Initiation of AGR-2 PIE at ORNL

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Receipt of First Shipment of AGR-2 Compacts

- Calculations were performed to determine eligibility for shipment of AGR-2 compacts in Type A packages.
- By mid-April (1.5 years after the end of irradiation) a number of compacts slated for PIE and safety testing had decayed to radiological inventories consistent with the Type A criteria.
- Four compacts were shipped in Type A drums and transferred into the ORNL hot cells at the beginning of May.
  - UCO Compact 2-2-3 for as-irradiated PIE to investigate suspected SiC failure
  - UO$_2$ Compact 3-3-2 for 1600°C safety testing
  - UO$_2$ Compact 3-4-2 for 1600°C safety testing
  - UO$_2$ Compact 3-3-1 for as-irradiated PIE to compare to 3-3-2 “twin” irradiated under similar conditions
AGR-2 UCO Compact 2-2-3: 1st As-irradiated PIE

- Irradiation conditions
  - Average burnup = 10.8% fissions per initial heavy metal atom (FIMA)
  - Fast fluence = $3.0 \cdot 10^{25}$ n/m$^2$
  - Time-averaged volume-averaged temperature (TAVA) = 1261°C
- Suspected of cesium release during irradiation

High concentration of $^{134}$Cs observed in graphite holder near Compact 2-2-3

Gamma scan intensity plot
from Jason Harp, “Preliminary Gamma Spectrometry Results from AGR-2,” TCT Meeting April 1, 2015.
IMGA Survey of AGR-2 UCO Compact 2-2-3

- Particles de consolidated from Compact 2-2-3 and acid leached.
- Survey with Irradiated Microsphere Gamma Analyzer (IMGA) identified five special particles (SP) with low cesium inventory.
**IMGA Survey of AGR-2 UCO Compact 2-2-3**

- Two of the five low-cesium particles (SP) also had low-cerium.
IMGA Survey of AGR-2 UCO Compact 2-2-3

- Adjusting the $^{137}$Cs inventory using the inventory of the non-volatile $^{144}$Ce helps to refine the data.
- Particle 223-SP04 does not appear to have released cesium.
Particle 223-SP02: Radiation-induced SiC Failure

- Extensive SiC degradation localized near region where shrunken buffer still attached to IPyC; no evident cracks in any of the carbon layers.
Particle 223-SP03: Radiation-induced SiC Failure

- Similar to 223-SP02
- Extensive SiC degradation localized near region where buffer still attached to IPyC
- No evident cracks in buffer or OPyC; possible crack in IPyC.
Comparison to AGR-1 SiC Failure

- Radiation-induced SiC degradation observed in AGR-1 particles was much less extensive (essentially pinholes)
- More extensive AGR-2 degradation is possibly related to higher irradiation temperatures

Waterfall Plot from
Particle 223-SP05: TRISO Failure

- Through-layer failure in all TRISO coatings; extensive SiC degradation.
- Exposed kernel was leached prior to IMGA survey.
Particle 223-SP05: TRISO Failure

- OPyC damage appears to be pre-irradiation impact fracture.
- SiC degradation aligned with OPyC cracks.
Exposed kernels in as-fabricated AGR-2 UCO fuel

- A 95%-confidence exposed kernel defect fraction of $\leq 2.5 \times 10^{-5}$ was measured during QC of AGR-2 UCO fuel and presumed to have been caused by physical damage of the TRISO coating during removal from the coater; observed TRISO failure in Compact 2-2-3 is consistent with expectation of one as-fabricated failed TRISO particle per UCO capsule.
AGR-2 UO₂ Compact 3-3-2: 1st AGR-2 Safety Test

- **Irradiation conditions**
  - Average burnup = 10.5% fissions per initial heavy metal atom (FIMA)
  - Fast fluence = $3.5 \cdot 10^{25}$ n/m²
  - Time-averaged volume-averaged temperature (TAVA) = 1062°C

- **Safety test conditions**
  - 1600°C for 300 hours
  - flowing helium
**UO₂ Compact 3-3-2 1600°C Safety Test Release**

- Silver release typical of AGR-1 release (matrix release)
- Cesium release (with no Kr release) indicative of SiC failure
- No significant measurable europium release

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Graph showing fractional release against elapsed time, with a peak at ~3 particles inventory.
**UO₂ Compact 3-3-2 1600°C Safety Test Release**

- Cesium release constantly increased throughout run.
- In AGR-1, we typically observed a brief high rate of release followed by a decaying rate.

![Graph showing fractional release rate vs. elapsed time and temperature](chart.png)

- 110mAg initially at 1E-3 hr⁻¹
Comparison to AGR-1 1600°C UCO Safety Test

- At least 3 orders of magnitude lower release of Eu from AGR-2 UO$_2$ Compact 3-3-2 (presumably related to different release during irradiation)
- Higher cesium release from AGR-2 UO$_2$ Compact 3-3-2 (IMGA found 5 low-cesium particles)
AGR-2 Compact 3-3-2 Particle Cross Sections

- Epoxy in gap
- Densified buffer
- Artifact from grinding
AGR-2 Compact 3-3-2 Particle Cross Sections

Some buffer remains on IPyC when buffer tears away

Buffer/IPyC still attached
AGR-2 Compact 3-3-2 Particle Cross Sections

Both SiC interfaces intact

SiC appears more prone to pitting during polishing
Summary of Initial AGR-2 PIE

• AGR-2 UCO Compact 2-2-3 released cesium during irradiation test—this was linked to 3 particles with apparent radiation-induced SiC failure and 1 particle with an apparent as-fabricated TRISO defect.

• The SiC degradation in the low-cesium particles from AGR-2 UCO Compact 2-2-3 irradiated at “margin test” temperatures was more extensive than that observed in AGR-1 irradiation test fuel.

• Gamma scanning of Capsule 2 holder did not indicate any other compacts contained particles that released significant cesium.

• AGR-2 UO₂ Compact 3-3-2 was safety tested at 1600°C and exhibited cesium release that appears to be associated with individual particles.
Plans for second shipment of AGR-2 Compacts

• Today, July 16, all but two AGR-2 compacts are eligible for Type A shipment.
• Four more compacts will be shipped in July–August.
  – Compact 5-2-3 (UCO) for as-irradiated PIE (suspected SiC failure)
  – Compact 2-2-2 (UCO) for 1600°C safety testing (high-temperature)
  – Compact 2-2-1 (UCO) for as-irradiated PIE (2-2-2 “twin”)
  – Compact 5-4-1 (UCO) for 1800°C safety testing
Questions?

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