



Graphite Oxidation Activities

July 2024

Changing the World's Energy Future

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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July 2024

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<http://www.inl.gov>

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GAS-COOLED REACTOR

ADVANCED REACTOR TECHNOLOGIES PROGRAM

Wednesday, July 17, 2024

Graphite Oxidation Activities

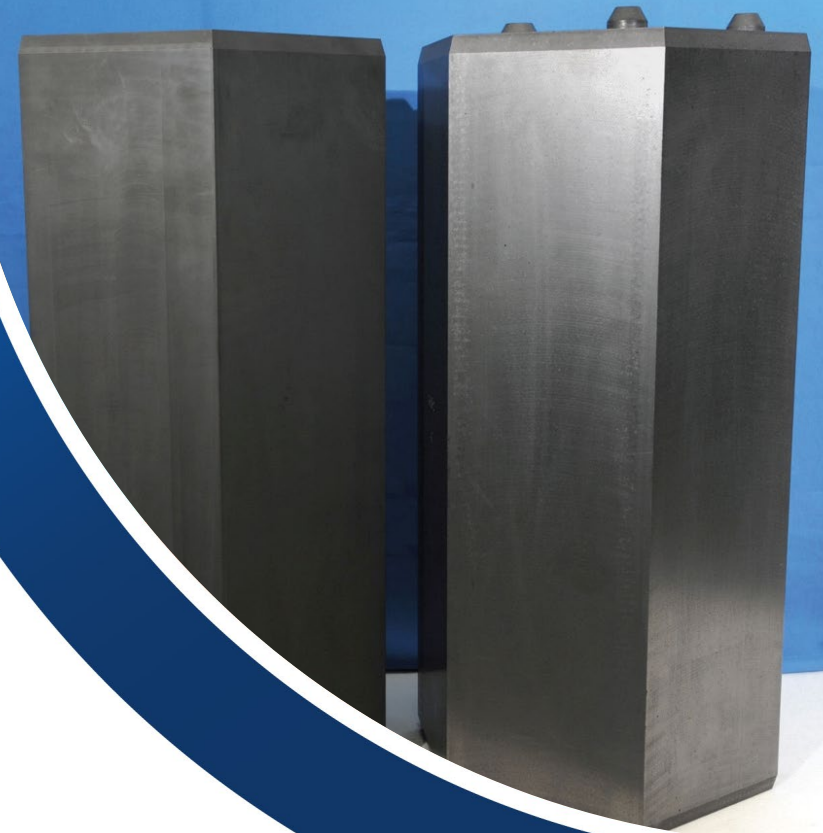
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Rebecca Smith

Staff Engineer

Idaho National Laboratory



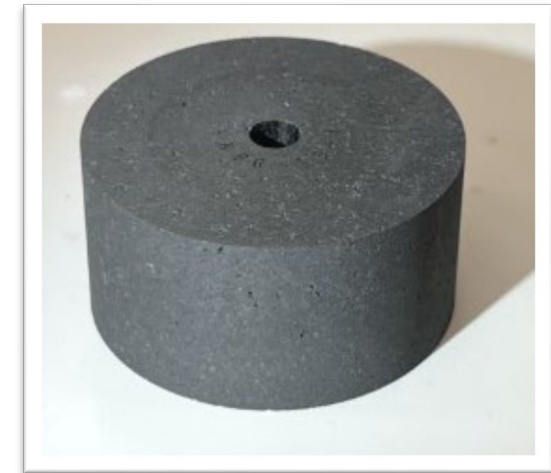
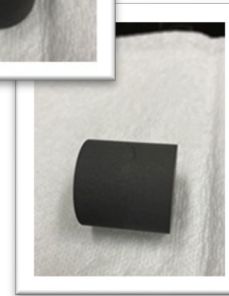
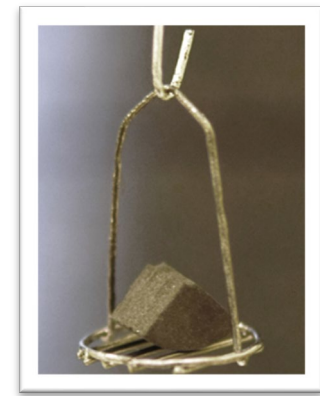
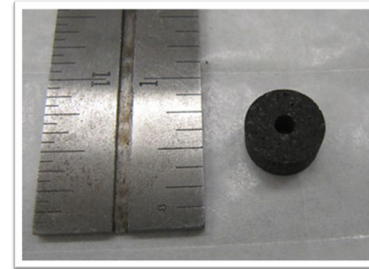
DOE ART GCR Review Meeting

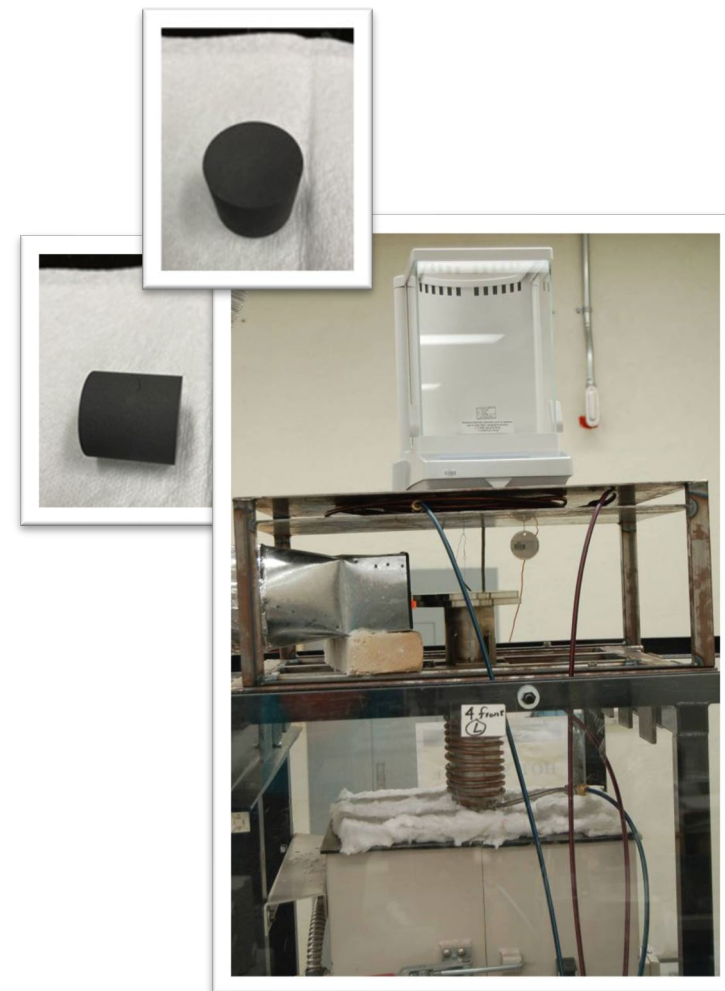
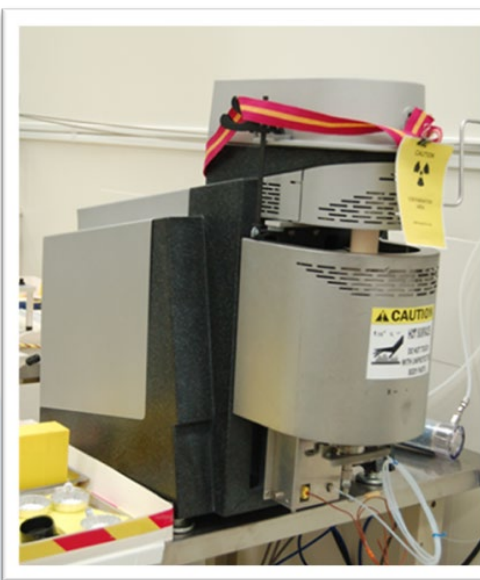
Hybrid Meeting at INL

July 16–18, 2024

Graphite Oxidation

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





Rate Determination

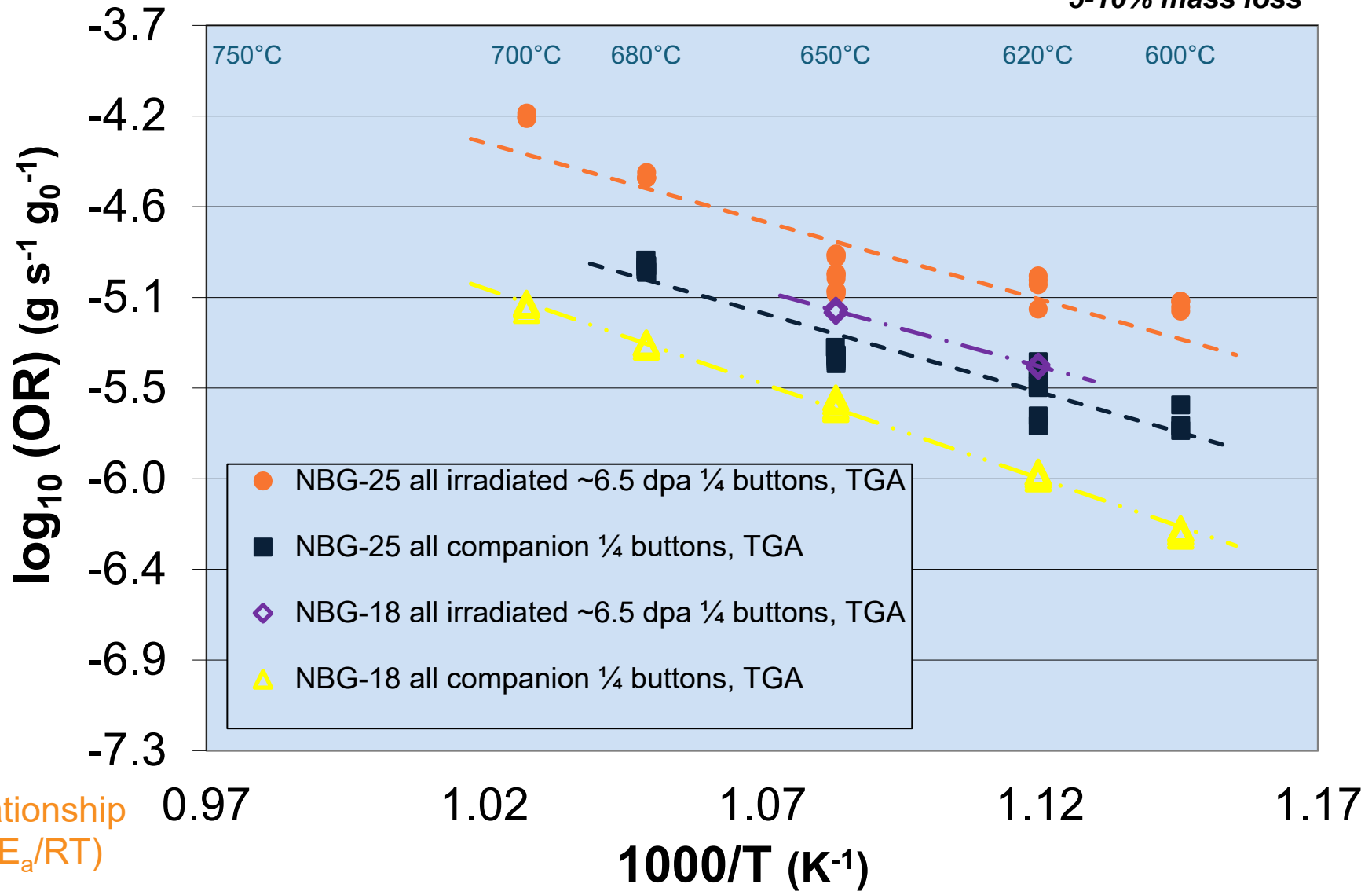
- ASTM D7542 (Vertical Furnace)
- Developed OR and Arrhenius Plot Analysis Tools
- Irradiated and Unirradiated Split Samples (TGA)

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

5-10% mass loss

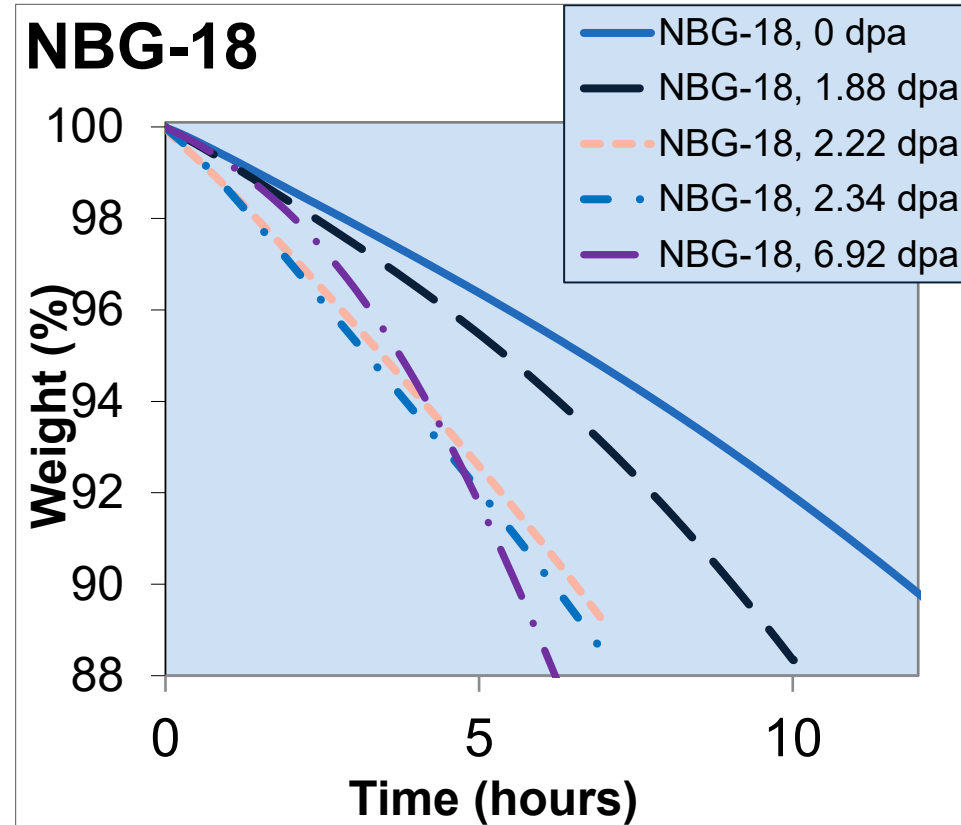
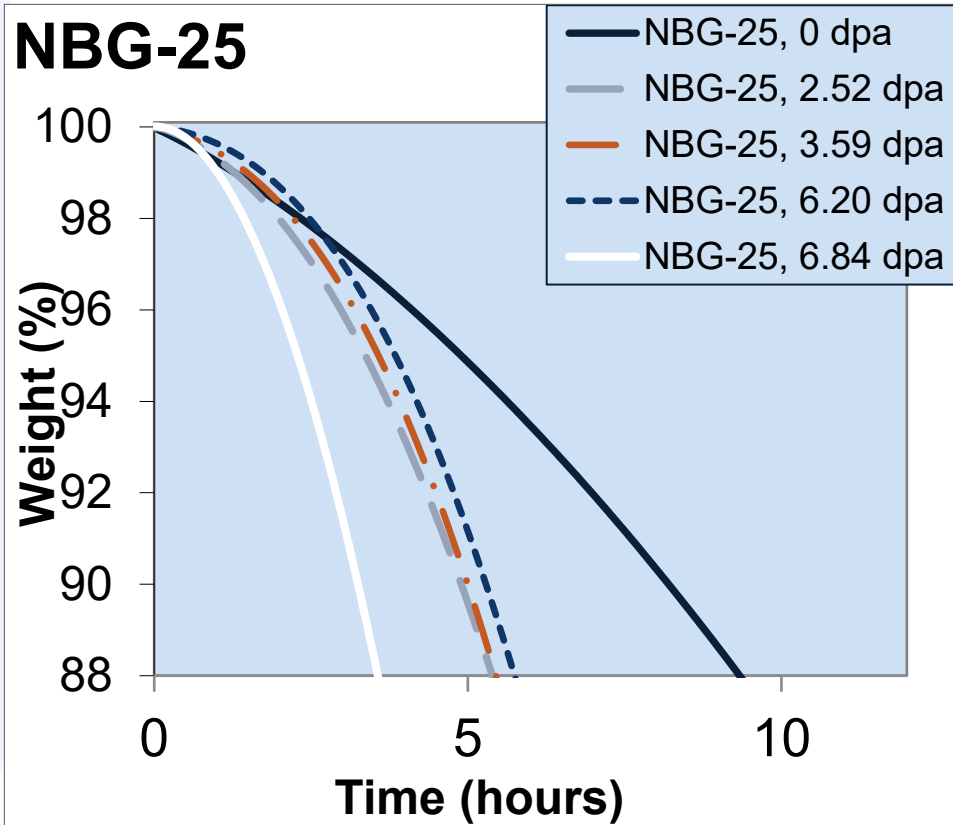


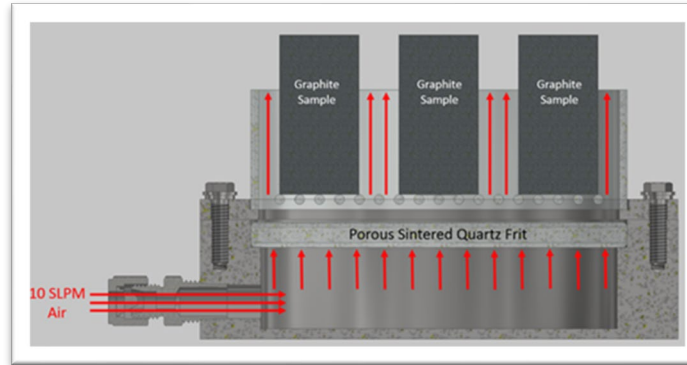
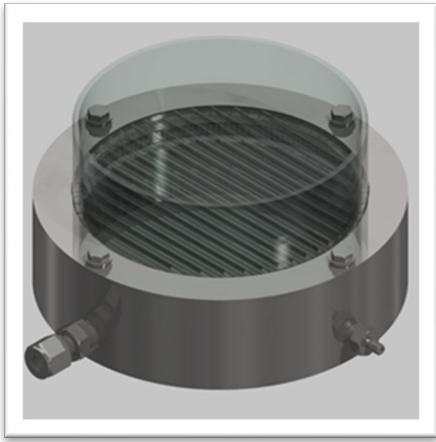
Arrhenius Relationship
 $k = A \cdot \exp(-E_a/RT)$



Oxidation Rates after Irradiation

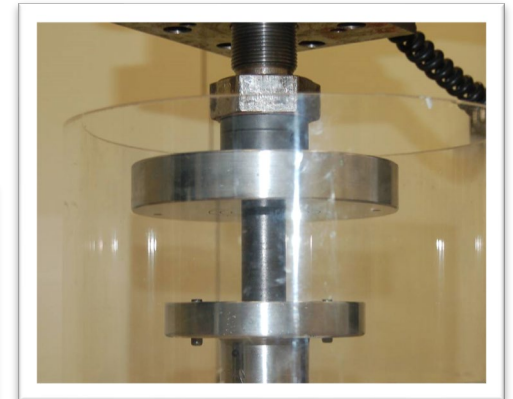
Representative Runs of Split Samples at 650°C





Strength After Oxidation

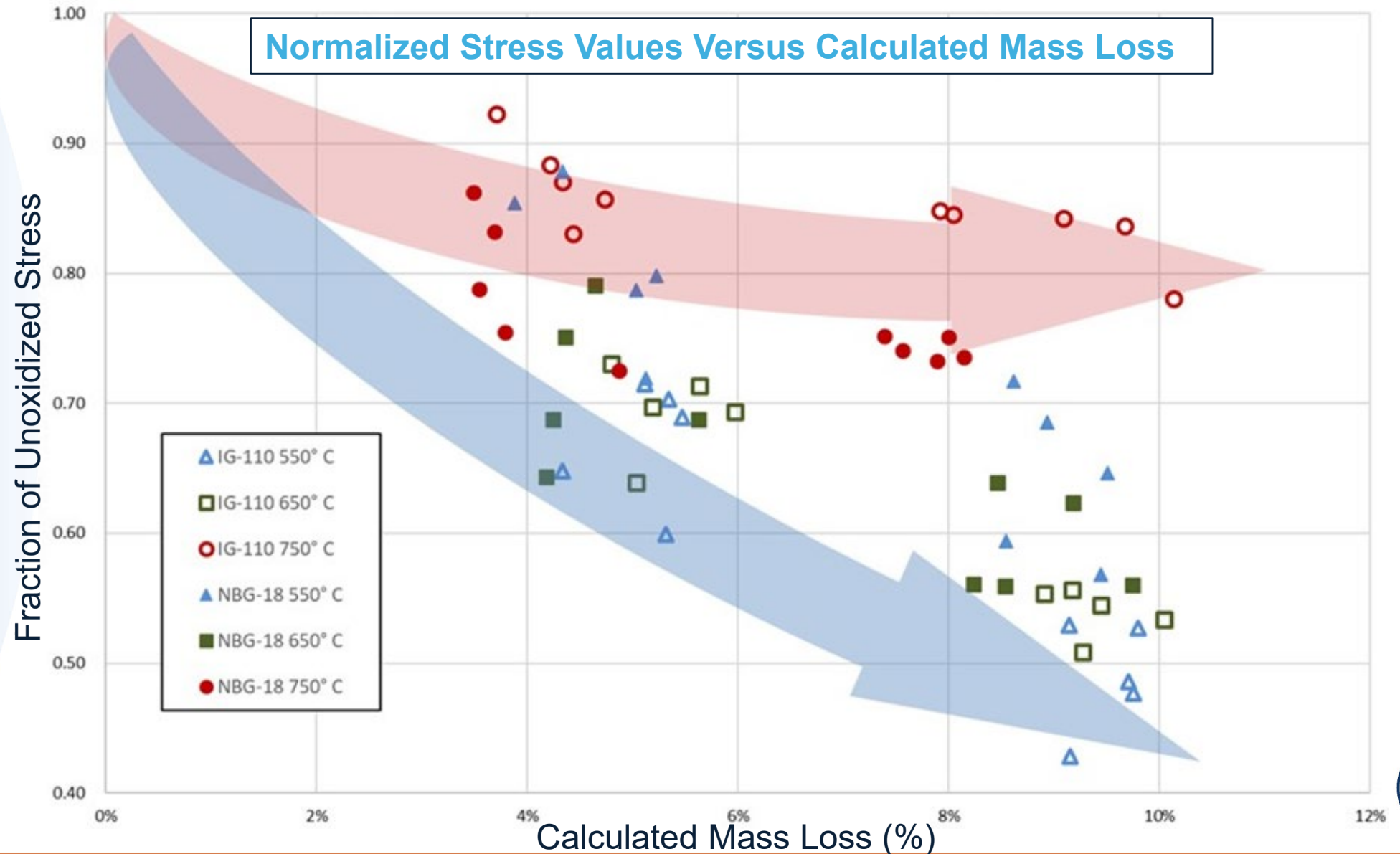
- Guidance
- Preferred Conditions
 - Sample Dimensions 1" diameter 2.25" tall (*before* oxidation)
 - Oxidation at 550°C in flowing air
- Trim after Oxidation
 - Sample Dimensions (1:2 aspect ratio *before* crush test)
 - ASTM C695

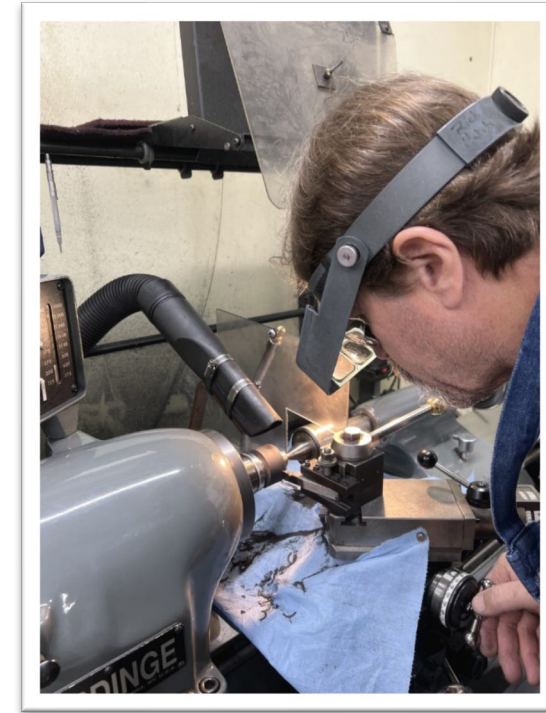
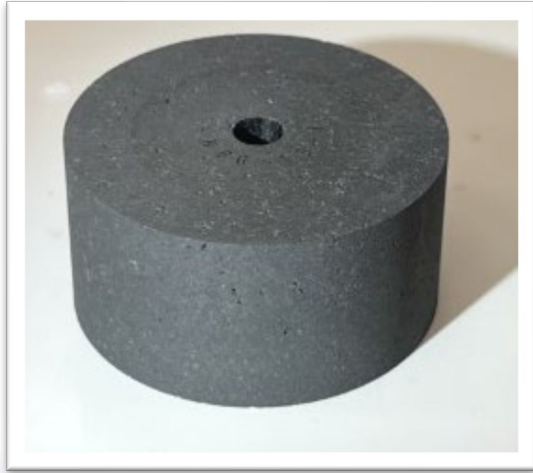


2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, PCEA

Strength After Oxidation

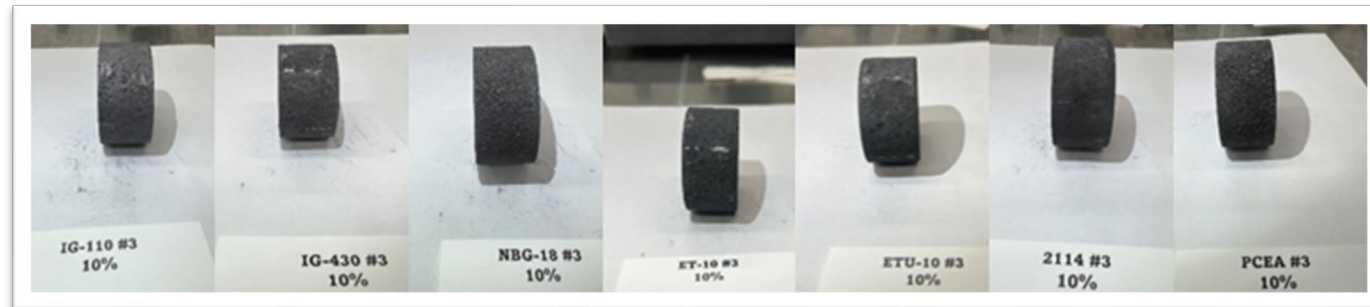
Recent testing includes 2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, and PCEA for three levels of mass loss at 550°C





Penetration Depth Analysis

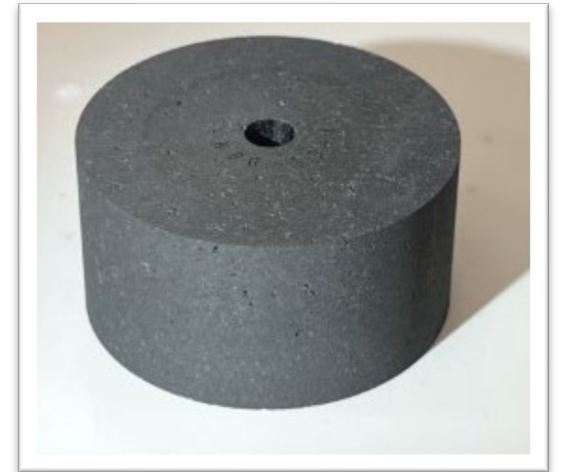
- Lathing Study (Density Determination)
 - Geometric
 - Archimedes
- Digital Image Evaluation
 - Optical
 - XCT



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

Lathing Study Density Analysis

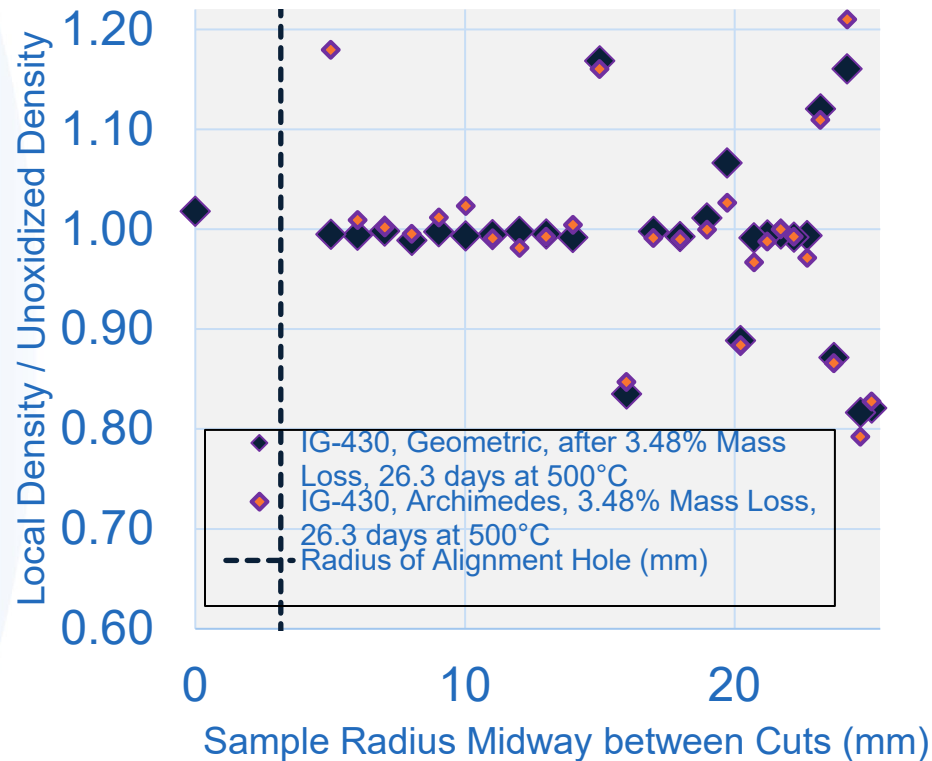
- Large Amount of Data (21 samples)
 - 7 graphite grades **2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, PCEA**
 - 3 mass loss values each (2%, 6%, 10% at 500°C)
- At least 26 cuts per sample
 - 50 mm initial diameter (before oxidation)
 - machined in 1 mm and 2 mm steps
- Density Determinations
 - Geometric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



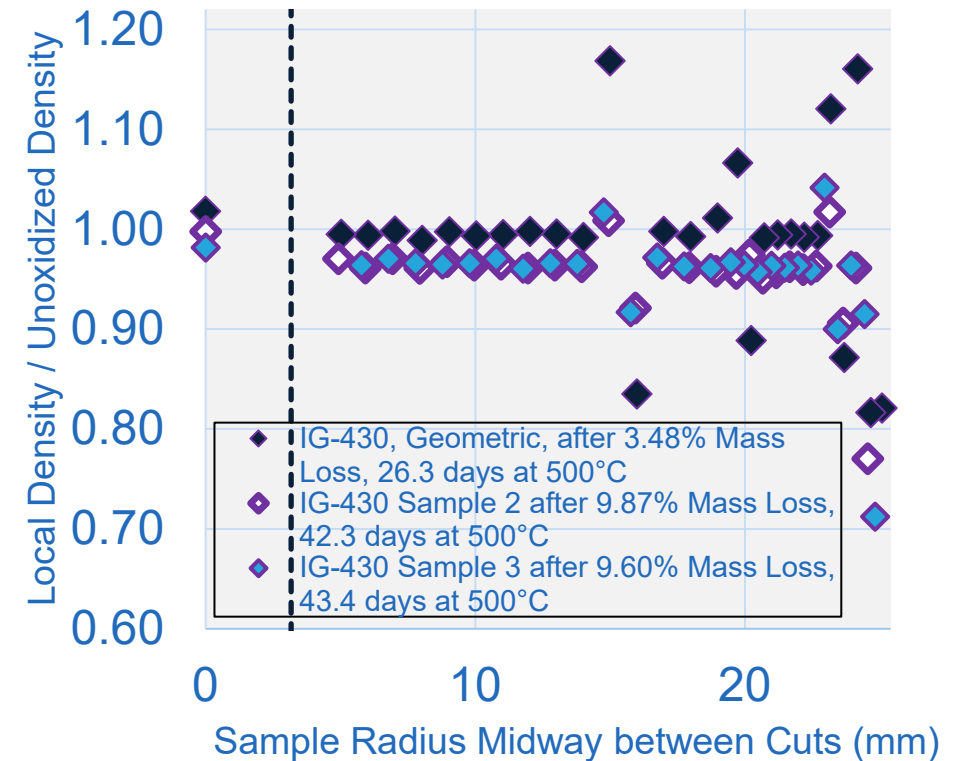
Density Profile

Trend matches expectations but with unanticipated variability

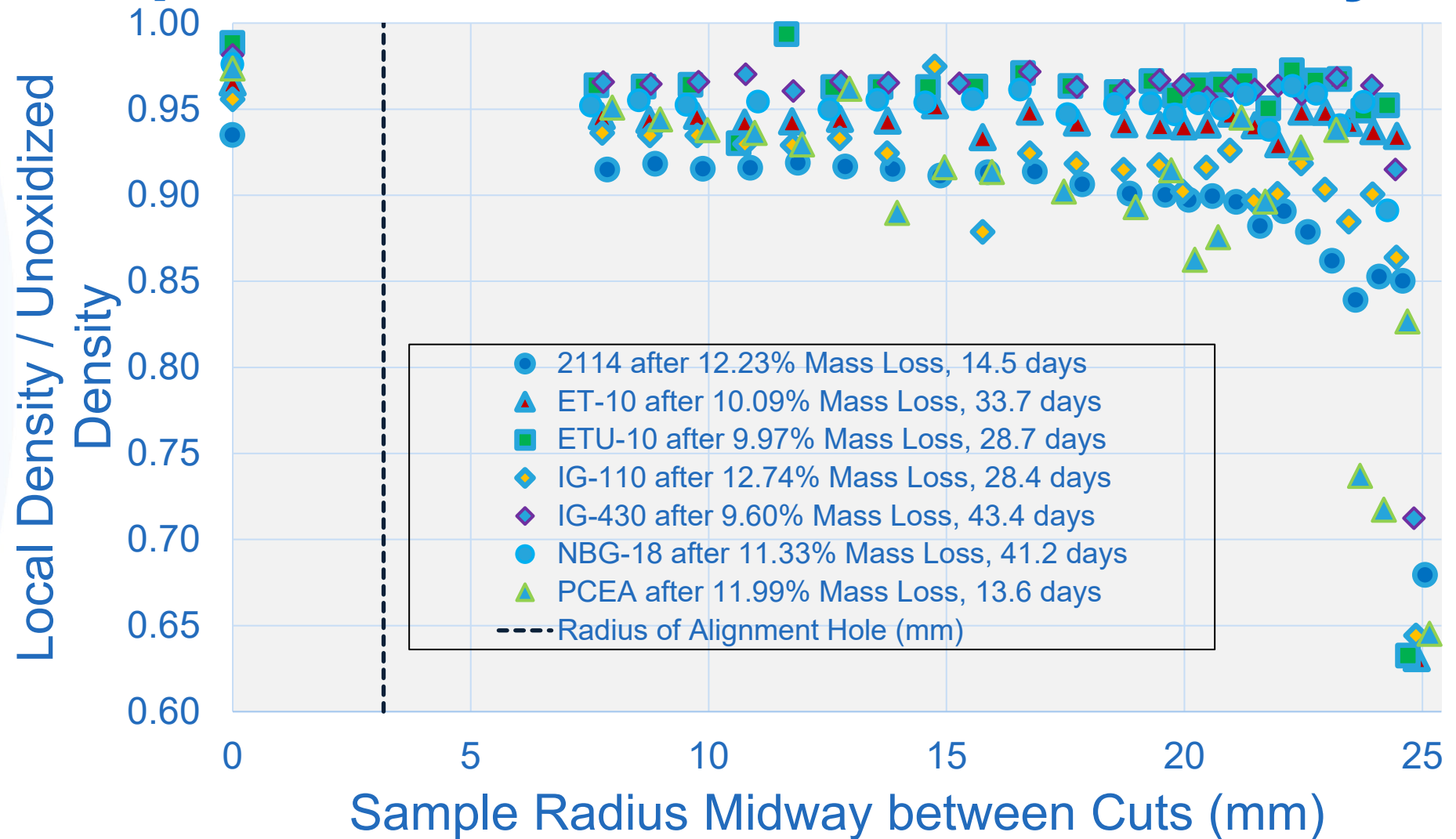
Geometric and Archimedes Compared



Same-Grade Samples (Geometric)



Local Geometric Density Profile: Comparison of Grades, Selective Analysis



Strategic Partnership Projects

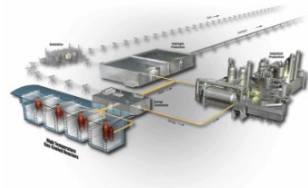
- Quality Assurance Documentation and Surveillance
- Receipt and Traceability of Materials
- Plans and Procedures

ET-10 and ETU-10

Document ID: PLN-6904
Revision ID: 1
Effective Date: 03/06/2024
INL/MIS-23-74149

Plan

Vertical Furnace Graphite Oxidation Characterization Plan



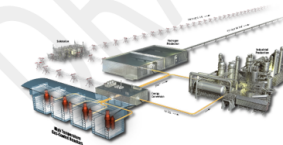
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Document ID: PLN-7041
Revision ID: 0
Effective Date: 10/07/2023

Project No.: 801525

Kairos Power Structural Graphite Oxidation Testing Quality Assurance Program Plan



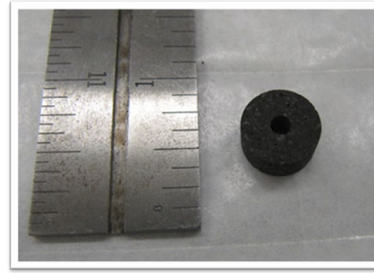
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Graphite Oxidation – Summary and Continuing Work



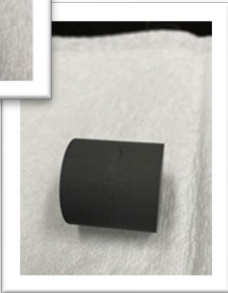
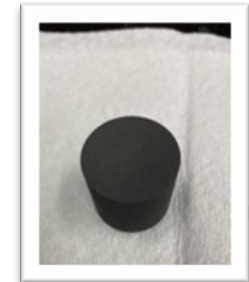
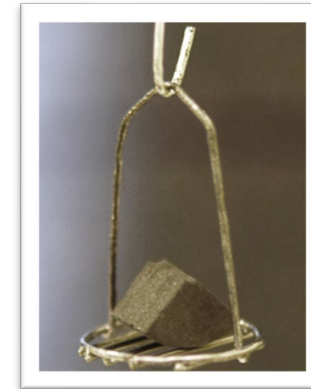
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- ASTM D7542 (Vertical Furnace)
- Developed OR and Arrhenius Plot Analysis Tools
- Irradiated and Unirradiated Split Samples (TGA)

2114, BAN, IG-110, IG-430, ET-10, ETU-10, NBG-17,
NBG-18, NBG-25, PCEA

- Strength After Oxidation

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

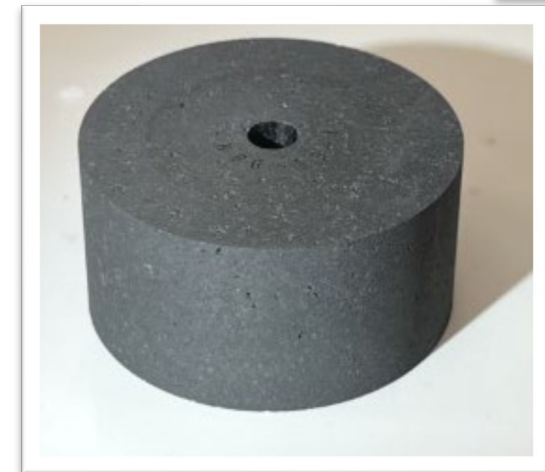


- Penetration Depth Analysis

- 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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ENERGY