



Designation: D 388 – 99

## Standard Classification of Coals by Rank<sup>1</sup>

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### 1. Scope

1.1 This standard covers the classification of coals by rank, that is, according to their degree of metamorphism, or progressive alteration, in the natural series from lignite to anthracite.

1.2 This classification is applicable to coals that are composed mainly of vitrinite.

NOTE 1—Coals rich in inertinite or liptinite (exinite), or both, cannot be properly classified because, in those macerals, the properties that determine rank (calorific value, volatile matter, and agglomerating character) differ greatly from those of vitrinite in the same coal. Often such coals can be recognized by megascopic examination. In North America, these coals are mostly nonbanded varieties that contain only a small proportion of vitrain and consist mainly of attrital materials. The degree of metamorphism of nonbanded and other vitrinite-poor coals can be estimated by determining the classification properties of isolated or concentrated vitrinite fractions, or by determining the reflectance of the vitrinite (see Test Method D 2798 and Appendix X1 of this classification). However, in the use of these vitrinite-poor coals, some properties normally associated with rank, such as rheology, combustibility, hardness, and grindability (as well as the rank determining properties) may differ substantially from those of vitrinite-rich coals of the same degree of metamorphism.

The precision of the classification of impure coal may be impaired by the effect of large amounts of mineral matter on the determination of volatile matter and calorific value, and on their calculation to the mineral-matter-free basis.

1.3 The values stated in British thermal units per pound are to be regarded as the standard. The SI equivalents of British thermal units per pound are approximate. All other values in SI units are to be regarded as standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 121 Terminology of Coal and Coke<sup>2</sup>
- D 720 Test Method for Free-Swelling Index of Coal<sup>2</sup>
- D 1412 Test Method for Equilibrium Moisture of Coal at 96 to 97 Percent Relative Humidity and 30°C<sup>2</sup>
- D 1757 Test Method for Sulfur in Ash from Coal and Coke<sup>2</sup>
- D 2013 Method of Preparing Coal Samples for Analysis<sup>2</sup>
- D 2234 Practice for Collection of a Gross Sample of Coal<sup>2</sup>

<sup>1</sup> This classification is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.18 on Classification of Coals.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 05.06.

- D 2798 Test Method for Microscopical Determination of the Reflectance of Vitrinite in a Polished Specimen of Coal<sup>2</sup>
- D 3172 Practice for Proximate Analysis of Coal and Coke<sup>2</sup>
- D 3173 Test Method for Moisture in the Analysis Sample of Coal and Coke<sup>2</sup>
- D 3174 Test Method for Ash in the Analysis Sample of Coal and Coke from Coal<sup>2</sup>
- D 3175 Test Method for Volatile Matter in the Analysis Sample of Coal and Coke<sup>2</sup>
- D 3177 Test Methods for Total Sulfur in the Analysis Sample of Coal and Coke<sup>2</sup>
- D 3180 Practice for Calculating Coal and Coke Analyses from As-Determined to Different Bases<sup>2</sup>
- D 3302 Test Method for Total Moisture in Coal<sup>2</sup>
- D 4596 Practice for Collection of Channel Samples of Coal in the Mine<sup>2</sup>
- D 5192 Practice for the Collection of Coal Samples from Core<sup>2</sup>
- D 5865 Test Method for Gross Calorific Value of Coal and Coke<sup>2</sup>

### 3. Terminology

3.1 *Definitions*—For additional definitions of terms used in this classification, refer to Terminology D 121.

3.1.1 *agglomerating, adj*—as applied to coal, the property of softening when it is heated to above about 400°C in a nonoxidizing atmosphere, and then appearing as a coherent mass after cooling to room temperature.

3.1.2 *apparent rank, n*—of coal, the rank designation obtained on samples other than channel samples or core samples with 100 % recovery, but otherwise conforming to procedures of Classification D 388.

3.1.3 *coal seam, n*—the stratum, layer, or bed of coal that lies between two other rock layers whose compositions differ significantly from that of coal.

3.2 *Abbreviations: Abbreviations*—Where it is desired to abbreviate the designation of the ranks of coal, the following abbreviations shall be used:

- ma—meta-anthracite
- an—anthracite
- sa—semianthracite
- lvb—low volatile bituminous
- m vb—medium volatile bituminous
- h vAb—high volatile A bituminous

hvBb—high volatile *B* bituminous  
 hvCb—high volatile *C* bituminous  
 subA—subbituminous *A*  
 subB—subbituminous *B*  
 subC—subbituminous *C*  
 ligA—lignite *A*  
 ligB—lignite *B*

moist, mineral-matter-free basis, and coals having fixed carbon of 69 % or more on the dry, mineral-matter-free basis, according to fixed carbon on the dry, mineral-matter-free basis. Classify coals having gross calorific values less than 14 000 Btu/lb on the moist, mineral-matter-free basis according to gross calorific value on the moist, mineral-matter-free basis, provided the fixed carbon on the dry, mineral-matter-free basis is less than 69 %.

**6.2 Agglomerating Character**—Classify coals having 86 % or more fixed carbon on the dry, mineral-matter-free basis, if agglomerating, in the low volatile group of the bituminous class. Classify coals having gross calorific values in the range from 10 500 to 11 500 Btu/lb on the moist, mineral-matter-free basis according to their agglomerating character (Table 1).

**6.3 Supplemental Information**—A correlation of the ranking property, volatile matter (100—fixed carbon), with the mean-maximum reflectance of the vitrinite group macerals in coals tested in one laboratory over a period of several years is shown in Appendix X1.

## 7. Sampling

**7.1 Samples**—Classify a coal seam, or part of a coal seam, in any locality based on the average analysis and gross calorific value (and agglomerating character where required) of not less than three and preferably five or more face channel samples or core samples taken in different and uniformly distributed localities, either within the same mine or closely adjacent mines representing a continuous and compact area not greater

## 4. Significance and Use

**4.1** This classification establishes categories of coal based on gradational properties that depend principally on the degree of metamorphism to which the coal was subjected while buried. These categories indicate ranges of physical and chemical characteristics that are useful in making broad estimates of the behavior of coal in mining, preparation, and use.

## 5. Basis of Classification

**5.1** Classification is according to fixed carbon and gross calorific value (expressed in British thermal units per pound) calculated to the mineral-matter-free basis. The higher-rank coals are classified according to fixed carbon on the dry basis; the lower-rank coals are classified according to gross calorific value on the moist basis. Agglomerating character is used to differentiate between certain adjacent groups.

## 6. Classification by Rank

**6.1 Fixed Carbon and Gross Calorific Value**—Coals shall be classified by rank in accordance with Table 1. Classify coals having gross calorific values of 14 000 Btu/lb or more on the

**TABLE 1 Classification of Coals by Rank<sup>A</sup>**

Class/Group	Fixed Carbon Limits (Dry, Mineral-Matter-Free Basis), %		Volatile Matter Limits (Dry, Mineral-Matter-Free Basis), %		Gross Calorific Value Limits (Moist, <sup>B</sup> Mineral-Matter-Free Basis)				Agglomerating Character
					Btu/lb		Mj/kg <sup>C</sup>		
	Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	Equal or Greater Than	Less Than	
<b>Anthracitic:</b>									
Meta-anthracite	98	...	...	2	...	...	...	...	} nonagglomerating
Anthracite	92	98	2	8	...	...	...	...	
Semianthracite <sup>D</sup>	86	92	8	14	...	...	...	...	
<b>Bituminous:</b>									
Low volatile bituminous coal	78	86	14	22	...	...	...	...	} commonly agglomerating <sup>F</sup>
Medium volatile bituminous coal	69	78	22	31	...	...	...	...	
High volatile <i>A</i> bituminous coal	...	69	31	...	14 000 <sup>E</sup>	...	32.6	...	
High volatile <i>B</i> bituminous coal	...	...	...	...	13 000 <sup>E</sup>	14 000	30.2	32.6	
High volatile <i>C</i> bituminous coal	...	...	...	...	11 500	13 000	26.7	30.2	} agglomerating
					10 500	11 500	24.4	26.7	
<b>Subbituminous:</b>									
Subbituminous <i>A</i> coal	...	...	...	...	10 500	11 500	24.4	26.7	} nonagglomerating
Subbituminous <i>B</i> coal	...	...	...	...	9 500	10 500	22.1	24.4	
Subbituminous <i>C</i> coal	...	...	...	...	8 300	9 500	19.3	22.1	
<b>Lignitic:</b>									
Lignite <i>A</i>	...	...	...	...	6 300 <sup>G</sup>	8 300	14.7	19.3	} nonagglomerating
Lignite <i>B</i>	...	...	...	...	...	6 300	...	14.7	

<sup>A</sup>This classification does not apply to certain coals, as discussed in Section 1.

<sup>B</sup>Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

<sup>C</sup>Megajoules per kilogram. To convert British thermal units per pound to megajoules per kilogram, multiply by 0.002 326.

<sup>D</sup>If agglomerating, classify in low volatile group of the bituminous class.

<sup>E</sup>Coals having 69 % or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of gross calorific value.

<sup>F</sup>It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and that there are notable exceptions in the high volatile<sup>C</sup> bituminous group.

<sup>G</sup>Editorially corrected.

than approximately four square miles in regions of geological uniformity. In regions in which conditions indicate that the coal probably varies rapidly in short distances, the spacing of sampling points and grouping of analyses to provide average values shall not be such that coals of obviously different rank will be used in calculating average values.

7.1.1 Take channel samples by excluding mineral partings more than 1 cm ( $\frac{3}{8}$  in.) and lenses or concretions (such as sulfur balls) more than 1.25 cm ( $\frac{1}{2}$  in.) thick and 5 cm (2 in.) wide, as specified in Practice D 4596.

7.1.2 A drill core sample may be used provided it was collected as specified in Practice D 5192 and meets the following provisions: core recovery is 100 % of the seam, the major mineral partings and concretions are excluded as specified in 7.1.1, and drilling mud is removed from the core (see also 7.1.6).

7.1.3 Place all samples in metal or plastic cans with airtight lids, or heavy vapor impervious bags, properly sealed to preserve inherent moisture.

7.1.4 Analyses of samples from outcrops or from weathered or oxidized coal shall not be used for classification by rank.

7.1.5 In case the coal is likely to be classified on the *moist* basis, that is, inclusive of its natural complement of inherent moisture, take samples in a manner most likely to preserve inherent moisture for purposes of analysis. Because some of the moisture in a freshly collected sample condenses on the inside of the sample container, weigh both the container and the coal before and after air drying, and report the total loss in weight as air-drying loss.

7.1.6 If the sample is a core or if it is impossible to sample the coal without including visible surface moisture, or if there may be other reasons to question the accuracy of inherent moisture content determinable from the sample, and the coal is likely to be classified on the *moist* basis, the sampler shall include the following statement in the description: *Moisture questionable*. Samples so marked shall not be used for classification on a moist basis unless brought to a standard condition of moisture equilibrium at 30°C in a vacuum desiccator containing a saturated solution of potassium sulfate (97 % humidity) as specified in Test Method D 1412. Analyses of such samples that have been treated in this manner shall be designated as *samples equilibrated at 30°C and 97 % humidity*.

7.2 *Other Types of Samples*—A standard rank determination cannot be made unless samples have been obtained in accordance with 7.1. However, the relation to standard determinations may be usefully given for other types of samples taken under unspecified conditions, providing the same standards of analysis and computation are followed. Designate these comparative indications as *apparent rank*, which indicates the correct relative position for the sample analyzed but does not imply any standards of sampling. Whenever apparent rank is stated, give additional information as to the nature of the sample.

7.2.1 The apparent rank of the coal product from a mine shall be based on representative samples taken in accordance with the Organization and Planning of Sampling Operations section (Section 7) of Practice D 2234.

7.2.2 In case the coal is likely to be classed on the *moist* basis, take samples at the tippel or preparation plant and seal the sample to prevent loss of moisture.

## 8. Methods of Analysis and Testing

8.1 *Laboratory Sampling and Analysis*—Prepare coal in accordance with Method D 2013 and analyze it in accordance with Test Methods D 3173, D 3174, D 3175, D 3177, D 3302, and Practice D 3172. Determine its gross calorific value in accordance with Test Method D 5865. Determine the sulfur trioxide (SO<sub>3</sub>) retained in the ash in accordance with Test Method D 1757 and express the result on a dry basis. Inherent moisture is reported as as-received moisture if the sample was collected according to 7.1.1 or as equilibrium moisture if 7.1.6 (Test Method D 1412) applies.

8.2 Adjust the ash value determined in accordance with Test Method D 3174 to be free of sulfate as follows:

$$A = A_d \left( 1 - \frac{SO_3}{100} \right) \left( 1 - \frac{M}{100} \right) \quad (1)$$

where:

- A = adjusted ash value on the inherent moist basis,
- A<sub>d</sub> = ash yield, dry basis, determined in accordance with Test Method D 3174,
- SO<sub>3</sub> = in the ash determined in accordance with Test Method D 1757, and
- M = inherent moisture.

Add to the value of fixed carbon that is determined in accordance with Practice D 3172 the value of the SO<sub>3</sub> determined in the ash to obtain the value FC to be used in Eq 2.

8.3 *Agglomerating Character*—The test carried out by the examination of the residue in the platinum crucible incident to the volatile matter determination shall be used.<sup>3</sup> Coals which, in the volatile matter determination, produce either an agglomerate button that will support a 500-g weight without pulverizing, or a button showing swelling or cell structure, shall be considered agglomerating from the standpoint of classification. In addition, a result of 1.0 or more on the Free Swelling Index test (Test Method D 720) may also be used to indicate the coal is agglomerating; a result of 0.5 or 0 indicates the coal is nonagglomerating.

## 9. Calculation to Mineral-Matter-Free Basis

9.1 *Calculation of Fixed Carbon and Calorific Value*—For classification of coal according to rank, calculate fixed carbon and gross calorific value to the mineral-matter-free (Mm-free) basis in accordance with the Parr formulas,<sup>4</sup> Eq 2-4. Background information concerning the development of the Parr formulas as well as other ranking considerations and examples of the calculations (Table 1) are provided in Appendix X2.

9.2 Calculate to Mm-free basis as follows:

9.2.1 *Parr Formulas*:

<sup>3</sup> Gilmore, R. E., Connell, G. P., and Nicholls, J. H. H., "Agglomerating and Agglutinating Tests for Classifying Weakly Caking Coals," *Transactions*, American Institute of Mining and Metallurgical Engineers, Coal Division, Vol 108, 1934, p. 255.

<sup>4</sup> Parr, S. W., "The Classification of Coal," *Bulletin No. 180*, Engineering Experiment Station, University of Illinois, 1928.