GAS-COOLED REACTOR
ADVANCED REACTOR TECHNOLOGIES PROGRAM

AGR-5/6/7 PIE Overview 2024

John Stempien, PhD

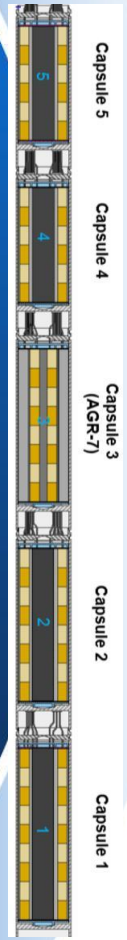
ART AGR TRISO FUEL Post-Irradiation Technical Lead

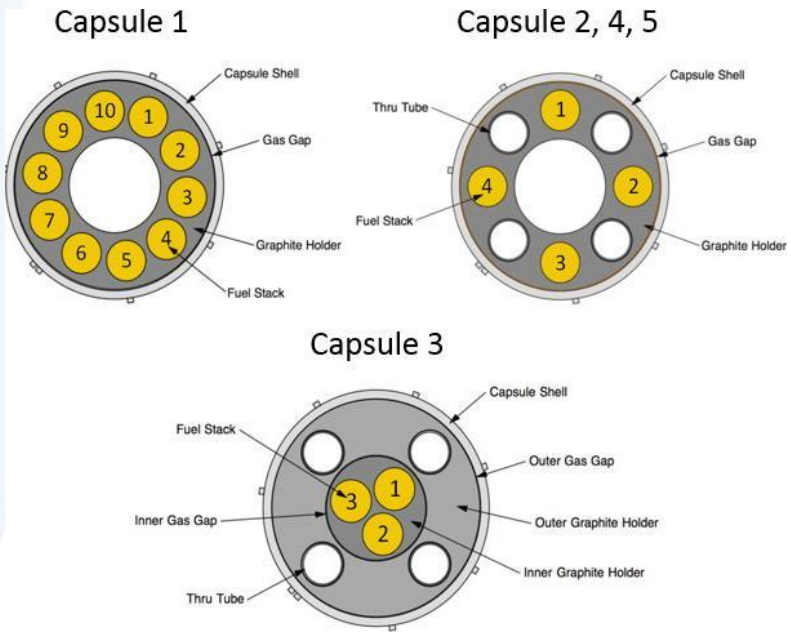
Collaborators in Post-Irradiation Examination (PIE)

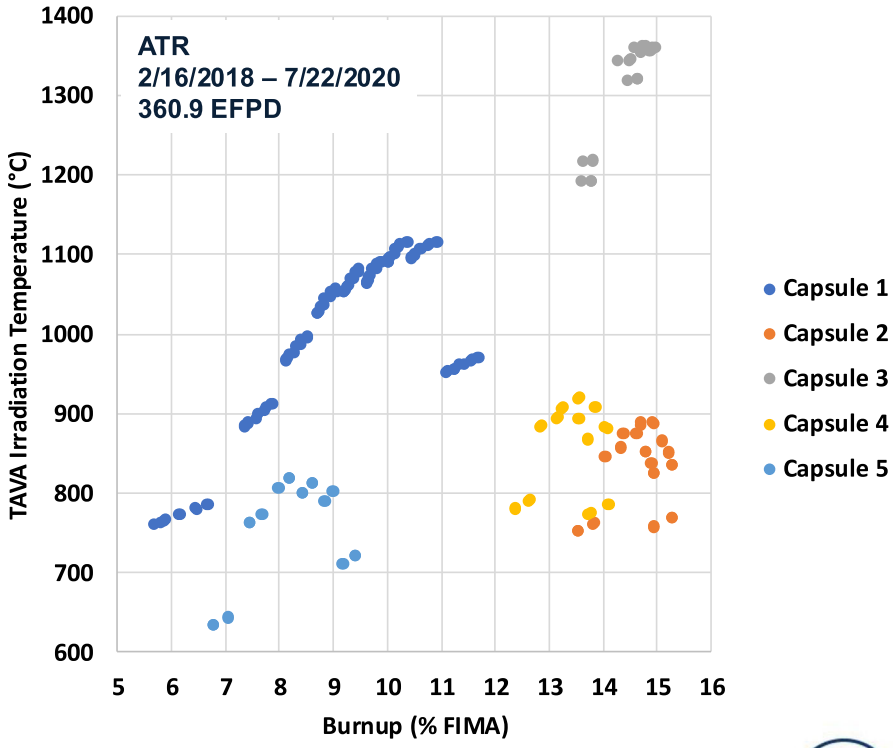
- Lu Cai
- David Laug
- Adriaan Riet
- Phil Winston
- Kelley Walker
- Cad Christensen
- Edward Reber
- Ryan Fronk
- BJ Camphouse
- Luiza Albuquerque
- Magen Coleman
- Irina Glagolenko
- Bill Chuirazzi
- Tanner Mauseth
- Ethan Hisle

- John Hunn
- Tyler Gerczak
- Fred Montgomery
- Will Cureton
- Grant Helmreich
- Martino Hooghkirk
- Chuck Baldwin
- Matt Jones
- Stephen Trewhitt
- Jesse Wereden
- Bob Morris
- Darren Skitt (honorable mention!)

Capsule and Test Train Design and ATR Irradiation Conditions



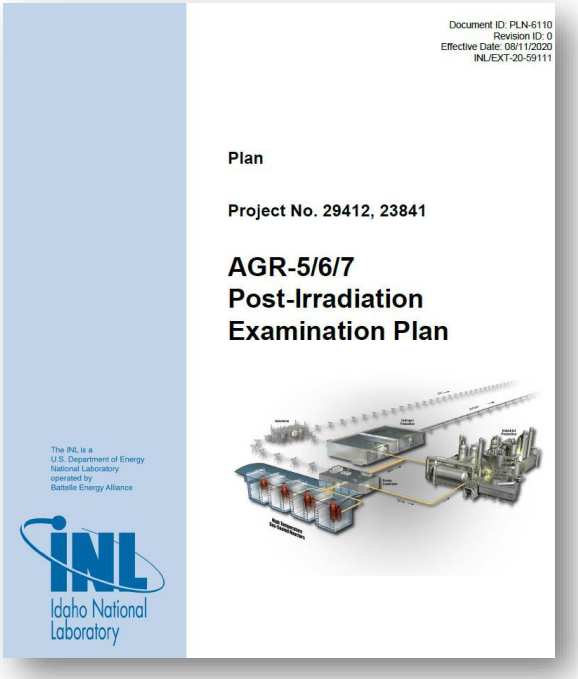




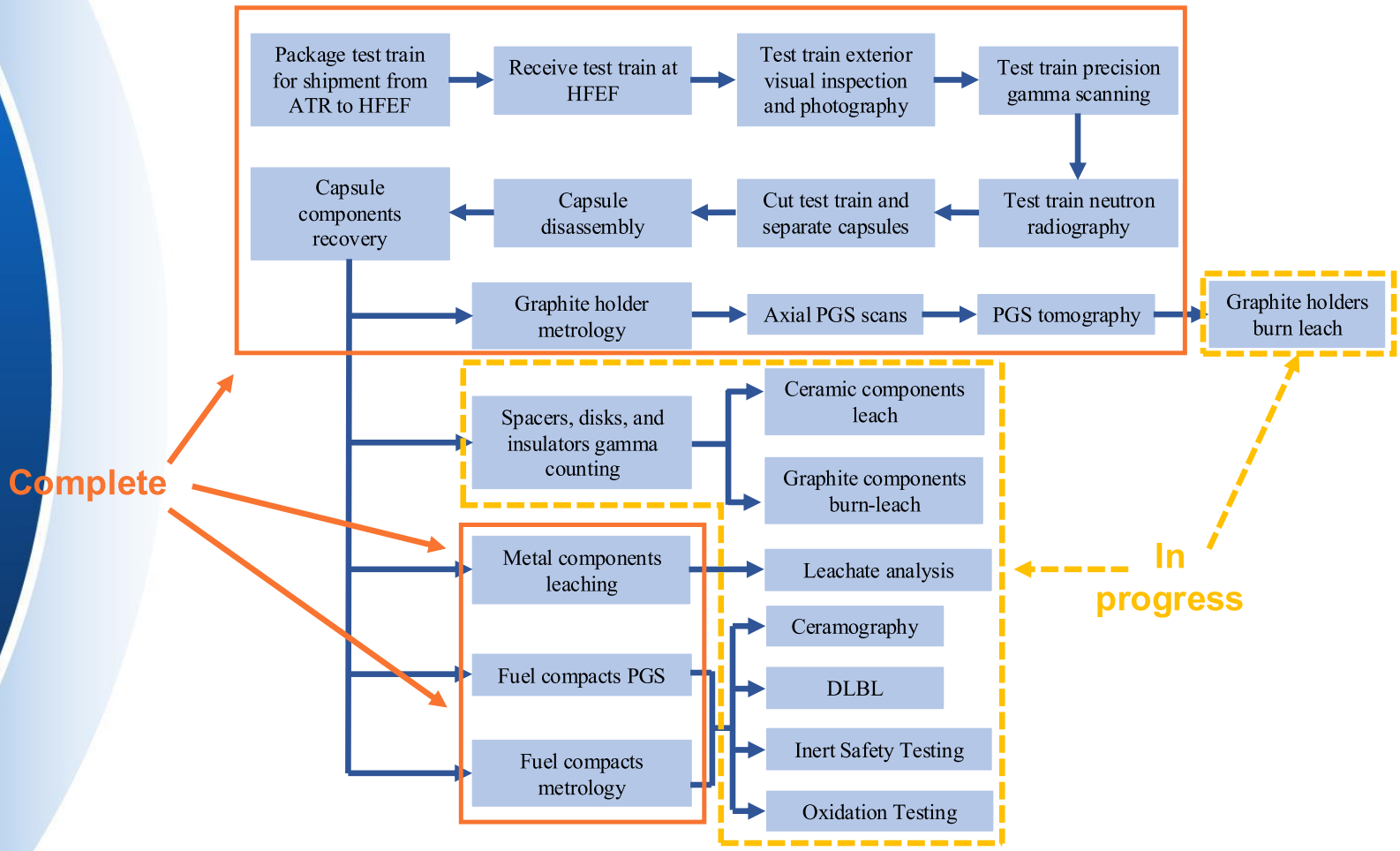
Major AGR-5/6/7 PIE Objectives

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

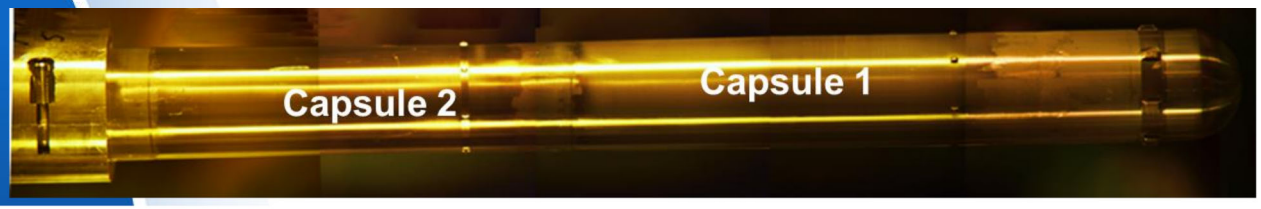
1. Evaluate and characterize unexpected Capsule 1 behavior.
2. Determine if there was acceptable performance and behavior of the fuel under normal irradiation conditions (Capsules 2, 4, and 5).
3. Evaluate performance and characterize behavior of fuel under high irradiation temperatures (Capsule 3: TAVA 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

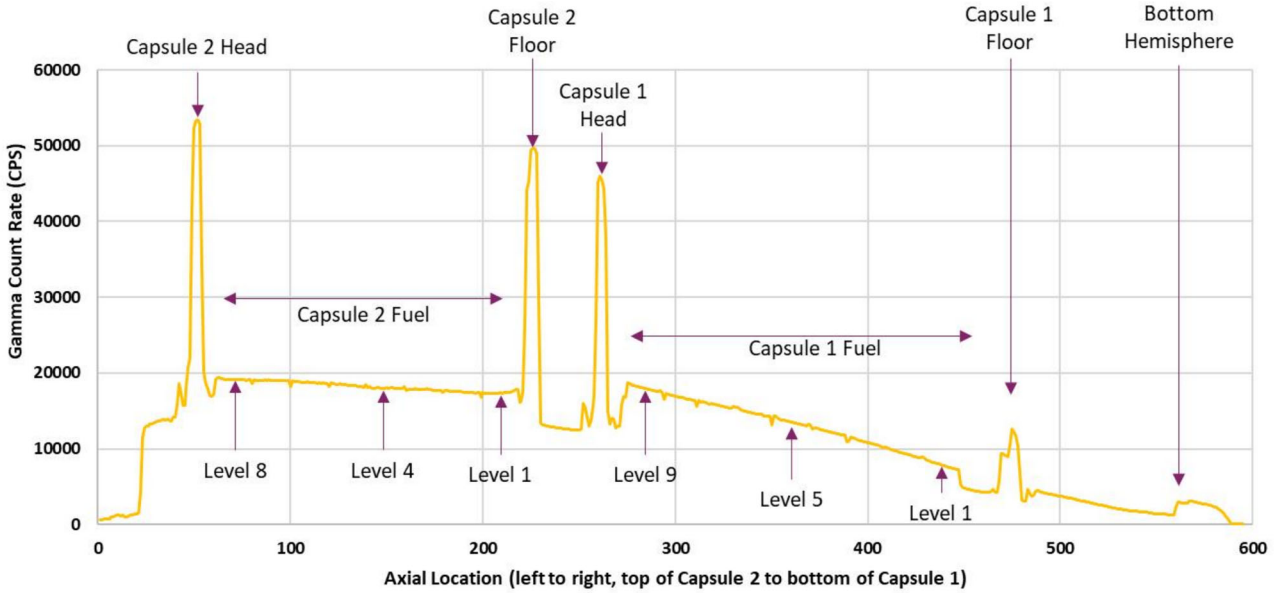


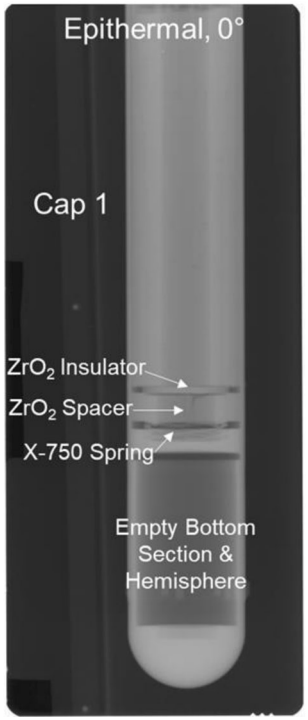
Process Flow of Major PIE Activities



Test Train Exams are Complete

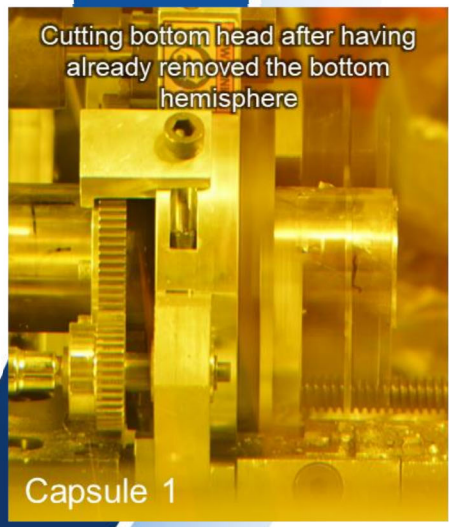


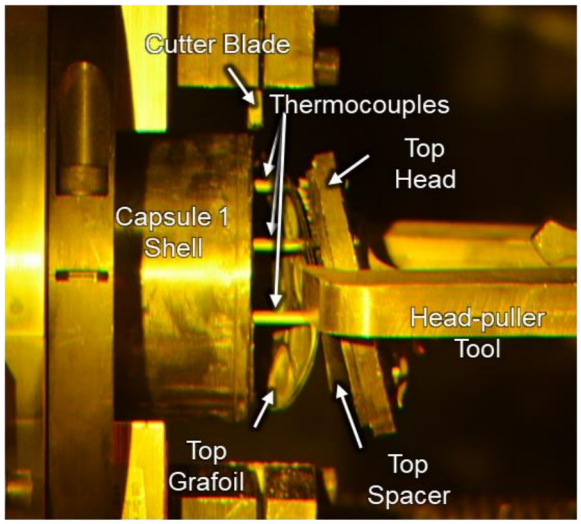


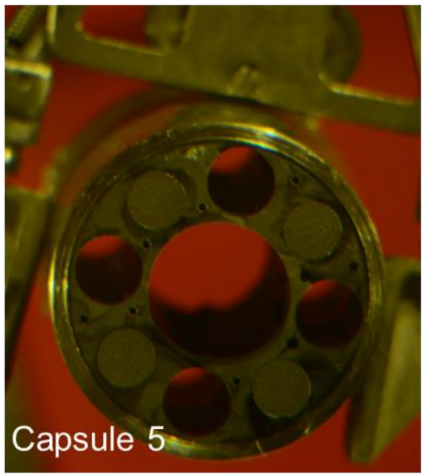


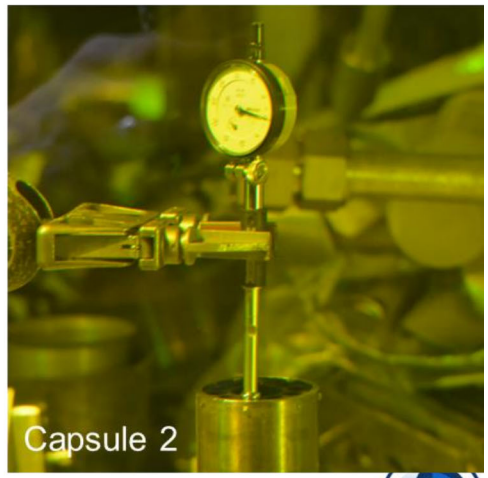
Disassembly and Metrology Complete

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



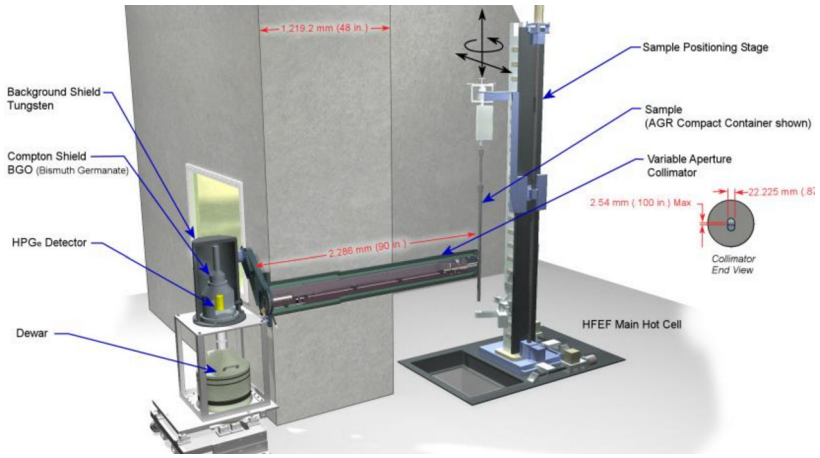




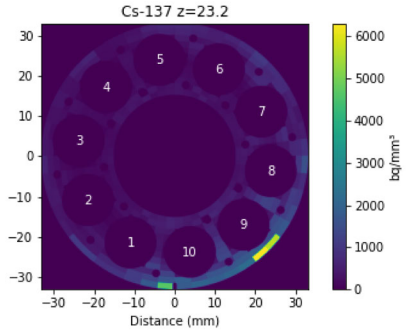


All Precision Gamma Scanning is Complete

Components	Number Complete
Compact Holders	
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
Compacts	
Overall	194/194
Capsule 1	90/90
Capsule 2	32/32
Capsule 3	24/24
Capsule 4	24/24
Capsule 5	24/24

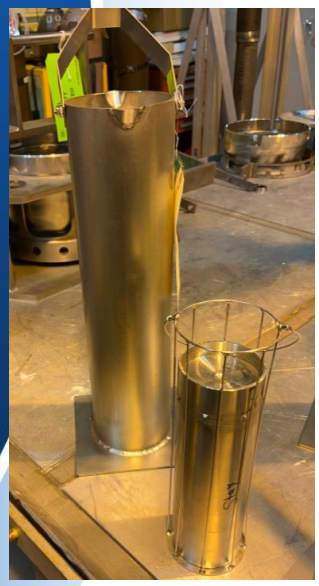


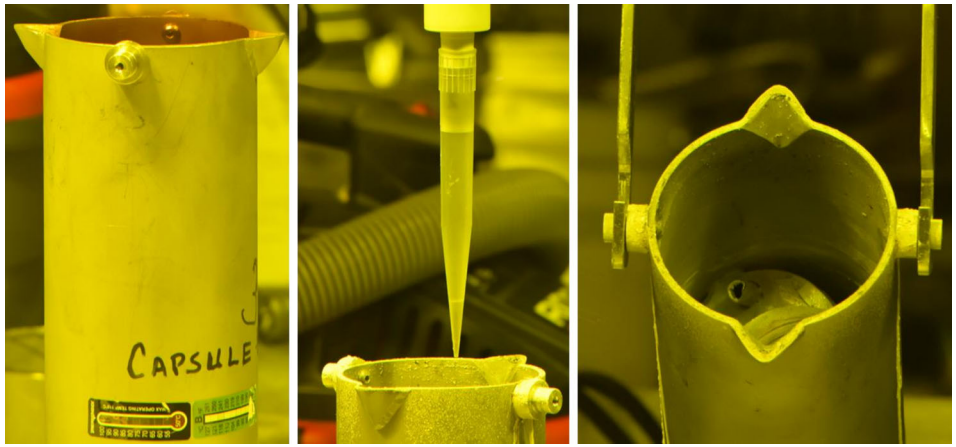
Precision Gamma Scanner (PGS)



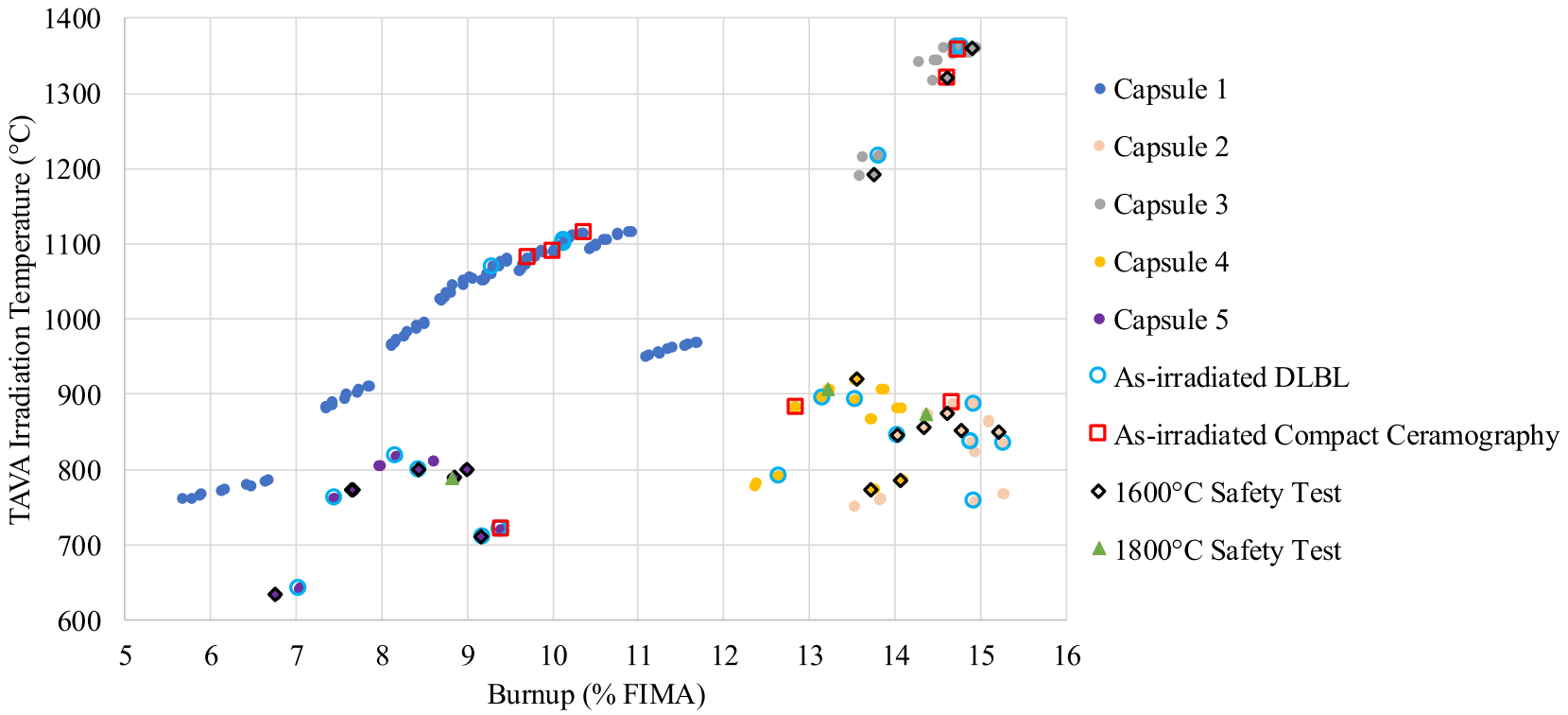
Metallic Test-Train Components Leaching Complete

- Completed leaching all five capsule shells and metallic components in boiling HNO3 at the end of FY22
- Completed analysis of leachates to assess fission product content at end of FY23
- Partial mass-balance to be discussed later in the meeting



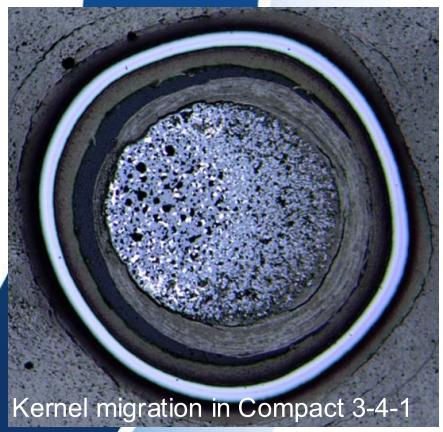


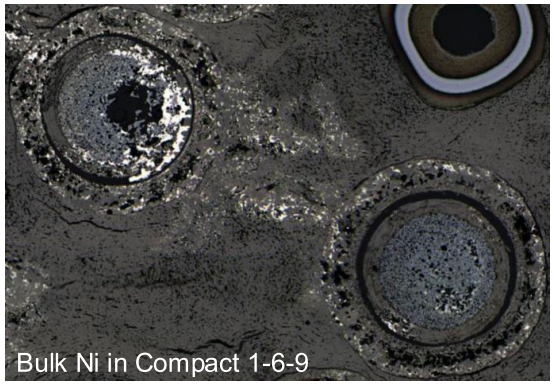
Compact Safety Tests and Exams: Visual Status

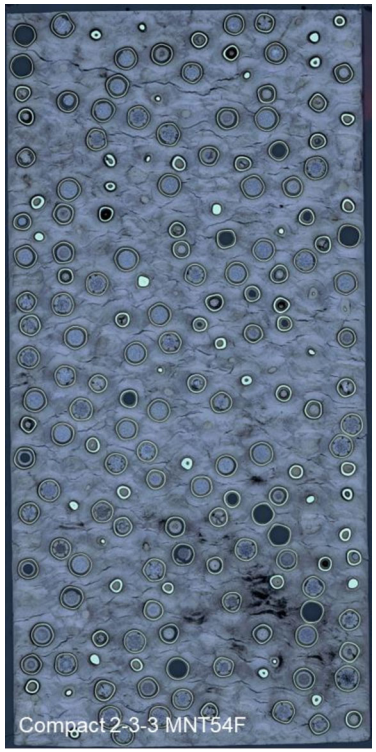


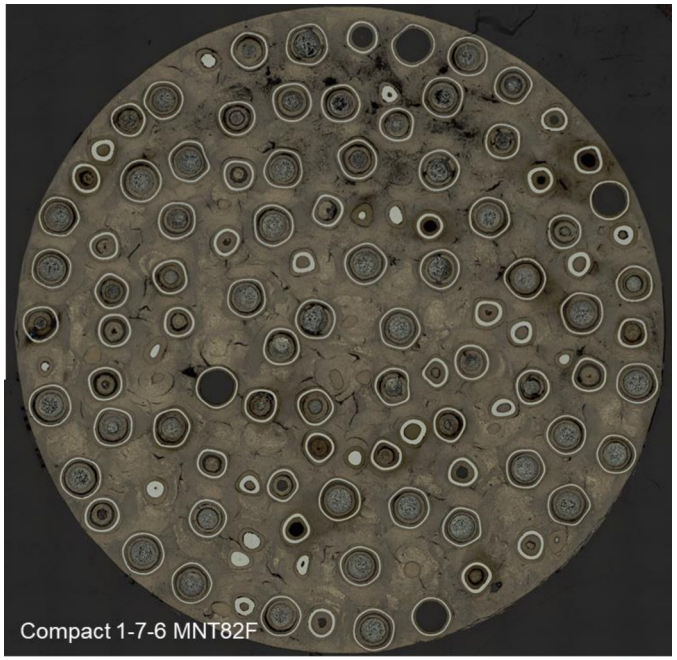
As-irradiated Compact Ceramography Complete. Some analyses still in progress.

Compact	Burnup	Fluence	TA Min	TAVA	TA Max	Lab	Year
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

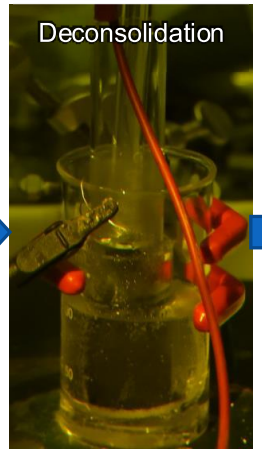

Kernel migration in Compact 3-4-1


Bulk Ni in Compact 1-6-9

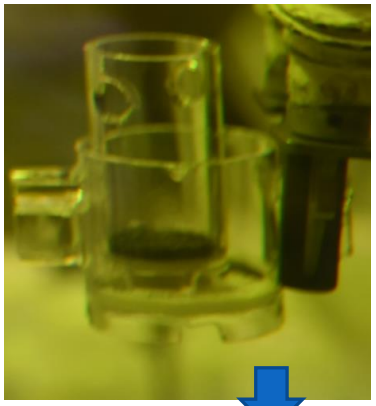

Compact 2-3-3 MNT54F

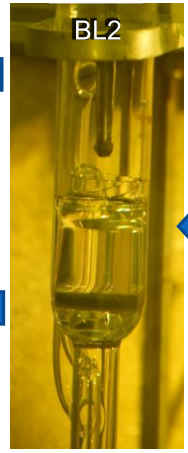

Compact 1-7-6 MNT82F

As-Irradiated Deconsolidation-Leach Burn-Leach (AI-DLBL)



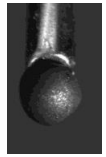
"Burn" at 750°C in air for 72 h

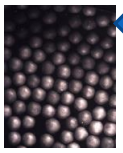


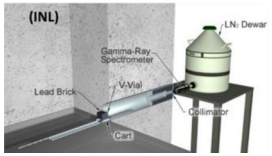


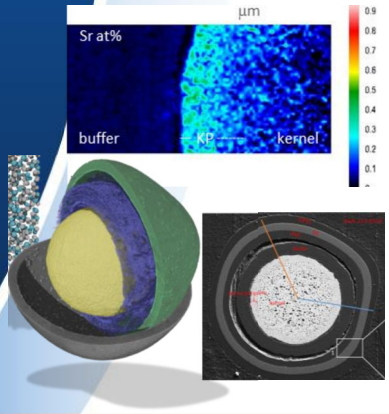
Analysis of solutions:
- gamma spec
- Sr-90 separation
- mass-spec

Particle Exams
- Gamma counting
- X-ray CT
- Microanalysis









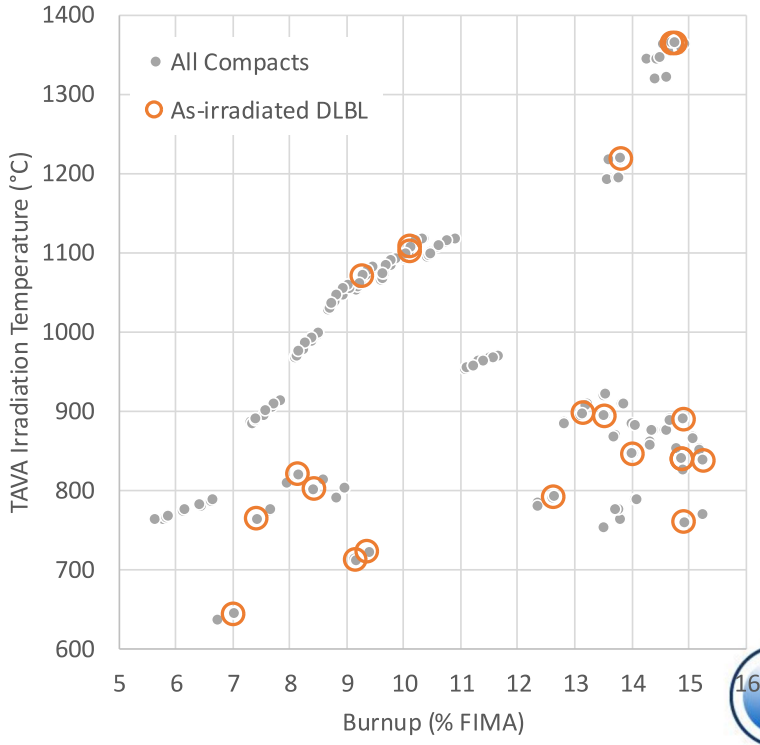
As-Irradiated Deconsolidation-Leach Burn-Leach (AI-DLBL)

FY24 Milestones due 9/13/2024

1. **Complete four DLBLs at INL – one remaining to complete.**
2. **Complete five DLBLs at ORNL – One complete. Completing radiochemistry or particle burn-leach on the other four.**

Compact	Burnup	Fluence	TA Min	TAVA	TA Max	Lab	Year
1-7-4	10.12	3.9	899	1100	1217	INL	2022
1-7-9	10.13	3.9	903	1106	1221	INL	2022
2-2-1	14.03	4.72	743	845	914	ORNL	2022
3-6-3	14.77	5.47	1264	1363	1432	ORNL	2023
5-1-2	9.17	3.25	499	710	821	INL	2022/FY23
1-5-9	9.29	3.3	889	1070	1169	ORNL	2022/FY23
3-6-2	14.72	5.46	1262	1363	1431	INL	2023
2-7-4	15.26	5.42	729	836	903	INL	2023
4-6-4	12.65	4.2	584	791	903	INL	2023
5-1-3	9.38	3.39	505	721	835	ORNL	2024
3-8-3	13.81	5.3	991	1218	1367	ORNL	2024
2-6-1	14.89	5.13	739	838	898	ORNL	2024
4-5-4	13.15	4.44	797	896	962	INL	2024
2-6-2	14.89	5.13	739	838	898	INL	2024
5-6-3	7.03	1.74	473	643	752	ORNL	TBD
5-5-2	7.44	2.05	676	762	830	INL	2024
5-3-1	8.43	2.71	721	800	849	INL	Planned FY24
5-4-3	8.16	2.48	748	819	864	ORNL	TBD, Shipment 7
4-3-2	13.53	4.55	800	893	950	ORNL	TBD, Shipment 7
2-8-1	14.93	5.21	554	758	861	ORNL	TBD, Shipment 8
2-4-4	14.92	5.19	788	888	945	INL	Planned FY24

Completed since July 2023



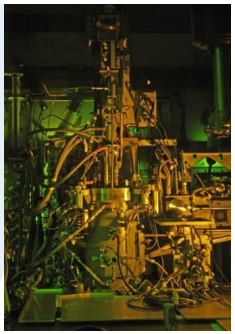
Irradiated Compact Inert Safety Tests

FY24 Milestones due 9/13/2024

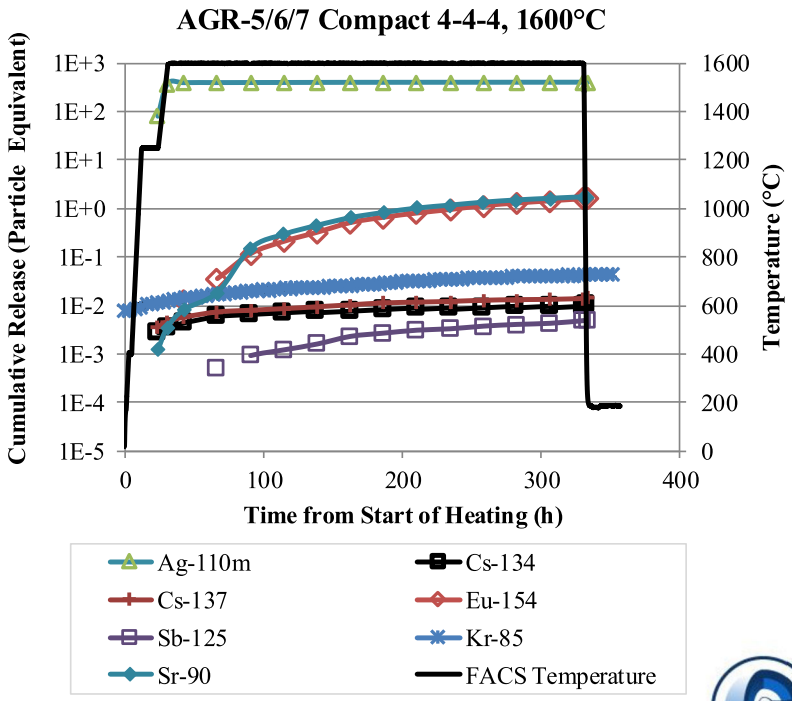
1. **Complete three tests in FACS at INL – need two more. May be delayed by FACS repairs**
2. **Complete four tests in CCCTF at ORNL – waiting on chemistry results from the 4th test**

- Determine SiC and TRISO failure rates in conditions like core-conduction-cooldown
- Typically hold temperature at 1600 and 1800°C for 300 h
- Measure fission product releases versus time and temperature
- Tests conducted in parallel at INL and ORNL

FACS Furnace (INL)



CCCTF Furnace (ORNL)



Irradiated Compact Inert Safety Tests

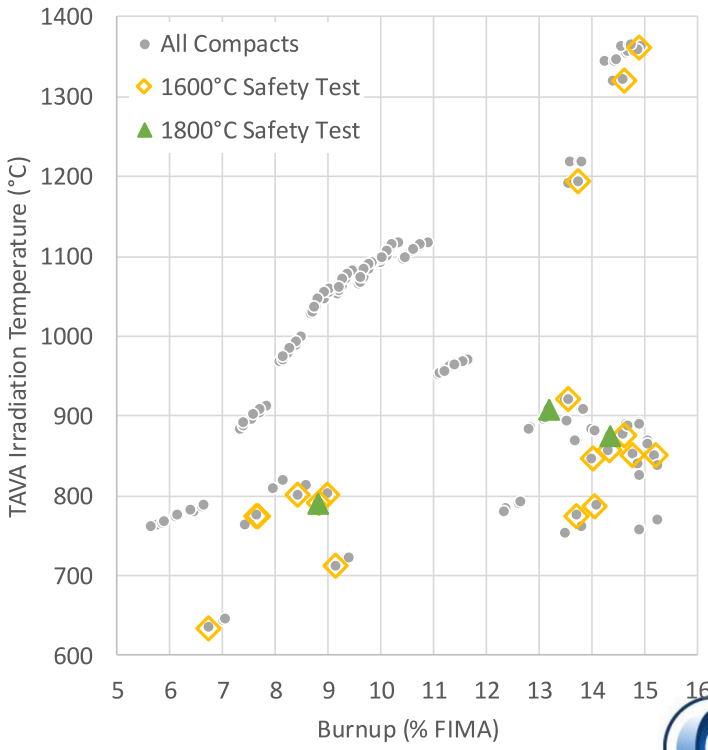
FY24 Milestones due 9/13/2024

1. **Complete three tests in FACS at INL – need two more. May be delayed by FACS repairs.**
2. **Complete four tests in CCCTF at ORNL – waiting on chemistry results from the 4th test**

	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	2023/FY24
	5-6-2	6.75	1.67	467	634	741	ORNL	FY23/FY24
	2-6-4	15.21	5.36	749	850	913	INL	2023/FY24
	5-2-1	8.84	3.01	700	790	846	ORNL	2024
	5-2-4	8.99	3.13	709	801	859		
	5-3-2	8.43	2.7	720	800	849		
	2-5-1	14.78	5.05	747	851	917	ORNL	FY23/FY24
	3-4-2	14.91	5.54	1271	1361	1420	INL	2023/FY24
	5-1-1	9.16	3.27	499	711	822	INL	2023/FY24
	3-2-2	14.61	5.54	1203	1320	1401	ORNL	Started 2024
	2-4-2	14.61	4.95	777	875	931	INL	Planned FY24

	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/FY23
	5-2-2	8.82	2.99	699	789	845	ORNL	2022/FY23
	4-4-2	13.21	4.4	822	906	954	ORNL	Planned FY24

Completed since July 2023



Compact Shipments to ORNL for PIE (slide 1/2)

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	Completed 11/2023	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

Milestones:

- **December 2023: completed shipments 4 - 6**
- **September 2024: Need to complete shipments 7-9 (projected to be late)**

Compact Shipments to ORNL for PIE (slide 2/2)

Shipment	Date	Compacts	Use
6	Completed 12/2023	5-5-4	Post-FACS DLBL
		3-2-2	1600°C CCCTF Test
		5-6-3	AI DLBL
		4-4-2	1800°C CCCTF Test
7	Late Summer 2024	3-1-1	1800°C CCCTF
		4-3-4	1800°C CCCTF Test
		5-4-3	AI DLBL
		4-3-2	AI DLBL
8	TBD in 2024		
9	TBD in 2024		

Milestones:

- **December 2023: completed shipments 4 - 6**
- **September 2024: Need to complete shipments 7-9 (projected to be late)**

Major Work in Progress

- Complete installation of AMIX in hot cell to test fuels in oxidizing atmospheres
- Complete remaining compact shipments to ORNL
- Continue working through inert 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”)
- Complete installation of SNIFF and RAPTOR equipment to screen fuel compacts for failed particles via short-lived fission gas
- Reporting results

GAS-COOLED REACTOR

ADVANCED REACTOR TECHNOLOGIES PROGRAM

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Thank you for your attention

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