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Author(s): **Russell D. Mosteller**

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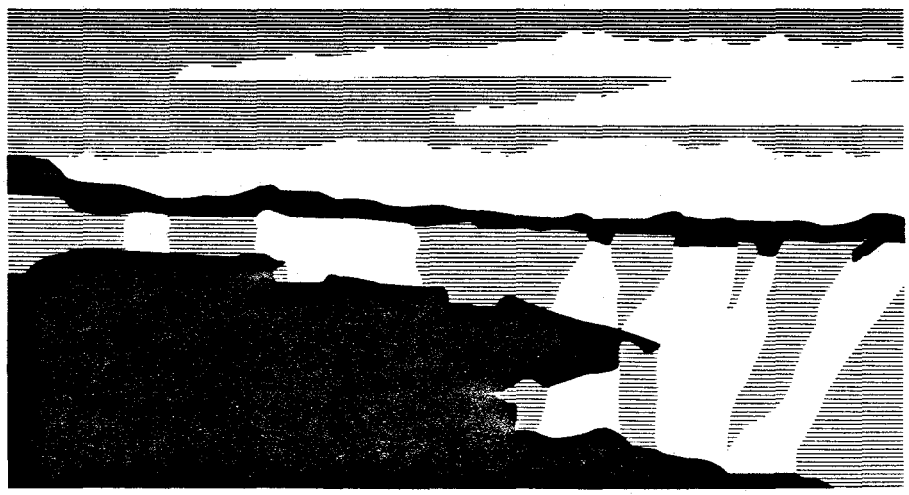

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BENCHMARKING OF MCNP

AGAINST B&W LRC CORE XI CRITICAL EXPERIMENTS

Russell D. Mosteller

Reactor Design and Analysis Group
Technology and Safety Assessment Division
Los Alamos National Laboratory

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The MCNP Monte Carlo code[1] and its ENDF/B-V continuous-energy cross-section library previously has been benchmarked[2,3] against a variety of critical experiments, and that benchmarking recently has been extended[4] to include its ENDF/B-VI continuous-energy cross-section library and additional critical experiments. This study further extends the benchmarking of MCNP and its two continuous-energy libraries to 17 large-scale mockup experiments[5] that closely resemble the core of a pressurized water reactor (PWR).

DESCRIPTION OF EXPERIMENTS

The experiments were performed at Babcock & Wilcox's Lynchburg Research Center in 1970 and 1971. The series was designated as Core XI, and the individual experiments were characterized as different "loadings." The experiments were performed inside a large aluminum tank that contained borated water. The water height for each loading was exactly 145 cm, and the soluble boron concentration in the water was adjusted until the configuration was slightly supercritical, with a value of 1.0007 for k_{eff}. Pin-by-pin power distributions were measured for several of the loadings. The standard deviation in the measured boron concentration was ±3 PPM. Based on calculations performed as part of this study, that variation in the soluble boron concentration corresponds to a variation in k_{eff} of approximately ±0.0005 Δk.

For loadings 2 through 15, the central region of the core closely resembled a 3 x 3 array of PWR fuel assemblies with fuel rods, water holes, and/or perturbing rods (made of Pyrex, Vicor, or Al_2O_3) arranged in a 15 x 15 lattice. The nine assemblies were surrounded by a buffer region containing 2936 UO_2 fuel rods, and the buffer region in turn was encompassed by a reflector region. All of the fuel pins were clad in aluminum, and they had an enrichment of 2.459 w/o.

Loadings 1, 16, and 17 differed from the others only in the arrangement of the central region of the core. Loading 1 had fuel pins in all locations in the central core. Loading 16 had six parallel lines of water holes in the central region that were separated from each other by 7 fuel pins, and loading 17 had six additional lines of water holes that were perpendicular to and intersected those lines.

RESULTS

MCNP calculations were performed for each of the loadings with both ENDF/B-V and ENDF/B-VI libraries, and the results are summarized in Table I. (For similar loadings where the difference in the soluble boron concentration was 3 PPM or less, the average of the two concentrations was used for both.) The calculations used octant symmetry for all of the loadings except 16, where quadrant symmetry was used. Each of the calculations employed 1050 generations with 4000 neutron histories per generation, and the first 50 generations were excluded from the statistics. The remaining 4 million active histories were sufficient to reduce the standard deviation in the relative pin powers to about 1%.

Both libraries produce results that match the measured k_{eff} quite well, although the ENDF/B-VI results are slightly but consistently lower than the corresponding ENDF/B-V results. The average value of k_{eff} based on the 17 sample means from the ENDF/B-V calculations is 0.9983, while the corresponding value from the ENDF/B-VI calculations is 0.9959. The difference between the highest and lowest ENDF/B-V values for k_{eff} is only 0.0030 Δk, and the corresponding ENDF/B-VI difference is only 0.0029 Δk.

CONCLUSIONS

The benchmarking of the MCNP Monte Carlo code and its continuous-energy ENDF/B-V and ENDF/B-VI libraries has been extended to large-scale mockup experiments that closely resemble the core of a PWR. Both libraries produce accurate and consistent values for k_{eff}: on average, the ENDF/B-V result is low by 0.0024 ± 0.0006 Δk, while the average ENDF/B-VI result is low by 0.0048 ± 0.0006 Δk.

References

1. Judith F. Briesmeister, Ed., "MCNP—A General Monte Carlo N-Particle Transport Code, Version 4A," Los Alamos National Laboratory report LA-12625-M (November 1993).
2. Daniel J. Whalen, David A. Cardon, Jennifer L. Uhle, and John S. Hendricks, "MCNP: Neutron Benchmark Problems," Los Alamos National Laboratory report LA-12212 (November 1991).
3. John C. Wagner, James E. Sisolak, and Gregg W. McKinney, "MCNP: Criticality Safety Benchmark Problems," Los Alamos National Laboratory report LA-12415 (October 1992).
4. J. L. Iverson and R. D. Mosteller, "MCNP Calculations for Criticality-Safety Benchmarks with ENDF/B-V and ENDF/B-VI Libraries," to be presented at the Fifth International Conference on Nuclear Criticality Safety (Albuquerque, NM, September 17-21, 1995).
5. M. N. Baldwin and M. E. Stern, "Physics Verification Program, Part III, Task 4, Summary Report," Babcock & Wilcox report BAW-3647-20 (March 1971).

Table I
Summary of Results

Loading	Fuel Rods	Water Holes	Pyrex Rods	Vicor Rods	Al_2O_3 Rods	Soluble Boron (PPM)	k_{eff}, ENDF/B-V	k_{eff}, ENDF/B-VI
1	4961	0	0	0	0	1511	0.9981 ± 0.0003	0.9963 ± 0.0003
2	4808	153	0	0	0	1335.5	0.9988 ± 0.0003	0.9964 ± 0.0003
3	4808	153	0	0	0	1335.5	0.9993 ± 0.0003	0.9962 ± 0.0003
4	4808	117	36	0	0	1182	0.9991 ± 0.0003	0.9957 ± 0.0003
5	4808	117	36	0	0	1182	0.9982 ± 0.0003	0.9967 ± 0.0003
6	4808	81	72	0	0	1032.5	0.9987 ± 0.0003	0.9962 ± 0.0003
7	4808	81	72	0	0	1032.5	0.9982 ± 0.0003	0.9956 ± 0.0003
8	4808	9	144	0	0	794	0.9965 ± 0.0003	0.9944 ± 0.0003
9	4808	9	144	0	0	779	0.9972 ± 0.0003	0.9946 ± 0.0003
10	4808	81	0	72	0	1245	0.9986 ± 0.0003	0.9966 ± 0.0003
11	4808	9	0	0	144	1384	0.9995 ± 0.0003	0.9970 ± 0.0003
12	4808	117	0	0	36	1348	0.9977 ± 0.0003	0.9963 ± 0.0003
13	4808	117	0	0	36	1348	0.9988 ± 0.0003	0.9969 ± 0.0003
14	4808	81	0	0	72	1362.5	0.9983 ± 0.0003	0.9959 ± 0.0003
15	4808	81	0	0	72	1362.5	0.9984 ± 0.0003	0.9953 ± 0.0003
16	4691	270	0	0	0	1158	0.9981 ± 0.0003	0.9959 ± 0.0003
17	4457	504	0	0	0	921	0.9972 ± 0.0003	0.9941 ± 0.0003