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VHTR Fuel and Fuel Cycle Project Management Board Overview

September 2022

Changing the World's Energy Future

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Idaho National Laboratory

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33rd VHTR System Steering Committee Meeting

29 Sep 2022

17th Official Meeting of the FFC PMB

- Virtual event held on 14-15 Sep 2021
- Canada participated as an observer

Korea
- Eung Seon Kim

France
- Thierry Lambert (*observer*)

China
- Bing Liu

Japan
- Jun Aihara

EU
- Waclaw Gudowski

USA
- Paul Demkowicz (chair)
- John Hunn
- Tyler Gerczak (*observer*)

Tech. Secretary
- Gabriele Grassi

UK
- Tim Abram (*observer*)

Canada
- Ali Siddiqui (observer)

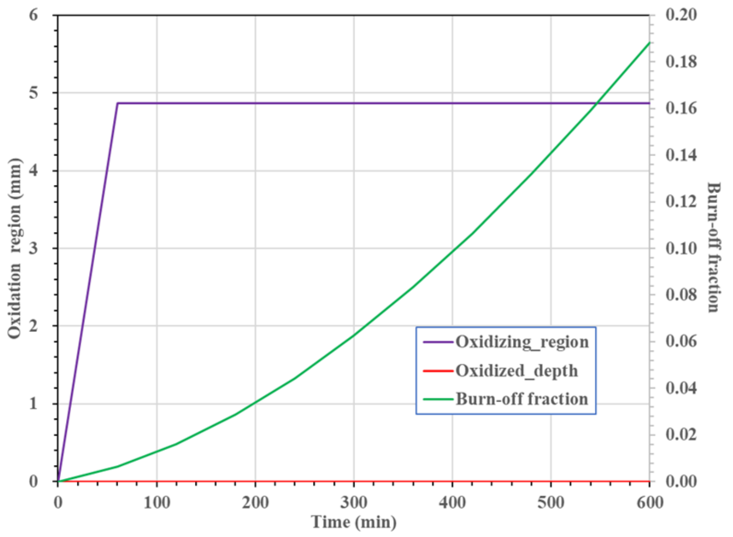
- Next PMB meeting is 18 Oct 2022 in Aix-en-Provence (first in-person meeting since May 2019)

Korea

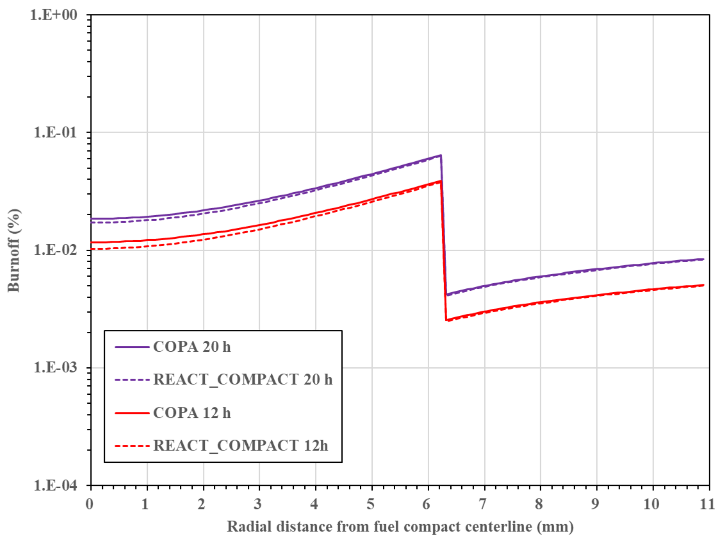
Fuel: Oxidation of a fuel element under air and water ingress conditions

– Air ingress: complete severing of the horizontal vessel between the reactor vessel and the power conversion system vessel and then depressurization and air diffusion into the core

– Water ingress: steam generator leak or failure of a heat exchanger tube with reactor depressurization and water vapor into the core



Oxidation of a graphite web during air ingress
(bulk temperature = 600 ℃, graphite thickness = 6.61 mm)



Oxidation of a compact and a graphite web during water ingress
Calculated using the COPA and REACT_COMPACT code

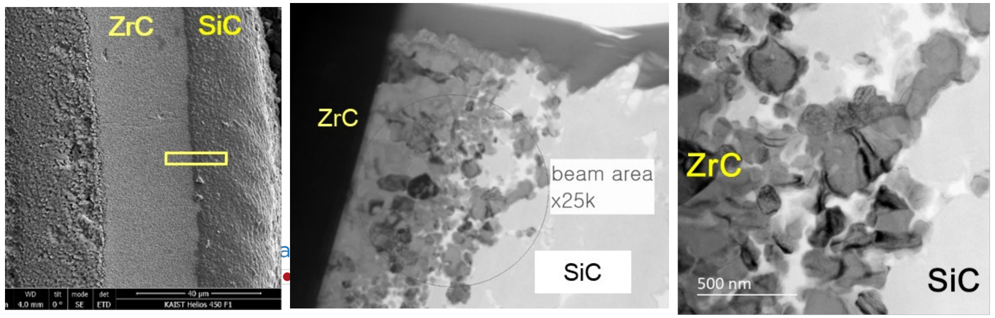
Korea

Fuel : Simulated irradiation test for ZrC/SiC coating layers

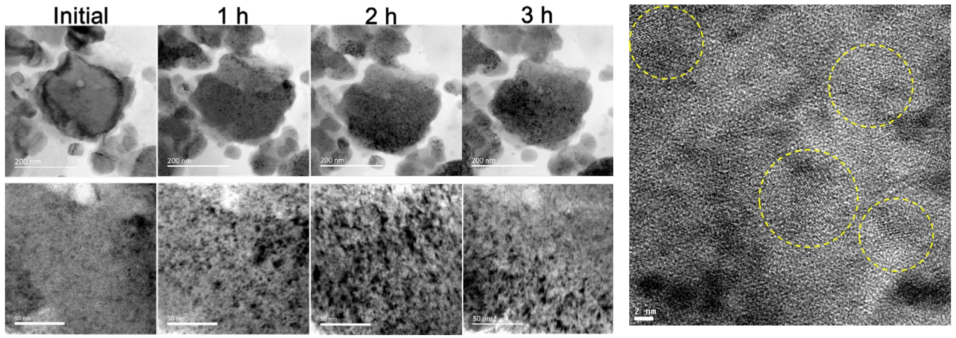
– Compatibility of ZrC and SiC layers under irradiation environment

- Excellent interfacial soundness of ZrC-SiC after Ar ion irradiation with a fluence of 1×10^{18} ions/cm^2 (~6.7 dpa)
- Dynamic defect evolution in a ZrC grain of Ar irradiated coating under HV-TEM irradiation

#	Acceleration voltage	Irradiation	Temperature	Analysis	Status
1	120 keV	Ar ion	25 ℃	- Investigated interfacial contact of ZrC-SiC and emerged defects in ZrC regions such as dislocation loops after ion irradiation	Completed
2	1250 keV	HV-TEM	25 ℃	- Investigated defect evolution and emerged black-dot defects in ZrC with increasing HV-TEM irradiation durations - Observed secondary phase evolution which seems to be zirconium oxides after electron irradiation	Completed
3	1250 keV	HV-TEM	700 ℃	- The influence of high temperature on the defect evolution under the in-situ HV-TEM irradiation - Final evaluation of interfacial compatibility of ZrC and SiC	Completed



Excellent interfacial contact of ZrC-SiC after Ar irradiation up to 10^{18} ions/cm^2



Defect and secondary phase evolutions in ZrC as increasing the duration of 1250 keV HVTEM

China

Deconsolidation and burnup measurement of irradiated HTR-10 fuel

- Three SFEs with low to medium burnup were selected and measured using destructive and non-destructive methods.
- Gamma and mass spectrometry were applied, and an electrochemical deconsolidation process was conducted to obtain TRISO fuel particles from specific regions.
- The uniformity of burnup in each SFE was also studied simultaneously by the mass spectrometry method.

HTR fuels before (left) and after (right) irradiation

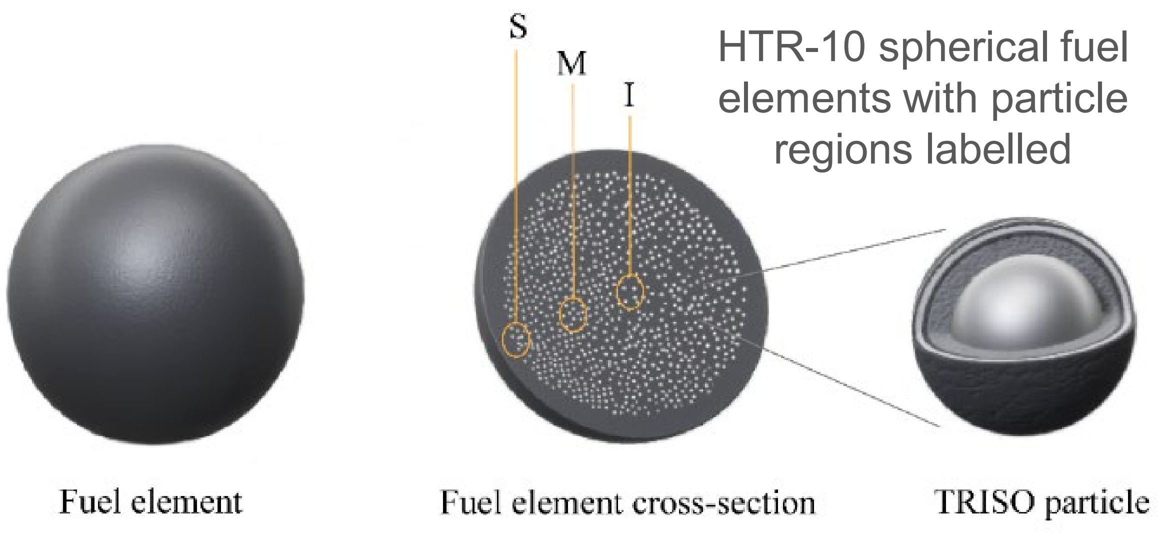
INET HOTLAB (for PIE of HTR fuel pebbles)

China

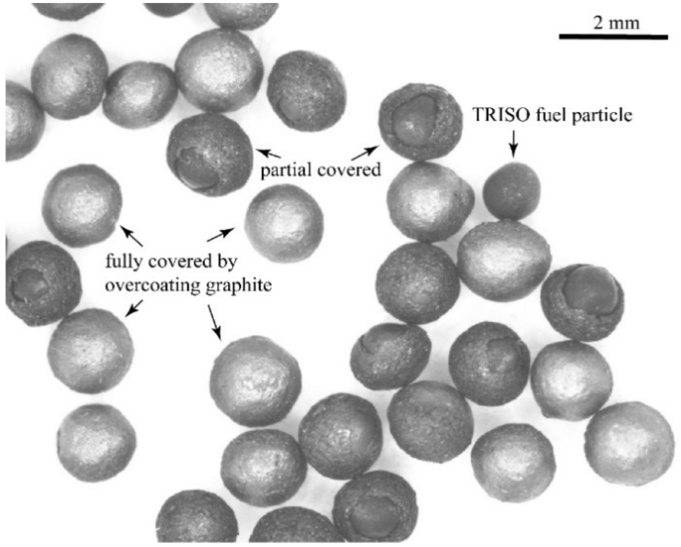
Leaching and Mass Spectrometry

- After the deconsolidation and separation, dozens of particles were randomly selected from different regions of the fuel zone and labelled as Surface, Middle and Inner.
- The selected particles were crushed to expose UO_2 kernels and transferred for the leaching process.
- Spectrometry (MC-ICP-MS, Neptune plus) was used to measure the content and isotope ratio of uranium, neodymium and plutonium nuclides.

HTR-10 spherical fuel elements with particle regions labelled



TRISO fuel particles after electrochemical deconsolidation



China

Burnup uniformity in SFE and distribution of Cs-137

- The total activity of Cs-137 in each irradiated SFE was measured separately by non-destructive gamma spectrometry and destructive gamma spectrometry of particle leachate solutions and remnants.
- Table lists the ratio of Cs-137 activities derived from non-destructive and destructive measurements (N/D). Differences caused by reasons of U-loading in one SFE, the deviation of UO_2 kernel diameter uranium contamination during fabrication and were calculated, and the ratio ranges among 0.92~1.09, which covers most values.

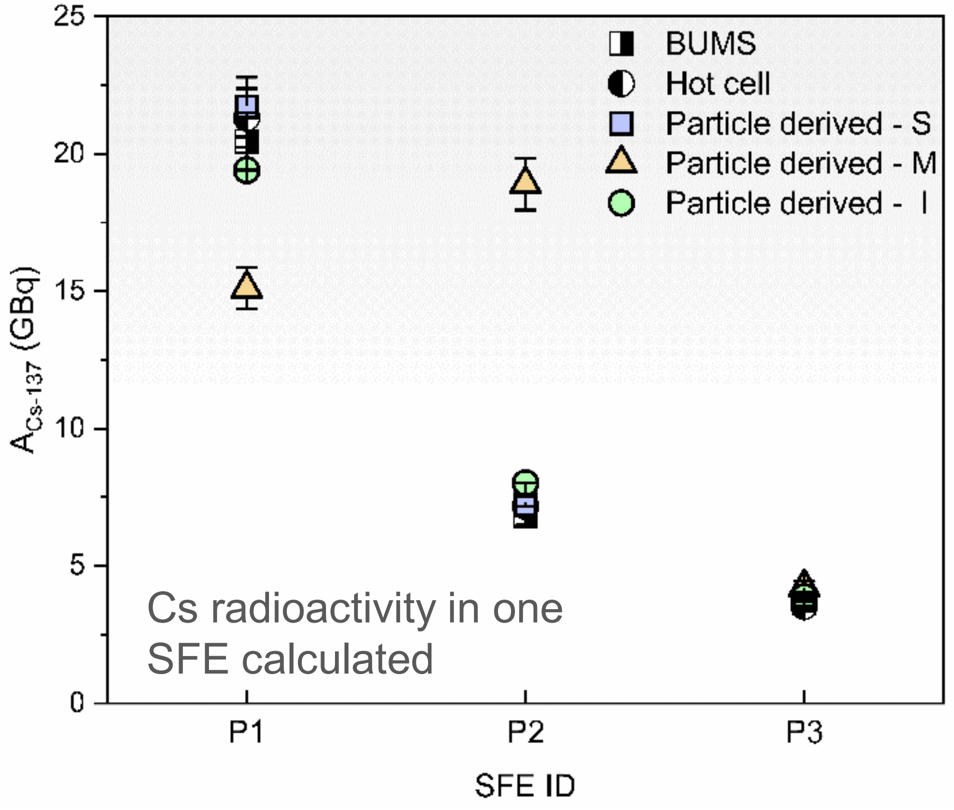


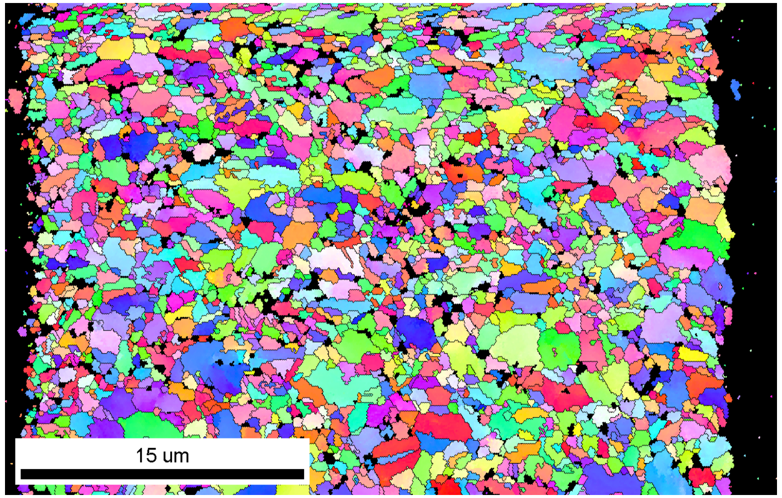
Table 3 Measured to derived activity ratio

Batch No.		N/D
P1	S	1.03
	M	0.72
	I	0.92
P2	S	1.05
	M	2.74
	I	1.11
P3	S	1.06
	M	1.12
	I	1.07

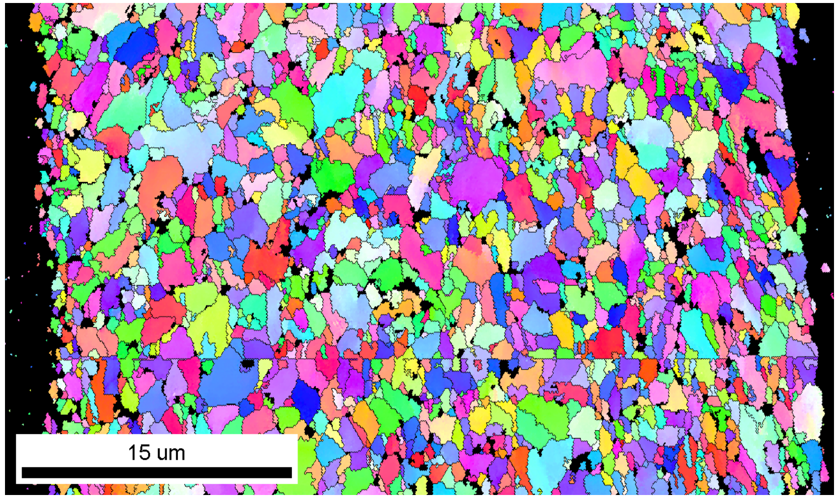
China

High temperature heating test of as-fabricated HTR fuels

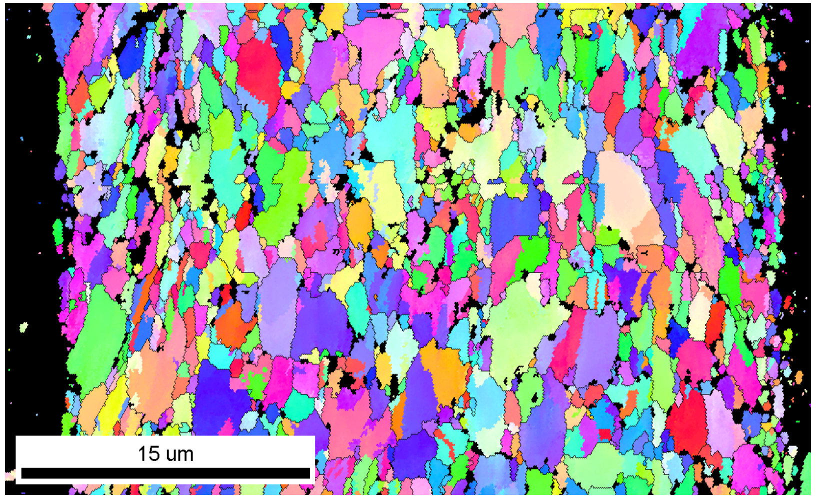
EBSD IPF图（Inverse pole figure）



As fabricated SiC



1800°C-1h heating SiC



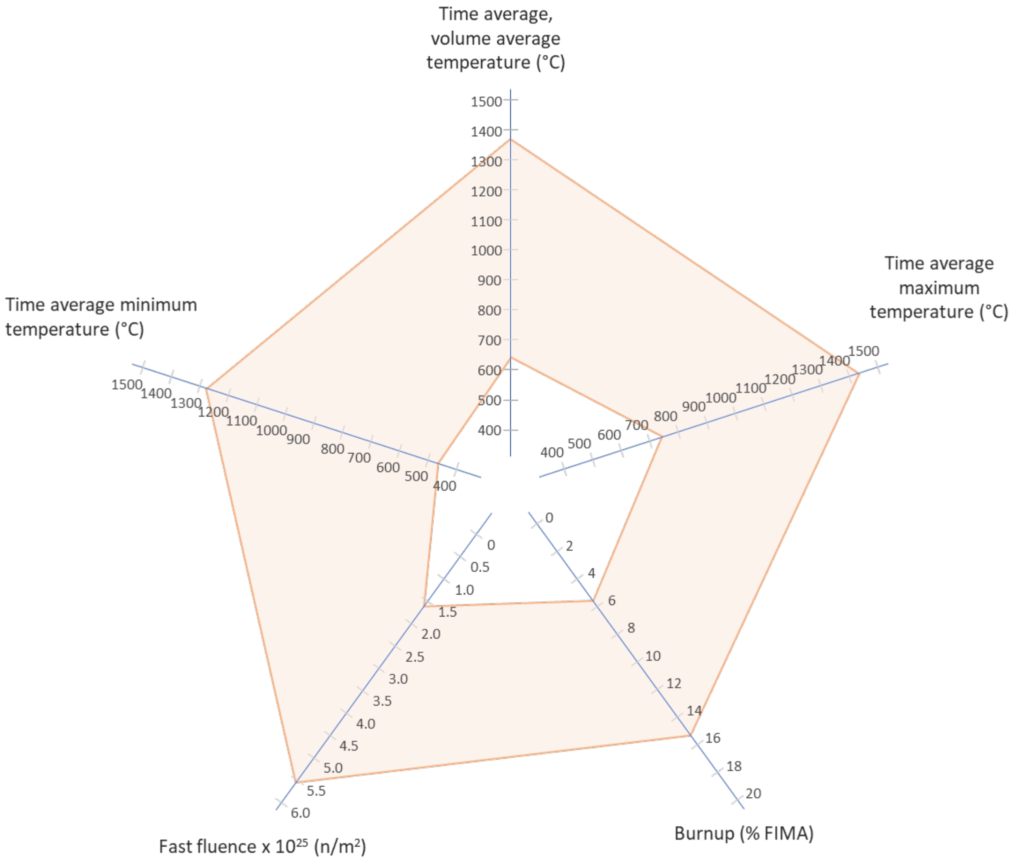
2000°C-1h heating SiC

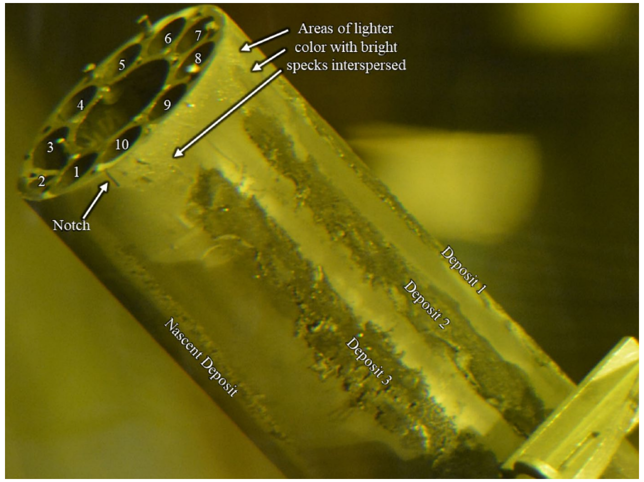
- SiC grain sizes were compared after high temperature heating tests
- The heated specimens exhibited grain growth during heating

US

AGR-5/6/7 Irradiation Update

- Final fuel qualification irradiation and performance margin test
- 194 UCO fuel compacts (~570,000 particles)
- Irradiation ended in July 2020 after 360 EFPD
- PIE began in spring 2021
- Capsule 1 investigation confirms that thermocouples degraded due to inadvertent high temperatures and Ni attack cause significant levels of particles failure
- Planned PIE includes extensive compact destructive exams and high-temperature post-irradiation safety tests

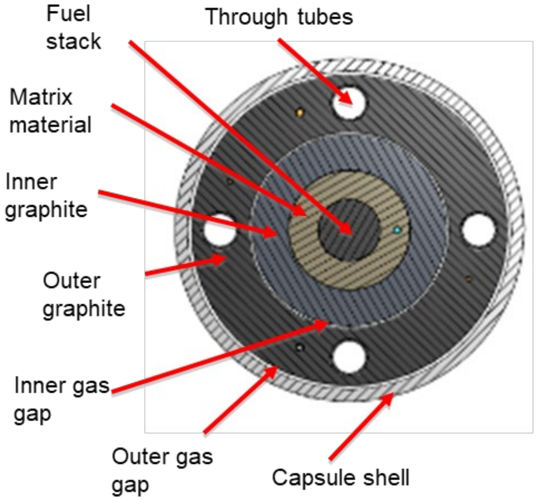




US

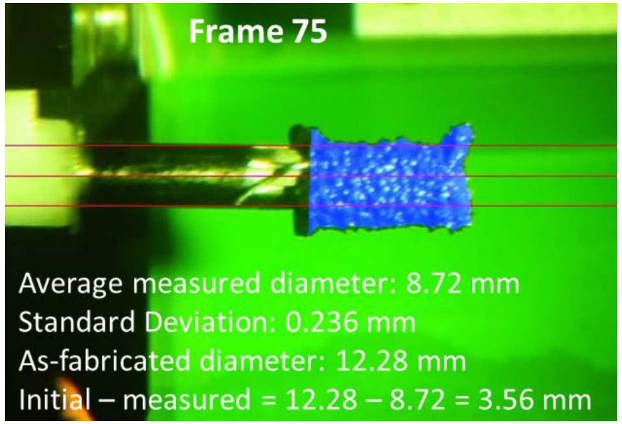
AGR-3/4 PIE and Post-Irradiation Heating Tests

- Experiment to assess fission product transport in fuel and core graphite materials
- PIE work is nearing completion
- Significant data analysis still needed

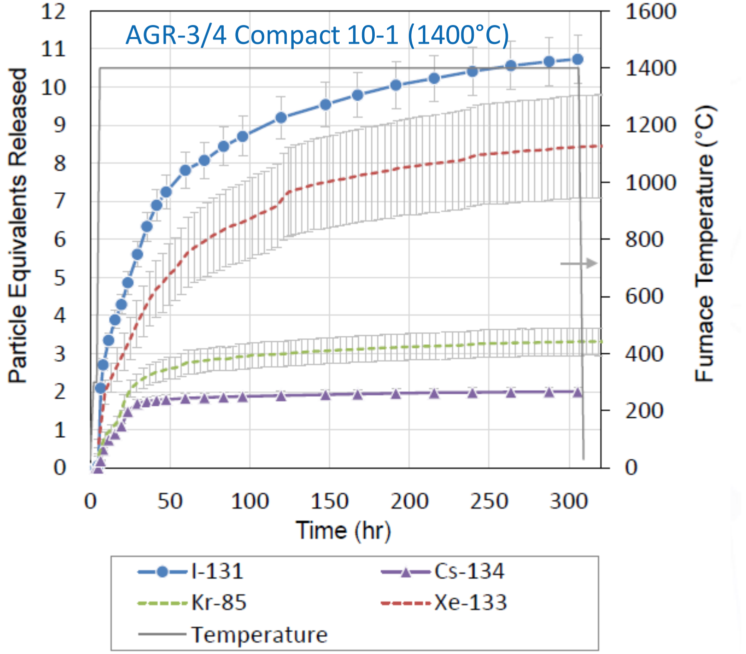


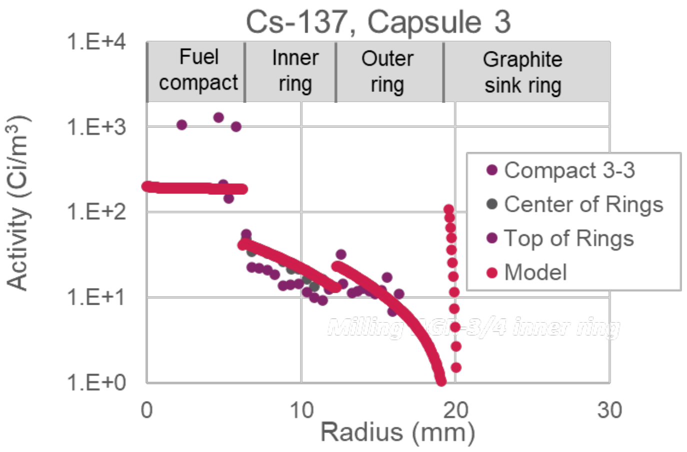
AGR-3/4 Capsule Cross Section

AGR-3/4 fuel compact after several deconsolidation steps, leaving only the core



Fission product release during heating of re-irradiated fuel compact to assess short-lived fission product behavior



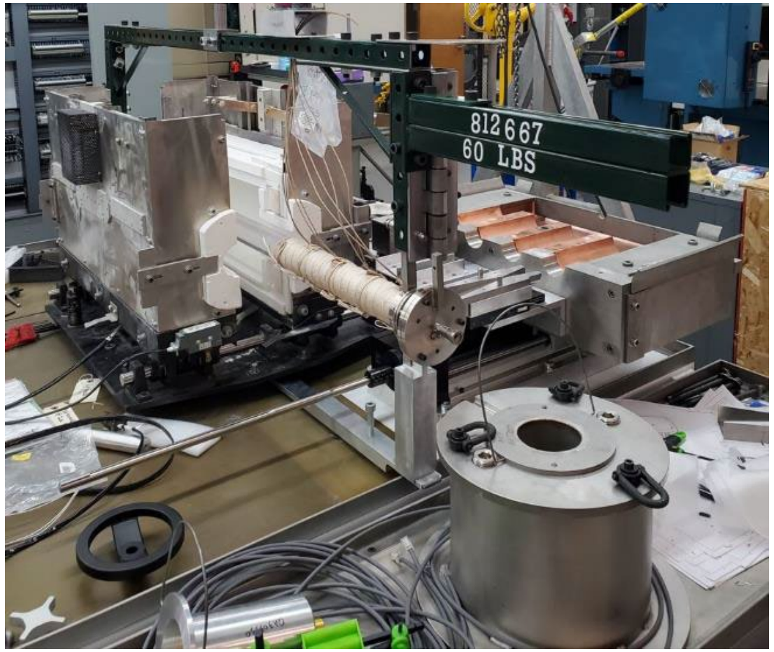


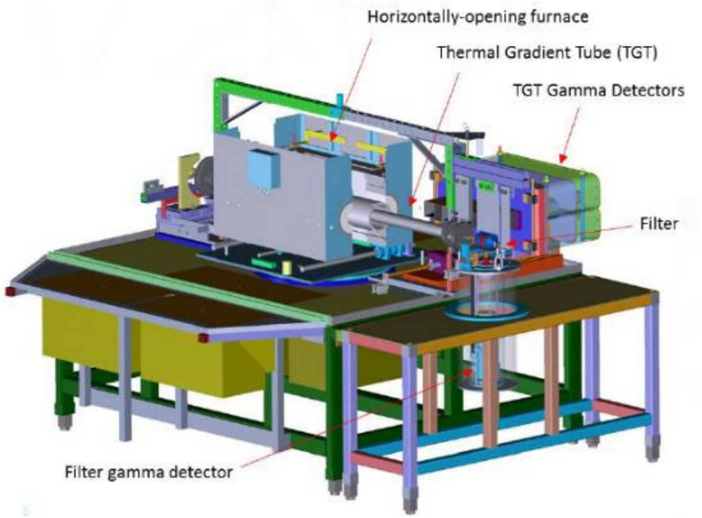
Measured and calculated ^{137}Cs profile in fuel and surrounding materials after irradiation

GEN IV International Forum
Expertise | Collaboration | Excellence

Task 3-2: Develop furnace system for air/steam tests on irradiated fuel

- Development of the Air Moisture Ingress Experiment (AMIX) furnace system continues at INL.
- System will be used to perform post-irradiation heating tests on fuel and materials specimens in oxidizing atmospheres while measuring the release of fission products
- Currently performing experiments with duplicate benchtop system to test performance
- System is expected to be operation in 2023





6th Workshop on Materials Properties of TRISO Fuel

- To be held in conjunction with the next FFC PMB meeting
- Location: *Aix-en-Provence and CEA Cadarache, France*
- Dates: *19-20 October 2022*
- 24 technical presentations are planned; 5 countries represented

Topics:

- Thermal property measurements
- PyC microstructure-property relationships
- Buffer microstructure and irradiation behavior
- SiC microstructure and irradiation behavior
- TRISO particle modeling and simulation
- Fission product transport in TRISO particles
- Unconventional TRISO fuels

Other FFC PMB Business

- LBL Round Robin:
  - Each participant is preparing a separate report on experimental results, to be combined into the GIF deliverable
- 2022 is the last year of existing 5-year workplan; preparation of next 5-year work plan to begin in Fall 2022
- Need to clarify the status of UK and Canada in the FFC PMB

Thank you for your attention

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