INL/MIS-23-73513-Revision-0

Pre-Transient Characterization of Historic EBR-II Pins for THOR-M-TOP-1

August 2023

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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Pre-Transient Characterization of Historic EBR-II Pins for THOR-M-TOP-1

Allison Probert | University of Florida | U210 | Jason Schulthess, Luca Capriotti

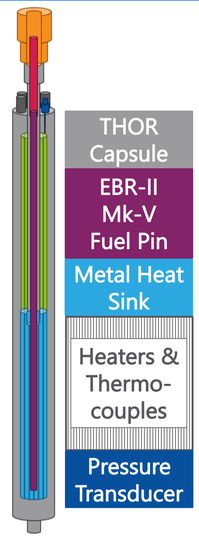
Background and Motivation

Deployment of sodium-cooled fast reactors (SFRs) demands safety testing of candidate metallic fuels.

Historically, **U-Pu-Zr and U-Zr have demonstrated benign behavior during accident conditions**, such as transient overpower (TOP) occurrences.

However**, available data is scarce** and shows fuel behavior depends on composition and irradiation history.

Expanded TOP testing will resume conducted within the modern and highly instrumented Transient Heatsink Overpower Response (THOR) capsule in the Transient Reactor Test (TREAT) facility.



Methods

Two high-burnup (11.1-11.6 at.%) U-19Pu-10Zr pins, irradiated in EBR-II and stored for 36 years, will be used in THOR-M-TOP-1.

Pin DP-40 will undergo TOP conditions in TREAT while DP-36 will be the sibling pin for pre-transient destructive analysis.

Pre-transient characterization conducted on **both pins** includes:

- Visual Examination Machine (VEM)
- Precise Gamma Spectrometry (PGS)
- Neutron Radiography (NR)
- Element Contact Profilometry (ECP)

Non-Destructive

DP-36 was also examined using:

- Gas Assay, Sample, and Recharge System (GASR)
- Sectioning and Optical Metallography (OM)

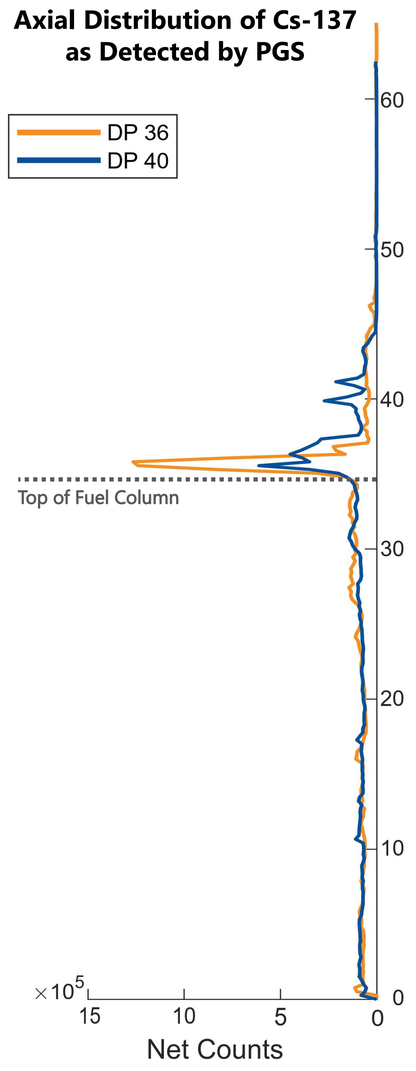
Destructive

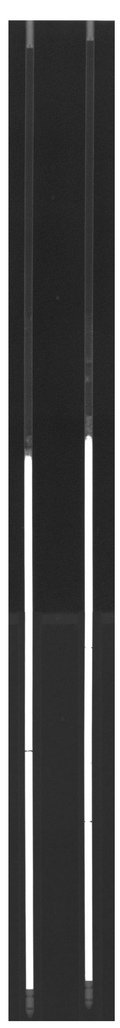
Non-Destructive Examination

Visual Examination:

No corrosion occurred during pin storage.

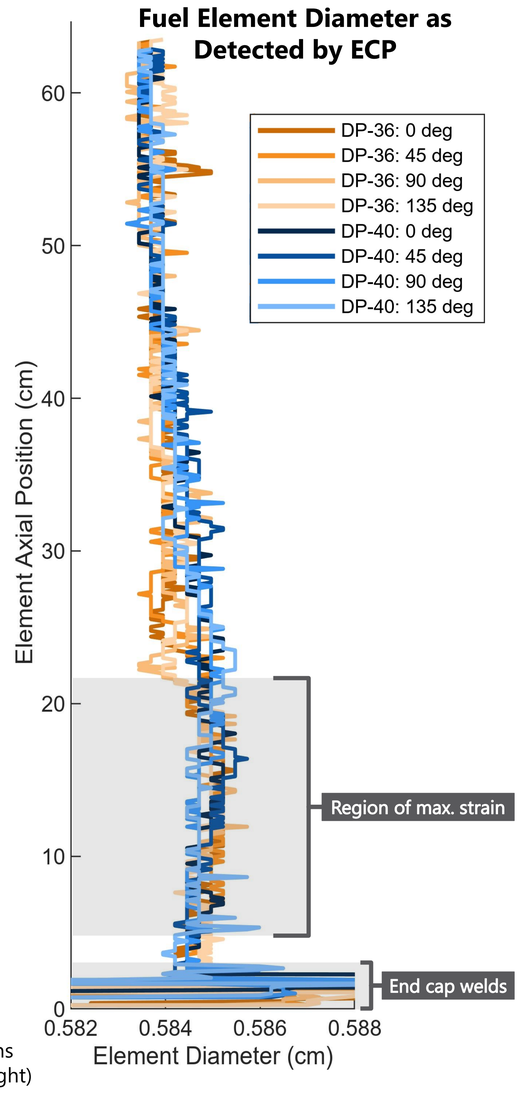
Axial Distribution of Cs-137 as Detected by PGS





Neutron radiograph of pins DP-36 (left) and DP-40 (right)

Fuel Element Diameter as Detected by ECP



Precise Gamma Spectroscopy:

Cs-137 fission product mobilized within the Na bond between the fuel and cladding.

Fuel expansion extrudes the liquid Na bond and dissolved Cs-137 to the plenum.

Neutron Radiography:

Low-density regions at the tops of the fuel elements indicate fuel-sodium bond interaction.

Collected measurements of fuel slugs from NR revealed 2.2-3.7% axial elongation.

Element Contact Profilometry:

Maximum strain of up to 0.3% occurred along the lower half of both fuel columns.

- Suspected fuel-cladding mechanical interaction from the small plenum-to-fuel volume ratio

Destructive Examination

Optical Metallography:

The transverse cross section of the low-density fluff structure can be seen at 0.98 x/L.

Constituent segregation is evident at 0.50 x/L as concentric regions of varying composition and material properties.

Initial redistribution is evident at 0.25 x/L but less distinguished than at 0.5 x/L.

Conclusions and Future Work

A solid baseline for steady state behavior has been established for high burnup U-19Pu-10Zr to attribute post-transient observations to transient fuel behavior.

Next Steps:

GASR analysis for DP-36 will be finalized.

THOR-M-TOP1, containing pin DP-40, will undergo an intermediate transient in TREAT.

- Post-transient analysis will include NR, ECP, PGS, GASR, OM, SEM, electron probe micro-analysis, burnup and fuel isotopic analysis, and bulk thermal property measurements.

Fuel behavior monitored and quantified through thermomechanical in-situ measurements and post-transient characterization will provide crucial understanding of metallic fuel behavior under accident conditions and further SFR fuel qualification.

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