INL/MIS-22-68897-Revision-0

Demonstrate Viability of Accelerated Fuel Qualification Approaches

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Changing the World's Energy Future

Seongtae Kwon, Boone Beausoleil, Christopher Glen Turner, Adrian R Wagner, Andrew John Bascom, Austen David Fradeneck, Gyanender Singh

Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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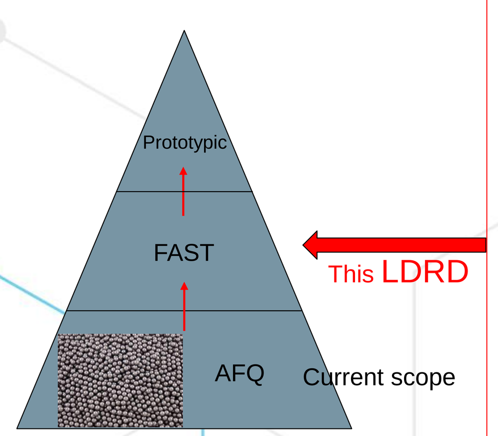
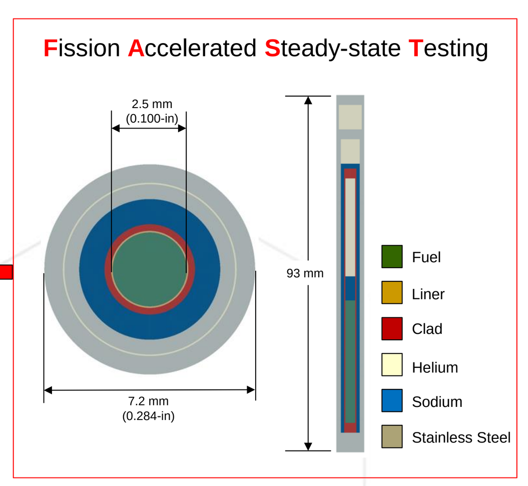
Title: Demonstrate Viability of Accelerated Fuel Qualification Approaches

Expansion of FAST to Uranium Carbide (UC) Fuel

PRESENTER: Seongtae Kwon

- Time and cost for the qualification of new fuel is significant.
- Fission Accelerated Steady-state Test (FAST) method saves time and money: reduced fuel diameter with high enrichment to achieve prototypic temperature and high burn up in shorter period.





METHODS

- Utilizing a FAST approach to capturing UC integral irradiation data.
- Opportunity for developing inhouse UC fabrication.
- Designed to fill in the gap in the Accelerated Fuel Qualification (AFQ) work performed by ORNL and GA.

RESULTS

- Neutronic, thermal and hydraulic analysis and design of test capsules.
- Development of in-house fabrication process of dense uranium carbide ceramics.

Analysis for Irradiation Design

Fueled drop-in experiment planned for irradiation in the B-3 position in ATR. (ECAR-5630)

- Utilizes stackable ISHA Capsules.
- Contained within a standard Y-Basket.

Full stack-up contains 4 ISHA capsules and 2 spacers.

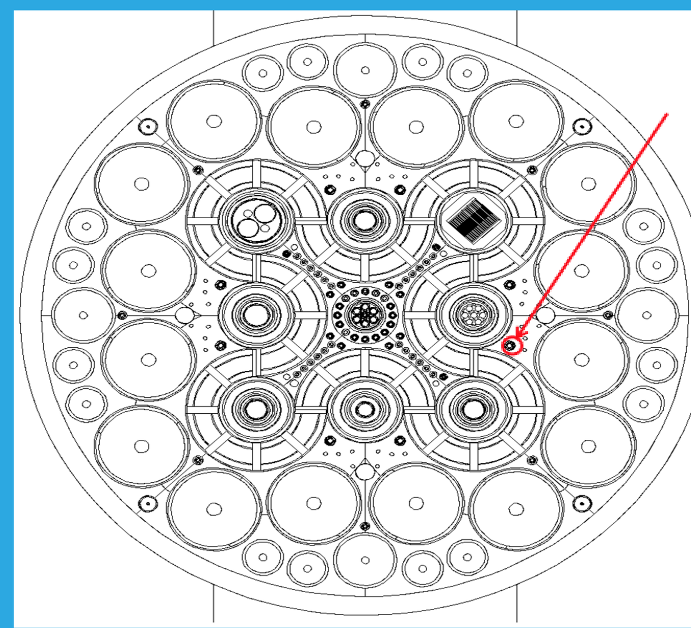
- 3 small rodlet assemblies.
- 1 large rodlet assembly.

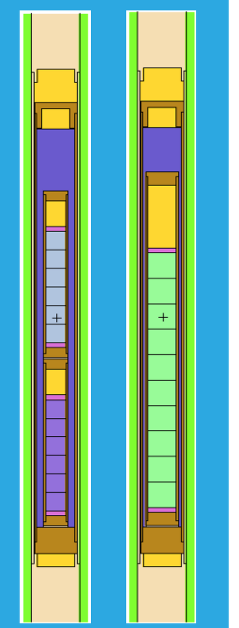
Thermal Analysis (ECAR-5515)

- Based on stack-up and maximum heat rate.

Created response surfaces for a wide range of conditions.

- Nominal, FCD, RIA-4.
- Minimum coolant flow rate for thermal conditions of UC-FAST experiment is 0.397 lb/s.





Capsule Number	Rodlet	Target LHGR (W/cm)*	Fuel Length (cm)	Fuel Radius (cm)	Cladding Inner Radius (cm)	Nominal LHGR at 23 MW SE Lobe Power (W/cm)
UC-ISHA-001	UC-01	500	3.597	0.302	0.306	503.20
	UC-02	500	3.597	0.302	0.306	470.40
UC-ISHA-002	UC-03	600	3.597	0.302	0.306	599.45
	UC-04	600	3.597	0.302	0.306	603.68
UC-ISHA-004	UC-06	550	8.204	0.410	0.413	435.46
UC-ISHA-005	UC-07	500	3.597	0.302	0.306	503.20
	UC-08	500	3.597	0.302	0.306	470.40
UC-ISHA-006	UC-09	600	3.597	0.302	0.306	599.45
	UC-10	600	3.597	0.302	0.306	603.68
UC-ISHA-007	UC-11	550	3.597	0.302	0.306	583.17
	UC-12	650	3.597	0.302	0.306	616.88

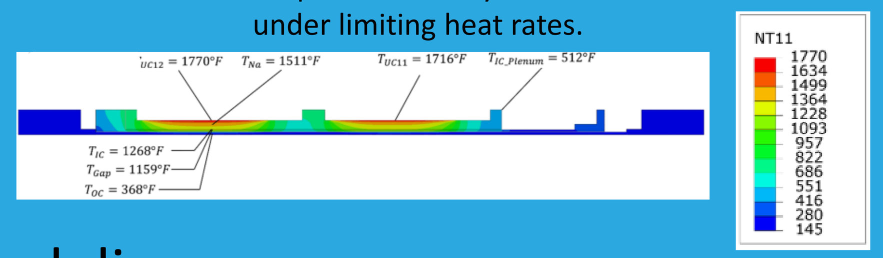
Enrichment (U235 at%): 1.91% for 12.92g/cc fuel, 2.30% for 10.2g/cc fuel

ISHA-UC Capsule Number	Maximum Component Temperature (°F)			
	Rodlet Centerline	Thermal Bond	Inner Capsule	Outer Capsule
4	914	819	787	262
5	1064	928	837	279
	1023			
6	1180	1029	916	308
	1185			
7	1162	1041	925	311
	1199			

Limiting temperatures and pressures for the hottest capsule (ISHA-UC-07) during requisite safety events.

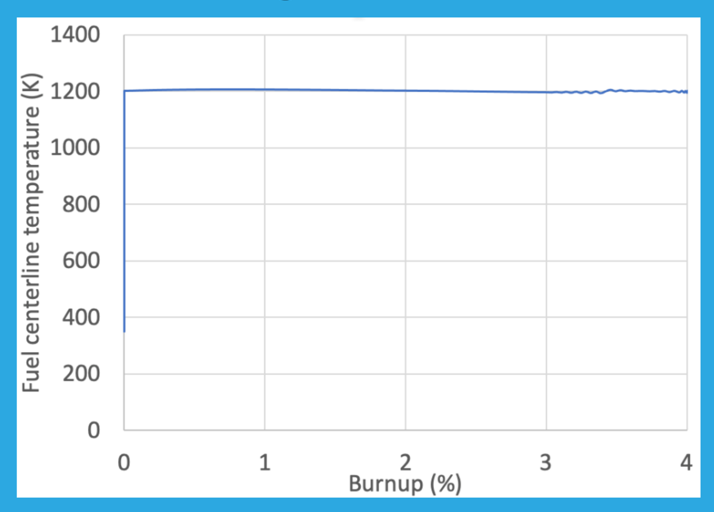
Condition	T_{Na}[°F]	T_{IC}[°F]	T_{OC}[°F]	P_{MAX}[psi]
Nominal	1404	1233	355	244
FCD	1413	1241	366	245
RIA-2	1525	1295	380	250

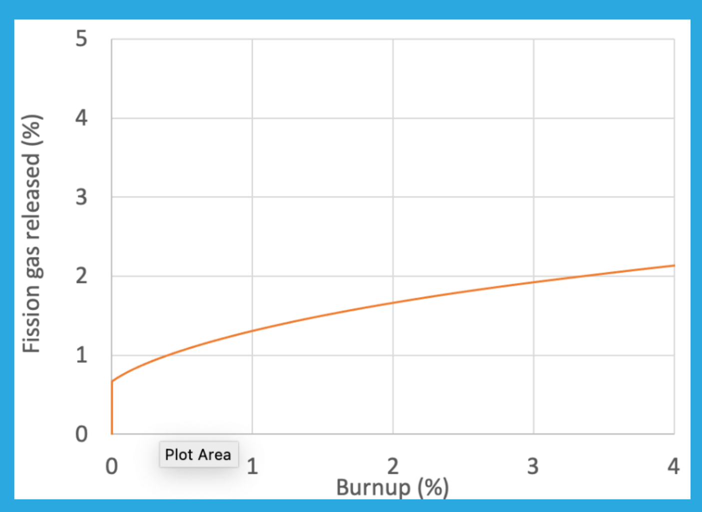
Resulting temperature distribution and peak temperature values for the ISHA-UC-07 capsule assembly 0.1706s into RIA-2 event under limiting heat rates.



UC Model Implementation in Bison

- Validate BISON code against the results for UC modeling obtained by General Atomics using other codes.
- BISON lacked several material models that were required for modeling of UC behavior such as irradiation induced swelling, densification, relocation, burnup, fission gas release etc.





Clad: 800HT
UC Fuel

Parameter	Value
Pellet height	8.90016 cm
Pellet radius	4.1021 mm
Pellet-cladding gap	0.0254 mm
Cladding thickness	0.635 mm
Power	~90 kW/m

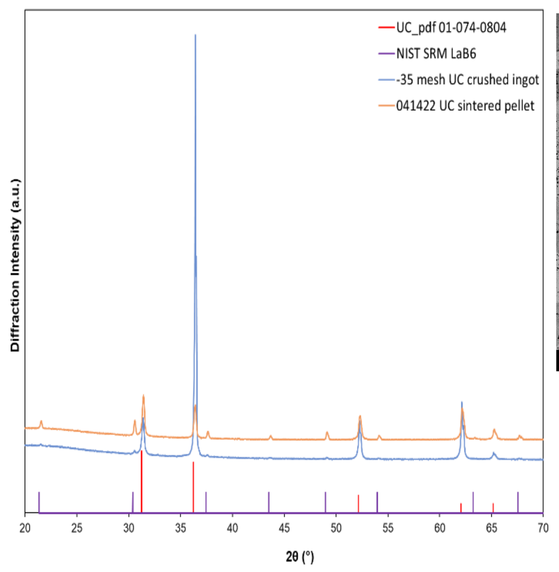
In-House UC Fabrication Capability

- Established method for fabricating UC at INL
  - Via arc-melting technique
  - Carbothermic reduction (CTR) of UO_2
- Fabricated UC fuel pellets for ATR experiment
- Mechanical testing of UC pellets
  - Preparing manuscript

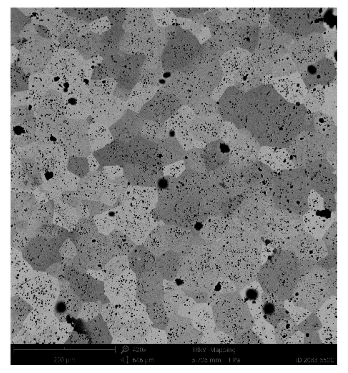
Using method developed for fabricating U_3Si_2

- Arc melting allows for tailored enrichment, significantly easier than tailoring UO_2 enrichment.
  - Allows for enrichments higher than 5% (commercially available)
  - Decrease O_2 impurities compared to CTR method
  - Fabrication of phase pure UC, no observable UC_2 or U_2C_3

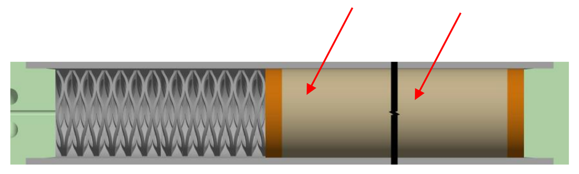
Sintered UC pellet
- 1800C, for 8 hours, Ar
- Sintered density >95%



XRD pattern for arc melted Ingot and sintered pellet
No UC_2 or U_2C_3 was observed



Sintered pellet
- No minor phases observed



Schematic of experiment capsule with UC pellets (red arrow)

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