Designation: C1783 – 15

Standard Guide for Development of Specifications for Fiber Reinforced Carbon-Carbon Composite Structures for Nuclear Applications[1]

This standard is issued under the fixed designation C1783; 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 document is a guide to preparing material specifications for fiber reinforced carbon-carbon (C-C) composite structures (flat plates, rectangular bars, round rods, and tubes) manufactured specifically for structural components in nuclear reactor core applications. The carbon-carbon composites consist of carbon/graphite fibers (from PAN, pitch, or rayon precursors) in a carbon/graphite matrix produced by liquid infiltration/pyrolysis and/or by chemical vapor infiltration.

1.2 This guide provides direction and guidance for the development of a material specification for a specific C-C composite component or product for nuclear reactor applications. The guide considers composite constituents and structure, physical and chemical properties, mechanical properties, thermal properties, performance durability, methods of testing, materials and fabrication processing, and quality assurance. The C-C composite materials considered here would be suitable for nuclear reactor core applications where neutron irradiation-induced damage and dimensional changes are a significant design consideration. (**1-4**)[2]

1.3 The component specification is to be developed by the designer/purchaser/user. The designer/purchaser/user shall define and specify in detail any and all application-specific requirements for necessary design, manufacturing, and performance factors of the ceramic composite component. This guide for material specifications does not directly address component/product-specific issues, such as geometric tolerances, permeability, bonding, sealing, attachment, and system integration.

1.4 This guide is specifically focused on C-C composite components and structures with flat panel, solid rectangular bar, solid round rod, or tubular geometries.

1.5 This specification may also be applicable to C-C composites used for other structural applications discounting the nuclear-specific chemical purity and irradiation behavior factors.

1.6 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *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:*[3]

C242 Terminology of Ceramic Whitewares and Related Products
C559 Test Method for Bulk Density by Physical Measurements of Manufactured Carbon and Graphite Articles
C561 Test Method for Ash in a Graphite Sample
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
C709 Terminology Relating to Manufactured Carbon and Graphite
C714 Test Method for Thermal Diffusivity of Carbon and Graphite by Thermal Pulse Method
C769 Test Method for Sonic Velocity in Manufactured Carbon and Graphite Materials for Use in Obtaining Young's Modulus
C816 Test Method for Sulfur 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

[1] This guide is under the jurisdiction of ASTM Committee C28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.07 on Ceramic Matrix Composites.

Current edition approved Sept. 1, 2015. Published November 2015. DOI: 10.1520/C1783–15.

[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] 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.

C1179 Test Method for Oxidation Mass Loss of Manufactured Carbon and Graphite Materials in Air
C1198 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance
C1233 Practice for Determining Equivalent Boron Contents of Nuclear Materials
C1239 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics
C1259 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Impulse Excitation of Vibration
C1274 Test Method for Advanced Ceramic Specific Surface Area by Physical Adsorption
C1275 Test Method for Monotonic Tensile Behavior of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section Test Specimens at Ambient Temperature
C1291 Test Method for Elevated Temperature Tensile Creep Strain, Creep Strain Rate, and Creep Time-to-Failure for Advanced Monolithic Ceramics
C1292 Test Method for Shear Strength of Continuous Fiber-Reinforced Advanced Ceramics at Ambient Temperatures
C1337 Test Method for Creep and Creep Rupture of Continuous Fiber-Reinforced Advanced Ceramics Under Tensile Loading at Elevated Temperatures
C1341 Test Method for Flexural Properties of Continuous Fiber-Reinforced Advanced Ceramic Composites
C1358 Test Method for Monotonic Compressive Strength Testing of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section Test Specimens at Ambient Temperatures
C1359 Test Method for Monotonic Tensile Strength Testing of Continuous Fiber-Reinforced Advanced Ceramics With Solid Rectangular Cross-Section Test Specimens at Elevated Temperatures
C1360 Practice for Constant-Amplitude, Axial, Tension-Tension Cyclic Fatigue of Continuous Fiber-Reinforced Advanced Ceramics at Ambient Temperatures
C1425 Test Method for Interlaminar Shear Strength of 1–D and 2–D Continuous Fiber-Reinforced Advanced Ceramics at Elevated Temperatures
C1468 Test Method for Transthickness Tensile Strength of Continuous Fiber-Reinforced Advanced Ceramics at Ambient Temperature
C1470 Guide for Testing the Thermal Properties of Advanced Ceramics
C1525 Test Method for Determination of Thermal Shock Resistance for Advanced Ceramics by Water Quenching
C1557 Test Method for Tensile Strength and Young's Modulus of Fibers
C1683 Practice for Size Scaling of Tensile Strengths Using Weibull Statistics for Advanced Ceramics
D2766 Test Method for Specific Heat of Liquids and Solids
D3171 Test Methods for Constituent Content of Composite Materials
D3529/D3529M Test Method for Matrix Solids Content and Matrix Content of Composite Prepreg
D3800 Test Method for Density of High-Modulus Fibers
D3878 Terminology for Composite Materials
D4018 Test Methods for Properties of Continuous Filament Carbon and Graphite Fiber Tows
D4284 Test Method for Determining Pore Volume Distribution of Catalysts and Catalyst Carriers by Mercury Intrusion Porosimetry
D4850 Terminology Relating to Fabrics and Fabric Test Methods
D5528 Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites
D5600 Test Method for Trace Metals in Petroleum Coke by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D5766 Test Method for Open-Hole Tensile Strength of Polymer Matrix Composite Laminates
D5961 Test Method for Bearing Response of Polymer Matrix Composite Laminates
D6484 Test Method for Open-Hole Compressive Strength of Polymer Matrix Composite Laminates
D6507 Practice for Fiber Reinforcement Orientation Codes for Composite Materials
D6671 Test Method for Mixed Mode I-Mode II Interlaminar Fracture Toughness of Unidirectional Fiber Reinforced Polymer Matrix Composites
D7136 Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event
D7137 Test Method for Compressive Residual Strength Properties of Damaged Polymer Matrix Composite Plates
D7219 Specification for Isotropic and Near-isotropic Nuclear Graphites
D7542 Test Method for Air Oxidation of Carbon and Graphite in the Kinetic Regime
E6 Terminology Relating to Methods of Mechanical Testing
E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
E132 Test Method for Poisson's Ratio at Room Temperature
E143 Test Method for Shear Modulus 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
E289 Test Method for Linear Thermal Expansion of Rigid Solids with Interferometry
E408 Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques
E423 Test Method for Normal Spectral Emittance at Elevated Temperatures of Nonconducting Specimens
E1269 Test Method for Determining Specific Heat Capacity

by Differential Scanning Calorimetry
E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases (Withdrawn 2015)[4]
E1461 Test Method for Thermal Diffusivity by the Flash Method
E1922 Test Method for Translaminar Fracture Toughness of Laminated and Pultruded Polymer Matrix Composite Materials
E2586 Practice for Calculating and Using Basic Statistics
2.2 *Non-ASTM Standards:*
CMH-17 Composite Materials Handbook
ASME B46.1-2009 Surface Texture (Surface Roughness, Waviness, and Lay)[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Many of the terms in this guide are defined in the terminology standards for graphite articles (C709), composite materials (D3878), fabrics and test methods (D4850), and mechanical testing (E6).

3.1.2 *apparent porosity, n*—the volume fraction of all pores, voids, and channels within a solid mass that are interconnected with each other and communicate with the external surface, and thus are measurable by gas or liquid penetration. (Synonym – open porosity) **C242**

3.1.3 *braided fabric, n*—a woven structure produced by interlacing three or more ends of yarns in a manner such that the paths of the yarns are diagonal to the vertical axis of the fabric. **D4850**

3.1.3.1 *Discussion*—Braided structures can have 2D or 3D architectures.

3.1.4 *bulk density, n*—the mass of a unit volume of material including both permeable and impermeable voids. **D7219**

3.1.5 *fabric, n—in textiles*, a planar structure consisting of yarns or fibers. **D4850**

3.1.6 *fiber, n*—a fibrous form of matter with an aspect ratio >10 and an effective diameter <1 mm. (Synonym – filament) A fiber/filament forms the basic element of fabrics and other textile structures. **D3878**

3.1.7 *fiber areal weight, n*—the mass per unit area of the fibrous reinforcement of a composite material. **D3529/D3529M**

3.1.8 *fiber content/fraction (volume or weight), n*—the amount of fiber present in a composite, expressed as either a percent by weight or a percent by volume. **D3878**

3.1.9 *fiber preform, n*—a preshaped fibrous reinforcement, normally without matrix, but often containing a binder to facilitate manufacture, formed by distribution/weaving of fibers to the approximate contour and thickness of the finished part. **D3878**

3.1.10 *fiber surface treatment, n*—a coating applied to fibers to improve fiber/fabric handleability during weaving and fabrication.

3.1.11 *fill, n—in a woven fabric*, the yarn running from selvage to selvage at right angles to the warp. **D3878**

3.1.12 *graphite, n*—allotropic crystalline form of the element carbon, occurring as a mineral, commonly consisting of a hexagonal array of carbon atoms (space group P 63/mmc) but also known in a rhombohedral form (space group R 3m). **C709**

3.1.13 *graphitization, n—in carbon and graphite technology*, the solid-state transformation of thermodynamically unstable amorphous carbon into crystalline graphite by a high temperature thermal treatment in an inert atmosphere. **C709**

3.1.13.1 *Discussion*—The degree of graphitization is a measure of the extent of long-range 3D crystallographic order as determined by diffraction studies only. The degree of graphitization affects many properties significantly, such as thermal conductivity, electrical conductivity, strength, and stiffness.

3.1.13.2 *Discussion*—A common, but incorrect, use of the term graphitization is to indicate a process of thermal treatment of carbon materials at T > 2200°C regardless of any resultant crystallinity. The use of the term graphitization without reporting confirmation of long range three dimensional crystallographic order determined by diffraction studies should be avoided, as it can be misleading.

3.1.14 *hybrid, n*—(for composite materials) containing at least two distinct types of matrix or reinforcement. Each matrix or reinforcement type can be distinct because of its a) physical or mechanical properties, or both, b) material form, or c) chemical composition. **D3878**

3.1.15 *injection molding, n—in composite fabrication*, the process of forcing liquid polymer under pressure into a closed mold that contains a fiber preform.

3.1.16 *knitted fabric, n*—a fiber structure produced by interlooping one or more ends of yarn or comparable material. **D4850**

3.1.17 *laminate, n*—any fiber- or fabric-reinforced composite consisting of laminae (plies) with one or more orientations with respect to some reference direction. **D3878**

3.1.18 *lay-up, n*—a process or fabrication involving the placement of successive layers of materials in specified sequence and orientation. **E1309, D6507**

3.1.19 *matrix, n*—the continuous constituent of a composite material, which surrounds or engulfs the embedded reinforcement in the composite and acts as the load transfer mechanism between the discrete reinforcement elements.

3.1.20 *matrix content, n*—the amount of matrix present in a composite expressed either as a percent by weight or a percent by volume. **D3878**

3.1.21 *ply, n—in 2D laminar composites*, the constituent single layer as used in fabricating, or occurring within, a composite structure. **D3878**

3.1.22 *prepreg, n*—the admixture of fibrous reinforcement and polymeric matrix used to fabricate composite materials. Its

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

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.