

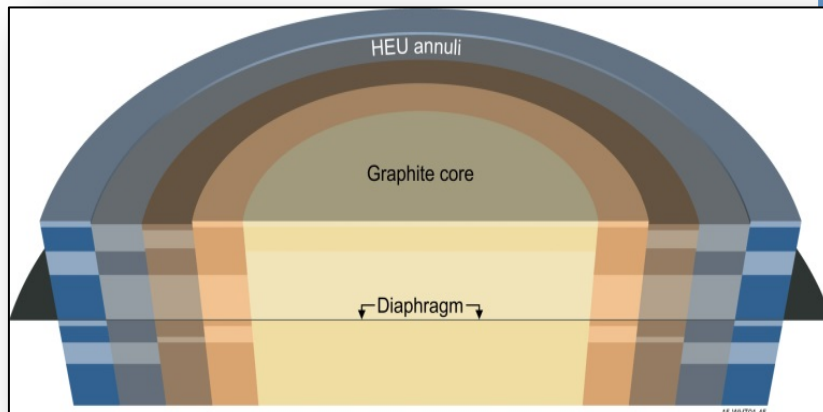
Benchmarking of HEU Metal Annuli Critical Assemblies with Internally Reflected Graphite Cylinder

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Case	Nominal Dimensions (in.)			Internal Material	Reactivity (cents)
	OD	ID	Height		
1	15	9	5-5/16	graphite	-11.5
2	15	7	4-1/16	graphite	-24.7
3	13	7	5-1/4	graphite	+15.6

Perturbed Parameter ^b (unit of measure)	1 σ Uncertainty	Uncertainty (Δk_{eff})		
		Case 1	Case 2	Case 3
Temperature (K)	± 2	0.00004	0.00004	0.00004
Reproducibility (ζ)	± 2	0.00013	0.00013	0.00013
Measured reactivity (ζ)	± 7.0	0.00046	0.00046	0.00046
β_{eff}	$\pm 5 \%$	0.00005	0.00005	0.00005
Uranium diameter (cm)	$\pm 0.001276/\sqrt{3}$ ^a	0.00003	0.00003	0.00003
Uranium height (cm)	$\pm 0.001276/\sqrt{3}$	0.00010	0.00010	0.00004
Uranium stack height (cm)	± 0.003949	0.00012	0.00013	0.00012
Uranium mass (g)	$\pm 0.507859/\sqrt{3}$	NEG ^b	NEG	NEG
Graphite diameter (cm)	$\pm 0.001276/\sqrt{3}$	NEG	NEG	NEG
Graphite height (cm)	$\pm 0.001276/\sqrt{3}$	NEG	NEG	NEG
Graphite stack height (cm)	± 0.003949	NEG	NEG	NEG
Graphite mass (g)	$\pm 0.507859/\sqrt{3}$	NEG	NEG	NEG
Lateral alignment (cm)	$\pm 0.0127/2\sqrt{3}$	NEG	NEG	NEG
²³⁴ U content (wt.%)	± 0.003917	0.00003	0.00004	0.00003
²³⁵ U content (wt.%)	± 0.018265	0.00019	0.00019	0.00019
²³⁶ U content (wt.%)	± 0.013494	NEG	0.00003	NEG
Uranium impurities (ppm)	- ^b	0.00004	0.00006	0.00007
Graphite impurities (ppm)	- ^b	NEG	0.00004	NEG
Water content in graphite (wt.%)	$\pm 0.03/\sqrt{3}$	0.00004	0.00008	NEG
Graphite arrangement	-	N/A	N/A	0.00006
Total Experimental Uncertainty	ICSBE Program	0.00055	0.00055	0.00055

Bias/Correction	Δk_{eff}		
	Case 1	Case 2	Case 3
1. Room Return and Air	-0.00117	-0.00125	-0.00094
2. Removal of Stainless Steel Diaphragm	0.00068	0.00108	0.00077
3. Removal of Diaphragm Support Ring	-0.00042	-0.00038	-0.00032
4. Removal of Support Structure	-0.00088	-0.00133	-0.00065
5. Temperature	NEG	NEG	NEG
6. Homogenization of Graphite Cylinder	-0.00035	-0.00003	-0.00015
7. Removal of Graphite Impurities	-0.00002	-0.00007	0.00000
8. Homogenization of HEU Annuli	-0.00070	-0.00043	-0.00039
9. Removal of HEU Impurities	0.00000	0.00000	0.00000
Total Bias for Detailed Model	-0.00179	-0.00189	-0.00114
for Simplified Model	-0.00286	-0.00286	-0.00286

Benchmarking the Three Experiments

- Two benchmark models were developed and the benchmark results were determined.

Case	Detailed Model			Simplified Model		
	k_{eff}	$\pm$	σ	k_{eff}	$\pm$	σ
1	0.9981	$\pm$	0.0006	0.9970	$\pm$	0.0006
2	0.9971	$\pm$	0.0006	0.9966	$\pm$	0.0006
3	1.0001	$\pm$	0.0006	0.9995	$\pm$	0.0006

- Calculation results with MCNP6-1.0 and ENDF/B-VII.1 neutron cross section libraries agree well to the benchmark experimental results within difference less than 0.2% (equivalently less than 3 times of experimental 1 σ uncertainty).