Designation: C781 – 20

An American National Standard

Standard Practice for Testing Graphite Materials for Gas-Cooled Nuclear Reactor Components[1]

This standard is issued under the fixed designation C781; 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 practice covers the application and limitations of test methods for measuring the properties of graphite materials. These properties may be used for the design and evaluation of gas-cooled reactor components.

1.2 The test methods referenced herein are applicable to materials used for replaceable and permanent components as defined in Section 7 and includes fuel elements; removable reflector elements and blocks; permanent side reflector elements and blocks; core support pedestals and elements; control rod, reserve shutdown, and burnable poison compacts; and neutron shield material. Specific aspects with respect to testing of irradiated materials are addressed.

1.3 This practice includes test methods that have been selected from ASTM standards and guides that are specific to the testing of materials listed in 1.2. Comments on individual test methods for graphite components are given in Section 8. The test methods are summarized in Table 1.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C559 Test Method for Bulk Density by Physical Measurements of Manufactured Carbon and Graphite Articles
C577 Test Method for Permeability of Refractories
C611 Test Method for Electrical Resistivity of Manufactured Carbon and Graphite Articles at Room Temperature
C625 Practice for Reporting Irradiation Results on Graphite
C651 Test Method for Flexural Strength of Manufactured Carbon and Graphite Articles Using Four-Point Loading at Room Temperature
C695 Test Method for Compressive Strength of Carbon and Graphite
C747 Test Method for Moduli of Elasticity and Fundamental Frequencies of Carbon and Graphite Materials by Sonic Resonance
C749 Test Method for Tensile Stress-Strain of Carbon and Graphite
C769 Test Method for Sonic Velocity in Manufactured Carbon and Graphite Materials for Use in Obtaining an Approximate Value of Young's Modulus
C816 Test Method for Sulfur Content in Graphite by Combustion-Iodometric Titration Method
C838 Test Method for Bulk Density of As-Manufactured Carbon and Graphite Shapes
C1039 Test Methods for Apparent Porosity, Apparent Specific Gravity, and Bulk Density of Graphite Electrodes
C1179 Test Method for Oxidation Mass Loss of Manufactured Carbon and Graphite Materials in Air
C1233 Practice for Determining Equivalent Boron Contents of Nuclear Materials
C1274 Test Method for Advanced Ceramic Specific Surface Area by Physical Adsorption
D346 Practice for Collection and Preparation of Coke Samples for Laboratory Analysis
D1193 Specification for Reagent Water
D2854 Test Method for Apparent Density of Activated Carbon

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.F0 on Manufactured Carbon and Graphite Products.

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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.

*A Summary of Changes section appears at the end of this standard

TABLE 1 Summary of Test Methods for Graphite Components

NOTE 1—Graphite Components include: Fuel, Removable Reflector and Core Support Elements; Pebble Bed Reflector, Key and Sleeves and Dowel Pins, Permanent Side Reflector Elements and Dowel Pins, Core Support Pedestals and Dowels.

	Test Method
Fabrication	
As Manufactured Bulk Density	C838
Mechanical Properties	
Compressive Strength	C695
Tensile Properties	C749
Poisson's Ratio	E132, C747
Flexural Strength	C651, D7972
Fracture Toughness	D7779
Modulus of Elasticity	C747, C769
Physical Properties	
Bulk Density–Machined Specimens	C559
Surface Area (BET)	C1274
Permeability	C577[A,B]
Apparent Porosity	C1039
Spectroscopic Analysis	[B]
Electrical Resistivity	C611
Thermal Properties	
Linear Thermal Expansion	E228[A]
Thermal Conductivity	E1461[A]
Chemical Properties	
Oxidative Mass Loss	C1179, D7542
Sulfur Concentration	C816
Equivalent Boron Content[C]	C1233[A]

[A] Modification of this test method is required. See Section 8 for details.
[B] New test methods are required. See Section 8 for details.
[C] There is no identified need for determining this property for core support pedestals and dowels.

D2862 Test Method for Particle Size Distribution of Granular Activated Carbon
D3104 Test Method for Softening Point of Pitches (Mettler Softening Point Method)
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4292 Test Method for Determination of Vibrated Bulk Density of Calcined Petroleum Coke
D5600 Test Method for Trace Metals in Petroleum Coke by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D7219 Specification for Isotropic and Near-isotropic Nuclear Graphites
D7542 Test Method for Air Oxidation of Carbon and Graphite in the Kinetic Regime
D7775 Guide for Measurements on Small Graphite Specimens
D7779 Test Method for Determination of Fracture Toughness of Graphite at Ambient Temperature
D7846 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Graphites
D7972 Test Method for Flexural Strength of Manufactured Carbon and Graphite Articles Using Three-Point Loading at Room Temperature
D8186 Test Method for Measurement of Impurities in Graphite by Electrothermal Vaporization Inductively Coupled Plasma Optical Emission Spectrometry (ETV-ICP OES)
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E132 Test Method for Poisson's Ratio at Room Temperature
E228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer
E261 Practice for Determining Neutron Fluence, Fluence Rate, and Spectra by Radioactivation Techniques
E639 Test Method for Measuring Total-Radiance Temperature of Heated Surfaces Using a Radiation Pyrometer (Withdrawn 2011)[3]
E1461 Test Method for Thermal Diffusivity by the Flash Method
E1269 Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry
E2716 Test Method for Determining Specific Heat Capacity by Sinusoidal Modulated Temperature Differential Scanning Calorimetry

3. Terminology

3.1 *Definitions*—Terminology D4175 shall be considered as applying to the terms used in this practice.

4. Significance and Use

4.1 Property data obtained with the recommended test methods identified herein may be used for research and development, design, manufacturing control, specifications, performance evaluation, and regulatory statutes pertaining to nuclear reactors that utilize graphite.

4.2 The referenced test methods are applicable primarily to specimens in the non-irradiated and non-oxidized state. Testing irradiated specimens often requires specimen geometries that

[3] The last approved version of this historical standard is referenced on www.astm.org.

do not meet the requirements of the standard. Specific instructions or recommendations with respect to testing nonconforming geometries can be found in STP 1578[4] and/or Guide D7775. When testing irradiated specimens at elevated temperatures, the effects of annealing should be considered (see Note 1).

NOTE 1—Exposure to fast neutron radiation will result in atomic and microstructural changes to graphite. This radiation damage occurs when energetic particles, such as fast neutrons, impinge on the crystal lattice and displace carbon atoms from their equilibrium positions, creating a lattice vacancy and an interstitial carbon atom. The lattice strain that results from displacement damage causes significant structural and property changes in the graphite and is a function of the irradiation temperature and dose. When the temperature of the graphite is brought above the temperature at which it was irradiated, enough energy is provided that the structure of the graphite will anneal back to its original condition. Therefore, measurement techniques that bring the specimen temperature above the irradiation temperature can result in property values that change during the measurement process. For this reason, measurements made on irradiated test specimens below the irradiation temperature will produce results that are representative of the irradiation damage. However, measurements made at temperatures above the irradiation temperature could include the effects of annealing.

4.3 Additional test methods are in preparation and will be incorporated. The user is cautioned to employ the latest revision.

5. Sample Selection

5.1 All test specimens should be selected from materials that are representative of those to be used in the intended application.

6. Test Reports

6.1 Test results should be reported in accordance with the reporting requirements included in the applicable test method. Where relevant, information on grade designation, lot number, billet number, orientation, and location (position of sample in the original billet) shall be provided.

6.2 Information on specimen irradiation conditions shall be reported in accordance with Practices C625 and E261 or referenced to source information of equivalent content.

GRAPHITE COMPONENTS

7. Description and Function

7.1 The following are identified as typical components of a graphite moderated gas-cooled reactor based on historical designs. This list is not intended to be inclusive of all possible components, which will depend upon the particular reactor design.

7.2 *Fuel and Removable Reflector Elements:*

7.2.1 In manufactured carbons and graphites, a fuel element is a removable graphite element that contains channels for the passage of coolant gas, the fuel material (typically in the form of a compact containing coated particle fuel), the alignment dowel pins, and for the insertion of a handling machine pickup head. A fuel element may also contain channels for reactivity control material (control rods), reserve shutdown compacts, and burnable poison compacts, and nuclear instrumentation.

7.2.2 The fuel elements serve multiple functions, including *(1)* vertical and lateral mechanical support for the fuel elements and removable reflector elements above and adjacent to them, and for the fuel, reactivity control materials, and nuclear instrumentation within them, *(2)* moderation of fast neutrons within the core region, *(3)* a thermal reservoir and conductor for nuclear heat generated in the fuel, *(4)* a physical constraint for the flow of coolant gases, and *(5)* a guide for and containment of fuel material, reactivity control materials, and nuclear instrumentation.

7.2.3 A removable reflector element is a removable graphite element that contains channels for the alignment dowel pins and the insertion of a handling machine pickup head. A removable reflector element may also contain channels for the passage of coolant gas, reactivity control materials (control rods), neutron flux control materials (neutron shield materials), and nuclear instrumentation.

7.2.4 The primary function of the removable reflector elements that are located at the boundaries of the active reactor core (fuel elements) is to provide moderation of fast neutrons escaping from and reflection of thermal neutrons back into the active core region.

7.2.5 Except for support, guide, and containment of fuel material, removable reflector elements may also serve any of the functions listed in 7.2.2.

7.3 *Permanent Side Reflector Element:*

7.3.1 A permanent side reflector element is a graphite block that is designed to remain permanently in the core but may be removed for inspection and replacement, if necessary. A permanent side reflector element contains channels for alignment dowel pins. It may also contain channels for neutron flux control materials (boronated steel pins) and nuclear instrumentation, and recessed areas along its length on its outer periphery to provide channels for the passage of coolant gas between the element and the metallic lateral restraint for the reactor core.

7.3.2 The permanent side reflector elements encircle the active (fuel) elements and passive (removable reflector) elements of the reactor core and serve multiple functions, including *(1)* vertical and lateral mechanical support for the permanent side reflector elements above and beside them, *(2)* lateral mechanical support for the fuel, removable reflector, and core support elements, *(3)* moderation of fast neutrons within the reflector region, *(4)* reflection of thermal neutrons back into the core region, and *(5)* support, guide, and containment of nuclear instrumentation and neutron flux control materials (boronated steel pins) for reducing the neutron flux to metallic structures outside the permanent side reflector boundary.

7.4 *Core Support Pedestals and Elements:*

7.4.1 A core support pedestal is a graphite column that is designed to remain permanently in the core but can be removed for inspection and replacement, if necessary. A core support pedestal has a central reduced cross-section (dog bone shape) that at its upper end contains channels for the passage of

[4] Tzelepi, N. and Carroll, M., Eds., *Graphite Testing for Nuclear Applications: The Significance of Test Specimen Volume and Geometry and the Statistical Significance of Test Specimen Population*, STP1578-EB, ASTM International, West Conshohocken, PA, 2014, https://doi.org/10.1520/STP1578-EB