as Affected by Solar Radiation, by F. C. Houghten, E. C. Hach, S. I. Taimuty and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 48, 1942, p. 91).

[11] Solar Heat Gain Through Walls and Roofs for Cooling Load Calculations, by J. P. Stewart (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, August 1948, p. 121).

[12] A.S.H.V.E. RESEARCH REPORT No. 1281—The Transmission of Solar Radiation Through Flat Glass Under Summer Conditions, by G. V. Parmelee (A.S.H.V.E. TRANSACTIONS, Vol. 51, 1945, p. 317).

[13] A.S.H.V.E. RESEARCH REPORT No. 1147—Heat Gain Through Glass Blocks by Solar Radiation and Transmittance, by F. C. Houghten, David Shore, H. T. Olson and Burt Gunst (A.S.H.V.E. TRANSACTIONS, Vol. 46, 1940, p. 83).

[14] A.S.H.V.E. RESEARCH REPORT No. 975—Studies of Solar Radiation Through Bare and Shaded Windows, by F. C. Houghten, Carl Gutberlet, and J. L. Blackshaw (A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934, p. 101). A.S.H.V.E. RESEARCH REPORT No. 1180—Heat Gain Through Western Windows With and Without Shading, by F. C. Houghten and David Shore (A.S.H.V.E. TRANSACTIONS, Vol. 47, 1941, p. 251).

[15] The Mechanism of Heat Transfer Panel Cooling Heat Storage, by C. S. Leopold (*Refrigerating Engineering*, July 1947, p. 33; and same title, Part II, by C. S. Leopold, *Refrigerating Engineering*, June 1948, p. 571). Hydraulic Analogue for the Solution of Problems of Thermal Storage, Radiation, Convection and Conduction, by C. S. Leopold (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping & Air Conditioning*, July, 1948, p. 105).

[16] See Reference 1, p. 8.

[17] Cooler Footcandles for Air Conditioning, by W. G. Darley (A.S.H.V.E. TRANSACTIONS, Vol. 46, 1940, p. 367). Lighting and Air Conditioning Design Factors, Report of *I.E.S.*—A.S.H.V.E. Joint Committee on Lighting in Air Conditioning (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, September, 1941. p. 605). Lighting and Air Conditioning, by Howard M. Sharp (*Heating and Ventilating*, November, 1942, p. 35).

[18] Compiled by J. P. Stewart from various sources.

CHAPTER 13

FUELS AND COMBUSTION

Classification of Coals, Cokes, Fuel Oils, and Gases, Dustless Treatment of Coal, Fundamental Principles of Combustion, Heat of Combustion, Air Required for Combustion, Excess Air, Heat Balance, Firing Methods, Secondary Air, Draft Requirements, Draft Regulation, Furnace Volume, Combustion of Gas, Soot, Condensation and Corrosion

FUELS may be classified according to their physical state as solid, liquid, or gaseous. The principal fuels used for domestic heating are coal, oil, and gas. However, coke, wood, kerosene, sawdust, briquettes, and other substances are used for heating in special applications or in localities where an adequate supply is available. Experiments are in progress in the use of a colloidal suspension of coal particles in fuel oil, but this fuel has not attained wide-spread usage as yet. The choice of fuel is usually based on dependability, cleanliness, availability, economy, operating requirements, and control.

CLASSIFICATION OF COALS

Coal has a complex composition that makes classification into clear-cut types difficult. Chemically it consists of carbon, hydrogen, oxygen, nitrogen, sulfur, and a mineral residue called ash. A chemical analysis provides some indication of the quality of a coal, but does not define its burning characteristics sufficiently. The coal user is interested principally in the available heat per pound of coal, in the handling and storing properties, the amount of ash and dust produced and the burning characteristics. A description of the relationship between the qualities of coals and these characteristics requires considerable space; a treatment applicable to heating boilers is given in a Bureau of Mines Bulletin.[1]

There are two forms of coal analyses, namely, the *proximate analysis* and the *ultimate analysis*. In the *proximate analysis* the proportions of moisture, volatile matter, fixed carbon, sulfur, and ash are determined. This analysis is more easily made and is satisfactory for indicating most of the characteristics which are of interest to the user. For the proximate analysis the moisture is determined by observing the loss of weight of a sample of coal when dried at about 220 F. To determine the volatile matter, the dried sample is heated to about 1750 F in a closed crucible, and the loss of weight is noted. The remaining sample is then burned in an open crucible, and the accompanying loss of weight represents the fixed carbon. The unburned residue is ash. Although determined separately, the sulfur content is frequently reported with the proximate analysis because the usefulness of a coal for certain purposes depends on its sulfur content.

In the *ultimate analysis*, which is difficult to make, the percentages of carbon, hydrogen, oxygen, nitrogen, sulfur, and ash in the coal sample are determined. It is used for detailed studies of fuels, and in computing a heat balance when required in testing of heating devices. Typical ultimate analyses of the various kinds of coal are shown in Table 1.[2]

Other important qualities of coals are the screen sizes, ash fusion temperature, friability, caking tendency, and the qualities of the volatile