



Baseline Graphite Characterization

July 2021

Changing the World's Energy Future

Austin C Matthews



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**Idaho National Laboratory
Idaho Falls, Idaho 83415**

<http://www.inl.gov>

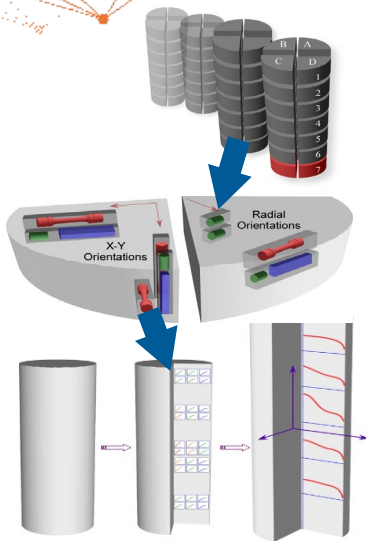
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Austin Matthews

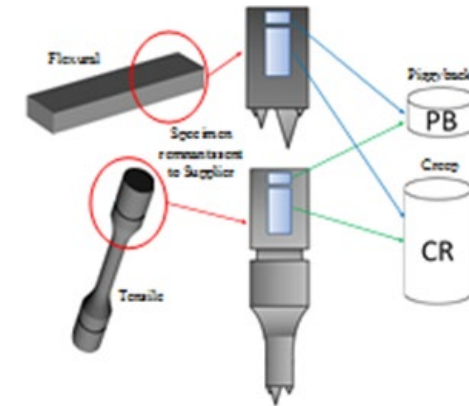
Baseline Graphite Characterization

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

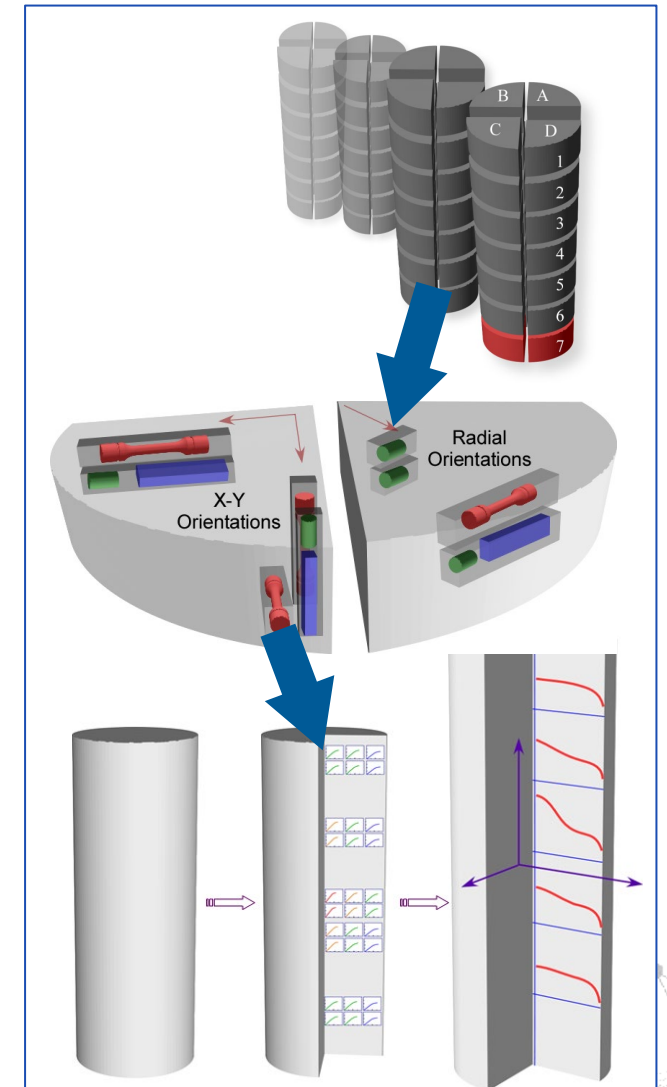
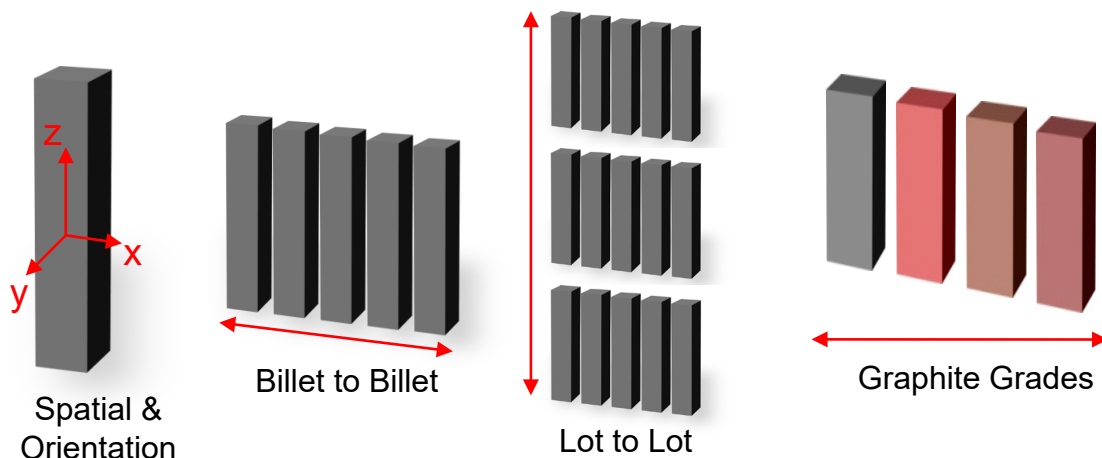
- Statistically valid
- Scalar value
- Distribution

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

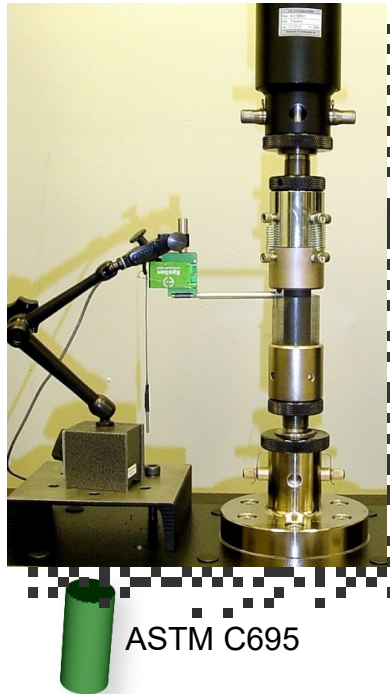


- **Current Grades**
 - NBG-18
 - PCEA
 - IG-110
 - 2114
 - NBG-17
- **Additional Grades**
 - IG-430

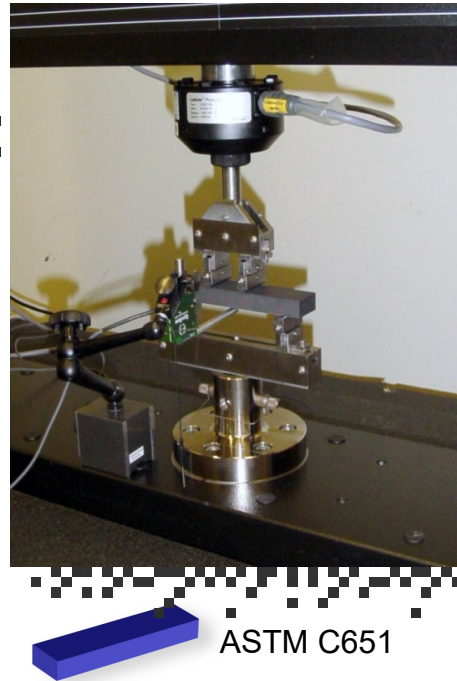


Baseline Property Measurements

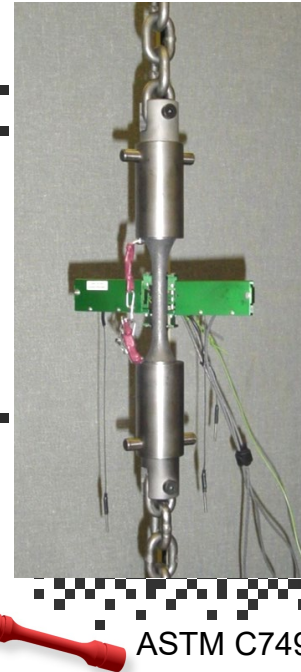
Compressive Strength



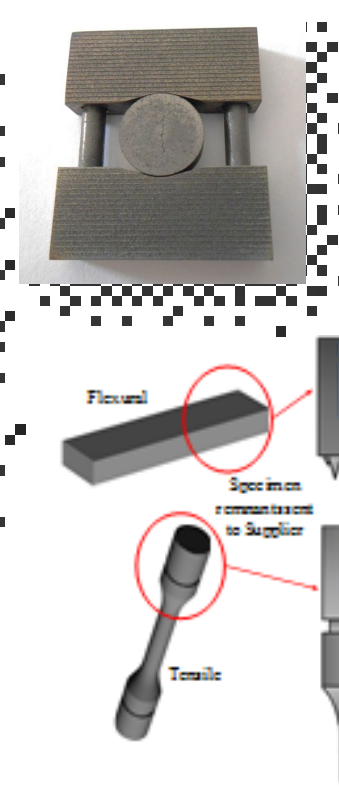
Flexural Strength



Tensile Strength



Brazilian Disc



Physical Properties Testing

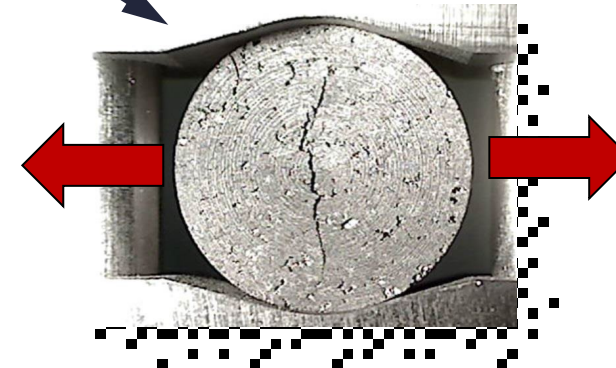
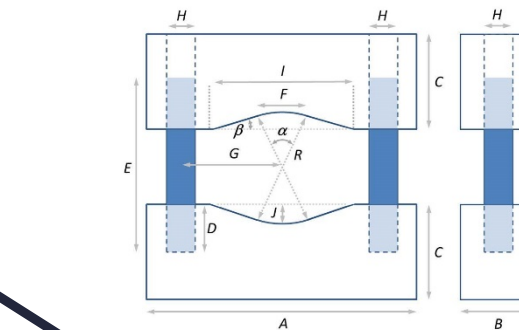
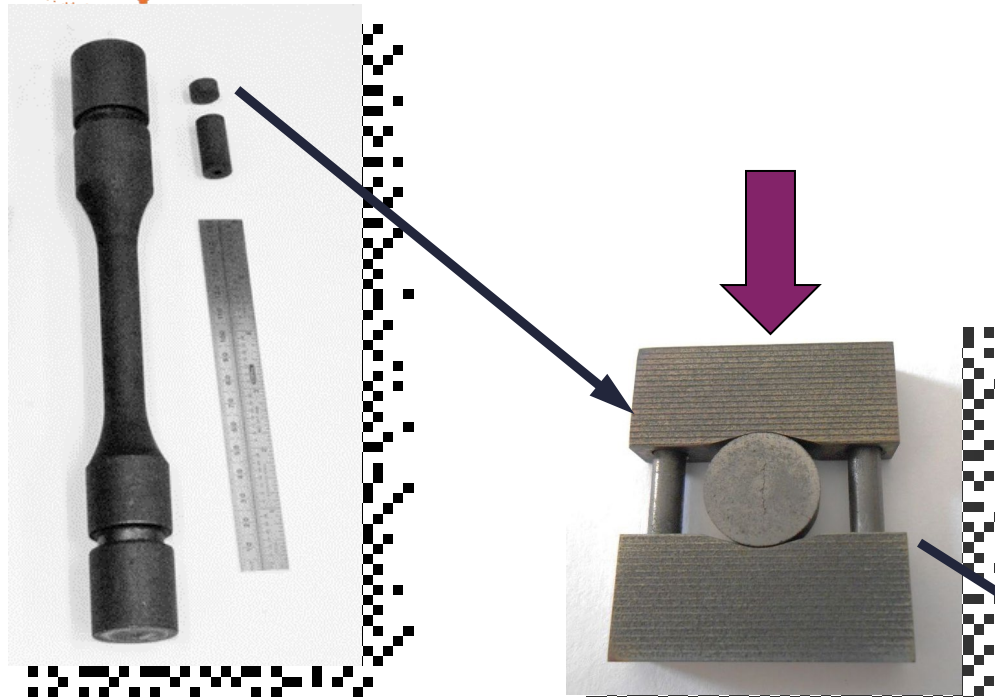
- Density
- Coefficient of Thermal Expansion
- Thermal Diffusivity
- Electrical Resistivity
- Elastic Modulus
 - Young's
 - Shear

Baseline Progress

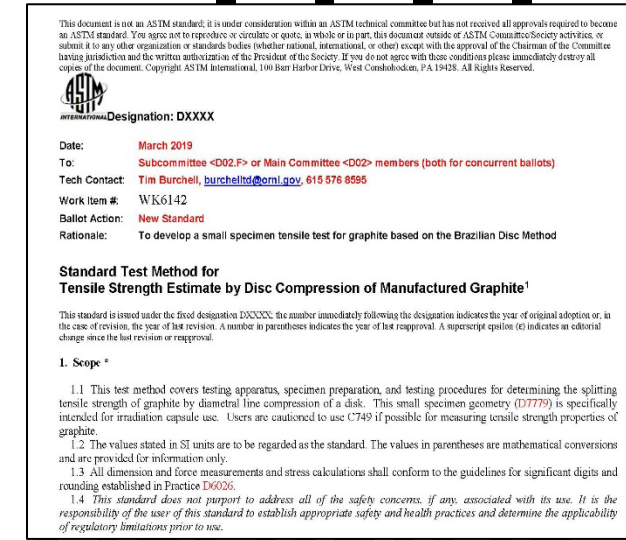
- Second and third billets of 2114 in progress.
- Second billet of NBG-17 currently being machined.
- A billet of IG-430 and a third billet of IG-110 to be initiated in FY-22.
- Over 18,000 NQA-1 qualified measurements taken so far.

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	ORNL
PCEA	INL	XPC02S8-7	100%	100%	100%	100%	100%	ECAR-3725	INL/EXT-13-30011
PCEA	INL	XPC01S8-9	100%	100%	100%	100%	100%		INL/EXT-14-33120, INL/EXT-13-30011
PCEA	INL	XPC02S8-5	100%	100%	100%	100%	100%		INL/EXT-14-33120, INL/EXT-13-30011
PCEA	INL	XPC01D3-35	Sectioned	0	0	0	0		
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	INL/EXT-13-30011, ORNL/TM-2010/219
NBG-18		Multiple Other Billets Available							
2114	INL	A20568	100%	100%	100%	50%	100%		
2114	INL	A20570	100%	100%	100%	100%	100%	ECAR-4322	INL/EXT-14-33120
2114	ORNL								
2114		Multiple Other Billets Available							
NBG-17	INL	830-3	100%	100%	100%	100%	100%	ECAR-3727	INL/EXT-14-33120
NBG-17	INL	005-04							
IG-110	INL	08-9-052 (Partial)	100%	100%	100%	100%	100%	ECAR-3621	INL/EXT-14-33120
IG-110	INL	10X69	100%	100%	100%	100%	100%	ECAR-4182	
IG-110	INL	10X63							
IG-430		08-Y-38							

Split Disc Tensile Strength: ASTM Tensile Strength Alternative

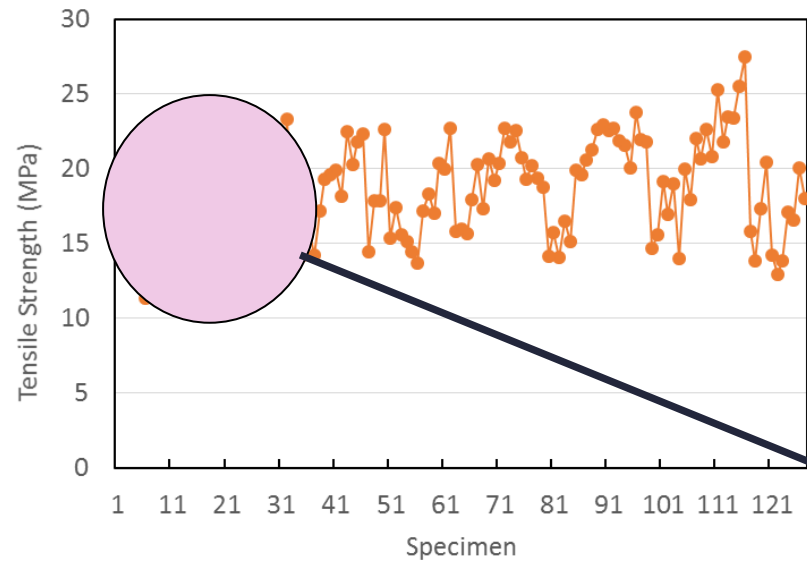


By compressively loading a disc-shaped specimen on edge the resulting tensile stresses, transverse to the loading axis, result in the specimen failing in tension transverse to the load. The load at failure, P , and geometry of the specimen provide an indication of the tensile strength.

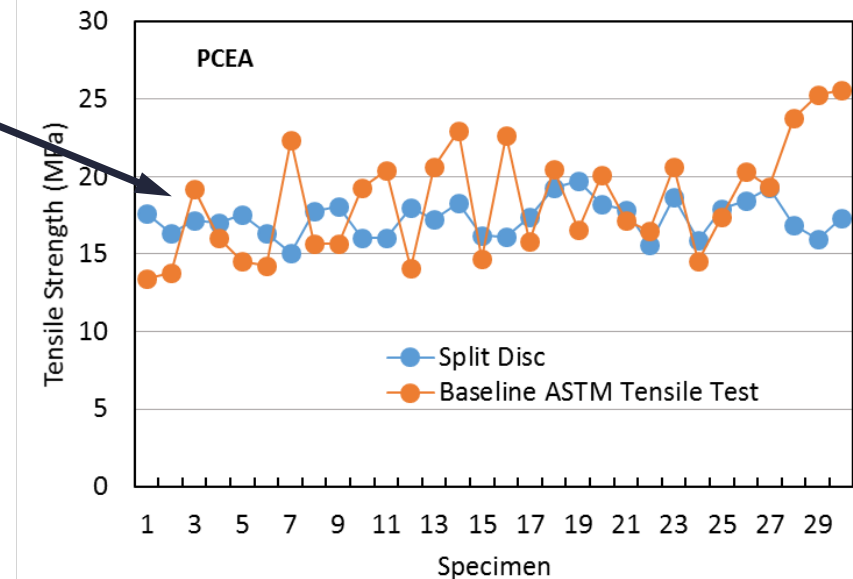
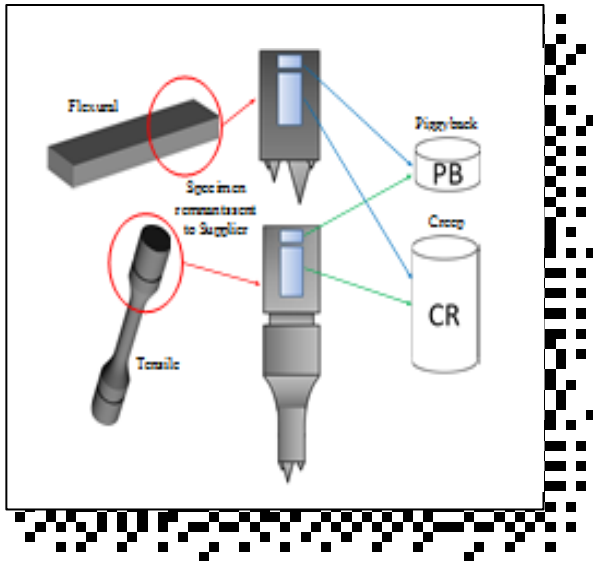


$$\sigma_{sts} \approx \frac{P}{\pi LR} \left[1 - \left(\frac{b}{R} \right)^2 \right]$$

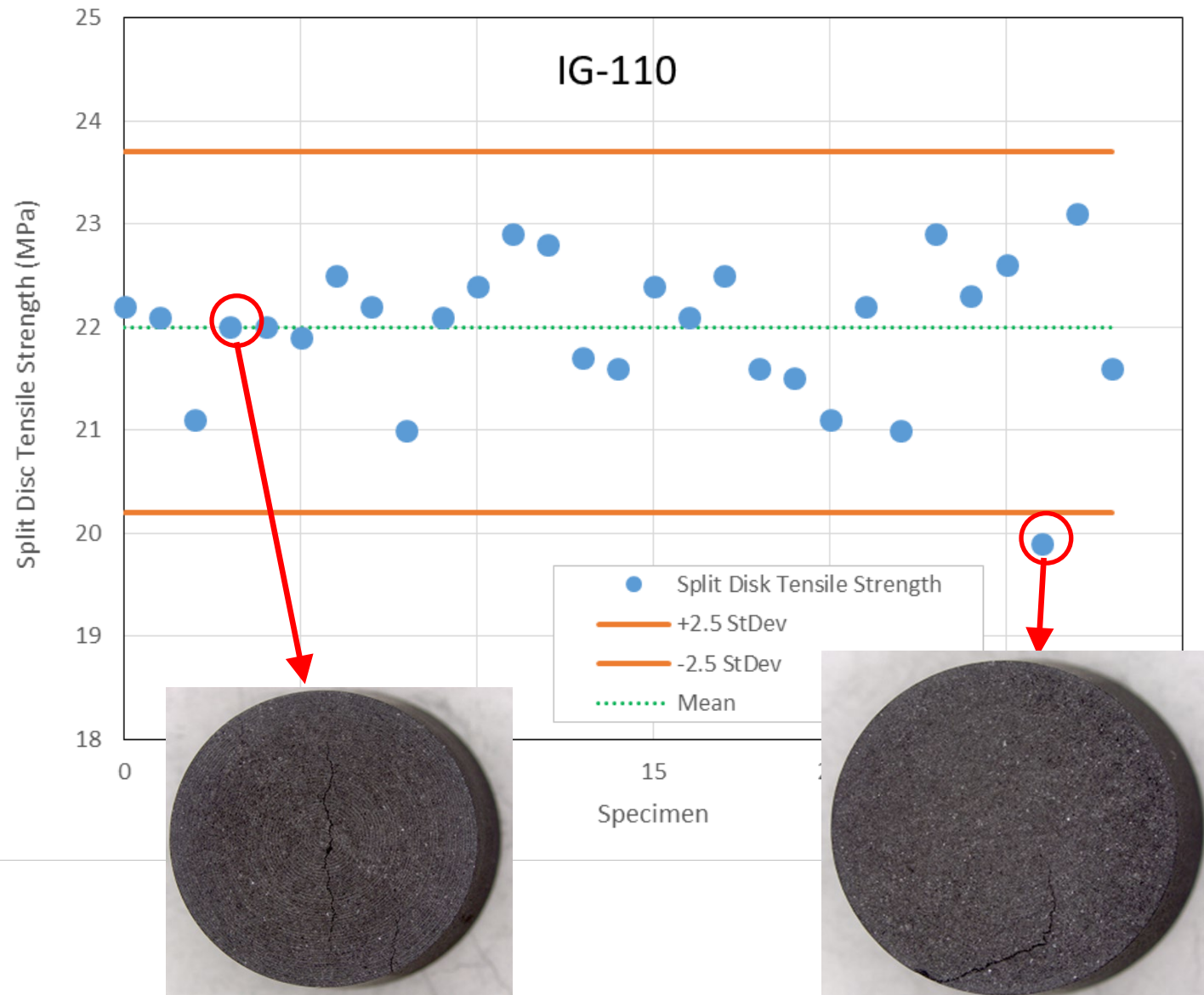
One to One Comparison of Breaking Strength Re-machined Baseline Specimens



- 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.



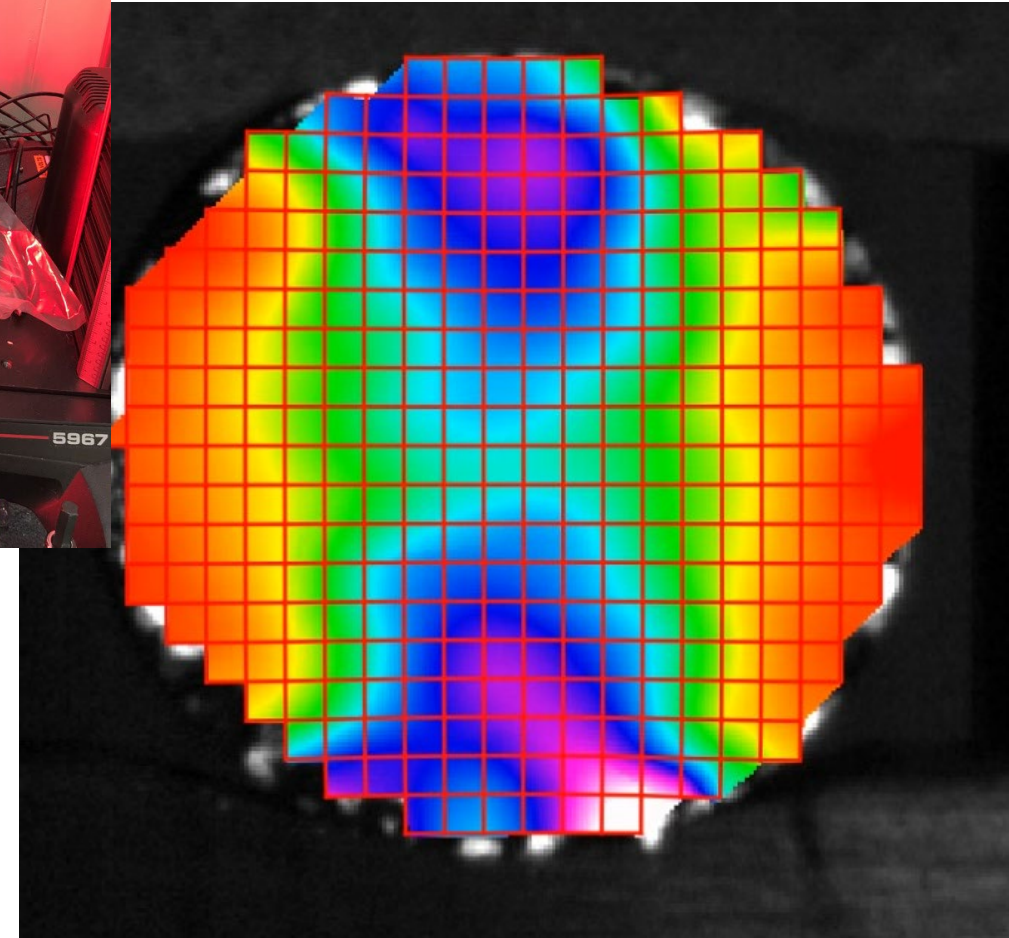
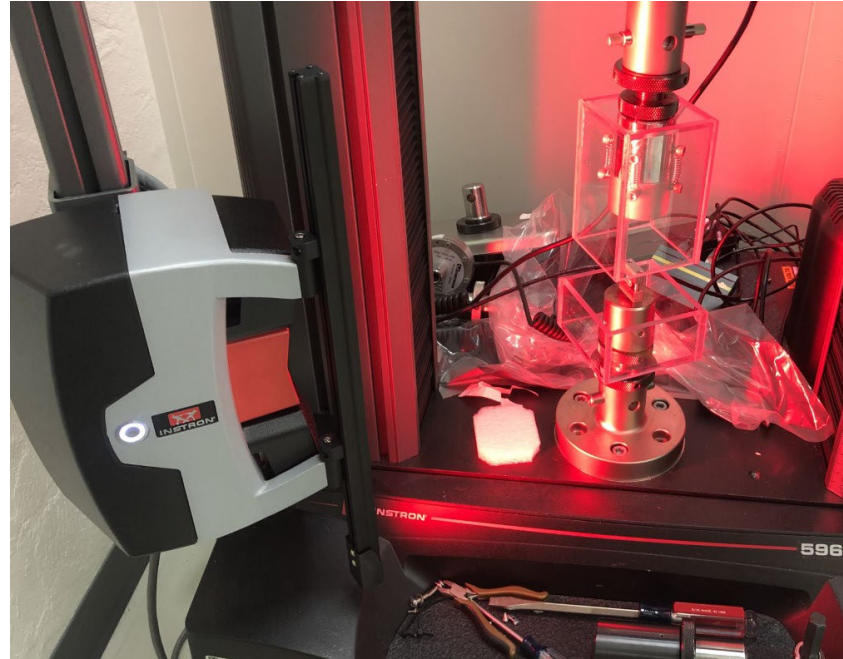
Identification of Proper Split Disk Fracture



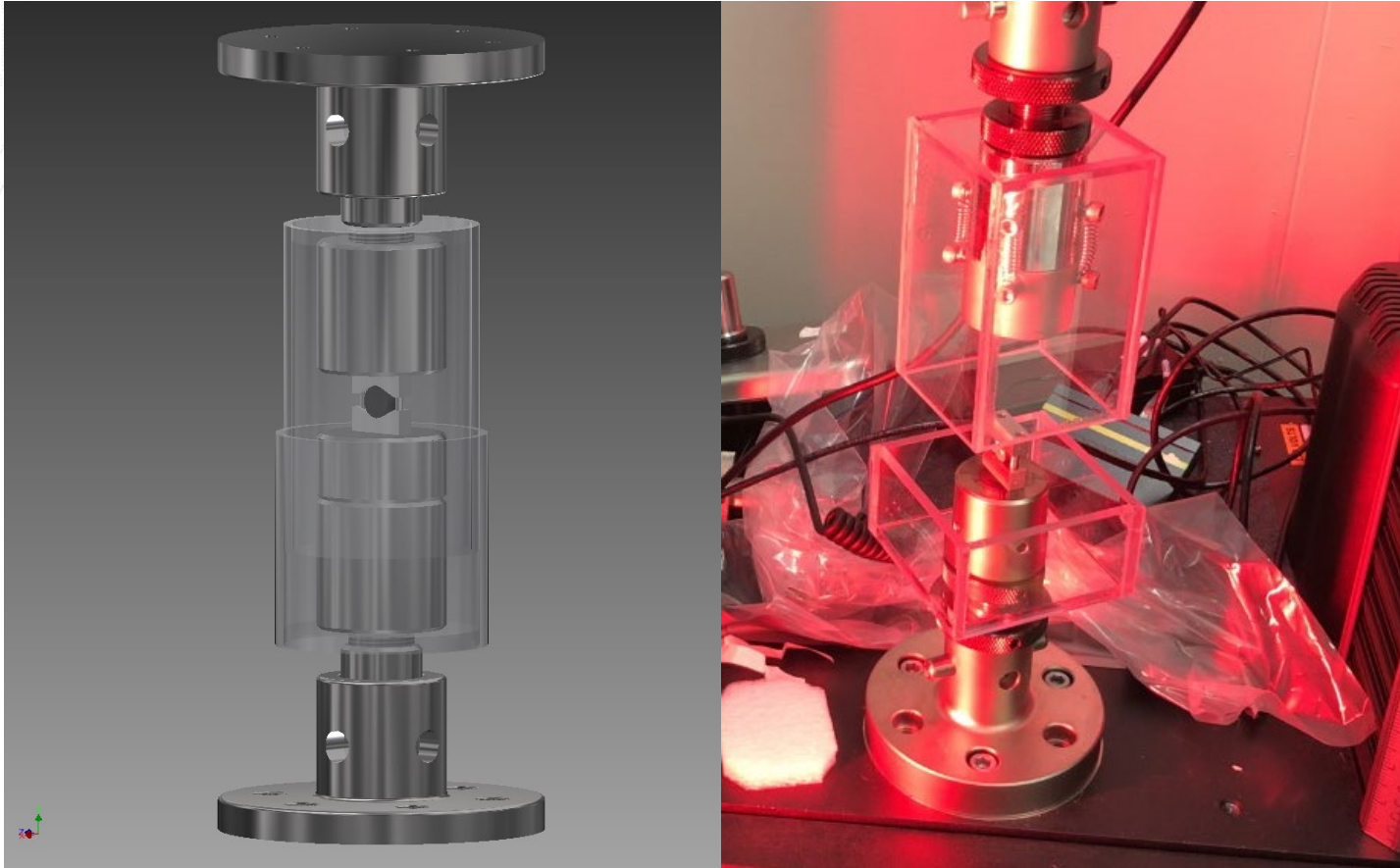
- This measurement technique originated in rock and concrete where the ratio of compressive to tensile strength is ~10. (Graphite ~3-4)
- Calculation of tensile stress in a compressed disc requires the fracture to initiate from the center of the disc.
- This occurs when the compressive strength is much 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 disk fracture.
- Measurement of actual stress/ strain curve.



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



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