BIBLIOGRAPHY

F. C. Houghten and Carl Gutberlet: Heat emission from iron and copper pipe (ASHVE TRANSACTIONS, Vol. 39, 1933, p. 97).

Heat Transmission from Surfaces (Philip Carey Mfg. Co., Bulletin 102-A).

R. H. Heilman: Surface heat transmission (Sec. 1, *Mechanical Engineering*, May 1929, p. 355).

S. Crocker: *Piping Handbook* (McGraw-Hill Book Co., New York, 1945, 4th ed.).

P. Swain: Insulation handbook (*Power*, Vol. 94, Nos. 2, 3, 5, 7, and 9, 1950).

U. W. Smith: How to insulate equipment (*Plant Engineering*, Vol. 1, December 1947, p. 32).

T. S. Nickerson and G. M. Dusinberre: Heat transfer through thick insulation on cylindrical enclosures (*ASME Transactions*, Vol. 70, 1948, p. 903).

H. J. Stoever: *Applied Heat Transmission* (McGraw-Hill Book Co., New York, 1941).

CHAPTER 33

FUELS AND COMBUSTION

Solid Fuels: Analysis, Classification of Coals, Classification of Cokes, Combustion of Solid Fuels, Firing Methods for Solid Fuels, Secondary Air, Draft Requirements and Regulations, Furnace Volume; Fuel Oils: Classification, Air Required; Fuel Gases: Classification, Heat Value, Combustion; General Combustion Principles; Air Required; Efficiency from Flue Gas Analysis; Heat Balance; Condensation and Corrosion; Soot; Air Supply to Furnace Rooms

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, kerosine, 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 widespread usage as yet. The choice of fuel is usually based on dependability, cleanliness, availability, economy, operating requirements, and control.

SOLID FUELS

Analysis of Fuels

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, the handling and storing properties, the amount of ash and dust produced, and the burning characteristics. A description of the qualities of coals and their characteristics can best be obtained from publications of the U. S. Bureau of Mines. A treatment applicable to heating boilers is given in a U. S. Bureau of Mines bulletin.[1]

There are two types 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 quite 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 matter. In considering these factors the following points are of interest. The volatile products given off by coals when they are heated differ materially in the ratios by weight of the gases to the oils and tars. No heavy oils or tars are given off by anthracite, and very small quantities are given off by semi-anthracite. As the volatile matter in the coal increases to as much as 40 percent of ash and moisture-free coal, increasing amounts of oils and tars are released. For coals of higher volatile content, the relative quantity of oils and tars decreases and is therefore low in the sub-bituminous coals and in lignite. The percentage of ash and its fusion temperature do not indicate the composition or distribution of the constituents.

Classification of Coals

A classification of coals is given in Table 2, and a brief description of the kinds of fuel is given in the following paragraphs, but it should be recognized that there are no distinct lines of demarcation between the kinds, and that they graduate into each other.

Anthracite is a clean, dense, hard coal which creates little dust in handling. It is comparatively hard to ignite, but it burns freely when well started. It is non-caking, it burns uniformly and smokelessly with a short flame, and it requires no attention to the fuel bed between firings.[3] Standard anthracite sizing specifications are shown in Table 3.

Semi-anthracite has a higher volatile content than anthracite. It is not so hard, and ignites somewhat more easily. Otherwise their properties are similar.

Semi-bituminous coal is soft and friable, and fines and dust are created by handling it. It ignites somewhat slowly and burns with a medium length of flame. Its caking properties increase as the volatile matter increases, but the coke formed is relatively weak. Having only half the volatile matter content of the bituminous coals, it can be burned with less production of smoke, and is sometimes called a *smokeless coal*.

Bituminous coal is a term covering a large range of coals and includes many types having distinctly different composition, properties, and burning characteristics. The coals range from the high-grade bituminous coals of the East to the poorer coals of the West. Their caking properties range from coals which melt completely, to those from which the volatiles and tars are distilled without change of form, so that they are classed as non-caking or free-burning. Most bituminous coals are strong and non-friable enough to permit the screened sizes being delivered free from fines. In general, they ignite easily and burn freely. The length of flame varies with different coals, but it is long. Much smoke and