WBS: 1.2.2.3
QA: L

Civilian Radioactive Waste Management System
Management and Operating Contractor

Selection of MCNP Cross Section Libraries

Revision 00

Document Identifier No.: B00000000-01717-5705-00099 REV 00

June 30, 1998

Prepared for:

U.S. Department of Energy
Yucca Mountain Site Characterization Project Office
P.O. Box 30307
Las Vegas, NV 89036-0307

Prepared by:

Civilian Radioactive Waste Management System
Management and Operating Contractor
1261 Town Center Drive
Las Vegas, NV 89134

Under Contract Number:
DE-AC08-91RW00134

Civilian Radioactive Waste Management System
Management and Operating Contractor

Selection of MCNP Cross Section Libraries

Document Identifier No.: B00000000-01717-5705-00099 REV 00

June 30, 1998

Prepared by: K. D. Wright — Date: 6/30/98
K. D. Wright, Preparer
Neutronics Methodology

Reviewed by: John M. Scaglione — Date: 6/30/98
J. M. Scaglione, Checker
Neutronics Methodology

Approved by: D. A. Thomas — Date: 06/30/98
D. A. Thomas, Supervisor
Neutronics Methodology

Approved by: D. A. Thomas FOR T. W. DOERING — Date: 06/30/98
T. W. Doering, Department Manager
Waste Package Design

Table of Contents

List of Figures

List of Tables

1. Introduction

The "Selection of MCNP Cross Section Libraries" report documents the selection of continuous-energy cross section libraries to be used with MCNP (Ref. 1) in criticality benchmark calculations. This report contains comparative graphical representations of the various continuous-energy cross section libraries available for each element or isotope. In the context of this report, the term "cross section library" refers to an individual cross section data table, delineated by a unique MCNP ZAID (cross section data table identifier), for any element or isotope.

1.1: Background

MCNP has the capability to model complex geometries and implement continuous-energy cross section libraries rather than only multi-group cross section libraries. For these reasons, MCNP is currently used by the Waste Package Design Department (WPDD) to perform criticality, shielding, and other particle-transport-based calculations. Cross section libraries must be assigned to each element or isotope defining a material composition in an MCNP input deck. Multiple continuous-energy cross section libraries are available for use with many elements and isotopes. A specified set of continuous-energy cross section libraries must be established to ensure consistency throughout the various criticality benchmark and design calculations.

1.2. Objective

The objective of the "Selection of MCNP Cross Section Libraries" report is to present the basis for selecting specific MCNP cross section libraries to be used in the criticality benchmark calculations that support the "Disposal Criticality Analysis Methodology Topical Report." The "Disposal Criticality Analysis Methodology Topical Report" will be presented to the United States Nuclear Regulatory Commission when approved by the United States Department of Energy Office of Civilian Radioactive Waste Management.

1.3. Scope

The "Selection of MCNP Cross Section Libraries" report will present the reasoning for selecting specific MCNP cross section libraries. The report is to be a supporting document for other reports and calculations that will support the "Disposal Criticality Analysis Methodology Topical Report."

1.4. Quality Assurance (QA)

The QA program applies to the development of this report. The information provided in the technical document is to be indirectly used in the evaluation of the Mined Geologic Repository waste package and engineered barrier segment. The waste package and engineered barrier segment have been identified as items important to safety, waste isolation, and physical protection of materials in the QAP-2-3 evaluation entitled "Classification of the Preliminary MGDS Repository Design" (Ref. 2, TBV-228). The WPDD responsible manager has evaluated the technical document development activity in accordance with QAP-2-0, "Conduct of

Activities." The QAP-2-0 activity evaluation, "Develop Technical Documents" (Ref. 3), has determined that the preparation and review of this technical document is subject to "Quality Assurance Requirements and Description" (Ref. 4) requirements. As specified in NLP-3-18, "Documentation of QA Controls on Drawings, Specifications, Design Analyses, and Technical Documents," this activity is subject to QA controls.

1.5. Use of Computer Software

The MCNP code (Ref. 1) was used to generate the cross section library plots documented in this report. The software specifications are as follow:

- Program Name: MCNP
- Version/Revision Number: Version 4B2
- CSCI Number: 30033 V4BLV
- Computer Type: HP 9000 Series Workstation

The MCNP input file used in the generation of the various cross section plots is presented in Section 5. The MCNP generated cross section plots are contained on the attached CD-ROM identified as Attachment I. The MCNP software used was: (a) appropriate for the application of cross section plotting, (b) used only within the range of validation, (c) obtained from the Software Configuration Manager in accordance with appropriate procedures.

2. Description of Cross Section Processing for MCNP

Figure 2.1 presents a graphical representation of the cross section processing for MCNP. Basically, the evaluated nuclear data files are processed into formats which are accessible to neutron transport codes. The evaluated nuclear data files are developed based on experimental measurements, predictions of nuclear models, and evaluator experience. Several sources of evaluated nuclear data files exist. The primary sources of evaluated nuclear data files used in the United States include the following (pp. 2-17 through 2-18, Ref. 1):

- ENDF/B system
- LLNL (Lawrence Livermore National Laboratory) Evaluated Nuclear Data Library
- LANL (Los Alamos National Laboratory) Nuclear Theory & Applications Group
- Los Alamos Master Data File

Processing codes are used to generate transport code accessible cross section data tables from the evaluated nuclear data files. These processing codes (such as NJOY (Ref. 6)) are comprehensive, sophisticated code packages that process evaluated nuclear data into forms appropriate for application codes. For radiation transport codes, the product of the processing code is a multi-group or pointwise (continuous-energy) cross section library.

This report discusses the selection of continuous-energy cross section libraries for use in MCNP criticality calculations. The continuous-energy cross section libraries are processed into the ACE format (p. F-1, Ref. 1) by various national laboratories. The ACE format cross section libraries are then distributed with the MCNP software.

The continuous-energy cross section libraries are essentially cross section tables containing all cross sections tabulated on a fixed main energy grid. The characteristics of the fixed main energy grid are the same for a given library, but may differ between various libraries. The main energy grid for each cross section library is fine enough that MCNP can use a linear-linear interpolation between energy points to reproduce the evaluated cross sections within a specified tolerance. Generally, this specified tolerance for data reproduction is established as being within 1% of the data contained in the evaluation (p. 2-18, Ref. 1). Therefore, the particle energies in the cross section tables are truly continuous. Each nuclear reaction is represented separately in the cross section tables. For each individual reaction, secondary particle angular and energy distributions are provided as a function of incident neutron energy (at specific energies with interpolation between energies). The cross section tables also contain other information needed by MCNP such as multiplicities, atomic weight ratios, average nu (prompt, total, or both prompt and total), average heating numbers, and reaction Q-values. The generated cross section tables are essentially application independent. The format of the cross section tables allow the transport codes to utilize the nuclear data in as much detail as required. Information on continuous-energy cross section data tables is available on pages F-4 through F-31 of Reference 1.

The use of the continuous-energy cross section libraries in MCNP involve some neutron physics approximations. Information on these neutron physics approximations are provided on pages 2-27 through 2-57 of Reference 1. The following are some of the primary neutron physics approximations:

- (n,xn) reactions are sampled independently (no conservation of energy)
- (n,f) and (n,xn) reactions are sampled as if they occur instantly
- unresolved resonances are treated as average cross sections
- tolerance on the main energy grid is generally set such that the evaluated nuclear data can be reproduced by linear-linear interpolation to within 1%
- angular distributions of scattered neutrons from neutron emitting reactions (as tabulated on reaction-dependent grids of incident neutron energy) are sampled to conserve energy on an average basis rather than on a single collision basis
- evaluated angular distributions for secondary neutrons and photons are approximated in MCNP cross section tables by 32 equally probable cosine bins
- secondary neutron energy distributions are sometimes approximated in MCNP cross section tables by 32 equally probable energy bins.

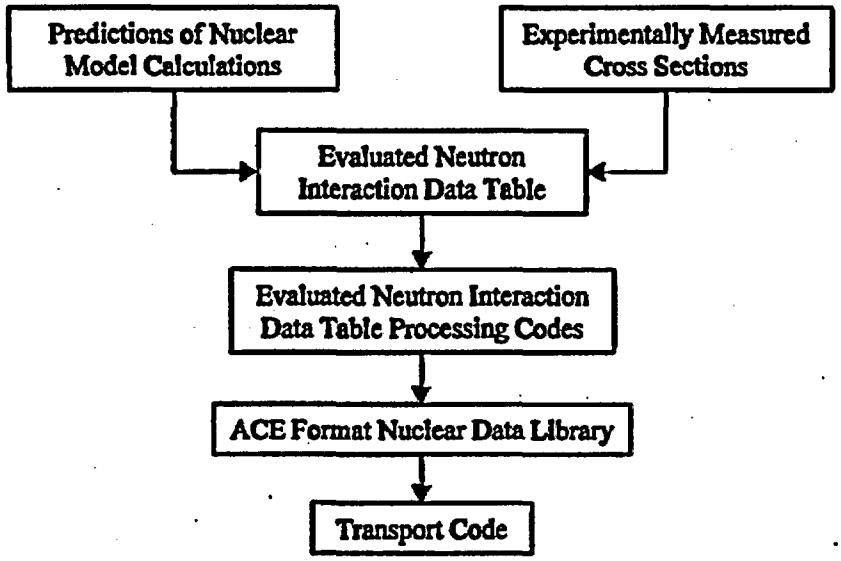

Figure 2-1. Sequence for MCNP Cross Section Processing

3. Criteria for Selecting MCNP Cross Section Libraries

More than one cross section library is available for most of the elements and isotopes for which ACE format cross section libraries have been developed. Some of the reasons for the existence of more than one cross section library for a given element or isotope include:

- different evaluated nuclear data sources
- different processing tolerances
- different temperatures at which the data was processed.

All of the cross section libraries for the various elements and isotopes are considered acceptable for use in MCNP transport calculations. However, depending on the evaluated system, some cross section libraries may provide a better representation of the nuclear reaction probabilities for a given element or isotope. Some things that should be considered when selecting neutron cross section libraries include:

- differences in evaluator's processing criteria (i.e., size optimization criteria for resulting cross section data tables)
- neutron energy spectrum
- temperature at which the evaluated nuclear data was processed to generate the cross section library
- sensitivity of results to different evaluations.

Bias and uncertainty values associated with the use of certain cross section libraries in the evaluation of systems having specific ranges of neutronic characteristics may be determined. The application of bias and uncertainty values to an evaluation is only appropriate if the bias and uncertainty values were determined from benchmark evaluations which bound both the

characteristics of the evaluated system and the utilized cross section libraries. Therefore, it is important to establish a consistent set of cross section libraries to be used in both criticality benchmarks and design calculations. This report documents a set of selected cross section libraries to be used in criticality benchmark and design calculations performed by the WPDD.

The performance of the selected cross section libraries in the evaluation of systems having varying neutronic characteristics may be quantified in the form of bias values through the evaluation of critical benchmarks which are representative of the various configurations. The performance of the selected cross section libraries as presented in this document has been shown to be acceptable based on the evaluation of numerous critical benchmark configurations representing a variety of neutronic characteristics (spectrum, geometry, reflection, etc.) (References 8, 9, 10, 11, and 12).

The following criteria were used to select the continuous-energy cross section libraries for use with MCNP:

- ENDF/B-V based cross section libraries were selected for use when available with the exceptions of H-2, B-11, Zr (natural), Ag-107, Ag-109, Eu-151, and Eu-153
- either ENDF/B-VI, T-2, or LLNL based cross section libraries were selected for use when ENDF/B-V based libraries were not available or selected
- parameters compared when selecting between ENDF/B-VI, T-2, or LLNL based cross section libraries included the following: number of energy points included in the main energy grid, date of evaluation, and availability of certain data.

Section 6 provides a listing of the continuous-energy cross section libraries that were selected for use with MCNP. Descriptions of how the criteria listed above were used to select the various cross section libraries are also provided in Section 6.

4. Available MCNP Cross Section Libraries

Table 4.1 lists all of the continuous-energy MCNP cross section libraries currently available for use by the WPDD. The information in Table 4.1 is obtained from pages G-8 through G-29 of Reference 1. The following index applies to the cross section library filenames in Table 4.1 (p. II-15, Ref. 5):

- endf5p: 23 tables from ENDF/B-V continuous energy
- endf5u: 31 tables from ENDF/B-V continuous energy neutron
- newxs: newly processed evaluations 4/19/91
- rmccs: 64 tables from ENDF/B-V, LANL, and ENDL85 (continuous energy neutron)
- rmccsa: 27 tables from ENDF/B-V, LANL, and ENDL85 (continuous energy neutron)
- kidman: data for a number of fission product nuclides at 300 K
- misc5xs: corrected data for ENDF/B-V based Zr, and data libraries IRNAT, MISCXS, ARKRC, TM169, GDT2GP, and T2DDC
- endf5mt: data previously available in the library EPRIXS (evaluations at various temperatures including 300 K, 600 K, and 900 K for 7 isotopes), along with the U600K data library

- endl85: ENDL85 based continuous energy neutron cross sections
- endf60: 124 nuclides with an individual data file for each (processed with NJOY91 at room temperature (300 K), using flat weighting, and thinned such that most nuclides had no more than 400,000 words)
- 100xs: data files for nuclides having an evaluation extending to 100 MeV

The entries in Table 4.1 are described as follows (pp. G-6 through G-7, Ref. 1):

ZAID: The ZAID is the nuclide identification number with the form ZZZAAA.nnX. "ZZZ" is the atomic number. "AAA" is the mass number (000 for naturally occurring elements). "nn" is the neutron cross section identifier. "X"="c" for continuous-energy neutron tables.

AWR (Atomic Weight Ratio): The AWR is the ratio of the atomic mass of the nuclide to a neutron. This is the AWR that is contained in the original evaluation and that was used in the NJOY processing of the evaluation. The atomic mass of a neutron is 1.008664904 atomic mass units.

Library Name: This entry is the name of the library that contains the data file for that ZAID. The number in brackets following a data file name refers to one of the special notes at the end of Table 4.1.

Source: The source indicates the originating evaluation for that data file.

> ENDF/B-V.# or ENDF/B-VI.# (such as B-V.0 and B-VI.1) are the Evaluated Nuclear Data Files, a United States effort coordinated by the National Nuclear Data Center at Brookhaven National Laboratory. The evaluations are updated periodically by evaluators from all over the country, and the release number of the evaluation is given. This is not necessarily the same as the ENDF revision number for that evaluation. For example, Pu-242 is noted as ENDF/B-VI.2 as it is from release 2 of ENDF/B-VI, but it is revision 1 of that evaluation.
>
> LLNL: This source refers to the evaluated nuclear data libraries compiled by the Nuclear Data Group at Lawrence Livermore National Laboratory. The number in the library name indicates the year the library was produced or received.
>
> T-2: This source refers to the nuclear data evaluations performed by the Nuclear Theory and Applications Group T-2 at Los Alamos National Laboratory.
>
> __:T-2 or __:XTM: This source identifier indicates that the original evaluation has been modified by the Los Alamos National Laboratory groups T-2 or XTM.

Eval Date: This entry indicates the year that the evaluation was completed or accepted. In cases where this information is not known, the date that the data library was produced is given. If minor corrections were made to an evaluation, the original evaluation date was kept. The notation "<1985" means "before" 1985.

Temp: Indicates the temperature (K) at which the data were processed. The temperature enters into the processing of the evaluation into a data file only through the Doppler broadening of cross sections. Doppler broadening refers to a change in cross section resulting from thermal motion of nuclei in a target material. Doppler broadening is done on all cross sections for incident neutrons (non-relativistic energies) on a target at some temperature (Temp) in which the free-atom approximation is valid. In general, an increase in the temperature of the material containing neutron-absorbing nuclei in a homogeneous system results in Doppler broadening of resonances and an increase in resonance absorption. Furthermore, a constant cross section at 0 K goes to 1/v behavior as the temperature increases.

Length: This entry is the total length of the particular cross section file in words. It is understood that the actual storage requirement in an MCNP problem will often be less because certain data that are not needed for a problem may be expunged.

NE: This entry is the number of energy points on the grid used for the neutron cross sections for that data file. In general, a finer energy grid (or greater number of points) indicates a more accurate representation of the cross sections, particularly through the resonance region.

E_{max}: The maximum incident energy for that data file. For all incident neutron energies greater than E_{max}, MCNP assumes the last cross section value given.

GPD: "yes" means that photon-production data are included. "no" means that photon-production data are not included.

$\bar{\nu}$: For fissionable material, this entry indicates the type of fission nu data available. "p" means that only prompt nu data are available. "t" means that only total nu data are available. "b" means that both prompt and total nu data are available.

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
Z=1**********Hydrogen**********										
H-1										
1001.35c	0.9992	endl85	LLNL	<1985	0	3,506	330	20	yes	no
1001.50c	0.9992	rmccs	B-V.0	1977	294	2,766	244	20	yes	no
1001.53c	0.9992	endf5mt[1]	B-V.0	1977	587	4,001	394	20	yes	no
1001.60c	0.9992	endf60	B-VI.1	1989	294	3,484	357	100	yes	no
H-2										
1002.35c	1.9968	endl85	LLNL	<1985	0	2,507	135	20	yes	no
1002.50c	1.9968	endf5p	B-V.0	1967	294	3,987	214	20	yes	no
1002.55c	1.9968	rmccs	T-2	1982	294	5,981	285	20	yes	no
1002.60c	1.9968	endf60[2]	B-VI.0	1967[2]	294	2,704	178	20	yes	no
H-3										
1003.35c	2.9901	endl85	LLNL	<1985	0	1,269	76	20	no	no
1003.50c	2.9901	rmccs	B-V.0	1965	294	2,428	184	20	no	no
1003.60c	2.9901	endf60	B-VI.0	1965	294	3,338	180	20	no	no
Z=2**********Helium**********										
He-3										

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
2003.35c	2.9901	endl85	LLNL	<1985	0	2,481	182	20	yes	no
2003.50c	2.9901	rmccs	B-V.0	1971	294	2,320	229	20	no	no
2003.60c	2.9890	endf60	B-VI.1	1990	294	2,834	342	20	no	no
He-4										
2004.35c	3.9682	endl85	LLNL	<1985	0	1,442	78	20	no	no
2004.50c	4.0015	rmccs	B-V.0	1973	294	3,061	345	20	no	no
2004.60c	4.0015	endf60	B-VI.0	1973	294	2,971	327	20	no	no
Z=3**********Lithium**********										
Li-6										
3006.50c	5.9634	rmccs	B-V.0	1977	294	9,932	373	20	yes	no
3006.60c	5.9634	endf60	B-VI.1	1989	294	12,385	498	20	yes	no
Li-7										
3007.50c	6.9557	endf5p	B-V.0	1972	294	4,864	343	20	yes	no
3007.55c	6.9557	rmccs	B-V.2	1979	294	13,171	328	20	yes	no
3007.60c	6.9557	endf60	B-VI.0	1988	294	14,567	387	20	yes	no
Z=4**********Beryllium**********										
Be-7										
4007.35c	6.9567	endl85	LLNL	<1985	0	1,834	180	20	no	no
Be-9										
4009.21c	8.9348	100xs[3]	T-2:XTM	1989	300	28,964	316	100	yes	no
4009.50c	8.9348	rmccs	B-V.0	1976	294	8,886	329	20	yes	no
4009.60c	8.9348	endf60	B-VI.0	1986	294	64,410	276	20	yes	no
Z=5**********Boron**********										
B-10										
5010.50c	9.9269	rmccs	B-V.0	1977	294	20,200	514	20	yes	no
5010.53c	9.9269	endf5mt[1]	B-V.0	1977	587	23,676	700	20	yes	no
5010.60c	9.9269	endf60	B-VI.1	1989	294	27,957	673	20	yes	no
B-11										
5011.35c	10.9147	endl85	LLNL	<1985	0	4,289	247	20	yes	no
5011.50c	10.9150	endf5p	B-V.0	1974	294	4,344	487	20	no	no
5011.55c	10.9150	rmccsa	B-V.0:T-2	1971	294	12,254	860	20	yes	no
5011.56c	10.9147	newxs	T-2	1986	294	56,929	1,762	20	yes	no
5011.60c	10.9147	endf60	B-VI.0	1989	294	108,351	2,969	20	yes	no
Z=6**********Carbon**********										
C-nat										
6000.50c	11.8969	rmccs	B-V.0	1977	294	23,326	875	20	yes	no
6000.60c	11.8980	endf60	B-VI.1	1989	294	22,422	978	32	yes	no
C-12										
6012.21c	11.8969	100xs[3]	T-2:XTM	1989	300	28,809	919	100	yes	no
6012.35c	11.8969	endl85	LLNL	<1985	0	5,154	225	20	yes	no
6012.50c	11.8969	rmccs[4,5]	B-V.0	1977	294	23,326	875	20	yes	no
C-13										
6013.35c	12.8916	endl85	LLNL	<1985	0	4,886	395	20	yes	no
Z=7**********Nitrogen**********										
N-14										
7014.50c	13.8830	rmccs	B-V.0	1973	294	45,457	1,196	20	yes	no
7014.60c	13.8828	endf60	T-2	1992	294	60,397	1,379	20	yes	no
N-15										
7015.55c	14.8710	rmccsa	T-2	1983	294	20,920	744	20	yes	no
7015.60c	14.8710	endf60	B-VI.0	1993	294	24,410	653	20	yes	no

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
Z=8**********Oxygen**********										
O-16										
8016.21c	15.8575	100xs[3]	T-2:XTM	1989	300	45,016	1,427	100	yes	no
8016.35c	15.8575	endl85	LLNL	<1985	0	10,357	465	20	yes	no
8016.50c	15.8580	rmccs	B-V.0	1972	294	37,942	1,391	20	yes	no
8016.53c	15.8580	endf5mt[1]	B-V.0	1972	587	37,989	1,398	20	yes	no
8016.54c	15.8580	endf5mt[1]	B-V.0	1972	881	38,017	1,402	20	yes	no
8016.60c	15.8532	endf60	B-VI.0	1990	294	58,253	1,609	20	yes	no
O-17										
8017.60c	16.8531	endf60	B-VI.0	1978	294	4,200	335	20	no	no
Z=9**********Fluorine**********										
F-19										
9019.35c	18.8352	endl85	LLNL	<1985	0	31,547	1,452	20	yes	no
9019.50c	18.8350	endf5p	B-V.0	1976	294	44,130	1,569	20	yes	no
9019.51c	18.8350	rmccs	B-V.0	1976	294	41,442	1,541	20	yes	no
9019.60c	18.8350	endf60	B-VI.0	1990	300	93,826	1,433	20	yes	no
Z=11**********Sodium**********										
Na-23										
11023.35c	22.7923	endl85	LLNL	<1985	0	22,777	1,559	20	yes	no
11023.50c	22.7920	endf5p	B-V.0	1977	294	52,252	2,703	20	yes	no
11023.51c	22.7920	rmccs	B-V.0	1977	294	48,863	2,228	20	yes	no
11023.60c	22.7920	endf60	B-VI.1	1977	294	50,294	2,543	20	yes	no
Z=12**********Magnesium**********										
Mg-nat										
12000.35c	24.0962	endl85	LLNL	<1985	0	9,686	675	20	yes	no
12000.50c	24.0963	endf5u	B-V.0	1978	294	56,334	2,430	20	yes	no
12000.51c	24.0963	rmccs	B-V.0	1978	294	48,917	1,928	20	yes	no
12000.60c	24.0963	endf60	B-VI.0	1978	294	55,776	2,525	20	yes	no
Z=13**********Aluminum**********										
Al-27										
13027.21c	26.7498	100xs[3]	T-2:XTM	1989	300	35,022	1,473	100	yes	no
13027.35c	26.7498	endl85	LLNL	<1985	0	36,895	2,038	20	yes	no
13027.50c	26.7500	rmccs	B-V.0	1973	294	54,162	2,028	20	yes	no
13027.60c	26.7500	endf60	B-VI.0	1973	294	55,427	2,241	20	yes	no
Z=14**********Silicon**********										
Si-nat										
14000.21c	27.8440	100xs[3]	T-2:XTM	1989	300	76,399	2,883	100	yes	no
14000.35c	27.8442	endl85	LLNL	<1985	0	19,016	1,012	20	yes	no
14000.50c	27.8440	endf5p	B-V.0	1976	294	98,609	2,440	20	yes	no
14000.51c	27.8440	rmccs	B-V.0	1976	294	88,129	1,887	20	yes	no
14000.60c	27.8440	endf60	B-VI.0	1976	294	104,198	2,824	20	yes	no
Z=15**********Phosphorus**********										
P-31										
15031.35c	30.7077	endl85	LLNL	<1985	0	5,875	303	20	yes	no
15031.50c	30.7080	endf5u	B-V.0	1977	294	5,733	326	20	yes	no
15031.51c	30.7080	rmccs	B-V.0	1977	294	5,732	326	20	yes	no
15031.60c	30.7080	endf60	B-VI.0	1977	294	6,715	297	20	yes	no
Z=16**********Sulfur**********										
S-nat										
16000.60c	31.7882	endf60	B-VI.0	1979	294	108,683	8,382	20	yes	no

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
S-32										
16032.35c	31.6974	endl85	LLNL	<1985	0	7,054	357	20	yes	no
16032.50c	31.6970	endf5u	B-V.0	1977	294	6,789	363	20	yes	no
16032.51c	31.6970	rmccs	B-V.0	1977	294	6,780	362	20	yes	no
16032.60c	31.6970	endf60	B-VI.0	1977	294	7,025	377	20	yes	no
Z=17**********		Chlorine	**********							
Cl-nat										
17000.35c	35.1484	endl85	LLNL	<1985	0	12,903	1,014	20	yes	no
17000.50c	35.1480	endf5p	B-V.0	1967	294	23,313	1,499	20	yes	no
17000.51c	35.1480	rmccs	B-V.0	1967	294	21,084	1,375	20	yes	no
17000.60c	35.1480	endf60	B-VI.0	1967	294	24,090	1,816	20	yes	no
Z=18**********		Argon	**********							
Ar-nat										
18000.35c	39.6048	rmccsa	LLNL	<1985	0	5,585	259	20	yes	no
18000.59c	39.6048	misc5xs[6,7]	T-2	1982	294	3,473	252	20	yes	no
Z=19**********		Potassium	**********							
K-nat										
19000.35c	38.7624	endl85	LLNL	<1985	0	11,130	714	20	yes	no
19000.50c	38.7660	endf5u	B-V.0	1974	294	22,051	1,243	20	yes	no
19000.51c	38.7660	rmccs	B-V.0	1974	294	18,798	1,046	20	yes	no
19000.60c	38.7660	endf60	B-VI.0	1974	294	24,482	1,767	20	yes	no
Z=20**********		Calcium	**********							
Ca-nat										
20000.35c	39.7357	endl85	LLNL	<1985	0	12,933	974	20	yes	no
20000.50c	39.7360	endf5u	B-V.0	1976	294	62,624	2,394	20	yes	no
20000.51c	39.7360	rmccs	B-V.0	1976	294	53,372	1,796	20	yes	no
20000.60c	39.7360	endf60	B-VI.0	1980	294	76,468	2,704	20	yes	no
Ca-40										
20040.21c	39.6193	100xs[3]	T-2:XTM	1989	300	53,013	2,718	100	yes	no
Z=21**********		Scandium	**********							
Sc-45										
21045.60c	44.5679	endf60	B-VI.2	1992	294	105,627	10,639	20	yes	no
Z=22**********		Titanium	**********							
Ti-nat										
22000.35c	47.4885	endl85	LLNL	<1985	0	13,421	1,337	20	yes	no
22000.50c	47.4676	endf5u	B-V.0	1977	294	54,801	4,434	20	yes	no
22000.51c	47.4676	rmccs	B-V.0	1977	294	31,832	1,934	20	yes	no
22000.60c	47.4676	endf60	B-VI.0	1977	294	76,454	7,761	20	yes	no
Z=23**********		Vanadium	**********							
V-nat										
23000.50c	50.5040	endf5u	B-V.0	1977	294	38,312	2,265	20	yes	no
23000.51c	50.5040	rmccs	B-V.0	1977	294	34,110	1,899	20	yes	no
23000.60c	50.5040	endf60	B-VI.0	1988	294	167,334	8,957	20	yes	no
Z=24**********		Chromium	**********							
Cr-nat										
24000.35c	51.5493	endl85	LLNL	<1985	0	9,218	358	20	yes	no
24000.50c	51.5490	rmccs	B-V.0	1977	294	134,454	11,050	20	yes	no
Cr-50										
24050.60c	49.5170	endf60	B-VI.1	1989	294	119,178	11,918	20	yes	no
Cr-52										

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
24052.60c	51.4940	endf60	B-VI.1	1989	294	117,680	10,679	20	yes	no
Cr-53										
24053.60c	52.4860	endf60	B-VI.1	1989	294	114,982	10,073	20	yes	no
Cr-54										
24054.60c	53.4760	endf60	B-VI.1	1989	294	98,510	9,699	20	yes	no
Z=25**********Manganese**********										
Mn-55										
25055.35c	54.4661	endl85	LLNL	<1985	0	7,493	446	20	yes	no
25055.50c	54.4661	endf5u	B-V.0	1977	294	105,093	12,525	20	yes	no
25055.51c	54.4661	rmccs	B-V.0	1977	294	25,727	1,578	20	yes	no
25055.60c	54.4661	endf60	B-VI.0	1988	294	184,269	8,207	20	yes	no
Z=26**********Iron**********										
Fe-nat										
26000.21c	55.3650	100xs[3]	T-2:XTM	1989	300	149,855	15,598	100	yes	no
26000.35c	55.3672	endl85	LLNL	<1985	0	30,983	2,772	20	yes	no
26000.50c	55.3650	endf5p	B-V.0	1978	294	115,447	10,957	20	yes	no
26000.55c	55.3650	rmccs	T-2	1986	294	178,392	6,899	20	yes	no
Fe-54										
26054.60c	53.4760	endf60	B-VI.1	1989	294	121,631	10,701	20	yes	no
Fe-56										
26056.60c	55.4540	endf60	B-VI.1	1989	294	174,517	11,618	20	yes	no
Fe-57										
26057.60c	56.4460	endf60	B-VI.1	1989	294	133,995	7,606	20	yes	no
Fe-58										
26058.60c	57.4360	endf60	B-VI.1	1989	294	93,450	6,788	20	yes	no
Z=27**********Cobalt**********										
Co-59										
27059.35c	58.4269	endl85	LLNL	<1985	0	38,958	4,177	20	yes	no
27059.50c	58.4269	endf5u	B-V.0	1977	294	117,075	14,502	20	yes	no
27059.51c	58.4269	rmccs	B-V.0	1977	294	28,355	1,928	20	yes	no
27059.60c	58.4269	endf60	B-VI.2	1992	294	186,618	11,838	20	yes	no
Z=28**********Nickel**********										
Ni-nat										
28000.50c	58.1826	rmccs	B-V.0	1977	294	139,913	8,927	20	yes	no
Ni-58										
28058.35c	57.4376	endl85	LLNL	<1985	0	42,744	4,806	20	yes	no
28058.60c	57.4380	endf60	B-VI.1	1989	294	172,069	16,445	20	yes	no
Ni-60										
28060.60c	59.4160	endf60	B-VI.1	1991	294	110,885	10,055	20	yes	no
Ni-61										
28061.60c	60.4080	endf60	B-VI.1	1989	294	93,801	5,882	20	yes	no
Ni-62										
28062.60c	61.3960	endf60	B-VI.1	1989	294	82,085	7,230	20	yes	no
Ni-64										
28064.60c	63.3790	endf60	B-VI.1	1989	294	66,656	6,144	20	yes	no
Z=29**********Copper**********										
Cu-nat										
29000.35c	63.0001	endl85	LLNL	<1985	0	7,039	293	20	yes	no
29000.50c	63.5460	rmccs	B-V.0	1978	294	51,850	3,435	20	yes	no
Cu-63										

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
29063.60c	62.3890	endf60	B-VI.2	1989	294	119,097	11,309	20	yes	no
Cu-65										
29065.60c	64.3700	endf60	B-VI.2	1989	294	118,385	11,801	20	yes	no
Z=31**********Gallium**********										
Ga-nat										
31000.35c	69.1211	endl85	LLNL	<1985	0	7,509	469	20	yes	no
31000.50c	69.1211	rmccs	B-V.0	1980	294	7,928	511	20	yes	no
31000.60c	69.1211	endf60	B-VI.0	1980	294	9,228	566	20	yes	no
Z=33**********Arsenic**********										
As-74										
33074.35c	73.2889	endl85	LLNL	<1985	0	50,881	6,424	20	yes	no
As-75										
33075.35c	74.2780	rmccsa	B-V.0	1974	0	50,931	6,421	20	yes	no
Z=35**********Bromine**********										
Br-79										
35079.55c	78.2404	misc5xs[6,8]	T-2	1982	294	10,431	1,589	20	no	no
Br-81										
35081.55c	80.2212	misc5xs[6,8]	T-2	1982	294	5,342	831	20	no	no
Z=36**********Krypton**********										
Kr-78										
36078.50c	77.2510	rmccsa	B-V.0	1978	294	9,057	939	20	no	no
Kr-80										
36080.50c	79.2298	rmccsa	B-V.0	1978	294	10,165	1,108	20	no	no
Kr-82										
36082.50c	81.2098	rmccsa	B-V.0	1978	294	7,220	586	20	no	no
36082.59c	81.2098	misc5xs[6,7]	T-2	1982	294	7,010	499	20	yes	no
Kr-83										
36083.50c	82.2018	rmccsa	B-V.0	1978	294	8,078	811	20	no	no
36083.59c	82.2018	misc5xs[6,7]	T-2	1982	294	8,069	704	20	yes	no
Kr-84										
36084.50c	83.1906	rmccsa	B-V.0	1978	294	9,364	944	20	no	no
36084.59c	83.1906	misc5xs[6,7]	T-2	1982	294	10,370	954	20	yes	no
Kr-86										
36086.50c	85.1726	rmccsa	B-V.0	1975	294	10,416	741	20	no	no
36086.59c	85.1726	misc5xs[6,7]	T-2	1982	294	8,740	551	20	yes	no
Z=37**********Rubidium**********										
Rb-85										
37085.55c	84.1824	misc5xs[6,8]	T-2	1982	294	27,304	4,507	20	no	no
Rb-87										
37087.55c	86.1626	misc5xs[6,8]	T-2	1982	294	8,409	1,373	20	no	no
Z=39**********Yttrium**********										
Y-88										
39088.35c	87.1543	endl85	LLNL	<1985	0	11,299	272	20	yes	no
Y-89										
39089.35c	88.1421	misc5xs[6]	LLNL		0	49,885	6,154	20	yes	no
39089.50c	88.1421	endf5u	B-V.0[9]	1985	294	18,631	3,029	20	no	no
39089.60c	88.1420	endf60	B-VI.0	1986	294	86,556	9,567	20	yes	no
Z=40**********Zirconium**********										
Zr-nat										
40000.35c	90.4364	endl85	LLNL	<1985	0	14,738	1,292	20	yes	no

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
40000.56c	90.4360	misc5xs[6,10]	B-V:XTM	1976	300	52,064	7944	20	no	no
40000.57c	90.4360	misc5xs[6,10]	B-V:XTM	1976	300	16,816	2,116	20	no	no
40000.58c	90.4360	misc5xs[6,10]	B-V:XTM	1976	587	57,528	8,777	20	no	no
40000.60c	90.4360	endf60	B-VI.1	1976[10]	294	66,035	10,298	20	no	no
Zr-93										
40093.50c	92.1083	kidman	B-V.0	1974	294	2,579	236	20	no	no
Z=41**********Niobium**********										
Nb-93										
41093.35c	92.1083	endl85	LLNL	<1985	0	50,441	6,095	20	yes	no
41093.50c	92.1051	endf5p	B-V.0	1974	294	128,960	17,279	20	yes	no
41093.51c	92.1051	rmccs	B-V.0	1974	294	14,675	963	20	yes	no
41093.60c	92.1051	endf60	B-VI.1	1990	294	110,269	10,678	20	yes	no
Z=42**********Molybdenum**********										
Mo-nat										
42000.35c	95.1158	endl85	LLNL	<1985	0	8,628	573	20	yes	no
42000.50c	95.1160	endf5u	B-V.0	1979	294	35,634	4,260	20	yes	no
42000.51c	95.1160	rmccs	B-V.0	1979	294	10,139	618	20	yes	no
42000.60c	95.1160	endf60	B-VI.0	1979	294	45,573	5,466	20	yes	no
Mo-95										
42095.50c	94.0906	kidman	B-V.0	1980	294	15,411	2,256	20	no	no
Z=43**********Technetium**********										
Tc-99										
43099.50c	98.1500	kidman	B-V.0	1978	294	12,152	1,640	20	no	no
43099.60c	98.1500	endf60	B-VI.0	1978	294	54,262	8,565	20	no	no
Z=44**********Ruthenium**********										
Ru-101										
44101.50c	100.0390	kidman	B-V.0	1980	294	5,299	543	20	no	no
Ru-103										
44103.50c	102.0220	kidman	B-V.0	1974	294	3,052	235	20	no	no
Z=45**********Rhodium**********										
Rh-103										
45103.50c	102.0210	rmccsa	B-V.0	1978	294	18,870	2,608	20	no	no
Rh-105										
45105.50c	104.0050	kidman	B-V.0	1974	294	1,591	213	20	no	no
Z=46**********Palladium**********										
Pd-105										
46105.50c	104.0040	kidman	B-V.0	1980	294	4,647	505	20	no	no
Pd-108										
46108.50c	106.9770	kidman	B-V.0	1980	294	4,549	555	20	no	no
Z=47**********Silver**********										
Ag-nat										
47000.55c	106.9420	rmccsa	T-2	1984	294	29,092	2,350	20	yes	no
Ag-107										
47107.35c	105.9867	endl85	LLNL	<1985	0	13,134	994	20	yes	no
47107.50c	105.9870	rmccsa	B-V.0	1978	294	12,111	1,669	20	no	no
47107.60c	105.9870	endf60	B-VI.0	1983	294	64,008	10,101	20	no	no
Ag-109										
47109.35c	107.9692	endl85	LLNL	<1985	0	13,452	1,094	20	yes	no
47109.50c	107.9690	rmccsa	B-V.0	1978	294	14,585	2,120	20	no	no
47109.60c	107.9690	endf60	B-VI.0	1983	294	76,181	11,903	20	no	no

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
Z=48**********Cadmium**********										
Cd-nat										
48000.35c	111.4443	endl85	LLNL	<1985	0	12,283	1,115	20	yes	no
48000.50c	111.4600	endf5u	B-V.0	1974	294	19,714	2,981	20	no	no
48000.51c	111.4600	rmccs	B-V.0	1974	294	6,734	818	20	no	no
Z=49**********Indium**********										
In-nat										
49000.60c	113.8340	endf60	B-VI.0	1990	294	93,662	10,116	20	yes	no
Z=50**********Tin**********										
Sn-nat										
50000.35c	117.6704	endl85	LLNL	<1985	0	5,970	205	20	yes	no
Z=53**********Iodine**********										
I-127										
53127.55c	125.8140	misc5xs[6,8]	T-2	1982	294	59,725	9,423	20	no	no
53127.60c	125.8143	endf60[12]	T-2	1991	294	399,760	7,888	30	yes	no
I-129										
53129.60c	127.7980	endf60	B-VI.0	1980	294	8,792	1,237	20	no	no
I-135										
53135.50c	133.7510	kidman	B-V.0	1974	294	1,232	194	20	no	no
Z=54**********Xenon**********										
Xe-nat										
54000.35c	130.1721	endl85	LLNL	<1985	0	41,432	5,228	20	yes	no
Xe-131										
54131.50c	129.7810	kidman	B-V.0	1978	294	22,572	3,376	20	no	no
Xe-134										
54134.35c	132.7551	endl85	LLNL	<1985	0	7,463	359	20	yes	no
Xe-135										
54135.50c	133.7480	endf5mt[1]	B-V	1975	294	5,529	704	20	no	no
54135.53c	133.7480	endf5mt[1]	B-V	1975	587	5,541	706	20	no	no
54135.54c	133.7480	endf5mt[1]	B-V	1975	881	5,577	712	20	no	no
Z=55**********Cesium**********										
Cs-133										
55133.50c	131.7640	kidman	B-V.0	1978	294	26,713	4,142	20	no	no
55133.55c	131.7640	misc5xs[6,8]	T-2	1982	294	67,893	11,025	20	no	no
55133.60c	131.7640	endf60	B-VI.0	1978	294	54,723	8,788	20	no	no
Cs-134										
55134.60c	132.7570	endf60	B-VI.0	1988	294	10,227	1,602	20	no	no
Cs-135										
55135.50c	133.7470	kidman	B-V.0	1974	294	1,903	199	20	no	no
55135.60c	133.7470	endf60	B-VI.0	1974	294	3,120	388	20	no	no
Cs-136										
55136.60c	134.7400	endf60	B-VI.0	1974	294	10,574	1,748	20	no	no
Cs-137										
55137.60c	135.7310	endf60	B-VI.0	1974	294	2,925	369	20	no	no
Z=56**********Barium**********										
Ba-138										
56138.35c	136.7206	endl85	LLNL	<1985	0	5,985	262	20	yes	no
56138.50c	136.7150	rmccs	B-V.0	1978	294	6,018	292	20	yes	no
56138.60c	136.7150	endf60	B-VI.0	1978	294	7,347	267	20	yes	no
Z=59**********Praseodymium**********										

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
Pr-141										
59141.50c	139.6970	kidman	B-V.0	1980	294	15,620	1,354	20	no	no
Z=60**********Neodymium**********										
Nd-143										
60143.50c	141.6820	kidman	B-V.0	1980	294	17,216	1,701	20	no	no
Nd-145										
60145.50c	143.6680	kidman	B-V.0	1980	294	38,473	3,985	20	no	no
Nd-147										
60147.50c	145.6540	kidman	B-V.0	1979	294	1,816	251	20	no	no
Nd-148										
60148.50c	146.6460	kidman	B-V.0	1980	294	10,867	1,054	20	no	no
Z=61**********Promethium**********										
Pm-147										
61147.50c	145.6530	kidman	B-V.0	1980	294	9,152	825	20	no	no
Pm-148										
61148.50c	146.6470	kidman	B-V.0	1979	294	1,643	257	20	no	no
Pm-149										
61149.50c	147.6390	kidman	B-V.0	1979	294	2,069	238	20	no	no
Z=62**********Samarium**********										
Sm-147										
62147.50c	145.6530	kidman	B-V.0	1980	294	33,773	2,885	20	no	no
Sm-149										
62149.50c	147.6380	endf5u	B-V.0	1978	294	15,662	2,008	20	no	no
Sm-150										
62150.50c	148.6290	kidman	B-V.0	1974	294	9,345	1,329	20	no	no
Sm-151										
62151.50c	149.6230	kidman	B-V.0	1980	294	7,303	605	20	no	no
Sm-152										
62152.50c	150.6150	kidman	B-V.0	1980	294	41,252	4,298	20	no	no
Z=63**********Europium**********										
Eu-nat										
63000.35c	150.6546	rmccsa	LLNL	<1985	0	6,926	364	20	yes	no
Eu-151										
63151.50c	149.6230	rmccs	B-V.0	1977	294	68,057	5,465	20	yes	no
63151.55c	149.6230	newxs	T-2	1986	294	86,575	4,749	20	yes	no
63151.60c	149.6230	endf60	B-VI.0	1986	294	96,099	7,394	20	yes	no
Eu-152										
63152.50c	150.6200	endf5u	B-V.0	1975	294	49,313	4,553	20	no	no
Eu-153										
63153.50c	151.6070	rmccs	B-V.0	1978	294	55,231	4,636	20	yes	no
63153.55c	151.6080	newxs	T-2	1986	294	72,971	4,174	20	yes	no
63153.60c	151.6080	endf60	B-VI.0	1986	294	86,490	6,198	20	yes	no
Eu-154										
63154.50c	152.6000	endf5u	B-V.0	1975	294	37,008	4,030	20	no	no
Eu-155										
63155.50c	153.5920	kidman	B-V.0	1974	294	4,532	273	20	no	no
Z=64**********Gadolinium**********										
Gd-nat										
64000.35c	155.8991	rmccsa	LLNL	<1985	0	7,878	454	20	yes	no
Gd-152										

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
64152.50c	150.6150	endf5u	B-V.0	1977	294	26,251	3,285	20	no	no
64152.55c	150.6150	misc5xs[6,13]	B-V.0:T-2	1986	294	32,590	3,285	20	yes	no
64152.60c	150.6150	endf60	B-VI.0	1977	294	32,760	4,391	20	no	no
Gd-154										
64154.50c	152.5990	endf5u	B-V.0	1977	294	49,572	7,167	20	no	no
64154.55c	152.5990	misc5xs[6,13]	B-V.0:T-2	1986	294	59,814	7,167	20	yes	no
64154.60c	152.5990	endf60	B-VI.0	1977	294	67,662	10,189	20	no	no
Gd-155										
64155.50c	153.5920	endf5u	B-V.0	1977	294	44,965	6,314	20	no	no
64155.55c	153.5920	misc5xs[6,13]	B-V.0:T-2	1986	294	54,346	6,314	20	yes	no
64155.60c	153.5920	endf60	B-VI.0	1977	294	61,398	9,052	20	no	no
Gd-156										
64156.50c	154.5830	endf5u	B-V.0	1977	294	37,371	3,964	20	no	no
64156.55c	154.5830	misc5xs[6,13]	B-V.0:T-2	1986	294	44,391	3,964	20	yes	no
64156.60c	154.5830	endf60	B-VI.0	1977	294	42,885	5,281	20	no	no
Gd-157										
64157.50c	155.5760	endf5u	B-V.0	1977	294	38,975	5,370	20	no	no
64157.55c	155.5760	misc5xs[6,13]	B-V.0:T-2	1986	294	47,271	5,370	20	yes	no
64157.60c	155.5760	endf60	B-VI.0	1977	294	56,957	8,368	20	no	no
Gd-158										
64158.50c	156.5670	endf5u	B-V.0	1977	294	95,876	15,000	20	no	no
64158.55c	156.5670	misc5xs[6,13]	B-V.0:T-2	1986	294	113,916	15,000	20	yes	no
64158.60c	156.5670	endf60	B-VI.0	1977	294	59,210	8,909	20	no	no
Gd-160										
64160.50c	158.5530	endf5u	B-V.0	1977	294	53,988	8,229	20	no	no
64160.55c	158.5530	misc5xs[6,13]	B-V.0:T-2	1986	294	65,261	8,229	20	yes	no
64160.60c	158.5530	endf60	B-VI.0	1977	294	54,488	8,304	20	no	no
Z=67**********Holmium**********										
Ho-165										
67165.35c	163.5135	rmccsa	LLNL	<1985	0	54,279	7,075	20	yes	no
67165.55c	163.5130	newxs	T-2	1986	294	56,605	2,426	30	yes	no
67165.60c	163.5130	endf60	B-VI.0	1988	294	75,307	4,688	30	yes	no
Z=69**********Thulium**********										
Tm-169										
69169.55c	167.4830	misc5xs[6]	T-2	1986	300	47,941	4,738	20	no	no
Z=72**********Hafnium**********										
Hf-nat										
72000.35c	176.9567	endl85	LLNL	<1985	0	75,862	9,636	20	yes	no
72000.50c	176.9540	newxs	B-V.0	1976	294	52,231	8,270	20	no	no
72000.60c	176.9540	endf60	B-VI.0	1976	294	84,369	13,634	20	no	no
Z=73**********Tantalum**********										
Ta-181										
73181.35c	179.3936	endl85	LLNL	<1985	0	33,547	2,812	20	yes	no
73181.50c	179.4000	endf5u	B-V.0	1972	294	60,740	6,341	20	yes	no
73181.51c	179.4000	rmccs	B-V.0	1972	294	21,527	753	20	yes	no
73181.60c	179.4000	endf60	B-VI.0	1972	294	91,374	10,352	20	yes	no
Ta-182										
73182.60c	180.3870	endf60	B-VI.0	1971	294	12,085	1,698	20	no	no
Z=74**********Tungsten**********										
W-nat										

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
74000.21c	182.2706	100xs[3]	T-2:XTM	1989	300	194,513	21,386	100	yes	no
74000.55c	182.2770	rmccs	B-V.2	1982	294	50,639	1,816	20	yes	no
W-182										
74182.50c	180.3900	endf5p	B-V.0	1973	294	94,367	11,128	20	yes	no
74182.55c	180.3900	rmccsa	B-V.2	1980	294	122,290	13,865	20	yes	no
74182.60c	180.3900	endf60	B-VI.0	1980	294	113,177	12,283	20	yes	no
W-183										
74183.50c	181.3800	endf5p	B-V.0	1973	294	58,799	5,843	20	yes	no
74183.55c	181.3800	rmccsa	B-V.2	1980	294	79,534	8,083	20	yes	no
74183.60c	181.3800	endf60	B-VI.0	1980	294	89,350	9,131	20	yes	no
W-184										
74184.50c	182.3700	endf5p	B-V.0	1973	294	58,870	6,173	20	yes	no
74184.55c	182.3700	rmccsa	B-V.2	1980	294	80,006	7,835	20	yes	no
74184.60c	182.3700	endf60	B-VI.0	1980	294	78,809	7,368	20	yes	no
W-186										
74186.50c	184.3600	endf5p	B-V.0	1973	294	63,701	6,866	20	yes	no
74186.55c	184.3600	rmccsa	B-V.2	1980	294	83,618	8,342	20	yes	no
74186.60c	184.3600	endf60	B-VI.0	1980	294	82,010	7,793	20	yes	no
Z=75**********Rhenium**********										
Re-185										
75185.32c	183.3612	misc5xs[6]	LLNL	<1985	0	13,650	1,488	20	yes	no
75185.35c	183.3641	endl85	LLNL	<1985	0	16,038	1,487	20	yes	no
75185.50c	183.3640	rmccsa	B-V.0	1968	294	9,190	1,168	20	no	no
75185.60c	183.3640	endf60	B-VI.0	1990	294	102,775	16,719	20	no	no
Re-187										
75187.32c	185.3539	misc5xs[6]	LLNL	<1985	0	12,318	1,296	20	yes	no
75187.35c	185.3497	endl85	LLNL	<1985	0	14,769	1,295	20	yes	no
75187.50c	185.3500	rmccsa	B-V.0	1968	294	8,262	959	20	no	no
75187.60c	185.3500	endf60	B-VI.0	1990	294	96,989	15,624	20	no	no
Z=77**********Iridium**********										
Ir-nat										
77000.55c	190.5630	misc5xs[6]	T-2	1986	300	43,071	3,704	20	no	no
Z=78**********Platinum**********										
Pt-nat										
78000.35c	193.4141	rmccsa	LLNL	<1985	0	15,371	1,497	20	yes	no
Z=79**********Gold**********										
Au-197										
79197.35c	195.2745	endl85	LLNL	<1985	0	31,871	3,781	20	yes	no
79197.50c	195.2740	endf5p	B-V.0	1977	294	139,425	22,632	20	no	no
79197.55c	195.2740	rmccsa	T-2	1983	294	134,325	17,909	20	yes	no
79197.56c	195.2740	newxs	T-2	1984	294	122,482	11,823	30	yes	no
79197.60c	195.2740	endf60	B-VI.1	1984	294	161,039	17,724	30	yes	no
Z=82**********Lead**********										
Pb-nat										
82000.35c	205.4200	endl85	LLNL	<1985	0	6,639	349	20	yes	no
82000.50c	205.4300	rmccs	B-V.0	1976	294	37,633	1,346	20	yes	no
Pb-206										
82206.60c	204.2000	endf60	B-VI.0	1989	294	148,815	12,872	20	yes	no
Pb-207										
82207.60c	205.2000	endf60	B-VI.1	1991	294	111,750	7,524	20	yes	no

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
Pb-208										
82208.60c	206.1900	endf60	B-VI.0	1989	294	70,740	5,105	20	yes	no
Z=83**********Bismuth**********										
Bi-209										
83209.35c	207.1851	endl85	LLNL	<1985	0	18,316	1,303	20	yes	no
83209.50c	207.1850	endf5u	B-V.0	1980	294	14,939	1,300	20	yes	no
83209.51c	207.1850	rmccs	B-V.0	1980	294	13,721	1,186	20	yes	no
83209.60c	207.1850	endf60	B-VI.0	1989	294	100,138	8,427	20	yes	no
Z=90**********Thorium**********										
Th-230										
90230.60c	228.0600	endf60	B-VI.0	1977	294	35,155	5,533	20	no	t
Th-231										
90231.35c	229.0516	endl85	LLNL	<1985	0	9,157	308	20	yes	p
Th-232										
90232.35c	230.0447	endl85	LLNL	<1985	0	56,091	6,169	20	yes	p
90232.50c	230.0400	endf5u	B-V.0	1977	294	152,782	17,901	20	yes	b
90232.51c	230.0400	rmccs	B-V.0	1977	294	17,925	1,062	20	yes	b
90232.60c	230.0400	endf60	B-VI.0	1977	294	127,606	16,381	20	yes	b
Th-233										
90233.35c	231.0396	endl85	LLNL	<1985	0	9,352	348	20	yes	p
Z=91**********Protactinium**********										
Pa-231										
91231.60c	229.0500	endf60	B-VI.0	1977	294	19,835	2,610	20	no	b
Pa-233										
91233.35c	231.0383	endl85	LLNL	<1985	0	19,170	1,910	20	yes	p
91233.50c	231.0380	endf5u	B-V.0	1974	294	19,519	2,915	20	no	t
91233.51c	231.0380	rmccs	B-V.0	1974	294	5,641	637	20	no	t
Z=92**********Uranium**********										
U-232										
92232.60c	230.0400	endf60	B-VI.0	1977	294	13,839	1,759	20	no	b
U-233										
92233.35c	231.0377	endl85	LLNL	<1985	0	29,674	2,924	20	yes	p
92233.50c	231.0430	rmccs	B-V.0	1978	294	18,815	2,293	20	no	b
92233.60c	231.0430	endf60[14]	B-VI.0	1978	294	32,226	3,223	20	yes	b
U-234										
92234.35c	232.0304	endl85	LLNL	<1985	0	8,557	237	20	yes	p
92234.50c	232.0300	endf5p	B-V.0	1978	294	89,433	12,430	20	no	t
92234.51c	232.0300	rmccs	B-V.0	1978	294	6,426	672	20	no	t
92234.60c	232.0300	endf60	B-VI.0	1978	294	77,059	10,660	17.5	no	b
U-235										
92235.50c	233.0250	rmccs	B-V.0	1977	294	60,489	5,725	20	yes	b
92235.52c	233.0250	endf5mt[1]	B-V.0	1977	587	65,286	6,320	20	yes	b
92235.53c	233.0250	endf5mt[1]	B-V.0	1977	587	36,120	2,685	20	yes	b
92235.54c	233.0250	endf5mt[1]	B-V.0	1977	881	36,008	2,671	20	yes	b
92235.60c	233.0250	endf60	B-VI.2	1989	294	289,975	28,110	20	yes	b
U-236										
92236.35c	234.0178	endl85	LLNL	<1985	0	8,699	224	20	yes	p
92236.50c	234.0180	endf5p	B-V.0	1978	294	138,715	19,473	20	no	t
92236.51c	234.0180	rmccs	B-V.0	1978	294	7,302	800	20	no	t
92236.60c	234.0180	endf60	B-VI.0	1989	294	82,819	10,454	20	no	b

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
U-237										
92237.35c	235.0123	endl85	LLNL	<1985	0	9,364	353	20	yes	p
92237.50c	235.0120	endf5p	B-V.0	1976	294	32,445	3,293	20	yes	t
92237.51c	235.0120	rmccs	B-V.0	1976	294	10,317	527	20	yes	t
U-238										
92238.21c	236.0060	100xs[3]	T-2:XTM	1989	300	279,245	30,911	100	yes	b
92238.35c	236.0058	endl85	LLNL	<1985	0	27,168	1,845	20	yes	p
92238.50c	236.0060	rmccs	B-V.0	1979	294	88,998	9,285	20	yes	b
92238.52c	236.0060	endf5mt[1]	B-V.0	1979	587	123,199	8,454	20	yes	b
92238.53c	236.0060	endf5mt[1]	B-V.0	1979	587	160,107	17,876	20	yes	b
92238.54c	236.0060	endf5mt[1]	B-V.0	1979	881	160,971	17,984	20	yes	b
92238.60c	236.0060	endf60	B-VI.2	1993	294	206,322	22,600	20	yes	b
U-239										
92239.35c	237.0007	rmccsa	LLNL	<1985	0	9,809	394	20	yes	p
U-240										
92240.35c	237.9944	endl85	LLNL	<1985	0	8,495	218	20	yes	p
Z=93**********Neptunium**********										
Np-235										
93235.35c	233.0249	endl85	LLNL	<1985	0	9,490	364	20	yes	p
Np-236										
93236.35c	234.0188	endl85	LLNL	<1985	0	8,821	284	20	yes	p
Np-237										
93237.35c	235.0118	endl85	LLNL	<1985	0	20,225	1,678	20	yes	p
93237.50c	235.0120	endf5p	B-V.0	1978	294	63,223	8,519	20	no	t
93237.55c	235.0120	rmccsa	T-2	1984	294	32,558	1,682	20	no	b
93237.60c	235.0118	endf60	B-VI.1	1990	294	105,150	7,218	20	yes	b
Np-238										
93238.35c	236.0060	endl85	LLNL	<1985	0	8,878	282	20	yes	p
Np-239										
93239.60c	236.9990	endf60	B-VI.0	1988	294	7,406	562	20	no	t
Z=94**********Plutonium**********										
Pu-236										
94236.60c	234.0180	endf60	B-VI.0	1978	294	33,448	4,610	20	no	t
Pu-237										
94237.35c	235.0120	endl85	LLNL	<1985	0	11,300	202	20	yes	p
94237.60c	235.0120	endf60	B-VI.0	1978	294	3,524	257	20	no	t
Pu-238										
94238.35c	236.0046	endl85	LLNL	<1985	0	15,619	958	20	yes	p
94238.50c	236.1670	endf5p	B-V.0	1978	294	18,763	2,301	20	no	t
94238.51c	236.1670	rmccs	B-V.0	1978	294	6,067	537	20	no	t
94238.60c	236.0045	endf60	B-VI.0	1978	294	29,054	3,753	20	no	b
Pu-239										
94239.50c	236.9990	endf5p	B-V.0	1976	294	74,049	7,809	20	yes	b
94239.55c	236.9990	rmccs	B-V.2	1983	294	102,099	10,318	20	yes	b
94239.60c	236.9986	endf60	B-VI.2	1993	294	283,354	26,847	20	yes	b
Pu-240										
94240.50c	237.9920	rmccs	B-V.0	1977	294	58,917	6,549	20	yes	b
94240.60c	237.9920	endf60	B-VI.2	1986	294	133,071	15,676	20	yes	b
Pu-241										

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
94241.35c	238.9860	endl85	LLNL	<1985	0	8,844	257	20	yes	p
94241.50c	238.9780	endf5p	B-V.0	1977	294	38,601	3,744	20	yes	b
94241.51c	238.9780	rmccs	B-V.0	1977	294	13,403	623	20	yes	b
94241.60c	238.9780	endf60	B-VI.1	1988	294	76,453	8,112	20	yes	b
Pu-242										
94242.35c	239.9793	endl85	LLNL	<1985	0	21,159	1,724	20	yes	p
94242.50c	239.9790	endf5p	B-V.0	1978	294	71,429	7,636	20	yes	b
94242.51c	239.9790	rmccs	B-V.0	1978	294	15,702	728	20	yes	b
94242.60c	239.9790	endf60	B-VI.0	1978	294	73,725	7,896	20	yes	b
Pu-243										
94243.35c	240.9740	endl85	LLNL	<1985	0	10,763	485	20	yes	p
94243.60c	240.9740	endf60	B-VI.2	1976	294	45,142	4,452	20	yes	t
Pu-244										
94244.60c	241.9680	endf60	B-VI.0	1978	294	23,654	3,695	20	no	t
Z=95**********Americium**********										
Am-241										
95241.35c	238.9860	endl85	LLNL	<1985	0	25,290	1,982	20	yes	p
95241.50c	238.9860	endf5u	B-V.0	1978	294	42,084	4,420	20	yes	t
95241.51c	238.9860	rmccs	B-V.0	1978	294	12,374	713	20	yes	t
95241.60c	238.9860	endf60	T-2	1994	300	168,924	13,556	30	yes	b
Am-242ms										
95242.35c	239.9801	endl85	LLNL	<1985	0	20,908	1,817	20	yes	p
95242.50c	239.9800	endf5u	B-V.0	1978	294	8,593	323	20	yes	t
95242.51c	239.9800	rmccs	B-V.0	1978	294	8,502	317	20	yes	t
Am-243										
95243.35c	240.9733	endl85	LLNL	<1985	0	39,400	4,093	20	yes	p
95243.50c	240.9730	endf5u	B-V.0	1978	294	92,015	11,921	20	yes	t
95243.51c	240.9730	rmccs	B-V.0	1978	294	13,684	757	20	yes	t
95243.60c	240.9730	endf60	B-VI.0	1988	294	104,257	11,984	20	yes	b
Z=96**********Curium**********										
Cm-241										
96241.60c	238.9870	endf60	B-VI.0	1978	294	3,132	278	20	no	t
Cm-242										
96242.35c	239.9794	endl85	LLNL	<1985	0	21,653	1,891	20	yes	p
96242.50c	239.9790	endf5u	B-V.0	1978	294	30,897	3,113	20	yes	t
96242.51c	239.9790	rmccs	B-V.0	1978	294	9,767	472	20	yes	t
96242.60c	239.9790	endf60	B-VI.0	1978	294	34,374	3,544	20	yes	b
Cm-243										
96243.35c	240.9733	endl85	LLNL	<1985	0	21,577	1,880	20	yes	p
96243.60c	240.9730	endf60	B-VI.0	1978	294	18,860	1,445	20	yes	t
Cm-244										
96244.35c	241.9661	endl85	LLNL	<1985	0	21,196	1,815	20	yes	p
96244.50c	241.9660	endf5u	B-V.0	1978	294	45,991	4,919	20	yes	t
96244.51c	241.9660	rmccs	B-V.0	1978	294	10,847	566	20	yes	t
96244.60c	241.9660	endf60	B-VI.0	1978	294	73,001	8,294	20	yes	t
Cm-245										
96245.35c	242.9602	endl85	LLNL	<1985	0	24,128	2,230	20	yes	p
96245.60c	242.9600	endf60	B-VI.2	1979	294	29,535	2,636	20	yes	b
Cm-246										

Table 4-1. Available Continuous-Energy MCNP Cross Section Libraries

ZAID	AWR	Library Name	Source	Eval Date	Temp (K)	Length (words)	NE	E_{max} (MeV)	GPD	$\bar{\nu}$
96246.35c	243.9534	endl85	LLNL	<1985	0	12,489	711	20	yes	p
96246.60c	243.9530	endf60	B-VI.2	1976	294	37,948	3,311	20	yes	t
Cm-247										
96247.35c	244.9479	endl85	LLNL	<1985	0	20,265	1,654	20	yes	p
96247.60c	244.9500	endf60	B-VI.2	1976	294	38,800	3,679	20	yes	t
Cm-248										
96248.35c	245.9413	endl85	LLNL	<1985	0	18,178	1,425	20	yes	p
96248.60c	245.9410	endf60	B-VI.0	1978	294	83,452	9,706	20	yes	t
Z=97**********Berkelium**********										
Bk-249										
97249.35c	246.9353	endl85	LLNL	<1985	0	11,783	633	20	yes	p
97249.60c	246.9400	endf60	B-VI:XTM	1986	294	50,503	5,268	20	no	b
Z=98**********Californium**********										
Cf-249										
98249.35c	246.9352	endl85	LLNL	<1985	0	28,055	2,659	20	yes	p
98249.60c	246.9400	endf60	B-VI:XTM	1989	294	41,271	4,329	20	no	b
Cf-250										
98250.35c	247.9281	endl85	LLNL	<1985	0	10,487	457	20	yes	p
98250.60c	247.9280	endf60	B-VI.2	1976	294	47,758	5,554	20	yes	t
Cf-251										
98251.35c	248.9227	endl85	LLNL	<1985	0	10,969	516	20	yes	p
98251.60c	248.9230	endf60	B-VI.2	1976	294	42,817	4,226	20	yes	b
Cf-252										
98252.35c	249.9161	endl85	LLNL	<1985	0	17,908	1,535	20	yes	p
98252.60c	249.9160	endf60	B-VI.2	1976	294	49,204	5,250	20	yes	b

Special Notes (pp. G-29 and G-30, Ref. 1):

Note 1: The data libraries previously known as EPRIXS and U600K are now a part of the data library ENDF5MT. (Affected cross section libraries: 1001.53c, 5010.53c, 8016.53c, 8016.54c, 54135.50c, 54135.53c, 54135.54c, 92235.52c, 92235.53c, 92235.54c, 92238.52c, 92238.53c, 92238.54c)

Note 2: Data translated to ENDF/B-VI format with some modifications by LANL. (Affected cross section library: 1002.60c)

Note 3: The 100XS data library contains data for 9 nuclides up to 100 MeV. Heating numbers on this data library are known to be incorrect, overestimating the energy deposition. (Affected cross section libraries: 4009.21c, 6012.21c, 8016.21c, 13027.21c, 14000.21c, 20040.21c, 26000.21c, 74000.21c, 92238.21c)

Note 4: The natural carbon data 6000.50c are repeated here with the ZAID of 6012.50c for the user's convenience. Both are based on the natural carbon ENDF/B-V.0 evaluation. (Affected cross section library: 6012.50c)

Note 5: The data libraries previously known as ARKRC, GDT2GP, IRNAT, MISCXS, TM169, and T2DDC are now part of the data library MISC5XS. (Affected cross section library: 6012.50c)

Note 6: Photon production data were added to the existing ENDF evaluation in 1984. A complete new evaluation was performed in 1986. (Affected cross section libraries: 18000.59c, 35079.55c, 35081.55c, 36082.59c, 36083.59c, 36084.59c, 36086.59c, 37085.55c, 37087.55c, 39089.35c, 40000.56c, 40000.57c, 40000.58c, 53127.55c, 55133.55c, 64152.55c, 64154.55c, 64155.55c, 64156.55c, 64157.55c, 64158.55c, 64160.55c, 69169.55c, 75185.32c, 75187.32c, 77000.55c)

Note 7: Photon production added to ENDF/B-V.0 neutron files by T-2, with the intent to estimate photon heating roughly. (Affected cross section libraries: 18000.59c, 36082.59c, 36083.59c, 36084.59c, 36086.59c)

Note 8: These data were taken from incomplete fission-product evaluations. (Affected cross section libraries: 35079.55c, 35081.55c, 37085.55c, 37087.55c, 53127.55c, 55133.55c)

Note 9: This is ENDF/B-V.0 after modification by evaluator to get better agreement with ENDL85. (Affected cross section library: 39089.50c)

Note 10: The following files for Zr have been replaced by the indicated ZAID, eliminating the rare problem of having a secondary neutron energy greater than the incident neutron energy caused by an ENDF/B-V.0 evaluation problem. Note that this correction has been made for the ENDF/B-VI evaluation (40000.60c).

40000.50c	rmccs	↦	40000.56c	misc5xs
40000.51c	endf5p	↦	40000.57c	misc5xs
40000.53c	eprixs	↦	40000.58c	misc5xs

Note 11: This note is not referenced in Table 4.1.

Note 12: The LANL/T-2 evaluation for I-127 was accepted for ENDF/B-VI.2 with modifications. These data are processed from the original LANL/T-2 evaluation. (Affected cross section library: 53127.60c)

Note 13: Photon production for GDT2GP. Photon production data were added to the ENDF/B-V.0 neutron cross sections by T-2. These data are valid only to 1 MeV. (Affected cross section libraries: 64152.55c, 64154.55c, 64155.55c, 64156.55c, 64157.55c, 64158.55c, 64160.55c)

Note 14: Photon production data added to original evaluation in 1981 by LANL. (Affected cross section library: 92233.60c)

5. Comparison of Available Cross Section Libraries

The comparison of the available continuous-energy cross section libraries documented in this report consisted of comparing the graphical representation of the various cross section libraries. A total of 757 plots were generated to compare the ACE format cross section libraries of 193 elements and isotopes. Table 5.10 presents the index for the 757 cross section plots. The cross section plots are presented in the Graphics Interchanged Format (GIF) on the attached CD-ROM identified as Attachment I. The filenames for the various cross section plots contained on the CD-ROM follow the format "p#.gif", where # corresponds to the plot number shown in Table 5.10. If multiple cross section libraries were available for each of the elements or isotopes, they were presented simultaneously in the various plots. If the natural cross section library and all of the constituent isotopic cross section libraries were available for a given element, a comparison plot was made for the natural cross section and isotopic representation of the natural cross section. The elements for which these natural versus isotopic-based natural cross section comparison plots were generated include: Cr, Fe, Ni, Cu, Ag, Eu, Gd, W, and Pb.

The natural versus isotopic-based natural cross section comparison plots for Eu are presented in Figures 5.1 through 5.6, as an example of the types of comparisons plots that are contained in Attachment I.

The various plots indexed in Table 5.10 were created using the MCPLOT feature available in MCNP4B (pp. B-10 through B-19, Ref. 1). The various cross section plots were generated using the following MCNP input deck:

```
Model for Cross Section Plotting
C
C   This model is used solely for cross section plotting.
C   The cross section plots for the QAP-3-5 technical
C   report entitled "Selection of MCNP Cross Section
C   Libraries" are generated using this model as a source.
C
C   Geometry Specifications
1   1   -1.0    -1    IMP:N=1   $ Sphere containing all cross section libraries
2   2   -1.0    +1 -2    IMP:N=1    $ Spherical shell containing natural Cr
3   3   -1.0    +2 -3    IMP:N=1    $ Spherical shell containing natural Fe
4   4   -1.0    +3 -4    IMP:N=1    $ Spherical shell containing natural Ni
5   5   -1.0    +4 -5    IMP:N=1    $ Spherical shell containing natural Cu
6   6   -1.0    +5 -6    IMP:N=1    $ Spherical shell containing natural Ag
7   7   -1.0    +6 -7    IMP:N=1    $ Spherical shell containing natural Ag
8   8   -1.0    +7 -8    IMP:N=1    $ Spherical shell containing natural Ag
9   9   -1.0    +8 -9    IMP:N=1    $ Spherical shell containing natural Eu
10   10   -1.0    +9 -10    IMP:N=1    $ Spherical shell containing natural Eu
11   11   -1.0    +10 -11    IMP:N=1    $ Spherical shell containing natural Eu
12   12   -1.0    +11 -12    IMP:N=1    $ Spherical shell containing natural Gd
13   13   -1.0    +12 -13    IMP:N=1    $ Spherical shell containing natural Gd
14   14   -1.0    +13 -14    IMP:N=1    $ Spherical shell containing natural Gd
15   15   -1.0    +14 -15    IMP:N=1    $ Spherical shell containing natural W
16   16   -1.0    +15 -16    IMP:N=1    $ Spherical shell containing natural W
17   17   -1.0    +16 -17    IMP:N=1    $ Spherical shell containing natural W
18   18   -1.0    +17 -18    IMP:N=1    $ Spherical shell containing natural Pb
19   0    +18    IMP:N=0    $ Zero importance region

C   Surface Specifications
1   SO   1
2   SO   2
3   SO   3
4   SO   4
5   SO   5
```

```
6   SO   6
7   SO   7
8   SO   8
9   SO   9
10   SO   10
11   SO   11
12   SO   12
13   SO   13
14   SO   14
15   SO   15
16   SO   16
17   SO   17
18   SO   18

C   Material Specifications
M1    1001.35c   -100
      1001.50c   -100
      1001.53c   -100
      1001.60c   -100
      1002.35c   -100
      1002.50c   -100
      1002.55c   -100
      1002.60c   -100
      1003.35c   -100
      1003.50c   -100
      1003.60c   -100
      2003.35c   -100
      2003.50c   -100
      2003.60c   -100
      2004.35c   -100
      2004.50c   -100
      2004.60c   -100
      3006.50c   -100
      3006.60c   -100
      3007.50c   -100
      3007.55c   -100
      3007.60c   -100
      4007.35c   -100
      4009.21c   -100
      4009.50c   -100
      4009.60c   -100
      5010.50c   -100
      5010.53c   -100
      5010.60c   -100
      5011.35c   -100
      5011.50c   -100
      5011.55c   -100
      5011.56c   -100
      5011.60c   -100
      6000.50c   -100
      6000.60c   -100
      6012.21c   -100
      6012.35c   -100
      6012.50c   -100
      6013.35c   -100
      7014.50c   -100
      7014.60c   -100
      7015.55c   -100
      7015.60c   -100
      8016.21c   -100
      8016.35c   -100
      8016.50c   -100
      8016.53c   -100
      8016.54c   -100
      8016.60c   -100
      8017.60c   -100
      9019.35c   -100
      9019.50c   -100
      9019.51c   -100
      9019.60c   -100
      11023.35c   -100
```

```
11023.50c   -100
11023.51c   -100
11023.60c   -100
12000.35c   -100
12000.50c   -100
12000.51c   -100
12000.60c   -100
13027.21c   -100
13027.35c   -100
13027.50c   -100
13027.60c   -100
14000.21c   -100
14000.35c   -100
14000.50c   -100
14000.51c   -100
14000.60c   -100
15031.35c   -100
15031.50c   -100
15031.51c   -100
15031.60c   -100
16000.60c   -100
16032.35c   -100
16032.50c   -100
16032.51c   -100
16032.60c   -100
17000.35c   -100
17000.50c   -100
17000.51c   -100
17000.60c   -100
18000.35c   -100
18000.59c   -100
19000.35c   -100
19000.50c   -100
19000.51c   -100
19000.60c   -100
20000.35c   -100
20000.50c   -100
20000.51c   -100
20000.60c   -100
20040.21c   -100
21045.60c   -100
22000.35c   -100
22000.50c   -100
22000.51c   -100
22000.60c   -100
23000.50c   -100
23000.51c   -100
23000.60c   -100
24000.35c   -100
24000.50c   -100
24050.60c   -100
24052.60c   -100
24053.60c   -100
24054.60c   -100
25055.35c   -100
25055.50c   -100
25055.51c   -100
25055.60c   -100
26000.21c   -100
26000.35c   -100
26000.50c   -100
26000.55c   -100
26054.60c   -100
26056.60c   -100
26057.60c   -100
26058.60c   -100
27059.35c   -100
27059.50c   -100
27059.51c   -100
27059.60c   -100
28000.50c   -100
```

```
28058.35c   -100
28058.60c   -100
28060.60c   -100
28061.60c   -100
28062.60c   -100
28064.60c   -100
29000.35c   -100
29000.50c   -100
29063.60c   -100
29065.60c   -100
31000.35c   -100
31000.50c   -100
31000.60c   -100
33074.35c   -100
33075.35c   -100
35079.55c   -100
35081.55c   -100
36078.50c   -100
36080.50c   -100
36082.50c   -100
36082.59c   -100
36083.50c   -100
36083.59c   -100
36084.50c   -100
36084.59c   -100
36086.50c   -100
36086.59c   -100
37085.55c   -100
37087.55c   -100
39088.35c   -100
39089.35c   -100
39089.50c   -100
39089.60c   -100
40000.35c   -100
40000.56c   -100
40000.57c   -100
40000.58c   -100
40000.60c   -100
40093.50c   -100
41093.35c   -100
41093.50c   -100
41093.51c   -100
41093.60c   -100
42000.35c   -100
42000.50c   -100
42000.51c   -100
42000.60c   -100
42095.50c   -100
43099.50c   -100
43099.60c   -100
44101.50c   -100
44103.50c   -100
45103.50c   -100
45105.50c   -100
45117.90c   -100
46105.50c   -100
46108.50c   -100
46119.90c   -100
47000.55c   -100
47107.35c   -100
47107.50c   -100
47107.60c   -100
47109.35c   -100
47109.50c   -100
47109.60c   -100
48000.35c   -100
48000.50c   -100
48000.51c   -100
49000.60c   -100
50000.35c   -100
53127.55c   -100
```

```
53127.60c   -100
53129.60c   -100
53135.50c   -100
54000.35c   -100
54131.50c   -100
54134.35c   -100
54135.50c   -100
54135.53c   -100
54135.54c   -100
55133.50c   -100
55133.55c   -100
55133.60c   -100
55134.60c   -100
55135.50c   -100
55135.60c   -100
55136.60c   -100
55137.60c   -100
56138.35c   -100
56138.50c   -100
56138.60c   -100
59141.50c   -100
60143.50c   -100
60145.50c   -100
60147.50c   -100
60148.50c   -100
61147.50c   -100
61148.50c   -100
61149.50c   -100
62147.50c   -100
62149.50c   -100
62150.50c   -100
62151.50c   -100
62152.50c   -100
63000.35c   -100
63151.50c   -100
63151.55c   -100
63151.60c   -100
63152.50c   -100
63153.50c   -100
63153.55c   -100
63153.60c   -100
63154.50c   -100
63155.50c   -100
64000.35c   -100
64152.50c   -100
64152.55c   -100
64152.60c   -100
64154.50c   -100
64154.55c   -100
64154.60c   -100
64155.50c   -100
64155.55c   -100
64155.60c   -100
64156.50c   -100
64156.55c   -100
64156.60c   -100
64157.50c   -100
64157.55c   -100
64157.60c   -100
64158.50c   -100
64158.55c   -100
64158.60c   -100
64160.50c   -100
64160.55c   -100
64160.60c   -100
67165.35c   -100
67165.55c   -100
67165.60c   -100
69169.55c   -100
72000.35c   -100
72000.50c   -100
```

```
72000.60c   -100
73181.35c   -100
73181.50c   -100
73181.51c   -100
73181.60c   -100
73182.60c   -100
74000.21c   -100
74000.55c   -100
74182.50c   -100
74182.55c   -100
74182.60c   -100
74183.50c   -100
74183.55c   -100
74183.60c   -100
74184.50c   -100
74184.55c   -100
74184.60c   -100
74186.50c   -100
74186.55c   -100
74186.60c   -100
75185.32c   -100
75185.35c   -100
75185.50c   -100
75185.60c   -100
75187.32c   -100
75187.35c   -100
75187.50c   -100
75187.60c   -100
77000.55c   -100
78000.35c   -100
79197.35c   -100
79197.50c   -100
79197.55c   -100
79197.56c   -100
79197.60c   -100
82000.35c   -100
82000.50c   -100
82206.60c   -100
82207.60c   -100
82208.60c   -100
83209.35c   -100
83209.50c   -100
83209.51c   -100
83209.60c   -100
90230.60c   -100
90231.35c   -100
90232.35c   -100
90232.50c   -100
90232.51c   -100
90232.60c   -100
90233.35c   -100
91231.60c   -100
91233.35c   -100
91233.50c   -100
91233.51c   -100
92232.60c   -100
92233.35c   -100
92233.50c   -100
92233.60c   -100
92234.35c   -100
92234.50c   -100
92234.51c   -100
92234.60c   -100
92235.50c   -100
92235.52c   -100
92235.53c   -100
92235.54c   -100
92235.60c   -100
92236.35c   -100
92236.50c   -100
92236.51c   -100
```

```
92236.60c  -100
92237.35c  -100
92237.50c  -100
92237.51c  -100
92238.21c  -100
92238.35c  -100
92238.50c  -100
92238.52c  -100
92238.53c  -100
92238.54c  -100
92238.60c  -100
92239.35c  -100
92240.35c  -100
93235.35c  -100
93236.35c  -100
93237.35c  -100
93237.50c  -100
93237.55c  -100
93237.60c  -100
93238.35c  -100
93239.60c  -100
94236.60c  -100
94237.35c  -100
94237.60c  -100
94238.35c  -100
94238.50c  -100
94238.51c  -100
94238.60c  -100
94239.50c  -100
94239.55c  -100
94239.60c  -100
94240.50c  -100
94240.60c  -100
94241.35c  -100
94241.50c  -100
94241.51c  -100
94241.60c  -100
94242.35c  -100
94242.50c  -100
94242.51c  -100
94242.60c  -100
94243.35c  -100
94243.60c  -100
94244.60c  -100
95241.35c  -100
95241.50c  -100
95241.51c  -100
95241.60c  -100
95242.35c  -100
95242.50c  -100
95242.51c  -100
95243.35c  -100
95243.50c  -100
95243.51c  -100
95243.60c  -100
96241.60c  -100
96242.35c  -100
96242.50c  -100
96242.51c  -100
96242.60c  -100
96243.35c  -100
96243.60c  -100
96244.35c  -100
96244.50c  -100
96244.51c  -100
96244.60c  -100
96245.35c  -100
96245.60c  -100
96246.35c  -100
96246.60c  -100
96247.35c  -100
```

```
        96247.60c   -100
        96248.35c   -100
        96248.60c   -100
        97249.35c   -100
        97249.60c   -100
        98249.35c   -100
        98249.60c   -100
        98250.35c   -100
        98250.60c   -100
        98251.35c   -100
        98251.60c   -100
        98252.35c   -100
        98252.60c   -100
M2      24050.60c   -4.173708 $ Natural Cr Using ENDF/B-VI Cross Section Libraries
        24052.60c   -83.700254
        24053.60c   -9.672640
        24054.60c   -2.453398
M3      26054.60c   -5.698834 $ Natural Fe Using ENDF/B-VI Cross Section Libraries
        26056.60c   -91.869632
        26057.60c   -2.141054
        26058.60c   -0.290481
M4      28058.60c   -67.394713 $ Natural Ni Using ENDF/B-VI Cross Section Libraries
        28060.60c   -26.652659
        28061.60c   -1.173193
        28062.60c   -3.788185
        28064.60c   -0.991250
M5      29063.60c   -68.499441 $ Natural Cu Using ENDF/B-VI Cross Section Libraries
        29065.60c   -31.500559
M6      47107.60c   -51.376290 $ Natural Ag Using ENDF/B-VI Cross Section Libraries (endf602)
        47109.60c   -48.623710
M7      47107.35c   -51.376290 $ Natural Ag Using ENDL Cross Section Libraries (endl852)
        47109.35c   -48.623710
M8      47107.50c   -51.376290 $ Natural Ag Using ENDF/B-V Cross Section Libraries (rmccsa2)
        47109.50c   -48.623710
M9      63151.60c   -47.471252 $ Natural Eu Using ENDF/B-VI Cross Section Libraries (endf602)
        63153.60c   -52.528748
M10     63151.50c   -47.471252 $ Natural Eu Using ENDF/B-V Cross Section Libraries (rmccs2)
        63153.50c   -52.528748
M11     63151.55c   -47.471252 $ Natural Eu Using ENDF/B-V Cross Section Libraries (newxs2)
        63153.55c   -52.528748
M12     64152.60c   -0.193219 $ Natural Gd Using ENDF/B-VI Cross Section Libraries (endf602)
        64154.60c   -2.133824
        64155.60c   -14.580782
        64156.60c   -20.296917
        64157.60c   -15.617353
        64158.60c   -24.946080
        64160.60c   -22.231825
M13     64152.50c   -0.193219 $ Natural Gd Using ENDF/B-V Cross Section Libraries (endf5u2)
        64154.50c   -2.133824
        64155.50c   -14.580782
        64156.50c   -20.296917
        64157.50c   -15.617353
        64158.50c   -24.946080
        64160.50c   -22.231825
M14     64152.55c   -0.193219 $ Natural Gd Using ENDF/B-V Cross Section Libraries (misc5xs2)
        64154.55c   -2.133824
        64155.55c   -14.580782
        64156.55c   -20.296917
        64157.55c   -15.617353
        64158.55c   -24.946080
        64160.55c   -22.231825
M15     74182.60c   -26.027729 $ Natural W Using ENDF/B-VI Cross Section Libraries (endf602)
        74183.60c   -14.209725
        74184.60c   -30.835720
        74186.60c   -28.926827
M16     74182.50c   -26.027729 $ Natural W Using ENDF/B-V Cross Section Libraries (endf5p2)
        74183.50c   -14.209725
        74184.50c   -30.835720
        74186.50c   -28.926827
M17     74182.55c   -26.027729 $ Natural W Using ENDF/B-V Cross Section Libraries (rmccsa2)
        74183.55c   -14.209725
```

```
      74184.55c   -30.835720
      74186.55c   -28.926827
M18   82206.60c   -23.948519 $ Natural Pb Using ENDF/B-VI Cross Section Libraries (endf602)
      82207.60c   -22.068637
      82208.60c   -53.982844
C
C   Fake control specifications
MODE N
KCODE   100 1 10 100
KSRC  0 0 0
PRINT -128
```

The natural compositions for material numbers M2 through M18 in the MCNP input deck presented above were calculated using Equations 5.1 and 5.2 and the data presented in Tables 5.1 through 5.9. The atomic weight ratio values for the various isotopes in Tables 5.1 through 5.9 were obtained from the *xsdir* file used by MCNP (p. F-2, Ref. 1 and p. III-3, Ref. 5). The atom percent in nature of the various isotopes in Tables 5.1 through 5.9 are obtained from Reference 7. The number of significant figures presented for the elemental atomic weight ratios and the isotopic weight percents in nature in Tables 5.1 through 5.9 are a function of the calculations and should not be interpreted as a reflection of accuracy.

Equation 5-1. Atomic Weight Ratio of Element in Nature (The atomic weight ratio of an entity is the ratio of the entity's mass to the mass of a neutron.)

$$\text{Atomic Weight Ratio of Element in Nature} = \sum_{i=1}^{I}\left[\begin{matrix}(\text{Atomic Weight Ratio of Isotope})_i * \\ (\text{Atom Percent of Isotope in Nature})_i\end{matrix}\right]$$

where I is the total number of isotopes composing the element in its natural state.

Equation 5-2. Weight Percent of an Isotope in a Natural Elemental Composition

$$\left[\begin{matrix}\text{Isotopic Weight Percent} \\ \text{in Elemental Composition}\end{matrix}\right] = \frac{\left[\begin{matrix}(\text{Atomic Weight Ratio of Isotope})* \\ (\text{Atom Percent of Isotope in Nature})\end{matrix}\right]}{(\text{Atomic Weight Ratio of Element in Nature})}$$

Table 5-1. Data for Isotopic Representation of Natural Chromium

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
Cr-50	49.5170	4.345	4.173708
Cr-52	51.4940	83.79	83.700254
Cr-53	52.4860	9.50	9.672640
Cr-54	53.4760	2.365	2.453398
Cr (natural)	51.549214	100	100

Table 5-2. Data for Isotopic Representation of Natural Iron

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
Fe-54	53.4760	5.9	5.698834
Fe-56	55.4540	91.72	91.869632
Fe-57	56.4460	2.1	2.141054
Fe-58	57.4360	0.28	0.290481
Fe (natural)	55.363680	100	100

Table 5-3. Data for Isotopic Representation of Natural Nickel

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
Ni-58	57.4380	68.27	67.394713
Ni-60	59.4160	26.10	26.652659
Ni-61	60.4080	1.13	1.173193
Ni-62	61.3960	3.59	3.788185
Ni-64	63.3790	0.91	0.991250
Ni (natural)	58.183974	100	100

Table 5-4. Data for Isotopic Representation of Natural Copper

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
Cu-63	62.3890	69.17	68.499441
Cu-65	64.3700	30.83	31.500559
Cu (natural)	62.999742	100	100

Table 5-5. Data for Isotopic Representation of Natural Silver

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
Ag-107	105.9870	51.839	51.376290
Ag-109	107.9690	48.161	48.623710
Ag (natural)	106.941551	100	100

Table 5-6. Data for Isotopic Representation of Natural Europium

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
Eu-151	149.6230	47.8	47.471252
Eu-153	151.6080	52.2	52.528748
Eu (natural)	150.659170	100	100

Table 5-7. Data for Isotopic Representation of Natural Gadolinium

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
Gd-152	150.6150	0.20	0.193219
Gd-154	152.5990	2.18	2.133824
Gd-155	153.5920	14.80	14.580782
Gd-156	154.5830	20.47	20.296917
Gd-157	155.5760	15.65	15.617353
Gd-158	156.5670	24.84	24.946080
Gd-160	158.5530	21.86	22.231825
Gd (natural)	155.901217	100	100

Table 5-8. Data for Isotopic Representation of Natural Tungsten

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
W-180	Cross Section Library Not Available	0.12	The atom % in nature of W-180 was added to the W-184 atom % in nature.
W-182	180.3900	26.3	26.027729
W-183	181.3800	14.28	14.209725
W-184	182.3700	30.7	30.835720
W-186	184.3600	28.6	28.926827
W (natural)	182.277028	100	100

Table 5-9. Data for Isotopic Representation of Natural Lead

Element or Isotope	Atomic Weight Ratio	Atom % in Nature	Weight % in Nature
Pb-204	Cross Section Library Not Available	1.4	The atom % in nature of Pb-204 was added to the Pb-208 atom % in nature.
Pb-206	204.2000	24.1	23.948519
Pb-207	205.2000	22.1	22.068637
Pb-208	206.1900	52.4	53.982844
Pb (natural)	205.491620	100	100

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
H-1	Elastic Scattering	Total	1
H-1	Total Absorption	Total	2
H-2	Elastic Scattering	Total	3
H-2	Total Absorption	Total	4
H-3	Elastic Scattering	Total	5
He-3	Elastic Scattering	Total	6
He-3	Total Absorption	Total	7
He-4	Elastic Scattering	Total	8
LI-6	Elastic Scattering	Total	9
LI-6	Total Absorption	Total	10
LI-7	Elastic Scattering	Total	11
LI-7	Total Absorption	Total	12
Be-7	Elastic Scattering	Total	13
Be-7	Total Absorption	Total	14
Be-9	Elastic Scattering	Total	15
Be-9	Total Absorption	Total	16
B-10	Elastic Scattering	Total	17
B-10	Elastic Scattering	0.1 to 50.0 MeV	18
B-10	Total Absorption	Total	19
B-10	Total Absorption	0.7 to 50.0 MeV	20
B-11	Elastic Scattering	Total	21
B-11	Elastic Scattering	0.01 to 20.0 MeV	22
B-11	Total Absorption	Total	23
B-11	Total Absorption	0.01 to 20.0 MeV	24
C (natural)	Elastic Scattering	Total	25
C (natural)	Elastic Scattering	1.0 to 20.0 MeV	26
C (natural)	Total Absorption	Total	27
C (natural)	Total Absorption	5.0 to 20.0 MeV	28
C-12	Elastic Scattering	Total	29
C-12	Elastic Scattering	1.0 to 20.0 MeV	30
C-12	Total Absorption	Total	31
C (natural) & C-12	Elastic Scattering	Total	32
C (natural) & C-12	Elastic Scattering	1.0 to 20.0 MeV	33
C (natural) & C-12	Total Absorption	Total	34
C (natural) & C-12	Total Absorption	1.0 to 20.0 MeV	35
C-13	Elastic Scattering	Total	36
C-13	Total Absorption	Total	37
N-14	Elastic Scattering	Total	38
N-14	Elastic Scattering	0.1 to 20.0 MeV	39
N-14	Total Absorption	Total	40

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
N-14	Total Absorption	0.1 to 20.0 MeV	41
N-15	Elastic Scattering	Total	42
N-15	Elastic Scattering	1.0 to 20.0 MeV	43
N-15	Total Absorption	Total	44
O-16	Elastic Scattering	Total	45
O-16	Elastic Scattering	0.3 to 20.0 MeV	46
O-16	Total Absorption	Total	47
O-16	Total Absorption	2.0 to 20.0 MeV	48
O-17	Elastic Scattering	Total	49
O-17	Total Absorption	Total	50
F-19	Elastic Scattering	Total	51
F-19	Elastic Scattering	0.01 to 20.0 MeV	52
F-19	Total Absorption	Total	53
F-19	Total Absorption	0.01 to 20.0 MeV	54
Na-23	Elastic Scattering	Total	55
Na-23	Elastic Scattering	0.001 to 20.0 MeV	56
Na-23	Total Absorption	Total	57
Na-23	Total Absorption	0.001 to 20.0 MeV	58
Mg (natural)	Elastic Scattering	Total	59
Mg (natural)	Elastic Scattering	0.01 to 20.0 MeV	60
Mg (natural)	Total Absorption	Total	61
Mg (natural)	Total Absorption	0.01 to 20.0 MeV	62
Al-27	Elastic Scattering	Total	63
Al-27	Elastic Scattering	0.003 to 20.0 MeV	64
Al-27	Total Absorption	Total	65
Si (natural)	Elastic Scattering	Total	66
Si (natural)	Elastic Scattering	0.005 to 20.0 MeV	67
Si (natural)	Total Absorption	Total	68
Si (natural)	Total Absorption	0.001 to 20.0 MeV	69
P-31	Elastic Scattering	Total	70
P-31	Elastic Scattering	0.002 to 20.0 MeV	71
P-31	Total Absorption	Total	72
P-31	Total Absorption	0.1 to 20.0 MeV	73
S (natural)	Elastic Scattering	Total	74
S (natural)	Total Absorption	Total	75
S-32	Elastic Scattering	Total	76
S-32	Elastic Scattering	0.01 to 20.0 MeV	77
S-32	Total Absorption	Total	78
S-32	Total Absorption	0.01 to 20.0 MeV	79
S (natural) & S-32	Elastic Scattering	Total	80
S (natural) & S-32	Elastic Scattering	0.01 to 20.0 MeV	81
S (natural) & S-32	Total Absorption	Total	82
S (natural) & S-32	Total Absorption	0.01 to 20.0 MeV	83
Cl (natural)	Elastic Scattering	Total	84
Cl (natural)	Elastic Scattering	1.0E-4 to 2.0 MeV	85
Cl (natural)	Total Absorption	Total	86
Ar (natural)	Elastic Scattering	Total	87
Ar (natural)	Total Absorption	Total	88
K (natural)	Elastic Scattering	Total	89
K (natural)	Elastic Scattering	0.001 to 10.0 MeV	90
K (natural)	Total Absorption	Total	91

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[a]
Ca (natural)	Elastic Scattering	Total	92
Ca (natural)	Elastic Scattering	0.01 to 20.0 MeV	93
Ca (natural)	Total Absorption	Total	94
Ca (natural)	Total Absorption	0.001 to 20.0 MeV	95
Ca-40	Elastic Scattering	Total	279
Ca-40	Total Absorption	Total	280
Sc-45	Elastic Scattering	Total	96
Sc-45	Elastic Scattering	0.001 to 0.2 MeV	97
Sc-45	Total Absorption	Total	98
Sc-45	Total Absorption	0.001 to 0.2 MeV	99
Ti (natural)	Elastic Scattering	Total	100
Ti (natural)	Elastic Scattering	0.002 to 0.3 MeV	101
Ti (natural)	Total Absorption	Total	102
Ti (natural)	Total Absorption	0.002 to 0.3 MeV	103
V (natural)	Elastic Scattering	Total	104
V (natural)	Elastic Scattering	0.001 to 20.0 MeV	105
V (natural)	Total Absorption	Total	106
V (natural)	Total Absorption	0.001 to 0.2 MeV	107
Cr (natural)	Elastic Scattering	Total	108
Cr (natural)	Elastic Scattering	0.01 to 5.0 MeV	109
Cr (natural)	Total Absorption	Total	110
Cr (natural)	Total Absorption	0.001 to 2.0 MeV	111
Cr Isotopic Cross Sections in Natural Composition & Natural Cr Cross Sections	Elastic Scattering	Total	112
Cr Isotopic Cross Sections in Natural Composition & Natural Cr Cross Sections	Elastic Scattering	1.0E-4 to 0.1 MeV	113
Cr Isotopic Cross Sections in Natural Composition & Natural Cr Cross Sections	Elastic Scattering	0.1 to 1.0 MeV	114
Cr Isotopic Cross Sections in Natural Composition & Natural Cr Cross Sections	Elastic Scattering	1.0 to 20.0 MeV	115
Cr Isotopic Cross Sections in Natural Composition & Natural Cr Cross Sections	Total Absorption	Total	116
Cr Isotopic Cross Sections in Natural Composition & Natural Cr Cross Sections	Total Absorption	0.001 to 0.01 MeV	117
Cr Isotopic Cross Sections in Natural Composition & Natural Cr Cross Sections	Total Absorption	0.01 to 1.0 MeV	118
Cr Isotopic Cross Sections in Natural Composition & Natural Cr Cross Sections	Total Absorption	1.0 to 20.0 MeV	119
Mn-55	Elastic Scattering	Total	120
Mn-55	Elastic Scattering	1.0E-4 to 0.01 MeV	121
Mn-55	Elastic Scattering	0.01 to 10.0 MeV	122
Mn-55	Total Absorption	Total	123
Mn-55	Total Absorption	1.0E-4 to 0.01 MeV	124
Mn-55	Total Absorption	0.01 to 0.2 MeV	125

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Fe (natural)	Elastic Scattering	Total	126
Fe (natural)	Elastic Scattering	0.001 to 0.1 MeV	127
Fe (natural)	Elastic Scattering	0.1 to 1.0 MeV	128
Fe (natural)	Elastic Scattering	1.0 to 10.0 MeV	129
Fe (natural)	Total Absorption	Total	130
Fe (natural)	Total Absorption	1.0E-4 to 0.01 MeV	131
Fe (natural)	Total Absorption	0.01 to 0.1 MeV	132
Fe (natural)	Total Absorption	0.1 to 1.0 MeV	133
Fe Isotopic Cross Sections in Natural Composition & Natural Fe Cross Sections	Elastic Scattering	Total	134
Fe Isotopic Cross Sections in Natural Composition & Natural Fe Cross Sections	Elastic Scattering	0.001 to 0.1 MeV	135
Fe Isotopic Cross Sections in Natural Composition & Natural Fe Cross Sections	Elastic Scattering	0.1 to 1.0 MeV	136
Fe Isotopic Cross Sections in Natural Composition & Natural Fe Cross Sections	Elastic Scattering	1.0 to 10.0 MeV	137
Fe Isotopic Cross Sections in Natural Composition & Natural Fe Cross Sections	Total Absorption	Total	138
Fe Isotopic Cross Sections in Natural Composition & Natural Fe Cross Sections	Total Absorption	0.001 to 0.1 MeV	139
Fe Isotopic Cross Sections in Natural Composition & Natural Fe Cross Sections	Total Absorption	0.1 to 1.0 MeV	140
Co-59	Elastic Scattering	Total	141
Co-59	Elastic Scattering	0.01 to 0.1 MeV	142
Co-59	Elastic Scattering	0.1 to 1.0 MeV	143
Co-59	Elastic Scattering	1.0 to 10.0 MeV	144
Co-59	Total Absorption	Total	145
Co-59	Total Absorption	0.001 to 0.01 MeV	146
Co-59	Total Absorption	0.01 to 0.1 MeV	147
Co-59	Total Absorption	0.1 to 20.0 MeV	148
Ni Isotopic Cross Sections in Natural Composition & Natural Ni Cross Sections	Elastic Scattering	Total	149
Ni Isotopic Cross Sections in Natural Composition & Natural Ni Cross Sections	Elastic Scattering	0.01 to 0.1 MeV	150
Ni Isotopic Cross Sections in Natural Composition & Natural Ni Cross Sections	Elastic Scattering	0.1 to 1.0 MeV	151
Ni Isotopic Cross Sections in Natural Composition & Natural Ni Cross Sections	Elastic Scattering	1.0 to 10.0 MeV	152
Ni Isotopic Cross Sections in Natural Composition & Natural Ni Cross Sections	Total Absorption	Total	153

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Ni Isotopic Cross Sections in Natural Composition & Natural Ni Cross Sections	Total Absorption	0.001 to 0.01 MeV	154
Ni Isotopic Cross Sections in Natural Composition & Natural Ni Cross Sections	Total Absorption	0.01 to 0.1 MeV	155
Ni Isotopic Cross Sections in Natural Composition & Natural Ni Cross Sections	Total Absorption	0.1 to 1.0 MeV	156
Ni-58	Elastic Scattering	Total	157
Ni-58	Elastic Scattering	0.01 to 1.0 MeV	158
Ni-58	Elastic Scattering	1.0 to 10.0 MeV	159
Ni-58	Total Absorption	Total	160
Ni-58	Total Absorption	0.001 to 0.1 MeV	161
Ni-58	Total Absorption	0.1 to 1.0 MeV	162
Cu Isotopic Cross Sections in Natural Composition & Natural Cu Cross Sections	Elastic Scattering	Total	163
Cu Isotopic Cross Sections in Natural Composition & Natural Cu Cross Sections	Elastic Scattering	2.0E-4 to 0.01 MeV	164
Cu Isotopic Cross Sections in Natural Composition & Natural Cu Cross Sections	Elastic Scattering	0.01 to 0.1 MeV	165
Cu Isotopic Cross Sections in Natural Composition & Natural Cu Cross Sections	Elastic Scattering	0.1 to 1.0 MeV	166
Cu Isotopic Cross Sections in Natural Composition & Natural Cu Cross Sections	Total Absorption	Total	167
Cu Isotopic Cross Sections in Natural Composition & Natural Cu Cross Sections	Total Absorption	1.0E-4 to 0.001 MeV	168
Cu Isotopic Cross Sections in Natural Composition & Natural Cu Cross Sections	Total Absorption	0.001 to 0.01 MeV	169
Cu Isotopic Cross Sections in Natural Composition & Natural Cu Cross Sections	Total Absorption	0.01 to 0.2 MeV	170
Ga (natural)	Elastic Scattering	Total	171
Ga (natural)	Total Absorption	Total	172
As-74	Elastic Scattering	Total	173
As-74	Total Absorption	Total	174
As-75	Elastic Scattering	Total	175
As-75	Total Absorption	Total	176
Br-79	Elastic Scattering	Total	177
Br-79	Total Absorption	Total	178
Br-81	Elastic Scattering	Total	179
Br-81	Total Absorption	Total	180
Kr-78	Elastic Scattering	Total	181
Kr-78	Total Absorption	Total	182
Kr-80	Elastic Scattering	Total	183

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number
Kr-80	Total Absorption	Total	184
Kr-82	Elastic Scattering	Total	185
Kr-82	Total Absorption	Total	186
Kr-83	Elastic Scattering	Total	187
Kr-83	Total Absorption	Total	188
Kr-84	Elastic Scattering	Total	189
Kr-84	Total Absorption	Total	190
Kr-86	Elastic Scattering	Total	191
Kr-86	Total Absorption	Total	192
Rb-85	Elastic Scattering	Total	193
Rb-85	Total Absorption	Total	194
Rb-87	Elastic Scattering	Total	195
Rb-87	Total Absorption	Total	196
Y-88	Elastic Scattering	Total	197
Y-88	Total Absorption	Total	198
Y-89	Elastic Scattering	Total	199
Y-89	Elastic Scattering	0.001 to 0.01 MeV	200
Y-89	Elastic Scattering	0.01 to 0.1 MeV	201
Y-89	Elastic Scattering	0.1 to 1.0 MeV	202
Y-89	Total Absorption	Total	203
Y-89	Total Absorption	0.001 to 0.01 MeV	204
Y-89	Total Absorption	0.01 to 0.1 MeV	205
Y-89	Total Absorption	0.1 to 1.0 MeV	206
Zr (natural)	Elastic Scattering	Total	207
Zr (natural)	Elastic Scattering	1.0E-4 to 0.001 MeV	208
Zr (natural)	Elastic Scattering	0.001 to 0.01 MeV	209
Zr (natural)	Elastic Scattering	0.01 to 0.1 MeV	210
Zr (natural)	Total Absorption	Total	211
Zr (natural)	Total Absorption	1.0E-4 to 0.001 MeV	212
Zr (natural)	Total Absorption	0.001 to 0.01 MeV	213
Zr (natural)	Total Absorption	0.01 to 0.1 MeV	214
Zr-93	Elastic Scattering	Total	215
Zr-93	Total Absorption	Total	216
Nb-93	Elastic Scattering	Total	217
Nb-93	Elastic Scattering	1.0E-4 to 0.001 MeV	218
Nb-93	Elastic Scattering	0.001 to 0.01 MeV	219
Nb-93	Total Absorption	Total	220
Nb-93	Total Absorption	1.0E-5 to 1.0E-4 MeV	221
Nb-93	Total Absorption	1.0E-4 to 0.001 MeV	222
Nb-93	Total Absorption	0.001 to 0.01 MeV	223
Nb-93	Total Absorption	0.01 to 1.0 MeV	224
Mo (natural)	Elastic Scattering	Total	225
Mo (natural)	Elastic Scattering	1.0E-5 to 0.01 MeV	226
Mo (natural)	Total Absorption	Total	227
Mo (natural)	Total Absorption	1.0E-5 to 0.002 MeV	228
Mo-95	Elastic Scattering	Total	229
Mo-95	Total Absorption	Total	230
Tc-99	Elastic Scattering	Total	231
Tc-99	Total Absorption	Total	232
Ru-101	Elastic Scattering	Total	233
Ru-101	Total Absorption	Total	234

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number
Ru-103	Elastic Scattering	Total	235
Ru-103	Total Absorption	Total	236
Rh-103	Elastic Scattering	Total	237
Rh-103	Total Absorption	Total	238
Rh-105	Elastic Scattering	Total	239
Rh-105	Total Absorption	Total	240
Pd-105	Elastic Scattering	Total	241
Pd-105	Total Absorption	Total	242
Pd-108	Elastic Scattering	Total	243
Pd-108	Total Absorption	Total	244
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Elastic Scattering	Total	245
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Elastic Scattering	1.0E-6 to 1.0E-5 MeV	246
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	247
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Elastic Scattering	1.0E-4 to 0.001 MeV	248
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Elastic Scattering	0.001 to 0.01 MeV	249
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Total Absorption	Total	250
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Total Absorption	1.0E-5 to 1.0E-4 MeV	251
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Total Absorption	1.0E-4 to 0.001 MeV	252
Ag Isotopic Cross Sections in Natural Composition & Natural Ag Cross Sections	Total Absorption	0.001 to 0.01 MeV	253
Ag-107	Elastic Scattering	Total	254
Ag-107	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	255
Ag-107	Elastic Scattering	1.0E-4 to 0.001 MeV	256
Ag-107	Elastic Scattering	0.001 to 0.01 MeV	257
Ag-107	Total Absorption	Total	258
Ag-107	Total Absorption	1.0E-5 to 1.0E-4 MeV	259
Ag-107	Total Absorption	1.0E-4 to 0.001 MeV	260
Ag-107	Total Absorption	0.001 to 0.01 MeV	261
Ag-109	Elastic Scattering	Total	262
Ag-109	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	263
Ag-109	Elastic Scattering	1.0E-4 to 0.001 MeV	264
Ag-109	Elastic Scattering	0.001 to 0.01 MeV	265
Ag-109	Total Absorption	Total	266
Ag-109	Total Absorption	1.0E-5 to 1.0E-4 MeV	267
Ag-109	Total Absorption	1.0E-4 to 0.001 MeV	268

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Ag-109	Total Absorption	0.001 to 0.01 MeV	269
Cd (natural)	Elastic Scattering	Total	270
Cd (natural)	Elastic Scattering	3.0E-5 to 0.002 MeV	271
Cd (natural)	Total Absorption	Total	272
Cd (natural)	Total Absorption	1.0E-5 to 1.0E-4 MeV	273
Cd (natural)	Total Absorption	1.0E-4 to 0.002 MeV	274
In (natural)	Elastic Scattering	Total	275
In (natural)	Total Absorption	Total	276
Sn (natural)	Elastic Scattering	Total	277
Sn (natural)	Total Absorption	Total	278
I-127	Elastic Scattering	Total	281
I-127	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	282
I-127	Elastic Scattering	1.0E-4 to 0.002 MeV	283
I-127	Total Absorption	Total	284
I-127	Total Absorption	1.0E-5 to 1.0E-4 MeV	285
I-127	Total Absorption	1.0E-4 to 0.002 MeV	286
I-129	Elastic Scattering	Total	287
I-129	Total Absorption	Total	288
I-135	Elastic Scattering	Total	289
I-135	Total Absorption	Total	290
Xe (natural)	Elastic Scattering	Total	291
Xe (natural)	Total Absorption	Total	292
Xe-131	Elastic Scattering	Total	293
Xe-131	Total Absorption	Total	294
Xe-134	Elastic Scattering	Total	295
Xe-134	Total Absorption	Total	296
Xe-135	Elastic Scattering	Total	297
Xe-135	Total Absorption	Total	298
Cs-133	Elastic Scattering	Total	299
Cs-133	Elastic Scattering	1.0E-5 to 2.0E-4 MeV	300
Cs-133	Elastic Scattering	2.0E-4 to 0.003 MeV	301
Cs-133	Total Absorption	Total	302
Cs-133	Total Absorption	2.0E-6 to 1.0E-4 MeV	303
Cs-133	Total Absorption	1.0E-4 to 0.004 MeV	304
Cs-134	Elastic Scattering	Total	305
Cs-134	Total Absorption	Total	306
Cs-135	Elastic Scattering	Total	307
Cs-135	Total Absorption	Total	308
Cs-136	Elastic Scattering	Total	309
Cs-136	Total Absorption	Total	310
Cs-137	Elastic Scattering	Total	311
Cs-137	Total Absorption	Total	312
Ba-138	Elastic Scattering	Total	313
Ba-138	Elastic Scattering	0.003 to 2.0 MeV	314
Ba-138	Total Absorption	Total	315
Pr-141	Elastic Scattering	Total	316
Pr-141	Total Absorption	Total	317
Nd-143	Elastic Scattering	Total	318
Nd-143	Total Absorption	Total	319
Nd-145	Elastic Scattering	Total	320
Nd-145	Total Absorption	Total	321

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Nd-147	Elastic Scattering	Total	322
Nd-147	Total Absorption	Total	323
Nd-148	Elastic Scattering	Total	324
Nd-148	Total Absorption	Total	325
Pm-147	Elastic Scattering	Total	326
Pm-147	Total Absorption	Total	327
Pm-148	Elastic Scattering	Total	328
Pm-148	Total Absorption	Total	329
Pm-149	Elastic Scattering	Total	330
Pm-149	Total Absorption	Total	331
Sm-147	Elastic Scattering	Total	332
Sm-147	Total Absorption	Total	333
Sm-149	Elastic Scattering	Total	334
Sm-149	Total Absorption	Total	335
Sm-150	Elastic Scattering	Total	336
Sm-150	Total Absorption	Total	337
Sm-151	Elastic Scattering	Total	338
Sm-151	Total Absorption	Total	339
Sm-152	Elastic Scattering	Total	340
Sm-152	Total Absorption	Total	341
Eu Isotopic Cross Sections in Natural Composition & Natural Eu Cross Sections	Elastic Scattering	Total	342
Eu Isotopic Cross Sections in Natural Composition & Natural Eu Cross Sections	Elastic Scattering	1.0E-6 to 1.0E-5 MeV	343
Eu Isotopic Cross Sections in Natural Composition & Natural Eu Cross Sections	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	344
Eu Isotopic Cross Sections in Natural Composition & Natural Eu Cross Sections	Total Absorption	Total	345
Eu Isotopic Cross Sections in Natural Composition & Natural Eu Cross Sections	Total Absorption	1.0E-6 to 1.0E-5 MeV	346
Eu Isotopic Cross Sections in Natural Composition & Natural Eu Cross Sections	Total Absorption	1.0E-5 to 2.0E-4 MeV	347
Eu-151	Elastic Scattering	Total	348
Eu-151	Elastic Scattering	1.0E-6 to 3.0E-5 MeV	349
Eu-151	Elastic Scattering	3.0E-5 to 2.0E-4 MeV	350
Eu-151	Total Absorption	Total	351
Eu-151	Total Absorption	1.0E-6 to 3.0E-5 MeV	352
Eu-151	Total Absorption	3.0E-5 to 2.0E-4 MeV	353
Eu-152	Elastic Scattering	Total	354
Eu-152	Total Absorption	Total	355
Eu-153	Elastic Scattering	Total	356
Eu-153	Elastic Scattering	1.0E-6 to 2.0E-5 MeV	357
Eu-153	Elastic Scattering	2.0E-5 to 2.0E-4 MeV	358
Eu-153	Total Absorption	Total	359
Eu-153	Total Absorption	1.0E-6 to 2.0E-5 MeV	360
Eu-153	Total Absorption	2.0E-5 to 2.0E-4 MeV	361

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number
Eu-154	Elastic Scattering	Total	362
Eu-154	Total Absorption	Total	363
Eu-155	Elastic Scattering	Total	364
Eu-155	Total Absorption	Total	365
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Elastic Scattering	Total	366
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Elastic Scattering	1.0E-6 to 1.0E-5 MeV	367
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	368
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Elastic Scattering	1.0E-4 to 0.001 MeV	369
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Elastic Scattering	0.001 to 0.02 MeV	370
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Total Absorption	Total	371
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Total Absorption	1.0E-6 to 1.0E-5 MeV	372
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Total Absorption	1.0E-5 to 1.0E-4 MeV	373
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Total Absorption	1.0E-4 to 0.001 MeV	374
Gd Isotopic Cross Sections in Natural Composition & Natural Gd Cross Sections	Total Absorption	0.001 to 0.02 MeV	375
Gd-152	Elastic Scattering	Total	376
Gd-152	Elastic Scattering	2.0E-6 to 3.0E-4 MeV	377
Gd-152	Total Absorption	Total	378
Gd-152	Total Absorption	2.0E-6 to 3.0E-4 MeV	379
Gd-154	Elastic Scattering	Total	380
Gd-154	Elastic Scattering	1.0E-5 to 0.002 MeV	381
Gd-154	Total Absorption	Total	382
Gd-154	Total Absorption	1.0E-5 to 1.0E-4 MeV	383
Gd-154	Total Absorption	1.0E-4 to 0.002 MeV	384
Gd-155	Elastic Scattering	Total	385
Gd-155	Elastic Scattering	1.0E-6 to 3.0E-5 MeV	386
Gd-155	Elastic Scattering	3.0E-5 to 2.0E-4 MeV	387
Gd-155	Total Absorption	Total	388
Gd-155	Total Absorption	1.0E-6 to 2.0E-5 MeV	389
Gd-155	Total Absorption	2.0E-5 to 3.0E-4 MeV	390
Gd-156	Elastic Scattering	Total	391
Gd-156	Elastic Scattering	2.0E-5 to 0.002 MeV	392
Gd-156	Total Absorption	Total	393

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Gd-156	Total Absorption	2.0E-5 to 0.002 MeV	394
Gd-157	Elastic Scattering	Total	395
Gd-157	Elastic Scattering	2.0E-5 to 8.0E-4 MeV	396
Gd-157	Total Absorption	Total	397
Gd-157	Total Absorption	1.0E-5 to 4.0E-4 MeV	398
Gd-158	Elastic Scattering	Total	399
Gd-158	Elastic Scattering	2.0E-4 to 0.02 MeV	400
Gd-158	Total Absorption	Total	401
Gd-158	Total Absorption	2.0E-4 to 0.004 MeV	402
Gd-158	Total Absorption	0.004 to 0.02 MeV	403
Gd-160	Elastic Scattering	Total	404
Gd-160	Elastic Scattering	2.0E-4 to 0.02 MeV	405
Gd-160	Total Absorption	Total	406
Gd-160	Total Absorption	2.0E-4 to 0.002 MeV	407
Gd-160	Total Absorption	0.002 to 0.02 MeV	408
Ho-165	Elastic Scattering	Total	409
Ho-165	Elastic Scattering	2.0E-6 to 1.0E-4 MeV	410
Ho-165	Elastic Scattering	1.0E-4 to 0.002 MeV	411
Ho-165	Total Absorption	Total	412
Ho-165	Total Absorption	1.0E-6 to 1.0E-4 MeV	413
Ho-165	Total Absorption	1.0E-4 to 0.002 MeV	414
Tm-169	Elastic Scattering	Total	415
Tm-169	Total Absorption	Total	416
Hf (natural)	Elastic Scattering	Total	417
Hf (natural)	Elastic Scattering	1.0E-6 to 1.0E-4 MeV	418
Hf (natural)	Elastic Scattering	1.0E-4 to 0.001 MeV	419
Hf (natural)	Elastic Scattering	0.001 to 0.02 MeV	420
Hf (natural)	Total Absorption	Total	421
Hf (natural)	Total Absorption	1.0E-5 to 3.0E-4 MeV	422
Hf (natural)	Total Absorption	3.0E-4 to 0.003 MeV	423
Hf (natural)	Total Absorption	0.003 to 0.02 MeV	424
Ta-181	Elastic Scattering	Total	425
Ta-181	Elastic Scattering	2.0E-6 to 1.0E-4 MeV	426
Ta-181	Elastic Scattering	1.0E-4 to 0.004 MeV	427
Ta-181	Total Absorption	Total	428
Ta-181	Total Absorption	2.0E-6 to 2.0E-4 MeV	429
Ta-181	Total Absorption	2.0E-4 to 5.0E-4 MeV	430
Ta-182	Elastic Scattering	Total	431
Ta-182	Total Absorption	Total	432
W Isotopic Cross Sections in Natural Composition & Natural W Cross Sections	Elastic Scattering	Total	433
W Isotopic Cross Sections in Natural Composition & Natural W Cross Sections	Elastic Scattering	1.0E-6 to 2.0E-4 MeV	434
W Isotopic Cross Sections in Natural Composition & Natural W Cross Sections	Elastic Scattering	2.0E-4 to 0.001 MeV	435
W Isotopic Cross Sections in Natural Composition & Natural W Cross Sections	Elastic Scattering	0.001 to 0.008 MeV	436

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
W Isotopic Cross Sections in Natural Composition & Natural W Cross Sections	Total Absorption	Total	437
W Isotopic Cross Sections in Natural Composition & Natural W Cross Sections	Total Absorption	1.0E-6 to 3.0E-4 MeV	438
W Isotopic Cross Sections in Natural Composition & Natural W Cross Sections	Total Absorption	3.0E-4 to 0.001 MeV	439
W Isotopic Cross Sections in Natural Composition & Natural W Cross Sections	Total Absorption	0.001 to 0.01 MeV	440
W-182	Elastic Scattering	Total	441
W-182	Elastic Scattering	2.0E-4 to 0.004 MeV	442
W-182	Total Absorption	Total	443
W-182	Total Absorption	2.0E-4 to 0.001 MeV	444
W-182	Total Absorption	0.001 to 0.08 MeV	445
W-183	Elastic Scattering	Total	446
W-183	Elastic Scattering	1.0E-5 to 0.002 MeV	447
W-183	Total Absorption	Total	448
W-183	Total Absorption	1.0E-4 to 0.002 MeV	449
W-184	Elastic Scattering	Total	450
W-184	Elastic Scattering	1.0E-4 to 0.003 MeV	451
W-184	Total Absorption	Total	452
W-184	Total Absorption	1.0E-4 to 0.003 MeV	453
W-186	Elastic Scattering	Total	454
W-186	Elastic Scattering	1.0E-4 to 0.005 MeV	455
W-186	Total Absorption	Total	456
W-186	Total Absorption	1.0E-4 to 0.008 MeV	457
Re-185	Elastic Scattering	Total	458
Re-185	Elastic Scattering	1.0E-6 to 1.0E-4 MeV	459
Re-185	Elastic Scattering	1.0E-4 to 0.003 MeV	460
Re-185	Total Absorption	Total	461
Re-185	Total Absorption	1.0E-6 to 1.0E-4 MeV	462
Re-185	Total Absorption	1.0E-4 to 0.003 MeV	463
Re-187	Elastic Scattering	Total	464
Re-187	Elastic Scattering	1.0E-6 to 1.0E-4 MeV	465
Re-187	Elastic Scattering	1.0E-4 to 0.003 MeV	466
Re-187	Total Absorption	Total	467
Re-187	Total Absorption	1.0E-6 to 1.0E-4 MeV	468
Re-187	Total Absorption	1.0E-4 to 0.003 MeV	469
Ir (natural)	Elastic Scattering	Total	470
Ir (natural)	Total Absorption	Total	471
Pt (natural)	Elastic Scattering	Total	472
Pt (natural)	Total Absorption	Total	473
Au-197	Elastic Scattering	Total	474
Au-197	Elastic Scattering	3.0E-6 to 2.0E-4 MeV	475
Au-197	Elastic Scattering	2.0E-4 to 0.002 MeV	476
Au-197	Elastic Scattering	0.002 to 0.01 MeV	477
Au-197	Total Absorption	Total	478
Au-197	Total Absorption	1.0E-6 to 0.001 MeV	479
Au-197	Total Absorption	0.001 to 0.006 MeV	480

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number
Pb Isotopic Cross Sections in Natural Composition & Natural Pb Cross Sections	Elastic Scattering	Total	481
Pb Isotopic Cross Sections in Natural Composition & Natural Pb Cross Sections	Elastic Scattering	0.001 to 0.1 MeV	482
Pb Isotopic Cross Sections in Natural Composition & Natural Pb Cross Sections	Elastic Scattering	0.1 to 1.0 MeV	483
Pb Isotopic Cross Sections in Natural Composition & Natural Pb Cross Sections	Elastic Scattering	1.0 to 10.0 MeV	484
Pb Isotopic Cross Sections in Natural Composition & Natural Pb Cross Sections	Total Absorption	Total	485
Pb Isotopic Cross Sections in Natural Composition & Natural Pb Cross Sections	Total Absorption	0.001 to 0.1 MeV	486
Pb Isotopic Cross Sections in Natural Composition & Natural Pb Cross Sections	Total Absorption	0.1 to 1.0 MeV	487
Pb-206	Elastic Scattering	Total	488
Pb-206	Total Absorption	Total	489
Pb-207	Elastic Scattering	Total	490
Pb-207	Total Absorption	Total	491
Pb-208	Elastic Scattering	Total	492
Pb-208	Total Absorption	Total	493
Bi-209	Elastic Scattering	Total	494
Bi-209	Elastic Scattering	7.0E-4 to 0.1 MeV	495
Bi-209	Elastic Scattering	0.1 to 2.0 MeV	496
Bi-209	Total Absorption	Total	497
Bi-209	Total Absorption	7.0E-4 to 0.02 MeV	498
Bi-209	Total Absorption	0.02 to 0.2 MeV	499
Th-230	Elastic Scattering	Total	500
Th-230	Total Absorption	Total	501
Th-230	Total Fission	Total	672
Th-231	Elastic Scattering	Total	502
Th-231	Total Absorption	Total	503
Th-231	Total Fission	Total	673
Th-232	Elastic Scattering	Total	504
Th-232	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	505
Th-232	Elastic Scattering	1.0E-4 to 0.001 MeV	506
Th-232	Elastic Scattering	0.001 to 0.005 MeV	507
Th-232	Total Absorption	Total	508
Th-232	Total Absorption	1.0E-5 to 3.0E-4 MeV	509
Th-232	Total Absorption	3.0E-4 to 0.001 MeV	510
Th-232	Total Absorption	0.001 to 0.005 MeV	511
Th-232	Total Fission	Total	674
Th-233	Elastic Scattering	Total	512
Th-233	Total Absorption	Total	513
Th-233	Total Fission	Total	675
Pa-231	Elastic Scattering	Total	514

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Pa-231	Total Absorption	Total	515
Pa-231	Total Fission	Total	676
Pa-233	Elastic Scattering	Total	516
Pa-233	Elastic Scattering	1.0E-6 to 6.0E-5 MeV	517
Pa-233	Total Absorption	Total	518
Pa-233	Total Absorption	1.0E-6 to 8.0E-5 MeV	519
Pa-233	Total Fission	Total	677
U-232	Elastic Scattering	Total	520
U-232	Total Absorption	Total	521
U-232	Total Fission	Total	678
U-233	Elastic Scattering	Total	522
U-233	Elastic Scattering	1.0E-6 to 1.0E-4 MeV	523
U-233	Total Absorption	Total	524
U-233	Total Absorption	1.0E-6 to 1.0E-5 MeV	525
U-233	Total Absorption	1.0E-5 to 1.0E-4 MeV	526
U-233	Total Fission	Total	679
U-233	Total Fission	1.0E-6 to 1.0E-4 MeV	680
U-234	Elastic Scattering	Total	527
U-234	Elastic Scattering	1.0E-6 to 1.0E-5 MeV	528
U-234	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	529
U-234	Elastic Scattering	1.0E-4 to 0.001 MeV	530
U-234	Elastic Scattering	0.001 to 0.01 MeV	531
U-234	Total Absorption	Total	532
U-234	Total Absorption	1.0E-5 to 3.0E-4 MeV	533
U-234	Total Absorption	3.0E-4 to 0.002 MeV	534
U-234	Total Fission	Total	681
U-234	Total Fission	1.0E-5 to 0.002 MeV	682
U-235	Elastic Scattering	Total	535
U-235	Elastic Scattering	1.0E-6 to 1.0E-5 MeV	536
U-235	Elastic Scattering	1.0E-5 to 1.0E-4 MeV	537
U-235	Elastic Scattering	1.0E-4 to 7.0E-4 MeV	538
U-235	Elastic Scattering	7.0E-4 to 0.003 MeV	539
U-235	Total Absorption	Total	540
U-235	Total Absorption	1.0E-6 to 4.0E-5 MeV	541
U-235	Total Absorption	4.0E-5 to 4.0E-4 MeV	542
U-235	Total Absorption	4.0E-4 to 0.001 MeV	543
U-235	Total Absorption	0.001 to 0.003 MeV	544
U-235	Total Fission	Total	683
U-235	Total Fission	1.0E-6 to 1.0E-5 MeV	684
U-235	Total Fission	1.0E-5 to 1.0E-4 MeV	685
U-235	Total Fission	1.0E-4 to 0.003 MeV	686
U-236	Elastic Scattering	Total	545
U-236	Elastic Scattering	1.0E-6 to 3.0E-4 MeV	546
U-236	Elastic Scattering	3.0E-4 to 0.002 MeV	547
U-236	Total Absorption	Total	548
U-236	Total Absorption	1.0E-6 to 3.0E-4 MeV	549
U-236	Total Absorption	3.0E-4 to 0.005 MeV	550
U-236	Total Fission	Total	687
U-236	Total Fission	3.0E-5 to 4.0E-4 MeV	688
U-236	Total Fission	4.0E-4 to 0.002 MeV	689
U-236	Total Fission	0.002 to 0.005 MeV	690

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[3]
U-237	Elastic Scattering	Total	551
U-237	Elastic Scattering	9.0E-6 to 2.0E-4 MeV	552
U-237	Total Absorption	Total	553
U-237	Total Absorption	4.0E-6 to 2.0E-4 MeV	554
U-237	Total Fission	Total	691
U-237	Total Fission	9.0E-6 to 2.0E-4 MeV	692
U-238	Elastic Scattering[4]	Total	555
U-238	Elastic Scattering[4]	1.0E-6 to 1.0E-4 MeV	556
U-238	Elastic Scattering[4]	1.0E-4 to 0.001 MeV	557
U-238	Elastic Scattering[4]	0.001 to 0.005 MeV	558
U-238	Elastic Scattering[4]	0.005 to 0.02 MeV	559
U-238	Total Absorption[4]	Total	560
U-238	Total Absorption[4]	7.0E-6 to 1.0E-4 MeV	561
U-238	Total Absorption[4]	1.0E-4 to 0.001 MeV	562
U-238	Total Absorption[4]	0.001 to 0.005 MeV	563
U-238	Total Absorption[4]	0.005 to 0.02 MeV	564
U-238	Total Fission[4]	Total	693
U-238	Total Fission[4]	7.0E-6 to 0.001 MeV	694
U-238	Total Fission[4]	0.001 to 0.3 MeV	695
U-239	Elastic Scattering	Total	565
U-239	Total Absorption	Total	566
U-239	Total Fission	Total	696
U-240	Elastic Scattering	Total	567
U-240	Total Absorption	Total	568
U-240	Total Fission	Total	697
Np-235	Elastic Scattering	Total	569
Np-235	Total Absorption	Total	570
Np-235	Total Fission	Total	698
Np-236	Elastic Scattering	Total	571
Np-236	Total Absorption	Total	572
Np-236	Total Fission	Total	699
Np-237	Elastic Scattering	Total	573
Np-237	Elastic Scattering	2.0E-6 to 1.0E-5 MeV	574
Np-237	Elastic Scattering	1.0E-5 to 2.0E-4 MeV	575
Np-237	Total Absorption	Total	576
Np-237	Total Absorption	2.0E-6 to 1.0E-5 MeV	577
Np-237	Total Absorption	1.0E-5 to 2.0E-4 MeV	578
Np-237	Total Fission	Total	700
Np-237	Total Fission	1.0E-7 to 1.0E-5 MeV	701
Np-237	Total Fission	1.0E-5 to 1.0E-4 MeV	702
Np-237	Total Fission	1.0E-4 to 0.001 MeV	703
Np-237	Total Fission	0.001 to 0.008 MeV	704
Np-238	Elastic Scattering	Total	579
Np-238	Total Absorption	Total	580
Np-238	Total Fission	Total	705
Np-239	Elastic Scattering	Total	581
Np-239	Total Absorption	Total	582
Np-239	Total Fission	Total	706
Pu-236	Elastic Scattering	Total	583
Pu-236	Total Absorption	Total	584
Pu-236	Total Fission	Total	707

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Pu-237	Elastic Scattering	Total	585
Pu-237	Total Absorption	Total	586
Pu-237	Total Fission	Total	708
Pu-238	Elastic Scattering	Total	587
Pu-238	Elastic Scattering	3.0E-6 to 1.0E-4 MeV	588
Pu-238	Elastic Scattering	1.0E-4 to 3.0E-4 MeV	589
Pu-238	Total Absorption	Total	590
Pu-238	Total Absorption	1.0E-6 to 1.0E-4 MeV	591
Pu-238	Total Absorption	1.0E-4 to 4.0E-4 MeV	592
Pu-238	Total Fission	Total	709
Pu-238	Total Fission	1.0E-6 to 1.0E-4 MeV	710
Pu-238	Total Fission	1.0E-4 to 4.0E-4 MeV	711
Pu-239	Elastic Scattering	Total	593
Pu-239	Elastic Scattering	7.0E-6 to 1.0E-4 MeV	594
Pu-239	Elastic Scattering	1.0E-4 to 0.001 MeV	595
Pu-239	Elastic Scattering	0.001 to 0.004 MeV	596
Pu-239	Total Absorption	Total	597
Pu-239	Total Absorption	5.0E-6 to 1.0E-4 MeV	598
Pu-239	Total Absorption	1.0E-4 to 0.001 MeV	599
Pu-239	Total Absorption	0.001 to 0.004 MeV	600
Pu-239	Total Fission	Total	712
Pu-239	Total Fission	1.0E-5 to 1.0E-4 MeV	713
Pu-239	Total Fission	1.0E-4 to 0.001 MeV	714
Pu-239	Total Fission	0.001 to 0.004 MeV	715
Pu-240	Elastic Scattering	Total	601
Pu-240	Elastic Scattering	1.0E-5 to 0.001 MeV	602
Pu-240	Elastic Scattering	0.001 to 0.01 MeV	603
Pu-240	Total Absorption	Total	604
Pu-240	Total Absorption	2.0E-5 to 0.001 MeV	605
Pu-240	Total Absorption	0.001 to 0.01 MeV	606
Pu-240	Total Fission	Total	716
Pu-240	Total Fission	2.0E-5 to 0.001 MeV	717
Pu-240	Total Fission	0.001 to 0.007 MeV	718
Pu-241	Elastic Scattering	Total	607
Pu-241	Elastic Scattering	1.0E-6 to 1.0E-4 MeV	608
Pu-241	Elastic Scattering	1.0E-4 to 4.0E-4 MeV	609
Pu-241	Total Absorption	Total	610
Pu-241	Total Absorption	1.0E-6 to 5.0E-5 MeV	611
Pu-241	Total Absorption	5.0E-5 to 2.0E-4 MeV	612
Pu-241	Total Absorption	2.0E-4 to 0.001 MeV	613
Pu-241	Total Fission	Total	719
Pu-241	Total Fission	3.0E-6 to 3.0E-5 MeV	720
Pu-241	Total Fission	3.0E-5 to 6.0E-4 MeV	721
Pu-242	Elastic Scattering	Total	614
Pu-242	Elastic Scattering	4.0E-5 to 0.002 MeV	615
Pu-242	Total Absorption	Total	616
Pu-242	Total Absorption	1.0E-5 to 3.0E-4 MeV	617
Pu-242	Total Absorption	3.0E-4 to 0.002 MeV	618
Pu-242	Total Fission	Total	722
Pu-242	Total Fission	2.0E-5 to 0.002 MeV	723
Pu-243	Elastic Scattering	Total	619

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Pu-243	Elastic Scattering	1.0E-6 to 2.0E-4 MeV	620
Pu-243	Total Absorption	Total	621
Pu-243	Total Absorption	1.0E-6 to 2.0E-4 MeV	622
Pu-243	Total Fission	Total	724
Pu-243	Total Fission	1.0E-6 to 2.0E-4 MeV	725
Pu-244	Elastic Scattering	Total	623
Pu-244	Total Absorption	Total	624
Pu-244	Total Fission	Total	726
Am-241	Elastic Scattering	Total	625
Am-241	Elastic Scattering	1.0E-7 to 1.0E-5 MeV	626
Am-241	Elastic Scattering	1.0E-5 to 2.0E-4 MeV	627
Am-241	Total Absorption	Total	628
Am-241	Total Absorption	1.0E-7 to 1.0E-5 MeV	629
Am-241	Total Absorption	1.0E-5 to 2.0E-4 MeV	630
Am-241	Total Fission	Total	727
Am-241	Total Fission	1.0E-7 to 1.0E-5 MeV	728
Am-241	Total Fission	1.0E-5 to 2.0E-4 MeV	729
Am-242m	Elastic Scattering	Total	631
Am-242m	Total Absorption	Total	632
Am-242m	Total Fission	Total	730
Am-243	Elastic Scattering	Total	633
Am-243	Elastic Scattering	1.0E-6 to 3.0E-5 MeV	634
Am-243	Elastic Scattering	3.0E-5 to 3.0E-4 MeV	635
Am-243	Total Absorption	Total	636
Am-243	Total Absorption	1.0E-6 to 1.0E-5 MeV	637
Am-243	Total Absorption	1.0E-5 to 1.0E-4 MeV	638
Am-243	Total Absorption	1.0E-4 to 3.0E-4 MeV	639
Am-243	Total Fission	Total	731
Am-243	Total Fission	1.0E-7 to 1.0E-5 MeV	732
Am-243	Total Fission	1.0E-5 to 3.0E-4 MeV	733
Cm-241	Elastic Scattering	Total	640
Cm-241	Total Absorption	Total	641
Cm-241	Total Fission	Total	734
Cm-242	Elastic Scattering	Total	642
Cm-242	Elastic Scattering	5.0E-6 to 8.0E-4 MeV	643
Cm-242	Total Absorption	Total	644
Cm-242	Total Absorption	1.0E-5 to 4.0E-4 MeV	645
Cm-242	Total Fission	Total	735
Cm-243	Elastic Scattering	Total	646
Cm-243	Total Absorption	Total	647
Cm-243	Total Fission	Total	736
Cm-243	Total Fission	1.0E-6 to 2.0E-4 MeV	737
Cm-244	Elastic Scattering	Total	648
Cm-244	Elastic Scattering	9.0E-5 to 0.001 MeV	649
Cm-244	Total Absorption	Total	650
Cm-244	Total Absorption	1.0E-5 to 0.001 MeV	651
Cm-244	Total Fission	Total	738
Cm-244	Total Fission	3.0E-6 to 9.0E-4 MeV	739
Cm-245	Elastic Scattering	Total	652
Cm-245	Total Absorption	Total	653
Cm-245	Total Fission	Total	740

Table 5-10. MCNP Continuous-Energy Cross Section Plot Index

Element or Isotope	Neutron Reaction	Energy Range	Plot Number[1]
Cm-245	Total Fission	1.0E-6 to 2.0E-4 MeV	741
Cm-246	Elastic Scattering	Total	654
Cm-246	Total Absorption	Total	655
Cm-246	Total Fission	Total	742
Cm-247	Elastic Scattering	Total	656
Cm-247	Total Absorption	Total	657
Cm-247	Total Fission	Total	743
Cm-247	Total Fission	3.0E-6 to 5.0E-5 MeV	744
Cm-247	Total Fission	5.0E-5 to 0.002 MeV	745
Cm-248	Elastic Scattering	Total	658
Cm-248	Total Absorption	Total	659
Cm-248	Total Absorption	4.0E-6 to 0.004 MeV	660
Cm-248	Total Fission	Total	746
Cm-248	Total Fission	2.0E-6 to 2.0E-4 MeV	747
Cm-248	Total Fission	2.0E-4 to 0.003 MeV	748
Bk-249	Elastic Scattering	Total	661
Bk-249	Total Absorption	Total	662
Bk-249	Total Fission	Total	749
Cf-249	Elastic Scattering	Total	663
Cf-249	Total Absorption	Total	664
Cf-249	Total Fission	Total	750
Cf-249	Total Fission	2.0E-6 to 4.0E-5 MeV	751
Cf-249	Total Fission	4.0E-5 to 3.0E-4 MeV	752
Cf-249	Total Fission	3.0E-4 to 0.003 MeV	753
Cf-250	Elastic Scattering	Total	665
Cf-250	Total Absorption	Total	666
Cf-250	Total Fission	Total	754
Cf-251	Elastic Scattering	Total	667
Cf-251	Total Absorption	Total	668
Cf-251	Total Fission	Total	755
Cf-252	Elastic Scattering	Total	669
Cf-252	Total Absorption	Total	670
Cf-252	Total Absorption	1.0E-5 to 0.001 MeV	671
Cf-252	Total Fission	Total	756
Cf-252	Total Fission	1.0E-5 to 4.0E-4 MeV	757

[1] The plot number refers to the # in the corresponding cross section plot filenames ("p#.gif") as contained on Attachment I (CD-ROM).
[2] The MCNP cross section library identified as 92238.21c was not included in the various plots for U-238 due to a limitation in the number of cross section representations that may be shown on a single plot and still maintain unique line styles and colors.

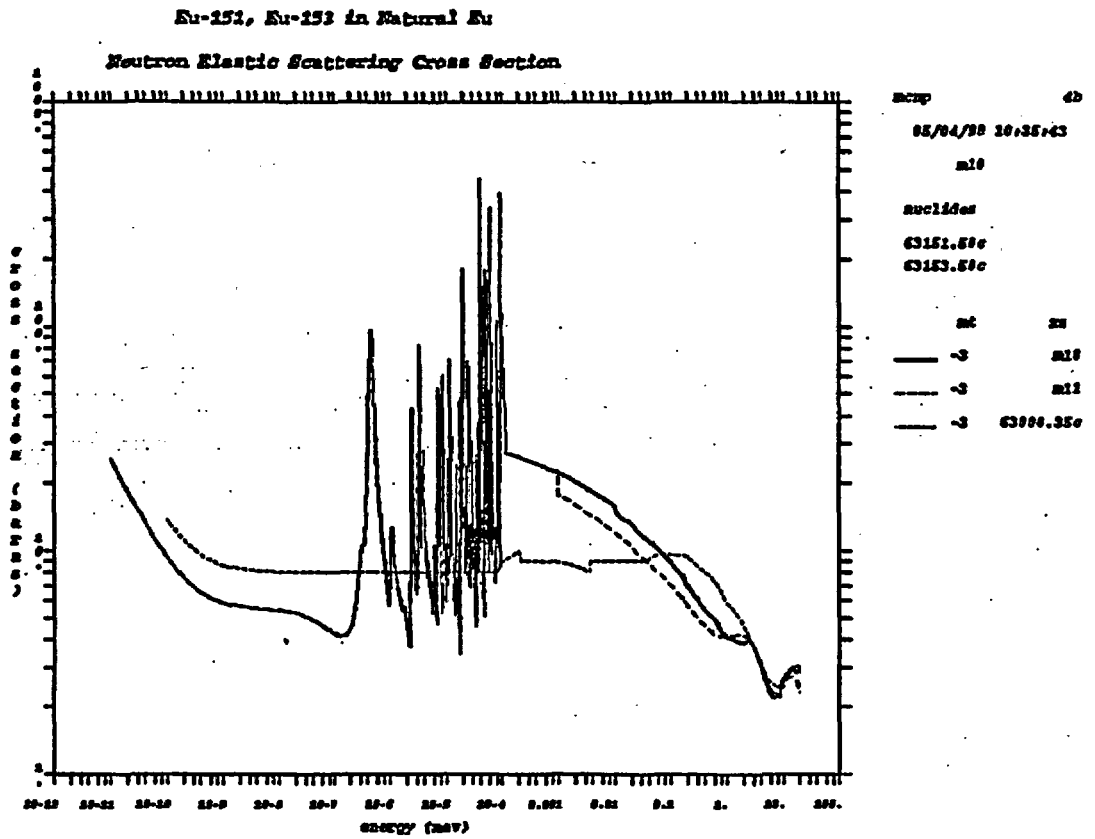

Figure 5-1. p342.gif (plot number 342 in Table 5-10)

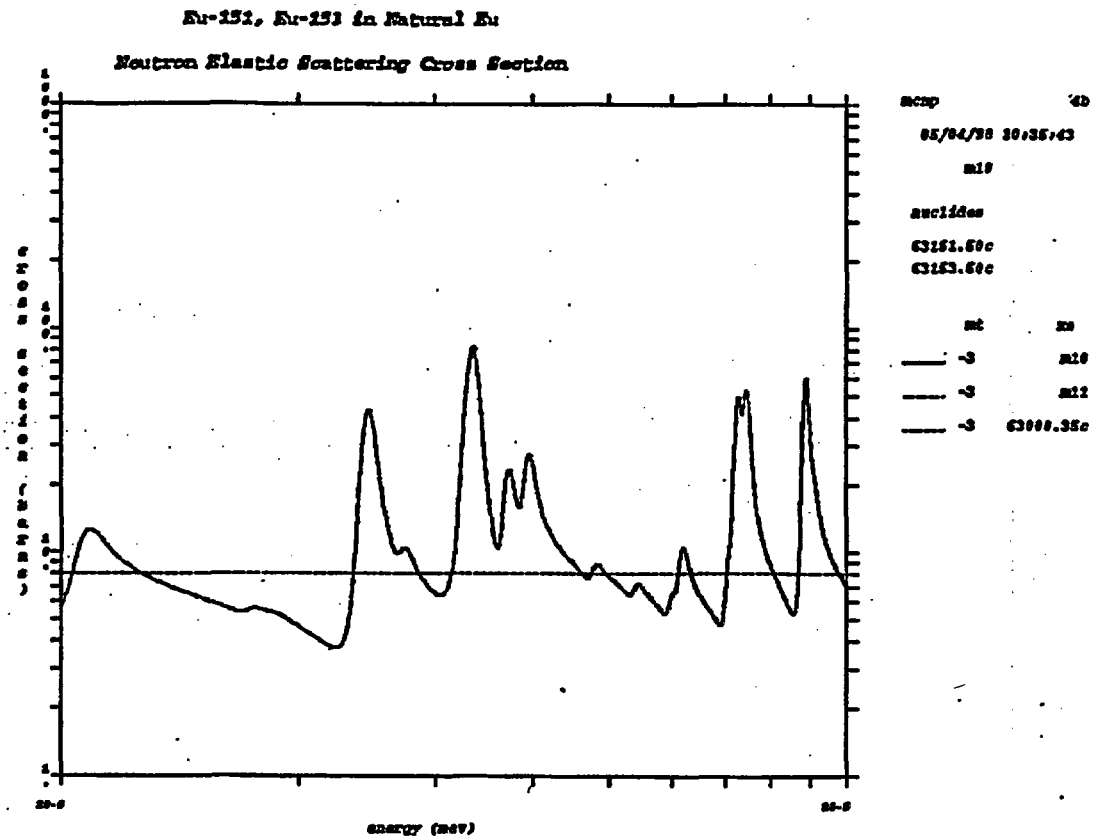

Figure 5-2. p343.gif (plot number 343 in Table 5-10)

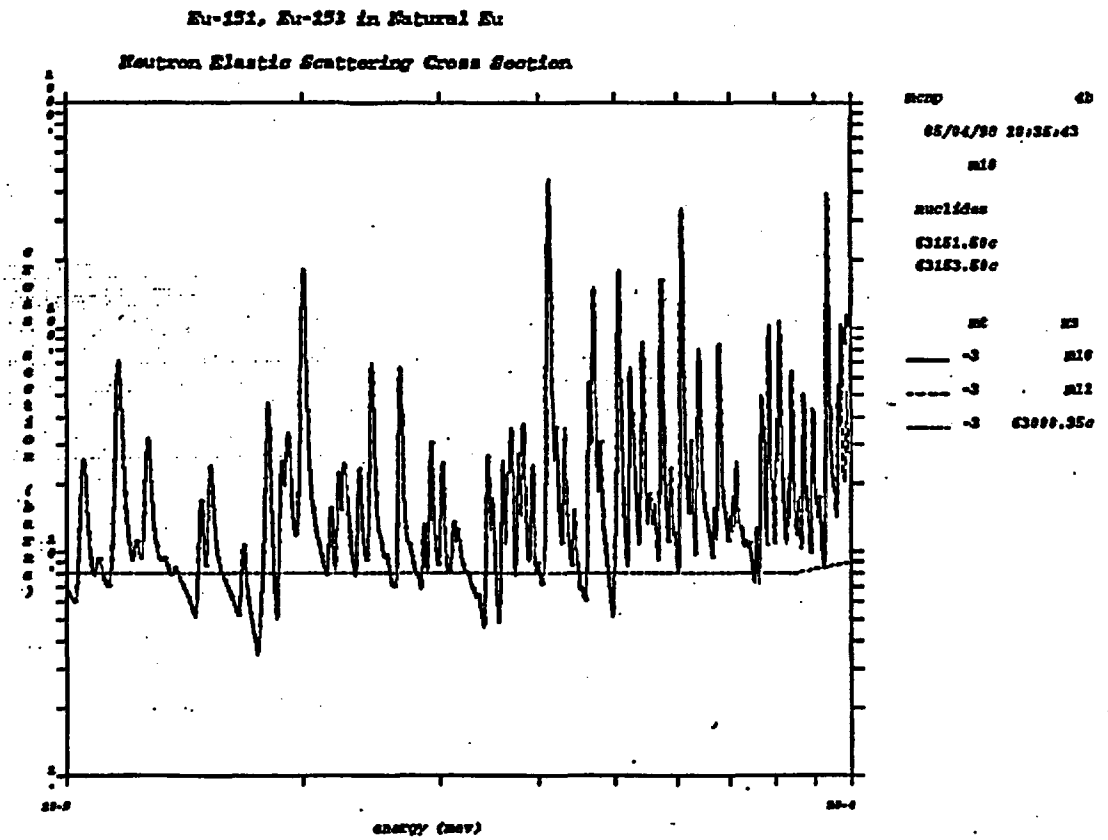

Figure 5-3. p344.gif (plot number 344 in Table 5-10)

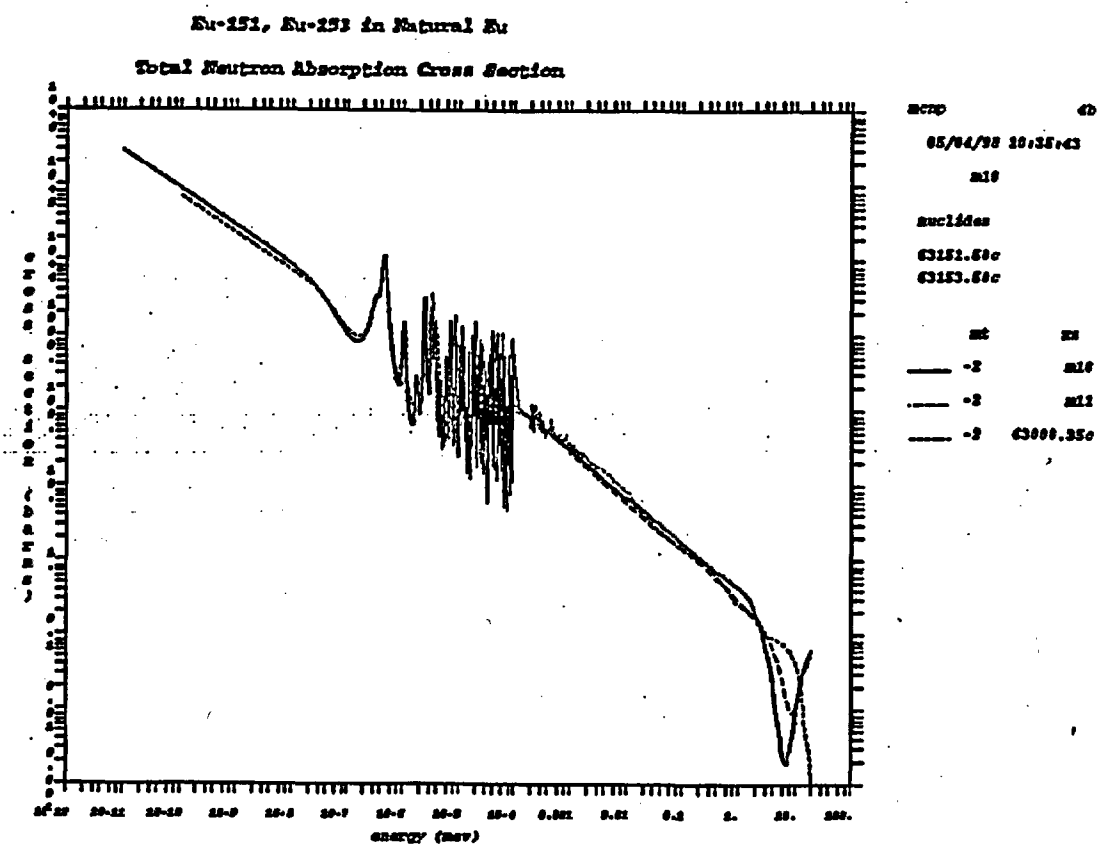

Figure 5-4. p345.gif (plot number 345 in Table 5-10)

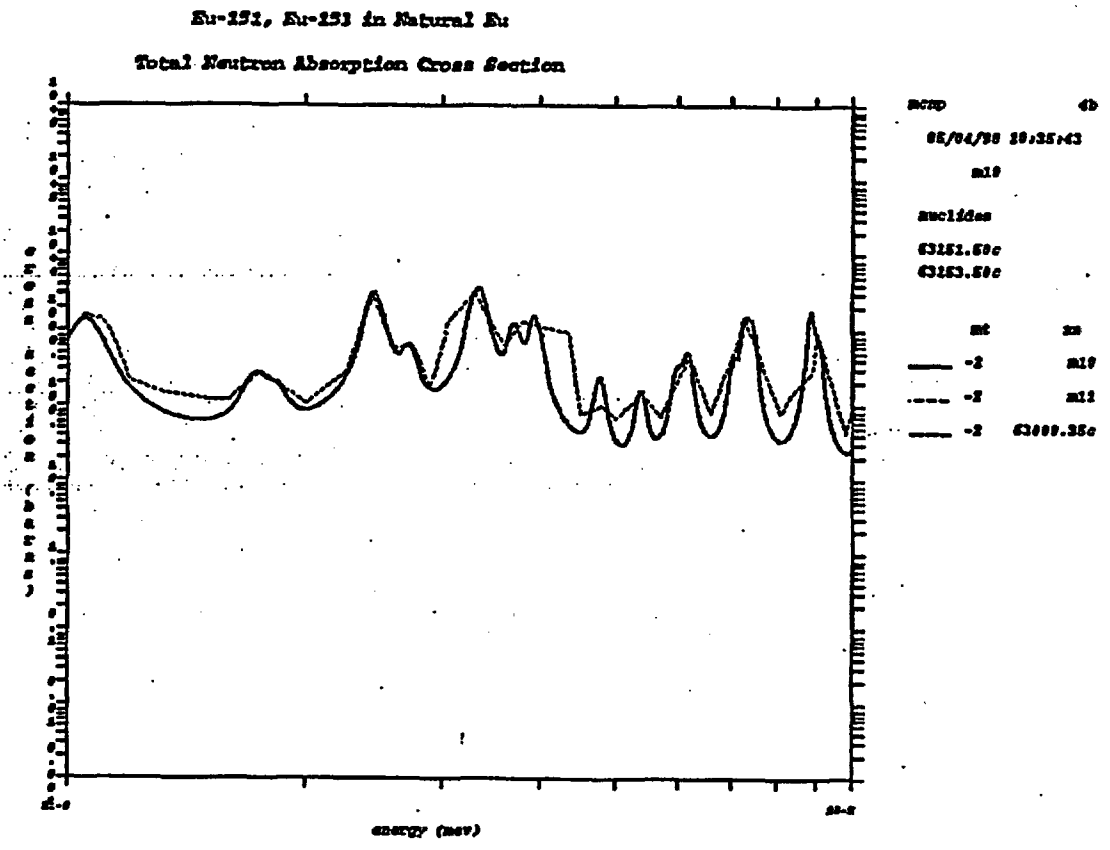

Figure 5-5. p346.gif (plot number 346 in Table 5-10)

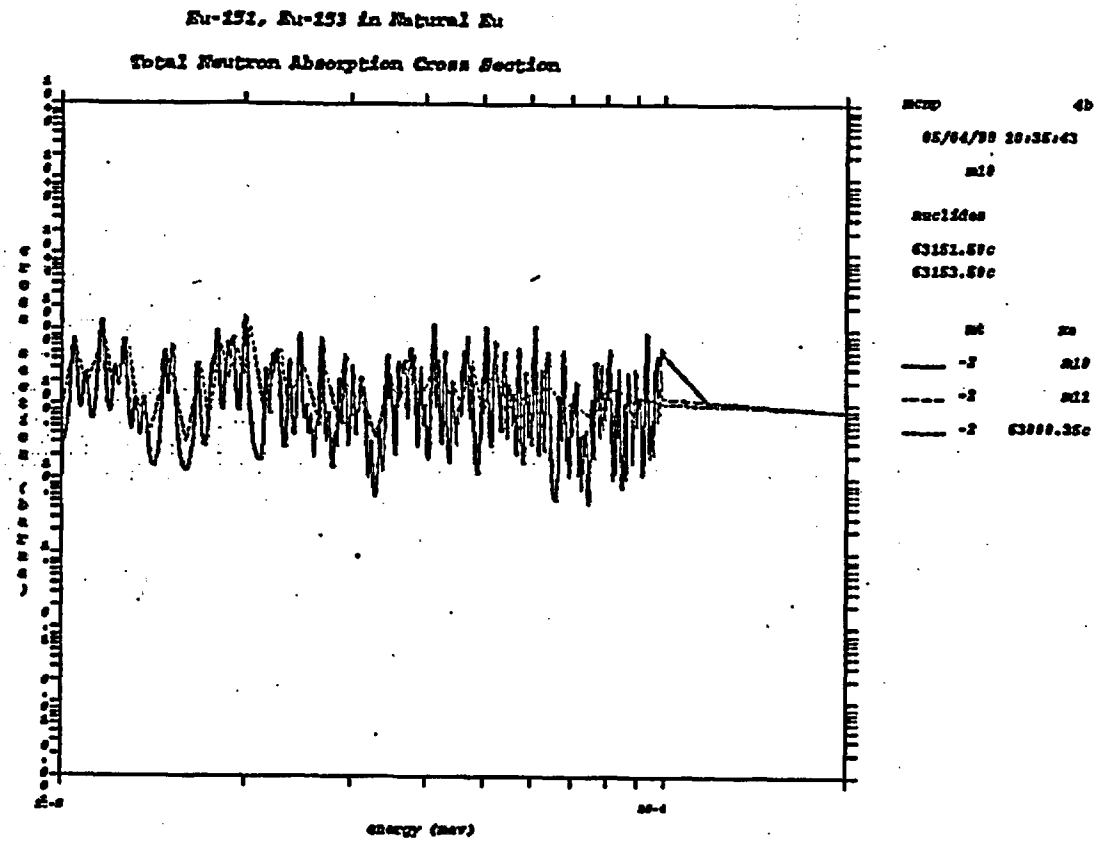

Figure 5-6. p347.gif (plot number 347 in Table 5-10)

6. Selected MCNP Cross Section Libraries

Table 6.1 presents the cross section libraries that have been selected for use in the criticality benchmark and design calculations of the WPDD. The selection of the specific libraries presented in Table 6.1 does not infer that these libraries are more correct than the other available libraries. Rather, the selection of the specific libraries presented in Table 6.1 establishes a set that will assist in ensuring consistent cross section library utilization throughout the criticality benchmark and design calculations of the WPDD.

As previously stated in Section 3, the following criteria were used to select the continuous-energy cross section libraries, as shown in Table 6.1, for use with MCNP:

- ENDF/B-V based cross section libraries were selected for use when available with the exceptions of H-2, B-11, Zr (natural), Ag-107, Ag-109, Eu-151, and Eu-153
- either ENDF/B-VI, T-2, or LLNL based cross section libraries were selected for use when ENDF/B-V based libraries were not available or selected
- parameters compared when selecting between ENDF/B-VI, T-2, or LLNL based cross section libraries included the following: number of energy points included in the main energy grid, date of cross section library processing, and availability of certain data.

The selected non-ENDF/B-V based cross section libraries are presented in Table 6.2. The following discussion provides a description of how the above criteria were used to select the non-ENDF/B-V based cross section libraries.

Fifty-five out of the seventy-nine non-ENDF/B-V based cross section libraries were selected because they were the only available cross section libraries distributed to the WPDD for the various elements and isotopes. The elements and isotopes to which this applies include the following: Be-7, C-13, O-17, S (natural), Ca-40, Sc-45, Cr-50, Cr-52, Cr-53, Cr-54, Fe-54, Fe-56, Fe-57, Fe-58, Ni-60, Ni-61, Ni-62, Ni-64, Cu-63, Cu-65, As-74, Br-79, Br-81, Rb-85, Rb-87, Y-88, In (natural), Sn (natural), I-129, Xe (natural), Xe-134, Cs-134, Cs-136, Cs-137, Tm-169, Ta-182, Ir (natural), Pt (natural), Pb-206, Pb-207, Pb-208, Th-230, Th-231, Th-233, Pa-231, U-232, U-239, U-240, Np-235, Np-236, Np-238, Np-239, Pu-236, Pu-244, Cm-241.

Non-ENDF/B-V based cross section libraries were selected for seven elements and isotopes for which ENDF/B-V cross section libraries were available. These elements and isotopes include the following: H-2, B-11, Zr (natural), Ag-107, Ag-109, Eu-151, and Eu-153.

For H-2, there are no significant differences between the neutron scattering cross section of the selected cross section library (1002.55c) and the ENDF/B-V based cross section library (1002.50c). There are also no significant differences between the total neutron absorption cross section of the selected cross section library and the ENDF/B-V based cross section library. At neutron energies below 3.0E-10 MeV, the selected cross section library shows a maximum total neutron absorption cross section difference of 0.001 barns with respect to the ENDF/B-V based cross section library.

For B-11, there are some differences in the resonance region between the selected cross section library (5011.56c) and the ENDF/B-V based cross section library (5011.55c). There are no significant differences between the total neutron absorption cross section of the selected cross section library and the ENDF/B-V based cross section library. The 5011.56c cross section library was processed more recently than 5011.55c. The 5011.56c cross section library has more than two times the number of energy points on the main energy grid than 5011.55c.

For Zr (natural), the ENDF/B-VI based cross section library (40000.60c) is selected because it contains corrections for a problem that is present in the previously released ENDF/B-V based cross section library. The corrected problem is that the ENDF/B-V based cross section library provides a secondary neutron energy greater than the incident neutron energy for some scattering interactions.

For Ag-107, the ENDF/B-VI based cross section library (47107.60c) is selected over the ENDF/B-V based cross section library (47107.50c) because it contains more detail in the resonance region of both the neutron elastic scattering and total neutron absorption cross sections. In the neutron elastic scattering cross section, the increased detail is primarily between energies of 2.0E-5 MeV and 0.003 MeV. In the total neutron absorption cross section, the increased detail is primarily between the energies of 2.0E-5 MeV and 0.003 MeV. Also, the ENDF/B-VI based cross section library contains more than six times the number of energy points on the main energy grid than the ENDF/B-V based cross section library.

For Ag-109, the ENDF/B-VI based cross section library (47109.60c) is selected over the ENDF/B-V based cross section library (47109.50c) because it contains more detail in the resonance region of both the neutron elastic scattering and total neutron absorption cross sections. In the neutron elastic scattering cross section, the increased detail is primarily between energies of 2.0E-4 MeV and 0.003 MeV. In the total neutron absorption cross section, the increased detail is primarily between the energies of 8.0E-4 MeV and 0.003 MeV. Also, the ENDF/B-VI based cross section library contains more than five times the number of energy points on the main energy grid than the ENDF/B-V based cross section library.

For Eu-151, there are no significant differences between the neutron scattering cross section of the selected cross section library (63151.55c) and the ENDF/B-V based cross section library (63151.50c). The total neutron absorption cross section of the 63151.55c and 63151.50c cross section libraries are generally the same. The 63151.55c total neutron absorption cross section is a maximum of 0.2 barns less than 63151.50c between the energies of 0.01 MeV and 3.0 MeV. Also, the 63151.55c total neutron absorption cross section is a maximum of 0.02 barns greater than 63151.50c between the energies of 3.0 MeV and 10.0 MeV. The 63151.55c cross section library was processed more recently than the 63151.50c cross section library.

For Eu-153, the neutron scattering cross section of the selected cross section library (63153.55c) and the ENDF/B-V based cross section library (63153.50c) are generally the same. The 63153.55c neutron elastic scattering cross section is a maximum of 0.005 barns less than 63153.50c between the energies of 0.001 MeV and 0.2 MeV. The total neutron absorption cross section of the 63153.55c and 63153.50c cross section libraries are generally the same. The 63153.55c total neutron absorption cross section is a maximum of 0.003 barns less than

63153.50c between the energies of 0.001 MeV and 2.0 MeV. Also, the 63153.55c total neutron absorption cross section is a maximum of 0.007 barns greater than 63153.50c between the energies of 2.0 MeV and 10.0 MeV. The 63153.55c cross section library was processed more recently than the 63153.50c cross section library.

The remaining elements and isotopes for which non-ENDF/B-V based cross section libraries were selected include the following: N-15, Ar (natural), Ni-58, I-127, Ho-165, Pu-237, Pu-243, Cm-243, Cm-245, Cm-246, Cm-247, Cm-248, Bk-249, Cf-249, Cf-250, Cf-251, Cf-252. There are no ENDF/B-V based cross section libraries available for these elements and isotopes. However, there are multiple non-ENDF/B-V based cross section libraries available for each of these elements and isotopes. The following discussion provides a description of how the previously identified selection criteria were used to select the various cross section libraries.

For N-15, there are two cross section libraries available (7015.55c and 7015.60c). The 7015.55c cross section library was selected. There are no significant differences between the neutron scattering cross section of 7015.55c and 7015.60c. There are no significant differences between the total neutron absorption cross section of 7015.55c and 7015.60c. The 7015.55c cross section library contains the largest number of energy points on the main energy grid.

For Ar (natural), the selected cross section library (18000.59c) is processed at 294 K rather than 0 K at which the other available cross section library (18000.35c) is processed.

For Ni-58, the selected cross section library (28058.60c) is processed at 294 K rather than 0 K at which the other available cross section library (28058.35c) is processed. The 28058.60c neutron elastic scattering cross section shows much more detail in the resonance region between the energies of 0.01 MeV and 6.0 MeV than 28058.35c. The 28058.60c total neutron absorption cross section shows much more detail in the resonance region between the energies of 0.08 MeV and 0.8 MeV than 28058.35c. The 28058.60c cross section library contains more than three times the number of energy points on the main energy grid than 28058.35c.

For I-127, the selected cross section library (53127.60c) is an update of the only other available cross section library (53127.55c). Also, the 53127.60c cross section library contains photon production data and the 53127.55c cross section library does not.

For Ho-165, the selected cross section library (67165.55c) was selected and used prior to the receipt of the ENDF/B-VI based cross section library (67165.60c) by WPDD. The other available cross section library is the LLNL based 67165.35c. The 67165.55c cross section library is processed at 294 K, and the 67165.35c cross section library is processed at 0 K.

For Pu-237, the selected cross section library (94237.35c) was selected and used prior to the receipt of the ENDF/B-VI based cross section library (94237.60c) by WPDD. Prior to the receipt of 94237.60c, the only available cross section library was 94237.35c. Additionally, the 94237.35c cross section library contains photon production data and the 94237.60c cross section library does not.

For Pu-243, the selected cross section library (94243.60c) is processed at 294 K rather than 0 K at which the other available cross section library (94243.35c) is processed. The 94243.60c cross section library also contains total nu data, and 94243.35c only contains prompt nu data. The 94243.60c cross section library contains more than nine times the number of energy points on the main energy grid than 94243.35c.

For Cm-243, Cm-245, Cm-246, and Cm-247, the selected cross section libraries (96243.35c, 96245.35c, 96246.35c, and 96247.35c, respectively) were selected and used prior to the receipt of the ENDF/B-VI based cross section libraries. The 96243.35c, 96245.35c, 96246.35c, and 96247.35c cross section libraries were the only available libraries for WPDD prior to the receipt of the ENDF/B-VI based libraries.

For Cm-248, the selected cross section library (96248.60c) is processed at 294 K rather than 0 K at which the other available cross section library (96248.35c) is processed. The 96248.60c cross section library contains total nu data, and 96248.35c only contains prompt nu data. The 96248.60c cross section library contains more than six times the number of energy points on the main energy grid than 96248.35c. Unlike the Cm-243, Cm-245, Cm-246, and Cm-247 isotopes, the Cm-248 isotope had not been used in a model prior to the receipt of the ENDF/B-VI based cross section libraries. Therefore, the 96248.60c cross section library could be selected with minimal impact.

For Bk-249, the selected cross section library (97249.60c) is processed at 294 K rather than 0 K at which the other available cross section library (97249.35c) is processed. The 97249.60c cross section library contains both prompt and total nu data, and 97249.35c only contains prompt nu data. The 97249.60c cross section library contains more than eight times the number of energy points on the main energy grid than 97249.35c.

For Cf-249, the selected cross section library (98249.60c) is processed at 294 K rather than 0 K at which the other available cross section library (98249.35c) is processed. The 98249.60c cross section library contains both prompt and total nu data, and 98249.35c only contains prompt nu data. The 98249.60c cross section library contains more than one and a half times the number of energy points on the main energy grid than 98249.35c.

For Cf-250, the selected cross section library (98250.60c) is processed at 294 K rather than 0 K at which the other available cross section library (98250.35c) is processed. The 98250.60c cross section library contains total nu data, and 98250.35c only contains prompt nu data. The 98250.60c cross section library contains more than twelve times the number of energy points on the main energy grid than 98250.35c.

For Cf-251, the selected cross section library (98251.60c) is processed at 294 K rather than 0 K at which the other available cross section library (98251.35c) is processed. The 98251.60c cross section library contains both prompt and total nu data, and 98251.35c only contains prompt nu data. The 98251.60c cross section library contains more than eight times the number of energy points on the main energy grid than 98251.35c.

For Cf-252, the selected cross section library (98252.60c) is processed at 294 K rather than 0 K at which the other available cross section library (98252.35c) is processed. The 98252.60c cross section library contains both prompt and total nu data, and 98252.35c only contains prompt nu data. The 98252.60c cross section library contains more than three times the number of energy point on the main energy grid than 98252.35c.

Table 6-1. Selected Continuous-Energy MCNP Cross Section Libraries

Element	Isotope	Selected Cross Section Library ZAID
Hydrogen	H-1	1001.50c
	H-2	1002.55c
	H-3	1003.50c
Helium	He-3	2003.50c
	He-4	2004.50c
Lithium	Li-6	3006.50c
	Li-7	3007.55c
Beryllium	Be-7	4007.35c
	Be-9	4009.50c
Boron	B-10	5010.50c
	B-10	5010.53c
	B-11	5011.56c
Carbon	C (natural)	6000.50c
	C-12	6012.50c
	C-13	6013.35c
Nitrogen	N-14	7014.50c
	N-15	7015.55c
Oxygen	O-16	8016.50c
	O-16	8016.53c
	O-16	8016.54c
	O-17	8017.60c
Fluorine	F-19	9019.50c
Sodium	Na-23	11023.50c
Magnesium	Mg (natural)	12000.50c
Aluminum	Al-27	13027.50c
Silicon	Si (natural)	14000.50c
Phosphorus	P-31	15031.50c
Sulfur	S (natural)	16000.60c
	S-32	16032.50c
Chlorine	Cl (natural)	17000.50c
Argon	Ar (natural)	18000.59c
Potassium	K (natural)	19000.50c
Calcium	Ca (natural)	20000.50c
	Ca-40	20040.21c
Scandium	Sc-45	21045.60c
Titanium	Ti (natural)	22000.50c
Vanadium	V (natural)	23000.50c
Chromium	Cr-50	24050.60c
	Cr-52	24052.60c
	Cr-53	24053.60c
	Cr-54	24054.60c
Manganese	Mn-55	25055.50c
Iron	Fe-54	26054.60c
	Fe-56	26056.60c

Table 6-1. Selected Continuous-Energy MCNP Cross Section Libraries

Element	Isotope	Selected Cross Section Library ZAID
	Fe-57	26057.60c
	Fe-58	26058.60c
Cobalt	Co-59	27059.50c
Nickel	Ni-58	28058.60c
	Ni-60	28060.60c
	Ni-61	28061.60c
	Ni-62	28062.60c
	Ni-64	28064.60c
Copper	Cu-63	29063.60c
	Cu-65	29065.60c
Gallium	Ga (natural)	31000.50c
Arsenic	As-74	33074.35c
	As-75	33075.35c
Bromine	Br-79	35079.55c
	Br-81	35081.55c
Krypton	Kr-78	36078.50c
	Kr-80	36080.50c
	Kr-82	36082.50c
	Kr-83	36083.50c
	Kr-84	36084.50c
	Kr-86	36086.50c
Rubidium	Rb-85	37085.55c
	Rb-87	37087.55c
Yttrium	Y-88	39088.35c
	Y-89	39089.50c
Zirconium	Zr (natural)	40000.60c
	Zr-93	40093.50c
Niobium	Nb-93	41093.50c
Molybdenum	Mo (natural)	42000.50c
	Mo-95	42095.50c
Technetium	Tc-99	43099.50c
Ruthenium	Ru-101	44101.50c
	Ru-103	44103.50c
Rhodium	Rh-103	45103.50c
	Rh-105	45105.50c
Palladium	Pd-105	46105.50c
	Pd-108	46108.50c
Silver	Ag-107	47107.60c
	Ag-109	47109.60c
Cadmium	Cd (natural)	48000.50c
Indium	In (natural)	49000.60c
Tin	Sn (natural)	50000.35c
Iodine	I-127	53127.60c
	I-129	53129.60c
	I-135	53135.50c
Xenon	Xe (natural)	54000.35c
	Xe-131	54131.50c
	Xe-134	54134.35c
	Xe-135	54135.50c
	Xe-135	54135.53c
	Xe-135	54135.54c

Table 6-1. Selected Continuous-Energy MCNP Cross Section Libraries

Element	Isotope	Selected Cross Section Library ZAID
Cesium	Cs-133	55133.50c
	Cs-134	55134.60c
	Cs-135	55135.50c
	Cs-136	55136.60c
	Cs-137	55137.60c
Barium	Ba-138	56138.50c
Praseodymium	Pr-141	59141.50c
Neodymium	Nd-143	60143.50c
	Nd-145	60145.50c
	Nd-147	60147.50c
	Nd-148	60148.50c
Promethium	Pm-147	61147.50c
	Pm-148	61148.50c
	Pm-149	61149.50c
Samarium	Sm-147	62147.50c
	Sm-149	62149.50c
	Sm-150	62150.50c
	Sm-151	62151.50c
	Sm-152	62152.50c
Europium	Eu-151	63151.55c
	Eu-152	63152.50c
	Eu-153	63153.55c
	Eu-154	63154.50c
	Eu-155	63155.50c
Gadolinium	Gd-152	64152.50c
	Gd-154	64154.50c
	Gd-155	64155.50c
	Gd-156	64156.50c
	Gd-157	64157.50c
	Gd-158	64158.50c
	Gd-160	64160.50c
Holmium	Ho-165	67165.55c
Thulium	Tm-169	69169.55c
Hafnium	Hf (natural)	72000.50c
Tantalum	Ta-181	73181.50c
	Ta-182	73182.60c
Tungsten	W (natural)	74000.55c
	W-182	74182.55c
	W-183	74183.55c
	W-184	74184.55c
	W-186	74186.55c
Rhenium	Re-185	75185.50c
	Re-187	75187.50c
Iridium	Ir (natural)	77000.55c
Platinum	Pt (natural)	78000.35c
Gold	Au-197	79197.50c
Lead	Pb (natural)	82000.50c
	Pb-206	82206.60c
	Pb-207	82207.60c
	Pb-208	82208.60c
Bismuth	Bi-209	83209.50c

Table 6-1. Selected Continuous-Energy MCNP Cross Section Libraries

Element	Isotope	Selected Cross Section Library ZAID
Thorium	Th-230	90230.60c
	Th-231	90231.35c
	Th-232	90232.50c
	Th-233	90233.35c
Protactinium	Pa-231	91231.60c
	Pa-233	91233.50c
Uranium	U-232	92232.60c
	U-233	92233.50c
	U-234	92234.50c
	U-235	92235.50c
	U-235	92235.53c
	U-235	92235.54c
	U-236	92236.50c
	U-237	92237.50c
	U-238	92238.50c
	U-238	92238.53c
	U-238	92238.54c
	U-239	92239.35c
	U-240	92240.35c
Neptunium	Np-235	93235.35c
	Np-236	93236.35c
	Np-237	93237.50c
	Np-238	93238.35c
	Np-239	93239.60c
Plutonium	Pu-236	94236.60c
	Pu-237	94237.35c
	Pu-238	94238.50c
	Pu-239	94239.55c
	Pu-240	94240.50c
	Pu-241	94241.50c
	Pu-242	94242.50c
	Pu-243	94243.60c
	Pu-244	94244.60c
Americium	Am-241	95241.50c
	Am-242	95242.50c
	Am-243	95243.50c
Curium	Cm-241	96241.60c
	Cm-242	96242.50c
	Cm-243	96243.35c
	Cm-244	96244.50c
	Cm-245	96245.35c
	Cm-246	96246.35c
	Cm-247	96247.35c
	Cm-248	96248.60c
Berkelium	Bk-249	97249.60c
Californium	Cf-249	98249.60c
	Cf-250	98250.60c
	Cf-251	98251.60c
	Cf-252	98252.60c

Table 6-2. Selected Non-ENDF/B-V-Based MCNP Cross Section Libraries		
Element or Isotope	MCNP ZAID	Evaluated Data Source
H-2	1002.55c	T-2
Be-7	4007.35c	LLNL
B-11	5011.56c	T-2
C-13	6013.35c	LLNL
N-15	7015.55c	T-2
O-17	8017.60c	B-VI.0
S (natural)	16000.60c	B-VI.0
Ar (natural)	18000.59c	T-2
Ca-40	20040.21c	T-2:XTM
Sc-45	21045.60c	B-VI.2
Cr-50	24050.60c	B-VI.1
Cr-52	24052.60c	B-VI.1
Cr-53	24053.60c	B-VI.1
Cr-54	24054.60c	B-VI.1
Fe-54	26054.60c	B-VI.1
Fe-56	26056.60c	B-VI.1
Fe-57	26057.60c	B-VI.1
Fe-58	26058.60c	B-VI.1
Ni-58	28058.60c	B-VI.1
Ni-60	28060.60c	B-VI.1
Ni-61	28061.60c	B-VI.1
Ni-62	28062.60c	B-VI.1
Ni-64	28064.60c	B-VI.1
Cu-63	29063.60c	B-VI.2
Cu-65	29065.60c	B-VI.2
As-74	33074.35c	LLNL
Br-79	35079.55c	T-2
Br-81	35081.55c	T-2
Rb-85	37085.55c	T-2
Rb-87	37087.55c	T-2
Y-88	39088.35c	LLNL
Zr (natural)	40000.60c	B-VI.1
Ag-107	47107.60c	B-VI.0
Ag-109	47109.60c	B-VI.0
In (natural)	49000.60c	B-VI.0
Sn (natural)	50000.35c	LLNL
I-127	53127.60c	T-2
I-129	53129.60c	B-VI.0
Xe (natural)	54000.35c	LLNL
Xe-134	54134.35c	LLNL
Cs-134	55134.60c	B-VI.0
Cs-136	55136.60c	B-VI.0
Cs-137	55137.60c	B-VI.0
Eu-151	63151.55c	T-2
Eu-153	63153.55c	T-2
Ho-165	67165.55c	T-2
Tm-169	69169.55c	T-2
Ta-182	73182.60c	B-VI.0
Ir (natural)	77000.55c	T-2
Pt (natural)	78000.35c	LLNL
Pb-206	82206.60c	B-VI.0

Table 6-2. Selected Non-ENDF/B-V-Based MCNP Cross Section Libraries		
Element or Isotope	MCNP ZAID	Evaluated Data Source
Pb-207	82207.60c	B-VI.1
Pb-208	82208.60c	B-VI.0
Th-230	90230.60c	B-VI.0
Th-231	90231.35c	LLNL
Th-233	90233.35c	LLNL
Pa-231	91231.60c	B-VI.0
U-232	92232.60c	B-VI.0
U-239	92239.35c	LLNL
U-240	92240.35c	LLNL
Np-235	93235.35c	LLNL
Np-236	93236.35c	LLNL
Np-238	93238.35c	LLNL
Np-239	93239.60c	B-VI.0
Pu-236	94236.60c	B-VI.0
Pu-237	94237.35c	LLNL
Pu-243	94243.60c	B-VI.2
Pu-244	94244.60c	B-VI.0
Cm-241	96241.60c	B-VI.0
Cm-243	96243.35c	LLNL
Cm-245	96245.35c	LLNL
Cm-246	96246.35c	LLNL
Cm-247	96247.35c	LLNL
Cm-248	96248.60c	B-VI.0
Bk-249	97249.60c	B-VI:XTM
Cf-249	98249.60c	B-VI:XTM
Cf-250	98250.60c	B-VI.2
Cf-251	98251.60c	B-VI.2
Cf-252	98252.60c	B-VI.2

7. Conclusions

This report documents the selection of continuous-energy cross section libraries to be used with MCNP in criticality benchmark and design calculations. The various cross section libraries were selected using the following criteria:

- ENDF/B-V based cross section libraries were selected for use when available with the exceptions of H-2, B-11, Zr (natural), Ag-107, Ag-109, Eu-151, and Eu-153
- either ENDF/B-VI, T-2, or LLNL based cross section libraries were selected for use when ENDF/B-V based libraries were not available or selected
- parameters compared when selecting between ENDF/B-VI, T-2, or LLNL based cross section libraries included the following: number of energy points included in the main energy grid, date of cross section library processing, and availability of certain data.

The application of the above criteria in the selection of the various cross section libraries is presented in Section 6. Table 6.1 presents the cross section libraries selected for use in MCNP criticality benchmark and design calculations.

All of the various continuous-energy MCNP cross section libraries available for use by the WPDD are considered acceptable. However, all MCNP criticality benchmark and design calculations performed by the WPDD should adhere to the selected set of cross section libraries, as presented in Table 6.1, to ensure consistency throughout the various benchmarks and design calculations.

The data reported herein is acceptable for quality affecting activities and for use in analyses affecting procurement, construction, or fabrication. The classification for the repository (which includes the waste package) carries TBV-228 because of the preliminary status of the basis for the Mined Geologic Repository design. This report conservatively assumes that the resolution of TBV-228 will find the waste package to be quality affecting; consequently, use of any of the data reported herein does not need to carry TBV-228.

8. References

1. J. F. Briesmeister. *MCNP 4B: Monte Carlo N-Particle Transport Code System.* Los Alamos National Laboratory report LA-12625-M (1997).

2. *Classification of the Preliminary MGDS Repository Design.* Document Identifier Number (DI#): B00000000-01717-0200-00134 REV 00, Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O).

3. *QAP-2-0 Activity Evaluation.* Activity Evaluation Number: WP-06, Develop Technical Documents, CRWMS M&O, August 3, 1997.

4. *Quality Assurance Requirements and Description.* DOE/RW-0333P, REV 8, United States Department of Energy Office of Civilian Radioactive Waste Management.

5. *Software Qualification Report for MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code.* DI#: 30033-2003 REV 01, CRWMS M&O.

6. R. E. MacFarlane and D. W. Muir. *The NJOY Nuclear Data Processing System, Version 91.* Los Alamos National Laboratory report LA-12740-M (1994).

7. *Nuclides and Isotopes, Fourteenth Edition.* GE Nuclear Energy, 1989.

8. *Laboratory Critical Experiment Reactivity Calculations.* DI#: B00000000-01717-0210-00018 REV 00, CRWMS M&O.

9. *CRC Reactivity Calculations for Crystal River Unit 3.* DI#: B00000000-01717-0210-00002 REV 00, CRWMS M&O.

10. *CRC Reactivity Calculations for Three Mile Island Unit 1.* DI#: B00000000-01717-0210-00008 REV 00, CRWMS M&O.

11. *CRC Reactivity Calculations for McGuire Unit 1.* DI#: B00000000-01717-0210-00004 REV 00, CRWMS M&O.

12. *CRC Reactivity Calculations for Sequoyah Unit 2.* DI#: B00000000-01717-0210-00006 REV 00, CRWMS M&O.