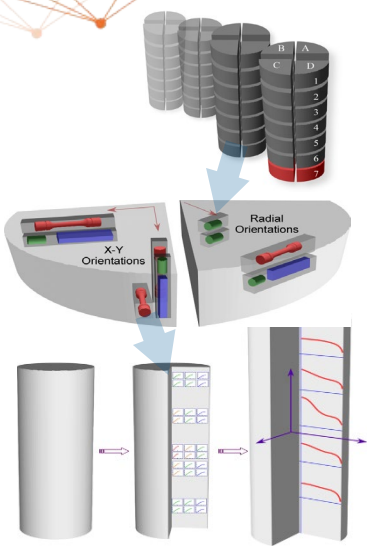
Austin Matthews

Baseline Graphite Characterization

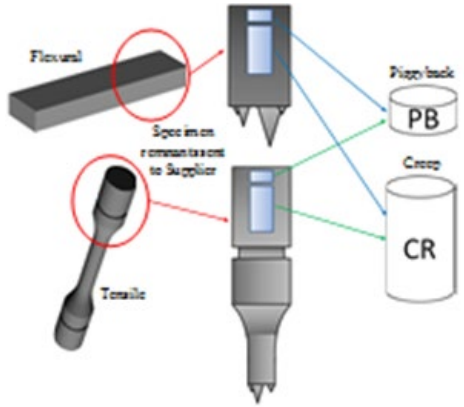
ART Advanced Reactor Technologies
GAS-COOLED REACTORS

Baseline Graphite Characterization Purpose and Results



Establish the physical and mechanical properties of nuclear grade graphite and their variability…

- Intra Billet
- Billet to Billet
- Batch to Batch
- Grade to Grade



Method and procedure for obtaining data

- NQA-1 Qualified Data Set
- Manufacturing process improvement
- Initial selection of graphite
- Qualify graphite as a structural material (ASME)

Development of measurement techniques, standards and design code

- Split disc tensile strength
- ASME BPVC.III.5
- ASTM D02.F0

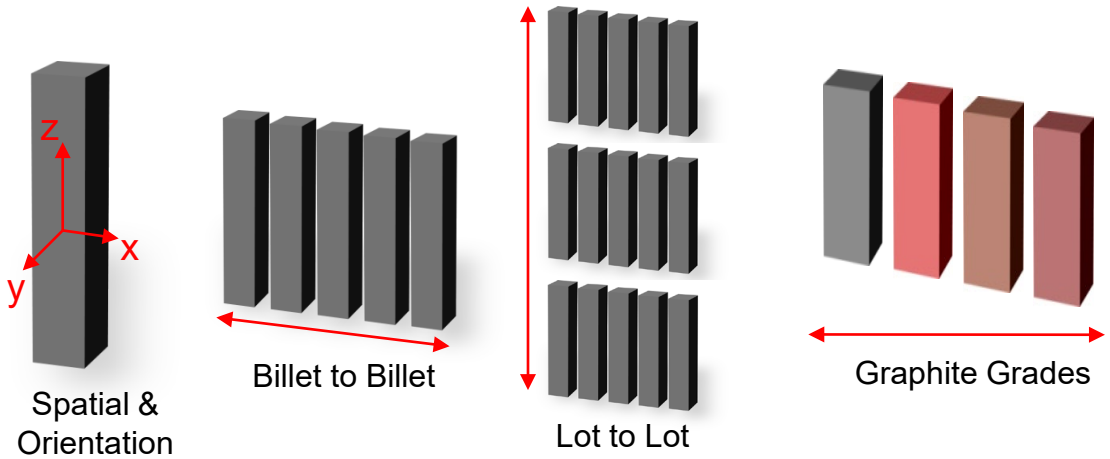
Baseline of un-irradiated properties for comparison to AGC irradiated properties

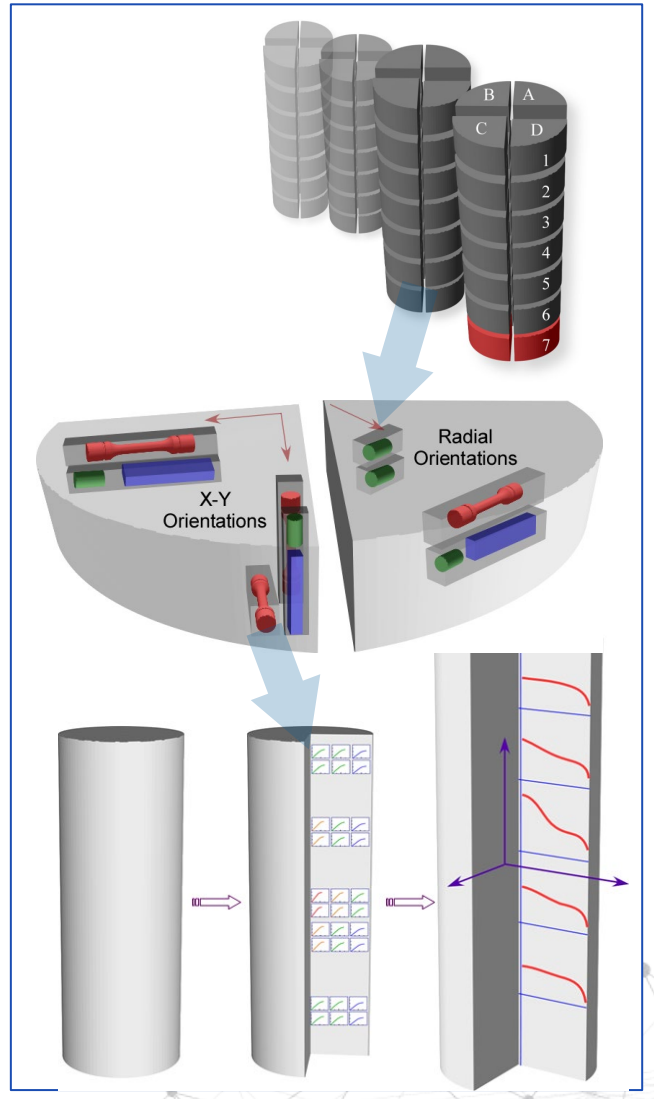
- Statistically valid
- Scalar value
- Distribution

Baseline Graphite Characterization Method

- Select necessary material properties
- Apply sampling plan
- Perform standardized testing
- Evaluate/compare properties
- Build NQA-1 qualified database
- Apply the “system” and database to the evaluation and qualification of future grades of graphite

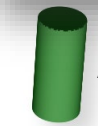
- **Current Grades**
  - NBG-18
  - PCEA
  - IG-110
  - 2114
  - NBG-17
- **Additional Grades**
  - IG-430





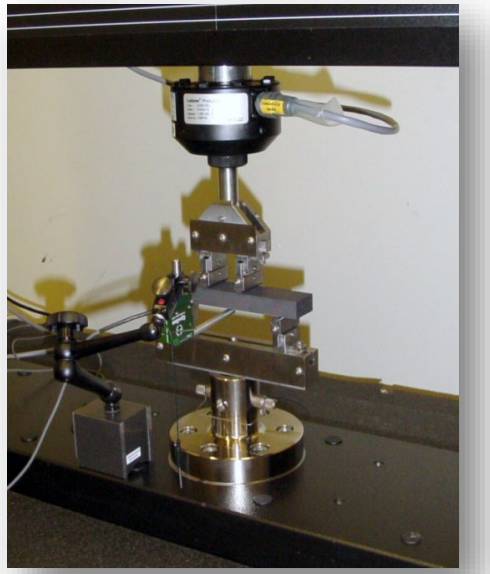
Baseline Property Measurements

Compressive Strength



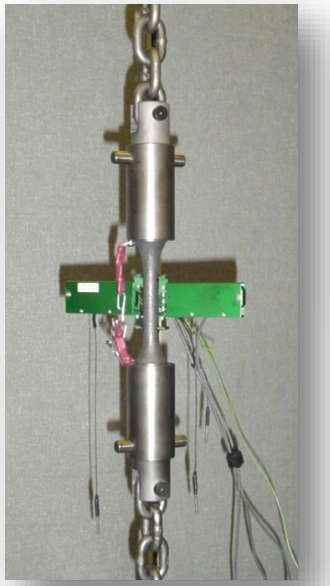
ASTM C695

Flexural Strength



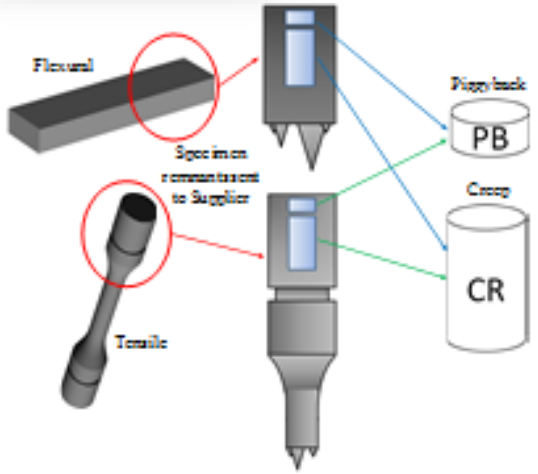
ASTM C651

Tensile Strength



ASTM C749

Brazilian Disc



Physical Properties Testing

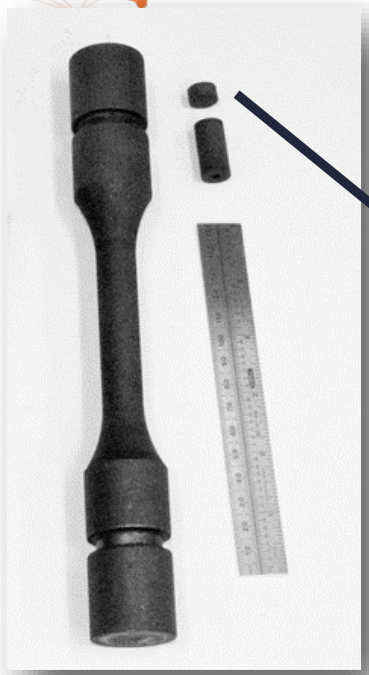
- Density
- Coefficient of Thermal Expansion
- Thermal Diffusivity
- Electrical Resistivity
- Elastic Modulus
  - Young's
  - Shear

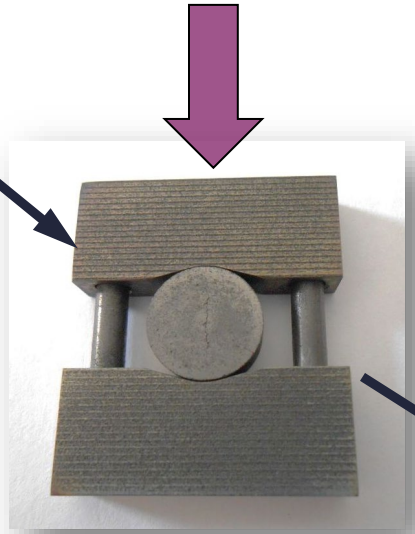
Baseline Progress

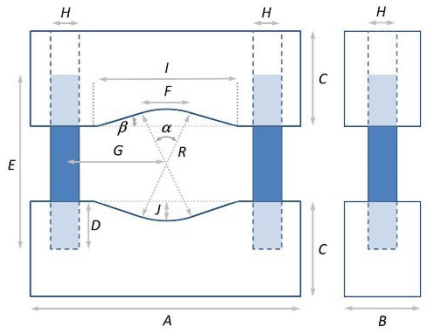
- Second and third billets of 2114 complete.
- Second billet of NBG-17 currently being tested.
- A billet of PCEA currently being machined.
- Over 18,000 NQA-1 qualified measurements taken so far.

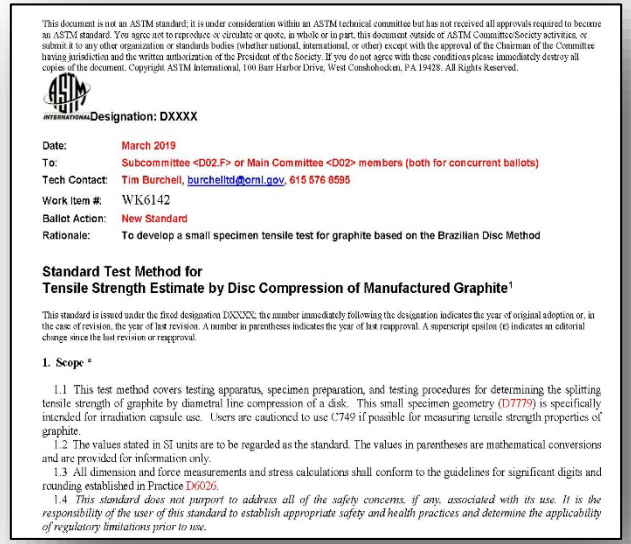
Graphite	Laboratory	Billet #	Percent Complete					Data Report	Analysis Reports
			Machining	Mass and Density	Elastic Testing	Mechanical Testing	Thermal Testing		
PCEA	ORNL	XPC01S8-11	**100%**	**100%**	**100%**	**100%**	**100%**	ORNL/TM-2015/765	ORNL/TM-2015/765
PCEA	INL	XPC02S8-7	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-3725	INL/EXT-13-30011
PCEA	INL	XPC01S8-9	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-6111	
PCEA	INL	XPC02S8-5	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-6110	
PCEA	INL	XPC01D3-35	**30%**						
PCEA	INL	XPC01D3-36	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-3677	INL/EXT-16-39604
PCEA		Multiple Other Billets Available							
NBG-18	INL	635-4	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-3726	INL/EXT-14-33120, INL/EXT-13-30011
NBG-18	INL	635-14	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-1930	INL/EXT-10-19910, INL/EXT-13-30011
NBG-18	ORNL	635-6	**100%**	**100%**	**100%**	**100%**	**100%**	ORNL/TM-2010/219	ORNL/TM-2010/219
NBG-18		Multiple Other Billets Available							
2114	INL	A20568	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-5798	
2114	INL	A20570	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-4322	INL/EXT-14-33120
2114	ORNL	116310	**100%**	**100%**	**100%**	**100%**	**100%**	2018/1038, 2019/1256	ORNL/TM-2018/1038, ORNL/TM-2019/1256
2114		Multiple Other Billets Available							
NBG-17	INL	830-3	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-3727	INL/EXT-14-33120
NBG-17	INL	V104	**66%**			**33%**			
NBG-17	INL	005-04	**30%**						
IG-110	INL	089052-7	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-3621	INL/EXT-14-33120
IG-110	INL	10X69	**100%**	**100%**	**100%**	**100%**	**100%**	ECAR-4182	ECAR-4182

Split Disc Tensile Strength: ASTM Tensile Strength Alternative









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Designation: DXXXX

Date: March 2019
To: Subcommittee <D02.F> or Main Committee <D02> members (both for concurrent ballots)
Tech Contact: Tim Burchell, burchelltd@ornl.gov, 615 576 8595
Work Item #: WK6142
Ballot Action: New Standard
Rationale: To develop a small specimen tensile test for graphite based on the Brazilian Disc Method

Standard Test Method for Tensile Strength Estimate by Disc Compression of Manufactured Graphite[1]

This standard is issued under the fixed designation DXXXX; 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 testing apparatus, specimen preparation, and testing procedures for determining the splitting tensile strength of graphite by diametral line compression of a disk. This small specimen geometry (D7779) is specifically intended for irradiation capsule use. Users are cautioned to use C749 if possible for measuring tensile strength properties of graphite.

1.2 The values stated in SI units are to be regarded as the standard. The values in parentheses are mathematical conversions and are provided for information only.

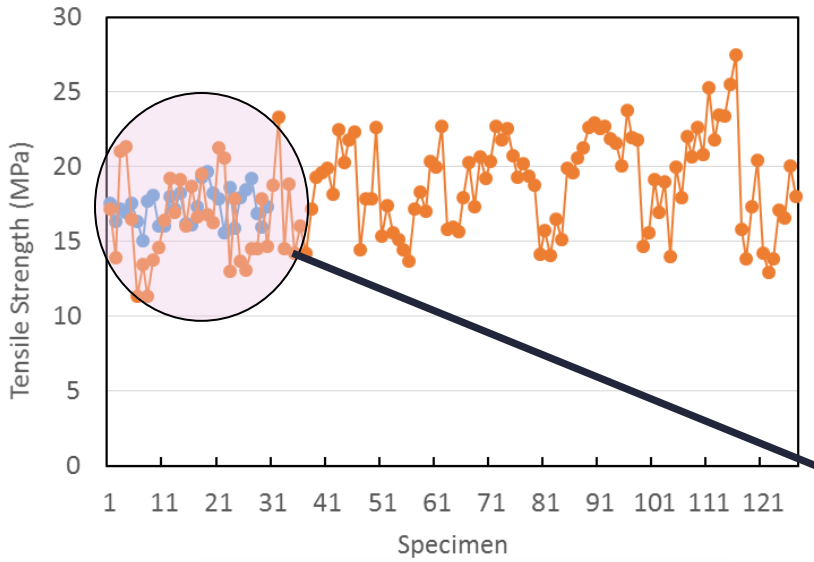
1.3 All dimension and force measurements and stress calculations shall conform to the guidelines for significant digits and rounding established in Practice D6026.

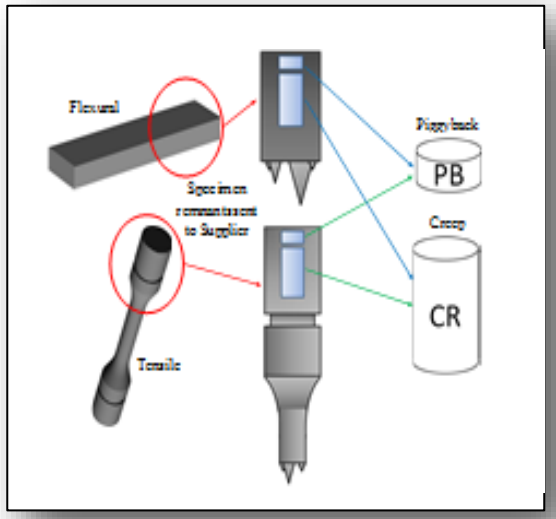
1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

By compressively loading a disc-shaped specimen on edge the resulting tensile stresses, transverse to the loading axis, result in the specimen failing in tension transverse to the load. The load at failure, P, and geometry of the specimen provide an indication of the tensile strength.

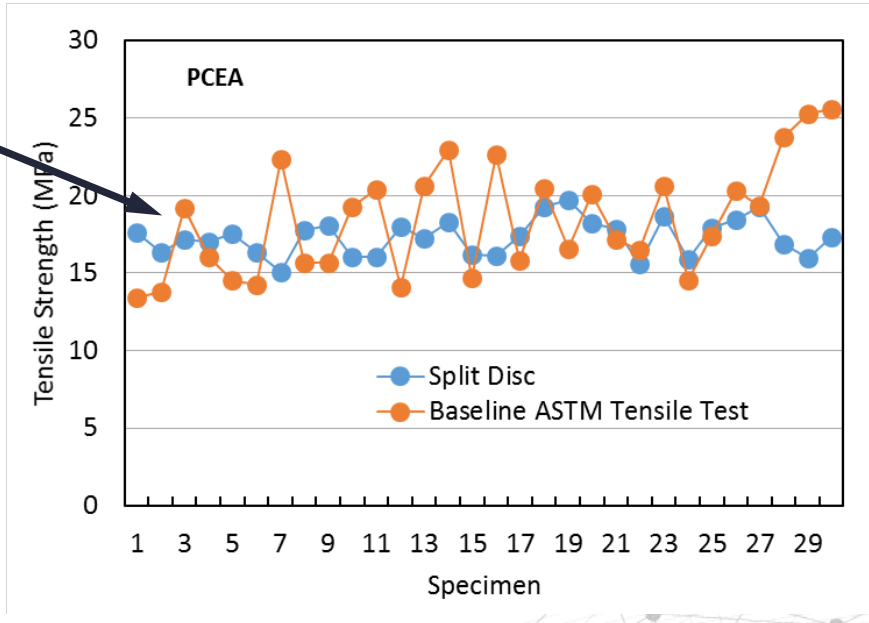
$$\sigma_{sts} \approx \frac{P}{\pi L R}\left[1-\left(\frac{b}{R}\right)^2\right]$$

One to One Comparison of Breaking Strength Re-machined Baseline Specimens

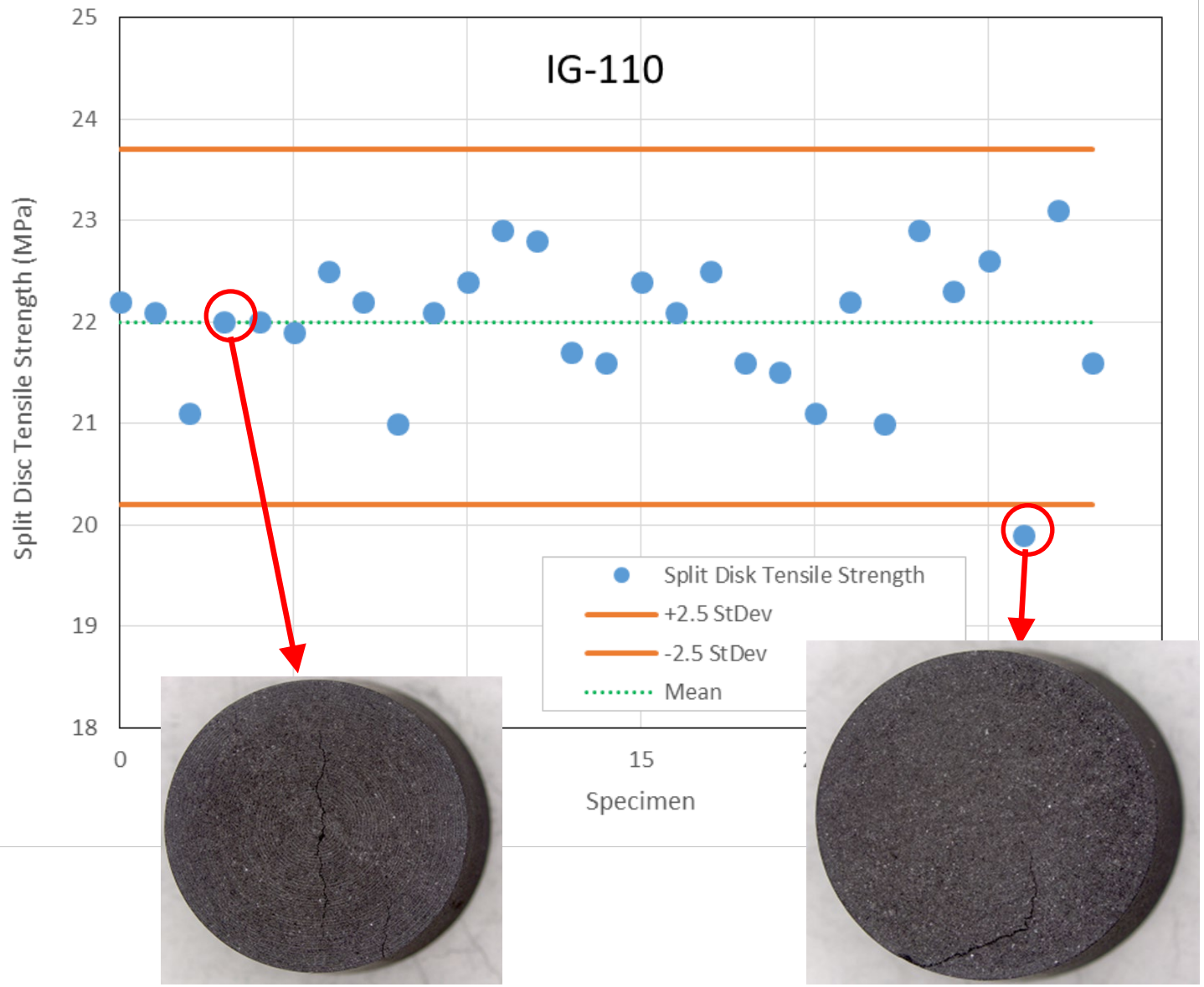




- Split disc specimens machined from broken ends of full-size tensile specimens.
- 12.7 mm dia. X 6.3 mm thk.
- One to one material correspondence between the Split disc specimen and the ASTM C749 full size uniaxial tensile specimen.



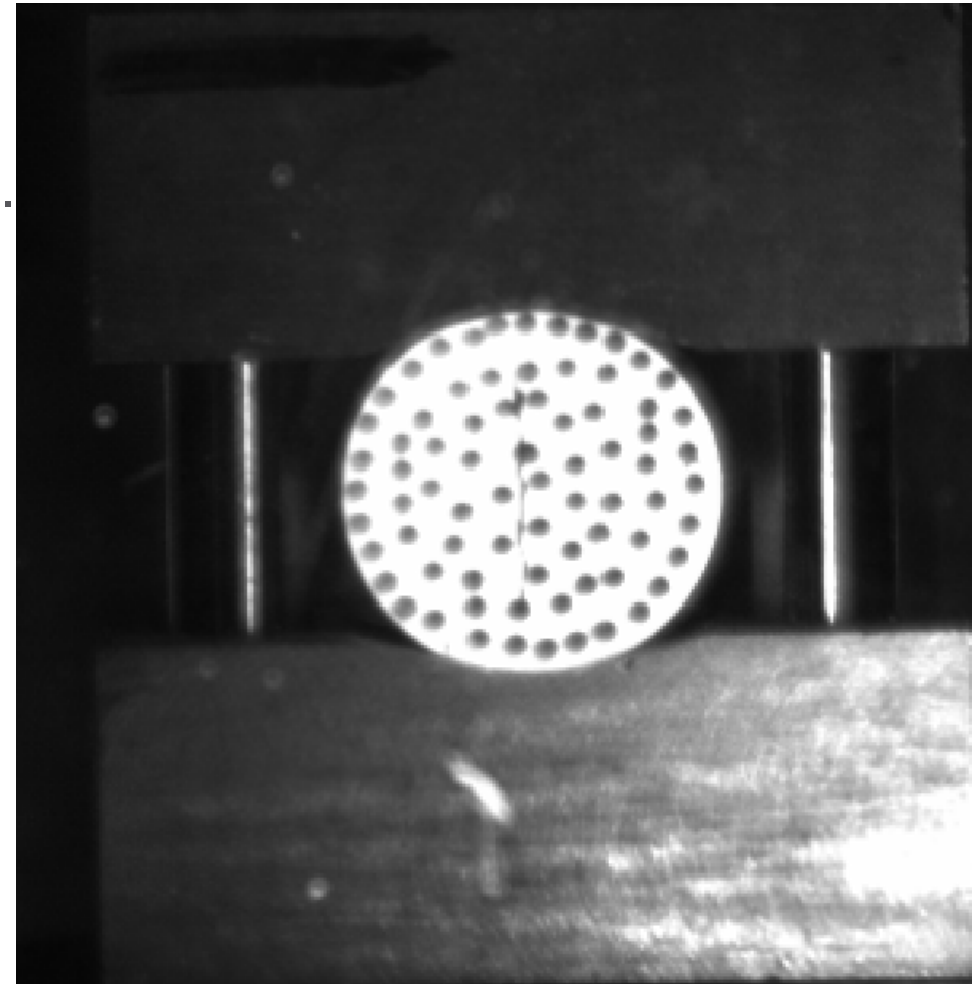
Identification of Proper Split Disk Fracture

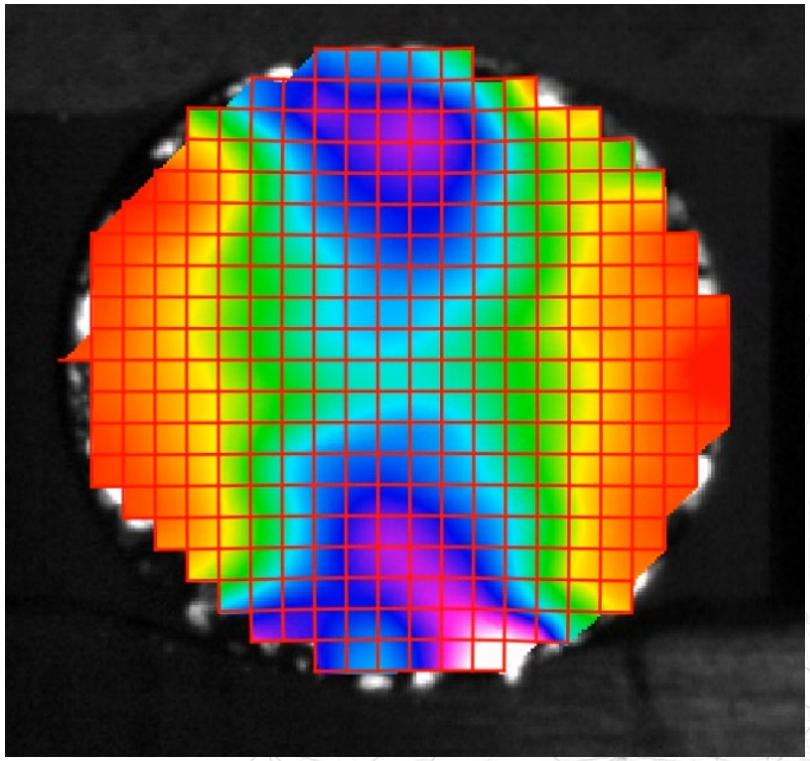


- This measurement technique originated in rock and concrete where the ratio of compressive to tensile strength is ~10. (Graphite ~3-4).
- Calculation of tensile stress in a compressed disc requires the fracture to initiate from the center of the disc.
- This occurs when the compressive strength is much higher than the tensile strength.
- **Proper crack/fracture initiation is easily identifiable.**

Identification of Proper Split Disk Fracture

- Instron DIC camera used to further verify proper split disc fracture.
- Measurement of actual stress/ strain curve.





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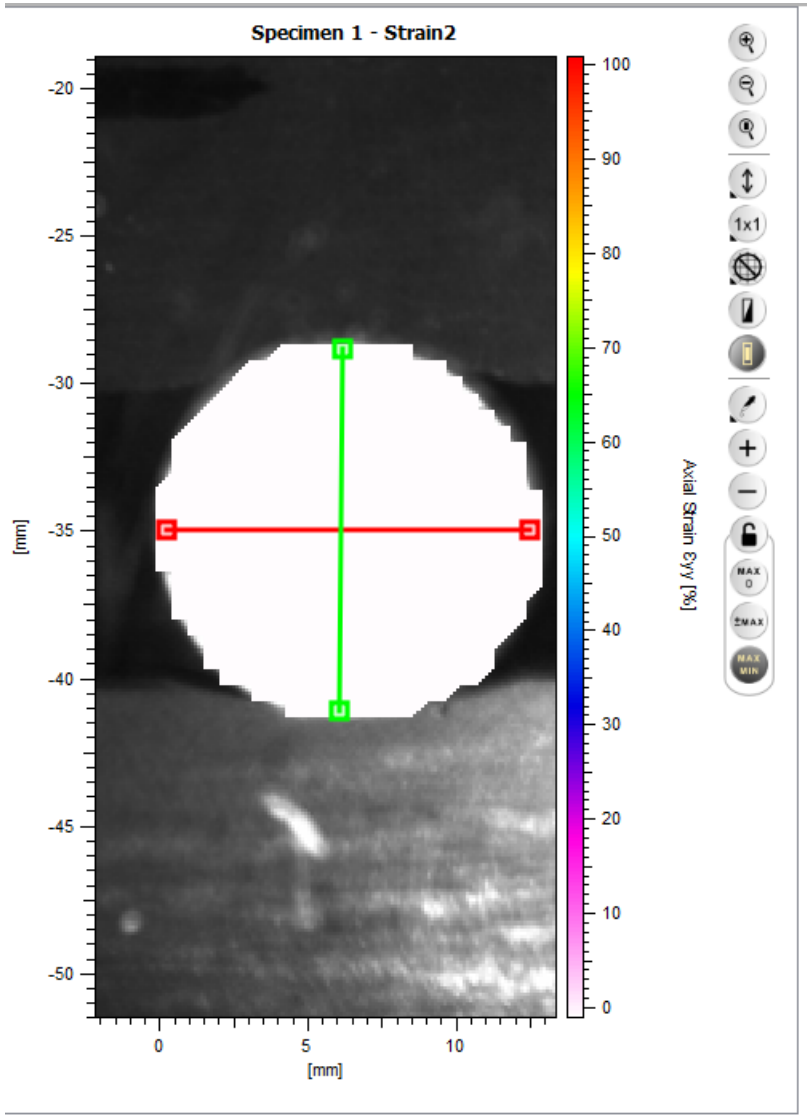
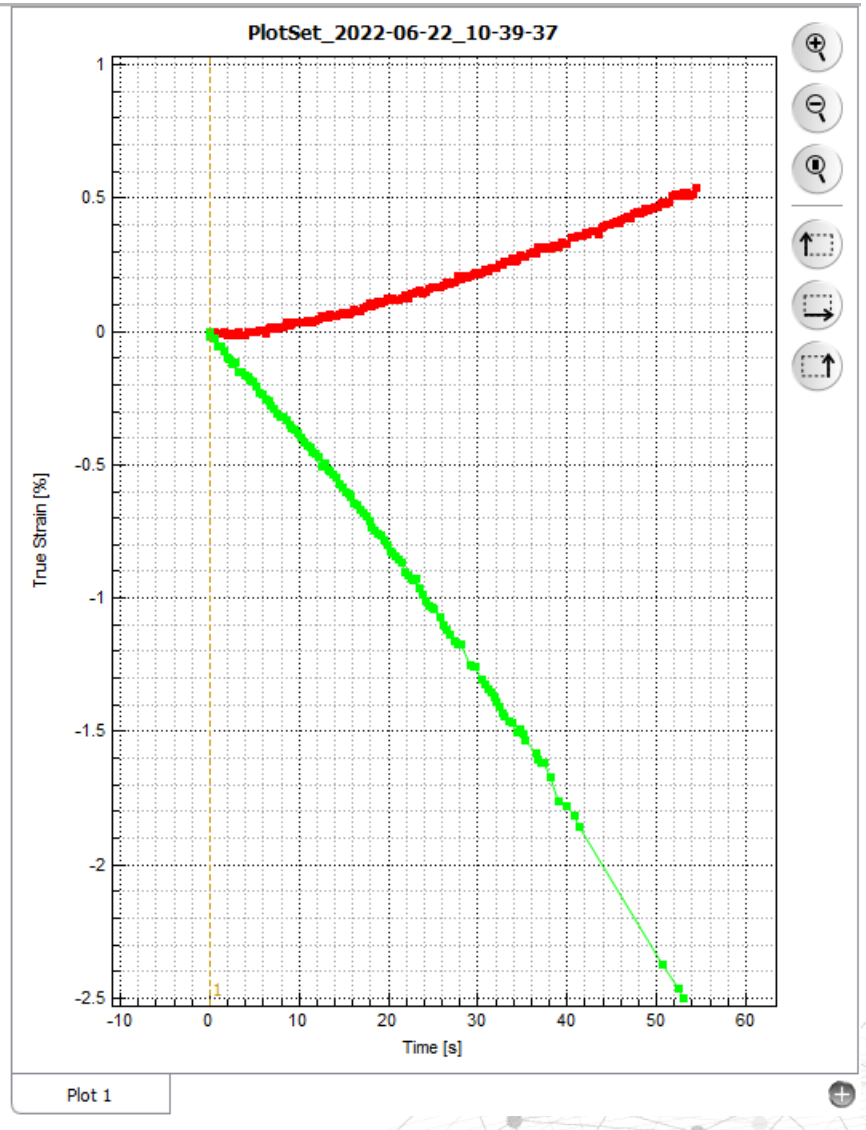
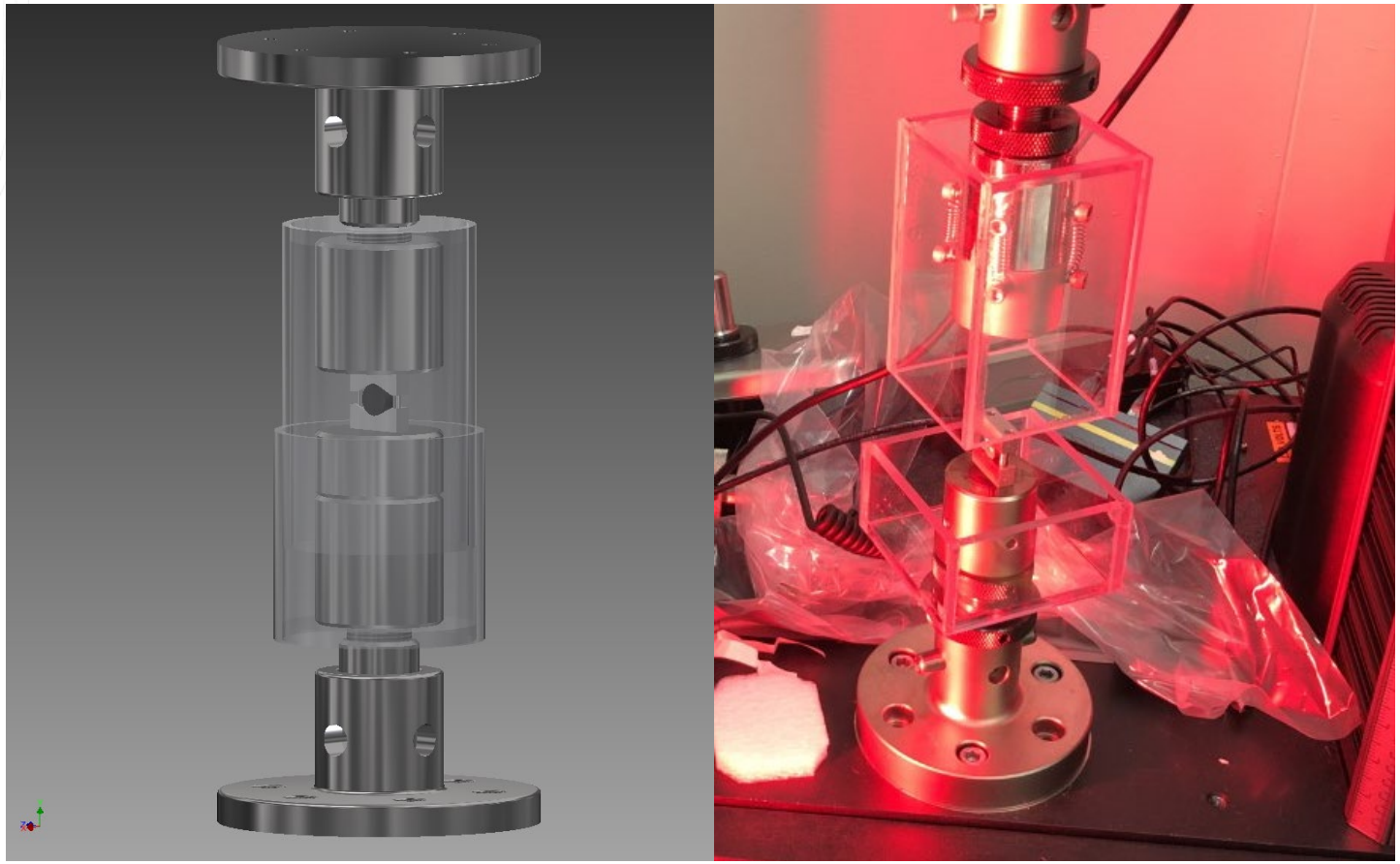




Irradiated Split Disc Testing



- Contamination control for testing of irradiated samples.
- The only method for comparing irradiated tensile strength.
- Future plans for oxidized testing.

Thank you