AGR-2 Safety Testing at ORNL (FY2017)

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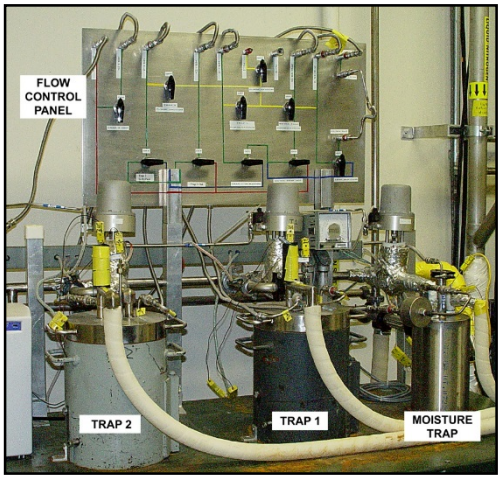
OAK RIDGE National Laboratory

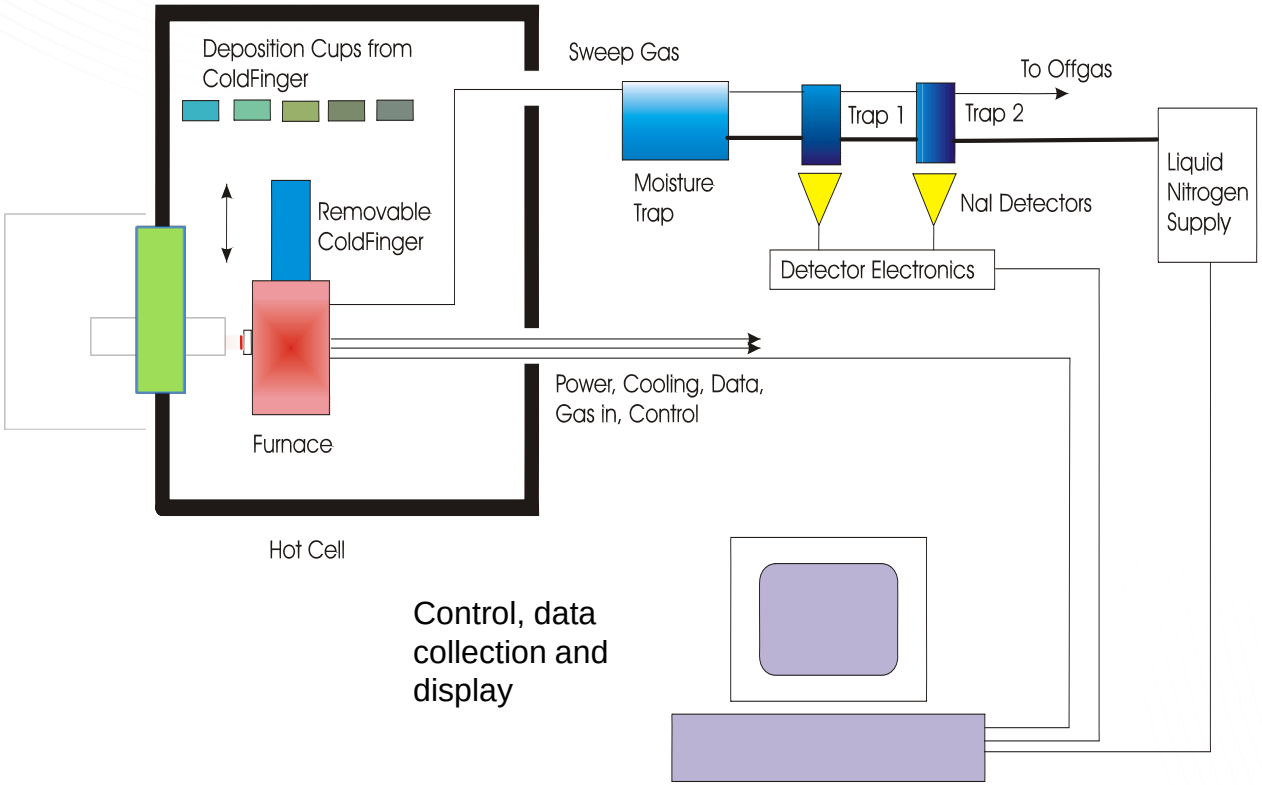
ORNL AGR-2 Safety Testing

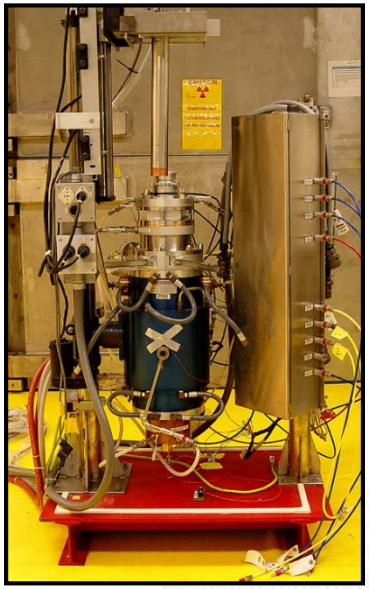
- Fuel performance is being tested at elevated temperature to simulate a depressurized inert atmosphere conduction cool-down event
- Irradiated compacts are heated at 1600 - 1800°C and held for ~300 hours
- Phenomena of interest:
  - release of fission products from matrix
  - fission product transport through SiC
  - corrosion of SiC (both Pd and CO)
  - failure of individual particle coatings
- Kr-85 release is continuously monitored throughout test to detect single particle failures
- Metallic fission product release is periodically monitored using cooled deposition cups, which are exchanged every 12 - 24 hours
- Post-test analysis is performed to further characterize fission product release and study microstructural changes in coated particles

Diagram of Core Conduction Cool-Down Test Facility (CCCTF)

- Furnace in dedicated hot cell
- Trap system outside cell
- Deposition cups transferred via airlock







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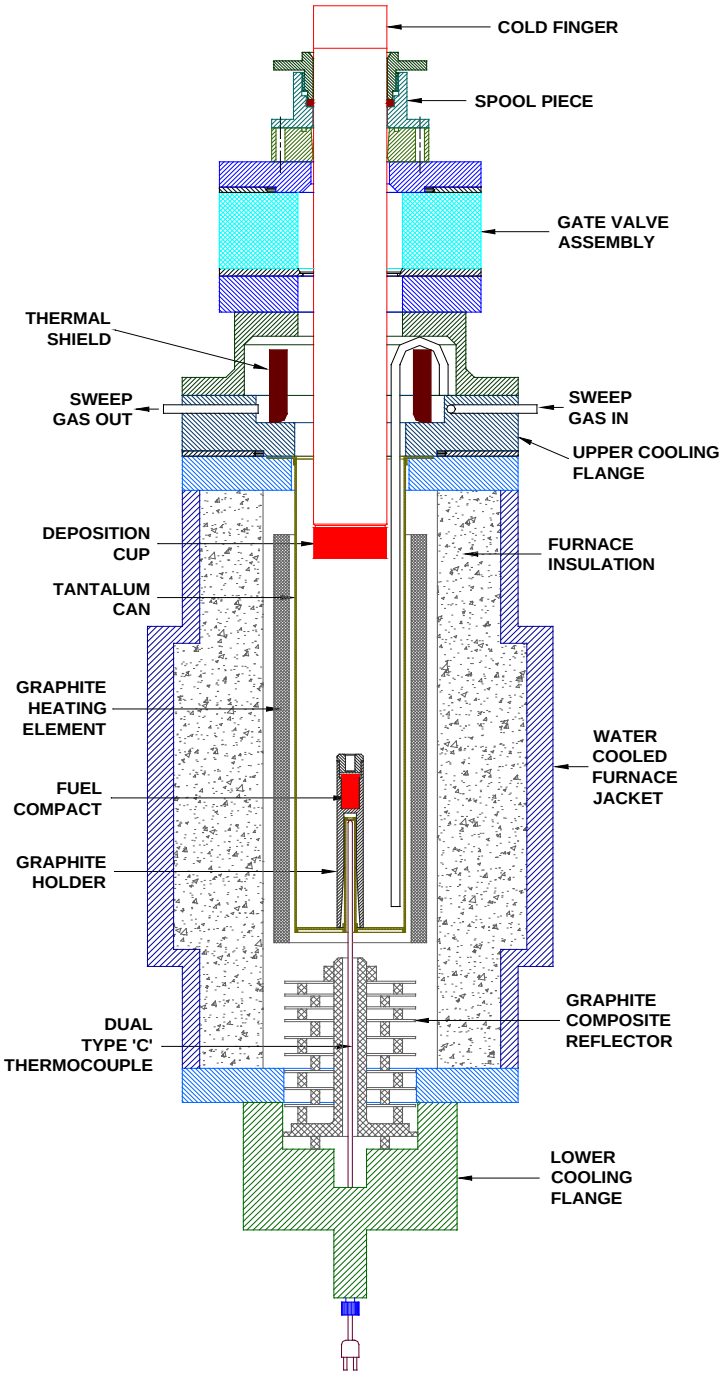
Graphite heating element furnace with cold-finger collection system



Three AGR-2 compacts have undergone heating in the CCCTF this FY, plus analysis completion of 4 from last FYs

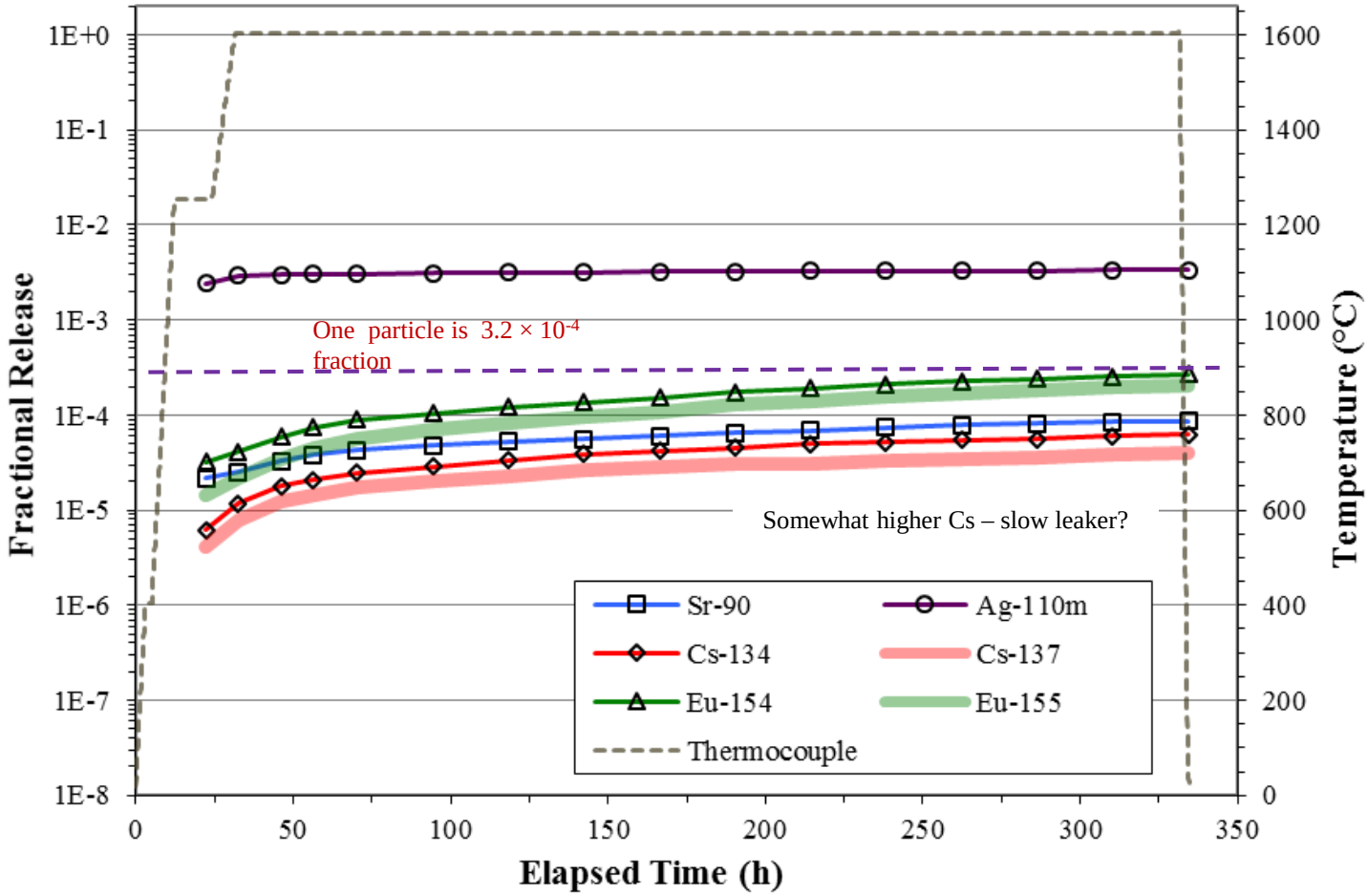
AGR-2 Compact	Burnup (% FIMA)	Fast Fluence (10^{25} n/m^2)	Irradiation Temperature (°C TAVA)	Fuel Type	Safety Test Temperature (°C)	Status
3-4-1	10.62	3.47	1013	UO_2	1700	FY17 Heating / In Analysis
2-1-2	12.62	3.25	1219	UCO	1800	FY17 Heating / FY18 Analysis
2-2-2	12.55	3.39	1287	UCO	1600	FY15 Heating / Done
2-3-1	12.63	3.42	1296	UCO	1600	FY 16 Heating / Done
2-3-2	12.68	3.46	1296	UCO	1800	FY16 / In Analysis
5-4-1	12.05	3.12	1071	UCO	1800	FY 16 Heating / Done
6-4-2	9.26	2.21	1018	UCO	1600	FY 17 Heating / Done

FIMA = fissions per initial metal atom, TAVA = time-average, volume-average temperature

Challenge due to higher Eu release from Capsule 2 compacts continues plus Capsule 3 compact Cs releases above 1600C

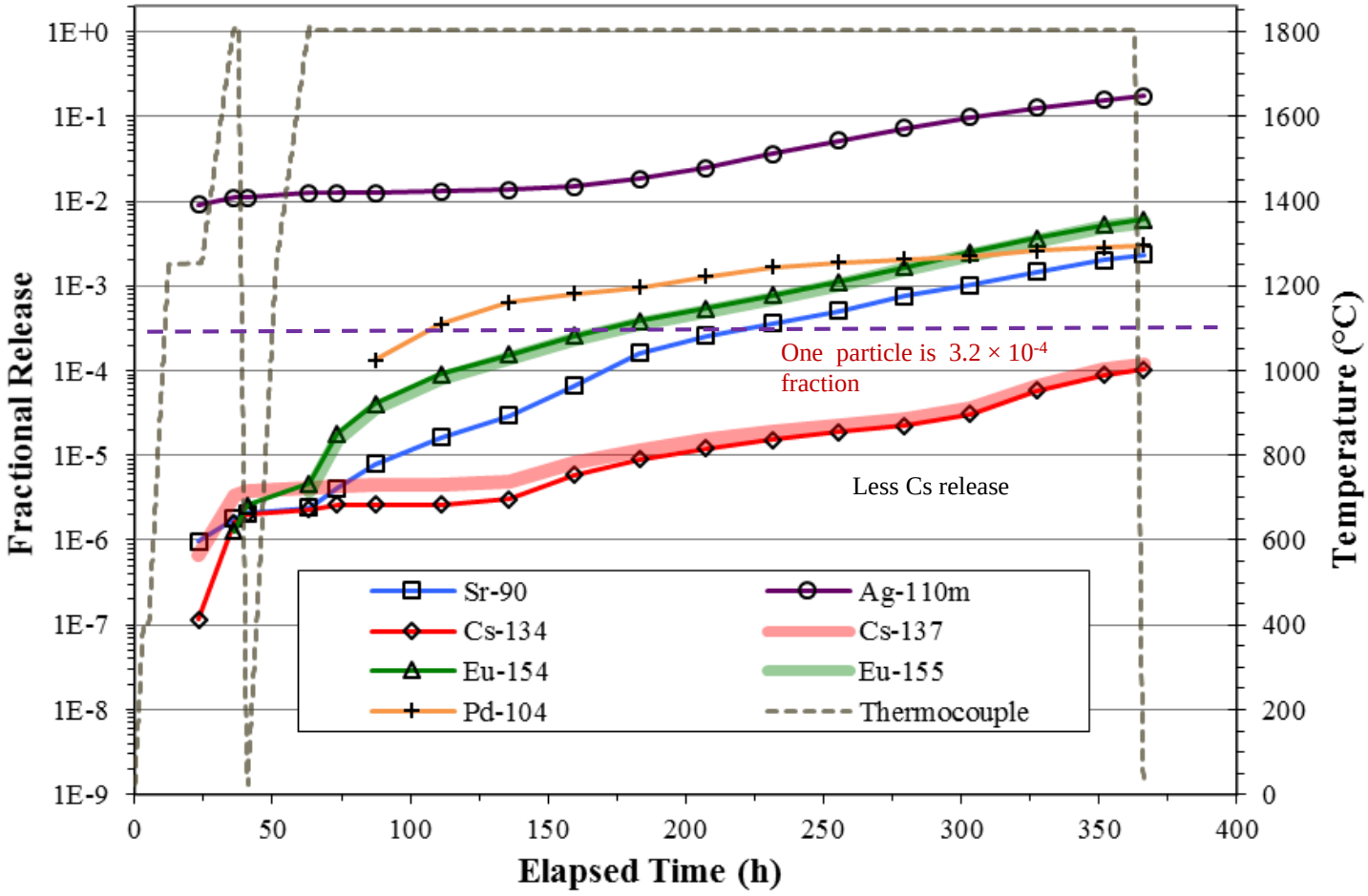
- Higher irradiation temperatures resulted in greater Eu diffusion into the matrix during irradiation which increased the Eu collected on both the deposition cups and furnace components during safety testing
- Higher Cs release from Capsule 3 (UO_2 compacts) at 1700°C due to CO corrosion also resulted in higher dose rates for cups and furnace components
- New work procedures have been developed and have been implemented over the past year
  - Need to watch Capsule 2 compact furnace disassembly dose levels, but the problem has been resolved
  - Transport to the radiochemical laboratory has been complicated by the higher dose

AGR-2 Compact 6-4-2 UCO [1018°C irrad.]: comparable to AGR-1 1600°C series



Kr-85 below detection (<7×10^{-7})

AGR-2 Compact 5-4-1 UCO [1071°C irrad.]: also comparable to AGR-1 1800°C series



Kr-85 below detection (<7×10^{-7})

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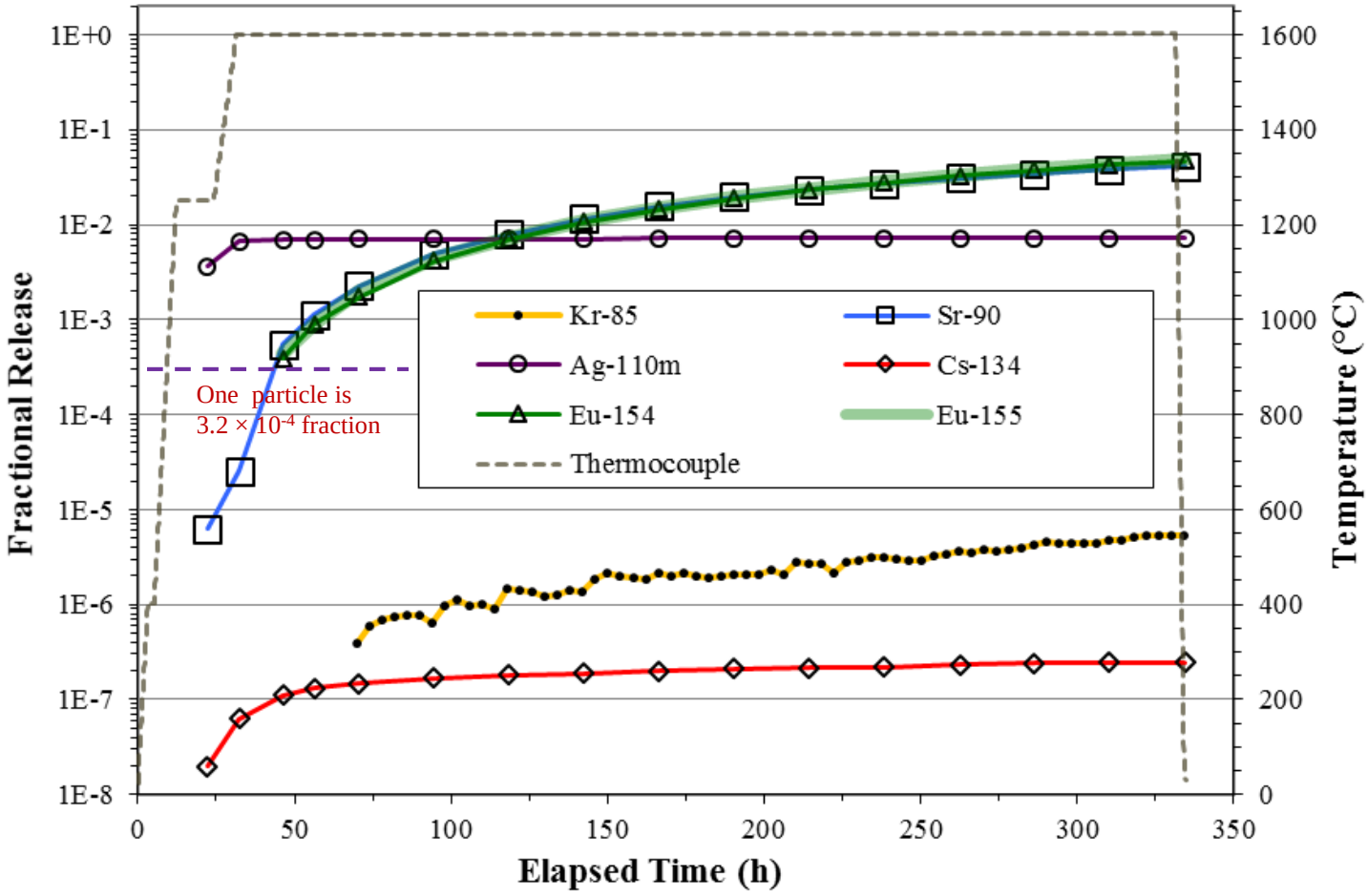
AGR-2 Compact 2-2-2 UCO [1287°C irrad.]: increased Eu & Sr release



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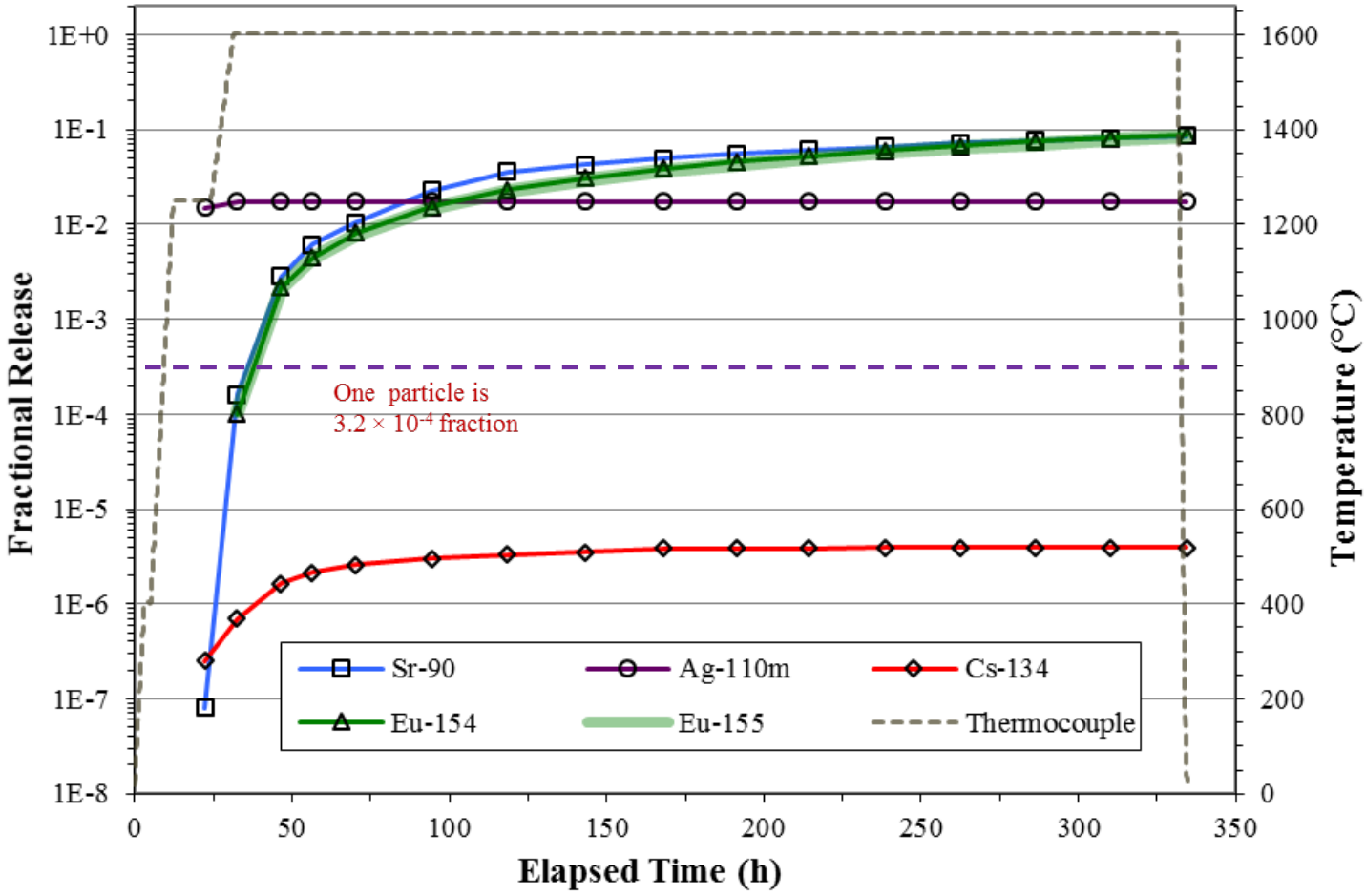
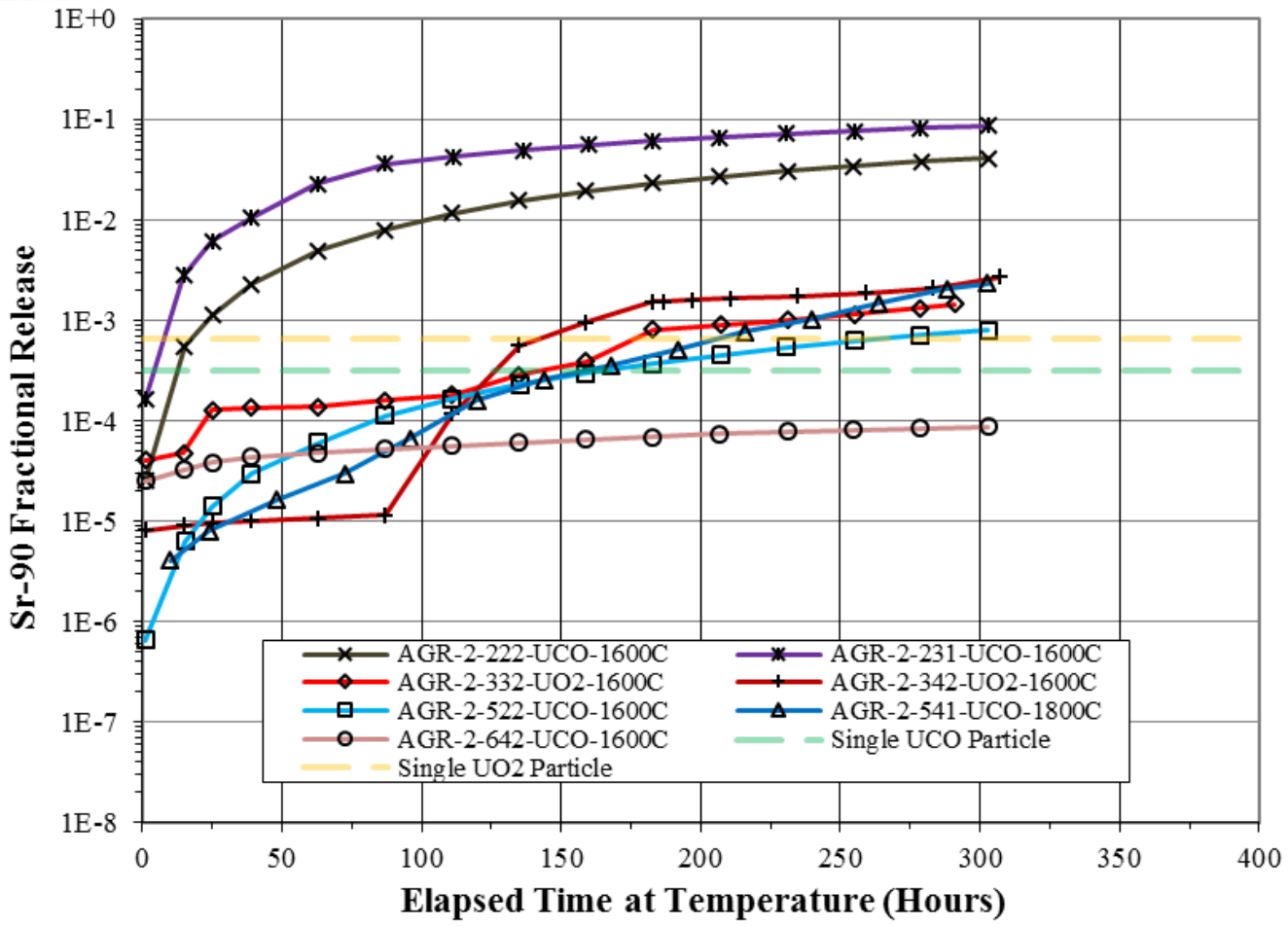
AGR-2 Compact 2-3-1 UCO [1296°C irrad.]: increased Eu & Sr release

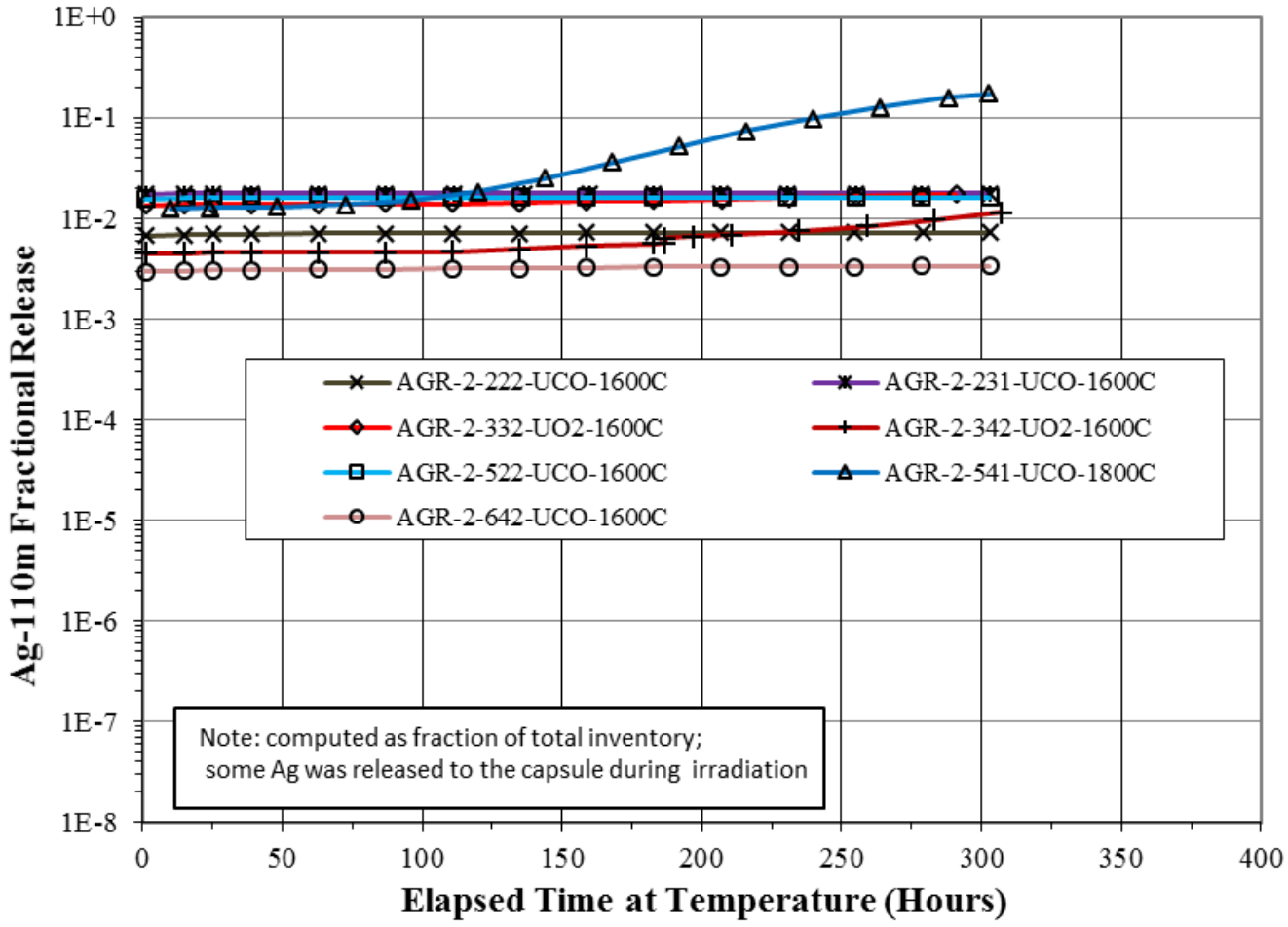


Kr-85 below detection (<7×10^{-7})

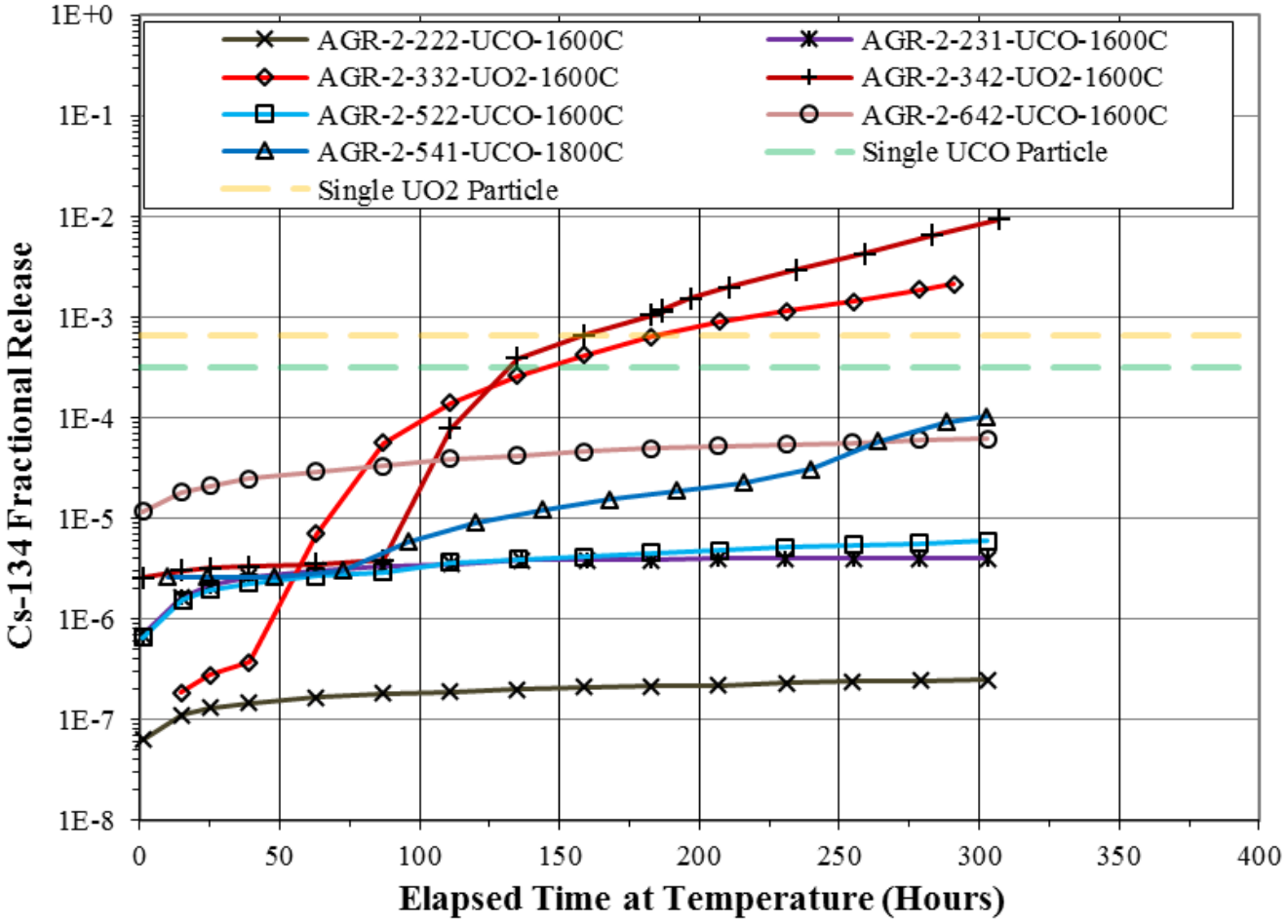
AGR-2 Sr-90 summary to date



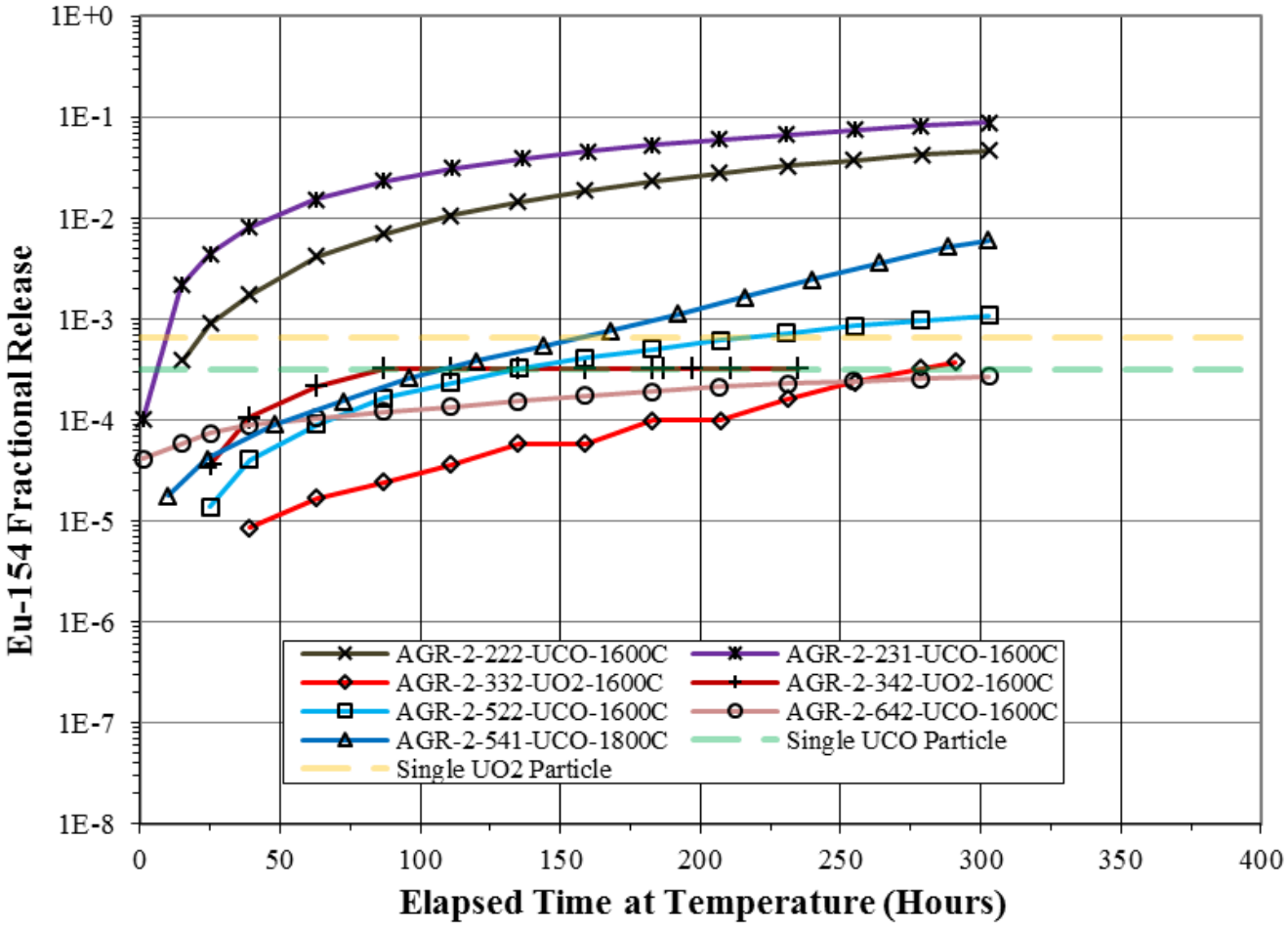
AGR-2 Ag-110m summary to date



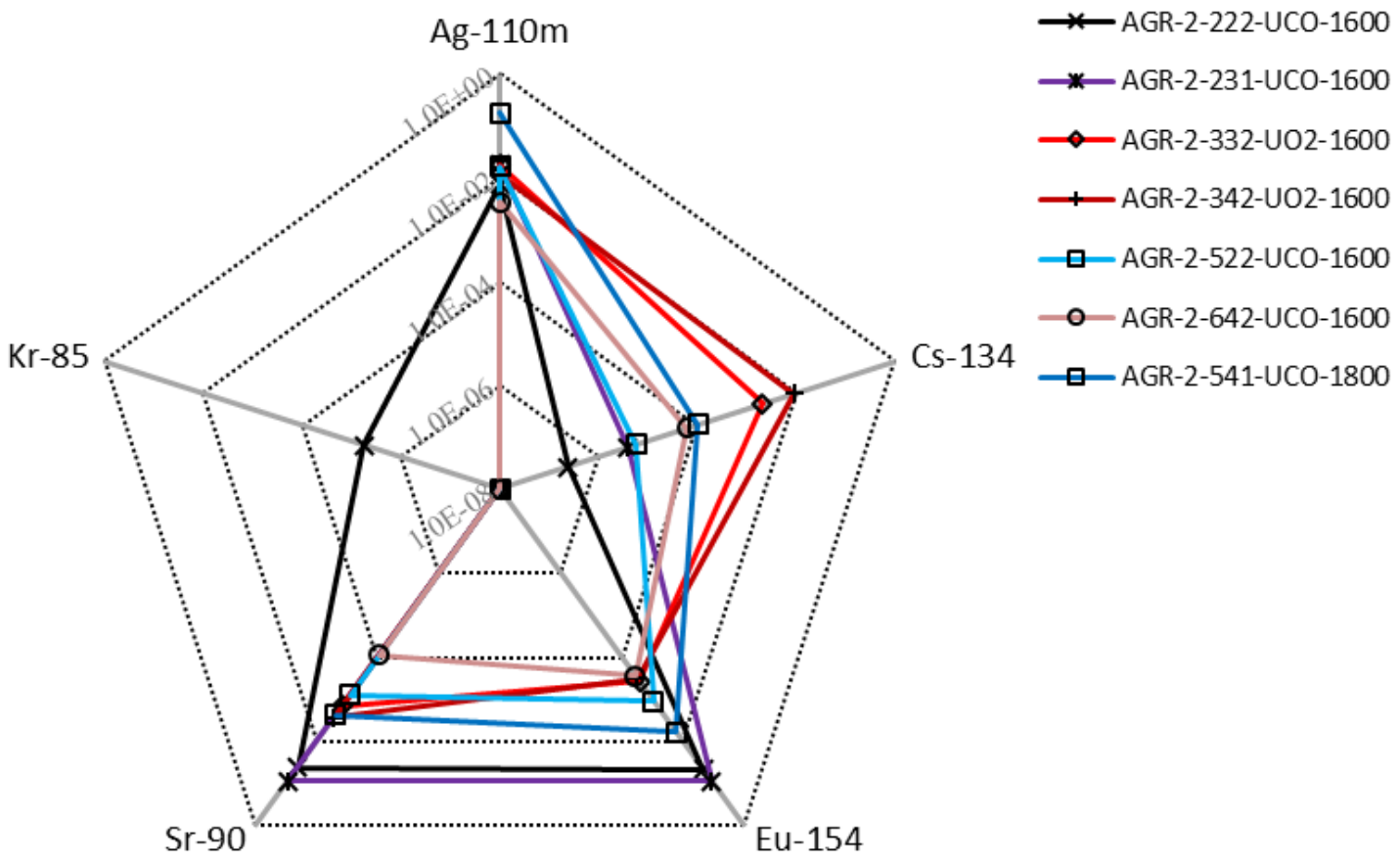
AGR-2 Cs-134 summary to date



AGR-2 Eu-154 summary to date



All together



Some preliminary comparisons

- At comparable irradiation and safety test temperatures, the AGR-2 UCO fission product release behavior appears to be comparable or better than AGR-1 UCO
- At the higher irradiation temperatures, AGR-2 UCO safety testing has seen more Eu & Sr release – due to higher release to matrix during irradiation from intact SiC
  - To date, DLBL of as-irradiated compacts doesn't show a large matrix inventory difference between compacts from AGR-1 and AGR-2 Capsules; however, AGR-2 Capsule compacts have an above average inventory of Eu and Sr
  - Both 1600 & 1800°C AGR-2 safety testing has been done
  - Irradiation temperature seems to be more important for AGR-2 Eu and Sr release

Some preliminary comparisons (cont.)

- UO_2 fuel at AGR-2 burnups shows more SiC failure and Cs release during safety testing compared to UCO fuel
  - Higher than German program burn-up – pushed harder
  - Appears to be less Sr and Eu in matrix - preliminary
    - Need more data from DLBL of as-irradiated compacts at relevant temperatures - underway
- UO_2 failures
  - Compact 3-3-2 – 5 to 6 particles
  - Compact 3-4-2 – at least 14 particles, still under investigation
  - Compact 3-4-1 – many particles, still under investigation

FY-17 summary

- Three compact heating tests completed
- Analysis underway on Compacts 341 and 232
  - Final analysis currently underway (radiochemical & IMGA)
- Working to complete IMGA/MET/SEM work
- Reporting continuing

FY-18 Plans

- Expecting at least 4 AGR program safety tests with room in schedule for additional testing
  - Continue to build statistical database for fuel performance
  - Examine higher temperatures to establish safety margin
  - Compare UCO and UO_2 performance
  - Perform single particle tests and variable temperature tests to study fission product transport in SiC (especially Ag and Eu)
- Post-safety test analysis will be performed after each safety test to understand fuel behavior and investigate any particle failure
  - DLBL
  - IMGA
  - X-Ray
  - MET
  - SEM

We wish to thank:

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