Molten Salt FP Release Tests in the GBI7 Experiment

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Grain Boundary Inventory 7 (GBI7) Experiment

- Last chance to use samples trace-reirradiated in NRU reactor
  - Trace-reirradiation technique was developed for GBI determination in $\text{UO}_2$

- Four different types of tests
  - GBI of MOX (similar to usual GBI of $\text{UO}_2$)
  - GBI of thoria (grinding; extension of previous work at Whiteshell Laboratories and elsewhere)
  - FP release from $\text{UO}_2$ under molten lead
  - FP release from molten salts

- Molten salt tests
  - 1000°C for about 4500 s – beyond design basis accident
  - Survey to determine whether FP release occurs
  - Inert, steam and air environments
  - preliminary results – data processing not complete
Molten Salt Preparation

- Trace-reirradiated UO$_2$ from NRU filler bundle
  - 38 kW peak linear power, 31 MWd/kgU burnup
  - Minimize segregation of noble metals into five-metal particles

- Grind to powder, mix with KHF$_2$ and NaF, add ~1% Zr
  - $\text{UO}_2 + 4 \text{KHF}_2 \rightarrow 2 \text{H}_2\text{O} + \text{K}_4\text{UF}_8$
  - Chvala studied reactor physics of 50.5%NaF – 21.5%KF – 28%UF$_4$
  - NaF lowers melting point
  - Zr consumes any excess F/HF from KHF$_2$, and will generate some “UF$_3$” in the mixture (desirable from reactor corrosion viewpoint)

- For some tests, substitute NaCl for NaF
  - Some fast reactor designs have chloride fuel salt separated from fluoride heat transfer salt
  - In order for significant FP release to occur, the fuel salt container must fail and the chloride and fluoride salts will mix
Molten Salt Test Technique

- Heat to ~400-500°C to cause reaction
  - Noble gases release during reaction – indicator for completeness of reaction
  - Minimal releases of other FP at this temperature

- Heat molten sample to 1000°C for about 4500 s
  - Observe using gamma spectrometry
  - Post-test analysis using SEM of cooled mixture
GBI7 Experimental Apparatus

Direct-Viewing \( \gamma \) Spectrometer

Pressure transducer

Gas supply

Ar
Air

Water supply

Delay Coil \( \gamma \) Spectrometers

Furnace

Nebulizer

Filter

Condenser

Gas outlet module

To water bubbler

In Cell

Sample
GBI7 Experimental Apparatus

- Sample
- Heat-traced Teflon fibre filter
- Gas out
- Water
- Argon
- SS Pushrod containing Type K thermocouple
- Hastelloy N furnace tube
- Furnace
## Tests

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Salt Type</th>
<th>Environment</th>
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<tbody>
<tr>
<td>MS1</td>
<td>UF$_4$-KF-NaF-1%Zr</td>
<td>Ar, 0.25 mmol/s</td>
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<tr>
<td>MS2</td>
<td>UF$_4$-KF-NaF-1%Zr</td>
<td>62% steam, 0.75 mmol/s</td>
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<tr>
<td>MS3</td>
<td>UF$_4$-KF-NaCl-1%Zr</td>
<td>69% steam, 0.67 mmol/s</td>
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<tr>
<td>MS4</td>
<td>UF$_4$-KF-NaCl-1%Zr</td>
<td>Ar, 0.25 mmol/s</td>
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<tr>
<td>MS5</td>
<td>UF$_4$-KF-NaF-1%Zr</td>
<td>air, 0.25 mmol/s</td>
</tr>
<tr>
<td>MS7</td>
<td>ThF$_4$-KF-NaF-1%Zr</td>
<td>Ar, 0.25 mmol/s</td>
</tr>
</tbody>
</table>
Preliminary results

- Fission product release at 1000°C
  - ~30% release of Cs isotopes
  - Comparable release of I-131
  - Much less I-131 release from chloride-fluoride salt than from fluoride-only salt
  - Release of Ru, particularly in oxidizing environment

- Fuel Behaviour
  - Inert-environment tests showed salt layer in bottom of boat
  - Oxidizing-environment tests showed salt “climbing over the walls” of the boat
  - Strong wetting of oxidized metal surface caused some salt to leave the boat
Future plans

- Molten salt samples will be examined
  - Completeness of reaction with $\text{UO}_2$
  - Oxidation state
  - FP segregation

- Future tests
  - Wetting behaviour in oxidizing environment
  - FP release at lower temperatures (NOC and transient)

- Establish trace-reirradiation capabilities with another reactor
  - Shorter time between irradiation and test to examine behaviour of other FP (e.g., Te, Mo)
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Thank you. Merci.

Questions?

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