



HERA Calibration Experiments

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Changing the World's Energy Future

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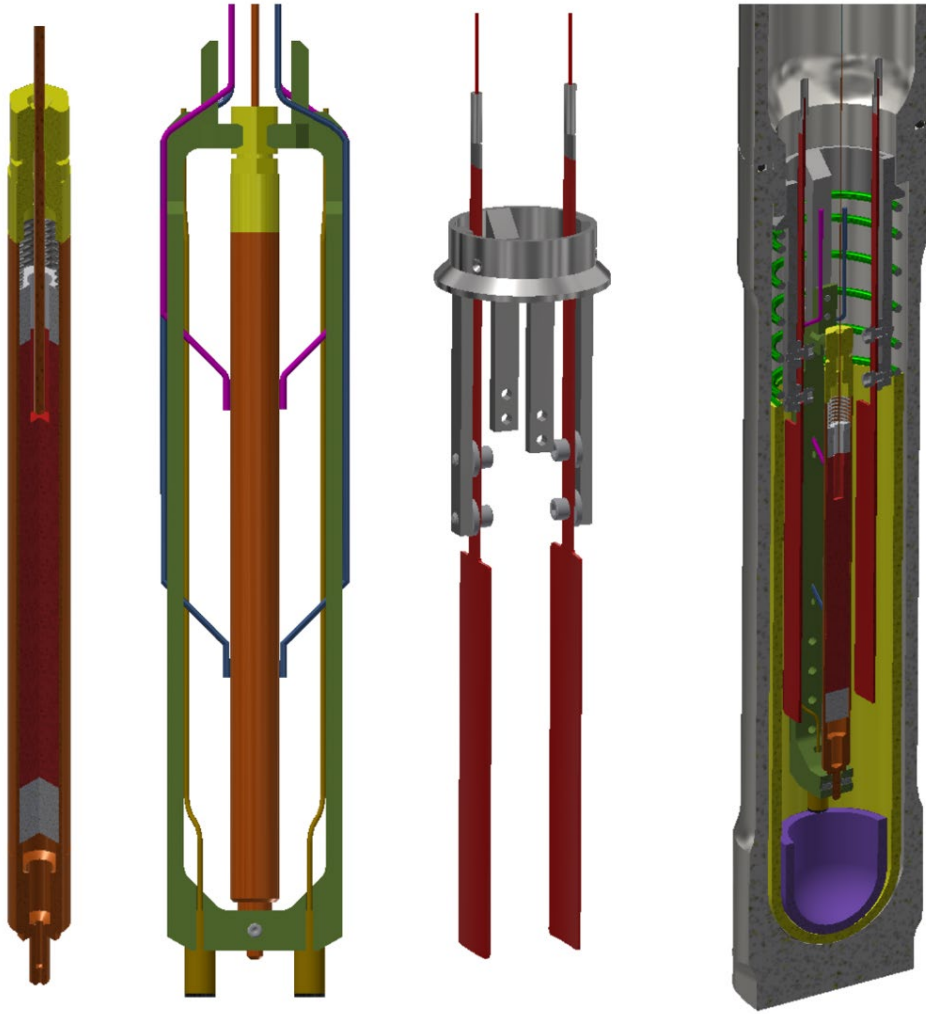
HERA Calibration Experiments

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Idaho National Laboratory

HERA Overview



- Use the Static Environment Rodlet Transient Test Apparatus (SERTTA) capsule with instrumentation modifications to target HERA objectives
- Simplified capsule design with a focused instrumentation package
 - Improved cladding TC attachment
 - Fuel Centerline TC
 - Boiling Detectors
 - Water TCs
 - Water Pressure Transducers (for detecting failure)
- All tests in RTP water
- All tests with 4.2% clipped transient (~90 ms FWHM)

HERA Overview

- Leveraged calibration transients with other experiment programs
 - Calibration capsule included 4 transients of increasing energy depositions
 - Utilized fuel centerline thermocouple data to perform thermal calibration
 - HERA-Zr-2 used to verify the transient for the pre-hydrided tests
 - Goal was to target 650 J/gUO₂ peak radial average enthalpy rise (PRAER)

Table 11. Transient operating guidelines.

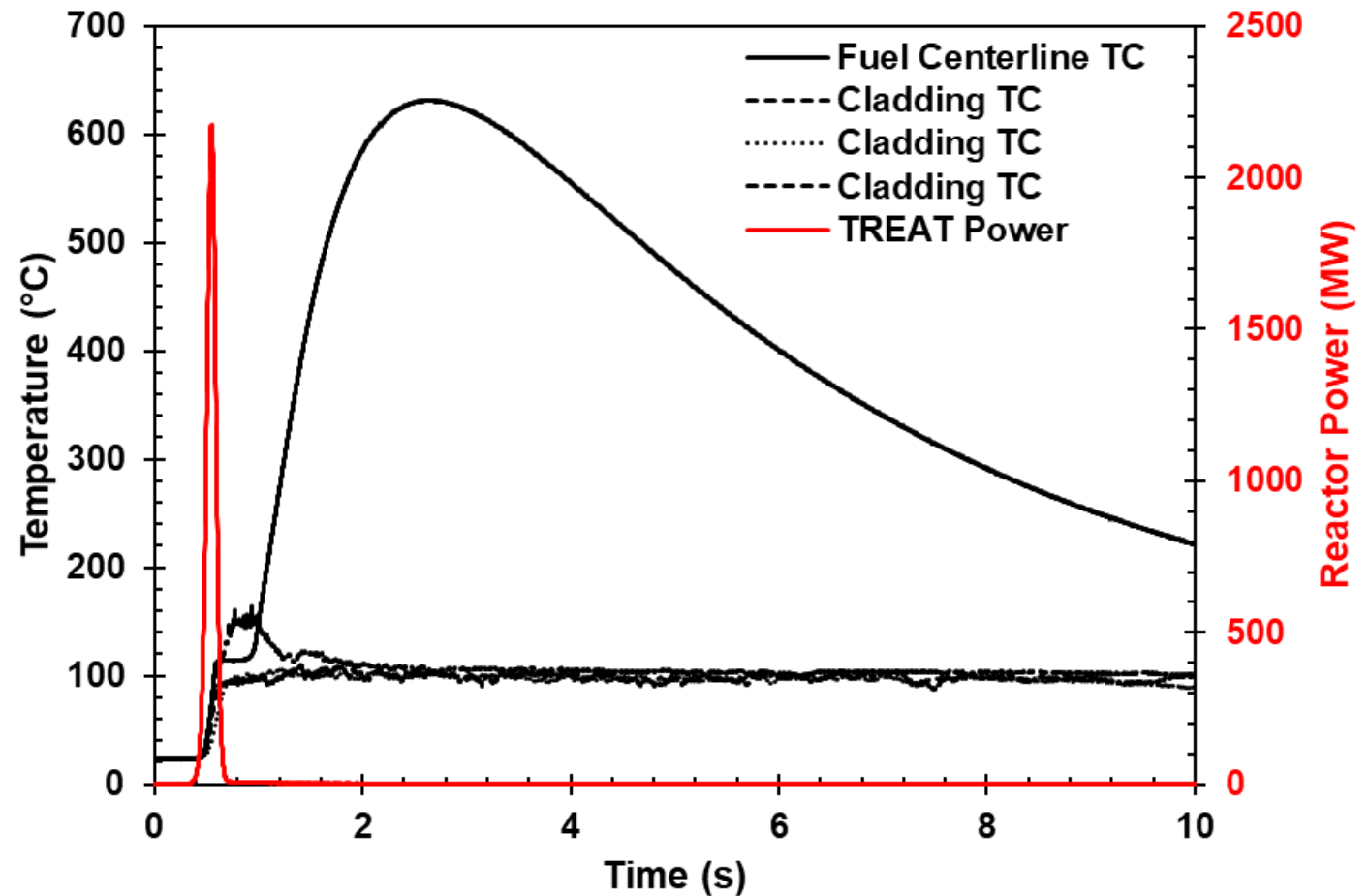
Test ID	Specimen ID	Cladding	Plenum Pressure (MPa)	Test Objectives		
				Specimen energy deposition target (J/g)	Step Insertion ¹ (dk/k)	Test Purpose
MSERTTA-aLEU-UO2-1A-Cal	HERA-aLEU-Cal	Zr-4	0.1	200	4.2% Clipped	Fuel Temp. Calibration Test
MSERTTA-aLEU-UO2-1B				500	4.2% Clipped	Fuel Temp. Calibration Test
MSERTTA-aLEU-UO2-1C				580	4.2% Clipped	Fuel Temp. Calibration Test
HERA-Cal-1				650	4.2% Clipped	Fuel Temp. Calibration Test
HERA-Zr-1	HERA-Zr-2	Zr-4	2	650	4.2% Clipped	Low Enthalpy Burst
HERA-PreH-1	HERA-PreH-1	Hydrided Zr-4	2	650	4.2% Clipped	PCMI Std. Pulse Width
HERA-PreH-2	HERA-PreH-2	Hydrided Zr-4	2	650	4.2% Clipped	PCMI Std. Pulse Width

Current Status Synopsis

- Recently completed a series of calibration experiments (4) to validate the TREAT core to specimen energy coupling factor
- Validation through thermal calculations
- Using the validated coupling factor designed and ran trial transients for the targeted 650 J/gUO₂ peak radial average enthalpy rise transients
- Very recently irradiated the HERA-Zr-2 specimen
- Share raw data from experiments (all experiments were performed within the last 6 weeks)
 - Fuel centerline thermocouple and some cladding thermocouple data available
 - Pressure transducers require processing of the data signal before results can be interpreted
 - Boiling detector data showed the initiation of the boiling event but did not capture the time of rewet

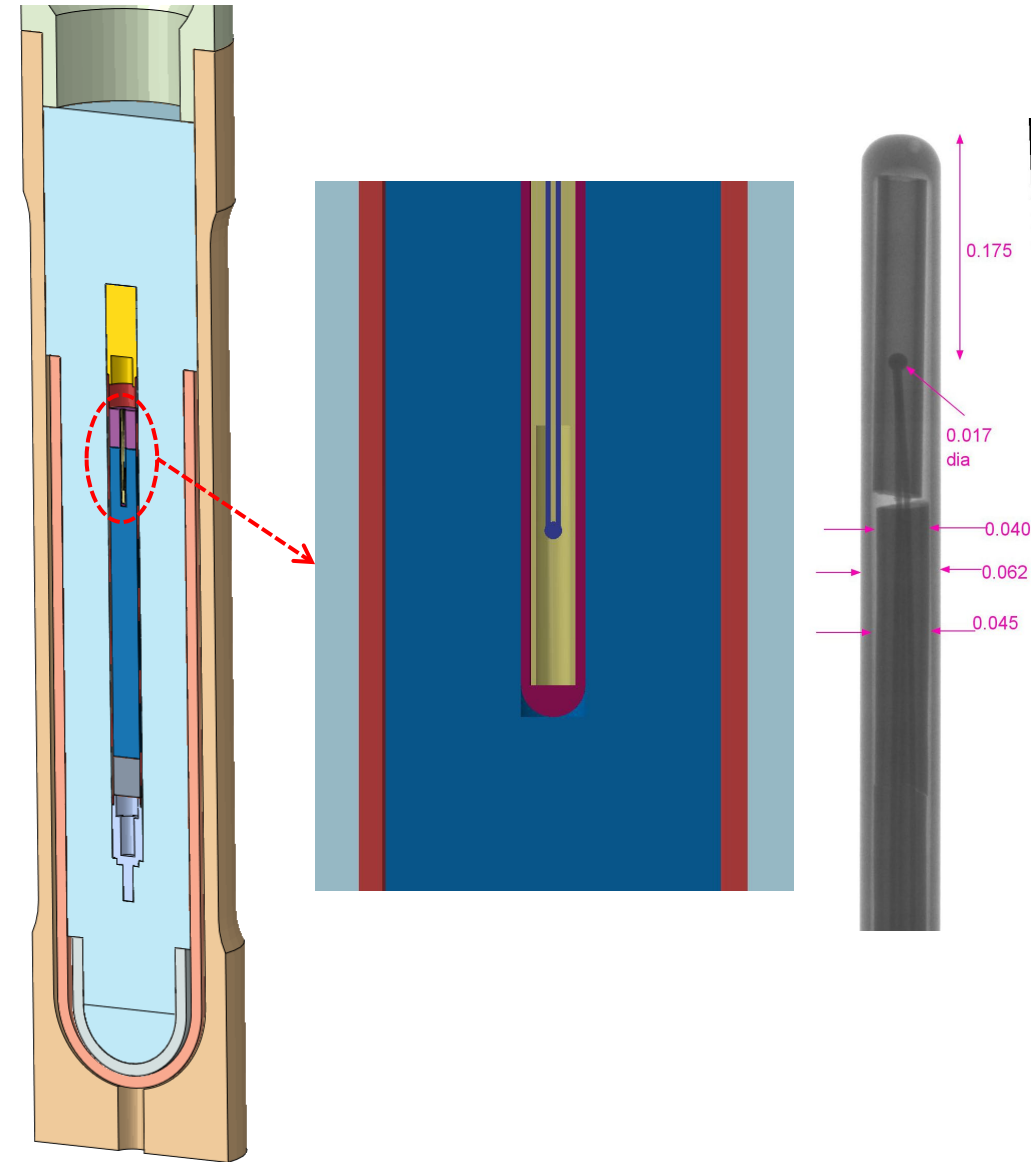
CAL-1A

- 240 MJ TREAT transient
 - 98 ms FWHM pulse
 - Estimated 220 J/gUO₂ energy deposition
- Fuel centerline TC provided clean results
- Cladding TCs indicate boiling may have occurred



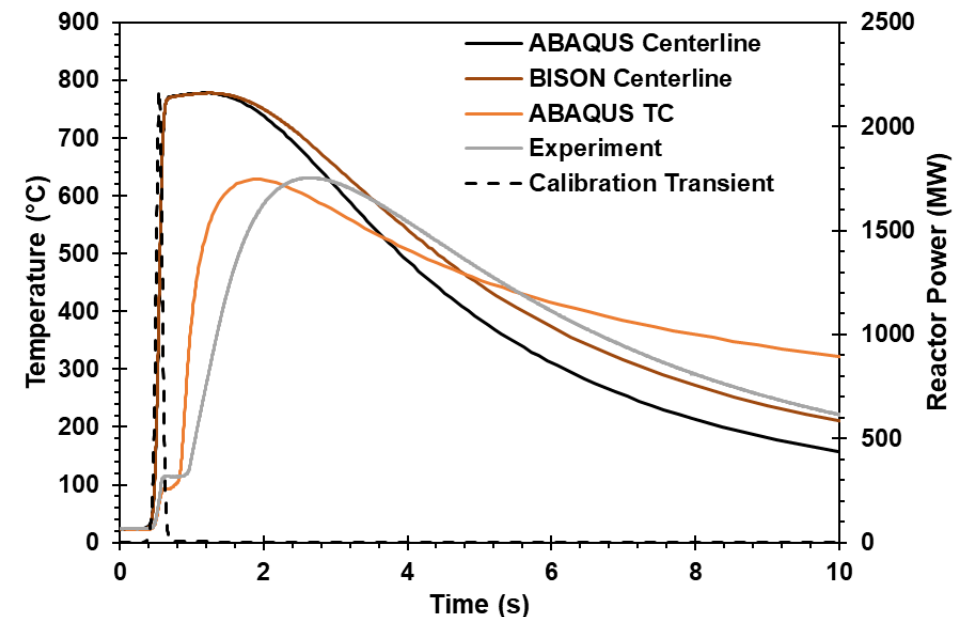
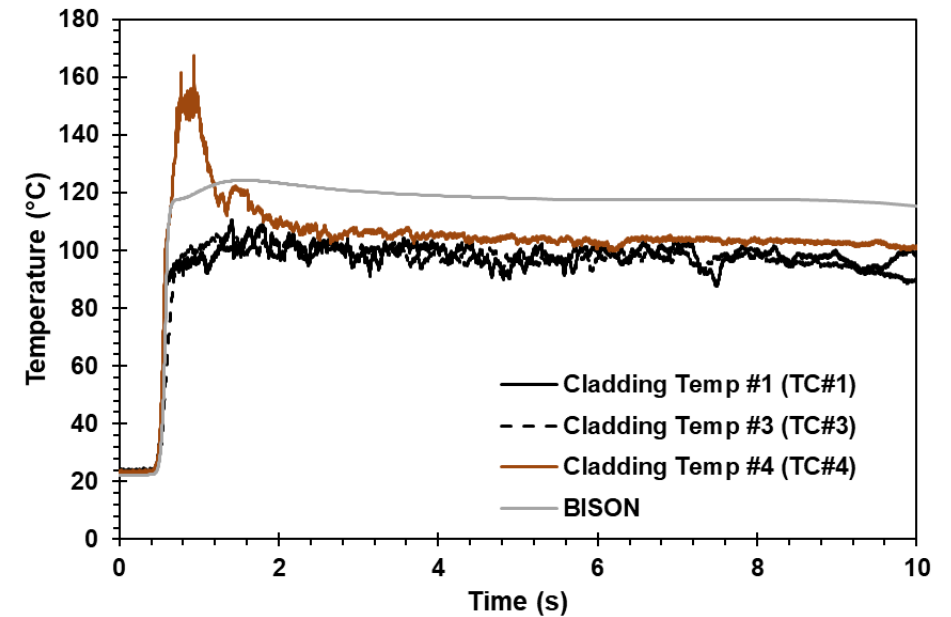
Validation Method

- Detailed ABAQUS model of the capsule, water, fuel rod, and fuel centerline temperature TC was created
 - CT scan of TC provided dimensions
- Best estimate boundary conditions and component coupling factors from neutronic analysis were applied
 - HGRs for all components modeled
 - TC wires, insulation, and sheath all important
 - Gap heat transfer between TC components and fuel impact timing of results but do not have a significant effect on peak temperature values predicted for TC bead
 - Coupling factor for fuel modified until reasonable agreement between model and experiment were met



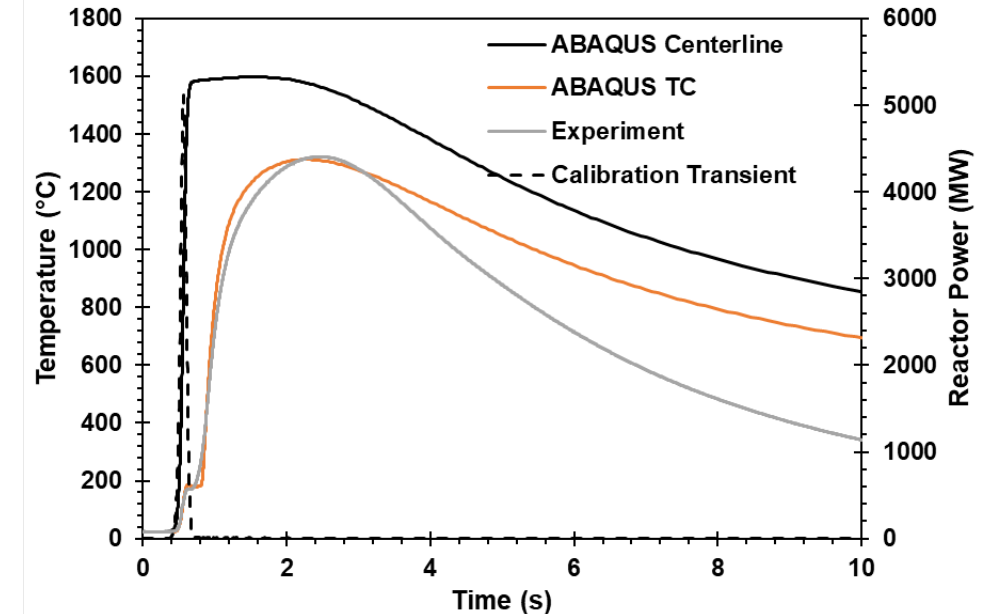
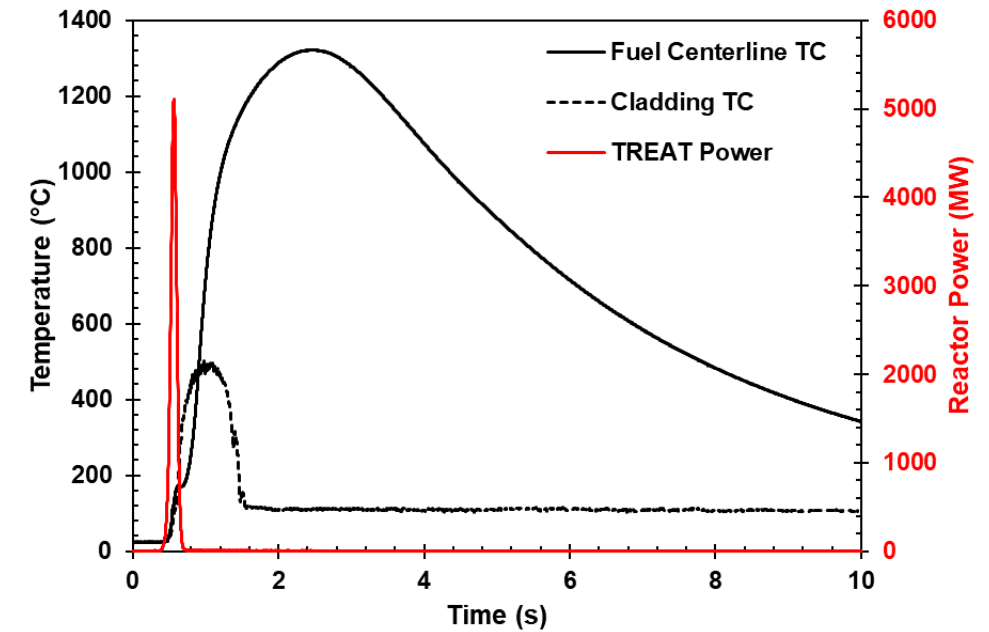
CAL-1A

- Experiment results compared to BISON and ABAQUS predictions assuming best estimate coupling factors
 - BISON model thermal-hydraulics BCs loosely coupled from RELAP5-3D
- Coupling factor from MCNP neutronic calculations results in less than 0.5% difference in measured vs. predicted thermocouple temperature prediction
 - Differences in time of peak
 - TC measures ~150°C lower than predicted peak fuel centerline temperature
 - Still looking at uncertainties related to TC measurements and reactor power
 - Plans to perform more detailed uncertainty analysis



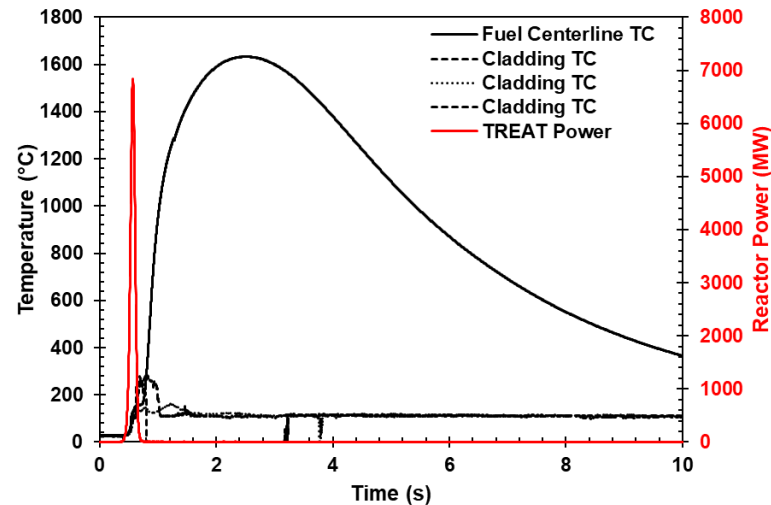
CAL-1B

- 526 MJ TREAT transient
 - 92 ms FWHM pulse
 - Estimated 490 J/gUO₂ energy deposition
- Coupling factor from MCNP neutronic calculations results in less than 0.7% difference in measured vs. predicted thermocouple temperature prediction
- TC measures ~280°C lower than predicted peak fuel centerline temperature

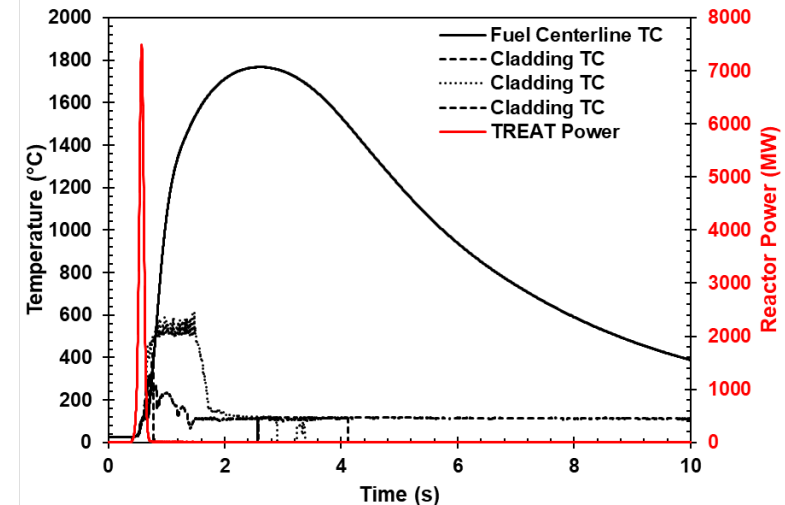


CAL-1C and CAL-1D

- CAL-1C
 - 652 MJ TREAT transient
 - 90 ms FWHM pulse
 - Estimated 607 J/gUO₂ energy deposition
- 0.14% difference in measured vs. predicted thermocouple temperature prediction
- Performance of cladding TCs degraded with each transient

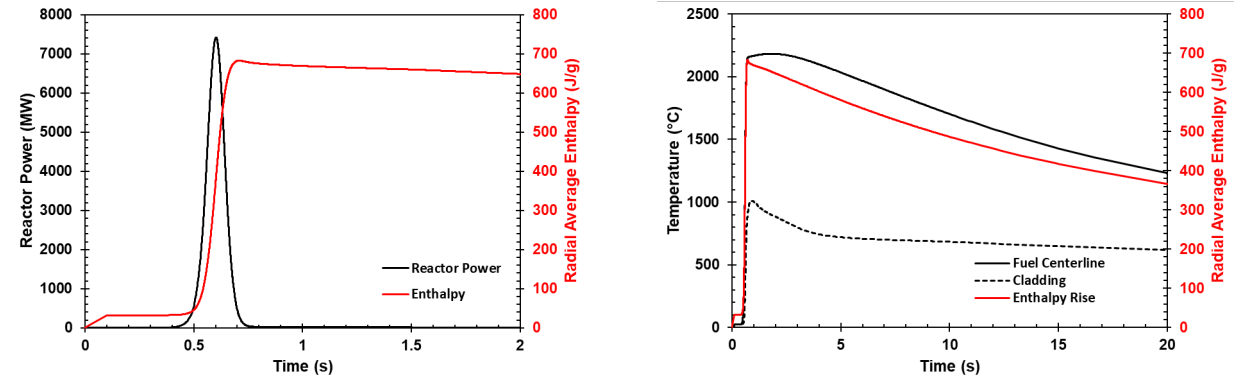


- CAL-1D
 - 758 MJ TREAT transient
 - 89 ms FWHM pulse
 - Estimated 706 J/gUO₂ energy deposition
- 0.08% difference in measured vs. predicted thermocouple temperature prediction

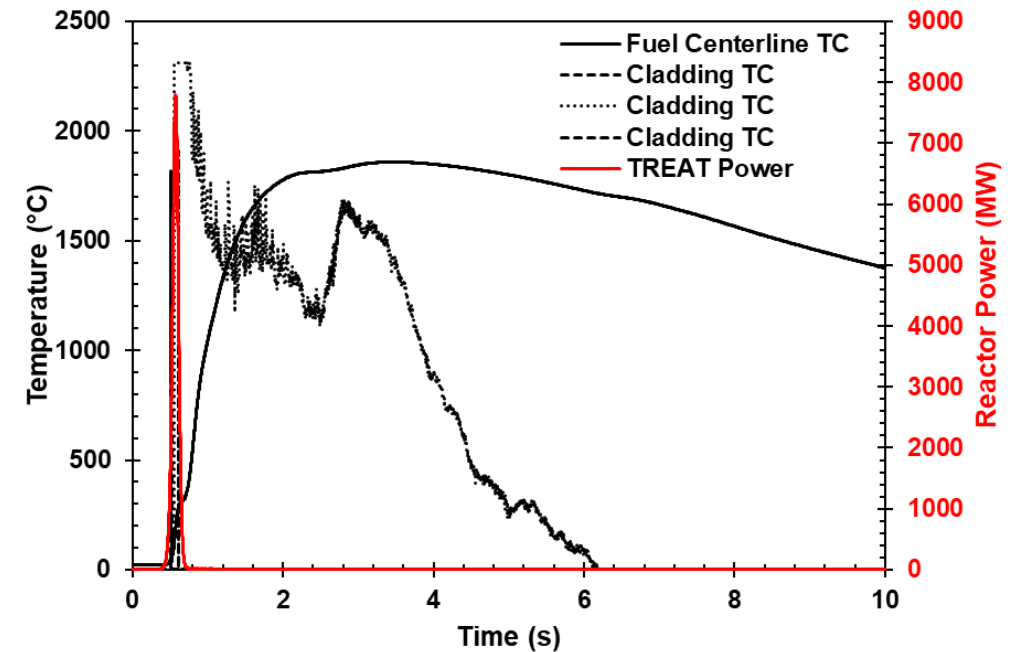


HERA-Zr-2

- The calibrated coupling factor from 4 previous tests used to design a transient that would target 650 J/gUO₂ peak radial average enthalpy rise
 - HERA-Zr2 rodlet has oversized pellets similar to the pre-hydrated rodlets
- BISON simulations used to determine a 795 MJ (740 J/gUO₂) would achieve 650 J/g PRAER
- Transient resulted in 789 MJ (735 J/gUO₂)
 - 89 ms FWHM
- The cladding TCs were damaged and did not provide a reading (1 provided erratic readings)

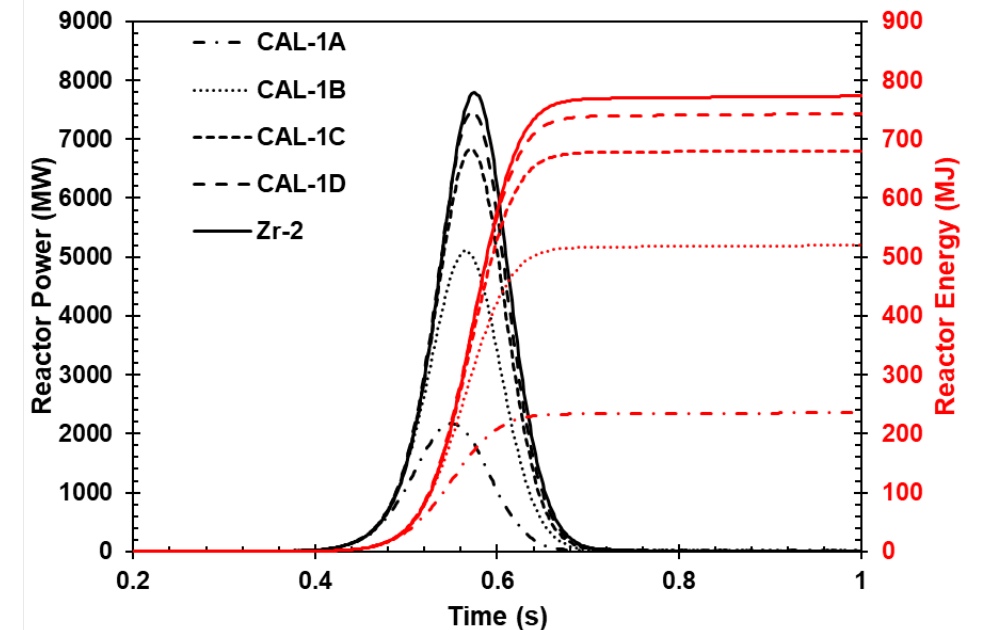
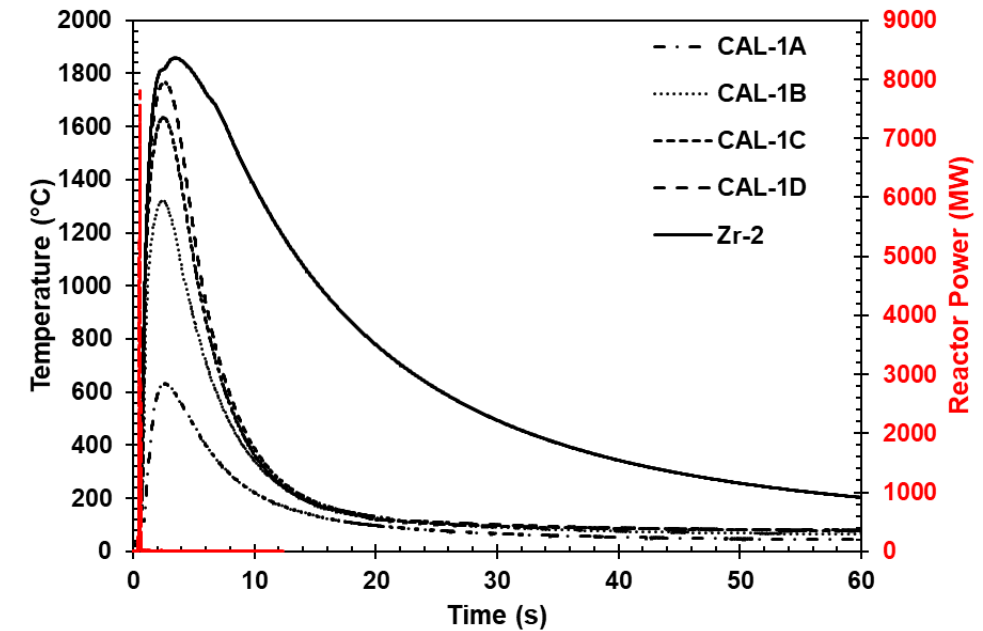


BISON predictions to target 650 J/g enthalpy increase



Summary

- Performed 5 transients to date
- Fuel centerline TC used to validate coupling factor
- Transient selected to target peak radial average enthalpy rise of 650 J/gUO₂
- Detailed fuel performance analysis of HERA-Zr-2 experiment still needs to be performed
 - Fuel centerline TC shows results expected to reach target enthalpy
- HERA-PreH-1 and 2 experiments are currently being assembled





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