



# NEAMS / AFC High Burnup Coordination Project - Assessment

March 2021

*Changing the World's Energy Future*

Kyle A Gamble



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**Kyle A Gamble**

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

**<http://www.inl.gov>**

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U.S. DEPARTMENT OF  
**ENERGY**

**Nuclear Energy**

## **NEAMS / AFC High Burnup Coordination Project – Assessment**

*Kyle Gamble, Idaho National Laboratory*

*Jason Harp, Oak Ridge National Laboratory*

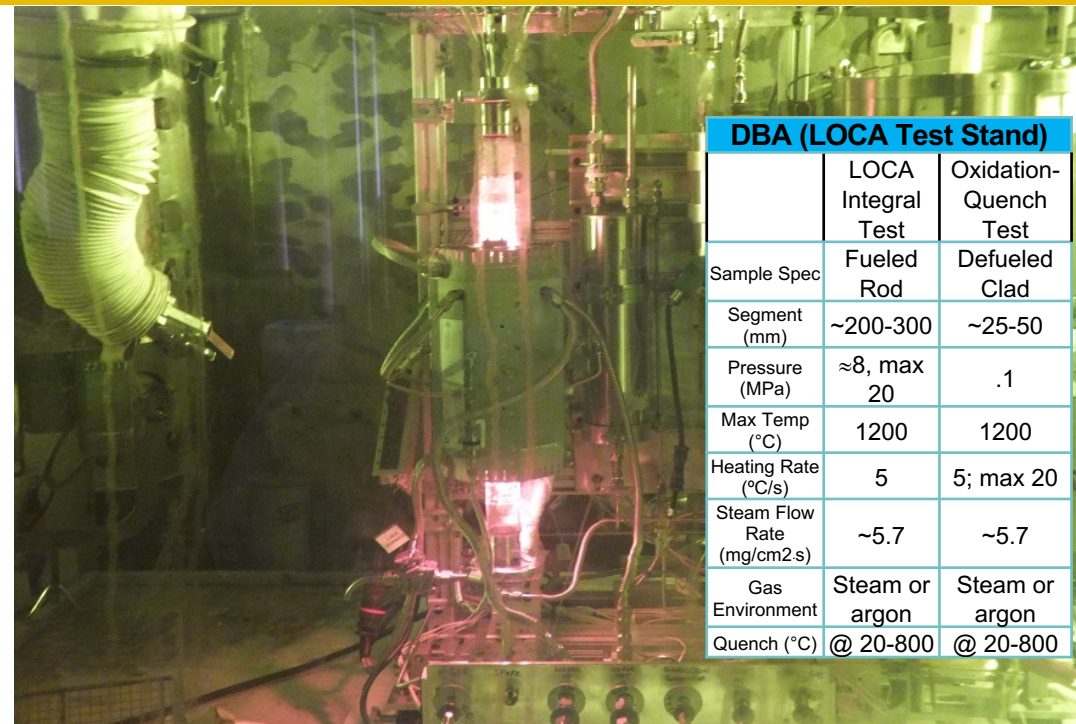
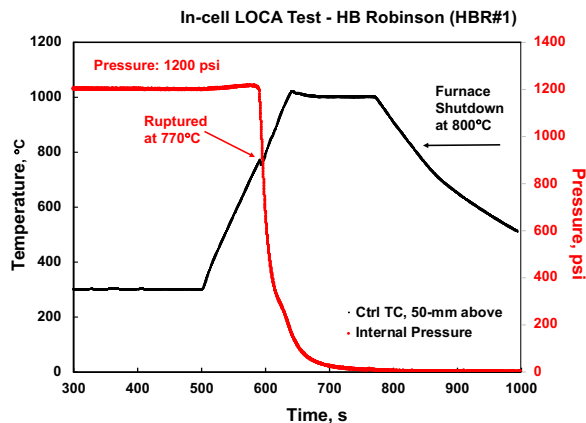
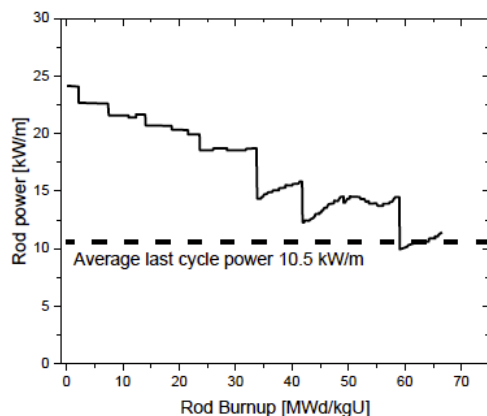




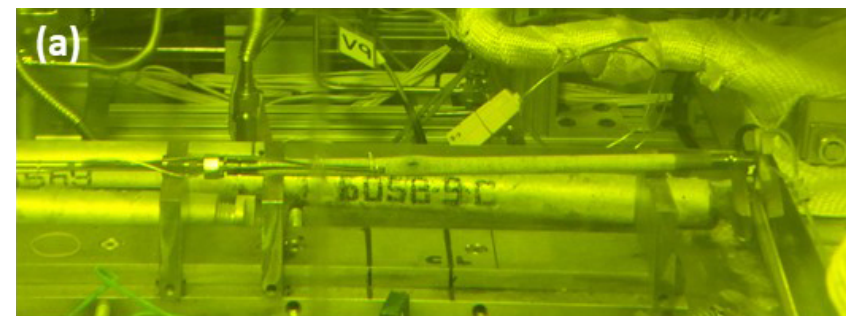
## H.B. Robinson SATS experiment

### Description

- The H.B. Robinson fueled test consisted of Zry-4 cladding with an outer diameter and wall thickness of 10.77 and 0.76 mm, respectively.
- Average discharge burnup of fuel rod was 66.5 MWd/kgU. Local burnup of specimen location was ~70 MWd/kgU.



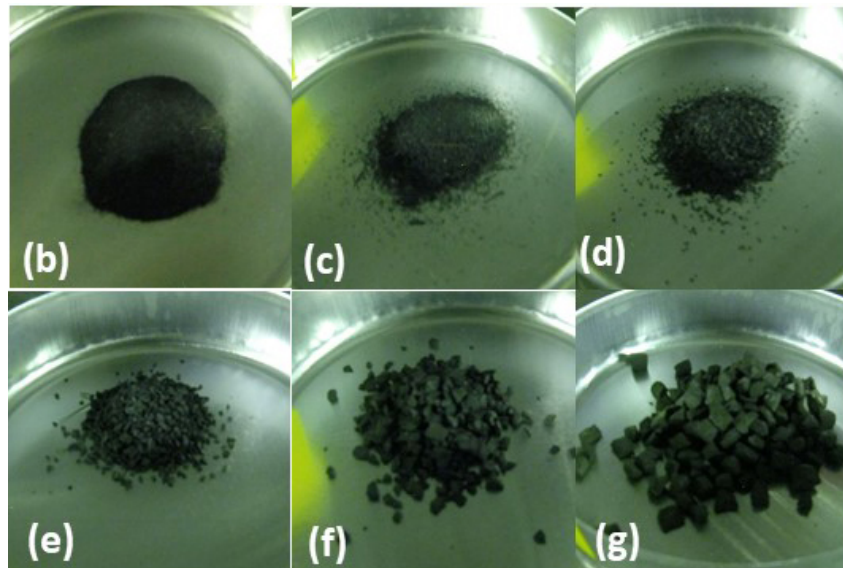
DBA (LOCA Test Stand)		
	LOCA Integral Test	Oxidation-Quench Test
Sample Spec	Fueled Rod	Defueled Clad
Segment (mm)	~200-300	~25-50
Pressure (MPa)	≈8, max 20	.1
Max Temp (°C)	1200	1200
Heating Rate (°C/s)	5	5; max 20
Steam Flow Rate (mg/cm2s)	~5.7	~5.7
Gas Environment	Steam or argon	Steam or argon
Quench (°C)	@ 20-800	@ 20-800



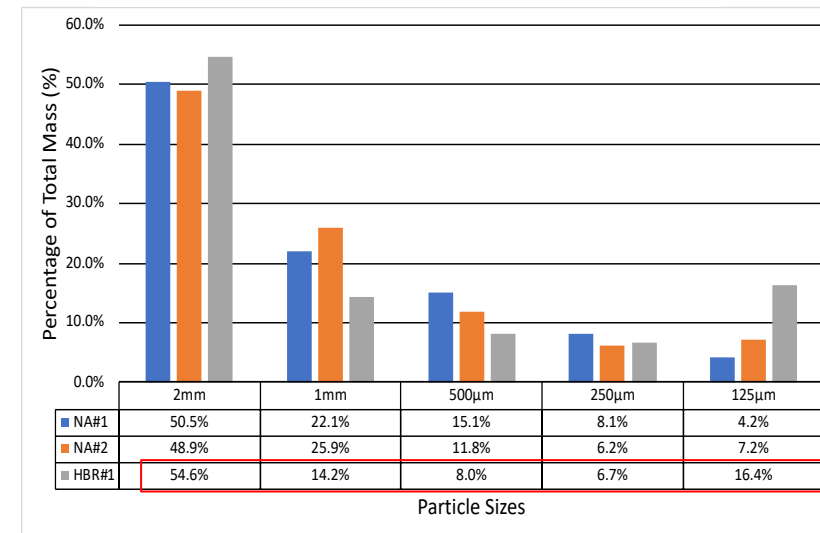
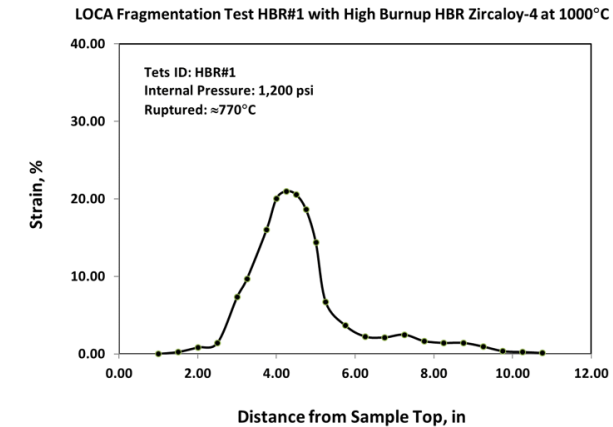
(a) Posttest appearance of LOCA Bust & fragmentation test sample HBR#1



# H.B. Robinson SATS experiment – post-test results



(b) fragmented fuel particles collected : (b) <0.125 mm; (c) 0.125–0.250 mm; (d) 0.250–0.500 mm; (e) 0.500–1.00 mm; (f) 1.00–2.00 mm; and (g) >2.00 mm.



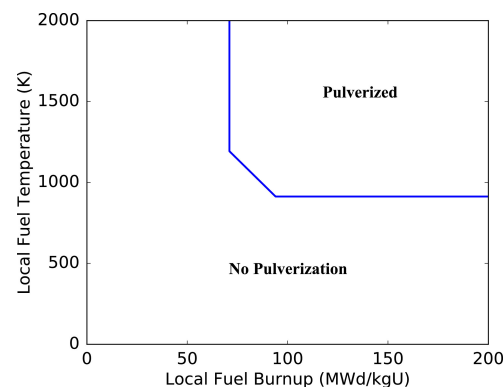
**Size distribution of fuel fragments collected after ORNL Burst & LOCA fragmentation and shake testing**



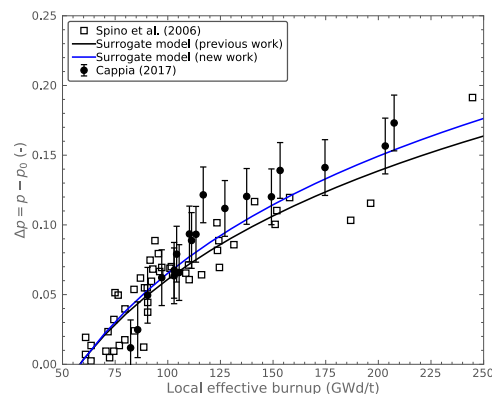
# BISON HBS and LOCA Models Overview

## Fuel Behavior

- High burnup thermal conductivity
- Turnbull pulverization (fine fragmentation) threshold
- Axial fuel relocation



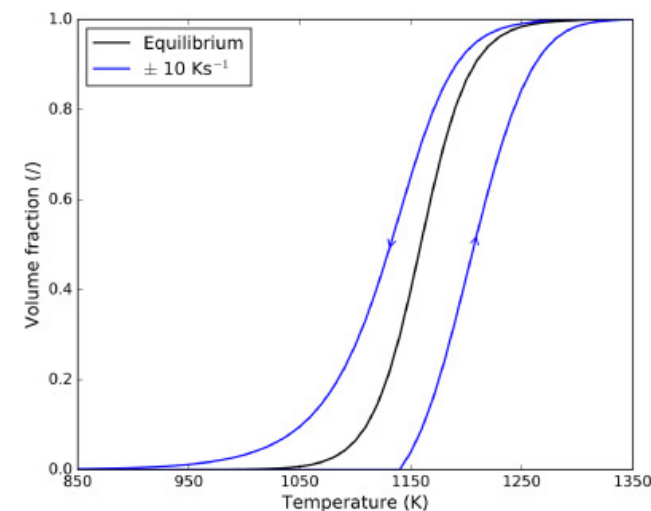
Turnbull pulverization threshold



Surrogate model for HBS porosity formation.

## Cladding Behavior

- High temperature steam oxidation
- High temperature creep
- Crystallographic phase transition
- Burst failure criteria

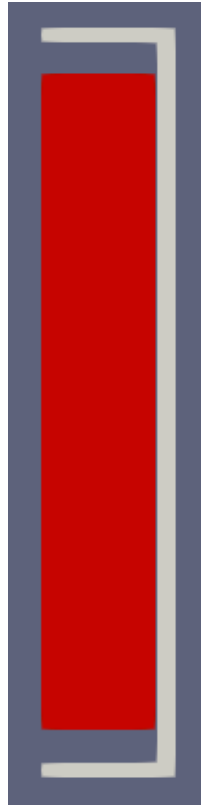


Crystallographic phase transition showing equilibrium and 10 K/s heating and and cooling rates.

# Preliminary BISON analysis of the H.B. Robinson SATS experiment

## Modeling Assumptions

- 2D-axisymmetric smeared pellet representation of experimental rodlet dimensions subjected to both base irradiation and transient.
- Axial temperature profile is required to facilitate localized ballooning.
  - A value of ~1.7 K/in was assumed which corresponds to a 20 K difference between ends of rodlet to maximum cladding temperature at the midplane.
- Simulation terminated at the time of cladding burst.



Scaled by 0.1 in the axial (y) direction.

## Results

- Parameters of interest include rod internal pressure, burst temperature, burst size, and fuel pulverization.
- A plastic instability failure criterion was used in BISON ( $\dot{\epsilon} = 0.02777\text{s}^{-1}$ )

Metrics	BISON	Experiment
Burst Temperature (K)	~1090	1043 (770 °C)
Rod Internal Pressure at Burst (MPa)	~5.53	~5.79(840 psi)
Mass Fraction Pulverized (<1.0 mm) (%)	~13	31.1
Max. strain (%) (engineering)	~29	25
Max stress (MPa) (engineering)	~46 MPa	59.3





## Future BISON HBS/LOCA developments and assessment

- **Implement a lower-length scale informed pulverization threshold that is more than just local burnup and temperature dependent.**
- **Modify the axial relocation algorithm to use a distribution of particle sizes in determining packing fraction over a simple binary system of fine and large fragments.**
- **Improve cladding mechanical models during LOCA transients.**
- **Assess the other two fueled SATS tests in greater detail.**
  - The base irradiation histories for the rodlets prior to the transient is required.