



**GAS-COOLED REACTOR**

ADVANCED REACTOR TECHNOLOGIES PROGRAM

*Wednesday, July 17, 2024*

# Graphite Oxidation Activities

Contributors:

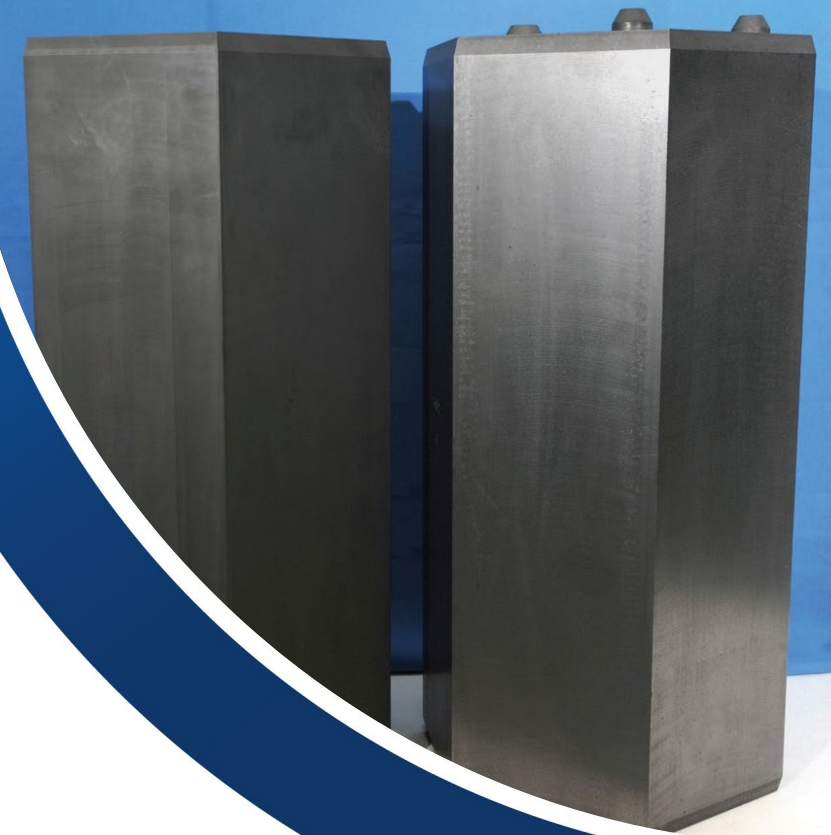
A. Matthews, D. Rohrbaugh, A. Cunningham,  
M. K. Ames, M. Barkdull, D. Cottle

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**Rebecca Smith**

*Staff Engineer*

*Idaho National Laboratory*



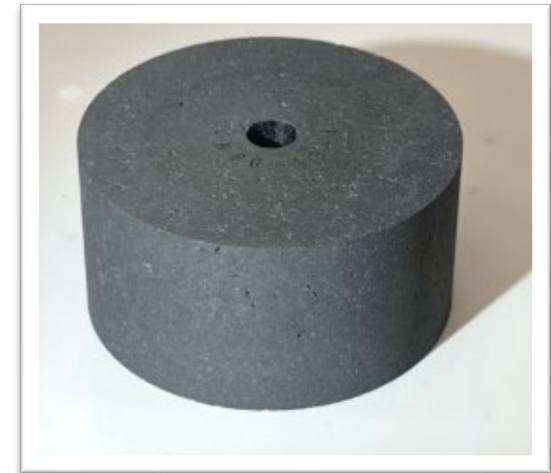
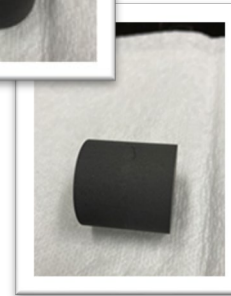
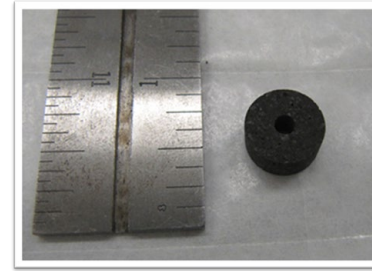
**DOE ART GCR Review Meeting**

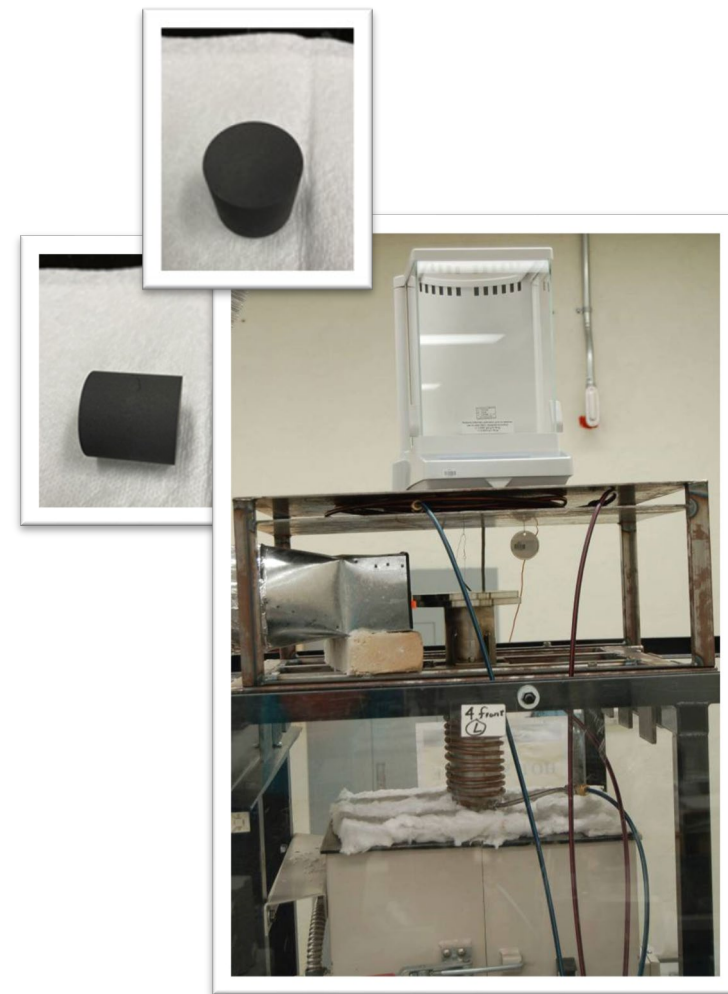
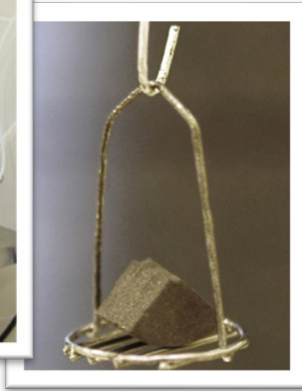
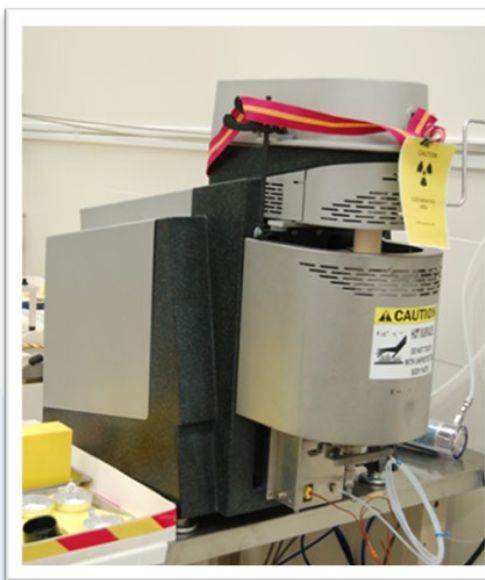
*Hybrid Meeting at INL*

**July 16–18, 2024**

# Graphite Oxidation

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





# Rate Determination

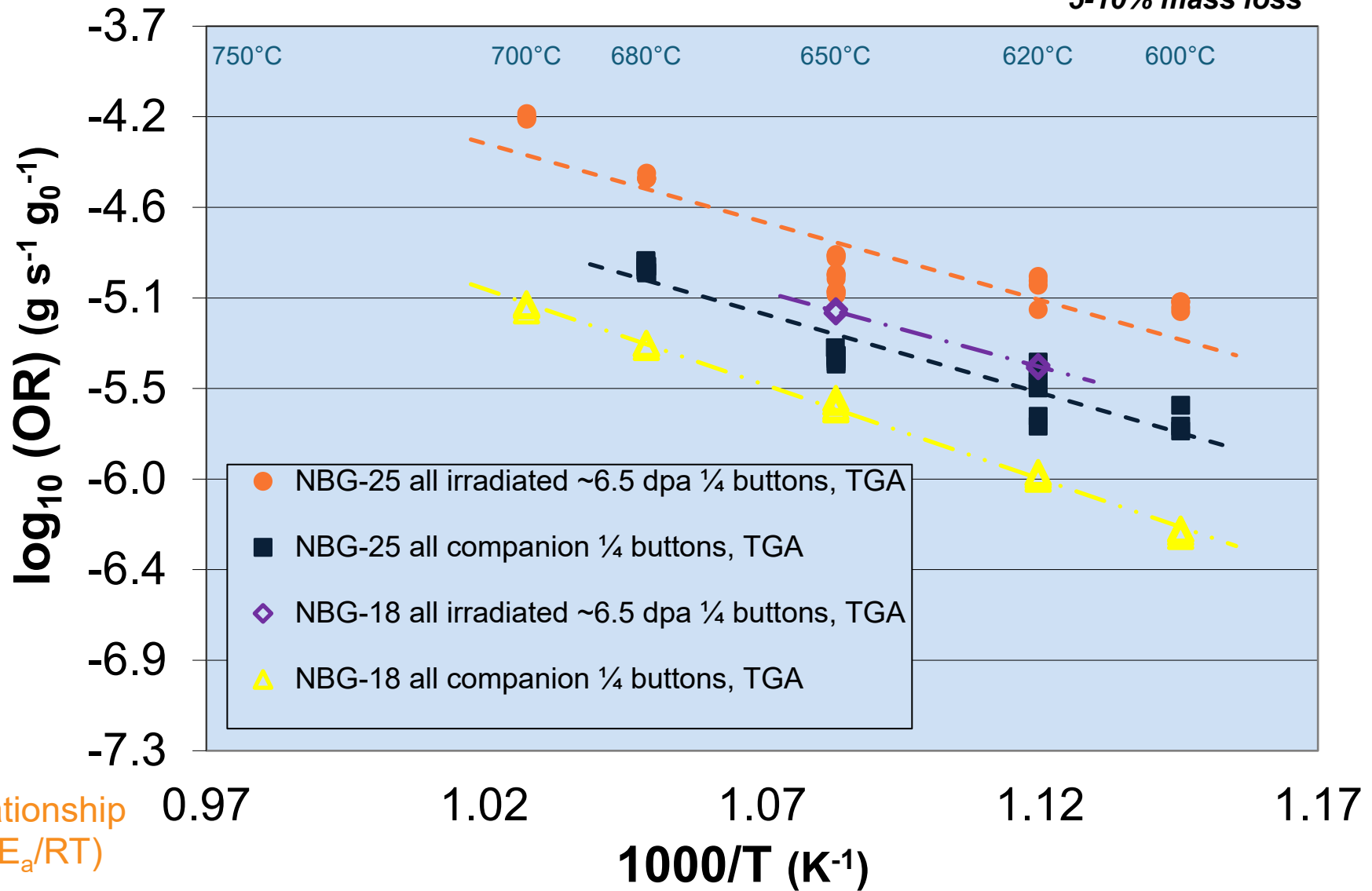
- ASTM D7542 (Vertical Furnace)
- Developed OR and Arrhenius Plot Analysis Tools
- Irradiated and Unirradiated Split Samples (TGA)

**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

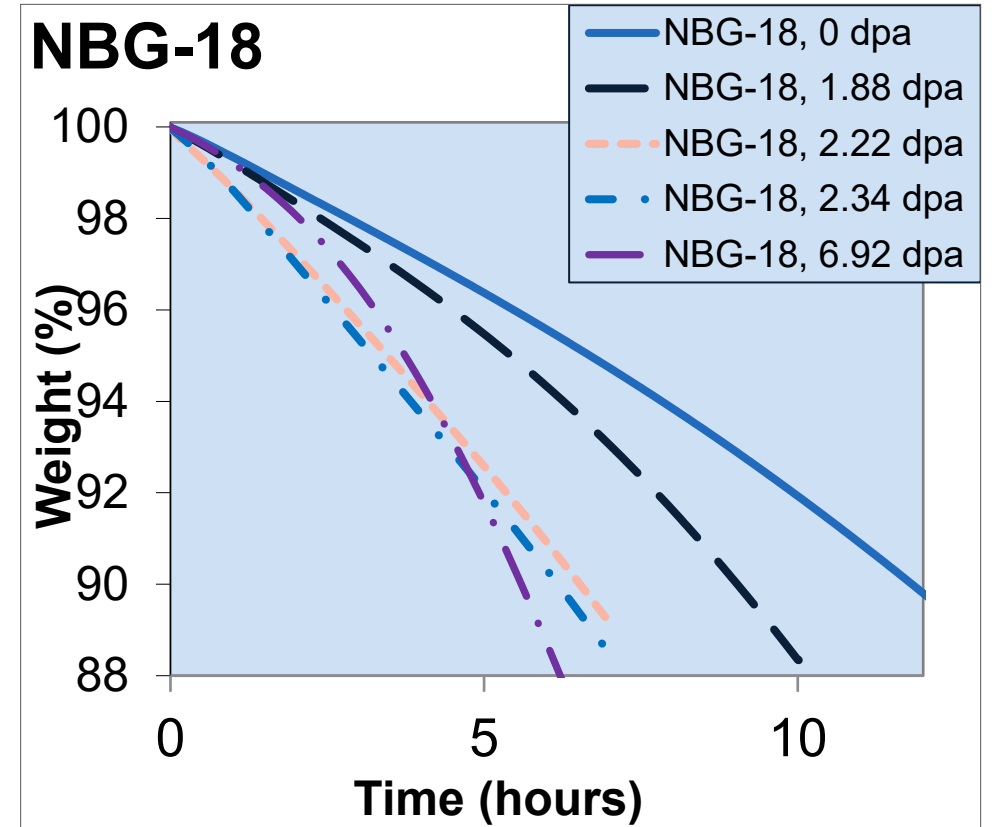
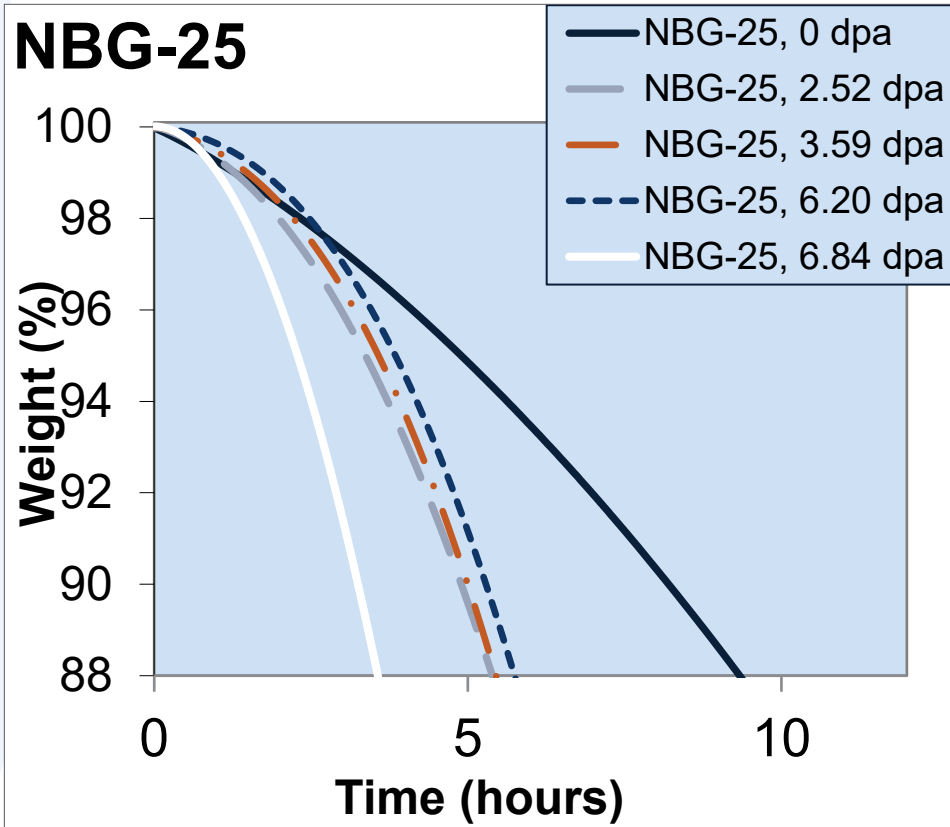


Arrhenius Relationship  
 $k = A \cdot \exp(-E_a/RT)$

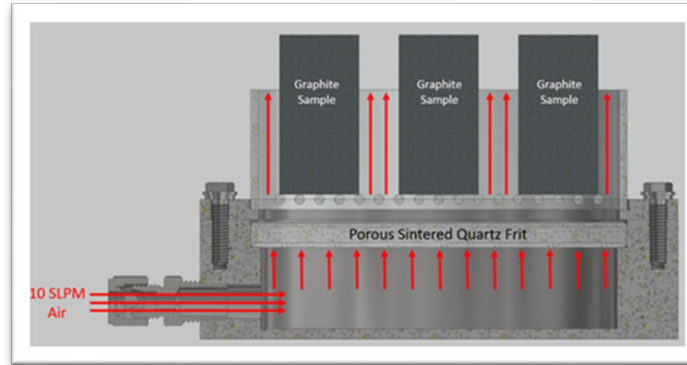
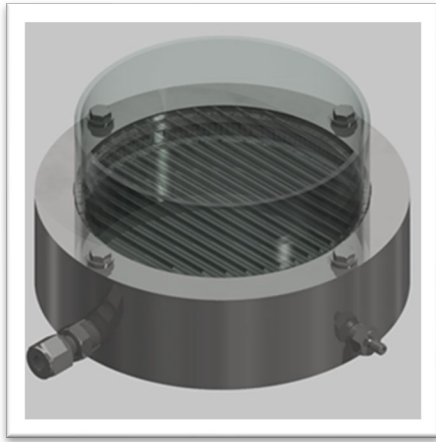


# Oxidation Rates after Irradiation

*Representative Runs of Split Samples at 650°C*

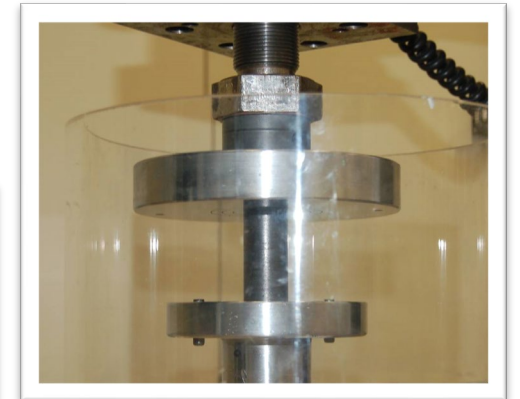






# Strength After Oxidation

- 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

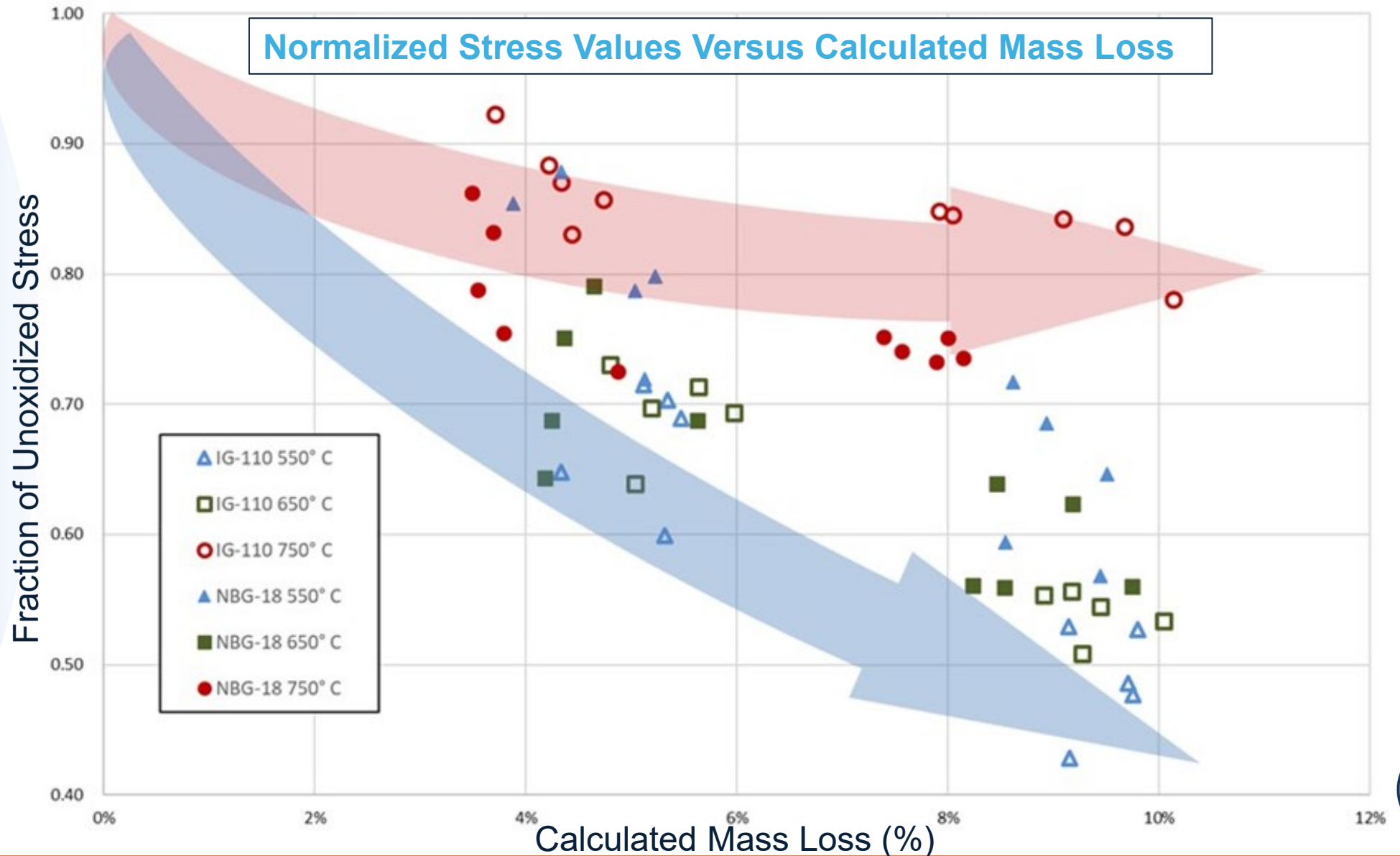


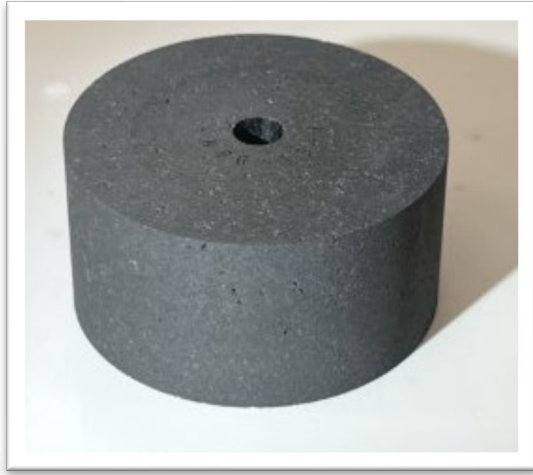
2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, PCEA



# Strength After Oxidation

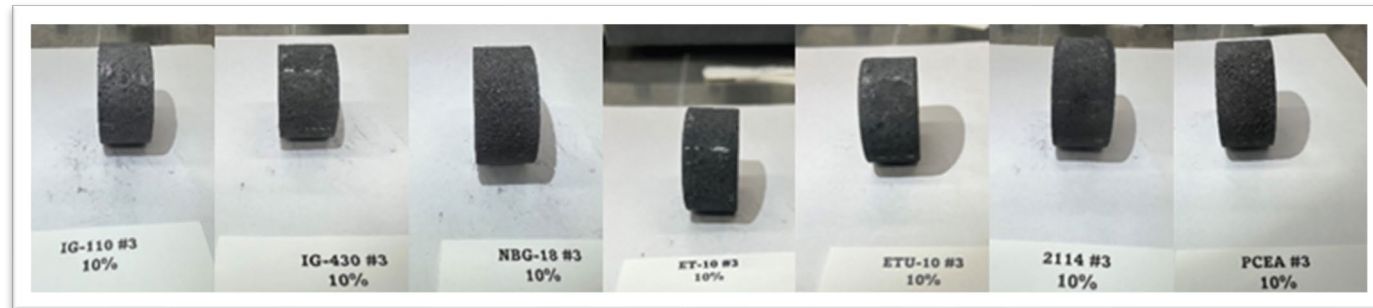
Recent testing includes 2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, and PCEA for three levels of mass loss at 550°C





# Penetration Depth Analysis

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



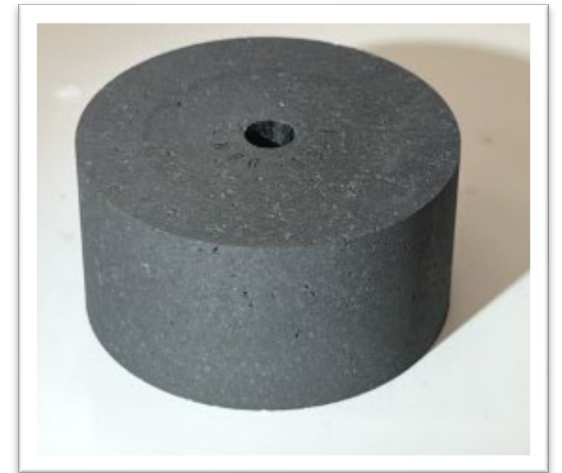
2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, PCEA





# Lathing Study Density Analysis

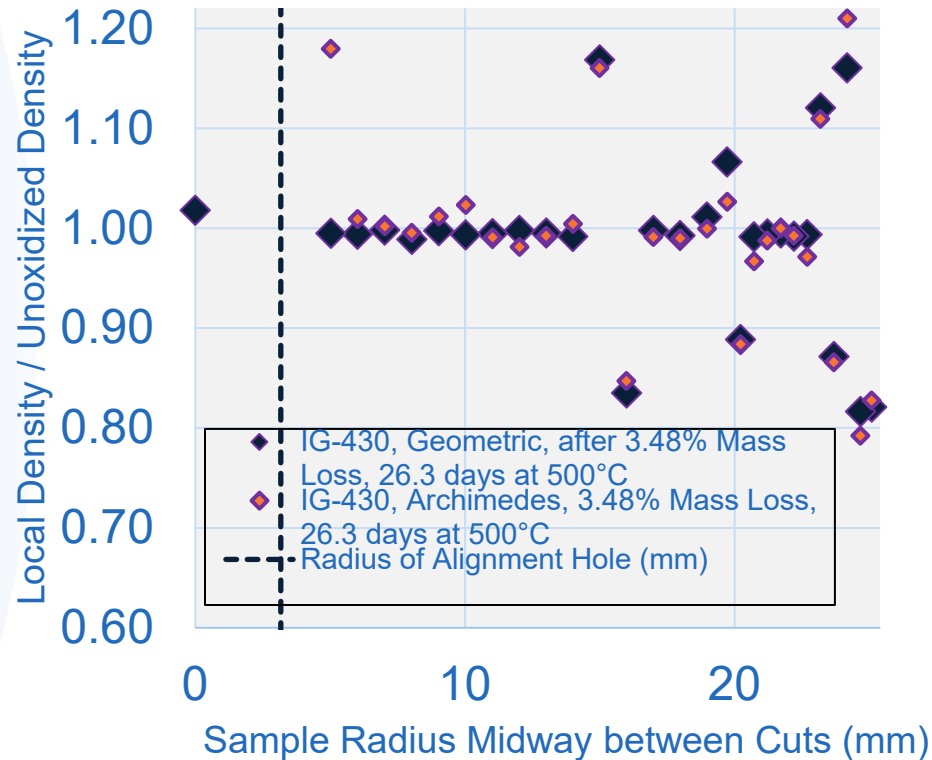
- Large Amount of Data (21 samples)
  - 7 graphite grades **2114, IG-110, IG-430, ET-10, ETU-10, NBG-18, PCEA**
  - 3 mass loss values each (2%, 6%, 10% at 500°C)
- At least 26 cuts per sample
  - 50 mm initial diameter (before oxidation)
  - machined in 1 mm and 2 mm steps
- Density Determinations
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



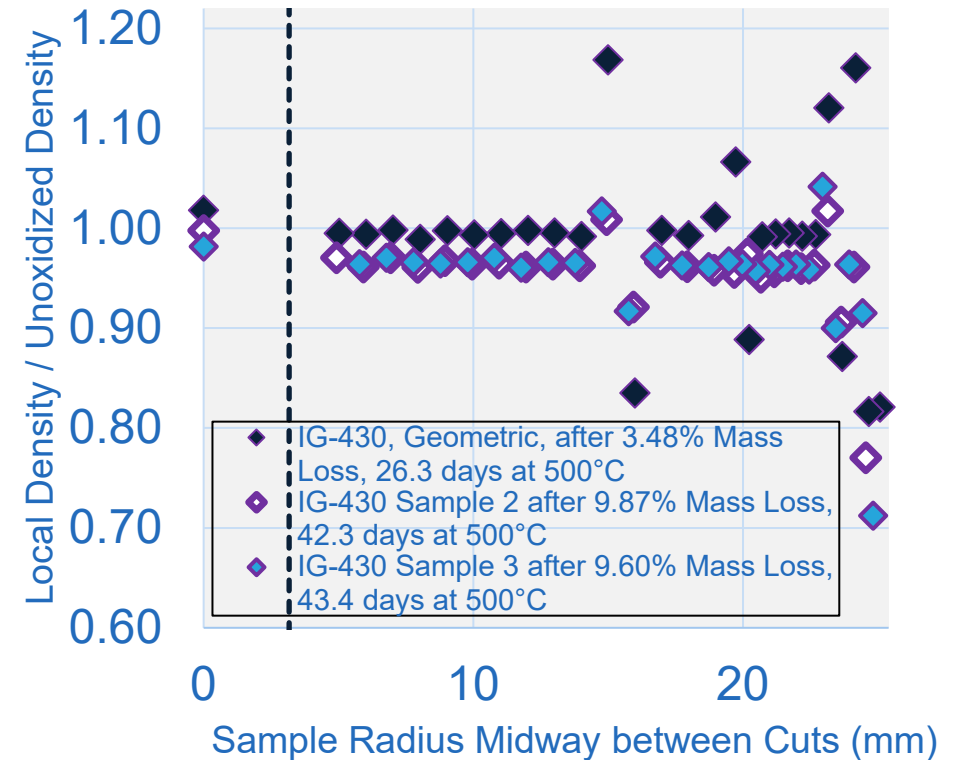
# Density Profile

*Trend matches expectations but with unanticipated variability*

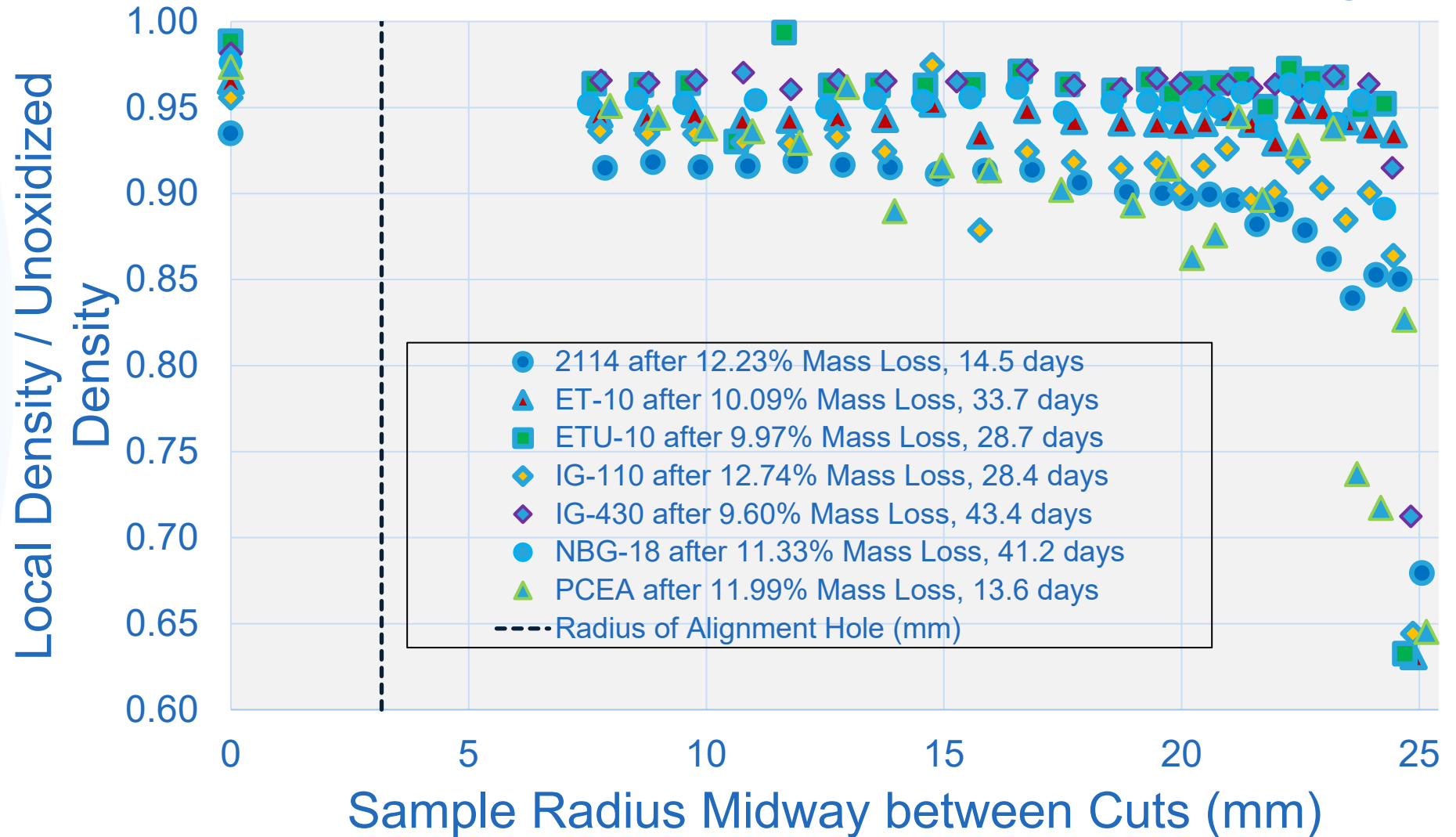
## Geometric and Archimedes Compared



## Same-Grade Samples (Geometric)



# Local Geometric Density Profile: Comparison of Grades, Selective Analysis



# Strategic Partnership Projects

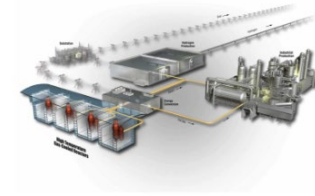
- Quality Assurance Documentation and Surveillance
- Receipt and Traceability of Materials
- Plans and Procedures

**ET-10 and ETU-10**

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

Plan

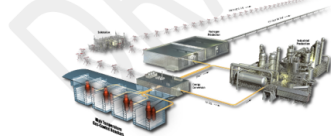
## Vertical Furnace Graphite Oxidation Characterization Plan



Document ID: PLN-7041  
Revision ID: 0  
Effective Date: xxx/xxx/xxxx

Project No.: 801525

## Kairos Power Structural Graphite Oxidation Testing Quality Assurance Program Plan

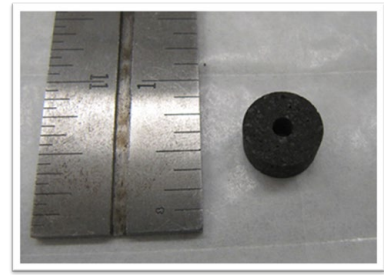


The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance





# Graphite Oxidation – Summary and Continuing Work



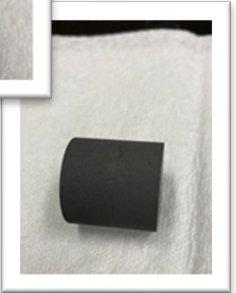
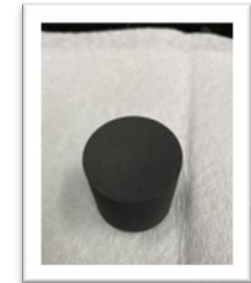
- **Rate Determination**

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- Developed OR and Arrhenius Plot Analysis Tools
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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

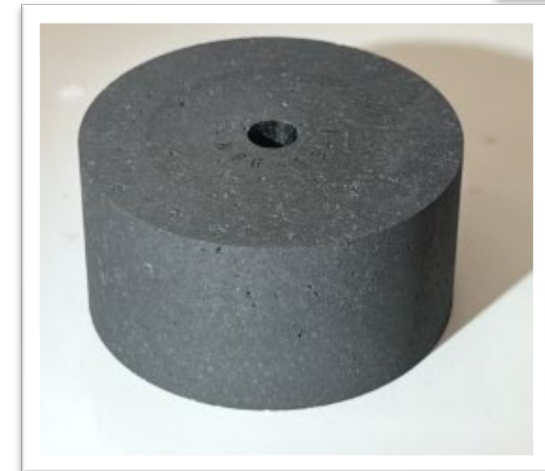


- **Penetration Depth Analysis**

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

- **Strategic Partnership Projects**

- Procedures
- Quality Assurance





# **GAS-COOLED REACTOR**

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# Thank You

# Questions?

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U. S. DEPARTMENT OF  
**ENERGY**