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Fuel cycle of DMSR with salt recycle

*** the first look ***

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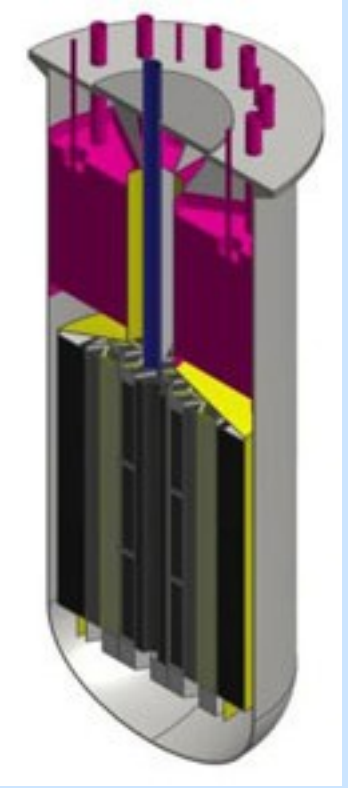
Presentation Overview

- Core management of a "once-through" LEU-fueled and refueled thermal MSR by material flow adjustments alone.
- Toy core with no flux flattening etc.
- Fuel cycle performance with simple dirty salt reprocessing.

Burnup ~250 GWd/MTU achievable!

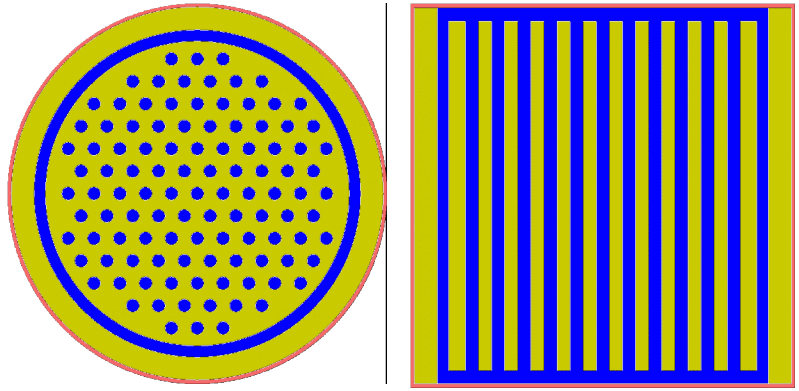


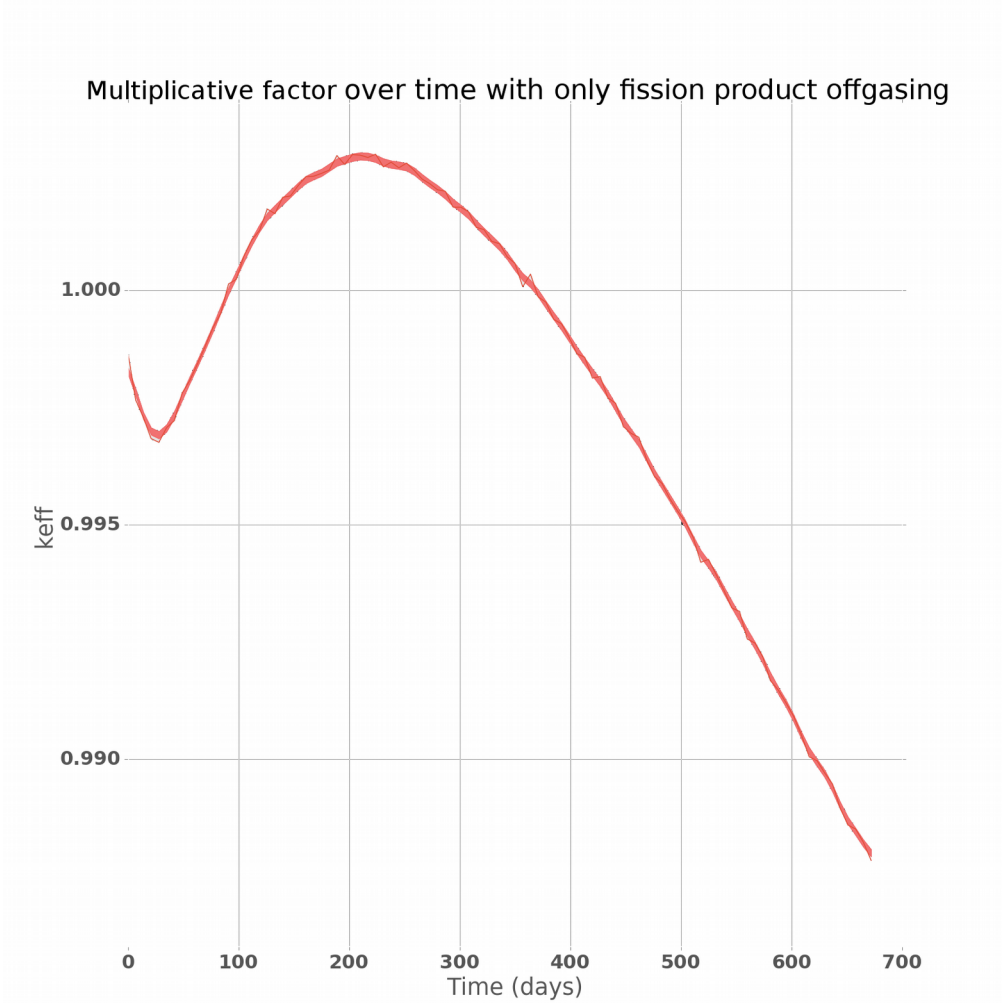
Why low-enriched uranium fueled MSR (DMSR)?

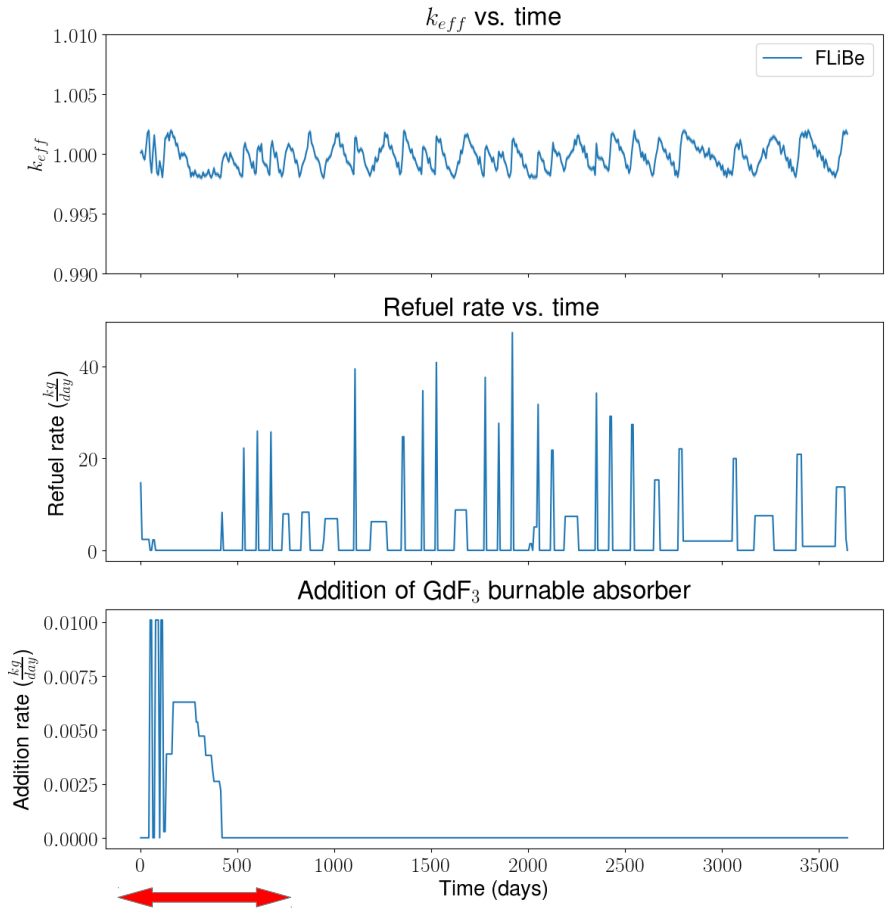
- Philosophy of the Smallest Step Forward →
  - LEU, no Th, no reprocessing, no outflow, no new materials.
  - Ascribed to by Terrestrial Energy Inc., Thorcon Power, …
- Start reactor on 2% LEU, add makeup 20% LEU fuel salt into the primary vessel bucket.
- Maintain DMSR burn by adjusting material flows only:
  - criticality by adding refuel salt or neutron absorber,
  - global charge balance (chemistry) by reductant addition.
  - Recent paper: G. Ridley, O. Chvala: "A Method for Predicting Fuel Maintenance in Once-through MSRs," Annals of Nuclear Energy (2017), in press.
  - **Adjusting material flow rates via Serpent MP interface?**
- What happens if we recycle the salt?

LEU-fueled FLiBe MSR under study

- 4x4 m core, 300 MWth for 10 years
- 2% LEU startup, 20% LEU makeup
- Salt: 72% ^{7}LiF - 16% BeF_2 - 12% UF_4

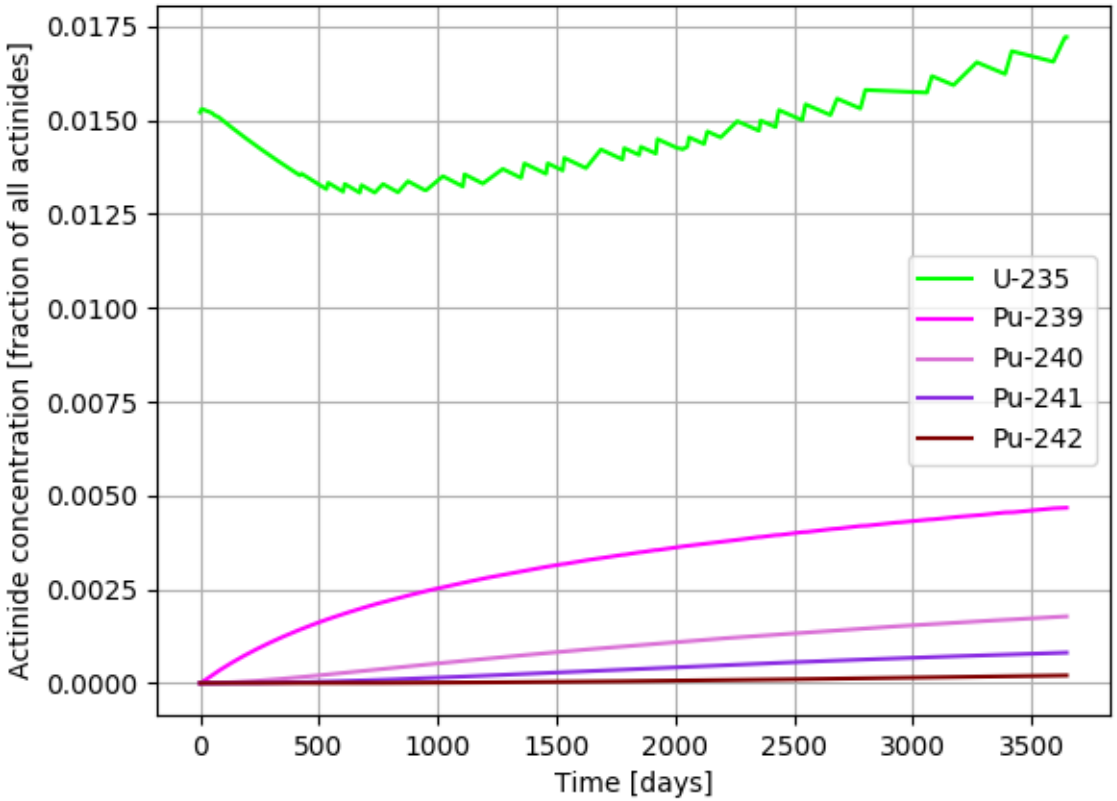






First depletion cycle results: 15.3 GWd/MTU

- Year 1 to 10, starting with fresh FLiBe-U salt, 300 MWth
- Startup is 65 tonnes of 2% LEU



Cycle 1	kg
20% LEU	4935
NU reducer	682
GdF_3	1.88

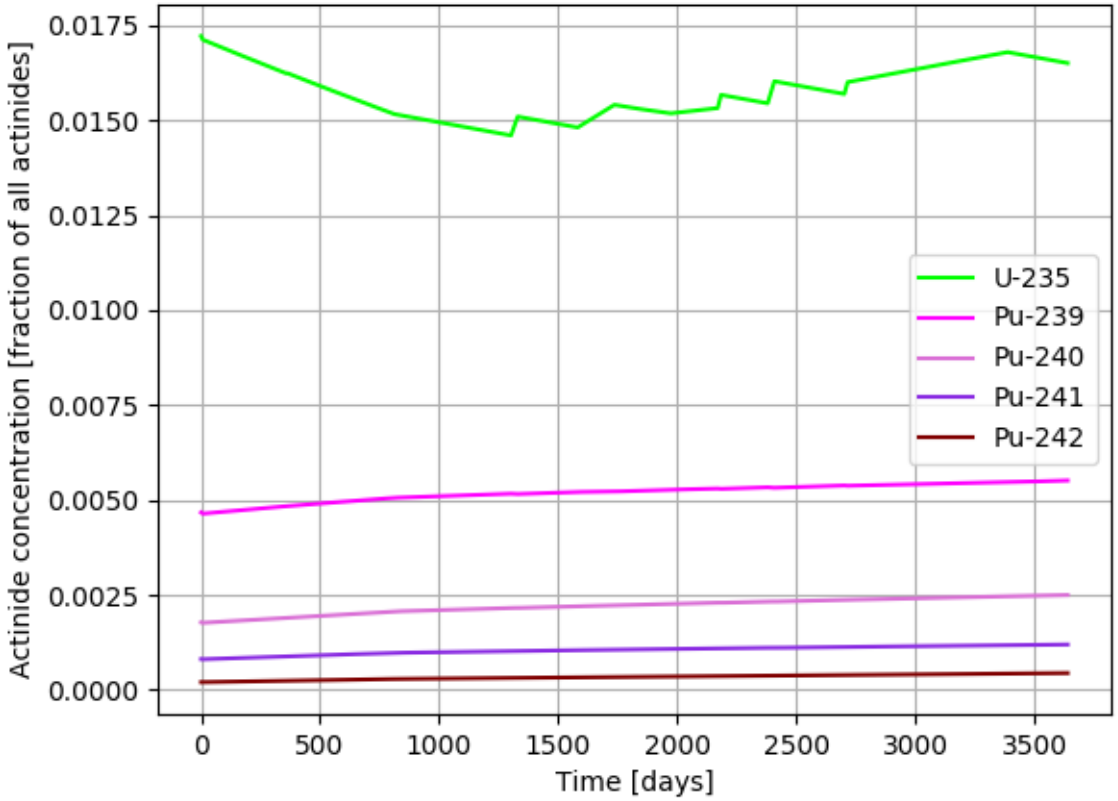
- Salt volume grows from 44.0 m^3 to 47.4 m^3.

After the burn cycle

- Core vessel needs replacement.
- What to do with this salt? Many options!
  - Convert to convenient disposal form (phosphate glass) and dump as-is.
  - Recover and recycle actinides only.
  - Strip most absorbing fission products and reuse.
  - Etc. etc.
- Choice in this presentation:
  - Strip gases, decrease remaining FPs to 10%!
  - Let k_{eff} coast down with depletion, then resume refuel.
- Motivation – quick look at possibilities with no chemistry research.

First recycle depletion results: 244.4 GWd/MTU

- Year 11 to 20, roughly cleaned salt, 300 MWth

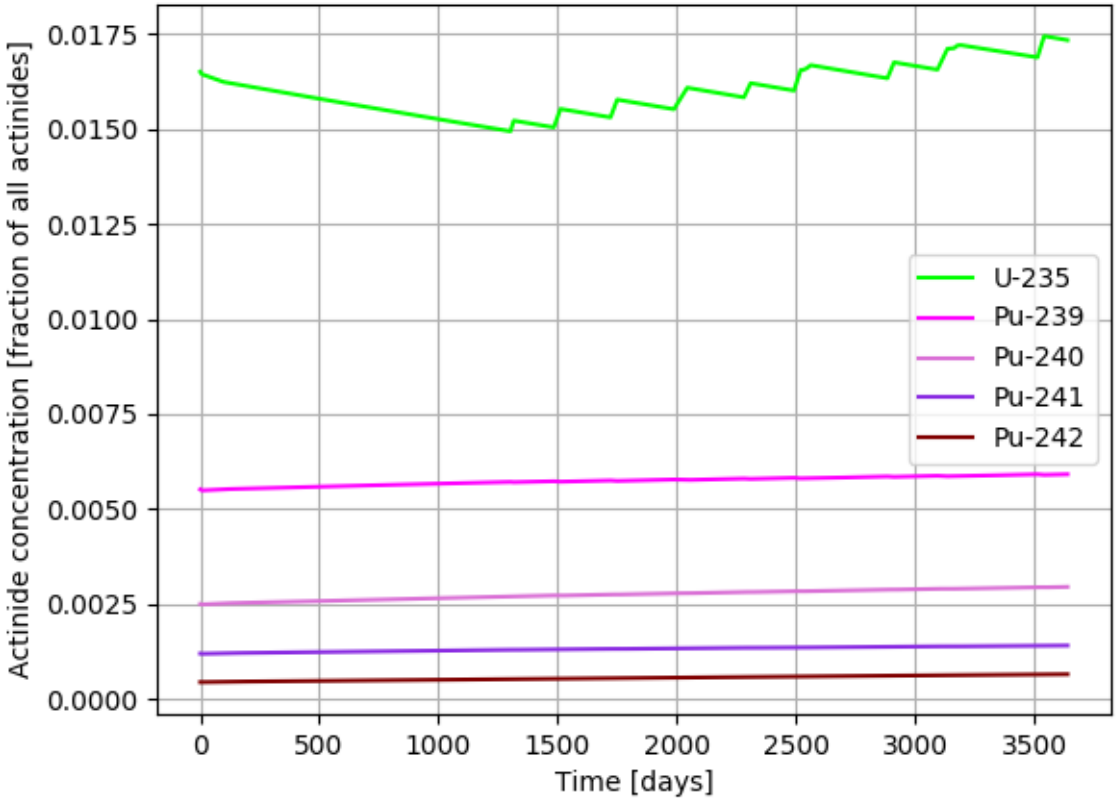


Cycle 2	kg
20% LEU	3568
NU reducer	912
GdF_3	0.0

- Salt volume grows from 47.4 m^3 to 49.8 m^3.

Second recycle depletion results: 231.5 GWd/MTU

- Year 21 to 30, roughly cleaned salt, 300 MWth

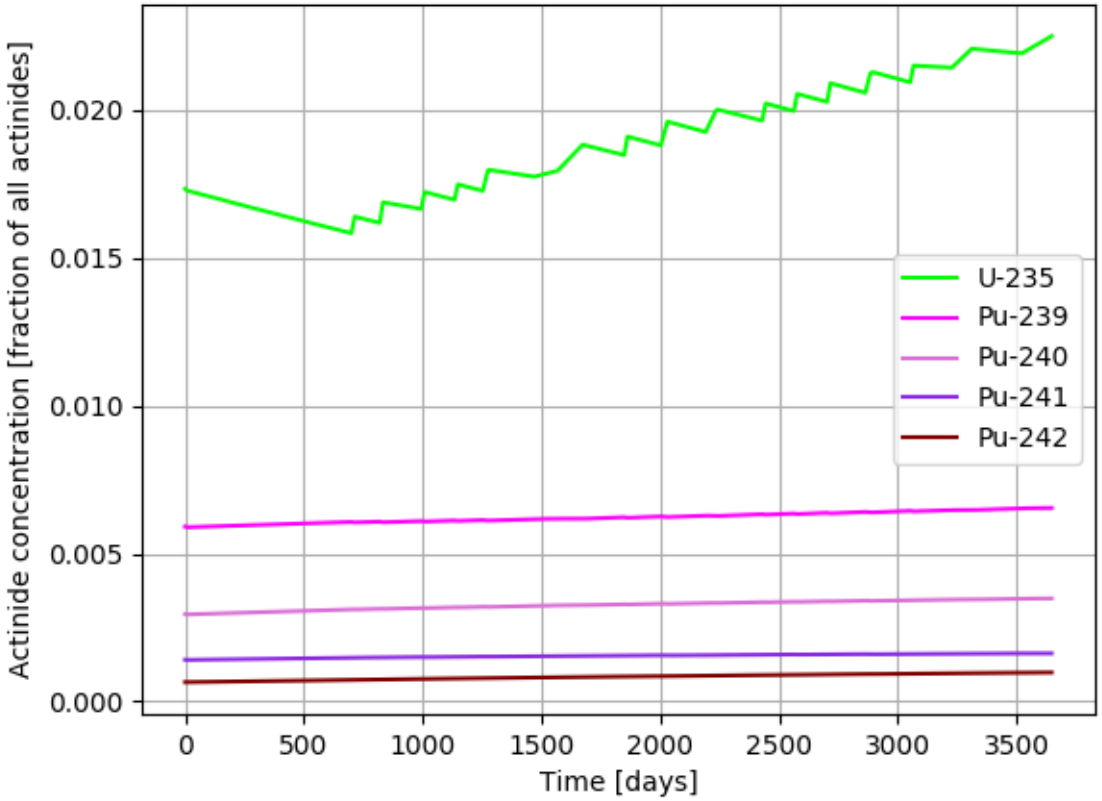


Cycle 3	kg
20% LEU	3915
NU reducer	816
GdF_3	0.0

- Salt volume grows from 49.8 m^3 to 52.5 m^3.

Third recycle depletion results: 172.7 GWd/MTU

- Year 31 to 40, roughly cleaned salt, 300 MWth

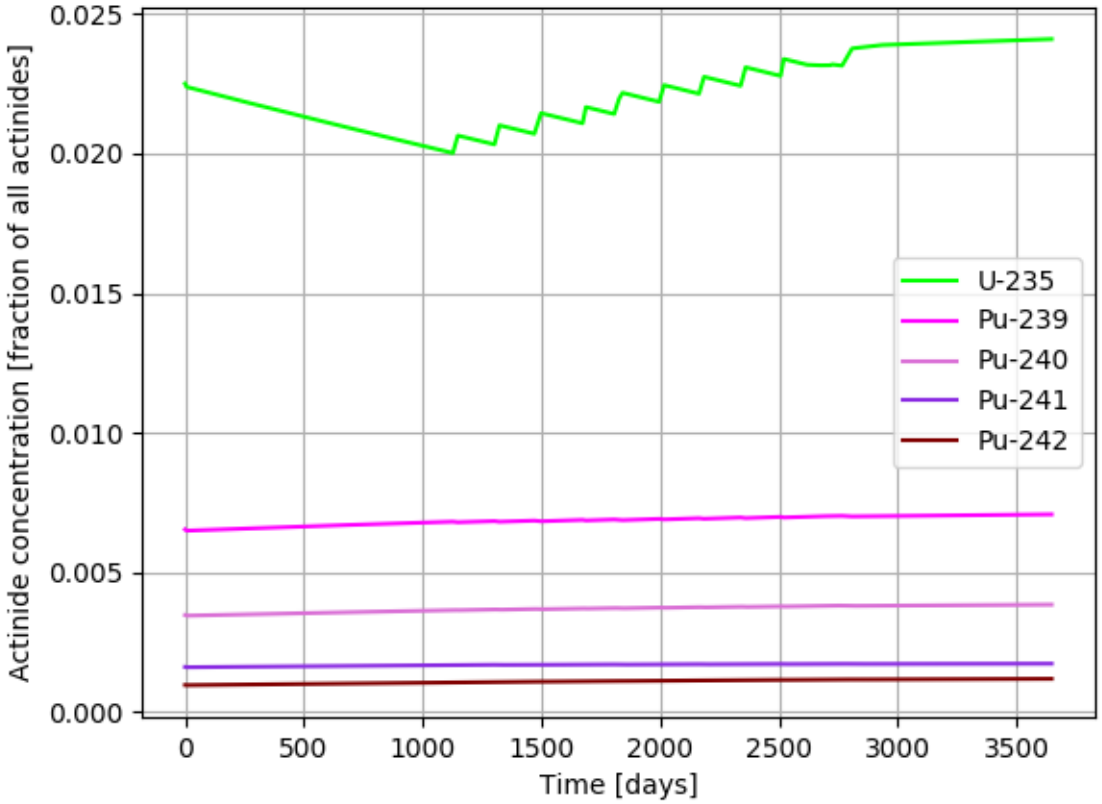


Cycle 4	kg
20% LEU	5569
NU reducer	772
GdF_3	0.0

- Salt volume grows from 49.8 m^3 to 56.3 m^3.

Fourth recycle depletion results: 193.6 GWd/MTU

- Year 41 to 50, roughly cleaned salt, 300 MWth

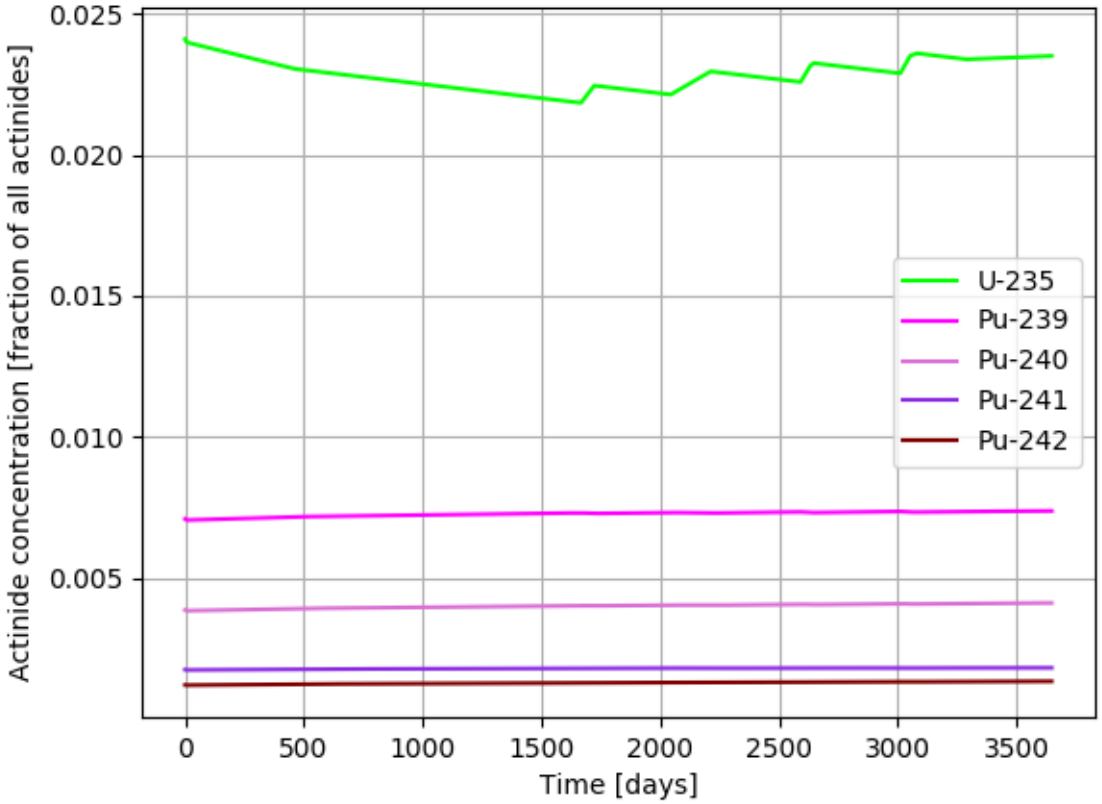


Cycle 5	kg
20% LEU	4774
NU reducer	881
GdF_3	0.0

- Salt volume grows from 56.3 m^3 to 59.6 m^3.

Fifth recycle depletion results: 251.3 GWd/MTU

- Year 51 to 60, roughly cleaned salt, 300 MWth



Cycle 6	kg
20% LEU	3502
NU reducer	855
GdF_3	0.0

- Salt volume grows from 59.6 m^3 to 62.0 m^3.

Conclusions

- Fluoride salt medium resistance to radiation damage and its liquid nature create new fuel cycle possibilities.
- This fuel cycle space is novel and was not analyzed previously.
- Even a simple unoptimized toy-like burner core achieves 250 GWd/MTU with LEU feed.
- Much improvement over a LWR burner!
- NU amount corresponding to LEU refuel needs to be considered for resource sustainability estimate.
- How to include it in DOE FC E&S methodology?