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Reference 4

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FOURTH EDITION

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Table 9-1. Analyses of Selected Coals of Various Ranks

"As received" basis

Rank*	State	Seam	Proximate analysis, %				Ultimate analysis, %					Heating value, B.t.u./lb.
			Moisture	Volatile matter	Fixed carbon	Ash	Carbon	Hydrogen	Oxygen	Sulfur	Nitrogen	
Anthracitic:												
Meta-anthracite	Rhode Island	Uncorrelated	1.0	4.0	66.7	28.3	....	....	....	....	....	9,620
Anthracite	Pennsylvania	Mammoth	2.3	3.1	87.7	6.9	86.7	2.2	2.9	0.5	0.8	13,540
Anthracite	Pennsylvania	Big Lykens	2.1	7.5	80.3	10.1	80.9	3.3	4.2	0.5	1.0	13,480
Semianthracite	Virginia	Merrimac	2.2	12.4	67.4	18.0	72.4	3.6	4.7	0.5	0.8	12,270
Bituminous:												
Low-volatile	West Virginia	Pocahontas No. 3	3.5	18.2	74.4	3.9	84.0	4.8	5.6	0.6	1.1	14,550
Medium-volatile	West Virginia	Sewell	3.1	25.0	66.8	5.1	....	....	....	1.3	....	14,290
High-volatile A	Pennsylvania	Pittsburgh	2.6	30.0	58.3	9.1	76.6	5.2	6.2	1.3	1.6	13,610
High-volatile A	Kentucky	Elkhorn	3.1	35.0	58.9	3.0	79.2	5.7	10.0	0.6	1.5	14,290
High-volatile B	Ohio	Middle Kittanning	8.2	36.1	48.7	7.0	68.4	5.6	16.4	1.2	1.4	12,160
High-volatile B	Kentucky	No. 6	7.2	39.8	48.8	4.2	71.5	5.8	14.3	2.6	1.6	12,950
High-volatile C	Illinois	No. 2	12.1	40.2	39.1	8.6	62.8	5.9	17.4	4.3	1.0	11,480
High-volatile C	Indiana	No. 6	12.4	36.6	42.3	8.7	63.4	5.7	18.6	2.3	1.3	11,420
Subbituminous:												
Subbituminous A or high-volatile bituminous C	Wyoming	Uncorrelated	16.5	34.2	38.1	11.2	....	....	....	2.1	....	9,740
Subbituminous B	Wyoming	Monarch	23.2	33.3	39.7	3.8	54.6	6.4	33.8	0.4	1.0	9,420
Subbituminous C	Wyoming	Uncorrelated	24.6	27.7	39.9	7.8	....	....	....	1.1	....	8,610
Lignitic:												
Lignite	North Dakota	Beulah	34.8	28.2	30.8	6.2	42.4	6.7	43.3	0.7	1.7	7,210

* According to A.S.T.M. method of classification.

Table 9-2. Ash-softening Temperatures and Ash Composition of Selected Coals*

Sample	Softening temperature, °F.	Analysis of ash, %							
		SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	$Na_2O + K_2O$	SO_3
Montana subbituminous	2060	30.7	19.6	18.9	1.1	11.3	3.7	2.4	12.2
Illinois bituminous	2320	46.2	22.9	7.7	1.0	10.1	1.6	1.5	8.9
Pennsylvania bituminous	2500	49.7	26.8	11.4	1.2	4.2	0.8	2.9	2.5
West Virginia semibituminous	2730	51.0	30.9	10.7	1.9	2.1	0.9	1.4	0.6
Kentucky bituminous	+2900	58.5	30.6	4.2	1.8	2.0	0.4	1.6	0.9

* *U.S. Bur. Mines Bull.* 209.

compounds are derived largely from the clay, shale, slate, pyrite, and other mineral constituents in the coal. **Fixed carbon** is determined by subtracting from 100 the percentages of moisture, volatile matter, and ash. It represents the coke residue, minus the ash.

The percentages of sulfur, heating value, and ash-softening temperature are commonly reported with the proximate analysis but are separate determinations.

The proximate analysis is the most widely used procedure for evaluating coal, particularly when the general characteristics of other coals from the same district are known. It falls far short, however, of being a complete criterion for evaluation for utilization in specific equipment or for a specific process.

For the ultimate analysis, the percentages of carbon, hydrogen, nitrogen, and sulfur are determined by direct analytical methods. Ash is determined as in the proximate analysis. Since there is no satisfactory method for the direct determination of oxygen, it is found by subtracting the sum of the other five components from 100. The percentage of oxygen found in this way is subject to the errors incurred in the other determinations, and especially by the change in weight of the ash-forming mineral constituents upon ignition. Because the air-dried samples used for these determinations contain moisture, the oxygen and hydrogen in this moisture are included in the analysis. When the moisture content is known, the results may be calculated to the "dry" basis.

Table 9-1 lists the results of proximate and ultimate analyses of selected American coals of various ranks, as reported by the U.S. Bureau of Mines.

The **heating value** is obtained by the complete combustion of a unit quantity of coal in an oxygen-bomb calorimeter under carefully defined conditions. The "gross" or "high" heating value is obtained by this method, as the latent heat of moisture in the combustion products is recovered. The results may be expressed on the "as received" or "dry" or "dry and ash-free" basis.

The **ash-softening temperature** of coal ash is determined by a standard method adopted by the A.S.T.M. Ashes that fuse in the range 1900° to 2200°F. are considered **low fusing**; those in the range 2200° to 2600°F. **medium fusing**; and those above 2600°F. **high fusing**. In general, coal ashes having low softening temperatures are likely to form clinkers, but the chemical composition of the ash, combustion conditions, and other factors affects the clinker formation. Table 9-2 shows the composition and softening temperatures of the ashes from several selected coals.

Physical Properties. The A.S.T.M. has adopted standard procedures for determining the **true** and **apparent specific gravities** of coal and coke. It is necessary to distinguish between the apparent specific gravity of a lump of porous material, such as coke, and the true specific gravity of the substance forming the lump (see Table 9-3).

Coals differ considerably in **specific heats**, depending upon the kind of coal, its ash and moisture content, etc. The range is from about 0.25 to 0.37. For metallurgical coke of 5 per cent ash, the specific heats shown in Table 9-4 have been determined.

The **bulk density** is a measure of the weight per cubic

Table 9-3. Typical Specific Gravities

Fuel	Specific gravity		Pores, %
	True	Apparent	
Bituminous coal	1.25–1.45		
By-product coke	1.75–2.00	0.75–1.1	40–60
Low-temperature coke	1.50–1.75	0.5 –1.1*	30–70
Charcoal	1.4 –1.7	0.3 –0.6	65–80
Anthracite	1.45–1.7		
Wood	0.5 –1.1		

* By unusual procedures in preparing coal previous to carbonisation, and control of carbonisation conditions, an apparent specific gravity as high as 1.4 may be obtained.

Table 9-4. Specific Heat of Coke

Temperature range, °C.	20–260	20–538	20–815	20–1093
Average specific heat	0.240	0.303	0.338	0.363