

July 25, 2023

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# 2023 AGR-5/6/7 PIE Overview

This presentation contains information that is preliminary in nature, and the results and conclusions may change as experiments and analyses continue.

**DOE ART Gas-Cooled Reactor (GCR) Review Meeting**

Virtual Meeting

July 25 – 27, 2023



# Collaborators in Post-Irradiation Examination (PIE)



- Lu Cai
- David Laug
- Kelley Verner
- Adriaan Riet
- Phil Winston
- Cad Christensen
- Katie Hawkins
- Edward Reber
- Skyler James
- Cassie Anderson-Thueson
- Jason Schulthess
- Julia Carter
- BJ Camphouse
- Luiza Albuquerque



- John Hunn
- Tyler Gerczak
- Grant Helmreich
- Darren Skitt
- Fred Montgomery

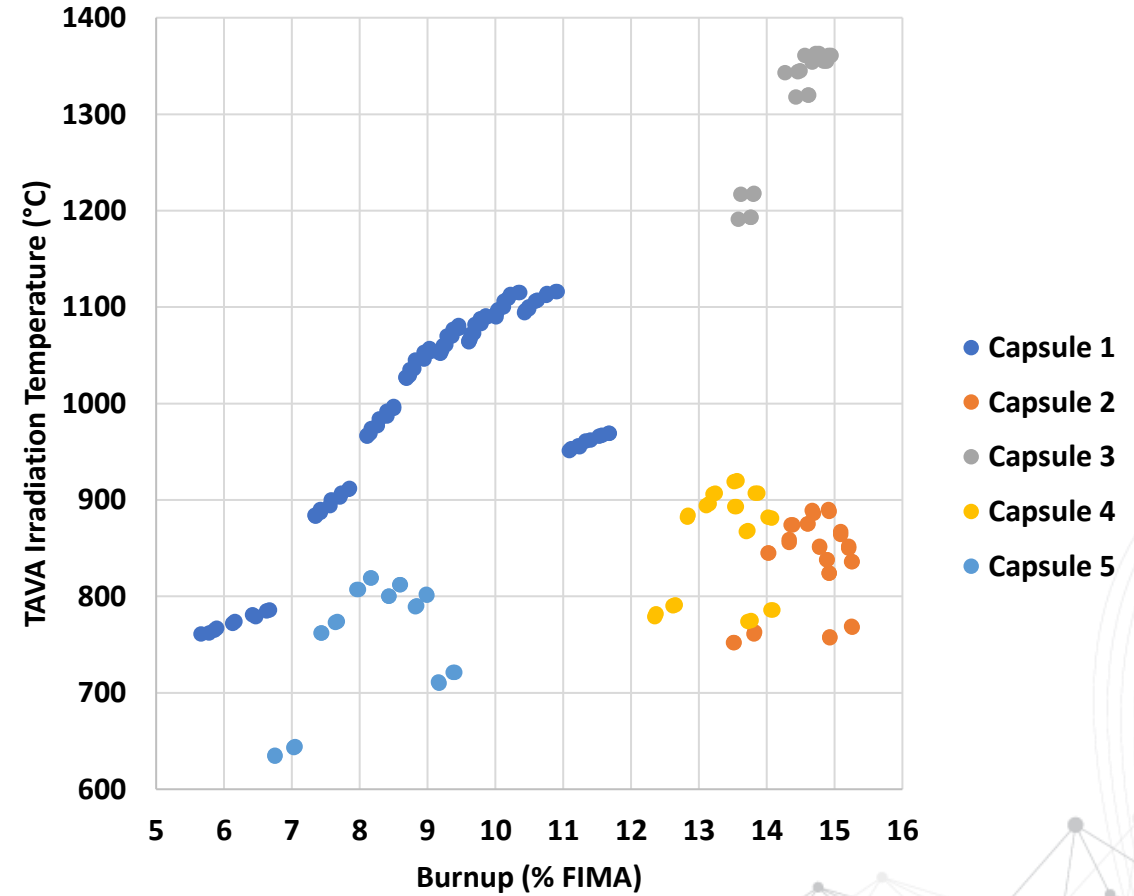
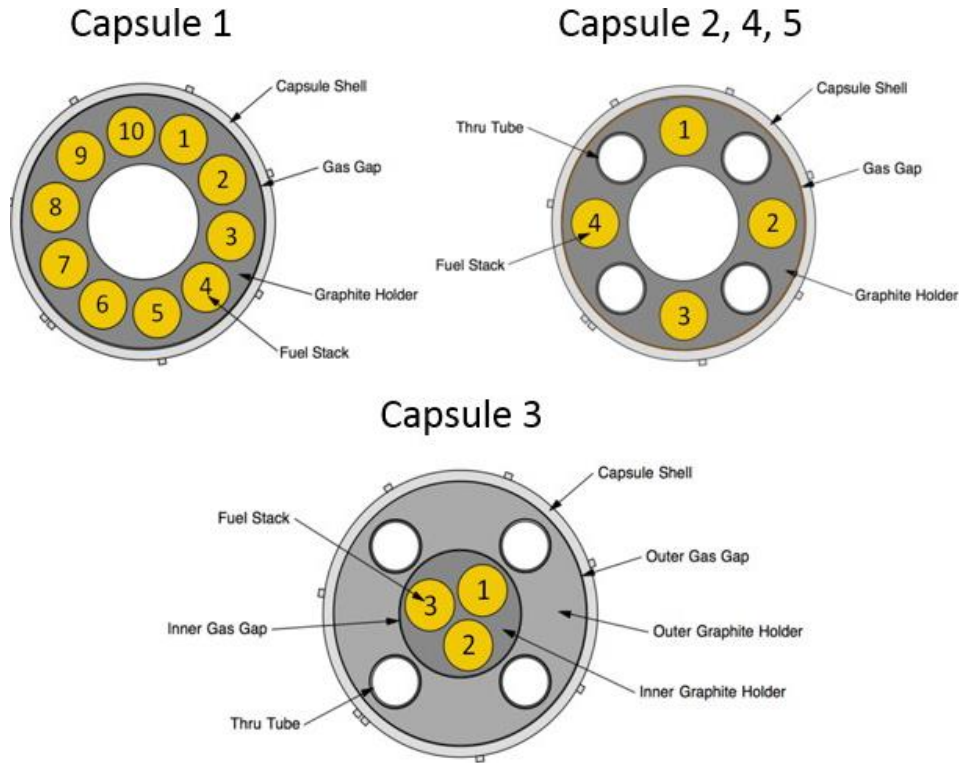
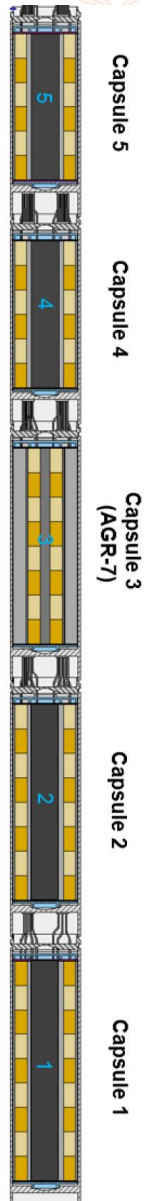
# Major AGR-5/6/7 PIE Objectives

**Overall:** Establish acceptable nominal, margin, and accident performance of fuel produced at the pilot scale.

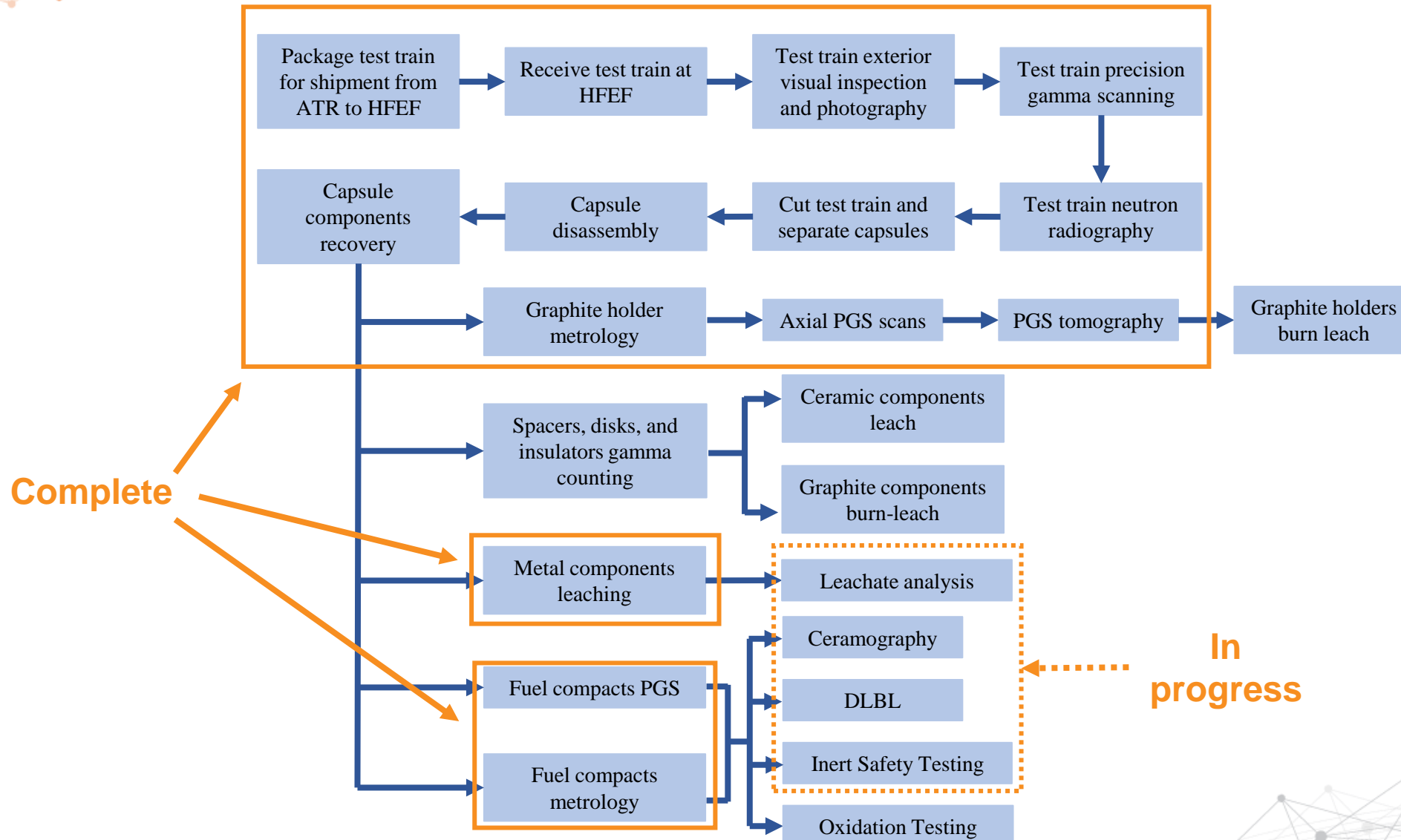
1. Evaluate and characterize unexpected Capsule 1 behavior.
2. Determine if there was acceptable performance and behavior of the fuel under normal irradiation conditions (Capsules 2, 4, and 5).
3. Evaluate performance and characterize behavior of fuel under high irradiation temperatures (Capsule 3: TAVA 1360°C, TA Peak 1430°C).
4. Conduct post-irradiation high-temperature testing in helium to verify acceptable fuel performance under conduction cool-down accidents. (CCCTF and FACS)
5. Perform oxidation testing to characterize fuel behavior during exposure to air or moisture at nominal and accident temperatures.



# Capsule and Test Train Design and Irradiation Conditions



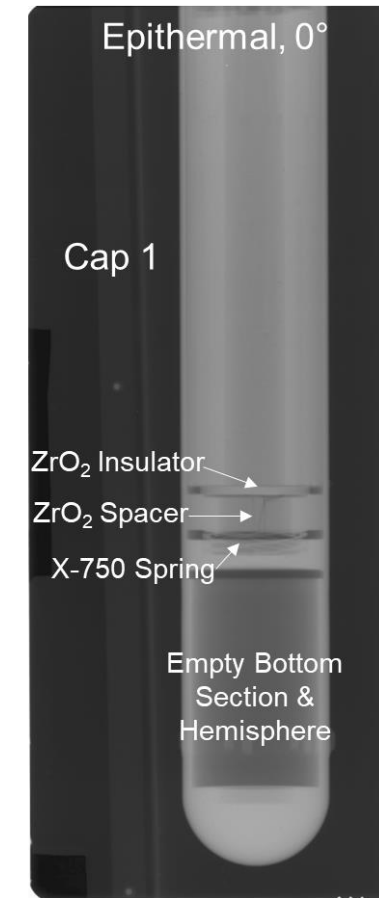
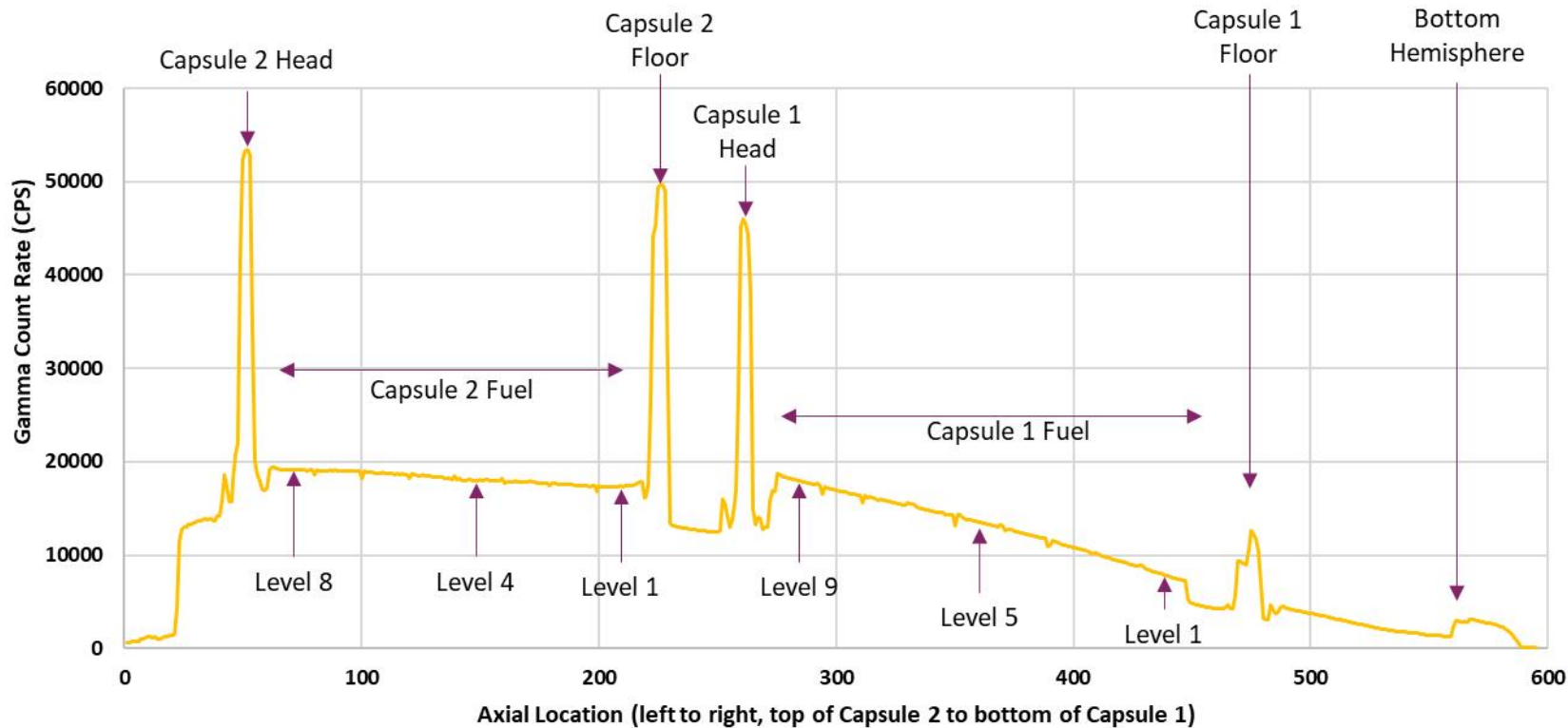
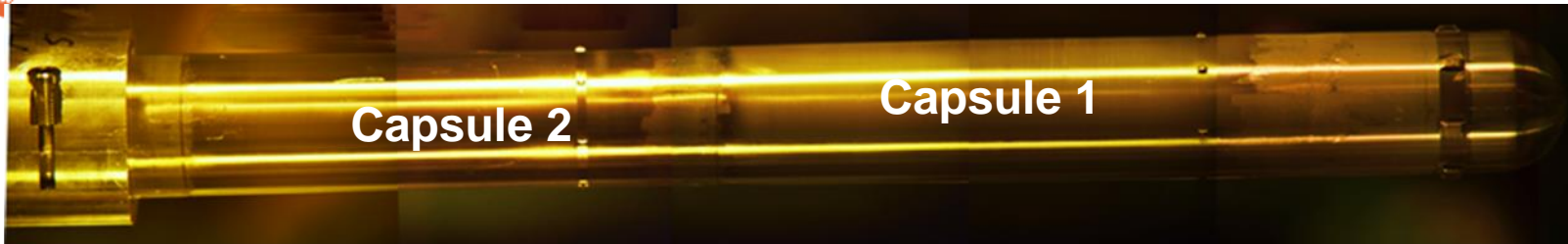
# Process Flow of Major PIE Activities



In progress



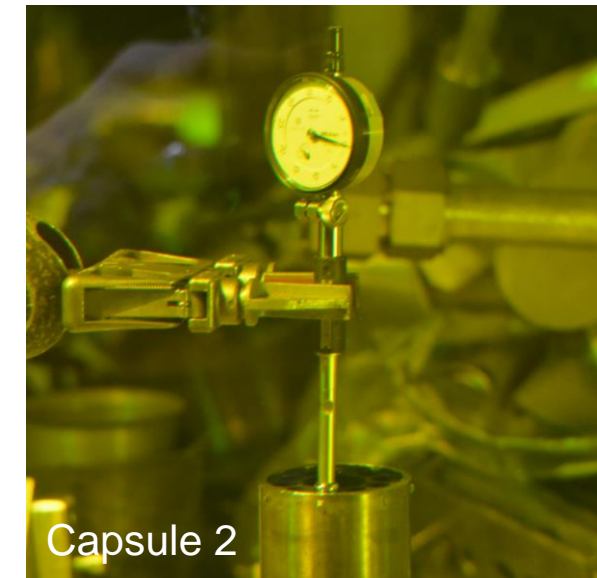
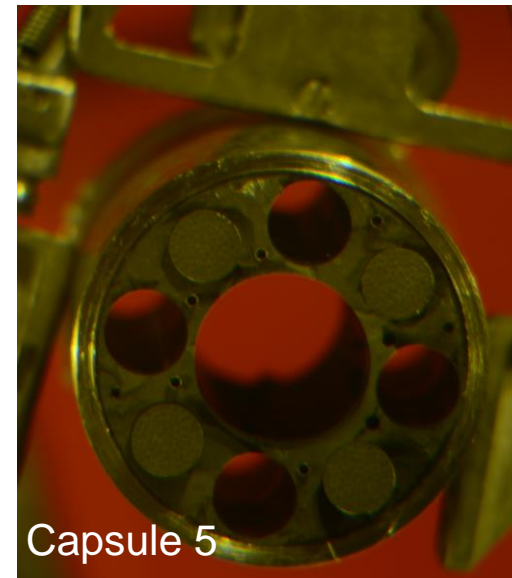
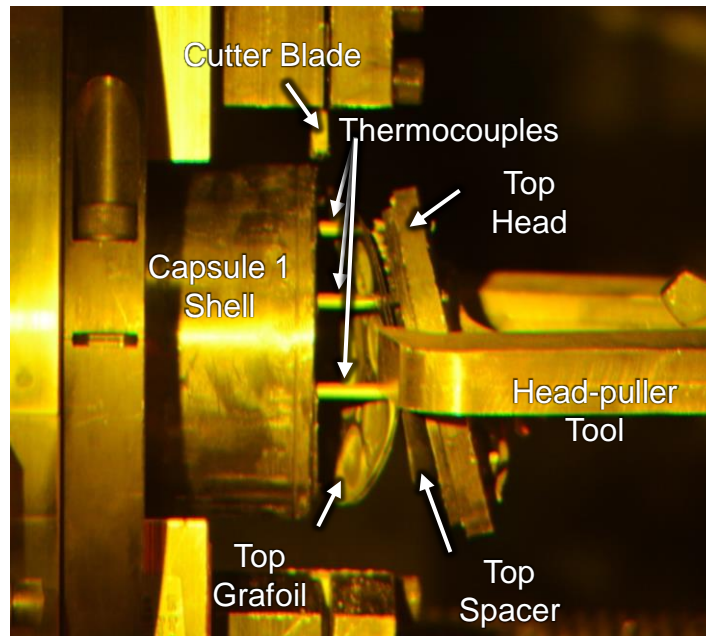
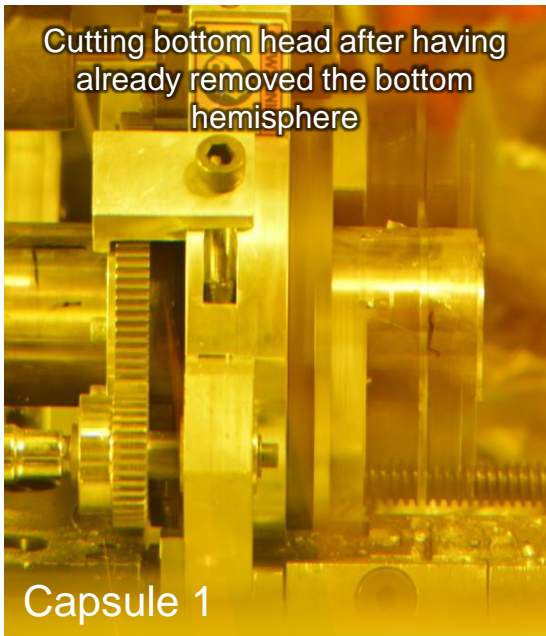
# Test Train Exams Example



# Disassembly and Metrology Complete

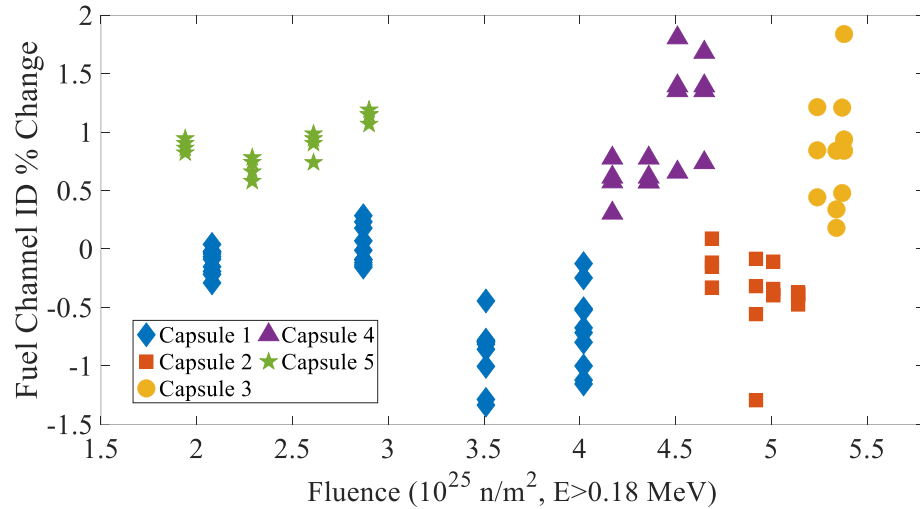
Level 2 Milestone report completed February 2023

Components	Number
Capsules Disassembled	5/5
Holder Measured	6/6
Compacts Recovered and Measured	194/194

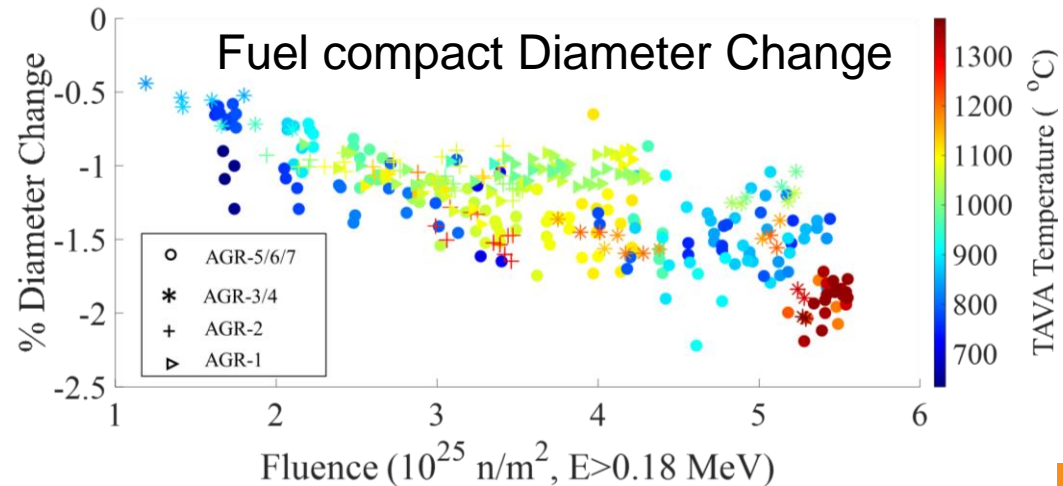
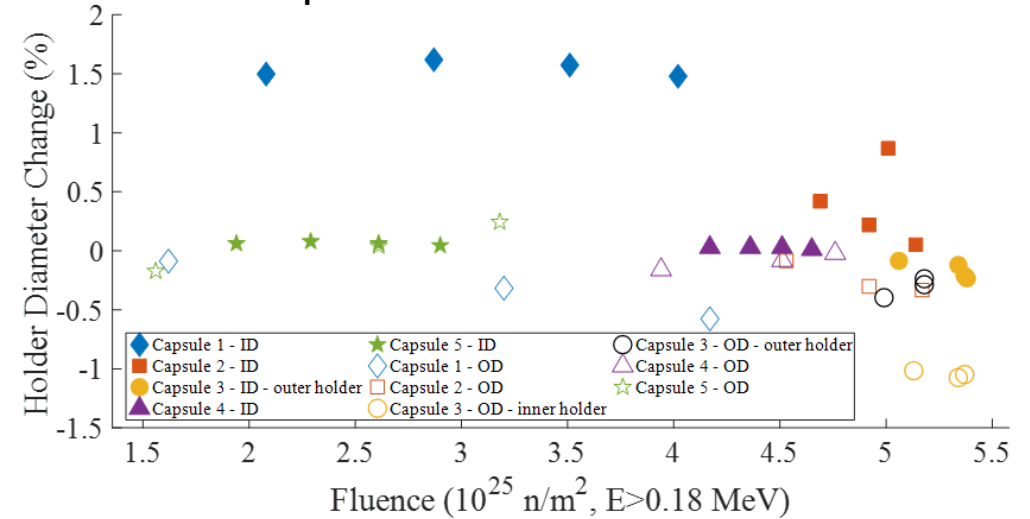


# Metrology on Graphite Holders and Fuel used to Update Thermal Calculations

## Graphite Holder Fuel Channel Diameters



## Graphite Holders Outer Diameters

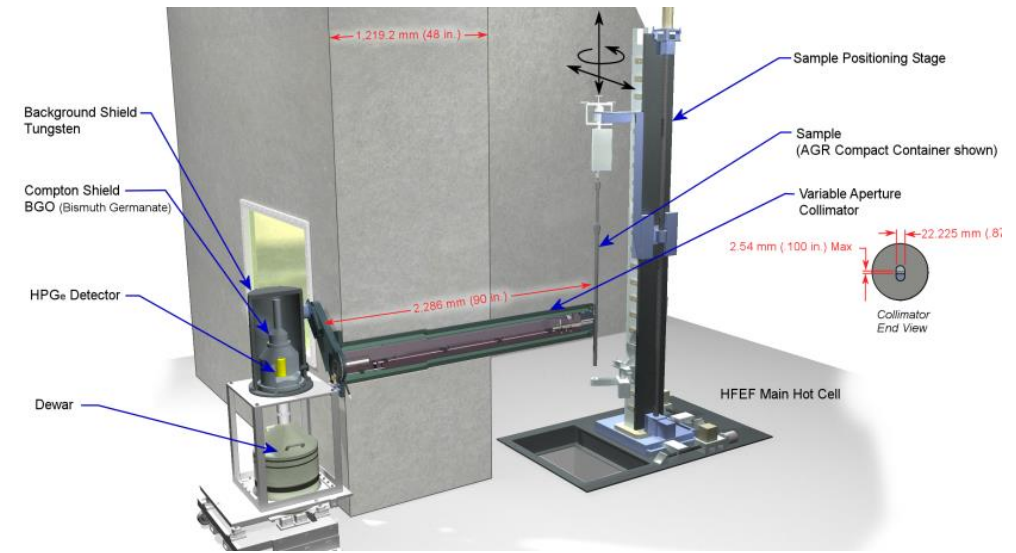




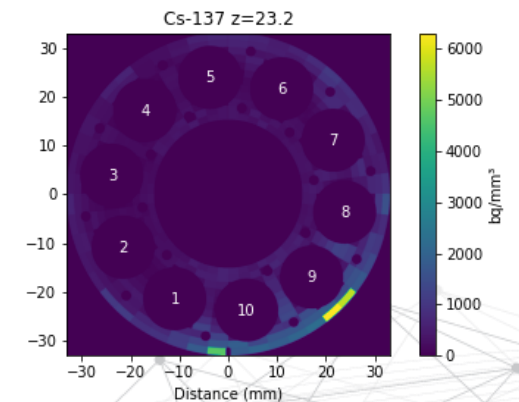
# All Precision Gamma Scanning Completed

Level 2 Milestone Completed July 13, 2023

Components	Number Complete
<b>Compact Holders</b>	
Axial Scan	6/6
Tomographic Scans	Cap 1: 3
	Cap 2: 2
	Cap 3 inner: 4
	Cap 3 outer: 1
	Cap 4: 1
	Cap 5: 1
	TOTAL: 12/12
<b>Compacts</b>	
Overall	194/194
Capsule 1	90/90
Capsule 2	32/32
Capsule 3	24/24
Capsule 4	24/24
Capsule 5	24/24

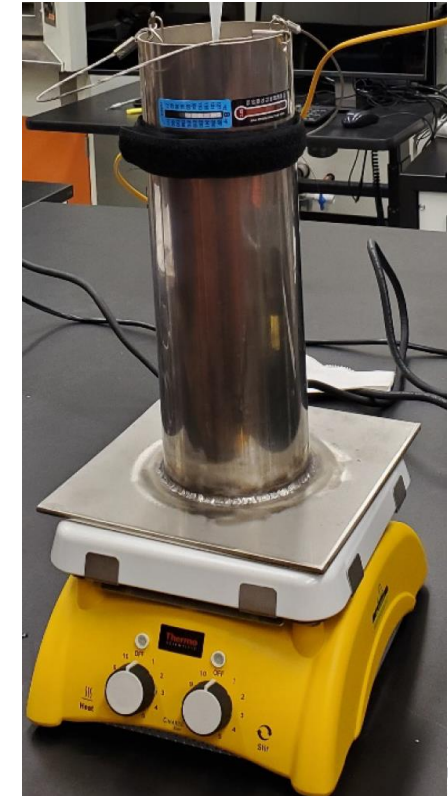
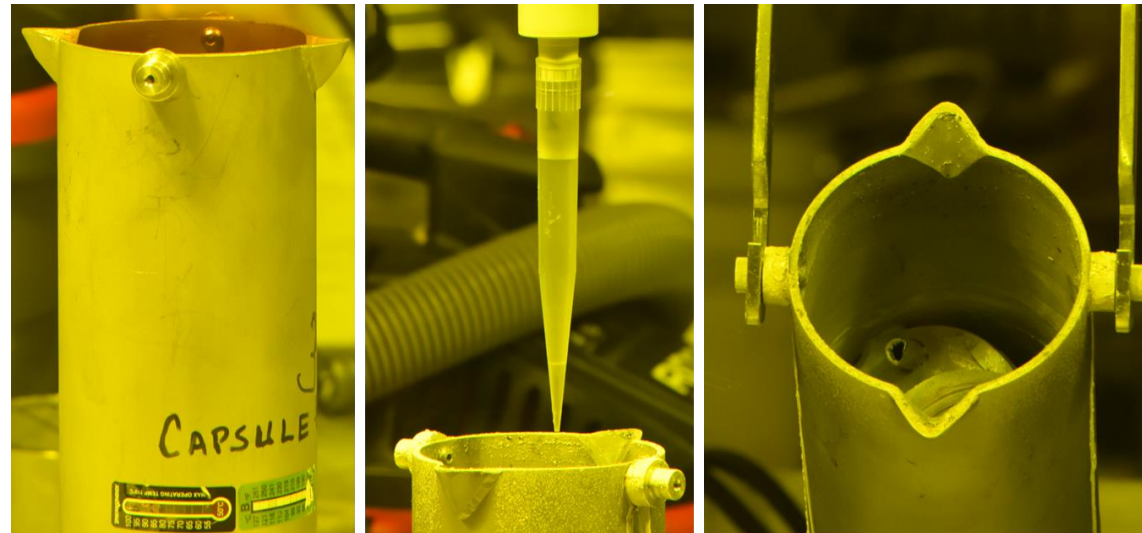


Precision Gamma Scanner (PGS)

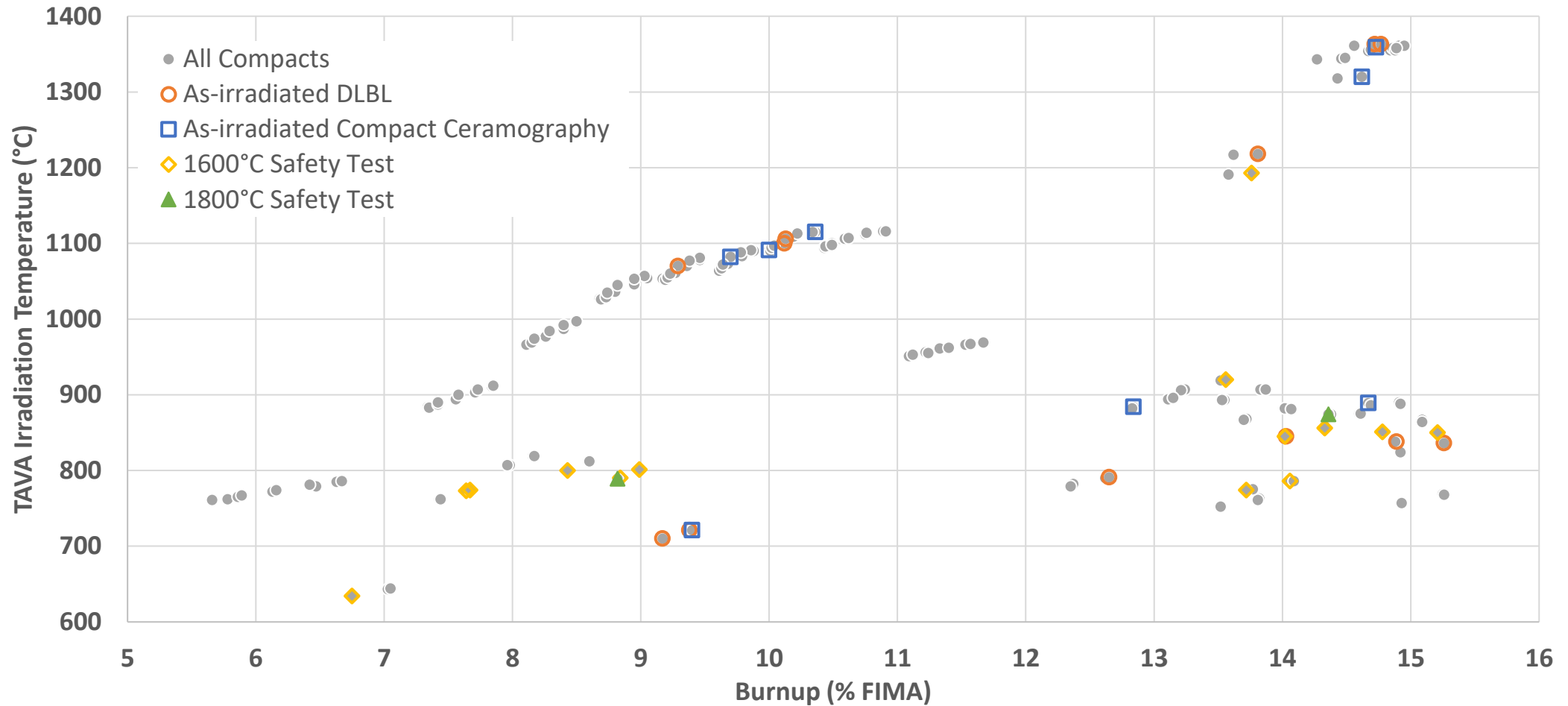


# Metallic Test Train Components Leaching

- Completed leaching all five capsule shells and metallic components in boiling  $\text{HNO}_3$  for a L2 milestone at the end of FY22
- **Analysis of leachates to assess fission product content out of the fuel is in progress for a L2 milestone due 9/15/2023**



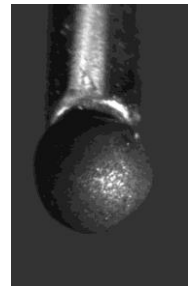
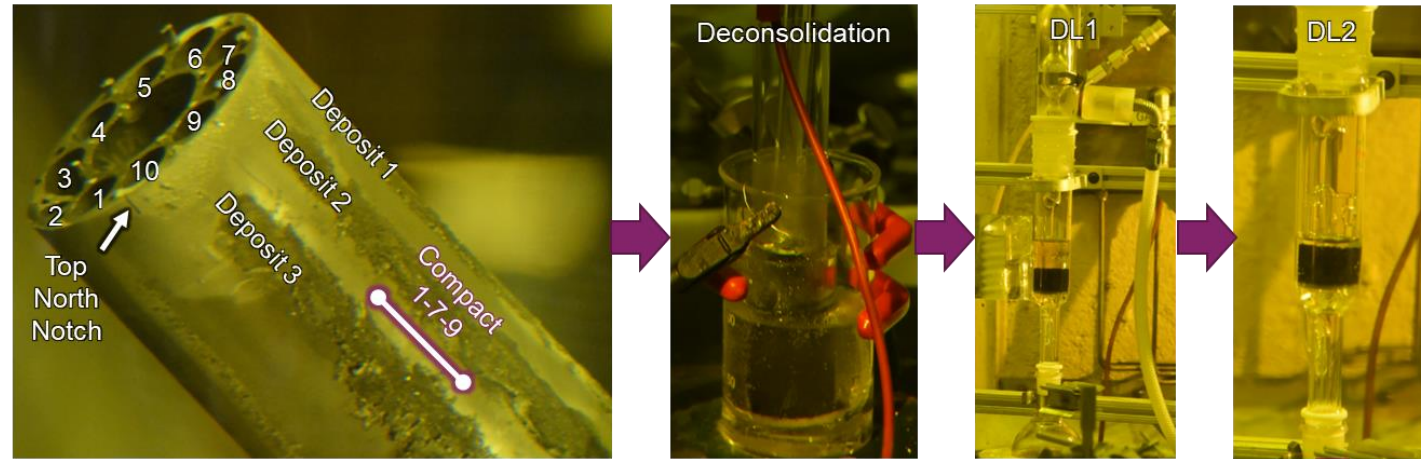
# Compact Exams Planned and Completed





# Compact Exams: Deconsolidation-Leach-Burn-Leach

	Compact	Burnup	Fluence	TAVA	Lab	Year
As-irradiated DLBL	1-7-4	10.12	3.9	1100	INL	2022
	1-7-9	10.13	3.9	1106	INL	2022
	2-2-1	14.03	4.72	845	ORNL	2022
	3-6-3	14.77	5.47	1363	ORNL	2023/FY23
	5-1-2	9.17	3.25	710	INL	2022/FY23
	1-5-9	9.29	3.3	1070	ORNL	2022/FY23
	3-6-2	14.72	5.46	1363	INL	2023/FY23
	2-7-4	15.26	5.42	836	INL	planned FY23
	4-6-4	12.65	4.2	791	INL	planned FY23
	5-1-3	9.38	3.39	721	ORNL	planned
3-8-3	13.81	5.3	1218	ORNL	planned	



- Analysis of solutions:
- gamma spec
  - Sr-90 separation
  - mass-spec

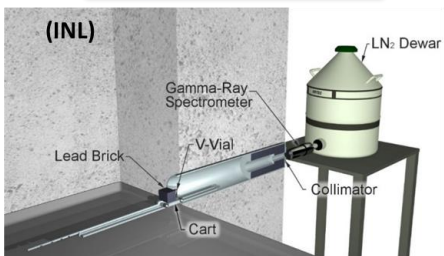


"Burn" at 750°C in air for 72 h

- Particle Exams
- Gamma counting
  - X-ray CT



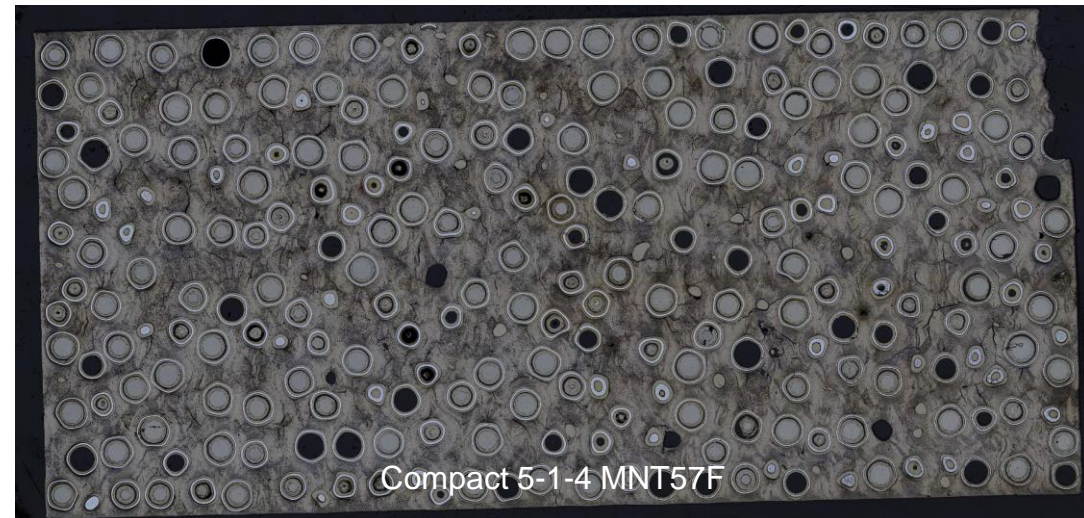
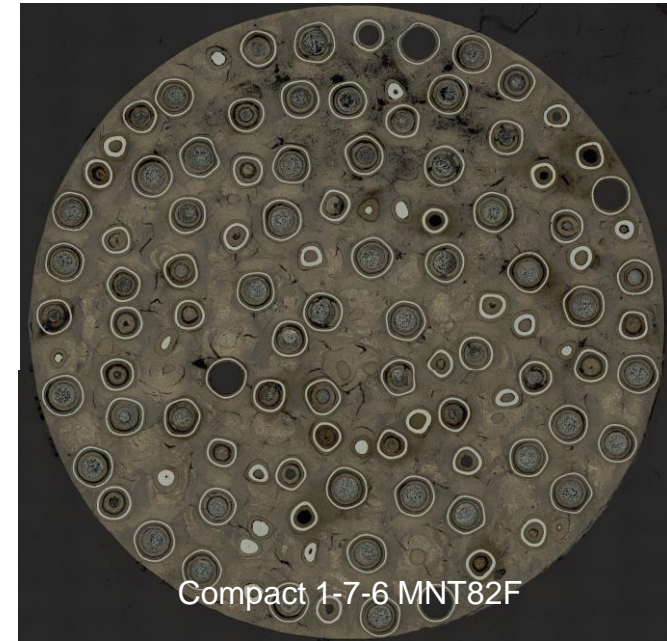
Need to complete a total of four DLBL at INL and four at ORNL for two L2 milestones by 9/15/2023.





# Compact Exams: Ceramography Finished

	Compact	Burnup	Fluence	TA Min	TAVA	TA Max	Lab	Year
As-irradiated Compact Ceramography	1-6-9	9.7	3.62	889	1082	1196	INL	2022
	2-3-3	14.67	5.07	794	889	947	INL	2022
	3-4-1	14.73	5.41	1268	1359	1419	INL	2022
	5-1-4	9.4	3.4	506	721	834	INL	2022
	1-7-1	10	3.76	893	1091	1205	INL	2022/FY23
	1-7-6	10.36	3.99	911	1115	1229	INL	2022/FY23
	3-2-3	14.62	5.54	1203	1320	1401	INL	2022/FY23
	4-5-1	12.84	4.24	787	884	947	INL	2022/FY23



# Compact Exams: Inert Safety Tests

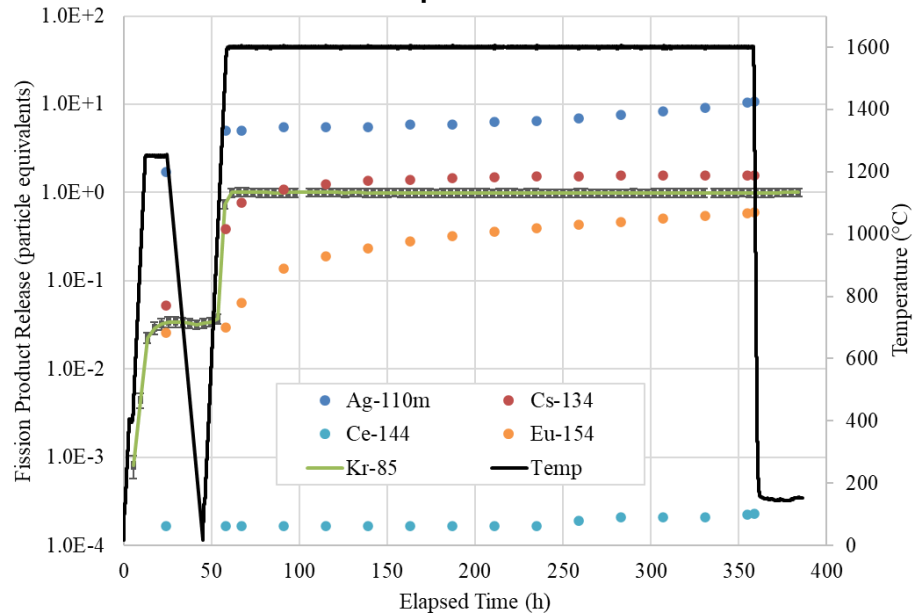
FACS Furnace (INL)



CCCTF Furnace (ORNL)



Compact 4-4-4



	Compact	Burnup	Fluence	TA Min	TAVA	TA Max	Lab	Year
1600°C Safety Test	2-2-2	14.02	4.72	743	845	914	ORNL	2022
	2-2-4	14.33	4.94	752	856	927	ORNL	2022
	4-1-3	14.06	5.01	565	786	902	INL	2022
	5-5-4	7.67	2.14	686	774	843	INL	2022
	3-1-2	13.76	5.48	990	1193	1329	ORNL	2023
	5-5-3	7.64	2.13	685	773	842	ORNL	2022/FY23
	4-4-4	13.56	4.62	833	920	970	INL	2023
	4-1-2	13.72	4.78	558	774	886	ORNL	planned FY23
	5-6-2	6.75	1.67	467	634	741	ORNL	planned FY23
	2-6-4	15.21	5.36	749	850	913	INL	In Progress
	5-2-1	8.84	3.01	700	790	846	ORNL	Planned
	5-2-4	8.99	3.13	709	801	859	ORNL	simultaneous
5-3-2	8.43	2.7	720	800	849	ORNL	FY23	

	Compact	Burnup	Fluence	TA Min	TAVA	TA Max	Lab	Year
1800°C Safety Test	2-3-2	14.36	4.85	782	874	931	ORNL	2022
	5-2-2	8.82	2.99	699	789	845	ORNL	2022

## FY23 Milestones due 9/15/2023

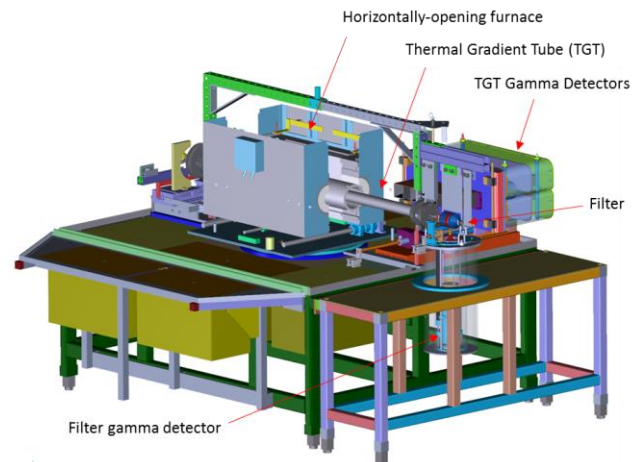
1. Complete three tests in FACS at INL
2. Complete four tests in CCCTF at ORNL

# Air-Moisture Ingress Experiment (AMIX)

- AMIX Purpose:
  - To date, safety testing AGR fuel compacts has only been conducted under helium. AMIX will test irradiated TRISO fuels in oxidizing environments representative of air and moisture ingress accidents in HTGRs
  - Measure fission product releases as a function of time
- Update:
  - System has been constructed
  - Software is 99.9% complete
  - 95% of integrated testing has been completed
  - Complete all of Phase II (remote assembly and checkout) by January 2024
  - Complete AMIX installation in Fuel Conditioning Facility (FCF) hot cell by spring 2024

## FY23 Milestones:

1. Complete Phase IIA integrated systems qualifications
2. Complete Phase IIB remote qualification

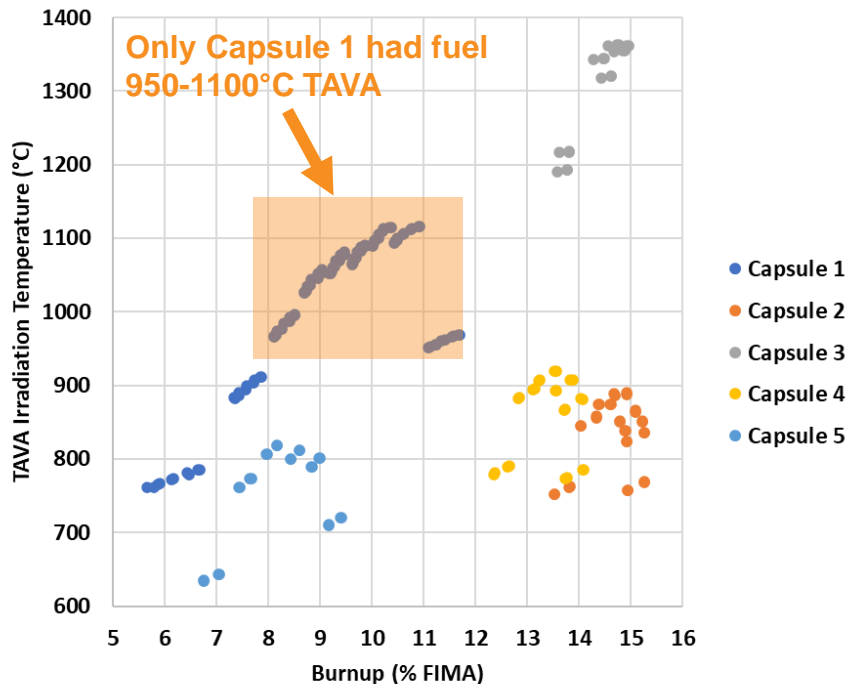




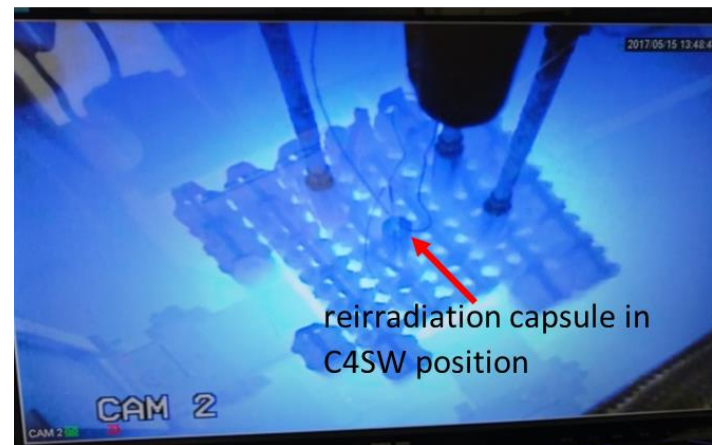
# NRAD Reirradiations for AGR-5/6/7 Capsule 1 Compacts

**L2 Milestone: complete design of all systems and components needed to conduct testing of irradiated AGR-5/6/7 fuel in furnace in NRAD and measure fission gas release due 9/15/2023**

- Approach:
  - Large reirradiation test train with space for ~12 fuel compacts for reirradiations  $\leq 5$  d
  - Heating and fission gas measurements to occur out-of-pile at temperatures  $\sim 1200^{\circ}\text{C}$
  - No condensable fission product measurements
  - Clean compacts could be used for fuel performance exams such as safety tests.



Neutron Radiography Reactor (NRAD)





# Compact Shipments to ORNL for PIE

Shipment	Date	Compacts	Use
1	Completed 3/2022	2-2-1	As-irradiated DLBL
		2-2-2	1600°C Safety Test
		2-2-3	Safety Test or As-irradiated DLBL
		2-2-4	1600°C CCCTF
2	Completed 10/2022	1-5-9	As-irradiated DLBL
		2-3-2	1800°C Safety Test
		4-1-3	Post-FACS DLBL
		5-5-3	1600°C Safety Test
3	Completed 12/2022	3-1-2	1600°C CCCTF
		3-6-3	as-irradiated DLBL
		5-1-3	as-irradiated DLBL
		5-2-2	1800°C CCCTF
4	Completed 4/2023	3-8-3	as-irradiated DLBL
		4-1-2	1600°C CCCTF
		5-2-1	Simultaneous 1600°C CCCTF
		5-6-2	1600°C CCCTF
5	Planned 7/2023	5-2-4	Simultaneous 1600°C CCCTF
		5-3-2	Simultaneous 1600°C CCCTF
		2-5-1	1600°C Safety Test
		2-6-1	As-irradiated DLBL



**Need to complete Shipments 5 and 6 for L3 milestone. Compacts for Shipment 6 TBD.**



# Major Work in Progress

- Complete installation of AMIX in hot cell to test fuels in oxidizing atmospheres
- Continue compact shipments to ORNL
- Continue working through safety tests at FACS and CCCTF
- Continue as-irradiated DLBLs at INL and ORNL
- Complete analyses for fission product inventory outside of the fuel (“mass balance”)
- Construct facility to enable screening fuel compacts for failed particles via short-lived fission gas measurements



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