Conf-940424--2

LA-UR 93-2967

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

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SUBMITTED TO: 8th International Conference on Radiation Shielding, April 24-27, 1994, Arlington, TX

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FORM NO 836 R4
ST NO 2629 5/81

MCNP ANALYSIS OF THE LIVERMORE PULSED SPHERES WITH ENDF/B-VI

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I. INTRODUCTION

Twenty-five Livermore pulsed sphere experiments have been modeled with the MCNP4A code using ENDF/B-VI cross sections processed by the NJOY nuclear data processing system. These calculations have been compared to an earlier study using ENDF/B-V data using the MCNP4 code. These are the first MCNP4A benchmarks, the first ENDF/B-VI benchmarks with MCNP, and the first analysis of these NJOY-processed data. In general, these results validate the MCNP code, demonstrate that ENDF/B-VI and ENDF/B-V generally agree, and in some cases show that ENDF/B-VI gives better results than ENDF/B-V.

II. THE LIVERMORE PULSED SPHERE EXPERIMENTS

The neutron pulsed-sphere experiments were performed at Lawrence Livermore National Laboratory in the late 1960's to evaluate the performance of several neutron transport codes.[1] The experiments involved the placement of a tritium target in the center of a sphere of a given material. The target was bombarded with deuterium ions to induce the reaction $T(d,n)^4He$, which produces a nearly isotropic source of 14-MeV neutrons. Then the time-of-flight energy spectrum of the neutrons was measured at particular angles. These experiments were modeled for different sphere materials including ^6Li, ^7Li, Be, C, N, O, Mg, Al, Ti, Fe, Pb, H_2O, D_2O, CH_2, CF_2 and concrete. The spheres were from 0.5 to 4.8 mean free paths thick.

III. MCNP4A CALCULATIONS

The MCNP Monte Carlo N-Particle radiation transport code was used to recalculate the Livermore pulsed sphere experiments. The new results are with MCNP4A[2] using ENDF/B-VI[3] data. These are compared with 1991 results[4] with MCNP4[5] using ENDF/B-V[6] data.

MCNP is a general-purpose Monte Carlo code for calculating the time-dependent continuous-energy transport of neutrons, photons, and/or electrons in three dimensional geometries. MCNP is used around the world for many diverse applications including nuclear criticality safety, radiation shielding, medical physics and radiotherapy, oil well logging, nuclear safeguards, and nuclear reactors.

The principal differences between MCNP4A and MCNP4 are (1) X-Windows graphics; (2) distributed memory multitasking; (3) a new, exclusive error analysis for assessing tally quality; (4) new criticality analysis and output; and (5) ENDF/B-VI physics. Only the inclusion of ENDF/B-VI physics is relevant to this study. In particular, the ^{9}Be ENDF/B-VI cross sections utilize the new ENDF/B-VI File 6-Law 7 coupled energy-angle distribution formulation. The deuterium cross sections utilize the new ENDF/B-VI File 6-Law 6 phase space formalism. And many of the nuclear data used to model the Livermore pulsed spheres, particularly Fe, use the new Kalbach-87 formalism (File 6-Law 1-Lang 2) which also has coupled energy-angle scattering.

The ENDF/B-VI data are preliminary. Although ENDF/B-VI has been available for some time, the NJOY[7] capability to utilize it for Monte Carlo continuous-energy data processing is new and still in the testing phase. The MCNP capabilities to utilize the new formats are also new and undergoing testing. However, the results presented here indicate that the ENDF/B-VI data, NJOY processed data, and MCNP4A all appear to be working correctly.

All the ENDF/B-V results were rerun instead of simply using the data of the 1991 MCNP Livermore pulsed sphere study[4] to ensure that differences were the result of differing neutron libraries and not due to differences in MCNP. However, the new ENDF/B-V and the 1991 results are in reasonable agreement except for iron. As shown in Table 1, the ENDF/B-V results for iron are not as good as those reported in the 1991 study, since a special iron evaluation[8] developed for the Fusion Materials Irradiation Test (FMIT) facility was used. Although ENDF/B-VI iron appears better than ENDF/B-V iron, neither is as good as the FMIT iron used in the 1991 study.

The ENDF/B-VI neutron libraries processed with NJOY[7] in some instances utilize isotopic data rather than elemental data. In these cases, the isotopes for each element were combined to simulate the naturally occurring elements.

IV. RESULTS

Table 1 shows the new MCNP4A ENDF/B-VI results compared to ENDF/B-V results and experimental measurements for twenty-five pulsed sphere experiments.

The ENDF/B-V and ENDF/B-VI results are about the same for O, Mg, Al, Ti, H_2O, D_2O, CH_2, and concrete.

In some cases the ENDF/B-VI results are better than the ENDF/B-V results: ^{7}Li, Be, N, Fe, and Pb.

Although the integral results in Table 1 look better for ENDF/B-VI in comparison to ENDF/B-V for carbon, the time of flight distribution for ENDF/B-VI carbon exhibits the greatest deviation from the experimental results of any material examined. Other materials such as ^{6}Li appear to give better results using ENDF/B-V than ENDF/B-VI, regardless of how the data is analyzed.

V. CONCLUSION

The ENDF/B-VI library used with MCNP appears to give reasonable answers to a widely accepted benchmark, which should provide renewed confidence in the validity of the ENDF/B-VI data as well as the NJOY nuclear data processing system.

TABLE 1

ENDF/B-VI - MCNP LIVERMORE PULSED SPHERE BENCHMARK COMPARISON

Material	mfp	ENDF/B-V 12-16 MeV[a]	ENDF/B-V 2-16 MeV[b]	ENDF/VI 12-16 MeV[a]	ENDF/VI 2-16 MeV[b]
^{6}Li	0.5	0.9733	0.9787	0.9446	0.9774
^{6}Li	1.6	1.0079	1.0229	0.9174	0.9844
^{7}Li	0.5	0.9546	0.9764	0.9866	0.9829
^{7}Li	1.6	0.9275	0.9889	1.0193	1.0056
Be	1.8	0.9312	0.9952	0.9570	0.9831
C	0.5	0.9681	0.9881	0.9883	1.0150
C	2.9	0.9304	0.9622	1.0101	1.0589
N	1.1	0.8570	0.9266	0.9445	0.9806
N	3.1	0.8363	0.9706	0.9304	1.0090
O	0.7	0.9217	0.9851	0.9212	0.9838
Mg	0.7	1.0391	1.0275	1.0402	1.0272
Mg	1.9	0.9921	0.9599	0.9935	0.9601
Al	0.9	0.9338	0.9424	0.9348	0.9420
Al	2.6	0.7904	0.8386	0.7919	0.8389
Ti	1.2	1.0549	0.9831	1.0559	0.9810
Ti	3.5	1.0828	0.9387	1.0826	0.9378
Fe	0.9	0.9830	0.9776	0.9940	1.0008
Fe	4.8	0.8651	0.8308	0.8995	0.9468
Pb	1.4	0.8759	0.8540	0.8775	0.9035
H_2O	1.1	0.8902	0.9474	0.8856	0.9406
H_2O	1.9	1.0064	1.0651	0.9979	1.0546
D_2O	1.2	0.8692	0.9212	0.8626	0.9100
D_2O	2.1	0.9785	1.0199	0.9668	1.0028
CH_2	0.8	0.9684	0.9967	0.9869	1.0157
CH_2	3.5	0.8930	0.9835	0.9483	1.0327
CF_2	0.9	0.9574	0.9736	1.0220	1.0417
CF_2	2.9	0.7502	0.7742	0.9169	0.9478
Con	2.0	1.0036	1.0452	0.9915	1.0347

[a] Energy range corresponds to 160 ns or less for all materials except concrete, which corresponds to 205 ns or less.

[b] Energy range corresponds to 350 ns or less for all materials except concrete, which corresponds to 477 ns or less.

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