¹

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 51.

REFERENCES

- ¹ Five Hundred Tests of Various Coals in Househeating Boilers (U. S. Bureau of Mines Bulletin No. 276).
- ² Combustion Efficiencies as Related to Performance of Domestic Heating Plants, by A. P. Kratz, S. Kōnzo and D. W. Thompson (University of Illinois, Engineering Experiment Station Circular No. 44).
- ³ Quality of Anthracite as Prepared at Breakers, 1935 (U. S. Bureau of Mines Report of Investigation, R. I. 3283).
- ⁴ Hand Firing Soft Coal Under Power Plant Boilers (U. S. Bureau of Mines Technical Paper No. 80).
- ⁵ Combustion Flames and Explosions of Gases. Lewis and von Elbe (Cambridge University Press, 1938).
- ⁶ Oil Burning, by H. A. Romp (Martinus Nijhoff, 1937).
- ⁷ ASTM Test Designation D287-39.
- ⁸ ASTM Test Designation D611-43T.
- ⁹ Tomorrow's Fuel Oil, by W. A. Sullivan and E. B. Glendenning (Fueloil and Oil Heat, Vol. 4, No. 1, May 1945 p. 36).
- ¹⁰ The Correlation of Cetane Number with Other Physical Properties of Diesel Fuels (Journal of the Institute of Petroleum, Vol. 30, 1944, p. 193-197).
- ¹¹ Characterization of Petroleum Fractions, by K. M. Watson, E. F. Nelson and G. B. Murphy (Industrial and Engineering Chemistry, Vol. 27, Dec. 1935, p. 1464).
- ¹² Burning Index for Distillates, by J. C. Reid and A. B. Hersberger. Fueloil and Oil Heat, Vol. 5, No. 9, Jan. 1947, p. 90).
- ¹³ Carbon Hydrogen Ratio of Catalytically Cracked Distillate Fuel Oils, by S. P. Cauley and E. B. Delgass (The Oil and Gas Journal, Vol. 45, No. 12 July 27, 1946, p. 166).
- ¹⁴ Rating of Fuel Oils by a Test Unit, by D. W. Locklin and G. V. Parmelee (ASHVE TRANSACTIONS, Vol. 57, 1951, p. 139).
- ¹⁵ Gaseous Fuels (American Gas Association, 1948, p. 32).
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- ¹⁷ Tentative Methods of Test for Specific Gravity of Gaseous Fuels (American Society for Testing Materials, ASTM Designation: 1070-49).
- ¹⁸ Standard Method of Test for Calorific Value of Gaseous Fuels by the Water-Flow Calorimeter (American Society for Testing Materials, ASTM Designation: 900-48).
- ¹⁹ American Standard for Installation of Gas Piping and Gas Appliances in Buildings. ASA Z 21.30 1950 (American Gas Association).
- ²⁰ NBFU Standard for the Installation of Oil Burning Equipments—NBFU pamphlet no. 31 (National Board of Fire Underwriters).
- ²¹ Domestic Gas Range Research (American Gas Association Laboratories Bulletin 7, p. 64).