

LA-UR-03-0954

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Based on ENDF/B-VI Release 6

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*Submitted to:* Documentation for the MCNP user community via the web.

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## ENDF66: A Continuous-Energy Neutron Data Library Based on ENDF/B-VI Release 6

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### SUMMARY

A new continuous-energy neutron data library for use with MCNP4C<sup>1</sup> has been produced at Los Alamos. This library, called ENDF66, contains data processed from ENDF/B-VI (Release 6)<sup>2</sup> evaluations by the NJOY99<sup>3</sup> code. The library includes data for delayed-neutron spectra, unresolved-resonance probability tables, detailed charged-particle production, and tabulated angular distributions.

### I. INTRODUCTION

ENDF66 is a continuous-energy neutron data library, formatted for use with MCNP version 4C or later. It consists of five MCNP type1 data files; ENDF66[a-e]. The ENDF66 library contains data for 173 nuclides based on ENDF/B-VI (Release 6) evaluations of the Cross Section Evaluation Working Group (CSEWG) and was processed with the NJOY99 code.

This library succeeds the ENDF60<sup>4</sup> library (based on ENDF/B-VI, Release 2), the URES library<sup>5</sup> (based on ENDF/B-VI, Release 4, and including unresolved-resonance probability tables), and the ENDF6DN library<sup>6</sup> (ENDF60 data with delayed-neutron data appended). Since the last comprehensive MCNP library, ENDF60, was released by LANL in June 1993, several important new evaluations

have been performed and the MCNP data library format has been expanded allowing for new data, including delayed-neutron spectra, unresolved-resonance probability tables, detailed charged-particle production, and tabular angular distributions. Relative to the ENDF60 library, the new ENDF66 library has added 58 new nuclides and data for 40 nuclides are based on new evaluations. In particular, updated evaluations for uranium, plutonium, tungsten, and iron isotopes have been performed. Additionally, some changes from ENDF60 have been made in NJOY processing, including the use of smaller resonance reconstruction tolerances and decreased thinning of energy points.

Data for all nuclides were processed at 293.6K. Additionally, nuclides having unresolved-resonance data were processed at 3000K and 35 nuclides were processed at 77K. A Doppler broadening code is being developed so that the user can broaden the data of any MCNP library. For data files that include unresolved-resonance data, one can only broaden to a temperature bounded by existing data. Hence the need for 3000K data for those nuclides. Other nuclides can be broadened to any temperature greater than the existing data.

MCNP4C is required to fully utilize the unresolved-resonance probability tables, the tabular angular distribution data and the delayed-neutron data contained in ENDF66. In fact, any earlier versions of MCNP will be incompatible with the new libraries due to the addition of tabulated angular distribution data.

## II. CREATION OF THE ENDF66 LIBRARY

One hundred and seventy-three (173) evaluations were chosen for ENDF66 from the data contained in ENDF/B-VI release 6, that was released in 1999. Version 50 of NJOY99 was used to process these evaluations into libraries suitable for use with MCNP. The table in Appendix A lists information about data contained within ENDF66, including ZAID identifiers, information about the evaluations used, the temperatures at which data were processed, and whether gamma production, nubar, detailed charged-particle production, delayed-neutron and unresolved-resonance probability tables are included for each nuclide.

### A. Evaluation Sources

The most recent ENDF/B-VI evaluation for each nuclide through Release 6 was examined for possible inclusion in ENDF66--a total of 325 nuclides. From these evaluations, 173 were chosen for processing. Selection was based on the completeness of the evaluation, whether the nuclide was contained in ENDF60, and the perceived importance of the material to a specific application. Isotopic evaluations were favored over elemental evaluations.

Sixteen evaluations were modified slightly to correct minor problems.

- The energy of the photon from radiative capture (MT=102) was updated in the  $^1\text{H}$  evaluation.
- The atomic weight ratio was corrected for  $^4\text{He}$ .
- The  $^{11}\text{B}$  evaluation was modified so that the threshold for the  $(n,n'cont)$  reaction, MT=91, was the same for the secondary particle production as for the cross section.
- Two negative probability values in the  $^{19}\text{F}$  evaluation (one in  $(n,\alpha)$  and one in  $(n,n^*)p$ ) were changed.
- Two modifications were made to the  $^{45}\text{Sc}$  evaluation: the value for the MT=3 (File 13) cross section at the reaction threshold was given improperly such that the processed data file had a non-zero cross section below the threshold; therefore, leading 0.0 values were added. Also the reference frame was corrected for MT=16, 22, 28, and 91.
- The nuclear temperature for the secondary neutron distributions in MT=91  $(n,n'cont)$  was changed for the Zr isotopes to properly conserve energy.
- A point was added to the  $(n,n^*)p$  (MT=28) cross section of  $^{110}\text{Cd}$  to force the correct value between 19.0 and 20.0 MeV.
- The evaluations for  $^{191}\text{Ir}$  and  $^{193}\text{Ir}$  were modified so that the radiative capture photon-production yields at 20 MeV did not artificially go to zero.
- In  $^{208}\text{Pb}$  a photon-production threshold inconsistency was fixed for MT=849  $(n,\alpha'cont)$ .
- For  $^{241}\text{Am}$ , a leading zero for the MT=3 inelastic cross section at the reaction threshold was added.
- The reference frame was corrected for  $(n,2n)$ ,  $(n,3n)$ , and fission in the  $^{249}\text{Cf}$  evaluation.

## B. NJOY Processing

After extensive testing, the code NJOY99 (version 50) was used to process the ENDF66 library. However, a modified NJOY99.50 was used to process several evaluations. The modified version of NJOY was version 50 with "update 60" (i.e. the changes added to NJOY99 version 60). This update handles evaluations containing a non-zero cross section at threshold and was required for  $^{110}\text{Cd}$ ,  $^{147}\text{Sm}$ ,  $^{155}\text{Eu}$ ,  $^{157}\text{Gd}$ ,  $^{158}\text{Gd}$ , and  $^{160}\text{Gd}$ .

The NJOY input files used for processing  $^{235}\text{U}$  at room temperature are reproduced in Appendix B. All materials were processed through NJOY using input files of this form and content. NJOY parameters to note are: 32 ladders were used to generate unresolved probability tables (except as described below); the fractional tolerance for reconstruction of cross sections in the resonance region was set to 0.001; and "no thinning" of the energy grid was specified. Evaluations were processed by NJOY for the temperatures described in the previous section. ZAIDs for data processed at 293.6K end in .66c, at 77K end in .64c, and at 3000K end in .65c. The type 1 data at room temperature use approximately 530Mb of disk space, the 77K data use 220Mb of disk space, and the 3000K data use 160Mb of disk space. The table in Appendix A lists ZAIDs and the temperatures for each data table. All processing was performed on an SGI Origin 2000 platform.

During the final testing of the ENDF66 library, we discovered that the unresolved-resonance data were not processed as accurately as required for data at multiple temperatures. A patch to NJOY was developed to correct the

problem for processing at multiple temperatures. The data were reprocessed with this special NJOY patch for 8 isotopes:  $^{182}\text{Ta}$ ,  $^{182,183,184,186}\text{W}$ ,  $^{235,238}\text{U}$ , and  $^{239}\text{Pu}$ .

## C. Postprocessing

Several modifications to the data library were necessary after completion of NJOY processing.

### 1. Delayed-Neutron Data.

NJOY99 version 50 does not have the capability to include delayed-neutron data into an MCNP library. (NJOY99 versions 63 and later do have this capability, however.) A special-purpose code called MERGE<sup>6</sup> was used to add delayed-neutron data to the library. MERGE reads the delayed-neutron data from the appropriate ENDF/B-VI evaluation file and adds it in the correct format to the MCNP library file.

### 2. Unresolved-Resonance Heating.

The heating numbers found in unresolved probability tables from NJOY Version 50 were inconsistent with what MCNP expected. (NJOY99 versions 62 and later do provide consistent values, however). Therefore, we used a special-purpose code to post-process the NJOY Version 50 output for unresolved probability table heating numbers.

### 3. Replacement of Extremely Small Numbers.

On some computing platforms, MCNP compiled in 32-bit mode will fail if it encounters cross-section or distribution values  $< 10^{-37}$ . Therefore, all cross sections and distribution values  $< 10^{-37}$  have been changed to have an exponent of -35 in scientific notation (i.e.  $n \times 10^{-35}$ ).

## D. Library Verification

We have relied on a number of methods developed in the past to verify continuous-energy MCNP data libraries. These are described below.

1. Internal NJOY Consistency Checks. The NJOY99 code performs several consistency checks on an MCNP data file. NJOY checks several attributes of reaction thresholds, energy grids, and secondary and angular distributions. It flags anything known to be wrong or considered likely to be unreasonable. Through the NJOY consistency checks, it was determined that the reference frame had to be corrected for  $(n,2n)$ ,  $(n,n')\alpha$ ,  $(n,n')p$ , and  $(n,n'cont)$  in  $^{45}\text{Sc}$  and for  $(n,2n)$ ,  $(n,3n)$ , and fission in  $^{249}\text{Cf}$ .

2. Special-purpose Checking Codes. Several small, special-purpose checking codes were used to verify the processed MCNP data files. These codes, described in more detail elsewhere,<sup>5,7,8</sup> were used to check unresolved-resonance probability tables, sums of partial-reactions, secondary neutron and photon distributions, MT=5 cross sections, and a comparison of threshold values with Q values. Several problems were brought to our attention during this phase. It was decided not to add unresolved probability tables to Mo and  $^{181}\text{Ta}$ , since negative cross-section backgrounds in the evaluations caused a large number of negative cross sections in the unresolved-resonance probability tables. It was discovered at this time that the use of 32 ladders in processing  $^{232}\text{Th}$ ,  $^{236}\text{U}$ , and  $^{239}\text{Pu}$  was not sufficient; the *check\_ures* code<sup>5</sup> detected several anomalous zero cross-section values. When the number of ladders was increased in processing these isotopes, the cross-section anomalies disappeared.

3. Plots of Cross-section Data. Plots of each individual reaction cross section for every data table were generated with the XSPLOT code (an updated version of XDATAP<sup>9</sup>). Each of the plots was displayed and examined for signs of possible processing errors. Most reactions were co-plotted with their original ENDF evaluation data and with the ENDF60 data when available.

4. Small, Standard MCNP Run. After each data table has passed through the previous checks, each file was used in a standard MCNP run to ensure that MCNP can read and use the file and to identify any additional problems.

### III. FUTURE WORK

As mentioned earlier, we plan to develop and release a Doppler broadening code. Also, it is expected that additional libraries will be produced with ENDF evaluations that were not chosen for inclusion in ENDF66. One example is the new ACTI library based largely on ENDF/B-VI Release 8.<sup>10</sup>

Additionally, results from a suite of criticality benchmarks<sup>11,12</sup> are available.<sup>13</sup>

### ACKNOWLEDGMENTS

The authors gratefully acknowledge R. E. MacFarlane for providing us with NJOY updates and for assistance and advice during the NJOY processing phase of this project.

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## Appendix A

The table shows information about the data contained in the ENDF66 library. The data entries are explained below.

The *Z A I D* is an isotopic identifier beginning with the form ZZAAA, where ZZ is the atomic number and AAA is the atomic mass of the isotope. The suffix following the decimal point identifies the data library and data type. A Z A I D suffix of "66c" indicates ENDF66 room temperature (293.6K) data, "64c" identifies ENDF66 77K data, and "65c" is used for ENDF66 3000K data.

The column labeled "*ENDF6 Rel.*" indicates which release of the ENDF/B-VI evaluation was used as the source of the data contained in ENDF66 for the given isotope. The most recent evaluation for each isotope through release 6 was used. Those entries which have ":X" behind the release number, show that the evaluation was modified for some reason by the LANL X-5 Data Team (see Section II.A of this report for explanation).

The column labeled "*Eval. Date*" gives the year the source evaluation was made.

The "*ENDF60 Eval.*" column indicates the relation of the evaluation used for ENDF66 to that of the evaluations used for ENDF60 data. The label "*older*" shows that the data in ENDF60 are based on an older evaluation than was used for ENDF66. The label "<20MeV" indicates that the data in ENDF60 is based on the same evaluation for energies up to 20 MeV, but the evaluation on which ENDF66 is based was updated for energies greater than 20MeV. "N/A" indicates that data for the isotope were not contained in ENDF60 and appears for the first time in ENDF66. "Same" indicates that the same evaluation was used in ENDF60 and ENDF66. It should be noted that the same evaluation source does not necessarily mean that the resulting data tables in ENDF60 and ENDF66 are equivalent. ENDF60 data tables do not include probability tables, delayed-neutron data, detailed charged particle production data, or tabulated angular distributions. Furthermore, the NJOY version and NJOY input files are substantially different now than they were at the time ENDF60 was created.

"*Temp*" indicates the temperature (in Kelvin) at which the data were processed by NJOY.

"*E<sub>max</sub>*" lists the maximum incident neutron energy (in MeV) for each isotope.

The column labeled "*GPD*" indicates whether gamma-production data are given for an isotope. "Yes" means the data are given, "no" means the data are not given.

"*Nubar*" specifies whether *nubar* data are given for an isotope. If only total *nubar* data are given in ENDF66, then "*total*" appears in the "*Nubar*" column. If only prompt *nubar* data are given, then "*prompt*" appears. And if both prompt and total *nubar* data are contained in ENDF66, then the label "*both*" is given.

The "*CP*" column indicates whether secondary charged-particle data are present in the library. The "*DN*" column shows if detailed delayed-neutron spectra are contained in the library for an isotope. The "*UR*" column indicates whether unresolved-resonance data are given.



**Continuous-Energy Neutron Data Contained in ENDF66**

<b>ZAID</b>	<b>ENDF6 Rel.</b>	<b>Eval. Date</b>	<b>ENDF60 Eval</b>	<b>Temp (K)</b>	<b>E<sub>max</sub> (MeV)</b>	<b>GPD</b>	<b>Nubar</b>	<b>CP</b>	<b>DN</b>	<b>UR</b>
1001.66c	6:X	1999	older	293.6	150.0	yes	no	yes	no	no
1002.66c	6	1999	older	293.6	150.0	yes	no	yes	no	no
1003.66c	0	1965	same	293.6	20.0	no	no	no	no	no
2003.66c	1	1990	same	293.6	20.0	no	no	yes	no	no
2004.66c	0:X	1973	same	293.6	20.0	no	no	no	no	no
3006.66c	1	1989	same	293.6	20.0	yes	no	no	no	no
3007.66c	0	1988	same	293.6	20.0	yes	no	no	no	no
4009.66c	0	1986	same	293.6	20.0	yes	no	yes	no	no
5010.66c	1	1989	same	293.6	20.0	yes	no	no	no	no
5011.66c	0:X	1989	same	293.6	20.0	yes	no	yes	no	no
6000.66c	6	1999	<20MeV	293.6	150.0	yes	no	yes	no	no
7014.66c	6	1997	older	293.6	150.0	yes	no	yes	no	no
7015.66c	0	1983	same	293.6	20.0	yes	no	no	no	no
8016.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	no
8017.66c	0	1978	same	293.6	20.0	no	no	no	no	no
9019.66c	0:X	1990	same	293.6	20.0	yes	no	yes	no	no
11023.66c	1	1977	same	293.6	20.0	yes	no	no	no	no
12000.64c	0	1978	same	77.0	20.0	yes	no	no	no	no
12000.66c	0	1978	same	293.6	20.0	yes	no	no	no	no
13027.64c	6	1997	older	77.0	150.0	yes	no	yes	no	no
13027.66c	6	1997	older	293.6	150.0	yes	no	yes	no	no
14028.64c	6	1997	N/A	77.0	150.0	yes	no	yes	no	no
14028.66c	6	1997	N/A	293.6	150.0	yes	no	yes	no	no
14029.64c	6	1997	N/A	77.0	150.0	yes	no	yes	no	no
14029.66c	6	1997	N/A	293.6	150.0	yes	no	yes	no	no
14030.64c	6	1997	N/A	77.0	150.0	yes	no	yes	no	no
14030.66c	6	1997	N/A	293.6	150.0	yes	no	yes	no	no
15031.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
16000.64c	0	1979	same	77.0	20.0	yes	no	no	no	no
16000.66c	0	1979	same	293.6	20.0	yes	no	no	no	no
16032.64c	0	1977	same	77.0	20.0	yes	no	no	no	no
16032.66c	0	1977	same	293.6	20.0	yes	no	no	no	no
17000.64c	0	1967	same	77.0	20.0	yes	no	no	no	no
17000.66c	0	1967	same	293.6	20.0	yes	no	no	no	no
19000.66c	0	1967	same	293.6	20.0	yes	no	no	no	no
20000.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
20000.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
21045.66c	2:X	1992	same	293.6	20.0	yes	no	no	no	no
22000.64c	0	1977	same	77.0	20.0	yes	no	no	no	no
22000.66c	0	1977	same	293.6	20.0	yes	no	no	no	no
23000.66c	0	1988	same	293.6	20.0	yes	no	no	no	no
24050.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
24050.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
24052.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
24052.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
24053.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
24053.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
24054.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
24054.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
25055.64c	5	1988	same	77.0	20.0	yes	no	yes	no	no
25055.66c	5	1988	same	293.6	20.0	yes	no	yes	no	no
26054.64c	6	1996	<20MeV	77.0	150.0	yes	no	yes	no	no
26054.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	no
26056.64c	6	1996	<20MeV	77.0	150.0	yes	no	yes	no	no
26056.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	no
26057.64c	6	1996	<20MeV	77.0	150.0	yes	no	yes	no	no
26057.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	no
26058.64c	5	1989	same	77.0	20.0	yes	no	yes	no	no

ZAID	ENDF6 Rel.	Eval. Date	ENDF60 Eval	Temp (K)	E <sub>max</sub> (MeV)	GPD	Nubar	CP	DN	UR
26058.66c	5	1989	same	293.6	20.0	yes	no	yes	no	no
27059.66c	2	1989	same	293.6	20.0	yes	no	no	no	no
28058.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
28058.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
28060.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
28060.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
28061.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
28061.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
28062.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
28062.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
28064.64c	6	1997	<20MeV	77.0	150.0	yes	no	yes	no	no
28064.66c	6	1997	<20MeV	293.6	150.0	yes	no	yes	no	no
29063.64c	6	1998	<20MeV	77.0	150.0	yes	no	yes	no	no
29063.66c	6	1998	<20MeV	293.6	150.0	yes	no	yes	no	no
29065.64c	6	1998	<20MeV	77.0	150.0	yes	no	yes	no	no
29065.66c	6	1998	<20MeV	293.6	150.0	yes	no	yes	no	no
31000.66c	0	1980	same	293.6	20.0	yes	no	no	no	no
36078.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
36080.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
36082.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
36083.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
36084.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
36086.66c	0	1972	N/A	293.6	20.0	no	no	no	no	no
37085.66c	0	1979	N/A	293.6	20.0	no	no	no	no	no
37087.66c	0	1979	N/A	293.6	20.0	no	no	no	no	no
39089.66c	4	1996	same	293.6	20.0	yes	no	no	no	no
40000.66c	1	1981	N/A	293.6	20.0	no	no	no	no	no
40090.66c	0:X	1981	N/A	293.6	20.0	no	no	no	no	no
40091.65c	0:X	1981	N/A	3000.	20.0	no	no	no	no	yes
40091.66c	0:X	1981	N/A	293.6	20.0	no	no	no	no	yes
40092.66c	0:X	1981	N/A	293.6	20.0	no	no	no	no	no
40094.66c	0:X	1981	N/A	293.6	20.0	no	no	no	no	no
40096.66c	0:X	1976	N/A	293.6	20.0	no	no	no	no	no
41093.66c	6	1997	older	293.6	150.0	yes	no	yes	no	no
42000.66c	0	1979	same	293.6	20.0	yes	no	no	no	no
43099.65c	0	1978	same	3000.	20.0	no	no	no	no	yes
43099.66c	0	1978	same	293.6	20.0	no	no	no	no	yes
45103.65c	0	1978	N/A	3000.	20.0	no	no	no	no	yes
45103.66c	0	1978	N/A	293.6	20.0	no	no	no	no	yes
46102.66c	5	1996	N/A	293.6	30.0	yes	no	yes	no	no
46104.66c	5	1996	N/A	293.6	30.0	yes	no	yes	no	no
46105.66c	5	1996	N/A	293.6	30.0	yes	no	yes	no	no
46106.66c	5	1996	N/A	293.6	30.0	yes	no	yes	no	no
46108.66c	5	1996	N/A	293.6	30.0	yes	no	yes	no	no
46110.66c	5	1996	N/A	293.6	30.0	yes	no	yes	no	no
47107.66c	0	1983	same	293.6	20.0	no	no	no	no	no
47109.66c	0	1983	same	293.6	20.0	no	no	no	no	no
48106.65c	4	1996	N/A	3000.	20.0	no	no	no	no	yes
48106.66c	4	1996	N/A	293.6	20.0	no	no	no	no	yes
48108.65c	4	1996	N/A	3000.	20.0	no	no	no	no	yes
48108.66c	4	1996	N/A	293.6	20.0	no	no	no	no	yes
48110.65c	4:X	1996	N/A	3000.	20.0	no	no	no	no	yes
48110.66c	4:X	1996	N/A	293.6	20.0	no	no	no	no	yes
48111.66c	3	1995	N/A	293.6	20.0	no	no	no	no	no
48112.65c	4	1996	N/A	3000.	20.0	no	no	no	no	yes
48112.66c	4	1996	N/A	293.6	20.0	no	no	no	no	yes
48113.66c	3	1995	N/A	293.6	20.0	no	no	no	no	no
48114.65c	4	1996	N/A	3000.	20.0	no	no	no	no	yes
48114.66c	4	1996	N/A	293.6	20.0	no	no	no	no	yes
48116.65c	4	1996	N/A	3000.	20.0	no	no	no	no	yes
48116.66c	4	1996	N/A	293.6	20.0	no	no	no	no	yes
49000.66c	0	1990	same	293.6	20.0	yes	no	no	no	no

ZAID	ENDF6 Rel.	Eval. Date	ENDF60 Eval	Temp (K)	E <sub>max</sub> (MeV)	GPD	Nubar	CP	DN	UR
53127.66c	2	1991	same	293.6	30.0	yes	no	yes	no	no
54124.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
54126.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
54128.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
54129.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
54130.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
54131.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
54132.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
54134.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
54136.66c	0	1978	N/A	293.6	20.0	no	no	no	no	no
55133.66c	0	1978	same	293.6	20.0	no	no	no	no	no
56138.66c	3	1995	older	293.6	20.0	yes	no	no	no	no
62147.65c	0	1989	N/A	3000.	20.0	no	no	no	no	yes
62147.66c	0	1989	N/A	293.6	20.0	no	no	no	no	yes
62149.65c	0	1978	N/A	3000.	20.0	no	no	no	no	yes
62149.66c	0	1978	N/A	293.6	20.0	no	no	no	no	yes
63151.65c	0	1986	same	3000.	20.0	yes	no	no	no	yes
63151.66c	0	1986	same	293.6	20.0	yes	no	no	no	yes
63152.65c	0	1988	N/A	3000.	20.0	no	no	no	no	yes
63152.66c	0	1988	N/A	293.6	20.0	no	no	no	no	yes
63153.65c	0	1986	same	3000.	20.0	yes	no	no	no	yes
63153.66c	0	1986	same	293.6	20.0	yes	no	no	no	yes
63154.65c	0	1989	N/A	3000.	20.0	no	no	no	no	yes
63154.66c	0	1989	N/A	293.6	20.0	no	no	no	no	yes
63155.66c	1	1988	N/A	293.6	20.0	no	no	no	no	no
64152.65c	4	1996	older	3000.	20.0	no	no	no	no	yes
64152.66c	4	1996	older	293.6	20.0	no	no	no	no	yes
64154.65c	4	1996	older	3000.	20.0	no	no	no	no	yes
64154.66c	4	1996	older	293.6	20.0	no	no	no	no	yes
64155.65c	0	1977	same	3000.	20.0	no	no	no	no	yes
64155.66c	0	1977	same	293.6	20.0	no	no	no	no	yes
64156.66c	0	1977	same	293.6	20.0	no	no	no	no	no
64157.65c	0	1977	same	3000.	20.0	no	no	no	no	yes
64157.66c	0	1977	same	293.6	20.0	no	no	no	no	yes
64158.66c	0	1977	same	293.6	20.0	no	no	no	no	no
64160.66c	0	1977	same	293.6	20.0	no	no	no	no	no
67165.66c	5	1988	same	293.6	30.0	yes	no	no	no	no
71175.65c	0	1967	N/A	3000.	20.0	no	no	no	no	yes
71175.66c	0	1967	N/A	293.6	20.0	no	no	no	no	yes
71176.65c	0	1967	N/A	3000.	20.0	no	no	no	no	yes
71176.66c	0	1967	N/A	293.6	20.0	no	no	no	no	yes
72174.65c	2	1992	N/A	3000.	20.0	no	no	no	no	yes
72174.66c	2	1992	N/A	293.6	20.0	no	no	no	no	yes
72176.65c	2	1992	N/A	3000.	20.0	no	no	no	no	yes
72176.66c	2	1992	N/A	293.6	20.0	no	no	no	no	yes
72177.65c	2	1991	N/A	3000.	20.0	no	no	no	no	yes
72177.66c	2	1991	N/A	293.6	20.0	no	no	no	no	yes
72178.65c	2	1991	N/A	3000.	20.0	no	no	no	no	yes
72178.66c	2	1991	N/A	293.6	20.0	no	no	no	no	yes
72179.65c	2	1992	N/A	3000.	20.0	no	no	no	no	yes
72179.66c	2	1992	N/A	293.6	20.0	no	no	no	no	yes
72180.65c	2	1991	N/A	3000.	20.0	no	no	no	no	yes
72180.66c	2	1991	N/A	293.6	20.0	no	no	no	no	yes
73181.64c	0	1972	same	77.0	20.0	yes	no	no	no	no
73181.66c	0	1972	same	293.6	20.0	yes	no	no	no	no
73182.64c	0	1971	same	77.0	20.0	no	no	no	no	yes
73182.65c	0	1971	same	3000.	20.0	no	no	no	no	yes
73182.66c	0	1971	same	293.6	20.0	no	no	no	no	yes
74182.64c	6	1996	<20MeV	77.0	150.0	yes	no	yes	no	yes
74182.65c	6	1996	<20MeV	3000.	150.0	yes	no	yes	no	yes
74182.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	yes
74183.64c	6	1996	<20MeV	77.0	150.0	yes	no	yes	no	yes

ZAID	ENDF6 Rel.	Eval. Date	ENDF60 Eval	Temp (K)	E <sub>max</sub> (MeV)	GPD	Nubar	CP	DN	UR
74183.65c	6	1996	<20MeV	3000.	150.0	yes	no	yes	no	yes
74183.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	yes
74184.64c	6	1996	<20MeV	77.0	150.0	yes	no	yes	no	yes
74184.65c	6	1996	<20MeV	3000.	150.0	yes	no	yes	no	yes
74184.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	yes
74186.64c	6	1996	<20MeV	77.0	150.0	yes	no	yes	no	yes
74186.65c	6	1996	<20MeV	3000.	150.0	yes	no	yes	no	yes
74186.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	yes
75185.65c	0	1990	same	3000.	20.0	no	no	no	no	yes
75185.66c	0	1990	same	293.6	20.0	no	no	no	no	yes
75187.65c	0	1990	same	3000.	20.0	no	no	no	no	yes
75187.66c	0	1990	same	293.6	20.0	no	no	no	no	yes
77191.65c	4:X	1996	N/A	3000.	20.0	yes	no	no	no	yes
77191.66c	4:X	1996	N/A	293.6	20.0	yes	no	no	no	yes
77193.65c	4:X	1996	N/A	3000.	20.0	yes	no	no	no	yes
77193.66c	4:X	1996	N/A	293.6	20.0	yes	no	no	no	yes
79197.66c	1	1984	same	293.6	30.0	yes	no	no	no	no
82206.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	no
82207.66c	6	1996	<20MeV	293.6	150.0	yes	no	yes	no	no
82208.66c	6:X	1996	older	293.6	150.0	yes	no	yes	no	no
83209.66c	3	1995	same	293.6	20.0	yes	no	no	no	no
90230.66c	0	1977	same	293.6	20.0	no	total	no	no	no
90232.65c	0	1977	same	3000.	20.0	yes	both	no	yes	yes
90232.66c	0	1977	same	293.6	20.0	yes	both	no	yes	yes
91231.65c	0	1977	same	3000.	20.0	no	both	no	yes	yes
91231.66c	0	1978	same	293.6	20.0	no	both	no	yes	yes
91233.65c	0	1978	same	3000.	20.0	no	total	no	no	yes
91233.66c	0	1978	same	293.6	20.0	no	total	no	no	yes
92232.65c	0	1977	same	3000.	20.0	no	both	no	yes	yes
92232.66c	0	1977	same	293.6	20.0	no	both	no	yes	yes
92233.65c	0	1978	same	3000.	20.0	yes	both	no	yes	yes
92233.66c	0	1978	same	293.6	20.0	yes	both	no	yes	yes
92234.65c	0	1978	same	3000.	20.0	no	both	no	yes	yes
92234.66c	0	1978	same	293.6	20.0	no	both	no	yes	yes
92235.64c	5	1998	older	77.0	20.0	yes	both	no	yes	yes
92235.65c	5	1998	older	3000.	20.0	yes	both	no	yes	yes
92235.66c	5	1998	older	293.6	20.0	yes	both	no	yes	yes
92236.65c	0	1989	same	3000.	20.0	no	both	no	yes	yes
92236.66c	0	1989	same	293.6	20.0	no	both	no	yes	yes
92237.65c	2	1976	N/A	3000.	20.0	yes	both	no	yes	yes
92237.66c	2	1976	N/A	293.6	20.0	yes	both	no	yes	yes
92238.64c	5	1993	older	77.0	20.0	yes	both	no	yes	yes
92238.65c	5	1993	older	3000.	20.0	yes	both	no	yes	yes
92238.66c	5	1993	older	293.6	20.0	yes	both	no	yes	yes
93237.66c	1	1990	same	293.6	20.0	yes	both	no	yes	no
93239.66c	0	1988	same	293.6	20.0	no	total	no	no	no
94236.66c	4	1996	older	293.6	20.0	no	both	no	no	no
94237.66c	0	1978	same	293.6	20.0	no	total	no	no	no
94238.65c	0	1978	same	3000.	20.0	no	both	no	yes	yes
94238.66c	0	1978	same	293.6	20.0	no	both	no	yes	yes
94239.64c	5	1993	older	77.0	20.0	yes	both	no	yes	yes
94239.65c	5	1993	older	3000.	20.0	yes	both	no	yes	yes
94239.66c	5	1993	older	293.6	20.0	yes	both	no	yes	yes
94240.65c	2	1986	same	3000.	20.0	yes	both	no	yes	yes
94240.66c	2	1986	same	293.6	20.0	yes	both	no	yes	yes
94241.65c	3	1995	older	3000.	20.0	yes	both	no	yes	yes
94241.66c	3	1995	older	293.6	20.0	yes	both	no	yes	yes
94242.65c	0	1978	same	3000.	20.0	yes	both	no	yes	yes
94242.66c	0	1978	same	293.6	20.0	yes	both	no	yes	yes
94243.65c	2	1976	same	3000.	20.0	yes	total	no	no	yes
94243.66c	2	1976	same	293.6	20.0	yes	total	no	no	yes
94244.65c	0	1978	same	3000.	20.0	no	total	no	no	yes

ZAID	ENDF6 Rel.	Eval. Date	ENDF60 Eval	Temp (K)	E <sub>max</sub> (MeV)	GPD	Nubar	CP	DN	UR
94244.66c	0	1978	same	293.6	20.0	no	total	no	no	yes
95241.65c	3	1995	older	3000.	30.0	yes	both	no	yes	yes
95241.66c	3:X	1995	older	293.6	30.0	yes	both	no	yes	yes
95242.65c	1	1978	N/A	3000.	20.0	yes	both	no	yes	yes
95242.66c	1	1978	N/A	293.6	20.0	yes	both	no	yes	yes
95243.65c	5	1996	older	3000.	30.0	yes	both	no	yes	yes
95243.66c	5	1996	older	293.6	30.0	yes	both	no	yes	yes
96241.66c	0	1978	same	293.6	20.0	no	total	no	no	no
96242.65c	0	1978	same	3000.	20.0	yes	both	no	yes	yes
96242.66c	0	1978	same	293.6	20.0	yes	both	no	yes	yes
96243.65c	0	1978	same	3000.	20.0	yes	total	no	no	yes
96243.66c	0	1978	same	293.6	20.0	yes	total	no	no	yes
96244.65c	0	1978	same	3000.	20.0	yes	total	no	no	yes
96244.66c	0	1978	same	293.6	20.0	yes	total	no	no	yes
96245.65c	2	1979	same	3000.	20.0	yes	both	no	yes	yes
96245.66c	2	1979	same	293.6	20.0	yes	both	no	yes	yes
96246.65c	2	1976	same	3000.	20.0	yes	total	no	no	yes
96246.66c	2	1976	same	293.6	20.0	yes	total	no	no	yes
96247.65c	2	1976	same	3000.	20.0	yes	total	no	no	yes
96247.66c	2	1976	same	293.6	20.0	yes	total	no	no	yes
96248.65c	0	1978	same	3000.	20.0	yes	total	no	no	yes
96248.66c	0	1978	same	293.6	20.0	yes	total	no	no	yes
97249.65c	0	1986	same	3000.	20.0	no	both	no	no	yes
97249.66c	0	1986	same	293.6	20.0	no	both	no	no	yes
98249.65c	0:X	1989	same	3000.	20.0	no	both	no	yes	yes
98249.66c	0:X	1989	same	293.6	20.0	no	both	no	yes	yes
98250.65c	2	1976	same	3000.	20.0	yes	total	no	no	yes
98250.66c	2	1976	same	293.6	20.0	yes	total	no	no	yes
98251.65c	2	1976	same	3000.	20.0	yes	both	no	yes	yes
98251.66c	2	1976	same	293.6	20.0	yes	both	no	yes	yes
98252.65c	2	1976	same	3000.	20.0	yes	total	no	no	yes
98252.66c	2	1976	same	293.6	20.0	yes	total	no	no	yes

## Appendix B

### NJOY PENDF Input File for <sup>235</sup>U

```
moder
20 -21
reconr
-21 -22
'pendf tape for endf/b-vi.5 92-u-235 njoy 99.50' /
9228 7 /
.001 /
'the following reaction types are added where available' /
'   mt152  bondarenko unresolved' /
'   mt153  unresolved probability tables' /
'   mt20x  gas production' /
'   mt221  free thermal scattering' /
'   mt301  total heating kerma factor' /
'   mt444  total damage energy production' /
0 /
broadr
-21 -22 -23
9228 3 0 1 /
.001 /
77. 293.6 3000. /
0 /
unresr
-21 -23 -24
9228 3 1 1
77. 293.6 3000. /
1e10 /
0 /
heatr
-21 -24 -25 /
9228 7 /
302 303 304 318 402 443 444 /
purr
-21 -25 -26
9228 3 1 20 64 /
77. 293.6 3000. /
1e10 /
0 /
gaspr
-21 -26 -27
moder
-27 30
stop
```

## ACER Input File for $^{235}\text{U}$ at Room Temperature

```
moder
20 -21
moder
30 -31
acer
-21 -31 0 50 51
1 0 1 0.66 /
'92-u-235 at 293.6K from endf-vi.5 njoy99.50' /
9228 293.6 /
/
/
acer
0 50 0 54 55
7 1 1 -1 /
'92-u-235 at 293.6K from endf-vi.5 njoy99.50' /
stop
```