

**ASTM COMMITTEE C28:**  
**INTERNATIONAL STANDARDS FOR**  
**PROPERTIES AND PERFORMANCE**  
**OF ADVANCED CERAMICS**  
**THREE DECADES OF HIGH-QUALITY,**  
**TECHNICALLY-RIGOROUS**  
**NORMALIZATION**

**Michael G. Jenkins**

**Bothell Eng & Science Tech**  
**Bothell, WA USA**

**Jonathan A. Salem**

**NASA Glenn Research Center**  
**Cleveland, OH USA**



**MS&T16**

OCTOBER 23 – 27, 2016  
SALT PALACE CONVENTION CENTER | SALT LAKE CITY, UTAH USA



# Outline

- **INTRODUCTION/BACKGROUND**
- **DISCUSSION**
  - **Formative Years** – Early Direction and Growth (1986-93)
  - **Transition Years** – International Harmonization (1993-2006)
  - **Present Years** – Applications and Validations (2006-Present)
- **TANGIBLE BENEFITS OF STANDARDS**
  - **F2393 Standard Specification Mg PSZ Impants**
  - **F2094/F2094M Standard Specification for SN Ball Bearings**
  - **Transparent Armor Ceramics as Spacecraft Windows**
  - **Standard Reference Materials**
- **CONCLUSIONS/SUMMARY**



# Introduction/Background

- **2016 marks the 30<sup>th</sup> Anniversary of ASTM Committee C28 on Advanced Ceramics**
- **Founded in Philadelphia in 1986 after Advanced Ceramics had been a subcommittee of Committee C08 Refractories**
- **Establishment of C28 reflected the driving forces and visionaries of the 1980's who realized that the time had come for ceramics to become commonly recognized, used, and fabricated as advanced engineering material along with metals; polymers and composites.**



# Introduction/Background

- Definition of **Advanced Ceramic** (a.k.a., engineering ceramic, structural ceramic, fine ceramics (Japan), and technical ceramic (Europe)).

*a highly engineered, high performance, predominately non-metallic, inorganic, ceramic material having specific functional attributes.*



# Introduction/Background

- **Scope of ASTM Committee C28 Advanced Ceramics.**

The promotion of knowledge, stimulation of research and development of

- standards (classifications, specifications, nomenclature, test methods, guides, and practices)
- relating to processing, properties, characterization, and performance of advanced ceramic materials.

Committee C28 works in concert with other technical committees (e.g., D30 "Composite Materials," E07 "Non Destructive Testing," E08 "Fatigue and Fracture," E28 "Mechanical Testing," F04 "Medical and Surgical Materials and Devices", and G02 "Wear and Erosion") and other national and international organizations having mutual or related interests



# Introduction/Background

## What is ASTM International?

**The primary standards writing organization (SWO) for testing materials in the United States.**

**Private nonprofit corporation for the development of voluntary, full-consensus standards on the characteristics and performance of materials, products, systems, and services and for the promotion of related knowledge.**

**Committees accomplish this work through the efforts of volunteer experts who follow established regulations to generate a standard that is high-quality, widely-recognized, well-accepted and generally-used.**



# Introduction/Background

**ASTM International publishes six different types of standards:**

- 1) Test method** is a definitive procedure that produces test results.
- 2) Specification** is an explicit set of requirements to be satisfied by a material, product, system or service.
- 3) Classification** is a systematic arrangement or division of materials, products, systems, or services into groups based on similar characteristics such as origin, composition, properties, or use.
- 4) Practice** is a definitive set of instructions for performing one or more specific operation that does not include a test result.
- 5) Guide** is a compendium of information or series of options that does not recommend a specific course of action.
- 6) Terminology** is a document comprising definitions of terms; explanations of symbols, abbreviations, or acronyms.



# Introduction/Background

**General process of developing an ASTM International standard:**

- 1.Establish** of task group of experts (both within and outside ASTM).
- 2.Create** a work item and prepare a draft standard.
- 3.Ballot** the draft standard at the subcommittee level only.
- 4.If approved** with no negative ballots, ballot the draft standard at the committee and society levels.
- 5.If approved** at the committee levels, the standard is published as a separate or within a volume in the Annual Book of ASTM Standards.





# Introduction/Background

General process of developing an ASTM International standard (cont'd):

- **Six months to two years** or more to complete.
- If negative ballots are received at any level then these must be resolved before the balloting can proceed to the next level, thereby ensuring the **full-consensus approval process**.
- Note that all ASTM standards undergo a **mandatory review process** every five years during which they are either reapproved or revised, so as to maintain the relevancy and currency of published standards.



# Introduction/Background

**Membership classification of ASTM International:**

- i) Users** (those who use ceramic materials or products in components or devices),
- ii) Producers** (those who make ceramic materials or products)
- iii) General interest** (those do not have a commercial interest in ceramics or ceramic components/devices).

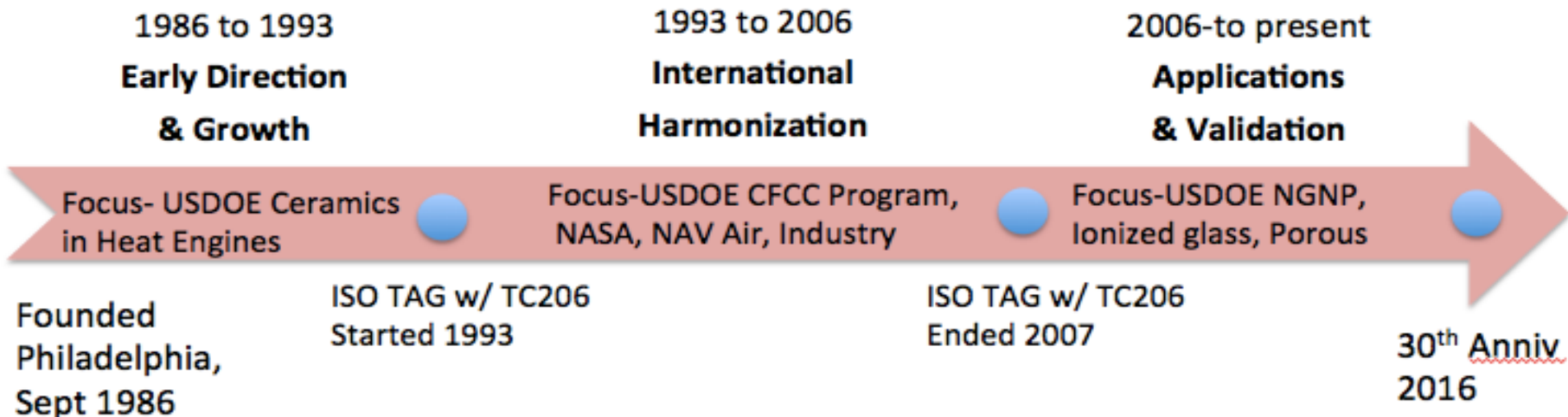
**Note: Number of Producers must be less than combined number of users and general interest members.**



# Discussion

The three decades of ASTM Committee C28's activities are divided into time periods: **Formative Years**; **Transition Years**; and **Present Years**

## ASTM Committee C28 Advanced Ceramics



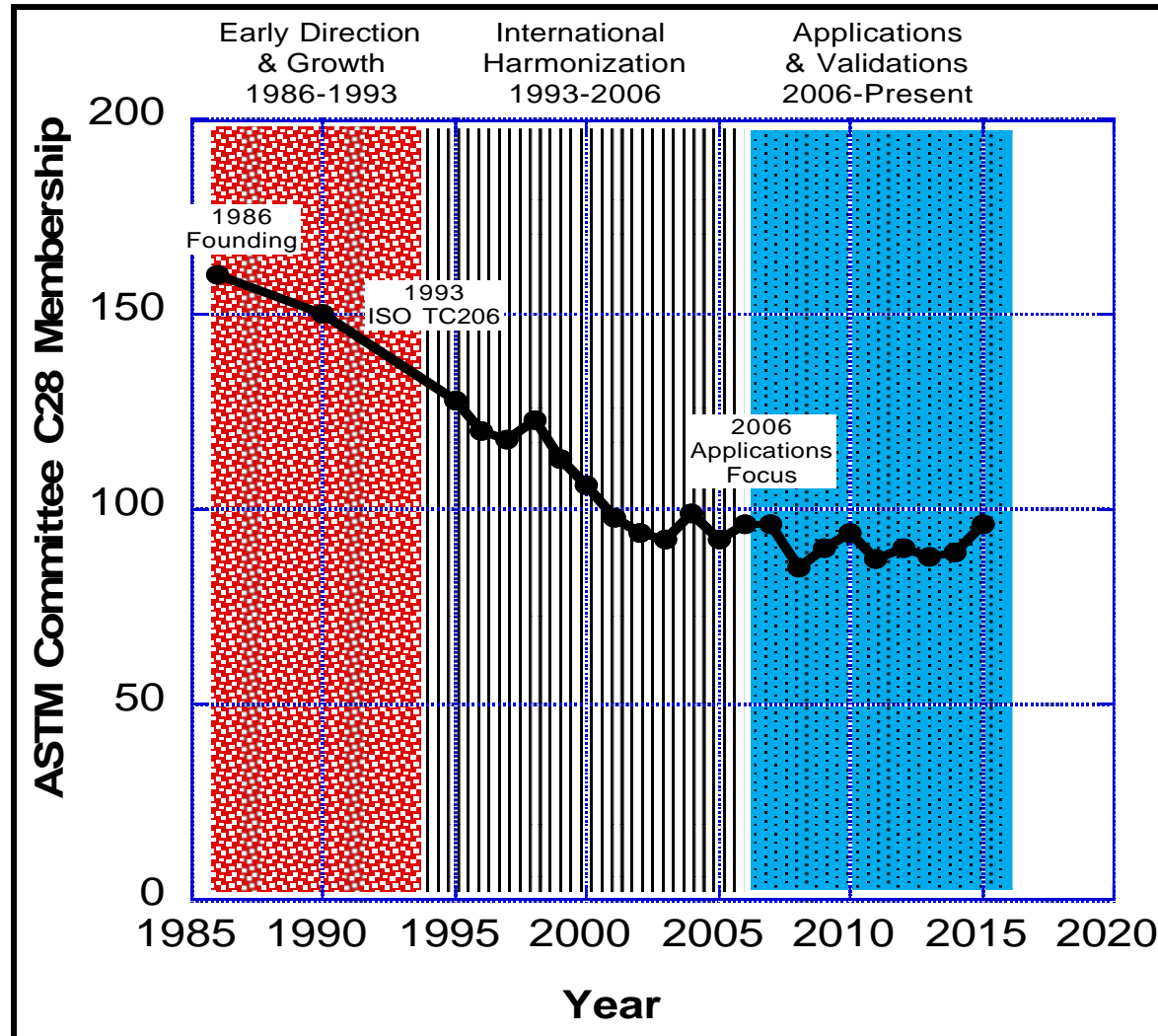
### Committee Chair (Affiliation)

S.J. Schneider Jr. 1986-94 (NIST)	G. D. Quinn 1994-98 (NIST)	C. R. Brinkman 1998-2000 (ORNL)	M.G. Jenkins 2000-04 (Univ Wash)	S.T. <u>Gonczy</u> 2004-10 (Gateway Mat)	J.A. Salem 2010-14 (NASA-GRC)	T.W. Thornton 2014-2018 ( <u>Micromeritics</u> )
---	----------------------------------	---------------------------------------	--	--	-------------------------------------	--



# Discussion

## Membership of ASTM Committee C28:



Busy,  
busy,  
busy....

Hardwork



# Discussion-Formative Years

**ASTM Committee C28 Advanced Ceramics was formed at a meeting held at ASTM headquarters in Philadelphia (1916 Race Street) in August 1986 and attended by over 150 interested parties,**

**Inaugural members included a breath of participants from **industry, government facilities, and universities.****



# Discussion-Formative Years

Early leadership included organizations that had interest in the technological and commercial successes of advanced ceramics.

For example:

**Inaugural C28 chair** = Samuel Schneider, Jr

**Inaugural C28 vice chair** = George Quinn

Both from Ceramics Division of NIST (US DoC)

Standardization  
benefits  
commercialization

**First C28.01 Chair** = Charles Brinkman

**First C28.02 Chair** = Robert McClung

Both from Metals & Ceramics Div at ORNL (US DOE)

**First C28.07 Chair** = David Cranmer

Ceramics Division of NIST (US DoC)

Application of  
ceramics to heat  
engines; efficiency  
and pollution



# Discussion-Formative Years

**Three administrative subcommittees and four technical subcommittees** comprised the initial organization of Committee C28

## Administrative

C28.90  
Executive

C28.91  
Nomenclature

C28.93  
Awards

## Technical

C28.01  
Properties &  
Performance

C28.02  
Design & Evaluation

C28.05  
Characterization &  
Processing

C28.07  
Ceramic Composites





# Discussion-Formative Years

Committee C28 developed and published 7 standards in its **Formative Years (1986-93)**

Number (current version year)	Title	Year Approved & First Published	Current Responsible Subcommittee
C1145 (2013)	Terminology on Advanced Ceramics	1990	C28.91
C1161 (2013)	Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature	1990	C28.01
C1175 (2010)	Guide to Test Methods for Nondestructive Testing of Advanced Ceramics	1991	C28.05
C1198 (2013)	Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance	1991	C28.01
C1211 (2013)	Test Method for Flexural Strength of Advanced Ceramics at Elevated Temperature	1992	C28.01
C1212 (2015)	Practice for Fabricating Ceramic Reference Specimens Containing Seeded Voids	1993	C28.02
C1239 (2013)	Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics	1993	C28.02

**7 baseline standards developed**





# Discussion-Transition Years

**During 1993, two developments occurred that would substantially affect the next decade of Committee C28:**

**i) the rise of ISO TC206**

**ii) the growth of the CFCC Program in US DOE and continued support of ceramics in heat engines projects in US DOE.**



# Discussion-Transition Years

- i) 1992, ISO TC206 Fine (technical, advanced) Ceramics formally established. First plenary meeting was held in 1994 with Samuel Schneider of NIST presided as chair of ISO TC206, a position he held until 2003. (10 P and 22 O national membership)

Major national and regional SWOs from which ISO TC206 **harmonized its standards** included CEN TC184 on Technical Ceramics (est. 1989), ASTM C28 on Advanced Ceramics (est. 1986), JIS R on Fine Ceramics (est. in 1979), BSI RPI/13 on Technical Ceramics (est. in 1984), DIN NMP291 on Technical Ceramics (est. in 1987), etc.



# Discussion-Transition Years

Committee C28 created a new subcommittee, **C28.94 ISO TC206 Technical Advisory Group (TAG)**. Because the official US representation to ISO is through ANSI, the C28.04 TAG acted only in an advisory role to ANSI for official ISO TC206 matters.

## Subcommittee C28.94:

- Created in 1993
- Dissolved in 2006 because of financial and time difficulties of maintaining both ASTM standards and developing ISO standards



# Discussion-Transition Years

**Partial list of ISO TC206 standards (25 total) developed with ASTM C28 leadership as convenor/US Expert**

ISO TC206 Number	Title ISO TC206 Fine ceramics (advanced ceramics, advanced technical ceramics)-	Year Approved	Relevant ASTM C28 Standard	ASTM C28 Project Convenor/US Expert
ISO 14703	Sample preparation for the determination of particle size distribution of ceramic powders	2000	C1282 Test Method for Determining the Particle Size Distribution of Advanced Ceramics by Centrifugal Photo sedimentation	S. G. Malghan (NIST) – US Expert
ISO 14704	Test method for flexural strength of monolithic ceramics at room temperature	2000	C1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature	G.D. Quinn (NIST) – Convenor/US Expert
ISO 14705	Test method for hardness of monolithic ceramics at room temperature	2000	<ul style="list-style-type: none"> <li>• C1326 Test Method for Knoop Indentation Hardness of Advanced Ceramics</li> <li>• C1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics</li> </ul>	G.D. Quinn (NIST) – Convenor/US Expert
ISO 15490	Test method for tensile strength of monolithic ceramics at room temperature	2000	C1273 Test Method for Tensile Strength of Monolithic Advanced Ceramics at Ambient Temperatures	M. G. Jenkins (UW, Seattle) –US Expert



# Discussion-Transition Years

ii) the growth of the **CFCC** Program within US DOE and continued support of ceramics in heat engines projects in US DOE.

Well-funded, broad-based program supported by US DOE and driven by industrial and aerospace applications of continuous fiber ceramic composites (**CFCCs**). **CFCCs** were the enabling technology for many types of advanced technologies that included chemical and petroleum refineries, next generation nuclear power, aerospace planes, gas turbines and scramjets.



# Discussion-Transition Years

**CFCCs** are fabricated quite differently than monolithic ceramics and behaved quite differently (i.e., nonlinear stress strain curve indicative of a cumulative damage, fracture resistant response), unique test methods were required.

- 11 standards for **CFCCs** were developed /published in the C28 Transition Years
- 2 symposia related to **CFCCs** were organized that resulted in two STPs (STP 1309 and 1392).
- Membership and participation in Subcommittee **C28.07 Ceramic Matrix Composites** grew.



# Discussion-Transition Years

## Symposia and STPs emanating from Committee C28

STP Number	Title	Year	Symposium Location
STP 1201	Life Prediction Methodologies and Data for Ceramic Materials	1994	Cocoa Beach, FL, Jan 1993 w/ACerS
STP 1309	Thermal and Mechanical Test Methods and Behavior of Continuous-Fiber Ceramic Composites	1996	Cocoa Beach, FL, Jan 1996 w/ACerS
STP 1392	Mechanical, Thermal and Environmental Testing and Performance of Ceramic Composites and Components	2000	Seattle, WA, May 1999
STP 1409	Fracture Resistance Testing of Monolithic and Composite Brittle Materials	2002	Orlando, FL, Nov 2000





# Discussion-Transition Years

**Subcommittee C28.95 Long Range Planning** was established and developed an ASTM-required, long-range plan (**LRP**) during this period with the following goals

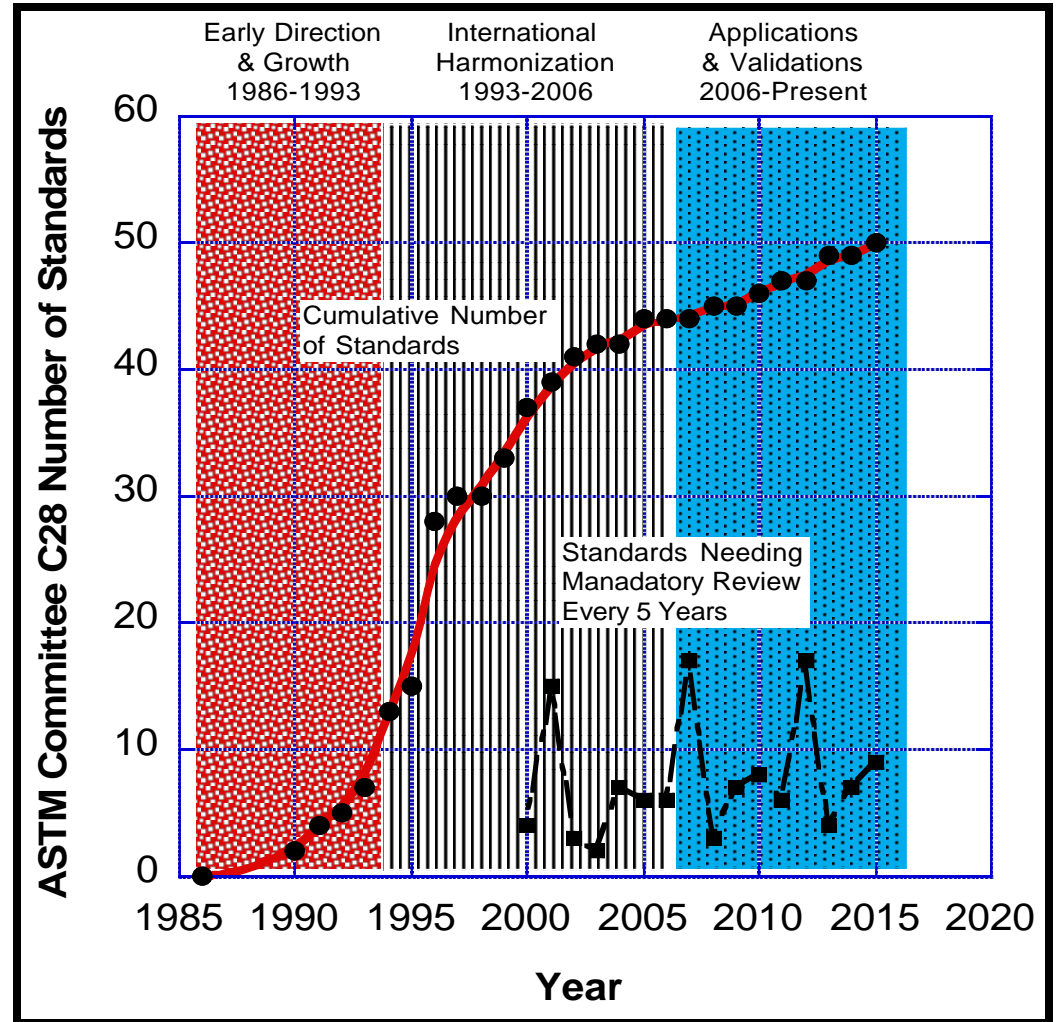
- 1) *Maintain and update existing ASTM standards* for advanced ceramics with emphasis on those that are most widely used.
- 2) *Maintain and update existing ISO standards* for advanced ceramics for which the committee has been convenor through its TAG.
- 3) *Develop new standards* for advanced ceramics that can provide support for evolving specifications, design codes and data bases
- 4) *Develop new standards* for advanced ceramics that can provide support for applications that are non structural based on user needs
- 5) *Coordinate and disseminate information* on advanced ceramics through standards, symposia and publications.





# Discussion-Transition Years

Growing number of C28 standards led to **first mandatory review** of existing standards per ASTM requirements: Individual standards must be re-approved or revised every five years or they will be subject to mandatory withdrawal as active standards. This requirement assures that standards remain relevant and up-to-date.



More work!



MS&T16

OCTOBER 23 - 27, 2016  
SALT PALACE CONVENTION CENTER | SALT LAKE CITY, UTAH USA



# Discussion-Transition Years

**Outreach and Education** were new activities that resulted from LRP overseen eventually by a new subcommittee **C28.92 Education and Outreach:**

➤ **Advanced Ceramic Sentinel**

➤ **Pictograph Poster**



# Discussion-Transition Years

## Advanced Ceramic Sentinel



An Information Summary for  
 ASTM Committee C28 on Advanced Ceramics  
 July 2016 – Celebrating 30 years of Excellence

### Scope of Committee C28

The promotion of knowledge, stimulation of research and development of standards (classifications, specifications, nomenclature, test methods, guides, and practices) relating to processing, properties, characterization, and performance of advanced ceramic materials.

This committee works in concert with other technical committees (e.g., D30 "Composite Materials," E07 "Non Destructive Testing," E08 "Fatigue and Fracture," E28 "Mechanical Testing," F04 "Medical and Surgical Materials and Devices", and G02 "Wear and Erosion") and other national and international organizations having mutual or related interests.

### What Committee C28 Does

Committee C28 develops and maintains standards for monolithic and composite advanced ceramics. An advanced ceramic is a highly-engineered, high-performance predominately non-metallic, inorganic, ceramic material having specific functional attributes. The C28 standards cover methods for testing bulk and constituent (powders, fibres, etc.) properties, thermal and physical properties, strengths and strength distributions, and performance under varying environmental, thermal, and mechanical conditions. The scope of application of the methods ranges from quality control through design data generation.

The Committee's primary objective is the development of technically rigorous standards which

are accessible to the general industrial laboratory and consequently are widely accepted and used in the design, production, and utilization of advanced ceramics.

While the committee's roots are in energy-related industries and programs, C28 supports the needs of automotive, aerospace, electronic, medical and other industries requiring advanced ceramics. Some specific applications include nano-ceramics, bio-ceramics, coatings, electronics, sensors/actuators, porous substrates and fuel cells. C28 actively pursues standards development to support these emerging applications.

Committee C28 coordinates its work with other organizations with mutual interests in advanced ceramics. The membership represents an international group of people interested in furthering advanced ceramic technology.

In addition to standards development, C28 sponsors symposia providing a forum for the timely transfer of technical information relevant to the design, analysis, processing, fabrication, and characterization of monolithic and composite advanced ceramics. Special workshops and technical presentations are often held to identify specific industrial needs and support the technical development of new standards.

The Committee meets twice a year in with an on-site meeting and a Web-teleconference. The Committee is self-regulated by committee-approved by-laws under the auspices of ASTM International

COMMITTEE C28 - ADVANCED CERAMICS 2016-18 Officers and Committee Structure				
<b>Chair:</b> Tony Thornton, Micromeritics				
<b>Vice Chair:</b> Michael Jenkins, Bothell Eng & Science Technologies				
<b>Recording Secretary:</b> Stephen Gonczy, Gateway Materials Technology				
<b>Membership Secretary:</b> Jonathan Salem, NASA Glenn Research Center				
<b>C28.90</b> Executive	<b>C28.92</b> Education / Outreach	<b>C28.93</b> Awards	<b>C28.95</b> Long Range Planning	
<b>C28.01</b> Mechanical Properties and Reliability	<b>C28.03</b> Physical Properties and NDE	<b>C28.04</b> Ceramic Applications	<b>C28.07</b> Ceramic Matrix Composites	<b>C28.91</b> Nomenclature and Editorial

Extra,  
 extra,  
 hard  
 copies  
 available!!



MS&T16

OCTOBER 23 – 27, 2016  
 SALT PALACE CONVENTION CENTER | SALT LAKE CITY, UTAH USA



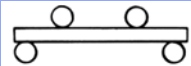
# Discussion-Transition Years



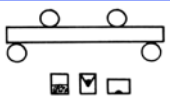
## Committee C28 Advanced Ceramic Standards

Visit the C28 website ( <http://www.astm.org/COMMITTEE/C28.htm> ) to purchase C28 standards or join Committee C28.


### Monolithics




C 1161 Flexural Strength (RT)  
C 1211 Flexural Strength (HT)  
C 1368 Slow Crack Growth (RT, Dyn Fatigue)  
C 1465 Slow Crack Growth (HT, Dyn Fatigue)  
C 1576 Slow Crack Growth (RT, Stress Rupture)  
C 1684 Flexural Strength (Rods)  
C 1834 Slow Crack Growth (HT, Stress Rupture)



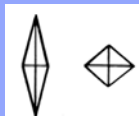
C 1421 RT Fracture Toughness



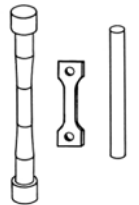
C 1322 Fractography  
C 1678 Fracture Mirror




C 1424 Compression Strength (RT)



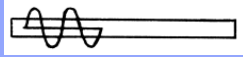
C 1326 Knoop Hardness  
C 1327 Vickers Hardness



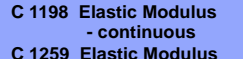
C 1273 Tensile Strength (RT)  
C 1291 Creep, Creep Rupture  
C 1366 Tensile Strength (HT)  
C 1361 Cyclic Fatigue



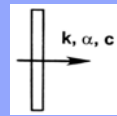
C 1499 Biaxial Strength (RT)



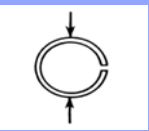
C 1198 Elastic Modulus - continuous



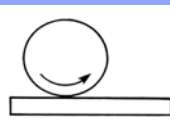
C 1259 Elastic Modulus - impulse



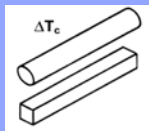
C 1470 Thermal Guide



C 1323 C-ring Strength




C 1495 Grinding

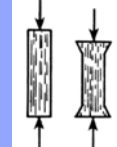


C 1525 Thermal Shock


### Composites, Coatings, Porous Ceramics




C 1275 CMC Tensile Strength (RT)  
C 1337 Creep, Creep Rupture  
C 1359 CMC Tensile Strength (HT)  
C 1360 Cyclic Fatigue  
C 1773 CMC Tube Axial Tensile (RT)



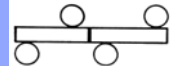
C 1358 CMC Compression Strength




C 1468 CMC Tensile Strength Trans Thickness  
C 1557 Filament Strength & Stiffness




C 1819 Hoop Tensile Strength of CMC tubes (elastomer insert)



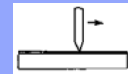
C 1469 Joint Strength



C 1341 CMC Flexure Strength  
C 1674 Honeycomb Flex Strength



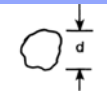
C 1292 CMC Shear Strength (RT)  
C 1425 Shear Strength (HT)



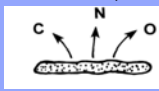
C 1624 Coatings - Scratch Adhesion

C 1835 Classification for SiC/SiC  
C 1836 Classification for C/C

### Powders

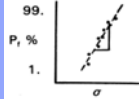


C 1070 Particle Size, Laser Light  
C 1274 Particle Size, BET  
C 1282 Particle Size, Centrifugal Sed.

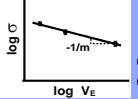


C 1494 C, N, O in silicon nitride


### NDE and Design



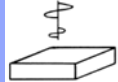
C 1239 Weibull




C 1683 Weibull Scaling



C 1212 Seeded Voids  
C 1336 Seeded Inclusions




C 1331 Ultrasonic Velocity  
C 1332 Ultrasonic Attenuation




C 1175 NDE Guide

### Terms, Workshops, Education



STP 1201 Life Prediction  
STP 1309 Composites  
STP 1392 Composites  
STP 1409 Fracture



C 1145 Terminology

ASTM C28 standards are found in Vol. 15.01 of the Annual Book of ASTM Standards

08-2016



MS&T16

OCTOBER 23 - 27, 2016  
SALT PALACE CONVENTION CENTER | SALT LAKE CITY, UTAH USA



# Discussion-Transition Years

**Four administrative subcommittees and four technical subcommittees** resulted from organization of Committee C28 to reflected user specific focus and involvement in ISO activities

## Administrative

C28.90  
Executive

C28.91  
Nomenclature

C28.93  
Awards

C28.94  
ISO TAG

C28.95  
LRP

## Technical

C28.01  
Mechanical  
Properties &  
Performance

C28.02  
Reliability

C28.03  
Physical  
Properties &  
Performance

C28.04  
Applications

C28.07  
Ceramic  
Composites



# Discussion-Transition Years

Committee C28 developed and published 37 standards in its **Transition Years (1993-2006)**

Partial list shown here

Number (current version year)	Title	Year Approved & First Published	Current Responsible Subcommittee
C1259 (2015)	Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Impulse Excitation of Vibration	1994	C28.01
C1273 (2015)	Test Method for Tensile Strength of Monolithic Advanced Ceramics at Ambient Temperatures	1994	C28.01
C1274 (2012)	Test Method for Advanced Ceramic Specific Surface Area by Physical Adsorption	1994	C28.03
C1275 (2015)	Test Method for Monotonic Tensile Behavior of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section at Ambient Temperatures	1994	C28.07
C1282 (2008) withdrawn 2014	Test Method for Determining the Particle Size Distribution of Advanced Ceramics by Centrifugal Photo-sedimentation	1995	C28.02





# Discussion-Present Years

**C28 reassessed its role in standards development at the beginning of Present Years**

- LRP directions
- Time and fiscal commitments from its duality of development/upkeep of ASTM standards and the development/upkeep of ISO TC206 standards,
- Applications focus: ionized glass for touch screens, electrolytes for solid oxide fuel cells (SOFCs), windows in aerospace applications, porous ceramics for filters, traps and substrates, and joining materials for ceramic joints.
- US-DOE Next Generation Nuclear Power (NGNP) focus on CMC tubes.



# Discussion-Present Years

**Four administrative subcommittees** and four technical subcommittees resulted from organization of Committee C28 to reflected new foci:

## Administrative

C28.90  
Executive

C28.91  
Nomenclature

C28.92  
Education &  
Outreach

C28.93  
Awards

C28.95  
LRP

## Technical

C28.01  
Mechanical  
Properties &  
Reliability

C28.03  
Physical  
Properties &  
NDE

C28.04  
Ceramic  
Applications

C28.07  
Ceramic  
Composites





# Discussion-Present Years

## Current C28 Administrative Subcommittees

- **C28.90 Executive** This subcommittee manages administrative matters of main Committee C28 through its membership comprised of the committee and subcommittee officers of C28.
- **C28.91 Nomenclature and Editorial** This subcommittee compiles nomenclature and terminology used in the various standards of Committee C28.
- **C28.92 Education and Outreach** This subcommittee develops and supports efforts for education and outreach for the C28 committee.
- **C28.93 Awards** This subcommittee accepts/acts on nominations for various awards
- **C28.95 Long Range Planning** This subcommittee proposes, facilitates and promotes long range planning activities consistent with the mission.

Still only \$75 a year!!



# Discussion-Present Years

## Current C28 Subcommittees

- **C28.01 Mechanical Properties & Reliability** Develops standards for mechanical properties and reliability (short term and long term) of monolithic advanced ceramics in a number of areas including flexural strength, tensile strength, compressive strength, cyclic fatigue, etc.
- **C28.03 Physical Properties & NDE** Develops standards for physical, chemical, micro-structural, and non-destructive characterization of powder and bulk advanced ceramics.
- **C28.04 Applications** Develops standards (including guides, specifications, practices, test methods) for various engineering applications of advanced ceramics, such as nanoceramics, coatings, electrodes, porous ceramics, fuel cells, armor, sensors/actuators, and thermal systems.
- **C28.07 Ceramic Matrix Composites** Develops standards for determination of the thermo-mechanical properties and performance of ceramic matrix composites including tension, compression, etc.



# Discussion-Present Years

## Round robin programs support and strengthen C28 standards

Sponsor: ASTM-International and Focus	Standard P&B Benefit
• Young's Modulus and Poisson's Ratio	ASTM C1259
• Flexural Strength of Ceramic Matrix Composites	ASTM C1341
• Trans-Laminar Tensile Strength of Ceramic Composites	ASTM C1468
• Tensile Creep of Silicon Nitride	ASTM C1291
Sponsor: International Energy Agreement (IEA)	
• Flexural Strength Testing of Ceramics	ASTM C1161
• Effect of Machining Conditions on the Strength of Silicon Nitride	ASTM C1495
• Tensile Strength Testing of Ceramics	ASTM C1273
Sponsor: Versailles Project on Advanced Materials and Standards (VAMAS)	
• Fracture Toughness by the Surface Crack Method	ASTM C1421
• Fracture Toughness of Silicon Nitride at High Temperature	JIS 1617
• Fractography of Advanced Ceramics	ASTM C1322
• Fracture Toughness of Advanced Ceramics at Room Temperature	ASTM C1421
• Fracture Toughness of Ceramic Matrix Composite	None at this time
• Fracture Toughness of Ceramics using the SEVNB Method	ISO 23146
• Inert Strength of Ceramics	None at this time
Sponsor: US DOE CFCC Programme	
• Tensile, Flexure and Shear Behavior of a Ceramic Matrix Composite	ASTM C1275, C1292, C1341, C1468



# Discussion-Present Years

Committee C28 developed and published 11 standards in its **Present Years** (2006 to Present)

Partial list shown here

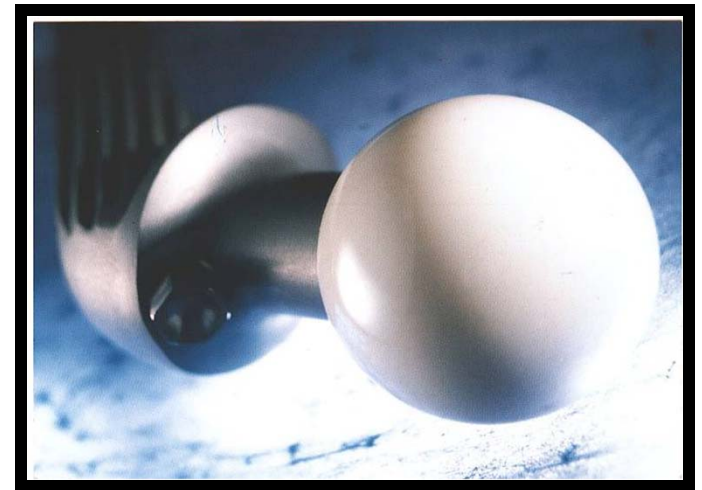
Number (current version year)	Title	Year Approved & First Published	Responsible Subcommittee
C1674 (2011)	Standard Test Method for Flexural Strength of Advanced Ceramics with Engineered Porosity (Honeycomb Cellular Channels) at Ambient Temperatures	2011	C28.05
C1678 (2010)	Standard Practice for Fractographic Analysis of Fracture Mirror Sizes in Ceramics and Glasses	2010	C28.01
C1683 (2015)	Standard Practice for Size Scaling of Tensile Strengths Using Weibull Statistics for Advanced Ceramics	2008	C28.01
C1684 (2013)	Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature - Cylindrical Rods	2013	C28.01



# Tangible Benefits

## 1) F2393 Standard Specification for High-Purity Dense Magnesia Partially Stabilized Zirconia (Mg-PSZ) for Surgical Implant Applications

**ASTM Committee F04 on Surgical and Medical Devices and the U.S. Food and Drug Administration used generic standards from Committee C28 for their standard specification, F2393.**



# Tangible Benefits

## 1) F2393 Standard Specification (cont'd)

- “The average room temperature flexural strength shall be 600 MPa (87 000 psi) or greater by 4 point bend testing in accordance with **Test Method C1161**, test configuration B. A minimum of 10 samples are to be tested.”
- “If Weibull modulus is determined, test results shall be evaluated in accordance with **Practice C1239**. The minimum number of test specimens shall be 30 and the minimum acceptable uncensored, unbiased Weibull modulus shall be 10.”
- “The minimum room temperature elastic modulus shall be 180 GPa (26 200 ksi) in accordance with **Test Method C1198**. A rectangular specimen with dimensions of 60 by 10 by 3 mm is recommended. An acceptable alternative test method for elastic modulus is **Test Method C1259**.”
- The minimum Vickers hardness value shall be 1000 HV in accordance with **Test Method C1327**. The load shall be 9.8 N (1kg) and the dwell time shall be 15 s.



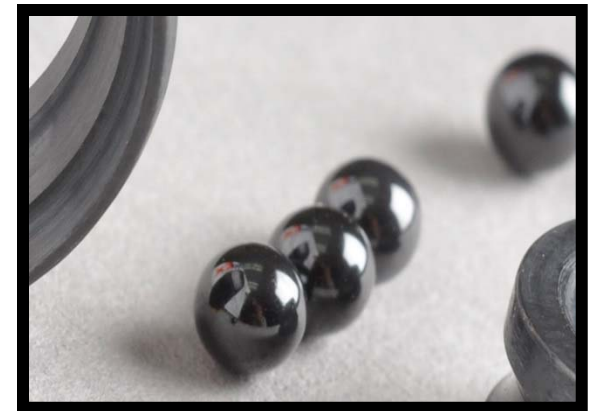


# Tangible Benefits

## 2) F2094/F2094M Standard Specification for Silicon Nitride Bearing Balls

ASTM Committee F34 on Rolling Element Bearings used generic standards from Committee C28 for their standard specification, F2094.

- “Either 3-point or 4-point test methods may be used for flexural strength, which should be measured in accordance with **Test Method C1161 (size B)**...”
- “Fracture resistance shall be measured by either ..... (see Annex A1) or by a standard fracture toughness test method.” (**Test Method C1421**)

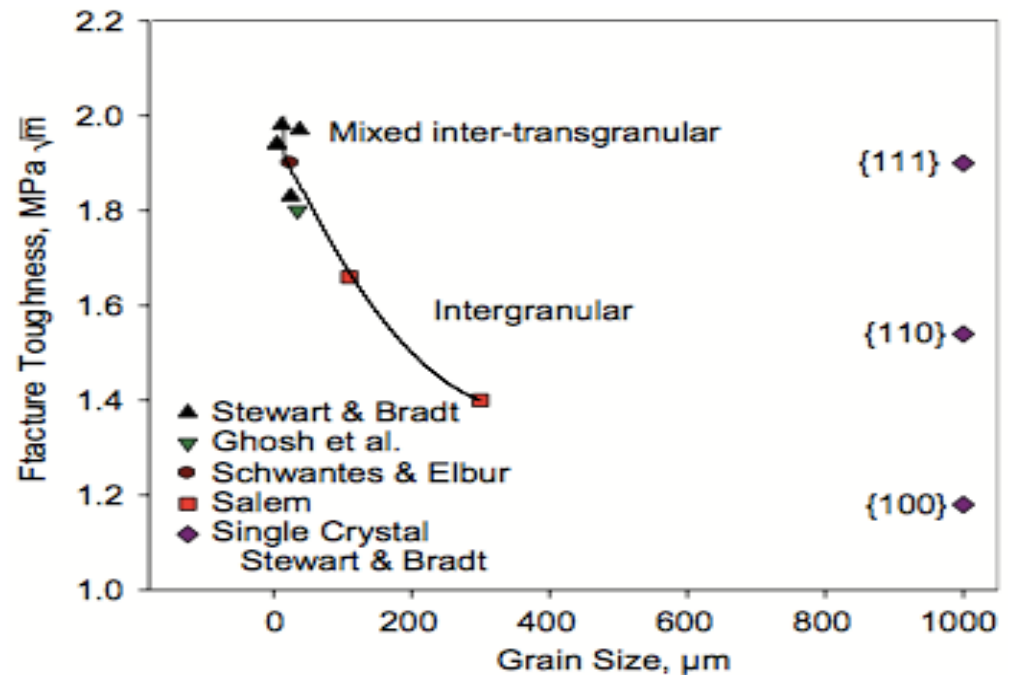


# Tangible Benefits

## 3) Transparent Armor Ceramics as Spacecraft Windows

Standards from Committee C28 allowed comparisons among authors and helped to interpret data.

- Standardized fracture toughness tests using **Test Method C1421** ensured correct comparisons

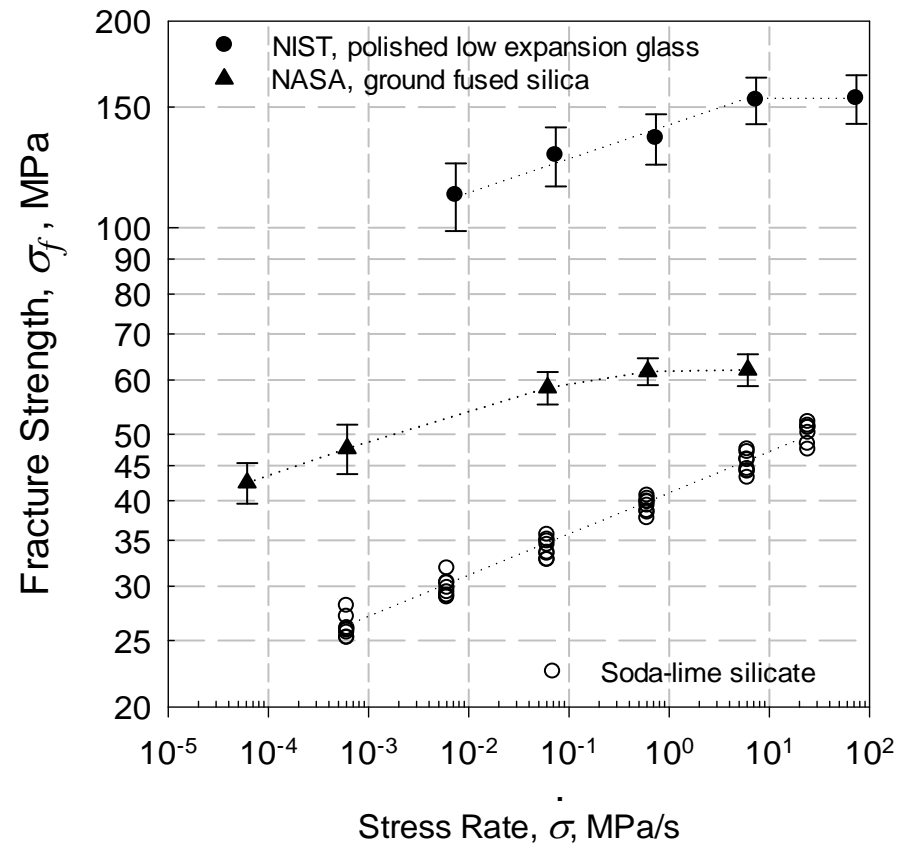
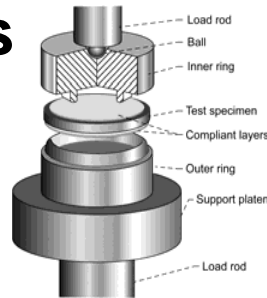




# Tangible Benefits

## 3) Transparent Armor Ceramics as Spacecraft Windows (cont'd)

• Standard-sized circular disks could be used to determine Poisson's ratio and Young's modulus via **Test Method C1259** and biaxial strength via **Test Method C1499** as well as the slow crack growth parameters,  $n$  and  $A$ , via **Test Method C1368**.



# Tangible Benefits

## 4) Standard Reference Materials

SRMs certified by NIST are available for users to verify test procedures including user techniques and test apparatus.

1) **SRM 2100** was developed to improve fracture toughness testing of ceramics. The SRM is a set of five hot-isostatically pressed silicon nitride test specimens. The fracture toughness is certified by a value of the SRM material.



# Tangible Benefits

## 4) Standard Reference Materials (cont'd)

ii) **SRM 2830** was developed to improve Knoop hardness testing of ceramics. The SRM is prepared from a silicon nitride ceramic bearing ball in which five indentations have been made at a load of 19.6 N (2 kgf).

iii) **SRM 2831** was developed to improve Vickers hardness testing of ceramics and hardmetals. The SRM is a hot-isostatically pressed tungsten carbide with 12% cobalt disk which has five indentations made at a load of 9.8 N (1 kgf).



# Summary/Conclusions

- **Market demand for advanced ceramics and ceramic matrix composites is expected to continue to grow as these materials improve in consistency and reliability while simultaneously reducing cost.**
- **Standardized test methods are expected to accelerate use of these materials as they become available and are used nationally and internationally.**



# Summary/Conclusions

- **ASTM Committee C28 on Advanced Ceramics has produced, as of this writing, over fifty high-quality, technically-rigorous consensus standards for processing, characterization, design, and evaluation of this class of materials.**
- **Standardization activities accelerated in recent years, and many more high-quality, technically-rigorous standards are expected to be completed in the near future. Questions??????**

