EPRI Transient Fission Gas Release Measurements and Gas Inventory Evaluation

Nuclear

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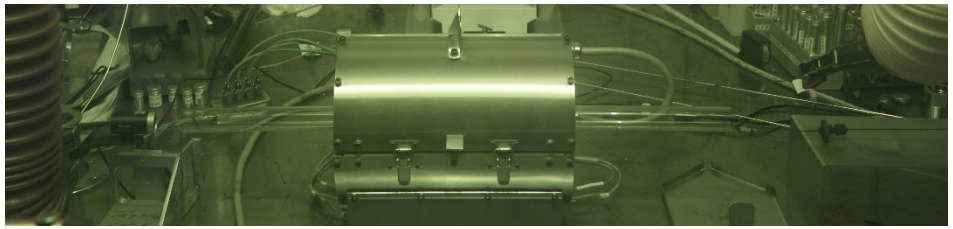
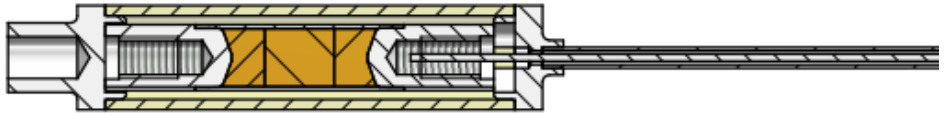
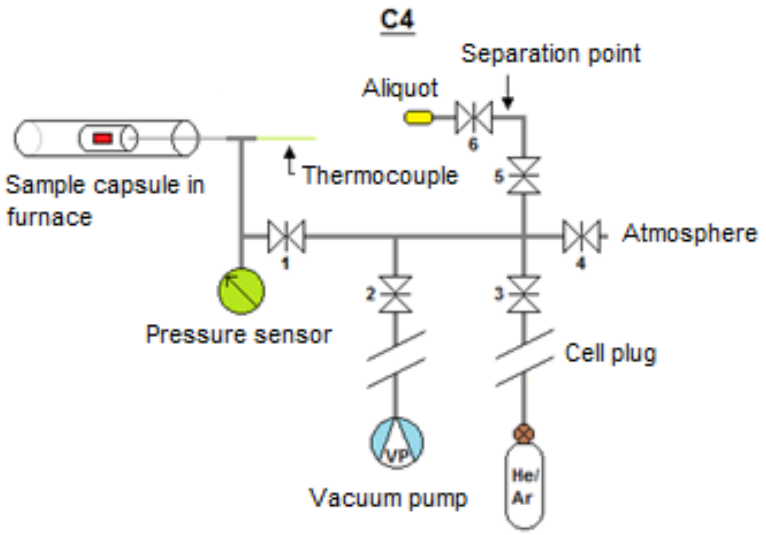
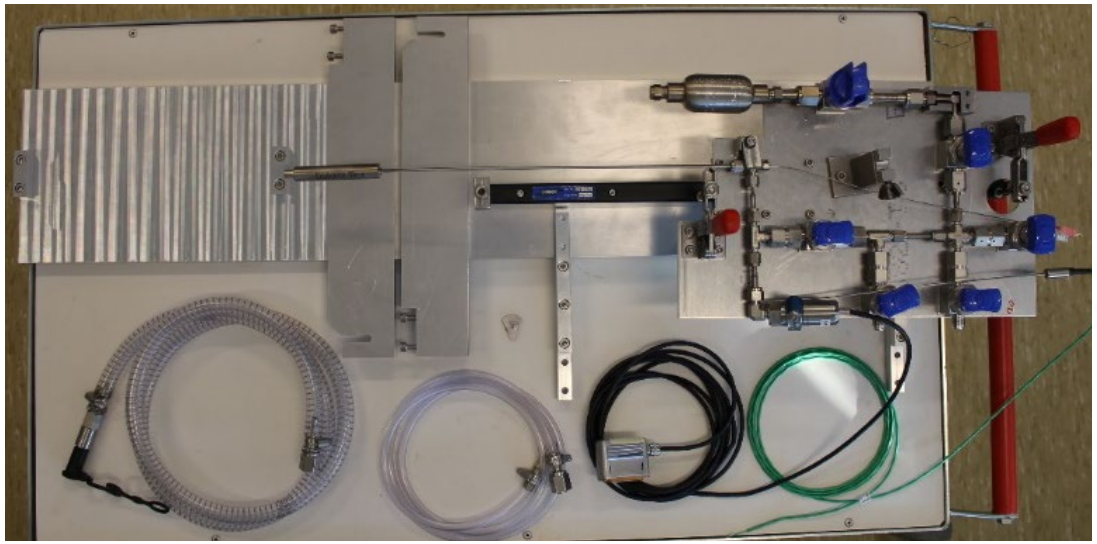
Transient Fission Gas Measurements

- EPRI conducted capsule tests at Studsvik
  - Multiple capsule wall thickness (1.5, 2 and 5 mm) to allow high internal pressure
  - Capsule inserted into pre-heated furnace









Materials Tested

- Multiple rods of different burnup and power history

Rod ID	Number of Cycles	Plant Type	Pellet Type	Rod Avg. Burnup Calculated (GWd/MTU)	Estimated Sample Burnup (GWd/MTU)
1	2	PWR	UO_2	55.2	60
2	NA	BWR	UO_2	57.1	62
3	NA	BWR	Dopped	59.1	64.3
4	4	PWR	UO_2	63.9	66
5	4	PWR	UO_2	68.2	78
A6	4	PWR	UO_2	70	78
Calculated burnup is based on in-core fuel management calculations.					

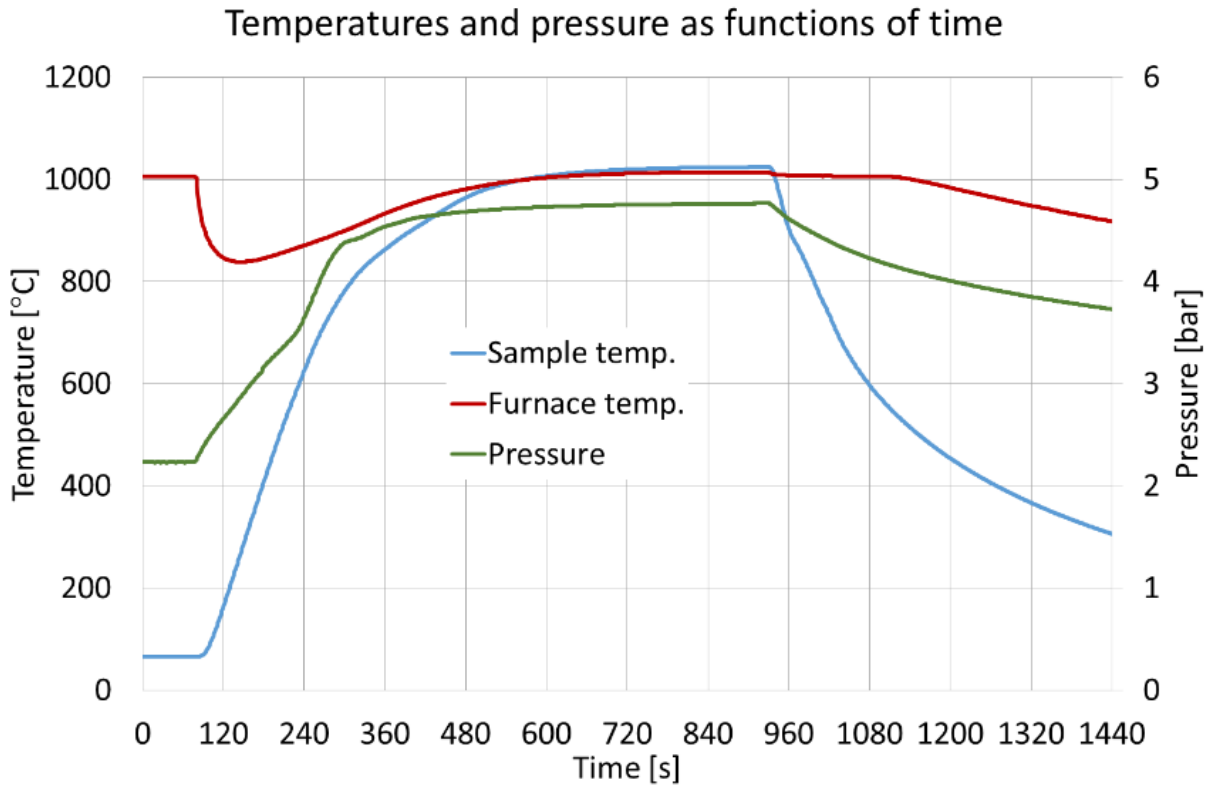
Test Condition

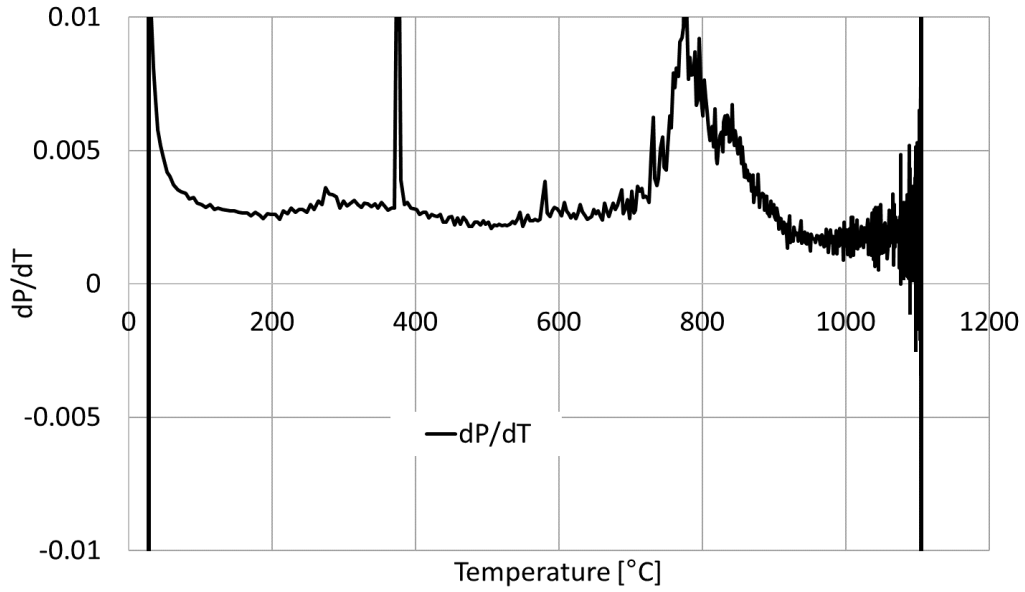
- A combination of different burnup, fill pressure and peak temperature

Test ID	Local Burnup (GWd/ MTU)	Capsule Wall (mm)	Peak Temp. (°C)	At Temp. Soak time (s)	Fill Pressure (bars/MPa)
1	78	1.5	1000	496	1.91/0.19
2	66	1.5	1000	355	1.67/0.17
3	77	5	1002	0	24.3/2.46
4	78	5	1004	0	11/1.11
5	78	2	1,113	0	2.02/0.20
6	70	2	1,105	0	2.01/0.20
7	~60	2	1,113	0	2.04/0.21
8	64.3	2	1,121	0	2.02/0.20
9	~62	2	1,108	0	2.13/0.22
10	78	5	1,100	0	2.01/0.20
11	78	5	1,094	0	39.97/4.05
12	78	5	750	0	80.2/8.13
13	78	5	750	0	46.0/4.66

Low Pressure Tests

- Initial tests were conducted at low fill pressure and more sensitive pressure transducer

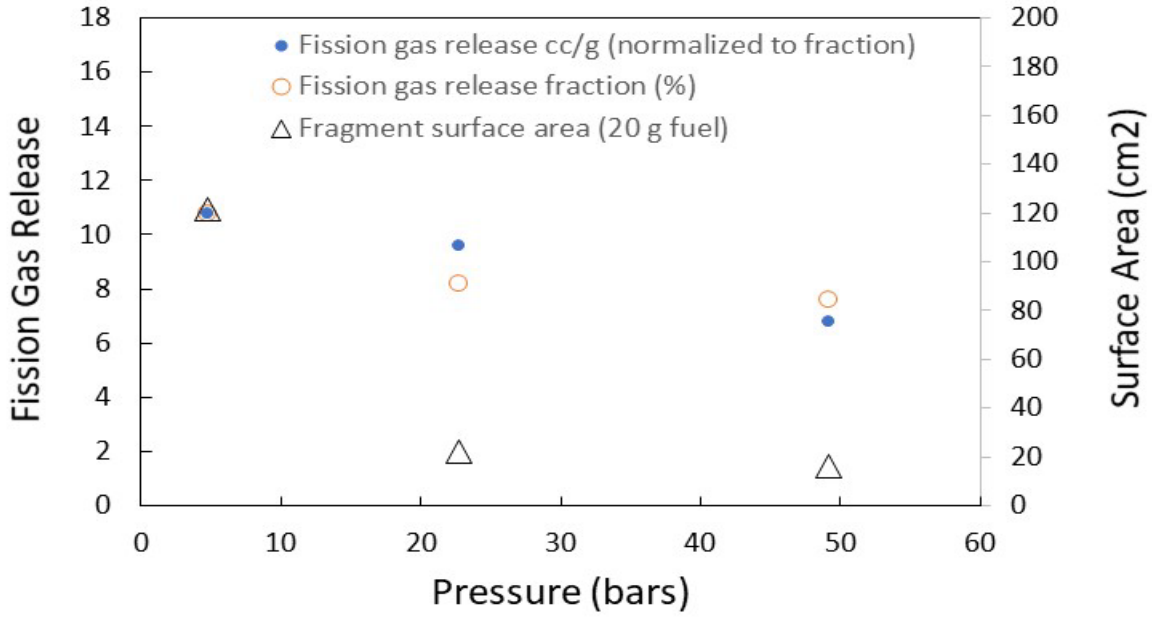




Higher Pressure

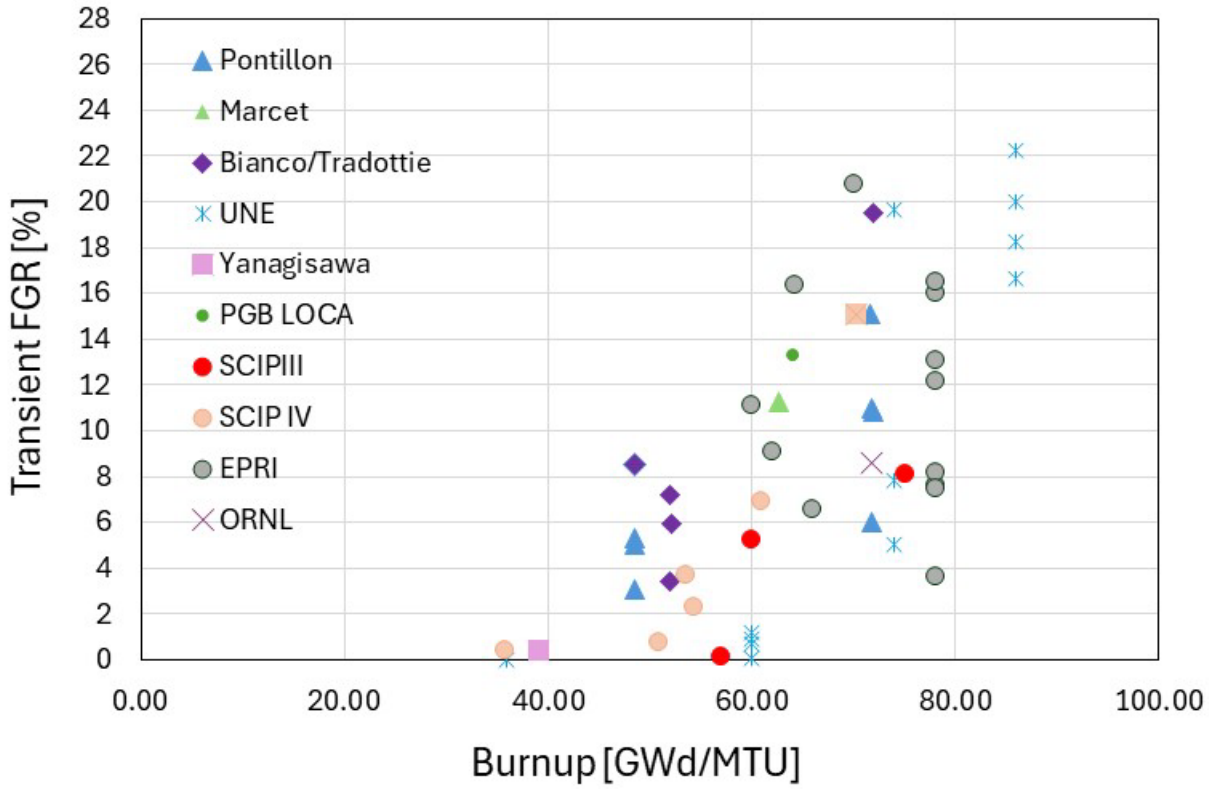
- Fuel Fragmentation

- Less fuel fragmentation when test sample under pressure (non-burst rods)
- Slightly less fission gas release under pressure
- tGR is not due to fragmentation



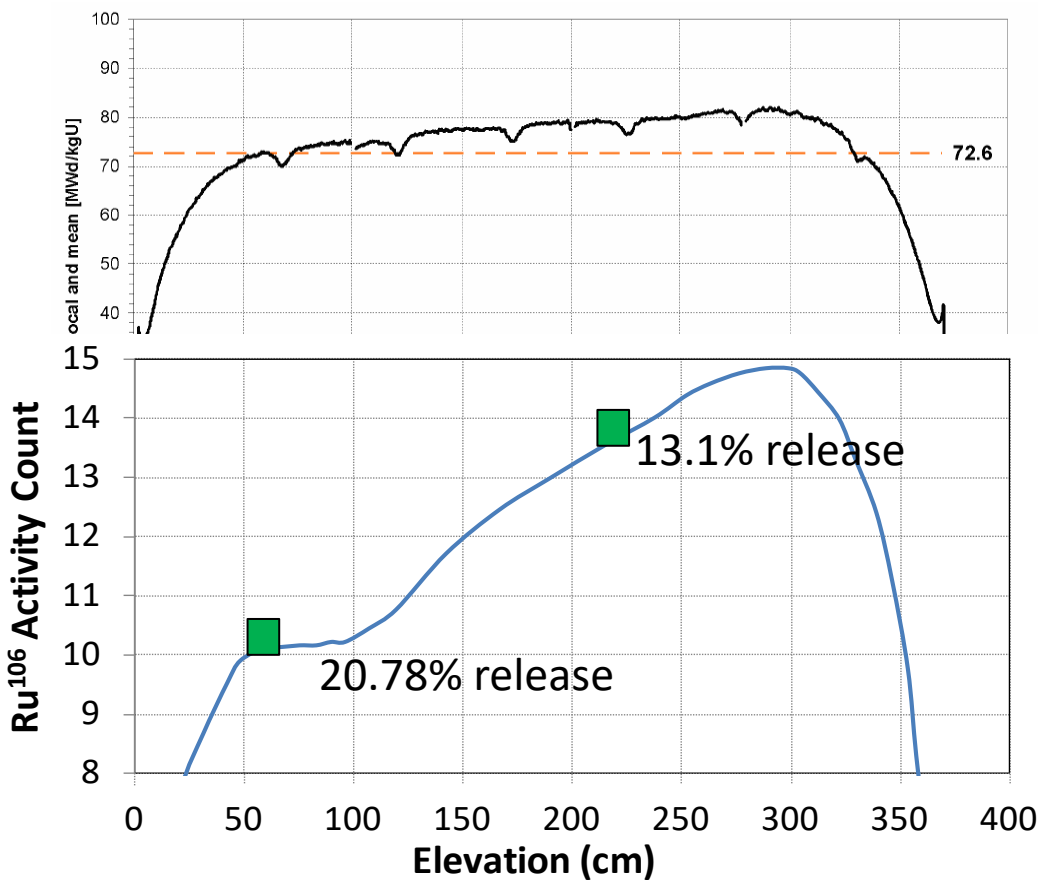
Tests Completed

- Samples heated up to 1100°C
  - Most of the gas is released by 850°C
  - Minor gas release from 1000°C to 1100°C
- Possible inverse relationship to operational gas release
- High pressure significantly suppresses tGR
- Less gas released at time of burst

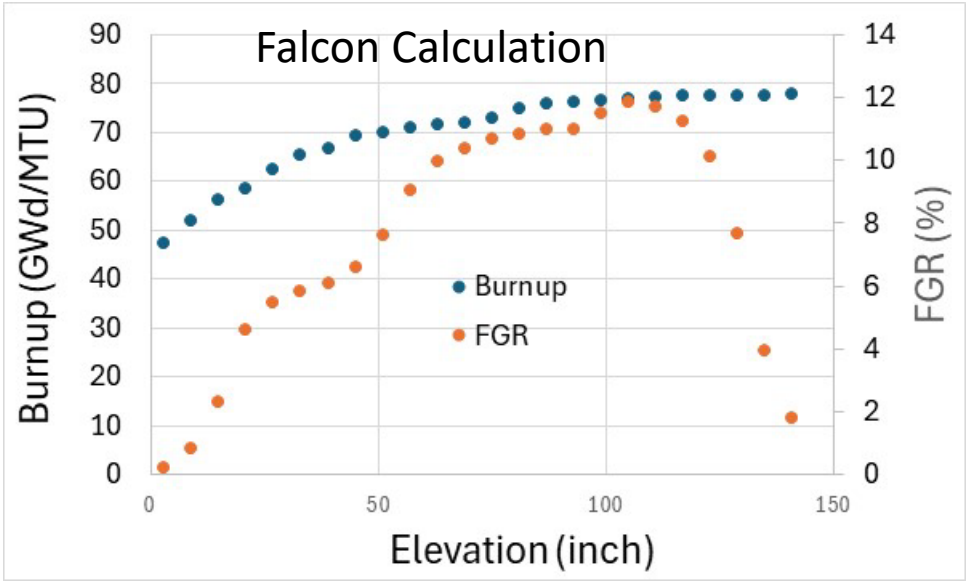


Operational Release Impact

- Higher operational release may lead to lower transient release

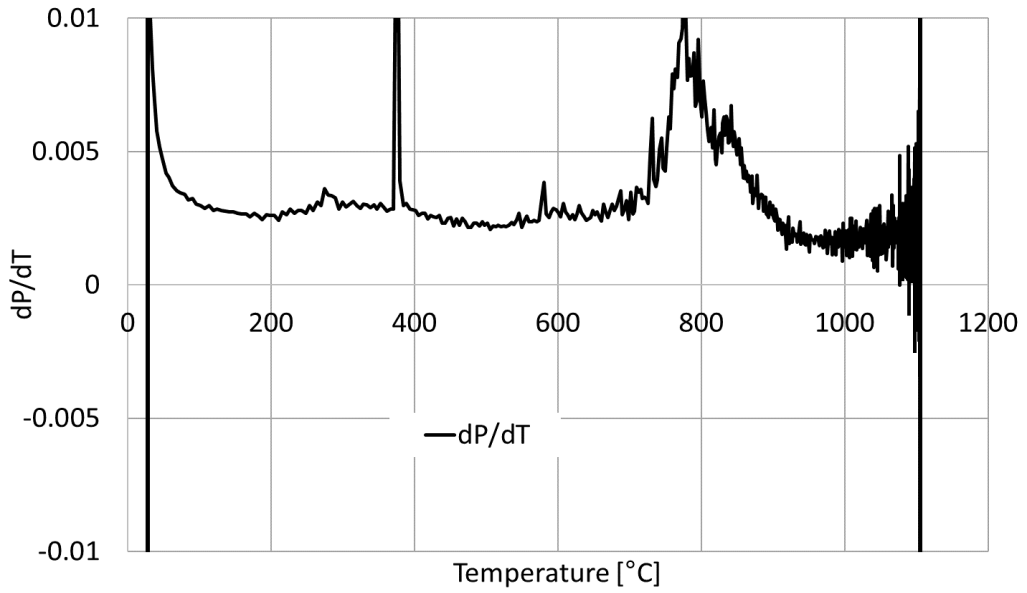


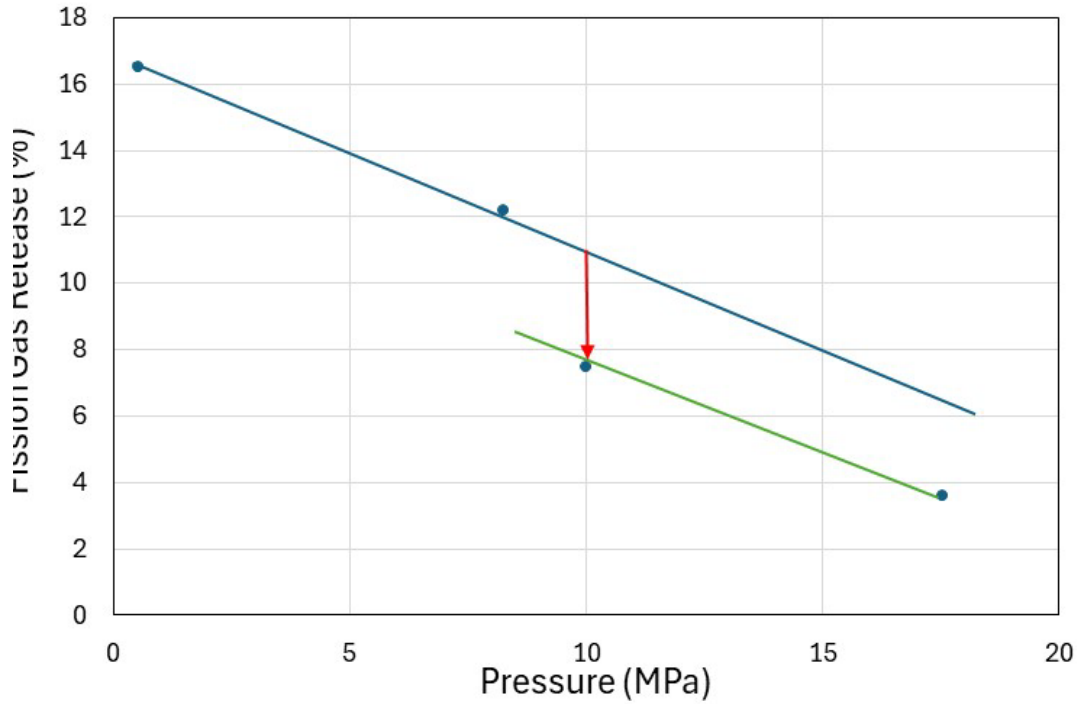
- Sample section from a rod with high operational fission gas release
- ^{106}Ru activity indicates last cycle power



Lower Peak Temperature Comparison

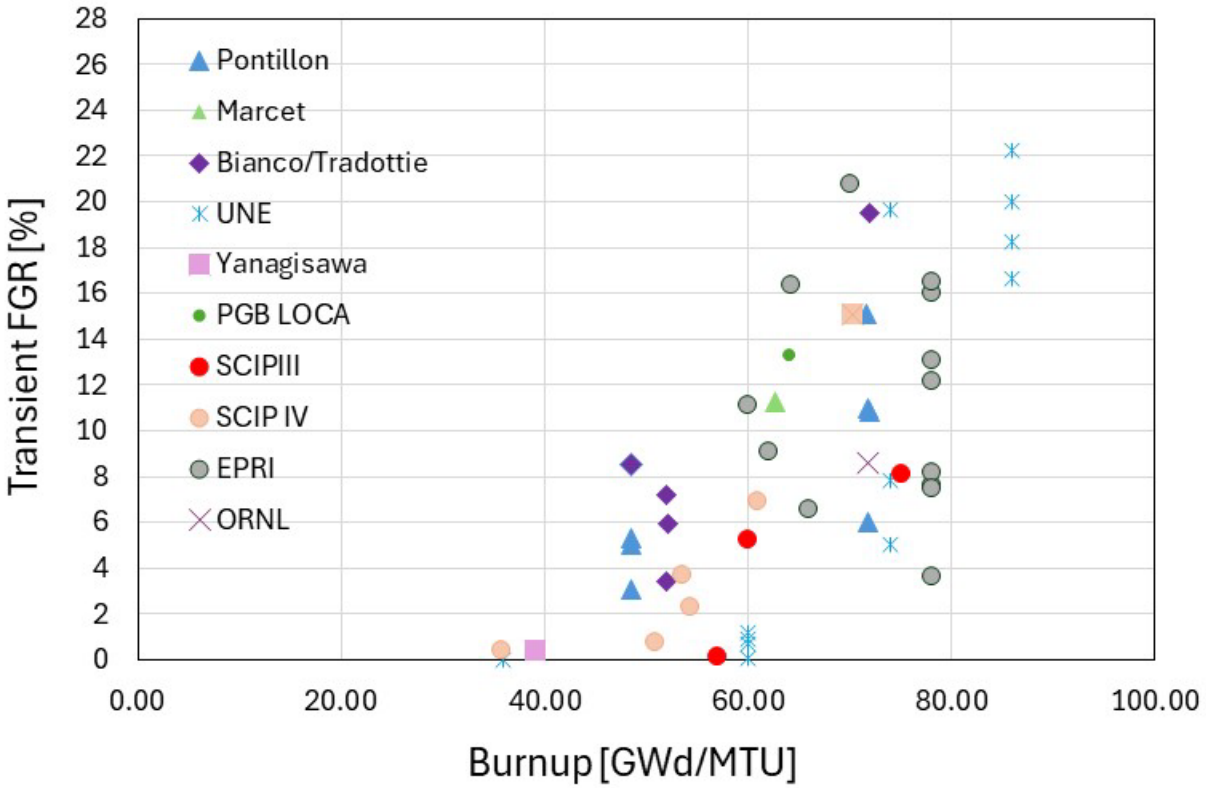
- Sample withdrawal at 750°C versus 1100°C at different pressure
  - Approximately ¼ less gas released at 750°C

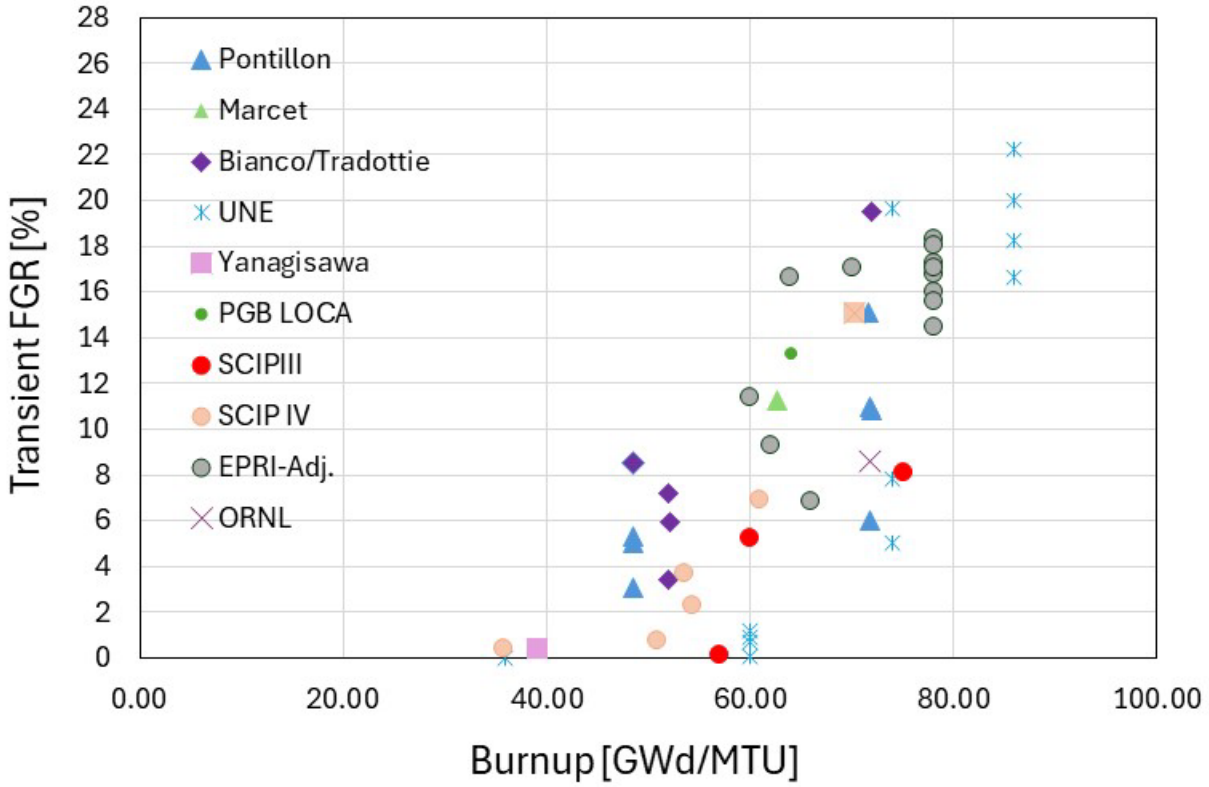




EPRI tFGR Data Adjustment

- Test pressure normalized to 0.1 Mpa
- Adjust for rod puncture fission gas release measurements
- 750°C withdrawal adjusted to 1000°C
- Falcon calculation on axial release with power gradient



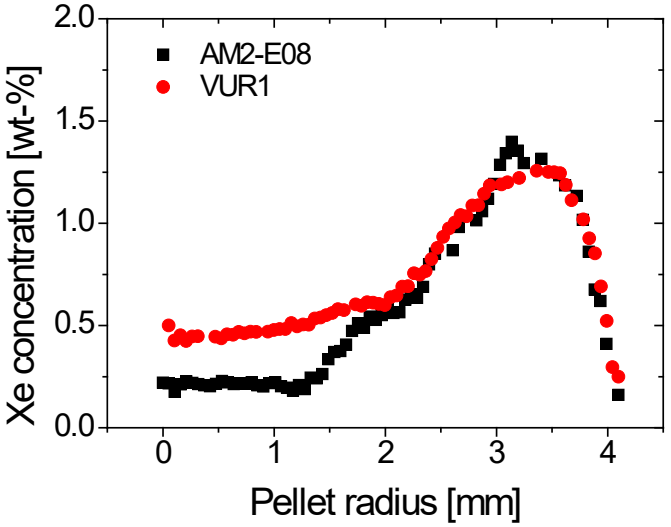


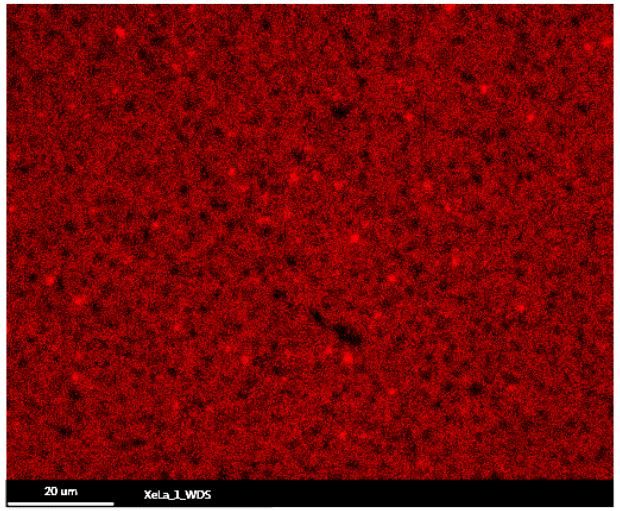
Model Grain Boundary Calculation

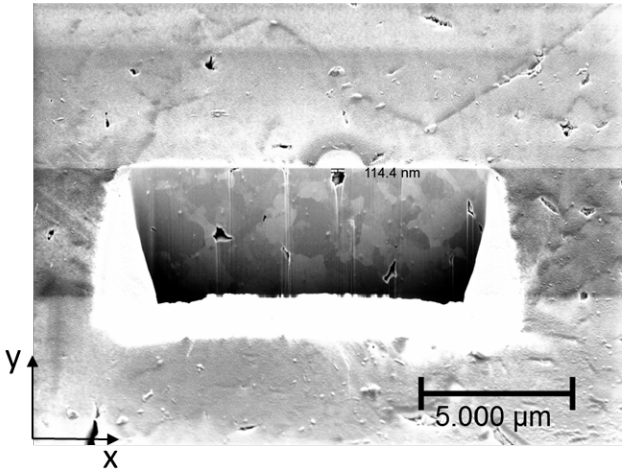
- Grain boundary fission gas inventory increases with power
- Not consistent with grain boundary oxidation measurements
  - Likely gas trapped in small bubbles near the grain boundary are release in grain oxidation experiments

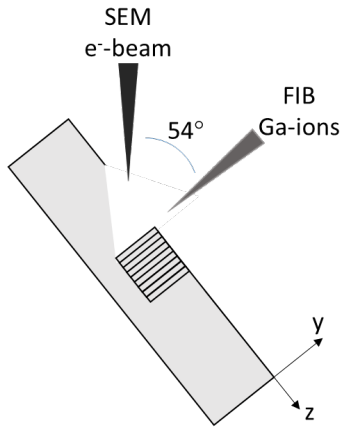
Fission Gas Distribution Quantification

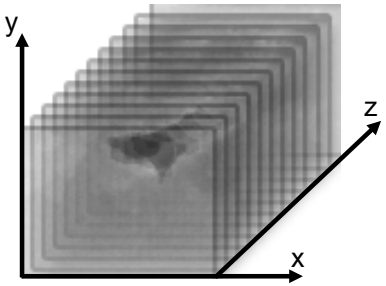
- EPRI evaluated feasibility to generate a holistic distribution of key fission gas in UO_2 fuel
  - Matrix
  - Bubbles
  - Grain boundary

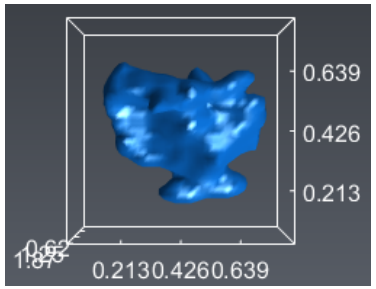


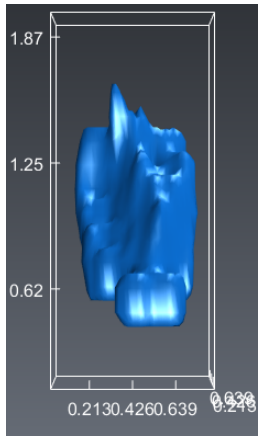


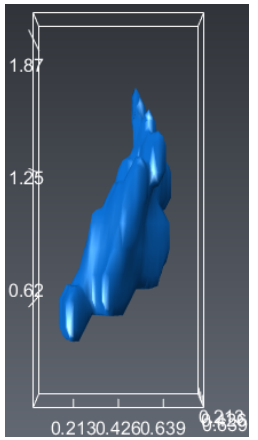






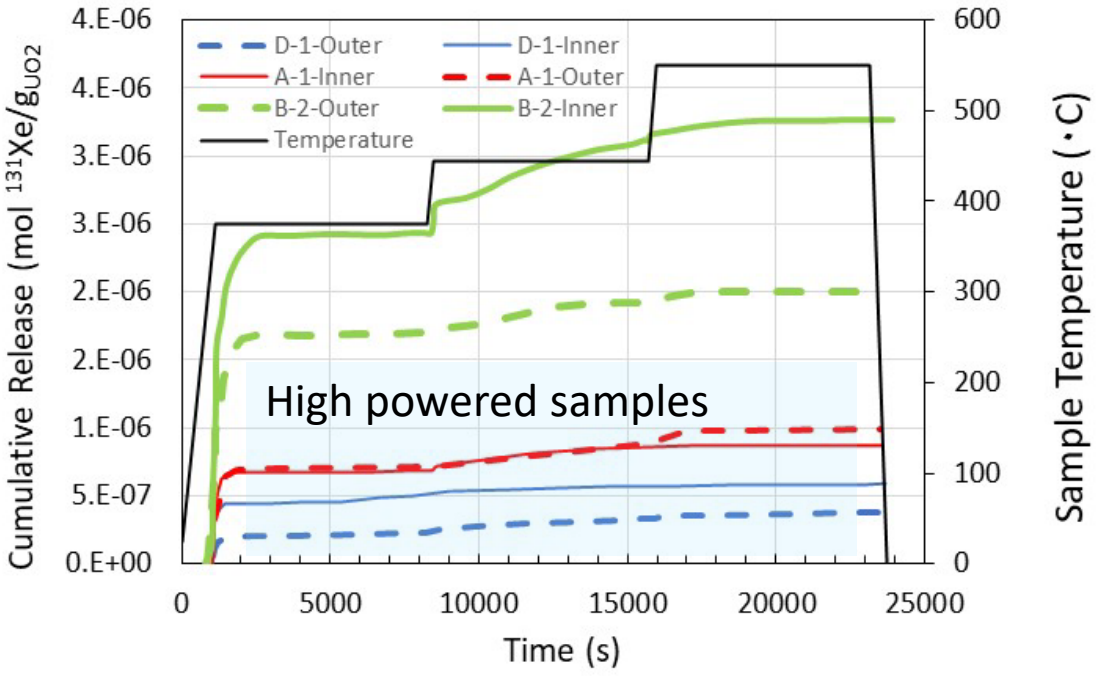


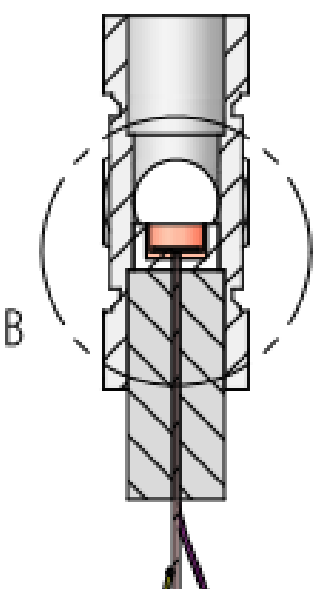


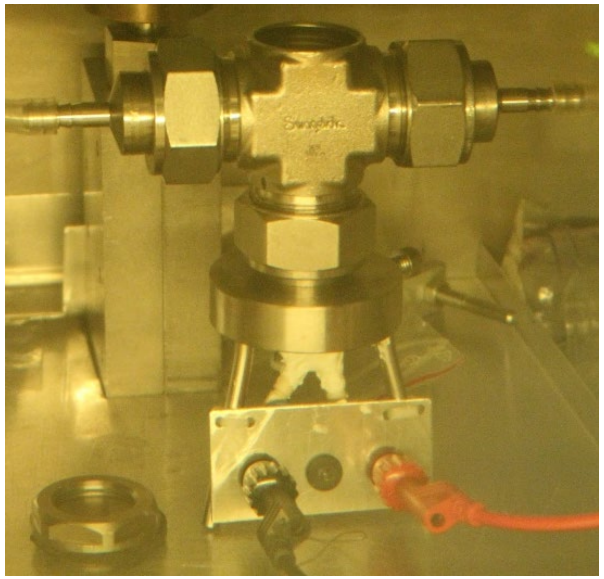


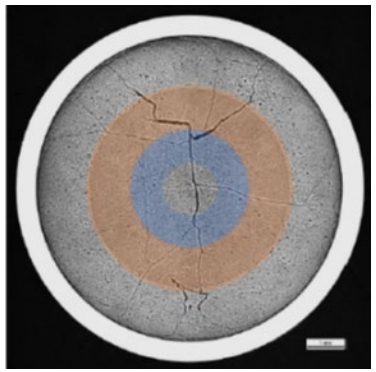
Grain Boundary Fission Gas Measurement

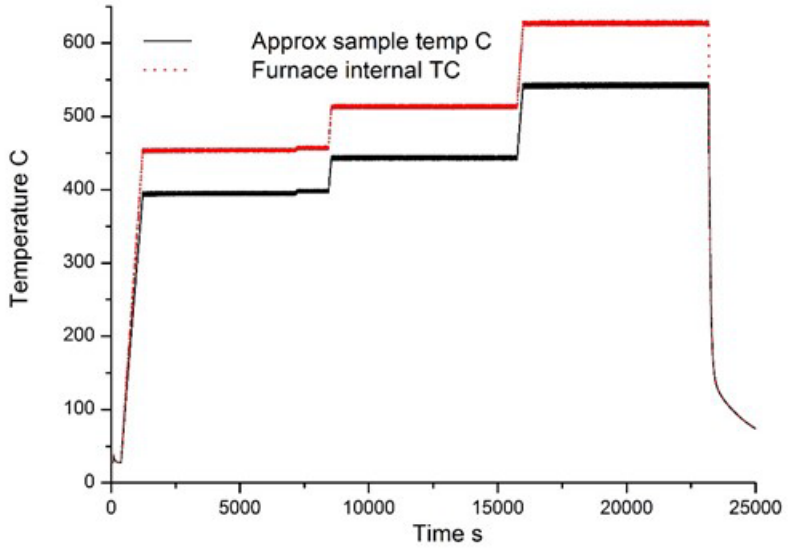
- Low temperature preferential oxidation of the grain boundary used to measure the grain boundary gas content
- High powered fuel rods has lower grain boundary fission gas content











Summary

- Measured tFGR is within open literature database
- Isostatic pressure suppresses transient fission gas release
- Possible tFGR link to operational release
  - Additional tests being conducted to verify
- Burst temperature withdrawal decreases tFGR by approximately ¼
- Possible factors contributing to data scatter explored
  - Operational release / resident gas inventory
  - Test pressure
  - Peak temperature
- Total gas quantification may be possible, but requires a lot of work
  - May improve model predictions

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