

easily and burn freely; the length of flame varies with different coals, but it is long. Much smoke and soot are possible especially at low rates of burning.

Sub-bituminous coals occur in the western states; they are high in moisture when mined and tend to break up as they dry or when exposed to the weather; they are liable to ignite spontaneously when piled or stored. They ignite easily and quickly and have a medium length flame, are non-caking and free-burning; the lumps tend to break into small pieces if poked; very little smoke and soot are formed.

Lignite is of woody structure, very high in moisture as mined, and of low heating value; it is clean to handle. It has a greater tendency than the sub-bituminous coals to disintegrate as it dries, and it also is more liable to spontaneous ignition. Freshly mined lignite, because of its high moisture, ignites slowly. It is non-caking. The char left after the moisture and volatile matter are driven off burns very easily, like charcoal. The lumps tend to break up in the fuel bed and pieces of char falling into the ash pit continue to burn. Very little smoke or soot is formed.

Coke is produced by the distillation of the volatile matter from coal. The type of coke depends on the coal or mixture of coals used, the temperatures and time of distillation and, to some extent, on the type of retort or oven; coke is also produced as a residue from the destructive distillation of oil.

TABLE 1. CLASSIFICATION OF COALS BY RANK¹

Legend: F.C. = Fixed Carbon. V.M. = Volatile Matter. Btu = British thermal units.

CLASS	GROUP	LIMITS OF FIXED CARBON OR BTU MINERAL-MATTER-FREE BASIS	REQUISITE PHYSICAL PROPERTIES
I. Anthracite	1. Meta-anthracite	Dry F.C., 98 per cent or more (Dry V.M., 2 per cent or less)	Non-agglutinating*
	2. Anthracite	Dry F.C., 92 per cent or more and less than 98 per cent (Dry V.M., 8 per cent or less and more than 2 per cent)	
	3. Semi-anthracite	Dry F.C., 86 per cent or more and less than 92 per cent (Dry V.M., 14 per cent or less and more than 8 per cent)	
II. Bituminous	1. Low volatile bituminous coal	Dry F.C., 77 per cent or more and less than 86 per cent (Dry V.M., 23 per cent or less and more than 14 per cent)	Either agglutinating or non-weathering
	2. Medium volatile bituminous coal	Dry F.C., 69 per cent or more and less than 77 per cent (Dry V.M., 31 per cent or less and more than 23 per cent)	
	3. High volatile A bituminous coal	Dry F.C., less than 69 per cent (Dry V.M., more than 31 per cent); and moist ² Btu, 14,000 ⁴ or more	
	4. High volatile B bituminous coal	Moist ² Btu, 13,000 or more and less than 14,000 ⁴	
	5. High volatile C bituminous coal	Moist Btu, 11,000 or more and less than 13,000 ⁴	
III. Sub-bituminous	1. Sub-bituminous A coal	Moist Btu, 11,000 or more and less than 13,000 ⁴	Both weathering and non-agglutinating
	2. Sub-bituminous B coal	Moist Btu 9500 or more and less than 11,000 ⁴	
	3. Sub-bituminous C coal	Moist Btu 8300 or more and less than 9500 ⁴	
IV. Lignite	1. Lignite	Moist Btu less than 8300	Consolidated Unconsolidated
	2. Brown coal	Moist Btu less than 8300	

*If agglutinating, classify in low-volatile group of the bituminous class.

²Moist Btu refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

³Pending the report of the Subcommittee on Origin and Composition and Methods of Analysis, it is recognized that there may be non-caking varieties in each group of the bituminous class.

⁴Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

⁵There are three varieties of coal in the High-volatile C bituminous coal group, namely, Variety 1, agglutinating and non-weathering; Variety 2, agglutinating and weathering; Variety 3, non-agglutinating and non-weathering.

⁶Adapted from A.S.T.M. Standards on Coal and Coke, p. 68, American Society for Testing Materials, Philadelphia, 1934.

High-temperature cokes. Coke as usually available is of the high-temperature type, and contains between 1 and 2 per cent volatile matter. High-temperature cokes are subdivided into *beehive coke* of which comparatively little is now sold for domestic use, *by-product coke*, which covers the greater part of the coke sold, and *gas-house coke*. The differences among these three cokes are relatively small; their denseness and hardness decrease and friability increases in the order named. In general, the lighter and more friable cokes ignite and burn the more easily.

Low-temperature cokes are produced at low coking temperatures, and only a portion of the volatile matter is distilled off. Cokes as made by various processes under development have contained from 10 to 15 per cent volatile matter. In general, these cokes ignite and burn more readily than high-temperature cokes. The properties of various low-temperature cokes may differ more than those of the various high-temperature cokes because of the differences in the quantities of volatile matter and because some may be light and others briquetted.

The sale of *petroleum cokes* for domestic furnaces has been small and is generally confined to the Middle West. They vary in the amount of volatile matter they contain, but all have the common property of a very low ash content, which necessitates the use of refractory pieces to protect the grates from being burned.

In order to obtain perfect combustion a definite amount of air is required for each pound of fuel fired. A deficiency of air supply will result in combustible products passing to the stack unburned. An excess of air absorbs heat from the products of combustion and results in a greater loss of sensible heat to the stack.

Total Air Required. The theoretical amount of air required per pound of fuel for perfect combustion is dependent upon the analysis of the fuel;

TABLE 2. POUNDS OF AIR PER POUND OF FUEL AS FIRED

ANTHRACITE	COKE	SEMI-BITUMINOUS	BITUMINOUS	LIGNITE
9.6	11.2	11.2	10.3	6.2

however, for estimating purposes the theoretical air required for different grades of fuel may roughly be taken from Table 2. An excess of about 50 per cent over the theoretical amount is considered good practice under usual operating conditions.

The amount of excess air, based upon the laws of combustion, can be determined by its relation to the percentage of CO₂ (carbon dioxide) in the products of combustion. This relationship is shown by the curves (Fig. 1) for high and low volatile coals and for coke. In hand-fired furnaces with long periods between firings the combustion goes through a cycle in each period and the quantity of excess air present varies.

Secondary Air. The division of the total into primary and secondary air necessary to produce the same rate of burning and the same excess air depends on a number of factors which include size of fuel, depth of fuel bed, and diameter of fire pot. The ratio of the secondary to the primary air increases with decrease in the size of the fuel pieces, with increase in the depth of the fuel bed, and with increase in the area of the fire pot; the ratio also increases with increase in rate of burning.

Size of the fuel is a very important factor in fixing the quantity of secondary air required for non-caking coals. With caking coals it is not