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Standard Terminology of Coal and Coke¹

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1. Scope

1.1 This standard defines the technical terms used in standards that are the responsibility of Committee D05 on Coal and Coke. The terms are used in:

1.1.1 The sampling of coal and coke under conditions required for most commercial and technical purposes related to coal and coke.

1.1.2 Bias and related statistical testing,

1.1.3 The description of coal, both visually in the field and microscopically in the laboratory,

1.1.4 Chemical and physical analyses of coal and coke,

1.1.5 Classification of coal, and

1.1.6 Certain other related practices and guides applicable to the coal and coke industries.

2. Referenced Documents

2.1 *ASTM Standards:*

¹ This terminology is under the jurisdiction of ASTM Committee D05 on Coal and Coke and is the direct responsibility of Subcommittee D05.30 on Quality Assurance. Current edition approved Jan. 10, 2001. Published October 2001. Originally published as D 121 – 21 T. Last previous edition ~~D 121 – 00^ε~~. D 121 – 01.

- D 388 Classification of Coals by Rank²
- D 1412 Test Method for Equilibrium Moisture of Coal at 96 to 97 Percent Relative Humidity and 30°C²
- D 1857 Test Method for Fusibility of Coal and Coke Ash²
- D 2013 Method of Preparing Coal Samples for Analysis²
- D 2015 Test Method for Gross Calorific Value of Coal and Coke by the Adiabatic Bomb Calorimeter²
- D 2234 Practice for Collection of a Gross Sample of Coal²
- D 2361 Test Method for Chlorine in Coal²
- D 2795 Test Methods for Analysis of Coal and Coke Ash²
- D 2796 Terminology Relating to Megascopic Description of Coal and Coal Seams and Microscopical Description and Analysis of Coal³
- D 2797 Practice for Preparing Coal Samples for Microscopical Analysis by Reflected Light²
- D 2798 Test Method for Microscopical Determination of the Reflectance of Vitrinite in a Polished Specimen of Coal²
- D 2799 Test Method for Microscopical Determination of Volume Percent of Physical Components of Coal²
- D 2961 Test Method for Total Moisture in Coal Reduced to 2.36–mm (No. 8) Mesh Top Sieve Size (Limited–Purpose Method)²
- D 3172 Practice for Proximate Analysis of Coal and Coke²
- D 3173 Test Method for Moisture in the Analysis Sample of Coal and Coke²
- D 3174 Test Method for Ash in the Analysis Sample of Coal and Coke from Coal²
- D 3175 Test Method for Volatile Matter in the Analysis Sample of Coal and Coke²
- D 3176 Practice for Ultimate Analysis of Coal and Coke²
- D 3180 Practice for Calculating Coal and Coke Analyses from As-Determined to Different Bases²
- D 3286 Test Method for Gross Calorific Value of Coal and Coke by the Isoperibol Bomb Calorimeter²
- D 3302 Test Method for Total Moisture in Coal²
- D 4371 Test Method for Determining the Washability Characteristics of Coal²
- D 4749 Test Method for Performing Sieve Analysis of Coal and Designating Coal Size²
- D 4915 Guide for Manual Sampling of Coal from Tops of Railroad Cars²
- D 4916 Practice for Mechanical Auger Sampling²
- D 5061 Test Method for Microscopical Determination of Volume Percent of Textural Components in Metallurgical Coke²
- D 5114 Test Method for Laboratory Froth Flotation of Coal in a Mechanical Cell²
- D 5192 Practice for Collection of Coal Samples from Core²
- D 6316 Test Method for Determination of Total, Combustible and Carbonate Carbon in Solid Residues from Coal and Coke²
- E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁴
- E 456 Terminology Relating to Quality and Statistics⁴

3. Terminology

air-dried moisture—this term has been used inappropriately to refer to both residual moisture and air-dry loss. Because of the potential for confusion, this term shall not be used.

air drying, *n*—a process of partial drying of coal to bring its moisture near to equilibrium with the atmosphere in the room in which further reduction and division of the sample will take place. **D 2013; D 2234**

air-dry loss, *n*— *in coal*, the loss in mass, expressed as a percentage, resulting from each air-drying stage or the sum of all sequential air-drying stages in which the results from each stage are adjusted to the as-received basis. **D 3302**

DISCUSSION—Air-dry loss is neither a standard state nor a characteristic property of a coal. Air drying only removes water that can evaporate at or near ambient laboratory conditions, leaving in the coal some fraction of the inherent moisture that is more tightly bound in the pores (residual moisture). Different laboratory environments or different drying temperatures or both will result in significant differences in air-dry loss and residual moisture.

D 3302

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.

alginite—See *alginite* under **maceral**.

analysis sample—See *analysis sample* under **sample**.

angle of repose, *n*—the greatest angle, measured from horizontal, attained by a coal so that material on the sides of top of the inverted cone or trench created in car top sampling remains stable, that is, will not shift or slide. Coal size and moisture content are contributing factors to this angle. In all cases, the coal shall be dug so that the physical angle is less than the angle of repose. **D 4915**

anisotropic, *adj*— *as used in Test Method D 5061*, exhibiting optical properties of different values when viewed with an optical microscope having mutually exclusive polarized light, for example, crossed nicols. **D 5061**

² Annual Book of ASTM Standards, Vol 05.06.

³ Discontinued; see 1994 Annual Book of ASTM Standards, Vol 05.05.

⁴ Annual Book of ASTM Standards, Vol 14.02.

anthracite—See *anthracite* under **rank**.

anthracitic class— See *anthracitic class* under **rank**.

apparent rank, n— of coal, the rank designation obtained on samples other than channel samples, but otherwise conforming to procedures of Classification D 388.

as-analyzed moisture—synonym for *as-determined moisture*.

as-determined basis— See *as-determined basis* under **reporting bases**.

ash, n—inorganic residue remaining after ignition of combustible substances, determined by definite prescribed methods.

DISCUSSION—Ash need not be identical, in composition or quantity, with the inorganic substances present in the material before ignition.

In the case of coal and coke, the methods used shall be those prescribed in Test Method D 3174.

as-mined coal—for the purpose of Test Method D 4749, same as **run-of-mine (ROM) coal**. **D 4749**

as-received basis— See *as-received basis* under **reporting bases**. **D 3180**

as-shipped or produced coal— for the purpose of Test Method D 4749, raw or prepared coal in any state or condition at which it leaves the mine property or loading facility. **D 4749**

attrital coal—See *attrital coal* under **coal**.

auger increment, n—the retained portion of one extraction operation of the auger. **D 4916**

banded coal—See *banded coal* under **coal**.

basis—See **reporting bases**.

bed moisture— synonym for *inherent moisture*.

beehive coke—See *beehive coke* under **coke**.

bias, n—the difference between the population mean of the test results and an accepted reference value.

DISCUSSION—Bias is a systematic error as contrasted to random error. There may be one or more systematic error components contributing to the bias. A larger systematic difference from the accepted reference value is reflected by a larger bias value. **E 456**

binder phase, n— as used in Test Method D 5061, a continuous solid carbon matrix formed during the thermoplastic deformation of those coal macerals that become plastic during carbonization.

DISCUSSION—The binder phase material is formed from the thermoplastic deformation of reactive (vitrinite and liptinite) and semi-inert (semifusinite) coal macerals of metallurgical bituminous coals. During thermoplasticity, the inert coal maceral and mineral are partly or wholly incorporated into the binder phase. Also, most of the coke pores are located in the binder phase. **D 5061**

bituminous class—See *bituminous class* under **rank**.

boghead coal—See *boghead coal* under **coal**.

bone coal—See *bone coal* under **coal**.

borehole, n—the circular hole through soil and rock strata made by boring.

bottomsize, nominal— for the purpose of Test Method D 4749, the sieve designating the lower limit or bottomsize shall be that sieve of the series given in the Standard Series of Sieves section with the largest openings through which passes a total of less than 15 % of the sample. This defined bottomsize is not to be confused with the size of the smallest particles in the lot.

DISCUSSION—(Warning—In the case of a commercial, double-screened product, for example, 37.5 by 9.5 mm (1½ by ¾ in.), this designation may not be valid. In such commercial or contractual situations, the amount of allowable material smaller than the bottomsize (for example, 9.5 mm) must be specified by the contract under which the coal is bought and sold.) **D 4749**

briquette, n—a cylindrical block composed of granulated coal or coke particles compressed and embedded with an epoxy binder.

by-product coke—See *by-product coke* under **coke**.

C test, n—a standard statistical test for homogeneity of variance.

calorific value, n—the heat of combustion of a unit quantity of a substance.

DISCUSSION—It is expressed in ASTM test methods in British thermal units per pound (Btu/lb). Calorific value can also be expressed in calories per gram (cal/g) or in the International System of Units, joules per gram (J/g), when required. **D 2015; D 3286**

calorimeter, n— as used in Test Method D 3286, the bomb and its contents, the calorimeter vessel with stirrer, the water in which the bomb is immersed, and the portions of the thermometer and the ignition leads within the calorimeter vessel. **D 3286**

calorimeter jacket, n—the insulating medium surrounding the calorimeter.

cannel coal—See *cannel coal* under **coal**.

carbonate carbon, n—the carbon content present in the solid products derived from the combustion or reaction of coal, coal by-products, or coke as carbonates and which is noncombustible in standard industry practice. **D 6316**

carbon form, n— as used in Test Method D 5061, microscopically distinguishable carbonaceous textural components of coke, but excluding mineral carbonates.

DISCUSSION—Carbon forms are recognized on the basis of their reflectance, anisotropy, and morphology. They are derived from the organic portion of coal and can be anisotropic or isotropic. **D 5061**

caves or washouts, *n*—zones of increased hole diameter caused by rock fragments that fall from the walls of a borehole and can block the hole or contaminate the cuttings and which erode or abrade the sidewall of the borehole by the action of the drilling. These zones can affect the accuracy of certain geophysical logs (especially density). Corrections to other geophysical logs can be made if a caliper log is available. The most common causes of caves or washouts include soft or fractured lithologies, the presence of water-producing zones, and the downhole pressure of the drilling medium (fluid or air) that often causes differential erosion of various strata within the borehole.

chance error, *n*—error that has equal probability of being positive or negative. The mean of the chance errors resulting from a series of observations tends toward zero as the number of observations approaches infinity.

circular anisotropic phase, *n*—*as used in Test Method D 5061*, a group of binder-phase anisotropic carbon textures that are distinguished by approximately circular domains (that is length equals width) and composed of fine circular (0.5- to 1.0- μm), medium circular (1.0- to 1.5- μm), and coarse circular (1.5- to 2.0- μm) size categories. **D 5061**

cleat, *n*—the joint system of coal seams, usually oriented normal or nearly normal to the bedding.

DISCUSSION—Cleat is most commonly found in bituminous coal, being most prominently developed in vitrain bands and bright layers. Some cleat, especially the more widely separated joints, extend through all or a large part of the seam. Cleat surfaces are commonly coated with minerals such as calcite, kaolinite, and pyrite. **D 2796**

coal, *n*—a brown to black combustible sedimentary rock (in the geological sense) composed principally of consolidated and chemically altered plant remains.

DISCUSSION—Conditions required for formation of coal are believed to include accumulation of plant remains and their partial decomposition under moist conditions, followed by sedimentary burial and subjection to increased pressure and temperature according to the geological history of the seam. Coals exhibit a wide range of properties as a result of differences in the kinds and relative amounts of different plant materials and intermixed mineral matter, the amount of alteration of the plant remains achieved before burial, and especially the degree of physical and chemical alteration after burial. See Classification D 388 for classification of coal in accordance with its degree of alteration or rank. The moisture content and the kind, amount, and mode of occurrence of mineral matter also vary greatly.

lithotype, *n*— any of the constituents of banded coal: vitrain, fusain, clarain, durain, or attrital coal or a specific mixture of two or more of these.

banded coal, *n*—coal that is visibly heterogeneous in composition, being composed of layers of vitrain and attrital coal, and, commonly, fusain.

attrital coal, *n*—the ground mass or matrix of banded coal in which vitrain and, commonly, fusain layers as well, are embedded or enclosed.

DISCUSSION—Layers in banded coal, often referred to as bands, are commonly 1 to 30 mm thick. Attrital coal in banded coal is highly varied in composition and appearance, its luster varying from a brilliance nearly equal to that of the associated vitrain to nearly as dull as fusain; it exhibits striated, granulose, or rough texture. In a few cases, relatively thick layers of such attrital coal are found that contain no interbedded vitrain. Nonbanded coal also is attrital coal but is not usually referred to as such. In contrast to the coarser and more variable texture of attrital coal in banded coal, nonbanded coal is notably uniform and fine in texture, being derived from size-sorted plant debris.

The luster of attrital coal, which ranges from bright (but less than that of associated vitrain) to dull, is commonly used to describe and characterize attrital coal. As an alternative, some petrographers subdivide attrital coal into clarain and durain. Clarain has bright luster and silky texture, being finely striated parallel to the coal bedding. Durain has dull luster and sometimes is referred to as dull coal. Similarly, coal consisting of vitrain or clarain or a mixture of the two is sometimes referred to as bright coal.

fusain, *n*— coal layers composed of chips and other fragments in which the original form of plant tissue structure is preserved; commonly has fibrous texture with a very dull luster.

DISCUSSION—Fusain is very friable and resembles charcoal. Commonly, it is concentrated in bedding layers or lenses that form planes of weakness in coal and thus is often exposed on bedding surfaces of broken coal. The many pores (cell cavities and cracks) of fusain are sometimes filled with mineral matter.

vitrain, *n*— shiny black bands, thicker than 0.5 mm, of subbituminous and higher rank banded coal.

DISCUSSION—Vitrain, attributed to the coalification of relatively large fragments of wood and bark, may range up to about 30 mm (approximately 1 in.) thick in eastern North American coals, but may be much thicker in the younger western deposits. Vitrain is commonly traversed by many fine cracks oriented normal to the banding.

In lignite, the remains of woody material lack the shiny luster of vitrain in the higher rank coals and may instead be called previtrain. It is differentiated from attrital bands of lignite by its smoother texture, often showing the grain of wood. Previtrain may be several inches thick.

nonbanded coal, *n*—consistently fine-granular coal essentially devoid of megascopic layers.

DISCUSSION—Nonbanded coal may be interbedded with common banded coal, or form a discrete layer at the top or at the bottom of the seam, or may compose the entire seam. It is formed from natural accumulations of finely comminuted plant detritus and commonly includes a significant amount and variety of remains of pollen grains, spores, planktonic algae, wax and resin granules, as well as other fragments of plants. These materials, containing markedly higher amounts of volatile matter than vitrain and some other attrital components, are more abundant in this variety of coal than they are in common types of banded coal. Also, nonbanded coal may contain more disseminated detrital mineral matter, chiefly clay, than associated banded coals, and in the field it may be difficult to distinguish from bone coal. Nonbanded coal is much less common than banded coal in North America.

cannel coal, n—nonbanded coal in which the liptinite is predominantly sporinite.

DISCUSSION—Transitions between cannel and boghead, that is, coals containing both types of liptinite, are also known. Microscopic examination is essential for differentiation of the two kinds of nonbanded coal and their transitions.

boghead coal, n—nonbanded coal in which the liptinite (the waxy component) is predominantly alginite.

impure coal, n—coal having 25 weight % or more, but less than 50 weight %, of ash on the dry basis.

DISCUSSION—Bone coal with more than 50 weight % ash is properly called coaly or carbonaceous shale or siltstone. Types of impure coal other than bone coal and mineralized coal sometimes occur, for example, sandy coal.

bone coal, n—impure coal that contains much clay or other fine-grained detrital mineral matter.

mineralized coal, n—impure coal that is heavily impregnated with mineral matter, either dispersed or discretely localized along cleat joints or other fissures. Pyritic or calcareous mineralized coal is most common. **D 2796**

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.

coal washability, n—the determination of the theoretical limits for the removal of mineral impurities from coal by beneficiation processes that rely on specific gravity separations. **D 4371**

coarse coal—See, *coarsen*—that portion of a coal sample being subjected to a washability study that is larger than a specific predetermined particle size, generally between 2.36 mm (No. 8 USA Standard Sieve Series) and 9.5 mm (3/8 in.) round in diameter.

DISCUSSION—This same particle size breakpoint should then be used in subsequent washability studies of the same material sampled from the same location for the same application. This breakpoint is determined by the analyst or the person designing the test procedure as the point that best suits the application. This coarse-coal fraction may be further sieved (generally by dry sieving) to produce additional size fractions, each of which may be processed through the desired specific gravity solutions. **D 4371**

coke—a carbonaceous solid produced from coal, petroleum, or other materials by thermal decomposition with passage through a plastic state.

beehive coke, n—coke manufactured in beehive, rectangular, or similar forms of ovens in a horizontal bed, where heat for the coking process is secured by combustion within the oven chamber.

by-product coke, n—coke manufactured with attendant recovery of by-products, in ovens that are heated externally.

coke breeze, n—the fine screenings from crushed coke or from coke as taken from the ovens, of a size varied in local practice but usually passing a 12.7-mm (1/2-in.) or 19.0-mm (3/4-in.) screen opening.

dry coke, n—a laboratory term applied to coke that has been dried to constant weight in accordance with definite prescribed methods.

DISCUSSION—The methods used shall be those for the determination of moisture prescribed in Test Method D 3302. In the case of lump coke, the temperature shall be not less than 104°C nor more than 200°C; in the case of coke passing a 250-µm (No. 60) sieve, the temperature shall be not less than 104°C nor more than 110°C for a period of 1 h.

coke pore, n—as used in Test Method D 5061, a microscopically distinguishable void that is a structural element of coke. **D 5061**

DISCUSSION—Coke pores are considered to be nearly spherical-shaped voids created by the entrapment of gaseous volatiles during the solidification of thermoplastic coal. However, other types of voids can be distinguished in coke that include fractures or cracks, interconnected and elongated pores, and the open cell lumens of fusinite and semifusinite. The size and shape of the voids are coal rank and grade, and to some degree, process dependent.

Pore sizes vary from tens of angstroms to tens of millimetres in any given coke. **D 5061**

coke reactivity, n—as used in Test Method D 5061, a measure of the mass loss when coke, held at a designated temperature, is contacted with gaseous carbon dioxide over a specific time interval. **D 5061**

coke wall, n—as used in Test Method D 5061, a predominantly carbonaceous layer that encloses a coke pore and which is a structural element and essence of coke. **D 5061**

collector, n—a reagent used in froth flotation to promote contact and adhesion between particles and air bubbles. **D 5114**

combustible carbon, n—carbon content remaining in the solid products derived from the combustion or reaction of coal, coal by-products, or coke, exclusive of carbonate in any form. **D 6316**

combustibles, n—the value obtained by subtracting the dry weight (in percent) of the ash (as determined in Test Method D 3174) from 100 % representing original weight of analyzed sample. **D 5114**

concentrate, n—the froth product recovered in coal froth flotation. **D 5114**

concretion, n—in a geological sense, a mass of mineral matter found in rock of a composition different from its own and produced by deposition from aqueous solution in the rock.

conditioning agents, n—all chemicals that enhance the performance of the collectors or frothers. Conditioning agents change the characteristics of the surface of the minerals or the environment. There are many subgroups according to their function: activators, depressants, emulsifiers, dispersants, flocculants, chelating reagents, froth depressants, pH modifiers, etc. **D 5114**

core, n—in drilling, a cylindrical section of rock (coal) that is usually 5 to 10 cm in diameter, taken as part of the interval

penetrated by a core bit and brought to the surface for geologic examination, representative sampling and laboratory analyses.

core barrels, *n*—two nested tubes above the bit of a core drill, the outer rotating with the bit, the inner receiving and preserving a continuous section or core of the material penetrated. The following two types of inner barrels are commonly used.

split-tube barrel, *n*—a type of inner barrel consisting of two longitudinal halves of pipe bound together by reinforced tape at intervals along the barrel length that allows easy access to a relatively intact core (by cutting the tape). (This is the preferred barrel type for coal exploration, where available.)

solid-tube barrel, *n*—a type of inner barrel consisting of a single solid-walled length of pipe in which removal of the core is accomplished by mechanical or hydraulic pressure at one end of the pipe thus extruding the core onto a core tray. (The core is likely to be less intact than when a split-tube barrel is used.)

core sample, *n*—that part of a core of rock or coal obtained so as to represent accurately a thickness of a unit penetrating by drilling. **D 5192**

corrected temperature rise, *n*—the temperature of the calorimeter, caused by the process that occurs inside the bomb; that is, the observed temperature change corrected for various effects.

DISCUSSION—Temperature is measured in either degrees Celsius or degrees Fahrenheit. Thermometer corrections should be applied. Temperatures may be recorded in ohms or other arbitrary units instead of degrees. Consistent units must be used in standardization and the actual calorific value determination. If arbitrary units other than degrees Celsius or Fahrenheit are used, the temperature interval over which all tests are made must not vary so much that an error greater than 0.001°C would be caused. **D 3286**

cutinite—See *cutinite* under **maceral**.

depositional carbon, *n*—as used in *Test Method D 5061*, a group of carbon forms that are formed from cracking and nucleation of gas-phase hydrocarbon molecules during coal carbonization. **D 5061**

pyrolytic carbon, *n*—as used in *Test Method D 5061*, an anisotropic carbon form that is formed by the deposition of carbon parallel to an inert substrate causing the resulting texture to appear ribbon-like. **D 5061**

sooty carbon, *n*—as used in *Test Method D 5061*, an isotropic carbon form comprised of approximately spherical particles of less than 1- μ m diameter sometimes referred to as combustion black. **D 5061**

spherulitic carbon, *n*—as used in *Test Method D 5061*, a spherical anisotropic carbon form sometimes referred to as thermal black that is formed by the deposition of carbon concentrically around a nucleus. **D 5061**

divided sample—See *divided sample* under **sample**.

domain, *n*—as used in *Test Method D 5061*, a region of anisotropy in a carbon form that is distinctively marked by its isochromatic boundary and cleavage. **D 5061**

dry, ash-free basis— See *dry, ash-free basis* under **reporting bases**.

dry basis—See *dry basis* under **reporting bases**.

dry coke—See *dry coke* under **coke**.

dry sieving—for the purpose of *Test Method D 4749*, the test method for the sieving of coal after the sample has been airdried under prescribed conditions; this is generally used when testing with coal particles larger than 600 μ m (No. 30 U.S.A. Standard Sieve Series.) **D 4749**

easily oxidized coals, *n*—low rank coals such as subbituminous or lignitic coals. **D 3302**

energy equivalent, heat capacity, or water equivalent, *n*—the energy required to raise the temperature of the calorimeter an arbitrary unit. This is the quantity that, when multiplied by the corrected temperature rise, then adjusted for extraneous heat effects, and divided by the weight of the sample, gives the gross calorific value.

DISCUSSION—Energy units for quantities listed throughout this test method are such that the number of energy units per gram of sample corresponds exactly to the number of British thermal units per pound of sample. For brevity, these are referred to as British thermal units. The actual energies are smaller than those stated by the ratio of the number of pounds per gram (1/453.59). The energy equivalent of the calorimeter has the units (British thermal units per pound) times (grams per degree). Time is expressed in minutes. Mass is expressed in grams. **D 2015; D 3286**

equilibrium, *n*—condition reached in air drying in which change in weight of the sample, under conditions of ambient temperature and humidity, is no more than 0.1 %/h or 0.05 %/½ h. **D 3302**

equilibrium moisture basis— See *equilibrium moisture basis* under **reporting bases**.

error—difference of an observation from the best obtainable estimate of the true value. **D 2234; D 4916**

excess moisture— synonym for *surface moisture*.

exinite—See *exinite* under **maceral**.

extraneous moisture—synonym for *surface moisture*.

filler phase, *n*— as used in *Test Method D 5061*, a discontinuous solid formed from coal macerals and minerals that do not deform thermoplastically during carbonization. **D 5061**

DISCUSSION—The filler phase material is formed from coal macerals that are inert with respect to development of thermoplasticity (inertinite), the inorganic components of coal (minerals), as well as normally reactive coal entities that are noncoking or have been rendered inert by thermal oxidation, natural weathering, or brecciation. These inert materials possess their original morphologies, but their reflectance and chemical properties have been altered prior to or during carbonization. **D 5061**

fine coal—See, *finen*— that portion of a coal sample being subject to a washability study that is smaller than the predetermined particle size, generally between 2.36 mm (No. 8 USA Standard Sieve Series) and 9.5 mm ($\frac{3}{8}$ in.) round in diameter, which is specified in Test Method D 4371.

DISCUSSION—This same particle size breakpoint should then be used in subsequent washability studies of the same material samples from the same location for the same application. This breakpoint is determined by the analyst or the person designing the test procedure as the point that best suits the application. This fine-coal fraction may be further sieved (generally by wet sieving) to produce additional size fractions, each of which is processed through the desired specific gravity solutions. **D 4371**

fixed carbon, n— in the case of coal, coke, and bituminous materials, the solid residue other than ash, obtained by destructive distillation, determined by definite prescribed methods.

DISCUSSION—It is made up principally of carbon but may contain appreciable amounts of sulfur, hydrogen, nitrogen, and oxygen. In the case of coal and coke, the methods used shall be those prescribed in Test Method D 3172.

float/sink, n—a reference to the physical action that particles undergo when immersed in a liquid of a predetermined specific gravity.

DISCUSSION—A series of float/sink tests is considered as being synonymous with a washability analysis. A float fraction or float material is the material or the specific gravity fraction that floats in a certain solution of specific gravity liquids. A sink fraction or sink material is the material or the specific gravity fraction that sinks in a certain solution of specific gravity liquids. **D 4371**

floor, n—the rock material immediately underlying a coal bed.

flotation cell, n—the vessel or compartment in which the flotation test is performed. **D 5114**

fluid temperature (FT), n— in reference to the fusibility of coal and coke ash according to Test Method D 1857, the temperature at which the fused mass has spread out in a nearly flat layer with a maximum height of 1.6 mm ($\frac{1}{16}$ in.). **D 1857**

free impurity, n—the impurities in a coal that exist as individual discrete particles that are not a structural part of the coal and that can be separated from it by coal preparation methods. **D 2234; D 4915**

free moisture— synonym for *surface moisture*.

froth, n—a collection of bubbles and particles on the surface of a pulp in a froth flotation cell. **D 5114**

froth flotation, n—a process for cleaning fine coal in which hydrophobic particles, generally coal, attach to air bubbles in a water medium and rise to the surface to form a froth. The hydrophilic particles, generally the ash-forming matter, remain in the water phase. **D 5114**

frother, n—a reagent used in froth flotation to control the size and stability of the air bubbles, principally by reducing the surface tension of water. **D 5114**

fusain—See *fusain* under **coal**.

fusinite—see *fusinite* under **maceral**.

geophysical log, n—a graphic record of the measured or computed physical characteristics of the rock section encountered in a borehole, plotted as a continuous function of depth. Measurements are made by a sonde which contains the detectors, as it is withdrawn from the borehole by a wire line. Several measurements are usually made simultaneously, and the resulting curves are displayed side by side on the common depth scale. A common suite of logs used in coal exploration include caliper, density (gamma-gamma), natural gamma, and resistivity.

caliper log, n—a continuous mechanical measurement of the diameter and thus the rugosity of the borehole. The tool identifies zones where swelling or cavings (washouts) have occurred during drilling. The tool's value is in allowing qualitative or quantitative corrections to be made to other geophysical logs which are affected by borehole size (especially density).

density log (gamma-gamma log), n—measures electron density within lithologic units which is related to their bulk density. The wireline tool records the intensity of gamma radiation (in counts per second) from a nuclear source within the tool after it has been attenuated and backscattered by lithologies within the borehole. Due to the distinctly low density of coals, the density log is essential in coal exploration for identifying coal seams and coal-seam partings. The bias/resolution of density logs can be affected by source-detector spacing (closer spacing increases resolution), borehole size, and irregularities (see *caves* or *washouts*), and the presence of casing and logging speed.

natural gamma-ray log, n—a record of the natural radioactivity of the lithologies encountered in the borehole environment. During recording of geophysical logs, the amount of natural radiation is recorded and presented in either counts per second (CPS) or American Petroleum Institute (API) units. Unlike many other log types, a representative natural gamma log can be obtained where borehole or fluid conditions, or both, are not optimal or where casing is present. The natural gamma log is most often used in the coal environment for identifying clastic lithologies and differentiating coal seams and coal-seam partings.

resistivity log, n—a measure of the voltage differential of strata along the walls of a borehole when electrical current is passed through the strata. The resistivity log requires a fluid-filled hole to provide a conductive medium constantly between electrodes on the tool. The spacing between the electrodes determines the precision of the bed boundary relationships in much the same manner as with the density log. The resistivity log is useful primarily in conjunction with other log types. The logs are affected by casing, logging speed, electrode spacing, formation porosity, and resistivity changes in the borehole fluid. **D 5192**

grade/recovery, n—the relationship between quality and quantity of the clean coal product. The quality can be defined in terms

of ash, sulfur, or Btu content. The quantity can be designated as yield or heating value recovery (Btu or combustibles).

D 5114

green coke, *n*—*as used in Test Method D 5061*, carbonaceous binder or filler phase material that has exceeded the temperature of thermoplasticity, but has not obtained the temperature of metallurgical coke.

DISCUSSION—Green coke is recognized on the basis of relative reflectance in comparison to fully carbonized coke. Green coke exhibits varying degrees of lower reflectance than fully carbonized coke.

D 5061

gross calorific value (gross heat of combustion at constant volume), $Q_v(\text{gross})$, *n*—the heat produced by combustion of unit quantity of a solid or liquid fuel when burned at constant volume in an oxygen bomb calorimeter under specified conditions, with the resulting water condensed to a liquid.

DISCUSSION—The conditions are initial oxygen pressure of 2 and 4 MPa (20 to 40 atm), initial and final temperatures between 20 and 35°C (68 to 95°F), products in the form of ash, water (aq), and gaseous carbon dioxide, sulfur dioxide, and nitrogen.

This definition is not applied to gaseous fuels and applies to a volatile liquid fuel only if it is suitably contained during the measurement so that the vapor does not mix with the combustion oxygen before combustion.

The gross calorific value is closely related to the internal energy of combustion for the same reaction at constant standard temperature and pressure, $\Delta U_c(\text{at } t_c)$. It is of opposite sign and differs by a small amount due to energy effects resulting from compression, temperature differences from t , and solution effects that vary with combustion conditions. Because of the variation of conditions allowed in the discussion above, the above definition does not lead to a unique value for any given fuel. However, the specified conditions limit the possible values to a narrow range for which approximate limits can be calculated for a given fuel.

gross sample—See *gross sample* under **sample**.

heat capacity, *n*—Synonym for **energy equivalent**.

hemispherical temperature (HT), *n*—*in reference to the fusibility of coal and coke ash according to Test Method D 1857*, the temperature at which the cone has fused down to a hemispherical lump at which point the height is one half the width of the base.

D 1857

high volatile A bituminous coal—See *high volatile A bituminous coal* under **rank**.

high volatile B bituminous coal—See *high volatile B bituminous coal* under **rank**.

high volatile C bituminous coal—See *high volatile C bituminous coal* under **rank**.

impure coal—See *impure coal* under **coal**.

incipient anisotropic phase, *n*—*as used in Test Method D 5061*, a binder-phase carbon texture having a domain size (less than 0.5 μm) that is near the measuring resolution of the light microscope.

D 5061

increment, *n*—a small portion of a lot collected by one operation of a sampling device and normally combined with other increments from the lot to make a gross sample.

D 2234; D 4916

inertinite—See *inertinite* under **maceral**.

inertodetrinite—See *inertodetrinite* under **maceral**.

inherent ash, *n*—the residue remaining from the inherent impurities after ignition under conditions specified for the ash determination.

D 2234

inherent impurity, *n*—the inorganic material in coal that is structurally part of the coal and cannot be separated from it by coal preparation methods.

D 2234

inherent moisture— See *inherent moisture* under **moisture** .

initial deformation temperature (IT), *n*—*in reference to the fusibility of coal and coke ash according to Test Method D 1857*, the temperature at which the first rounding of the apex of the cone occurs. Shrinkage or warping of the cone is ignored if the tip remains sharp.

isoperibol, *adj*—a term used in combustion calorimetry meaning constant temperature jacket (environment).

isotropic phase, *n*— *as used in Test Method D 5061*, a binder-phase carbon texture that exhibits optical properties that are the same in all directions when viewed with an optical microscope having mutually exclusive polarized light, for example, crossed nicols.

D 5061

laboratory sample— See *laboratory sample* under **sample** .

lenticular anisotropic phase, *n*—*as used in Test Method D 5061*, a group of binder-phase anisotropic carbon textures distinguished by their lens-shaped domains (that is, length (L) to width (W) ratio of $2W < L < 4W$) and subdivided based on domain widths as fine lenticular (1.0- to 3.0- μm), medium lenticular (3.0- to 8.0- μm), and coarse lenticular (8.0- to 12.0- μm) size categories.

D 5061

lignite A—See *lignite A* under **rank**.

lignite B—See *lignite B* under **rank**.

lignitic class—See *lignitic class* under **rank**.

liptinite—See *liptinite* under **macerals**.

lot, *n*—a discrete quantity of coal for which the overall quality to a particular precision needs to be determined.

D 2234

low volatile bituminous coal—See *low volatile bituminous coal* under **rank**.

maceral, *n*—a microscopically distinguishable organic component of coal, but including any mineral matter not discernible under substance in coal that is distinguished and classified on the basis of its optical microscopic properties.

DISCUSSION—Macerals are recognized on the basis of their reflectance originate from plant tissues, secretions, and morphology. A given maceral may differ significantly in composition exudates that have been altered by geological processes and other properties from one coal to another; for some macerals the variation depends mostly on the rank of the coal. Inorganic impurities of submicroscopic size, considered to be part of the maceral; may amount contain up to several weight percent of inorganic elements in attrital coal—microscopically indistinguishable form.

exinite—Synonym for—Deprecated term. Use preferred term **liptinite**; sometimes has also been used as a synonym for **sporinite**.

liptinite, n—a group of— macerals composed of alginite, cutinite, resinite, that exhibit lower reflectance than other organic substances in a coal, appearing black to dark gray and that fluoresce under blue to ultraviolet light in coals ranked high volatile bituminous and lower.

DISCUSSION—The fluorescence of liptinite distinguishes fine-grained liptinite from similar sized, low reflectance, nonfluorescing clay minerals. Liptinite is derived principally from lipid substances forming skins (exines) and resinous secretions or exudates of plants and are distinguished from one another by their morphologies. The reflectance of alginite, cutinite, and sporinite plants. Liptinite is distinctly lower and their volatile matter content higher than that subclassified on the basis of associated vitrinite in all morphology inherited from plant structure. In coals lower in rank than medium volatile bituminous (Classification D 388). Their reflectance and composition converge toward those of which vitrinite in higher ranks, being essentially equal above about 1.4% reflectance under oil immersion (Test Method D 2798) or below exceeds about 20% 1.4%, liptinite can be indistinguishable from vitrinite. Liptinite has the highest volatile matter. The same generally applies to resinite except that its reflectance even in low rank coal may range up to that matter yield of the vitrinite of the same coal. macerals in a coal.

alginite, n— a liptinite maceral that is generally spherical or ovoid, frequently having a crenulated border and somewhat irregular reflectance and sometimes occurring in clusters reflecting an origin from waxy walls (thimble cups) of *Botryococcus* or allied types of algae.

DISCUSSION—Alginite often occurs as degraded fragments derived from colonial or unicellular bodies.

cutinite, n— a liptinite maceral derived from in the waxy coatings (cuticles) form of leaves and other a sheet reflecting its origin from leaf- or twig-covering plant cuticle, frequently exhibiting reticulation in planar section and a serrated edge in cross section.

resinite, n— a liptinite maceral derived from the resinous secretions and exudates of plant cells; occurring as discrete homogeneous bodies rounded, ovoid, or clusters, individuals rod-like bodies assuming the shape of which are usually round, oval, an enclosing cell lumen or rod-like as irregular shapes filling cracks in cross section. the coal.

sporinite, n— a liptinite maceral derived from exhibiting various lenticular, oval, or round forms that reflect the waxy coatings (exines) cross-sectioning of a flattened, hollow, ovoid body; sometimes exhibits rod-like projections that are small relative to the size of the total body.

DISCUSSION—Sporinite originated as a lipid substance that covered, as a skin, ovoid spore or pollen grains which commonly ranged from around ten to several hundred micrometres in diameter. Sporinite often occurs as fragments derived from these initially ovoid bodies.

inertinite, n—a group of macerals composed of fusinite, inertodetrinite, macrinite, micrinite, sclerotinite, and semifusinite.—macerals that exhibit higher reflectance than other organic substances in the coal.

DISCUSSION—These macerals, even in bituminous—In any coal ranked lower than anthracitic, inertinite reflectance commonly spans the range from only slightly higher than associated vitrinite to very high reflectance (often as high as $R_o > 6\%$). In anthracitic rank coals, show little or no plasticity when heated inertinite reflectance may be lower than that of vitrinite, and so are inert or show only a little agglutinating tendency is then recognized by its morphology and form of anisotropy. Highly reflecting inertinite commonly exhibits relief on polished surface. Its name derives from the fact that most varieties behave inertly in the thermoplastic deformation during the coking. Th process (except in its lowest reflecting manifestation). The volatile matter yield of inertinite is higher lower than that of associated vitrinite. other macerals in the same coal.

fusinite, n— an inertinite maceral distinguished principally by the well-preserved original form preservation of some feature(s) of the plant cell wall structure, intact or broken, with open or mineral-filled cell lumens (cavities); and by having with a reflectance (except in meta-anthracite), well above that of associated vitrinite. The particle size is generally greater than 50 μm except when isolated from other macerals.

DISCUSSION—Occurrences of fusinite in peat and low-rank coals suggests that it is derived from relatively rapid alteration; occurs as by charring; of plant cell walls before deposition or in surficial layers of a fragment within the peat bed; binder matrix; see also **semifusinite**.

inertodetrinite, n—an inertinite maceral occurring as individual, angular, clastic fragments incorporated within the matrix of other inertinite macerals, surrounded by other macerals, commonly vitrinite, macerals (commonly vitrinite) or minerals, and also distinguished by a reflectance higher than that of associated vitrinite. The size of in the particles is generally greater than size range from 2- μm and less than to 50 μm .

macrinite, n—the maceral that is distinguished by a reflectance higher than that of associated vitrinite, absence of recognizable— an inertinite maceral, generally nonangular, exhibiting no relict plant cell wall structure; and a nonangular shape. The particle size is generally greater larger than 10 μm .

micrinite, n—the maceral that is distinguished by reflectance higher than that of associated vitrinite, absence of recognizable— an inertinite maceral, generally nonangular, exhibiting no relict plant cell wall structure, and occurring as individual particles of size less smaller than 10 μm and most commonly occurring as particles around 1- to 5- μm diameter.

sclerotinite, n—maceral having reflectance between that of fusinite and associated vitrinite and—an inertinite maceral occurring as round or oval cellular bodies of varying size (20 to 300 μm) or ovoid bodies, frequently containing voids, reflecting an origin from fungal sclerotia; also occurs (especially in lower rank coals) as interlaced, strissungy materials derived from fungal remains-hyphae.

semifusinite, n—an inerthinite maceral that is intermediate in reflectance between with morphology like fusinite and associated vitrinite, that shows plant cell wall structure sometimes with cavities generally oval or elongated in cross section, but in some specimens less well defined distinct evidence of cellular structure, but with reflectance ranging from slightly greater than that of associated vitrinite to some value intermediate to that of the brightest fusinite. The particle size is generally also greater than 50 μm except when isolated from other macerals. Often, it occurs as a transitional material fragment within the binder matrix.

DISCUSSION—The precise reflectance boundary between vitrinite semifusinite and fusinite has not been universally defined, although some practitioners place the division at $R_o = 2.0\%$; hence, semifusinite is somewhat vaguely defined as “fusinite with low reflectance.”

vitrinite, n—the predominant maceral and maceral group composing all or almost all in most coals of the vitrain, and like material intermediate reflectance occurring in attrital coal as the component substantial volumes of reflectance intermediate between those more or less uniformly reflecting material or as a matrix enclosing particles of exinite other macerals and mineral matter or as particles or bands intermixed with other maceral fragments.

DISCUSSION—Vitrinite, the predominant maceral in—Because most coals, vitrinite is produced by derived from the gradual alteration cellular, structural tissues of plants, it may exhibit relict cell-substances, the structure structure. The reflectance of which may either be well discernible or more or less obscured by vitrinite is related to the effects rank of degradation. In extreme cases, tissue may be reduced to a featureless substance, so that the material coal in which it is quite homogeneous found. Reflectance increases (from around $R_o = 0.3\%$ in appearance. The optical properties of vitrinite change progressively with increase lignitic coals) in coal rank, parallel with the change being measured best by the progressive increase in reflectance determined in accordance fixed carbon yield associated with Practice D 2797 and Test Method D 2798. The change increasing rank. Because many of reflectance of vitrinite correlates well with the change properties of its other properties, such as volatile matter and carbon content, calorific value, porosity, hardness, and plasticity during carbonization. Within the range of typical coals possessing coking properties, vitrinite is reflect the material most responsible for swelling, agglomerating, and agglutinating properties of coal. Because it is the predominant maceral group in most coals and because of its importance in the coking process, dominating vitrinite, it is common practice in petrographic analyses to estimate coal properties and process behaviors by measuring the reflectance of a representative sampling of vitrinite; in addition the specimen according to analysis for several macerals (Test procedures described in Test Method D 2799);8. Pseudovitrinite, a certain variety of vitrinite, is differentiated by some practitioners. It exhibits slightly higher reflectance than most of the vitrinite in the coal and is commonly slitted, with indistinct remnant cell structure and angular or jagged edges. Pseudovitrinite has been postulated to be less thermoplastic in the frequency distribution coking process. The term vitrinite is currently used as both a maceral and maceral group. The subcommittee is actively working on defining subcategories of its reflectance values (Test Method D 2798).

D 2796 the maceral group-vitrinite.

macrinite—See *macrinite* under **maceral**.

mechanical cell, n—a type of flotation cell that uses mechanical agitation of a pulp by means of an immersed impeller (rotor) and stator stirring mechanism. Aeration to the cell can be from an external pressurized air source or self-induced air. **D 5114**

medium volatile bituminous coal—See *medium volatile bituminous coal* under **rank**.

meta-anthracite—See *meta-anthracite* under **rank**.

micrinite—See *micrinite* under **maceral**.

microprocessor, n—a central processing chip within the electronic controller section of the apparatus.

mineralized coal—See *mineralized coal* under **coal**.

mineral parting, n—discrete layer of mineral or mineral-rich sediment interbedded with coal along which, in mining, separation commonly occurs. Layers of bone coal having indefinite boundaries usually are not considered to be partings because they do not form planes of physical weakness. They may merge vertically or horizontally with layers that are bony or coaly shale and that do form planes of physical weakness. **D 2796**

moisture, n—*in coal*, that water in and on coal assayed in accordance with standard test methods in which the final step is the measurement of mass loss from a coal sample heated to 104 to 110°C at specified conditions of residence time, atmosphere, sample mass, and equipment configuration.

DISCUSSION—All coals are porous and, in their natural state, the pores are essentially full of water (inherent moisture). When coal is mined and processed, water may also be present on the surface of the pieces of coal (surface moisture). Water formed by the thermal decomposition of the organic fraction of coal or associated mineral matter is not considered part of the moisture content of coal. In some coals, a very small portion of the assayed mass loss may be volatile hydrocarbons and dissolved or adsorbed gases. ASTM-standardized procedures for the determination of moisture in coal are designed for commercial purposes to facilitate trade and resource evaluation; they may not be adequate for research or other activities with different requirements. **D 3302, D 3173, D 2961**

equilibrium moisture, n—the moisture in a coal sample as determined in accordance with Test Method D 1412. **D 1412**

inherent moisture, n—*in coal*, the moisture that exists as an integral part of the coal in its natural state, including water in pores, but not that present in macroscopically visible fractures.

DISCUSSION—In coal as it exists in the ground before it is disturbed, the pores are essentially filled with water (gases, for example, methane, may occupy a minor proportion of the pore volume in some coals); this pore-filling moisture is determined as total moisture and referred to as inherent moisture in a freshly collected sample that (1) does not exhibit visible water on fracture surfaces, (2) has not been allowed to dry after collection, and

(3) was collected from a fresh coal face that is not dried (see Classification D 388). On samples not meeting these criteria, inherent moisture may be estimated by determining equilibrium moisture in accordance with Test Method D 1412. **D 388, D 1412**

pore moisture, n—moisture in the pores of coal, which may be quantitatively equivalent to or less than inherent moisture depending upon the state of dryness of the sample.

residual moisture, n—that moisture remaining in the sample after air drying.

DISCUSSION—Residual moisture is neither a standard state nor a characteristic property of a coal. Air drying only removes water that can evaporate at or near ambient laboratory conditions leaving in the coal water that will not evaporate at those conditions. Different laboratory environments or different drying temperature or both will produce significant differences in air-dry loss and residual moisture. Residual moisture is assayed by determining the mass lost from drying the sample at 104 to 110°C at specified conditions of residence time, atmosphere, particle size, sample mass, and equipment configuration. **D 3173, D 3302**

surface moisture, n—that portion of total moisture in a consignment or sample of coal that is in excess of inherent moisture.

DISCUSSION—Surface moisture is not to be equated with mass loss upon air drying—a practice in some countries. Some sources of surface moisture are: groundwater, drilling fluids, dust-suppressant sprays, preparation plant water, and precipitation.

total moisture, n—all of the moisture in and on a consignment or sample of coal.

DISCUSSION—In a consignment or sample of coal in which surface moisture is present, total moisture is the sum of surface moisture and pore moisture. In consignments or samples of coal in which some portion of the as-mined moisture may have been removed by partial drying, total moisture may be less than the inherent moisture. Total moisture is commonly determined by quantitatively air drying a sample and then assaying residual moisture in the air-dried sample; thus, total moisture is the sum of the air-dry loss and the residual moisture adjusted to the as-received basis. **D 3302, D 2961**

natural pH, n—the measured pH of the pulp before the addition of collector, frother, or any conditioning agents. **D 5114**

net calorific value (net heat of combustion at constant pressure), n—the heat produced by combustion of unit quantity of a solid or liquid fuel when burned, at a constant pressure of 1 atm (0.1 MPa), under conditions such that all the water in the products remains in the forms of vapor.

DISCUSSION—The net calorific value is a lower heating value that can be calculated from the gross calorific value by making a correction for the difference between a constant volume process and a constant pressure process, and a deduction for the vaporization of the water in the combustion products, including both the water initially present as moisture and that formed by combustion. At 20°C (68°F), the total deduction is 1030 Btu/lb of water (2.395 MJ/kg) including 1055 Btu/lb of water (2.454 MJ/kg) for the enthalpy of vaporization of water.

The net calorific value is closely related to the net enthalpy change of combustion at standard temperature and pressure, $\Delta H_{\text{c}}(t_{\text{c}})$. It is of opposite sign and differs in magnitude by a small amount due to enthalpy effects resulting from compression, temperature differences from t , and solution effects, that vary with the combustion conditions.

nonbanded coal—See *nonbanded coal* under **coal**.

nonprobability sample, n—a sample of which the sampling units have not been selected in a manner that satisfies the minimum requirements for probability sampling.

DISCUSSION—No meaningful statistical inference can be made with data obtained from a nonprobability sample. No meaningful statement can be made concerning the precision, standard error, or bias of the sample.

opening—for the purpose of Test Method D 4749, openings and apertures shall be regarded as synonymous terms. Dimensions for round and square openings shall be determined as follows: for round holes, dimensions shall refer to the opening diameter; for square holes, dimensions shall refer to the distance between parallel wires.

prepared coal—for the purpose of Test Method D 4749, any coal, regardless of its topsize, that has been manually or mechanically cleaned. This includes coal that has been processed over a picking table or air tables through a breaker, jig, or other device which segregates according to size or density (specific gravity).

probability sample, n—a sample of which the sampling units have been selected by a chance process such that, at each step of selection, a specified probability of selection can be attached to each member available for selection.

DISCUSSION—To satisfy the minimum requirements for probability sampling, it is necessary: (1) that every part of the pile, lot, or shipment has a nonzero chance of selection, (2) that these probabilities of selection be known, at least for the parts actually selected, and (3) that, either in measurement or in computation, each item be weighted in inverse proportion to its probability of selection. **E 456**

proximate analysis, n—in the case of coal and coke, the determination, by prescribed methods, of moisture, volatile matter, fixed carbon (by difference), and ash.

DISCUSSION—Unless otherwise specified, the term *proximate analysis* does not include determinations of sulfur or phosphorus or any determinations other than those named.

pulp, n—a fluid mixture of solids and water, also known as slurry. **D 5114**

random variance of increment collection (unit variance)—See *random variance of increment collection (unit variance)* under **variance**.

rank, *n*—of coal, a classification designation that indicates the degree of metamorphism, or progressive alteration, from lignite to anthracite.

anthracite, n—the rank of coal, within the anthracitic class of Classification D 388, such that on the dry and mineral-matter-free basis, the volatile matter content of the coal is greater than 2 % but equal to or less than 8 % (or the fixed carbon content is equal to or greater than 92 % but less than 98 %), and the coal is nonagglomerating.

anthracitic class, n—a class of rank consisting of semianthracite, anthracite, and meta-anthracite.

bituminous class, n—a class of rank consisting of high volatile C bituminous coal, high volatile B bituminous coal, high volatile A bituminous coal, medium volatile bituminous coal, and low volatile bituminous coal.

high volatile A bituminous coal, n—the rank of coal, within the bituminous class of the Classification D 388, such that on the dry and mineral-matter-free basis, the volatile matter content of the coal is greater than 31 % (or the fixed carbon content is less than 69 %), and its gross calorific value is equal to or greater than 14 000 Btu/lb (32.65 MJ/kg) of coal on the moist, mineral-matter-free basis, and the coal is commonly agglomerating.

high volatile B bituminous coal, n—the rank of coal, within the bituminous class of Classification D 388, such that, on the moist, mineral-matter-free basis, the gross calorific value of the coal in British thermal units per pound is equal to greater than 13 000 (30.24 MJ/kg) but less than 14 000 (32.54 MJ/kg) and the coal commonly agglomerates.

high volatile C bituminous coal, n—the rank of coal, within the bituminous class of Classification D 388, such that, on the moist, mineral-matter-free basis, the gross calorific value of the coal in British thermal units per pound is equal to or greater than 11 500 (26.75 MJ/kg) but less than 13 000 (30.24 MJ/kg) and the coal commonly agglomerates, or equal to or greater than 10 500 (24.42 MJ/kg) but less than 11 500 (26.75 MJ/kg) and the coal agglomerates.

lignite A, n—the rank of coal, within the lignitic class of Classification D 388, such that, on the moist, mineral-matter-free basis, the gross calorific value of the coal in British thermal units per pound is equal to greater than 6300 (14.65 MJ/kg) but less than 8300 (19.31 MJ/kg), and the coal is nonagglomerating.

lignite B, n—the rank of coal, within the lignitic class of Classification D 388, such that, on the moist, mineral-matter-free basis, the gross calorific value of the coal in British thermal units per pound is less than 6300 (14.65 MJ/kg), and the coal is nonagglomerating.

lignitic class, n—a class of rank consisting of lignite A and lignite B.

low volatile bituminous coal, n—the rank of coal, within the bituminous class of Classification D 388, such that, on the dry and mineral-matter-free basis, the volatile matter content of the coal is greater than 14 % but equal to or less than 22 % (or the fixed carbon content is equal to or greater than 78 % but less than 86 %), and the coal commonly agglomerates.

medium volatile bituminous coal, n—the rank of coal, within the bituminous class of Classification D 388, such that, on the dry and mineral-matter-free basis, the volatile matter content of the coal is greater than 22 % but equal to or less than 31 % (or the fixed carbon content is equal to or greater than 69 % but less than 78 %), and the coal commonly agglomerates.

meta-anthracite, n—the rank of coal, within the anthracite class of Classification D 388, such that, on the dry and mineral-matter-free basis, the volatile matter content of the coal is equal to or less than 2 % (or the fixed carbon is equal to or greater than 98 %), and the coal is nonagglomerating.

semianthracite, n—the rank of coal, within the anthracitic class of Classification D 388, such that, on the dry and mineral-matter-free basis, the volatile matter content of the coal is greater than 8 % but equal to or less than 14 % (or the fixed carbon content is equal to or greater than 86 % but less than 92 %), and the coal is nonagglomerating.

subbituminous class, n—a class of rank consisting of subbituminous C coal, subbituminous B coal, and subbituminous A coal.

subbituminous C coal, n—the rank of coal, within the subbituminous class of Classification D 388, such that, on the moist, mineral-matter-free basis, the gross calorific value of the coal in British thermal units per pound is equal to greater than 8300 (19.31 MJ/kg) but less than 9500 (22.10 MJ/kg), and the coal is nonagglomerating.

subbituminous B coal, n—the rank of coal, within the subbituminous class of Classification D 388, such that, on the moist, mineral-matter-free basis, the gross calorific value of the coal in British thermal units per pound is equal to greater than 9500 (22.10 MJ/kg) but less than 10 500 (24.42 MJ/kg) and the coal is nonagglomerating.

subbituminous A coal, n—the rank of coal, within the subbituminous class of Classification D 388, such that, on the moist, mineral-matter-free basis, the gross calorific value of the coal in British thermal units per pound is equal to greater than 10 500 (24.42 MJ/kg) but less than 11 500 (26.75 MJ/kg) and the coal is nonagglomerating.

raw coal—for the purpose of Test Method D 4749, any coal, regardless of its topsize, that has not been manually or mechanically cleaned. Crushed coal that has not been mechanically cleaned (including coal that has not been through a breaker which normally rejects oversize) is considered to be raw coal. Coal delivered to the surface from an underground mine is considered to be raw coal even when crushing and grinding is done underground. Coal removed from the pit of a surface mine is considered to be raw coal even when breaking and crushing facilities are provided *in the pit*. **D 4749**

recovery, *n*—the percent of the valuable component (that is, Btu or combustible) from the feed that reports to the froth concentrate product. **D 5114**

repeatability limit (*r*)—The value below which the absolute difference between two results from separate and consecutive test determinations, carried out on the same sample in the same laboratory by the same operator using the same apparatus on the

samples taken at random from a single quantity of homogeneous material, may be expected to occur with a probability of approximately 95%.

DISCUSSION—The value below which will fall approximately 95% of the absolute differences between two consecutive test results obtained in the shortest practical period of time by the same operator using the same test method in the same laboratory with the same equipment on test portions from one test sample.

The repeatability limit is $2.8 (1.96 \times \sqrt{2})$ times the repeatability standard deviation. This multiplier is independent of the size of the interlaboratory study, as explained in Practice E 177.

The approximation to 0.95 is reasonably good (say, 0.90 to 0.98) when many laboratories (30 or more) are involved, but it is likely to be poor when fewer than eight laboratories are studied. **E 456**

reporting bases:

as-determined basis, n—analytical data obtained from the analysis sample of coal or coke after conditioning and preparation to No. 60 (250- μ m) sieve in accordance with Method D 2013. As-determined data represents the numerical values obtained at the particular moisture level in the sample at the time of analysis. These are normally converted, according to formulae contained in Practice D 3180, to conventional reporting bases.

as-received basis, n—analytical data calculated to the moisture condition of the sample as it arrived at the laboratory and before any processing or conditioning. If the sample has been maintained in a sealed state so that there has been no gain or loss, the as-received basis is equivalent to the moisture basis as sampled.

dry, ash-free basis, n—data calculated to a theoretical base of no moisture or ash associated with the sample. Numerical values as established by Test Methods D 3173 and D 3174 are used for converting the as-determined data to a moisture- and ash-free basis.

dry basis, n—data calculated to a theoretical base of no moisture associated with the sample. The numerical value as established by Test Method D 3173 is used for converting the as-determined data to a dry basis.

equilibrium moisture basis, n—data calculated to the moisture level established as the equilibrium moisture. Numerical values as established by Test Method D 1412 are used for the calculation. **D 3180**

representative sample— See *representative sample* under **sample**.

residual moisture— See *residual moisture* under **moisture**.

resinite—See *resinite* under **maceral**.

reproducibility limit, n—the value below which the absolute difference between two test results obtained under reproducibility conditions may be expected to occur with a probability of approximately 0.95 (95 %).

DISCUSSION—The reproducibility limit is $2.8 (1.96 \times \text{square root of } 2)$ times the reproducibility standard deviation. The multiplier is independent of the size of the interlaboratory study (that is, of the number of laboratories participating), as explained in Practice E 177. The approximation to 0.95 is reasonably good (say 0.90 to 0.98) when many laboratories (30 or more) are involved but is likely to be poor when fewer than 8 laboratories are studied. **E 456**

reproducibility standard deviation, n— the standard deviation of test results obtained under reproducibility conditions.

DISCUSSION—Other measures of the dispersion of test results obtained under the reproducibility conditions are the reproducibility variance and the reproducibility coefficient of variation.

The reproducibility standard deviation includes, in addition to between-laboratory variability, the repeatability standard deviation and a contribution from the interaction of laboratory factors (that is, differences between operators, equipment, and environments) with material factors (that is, the differences between properties of the materials other than that property of interest). **E 456**

ribbon anisotropic phase, n—*as used in Test Method D 5061*, a group of binder-phase anisotropic carbon textures distinguished by their ribbon-like domains (that is, length (L) to width (W) ratio of $L > 4W$), and subdivided based on domain width as fine ribbon (2.0- to 12.0- μ m), medium ribbon (12.0- to 25.0- μ m), and coarse ribbon (>25.0- μ m) size categories. **D 5061**

rifle, n—a hand-fed sample divider device that divides the sample into two parts of approximately the same weight. **D 2013**

roof, n—the rock material immediately overlying a coal bed.

run-of-mine (ROM) coal— *for the purpose of Test Method D 4749, (1) in the case of an underground mine*, it is that coal delivered to the surface by a slope belt, hoist, and so forth.

(2) *in the case of a surface mine*, it is that coal as it exists after it has been removed from the pit and placed into the initial means of transportation whether it be an on-the-road or off-the-road haul truck, dump hopper which feeds a pit-to-plant conveyor, and so forth. For both underground and surface mines, ROM coal is as-mined and has not been exposed to any treatment such as breaking, crushing, or cleaning except for that done by the normal operations used to extract the coal from the ground, that is, blasting, ripping, loading, cutting, and so forth.

sample, n—a quantity of material taken from a larger quantity for the purpose of estimating properties or composition of the larger quantity. **D 2234**

analysis sample, n—final subsample prepared from the original gross sample but reduced to 100 % through No. 60 (250- μ m) sieve and divided to not less than 50 g. **D 2013; D 2234**

coarse coal, n—that portion of a coal sample being subjected to a washability study that is larger than a specific predetermined particle size, generally between 2.36 mm (No. 8 USA Standard Sieve Series) and 9.5 mm ($\frac{3}{8}$ in.) round in diameter.

DISCUSSION—This same particle size breakpoint should then be used in subsequent washability studies of the same material sampled from the same location for the same application. This breakpoint is determined by the analyst or the person designing the test procedure as the point that best suits the application. This coarse-coal fraction may be further sieved (generally by dry sieving) to produce additional size fractions, each of which may be processed through the desired specific gravity solutions. **D 4371**

—*divided sample, n*—a sample that has been reduced in quantity. **D 2013**—See *subsample*.

fine coal, n—that portion of a coal sample being subject to a washability study that is smaller than the predetermined particle size, generally between 2.36 mm (No. 8 USA Standard Sieve Series) and 9.5 mm (3/8 in.) round in diameter, which is specified in Test Method D 4371.

DISCUSSION—This same particle size breakpoint should then be used in subsequent washability studies of the same material samples from the same location for the same application. This breakpoint is determined by the analyst or the person designing the test procedure as the point that best suits the application. This fine-coal fraction may be further sieved (generally by wet sieving) to produce additional size fractions, each of which is processed through the desired specific gravity solutions. **D 4371**

—*gross moisture sample, n*—a sample representing one lot of coal and composed of a number of increments on which neither reduction nor division has been performed or a subsample for moisture testing taken.

—*gross sample, n*—a sample representing one lot of coal and composed of a number of increments on which neither reduction nor division has been performed. **D 2013; D 2234**

laboratory sample, n—the sample, not less than the permissible weight delivered to the laboratory for further preparation and analysis. **D 2013**

representative sample, n—a sample collected in such a manner that every particle in the lot to be sampled is equally represented in the gross or divided sample. **D 2013; D 2234; D 4916**

subsample, n—a sample taken from another sample. **D 2013; D 2234; D 4916**

unbiased sample (representative sample)—a sample free of bias. **D 2013; D 2234; D 4916**

sample division, n—the process whereby a sample is reduced in weight without change in particle size. **D 2013; D 2234; D 4916**

sample reduction, n—the process whereby a sample is reduced in particle size by crushing or grinding without significant change. **D 2013**

sample preparation, n—the process that may include air drying, crushing, division, and mixing of a gross sample for the purpose of obtaining an unbiased analysis sample. **D 2013**

sclerotinite—See *sclerotinite* under **maceral**.

seam moisture, n—synonym for *inherent moisture*.

semianthracite—See *semianthracite* under **rank**.

semifusinite—See *semifusinite* under **maceral**.

significant loss, n—any loss that introduces a bias in final results that is of appreciable economic importance to the concerned parties. **D 2013; D 2234; D 4915; D 4916**

size consist, n—the particle size distribution of a coal. **D 2013; D 2234; D 4915; D 4916**

softening temperature (ST), n—*in reference to the fusibility of coal and coke ash according to Test Method D 1857*, the temperature at which the cone has fused down to a spherical lump in which the height is equal to the width at the base.

solids concentration, n—the ratio, expressed as a percent, of the weight (mass) of solids to the sum of the weight of solids plus water. **D 5114**

sonde, n—an elongate cylindrical tool assembly used in a borehole to acquire a geophysical log.

spacing of increments, n—pertains to the kind of intervals between increments. Two spacing methods are recognized: systematic and random. Systematic spacing is usually preferable.

systematic spacing 1, n—in which the movements of individual increment collection are spaced evenly in time or in position over the lot.

random spacing 2, n—in which the increments are spaced at random in time or in position over the lot. **D 4916**

sparking fuels, n—*within the context of Test Method D 3175*, fuels that do not yield a coherent cake as residue in the volatile matter determination but do evolve gaseous products at a rate sufficient to mechanically carry solid particles out of the crucible when heated at the standard rate. Such coals normally include all low-rank noncaking coals and lignites but may also include those anthracites, semianthracites, bituminous, chars, and cokes that lose solid particles as described above. These are defined as *sparking fuels* because particles escaping at the higher temperatures may become incandescent and spark as they are emitted.

sporinite—See *sporinite* under **maceral**.

standard deviation, n—the most usual measure of the dispersion of observed values or results expressed as the positive square root of the variance. **D 2013; D 2234**

subbituminous A coal— See *subbituminous A coal* under **rank**.

subbituminous B coal— See *subbituminous B coal* under **rank**.

subbituminous C coal— See *subbituminous C coal* under **rank**.

subbituminous class— See *subbituminous class* under **rank**.

subsample—See *subsample* under **sample**.

tailings, n—the underflow product from coal froth flotation.

D 5114

test portion, n—a quantity of material that is representative of the analysis sample and sufficient to obtain a single test result for the property or properties to be measured.

test specimen, n—synonym for **test portion**.

test unit, n—synonym for **analysis sample**.

textural component, n—as used in *Test Method D 5061*, the collective term used to describe carbon forms and recognizable coal- and process-derived components (binder-phase, filler-phase, and miscellaneous material), in coke.

D 5061

topsize, n—the opening of the smallest screen in the series upon which is retained less than 5 % of the sample (see *Test Method D 4749*).

D 2013; D 2234; D 4916

topsize, nominal—for the purpose of *Test Method D 4749*, the sieve designating the upper limit or topsize shall be that sieve of the series given in the Standard Series of Sieves section with the smallest openings upon which is cumulatively retained a total of less than 5 % of the sample. This defined topsize is not to be confused with the size of the largest particle in the lot.

D 4749

total carbon, n—carbon content remaining in the solid products derived from the combustion or reaction of coal, coal by-products, or coke, inclusive of carbonate in any form.

D 6316

total moisture—See *total moisture* under **moisture**.

total variance—See *total variance* under **variance**.

ultimate analysis, n—in the case of coal and coke, the determination of carbon and hydrogen in the material, as found in the gaseous products of its complete combustion, the determinations of sulfur, nitrogen, and ash in the material as a whole, and the calculation of oxygen by difference.

DISCUSSION—The determination of phosphorus or chlorine is not by definition a part of the ultimate analysis of coal or coke. See *Test Method D 2361* for the determination of chlorine and *Test Methods D 2795* for the determination of phosphorus.

Moisture is not by definition a part of the ultimate analysis of coal or coke but must be determined so that analytical data may be converted to bases other than that of the analysis sample.

Inasmuch as some coals contain mineral carbonates, and practically all contain clay or shale containing combined water, a part of the carbon, hydrogen, and oxygen found in the products of combustion may arise from these mineral components.

D 3176

unbiased sample—See *unbiased sample* under **sample**.

variance, n—the mean square of deviations (or errors) of a set of observations; the sum of squared deviations (or errors) of individual observations with respect to their arithmetic mean divided by the number of observations less one (degrees of freedom); the square of the standard deviation (or standard error).

D 2013; D 2234

random variance of increment collection (unit variance), S_r^2 , n—the theoretical variance calculated for a uniformly mixed lot and extrapolated to 0.5-kg (1-lb) increment size.

D 2234

segregation variance of increment collection, S_s^2 , n—the variance caused by nonrandom distribution of ash content or other constituent in the lot. For a method of estimating this variance, see Annex A1 of *Test Methods D 2234*.

D 2234

total variance, S_o^2 , n—the overall variance resulting from collecting single increments and including division and analysis of the single increments.

D 2013; D 2234

variance of analysis, S_a^2 , n—the variance caused by chance errors (deviations) of analysis.

D 2013

variance of division, S_d^2 , n—the variance caused by chance errors (deviations) of sample division.

D 2013

variance of division and analysis, S_{da}^2 , n—the variance caused by the combined chance errors of division and analysis.

D 2013

vitrain—See *vitrain* under **coal**.

vitritinite—See *vitritinite* under **maceral**.

vitritinite type, n—as used in *Test Method D 5061*, reflectance classes of vitritinite which span 0.1 % reflectance intervals.

DISCUSSION—This term is commonly referred to as V-type. For example, V-type 6 includes vitritinite reflectance values from 0.6 through 0.69 %.

D 5061

volatile matter, n—those products, exclusive of moisture, given off by a material such as gas or vapor, determined by definite prescribed methods which may vary according to the nature of the material.

DISCUSSION—In the case of coal and coke, the methods used shall be those prescribed in *Test Method D 3175*.

washability analysis of coal, n—the analysis of the specific gravity distribution of chemical and physical characteristics of coal.

DISCUSSION—The specific gravity fractions are obtained by subjecting the material being studied to a series of solutions, each with a discrete specific gravity, that cover the range of specific gravities in question. In the case of the washability analysis of coal, these solutions are obtained by the mixing of various organic liquids that are relatively inert toward the majority of coal types. The distribution, as determined by the analysis, is affected by the physical condition of the sample subjected to the washability analysis, for example, the moisture content and the size content of the material.

D 4371

water equivalent, n—Synonym for **energy equivalent**.

wet sieving—for the purpose of *Test Method D 4749*, the test method for the sieving of coal that uses water as a medium for

facilitating the segregation of the sample into particle size; this is generally used when testing coal particles 600 μm (No. 30 U.S.A. Standard Series) or smaller.

yield, *n*—the weight percent of the feed that reports to the concentrate.

D 4749
D 5114

4. Classification and Relationship of Terms

4.1 Terms Used to Classify Coal by Rank:

4.1.1 *Classification*—The classification of terms used to classify coal by rank in accordance with Classification D 388 are as follows:

Class	Group
Anthracitic	meta-anthracite anthracite semianthracite
Bituminous	low volatile bituminous coal medium volatile bituminous coal high volatile A bituminous coal high volatile B bituminous coal high volatile C bituminous coal
Subbituminous	subbituminous A coal subbituminous B coal subbituminous C coal
Lignitic	lignite A lignite B

4.2 Terms Used in Megascopic Descriptions of Coal Seams and Hand Specimens of Coal:

4.2.1 Some relationships of terms are shown in outline form below. Defined terms are indicated by bold type. **Coal:**

banded coal:

atrrital coal

fusain

vitrain

nonbanded coal:

cannel or **boghead** or transition between these varieties

impure coal:

bone coal

mineralized coal

other impure coal

4.3 Terms Used in Microscopical Description and Analysis of Coal:

4.3.1 *Classification*—The classification of the microscopic constituents into groups of similar properties in a given coal is as follows:

Maceral Group	Maceral
Vitrinite	vitritite
Liptinite	alginite cutinite resinite sporinite
Inertinite	fusinite inertodetrinite macrinite micrinite sclerotinite semifusinite

5. Keywords

5.1 analysis; coal; coke; definitions; sampling; terminology; terms

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