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Standard Test Method for Microscopical Determination of the Textural Components of Metallurgical Coke[1]

This standard is issued under the fixed designation D5061; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the equipment and procedures used for determining the types and amounts of coke carbon forms and associated recognizable coal- and process-derived textural components in metallurgical coke in terms of volume percent. This test method does not include coke structural components such as coke pores, coke wall dimensions, or other structural associations.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D121 Terminology of Coal and Coke

~~D3997~~D3997/D3997M Practice for Preparing Coke Samples for Microscopical Analysis by Reflected Light

3. Terminology

3.1 *Definitions*—For additional definitions of terms used in this test method, refer to Terminology D121.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *anisotropic, adj*—exhibiting optical properties of different values when viewed with an optical microscope having mutually exclusive polarized light, for example, crossed nicols.

3.2.2 *binder phase, n*—a continuous solid carbon matrix formed during the thermoplastic deformation of those coal macerals that become plastic during carbonization.

[1] This test method is under the jurisdiction of ASTM Committee D05 on Coal and Coke and is the direct responsibility of Subcommittee D05.28 on Petrographic Analysis of Coal and Coke.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.2.1 *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.

3.2.3 *carbon form, n*—microscopically distinguishable carbonaceous textural components of coke, but excluding mineral carbonates.

3.2.3.1 *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.

3.2.4 *circular anisotropic phase, n*—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.

3.2.5 *coke pore, n*—a microscopically distinguishable void that is a structural element of coke.

3.2.5.1 *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.

3.2.6 *coke reactivity, n*—a measure of the mass loss when coke, held at a designated temperature, is contacted with gaseous carbon dioxide over a specific time interval.

3.2.7 *coke wall, n*—a predominantly carbonaceous layer that encloses a coke pore and which is a structural element and essence of coke.

3.2.8 *depositional carbon, n*—a group of carbon forms that are formed from cracking and nucleation of gas-phase hydrocarbon molecules during coal carbonization.

3.2.8.1 *pyrolytic carbon, n*—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.

3.2.8.2 *sooty carbon, n*—an isotropic carbon form comprised of approximately spherical particles of less than 1-μm diameter sometimes referred to as combustion black.

3.2.8.3 *spherulitic carbon, n*—a spherical anisotropic carbon form sometimes referred to as thermal black that is formed by the deposition of carbon concentrically around a nucleus.

3.2.9 *domain, n*—a region of anisotropy in a carbon form that is distinctively marked by its isochromatic boundary and cleavage.

3.2.10 *filler phase, n*—a discontinuous solid formed from coal macerals and minerals that do not deform thermoplastically during carbonization.

3.2.10.1 *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.

3.2.11 *green coke, n*—carbonaceous binder or filler phase material that has exceeded the temperature of thermoplasticity, but has not obtained the temperature of metallurgical coke.

3.2.11.1 *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.

3.2.12 *incipient anisotropic phase, n*—a binder-phase carbon texture having a domain size (less than 0.5 μm) that is near the measuring resolution of the light microscope.

3.2.13 *isotropic phase, n*—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.

3.2.14 *lenticular anisotropic phase, n*—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.

3.2.15 *ribbon anisotropic phase, n*—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-μm), medium ribbon (12.0 to 25.0-μm), and coarse ribbon (>25.0-μm) size categories.

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

3.2.17 *vitrinite type, n*—reflectance classes of vitrinite which span 0.1 % reflectance intervals.

3.2.17.1 *Discussion*—

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

4. Summary of Test Method

4.1 The textural components of coke (coke carbon forms and associated coal- and process-related components) in a representative crushed particulate coke sample, prepared in the form of a briquetted, polished specimen as described in Practice ~~D3997~~D3997/D3997M, are identified under a microscope according to their degree of anisotropism, carbon form domain sizes, boundary size, color of individual isochromatic domains, their morphology, relative reflectance, and other optical properties. The proportions of these textural components in a sample are determined by observing a statistically adequate number of points, and summing those representative of each component. Only area proportions of components are observed on the briquette surface. However, the area and volume proportions are the same when the components are randomly distributed throughout the sample.

4.1.1 Color photomicrographs of the textural components of metallurgical coke illustrating their microscopic features are available from various publications and websites.[3,4]

5. Significance and Use

5.1 The determination of the volume percent of the textural components in coke is useful to characterize the optical properties of coke as it relates to utilization. Specifically, the technique has been used as an aid in determining coal blend ~~proportions (after correcting for coke yield),~~ proportions, and recognition of features present in the coke that can be responsible for coke quality or production problems such as reduced coke strength or difficulty in removing coke from commercial coke ovens, or both. The study of coke textures is also useful in promoting a better understanding of coke reactivity, and the relationship between coal petrography and its conversion to coke.[4]

5.2 This test method is used in scientific and industrial research, but not for compliance or referee tests.

6. Apparatus

6.1 *Microscope*—A high quality reflected-light microscope with a vertical illuminator and rotating mechanical stage is used, provided that the objective and eyepiece lenses permit resolution of objects on the order of 0.5 µm. The objective lens shall be of such construction that samples can be studied in oil with plane-polarized light. A minimum total magnification of approximately 500 diameters is recommended. Use of an accessory plate (quartz, gypsum, or mica), an analyzer, and polarizer combination is recommended to achieve optimum optical effect for discriminating among the various textural components. Either a prism or a partially reflecting glass plate may be employed in the illuminator. One eyepiece of the microscope must be fitted with a special ruled graticule disc.

6.1.1 *Eyepiece Disc*—The eyepiece shall contain a ruled graticule disc to enable size estimations and to provide a field-of-view grid for point counting. The design may be a squared pattern (10 by 10 squares) containing a bolder crosshair with one of the squares near the center crosshair intersection divided into 25 subsquares. The ruled portion of the disc shall cover at least one third of the field of view.

6.1.2 *Mechanical Stage*—The mechanical stage shall be of such type that the specimen can be quickly advanced by definite fixed increments in two perpendicular directions (referred to as the *X* and *Y* directions).

6.2 *Counter*—The counter shall be capable of recording counts for at least eight components (preferably twelve or more) equipped with a totalizer. The counter design can either be mechanical or electrical.

6.3 *Immersion Oil*—The oil shall be a nondrying, noncorrosive, noncarcinogenic type having similar properties as used for coal microscopic techniques.

7. Organization of Analysis[4]

7.1 Textural components are grouped into three major categories; (*1*) binder phase carbon forms, (*2*) filler phase carbon forms (including coal-related inorganic material), and (*3*) miscellaneous materials. These categories are shown in summary form in Table 1. Volume percent of the various types of binder phase carbon forms should be determined during the first microscopic analyses. The volume percent of the filler phase (including coal-related inorganic material) should be determined as a second analysis. The miscellaneous materials are commonly determined during analysis of the filler phase.

7.1.1 *Binder Phase Carbon Form Determinations*—The components counted and kept separate shall be the following: isotropic, incipient, circular anisotropic (fine), circular anisotropic (medium), circular anisotropic (coarse), lenticular anisotropic (fine), lenticular anisotropic (medium), lenticular anisotropic (coarse), ribbon anisotropic (fine), ribbon anisotropic (medium), ribbon

[3] Crelling, J.C., and Rimmer, S.M., 2015, Crelling's Petrographic Atlas of ~~Coals, Cokes, Char, Carbons, and Graphites available from http://mccoy.lib.siu.edu/projects/crelling2/atlas/.~~ Coals and Carbons, Southern Illinois University Carbondale, http://www.coalandcarbonatlas.siu.edu/.

[4] Gray, R. J., and DeVanney, K. F., "Coke Carbon Forms: Microscopic Classification ~~And~~and Industrial Applications," *International Journal of Coal Geology*, Vol 6, 1986, pp. 277–297.