LA-UR- 11-01162

Approved for public release;
distribution is unlimited.

Title:	A Rossi Alpha Validation Suite for MCNP
Author(s):	Russell D. Mosteller Brian C. Kiedrowski
Intended for:	International Conference on Nuclear Criticality 2011 Edinburgh, Scotland September 19-22, 2011

Los Alamos
NATIONAL LABORATORY
EST. 1943

Form 836 (7/06)

JPN037

TOPIC(S) 3 (Criticality codes and nuclear data) for oral presentation

A ROSSI α VALIDATION SUITE FOR MCNP

R. MOSTELLER AND B. KIEDROWSKI

Los Alamos National Laboratory
Los Alamos, NM, USA 87545
mosteller@lanl.gov and bckiedro@lanl.gov

The MCNP5 Monte Carlo code [1] version 1.60, released from RSICC in November 2010, is capable of computing Rossi α in criticality calculations [2]. As part of the validation of that capability, a Rossi α validation suite has been developed to complement the existing criticality [3,4] and radiation-shielding [5] validation suites for MCNP.

Rossi α characterizes the exponential change in the population of prompt neutrons that produce fissions in a system that is close to delayed critical:

$$n_{pf}(t) = n_{pf\,0} e^{\alpha_R t}$$

where α_R is Rossi α, n_{pf} is the population of prompt neutrons that produce fissions, and t is time. By definition, Rossi α is zero at prompt critical, negative below it, and positive above it. It is straightforward to show that

$$\alpha_R = \frac{k_p - 1}{\Lambda_{pf}} \cong -\frac{\beta_{eff}}{\Lambda_{pf}}$$

where k_p is the multiplication factor for prompt neutrons, Λ_{pf} is the lifetime for prompt neutrons that produce fission, and β_{eff} is the effective delayed neutron fraction. A technique to measure Rossi α using correlated fission chains was developed by Bruno Rossi in the 1950s [6].

The Rossi α validation suite includes ^{233}U, highly enriched uranium (HEU), intermediate enriched uranium (IEU), and plutonium (Pu) benchmarks. Those benchmarks include systems with thermal, intermediate, and fast spectra. Some of the benchmarks are unreflected, while the others are reflected by normal uranium, depleted uranium, thorium, copper, or water. Succinct descriptions of the 12 benchmarks in the suite are given in Table 1.

Specifications for each of the benchmarks are taken from the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* [7], and the specific evaluations from which those specifications are taken are included in Table 1. The measured values of Rossi α for all but four of the benchmarks are taken from the CSEWG Benchmark Book [8]. The measured values for Zeus-1 and Zeus-4 are taken from the *Handbook*, and the values for STACY-30 and STACY-46 are taken from a journal article [9].

Calculated results for the benchmarks in the suite obtained with MCNP5 and its ENDF/B-VI and ENDF/B-VII.0 nuclear data libraries are presented in Table 2. Overall, ENDF/B-VII.0 produces marginally better results than ENDF/B-VI.

REFERENCES

(1) X-5 Monte Carlo Team, "MCNP — A General Monte Carlo Transport Code, Version 5," Los Alamos National Laboratory report LA-UR-03-1987 (April 2003).

(2) B. Kiedrowski, F. Brown, and P. Wilson, "Calculating Kinetics Parameters and Reactivity Changes with Continuous Energy Monte Carlo," *Proceedings of PHYSOR 2010*, Pittsburgh, PA (May 2010).

(3) R. Mosteller, "An Expanded Criticality Validation Suite for MCNP," Los Alamos National Laboratory report LA-UR-10-06230 (2010).

(4) R. Mosteller, F. Brown, and B. Kiedrowski, "An Expanded Criticality Validation Suite for MCNP," submitted for presentation at ICNC 2011.

(5) R. Mosteller, "Validation Suites for MCNP," *Proceedings of the American Nuclear Society Radiation Protection and Shielding Division 12th Biennial Topical Meeting*, Santa Fe, New Mexico, USA (April 2002).

(6) J. Orndoff, "Prompt Neutron Periods of Metal Critical Assemblies," *Nucl. Sci. Eng.*, **2**, pp. 450-460 (July 1957).

(7) *International Handbook of Evaluated Criticality Safety Benchmark Experiments*, OECD Nuclear Energy Agency report NEA/NSC/DOC(95)03 (2009 Edition).

(8) *Cross Section Evaluation Working Group Benchmark Specifications*, Brookhaven National Laboratory report BNL-19302, ENDF-202 (Rev., September 1986).

(9) K. Tonoike, Y. Miyoshi, T. Kikuchi, and T. Yamamoto, "Kinetic Parameter β_{eff}/ℓ Measurement on Low Enriched Uranyl Nitrate Solution with Single Unit Cores (600φ, 280T, 800φ) of STACY," *J. Nucl. Sci. Tech.*, **39**, 11, pp 1227-1236 (November 2002).

Table 2. Comparison of Measured and Calculated Values for Rossi α

Benchmark Name	Rossi α (10^4 generations/second) at Delayed Critical		
	Measured	Calculated with MCNP5 1.60	
		ENDF/B-VI	ENDF/B-VII.0
Jezebel-233	-100 ± 1	-109 ± 1	-108 ± 1
Flattop-23	-26.7 ± 0.5	-30.9 ± 0.4	-30.2 ± 0.4
Godiva	-111 ± 2	-117 ± 2	-111 ± 2
Flattop-25	-38.2 ± 0.2	-40.9 ± 0.2	-39.7 ± 0.2
Zeus-1	-0.338 ± 0.008	-0.372 ± 0.002	-0.360 ± 0.002
Zeus-4	-2.61 ± 0.02	-3.27 ± 0.01	-3.21 ± 0.01
BIG TEN	-11.7 ± 0.1	-12.5 ± 0.1	-11.8 ± 0.2
STACY-30	-0.0127 ± 0.0003	-0.0133 ± 0.0003	-0.0133 ± 0.0003
STACY-46	-0.0106 ± 0.0004	-0.0110 ± 0.0002	-0.0104 ± 0.0002
Jezebel	-64 ± 1	-64 ± 1	-65 ± 1
Flattop-Pu	-21.4 ± 0.5	-21.6 ± 0.3	-21.0 ± 0.3
THOR	-19 ± 1	-20 ± 2	-21 ± 1

Table 1. Benchmarks in the Rossi α Benchmark Suite

Fuel	Name	Spectrum	*Handbook* Identifier	Description
^{233}U	Jezebel-233	Fast	U233-MET-FAST-001	Bare sphere of ^{233}U
	Flattop-23	Fast	U233-MET-FAST-006	^{233}U sphere reflected by normal U
HEU	Godiva	Fast	HEU-MET-FAST-001	Bare sphere of HEU
	Flattop-25	Fast	HEU-MET-FAST-028	HEU sphere reflected by normal U
	Zeus-1	Intermediate	HEU-MET-INTER-006	HEU and graphite cylinder reflected by copper
	Zeus-4	Intermediate	HEU-MET-INTER-006	HEU and graphite cylinder reflected by copper
IEU	BIG TEN	Fast	IEU-MET-FAST-007	Stacked cylinders of IEU reflected by depleted U
	STACY-30	Thermal	LEU-SOL-THERM-007	Unreflected cylinder of IEU solution
	STACY-46	Thermal	LEU-SOL-THERM-004	Cylinder of IEU solution reflected by water
Pu	Jezebel	Fast	PU-MET-FAST-001	Bare sphere of Pu
	Flattop-Pu	Fast	PU-MET-FAST-006	Pu sphere reflected by normal U
	THOR	Fast	PU-MET-FAST-008	Pu sphere reflected by thorium