

Summary of SPERT Reactor Tests

Hot Rods

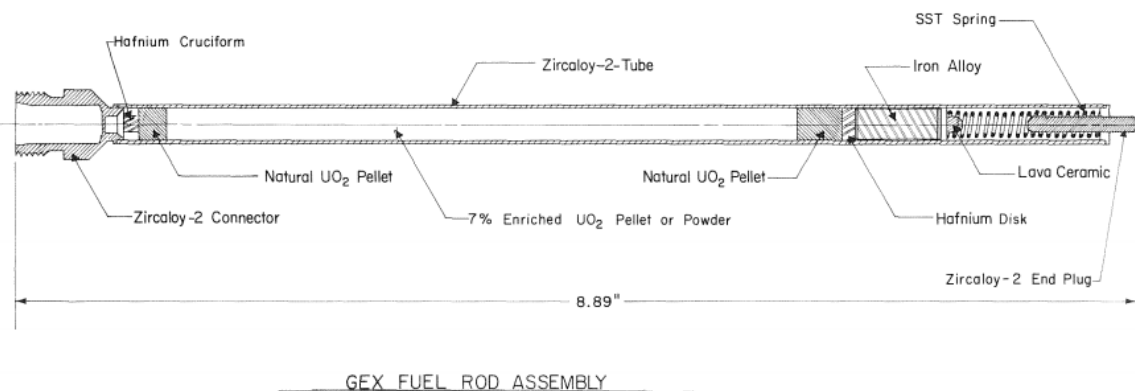
The Response of UO_2 Fuel Rods to Power Bursts

IN-1302

- Question: What happens when fuel rods react with no cooling system in place?
- Rod Dimensions

	GEX Rods	GEP Rods
Cladding	Zr-2 (10% CW)	Zr-2 (10% CW)
Outer Diameter (in)	0.3125	0.562
Cladding Thickness (in)	0.020	0.032
Fuel Length Active (in)	5.2	5.2 or 5.6

- Active Length vs. Part Length



- Energy Release
 - “A clean fuel rod of the type in question, is irradiated in the CDC (steady state) until a specific energy of about 200 cal/g UO_2 has been released.”
 - “Measurement of the energy deposition in any test is defined as the maximum possible adiabatic enthalpy change of the fuel.”
- Failure



COMPLETE CLADDING FAILURE, TEST 524

- Fuel status before and after tests was checked using neutron radiography.
- Results
 - Failure threshold between 266 and 292 cal/g UO_2
 - Axial cladding displacement, elongation, and pressure are functions of energy deposition

Behavior of Zircaloy Fuel Rods Subjected to Power Bursts

IN-ITR-107

- Question: What is the failure threshold for Zircaloy-2 fuel rods?
- Rod Dimensions

	SPXM Rods
Cladding	Zr-2
Outer Diameter (in)	0.25
Cladding Thickness (in)	0.014
Fuel Length Active (in)	5
Overall Length (in)	7.662

- Actual fuel rods are 18 - 24" long, and deformation and energy release by the fuel varies widely over the length of the rod. The 5" rod removes this variance and the cladding on the active length reacts uniformly.
- Theoretical enthalpy of 269 cal/g UO_2 required to reach Zr-2 melting point of 2842°C.
- Results
 - Mathematical Models for mechanical energy conversion, surface to volume particle size, and metal-water reaction extent
 - Failure Thresholds
 - Initial Failure (brittle fracture): 240 / 257 cal/g UO_2
 - Melting Failure: 257 / 267 cal/g UO_2
 - Prompt Failure (fracture before heat transfer): 338 / 360 cal/g UO_2
 - When the rods fail, the fuel is retaining the heat because there's only about a 25 msec window to transfer it before complete failure.

Measurements of the Reaction of UO_2 With Water

IN-ITR-108

- Question: What kind of reactions happen when molten UO_2 is released in water?
- Rod Dimensions

	SPXMG Rods
Cladding	Flint Glass

Outer Diameter (in)	0.3150
Cladding Thickness (in)	0.0433
Fuel Length Active (in)	4.5
Overall Length (in)	7

- Results
 - Failure thresholds range from 70 - 91% of total energy deposition

Effects of Axial Length on Fuel Rods' Response to Power Bursts *IN-ITR-109*

- Question: Is an axial fuel length of 5" enough to accurately simulate real fuel performance?
- Rod Dimensions

	GEP (SL 1/2)	GEX (SL 3/4)
Cladding	ZR-2	ZR-2
Outer Diameter (in)	0.562	0.3125
Cladding Thickness (in)	0.035	0.019
Fuel Length Active (in)	24.56 (L) / 5 (S)	24.16 (L) / 5 (S)
Overall Length (in)	28	28

- Results
 - 5" rods exhibit more severe reactions than long rods, because the average energy deposition was lower per unit length in long rods than for the short rods.
 - Axial fuel length of 5" is sufficient for testing.

New Questions

- What will this new round of experiments look like? What are the specific objectives?
- What is the material of the rods we'll be examining?
- What levels of fuel energy deposition will be tested? Are you testing for failure?
- Should we be expecting to handle fractured samples? In the final application, will those fractured samples be potentially leaking fuel?
- Is determining fuel fragmentation part of our project? If so, could thermal imaging be used?
- Will our test bench need to accommodate additional lengths?
- What is the cool down period like for these rods before testing?

Report Data

Report IN-1302

Test No.	Burst Length [ms]	Energy Deposition (failure) [cal/g UO ₂]	Max Temp [°C]	Result
523	8.53	151	870	Minor Discoloration
472	6.65	200	Unknown	Warping, Discoloration
477	5.02	255	Unknown	Warping, Discoloration
518	5.13	262	1575	Warping, Discoloration
520	4.94	266	1550	Discoloration
519	4.62	292 (unknown)	2050	Melted cladding
525	4.22	314 (290)	1875	Melted cladding, Fuel loss
480	3.88	342 (335)	Unknown	Melted cladding, Fuel loss
524	3.93	343 (330)	1775	Complete separation of cladding, Fuel loss
483	3.00	440 (425)	Unknown	Complete separation of cladding, Fuel loss

Report IN-ITR-107

Test No.	Burst Length [ms]	Energy Deposition (at failure) [cal/g UO]	Max Temp [°C]	Result (all measurements in mils)
510	11.7	168	Not Measured	Diameter Growth (Max/Perm), 2.7/1.8 Axial Growth (Max/Perm), 80/40 Warping/Bowing
537	8.25	235	1720	Diameter Growth (Max/Perm), 9.5/8 Axial Growth (Max/Perm), 170/100 Slight bowing
539	8.11	240	1700	Diameter Growth (Max/Perm), 22.5/7.8 Axial Growth (Max/Perm), 250/170 Cladding deformation, cracked pellets
503	7.60	257	NM	Diameter Growth (Max/Perm), 22.5/7.8 Axial Growth (Max/Perm), 180/73 Cladding fracture (upper end of fuel)
545	7.26	267 (unknown)	1860	Axial Growth (Max/Perm), 180/120 Cladding deformation, triple fracture (probably during cool-down)

Test No.	Burst Length [ms]	Energy Deposition (at failure) [cal/g UO	Max Temp [°C]	Result (all measurements in mils)
504	6.86	287 (unknown)	NM	Axial Growth (Max/Perm), 180/N-A Cladding melt, fractures, multiple holes
541	5.59	338 (unknown)	1880	Axial Growth (Max/Perm), 110/N-A Cladding melt, slight fragmentation
543	5.20	360 (330)	1800	Axial Growth (Max/Perm), 100/N-A Cladding melt, failure at 1440°C.
506	4.93	378 (365)	NM	Axial Growth (Max/Perm), 90/N-A Cladding melt
507	4.10	490 (400)	NM	Axial Growth (Max), 65 Near complete melting 99.8% of fuel lost
505	3.27	613 (470)	NM	Axial Growth (Max), 50 Complete melt 99.9% of fuel fragmented and lost
536	3.28	620 (420)	500	Axial Growth (Max), 40 Complete melt, 100% fuel loss
551	2.99	653 (400)	300	Axial Growth (Max), 50 Complete melt, 100% fuel loss
549	3.01	655 (360)	300	Axial Growth (Max), 50 Complete melt, 100% fuel loss

Report IN-ITR-108

Test No.	Burst Length [ms]	Energy Deposition (at failure) [cal/g UO	Capsule Pressure [psig]	Result
517	3.11	550 (390)	310	Failure
533	3.42	510 (420)	830	Failure
550	3.00	510 (375)	1500	Failure
526	3.84	450 (415)	40	Extensive fragmentation
529	4.29	410 (375)	185	Fragmented
531	4.56	390 (310)	90	Failure
532	5.07	330 (unknown)	unknown	Failure
481	2.97	605	410	N/A

- Note: Test 481 was made on unclad fuel held in an alumina crucible.

Report IN-ITR-109

Test No.	Rod Type	Burst Length [ms]	Energy Deposition [cal/g UO	Cladding Expansion (max) [mils]	Fuel Expansion (max) [mils]	Capsule Pressure [psig]
682	GEP-L	3.0	245	260	365	40
487	GEP-S	3.0	245	15	310	40
509	GEP-L	3.0	250	145	125	40
488	GEP-S	3.0	255	130	380	0
491	GEX-L	3.0	425 (330)	70	Disintegration	715
479	GEX-S	3.0	415 (375)	Disintegration	Disintegration	720
492	GEX-L	3.0	460 (390)	25	Disintegration	575
483	GEX-S	3.0	440 (425)	Disintegration	Disintegration	400