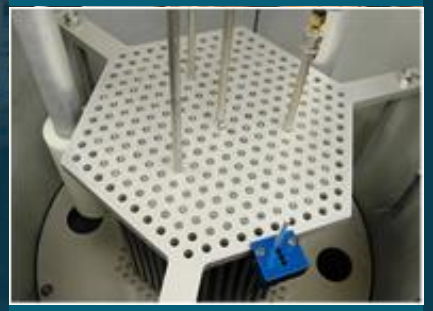
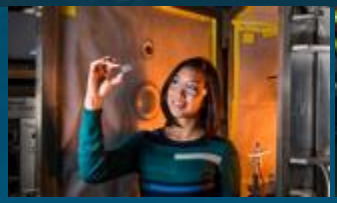
IER-451 Titanium and Aluminum Sleeve Experiments in the BUCCX





PRESENTED BY

David Ames

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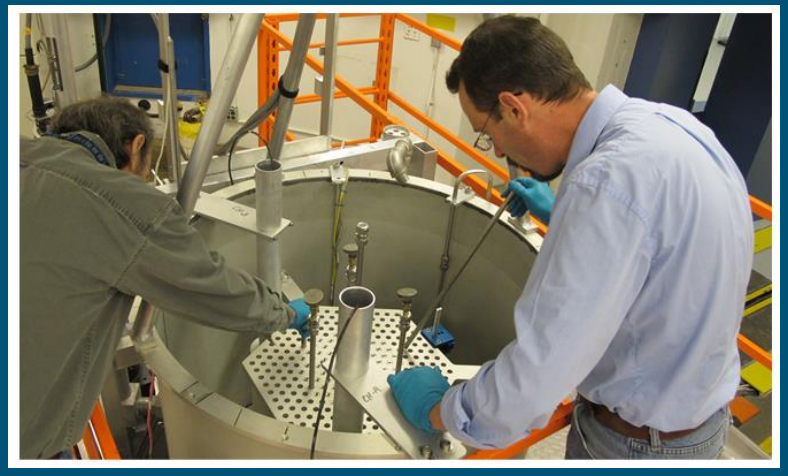
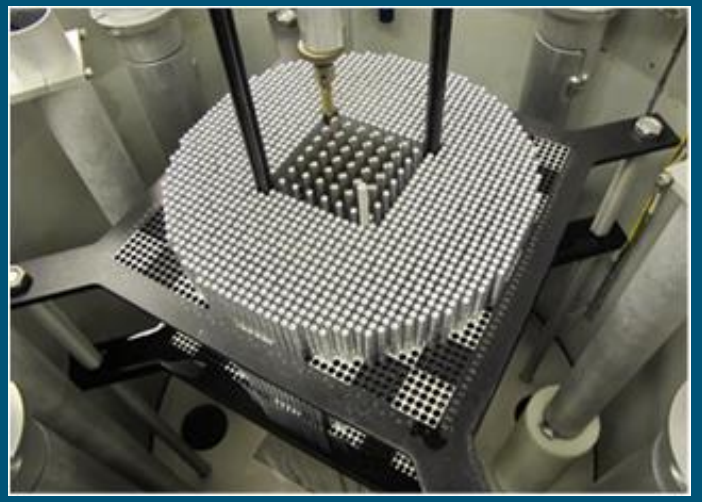


Sandia Critical Experiments Facility

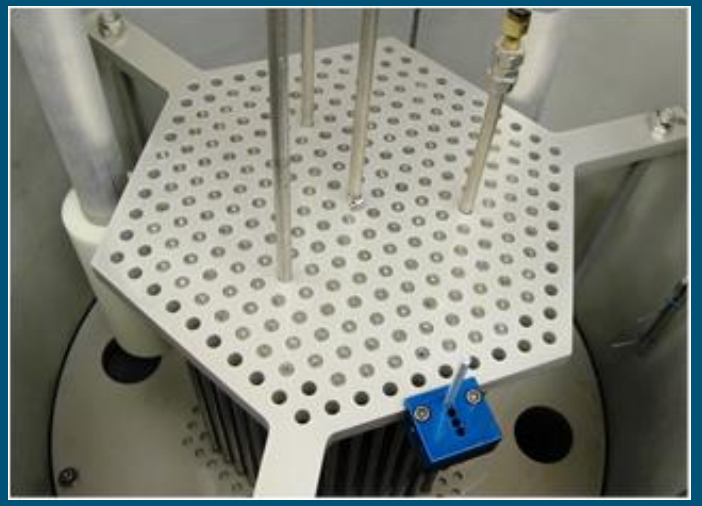
The Seven Percent Critical Experiment (7uPCX)

- UO_2 fuel (6.9%)
- 45x45 Square array (pitch 0.315 and 0.337 inch)
- Fuel locations 2025
- Fuel rod diameter 0.25 inch
- Fuel length 19.25 inch
- LCT-078, 080, 096, 097



The Burnup Credit Critical Experiment (BUCCX)

- UO_2 fuel (4.3%)
- Triangular pitch (0.787 and 1.1 inch)
- Fuel locations 397 and 271
- Fuel rod diameter 0.544 inch
- Fuel length 19.37 inch
- LCT-079, 099



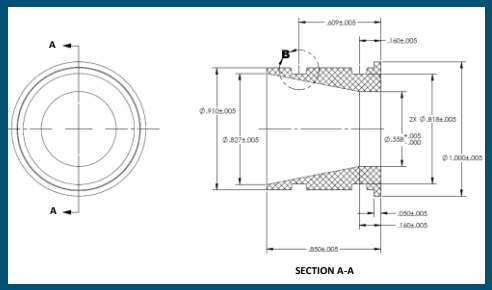
Titanium and Aluminum Sleeves

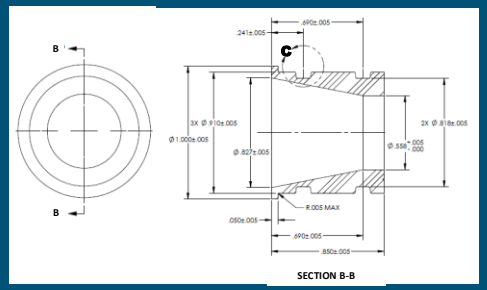
Titanium sleeves

- Grade 2
- Outer diameter 1.0 inch
- Wall thickness 0.035 inch
- Length 19.6 inch
- Laser etched with ID number

Polyethylene Centering Pieces

- Length 0.85 inch
- O-rings hold in place





Sleeve ID number

Top and bottom centering pieces

Top centering piece inserted

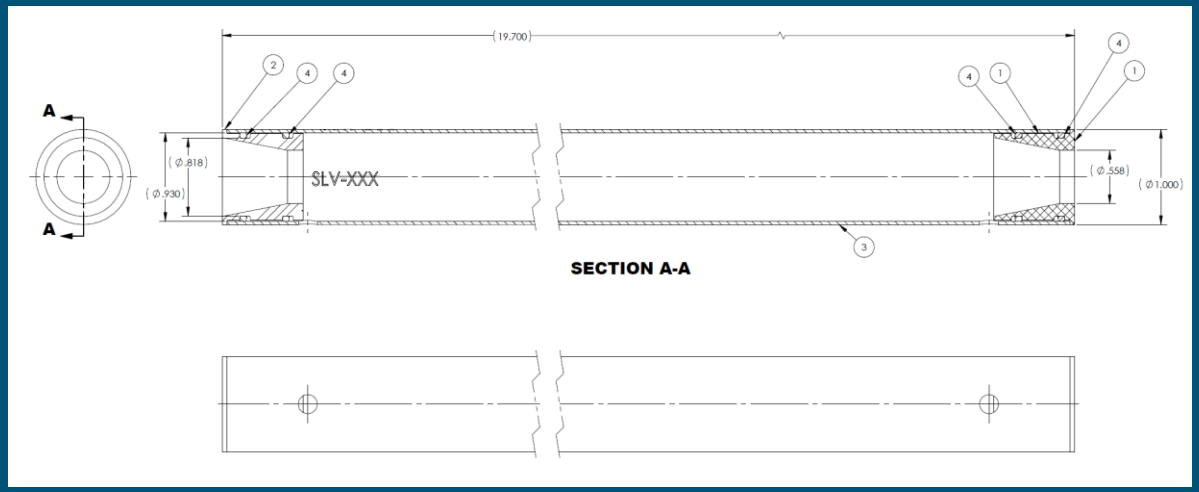
Top centering piece inserted

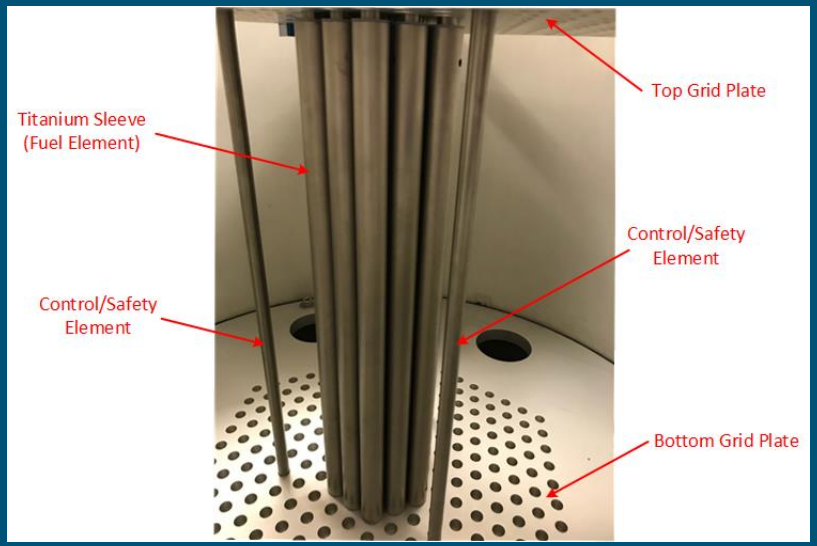
Sleeves ready to be placed in assembly

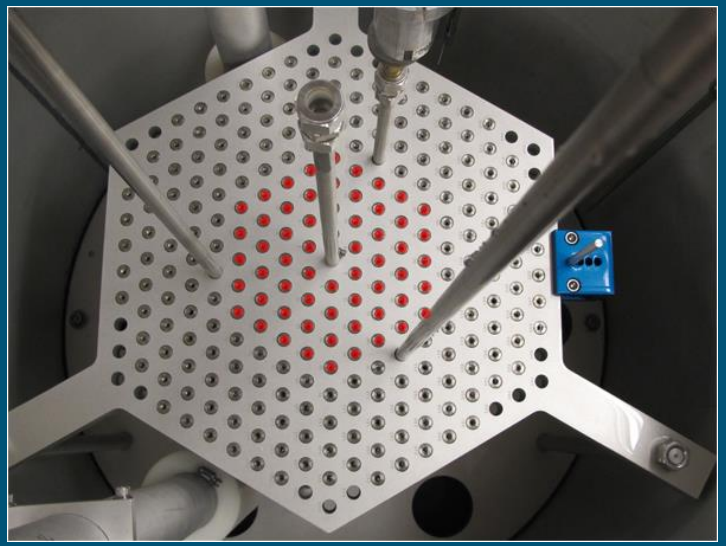
Titanium and Aluminum Sleeves

Sleeves are placed between the top and bottom grid plates (fueled section)

- Fuel element fed through top grid plate hole into the sleeve and into bottom grid plate hole
- Fuel element outer diameter 0.544 inch
- Sleeve inner diameter 0.93 inch







Experiment Method

Measure the effects of titanium and aluminum sleeves in the fuel array on the critical array size.

- All titanium experiments have corresponding aluminum experiments
  - Configuration of the sleeves (titanium and aluminum) the same for each case
  - Number of fuel rods in the array will differ due to the effects of titanium and aluminum

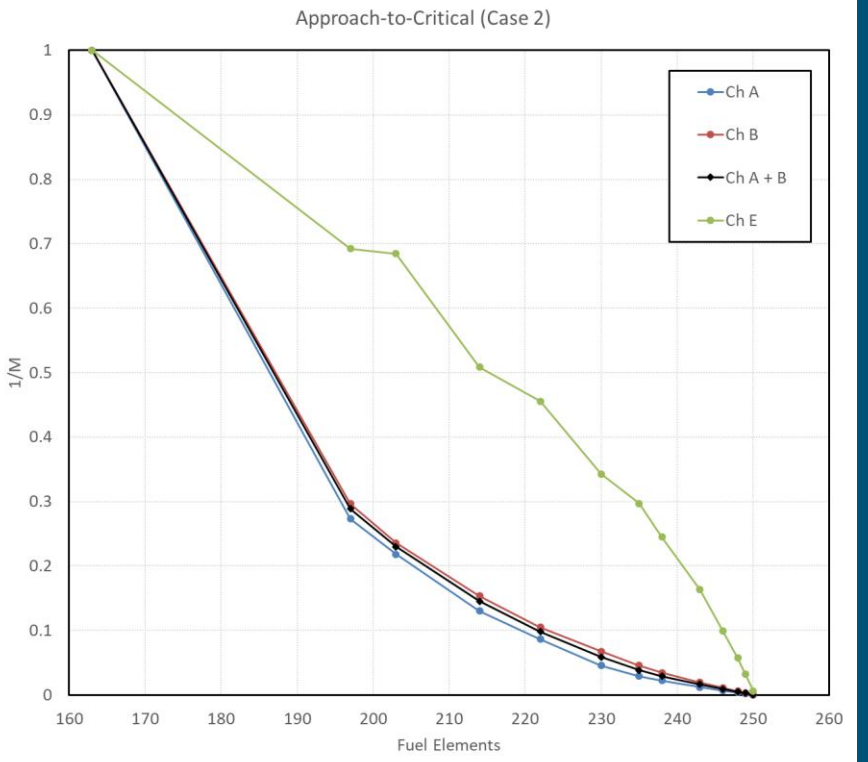
Critical array size for each configuration determined by an approach-to-critical experiment

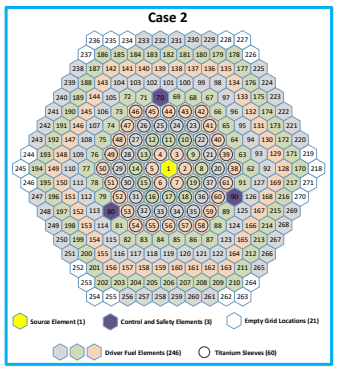
- Array fully reflected by water
- Approach parameter is the number of fuel rods
  - Load from center toward the outside while maintaining a roughly cylindrical cross section of the array
  - Inverse count rate as function of number of fuel rods extrapolated to zero to obtain critical array size
- Initial two arrays for each configuration determined by calculations
  - 1st array: $k_{eff} = 0.90$
  - 2nd array: $k_{eff} = 0.95$
- Subsequent measurements guided by count rate results
  - Loading order guided by fuel element incremental worth calculations

17 critical experiments performed

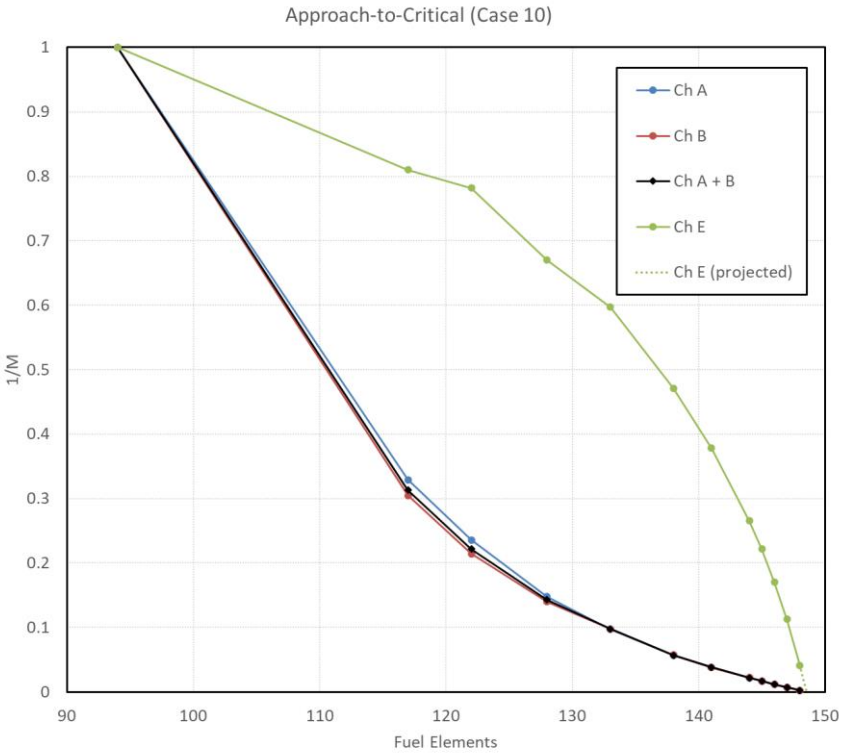
- 1 with no sleeves
- 8 cases with titanium sleeves (varying quantities and configurations)
- 8 cases with aluminum sleeves (matching titanium cases)

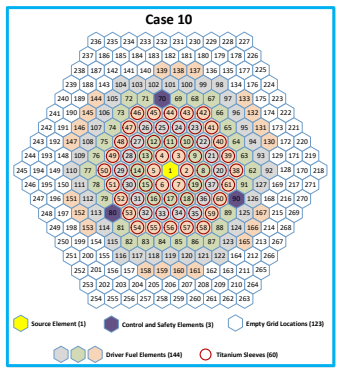
Approach-to-Critical (case 2 and 10)





Fuel elements	Projection (A+B)	Uncertainty
163	-	-
197	210.7931	0.3524
203	226.4541	1.2581
214	232.8661	0.5437
222	238.6815	0.4697
230	241.8655	0.2289
235	244.5458	0.1571
238	247.5537	0.1218
243	249.2936	0.0355
246	249.8935	0.0167
248	250.2748	0.0068
249	250.1985	0.0027
250	250.2276	0.0002

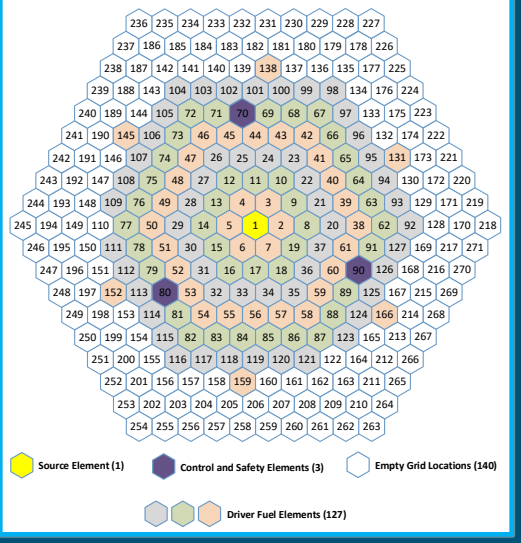




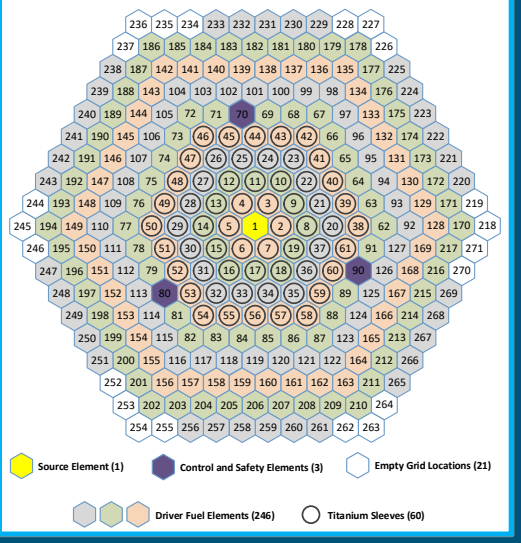
Fuel elements	Projection (A+B)	Uncertainty
94	-	-
117	127.4899	0.3654
122	134.0724	0.7031
128	138.8769	0.4713
133	143.7873	0.4024
138	145.0113	0.1653
141	147.0648	0.1404
144	148.0980	0.0500
145	148.3521	0.0537
146	148.2732	0.0235
147	148.4754	0.0093
148	148.4934	0.0013

Fuel Element Layout for Largest Array Measured(17 cases)

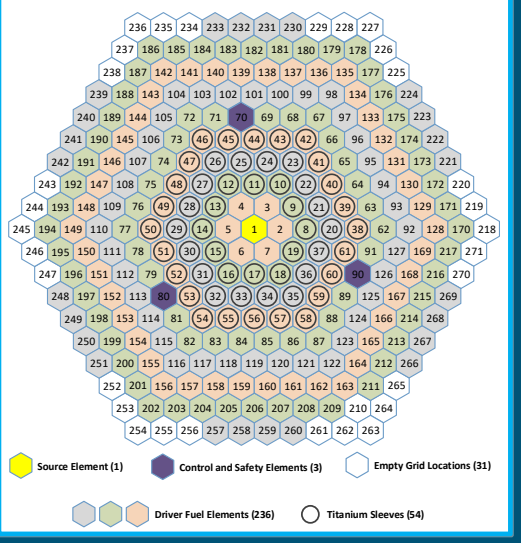
Case 1



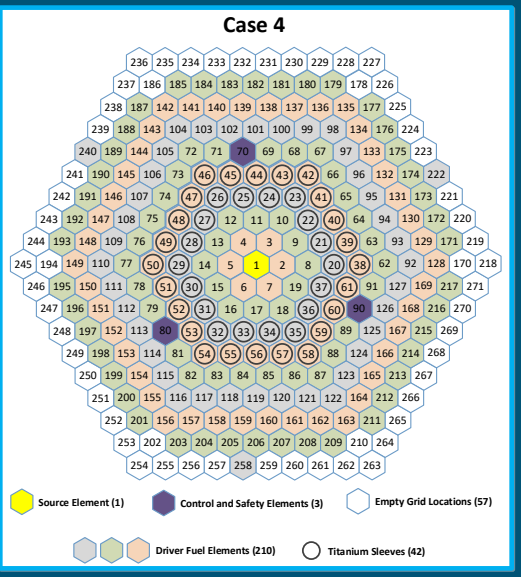
Case 2



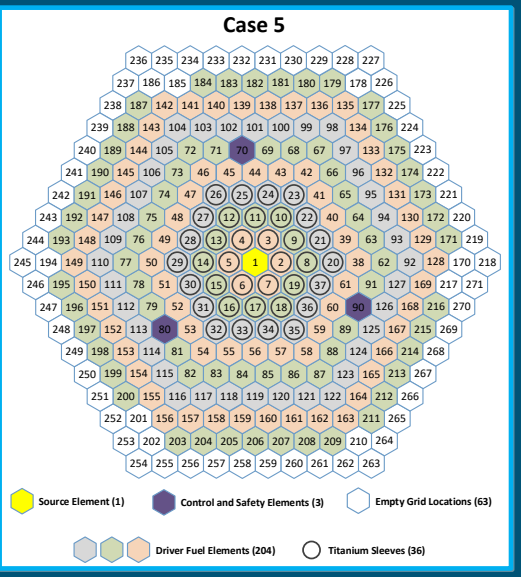
Case 3



Case 4



Case 5



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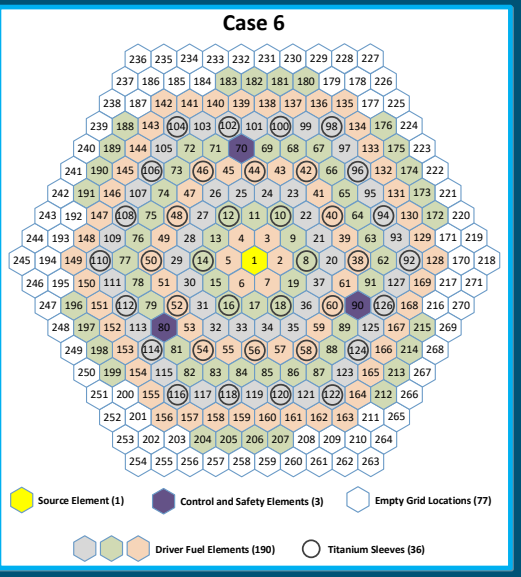
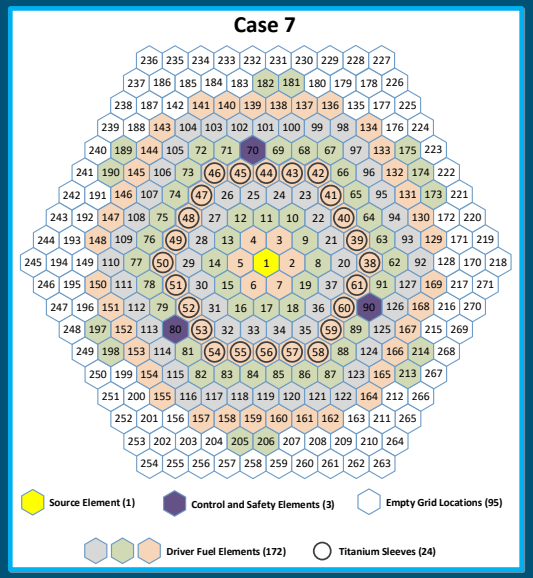
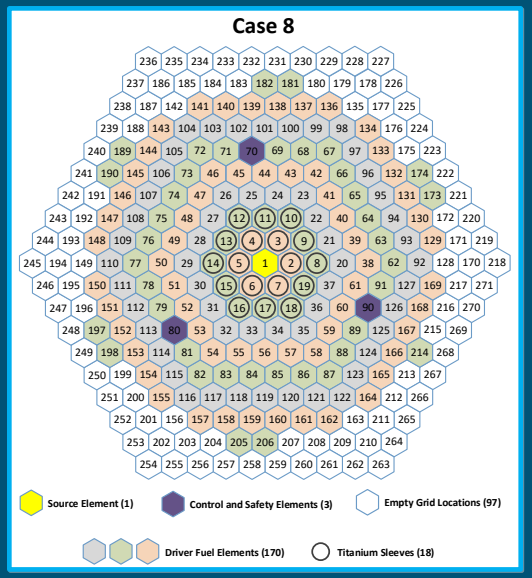
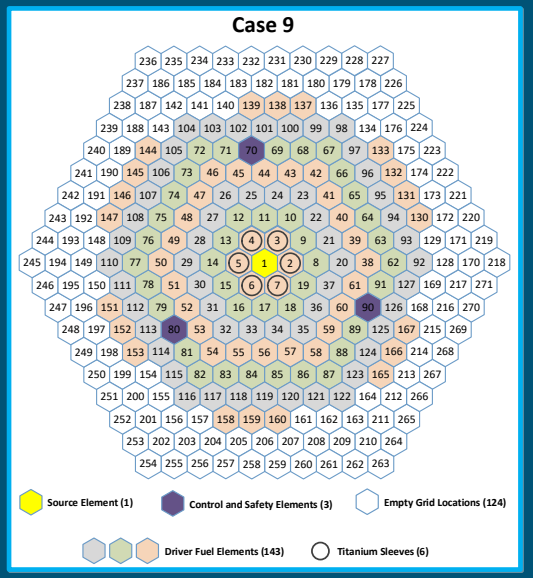
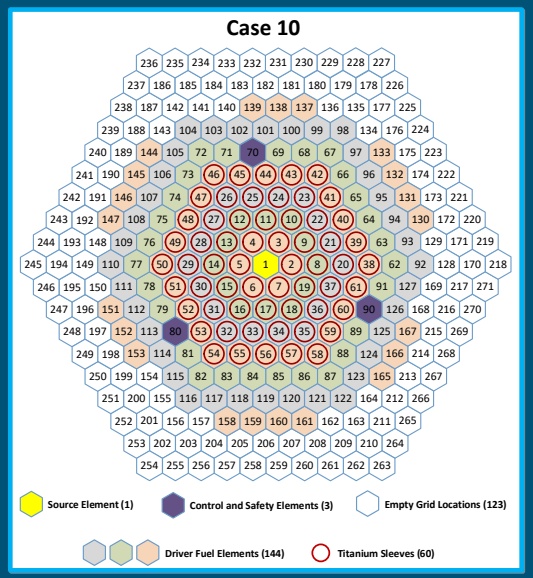


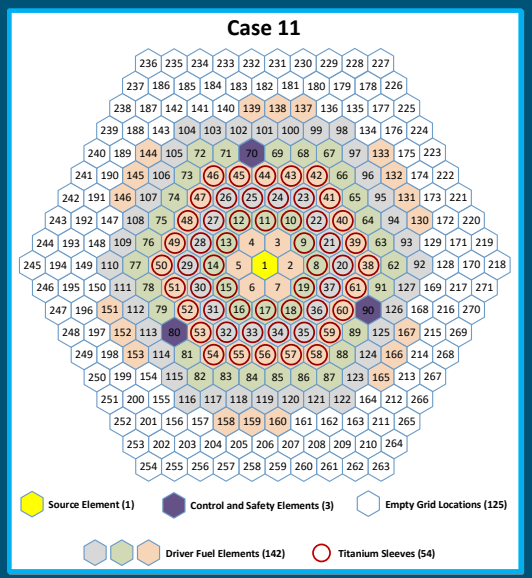
Fuel Element Layout for Largest Array Measured(17 cases)

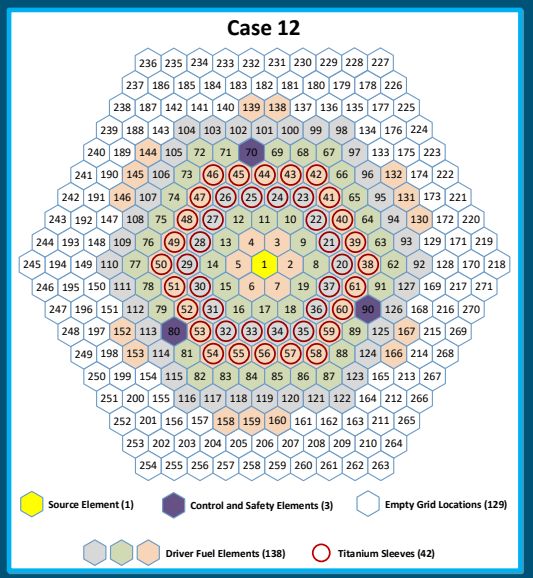












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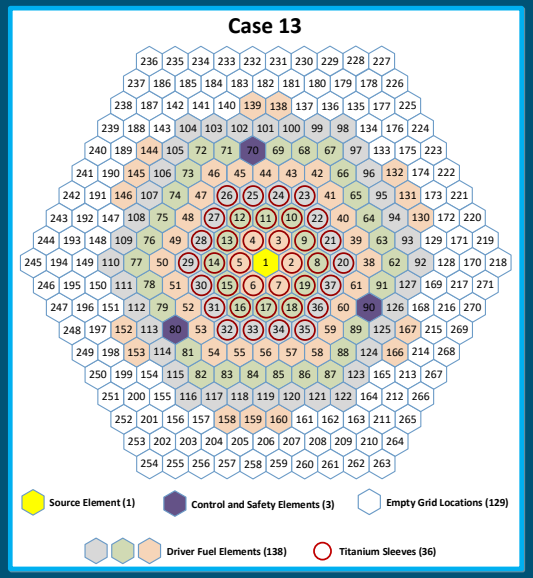
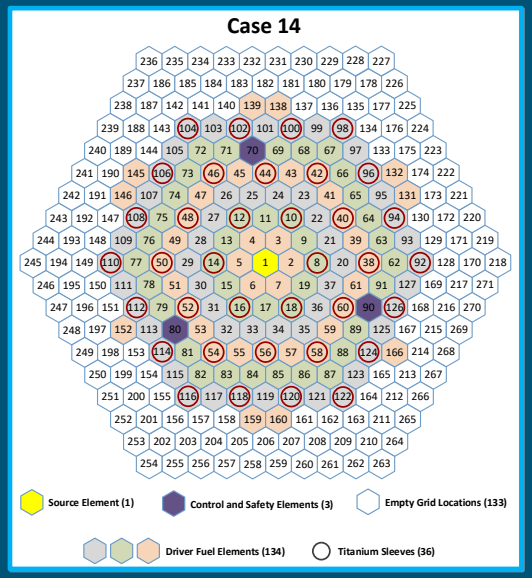
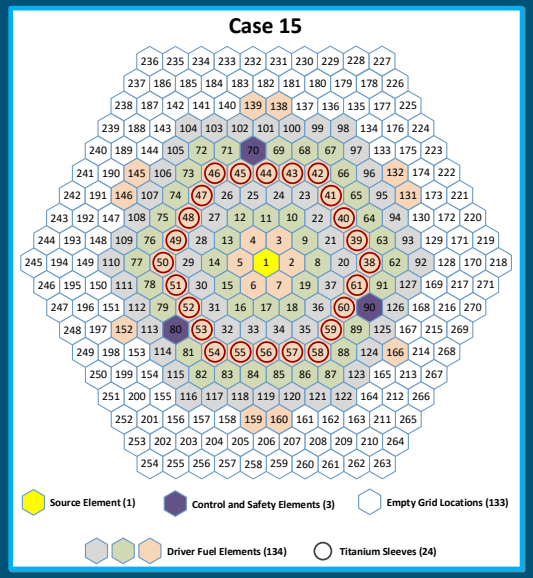
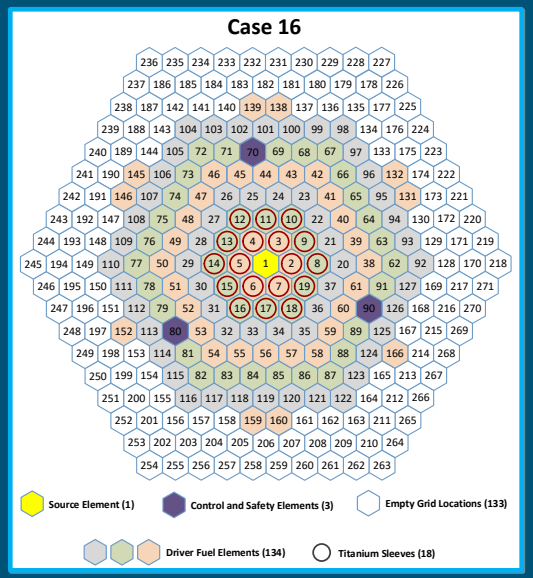
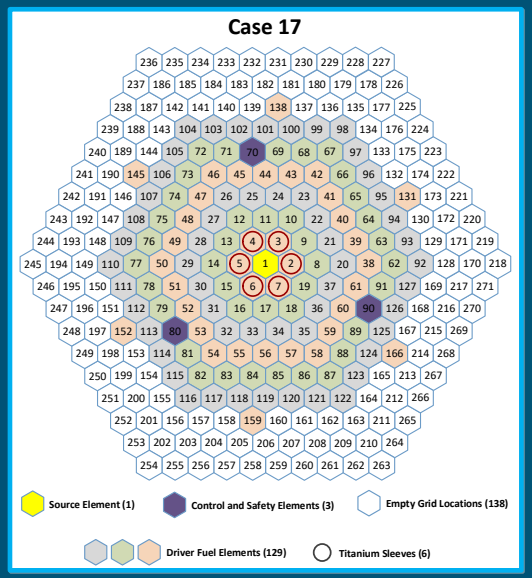




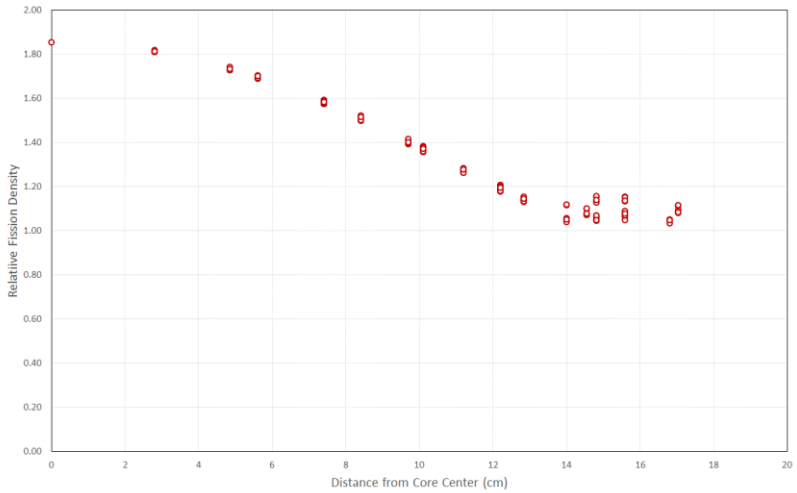


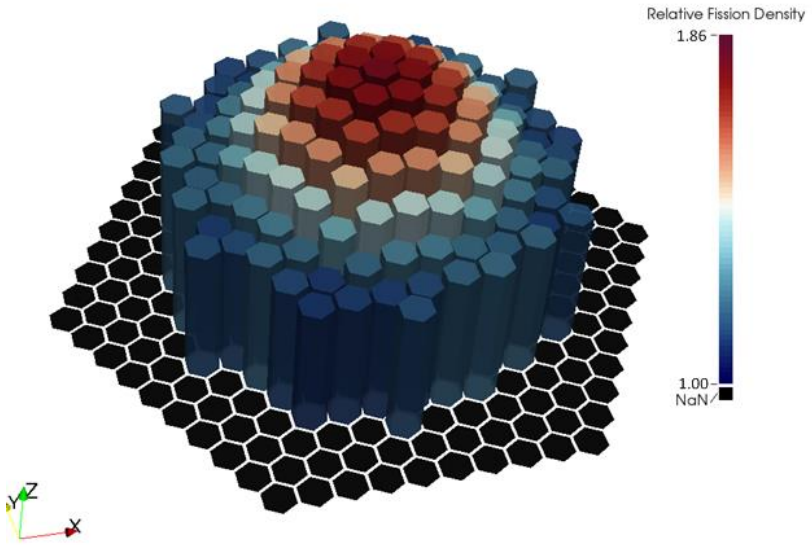




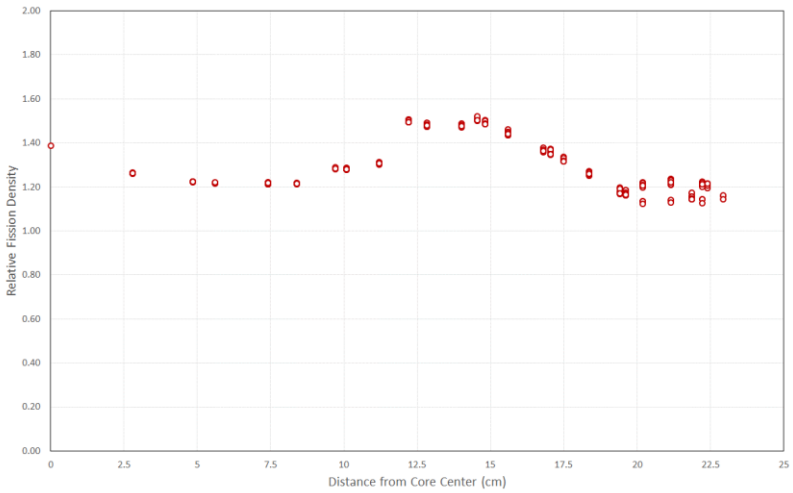
Core Analysis (Fission Density)

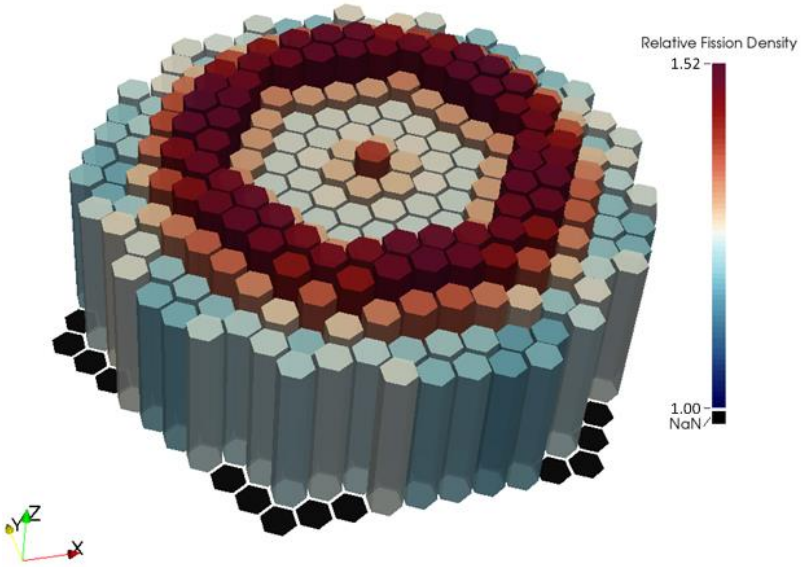
Case 1 (no sleeves)





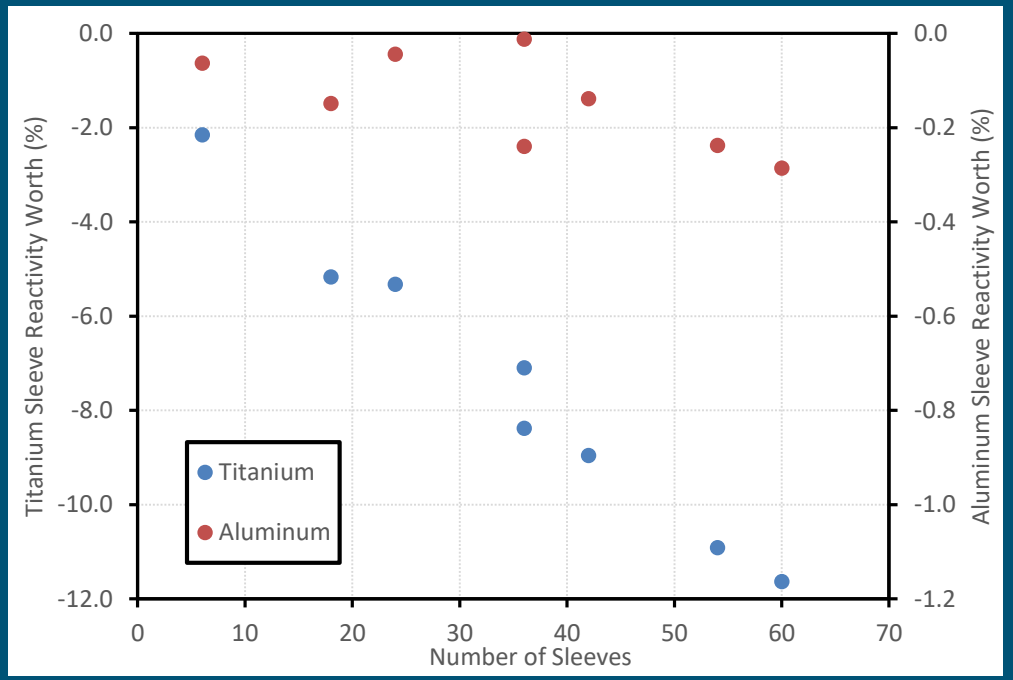
Case 2 (60 titanium sleeves)

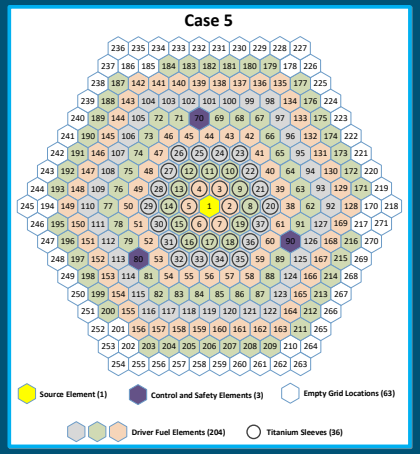


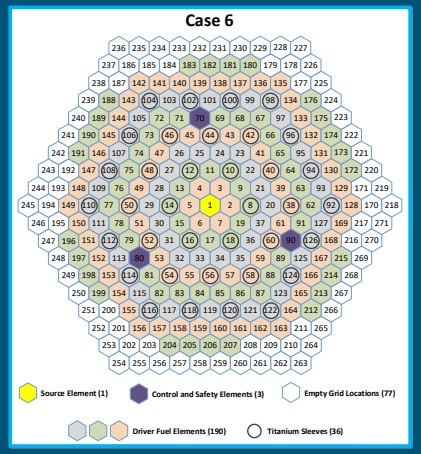


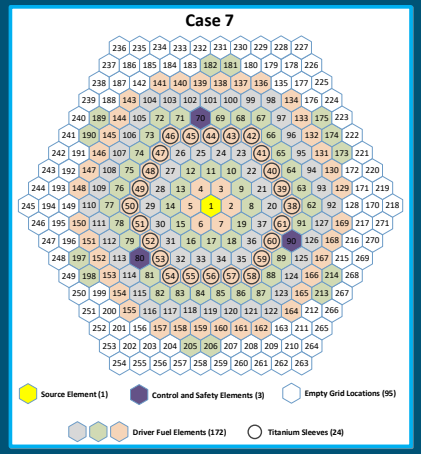
Titanium and Aluminum Sleeve Reactivity Worth

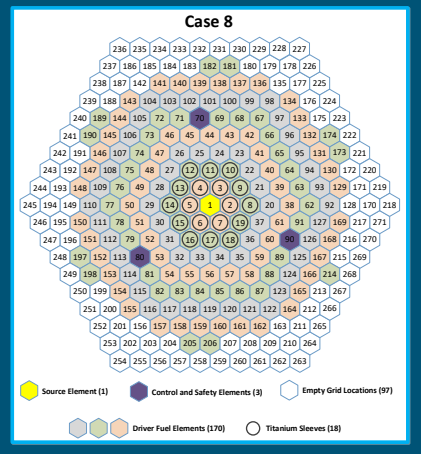
Case	Number of Experiment Sleeves		Experiment Sleeve Reactivity Worth (%)	Uncertainty
	Titanium	Aluminum		
1	0	0	0	-
2	60	0	-11.632	0.003
3	54	0	-10.915	0.003
4	42	0	-8.953	0.003
5	36	0	-8.380	0.003
6	36	0	-7.092	0.003
7	24	0	-5.319	0.003
8	18	0	-5.162	0.003
9	6	0	-2.151	0.003
10	0	60	-0.286	0.003
11	0	54	-0.238	0.003
12	0	42	-0.138	0.003
13	0	36	-0.240	0.003
14	0	36	-0.012	0.003
15	0	24	-0.044	0.003
16	0	18	-0.148	0.003
17	0	6	-0.063	0.004



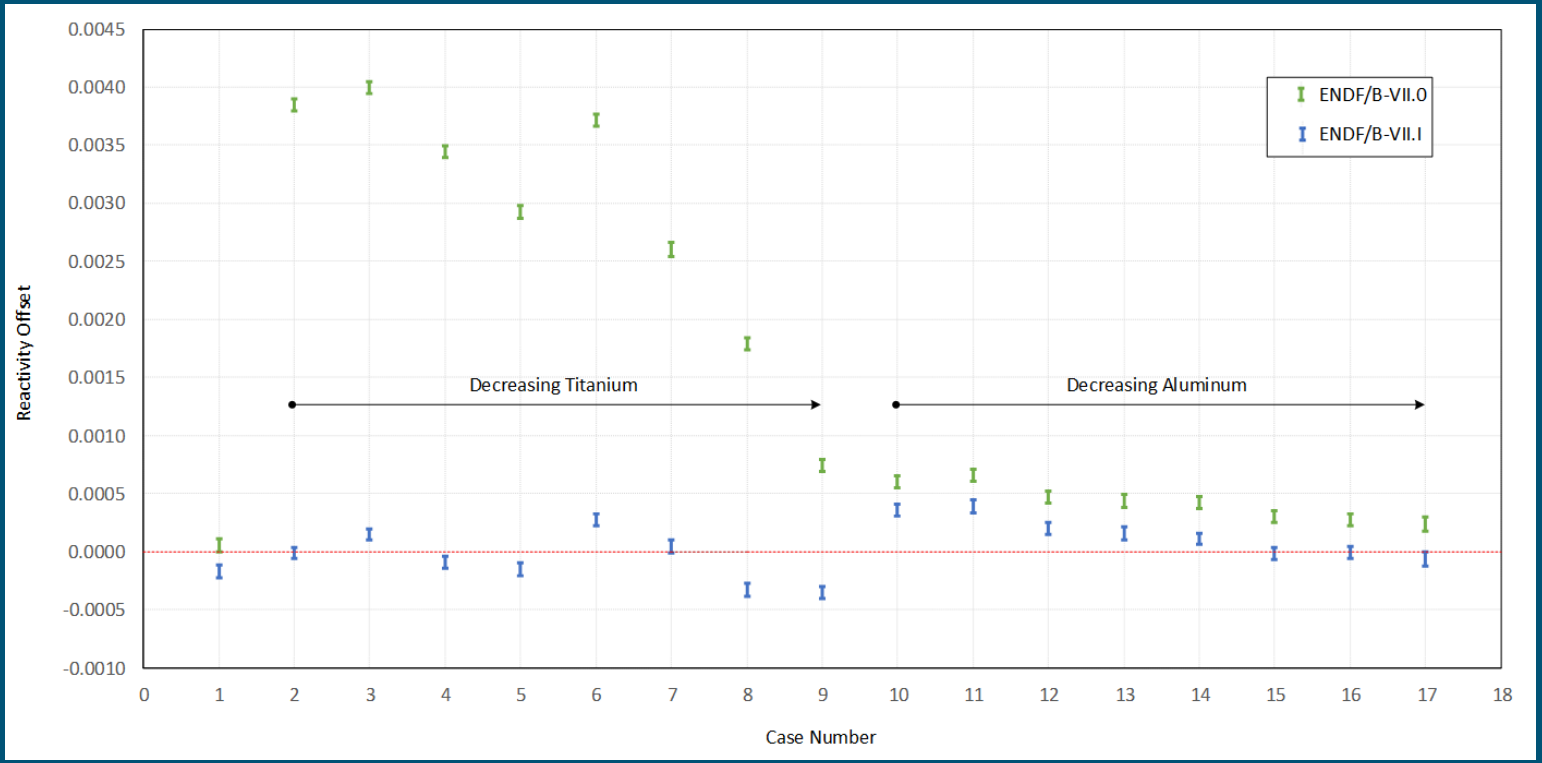








Reactivity Offset for MCNP6.1.1 Calculations (ENDF/B-VII.0 and ENDF/B-VII.I)



$$\rho = \frac{k_c - k_b}{k_c \cdot k_b}$$

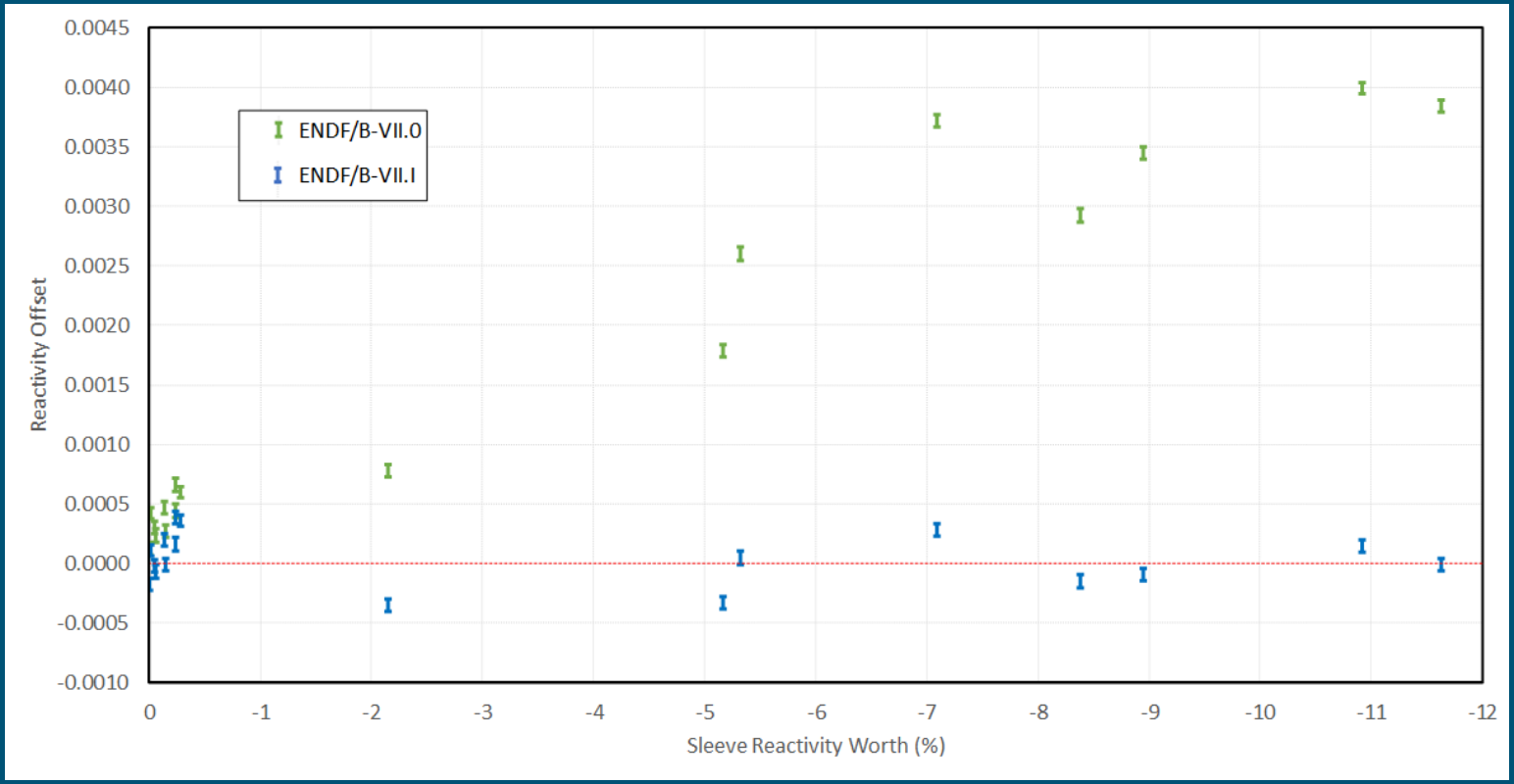
$\rho =$ reactivity offset

$k_c =$ calculated k_{eff}

$k_b =$ evaluated benchmark k_{eff}

Library	Average Reactivity Offset (all cases)	Average Reactivity Offset (Ti cases)	Average Reactivity Offset (Al cases)
ENDF/B-VII.0	0.001559	0.002882	0.000424
ENDF/B-VII.1	0.000028	-0.000059	0.000140

Reactivity Offset for MCNP6.1.1 Calculations (ENDF/B-VII.0 and ENDF/B-VII.I)



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Library	Average Reactivity Offset (all cases)	Average Reactivity Offset (Ti cases)	Average Reactivity Offset (Al cases)
ENDF/B-VII.0	0.001559	0.002882	0.000424
ENDF/B-VII.1	0.000028	-0.000059	0.000140

Conclusions

- Sleeve experiments in the BUCCX completed end of January 2018.
- Results to be submitted for review at the 2018 Annual ICSBEP working group meeting

Acknowledgements

The critical experiments performed at Sandia are supported by the DOE Nuclear Criticality Safety Program. Sandia National Laboratories is a multi-program laboratory managed and operated by National Technology and Engineering Solutions of Sandia, a wholly owned subsidiary of Honeywell International, for the U.S. Department of Energy's National Security Administration.