INL/MIS-24-79200-Revision-0

Graphite Oxidation Activities

July 2024

Rebecca E Smith, Austin C Matthews, David T Rohrbaugh, Arvin Burnell Cunningham, Mary Kaye Ames, Michael Charles Barkdull, David L Cottle

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Idaho National Laboratory

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GAS-COOLED REACTOR
ADVANCED REACTOR TECHNOLOGIES PROGRAM

Wednesday, July 17, 2024

Graphite Oxidation Activities

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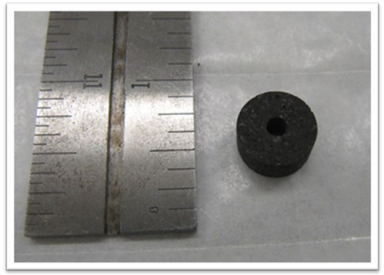
DOE ART GCR Review Meeting

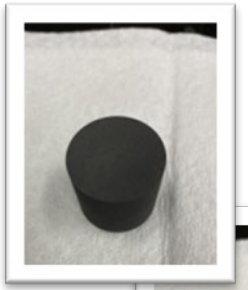
Hybrid Meeting at INL

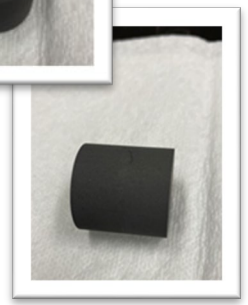
July 16–18, 2024

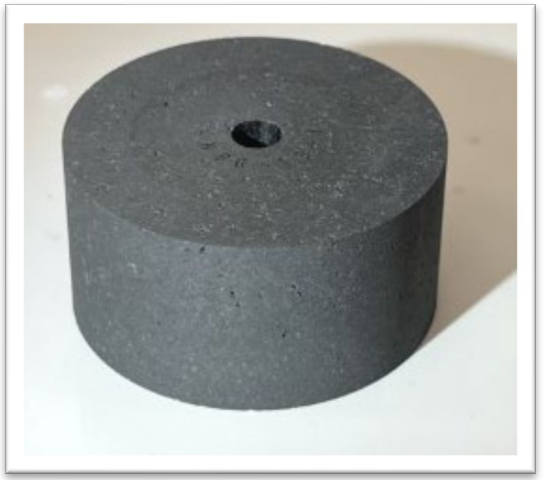
Graphite Oxidation

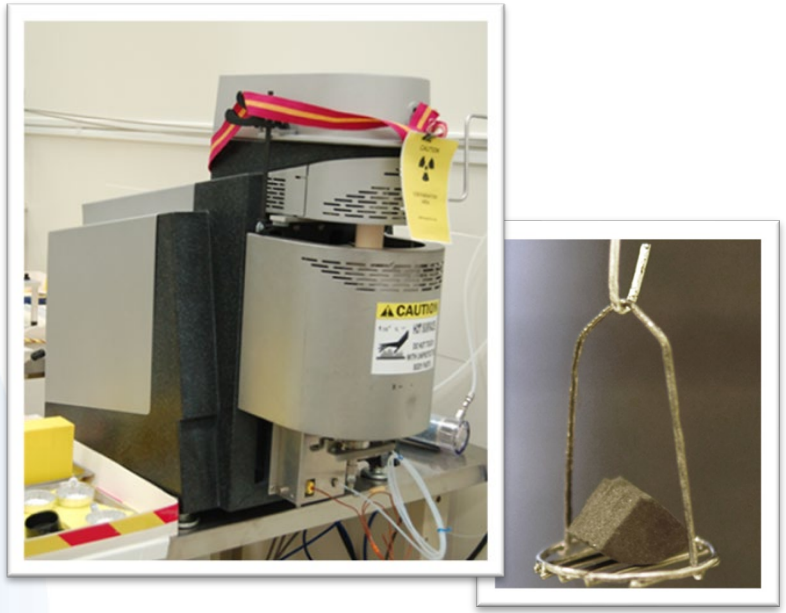
- Introduction
- Rate Determination
- Strength After Oxidation
- Penetration Depth Analysis
- Strategic Partnership Projects
- Summary and Continuing Work

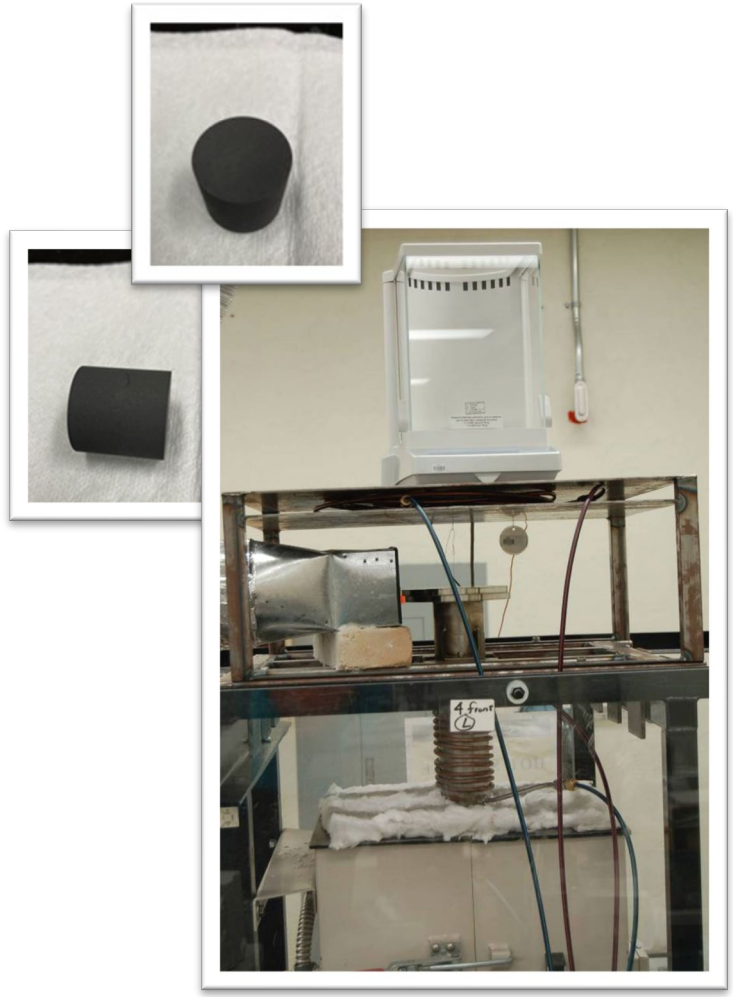












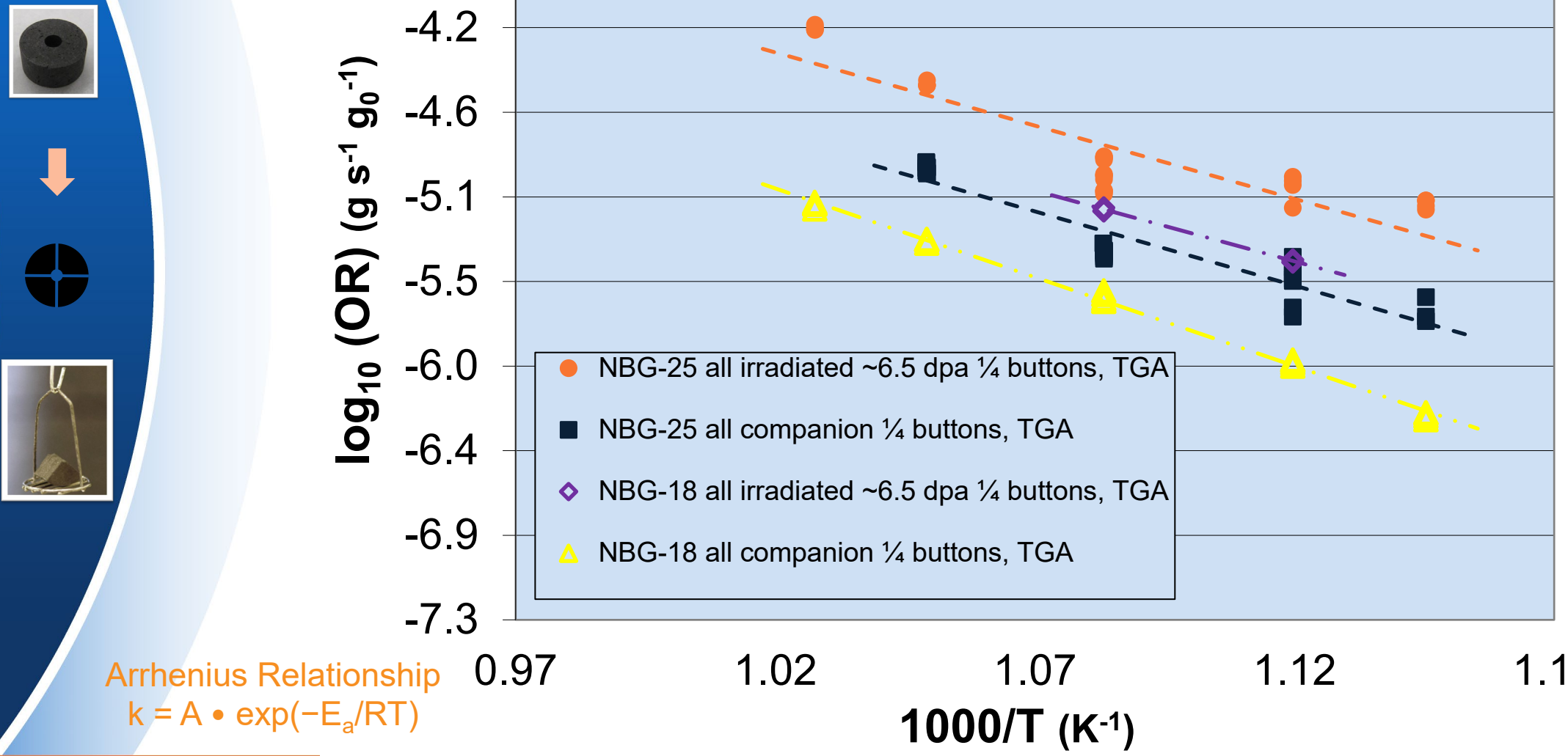
Rate Determination

- ASTM D7542 (Vertical Furnace)
- Developed OR and Arrhenius Plot Analysis Tools
- Irradiated and Unirradiated Split Samples (TGA)

BAN, IG-110, ETU-10, NBG-17, NBG-18, NBG-25, PCEA, [ET-10 (in progress)]

Oxidation Rates after Irradiation

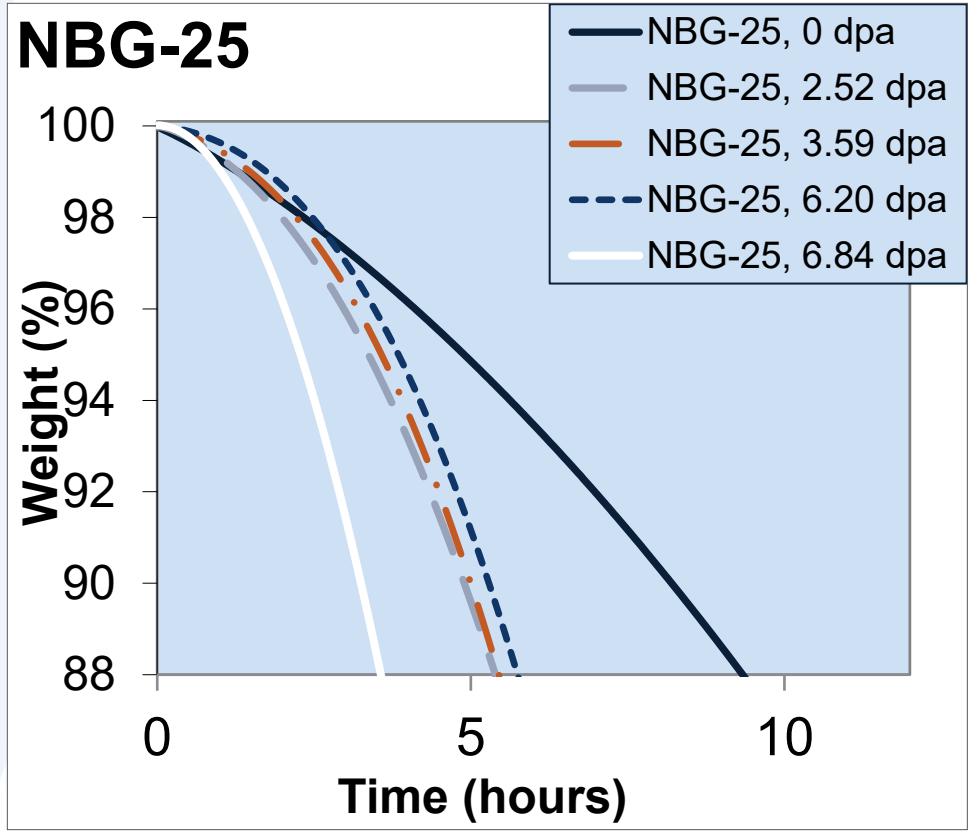
Mass Normalized Split Sample TGA Data

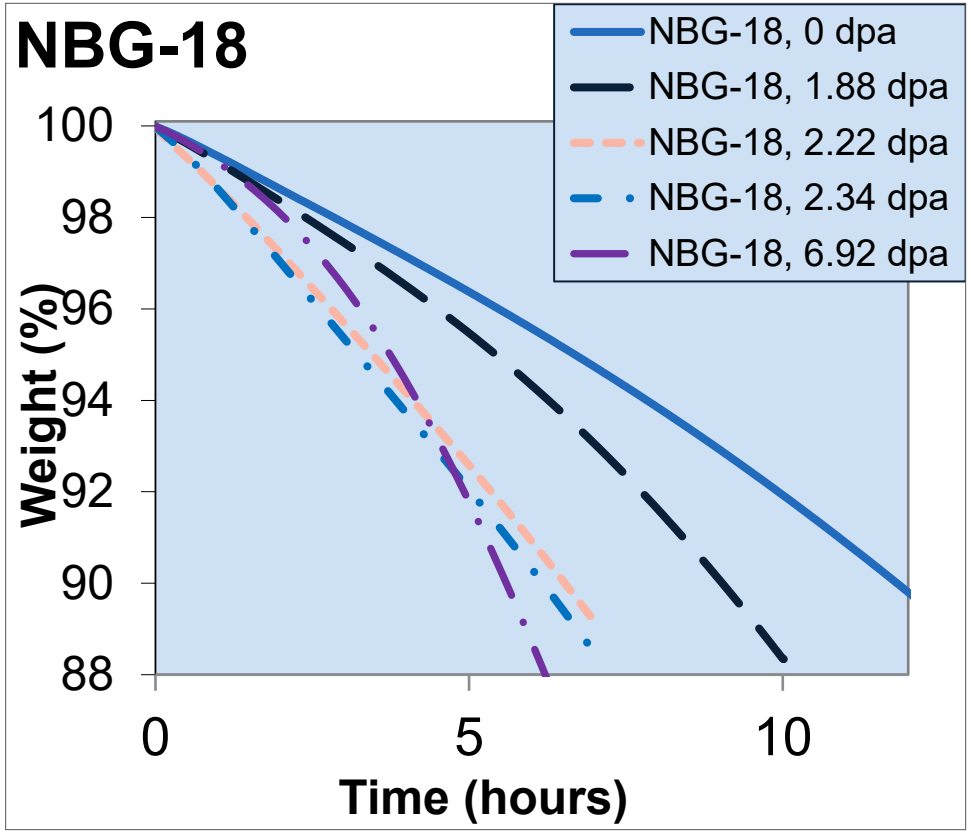


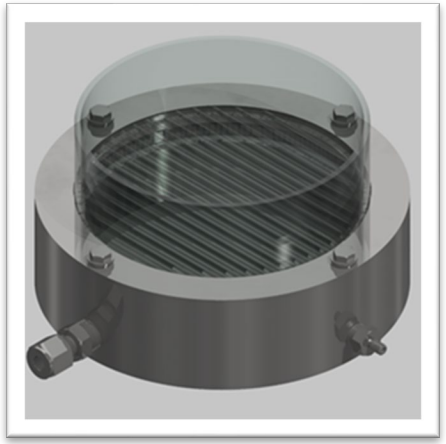
Arrhenius Relationship
$k = A \bullet \exp(-E_a/RT)$

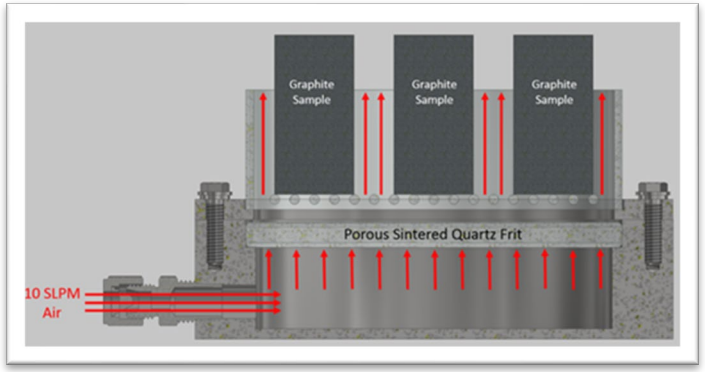
Oxidation Rates after Irradiation

Representative Runs of Split Samples at 650°C



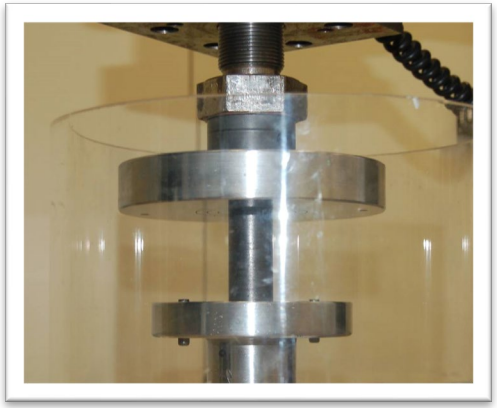






Strength After Oxidation

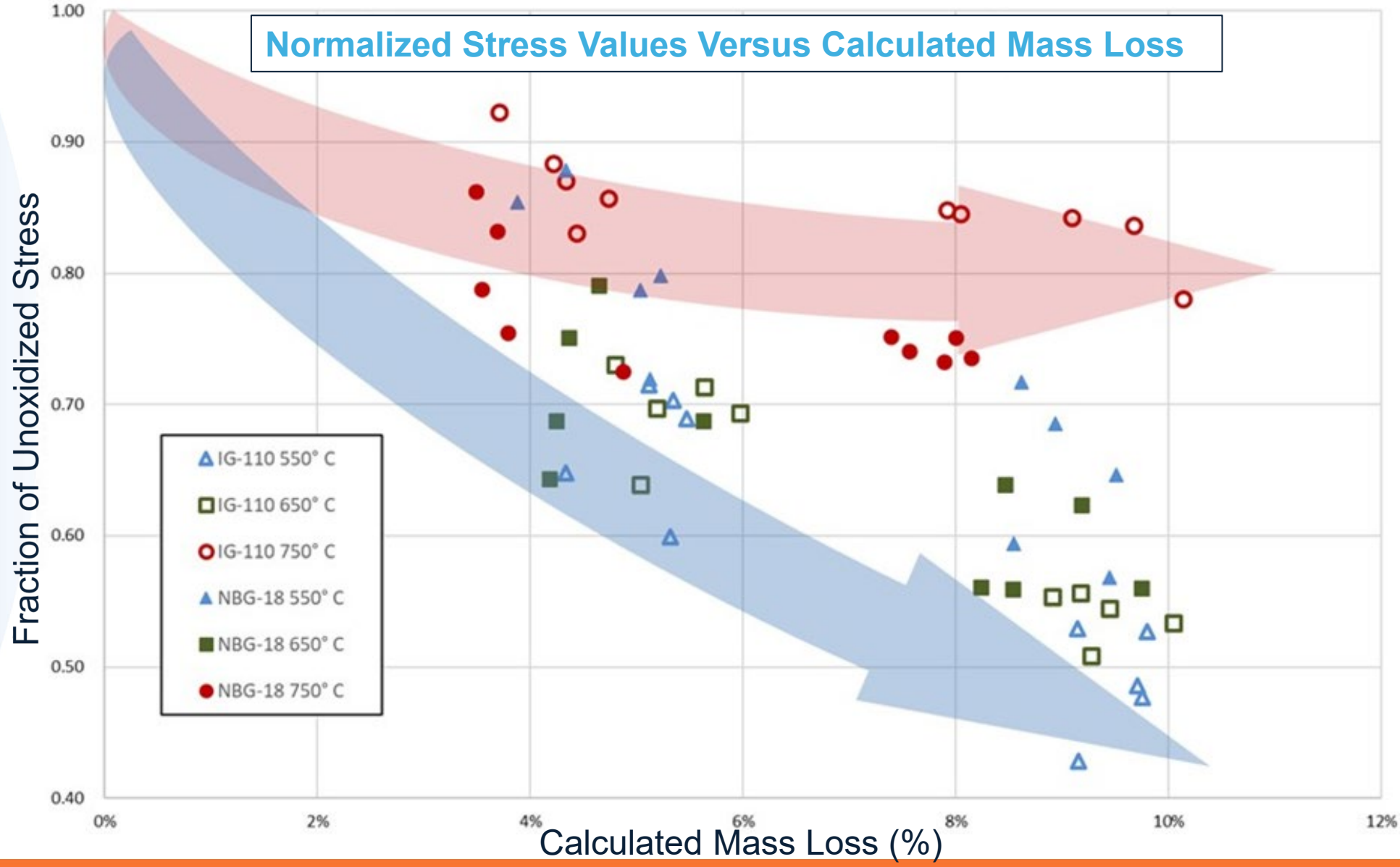
- Guidance
- Preferred Conditions
  - Sample Dimensions 1” diameter 2.25” tall (*before* oxidation)
  - Oxidation at 550°C in flowing air
- Trim after Oxidation
  - Sample Dimensions (1:2 aspect ratio *before* crush test)
  - ASTM C695

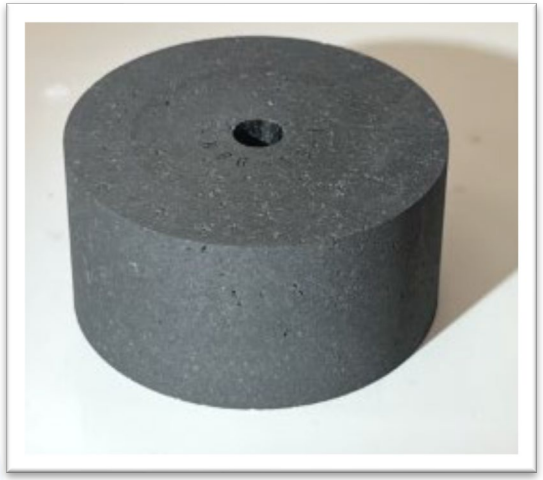


2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, PCEA

Strength After Oxidation

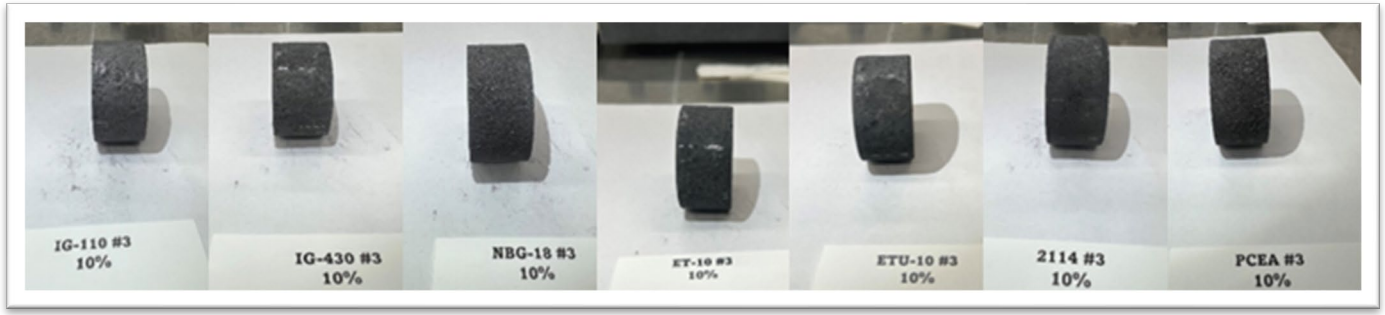
Recent testing includes 2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, and PCEA for three levels of mass loss at 550°C





Penetration Depth Analysis

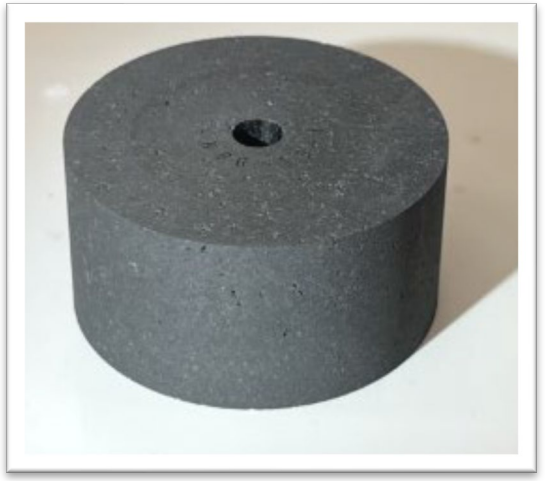
- Lathing Study (Density Determination)
  - Geometric
  - Archimedes
- Digital Image Evaluation
  - Optical
  - XCT



2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, PCEA

Lathing Study Density Analysis

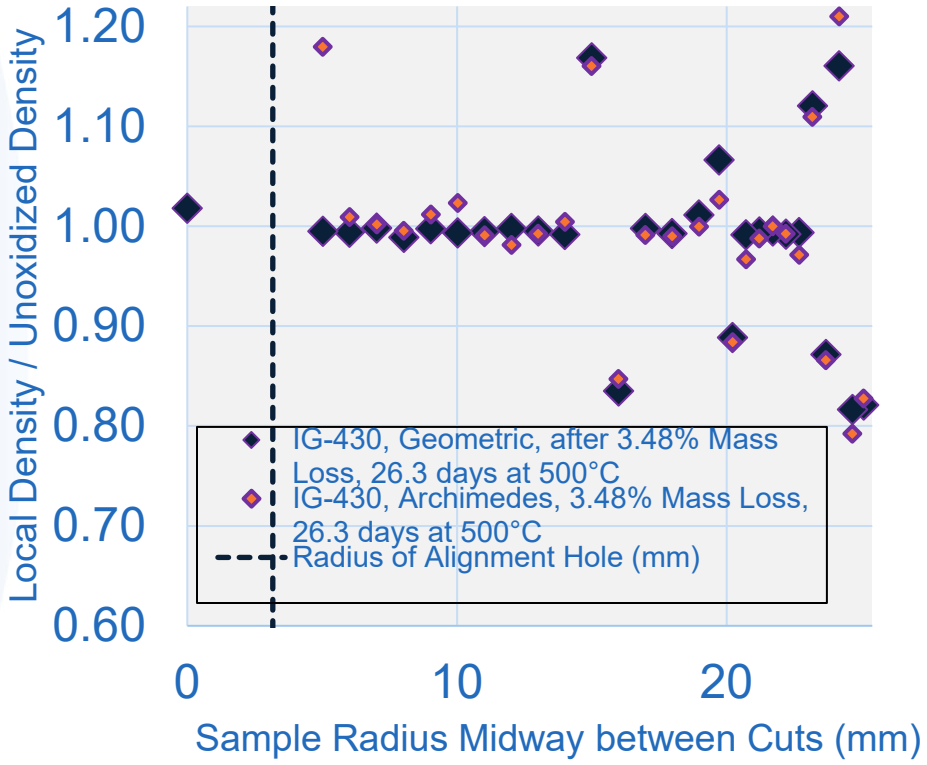
- Large Amount of Data (21 samples)
  - 7 graphite grades **2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, PCEA**
  - 3 mass loss values each (2%, 6%, 10% at 500°C)
- At least 26 cuts per sample
  - 50 mm initial diameter (before oxidation)
  - machined in 1 mm and 2 mm steps
- Density Determinations
  - Geometric and Archimedes
  - Similar values
  - Large unexpected variations
    - scatter in inner local density
    - density values exceeding that of the virgin material



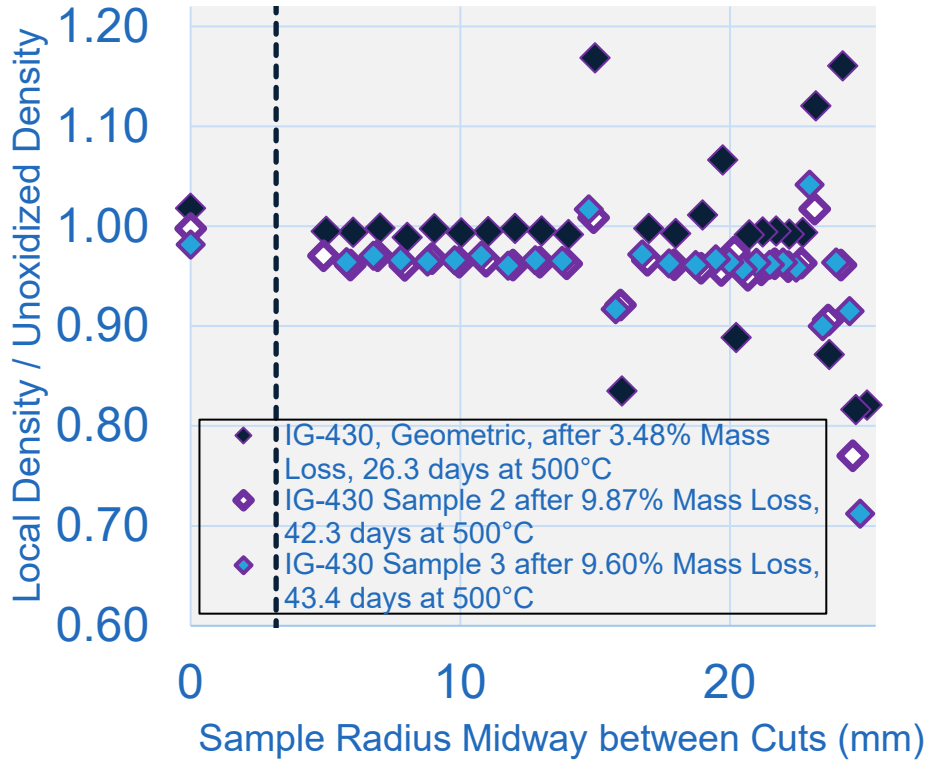
Density Profile

Trend matches expectations but with unanticipated variability

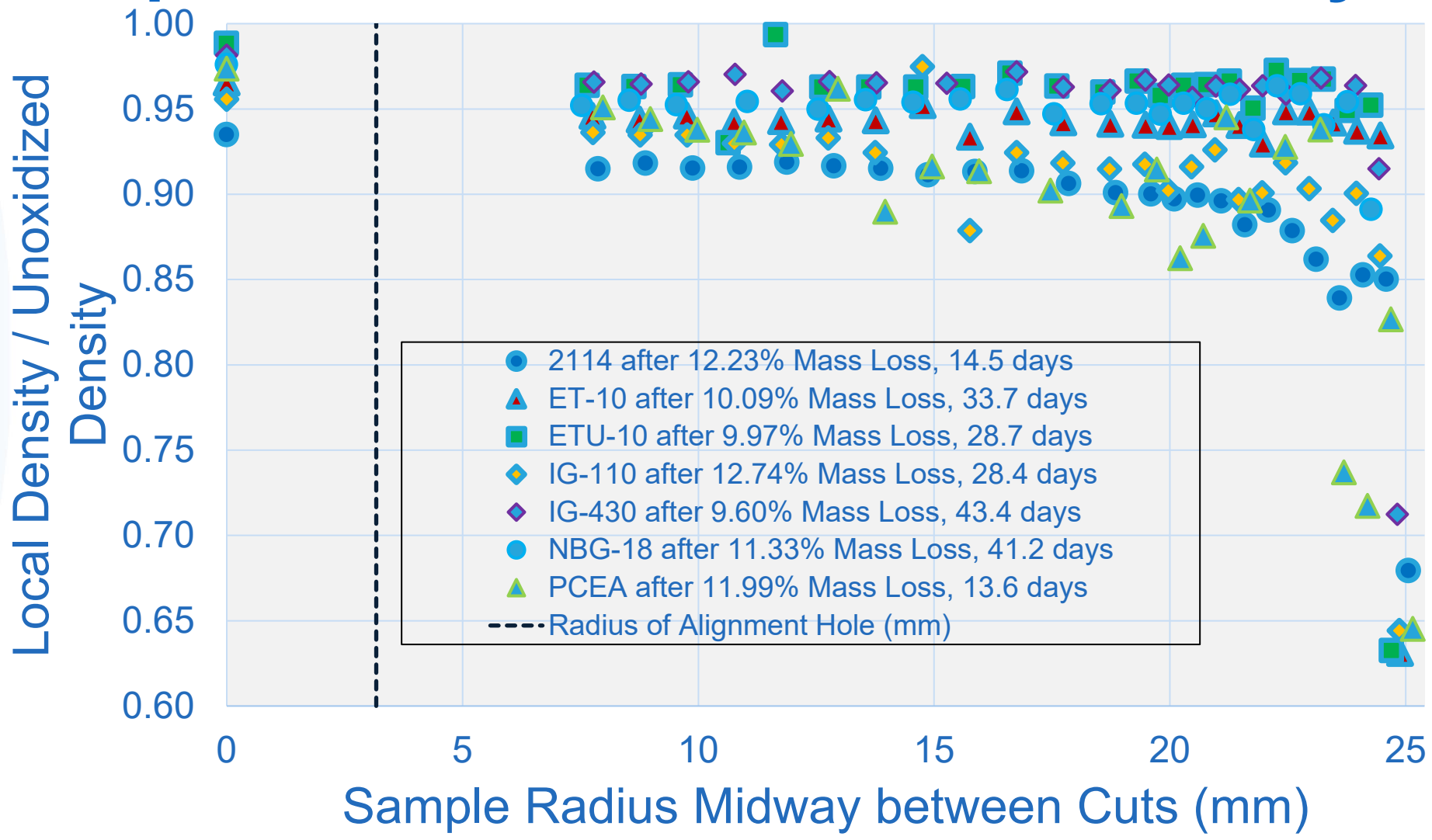
Geometric and Archimedes Compared



Same-Grade Samples (Geometric)



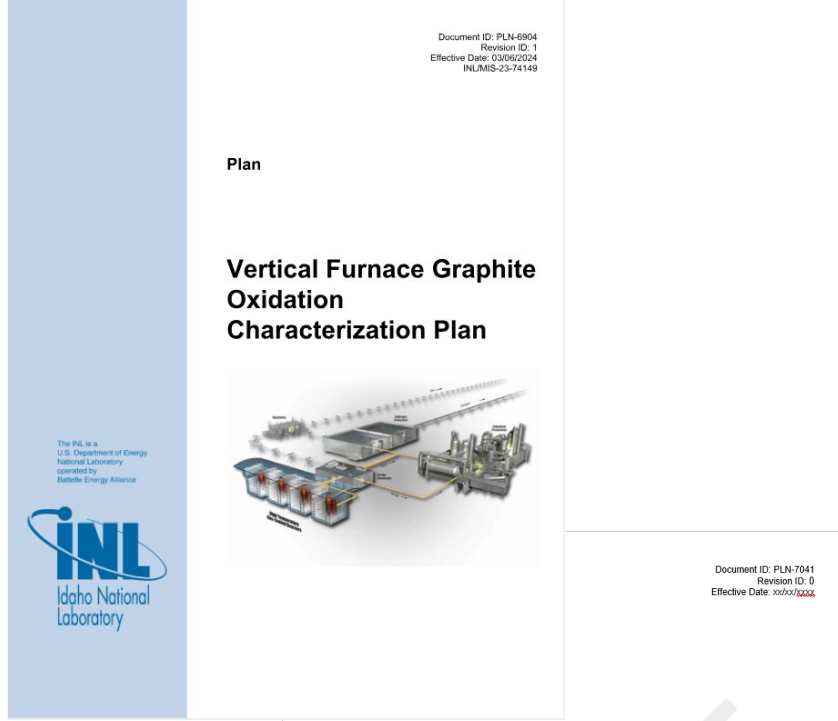
Local Geometric Density Profile: Comparison of Grades, Selective Analysis



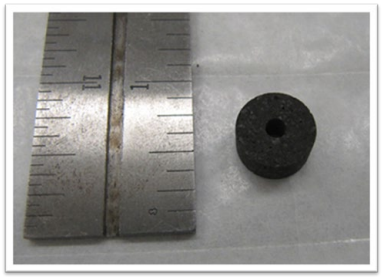
Strategic Partnership Projects

- Quality Assurance Documentation and Surveillance
- Receipt and Traceability of Materials
- Plans and Procedures

ET-10 and ETU-10



Graphite Oxidation – Summary and Continuing Work



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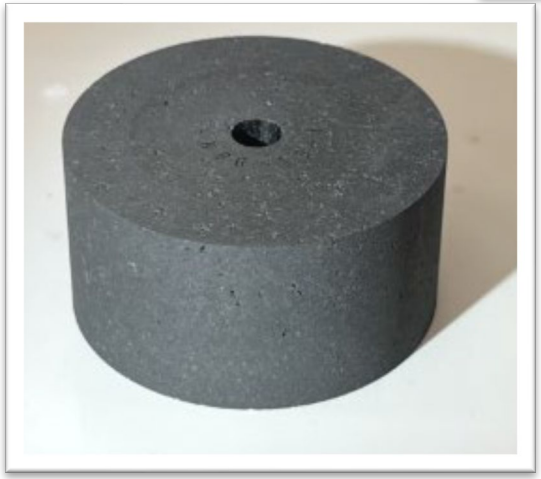
  - Irradiated and Unirradiated Split Samples (TGA)

- Strength After Oxidation
  - Preferred Oxidation Conditions, Sample Dimensions
  - Trim after Oxidation in Keeping with ASTM C695

- Penetration Depth Analysis
  - Guidance
  - Lathing Study (Geometric and Archimedes Density Determinations)
  - Optical and XCT (Digital Evaluation of Penetration Depth)



- Strategic Partnership Projects
  - Procedures
  - Quality Assurance

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Thank You

Questions?

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