Advanced Gas Reactor Fuels Program Review

AGR-2 Inspection, Disassembly, and Metrology

Paul Demkowicz, Technical Lead for Fuels Post-Irradiation Examination

July 15-16, 2015

www.inl.gov

Idaho National Laboratory

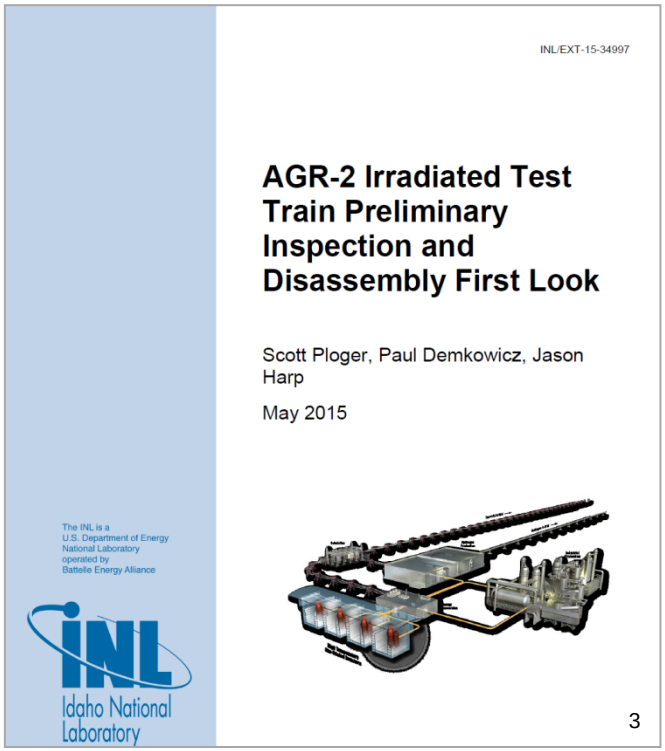
Outline

- Test train receipt and nondestructive analysis
- Disassembly
- Metrology
  - Fuel compacts
  - Graphite holders
  - Capsule shells
- Summary

Timeline and Reporting

- Timeline:
  - Experiment shipped from ATR to MFC July 2014
  - Nondestructive exams completed July 2014
  - Disassembly: August - October 2014
  - Metrology (in-cell activities): September - December 2014

- AGR-2 Irradiated Test Train Preliminary Inspection and Disassembly First Look (INL/EXT-15-34997, May 2015)
  - Capsule 1 and 4 compact metrology data only available in proprietary appendices


INL/EXT-15-34997

AGR-2 Irradiated Test Train Preliminary Inspection and Disassembly First Look

Scott Ploger, Paul Demkowicz, Jason Harp

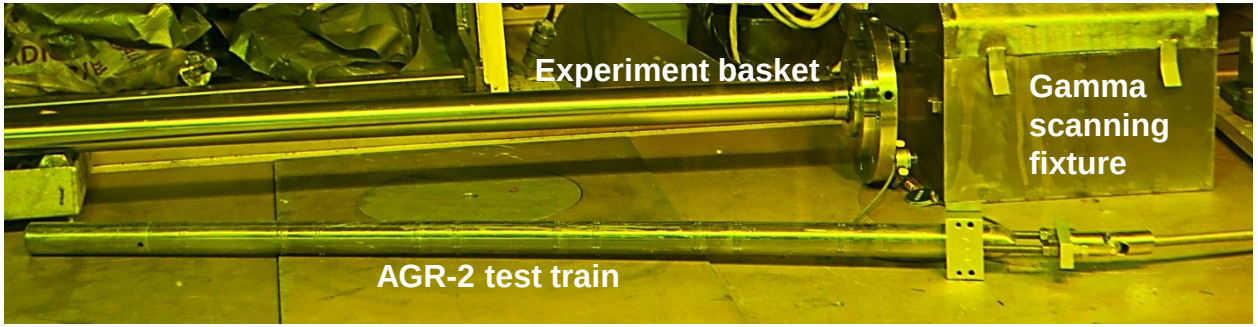
May 2015

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance

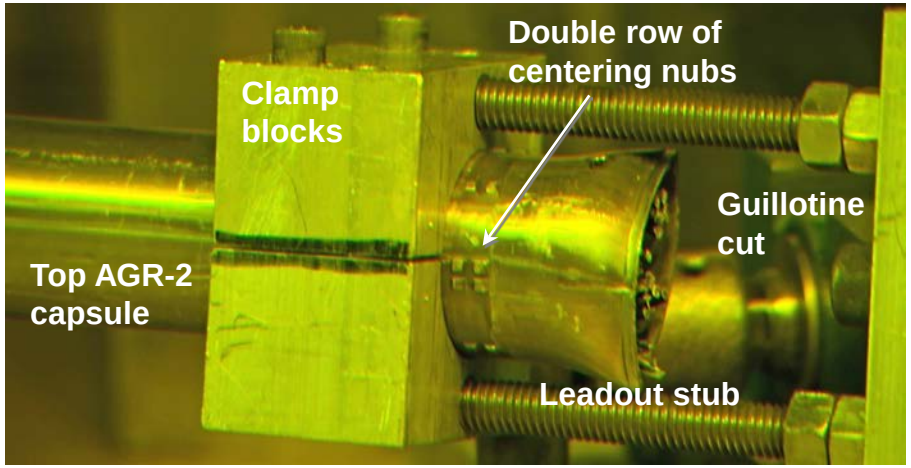
Idaho National Laboratory

Test train inspection

- No significant damage noted

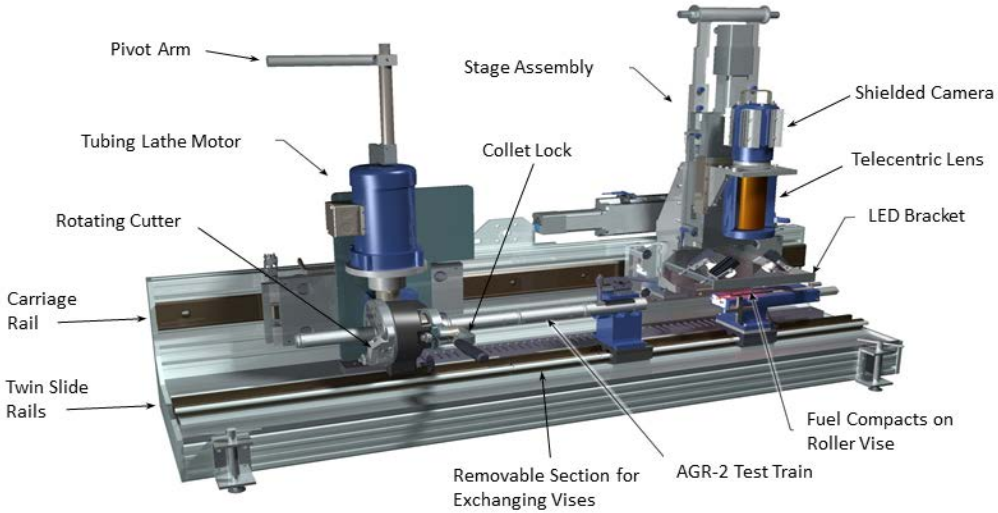


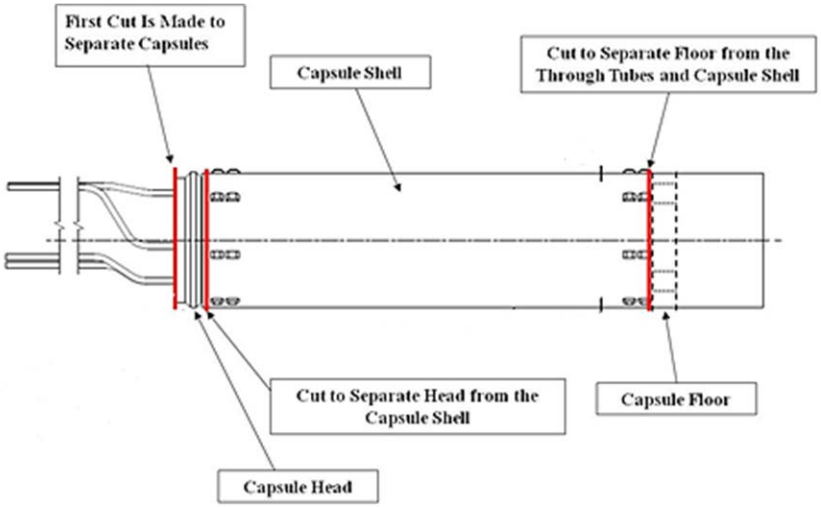
- Significant deformation at the guillotine cut did not extend below the top set of centering nubs
- Clamp fixture attached for gamma scanning
- Gamma scanning completed (J. Harp presentation, July 2015)



AGR-2 Disassembly

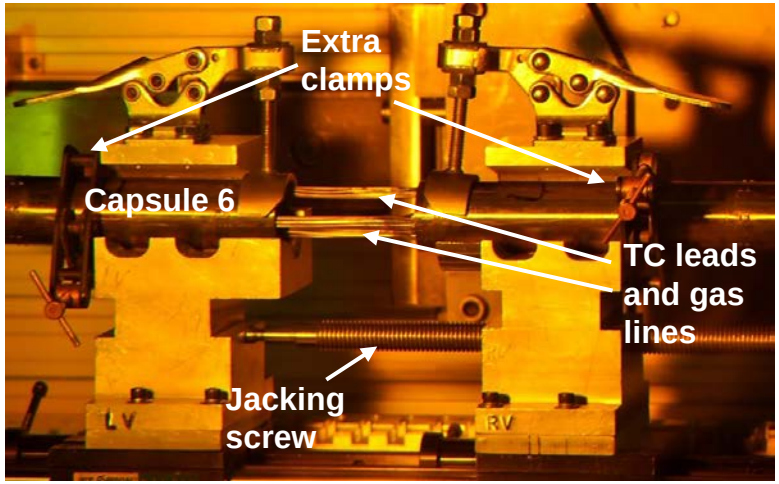
- Repurposed the AGR-1 disassembly and metrology equipment for use on AGR-2
- Tubing lathe used to make circumferential cuts to the capsule wall
- Vises on slide rails used to grip and separate components
- AGR-1 lessons-learned applied to AGR-2 disassembly



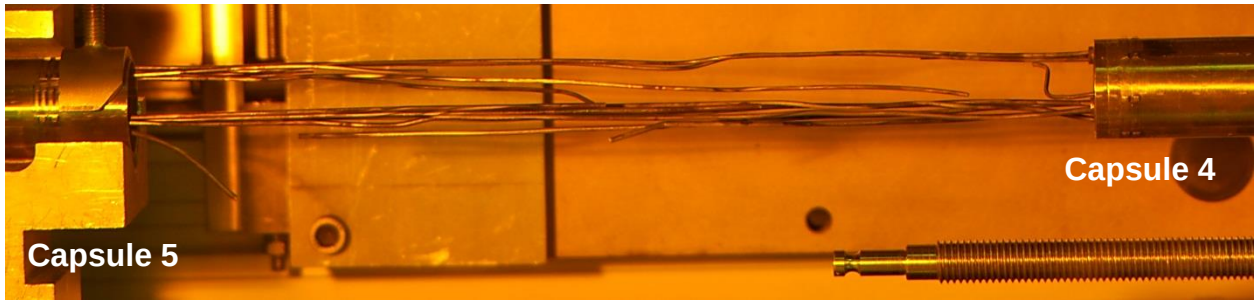


AGR-2 Capsule Separation

- Issues were encountered during Capsule 6 and Capsule 5 separation due to gas lines and thermocouple leads jammed in the through-tubes
- Use of a jacking screw was needed to remove Capsule 6

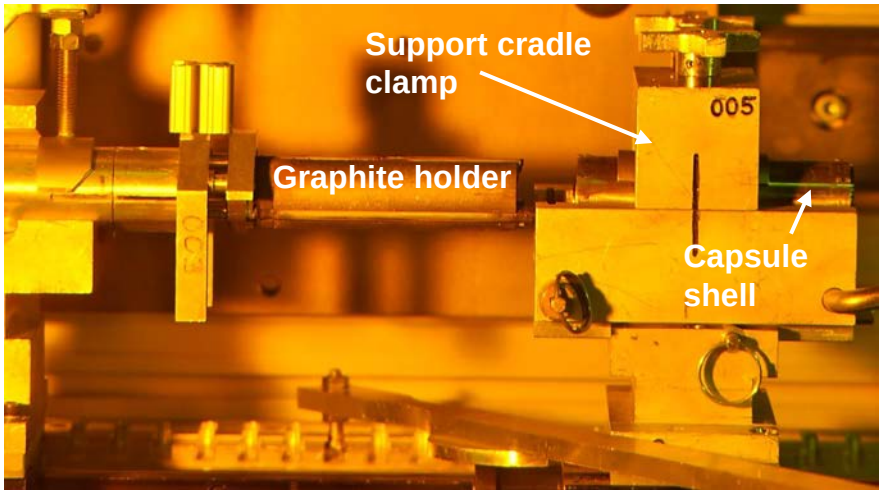


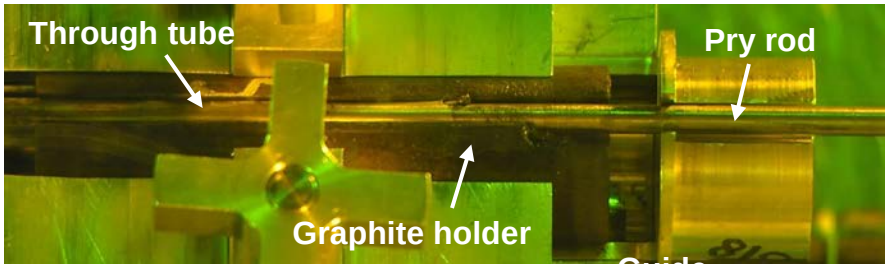
- Wire bundles were severely jammed in Capsule 5, and began to be pulled out of the lower capsules when separated with jacking screw; bundles were cut and later removed from the through-tubes with special tooling
- Removal of Capsules 1 – 4 proceeded without incident

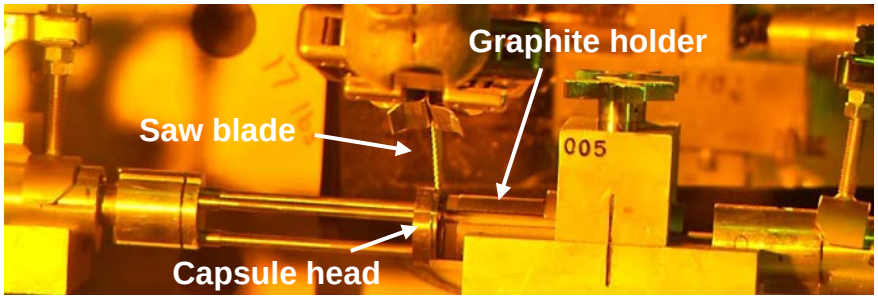


AGR-2 Capsule Disassembly

- Sequence:
  - Remove base
  - Remove shell
  - Remove graphite holder from capsule head
  - Push out compacts
- Some difficulties encountered removing graphite holder from capsule head
- Through-tubes needed to be broken; gas lines and TCs often were seized in the graphite holder and needed to be cut
- Compacts usually removed from holders with little force; 12-14lbf needed on two stacks (Capsules 1 and 5)

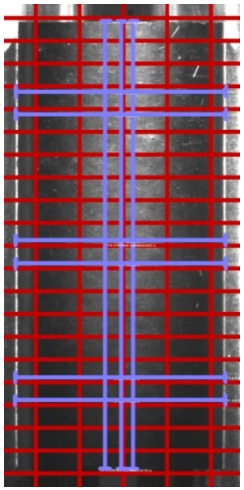






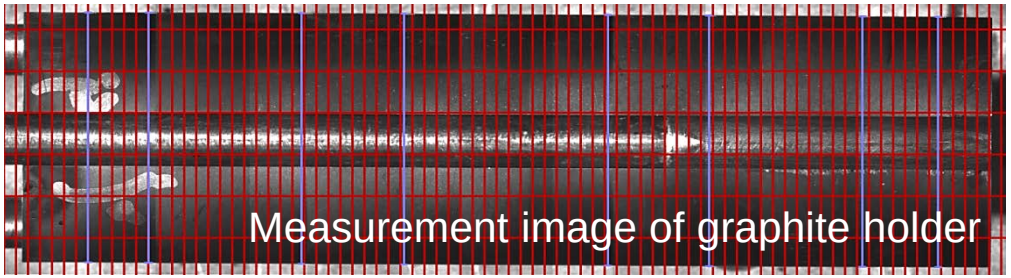
AGR-2 Metrology

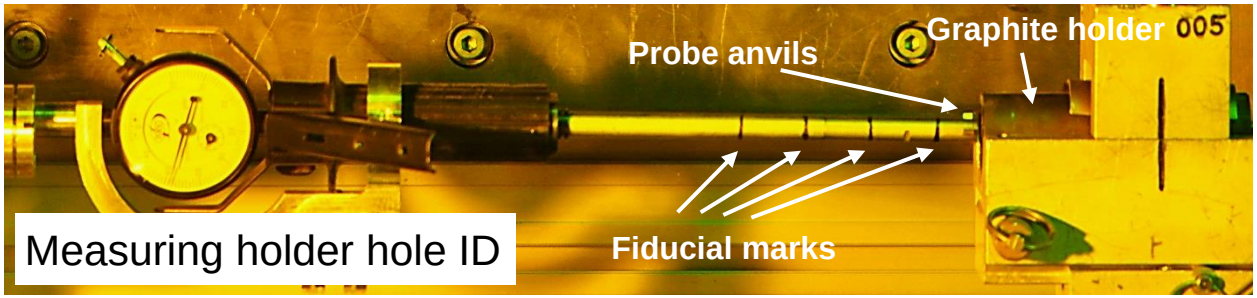
Measurement image of fuel compact



- Measurements on fuel compacts and graphite holders made from digital images (several images stitched together for graphite holders)
  - Compacts: Two measurements at top, middle, and bottom positions at one azimuth
  - Holders: Two measurements at approximate location of fuel compacts at one azimuth

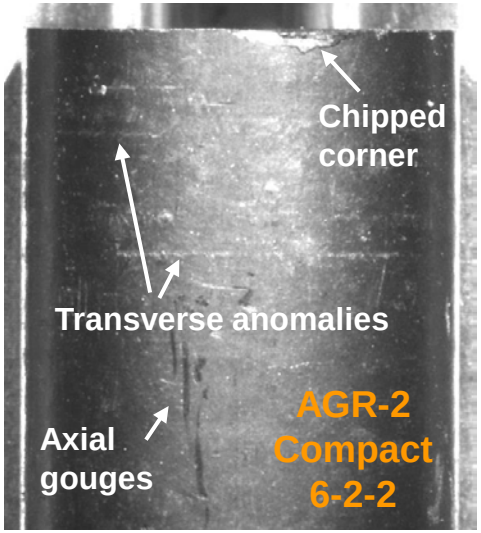
- Graphite holder hole and capsule shell inner diameters measured with bore gauges

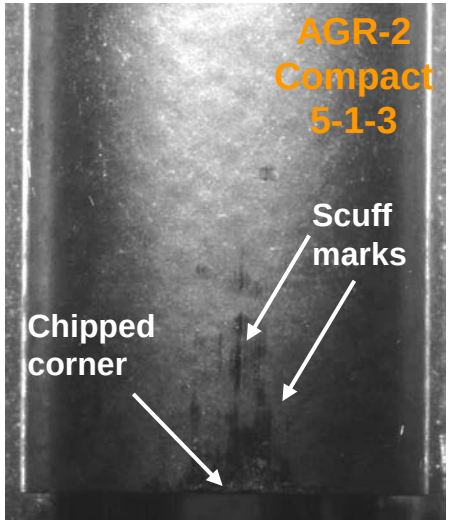


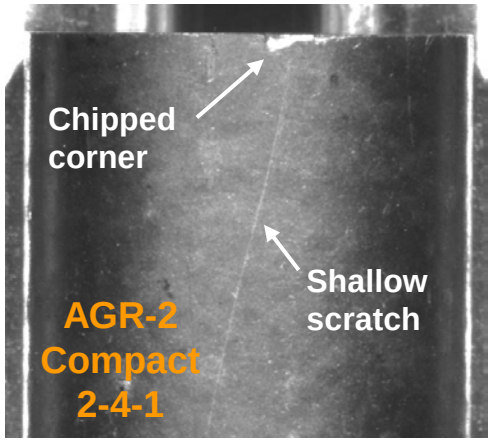


Compact visual inspections

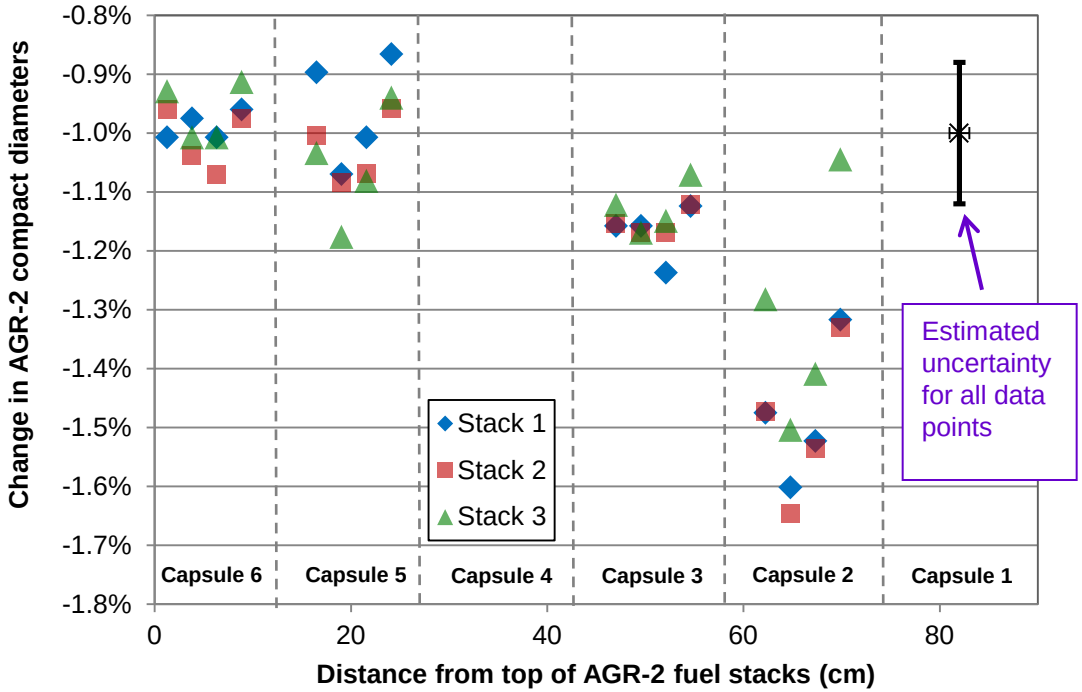
- Fuel compacts were generally in excellent condition
- A few compacts exhibited minor surface features; not all of these could be readily attributed to disassembly handling damage
- No evidence of particle loss or damage







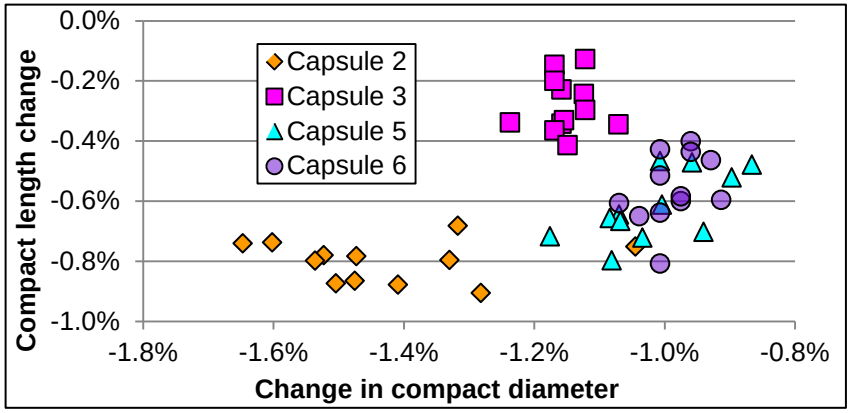
AGR-2 Compact Dimensional Change

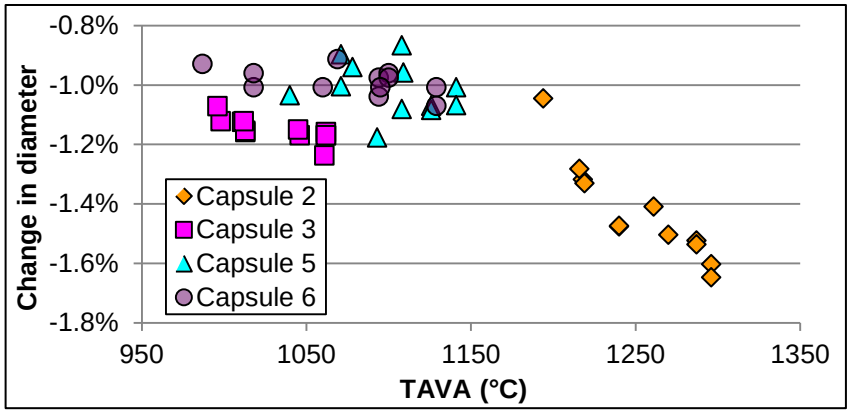


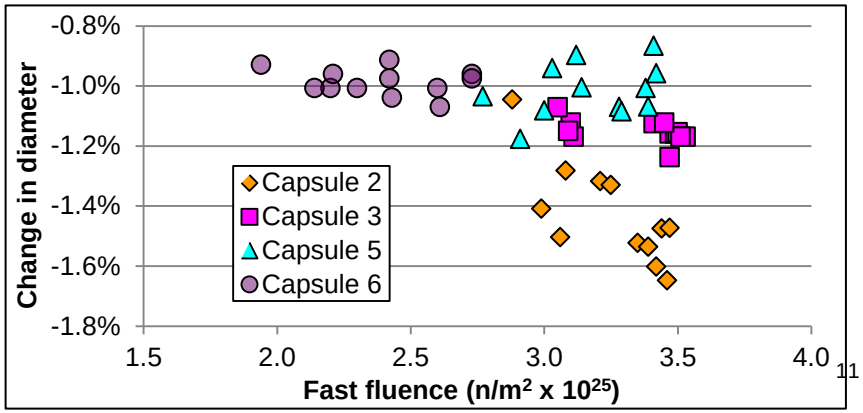
- All compacts in Capsules 2, 3, 5, and 6 shrank both radially (0.8 to 1.7%) axially (0.1 to 0.9%)
- Capsule 2 compacts exhibited the most shrinkage

AGR-2 Compact Dimensional Change

- Compacts from Capsules 5 and 6 behaved similarly while Capsule 2 compacts and Capsule 3 compacts were separate populations.
- Capsule 2 compacts evidently shrank more (especially radially) from higher irradiation temperature.
- Capsule 5 and 6 compacts shrank approximately the same radially and axially despite a substantial difference in fast neutron fluence.
- Anomalously low axial shrinkage on Capsule 3 compacts likely related to larger particles with UO_2 kernels and/or lower packing fraction.

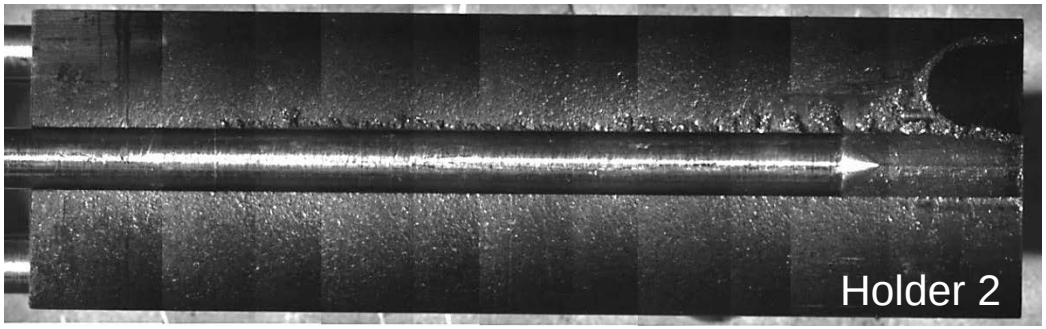


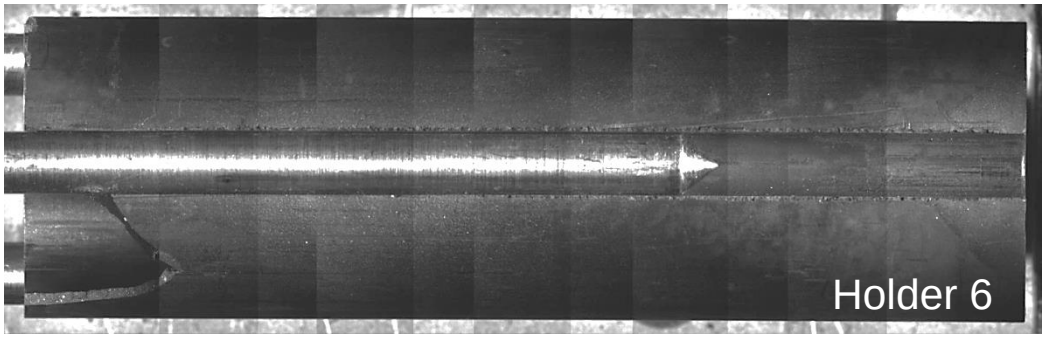


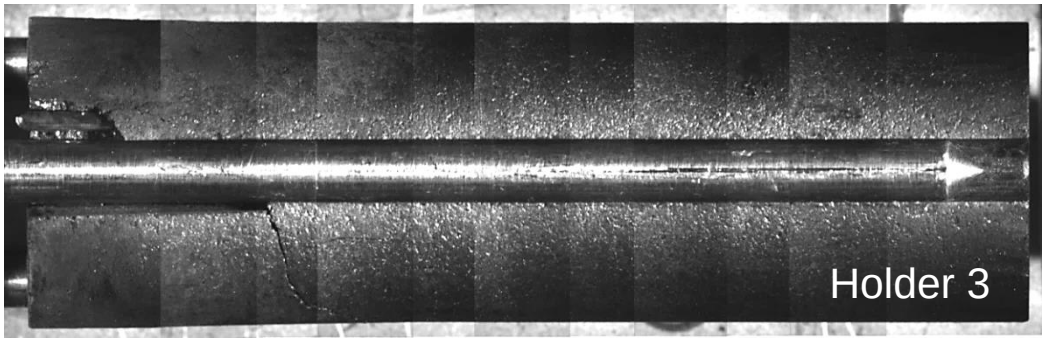


Damage to AGR-2 Graphite Holders

- One AGR-2 holder damaged during disassembly while prying up a through tube.
- Two empty holders cracked while loading onto pronged fixture for metrology imaging.
  - Images captured after disassembly to limit radiation dose from fuel compacts to camera/lens.
  - Only 1 camera for AGR-2 metrology (3 for AGR-1).
- Fragments recovered for fission products assays.
- Frequency and severity of AGR-2 holder damage less than AGR-1 despite increased remote handling.



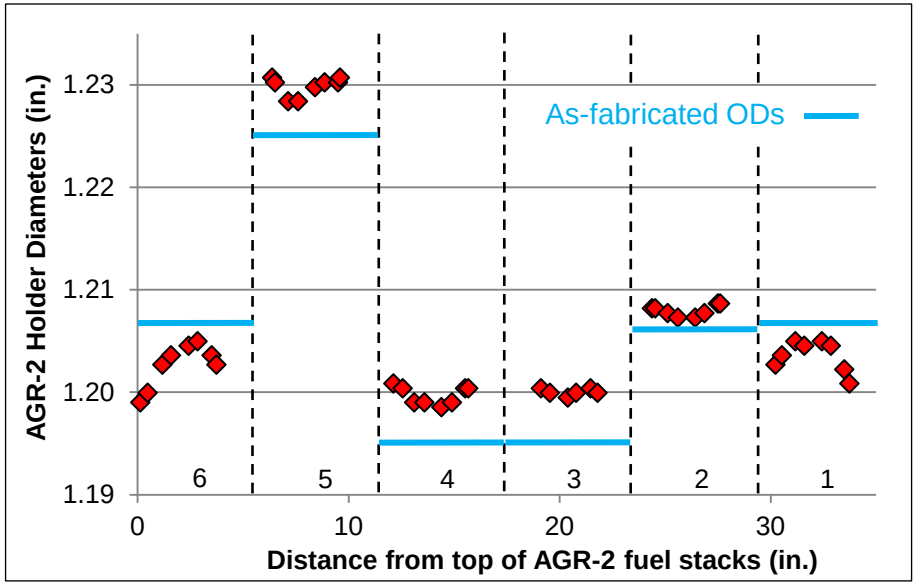


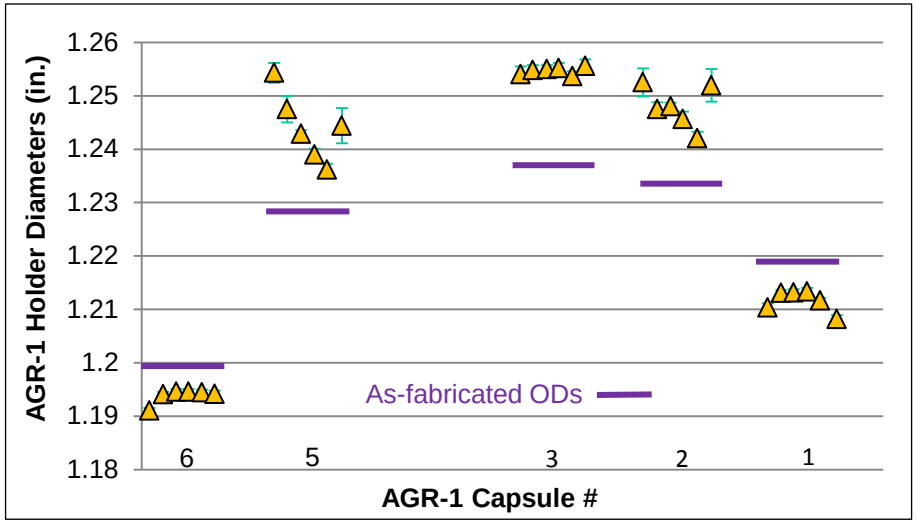


Graphite holder ODs

- AGR-2 graphite holders shrank radially at the top and bottom of the test train while expanding within four interior capsules.
- Same behavior was measured on AGR-1 holders except that AGR-1 deformations were larger.
- AGR-1 pattern was attributed to 5.5 w/o B_4C in outer holders versus 7.0 w/o B_4C in inner four (lot assays), as well as fluence differences. But B_4C loadings (cylinder assays) in AGR-2 Holders 6 and 1 were barely lower than in Holders 4 and 3.

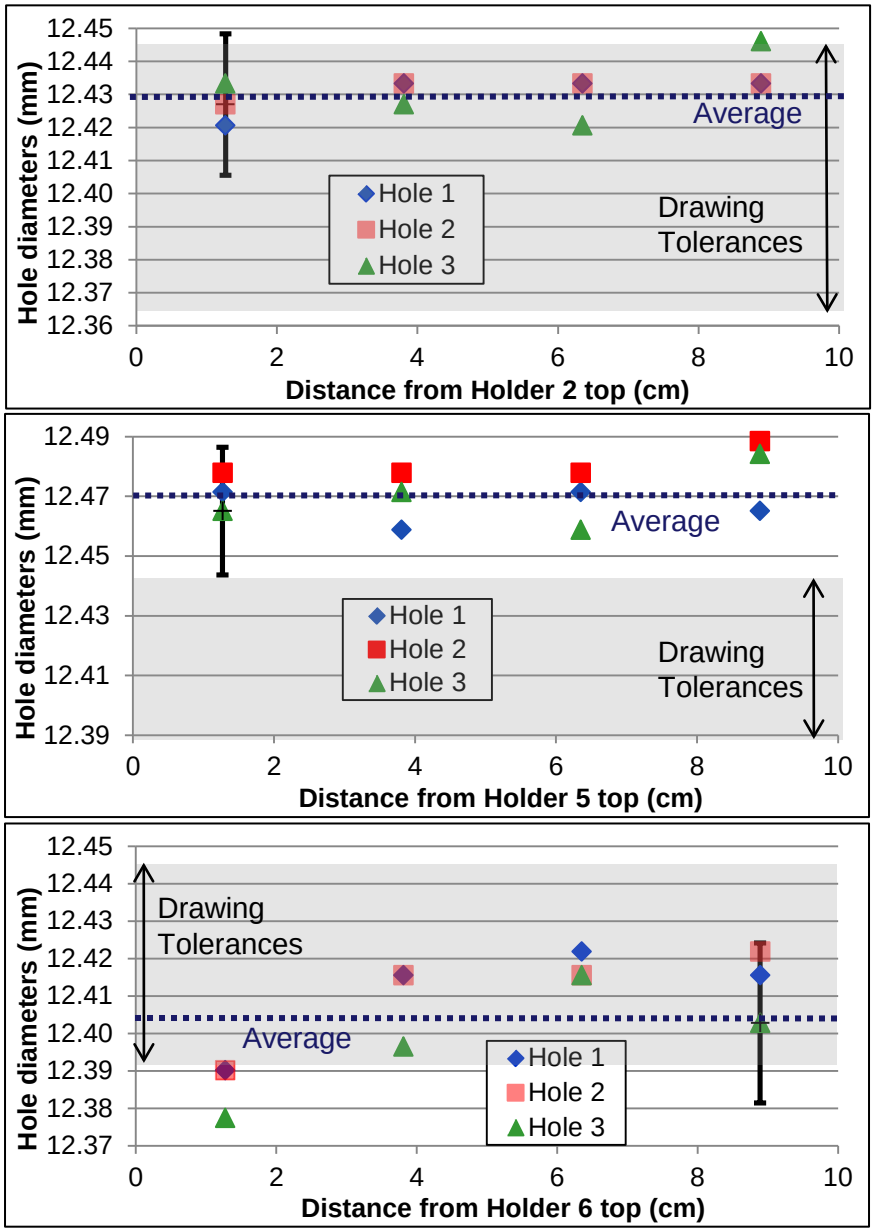
AGR-2 Holder	6	5	4	3	2	1
B_4C wt%	4.83	5.75	4.92	4.92	5.75	4.29





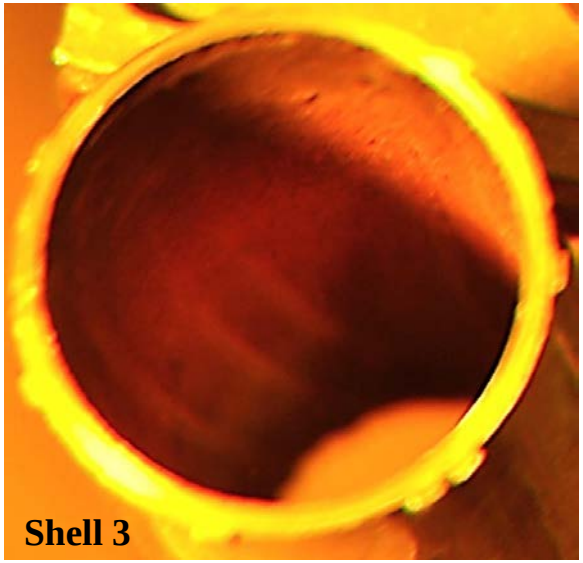
Holder Hole IDs

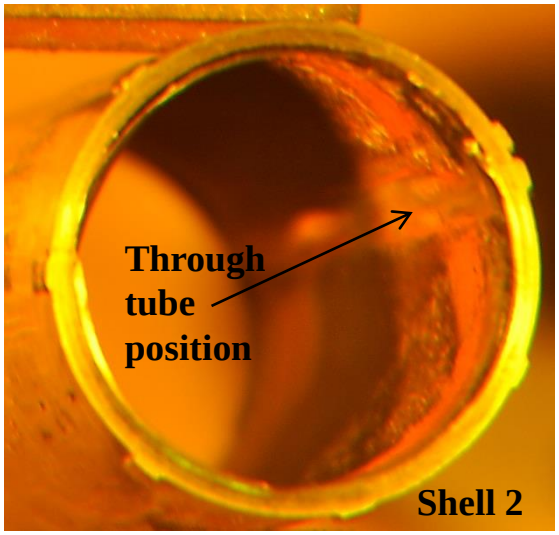
- As-fabricated IDs for individual holder holes are not available.
  - ID recorded to confirm that drawing tolerances were met was size of largest pin gauge that passed through all 3 holes.
  - Larger pins could go halfway before reaching a misalignment step (bored from both ends).
- PIE IDs measured with carefully aligned, calibrated bore gauge.
- PIE hole IDs for Holders 1 and 2 are within drawing tolerances.
- Nearly all holes in Holders 3, 4, and 5 are now larger than drawing tolerances (expanded).
- Holder 6 holes may have shrank slightly near top of test train.

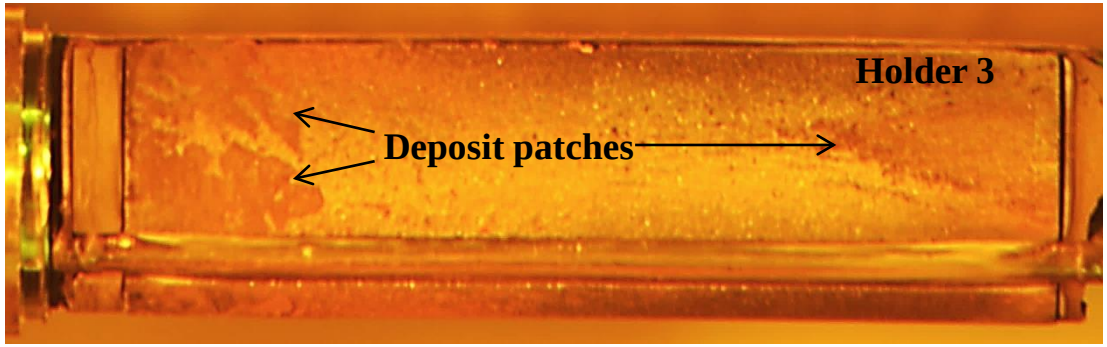


Unknown deposits between holders and shells

- Unknown material seen inside AGR-2 shells (similar to AGR-1).
- Much thinner at through tube azimuths.
- Average deposit thickness on shell liners between 0.003 and 0.005 in.
  - Always thicker at mid-length.
  - Slightly thicker than AGR-1 deposits (on average).
- Deposits on inner four AGR-2 holders may have contributed to OD expansion (as evidently occurred on inner AGR-1 holders).







AGR-2 Disassembly and Metrology Summary

- AGR-2 disassembly and metrology campaign was completed rapidly and economically by reusing AGR-1 equipment and employing basic approaches that evolved during AGR-1 campaign.
- AGR-2 fuel compacts and their graphite holders were generally in better condition after disassembly than AGR-1 counterparts.
- AGR-2 measurement uncertainties met ≤0.001-in. AGR-1 requirement.
- All AGR-2 compacts (Capsules 2, 3, 5, and 6) shrank radially and axially.
  - More shrinkage measured on hotter Capsule 2 compacts.
  - Little or no effect of fast neutron fluence on compact shrinkage.
  - Less axial shrinkage on Capsule 3 compacts (larger UO_2 particles and lower packing fraction).
- Outer AGR-2 graphite holders shrank radially while four interior holders expanded, but difference not clearly related to B_4C concentrations.
- Deposits of unknown material again found inside capsule shell liners and also on some graphite holders (often in patches).
- Holes for fuel compacts expanded in at least three interior holders
- *Additional details are available in INL/EXT-15-34997*

Questions?

Paul Demkowicz
Paul.Demkowicz@inl.gov

Idaho National Laboratory
(208) 526-3846