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DEVELOPMENT OF ASTM STANDARDS IN SUPPORT OF ADVANCED CERAMICS - CONTINUING EFFORTS*

Charles R. Brinkman

Metals and Ceramics Division
OAK RIDGE NATIONAL LABORATORY
P.O. Box 2008
Oak Ridge, TN 37831-6154

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DISCLAIMER

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ABSTRACT

An update is presented of the activities of the American Society for Testing and Materials (ASTM) Committee C-28 on Advanced Ceramics. Since its inception in 1986, this committee, which has five standard producing subcommittees, has written and published over 32 consensus standards. These standards are concerned with mechanical testing of monolithic and composite ceramics, nondestructive examination, statistical analysis and design, powder characterization, quantitative microscopy, fractography, and terminology. These standards ensure optimum material behavior with physical and mechanical property reproducibility, component reliability, and well-defined methods of data treatment and material analysis for both monolithic and composite materials. Committee C-28 continues to sponsor technical symposia and to cooperate in the development of international standards. An update of recent and current activities as well as possible new areas of standardization work will be presented.

INTRODUCTION

The American Society for Testing and Materials (ASTM) is the primary standards writing establishment in the United States for testing of materials, and is a private, nonprofit corporation for the development of full voluntary consensus standards on characteristics and performance of materials, products, systems, and services, and for the promotion of related knowledge. This is accomplished through the work of various ASTM committees consisting of volunteer experts who, following previously established regulations, generate a product (standard) that is widely recognized, accepted, and used. ASTM Committee C-28 on Advanced Ceramics was organized in 1986 when it became apparent that ceramics were being considered for many new high technology applications in the aerospace, biomedical, military, and automotive areas. These applications were viewed as being particularly demanding in terms of behavior requirements. Hence, it was important that standards be written for the production, inspection, testing, data analysis, and probabilistic design of advanced structural ceramics. An advanced ceramic can be defined as "a highly engineered, high performance, predominantly nonmetallic, inorganic ceramic material having specific functional attributes," and includes both monolithic and composite ceramic materials. Accordingly, Committee C-28 was organized with various subcommittees as shown in Fig. 1 with task groups addressing specific technical topics under each subcommittee and writing appropriate standards. These standards may take the form of guides, practices, or test methods. Approximately 150 members from industry, government, and academia serve on these various subcommittees. Additional participation and membership are always encouraged, especially as new technical issues are defined and additional expertise required. Subcommittee C-28.94 conducts liaison activities with the International Standards Organization (ISO 206) technical committee on fine or advanced ceramics. A listing is given in Table 1 of completed, in-ballot, draft standards, and task group projects which will lead to standards by subcommittee. Table 1 shows that 32 standards have been completed since 1989 by the various subcommittees and that the level of effort is intensifying with time with a number of standards currently in the balloting and draft form while still others are being contemplated. In 1993, when a similar report was made, only six standards had been published (Brinkman et al./1993).

Figure 2 shows a number of standards developed by C-28, and listed in Table 1, as well as several developed by Committee G-2, Wear and Erosion, on measuring wear resistance of advanced ceramics. After completion of a standard, via the balloting process, it is published by ASTM in an annually revised book of standards. The standard designation number gives the year the standard was approved. In addition to activities directly related to preparation of standards, the biannual meetings also sponsor technical workshops and symposia addressing state-of-the-art issues relevant to the work of the subcommittee. Two symposia have been completed to date which have resulted in ASTM Special Technical Publications (STPs): STP 1201 - Life Prediction Methodologies and Data for Ceramic Materials, and STP 1309 - Thermal and Mechanical Test Methods and Behavior of Continuous-Fiber Ceramic Composites.

Upcoming symposia include, "Environmental, Mechanical, and Thermal Properties and Performance of Continuous Fiber Ceramic Composite (CFCC) Materials and Components," (1999), and "Fracture Toughness Testing of Brittle Materials" (2000).

It is the objective of this paper to give a brief report on progress in the development and verification of standards by the various subcommittees for advanced ceramic materials. A brief summary of liaison activities associated with foreign and international standard formulating organizations will also be given.

PROPERTIES AND PERFORMANCE

Subcommittee C-28.01 on Properties and Performance has been developing standards associated with mechanical properties measurement for monolithic ceramics. Its standards are also applicable to particulate, platelets, whisker or discontinuous fiber-reinforced ceramic composites which are essentially isotropic and homogeneous.

As indicated in Table 1 and Fig. 2, this work has focused on a number of key mechanical properties including flexural strength C1161-90 and C1211-92 for ambient and elevated temperatures, C1198-91 and C1259-96 for elastic properties; C1273-95 and C1366 for tensile properties at ambient and elevated temperatures, C-1291-95 for creep behavior, C1326-96 and C1327-96 for hardness determination, C1361-97 for tension-tension fatigue, C1368-97 for slow crack growth determination, and PS070-97 (provisional standard) for fracture toughness determination. The need to determine the ultimate tensile strength of tubular products from actual components led to the development of the compressed C-ring test, C1323-96, which determines the strength of the external surfaces. The O-ring standard when completed will specify specifics for determining the strength of the internal surface. Additional details concerning development of these standards can be found in Brinkman et al. (1996), and Brinkman and Quinn (1997).

Current work by this subcommittee, as indicated in Table 1, includes development of standards for measuring compressive strength, fracture toughness, ultimate strength of tubes via an O-ring test, and thermal shock resistance.

DESIGN AND EVALUATION

Subcommittee C-28.02 on Design and Evaluation has two active sections - one on nondestructive examination and the other on probabilistic data analysis and design procedures.

The Section on Probabilistic Procedures (SPP), is concerned with preparation of standards related to such analytical procedures as bimodal analyses, fast fracture data analysis using Weibull statistics, size scaling of uniaxial strengths, pooling of data from multiple specimen geometries, and others. A major effort was put into the development of C1239-95 "Standard Practice for Reporting Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics." This standard is restricted to uniaxial stress states, i.e., tensile, flexural, pressurized ring, etc., but is able to analyze multiple flaw populations and their effect upon the strength distribution. A maximum likelihood estimator computer code is available in digital form as an "adjunct" to this standard to perform the Weibull analysis.

The Section on Nondestructive Evaluation (SNDE) has established a strong liaison with ASTM Committee E-7 on Nondestructive Testing to gain the benefit of the expertise available in that longstanding committee. An early activity of the SNDE was a technical review of E-7 standards (primarily in radiography, ultrasonics and liquid penetrants) to identify those that were considered (by the SNDE) to be relevant to advanced ceramics (although the original intent of E-7 was for application to metals). Some of the standards were recognized as directly applicable without change, some required minor modification for application to ceramics (without jeopardizing the original intent); others needed extensive change for applicability. Requests submitted to E-7 for the desired minor modification have been well accepted and the changes have been incorporated and balloted by E-7. The more difficult extensive changes are in the current work program of the SNDE. A guideline standard that identifies the standards that are considered applicable to advanced ceramics (as originally accepted or modified) is C1175-95, "Standard Guide to Test Methods and Standards for Nondestructive Testing of Advanced Ceramics." Other approved documents developed by the SNDE are illustrated in Fig. 2 and listed in Table 1. An additional overview was published by Vary (1995) of NDE techniques and standards developed for monolithic and composite materials, and the reader is referred to this reference for additional information in this area.

CHARACTERIZATION AND PROCESSING

Subcommittee C-28.05 deals with processing and characterization techniques. Areas of concern include techniques for physical, chemical, structural, as well as fractographic and microstructural analyses. There is considerable activity in powder characterization and several IEA round robins in support of powder characterization standardization have been very fruitful. Table 1 indicates that three standard practices have been completed in this area with an additional six standards currently either balloting or in preparation.

An example of a recently completed effort by this subcommittee is C1322-96, "Standard Practice for Fractography and Characterization of Fracture Origins in Advanced Ceramics." This standard outlines an efficient and consistent methodology to locate and characterize fracture origins. While this standard is primarily applicable to laboratory specimens, it may also be used to assist in component failure analysis as well. A knowledge of fracture origins is considered a necessity in use of mechanical properties data in the evolving life prediction methodologies used in design. Recent publications give additional details concerning the origin of this standard, Swab and Quinn (1994a), as well as results from an associated VAMAS round robin, Swab and Quinn (1994b).

CERAMIC COMPOSITES

Subcommittee C-28.07 on Ceramic Matrix composites was formed due to the rapid development of ceramic matrix composites that occurred during the 1980s and is concerned with standards issues related to mechanical property characterization of continuous fiber-reinforced ceramic composites (CFCCs).

Work on CFCCs is separated from that of monolithic or discontinuous reinforced materials due to their unique properties and behavior such as increased "toughness," differences in failure mechanisms, and the fact that CFCCs typically consist of a brittle matrix with a stiffness similar to or greater than the reinforcing brittle fibers. These differences then define special test requirements associated with the necessity for appropriate specimen geometries and fabrication requirements, gripping test fixtures, specimen alignment, and specified optimal test conditions, e.g., strain rates, temperature control and measurement. Table 1 and Fig. 2 indicate that seven standards have been completed in this area to date. Additional details concerning experience in composite testing can be found in a recent publication, Jenkins et al. (1997). Task groups are addressing issues related to standard development in tension, flexure, shear, compression, tension-tension fatigue, creep-rupture, ceramic fibers, interfacial and thermal properties, environmental effects, thermomechanical fatigue, and components and structures.

NOMENCLATURE

Subcommittee C-28.91 on Nomenclature provides the definitions of technical terms related to the development and characterization of advanced ceramics as used in the standards. As indicated in Table 1, Standard C 1145 provides this terminology. This standard continues to grow as new terms are added each year. A Standard System for Classification of Advanced Ceramics, C 1286-95, is another product of this subcommittee and provides a system by which ceramics, including composites, can be classified.

INTERNATIONAL STANDARDS ACTIVITIES

Subcommittee C-28.94, ISO 206 Technical Advisory Group (TAG), through the American National Standards Institute (ANSI) is the U.S. representation to the ISO Technical Committee (TC) 206 on Fine (Advanced) Ceramics. The aim of this committee is to provide international standardization in the field of fine ceramics powder, monolithic ceramics, fine ceramics based composite materials, and fine ceramic coatings. Currently ISO/TC 206 is comprised of members representing about 15 countries. C-28.94 provides delegates to attend meetings and to work on international standards and requires U.S. consensus positions on all ISO TC 206 standards. Participation is important since ISO standards may affect international trade. Current collaborative effort includes work in a number of areas including flexural strength and tensile strength of both monolithics and composites, hardness, classification, fracture strength, particle size distribution and particle surface area.

CONCLUSIONS

ASTM Committee C-28 on Advanced Ceramics has produced 32 technically rigorous consensus standards in the areas of processing, characterization, and evaluation. Many others are under development.

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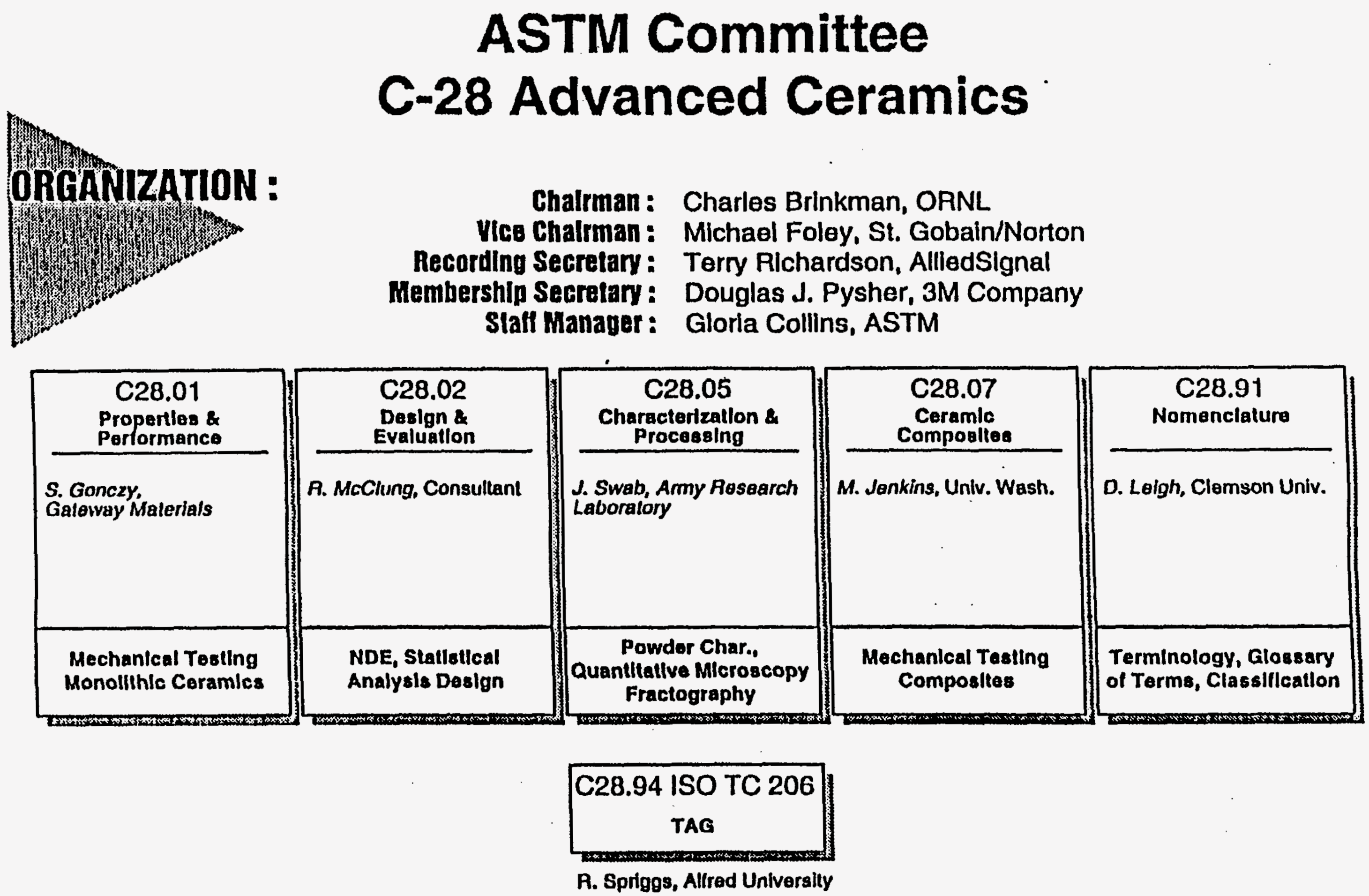

Fig. 1. Organization of ASTM Committee C-28.

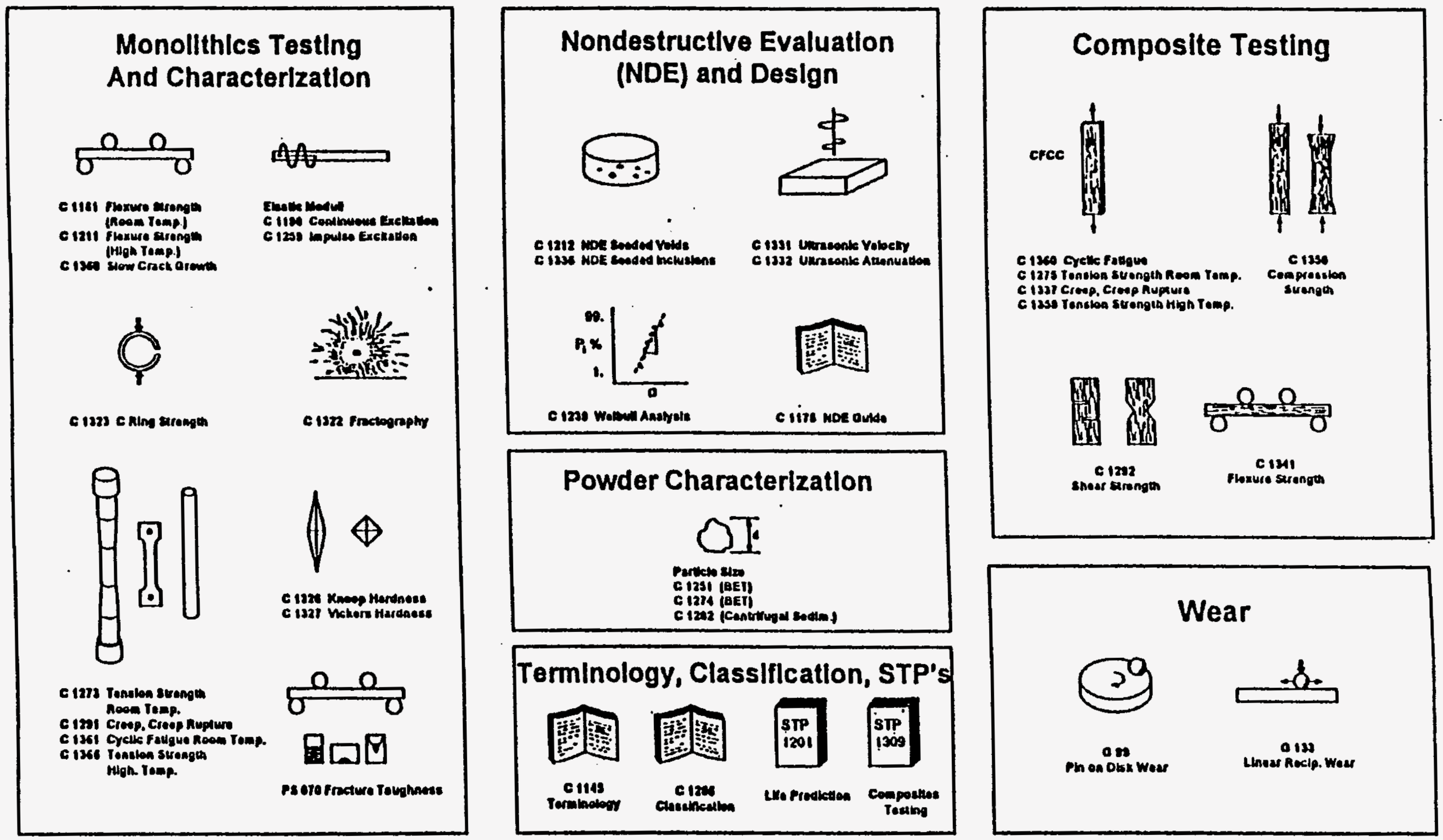

Fig. 2. Standards developed by Committee C-28.

Table 1. Completed and In Progress Standards under the Jurisdiction of ASTM Committee C-28

COMPLETED STANDARDS, ASTM Annual Book of Standards, Vol. 15.01

Terminology C-28.91

C 1145-89 (96)	Standard Definition of Terms Relating to Advanced Ceramics
C 1286-94	Standard System for Classification of Advanced Ceramics

Properties and Performance (Monolithic) C-28.01

C 1161-90 (94)	Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature
C 1198-91 (96)	Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance
C 1211-92	Standard Test Method for Flexural Strength of Advanced Ceramics at Elevated Temperature
C 1259-96	Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Impulse Excitation of Vibration
C 1273-95a	Standard Test Method for Tensile Strength of Monolithic Advanced Ceramics at Ambient Temperatures
C 1291-95	Standard Test method for Elevated Temperature Tensile Creep Strain, Creep Strain Rate, and Creep Time-to-Failure for Advanced Monolithic Ceramics
C 1323-96	Standard Test Method for Ultimate Strength of Advanced Ceramics with Diametrally Compressed C-Ring Specimens at Ambient Temperature
C 1326-96a	Standard Test Method for Knoop Indentation Hardness of Advanced Ceramics
C 1327-96a	Standard Test Method for Vickers Indentation Hardness of Advanced Ceramics
C 1361-97	Standard Practice for Constant-Amplitude, Axial, Tension-Tension Cyclic Fatigue of Advanced Ceramics at Ambient Temperatures
C 1366-97	Standard Test Method for Tensile Strength of Monolithic Advanced Ceramics at Elevated Temperatures
C 1368-97	Standard Test Method for Determination of Slow Crack Growth Parameters of Advanced Ceramics by Constant Stress-Rate Flexural Testing at Ambient Temperature
PS 070-97	Standard Test Methods for the Determination of Fracture Toughness of Advanced Ceramics

Design and Evaluation C-28.02

C 1175-95	Standard Guide to Test Methods for Nondestructive Testing of Advanced Ceramics
C 1212-92	Standard Practice for Fabricating Ceramic Reference Specimens Containing Seeded Voids
C 1239-95	Standard Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics
C 1331-96	Standard Practice for Measuring Ultrasonic Velocity in Advanced Ceramics with the Broadband Pulse-Echo Cross-Correlation Method
C 1332-96	Standard Test Method for Measurement of Ultrasonic Attenuation Coefficients of Advanced Ceramics by the Pulse-Echo Contact Technique
C 1336-96	Standard Practice for Fabricating Non-Oxide Ceramic Reference Specimens Containing Seeded Inclusions

Characterization and Processing C-28.05

C 1251-95	Standard Guide for Determination of Specific Surface Area of Advanced Ceramics by Gas Adsorption
C 1274-95	Standard Test Method for Advanced Ceramic Specific Surface Area by Physical Adsorption
C 1282-94	Standard Test Method for Determining the Particle Size Distribution of Advanced Ceramics by Centrifugal Photosedimentation
C 1322-96a	Standard Practice for Fractography and Characterization of Fracture Origins in Advanced Ceramics

Ceramic Composites C-28.07

C 1275-95	Standard Test Method for Monotonic Tensile Strength Testing of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section at Ambient Temperatures
C 1292-95	Standard Test Method for Shear Strength of Continuous Fiber-Reinforced Advanced Ceramics at Ambient Temperatures
C 1337-96	Standard Test Method for Creep and Creep Rupture of Continuous Fiber-Reinforced Ceramic Composites Under Tensile Loading at Elevated Temperature
C 1341-97	Standard Test Method for Flexural Properties of Continuous Fiber-Reinforced Advanced Ceramic Composites
C 1358-97	Standard Test Method for Monotonic Compressive Strength Testing of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section Specimens at Ambient Temperatures
C 1359-97	Standard Test Method for Monotonic Tensile Strength Testing of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section Specimens at Elevated Temperatures
C 1360-97	Standard Practice for Constant-Amplitude, Axial, Tension-Tension Cyclic Fatigue of Continuous Fiber-Reinforced Advanced Ceramics at Ambient Temperatures

NEW STANDARDS IN THE BALLOTING PROCESS

Properties and Performance (Monolithic) C-28.01

C 1211-92	Continuing revision, expansion and additions
C XXXX	Standard Test Method for Compressive Strength of Monolithic Ceramics at Ambient Temperatures
C XXXX	Standard Test Methods for the Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperatures
C 1259	Addition of annex for disc-shaped specimens

Design and Evaluation C-28.02

C 1175	Revision

Characterization and Processing C-28.05

C XXXX	Standard Test Method for Particle Size Distribution of Silicon Nitride or Silicon Carbide Powders by X-Ray Monitoring of Gravity Sedimentation

Ceramic Composites C-28.07

C XXXX	Standard Test Method for Tensile Strength and Young's Modulus for High-Modulus Single-Filament Materials (D3379-75)

Terminology C-28.91

C 1145	Continuing expansion and additions

DRAFT STANDARDS

Design and Evaluation C-28.02

C XXXX	Standard Practice for Size Scaling of Uniaxial Strengths using Weibull Statistics

Characterization and Processing C-28.05

C XXXX	Standard Test Method for Determination of Total Carbon in Oxide and Nitride Advanced Ceramic Powders by Direct Combustion-Infrared Detection Method
C XXXX	Standard Test Method for Determination of Total Oxygen in Carbide and Nitride Advanced Ceramic Powders by Direct Combustion-Infrared Detection Method
C XXXX	Standard Test Method for Determination of Total Nitrogen in Carbide and Oxide Advanced Ceramic Powders by Direct Combustion-Infrared Detection Method
C XXXX	Standard Test Method for X-Ray Emission Spectrometric Analysis of Ceramic Powders

Ceramic Composites C-28.07

C XXXX	Standard Test Method for Shear Strength of Continuous Fiber Ceramic Matrix Composites at Elevated Temperatures

TASK GROUP PROJECTS - Draft Outlines

Properties and Performance (Monolithic) C-28.01

C XXXX	Standard Test Method for Determining Ultimate Strength of Advanced Ceramics with Diametrally Compressed O-Ring Specimens at Ambient Temperatures
C XXXX	Standard Method for Determining Thermal Shock Resistance of Advanced Ceramics

Design and Evaluation C-28.02

C XXXX	Standard Practice for Pooling Strength Data (?)

Characterization and Processing C-28.05

C XXXX	Standard Test Method for Determining the Effect of Surface Grinding on Flexure Strength of Advanced Ceramics

Ceramic Composites C-28.07

C XXXX	Standard Test Method for Determining the Shear Strength of Continuous Fiber Ceramic Matrix Composites at Elevated Temperatures
C XXXX	Standard Test Method for Trans-Thickness Tensile Strength of Continuous Fibre Reinforced Advanced Ceramics
C XXXX	Standard Test Method for Determining Tensile Hoop Strength of Continuous Fibre Reinforced Advanced Ceramic Tubular Specimens at Ambient Temperatures

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