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Water Capsule RIA Testing

December 2020

Charles P Folsom

Changing the World's Energy Future

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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Advanced Fuels Campaign

Water Capsule RIA Testing

Charles Folsom (INL)
charles.Folsom@inl.gov

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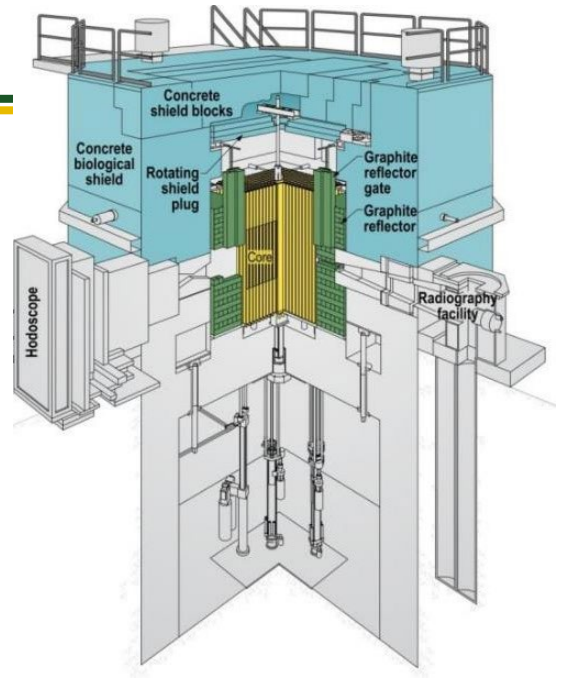
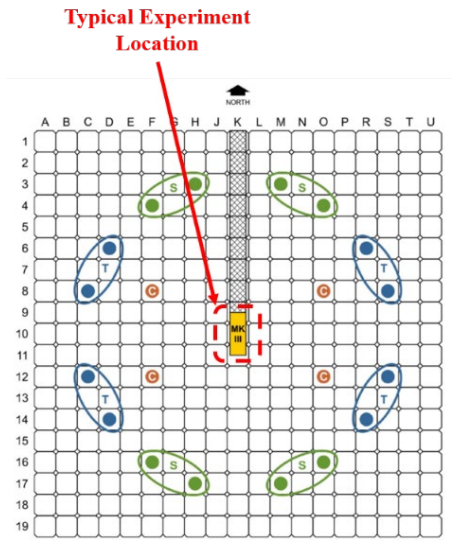
RIA Testing Overview

- **INL is trying to revive/restore the testing capability in the US (especially regarding LWR technology)**
  - These testing capabilities are critical to support the ATF campaign
- **INL current/planned capabilities:**
  - Steady state irradiation in ATR (drop-in capsules and pressurized water loops)
  - Post irradiation examination (full-size rods through cutting edge material science)
  - Transient testing in TREAT (design basis accident including RIA and LOCA)
  - Operational transients in ATR (instrumented ramp testing in i-loops)
- **In 2017 TREAT resumed operations to support fuel safety testing**
  - Currently capable of 89 ms FWHM pulse width, ^{3}He clipping system to be deployed in 2022 for ~45 ms
- **Collocated at INL with other complimentary facilities**
  - Fuel fabrication, characterization, and PIE facilities





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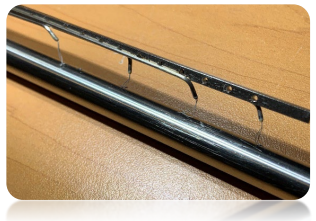
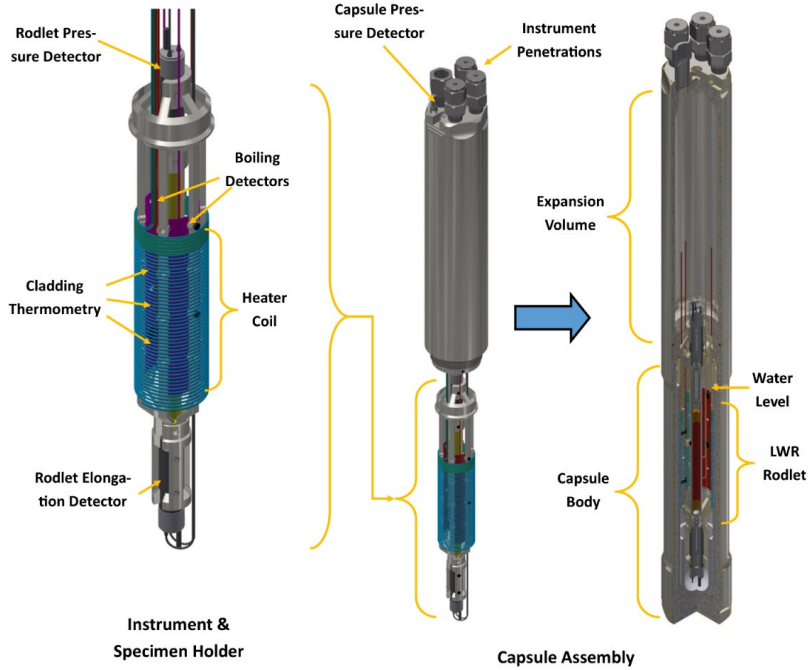
RIA Water Capsule

- **MARCH Static Environment Rodlet Transient Test Apparatus (M-SERTTA)**
  - First tests up 200°C starting temperature with PWR-representative sub-cooling, system uprate-able to 280°C and 16 MPa
- **Instrumentation for water-based objectives**
  - LVDT for rod elongation and pressure
  - Electro-impedance water void detector
  - Cladding TC and multispectral pyrometry
  - Configurable for different data objectives
- **Commissioning tests underway**
  - Fresh fuel for energy injection calibration and instrument qualification
  - Novel configuration for nuclear-heated real time transient CHF measurement (CHF-SERTTA)
  - First pre-irradiated rods loaded in hot cell (ATF-R)

DMLS Capsule

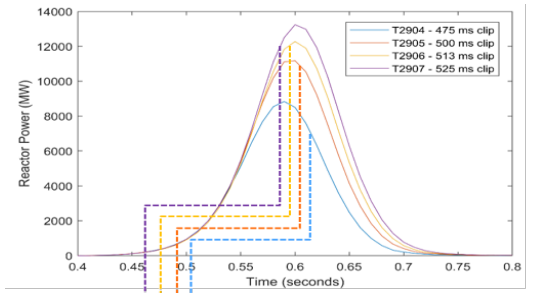


Cladding TC weldment



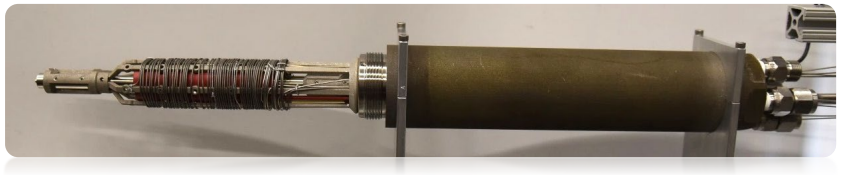
Instrument & Specimen Holder

Capsule Assembly



FWHM (ms)	Specimen Energy Injection (J/gUO$_2$)
90	550
89	710
90	780
92	850

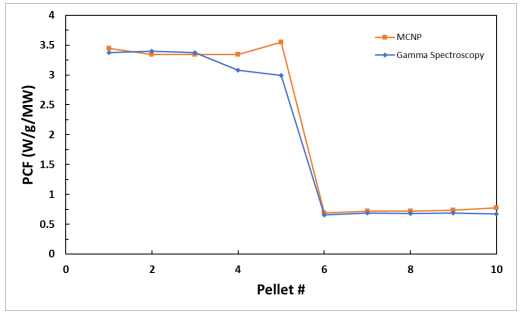
Transient shapes and energy injections for natural enriched fresh UO_2

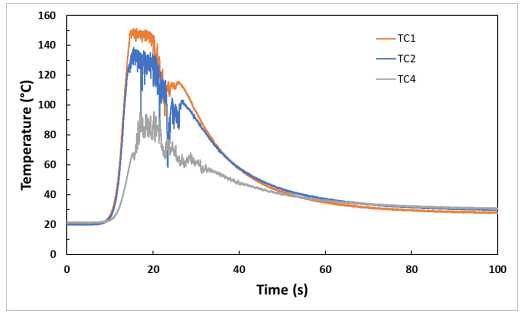


Assembled Capsule (capsule bottom not shown)

MARCH-SERTTA Commissioning Test

- **Commissioning Project Test Matrix**
  - Five tests to follow the Gamma test
  - Successfully irradiated ATF-RIA-1-A through D capsules to meet a PEMP notable outcome in FY20
  - First safety analysis test in water
- **ATF-RIA-1-Gamma**
  - Gamma test utilized 5 4.95% U^{235} pellets and 5 0.74% U^{235} pellets
    - *Provide upper and lower PCF bounds for all UO_2 tests*
  - Irradiated using a 0.6%Δk/k transient clipped to 100 MJ





Pellet by pellet PCF and cladding temperature measurements

Test ID	Rodlet Pressure	Capsule Pressure at Temp.	Capsule Temp. (°C)	Step Insertion (%Δk/k)	Specimen Energy Deposition Target (J/g)	Reactor Energy (MJ)	FWHM (ms)	Cladding Temp. Targets (°C)	Anticipated Failure Mechanism	Test Purpose
ATF-RIA-1-A	Atm.	0.38 MPa	25	4.2	860	1260	90.5	≤ 1200	None	Achieve Film Boiling from RTP Initial Conditions
ATF-RIA-1-B	Atm.	0.38 MPa	25	4.2	1110	1617	99.4	> 1200	High Temp Embrittlement	Observe Cladding Embrittlement without Burst
ATF-RIA-1-C	Atm.	1.8 MPa	200	4.2	530	1051	89.8	~850	None	Achieve Film Boiling with slightly subcooled initial conditions
ATF-RIA-1-D	2 MPa	1.8 MPa	200	4.2	740	1470*	93.8	≤ 1200	Ballooning and Burst	Demonstrate Ballooning and Bursting during Film Boiling
ATF-RIA-1-E	2 MPa	1.8 MPa	200	4.2	940	1860*	109.2	> 1200	Ballooning and Burst + HT Embrittlement	Demonstrate Cladding Embrittlement with Ballooning and Bursting
	*Based on previous test results the energy deposition may be able to be adjusted down using other transient prescriptions									

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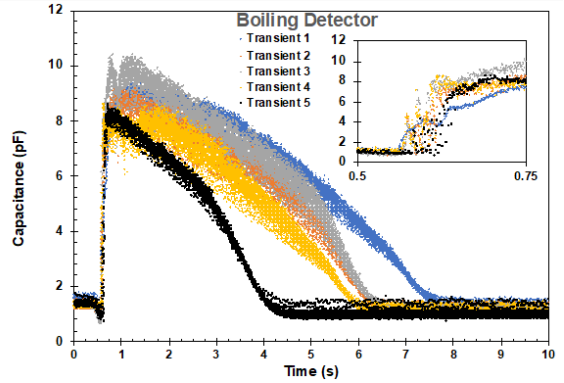
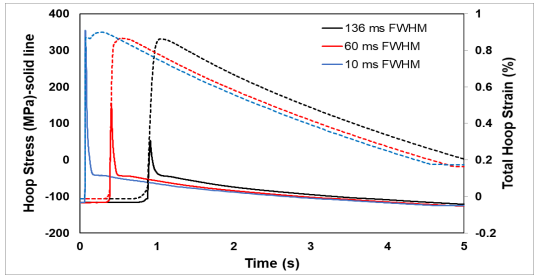
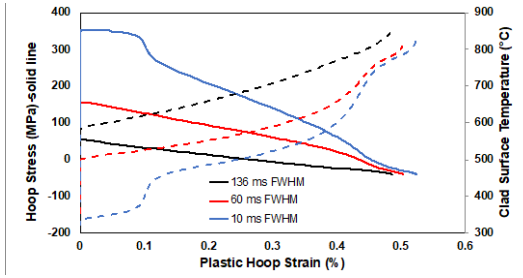
RIA Testing Moving Forward

- **MARCH-SERTTA commissioning tests and CHF-SERTTA tests have demonstrated the capsule is capable for RIA testing in TREAT**
  - Electro-impedance boiling detector has shown great promise in CHF-SERTTA tests
  - First-look at LVDT elongation and plenum pressure show good performance from instruments
  - Thermocouple performance has shown some anomalies that are currently being investigated
- **Future test programs include:**
  - Completing ATF-RIA-1-E test (December 2020-January 2021)
  - ATF-R test campaign
    - *Demonstrate capability to test previously irradiated fuel rods in TREAT*
    - *Evaluate post-DNB survivability of Zircaloy clad fuel*
    - *Plans to test up to 5 ATF-2 rods from ATR*
    - *FY20 a PEMP notable outcome was completed to demonstrate ability to assembly a rod in a capsule in HFEF*
  - DNB/AOO testing (short, low temperature transients)
  - HERA (international program under the NEA FIDES program)
    - *Study impact of transient pulse width on simulated high-burnup fuel rods*
    - *Pulse width impacts cladding temperature which can determine failure mode*



CHF-SERTTA electro-impedance boiling detector data





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