Annular Core Research Reactor

ACRR Advanced In-Service Fuel Inspections

SAND # TBD
TRTR Conference 2021

Joshua Smith, Reactor Operator

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Abstract

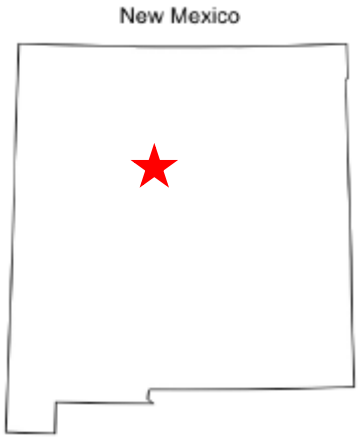
The Annular Core Research Reactor (ACRR) has been in a prolonged maintenance period since 2020 to perform advanced in-service fuel inspections. Traditional methods of fuel inspections at ACRR consist of visual observations of the fuel element while suspended from a fuel handling tool. This method has drawbacks such as poor video quality, poor lighting control, and difficulties obtaining a stable visual inspection. To improve fuel inspections, a Fuel Element Inspection Jig (FEIJ) has been built. The FEIJ is a stable platform with precise camera and lighting control for inspecting fuel elements. The FEIJ was also built to incorporate advance fuel inspection techniques including a load cell for weight measurements, a Go/No-Go fit test, and ultrasonic probes for the purpose of detecting a cladding breach and water ingress.

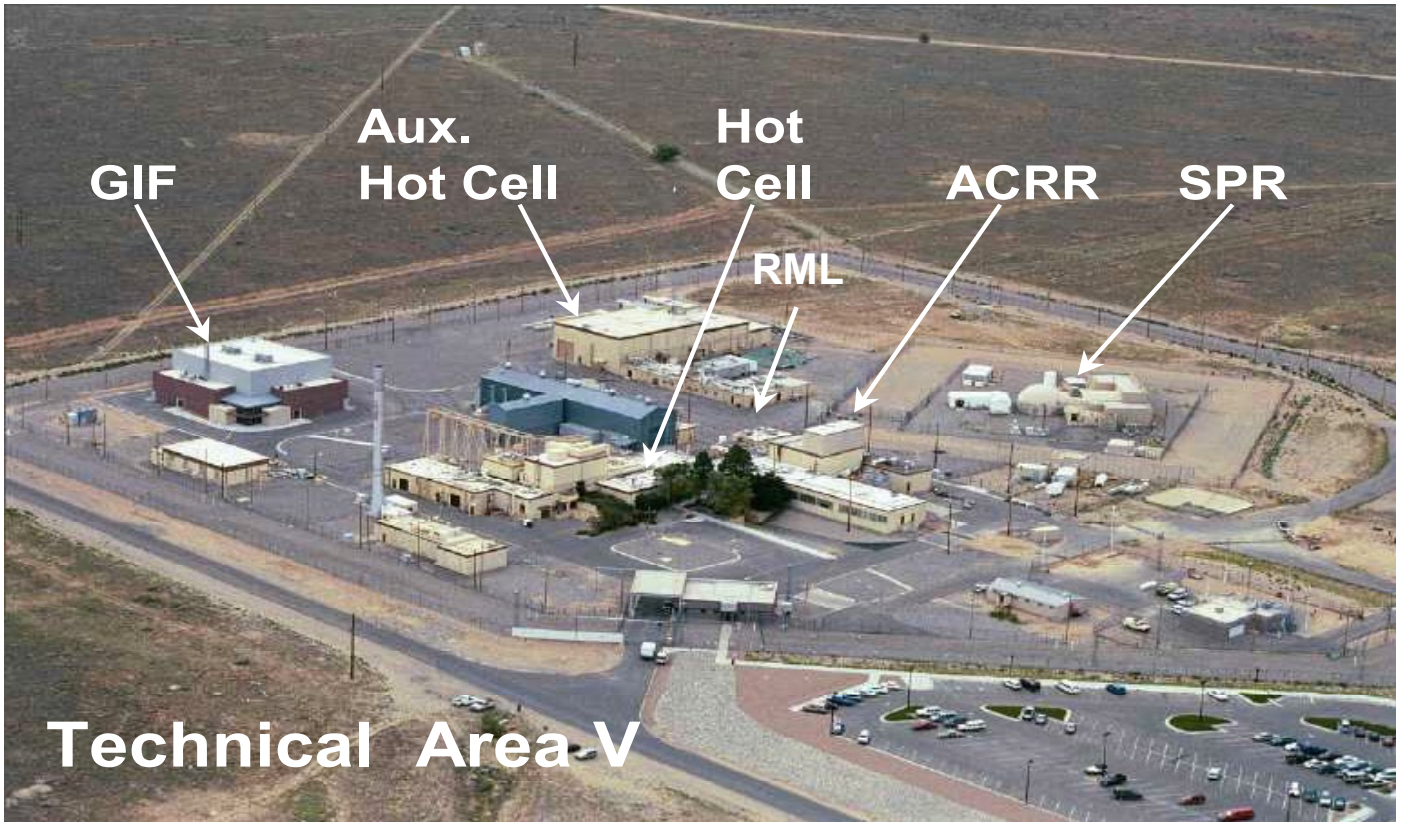
To characterize the fuel, a Fuel Health Program was developed to describe the process and criteria for grading fuel elements. Visual inspection criteria were developed with the help of Subject Matter Experts (SMEs) in the fields of welding, corrosion, and mechanical damage such as dents and scratches. Ultrasonic testing criteria and reference standards were also developed and built with the help of Ultrasonic SMEs. The fuel inspection process and criteria, as well as lessons learned from ACRR fuel inspection campaigns, will be described in further detail.

To use the FEIJ, the ACRR fuel inspection procedure had to be significantly revised. In addition, Management, Contractor, and Federal readiness assessments were performed to evaluate the ACRR fuel inspection process. A major fuel inspection campaign began late June 2021. The goal of this campaign was to inspect all remaining fuel elements in the core that had not been previously inspected in 2020. Approximately 169 elements were identified for the 2021 fuel campaign and as of the end of July, ~111 fuel elements have been inspected and evaluated. The frequency for future ACRR fuel inspections is a target of 20%/year (~47 elements/year), not including the Fuel Ringed External Cavity (FREC) fuel elements. Selected results from the ACRR fuel inspection campaigns will be described in further detail.

SNL TECHNICAL AREA V (TA-V)

- **Sandia National Labs is located on Kirtland Airforce Base in Albuquerque, NM**





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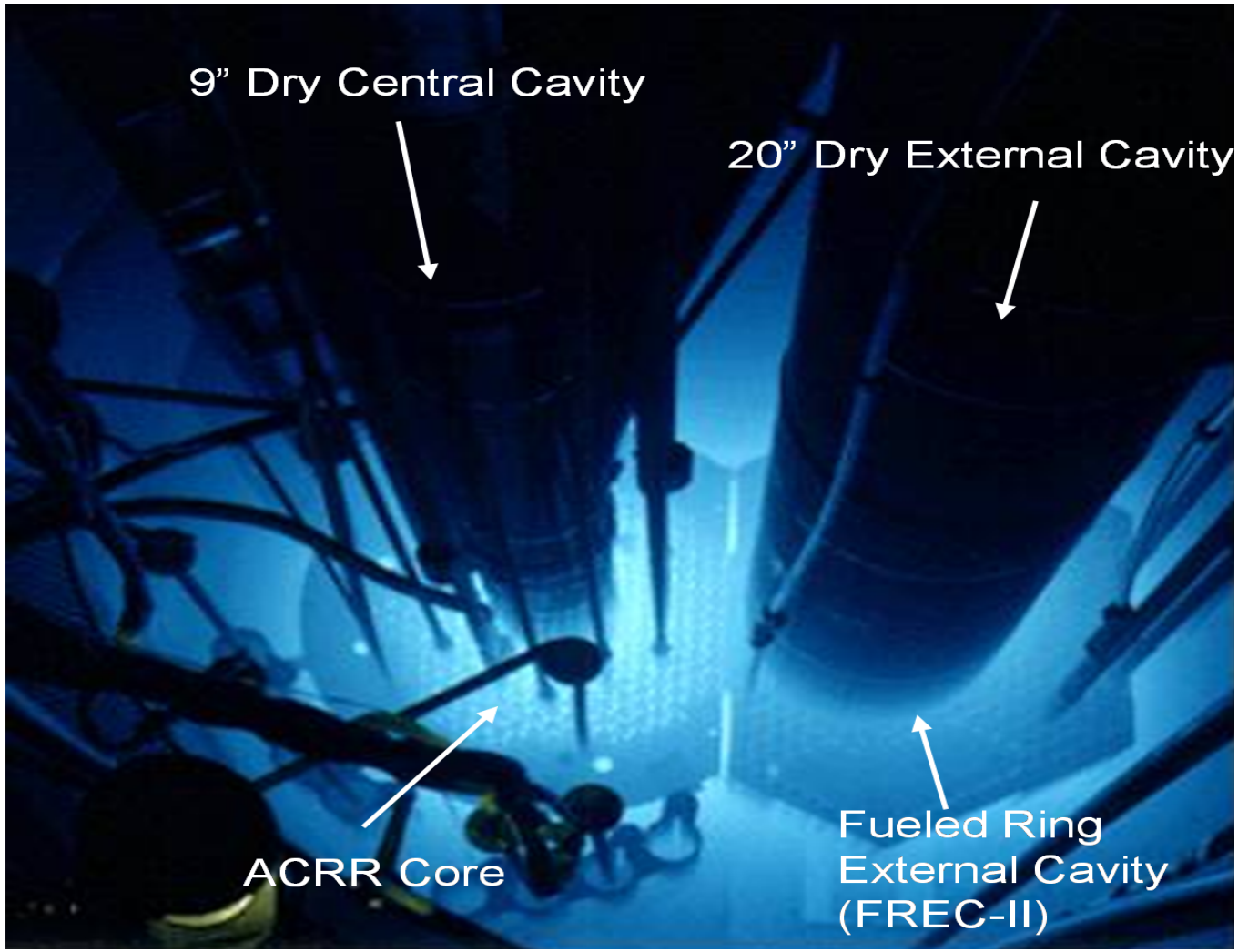
ACRR Current Configuration



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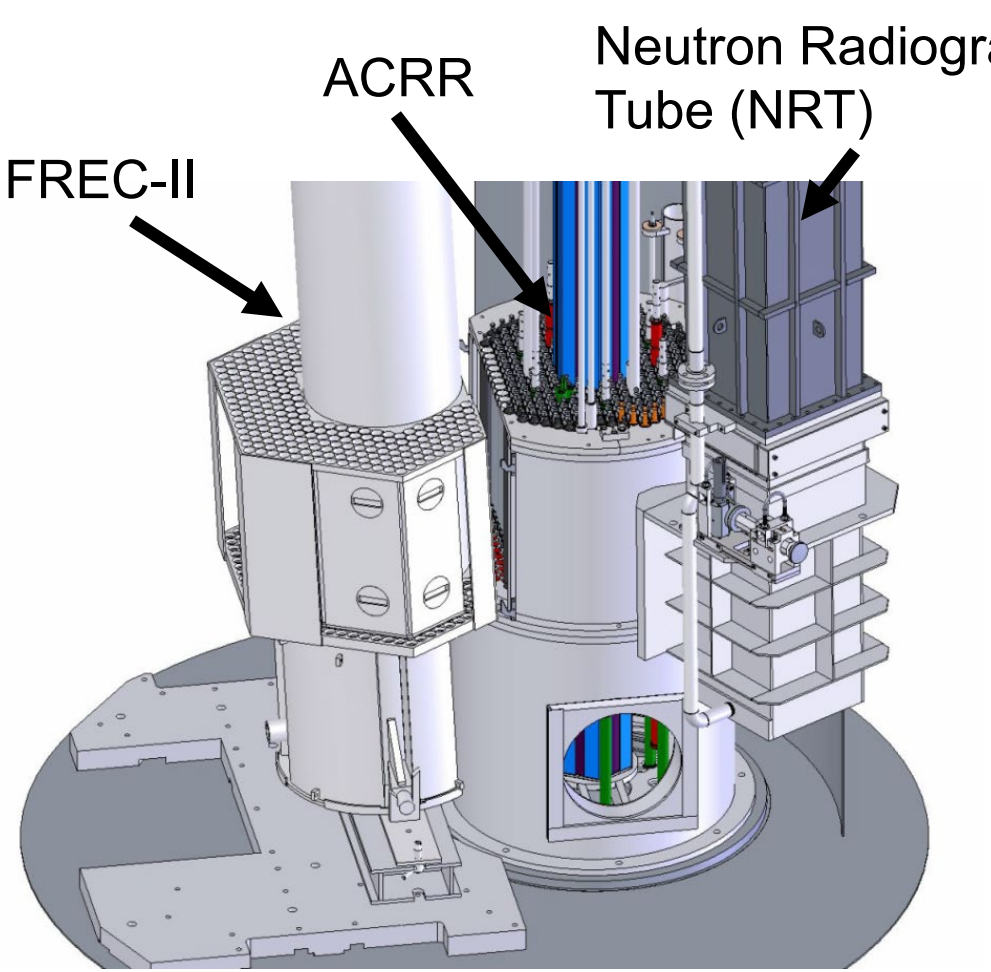
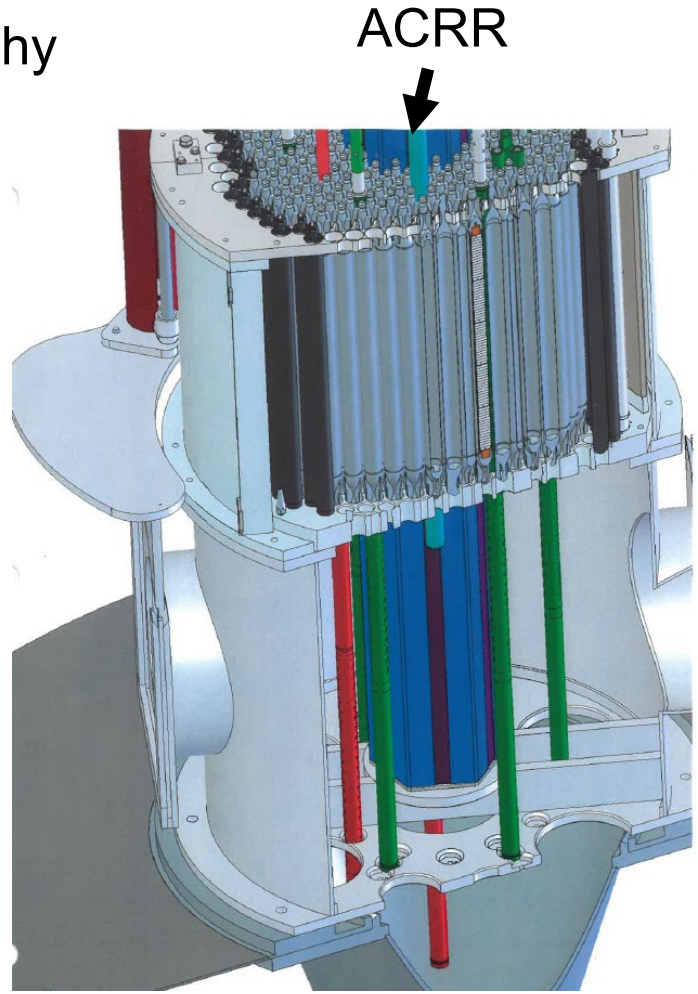
ACRR 3D Views

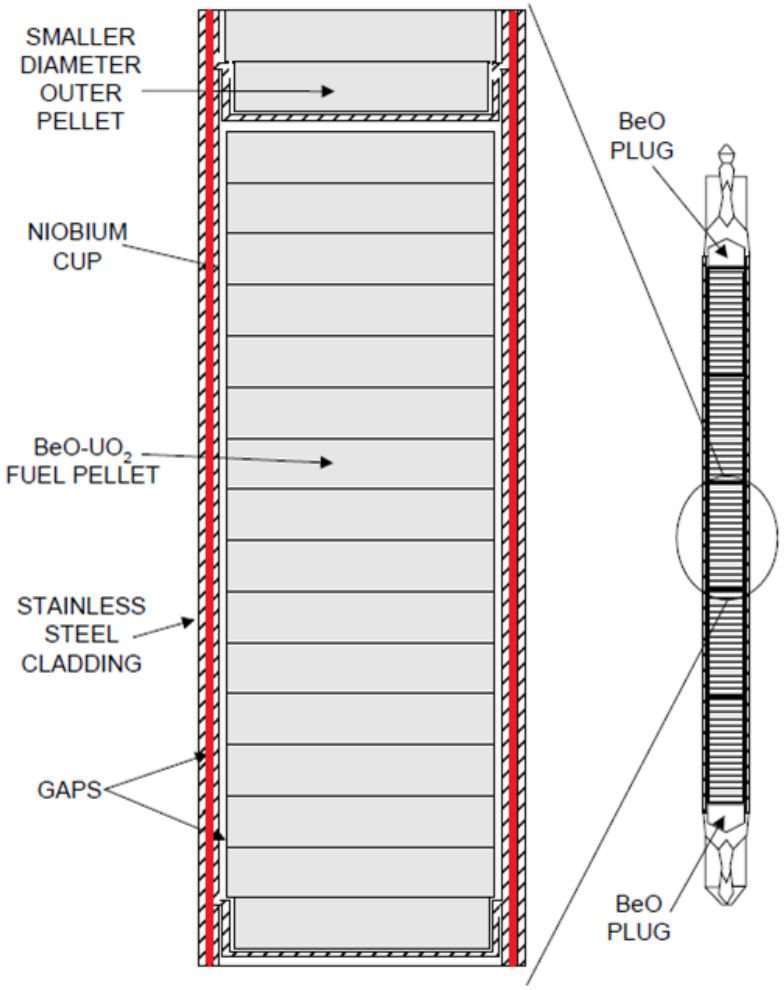




Fuel Inspection Timeline

Dec 2019	• Cladding breach found on Safety Rod 1 (SR1)
Jan 2020	• Removed SR1 from core and into storage • 16 elements were inspected around SR1, which lead to identification of a suspect Fuel Element (FE #134) with unusual discoloration and a potential crack in the clad
Sept 2020	• Inspected 42 elements using the traditional (visual) method and applied grading criteria to obtain more statistical data on potential cladding defects overall in the core
Nov 2020	• Ultrasonic method ready for deployment. Performed UT scan of FE #134 and determined no water ingress.
Dec 2020 – Apr 2021	• Performed many readiness assessments (Management, Contractor, Federal) using the Fuel Element Inspection Jig (FEIJ) and a mock element
Jun 2021 – Aug 2021	• Performed the 2021 fuel inspection campaign. Target was to inspect 169 fuel elements.

ACRR Fuel Design

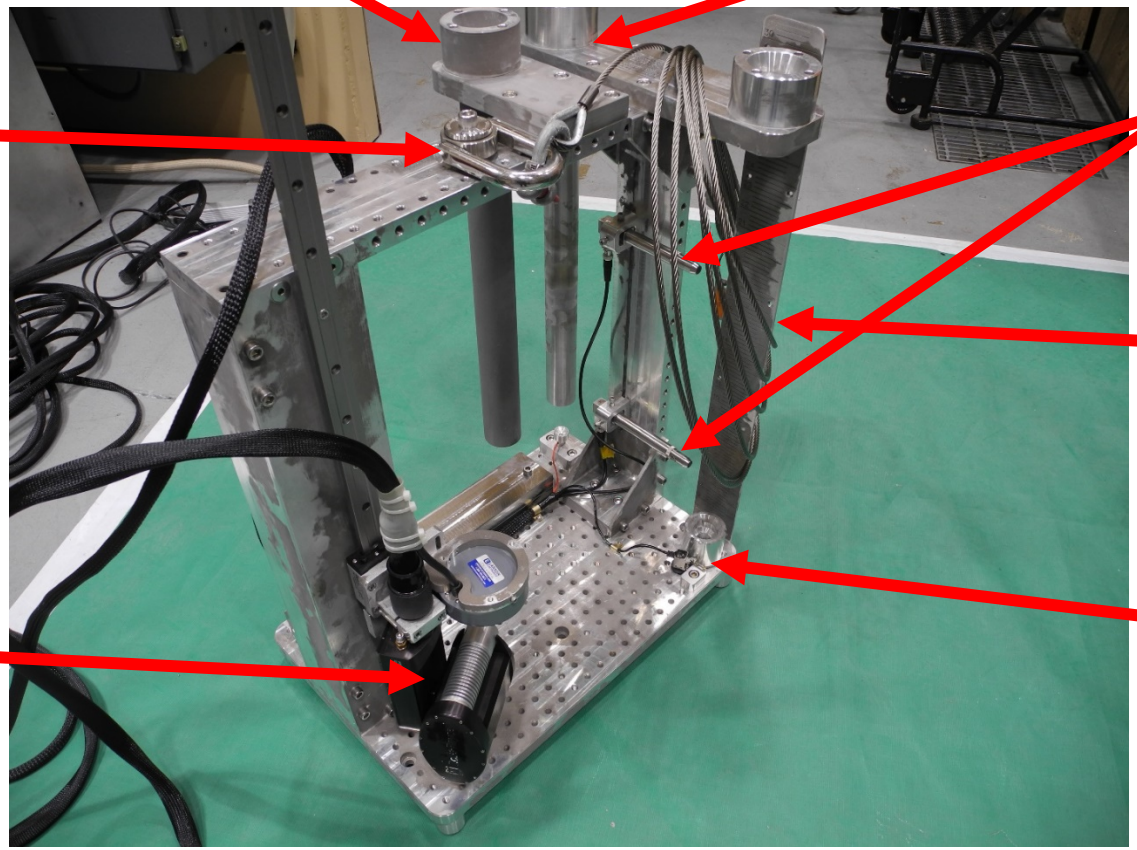


- ACRR UO_2-BeO fuel was fabricated in the late 1970's
- Fuel cladding is a 20 mil thick tube of stainless steel that is welded to top and bottom end caps
- Clad acts as barrier to maintain helium backfill and prevent fission product escape
- A breach of the clad is a safety concern requiring removal of element from service

Fuel Inspection Methods

- Historically, fuel inspections were performed using visual techniques
  - Fuel lifted out of core with a tool, held in place, and inspected with underwater camera
  - Stability, lighting, video quality, and rotating the fuel were issues
- Visual inspections alone could not quantify if the cladding had been breached
- Various techniques were considered and the following were implemented:
  - Visual
  - Dimensional (Go/No-Go gauge)
  - Ultrasonic
  - Mass measurement
  - Bubble Test (lift element to cause change in hydrostatic pressure and force gas out of a potential breach)

Fuel Element Inspection Jig (FEIJ)



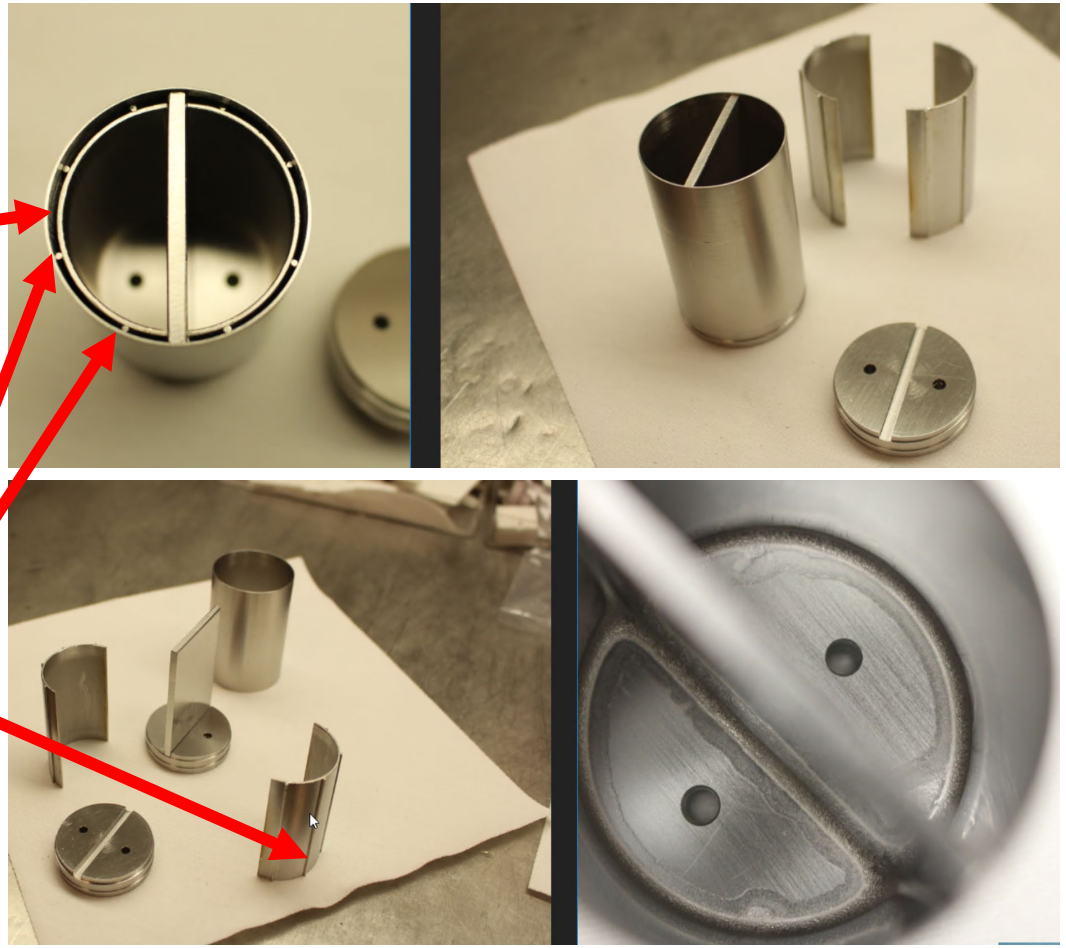
Ultrasonic Testing

- Ultrasonics required additional equipment and testing to function
  - A reference standard was built to compare a water filled vs dry fuel element
  - Extensive testing was done on the reference standard with a UT expert
  - UT probes were irradiated to verify radiation tolerance
    - Ideally, a UT probe would be as close to the surface as possible, but radiation damage was a concern and so the FEIJ design had offset probes (1 and 2 in probes)

UT Reference Standard Construction

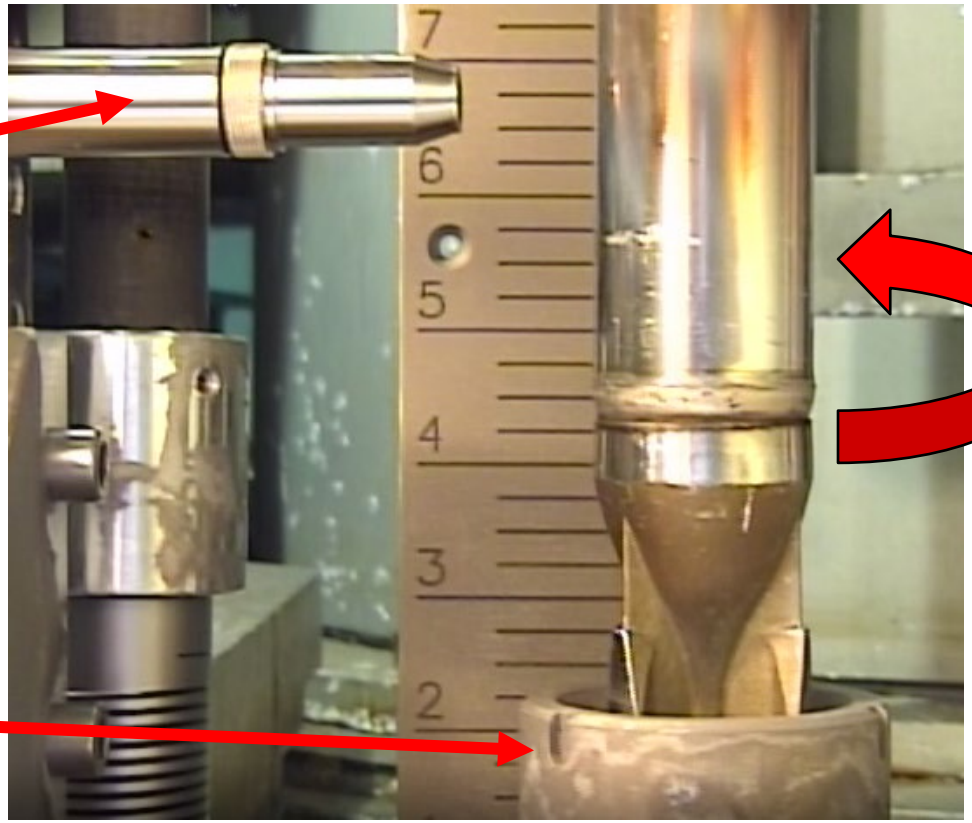
Water is added to half the cylinder while the other half remains dry

Niobium cup ridges will only be detected when water is present



Performing UT

Bottom UT probe (channel 1)



Fuel element rotated 360° while UT data is collected

Rotatable saddle with encoder

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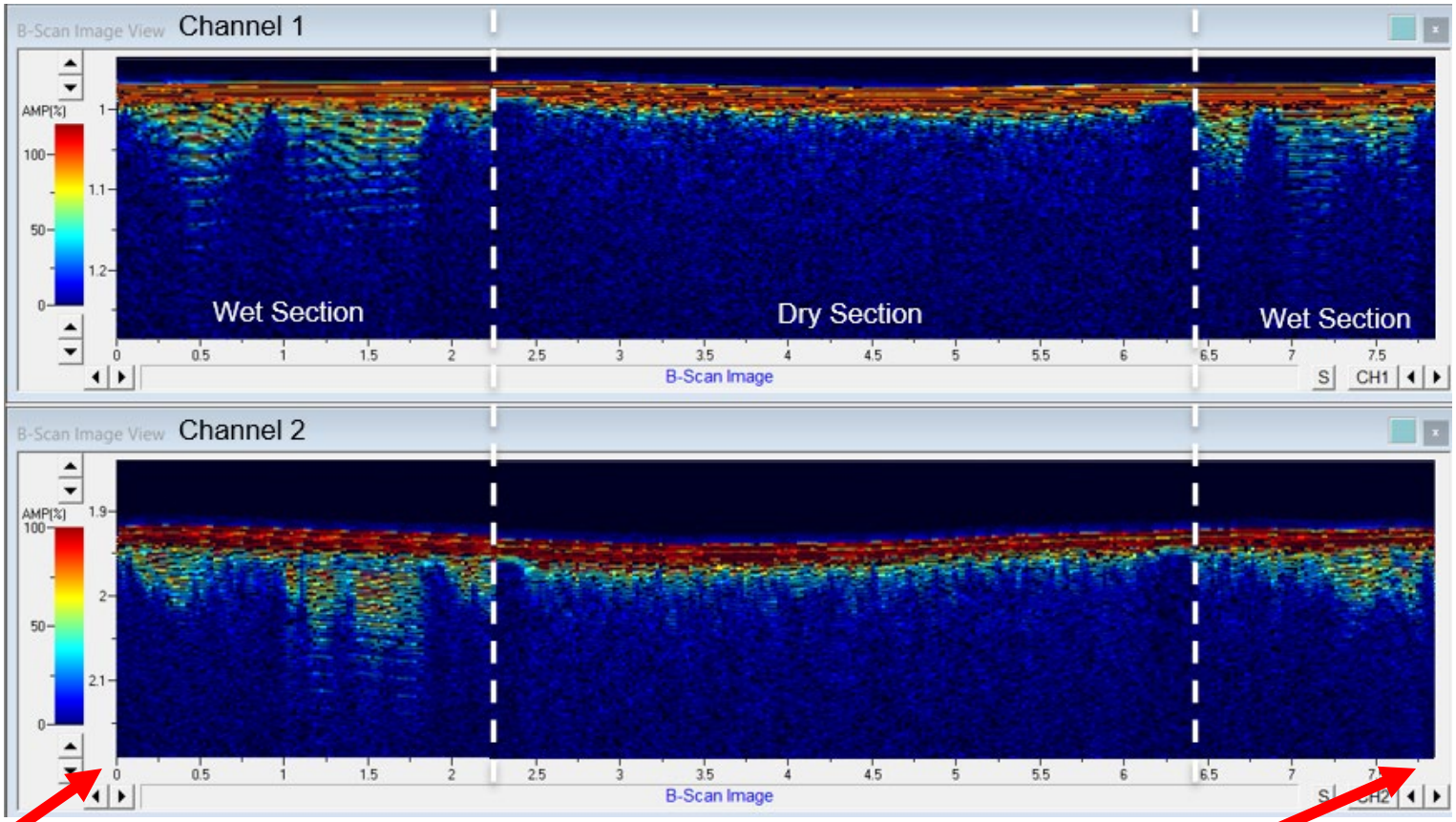
UT Reference Standard Results



0°

360°

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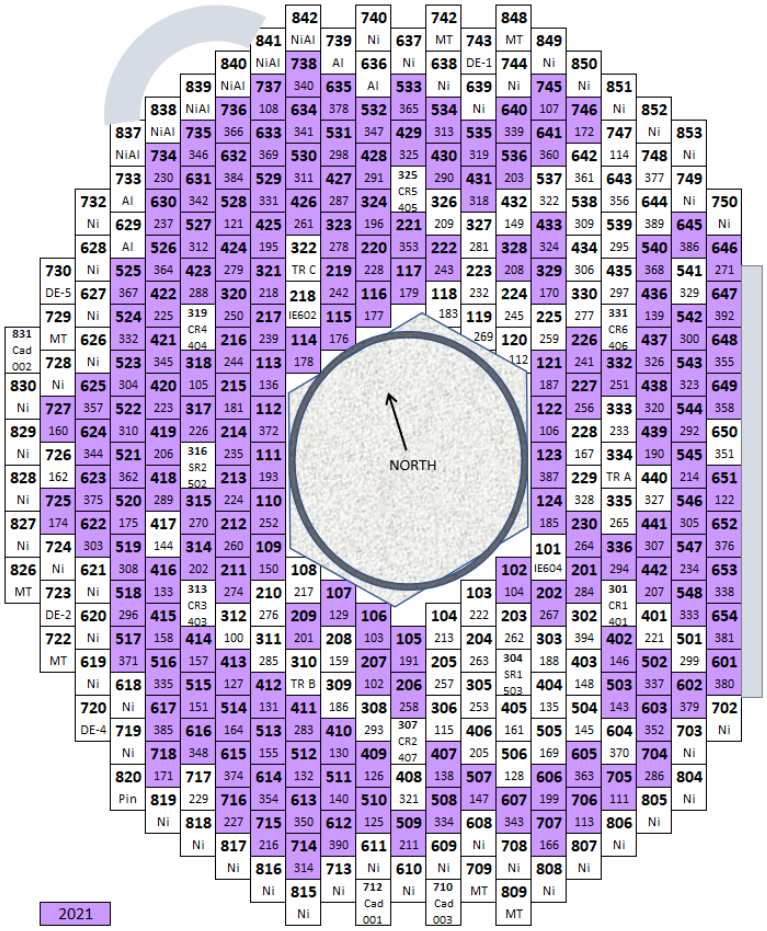
Inspection Criteria

- Developed criteria with input from Ultrasonic, Material Science, and Welding Subject Matter Experts
- Fuel elements would be graded as follows:
  - ‘A’ Grade
    - Pass
    - FEs are in like-new condition or have minor defects
  - ‘B’ Grade
    - Pass, but FEs have increased inspection frequency (e.g. <5 year interval)
    - These FEs have defects that have the potential to grow or evolve over time
  - ‘C’ Grade
    - Further analysis needed, remove from service until recategorized
    - More thorough defect characterization, experimental data, and analysis by a subject matter expert is need
  - ‘D’ Grade
    - Failure, immediately remove from service
    - A confirmed cladding breach or a defect that is very likely to produce a cladding breach

2021 Fuel Inspection Campaign



- Planned to inspect 169 (highlighted purple) out of 236 FEs
- 57 FEs were already inspected in 2020, so they were excluded from this list

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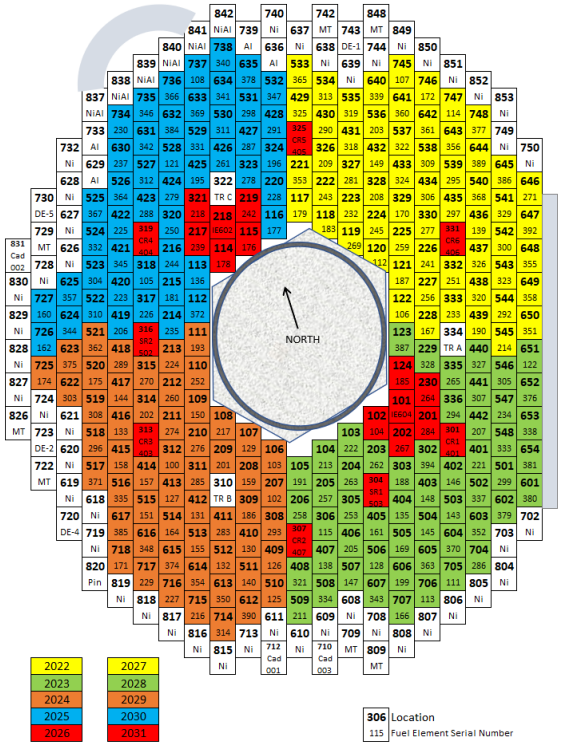
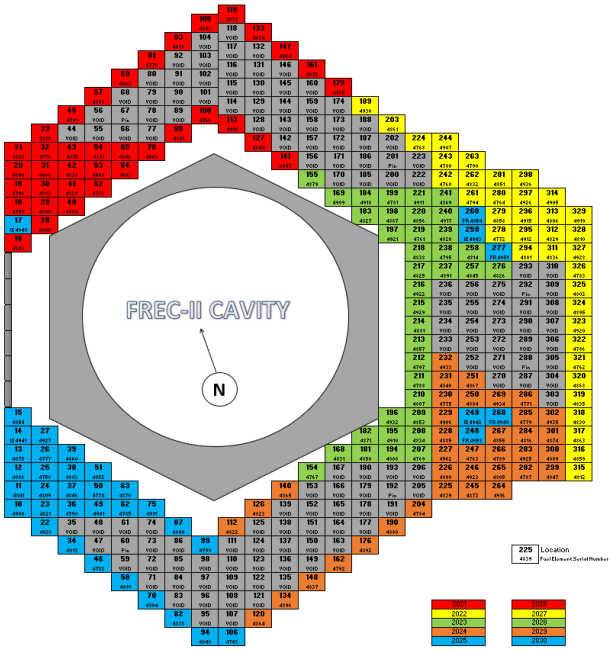
Fuel Inspection Interval

- **Long term goal is to inspect ~20% of ACRR fuel and FREC fuel per year**





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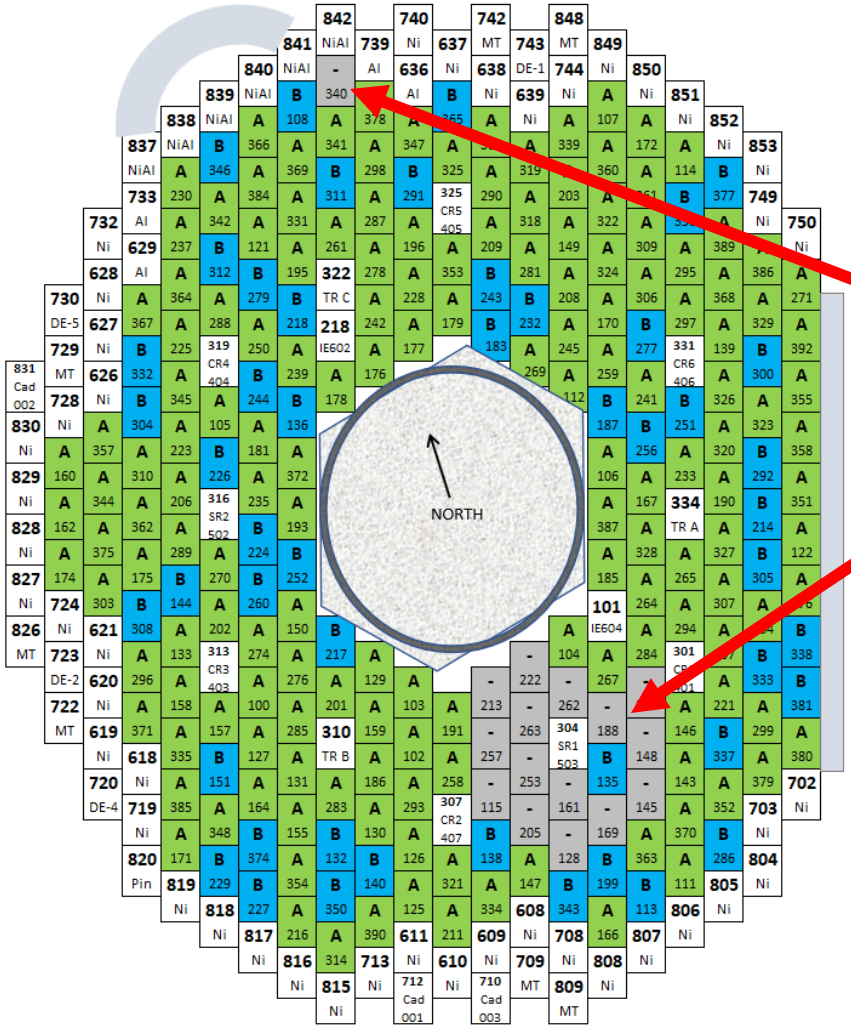
Inspection Summary

- All fuel elements passed ultrasonic inspection (no water ingress)
- Mass measurements were within expected range for all elements
- All elements passed Go/No-Go inspection (no bowing or swelling)
- Replaced three “B” graded elements with spares
  - These were selected as initial candidates for a fuel recladding program
- The 2021 fuel campaign took a significant amount of effort and resources
  - Estimated ~42 hours for fuel movement and data gathering
  - Estimated ~128 hours for data review and analysis
  - Year+ for FEIJ development, fabrication, testing, procedure changes, readiness assessments, etc.

Distribution of Grades



Year	"A" Grades	"B" Grades	Total
2020	35	8	43
2021	128	40	168

- **One element could not be physically removed from the core due to an obstruction**
- **15 elements were inspected prior to the grading criteria being developed, therefore no grades were assigned**

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Issues and Lessons Learned

- The encoder failed unexpectedly on two separate occasions
  - Caused a delay of a few days
  - UT measurements had to be repeated on eleven elements
- Mass measurement
  - Initially mass measurements varied significantly
  - Modified the FEIJ load cell chamfer to allow better seating
- Fuel rotational tool would not fit over some fuel elements
  - Center bore of the tool had to be modified
- Core grid obstruction prevented inspection of one fuel element

The End

- Thank you for your time
- Contact info
  - Joshua Smith: jsmit19@sandia.gov