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Comparison of ENDF/B-VI and Preliminary ENDF/B-VII Results for the MCNP™ Criticality Validation Suite

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An initial assessment of the impact of preliminary data proposed for ENDF/B-VII has been made using the MCNP criticality validation suite. Relative to ENDF/B-VI, the data changes primarily involve high-energy elastic and inelastic scattering in the uranium isotopes and ^{239}Pu, as well as resonance parameters for ^{238}U.

The criticality validation suite is a collection of 31 benchmarks taken from the *International Handbook of Evaluated Criticality Benchmark Experiments*.[1] It contains cases for a variety of fuels, including ^{233}U, highly enriched uranium (HEU), intermediate-enriched uranium (IEU), low-enriched uranium (LEU), and plutonium. For each fuel type, there are cases with a variety of moderators, reflectors, spectra, and geometries. The cases in the suite are summarized in Table I.

Three sets of calculations were performed for the suite using the MCNP5 Monte Carlo code.[2] The first set employed nuclear data from ENDF/B-VI Release 8, the final release for ENDF/B-VI. The second set employed preliminary ENDF/B-VII data generated by group T-16 at Los Alamos National Laboratory for the uranium isotopes and for ^{239}Pu but retained ENDF/B-VI data for all other nuclides. The third set was the same as the second except that a new set of ^{238}U resonance parameters generated by researchers at Oak Ridge National Laboratory (ORNL) was added to the T-16 evaluation.

The MCNP5 calculations were run with 5,000,000 active neutron histories for all but two cases in the suite. Only 3,000,000 active histories were used for those cases, SB-5 and Zebra-8H, because they require substantially more computer time per history than the other cases. Nonetheless, the standard deviation for k_{eff} from those cases is comparable to those for other cases in the suite. The results from these calculations are presented in Table II.

The preliminary ENDF/B-VII data produce marked improvements in k_{eff} for bare spheres of ^{233}U (Jezebel-233), HEU (Godiva), and plutonium (Jezebel and Jezebel-240) as well as the other unreflected HEU and plutonium cases (Tinkertoy02 (c-11) and Pu Buttons, respectively). Furthermore, the reactivity swings between those bare spheres and the corresponding Flattop cases (which enclose the sphere inside an annulus of normal uranium) are substantially decreased. The changes also significantly improve k_{eff} for BIG TEN and for HEU and plutonium spheres immersed in water (Godiver and Pu-MF-11, respectively). In addition, inclusion of the ORNL

Table I. MCNP Criticality Validation Suite.

Spectrum	Fast			Intermediate	Thermal	
Geometry	Bare	Heavy Reflector	Light Reflector	Any	Lattice of Fuel Pins in Water	Solution
^{233}U	Jezebel-233	Flattop-23	U233-MF-05 (2)*	Falstaff (1)†	SB-2½	ORNL-11
HEU	Godiva Tinkertoy-2 (c-11)	Flattop-25	Godiver	UH_3 (6) Zeus (2)	SB-5	ORNL-10
IEU	IEU-MF-03	BIG TEN	IEU-MF-04	Zebra-8H‡	IEU-CT-02 (3)	STACY-36
LEU					BaW XI (2)	LEU-ST-02 (2)
Pu	Jezebel Jezebel-240 Pu Buttons (3)	Flattop-Pu THOR	Pu-MF-11	HISS/HPG‡	PNL-33	PNL-2

* Numbers in parentheses identify a specific case within a sequence of benchmarks
† Extrapolated to critical
‡ k_∞ measurement

Table II MCNP5 Results for Criticality Safety Validation Set.

Type	Spectrum	Case	Benchmark k_{eff}	Calculated k_{eff}		
				T-16 + ORNL ^{238}U	T-16	ENDF/B-VI
^{233}U	Fast	Jezebel-233	1.0000 ± 0.0010	0.9984 ± 0.0003	0.9989 ± 0.0002	0.9931 ± 0.0002
		Flattop-23	1.0000 ± 0.0014	0.9988 ± 0.0003	0.9985 ± 0.0003	1.0003 ± 0.0003
		U233-MF-05 (2)	1.0000 ± 0.0030	0.9964 ± 0.0003	0.9968 ± 0.0003	0.9976 ± 0.0003
	Intermediate	Falstaff (1)	1.0000 ± 0.0083	0.9876 ± 0.0005	0.9876 ± 0.0005	0.9894 ± 0.0005
	Thermal	SB-2½	1.0000 ± 0.0024	0.9948 ± 0.0005	0.9946 ± 0.0005	0.9967 ± 0.0005
		ORNL-11	1.0006 ± 0.0029	1.0004 ± 0.0002	1.0002 ± 0.0002	0.9968 ± 0.0002
HEU	Fast	Godiva	1.0000 ± 0.0010	0.9992 ± 0.0003	0.9990 ± 0.0003	0.9962 ± 0.0003
		Tinkertoy-2 (c-11)	1.0000 ± 0.0038	1.0001 ± 0.0003	1.0001 ± 0.0003	0.9972 ± 0.0004
		Flattop-25	1.0000 ± 0.0030	1.0025 ± 0.0003	1.0023 ± 0.0003	1.0024 ± 0.0003
		Godiver	0.9985 ± 0.0011	0.9978 ± 0.0004	0.9969 ± 0.0004	0.9948 ± 0.0003
	Intermediate	UH_3 (6)	1.0000 ± 0.0047	0.9926 ± 0.0003	0.9925 ± 0.0003	0.9914 ± 0.0003
		Zeus (2)	0.9997 ± 0.0008	0.9948 ± 0.0003	0.9945 ± 0.0004	0.9942 ± 0.0003
	Thermal	SB-5	1.0015 ± 0.0028	0.9943 ± 0.0005	0.9941 ± 0.0005	0.9963 ± 0.0005
		ORNL-10	1.0015 ± 0.0026	0.9994 ± 0.0002	0.9986 ± 0.0002	0.9992 ± 0.0002
IEU	Fast	IEU-MF-03	1.0000 ± 0.0017	1.0026 ± 0.0003	1.0032 ± 0.0003	0.9987 ± 0.0003
		BIG TEN	0.9948 ± 0.0013	0.9950 ± 0.0002	0.9953 ± 0.0002	1.0071 ± 0.0003
		IEU-MF-04	1.0000 ± 0.0030	1.0077 ± 0.0003	1.0081 ± 0.0003	1.0038 ± 0.0003
	Intermediate	Zebra-8H	1.0300 ± 0.0025	1.0190 ± 0.0002	1.0197 ± 0.0003	1.0405 ± 0.0002
	Thermal	IEU-CT-02 (3)	1.0017 ± 0.0044	1.0005 ± 0.0003	0.9997 ± 0.0003	1.0007 ± 0.0003
		STACY-36	0.9988 ± 0.0013	0.9983 ± 0.0003	0.9973 ± 0.0003	0.9988 ± 0.0003
LEU	Thermal	BaW XI (2)	1.0007 ± 0.0012	0.9997 ± 0.0003	0.9977 ± 0.0003	0.9968 ± 0.0003
		LEU-ST-02 (2)	0.9991 ± 0.0029	0.9957± 0.0003	0.9944 ± 0.0003	0.9957 ± 0.0003
Pu	Fast	Jezebel	1.0000 ± 0.0020	1.0004 ± 0.0003	1.0004 ± 0.0003	0.9975 ± 0.0003
		Jezebel-240	1.0000 ± 0.0020	1.0001 ± 0.0003	1.0001 ± 0.0003	0.9979 ± 0.0003
		Pu Buttons (3)	1.0000 ± 0.0030	0.9986 ± 0.0003	0.9986 ± 0.0003	0.9962 ± 0.0003
		Flattop-Pu	1.0000 ± 0.0030	1.0006 ± 0.0003	1.0008 ± 0.0003	1.0013 ± 0.0003
		THOR	1.0000 ± 0.0006	1.0081 ± 0.0003	1.0081 ± 0.0003	1.0062 ± 0.0003
		Pu-MF-11	1.0000 ± 0.0010	0.9986 ± 0.0003	0.9986 ± 0.0003	0.9970 ± 0.0003
	Intermediate	HISS/HPG	1.0000 ± 0.0110	1.0111 ± 0.0005	1.0111 ± 0.0005	1.0104 ± 0.0003
	Thermal	PNL-33	1.0024 ± 0.0021	1.0057 ± 0.0003	1.0053 ± 0.0007	1.0029 ± 0.0003
		PNL-2	1.0000 ± 0.0065	1.0039 ± 0.0010	1.0039 ± 0.0010	1.0033 ± 0.0005

resonance parameters for ^{238}U produces a significantly better value for k_{eff} for B&W XI (2), a lattice of LEU fuel pins in water, and ORNL-11, an unreflected sphere of uranyl nitrate solution enriched in ^{233}U.

At the same time, the preliminary ENDF/B-VII data produce worse results for thermal lattices of ^{233}U and HEU pins in water (SB-2½ and SB-5, respectively), for the bare IEU sphere (IEU-MF-03) and the IEU sphere reflected by graphite (IEU-MF-04), for a plutonium sphere reflected by thorium (THOR), and for a MOX lattice in water (PNL-33). Furthermore, k_{eff} for the uranium cases with intermediate spectra remains substantially underpredicted, while k_{eff} for the plutonium case with an intermediate spectrum (HISS/HPG) continues to be significantly over-predicted.

In conclusion, preliminary ENDF/B-VII data for the uranium isotopes and ^{239}Pu produce improvements for most of the cases with fast spectra, BIG TEN, and the lattice of LEU fuel pins in water. However, improvements still are needed in some areas, particularly those cases with intermediate spectra.

REFERENCES

1. *International Handbook of Evaluated Criticality Safety Benchmark Experiments*, OECD Nuclear Energy Agency report NEA/NSC/DOC(95)03, September 2003 Edition.

2. X-5 Monte Carlo Team, "MCNP — A General Monte Carlo N-Particle Transport Code, Version 5, Volume I: Overview and Theory," LA-UR-03-1987, Los Alamos National Lab. (April 2003).