Reirradiation Tests to Determine Release of Short-Lived Fission Products

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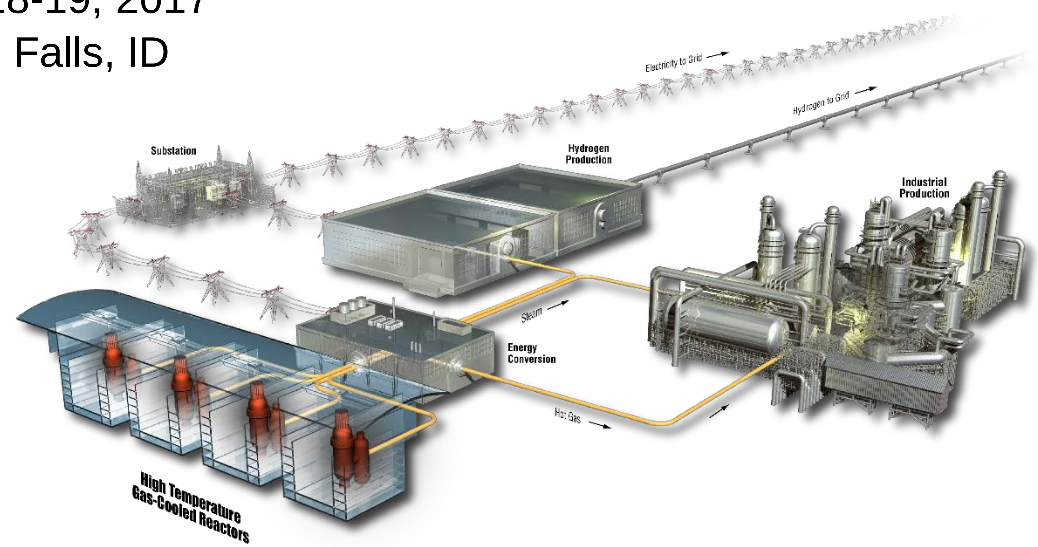
Advanced Gas Reactor TRISO Fuels Program Review
July 18-19, 2017
Idaho Falls, ID



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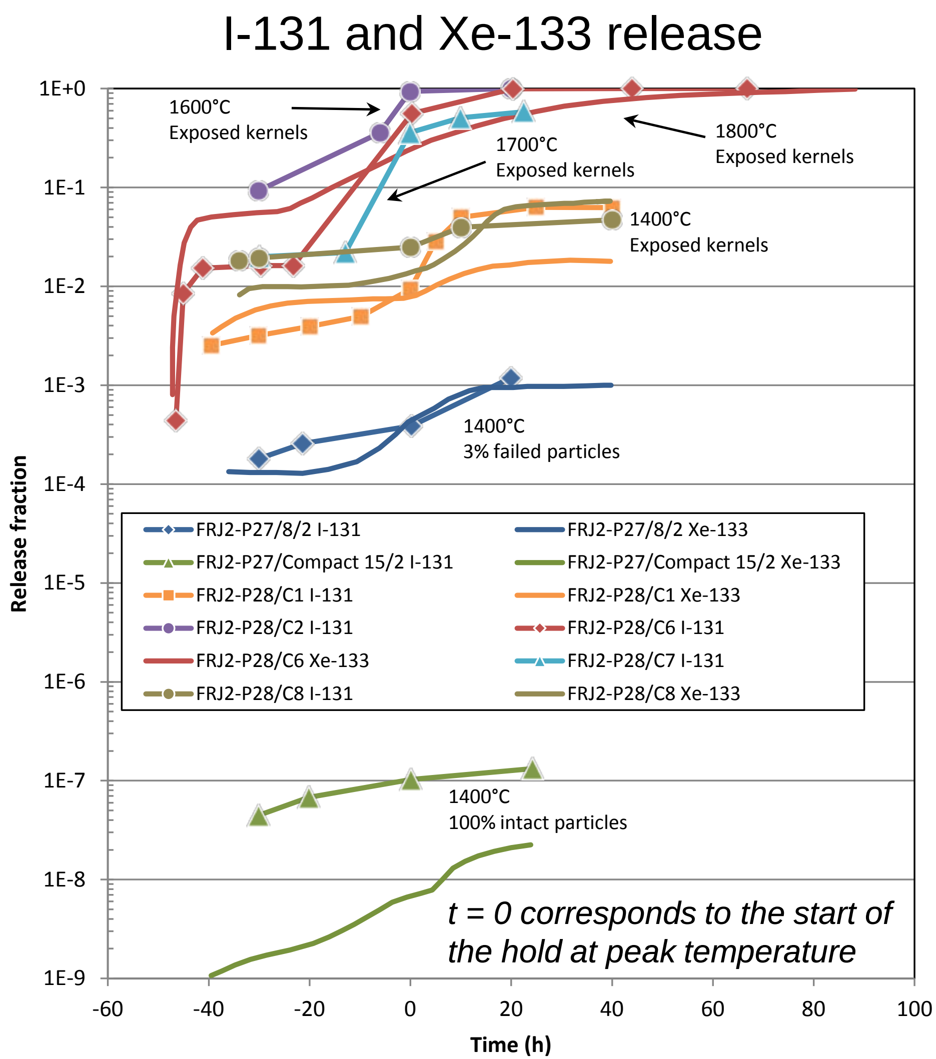
Importance of determining short-lived fission product release

- Iodine-131 ($t_{1/2}$ = 8.02 d) is a major contributor to offsite dose during accident scenarios
- Xe only has stable and short-lived isotopes
- Decay eliminates inventory within several months of irradiation
- Need a means to reirradiate the fuel that allows rapid testing while I-131 and Xe-133 ($t_{1/2}$ = 5.2 d) inventory is measureable.

Historic I-131 and Xe-133 release data

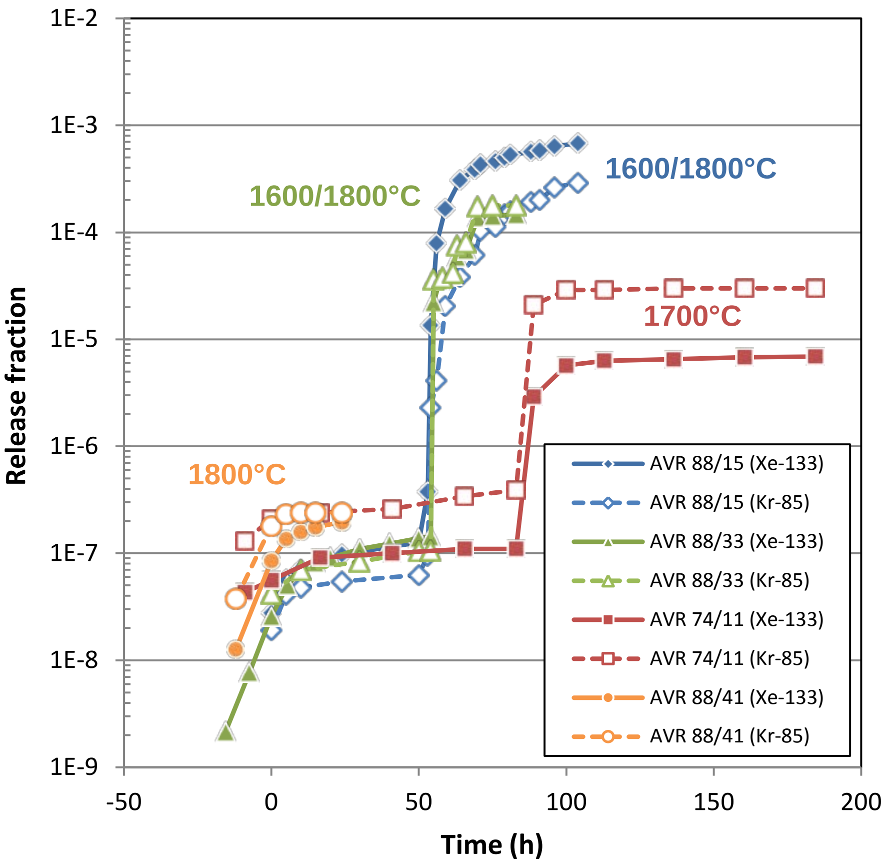


FRJ2 tests in Germany

- UO_2 TRISO fuel with burnup 7.6 – 9% FIMA
- FRJ2-P28: 5 kernels with a buffer layer only (burnup ~8% FIMA)
- FRJ2-P27: Intact TRISO particles (one failed particle in FRJ2-P27/8/2); burnup 7.6 – 9% FIMA)
- Most specimens irradiated in FRJ2 reactor, then reirradiated in FRJ1 prior to heating (P28/C7 and P28/C8 only irradiated in FRJ1 and had very low total burnup ~0.4% FIMA)
- Results:
  - I-131 and Xe-133 release very similar
  - Negligible release from intact particles

Kr and Xe release from UO_2 fuel

Kr-85 and Xe-133 release



AVR heating tests

- UO_2 spheres from the AVR reactor (burnup 6.2 – 8.5 % FIMA)
- Intention was to measure I-131 release; however, no I-131 was measured (due to decay or measurement issues)
- Rapid transfer to KÜFA after removal from reactor
- Various KÜFA heating schedules
- Kr-85 and Xe-133 releases are very similar

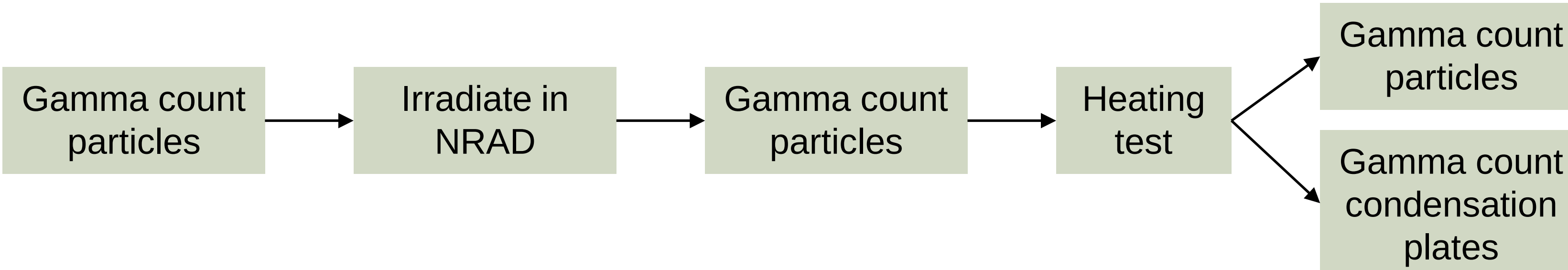
Fuel reirradiation approach

- Need exposed kernels to measure iodine release (release through intact TRISO is negligible)
- Three potential types of AGR specimens:
  - Loose kernels
  - Mechanically-cracked, irradiated particles
  - Irradiated AGR-3/4 fuel compacts containing designed-to-failed particles
- The Neutron Radiography (NRAD) reactor in the MFC Hot Fuel Examination Facility (HFEF) is an ideal location for performing reirradiation
  - 250kW TRIGA reactor
  - Located in the basement of the hot cell facility where FACS furnace is located

Loose kernels

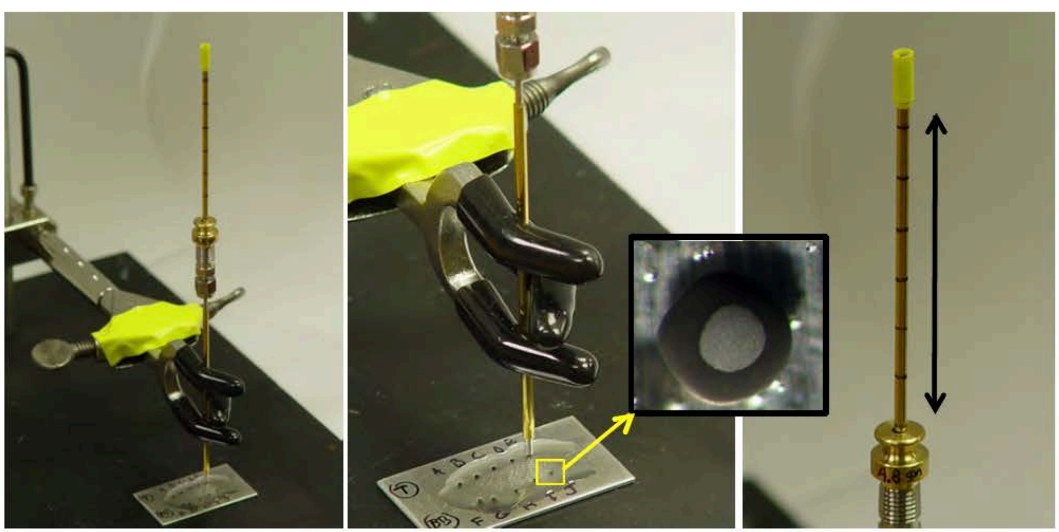
- Trial heating test in FACS furnace with loose kernels (no reirradiation) performed in FY16
  - Methodology was demonstrated
  - Kernels exhibited significant reaction/degradation during heating test

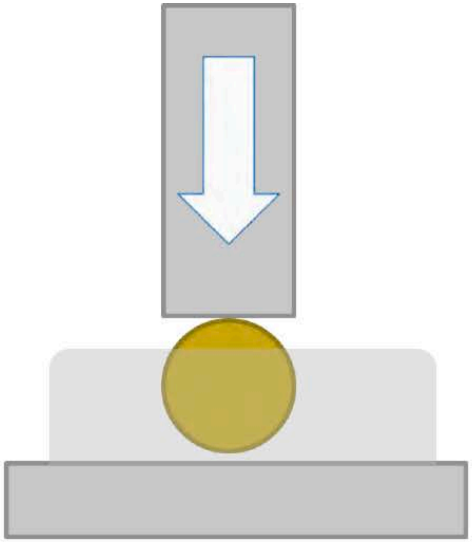
- Crushed kernels reirradiated in NRAD for 32 h (4 × 8 h shifts), followed by heating test in FACS
  - All aspects of reirradiation worked well, but FACS furnace malfunction resulted in early termination of heating test



Reirradiation of failed particles

- Testing of loose/crushed kernels raises concerns about how prototypic the sample configuration is relative to in-situ exposed kernels
- Currently pursuing the use of irradiated TRISO particles with mechanically-induced coating failures
- ORNL is using methods similar to those used to generate through-coating fractures in unirradiated particles (“pre-burn leach defects”)

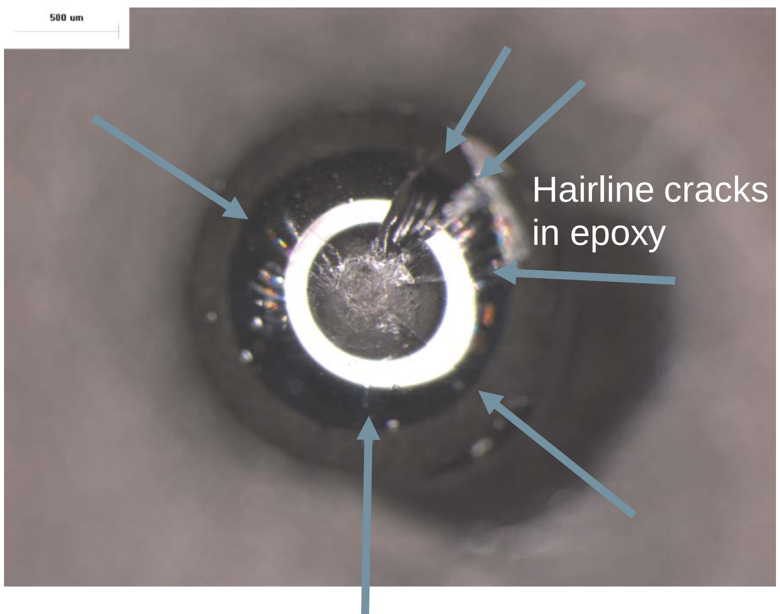




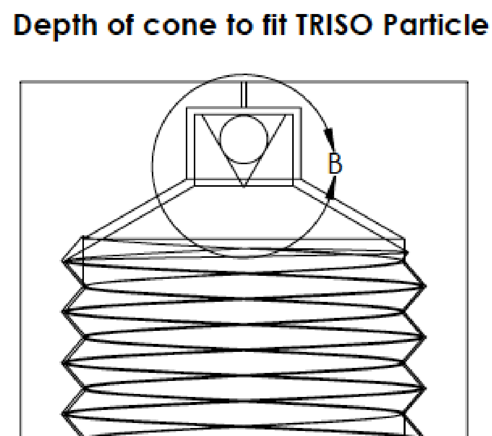
Mechanical fracture apparatus Schematic of impact area

Fractured particles

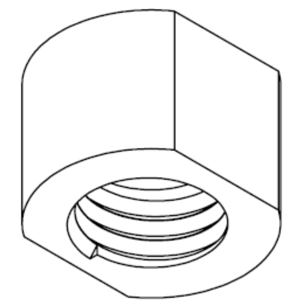
- ORNL is currently in the process of generating suitable cracked particles and individual graphite holders

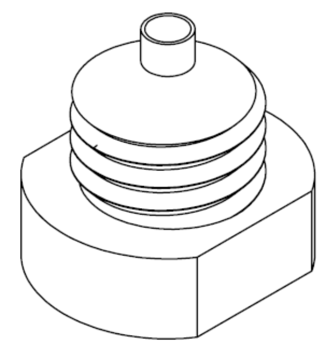


Particle after fracture attempt



Graphite particle holder for insertion in NRAD and FACS



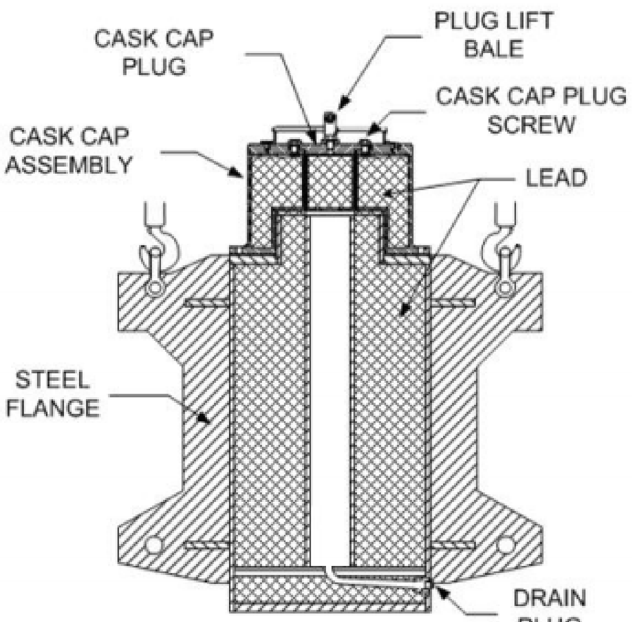


Compact reirradiation in NRAD

- An additional option is currently being explored: manual insertion of whole compacts into the NRAD core.
  - AGR-3/4 compacts are ideal specimens, as they contain designed-to-fail particles
  - Dose significantly higher than for handling of a small number of particles; would require remote insertion of specimen to the pool, or loading/unloading underwater
  - May be possible using the TRIGA fuel transfer cask (loaded in the NRAD pool and mates with the HFEF hot cell)
  - A preliminary evaluation is underway
  - Gamma analysis of whole compacts for I-131 (and other short-lived isotopes) inventory would have to take place in HFEF hot cell, perhaps using PGS

Compact reirradiation in NRAD (cont'd)

- Met with NRAD Operations and Nuclear Safety personnel to determine path forward to irradiate a compact in NRAD
- Items the need to be addressed:
  - Develop and approve new Experimental Safety Analysis (ESA)
  - Shielding analysis
  - Develop handling fixture
  - Return the NRAD Fuel Cask to "OPERABLE" status
  - Develop/revise new cask operating instructions
  - Perform dry run – validation of procedures/training
  - Perform a Contractor Readiness Assessment (CRA)
- Goal is to perform an AGR-3/4 compact reirradiation in FY18



Reference INL Drawings:
W0170-0054-DE-01 FUEL HANDLING CASK, SHEET 1 OF 3
755507 CASK CAP ASSEMBLY

Summary

- Methodology for reirradiating loose particles or kernels in NRAD has been developed and demonstrated
- One loose kernel irradiation has been performed
- Preparation of cracked particles is in progress
- Irradiation of whole compacts in NRAD is currently being pursued; goal is to perform an AGR-3/4 compact reirradiation in FY18

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