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Production and Testing of the Revised VITAMIN-B6 Fine-Group and the BUGLE-93 Broad-Group Neutron/Photon Cross-Section Libraries Derived From ENDF/B-VI.3 Nuclear Data

Oak Ridge National Laboratory

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U.S. Nuclear Regulatory Commission
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ABSTRACT

A revised multigroup cross-section library based on Release 3 of ENDF/B-VI data has been produced and tested for light-water-reactor shielding and reactor pressure vessel dosimetry applications. This new broad-group library, which is designated BUGLE-96, represents an improvement over the BUGLE-93 data library released in February 1994 and replaces the data package for BUGLE-93 in the Radiation Safety Information Computational Center (formerly RSIC). The processing methodology is the same as that used for producing BUGLE-93 and is consistent with ANSI/ANS 6.1.2. The ENDF data were first processed into a fine-group, pseudo-problem-independent format and then collapsed into the final broad-group format. The fine-group library, which is designated VITAMIN-B6, contains 120 nuclides. The BUGLE-96 47-neutron-group/20-gamma-ray-group library contains the same 120 nuclides processed as infinitely dilute and collapsed using a weighting spectrum typical of a concrete shield. Additionally, nuclides processed with resonance self-shielding and weighted using spectra specific to BWR and PWR material compositions and reactor models are available. As an added feature of BUGLE-96, cross-section sets having upscatter data for four thermal neutron groups are included. The upscattering data should improve the application of BUGLE-96 to the calculation of more accurate thermal fluences, although more computer time will be required. Several new dosimetry response functions and kerma factors for all 120 nuclides are also included in the library. The incorporation of feedback from users has resulted in a data library that addresses a wider spectrum of user needs.

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FOREWORD

Since the January 1995 publication of NUREG/CR-6214, "Production of the VITAMIN-B6 Fine Group and the BUGLE-93 Broad-Group Neutron/Photon Cross-Section Libraries Derived from ENDF/B-VI Nuclear Data," additional enhancements have been made to the multigroup constants used by the worldwide light-water-reactor (LWR) community. Whereas, the initial BUGLE-93 report documented the development of multigroup data derived from Release 2 of ENDF/B-VI, the objective of this revised report is to document the BUGLE-96 data library, which is based on Release 3 of ENDF/B-VI reference data.

The documentation of BUGLE-93 improved on the standard for LWR cross-section data development with highly detailed descriptions of both the data development and data testing components of the original task. New reference evaluated data for several important nuclides combined with a need to improve the self-shielding for the materials in the reactor pressure vessel, and a need to provide better data for LWR applications sensitive to the thermal flux, motivated continued work toward improving the BUGLE-93 product. Sponsorship of the current work to help meet the ANSI/ANS 6.1.2 requirements for updating the standard on nuclear radiation protection calculations for nuclear power plants was provided by the U.S. Nuclear Regulatory Commission.

This revision to NUREG/CR-6214 represents an attempt to reduce confusion, and hopefully errors, in usage caused by the anticipated burden on readers switching between an addendum and the original report in order to obtain the correct data for nuclear engineering analysis. In part, the approach taken in preparing this revision was to integrate work performed during the past 2 ½ years with the original work and rewrite the data preparation sections of NUREG/CR-6214. For completeness, the section of the original report describing the data testing program is included. Although new data testing activity was not supported in the present effort, a few selected CSEWG benchmarks were calculated with BUGLE-96 to gain some confidence in the performance of the new Release 3 evaluations. No expected differences were observed in the performance parameters for the benchmarks checked.

ACKNOWLEDGMENTS

The authors are grateful to all individuals who helped directly or indirectly with developing the library specifications, processing the cross-section data, or analyzing the benchmark experiments. We wish to explicitly acknowledge our gratitude to Professor Mark Williams of Louisiana State University for valuable discussions and contributions in the processing and data testing activities, and to Mike Mayfield and Carolyn Fairbanks of the U.S. Nuclear Regulatory Commission for their sponsorship of this project.

1 INTRODUCTION

The generation of multigroup cross-section libraries with broad energy group structures is primarily for reasons of economy. Despite the impressive performance of modern supercomputers, it is still often impractical to perform two- and three-dimensional radiation transport analyses using pointwise data or finely structured multigroup data, especially if fine resolution is needed for the space or angular meshes. Even for one-dimensional analyses, it is often more efficient to use few-group data to perform the initial scoping analysis, and then advance to finer group data as accuracy requirements become more stringent. The establishment of reference broad-group libraries is desirable to avoid duplication of effort, both in terms of the library generation and verification, and to assure a common database for comparisons among program participants.

A revised multigroup cross-section library based on Release 3 of ENDF/B-VI data[1] has been produced and tested for light-water-reactor shielding and reactor pressure vessel dosimetry applications. The broad-group library, which is designated BUGLE-96, represents an improvement over the BUGLE-93 data library (D. T. Ingersoll et al., NUREG/CR-6214, 1995), which was released in February 1994 as a replacement for the outdated BUGLE-80[2] and SAILOR[3] libraries. The data were initially prepared by processing the ENDF data into a fine-group, pseudo-problem-independent format using the NJOY processing system[4] and then by collapsing the fine-group data into the final broad-group format using the AMPX code system.[5] The fine-group library is designated VITAMIN-B6 and is modeled after the earlier VITAMIN-C[6] and VITAMIN-E[7] libraries. BUGLE-93 is available in a format for direct use in radiation transport codes such as ANISN,[8] DORT,[9] TORT,[10] MORSE,[11] and other similar multigroup codes. It is expected that the general nature of BUGLE-96, and especially VITAMIN-B6, will make these libraries useful for other shielding applications and potentially for reactor physics analyses.

1.1 Background

In 1974, the Cross-Section Evaluation Working Group (CSEWG) released Version 4 of the Evaluated Nuclear Data Files (ENDF/B-IV).[12] Subsequently, several independent efforts were undertaken to develop multigroup cross-section libraries based on these improved data files. At the same time, the ANS 6.1 Working Group was working to develop a standardized approach for generating multigroup cross sections to be used in radiation protection and shielding analyses for nuclear power plants. Their goal was to establish the recommended methodology for generating a problem-dependent cross-section library and also to select a reference library utilizing this methodology as an industry standard.

The recommended methodology adopted by ANS 6.1 consists of a two-stage process: (1) the processing of ENDF files into a fine-group, pseudo-problem-independent library, followed by (2) the collapsing of the fine-group library into the desired broad-group, problem-dependent library. The library generated in the first stage is considered pseudo-problem-independent if it has been prepared with enough detail in energy, temperatures, and resonance self-shielding so as to be applicable to a wide range of specific problems. The problem-dependent library is then derived from the fine-group library by applying temperature and resonance self-shielding information and collapsing to a smaller number of groups. This approach removes from the end user the need to deal with the complex and tedious task of producing a group-averaged library from the ENDF files, which contain a mix of point and functional data. This approach also reduces the user's responsibility to the operation of a finite number of well-defined processing codes. Hence, a higher level of standardization is achieved, along with a higher level of reliability since the user can focus on only those features that are special to his application.

The activities of the ANS 6.1 Working Group motivated the development and generation of a broad-group library, designated BUGLE, specifically tailored for power reactor radiation shielding analyses. The library, which was derived from the ENDF/B-IV-based VITAMIN-C fine-group library,[6] contained 45 neutron energy groups and 16 gamma-ray energy groups. However, initial experience with the BUGLE library indicated specific deficiencies, especially with respect to the group structure and the energy weighting function. As a result, the library specifications were modified and a new library was prepared and designated as BUGLE-80.[2] In parallel to the BUGLE-80 effort was an independent project to analyze fluence levels at the pressure vessel location in specific light-water power reactors. This project culminated in the production of a broad-group cross-section library, designated SAILOR.[3] The SAILOR library is similar to BUGLE-80, using the same 47 neutron energy groups and 20 gamma-ray energy groups, but differs in the weighting spectra used to collapse from the VITAMIN-C data. Whereas BUGLE-80 uses only a single energy weighting, which corresponds to the spectrum within the concrete shield of an LWR, SAILOR uses five different spectra corresponding to specific core, downcomer, and pressure vessel locations within specific PWR and BWR models.

At the completion of their effort, the ANS 6.1 Working Group issued a standard describing the methodology for producing multigroup cross sections for nuclear power plant shielding analyses. This standard, ANSI/ANS 6.1.2,[13] explicitly mentions the fine-group VITAMIN-C cross-section library and the derived broad-group BUGLE-80 library as satisfying the preferred processing methodology. The SAILOR library also employs the same methodology and is cited in the standard. These libraries, derived from ENDF/B-IV, have been used extensively in the LWR shielding community, but were in need of updating with more modern and accurate nuclear data. Because of this, the U.S. Nuclear Regulatory Commission (NRC) supported an effort to update the BUGLE-80 and SAILOR libraries. In the initial phase of the project, specifications for the new library were developed[14] and extensively reviewed. The driving constraints for the project were to construct a cross-section library that was based on the best available nuclear data and which was "plug compatible" with the previous libraries to facilitate its rapid implementation by the LWR community.

The project resulted in the production of a new fine-group library, designated VITAMIN-B6, and a new broad-group library, designated BUGLE-93.[38] The BUGLE-93 library was released for general distribution in February 1994, and was quickly implemented by the LWR shielding community. Feedback from the user community indicated the need for a few further improvements to the data library. Specifically, it is desirable for some users to have the new data provided in a format which is <u>exactly</u> compatible with the previous SAILOR library, (i.e. the nuclides should be premixed into compound materials having the same nuclide densities and material identifiers as SAILOR. More significantly, accuracy issues related to the treatment of thermal scattering reactions were studied by users at Louisiana State University (LSU). Conclusions from the LSU study indicated that for some problems of interest, it is important to retain neutron "upscatter" reactions in the multigroup data. For these reasons, and because revised versions of the ENDF/B-VI data had been released subsequent to the generation of BUGLE-93, a project was undertaken to produce a revised multigroup library, which is designated as BUGLE-96 and is described in this report.

1.2 Evaluated Nuclear Data Files

Version VI of the U.S. Evaluated Nuclear Data File (ENDF/B-VI)[1] was released for open distribution in 1990 after an extensive measurement and evaluation effort spanning nearly 10 years. The multilaboratory project was coordinated by CSEWG, which is operated through the National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. Seventy-four of the 320 evaluations contained in the library are new for Version VI. Most of the new evaluations represent relatively important nuclides throughout the mass range, and many of them include substantial changes to the cross-section data. Subsequent to the initial release of ENDF/B-VI in 1991, revisions to some of the evaluations and additional new evaluations were prepared and released. The latest of these major releases is Release 3, which was distributed in May 1995. The BUGLE-96 library reported herein is derived from this release of ENDF.

ENDF/B-VI contains numerous significant changes relative to earlier versions. Improved experimental data and model predictions are included, and several format changes were made to provide for better representation of the underlying physics and the extension to higher energies. Some of the more significant changes include:

- new resonance region evaluation for ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu (first update since ENDF/B-III)
- simultaneous evaluation of several neutron standard cross sections
- addition of sublibraries in File 1 for charged particle reactions
- File 6 formats for angle-energy correlations of recoil and secondary particles
- Reich-Moore formalism for resonance region
- representation separate isotopic evaluations for structural elements

Note that even though the format changes were well-intended and thoroughly reviewed before implementation, they have adversely affected the timely utilization of Version VI data since processing codes must be correspondingly altered to treat the new formats. Unfortunately, the steady decline in funding support for work of this type during the past decade has caused most of the processing code systems to become out of date. Currently, only the NJOY code system developed by Los Alamos National Laboratory is available to process ENDF/B-VI.

Of special interest for LWR shielding analyses are improvements to the iron evaluation. For more than a decade, it had been widely observed in integral benchmark experiments that neutron transmission through thick iron was consistently underpredicted in the energy range of 3 to 10 MeV. It became apparent that at least a portion of the discrepancies were due to the continuum inelastic scattering cross section for ^{56}Fe. Specifically, ENDF/B-V (and previous versions) treat the continuum inelastic cross section as isotropic for the outgoing neutrons; however, differential data indicate that the angular distribution for outgoing neutrons is in fact forward directed, which if incorporated into the cross-section data, would increase the transmission of neutrons through iron. To test this theory, a preliminary version of ENDF/B-VI iron data[15] was prepared and used to analyze several benchmarks. The new iron data showed significant improvements in the calculated-to-experiment ratios for those benchmarks.

An especially important result was obtained from dosimetry data taken from the reactor cavity region of Arkansas Nuclear One Unit-1 (ANO-1). The original analysis of ANO-1 was performed using two-dimensional (2-D) transport methods incorporating ENDF/B-IV data and showed a consistent underprediction of the pressure vessel dosimetry.[16] Since the reactor included a thick iron thermal shield and an iron pressure vessel, it was expected that the discrepancies might be due to the iron data. A reanalysis of ANO-1 using scaled one-dimensional (1-D) methods and preliminary Version 6 iron data showed significant improvements in the agreement with the measured dosimeter data.[17]

Because of these observations and other known improvements contained in ENDF/B-VI, it became clear that use of these data will substantially benefit light-water-reactor shielding applications. Our processing of ENDF/B-VI into multigroup format for use in radiation transport calculations now provides analysts with the most currently available nuclear data, which will help to reduce design biases and uncertainties.

1.3 Cross-Section Processing and Testing

The calculational approach used to produce a new ENDF/B-VI library is consistent with the ANS 6.1.2 standard. Specifically, the ENDF data were first processed into a fine-group set similar to the VITAMIN-C and VITAMIN-E libraries and then collapsed into a broad-group set similar to BUGLE-80. Although the overall methodology is the same, a different set of processing codes were used to perform the initial phase of the processing. The earlier VITAMIN-C and VITAMIN-E libraries were created from ENDF/B-IV and ENDF/B-V using a combination of the AMPX code system and the MINX code. However, these codes were not kept current with the format changes in ENDF/B-VI, and it was prohibitively expensive to make the required changes to the codes for this project. Instead, the selected approach employs both the NJOY modular code system and the AMPX code system.

Several modules of NJOY were used to process the neutron interaction, gamma-ray production, and gamma-ray interaction data from the ENDF/B-VI formats to a group-averaged format. The SMILER module in the AMPX code system was then used to translate the intermediate NJOY file into the AMPX master format for the fine-group library. A detailed description of the VITAMIN-B6 fine-group library and the processing system is given in Chapter 2. Additional modules from the AMPX system were then used to perform the computations and manipulations needed to produce the final broad-group library. The specifications and processing methods used to generate the BUGLE-96 broad-group library are described in Chapter 3.

Finally, the BUGLE-96 verification and validation effort described in Chapter 4 includes the results of a thorough benchmark testing effort for the preceding BUGLE-93 library.

2 FINE-GROUP LIBRARY SPECIFICATIONS

2.1 Name

The fine-group pseudo-problem-independent library is designated as VITAMIN-B6. This continues the "VITAMIN" naming convention initially started with the ENDF/B-IV-based VITAMIN-C library and the follow-on ENDF/B-V-based VITAMIN-E library. The "B6" designation conveniently reflects the origin of the evaluated data, but also was chosen since vitamin B_6 represents an element of broad nutritional value -- something that we feel will characterize this new library.

2.2 Materials, Temperatures and Background Cross Sections

The set of 120 nuclides processed for VITAMIN-B6 are listed in Table 2.1, which also indicates the ENDF/B-VI MAT number and tape number. The nuclides that underwent major revisions for Version 6 of ENDF are flagged in the table, along with the nuclides which are contained in BUGLE-80. Even though all nuclides contain neutron interaction and photon interaction data, only some of the nuclides contain gamma-ray production data, as indicated in the table. Two of the nuclides, tin and Zirc-2, were not available from ENDF/B-VI and were obtained elsewhere. Tin was obtained from the Livermore Evaluated Nuclear Data Library (LENDL-V),[18] and Zirc-2 was obtained from Version IV of ENDF. Seven additional nuclides that contain only a limited number of specific reactions were also processed. These nuclides are important for dosimetry applications and are listed in Table 2.2. It is expected that additional materials beyond those listed in Tables 2.1 and 2.2 will be processed and added to the library as needed for future analysis projects.

The Bondarenko (f-factor) method is used for handling resonance self-shielding and temperature effects. All materials were processed at temperatures of 300, 600, 1000, and 2100 K, and most materials were processed with 6 to 8 values of the background cross section, σ_0. These parameters are summarized in Table 2.3. As seen in Table 2.3, nearly all materials are processed with the following values of σ_0: 1, 10, 10^2, 10^3, 10^4, and 10^{10} barns. Even though these values of σ_0 appear adequate for most circumstances, additional values were added to this library to improve the accuracy of the cross-section interpolation between σ_0 values. These additional values are based on experience obtained in the utilization of VITAMIN-E. Consistent with most other libraries, we elected to use infinitely dilute cross sections for nuclides with Z less than 7, with the exception of ^{11}B. Hence, only a background cross section of 10^{10} barns was used for these nuclides. The thermal scattering law data for graphite, polyethylene, beryllium metal, heavy water, and light water were processed at all temperatures available on the ENDF tape.

Table 2.1 ENDF/B-VI nuclides processed for the VITAMIN-B6 library

Z	Nuclide	MAT	ENDF[a] tape	New for Ver. 6	BUGLE-80 nuclides	Gamma-ray production
1	H-1 (H_2O)	125/1	120/118	X	X	X
	H-1 (CH_2)	125/37	120/118	X		X
	H-2 (D_2O)	128/11	134/118[b]	X		X
	H-3	131	101		X	
2	He-3	225	120	X		
	He-4	228	101		X	
3	Li-6	325	120	X	X	X
	Li-7	328	100	X	X	X
4	Be-9	425	100	X	X	X
	Be-9 (Thermal)	425/26	100/118	X		X
5	B-10	525	120	X	X	X
	B-11	528	100	X	X	X
6	C	600	120	X	X	X
	C (Graphite)	600/31	120/118[b]	X		X
7	N-14	725	134	X	X	X
	N-15	728	116	X		X
8	O-16	825	116	X	X	X
	O-17	828	101			
9	F-19	925	115	X	X	X
11	Na-23	1125	120		X	X
12	Mg	1200	101		X	X
13	Al-27	1325	134		X	X
14	Si	1400	116		X	X
15	P-31	1525	101		X	X
16	S	1600	101		X	X
	S-32	1625	101			X
17	Cl	1700	101			X
19	K	1900	101		X	X
20	Ca	2000	101		X	X
22	Ti	2200	102		X	X
23	V	2300	103	X	X	X
24	Cr-50	2425	122	X	X	X
	Cr-52	2431	122	X	X	X
	Cr-53	2434	122	X	X	X
	Cr-54	2437	122	X	X	X
25	Mn-55	2525	114	X	X	X
26	Fe-54	2625	123	X	X	X
	Fe-56	2631	123	X	X	X
	Fe-57	2634	123	X	X	X
	Fe-58	2637	123	X	X	X
27	Co-59	2725	129	X	X	X
28	Ni-58	2825	124	X	X	X
	Ni-60	2831	124	X	X	X
	Ni-61	2834	124	X	X	X
	Ni-62	2837	124	X	X	X
	Ni-64	2843	124	X	X	X
29	Cu-63	2925	129	X	X	X
	Cu-65	2931	129	X	X	X

Table 2.1 cont'd

Z	Nuclide	MAT	ENDF tape	New for Ver. 6	BUGLE-80 nuclides	Gamma-ray production
31	Ga	3100	102			X
39	Y-89	3925	103	X		X
40	Zr	4000	120		X	
40	Zirc-2	1284	411[c]		X	
41	Nb-93	4125	120	X	X	X
42	Mo	4200	104		X	X
47	Ag-107	4725	104		X	
	Ag-109	4731	104		X	
48	Cd	4800	104		X	
49	In	4900	116	X		X
50	Sn	7850	---[d]		X	X
56	Ba-138	5649	134		X	X
63	Eu-151	6325	103	X	X	X
	Eu-152	6328	103	X	X	
	Eu-153	6331	103	X	X	X
	Eu-154	6334	103	X	X	
	Eu-155	6337	120	X		
72	Hf-174	7225	127	X		
	Hf-176	7231	127	X		
	Hf-177	7234	127	X		
	Hf-178	7237	127	X		
	Hf-179	7240	127	X		
	Hf-180	7243	127	X		
73	Ta-181	7328	106		X	X
	Ta-182	7331	106			
74	W	7400	120			X
	W-182	7431	107		X	X
	W-183	7434	107		X	X
	W-184	7437	107		X	X
	W-186	7443	107		X	X
75	Re-185	7525	115	X		
	Re-187	7531	115	X		
79	Au-197	7925	120	X		X
82	Pb-206	8231	115	X	X	X
	Pb-207	8234	120	X	X	X
	Pb-208	8237	115	X	X	X
83	Bi-209	8325	108	X		X
90	Th-230	9034	110			
	Th-232	9040	109		X	X
91	Pa-231	9131	109			
	Pa-233	9137	110			
92	U-232	9219	109			
	U-233	9222	109		X	X
	U-234	9225	109		X	
	U-235	9228	135	X	X	X
	U-236	9231	108	X	X	
	U-237	9234	129			X
	U-238	9237	128	X	X	X

Table 2.1 cont'd

Z	Nuclide	MAT	ENDF tape	New for Ver. 6	BUGLE-80 nuclides	Gamma-ray production
93	Np-237	9346	121	X		X
	Np-238	9349	128			
	Np-239	9352	108	X		
94	Pu-236	9428	110			
	Pu-237	9431	110			
	Pu-238	9434	109		X	
	Pu-239	9437	128	X	X	X
	Pu-240	9440	128	X	X	X
	Pu-241	9443	135	X	X	X
	Pu-242	9446	109		X	X
	Pu-243	9449	129			X
	Pu-244	9452	110			
95	Am-241	9543	135	X	X	X
	Am-242	9546	121			
	Am-242m	9547	121			X
	Am-243	9549	108	X		X
96	Cm-241	9628	110			
	Cm-242	9631	109			X
	Cm-243	9634	110			X
	Cm-244	9637	110			X
	Cm-245	9640	129			X
	Cm-246	9643	129			X
	Cm-247	9646	129			X
	Cm-248	9649	110			X

[a] Tapes 100-119 are from initial release of ENDF/B-VI (April 1991);
Tapes 120-126 are from Revision 1 of ENDF/B-VI (August 1992);
Tapes 127-129 are from Revision 2 of ENDF/B-VI (June 1993);
Tapes 132-135 are from Revision 3 of ENDF/B-VI (May 1995).
[b] Incorporates improved thermal scattering law data from ORNL.
[c] From Revision 1 of ENDF/B-IV.
[d] From LENDL-V.

Table 2.2 ENDF/B-VI nuclides processed for dosimetry reactions only

Z	Nuclide	MAT	ENDF tape
21	Sc-45	2125	127[a]
22	Ti-46	2225	102
	Ti-47	2228	102
	Ti-48	2231	102
45	Rh-103	4525	104
49	In-115	4931	116
53	I-127	5325	127[a]

[a] Revision 2 of ENDF/B-VI (June 1993).

Table 2.3 Background cross-section values at which Bondarenko factors are tabulated in the VITAMIN-B6 library. All nuclides were processed at four temperatures: 300, 600, 1000, and 2100 K

Nuclide	Background cross sections (barns)										Legendre order
	10+10[a]	10+6	10+5	10+4	1000	300	100	50	10	1	
H-1	X										7
H-2	X										7
H-3	X										7
He-3	X										7
He-4	X										7
Li-6	X										7
Li-7	X										7
Be-9	X										7
B-10	X										7
B-11	X				X		X		X	X	7
C	X										7
N-14	X				X		X		X	X	7
N-15	X				X		X		X	X	7
0-16	X				X		X		X	X	7
O-17	X				X		X		X	X	7
F-19	X				X		X		X	X	7
Na-23	X				X	X	X	X	X	X	7
Mg	X		X	X	X		X		X	X	7
Al-27	X			X	X		X	X	X	X	7
Si	X		X	X	X		X		X	X	7
P-31	X			X	X		X		X	X	7
S	X			X	X		X		X	X	7
S-32	X			X	X		X		X	X	7
Cl	X			X	X		X		X	X	7
K	X			X	X		X		X	X	7
Ca	X		X	X	X		X		X	X	7
Ti	X		X	X	X		X		X	X	7
V	X			X	X		X		X	X	7
Cr-50	X		X	X	X		X		X	X	7
Cr-52	X		X	X	X		X		X	X	7
Cr-53	X		X	X	X		X		X	X	7
Cr-54	X		X	X	X		X		X	X	7
Mn-55	X		X	X	X		X		X	X	7
Fe-54	X		X	X	X		X		X	X	7
Fe-56	X		X	X	X		X	X	X	X	7
Fe-57	X		X	X	X		X		X	X	7
Fe-58	X		X	X	X		X		X	X	7
Co-59	X		X	X	X		X		X	X	7
Ni-58	X		X	X	X		X	X	X	X	7
Ni-60	X		X	X	X		X	X	X	X	7
Ni-61	X		X	X	X		X		X	X	7
Ni-62	X		X	X	X		X		X	X	7
Ni-64	X		X	X	X		X		X	X	7
Cu-63	X		X	X	X		X		X	X	7
Cu-65	X		X	X	X		X		X	X	7
Ga	X		X	X	X		X		X	X	5

Table 2.3 cont'd

Nuclide	Background cross sections (barns)										Legendre order
	10+10[a]	10+6	10+5	10+4	1000	300	100	50	10	1	
Y-89	X		X	X	X		X		X	X	5
Zr	X		X	X	X		X		X	X	5
Zirc2	X		X	X	X		X		X	X	5
Nb-93	X		X	X	X		X		X	X	5
Mo	X		X	X	X		X				5
Ag-107	X		X	X	X		X		X	X	5
Ag-109	X		X	X	X		X		X	X	5
Cd	X		X	X	X		X		X	X	5
In	X		X	X	X		X		X	X	5
Sn	X		X	X	X		X		X	X	5
Ba-138	X		X	X	X		X		X	X	5
Eu-151	X		X	X	X		X	X			5
Eu-152	X	X	X	X	X		X				5
Eu-153	X		X	X	X		X	X			5
Eu-154	X	X	X	X	X		X				5
Eu-155	X	X	X	X	X		X				5
Hf-174	X		X	X	X		X		X	X	5
Hf-176	X		X	X	X		X		X	X	5
Hf-177	X		X	X	X		X	X			5
Hf-178	X		X	X	X		X		X	X	5
Hf-179	X		X	X	X		X	X			5
Hf-180	X		X	X	X		X		X	X	5
Ta-181	X		X	X	X		X	X			5
Ta-182	X		X	X	X		X	X			5
W	X		X	X	X		X		X	X	5
W-182	X		X	X	X		X		X	X	5
W-183	X		X	X	X		X	X			5
W-184	X		X	X	X		X		X	X	5
W-186	X		X	X	X		X		X	X	5
Re-185	X	X	X	X	X		X				5
Re-187	X	X	X	X	X		X				5
Au-197	X		X	X	X		X		X	X	5
Pb-206	X		X	X	X		X		X	X	5
Pb-207	X		X	X	X		X		X	X	5
Pb-208	X		X	X	X		X		X	X	5
Bi-209	X		X	X	X		X		X	X	5
Th-230	X	X	X	X	X		X				5
Th-232	X			X	X	X	X	X	X	X	5
Pa-231	X		X	X	X		X	X			5
Pa-233	X		X	X	X		X	X			5
U-232	X		X	X	X		X	X			5
U-233	X		X	X	X		X	X			5
U-234	X		X	X	X		X		X	X	5
U-235	X	X	X	X	X		X	X			5
U-236	X		X	X	X		X		X	X	5
U-237	X		X	X	X		X	X			5
U-238	X			X	X	X	X	X	X	X	5

Table 2.3 cont'd

Nuclide	Background cross sections (barns)										Legendre order
	10+10[a]	10+6	10+5	10+4	1000	300	100	50	10	1	
Np-237	X		X	X	X		X		X	X	5
Np-238	X		X	X	X		X	X			5
Np-239	X		X	X	X		X	X			5
Pu-236	X		X	X	X		X		X	X	5
Pu-237	X		X	X	X		X	X			5
Pu-238	X		X	X	X		X		X	X	5
Pu-239	X		X	X	X		X	X			5
Pu-240	X		X	X	X		X		X	X	5
Pu-241	X		X	X	X		X	X			5
Pu-242	X		X	X	X		X		X	X	5
Pu-243	X		X	X	X		X	X			5
Pu-244	X		X	X	X		X		X	X	5
Am-241	X		X	X	X		X	X			5
Am-242	X		X	X	X		X	X			5
Am-242m	X		X	X	X						5
Am-243	X		X	X	X		X	X			5
Cm-241	X		X	X	X		X	X			5
Cm-242	X		X	X	X		X	X			5
Cm-243	X		X	X	X		X	X			5
Cm-244	X		X	X	X		X	X			5
Cm-245	X		X	X	X		X	X			5
Cm-246	X		X	X	X		X	X			5
Cm-247	X		X	X	X		X	X			5
Cm-248	X		X	X	X		X	X			5

[a] Read as 1×10^{10}

2.3 Energy-Group Structure

Feedback from users of previous VITAMIN libraries, which were developed primarily for "fast" neutron applications, indicated that the neutron energy group structure appears adequate at higher energies, but that refining the neutron group structure in the thermal energy range would greatly expand the usefulness of the fine-group library for a broader range of applications. On the other hand, experience with a 27-neutron-group library from the SCALE system,[19] which was developed primarily for criticality safety and for out-of-core shielding applications, has been favorable in terms of the number of thermal energy groups, but has indicated inadequate resolution in the high energy range (E > 0.1 MeV). Hence, the VITAMIN-B6 neutron energy group structure was constructed as a compromise and improvement over the 174 neutron group structure used for VITAMIN-E and the 27-neutron-group structure used for SCALE.

The VITAMIN-B6 thermal energy range (i.e., the range of groups which include upscatter) contains 36 groups and has 5.043 eV as the uppermost boundary. The group boundaries are listed in Table 2.4, which also labels corresponding boundaries from the VITAMIN-E and the 27-group libraries. Figure 2.1 provides a graphical comparison of the neutron group boundaries below 5.043 eV for the VITAMIN-B6, VITAMIN-E, SCALE, and BUGLE-96 group structures. By combining the best features of the VITAMIN and 27-group neutron energy grids, we have maximized our options for creating the best problem-independent energy grid for a variety of reactor designs including thermal (water- or graphite- moderated) and fast reactor systems. Consequently, problem-dependent libraries can be easily derived from VITAMIN-B6 without having to repeat the multigroup averaging directly from the ENDF files.

The full VITAMIN-B6 neutron energy group structure is given in Table 2.5. The 199-group boundaries are based on the 175 groups in VITAMIN-J (a European library based on the VITAMIN-C and VITAMIN-E structures) with an expanded number of thermal groups as discussed above. At higher energies, the boundaries are almost identical with the earlier VITAMIN libraries, which consist of a basic 100-group-mesh of equal lethargy width plus numerous additional boundaries to resolve resonance minima that are important for shielding calculations.

The photon energy group structure is given in Table 2.6. It is based on a combination of the 42 gamma-ray groups in VITAMIN-J and the 18 groups in the SCALE shielding library. The top energy group extends to 30 MeV, which allows proper representation of high-energy gamma rays from neutron capture at high energies. Although the cross section for capture at neutron energies between 20 and 30 MeV is small, such a reaction in some materials can produce gamma rays with energies between 20 and 30 MeV.

2.4 Weighting Function

The neutron weighting function is of the form typically chosen for fission reactor shielding problems (i.e., it consists of a smoothly varying combination of a Maxwellian thermal spectrum, a fission spectrum, and a "1/E" slowing-down spectrum). This corresponds to an IWT=4 option in the GROUPR module of NJOY. The breakpoint energies for

Table 2.4 VITAMIN-B6 thermal neutron energy range

Group	Upper energy (eV)	Lethargy Width	Group	Upper energy (eV)	Lethargy Width
164	5.0435*	0.250	182	0.36680	0.121
165	3.9279*	0.250	183	0.3250#	0.167
166	3.0590*	0.250	184	0.2750	0.201
167	2.3824*	0.250	185	0.2250#	0.210
168	1.8554*	0.250	186	0.1840	0.204
169	1.4450*	0.106	187	0.1500	0.182
170	1.3000#	0.144	188	0.1250	0.223
171	1.1253*	0.041	189	0.1000*#	0.357
172	1.0800	0.038	190	0.0700	0.366
173	1.0400	0.039	191	0.0500#	0.223
174	1.0000#	0.132	192	0.0400	0.288
175	0.87643*	0.091	193	0.0300#	0.357
176	0.8000#	0.159	194	0.0210	0.370
177	0.68256*	0.088	195	0.0145	0.372
178	0.62506	0.162	196	0.0100#	0.693
179	0.53158*	0.061	197	0.0050	0.916
180	0.5000	0.188	198	0.0020	1.386
181	0.41399*	0.121	199	0.0005	3.912
				0.00001*#	

* VITAMIN-E boundary.
# 27-group SCALE boundary.

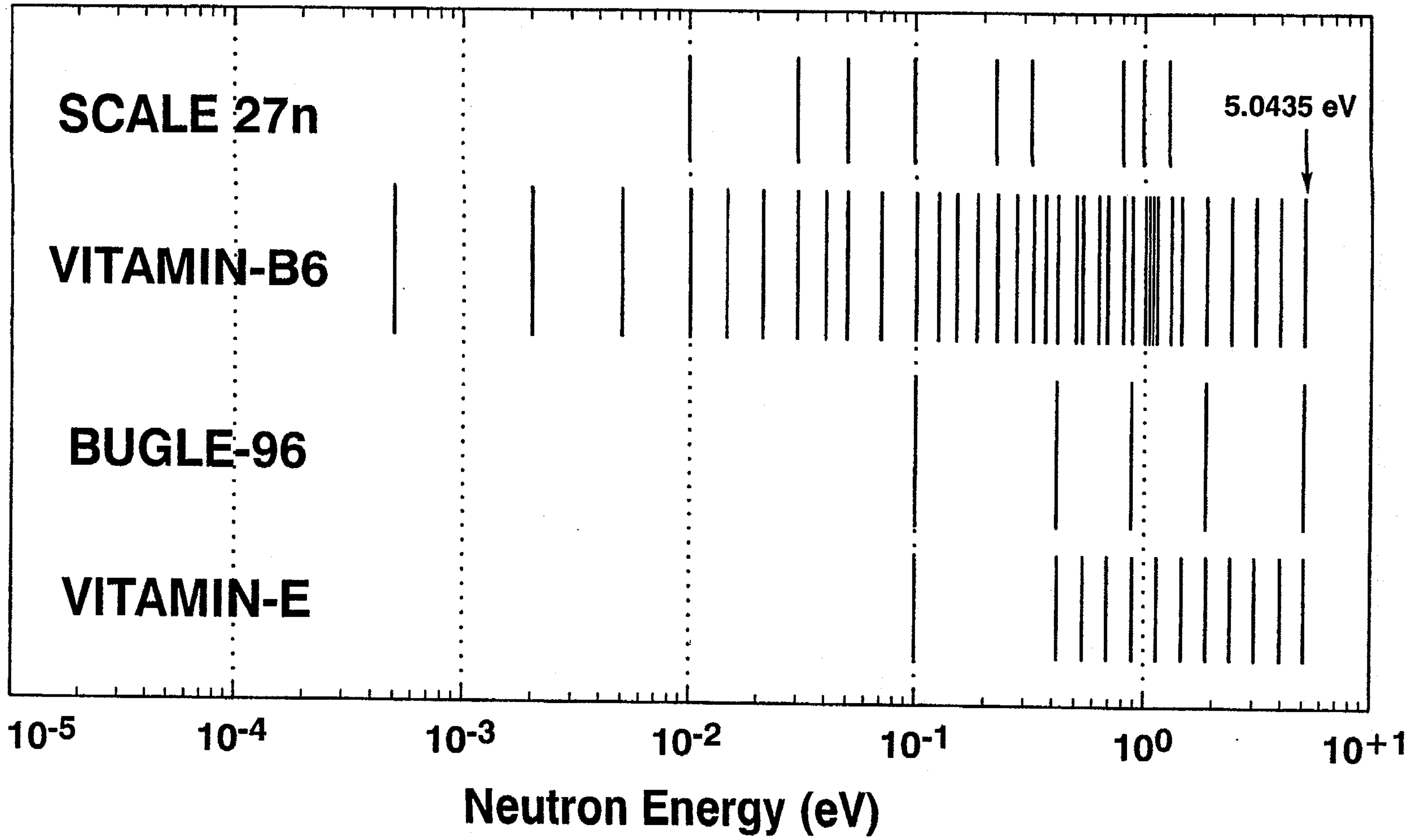


Fig. 2.1 Graphical display of neutron group boundaries below 5.0435 eV for several related cross-section libraries

Table 2.5 Neutron group energy boundaries for VITAMIN-B6

Fine group	Upper energy (eV)	Upper lethargy	Fine group	Upper energy (eV)	Upper lethargy
1	1.9640E+07	-6.7498E-01	48	2.2313E+06	1.5000E+00
2	1.7332E+07	-5.4997E-01	49	2.1225E+06	1.5500E+00
3	1.6905E+07	-5.2502E-01	50	2.0190E+06	1.6000E+00
4	1.6487E+07	-5.0000E-01	51	1.9205E+06	1.6500E+00
5	1.5683E+07	-4.5000E-01	52	1.8268E+06	1.7000E+00
6	1.4918E+07	-3.9998E-01	53	1.7377E+06	1.7500E+00
7	1.4550E+07	-3.7501E-01	54	1.6530E+06	1.8000E+00
8	1.4191E+07	-3.5002E-01	55	1.5724E+06	1.8500E+00
9	1.3840E+07	-3.2498E-01	56	1.4957E+06	1.9000E+00
10	1.3499E+07	-3.0003E-01	57	1.4227E+06	1.9500E+00
11	1.2840E+07	-2.4998E-01	58	1.3534E+06	2.0000E+00
12	1.2523E+07	-2.2498E-01	59	1.2874E+06	2.0500E+00
13	1.2214E+07	-2.0000E-01	60	1.2246E+06	2.1000E+00
14	1.1618E+07	-1.4997E-01	61	1.1648E+06	2.1500E+00
15	1.1052E+07	-1.0003E-01	62	1.1080E+06	2.2000E+00
16	1.0513E+07	-5.0028E-02	63	1.0026E+06	2.3000E+00
17	1.0000E+07	0.0000E+00	64	9.6164E+05	2.3417E+00
18	9.5123E+06	5.0000E-02	65	9.0718E+05	2.4000E+00
19	9.0484E+06	9.9997E-02	66	8.6294E+05	2.4500E+00
20	8.6071E+06	1.5000E-01	67	8.2085E+05	2.5000E+00
21	8.1873E+06	2.0000E-01	68	7.8082E+05	2.5500E+00
22	7.7880E+06	2.5000E-01	69	7.4274E+05	2.6000E+00
23	7.4082E+06	3.0000E-01	70	7.0651E+05	2.6500E+00
24	7.0469E+06	3.5000E-01	71	6.7206E+05	2.7000E+00
25	6.7032E+06	4.0000E-01	72	6.3928E+05	2.7500E+00
26	6.5924E+06	4.1667E-01	73	6.0810E+05	2.8000E+00
27	6.3763E+06	4.5000E-01	74	5.7844E+05	2.8500E+00
28	6.0653E+06	5.0000E-01	75	5.5023E+05	2.9000E+00
29	5.7695E+06	5.5000E-01	76	5.2340E+05	2.9500E+00
30	5.4881E+06	6.0000E-01	77	4.9787E+05	3.0000E+00
31	5.2205E+06	6.5000E-01	78	4.5049E+05	3.1000E+00
32	4.9659E+06	7.0000E-01	79	4.0762E+05	3.2000E+00
33	4.7237E+06	7.5000E-01	80	3.8774E+05	3.2500E+00
34	4.4933E+06	8.0000E-01	81	3.6883E+05	3.3000E+00
35	4.0657E+06	9.0000E-01	82	3.3373E+05	3.4000E+00
36	3.6788E+06	1.0000E+00	83	3.0197E+05	3.5000E+00
37	3.3287E+06	1.1000E+00	84	2.9849E+05	3.5116E+00
38	3.1664E+06	1.1500E+00	85	2.9721E+05	3.5159E+00
39	3.0119E+06	1.2000E+00	86	2.9452E+05	3.5250E+00
40	2.8651E+06	1.2500E+00	87	2.8725E+05	3.5500E+00
41	2.7253E+06	1.3000E+00	88	2.7324E+05	3.6000E+00
42	2.5924E+06	1.3500E+00	89	2.4724E+05	3.7000E+00
43	2.4660E+06	1.4000E+00	90	2.3518E+05	3.7500E+00
44	2.3852E+06	1.4333E+00	91	2.2371E+05	3.8000E+00
45	2.3653E+06	1.4417E+00	92	2.1280E+05	3.8500E+00
46	2.3457E+06	1.4500E+00	93	2.0242E+05	3.9000E+00
47	2.3069E+06	1.4667E+00	94	1.9255E+05	3.9500E+00

Table 2.5 cont'd

Fine group	Upper energy (eV)	Upper lethargy	Fine group	Upper energy (eV)	Upper lethargy
95	1.8316E+05	4.0000E+00	142	1.2341E+03	9.0000E+00
96	1.7422E+05	4.0500E+00	143	9.6112E+02	9.2500E+00
97	1.6573E+05	4.1000E+00	144	7.4852E+02	9.5000E+00
98	1.5764E+05	4.1500E+00	145	5.8295E+02	9.7500E+00
99	1.4996E+05	4.2000E+00	146	4.5400E+02	1.0000E+01
100	1.4264E+05	4.2500E+00	147	3.5357E+02	1.0250E+01
101	1.3569E+05	4.3000E+00	148	2.7536E+02	1.0500E+01
102	1.2907E+05	4.3500E+00	149	2.1445E+02	1.0750E+01
103	1.2277E+05	4.4000E+00	150	1.6702E+02	1.1000E+01
104	1.1679E+05	4.4500E+00	151	1.3007E+02	1.1250E+01
105	1.1109E+05	4.5000E+00	152	1.0130E+02	1.1500E+01
106	9.8037E+04	4.6250E+00	153	7.8893E+01	1.1750E+01
107	8.6517E+04	4.7500E+00	154	6.1442E+01	1.2000E+01
108	8.2503E+04	4.7975E+00	155	4.7851E+01	1.2250E+01
109	7.9499E+04	4.8346E+00	156	3.7266E+01	1.2500E+01
110	7.1998E+04	4.9337E+00	157	2.9023E+01	1.2750E+01
111	6.7379E+04	5.0000E+00	158	2.2603E+01	1.3000E+01
112	5.6562E+04	5.1750E+00	159	1.7604E+01	1.3250E+01
113	5.2475E+04	5.2500E+00	160	1.3710E+01	1.3500E+01
114	4.6309E+04	5.3750E+00	161	1.0677E+01	1.3750E+01
115	4.0868E+04	5.5000E+00	162	8.3153E+00	1.4000E+01
116	3.4307E+04	5.6750E+00	163	6.4760E+00	1.4250E+01
117	3.1828E+04	5.7500E+00	164	5.0435E+00	1.4500E+01
118	2.8501E+04	5.8604E+00	165	3.9279E+00	1.4750E+01
119	2.7000E+04	5.9145E+00	166	3.0590E+00	1.5000E+01
120	2.6058E+04	5.9500E+00	167	2.3824E+00	1.5250E+01
121	2.4788E+04	6.0000E+00	168	1.8554E+00	1.5500E+01
122	2.4176E+04	6.0250E+00	169	1.4450E+00	1.5750E+01
123	2.3579E+04	6.0500E+00	170	1.3000E+00	1.5856E+01
124	2.1875E+04	6.1250E+00	171	1.1253E+00	1.6000E+01
125	1.9305E+04	6.2500E+00	172	1.0800E+00	1.6041E+01
126	1.5034E+04	6.5000E+00	173	1.0400E+00	1.6079E+01
127	1.1709E+04	6.7500E+00	174	1.0000E+00	1.6118E+01
128	1.0595E+04	6.8500E+00	175	8.7643E-01	1.6250E+01
129	9.1188E+03	7.0000E+00	176	8.0000E-01	1.6341E+01
130	7.1017E+03	7.2500E+00	177	6.8256E-01	1.6500E+01
131	5.5308E+03	7.5000E+00	178	6.2506E-01	1.6588E+01
132	4.3074E+03	7.7500E+00	179	5.3158E-01	1.6500E+01
133	3.7074E+03	7.9000E+00	180	5.0000E-01	1.6811E+01
134	3.3546E+03	8.0000E+00	181	4.1399E-01	1.7000E+01
135	3.0354E+03	8.1000E+00	182	3.6680E-01	1.7121E+01
136	2.7465E+03	8.2000E+00	183	3.2500E-01	1.7242E+01
137	2.6126E+03	8.2500E+00	184	2.7500E-01	1.7409E+01
138	2.4852E+03	8.3000E+00	185	2.2500E-01	1.7610E+01
139	2.2487E+03	8.4000E+00	186	1.8400E-01	1.7811E+01
140	2.0347E+03	8.5000E+00	187	1.5000E-01	1.8015E+01
141	1.5846E+03	8.7500E+00	188	1.2500E-01	1.8198E+01

Table 2.5 cont'd

Fine group	Upper energy (eV)	Upper lethargy	Fine group	Upper energy (eV)	Upper lethargy
189	1.0000E-01	1.8421E+01	195	1.4500E-02	2.0352E+01
190	7.0000E-02	1.8777E+01	196	1.0000E-02	2.0723E+01
191	5.0000E-02	1.9114E+01	197	5.0000E-03	2.1416E+01
192	4.0000E-02	1.9337E+01	198	2.0000E-03	2.2333E+01
193	3.0000E-02	1.9625E+01	199	5.0000E-04	2.3719E+01
194	2.1000E-02	1.9981E+01		1.0000E-05	2.7631E+01

Table 2.6 Photon group energy boundaries for VITAMIN-B6

Fine group	Upper energy (eV)	Fine group	Upper energy (eV)
1	3.0000E+07	23	1.0000E+06
2	2.0000E+07	24	8.0000E+05
3	1.4000E+07	25	7.0000E+05
4	1.2000E+07	26	6.0000E+05
5	1.0000E+07	27	5.1200E+05
6	8.0000E+06	28	5.1000E+05
7	7.5000E+06	29	4.5000E+05
8	7.0000E+06	30	4.0000E+05
9	6.5000E+06	31	3.0000E+05
10	6.0000E+06	32	2.0000E+05
11	5.5000E+06	33	1.5000E+05
12	5.0000E+06	34	1.0000E+05
13	4.5000E+06	35	7.5000E+04
14	4.0000E+06	36	7.0000E+04
15	3.5000E+06	37	6.0000E+04
16	3.0000E+06	38	4.5000E+04
17	2.5000E+06	39	4.0000E+04
18	2.0000E+06	40	3.0000E+04
19	1.6600E+06	41	2.0000E+04
20	1.5000E+06	42	1.0000E+04
21	1.3400E+06		1.0000E+03
22	1.3300E+06		

the 3-region spectrum are similar to those used in VITAMIN-C. The breakpoint energy between the Maxwellian and 1/E shapes is 0.125 eV. The fission temperature has been adjusted to better reflect the neutron spectrum in a thermal reactor (σ_0 = 1.273 MeV versus σ_0 = 1.41 MeV for VITAMIN-E). The use of a large number of energy groups should make the exact functional form and energy break points less important compared with generating a broad-group library directly from ENDF/B data.
The functional form of the weighting spectrum is given by the following:

Functional form	Energy limits	Groups
1. Maxwellian Thermal Spectrum (kT = 0.025 eV)		
$W_1(E) = C_1 E e^{-E/kT}$	10^{-5} eV to 0.125 eV	188-199
2. "1/E" slowing-Down Spectrum		
$W_2(E) = C_2/E$	0.125 eV to 820.8 keV	167-187
3. Fission Spectrum (θ= 1.273 MeV)		
$W_3(E) = C_3 E^{1/2} e^{-E/\theta}$	820.8 keV to 20 MeV	1-66

A continuous weighting spectrum is achieved with the following constants: $C_1 = 9498.4$ eV^{-2}; $C_2 = 1.0$; and $C_3 = 2.5625$ MeV$^{-1.5}$. The neutron weighting function is shown in Fig. 2.2 and listed in Table 2.7 in a 199-group form.

The photon weighting spectrum consists of a 1/E spectrum with a "roll-off" of the spectrum at lower energies to represent photoelectric absorption and a similar drop-off of the spectrum at higher energies corresponding to the Q-value for neutron capture. This corresponds to the IWT=3 input option in the GAMINR module of NJOY. The gamma-ray weighting function is shown in Fig. 2.3 and listed in Table 2.8 in a 42-group form.

2.5 Legendre Order of Scattering

The order of scattering used for both neutrons and photons is P_7 for nuclides with Z=1 through Z=29 (copper) and P_5 for the remainder of the nuclides. Most calculations are likely to be done with P_3 scattering, but for some problems (e.g., when single scatter events dominate), higher orders may be required.

2.6 Convergence Parameters

The fractional error tolerances are input parameters to NJOY and were chosen based on our experience with the VITAMIN libraries and the experience of NJOY users. Specifically, the resolved resonance reconstruction tolerance was chosen to be 0.2% for all nuclides. The other tolerances were chosen to be: 0.2% for linearization, 0.2% for thinning, and 0.1% for integration.

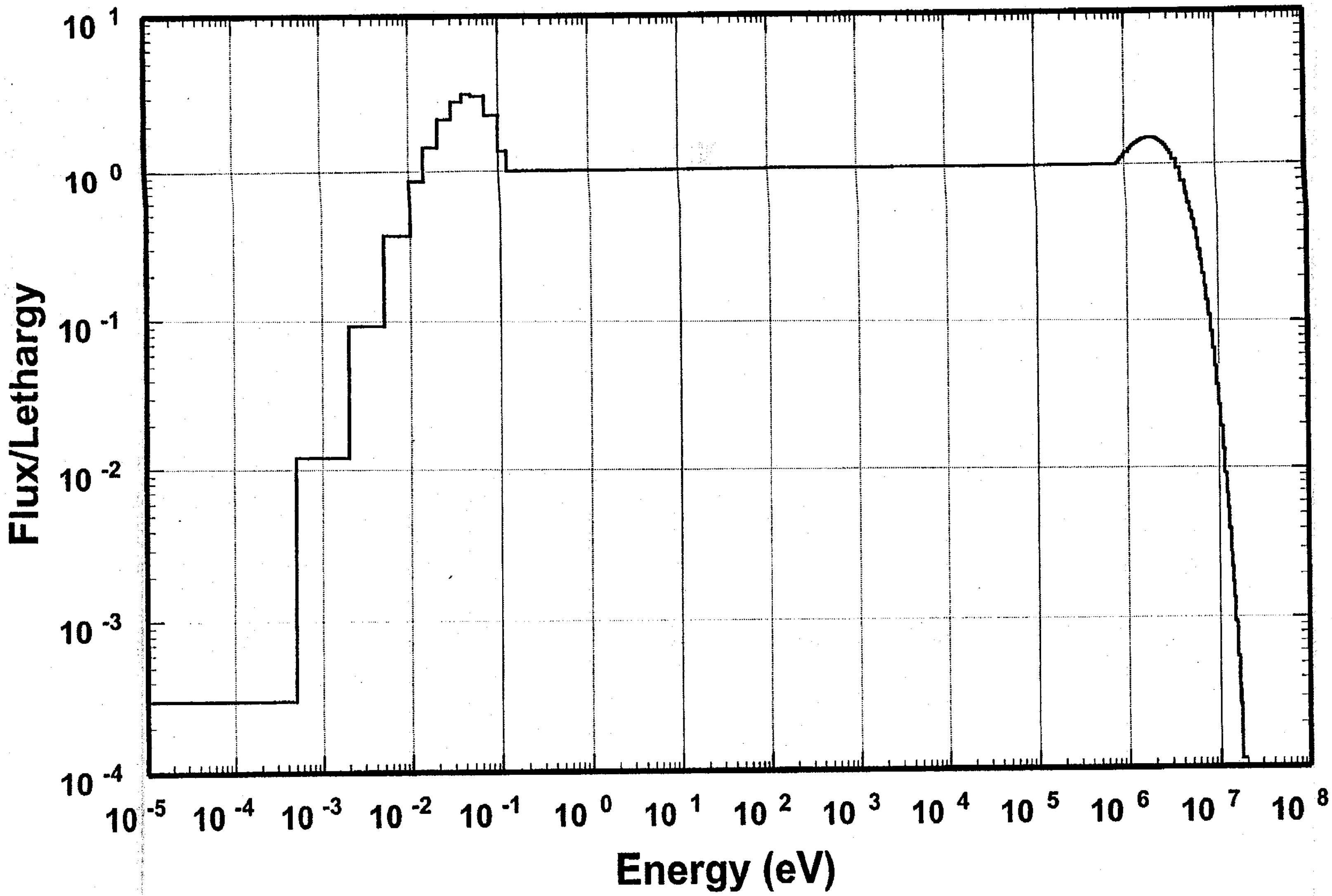


Fig. 2.2 199-Group representation of standard weighting spectrum used to create VITAMIN-B6 neutron cross sections from ENDF/B-VI pointwise data

Table 2.7 Neutron energy weighting spectrum for VITAMIN-B6

Group	Weight	Group	Weight	Group	Weight
1	1.423E-05	48	7.440E-02	95	5.004E-02
2	6.578E-06	49	7.503E-02	96	4.996E-02
3	8.861E-06	50	7.539E-02	97	5.005E-02
4	2.733E-05	51	7.543E-02	98	4.995E-02
5	4.690E-05	52	7.516E-02	99	5.004E-02
6	3.419E-05	53	7.461E-02	100	4.995E-02
7	4.380E-05	54	7.389E-02	101	5.002E-02
8	5.590E-05	55	7.295E-02	102	5.004E-02
9	7.036E-05	56	7.181E-02	103	4.994E-02
10	1.991E-04	57	7.031E-02	104	5.004E-02
11	1.368E-04	58	6.888E-02	105	1.250E-01
12	1.684E-04	59	6.723E-02	106	1.250E-01
13	4.576E-04	60	6.552E-02	107	4.751E-02
14	6.684E-04	61	6.354E-02	108	3.709E-02
15	9.574E-04	62	1.211E-01	109	9.911E-02
16	1.342E-03	63	4.809E-02	110	6.631E-02
17	1.843E-03	64	6.474E-02	111	1.750E-01
18	2.482E-03	65	5.321E-02	112	7.500E-02
19	3.285E-03	66	5.108E-02	113	1.250E-01
20	4.272E-03	67	5.000E-02	114	1.250E-01
21	5.465E-03	68	5.000E-02	115	1.750E-01
22	6.882E-03	69	5.001E-02	116	7.500E-02
23	8.540E-03	70	4.999E-02	117	1.104E-01
24	1.045E-02	71	5.001E-02	118	5.410E-02
25	3.951E-03	72	5.000E-02	119	3.551E-02
26	8.659E-03	73	5.000E-02	120	4.997E-02
27	1.503E-02	74	5.000E-02	121	2.500E-02
28	1.769E-02	75	4.999E-02	122	2.500E-02
29	2.058E-02	76	5.001E-02	123	7.501E-02
30	2.368E-02	77	1.000E-01	124	1.250E-01
31	2.697E-02	78	1.000E-01	125	2.501E-01
32	3.041E-02	79	5.000E-02	126	2.500E-01
33	3.397E-02	80	5.000E-02	127	9.998E-02
34	7.885E-02	81	1.000E-01	128	1.500E-01
35	9.338E-02	82	1.000E-01	129	2.500E-01
36	1.073E-01	83	1.159E-02	130	2.500E-01
37	5.848E-02	84	4.297E-03	131	2.500E-01
38	6.148E-02	85	9.092E-03	132	1.500E-01
39	6.413E-02	86	2.499E-02	133	1.000E-01
40	6.666E-02	87	5.000E-02	134	9.999E-02
41	6.879E-02	88	9.999E-02	135	1.000E-01
42	7.065E-02	89	5.001E-02	136	4.998E-02
43	4.797E-02	90	5.000E-02	137	4.999E-02
44	1.216E-02	91	5.000E-02	138	1.000E-01
45	1.212E-02	92	5.001E-02	139	1.000E-01
46	2.439E-02	93	4.999E-02	140	2.500E-01
47	4.909E-02	94	5.000E-02	141	2.500E-01

Table 2.7 cont'd

Group	Weight	Group	Weight	Group	Weight
142	2.500E-01	162	2.500E-01	182	1.210E-01
143	2.500E-01	163	2.500E-01	183	1.671E-01
144	2.500E-01	164	2.500E-01	184	2.007E-01
145	2.500E-01	165	2.500E-01	185	2.012E-01
146	2.500E-01	166	2.500E-01	186	2.043E-01
147	2.500E-01	167	2.500E-01	187	1.823E-01
148	2.500E-01	168	2.500E-01	188	3.037E-01
149	2.500E-01	169	1.057E-01	189	8.282E-01
150	2.500E-01	170	1.443E-01	190	1.038E+00
151	2.500E-01	171	4.109E-02	191	7.060E-01
152	2.500E-01	172	3.774E-02	192	8.174E-01
153	2.500E-01	173	3.922E-02	193	7.820E-01
154	2.500E-01	174	1.319E-01	194	5.360E-01
155	2.500E-01	175	9.125E-02	195	3.194E-01
156	2.500E-01	176	1.588E-01	196	2.614E-01
157	2.500E-01	177	8.800E-02	197	8.601E-02
158	2.500E-01	178	1.620E-01	198	1.684E-02
159	2.500E-01	179	6.125E-02	199	1.171E-03
160	2.500E-01	180	1.888E-01		
161	2.500E-01	181	1.210E-01		

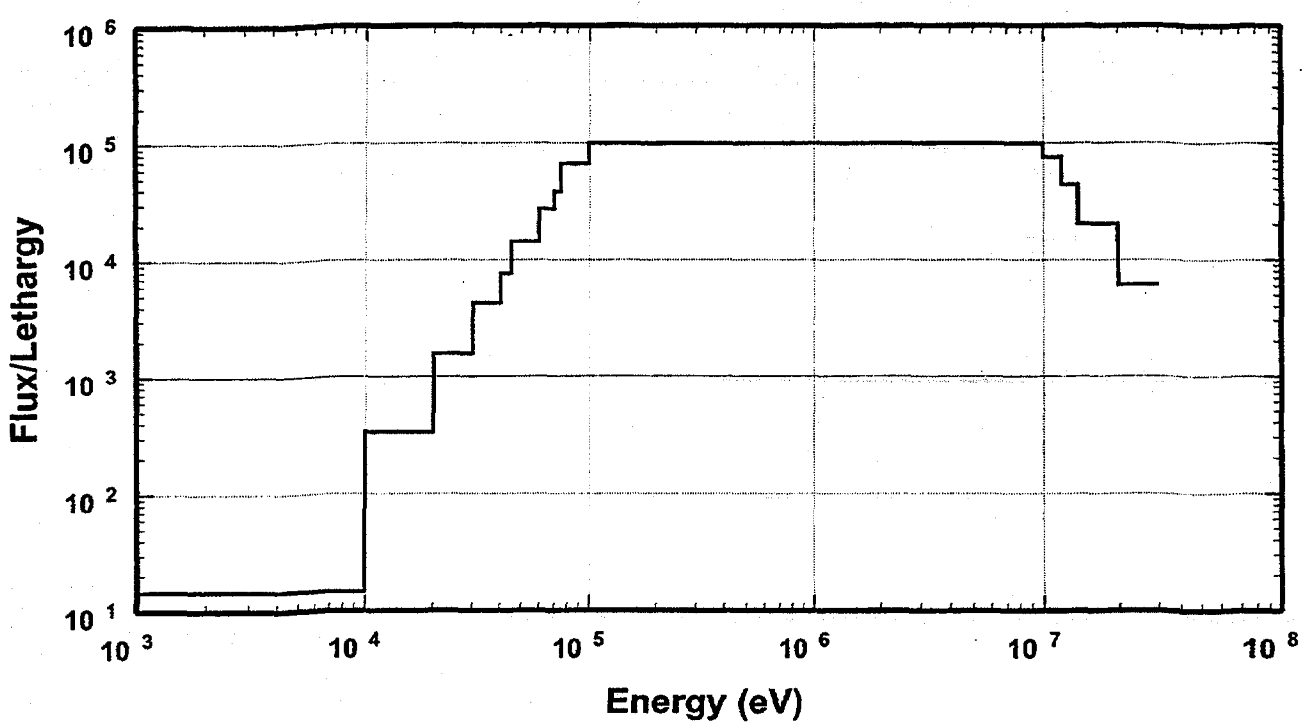


Fig. 2.3 42-Group representation of standard weighting spectrum used to create VITAMIN-B6 gamma-ray cross sections from ENDF/B-VI pointwise data

Table 2.8 Photon energy weighting spectrum for VITAMIN-B6

Group	Weight	Group	Weight	Group	Weight
1	2.498E+03	15	1.542E+04	29	1.178E+04
2	7.298E+03	16	1.824E+04	30	2.877E+04
3	6.824E+03	17	2.232E+04	31	4.055E+04
4	1.387E+04	18	1.864E+04	32	2.877E+04
5	2.232E+04	19	1.014E+04	33	4.055E+04
6	6.455E+03	20	1.128E+04	34	1.927E+04
7	6.901E+03	21	7.491E+02	35	2.629E+03
8	7.413E+03	22	2.852E+04	36	4.233E+03
9	8.006E+03	23	2.232E+04	37	4.163E+03
10	8.703E+03	24	1.335E+04	38	9.042E+02
11	9.534E+03	25	1.542E+04	39	1.233E+03
12	1.054E+04	26	1.586E+04	40	6.333E+02
13	1.178E+04	27	3.914E+02	41	2.333E+02
14	1.336E+04	28	1.252E+04	42	3.330E+01

2.7 Processing Codes and Procedures

The NJOY91.94M processing system[4] was used on a Cray Y-MP/864 to produce the point data and to produce multigroup averaged data in GENDF format for ENDF/B-VI.2 evaluations. NJOY94.15 was needed to correctly process the ENDF/B-VI.3 nuclides. Specifically, the RECONR, BROADR, UNRESR, HEATR, THERMR, GROUPR, and GAMINR modules were used in the fine-group processing task. Only those evaluations which contain unresolved resonance parameters were processed through the UNRESR module. The SMILER code from the AMPX-77 code system[5] was used to translate the multigroup data into the AMPX master library format. The RADE code, also from AMPX-77, was used to check and screen the data for internal consistency and "sanity," (i.e., the data values are physical and within expected bounds). These modules are described in Table 2.9. A schematic diagram illustrating the VITAMIN-B6 processing procedure is given in Fig. 2.4. Listings of the NJOY input for the three job steps used to process ^{235}U are given in Tables A.1-A.3, and the corresponding SMILER input listing is given in Table A.4 in Appendix A.

Table 2.9 Modules from the NJOY91/NJOY94 and the AMPX-77 nuclear cross-section processing systems used to process VITAMIN-B6

Module	Function
NJOY91/NJOY94 System:	
RECONR	Reconstruct pointwise cross sections from ENDF/B resonance parameters and interpolation schemes.
BROADR	Doppler broaden and thin pointwise cross sections.
UNRESR	Compute effective pointwise self-shielded cross sections in the unresolved energy range.
HEATR	Generates pointwise heat production cross sections (kerma factors) and radiation-damage-production cross sections.
THERMR	Generate neutron scattering cross sections and point-to-point scattering kernels in the thermal range for free or bound atoms.
GROUPR	Generate self-shielded multigroup cross sections and group-to-group scattering and photon production matrices in GENDF format.
GAMINR	Compute multigroup photon interaction cross sections, scattering matrices, and heat production in GENDF format.
AMPX-77 System:	
SMILER	Translate GENDF files produced by NJOY into AMPX master interface format.
RADE	Perform sanity and consistency tests on multigroup libraries.

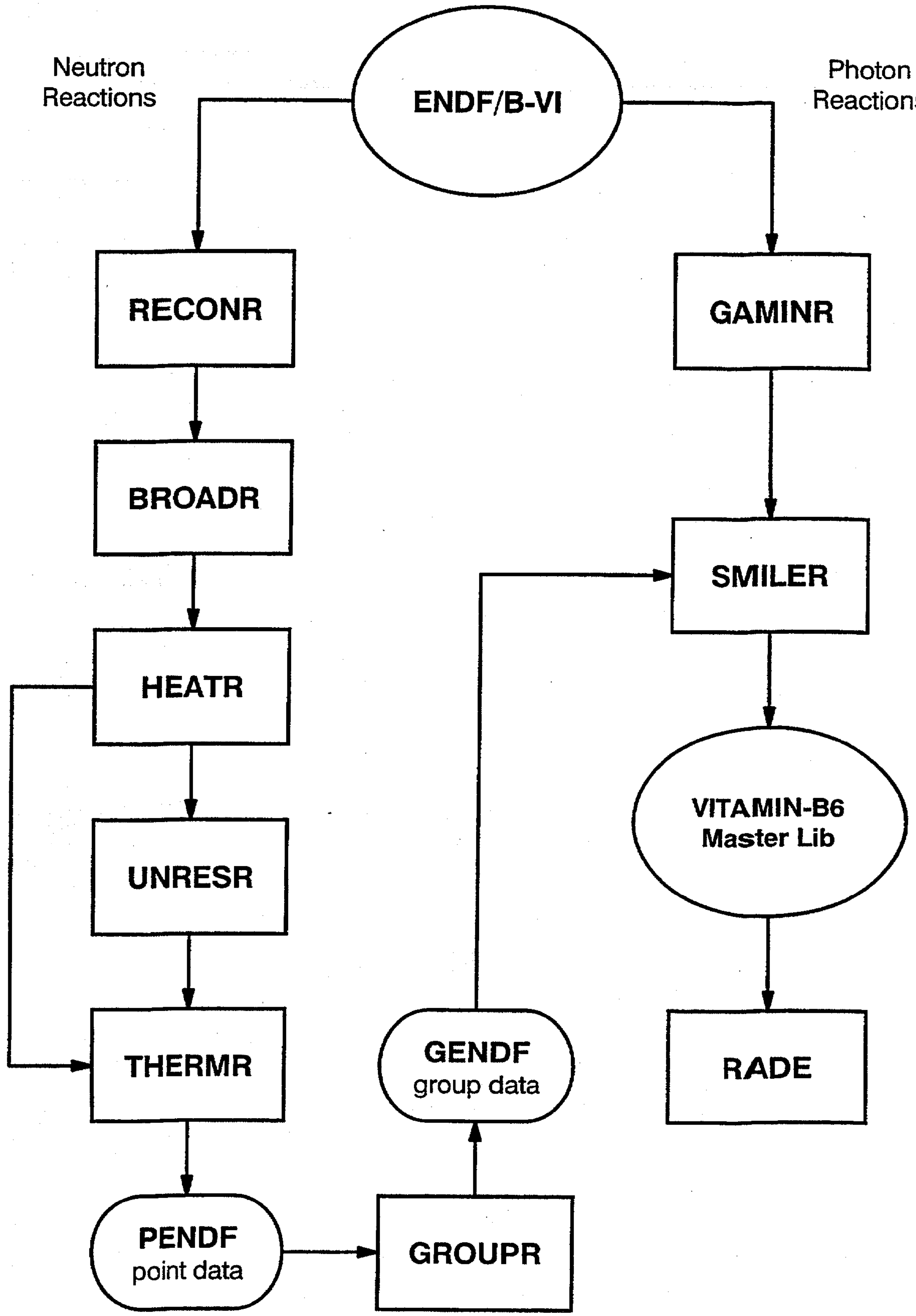


Fig. 2.4 Procedure for generating VITAMIN-B6 library from ENDF/B-VI.

3 BROAD-GROUP LIBRARY SPECIFICATIONS

3.1 Name

The problem-dependent broad-group cross-section library derived from VITAMIN-B6 is designated as BUGLE-96. The name was chosen to be consistent with the earlier BUGLE libraries and indicates its year of production.

3.2 Materials and Energy Group Structure

BUGLE-96 contains all nuclides available in the VITAMIN-B6 fine-group library as listed in Table 2.1. Some nuclides appear multiple times due to the inclusion of different resonance self-shielding and energy weighting options for key fuel and structural materials. Both the neutron and the gamma-ray group structures are identical with the previously developed BUGLE-80 library. The energy boundaries for the 47 neutron groups are given in Table 3.1 along with the corresponding VITAMIN-B6 groups numbers which were collapsed to form the BUGLE-96 groups. Similarly, the 20 gamma-ray group structure is given in Table 3.2.

3.3 Weighting Spectra

The accuracy of results from a radiation transport calculation that uses broad-group cross-section data can be significantly affected by the energy-dependent weighting spectrum used to collapse the data from pointwise or fine-group data. It is important to use a weighting spectrum which is sufficiently prototypical to provide the desired accuracy. In general, a broad-group library is useful only for the range of problems represented by the specific weighting functions. For BUGLE-96, this range includes in-vessel and reactor cavity analyses for light-water-cooled reactors (PWR and BWR). For other applications, the validity of BUGLE-96 data will need to be explicitly demonstrated. Even for LWR applications, it is important that the proper data sets be used for specific regions of the reactor geometry to ensure sufficiently accurate results.

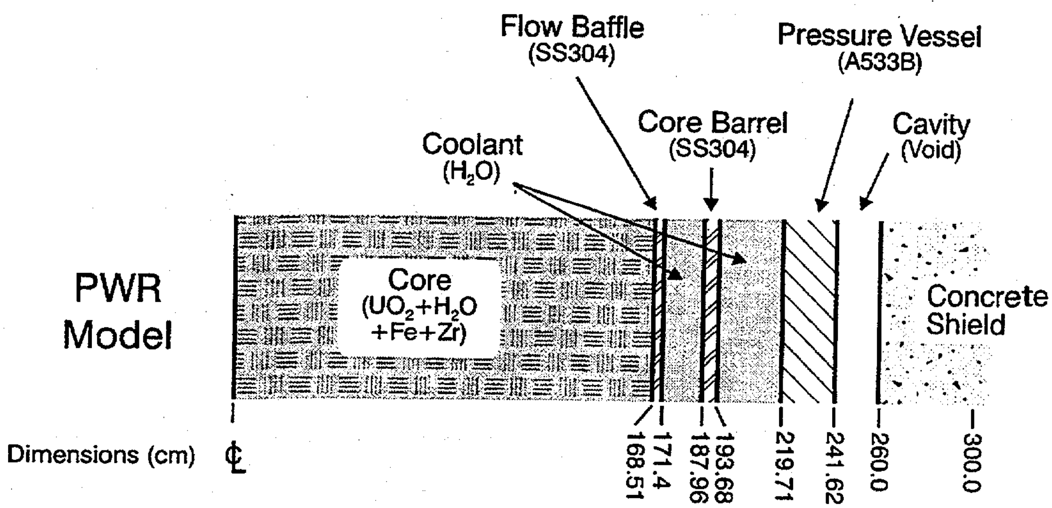
BUGLE-93 was produced by collapsing the VITAMIN-B6 fine-group library with the same methodology and reactor models used for the earlier BUGLE and SAILOR libraries. Specifically, five separate sets of broad-group cross sections were generated using five different weighting spectra. To determine the spectra, 1-D calculations were performed for two specific reactor models: one representing a typical PWR plant and one representing a BWR plant. These models, which correspond exactly to the models listed in the SAILOR report, are shown in Fig. 3.1. Number densities for the various regions are given in Table 3.3. [Note: The corresponding table (Table A.3) in the SAILOR report[3] contained errors in the number densities for the BWR and PWR core mixtures. These errors have been corrected in Table 3.3.] Flux spectra from five specific locations within these models were then selected corresponding to: (1) off-center in the BWR core region, (2) off-center in the PWR core region, (3) the downcomer region in the PWR model, (4) within the pressure vessel at a depth of one-fourth the total thickness, and (5) within the concrete shield surrounding the reactor vessel.

Table 3.1. Neutron group energy boundaries for BUGLE-96

Broad group	Upper energy (eV)	Upper lethargy	VITAMIN-B6 groups
1	1.7332E+07	-5.4997E-01	2-7
2	1.4191E+07	-3.5002E-01	8-12
3	1.2214E+07	-2.0000E-01	13-16
4	1.0000E+07	0.0000E+00	17-19
5	8.6071E+06	1.5000E-01	20-22
6	7.4082E+06	3.0000E-01	23-27
7	6.0653E+06	5.0000E-01	28-31
8	4.9659E+06	7.0000E-01	32-35
9	3.6788E+06	1.0000E+00	36-38
10	3.0119E+06	1.2000E+00	39-40
11	2.7253E+06	1.3000E+00	41-42
12	2.4660E+06	1.4000E+00	43-44
13	2.3653E+06	1.4417E+00	45
14	2.3457E+06	1.4500E+00	46-47
15	2.2313E+06	1.5000E+00	48-50
16	1.9205E+06	1.6500E+00	51-53
17	1.6530E+06	1.8000E+00	54-57
18	1.3534E+06	2.0000E+00	58-62
19	1.0026E+06	2.3000E+00	63-66
20	8.2085E+05	2.5000E+00	67-68
21	7.4274E+05	2.6000E+00	69-72
22	6.0810E+05	2.8000E+00	73-76
23	4.9787E+05	3.0000E+00	77-80
24	3.6883E+05	3.3000E+00	81-84
25	2.9721E+05	3.5159E+00	85-94
26	1.8316E+05	4.0000E+00	95-104
27	1.1109E+05	4.5000E+00	105-110
28	6.7379E+04	5.0000E+00	111-114
29	4.0868E+04	5.5000E+00	115-116
30	3.1828E+04	5.7500E+00	117-119
31	2.6058E+04	5.9500E+00	120-121
32	2.4176E+04	6.0250E+00	122-123
33	2.1875E+04	6.1250E+00	124-125
34	1.5034E+04	6.5000E+00	126-129
35	7.1017E+03	7.2500E+00	130-133
36	3.3546E+03	8.0000E+00	134-140
37	1.5846E+03	8.7500E+00	141-145
38	4.5400E+02	1.0000E+01	146-148
39	2.1445E+02	1.0750E+01	149-151
40	1.0130E+02	1.1500E+01	152-155
41	3.7266E+01	1.2500E+01	156-160
42	1.0677E+01	1.3750E+01	161-163
43	5.0435E+00	1.4500E+01	164-167
44	1.8554E+00	1.5500E+01	168-174
45	8.7643E-01	1.6250E+01	175-180
46	4.1399E-01	1.7000E+01	181-188
47	1.0000E-01	1.8421E+01	189-199
	1.0000E-05	2.7631E+01	

Table 3.2 Photon group energy boundaries for BUGLE-96

Broad group	Upper energy (eV)	VITAMIN-B6 groups
1	1.4000E+07	3-4
2	1.0000E+07	5
3	8.0000E+06	6-7
4	7.0000E+06	8-9
5	6.0000E+06	10-11
6	5.0000E+06	12-13
7	4.0000E+06	14-15
8	3.0000E+06	16-17
9	2.0000E+06	18-19
10	1.5000E+06	20-22
11	1.0000E+06	23
12	8.0000E+05	24
13	7.0000E+05	25
14	6.0000E+05	26-29
15	4.0000E+05	30-31
16	2.0000E+05	32-33
17	1.0000E+05	34-36
18	6.0000E+04	37-39
19	3.0000E+04	40
20	2.0000E+04	41
	1.0000E+04	



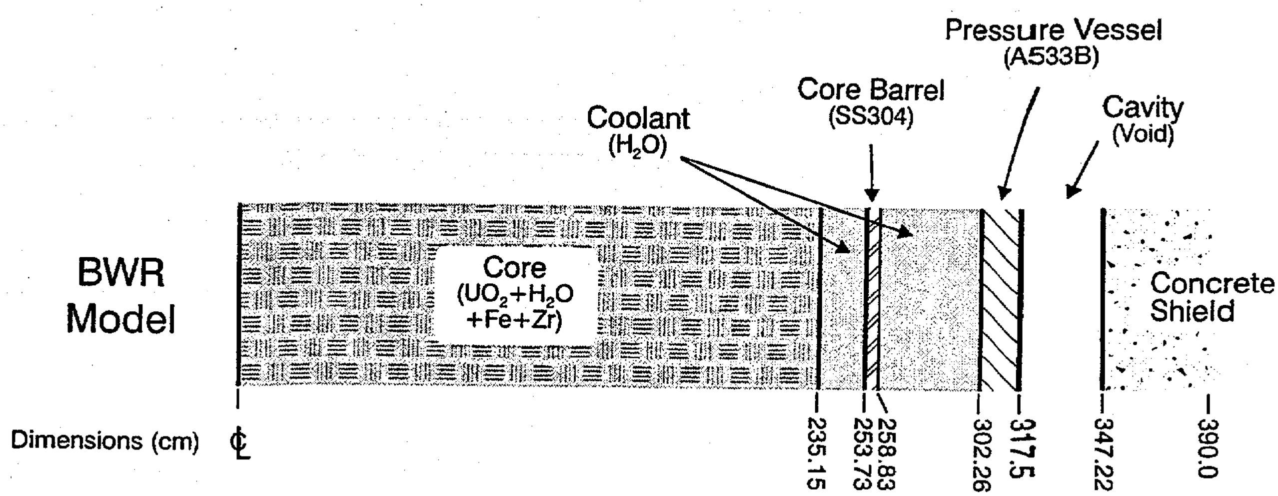


Fig. 3.1 One-dimensional models used to calculate the specific flux spectra for collapsing BUGLE-96 cross sections from VITAMIN-B6

Table 3.3 Number densities[a] and natural abundances used in BWR and PWR models

	HOMOGENEOUS CORES		COOLANT	
	BWR	PWR	BWR	PWR
Hydrogen	1.535-2[b]	2.768-2	4.950-2	4.714-2
Oxygen	7.677-3	1.384-2	2.475-2	2.357-2
Boron-10	0	2.466-6	0	4.200-6
Zirconium	5.765-3	4.257-3		
Iron	2.003-5	1.444-5		
U-235	1.213-4	1.903-4		
U-238	5.322-3	6.515-3		
Fuel Oxygen	1.088-2	1.343-2		

	STEELS			CONCRETE
	SS-304	A533-B		Type 04
Carbon	2.37-4	9.81-4	Hydrogen	7.77-3
Silicon	8.93-4	3.71-4	Carbon	1.15-4
Chromium	1.74-2	1.27-4	Oxygen	4.38-2
Manganese	1.52-3	1.12-3	Sodium	1.05-3
Iron	5.83-2	8.19-2	Magnesium	1.48-4
Nickel	8.55-3	4.44-4	Aluminum	2.39-3
			Silicon	1.58-2
			Potassium	6.93-4
			Calcium	2.29-3
			Iron	3.13-4

NATURAL ABUNDANCES (%)

Cr-50	4.345	Fe-54	5.9	Ni-58	68.27
Cr-52	83.79	Fe-56	91.72	Ni-60	26.10
Cr-53	9.5	Fe-57	2.1	Ni-61	1.13
Cr-54	2.365	Fe-58	0.28	Ni-62	3.59
				Ni-64	0.91

[a] In units of $b^{-1} \cdot cm^{-1}$.
[b] Read as 1.535×10^{-2}.

The calculated neutron flux spectra are compared in Fig. 3.2 and listed in Table 3.4. The corresponding gamma-ray flux spectra are compared graphically in Fig. 3.3 and listed in Table 3.5.

The specific nuclides contained within the various PWR and BWR regions were resonance self-shielded, corrected for temperature effects, and collapsed using the corresponding flux spectrum. In the core region, the nuclides were self-shielded using a fuel-clad-moderator pin model. The key parameters for the BWR and PWR pin cell models are given in Table 3.6. In the pressure vessel, the constituents of steel were self-shielded for carbon steel and stainless steel (type 304) using the number densities given in Table 3.7 and collapsed using the quarter-thickness (1/4T) flux spectrum. The SAILOR approach used in preparing BUGLE-93, which resulted in self-shielding the steel constituents for a 50-50 mixture of water and stainless steel, was abandoned in favor of a self-shielding approach that contained only steel. A reanalysis of ANO-1 using scaled 1-D methods and ENDF/B-VI iron cross sections prepared using this approach showed significant improvements in the agreement with measured dosimeter data. Finally, all nuclides in VITAMIN-B6 were collapsed to 47 neutron groups and 20 gamma-ray groups using the flux spectrum calculated within the concrete shield. These nuclides are infinitely dilute (i.e., they have not been energy self-shielded).

3.4 Processing Codes and Procedures

All computational tools used to self-shield, temperature-correct, and collapse the fine-group library into the broad-group format were modules of the SCAMPI code package operational on an IBM/RISC 6000 workstation cluster. The development of the SCAMPI package was stimulated by the need for access to tested operational modules to perform the above mentioned tasks in a workstation environment. The names and a brief description of the primary modules are given in Table 3.8. The names and functionality of the SCAMPI modules are the same as the modules in AMPX-77 operational on the Hitachi AS/EX60 mainframe.

The first portion of the collapsing procedure is given in Fig. 3.4, which diagrams the sequence of steps needed to select and self-shield specific sets of cross sections and perform the PWR and BWR 1-D transport calculations. The results of this procedure are the five flux spectra calculated using the XSDRNPM module (Tables 3.4 and 3.5). Complete input listings for the BONAMI case and the two XSDRNPM cases are given in Tables A.5-7 in Appendix A. The second portion of the collapsing procedure is diagramed in Fig. 3.5. In this sequence, the MALOCS module was used to perform the group collapsing of the cross sections which were previously self-shielded. Complete input listings for the five MALOCS cases are given in Tables A.8-12 in Appendix A. In MALOCS, the ANISN methodology was selected for removal of the upscatter transfer matrix in the thermal energy range. Removing upscatter is done for purposes of economy, since it eliminates the need to perform outer (source) iterations during flux convergence. However, removing the upscatter terms does require a nonphysical adjustment to the cross sections, since in reality, low-energy neutrons can increase their kinetic energy by scattering off low-Z nuclei such as hydrogen. For most shielding problems, this is an acceptable approximation because the leading shielding issues are frequently dominated by the transport of higher-energy neutrons and accurate transport of the thermal neutrons is relatively unimportant.

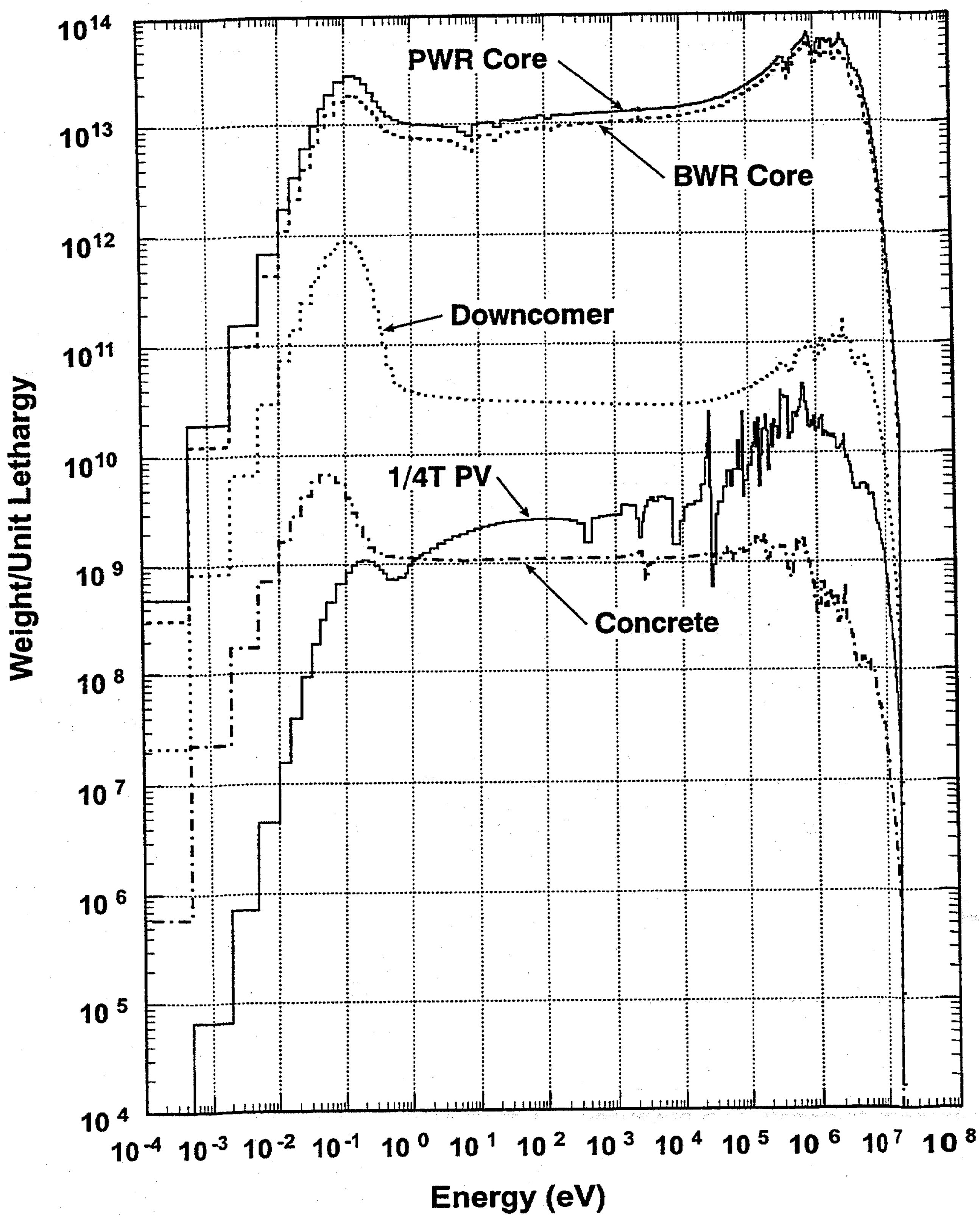


Fig. 3.2 Comparison of five BWR- and PWR-specific neutron flux spectra

Table 3.4 Neutron weighting spectra from PWR/BWR models

Fine group	BWR Core (Int#57)[a]	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
1	7.6014E+05	1.1857E+06	1.3992E+04	2.0322E+03	7.4909E+01
2	2.9063E+08	4.4430E+08	3.5437E+06	4.1806E+05	1.1745E+04
3	3.2764E+08	5.0619E+08	5.1882E+06	6.8186E+05	2.1886E+04
4	1.0879E+09	1.6731E+09	1.6038E+07	2.0892E+06	6.6519E+04
5	1.7894E+09	2.7442E+09	2.4356E+07	3.0216E+06	9.0301E+04
6	1.2795E+09	1.9618E+09	1.6908E+07	2.0476E+06	5.9386E+04
7	1.6212E+09	2.4859E+09	2.1181E+07	2.5433E+06	7.2338E+04
8	2.0203E+09	3.0928E+09	2.5630E+07	3.0380E+06	8.5215E+04
9	2.4974E+09	3.8192E+09	3.0790E+07	3.5930E+06	9.9695E+04
10	6.8570E+09	1.0462E+10	8.0350E+07	9.1808E+06	2.4993E+05
11	5.0533E+09	7.6947E+09	5.6091E+07	6.2320E+06	1.6774E+05
12	5.1790E+09	7.8920E+09	5.9741E+07	6.7181E+06	1.8331E+05
13	1.4387E+10	2.1726E+10	1.4130E+08	1.5051E+07	3.8628E+05
14	2.0400E+10	3.0693E+10	1.8623E+08	1.8952E+07	4.7584E+05
15	3.0204E+10	4.5810E+10	2.9767E+08	3.0523E+07	7.9125E+05
16	4.0207E+10	6.0559E+10	3.6107E+08	3.6988E+07	9.0927E+05
17	5.4451E+10	8.1919E+10	4.7257E+08	4.7636E+07	1.1652E+06
18	7.4005E+10	1.1144E+11	6.3892E+08	6.2995E+07	1.5759E+06
19	9.3816E+10	1.4028E+11	7.3635E+08	7.0983E+07	1.7282E+06
20	1.1784E+11	1.7524E+11	8.3471E+08	7.7222E+07	1.7890E+06
21	1.5342E+11	2.2863E+11	1.0758E+09	9.5841E+07	2.1595E+06
22	1.8930E+11	2.8099E+11	1.2410E+09	1.0845E+08	2.3460E+06
23	2.2772E+11	3.3625E+11	1.3603E+09	1.1545E+08	2.4542E+06
24	2.8858E+11	4.2849E+11	1.7843E+09	1.4853E+08	3.2244E+06
25	1.0960E+11	1.6276E+11	6.6926E+08	5.5309E+07	1.2270E+06
26	2.4284E+11	3.6105E+11	1.4922E+09	1.2280E+08	2.7601E+06
27	4.1934E+11	6.2258E+11	2.5251E+09	2.0767E+08	4.6736E+06
28	4.7169E+11	6.9506E+11	2.5471E+09	2.0499E+08	4.5228E+06
29	5.3282E+11	7.8039E+11	2.6024E+09	2.0163E+08	4.5017E+06
30	6.4332E+11	9.4649E+11	3.2565E+09	2.4333E+08	5.8738E+06
31	6.9818E+11	1.0174E+12	3.0795E+09	2.2665E+08	5.3815E+06
32	8.1827E+11	1.1956E+12	3.6387E+09	2.5404E+08	6.1616E+06
33	8.6813E+11	1.2579E+12	3.5684E+09	2.5844E+08	6.0520E+06
34	1.9788E+12	2.8466E+12	7.2447E+09	5.0637E+08	1.2768E+07
35	2.1051E+12	2.9764E+12	6.2737E+09	4.5988E+08	1.0881E+07
36	2.3604E+12	3.3044E+12	6.1904E+09	4.5914E+08	1.0454E+07
37	1.4272E+12	1.9985E+12	3.6976E+09	2.5404E+08	6.7006E+06
38	1.7175E+12	2.4181E+12	4.9169E+09	3.2145E+08	9.2899E+06
39	1.7232E+12	2.4049E+12	4.9999E+09	3.7451E+08	1.0411E+07
40	1.8334E+12	2.5492E+12	5.2145E+09	4.0421E+08	1.1942E+07
41	2.0060E+12	2.7833E+12	5.6926E+09	4.6380E+08	1.4419E+07
42	2.0207E+12	2.7870E+12	5.5291E+09	4.4053E+08	1.4248E+07
43	1.3990E+12	1.9262E+12	4.1332E+09	3.4510E+08	1.2761E+07
44	3.8119E+11	5.2752E+11	1.2814E+09	1.0683E+08	4.0738E+06
45	3.9189E+11	5.4259E+11	1.4253E+09	1.2151E+08	5.2299E+06
46	7.7035E+11	1.0593E+12	2.4544E+09	1.9714E+08	8.7365E+06
47	1.3878E+12	1.8807E+12	4.2117E+09	4.1548E+08	1.4817E+07

Table 3.4 cont'd

Fine group	BWR Core (Int#57)	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
48	1.9486E+12	2.6230E+12	5.5468E+09	5.7974E+08	1.8475E+07
49	1.9002E+12	2.5451E+12	5.2346E+09	5.5301E+08	1.7250E+07
50	1.8523E+12	2.4685E+12	5.0260E+09	5.3525E+08	1.4577E+07
51	1.7986E+12	2.3819E+12	4.6236E+09	5.4017E+08	1.3568E+07
52	2.1429E+12	2.8356E+12	5.7403E+09	6.6889E+08	2.3418E+07
53	2.0862E+12	2.7268E+12	5.4109E+09	7.2457E+08	2.1223E+07
54	2.0303E+12	2.6397E+12	5.0716E+09	6.8383E+08	1.9533E+07
55	2.1195E+12	2.7471E+12	5.2927E+09	7.1767E+08	2.3193E+07
56	2.2334E+12	2.8745E+12	5.3374E+09	6.9612E+08	2.6000E+07
57	2.1946E+12	2.8017E+12	5.2406E+09	7.4485E+08	2.7047E+07
58	1.8253E+12	2.3166E+12	4.0697E+09	7.6978E+08	1.8758E+07
59	2.2598E+12	2.8730E+12	5.1405E+09	7.0174E+08	2.7308E+07
60	2.2722E+12	2.8567E+12	5.2930E+09	1.0579E+09	3.1954E+07
61	2.1197E+12	2.6485E+12	4.8119E+09	9.9314E+08	3.1610E+07
62	3.4717E+12	4.3330E+12	7.4956E+09	1.6359E+09	3.9464E+07
63	1.3523E+12	1.6863E+12	2.8273E+09	6.5092E+08	1.2763E+07
64	2.2461E+12	2.7832E+12	4.7439E+09	1.2262E+09	2.6095E+07
65	2.1527E+12	2.6374E+12	4.3651E+09	8.7398E+08	3.1673E+07
66	2.4966E+12	3.0184E+12	4.8423E+09	9.5481E+08	3.6840E+07
67	2.7866E+12	3.3223E+12	5.0440E+09	8.4716E+08	4.4539E+07
68	2.6379E+12	3.1234E+12	4.7312E+09	8.7009E+08	4.9423E+07
69	2.4497E+12	2.8870E+12	4.5466E+09	1.2146E+09	5.3916E+07
70	2.3657E+12	2.7761E+12	4.4199E+09	1.4239E+09	5.9797E+07
71	2.3067E+12	2.6960E+12	4.3737E+09	1.9155E+09	6.9196E+07
72	2.2406E+12	2.6124E+12	4.2628E+09	2.0771E+09	8.0206E+07
73	2.1674E+12	2.5268E+12	4.1845E+09	1.4915E+09	8.0704E+07
74	2.0923E+12	2.4439E+12	4.0544E+09	1.2694E+09	7.3678E+07
75	2.0230E+12	2.3644E+12	3.9255E+09	1.1742E+09	8.0799E+07
76	1.9601E+12	2.2780E+12	3.7700E+09	1.0472E+09	7.7852E+07
77	3.2152E+12	3.7930E+12	6.4249E+09	2.2668E+09	1.2068E+08
78	2.4643E+12	2.9533E+12	5.1746E+09	1.5029E+09	7.1761E+07
79	1.4395E+12	1.7259E+12	3.0031E+09	6.6521E+08	4.1648E+07
80	1.4439E+12	1.7218E+12	3.0012E+09	1.5819E+09	4.3434E+07
81	3.2862E+12	3.8670E+12	6.4175E+09	3.1216E+09	1.1610E+08
82	3.3426E+12	3.8826E+12	6.3070E+09	3.2634E+09	1.3893E+08
83	3.6986E+11	4.2912E+11	7.0208E+08	4.2565E+08	1.6070E+07
84	1.3577E+11	1.5770E+11	2.5880E+08	1.3992E+08	6.0513E+06
85	2.8528E+11	3.3159E+11	5.4483E+08	2.2296E+08	1.2613E+07
86	7.7468E+11	9.0115E+11	1.4810E+09	3.5082E+08	3.4080E+07
87	1.5260E+12	1.7672E+12	2.8994E+09	6.7539E+08	6.9831E+07
88	2.8973E+12	3.3576E+12	5.5716E+09	1.6973E+09	1.3824E+08
89	1.3798E+12	1.6013E+12	2.6869E+09	9.8426E+08	6.8042E+07
90	1.3408E+12	1.5546E+12	2.6208E+09	5.6123E+08	6.7378E+07
91	1.3104E+12	1.5159E+12	2.5645E+09	8.9812E+08	6.1649E+07
92	1.2746E+12	1.4759E+12	2.5075E+09	5.7687E+08	5.9660E+07
93	1.2330E+12	1.4333E+12	2.4526E+09	3.4443E+08	5.5122E+07
94	1.1929E+12	1.3920E+12	2.4030E+09	7.9023E+08	5.3248E+07

Table 3.4 cont'd

Fine group	BWR Core (Int#57)	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
95	1.1626E+12	1.3577E+12	2.3576E+09	1.0874E+09	6.1596E+07
96	1.1333E+12	1.3239E+12	2.3056E+09	8.2475E+08	7.6839E+07
97	1.1127E+12	1.2983E+12	2.2672E+09	8.0635E+08	8.7483E+07
98	1.0849E+12	1.2660E+12	2.2181E+09	4.7413E+08	8.2073E+07
99	1.0637E+12	1.2413E+12	2.1781E+09	2.4867E+08	7.5415E+07
100	1.0396E+12	1.2133E+12	2.1383E+09	1.0220E+09	7.5266E+07
101	1.0180E+12	1.1897E+12	2.1074E+09	5.6137E+08	8.3036E+07
102	9.9590E+11	1.1651E+12	2.0728E+09	9.3099E+08	8.4422E+07
103	9.7191E+11	1.1383E+12	2.0318E+09	6.0688E+08	7.4200E+07
104	9.5366E+11	1.1183E+12	2.0022E+09	5.6458E+08	7.5582E+07
105	2.2988E+12	2.6993E+12	4.8571E+09	9.5425E+08	1.7880E+08
106	2.1954E+12	2.5797E+12	4.6786E+09	6.8965E+08	1.5669E+08
107	8.1357E+11	9.5443E+11	1.7339E+09	1.8919E+08	5.8538E+07
108	6.1940E+11	7.3095E+11	1.3451E+09	8.6516E+08	5.1180E+07
109	1.6144E+12	1.9097E+12	3.5112E+09	6.8522E+08	1.3293E+08
110	1.0765E+12	1.2591E+12	2.3040E+09	8.5464E+08	8.6381E+07
111	2.7259E+12	3.2004E+12	5.9041E+09	1.2326E+09	2.0691E+08
112	1.1223E+12	1.3247E+12	2.4630E+09	3.7239E+08	7.9185E+07
113	1.8079E+12	2.1463E+12	4.0292E+09	8.5308E+08	1.6892E+08
114	1.7315E+12	2.0734E+12	3.9346E+09	6.0822E+08	1.4904E+08
115	2.4477E+12	2.8666E+12	5.3738E+09	6.2088E+08	1.8696E+08
116	1.0094E+12	1.1926E+12	2.2638E+09	2.0579E+08	8.6509E+07
117	1.4621E+12	1.7283E+12	3.2884E+09	1.0450E+08	1.2952E+08
118	7.0112E+11	8.3308E+11	1.5968E+09	3.1919E+07	6.0340E+07
119	4.5828E+11	5.4333E+11	1.0508E+09	1.7075E+08	4.1696E+07
120	6.4210E+11	7.6042E+11	1.4745E+09	1.1786E+09	5.9485E+07
121	3.1209E+11	3.7446E+11	7.3457E+08	5.7478E+08	2.9959E+07
122	3.1366E+11	3.7501E+11	7.3004E+08	3.0145E+08	2.9573E+07
123	9.5244E+11	1.1269E+12	2.1771E+09	6.7403E+08	8.7929E+07
124	1.5235E+12	1.8312E+12	3.5856E+09	6.4125E+08	1.4387E+08
125	3.0679E+12	3.6326E+12	7.0741E+09	9.0441E+08	2.8453E+08
126	2.9560E+12	3.5283E+12	6.9986E+09	8.4477E+08	2.8109E+08
127	1.1576E+12	1.3868E+12	2.7767E+09	3.2006E+08	1.1144E+08
128	1.7117E+12	2.0574E+12	4.1380E+09	3.5490E+08	1.6356E+08
129	2.7997E+12	3.3810E+12	6.8664E+09	3.6442E+08	2.7629E+08
130	2.8083E+12	3.3579E+12	6.8508E+09	9.5878E+08	2.7318E+08
131	2.7306E+12	3.2951E+12	6.8368E+09	1.0008E+09	2.7435E+08
132	1.6258E+12	1.9652E+12	4.1113E+09	5.4361E+08	1.6186E+08
133	1.0837E+12	1.3102E+12	2.7472E+09	3.9444E+08	9.9435E+07
134	1.0698E+12	1.2989E+12	2.7506E+09	3.7012E+08	9.5232E+07
135	1.0442E+12	1.2832E+12	2.7536E+09	3.2676E+08	6.9448E+07
136	5.0930E+11	6.3214E+11	1.3766E+09	1.4304E+08	4.2418E+07
137	5.7688E+11	6.7398E+11	1.3767E+09	1.1749E+08	5.5639E+07
138	1.0466E+12	1.2736E+12	2.7552E+09	1.7070E+08	1.2521E+08
139	1.0729E+12	1.2986E+12	2.7652E+09	2.5220E+08	1.2185E+08
140	2.5908E+12	3.1687E+12	6.9321E+09	8.3409E+08	2.9225E+08
141	2.5866E+12	3.1590E+12	6.9480E+09	8.4646E+08	2.8320E+08

Table 3.4 cont'd

Fine group	BWR Core (Int#57)	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
142	2.5674E+12	3.1437E+12	6.9617E+09	6.8885E+08	2.7938E+08
143	2.5228E+12	3.1021E+12	6.9992E+09	6.7981E+08	2.7845E+08
144	2.4942E+12	3.0755E+12	7.0424E+09	6.7033E+08	2.7836E+08
145	2.4611E+12	3.0484E+12	7.0851E+09	6.4446E+08	2.7846E+08
146	2.4418E+12	3.0331E+12	7.1189E+09	3.8489E+08	2.7805E+08
147	2.4295E+12	3.0205E+12	7.1753E+09	5.7452E+08	2.7810E+08
148	2.3681E+12	2.9654E+12	7.2171E+09	6.1188E+08	2.7799E+08
149	2.3608E+12	2.9580E+12	7.2565E+09	6.2634E+08	2.7773E+08
150	2.3193E+12	2.9203E+12	7.2991E+09	6.3304E+08	2.7749E+08
151	2.1291E+12	2.7297E+12	7.3377E+09	6.3556E+08	2.7699E+08
152	2.3171E+12	2.9176E+12	7.3799E+09	6.3552E+08	2.7652E+08
153	2.2010E+12	2.7991E+12	7.4240E+09	6.3317E+08	2.7603E+08
154	2.1980E+12	2.7992E+12	7.4678E+09	6.2858E+08	2.7546E+08
155	2.0932E+12	2.7023E+12	7.5112E+09	6.2159E+08	2.7481E+08
156	2.0618E+12	2.6513E+12	7.5532E+09	6.1205E+08	2.7404E+08
157	2.0776E+12	2.6828E+12	7.5953E+09	5.9999E+08	2.7322E+08
158	1.7509E+12	2.3239E+12	7.6346E+09	5.8498E+08	2.7225E+08
159	1.9646E+12	2.5683E+12	7.6758E+09	5.6740E+08	2.7129E+08
160	1.9399E+12	2.5343E+12	7.7154E+09	5.4695E+08	2.7021E+08
161	1.8849E+12	2.4760E+12	7.7514E+09	5.2351E+08	2.6894E+08
162	1.4075E+12	1.9385E+12	7.7869E+09	4.9745E+08	2.6759E+08
163	1.5368E+12	2.1172E+12	7.8208E+09	4.6893E+08	2.6615E+08
164	1.7526E+12	2.3600E+12	8.0873E+09	4.4722E+08	2.7198E+08
165	1.7577E+12	2.3645E+12	8.1924E+09	4.1562E+08	2.7048E+08
166	1.7962E+12	2.4154E+12	8.3518E+09	3.8285E+08	2.7243E+08
167	1.8100E+12	2.4376E+12	8.5254E+09	3.4962E+08	2.7446E+08
168	1.8282E+12	2.4649E+12	8.6685E+09	3.1794E+08	2.7502E+08
169	7.8372E+11	1.0586E+12	3.7590E+09	1.2734E+08	1.1746E+08
170	1.0585E+12	1.4326E+12	5.1991E+09	1.6389E+08	1.6134E+08
171	2.9525E+11	4.0175E+11	1.4983E+09	4.3662E+07	4.5576E+07
172	2.7622E+11	3.7507E+11	1.3875E+09	3.9726E+07	4.2030E+07
173	2.9452E+11	3.9883E+11	1.4632E+09	4.1436E+07	4.4357E+07
174	9.8802E+11	1.3427E+12	4.9575E+09	1.2771E+08	1.5065E+08
175	6.9497E+11	9.4532E+11	3.5026E+09	7.5292E+07	1.0270E+08
176	1.2094E+12	1.6537E+12	6.2593E+09	1.1885E+08	1.8035E+08
177	7.1270E+11	9.6780E+11	3.7042E+09	6.6562E+07	1.0179E+08
178	1.3076E+12	1.7867E+12	7.3338E+09	1.1579E+08	1.8845E+08
179	5.1912E+11	7.0919E+11	3.1993E+09	4.4578E+07	7.3052E+07
180	1.6390E+12	2.2532E+12	1.2519E+10	1.3620E+08	2.2386E+08
181	1.1527E+12	1.5953E+12	1.2117E+10	9.9478E+07	1.4981E+08
182	1.2443E+12	1.7406E+12	1.7649E+10	1.0740E+08	1.5278E+08
183	1.9264E+12	2.7344E+12	3.7842E+10	1.6162E+08	2.1853E+08
184	2.7400E+12	3.9582E+12	7.3472E+10	2.1165E+08	2.8535E+08
185	3.2491E+12	4.7730E+12	1.0973E+11	2.2014E+08	3.4177E+08
186	3.6846E+12	5.4877E+12	1.4621E+11	2.1716E+08	4.5240E+08
187	3.4325E+12	5.1666E+12	1.5221E+11	1.7828E+08	5.4530E+08
188	4.1033E+12	6.2277E+12	1.9836E+11	1.8848E+08	9.1237E+08

Table 3.4 cont'd

Fine group	BWR Core (Int#57)	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
189	5.7735E+12	8.8230E+12	3.0308E+11	2.3581E+08	2.0281E+09
190	4.1119E+12	6.3203E+12	2.3105E+11	1.4998E+08	2.2419E+09
191	2.0543E+12	3.1645E+12	1.2007E+11	6.8890E+07	1.5004E+09
192	1.8433E+12	2.8527E+12	1.1159E+11	5.2655E+07	1.6613E+09
193	1.4011E+12	2.1755E+12	8.7498E+10	3.2323E+07	1.5405E+09
194	7.9923E+11	1.2448E+12	5.1289E+10	1.4335E+07	1.0340E+09
195	4.1425E+11	6.4681E+11	2.7137E+10	5.7491E+06	6.0430E+08
196	3.0353E+11	4.7504E+11	2.0216E+10	3.1162E+06	4.8835E+08
197	9.0752E+10	1.4238E+11	6.1339E+09	6.5168E+05	1.5854E+08
198	1.7077E+10	2.6847E+10	1.1620E+09	9.1680E+04	3.1176E+07
199	1.2189E+09	1.9161E+09	8.2470E+07	5.5538E+03	2.2896E+06

[a] Spatial mesh interval number from PWR or BWR model.

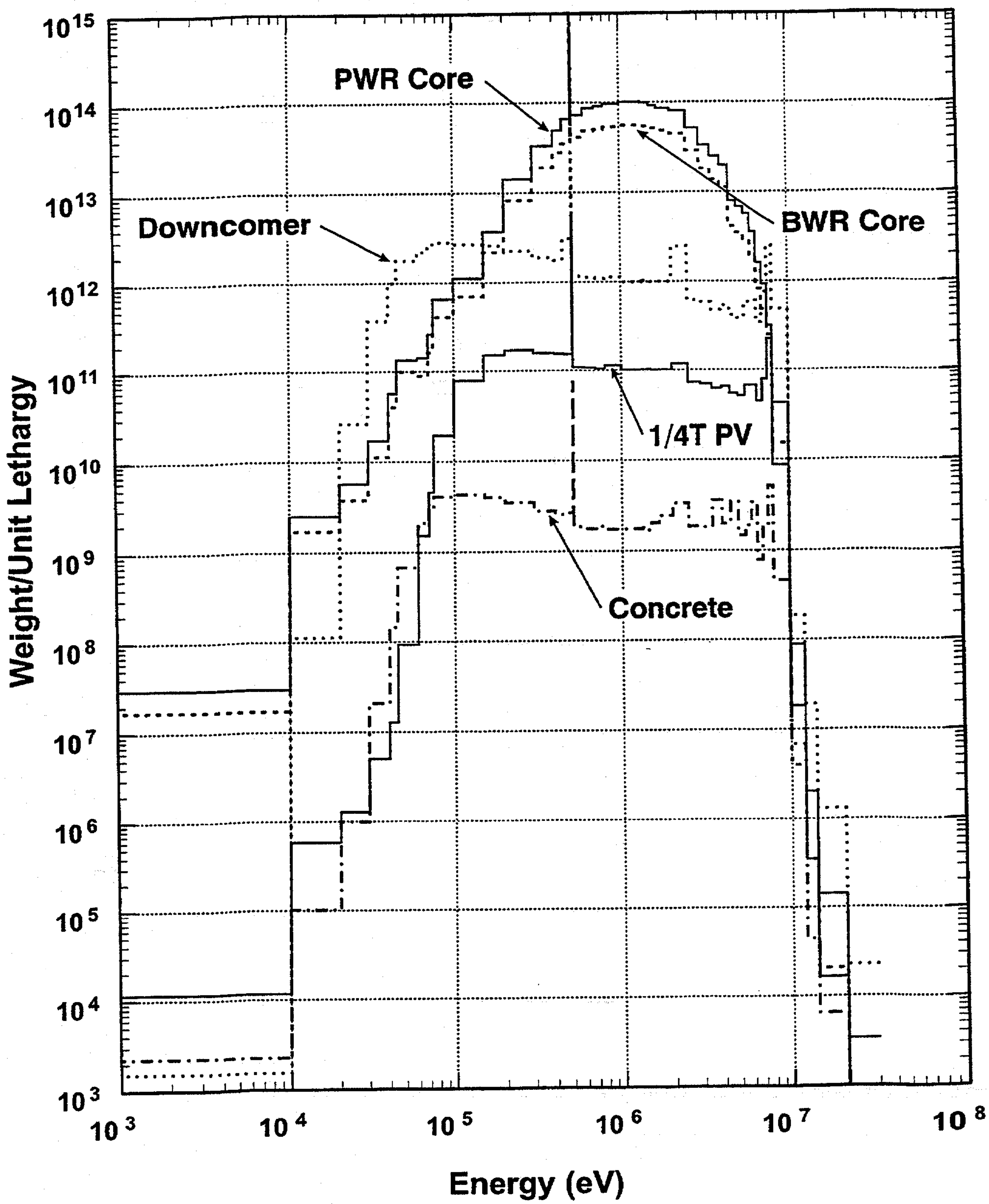


Fig. 3.3 Comparison of five BWR- and PWR-specific gamma-ray flux spectra

Table 3.5 Photon weighting spectra from PWR/BWR models

Fine group	BWR Core (Int#57) [a]	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
1	1.9547E+02	1.5655E+02	9.0787E+03	1.3628E+03	7.4294E+01
2	7.3440E+03	5.7882E+03	4.6403E+05	5.0416E+04	2.3094E+03
3	5.4214E+04	5.3624E+04	2.9763E+06	3.1112E+05	6.8232E+03
4	7.3186E+05	1.6065E+07	3.4042E+07	3.3750E+06	1.2494E+06
5	3.4053E+09	1.9415E+09	1.0869E+11	9.4134E+09	1.0352E+08
6	1.6127E+10	2.0406E+10	1.6115E+11	1.4477E+10	3.2567E+08
7	3.3580E+10	6.4002E+10	5.2344E+10	5.3331E+09	1.2039E+08
8	6.0772E+10	1.1918E+11	2.5596E+10	3.2544E+09	5.8387E+07
9	1.4424E+11	2.8176E+11	4.8644E+10	5.3072E+09	2.6821E+08
10	2.5191E+11	4.9552E+11	5.0823E+10	5.7485E+09	1.6168E+08
11	3.3148E+11	6.5235E+11	3.6726E+10	4.8259E+09	1.3763E+08
12	4.3191E+11	8.3489E+11	4.4162E+10	5.6962E+09	3.6002E+08
13	1.3098E+12	2.3203E+12	6.3174E+10	7.5884E+09	2.2969E+08
14	1.8248E+12	3.3116E+12	6.3588E+10	8.2049E+09	4.7275E+08
15	2.7959E+12	5.0940E+12	8.9986E+10	1.0604E+10	2.7411E+08
16	5.2407E+12	9.4059E+12	1.1119E+11	1.3094E+10	3.3173E+08
17	9.9650E+12	1.7891E+13	5.4933E+11	2.6342E+10	7.3526E+08
18	9.0207E+12	1.5980E+13	1.8532E+11	1.8730E+10	4.4644E+08
19	5.1662E+12	9.3044E+12	1.0037E+11	1.0205E+10	2.0131E+08
20	6.0964E+12	1.1096E+13	1.1621E+11	1.1451E+10	1.8789E+08
21	4.1680E+11	7.6217E+11	8.2872E+09	7.6663E+08	1.3326E+07
22	1.5671E+13	2.8573E+13	2.8119E+11	2.8838E+10	4.9424E+08
23	1.1821E+13	2.1472E+13	2.5168E+11	2.5520E+10	3.8663E+08
24	6.6588E+12	1.2076E+13	1.4492E+11	1.4004E+10	2.4889E+08
25	7.4922E+12	1.3364E+13	1.7191E+11	1.6579E+10	2.6908E+08
26	6.5261E+12	1.1511E+13	1.8216E+11	1.7368E+10	2.9002E+08
27	3.6455E+12	6.5041E+12	1.1050E+11	2.2830E+10	2.8719E+08
28	4.3752E+12	8.2640E+12	3.7988E+11	1.9379E+10	3.3261E+08
29	3.2865E+12	5.7981E+12	2.0662E+11	1.8396E+10	2.9771E+08
30	5.4453E+12	9.5029E+12	5.4003E+11	4.6215E+10	7.9939E+08
31	3.3447E+12	5.7340E+12	9.1141E+11	6.9971E+10	1.3968E+09
32	6.2751E+11	1.0611E+12	7.4080E+11	4.4214E+10	1.1394E+09
33	2.8465E+11	4.5365E+11	1.0790E+12	3.1517E+10	1.7201E+09
34	1.1880E+11	1.9030E+11	8.0600E+11	5.5368E+09	1.1588E+09
35	1.1372E+10	1.8273E+10	1.7852E+11	3.1301E+08	2.1005E+08
36	1.3723E+10	2.2156E+10	3.4083E+11	2.3179E+08	3.1880E+08
37	2.8436E+10	3.9079E+10	5.0736E+11	2.6963E+07	1.9505E+08
38	4.6868E+09	6.5907E+09	1.1665E+11	1.5119E+06	1.7075E+07
39	3.2328E+09	4.8742E+09	1.0756E+11	1.4611E+06	6.0232E+06
40	1.5135E+09	2.2716E+09	1.0578E+10	5.1770E+05	4.0161E+05
41	1.1685E+09	1.7329E+09	7.8063E+07	4.0173E+05	7.0674E+04
42	3.9574E+07	6.9099E+07	3.4983E+03	2.6474E+04	5.1938E+03

[a] Spatial mesh interval number from PWR or BWR model.

Table 3.6 Key parameters for BWR and PWR pin cells

	BWR	PWR
Inner radius clad (cm)	0.53213	0.41783
Outer radius clad (cm)	0.6134	0.47498
Outer radius cell (cm)	0.9174	0.71079
Region temperature (K)		
Pellet	921	921
Clad	672	672
Moderator	583	551
Pellet nuclear density ($b^{-1} \cdot cm^{-1}$)		
U-235	4.959-4[a]	6.325-4
U-238	2.177-2	2.166-2
Oxygen	4.455-2	4.465-2
Moderator density ($b^{-1} \cdot cm^{-1}$)		
Hydrogen	2.475-2	4.714-2
Oxygen	1.238-2	2.357-2
Boron-10	0	4.200-6
Zircalloy-4 density ($b^{-1} \cdot cm^{-1}$)		
Chromium	7.64-5	
Iron	1.45-4	
Nickel	8.77-4	
Zirconium	4.27-2	

[a] Read as 4.959×10^{-4}.

Table 3.7 Number densities[a] used for steel constituents

	Stainless Steel	Carbon Steel
Carbon	2.37-4[b]	9.81-4
Chromium	1.74-2	1.27-4
Manganese	1.52-3	1.12-3
Iron	5.83-2	8.19-2
Nickel	8.55-3	4.44-4

[a] In units of $b^{-1} \cdot cm^{-1}$.
[b] Read as 2.37×10^{-4}.

Table 3.8 Processing codes from AMPX-77 used to produce BUGLE-96.

Module	Function
AJAX	Merge and delete nuclides from master libraries.
AIM	BCD-to-binary (or vice-versa) conversion of master libraries.
ALE	Display information contained in either an AMPX master or working library.
ALPO	Produce ANISN library from AMPX working library format.
BONAMI-S	Perform interpolation on Bondarenko factors to self-shield reaction cross sections.
MALOCS	Collapse energy group structure of master library.
NITAWL	Convert master library to working library format.
WORKER	Prepare working libraries for use in transport calculations. Interpolate thermal scattering matrices; particularly useful for nuclides with upscattering.
XSDRNPM	Perform a one-dimensional discrete-ordinates or diffusion theory calculation using cross sections in an AMPX working library. Also, perform spatial cross-section weighting.

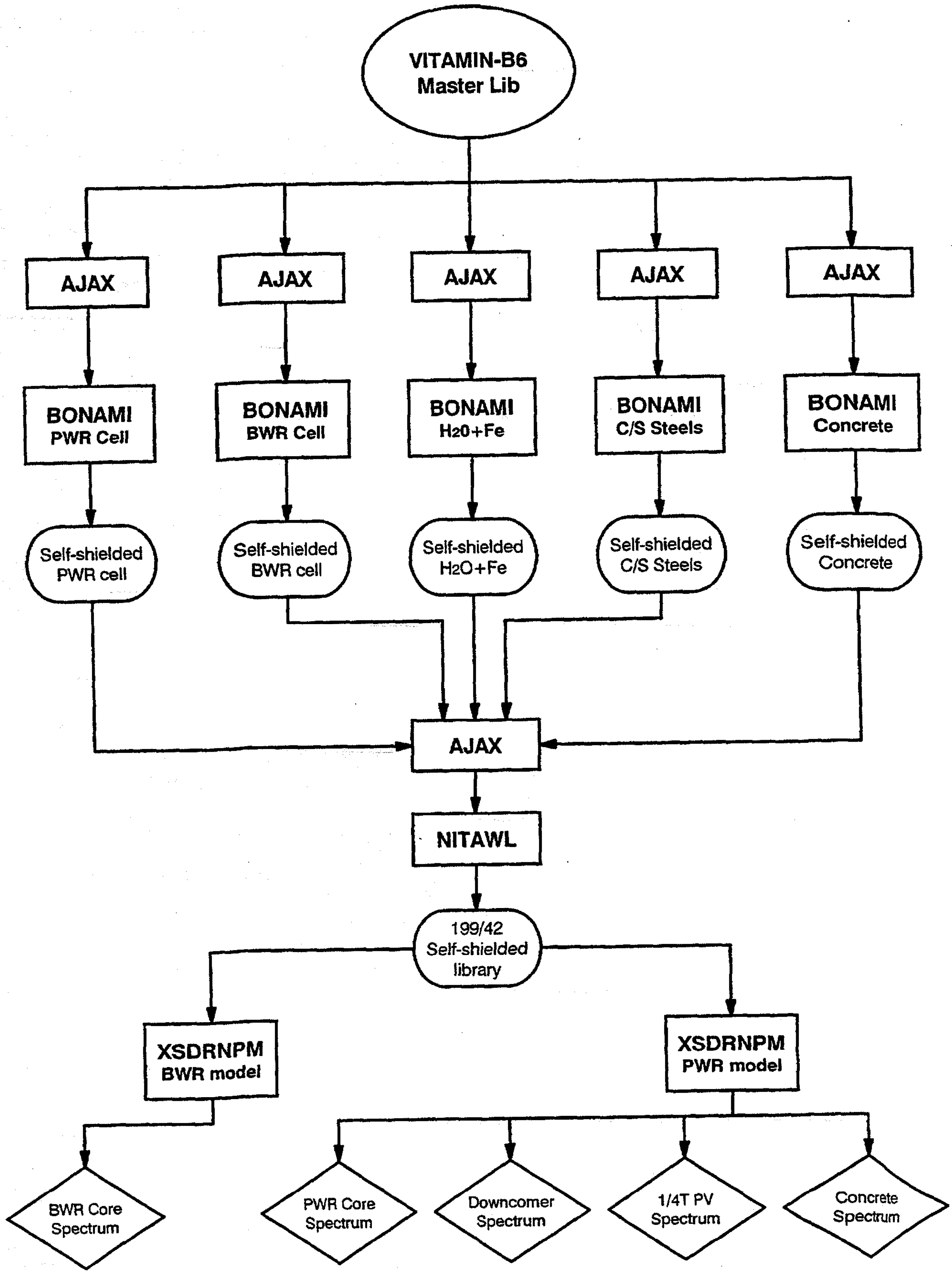


Fig. 3.4 Procedure for calculating BWR- and PWR-specific flux spectra

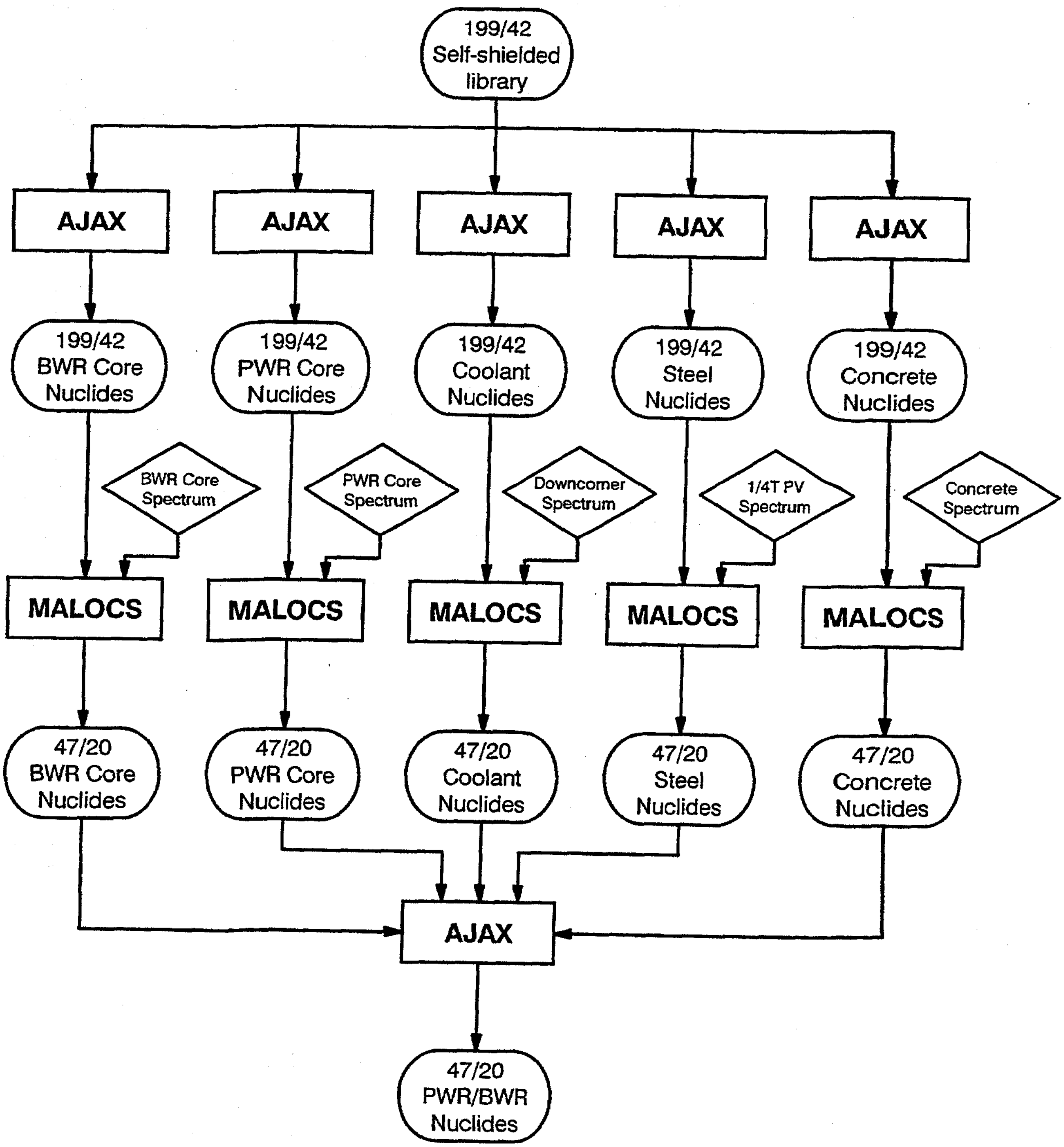


Fig. 3.5 Procedure for collapsing fine-group cross sections using BWR- and PWR-specific flux spectra

The approach used for removing the upscatter terms in BUGLE-96 is the same as implemented in the ANISN code. Conceptually, the upscatter between two groups is set to zero and the downscatter is reduced an equivalent amount to preserve the net transfer reaction rate between the two groups. The within-group scatter terms of both groups are increased a corresponding amount to preserve the total scatter reaction rate. Although this yields an acceptable solution in most circumstances, it can cause the generation of negative downscatter terms if the upscatter is greater than the downscatter between two groups. This highlights the importance of using a particular cross-section set only in the type of application for which it was intended.

The final processing sequence is diagramed in Fig. 3.6, which is the process used to generate a full set of infinitely dilute cross sections collapsed with a concrete weighting spectrum. Nuclides from this set can be used for general purposes and for cases where the problem-specific self-shielded/weighted data sets are not appropriate. The complete BUGLE-96 library is actually contained in three distinct data sets: (1) the full set of general nuclides just described, (2) the set of self-shielded and energy weighted nuclides specific to BWR and PWR models, and (3) a set of response functions and kerma factors.

NOTE: The preceding BUGLE-93 library contained an additional processing sequence for generating data sets specific to the constituents of carbon steel and stainless steel and self-shielded at a temperature of 300 K. For BUGLE-96, these data sets were included in the BWR/PWR-specific processing sequences, so that a separate processing step was not needed. However, this approach results in data sets for carbon steel and stainless steel which are self-shielded at a temperature of 600 K rather than the earlier 300 K.

3.5 Library Format and Content

The BUGLE-96 data library package consists of four major parts:

BUGLE-96 - complete replacement for all files previously contained in BUGLE-93.

BUGLE-96T - the same cross sections as BUGLE-96 with the thermal upscattering cross sections retained in the thermal region.

SAILOR-96 - the same cross sections as BUGLE-96 with the ANISN identifiers arranged to be plug compatible with DLC-76/SAILOR.

SAILOR-96T - the same cross sections as BUGLE-96T with the ANISN identifiers arranged to be plug compatible with DLC-76/SAILOR.

The BUGLE-96 broad-group data library package is available in ANISN card image format.[8] For BUGLE-96 and SAILOR-96, the table width is 67 (number of groups) and the table length is 70 (number of groups plus 3). For BUGLE-96T and SAILOR-96T, the table width is 67 (number of groups) and the table length is 74 (number of groups plus 3 plus 4 upscatter groups).

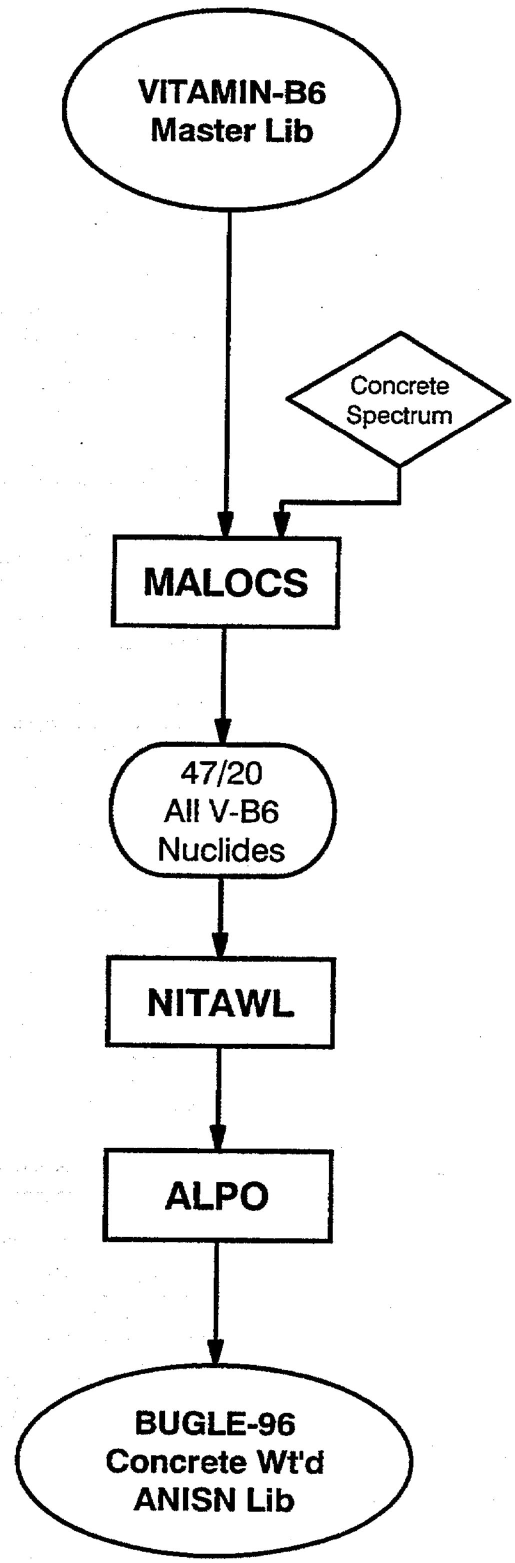


Fig. 3.6 Procedure for generating complete infinitely dilute BUUGLE-96 library using concrete flux spectrum

Table positions 1 through 4 are defined as:

1. absorption cross section (σ_a),
2. fission cross section times the number of neutrons produced per fission ($\nu\sigma_f$),
3. total cross section (σ_T), and
4. within-group scattering cross section (σ_{g-g}).

These positions are followed by the standard down-scatter transfer matrix. As mentioned in the previous section, the upscatter transfer matrix was removed using the ANISN methodology option in MALOCS for BUGLE-96 and SAILOR-96.

Each cross-section matrix is preceded by a title card containing four integer parameters, an alpha/numeric descriptor, and a Pedigree Identification Code. The integer parameters (4I6 format) include: (1) the number of columns in the cross-section table (total number of energy groups), (2) the number of rows in the table (normally equals the number of columns plus 3), (3) a control code, which is generally not used, and (4) a unique identification number. The 36-character descriptor field (36H format) can contain any pertinent information, but usually includes the order of P_L expansion, the specific isotope or element, and special processing treatments such as self-shielding or energy weighting.

On the first pass, the collapsing procedure outlined in Fig. 3.5 regenerated the files needed to replace BUGLE-93 (no thermal upscattering data). The collapsing procedure was then repeated for the five MALOCS cases to produce self-shielded cross sections with upscattering data. On this second pass, a new library with upscattering data designated as BUGLE-96T was created. The difference between the production of the collapsed data for BUGLE-96 and BUGLE-96T is a single parameter in the MALOCS module.

Starting with BUGLE-93 and continuing with BUGLE-96, we added to the title record a 20-character Pedigree Identification Code (PIC) in the final 20 columns of the card (20H format). As the name suggests, the intent of the PIC is to put into a compact form information which is pertinent to the original source and ancestry of the data. The format and content of the PIC is given in Table 3.9. As an example, the PIC for ^{56}Fe is "E622631B96VB63020194." Most BUGLE-96 nuclides have this same PIC except for the nuclide MAT number and, in some cases, the ENDF/B-VI MOD number. This information is typically well understood at the time of the initial release of a library, but experience has shown us that the pedigree information can become vague or lost entirely as the library evolves. Frequently, the library grows with the addition of data sets based on later revisions to the evaluated data or processing options, or with the addition of data processed from alternative evaluations. Many analyses have gone amuck because of confusions regarding the actual nature and pedigree of a particular data set. The PIC is an attempt to avoid this problem. It is hoped that future libraries will adopt the same PIC format so that a standard will emerge.

Listings of the library contents for BUGLE-96 are given in Tables 3.10-3.12. Table 3.10 lists all materials which comprise the "standard weighted" library (i.e., the collection of all materials which were

Table 3.9 Pedigree Indentification Code [a]

Field(s)	Parameter	Comments/Options	
1	Evaluated File	B=BROND C=CENDL D=EFF E=ENDF	F=FENDL G=JENDL J=JEFF L=LENDL
2	Evaluation Version		
3	Evaluation "MOD"		
4-7	Material identifer	e.g., MAT number for ENDF	
8-10	Library designation	B93=BUGLE-93 B96=BUGLE-96 S96=SAILOR-96	VNC=VITAMIN-C VNE=VITAMIN-E VB6=VITAMIN-B6
11-13	Parent library	For derived libraries. Use "000" if no parent library.	
14	Data completeness	0=response fcts 1=neutron only 2=photon only	3=neutron+photon 4=(3)+delayed photons 5=thermal upscatter
15-20	Date of processing	"mmddyy" for month, day, and year	

[a] Appears in columns 61-80 of P_0 cross-section title cards.

Table 3.10 Nuclides in BUGLE-96 which are infinitely dilute and weighted with a concrete flux spectrum

Entry	Nuclide	ANISN-ID	Entry	Nuclide	ANISN-ID
1	Ag-107	1-6	46	H-1 (H2O)	313-320
2	Ag-109	7-12	47	H-1 (CH2)	321-328
3	Al-27	13-20	48	H-2 (D2O)	329-336
4	Am-241	21-26	49	H-3	337-344
5	Am-242	27-32	50	He-3	345-352
6	Am-242m	33-38	51	He-4	353-360
7	Am-243	39-44	52	Hf-174	361-366
8	Au-197	45-50	53	Hf-176	367-372
9	B-10	51-58	54	Hf-177	373-378
10	B-11	59-66	55	Hf-178	379-384
11	Ba-138	67-72	56	Hf-179	385-390
12	Be-9	73-80	57	Hf-180	391-396
13	Be-9 (Thermal)	81-88	58	In-Nat	397-402
14	Bi-209	89-94	59	K	403-410
15	C	95-102	60	Li-6	411-418
16	C (Graphite)	103-110	61	Li-7	419-426
17	Ca	111-118	62	Mg	427-434
18	Cd-Nat	119-124	63	Mn-55	435-442
19	Cl-Nat	125-132	64	Mo	443-448
20	Cm-241	133-138	65	N-14	449-456
21	Cm-242	139-144	66	N-15	457-464
22	Cm-243	145-150	67	Na-23	465-472
23	Cm-244	151-156	68	Nb-93	473-478
24	Cm-245	157-162	69	Ni-58	479-486
25	Cm-246	163-168	70	Ni-60	487-494
26	Cm-247	169-174	71	Ni-61	495-502
27	Cm-248	175-180	72	Ni-62	503-510
28	Co-59	181-188	73	Ni-64	511-518
29	Cr-50	189-196	74	Np-237	519-524
30	Cr-52	197-204	75	Np-238	525-530
31	Cr-53	205-212	76	Np-239	531-536
32	Cr-54	213-220	77	O-16	537-544
33	Cu-63	221-228	78	O-17	545-552
34	Cu-65	229-236	79	P-31	553-560
35	Eu-151	237-242	80	Pa-231	561-566
36	Eu-152	243-248	81	Pa-233	567-572
37	Eu-153	249-254	82	Pb-206	573-578
38	Eu-154	255-260	83	Pb-207	579-584
39	Eu-155	261-266	84	Pb-208	585-590
40	F-19	267-274	85	Pu-236	591-596
41	Fe-54	275-282	86	Pu-237	597-602
42	Fe-56	283-290	87	Pu-238	603-608
43	Fe-57	291-298	88	Pu-239	609-614
44	Fe-58	299-306	89	Pu-240	615-620
45	Ga	307-312	90	Pu-241	621-626

Table 3.10 cont'd

Entry	Nuclide	ANISN-ID	Entry	Nuclide	ANISN-ID
91	Pu-242	627-632	106	U-233	725-730
92	Pu-243	633-638	107	U-234	731-736
93	Pu-244	639-644	108	U-235	737-742
94	Re-185	645-650	109	U-236	743-748
95	Re-187	651-656	110	U-237	749-754
96	S	657-664	111	U-238	755-760
97	S-32	665-672	112	V	761-768
98	Si	673-680	113	W-Nat	769-774
99	Sn-Nat	681-686	114	W-182	775-780
100	Ta-181	687-692	115	W-183	781-786
101	Ta-182	693-698	116	W-184	787-792
102	Th-230	699-704	117	W-186	793-798
103	Th-232	705-710	118	Y-89	799-804
104	Ti	711-718	119	Zr	805-810
105	U-232	719-724	120	Zr (Zirc-2)	811-816

Table 3.11a Nuclides in BUGLE-96 which are self-shielded and weighted with BWR- and PWR-specific flux spectra

Nuclide	ANISN-ID	Description
B-10	1001-1008	PWR core coolant
Cr-50	1009-1016	PWR core clad
Cr-52	1017-1024	PWR core clad
Cr-53	1025-1032	PWR core clad
Cr-54	1033-1040	PWR core clad
Fe-54	1041-1048	PWR core clad
Fe-56	1049-1056	PWR core clad
Fe-57	1057-1064	PWR core clad
Fe-58	1065-1072	PWR core clad
H-1(H2O)	1073-1080	PWR core coolant
Ni-58	1081-1088	PWR core clad
Ni-60	1089-1096	PWR core clad
Ni-61	1097-1104	PWR core clad
Ni-62	1105-1112	PWR core clad
Ni-64	1113-1120	PWR core clad
O-16	1121-1128	PWR core coolant
O-16	1129-1136	PWR core fuel
U-235	1137-1142	PWR core fuel
U-238	1143-1148	PWR core fuel
Zr	1149-1154	PWR core clad
H-1(H2O)	2001-2008	PWR downcomer
O-16	2009-2016	PWR downcomer
C	2017-2024	PWR downcomer
Cr-50	2025-2032	PWR downcomer
Cr-52	2033-2040	PWR downcomer
Cr-53	2041-2048	PWR downcomer
Cr-54	2049-2056	PWR downcomer
Fe-54	2057-2064	PWR downcomer
Fe-56	2065-2072	PWR downcomer
Fe-57	2073-2080	PWR downcomer
Fe-58	2081-2088	PWR downcomer
Mn-55	2089-2096	PWR downcomer
Ni-58	2097-2104	PWR downcomer
Ni-60	2105-2112	PWR downcomer
Ni-61	2113-2120	PWR downcomer
Ni-62	2121-2128	PWR downcomer
Ni-64	2129-2136	PWR downcomer
C	3001-3008	PWR 1/4 T in Pressure Vessel
Cr-50	3009-3016	PWR 1/4 T in Pressure Vessel
Cr-52	3017-3024	PWR 1/4 T in Pressure Vessel
Cr-53	3025-3032	PWR 1/4 T in Pressure Vessel
Cr-54	3033-3040	PWR 1/4 T in Pressure Vessel
Fe-54	3041-3048	PWR 1/4 T in Pressure Vessel
Fe-56	3049-3056	PWR 1/4 T in Pressure Vessel

Table 3.11a cont'd

Nuclide	ANISN-ID	Description
Fe-57	3057-3064	PWR 1/4 T in Pressure Vessel
Fe-58	3065-3072	PWR 1/4 T in Pressure Vessel
Mn-55	3073-3080	PWR 1/4 T in Pressure Vessel
Ni-58	3081-3088	PWR 1/4 T in Pressure Vessel
Ni-60	3089-3096	PWR 1/4 T in Pressure Vessel
Ni-61	3097-3104	PWR 1/4 T in Pressure Vessel
Ni-62	3105-3112	PWR 1/4 T in Pressure Vessel
Ni-64	3113-3120	PWR 1/4 T in Pressure Vessel
Al-27	4001-4008	Concrete type 04
C	4009-4016	Concrete type 04
Ca	4017-4024	Concrete type 04
Fe-54	4025-4032	Concrete type 04
Fe-56	4033-4040	Concrete type 04
Fe-57	4041-4048	Concrete type 04
Fe-58	4049-4056	Concrete type 04
H-1(H2O)	4057-4064	Concrete type 04
K	4065-4072	Concrete type 04
Mg	4073-4080	Concrete type 04
Na-23	4081-4088	Concrete type 04
O-16	4089-4096	Concrete type 04
Si	4097-4104	Concrete type 04
C	5001-5008	Carbon steel
C	5009-5016	Stainless steel
Cr-50	5017-5024	Carbon steel
Cr-50	5025-5032	Stainless steel
Cr-52	5033-5040	Carbon steel
Cr-52	5041-5048	Stainless steel
Cr-53	5049-5056	Carbon steel
Cr-53	5057-5064	Stainless steel
Cr-54	5065-5072	Carbon steel
Cr-54	5073-5080	Stainless steel
Fe-54	5081-5088	Carbon steel
Fe-54	5089-5096	Stainless steel
Fe-56	5097-5104	Carbon steel
Fe-56	5105-5112	Stainless steel
Fe-57	5113-5120	Carbon steel
Fe-57	5121-5128	Stainless steel
Fe-58	5129-5136	Carbon steel
Fe-58	5137-5144	Stainless steel
Mn-55	5145-5152	Carbon steel
Mn-55	5153-5160	Stainless steel
Ni-58	5161-5168	Carbon steel

Table 3.11a cont'd

Nuclide	ANISN-ID	Description
Ni-58	5169-5176	Stainless steel
Ni-60	5177-5185	Carbon steel
Ni-60	5186-5192	Stainless steel
Ni-61	5193-5200	Carbon steel
Ni-61	5201-5208	Stainless steel
Ni-62	5209-5216	Carbon steel
Ni-62	5217-5224	Stainless steel
Ni-64	5225-5232	Carbon steel
Ni-64	5233-5240	Stainless steel
Fe-54	6001-6008	BWR core clad
Fe-56	6009-6016	BWR core clad
Fe-57	6017-6024	BWR core clad
Fe-58	6025-6032	BWR core clad
H-1(H2O)	6033-6040	BWR core coolant
O-16	6041-6048	BWR core coolant
O-16	6049-6056	BWR core fuel
U-235	6057-6062	BWR core fuel
U-238	6063-6068	BWR core fuel
Zr	6069-6074	BWR core clad

Table 3.11b Nuclides in SAILOR-96 which are self-shielded and weighted with BWR- and PWR-specific flux spectra

Nuclide	ANISN-ID	Description
BUGLE-96	1	RESPONSE FUNCTIONS 1-55(FLAT WTNG)
BUGLE-96	2	RESPONSE FUNCTIONS 1-55(1/4T PV WTNG)
H-1 (H2O)	3-6	PWR core coolant
B-10	7-10	PWR core coolant
O-16	11-14	PWR core coolant
Cr	15-18	PWR core clad
Fe	19-22	PWR core clad
Ni	23-26	PWR core clad
Zr	27-30	PWR core clad
U-235	31-34	PWR core fuel
U-238	35-38	PWR core fuel
O-16	39-42	PWR core fuel
U-235	43-46	BWR core fuel
U-238	47-50	BWR core fuel
O-16	51-54	BWR core fuel
H-1 (H2O)	55-58	PWR downcomer
O-16	59-62	PWR downcomer
Cr	63-66	PWR downcomer
Mn-55	67-70	PWR downcomer
Fe	71-74	PWR downcomer
Ni	75-78	PWR downcomer
C	79-82	PWR downcomer
H1(h2o)	83-86	Concrete type 04
C	87-90	Concrete type 04
O-16	91-94	Concrete type 04
Na-23	95-98	Concrete type 04
Mg	99-102	Concrete type 04
Al-27	103-106	Concrete type 04
Si	107-110	Concrete type 04
K	111-114	Concrete type 04
Ca	115-118	Concrete type 04
Fe	119-122	Concrete type 04
Cr	123-126	PWR 1/4 T in PV
Mn-55	127-130	PWR 1/4 T in PV
Fe	131-134	PWR 1/4 T in PV
Ni	135-138	PWR 1/4 T in PV
C	139-142	PWR 1/4 T in PV

Table 3.12 Data Sets in BUGLE-96 which contain response functions or kerma factors

ANISN-ID	Description
1	199/42-group response functions
7001	Response functions (first 55 responses) with flat weighting
7002	Response functions (last 16 responses) with flat weighting
7003	Response functions (first 55 responses) with 1/4T PV weighting
7004	Response functions (last 16 responses) with 1/4T PV weighting
8001	Neutron kerma factors for first 60 nuclides (^{107}Ag - ^{6}Li)
8002	Neutron kerma factors for last 60 nuclides (^{7}Li - Zirc-2)
8003	Gamma-ray kerma factors for first 60 nuclides (^{107}Ag - ^{6}Li)
8004	Gamma-ray kerma factors for last 60 nuclides (^{7}Li - Zirc-2)

processed as infinitely dilute and collapsed using the concrete flux spectrum). Table 3.11a lists the "special weighted" library (i.e., the collection of materials which were processed with specific self-shielding compositions and collapsed using the PWR and BWR flux spectra). The range of ANISN IDs for each nuclide are for the P_0 through P_L components, where "L" is either 5 or 7. Table 11.b lists the SAILOR-96 nuclides which have exactly the same ANISN identifiers as the earlier SAILOR data based on ENDF/B-VI. Note that the maximum order of Legendre scattering components for SAILOR-96 cross sections is P_3, which is less than BUGLE-96. Finally, Table 3.12 lists the ANISN IDs for the response functions and kerma factors data sets provided with the library. These responses and kerma factors are described in the following section.

3.6 Response Functions

We have continued the practice of including with the cross-section library additional data sets consisting of selected response functions which are expected to be of use to the user community. The following response functions are included with BUGLE-96:

- Dosimetry reaction cross sections based on ENDF/B-VI evaluations, including the 45 neutron responses in the SAILOR library.
- Neutron group boundaries, midpoint energy values, energy intervals, lethargy intervals, etc.
- Silicon displacement kerma.
- Total kerma factors for neutrons and photons calculated with the HEATR (neutron) and GAMINR (photons) modules of NJOY.

A list of the 55 original response functions included in BUGLE-93 and 16 additional response functions is given in Table 3.13 All but three of the responses are from the ENDF/B-VI evaluations. The ^{6}Li helium production cross section, the ^{32}S(n,p) cross section, and the Si displacement kerma, were obtained from Sandia National Laboratories compendium of dosimetry data.[20] The broad-group responses were prepared for two different energy weightings: a flat (uniform) weighting spectrum and the 1/4T pressure vessel weighting spectrum (listed in Table 3.4). The response functions are included in the library as "pseudo cross sections," i.e., they appear as normal 67-by-70 cross-section matrices. Within a matrix, each row represents a different response function. The row positions of the various response functions are given in Table 3.13. The group-wise responses are listed in Tables 3.14 and 3.15. The ANISN IDs of the four response tables are 7001-7002 for the flat-weighted responses and 7003-7004 for the 1/4T-weighted responses.

Even though the different weightings resulted in only a few percent change for most of the group-wise responses, differences of 20 to 30% were observed for several group constants, especially near reaction thresholds, and a maximum difference of 60% was observed for Group 30 of the ^{28}Fe (n,γ) reaction. Because of the observed sensitivity of the broad-group responses to the weighting function, a fine-group set of responses was prepared and is included in the BUGLE-96 package. The fine-group response matrix has an ANISN ID of 1 and contains 241

Table 3.13. Neutron response functions included with BUGLE-96 indicating row positions in data sets 7001-7004

Row	Response	Row	Response
	Data Sets 7001 and 7003		
1	Group upper energy (MeV)	29	I-127 (n,2n)
2	U-235 fission spectrum (χ)	30	Sc-45 (n,γ)
3	Li-6 (n,x) He-4	31	Na-23 (n,γ)
4	B-10 (n,α)	32	Fe-58 (n,γ)
5	Th-232 (n,fission)	33	Co-59 (n,γ)
6	U-235 (n,fission)	34	Cu-63 (n,γ)
7	U-238 (n,fission)	35	In-115 (n,γ)
8	Np-237 (n,fission)	36	Au-197 (n,γ)
9	Pu-239 (n,fission)	37	Th-232 (n,γ)
10	Al-27 (n,p)	38	U-238 (n,γ)
11	Al-27 (n,α)	39	Square-root(E_{mid}) ($MeV^{1/2}$)
12	S-32 (n,p)	40	Total neutron flux
13	Ti-46 (n,p)	41	U-234 (n,fission)
14	Ti-47 (n,p)	42	U-236 (n,fission)
15	Ti-47 (n,n'p)	43	Pu-240 (n,fission)
16	Ti-48 (n,p)	44	Pu-241 (n,fission)
17	Ti-48 (n,n'p)	45	Pu-242 (n,fission)
18	Mn-55 (n,2n)	46	Rh-103 (n,n')
19	Fe-54 (n,p)	47	Si displacement kerma (eV·b)
20	Fe-56 (n,p)	48	U-238 fission spectrum (χ)
21	Co-59 (n,2n)	49	Pu-239 fission spectrum (χ)
22	Co-59 (n,α)	50	E > 1.0 MeV neutron flux
23	Ni-58 (n,p)	51	E > 0.1 MeV neutron flux
24	Ni-58 (n,2n)	52	E < 0.414 eV neutron flux
25	Ni-60 (n,p)	53	Midpoint energy (MeV)
26	Cu-63 (n,α)	54	Group energy width (MeV)
27	Cu-65 (n,2n)	55	Group lethargy width
28	In-115 (n,n')		
	Data Sets 7002 and 7004		
1	Pu-238 (n,fission)	9	Pu-241 neutrons per fission (ν)
2	U-234 neutrons per fission (ν)	10	Pu-242 neutrons per fission (ν)
3	U-235 neutrons per fission (ν)	11	U-234 fission spectrum (χ)
4	U-236 neutrons per fission (ν)	12	U-236 fission spectrum (χ)
5	U-238 neutrons per fission (ν)	13	Pu-238 fission spectrum (χ)
6	Pu-238 neutrons per fission (ν)	14	Pu-240 fission spectrum (χ)
7	Pu-239 neutrons per fission (ν)	15	Pu-241 fission spectrum (χ)
8	Pu-240 neutrons per fission (ν)	16	Pu-242 fission spectrum (χ)

Table 3.14 Neutron response functions collapsed using flat weighting

Grp	Upper Energy	U-235 χ	Li-6 He-4 prd	B-10 (n,α)	Th-232 (n,f)	U-235 (n,f)
1	1.7332E+01	5.0179E-05	4.7232E-01	4.2156E-02	4.3136E-01	2.0735E+00
2	1.4191E+01	2.0166E-04	5.1684E-01	4.2619E-02	3.2663E-01	1.9282E+00
3	1.2214E+01	1.1460E-03	5.5853E-01	4.4402E-02	3.0836E-01	1.7293E+00
4	1.0000E+01	2.5222E-03	6.3289E-01	5.7616E-02	3.2388E-01	1.7612E+00
5	8.6071E+00	5.6568E-03	7.0577E-01	8.0408E-02	3.6062E-01	1.7464E+00
6	7.4082E+00	1.6147E-02	7.7178E-01	1.1269E-01	3.0408E-01	1.4230E+00
7	6.0653E+00	3.0712E-02	8.0511E-01	1.2197E-01	1.4357E-01	1.0552E+00
8	4.9659E+00	8.0512E-02	7.7062E-01	2.6313E-01	1.4232E-01	1.1106E+00
9	3.6788E+00	7.6758E-02	6.0925E-01	3.0406E-01	1.3969E-01	1.1703E+00
10	3.0119E+00	4.4010E-02	3.9611E-01	3.6913E-01	1.2703E-01	1.2150E+00
11	2.7253E+00	4.6685E-02	2.8706E-01	3.1882E-01	1.2045E-01	1.2429E+00
12	2.4660E+00	2.0028E-02	2.5208E-01	2.8462E-01	1.1507E-01	1.2552E+00
13	2.3653E+00	4.0262E-03	2.4746E-01	2.9288E-01	1.1585E-01	1.2592E+00
14	2.3457E+00	2.4344E-02	2.4252E-01	3.0917E-01	1.2609E-01	1.2638E+00
15	2.2313E+00	7.3547E-02	2.3399E-01	4.1159E-01	1.2266E-01	1.2702E+00
16	1.9205E+00	7.1946E-02	2.2020E-01	5.0278E-01	9.1294E-02	1.2595E+00
17	1.6530E+00	8.9495E-02	2.1291E-01	3.0979E-01	8.1353E-02	1.2321E+00
18	1.3534E+00	1.1503E-01	2.2016E-01	2.1852E-01	8.6693E-03	1.2003E+00
19	1.0026E+00	6.2685E-02	2.3861E-01	2.5376E-01	7.1248E-04	1.1517E+00
20	8.2085E-01	2.7239E-02	2.5648E-01	3.2103E-01	1.2603E-04	1.1110E+00
21	7.4274E-01	4.6851E-02	2.8261E-01	4.3035E-01	3.4442E-05	1.1157E+00
22	6.0810E-01	3.7615E-02	3.3814E-01	6.6683E-01	5.8520E-06	1.1278E+00
23	4.9787E-01	4.1771E-02	4.9376E-01	8.4399E-01	0	1.1797E+00
24	3.6883E-01	2.1390E-02	1.0122E+00	9.5140E-01	0	1.2260E+00
25	2.9721E-01	3.0048E-02	2.4377E+00	1.2647E+00	0	1.2984E+00
26	1.8316E-01	1.5408E-02	9.2165E-01	1.6957E+00	0	1.4372E+00
27	1.1109E-01	7.4251E-03	6.5334E-01	2.0955E+00	0	1.6021E+00
28	6.7379E-02	3.5461E-03	7.1593E-01	2.6030E+00	0	1.8105E+00
29	4.0868E-02	9.9806E-04	8.2619E-01	3.1216E+00	0	1.9686E+00
30	3.1828E-02	5.6977E-04	9.0935E-01	3.4799E+00	0	2.1196E+00
31	2.6058E-02	1.7337E-04	9.6818E-01	3.7273E+00	0	2.1831E+00
32	2.4176E-02	2.0305E-04	1.0067E+00	3.8907E+00	0	2.2818E+00
33	2.1875E-02	5.4037E-04	1.1233E+00	4.3737E+00	0	2.3938E+00
34	1.5034E-02	4.8419E-04	1.4537E+00	5.7400E+00	0	2.8863E+00
35	7.1017E-03	1.5746E-04	2.1032E+00	8.4066E+00	0	3.9988E+00
36	3.3546E-03	5.1156E-05	3.0547E+00	1.2293E+01	0	5.5154E+00
37	1.5846E-03	2.0827E-05	4.8963E+00	1.9816E+01	0	9.1358E+00
38	4.5400E-04	2.5484E-06	8.3350E+00	3.3846E+01	0	1.5618E+01
39	2.1445E-04	8.2729E-07	1.2133E+01	4.9359E+01	0	2.0654E+01
40	1.0130E-04	3.0899E-07	1.8549E+01	7.5517E+01	0	3.1806E+01
41	3.7266E-05	5.9997E-08	3.2034E+01	1.3049E+02	0	5.0522E+01
42	1.0677E-05	5.4050E-12	5.4477E+01	2.2211E+02	0	5.5389E+01
43	5.0435E-06	0	8.3285E+01	3.3957E+02	0	1.5699E+01
44	1.8554E-06	0	1.3057E+02	5.3243E+02	0	3.8833E+01
45	8.7643E-07	0	1.8991E+02	7.7447E+02	0	6.8464E+01
46	4.1399E-07	0	3.1296E+02	1.2766E+03	0	1.7917E+02
47	1.0000E-07	0	9.1977E+02	3.7523E+03	0	5.6297E+02

Table 3.14 cont'd

Grp	U-238 (n,f)	Np-237 (n,f)	Pu-239 (n,f)	Al-27 (n,p)	Al-27 (n,α)	S-32 (n,p)
1	1.2234E+00	2.2132E+00	2.3625E+00	5.8405E-02	9.7543E-02	1.7951E-01
2	1.0486E+00	2.0859E+00	2.3204E+00	7.8881E-02	1.2293E-01	3.1087E-01
3	9.8453E-01	2.0992E+00	2.2254E+00	8.7649E-02	1.0656E-01	3.8390E-01
4	9.9428E-01	2.1700E+00	2.2727E+00	8.4350E-02	7.6501E-02	3.4238E-01
5	9.9215E-01	2.2408E+00	2.2611E+00	7.2316E-02	4.1129E-02	3.1792E-01
6	8.5700E-01	1.9945E+00	2.0237E+00	5.4283E-02	1.1752E-02	3.0879E-01
7	5.6212E-01	1.4976E+00	1.6988E+00	3.7175E-02	4.8068E-04	2.5253E-01
8	5.4633E-01	1.5300E+00	1.7474E+00	1.1781E-02	1.5439E-06	2.7643E-01
9	5.2636E-01	1.6067E+00	1.8144E+00	4.7024E-03	0	1.9069E-01
10	5.2305E-01	1.6503E+00	1.8558E+00	6.2519E-04	0	1.0029E-01
11	5.3272E-01	1.6634E+00	1.8915E+00	1.1762E-04	0	6.8771E-02
12	5.3687E-01	1.6604E+00	1.9184E+00	1.2707E-05	0	7.2443E-02
13	5.3770E-01	1.6697E+00	1.9292E+00	8.2121E-06	0	6.6468E-02
14	5.3830E-01	1.6825E+00	1.9449E+00	3.2863E-06	0	6.1205E-02
15	5.3017E-01	1.6822E+00	1.9615E+00	1.5040E-07	0	2.1312E-02
16	4.7751E-01	1.6480E+00	1.9371E+00	8.5882E-10	0	4.1410E-03
17	3.2418E-01	1.5871E+00	1.9115E+00	0	0	5.9892E-04
18	4.3223E-02	1.4768E+00	1.8000E+00	0	0	6.0849E-05
19	1.2452E-02	1.3441E+00	1.6990E+00	0	0	1.8438E-07
20	3.7815E-03	1.1943E+00	1.6642E+00	0	0	0
21	1.5308E-03	9.5046E-01	1.6287E+00	0	0	0
22	6.1396E-04	6.0631E-01	1.5850E+00	0	0	0
23	2.8064E-04	2.6755E-01	1.5585E+00	0	0	0
24	1.5625E-04	9.3890E-02	1.5465E+00	0	0	0
25	7.9030E-05	4.6082E-02	1.5103E+00	0	0	0
26	1.0871E-04	2.3472E-02	1.5002E+00	0	0	0
27	3.3874E-05	1.5002E-02	1.5312E+00	0	0	0
28	9.1657E-05	1.1899E-02	1.5312E+00	0	0	0
29	3.0299E-05	1.0679E-02	1.5819E+00	0	0	0
30	9.9116E-05	1.0210E-02	1.6082E+00	0	0	0
31	2.4563E-05	9.9114E-03	1.5928E+00	0	0	0
32	2.7250E-05	9.7667E-03	1.5685E+00	0	0	0
33	1.5467E-04	9.5391E-03	1.7034E+00	0	0	0
34	4.5649E-04	9.1165E-03	1.9090E+00	0	0	0
35	1.6245E-05	8.7492E-03	2.2946E+00	0	0	0
36	4.4009E-09	9.2726E-03	3.5612E+00	0	0	0
37	9.2651E-04	1.3921E-02	6.6004E+00	0	0	0
38	9.9456E-06	2.4388E-02	1.1588E+01	0	0	0
39	1.9059E-05	3.2385E-02	1.8998E+01	0	0	0
40	3.2121E-05	4.3443E-02	4.9683E+01	0	0	0
41	1.4170E-04	3.4089E-02	5.2670E+01	0	0	0
42	7.3600E-05	7.3561E-03	3.6908E+01	0	0	0
43	1.7630E-06	3.9811E-03	9.8234E+00	0	0	0
44	1.8730E-06	1.0127E-02	2.5775E+01	0	0	0
45	2.5176E-06	8.5747E-03	1.3269E+02	0	0	0
46	3.9946E-06	5.1855E-03	1.3889E+03	0	0	0
47	1.1524E-05	1.7418E-02	7.5572E+02	0	0	0

Table 3.14 cont'd

Grp	Ti-46 (n,p)	Ti-47 (n,p)	T-47 (n,n'p)	Ti-48 (n,p)	Ti-48 (n,n'p)	Mn-55 (n,2n)
1	2.3185E-01	1.0126E-01	1.1057E-01	5.7867E-02	2.2238E-02	8.0975E-01
2	2.6548E-01	1.2747E-01	2.3093E-02	6.1081E-02	3.5666E-03	5.8141E-01
3	2.6304E-01	1.3799E-01	1.7344E-03	4.2421E-02	1.2965E-04	1.2730E-01
4	2.3755E-01	1.3120E-01	0	2.3314E-02	0	0
5	2.0627E-01	1.1822E-01	0	1.3187E-02	0	0
6	1.5952E-01	1.0506E-01	0	5.3056E-03	0	0
7	9.9284E-02	9.0214E-02	0	6.7628E-04	0	0
8	4.0704E-02	7.3510E-02	0	1.7157E-05	0	0
9	5.8083E-03	5.2088E-02	0	1.2844E-08	0	0
10	4.8186E-04	3.5199E-02	0	0	0	0
11	6.8546E-06	3.0687E-02	0	0	0	0
12	1.1050E-06	3.1258E-02	0	0	0	0
13	3.7716E-07	3.0536E-02	0	0	0	0
14	3.4272E-07	2.5942E-02	0	0	0	0
15	2.3359E-07	1.8030E-02	0	0	0	0
16	8.5452E-08	9.8049E-03	0	0	0	0
17	9.3494E-10	3.9990E-03	0	0	0	0
18	0	1.9598E-03	0	0	0	0
19	0	2.1140E-07	0	0	0	0
20	0	2.5346E-09	0	0	0	0
21	0	1.5774E-09	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0

Table 3.14 cont'd

Grp	Fe-54 (n,p)	Fe-56 (n,p)	Co-59 (n,2n)	Co-59 (n,α)	Ni-58 (n,p)	Ni-58 (n,2n)
1	2.3759E-01	9.1463E-02	7.8082E-01	2.5970E-02	2.2483E-01	5.1877E-02
2	3.9440E-01	1.1418E-01	5.4103E-01	2.7977E-02	4.5434E-01	9.4648E-03
3	4.6660E-01	8.5175E-02	8.9558E-02	1.9845E-02	5.8459E-01	0
4	4.8187E-01	5.7662E-02	0	1.2993E-02	6.2224E-01	0
5	4.8244E-01	4.1566E-02	0	7.7581E-03	6.2576E-01	0
6	4.7882E-01	2.4502E-02	0	2.7350E-03	6.0747E-01	0
7	4.3636E-01	5.7549E-03	0	4.5752E-04	5.1342E-01	0
8	3.1456E-01	1.8636E-04	0	1.4630E-05	3.8294E-01	0
9	1.9525E-01	1.4495E-07	0	0	2.4987E-01	0
10	1.3386E-01	6.9837E-10	0	0	1.7178E-01	0
11	7.8687E-02	0	0	0	1.2493E-01	0
12	5.6738E-02	0	0	0	9.6834E-02	0
13	5.1201E-02	0	0	0	8.8545E-02	0
14	4.5028E-02	0	0	0	7.9250E-02	0
15	2.9369E-02	0	0	0	5.0693E-02	0
16	9.5342E-03	0	0	0	2.8424E-02	0
17	2.9663E-03	0	0	0	1.4874E-02	0
18	7.8443E-04	0	0	0	5.9147E-03	0
19	9.0086E-05	0	0	0	1.3076E-03	0
20	6.6386E-06	0	0	0	8.9429E-04	0
21	3.9069E-07	0	0	0	5.5658E-04	0
22	0	0	0	0	1.6795E-04	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0

Table 3.14 cont'd

Grp	Ni-60 (n,p)	Cu-63 (n,α)	Cu-65 (n,2n)	In-115 (n,n')	I-127 (n,2n)	Sc-45 (n,γ)
1	1.0970E-01	3.2358E-02	1.0154E+00	5.9912E-02	1.5110E+00	1.6777E-04
2	1.4476E-01	4.3444E-02	7.5293E-01	8.8137E-02	1.3317E+00	2.6797E-04
3	1.1942E-01	3.7670E-02	2.0051E-01	1.9048E-01	7.9571E-01	3.5059E-04
4	8.8511E-02	2.7224E-02	0	2.6858E-01	4.8966E-02	4.2128E-04
5	6.5210E-02	1.8464E-02	0	2.9499E-01	0	4.7210E-04
6	3.8780E-02	1.0490E-02	0	3.1974E-01	0	5.2193E-04
7	1.5557E-02	3.3924E-03	0	3.3184E-01	0	5.7001E-04
8	2.2826E-03	5.9165E-04	0	3.1564E-01	0	7.5871E-04
9	3.0367E-05	4.8528E-05	0	3.3119E-01	0	1.0959E-03
10	7.6355E-08	8.2245E-06	0	3.3545E-01	0	1.3400E-03
11	4.2868E-08	2.9883E-06	0	3.3299E-01	0	1.5084E-03
12	2.8031E-08	9.4358E-07	0	3.2355E-01	0	1.6292E-03
13	2.3077E-08	8.1765E-07	0	3.1936E-01	0	1.6702E-03
14	1.7521E-08	6.7643E-07	0	3.1211E-01	0	1.7172E-03
15	2.8931E-09	2.4778E-07	0	2.7333E-01	0	2.0518E-03
16	0	1.6179E-08	0	2.1137E-01	0	2.6434E-03
17	0	0	0	1.6837E-01	0	3.2035E-03
18	0	0	0	9.3883E-02	0	4.6661E-03
19	0	0	0	4.9097E-02	0	5.5650E-03
20	0	0	0	2.5136E-02	0	6.0290E-03
21	0	0	0	1.3610E-02	0	6.7108E-03
22	0	0	0	3.7611E-03	0	7.7269E-03
23	0	0	0	1.7964E-03	0	9.0921E-03
24	0	0	0	1.0768E-04	0	1.1026E-02
25	0	0	0	0	0	1.6553E-02
26	0	0	0	0	0	2.4130E-02
27	0	0	0	0	0	4.1520E-02
28	0	0	0	0	0	4.4403E-02
29	0	0	0	0	0	6.1024E-02
30	0	0	0	0	0	6.3981E-02
31	0	0	0	0	0	2.6273E-02
32	0	0	0	0	0	4.5354E-02
33	0	0	0	0	0	1.1275E-01
34	0	0	0	0	0	1.6751E-01
35	0	0	0	0	0	2.0048E-01
36	0	0	0	0	0	2.0606E-01
37	0	0	0	0	0	6.7725E-02
38	0	0	0	0	0	1.0632E-01
39	0	0	0	0	0	2.2321E-01
40	0	0	0	0	0	4.3439E-01
41	0	0	0	0	0	8.5889E-01
42	0	0	0	0	0	1.5330E+00
43	0	0	0	0	0	2.3777E+00
44	0	0	0	0	0	3.7547E+00
45	0	0	0	0	0	5.4741E+00
46	0	0	0	0	0	9.0321E+00
47	0	0	0	0	0	2.6560E+01

Table 3.14 cont'd

Grp	Na-24 (n,γ)	Fe-58 (n,γ)	Co-59 (n,γ)	Cu-63 (n,γ)	In-115 (n,γ)	Au-197 (n,γ)
1	2.3070E-04	9.1567E-04	6.8770E-04	2.5623E-03	1.1155E-03	6.8982E-04
2	2.0005E-04	7.3968E-04	8.5053E-04	2.8175E-03	1.1891E-03	1.6116E-03
3	1.7988E-04	6.5168E-04	6.8172E-04	3.0696E-03	1.2659E-03	1.6731E-03
4	1.7403E-04	6.3263E-04	6.3552E-04	3.3421E-03	1.8208E-03	1.1750E-03
5	1.7014E-04	6.4504E-04	7.1898E-04	3.6106E-03	2.8639E-03	9.1819E-04
6	1.6691E-04	6.7390E-04	9.2215E-04	3.9385E-03	5.1798E-03	3.0070E-03
7	1.6343E-04	7.2704E-04	1.1725E-03	4.2639E-03	1.1665E-02	6.0744E-03
8	1.6076E-04	8.3040E-04	1.5502E-03	4.8109E-03	2.6232E-02	1.0718E-02
9	1.6781E-04	1.0115E-03	2.0452E-03	5.3953E-03	5.2041E-02	1.9549E-02
10	1.7459E-04	1.2784E-03	2.3427E-03	5.7193E-03	7.6962E-02	2.7051E-02
11	1.7922E-04	1.6654E-03	2.5345E-03	5.9647E-03	9.7501E-02	3.1768E-02
12	1.8259E-04	1.9218E-03	2.6931E-03	6.1262E-03	1.1492E-01	3.5664E-02
13	1.8379E-04	2.0081E-03	2.7590E-03	6.1801E-03	1.2038E-01	3.7626E-02
14	1.8519E-04	2.1048E-03	2.8329E-03	6.2406E-03	1.2621E-01	4.0078E-02
15	1.9004E-04	2.3984E-03	3.0750E-03	6.4744E-03	1.4765E-01	4.9414E-02
16	1.9765E-04	2.5584E-03	3.5505E-03	7.5680E-03	1.7647E-01	6.0164E-02
17	2.0684E-04	2.6095E-03	4.2985E-03	9.1289E-03	2.0634E-01	6.7846E-02
18	2.2063E-04	2.6680E-03	5.9988E-03	1.1900E-02	2.2849E-01	7.5082E-02
19	2.3988E-04	2.7737E-03	6.4521E-03	1.3725E-02	2.2849E-01	8.3994E-02
20	2.8913E-04	2.8823E-03	6.5376E-03	1.3879E-02	2.1788E-01	9.0859E-02
21	3.4120E-04	2.9711E-03	6.7224E-03	1.3950E-02	2.0476E-01	9.8884E-02
22	3.1318E-04	3.0732E-03	7.1180E-03	1.4474E-02	1.9281E-01	1.2062E-01
23	4.9395E-04	2.7341E-03	7.8534E-03	1.6377E-02	1.8393E-01	1.5151E-01
24	5.9582E-04	3.7273E-03	8.9120E-03	1.9019E-02	1.9209E-01	1.8524E-01
25	8.5059E-04	3.8525E-03	1.0952E-02	2.3569E-02	2.3042E-01	2.3561E-01
26	1.0398E-03	9.3131E-03	1.5506E-02	2.8106E-02	3.1100E-01	2.7524E-01
27	1.8591E-05	1.2589E-02	1.7452E-02	3.2226E-02	4.1669E-01	3.2856E-01
28	1.4633E-03	1.6917E-02	1.8170E-02	3.9129E-02	5.5833E-01	4.2178E-01
29	4.8595E-03	1.3672E-02	2.7343E-02	5.9252E-02	6.8908E-01	5.3222E-01
30	2.1801E-05	1.4391E-02	3.0530E-02	5.7142E-02	7.7226E-01	5.9594E-01
31	2.1729E-05	3.8969E-03	7.4013E-02	8.8300E-02	8.2002E-01	6.2972E-01
32	2.2866E-05	2.2993E-03	2.5812E-02	9.8415E-02	8.4271E-01	6.5357E-01
33	3.2827E-05	1.4997E-02	4.3350E-02	1.1565E-01	8.9870E-01	7.6550E-01
34	4.2580E-04	6.2677E-02	6.9895E-02	1.7697E-01	1.0695E+00	1.1601E+00
35	4.3323E-03	3.7572E-02	2.1806E-01	2.8514E-01	1.3063E+00	1.8692E+00
36	1.0226E-01	6.2123E-03	7.9458E-02	5.1503E-01	1.6452E+00	3.1238E+00
37	7.0401E-03	6.7240E-03	4.5000E-02	1.0560E+00	2.4899E+00	9.3400E+00
38	6.0157E-03	1.3475E+00	2.4559E-01	2.8621E-02	6.3837E+00	1.5854E+01
39	7.6425E-03	1.6327E-02	6.8796E+01	3.3434E-02	7.2317E+00	1.1622E+01
40	1.0955E-02	2.3040E-02	3.2785E+00	6.5824E-02	8.8408E+00	3.2960E+01
41	1.8351E-02	3.9539E-02	1.7355E+00	1.3611E-01	9.2816E+00	6.6678E-01
42	3.0776E-02	6.7097E-02	2.3647E+00	2.4869E-01	7.1728E+01	1.9950E+02
43	4.6918E-02	1.0243E-01	3.4231E+00	3.8882E-01	8.2452E+01	1.7419E+03
44	7.3364E-02	1.6040E-01	5.2409E+00	6.1624E-01	4.6433E+03	2.5042E+01
45	1.0657E-01	2.3303E-01	7.5609E+00	8.9960E-01	1.3505E+02	2.5533E+01
46	1.7562E-01	3.8345E-01	1.2401E+01	1.4854E+00	9.7434E+01	3.5695E+01
47	5.1603E-01	1.1251E+00	3.6358E+01	4.3703E+00	2.0867E+02	9.6877E+01

Table 3.14 cont'd

Grp	Th-232 (n,γ)	U-238 (n,γ)	Sqr-root E-mid	N flux Total	U-234 (n,f)	U-236 (n,f)
1	1.4711E-03	5.3381E-04	3.9701E+00	1.0000E+00	2.1363E+00	1.7831E+00
2	1.6025E-03	1.4080E-03	3.6335E+00	1.0000E+00	2.0083E+00	1.5576E+00
3	1.8642E-03	1.5809E-03	3.3327E+00	1.0000E+00	1.9630E+00	1.4867E+00
4	2.6395E-03	1.0527E-03	3.0502E+00	1.0000E+00	2.1259E+00	1.5594E+00
5	3.9834E-03	1.3611E-03	2.8298E+00	1.0000E+00	2.1237E+00	1.5170E+00
6	6.4657E-03	2.4189E-03	2.5955E+00	1.0000E+00	1.7644E+00	1.2776E+00
7	1.0451E-02	4.6746E-03	2.3485E+00	1.0000E+00	1.3307E+00	8.8677E-01
8	1.6721E-02	8.9088E-03	2.0790E+00	1.0000E+00	1.4087E+00	8.6255E-01
9	2.5906E-02	1.5632E-02	1.8290E+00	1.0000E+00	1.4985E+00	8.8156E-01
10	3.3183E-02	2.1387E-02	1.6937E+00	1.0000E+00	1.5197E+00	8.6630E-01
11	3.9772E-02	2.6327E-02	1.6111E+00	1.0000E+00	1.5359E+00	8.8603E-01
12	4.5724E-02	3.0714E-02	1.5542E+00	1.0000E+00	1.5159E+00	8.7609E-01
13	4.8360E-02	3.2635E-02	1.5348E+00	1.0000E+00	1.5188E+00	8.7113E-01
14	5.1316E-02	3.4790E-02	1.5128E+00	1.0000E+00	1.5306E+00	8.6616E-01
15	6.1054E-02	4.2993E-02	1.4408E+00	1.0000E+00	1.5483E+00	8.1253E-01
16	8.0735E-02	5.6288E-02	1.3367E+00	1.0000E+00	1.5533E+00	7.5492E-01
17	9.8678E-02	7.1126E-02	1.2261E+00	1.0000E+00	1.3866E+00	6.9303E-01
18	1.1984E-01	1.0332E-01	1.0854E+00	1.0000E+00	1.2338E+00	5.6177E-01
19	1.4631E-01	1.2356E-01	9.5484E-01	1.0000E+00	1.2293E+00	2.7796E-01
20	1.6073E-01	1.2002E-01	8.8419E-01	1.0000E+00	1.2729E+00	1.2361E-01
21	1.6466E-01	1.1688E-01	8.2184E-01	1.0000E+00	1.0312E+00	4.6719E-02
22	1.5789E-01	1.1021E-01	7.4363E-01	1.0000E+00	7.1936E-01	1.3408E-02
23	1.4506E-01	1.1104E-01	6.5829E-01	1.0000E+00	4.0382E-01	4.9630E-03
24	1.4402E-01	1.1404E-01	5.7708E-01	1.0000E+00	1.7843E-01	2.6411E-03
25	1.5519E-01	1.2069E-01	4.9009E-01	1.0000E+00	9.4149E-02	2.4220E-03
26	1.9093E-01	1.4577E-01	3.8357E-01	1.0000E+00	4.6307E-02	2.2758E-03
27	2.4693E-01	1.9617E-01	2.9872E-01	1.0000E+00	2.3625E-02	4.6449E-03
28	3.6550E-01	3.0660E-01	2.3265E-01	1.0000E+00	1.7090E-02	6.3696E-03
29	4.3004E-01	4.0574E-01	1.9065E-01	1.0000E+00	1.8465E-02	7.7069E-03
30	4.6127E-01	4.5034E-01	1.7013E-01	1.0000E+00	1.4649E-02	8.6163E-03
31	4.9104E-01	4.8046E-01	1.5848E-01	1.0000E+00	1.2794E-02	9.2138E-03
32	5.1166E-01	5.0036E-01	1.5174E-01	1.0000E+00	1.3076E-02	9.6306E-03
33	5.6866E-01	5.5622E-01	1.3585E-01	1.0000E+00	1.4194E-02	1.0705E-02
34	7.1318E-01	6.5641E-01	1.0520E-01	1.0000E+00	1.6265E-02	1.3460E-02
35	9.8950E-01	9.0722E-01	7.2306E-02	1.0000E+00	1.2172E-02	1.8299E-02
36	1.7641E+00	1.4524E+00	4.9695E-02	1.0000E+00	6.4100E-03	2.6387E-02
37	2.8651E+00	2.6019E+00	3.1927E-02	1.0000E+00	8.0287E-02	5.4766E-02
38	7.7534E+00	4.1837E+00	1.8282E-02	1.0000E+00	3.1568E-02	1.0906E-01
39	1.4214E+01	1.7907E+01	1.2565E-02	1.0000E+00	6.4810E-02	1.7891E-01
40	1.7431E+01	1.4532E+01	8.3236E-03	1.0000E+00	1.2787E-02	5.8900E-01
41	3.6855E+01	1.0186E+02	4.8961E-03	1.0000E+00	7.2656E-03	7.3626E-02
42	2.6913E-01	1.6854E+02	2.8036E-03	1.0000E+00	2.3900E-01	3.3532E+00
43	4.2428E-01	7.4634E-01	1.8573E-03	1.0000E+00	3.1591E-02	5.8630E-02
44	8.0707E-01	4.8598E-01	1.1687E-03	1.0000E+00	2.5390E-02	1.0576E-02
45	1.3155E+00	6.0912E-01	8.0325E-04	1.0000E+00	5.6768E-02	1.1566E-02
46	2.3457E+00	9.3643E-01	5.0695E-04	1.0000E+00	1.2756E-01	1.6726E-02
47	7.2285E+00	2.6611E+00	2.2362E-04	1.0000E+00	4.5017E-01	4.6180E-02

Table 3.14 cont'd

Grp	Pu-240 (n,f)	Pu-241 (n,f)	Pu-242 (n,f)	Rh-103 (n,n')	Silicon dspl kerma	U-238 χ
1	2.2815E+00	2.0603E+00	2.0296E+00	0	1.7344E+05	2.5568E-05
2	2.1344E+00	2.1270E+00	1.9071E+00	0	1.6731E+05	1.3895E-04
3	2.1609E+00	1.9857E+00	1.8646E+00	0	1.6249E+05	9.2397E-04
4	2.2159E+00	1.9749E+00	1.9025E+00	0	1.6207E+05	2.3012E-03
5	2.2112E+00	1.9257E+00	1.9413E+00	0	1.6748E+05	5.3971E-03
6	1.9505E+00	1.6897E+00	1.7055E+00	0	1.4984E+05	1.5970E-02
7	1.5387E+00	1.3549E+00	1.2780E+00	4.3283E-03	1.4845E+05	3.1340E-02
8	1.5634E+00	1.3593E+00	1.2483E+00	1.7584E-02	1.3904E+05	8.3571E-02
9	1.6622E+00	1.4678E+00	1.3236E+00	4.6854E-02	1.1339E+05	7.8777E-02
10	1.6997E+00	1.5338E+00	1.3706E+00	7.0324E-02	1.1449E+05	4.4513E-02
11	1.6943E+00	1.5636E+00	1.3958E+00	8.9127E-02	1.2594E+05	4.6779E-02
12	1.6995E+00	1.6007E+00	1.4098E+00	1.0254E-01	1.0160E+05	1.9959E-02
13	1.7089E+00	1.6171E+00	1.4137E+00	1.0726E-01	1.0711E+05	4.0056E-03
14	1.7223E+00	1.6339E+00	1.4177E+00	1.1272E-01	1.0253E+05	2.4181E-02
15	1.7421E+00	1.6703E+00	1.4274E+00	1.3093E-01	1.0992E+05	7.2808E-02
16	1.6785E+00	1.7137E+00	1.4248E+00	1.5239E-01	1.0911E+05	7.1180E-02
17	1.5919E+00	1.7179E+00	1.3992E+00	1.7411E-01	1.1614E+05	8.8822E-02
18	1.5513E+00	1.6078E+00	1.4744E+00	1.8893E-01	7.7796E+04	1.1438E-01
19	1.4110E+00	1.5435E+00	1.2242E+00	1.9972E-01	9.8770E+04	6.2108E-02
20	1.1379E+00	1.5251E+00	8.4627E-01	2.0256E-01	1.0260E+05	2.6880E-02
21	9.0043E-01	1.4900E+00	5.7579E-01	1.8343E-01	5.6951E+04	4.6032E-02
22	5.9099E-01	1.5016E+00	3.2958E-01	1.6137E-01	7.7366E+04	3.6806E-02
23	2.7018E-01	1.5513E+00	1.5223E-01	1.3692E-01	5.2779E+04	4.1012E-02
24	1.5493E-01	1.6583E+00	8.6297E-02	1.1553E-01	4.9906E+04	2.1221E-02
25	1.0764E-01	1.8201E+00	4.7899E-02	7.9194E-02	7.0893E+04	3.0246E-02
26	7.3462E-02	1.9989E+00	2.0971E-02	3.5464E-02	1.8165E+04	1.5802E-02
27	7.9696E-02	2.1701E+00	1.4350E-02	1.1422E-02	5.8684E+03	7.7209E-03
28	9.2867E-02	2.3309E+00	1.2428E-02	2.0690E-03	8.9068E+03	3.7220E-03
29	9.7825E-02	2.5058E+00	1.1888E-02	3.8639E-07	3.1172E+03	1.0529E-03
30	9.7560E-02	2.6975E+00	1.1668E-02	0	2.5502E+03	6.0240E-04
31	9.7050E-02	2.8117E+00	1.1553E-02	0	2.2858E+03	1.8351E-04
32	9.6430E-02	2.9086E+00	1.1490E-02	0	2.1499E+03	2.1506E-04
33	9.4366E-02	3.1356E+00	1.1352E-02	0	1.8075E+03	5.7311E-04
34	8.5520E-02	3.6408E+00	1.4205E-02	0	1.1483E+03	5.1466E-04
35	7.7704E-02	5.1444E+00	1.7569E-02	0	5.8705E+02	1.6766E-04
36	1.9789E-01	7.3033E+00	1.3134E-02	0	2.8353E+02	5.4512E-05
37	2.5020E-01	1.0762E+01	3.8552E-02	0	1.2074E+02	2.2199E-05
38	4.7740E-02	2.3305E+01	2.1200E-02	0	4.1562E+01	2.7146E-06
39	4.4803E-02	2.6230E+01	7.2759E-02	0	6.9815E+00	8.8031E-07
40	6.8179E-02	4.0447E+01	5.1272E-02	0	1.9451E+00	3.2884E-07
41	1.4532E-01	9.5972E+01	8.2924E-05	0	3.3620E+00	7.9696E-08
42	7.1568E-04	2.3536E+02	7.2308E-05	0	5.6956E+00	9.5563E-09
43	2.6864E-03	1.2366E+02	9.9111E-05	0	8.7047E+00	2.6717E-09
44	1.7088E+00	2.7696E+01	1.4864E-04	0	1.3654E+01	2.1631E-11
45	9.7596E-02	4.6301E+01	2.1317E-04	0	1.9892E+01	0
46	3.3352E-02	8.1545E+02	3.4837E-04	0	3.2798E+01	0
47	6.3706E-02	1.0225E+03	1.0197E-03	0	9.6064E+01	0

Table 3.14 cont'd

Grp	Pu-239 χ	N flux > 1.0 MeV	N flux > 0.1 MeV	N flux < 0.414 eV	Midpoint energy	Energy width
1	5.6208E-05	1.0000E+00	1.0000E+00	0	1.5762E+01	3.1410E+00
2	2.2677E-04	1.0000E+00	1.0000E+00	0	1.3203E+01	1.9770E+00
3	1.2921E-03	1.0000E+00	1.0000E+00	0	1.1107E+01	2.2140E+00
4	2.9394E-03	1.0000E+00	1.0000E+00	0	9.3035E+00	1.3929E+00
5	6.4700E-03	1.0000E+00	1.0000E+00	0	8.0077E+00	1.1989E+00
6	1.8109E-02	1.0000E+00	1.0000E+00	0	6.7368E+00	1.3429E+00
7	3.4016E-02	1.0000E+00	1.0000E+00	0	5.5156E+00	1.0994E+00
8	8.7792E-02	1.0000E+00	1.0000E+00	0	4.3224E+00	1.2871E+00
9	8.1231E-02	1.0000E+00	1.0000E+00	0	3.3454E+00	6.6690E-01
10	4.5561E-02	1.0000E+00	1.0000E+00	0	2.8686E+00	2.8660E-01
11	4.7656E-02	1.0000E+00	1.0000E+00	0	2.5956E+00	2.5930E-01
12	2.0272E-02	1.0000E+00	1.0000E+00	0	2.4156E+00	1.0070E-01
13	4.0474E-03	1.0000E+00	1.0000E+00	0	2.3555E+00	1.9600E-02
14	2.4523E-02	1.0000E+00	1.0000E+00	0	2.2885E+00	1.1440E-01
15	7.3440E-02	1.0000E+00	1.0000E+00	0	2.0759E+00	3.1080E-01
16	7.1233E-02	1.0000E+00	1.0000E+00	0	1.7867E+00	2.6750E-01
17	8.8012E-02	1.0000E+00	1.0000E+00	0	1.5032E+00	2.9960E-01
18	1.1158E-01	1.0000E+00	1.0000E+00	0	1.1780E+00	3.5080E-01
19	5.9861E-02	1.3000E-02	1.0000E+00	0	9.1172E-01	1.8175E-01
20	2.5776E-02	0	1.0000E+00	0	7.8180E-01	7.8110E-02
21	4.3929E-02	0	1.0000E+00	0	6.7542E-01	1.3464E-01
22	3.4950E-02	0	1.0000E+00	0	5.5299E-01	1.1023E-01
23	3.8841E-02	0	1.0000E+00	0	4.3335E-01	1.2904E-01
24	2.0200E-02	0	1.0000E+00	0	3.3302E-01	7.1620E-02
25	2.8665E-02	0	1.0000E+00	0	2.4018E-01	1.1405E-01
26	1.5048E-02	0	1.0000E+00	0	1.4713E-01	7.2070E-02
27	7.4971E-03	0	2.1034E-01	0	8.9235E-02	4.3711E-02
28	3.5511E-03	0	0	0	5.4123E-02	2.6511E-02
29	9.9694E-04	0	0	0	3.6348E-02	9.0400E-03
30	5.6378E-04	0	0	0	2.8943E-02	5.7700E-03
31	1.7409E-04	0	0	0	2.5117E-02	1.8820E-03
32	2.1284E-04	0	0	0	2.3025E-02	2.3010E-03
33	5.3012E-04	0	0	0	1.8454E-02	6.8410E-03
34	5.1937E-04	0	0	0	1.1068E-02	7.9323E-03
35	1.5779E-04	0	0	0	5.2282E-03	3.7471E-03
36	5.3309E-05	0	0	0	2.4696E-03	1.7700E-03
37	2.1981E-05	0	0	0	1.0193E-03	1.1306E-03
38	2.6501E-06	0	0	0	3.3423E-04	2.3955E-04
39	8.6276E-07	0	0	0	1.5787E-04	1.1315E-04
40	3.1417E-07	0	0	0	6.9283E-05	6.4034E-05
41	6.1447E-08	0	0	0	2.3971E-05	2.6589E-05
42	2.1765E-11	0	0	0	7.8602E-06	5.6335E-06
43	8.2907E-12	0	0	0	3.4495E-06	3.1881E-06
44	6.8575E-13	0	0	0	1.3659E-06	9.7897E-07
45	0	0	0	0	6.4521E-07	4.6244E-07
46	0	0	0	1.0000E+00	2.5700E-07	3.1399E-07
47	0	0	0	1.0000E+00	5.0005E-08	9.9990E-08

Table 3.14 cont'd

Grp	Lethargy width	Pu-238 (n,f)	U-234 ν	U-235 ν	U-236 ν	U-238 ν
1	1.9995E-01	2.6638E+00	4.4762E+00	4.6543E+00	4.3783E+00	4.7063E+00
2	1.5002E-01	2.6787E+00	4.1324E+00	4.2759E+00	4.0447E+00	4.3320E+00
3	2.0000E-01	2.7064E+00	3.8486E+00	3.9841E+00	3.7694E+00	4.0125E+00
4	1.5000E-01	2.7080E+00	3.6060E+00	3.7362E+00	3.5339E+00	3.7394E+00
5	1.5000E-01	2.6711E+00	3.4317E+00	3.5505E+00	3.3647E+00	3.5465E+00
6	2.0000E-01	2.5139E+00	3.2609E+00	3.3563E+00	3.1990E+00	3.3588E+00
7	1.9999E-01	2.2263E+00	3.0960E+00	3.1339E+00	3.0391E+00	3.1769E+00
8	3.0001E-01	2.2412E+00	2.9344E+00	2.9398E+00	2.8822E+00	2.9675E+00
9	2.0002E-01	2.2842E+00	2.8030E+00	2.8079E+00	2.7547E+00	2.7830E+00
10	9.9993E-02	2.2472E+00	2.7391E+00	2.7510E+00	2.6926E+00	2.6990E+00
11	9.9981E-02	2.2258E+00	2.7023E+00	2.7178E+00	2.6569E+00	2.6770E+00
12	4.1693E-02	2.2118E+00	2.6781E+00	2.6963E+00	2.6334E+00	2.6642E+00
13	8.3210E-03	2.2071E+00	2.6700E+00	2.6892E+00	2.6256E+00	2.6600E+00
14	4.9999E-02	2.2019E+00	2.6609E+00	2.6813E+00	2.6168E+00	2.6552E+00
15	1.5000E-01	2.1852E+00	2.6322E+00	2.6560E+00	2.5889E+00	2.6400E+00
16	1.4999E-01	2.1615E+00	2.5932E+00	2.6213E+00	2.5510E+00	2.6194E+00
17	1.9997E-01	2.1240E+00	2.5549E+00	2.5879E+00	2.5139E+00	2.5993E+00
18	3.0002E-01	2.0769E+00	2.5110E+00	2.5509E+00	2.4714E+00	2.5763E+00
19	2.0001E-01	2.0078E+00	2.4750E+00	2.5221E+00	2.4365E+00	2.5571E+00
20	9.9994E-02	1.9126E+00	2.4575E+00	2.5078E+00	2.4195E+00	2.5479E+00
21	2.0001E-01	1.7486E+00	2.4432E+00	2.4971E+00	2.4056E+00	2.5403E+00
22	2.0000E-01	1.5305E+00	2.4267E+00	2.4857E+00	2.3895E+00	2.5315E+00
23	3.0000E-01	1.2346E+00	2.4106E+00	2.4743E+00	2.3739E+00	2.5230E+00
24	2.1590E-01	1.0286E+00	2.3970E+00	2.4645E+00	2.3606E+00	2.5159E+00
25	4.8408E-01	8.5123E-01	2.3844E+00	2.4553E+00	2.3485E+00	2.5092E+00
26	5.0002E-01	7.1708E-01	2.3719E+00	2.4431E+00	2.3363E+00	2.5026E+00
27	5.0001E-01	6.2535E-01	2.3640E+00	2.4299E+00	2.3287E+00	2.4984E+00
28	4.9999E-01	6.2532E-01	2.3593E+00	2.4233E+00	2.3241E+00	2.4960E+00
29	2.5000E-01	6.7442E-01	2.3569E+00	2.4236E+00	2.3217E+00	2.4946E+00
30	2.0002E-01	6.9956E-01	2.3559E+00	2.4255E+00	2.3208E+00	2.4942E+00
31	7.4964E-02	7.2033E-01	2.3554E+00	2.4267E+00	2.3203E+00	2.4939E+00
32	1.0002E-01	7.3218E-01	2.3551E+00	2.4275E+00	2.3200E+00	2.4937E+00
33	3.7503E-01	6.5599E-01	2.3545E+00	2.4291E+00	2.3194E+00	2.4933E+00
34	7.4998E-01	8.5059E-01	2.3535E+00	2.4327E+00	2.3184E+00	2.4929E+00
35	7.5000E-01	1.4380E+00	2.3527E+00	2.4338E+00	2.3177E+00	2.4925E+00
36	7.5000E-01	1.6541E+00	2.3523E+00	2.4338E+00	2.3173E+00	2.4923E+00
37	1.2500E+00	2.3178E+00	2.3521E+00	2.4338E+00	2.3171E+00	2.4922E+00
38	7.5002E-01	3.3753E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
39	7.4999E-01	6.5745E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
40	1.0000E+00	1.7268E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
41	1.2500E+00	1.1965E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
42	7.4999E-01	2.6274E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
43	1.0000E+00	1.0651E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
44	7.5000E-01	2.0749E-01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
45	7.5002E-01	6.7838E-01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
46	1.4207E+00	2.7370E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
47	9.2103E+00	1.6171E+01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00

Table 3.14 cont'd

Grp	Pu-238 ν	Pu-239 ν	Pu-240 ν	Pu-241 ν	Pu-242 ν	U-234 χ
1	5.2231E+00	5.1730E+00	5.1923E+00	5.3119E+00	5.2892E+00	1.5159E-04
2	4.8457E+00	4.8321E+00	4.8051E+00	4.9186E+00	4.8875E+00	4.6489E-04
3	4.5344E+00	4.5426E+00	4.4856E+00	4.5938E+00	4.5560E+00	2.0914E-03
4	4.2682E+00	4.2850E+00	4.2124E+00	4.3160E+00	4.2724E+00	4.0422E-03
5	4.0768E+00	4.0819E+00	4.0160E+00	4.1164E+00	4.0687E+00	7.9523E-03
6	3.8894E+00	3.8857E+00	3.8239E+00	3.9216E+00	3.8693E+00	2.0119E-02
7	3.7097E+00	3.6875E+00	3.6394E+00	3.7361E+00	3.6777E+00	3.4986E-02
8	3.5333E+00	3.5013E+00	3.4585E+00	3.5540E+00	3.4898E+00	8.4943E-02
9	3.3895E+00	3.3594E+00	3.3108E+00	3.4016E+00	3.3365E+00	7.6300E-02
10	3.3194E+00	3.2979E+00	3.2389E+00	3.3263E+00	3.2619E+00	4.2488E-02
11	3.2790E+00	3.2576E+00	3.1974E+00	3.2829E+00	3.2189E+00	4.4430E-02
12	3.2525E+00	3.2319E+00	3.1701E+00	3.2544E+00	3.1907E+00	1.8922E-02
13	3.2436E+00	3.2238E+00	3.1610E+00	3.2449E+00	3.1812E+00	3.7965E-03
14	3.2337E+00	3.2151E+00	3.1508E+00	3.2342E+00	3.1706E+00	2.2916E-02
15	3.2022E+00	3.1867E+00	3.1185E+00	3.2003E+00	3.1371E+00	6.9064E-02
16	3.1594E+00	3.1443E+00	3.0745E+00	3.1544E+00	3.0915E+00	6.7814E-02
17	3.1174E+00	3.0975E+00	3.0315E+00	3.1093E+00	3.0469E+00	8.5334E-02
18	3.0693E+00	3.0441E+00	2.9820E+00	3.0576E+00	2.9956E+00	1.1157E-01
19	3.0299E+00	3.0049E+00	2.9416E+00	3.0152E+00	2.9537E+00	6.1607E-02
20	3.0107E+00	2.9867E+00	2.9218E+00	2.9945E+00	2.9333E+00	2.6932E-02
21	2.9949E+00	2.9717E+00	2.9057E+00	2.9776E+00	2.9165E+00	4.6550E-02
22	2.9768E+00	2.9546E+00	2.8871E+00	2.9581E+00	2.8972E+00	3.7658E-02
23	2.9591E+00	2.9400E+00	2.8690E+00	2.9457E+00	2.8784E+00	4.2494E-02
24	2.9443E+00	2.9290E+00	2.8536E+00	2.9453E+00	2.8625E+00	2.2243E-02
25	2.9305E+00	2.9192E+00	2.8395E+00	2.9453E+00	2.8479E+00	3.2067E-02
26	2.9168E+00	2.9088E+00	2.8254E+00	2.9453E+00	2.8332E+00	1.6963E-02
27	2.9082E+00	2.9029E+00	2.8165E+00	2.9453E+00	2.8241E+00	8.3563E-03
28	2.9030E+00	2.8992E+00	2.8112E+00	2.9453E+00	2.8185E+00	4.0490E-03
29	2.9004E+00	2.8976E+00	2.8085E+00	2.9453E+00	2.8157E+00	1.1485E-03
30	2.8993E+00	2.8969E+00	2.8074E+00	2.9453E+00	2.8146E+00	6.5783E-04
31	2.8987E+00	2.8965E+00	2.8068E+00	2.9453E+00	2.8140E+00	2.0051E-04
32	2.8984E+00	2.8963E+00	2.8065E+00	2.9453E+00	2.8136E+00	2.3506E-04
33	2.8977E+00	2.8958E+00	2.8058E+00	2.9453E+00	2.8129E+00	6.2681E-04
34	2.8966E+00	2.8951E+00	2.8047E+00	2.9453E+00	2.8117E+00	5.6349E-04
35	2.8958E+00	2.8948E+00	2.8038E+00	2.9453E+00	2.8108E+00	1.8373E-04
36	2.8954E+00	2.8945E+00	2.8034E+00	2.9453E+00	2.8104E+00	5.9785E-05
37	2.8951E+00	2.8903E+00	2.8031E+00	2.9453E+00	2.8102E+00	2.4392E-05
38	2.8950E+00	2.8651E+00	2.8030E+00	2.9453E+00	2.8100E+00	3.0037E-06
39	2.8950E+00	2.8718E+00	2.8030E+00	2.9453E+00	2.8100E+00	9.8697E-07
40	2.8950E+00	2.8668E+00	2.8030E+00	2.9453E+00	2.8100E+00	3.8048E-07
41	2.8950E+00	2.8632E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.0297E-07
42	2.8950E+00	2.8643E+00	2.8030E+00	2.9453E+00	2.8100E+00	9.1138E-09
43	2.8950E+00	2.8770E+00	2.8030E+00	2.9453E+00	2.8100E+00	5.0382E-09
44	2.8950E+00	2.8784E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.5297E-09
45	2.8950E+00	2.8700E+00	2.8030E+00	2.9453E+00	2.8100E+00	7.9147E-10
46	2.8950E+00	2.8615E+00	2.8030E+00	2.9453E+00	2.8100E+00	4.3746E-10
47	2.8950E+00	2.8768E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.8584E-10

Table 3.14 cont'd

Grp	U-236 χ	Pu-238 χ	Pu-240 χ	Pu-241 χ	Pu-242 χ
1	1.0898E-04	8.0233E-05	1.0673E-04	9.9677E-05	1.1131E-04
2	3.5098E-04	2.8002E-04	3.5394E-04	3.3529E-04	3.6640E-04
3	1.6611E-03	1.4154E-03	1.7054E-03	1.6360E-03	1.7532E-03
4	3.3451E-03	2.9768E-03	3.4603E-03	3.3494E-03	3.5386E-03
5	6.7995E-03	6.2305E-03	7.0470E-03	6.8657E-03	7.1773E-03
6	1.7797E-02	1.6736E-02	1.8416E-02	1.8057E-02	1.8681E-02
7	3.1944E-02	3.0672E-02	3.2916E-02	3.2452E-02	3.3263E-02
8	8.0131E-02	7.8339E-02	8.1967E-02	8.1247E-02	8.2519E-02
9	7.3775E-02	7.2970E-02	7.4920E-02	7.4551E-02	7.5211E-02
10	4.1592E-02	4.1353E-02	4.2059E-02	4.1931E-02	4.2163E-02
11	4.3812E-02	4.3685E-02	4.4185E-02	4.4099E-02	4.4256E-02
12	1.8748E-02	1.8727E-02	1.8873E-02	1.8850E-02	1.8893E-02
13	3.7676E-03	3.7654E-03	3.7902E-03	3.7865E-03	3.7936E-03
14	2.2782E-02	2.2785E-02	2.2903E-02	2.2886E-02	2.2918E-02
15	6.9061E-02	6.9211E-02	6.9262E-02	6.9270E-02	6.9262E-02
16	6.8334E-02	6.8659E-02	6.8309E-02	6.8393E-02	6.8248E-02
17	8.6641E-02	8.7260E-02	8.6317E-02	8.6519E-02	8.6166E-02
18	1.1426E-01	1.1537E-01	1.1337E-01	1.1378E-01	1.1306E-01
19	6.3535E-02	6.4276E-02	6.2828E-02	6.3116E-02	6.2606E-02
20	2.7870E-02	2.8221E-02	2.7513E-02	2.7653E-02	2.7405E-02
21	4.8306E-02	4.8948E-02	4.7619E-02	4.7880E-02	4.7416E-02
22	3.9204E-02	3.9757E-02	3.8583E-02	3.8811E-02	3.8404E-02
23	4.4378E-02	4.5037E-02	4.3602E-02	4.3879E-02	4.3384E-02
24	2.3290E-02	2.3651E-02	2.2851E-02	2.3005E-02	2.2730E-02
25	3.3658E-02	3.4196E-02	3.2980E-02	3.3213E-02	3.2796E-02
26	1.7848E-02	1.8144E-02	1.7465E-02	1.7594E-02	1.7363E-02
27	8.8057E-03	8.9545E-03	8.6096E-03	8.6750E-03	8.5576E-03
28	4.2707E-03	4.3438E-03	4.1735E-03	4.2057E-03	4.1478E-03
29	1.2120E-03	1.2328E-03	1.1841E-03	1.1933E-03	1.1768E-03
30	6.9430E-04	7.0627E-04	6.7824E-04	6.8355E-04	6.7402E-04
31	2.1165E-04	2.1530E-04	2.0674E-04	2.0836E-04	2.0545E-04
32	2.4813E-04	2.5242E-04	2.4237E-04	2.4427E-04	2.4086E-04
33	6.6174E-04	6.7317E-04	6.4634E-04	6.5142E-04	6.4229E-04
34	5.9501E-04	6.0531E-04	5.8109E-04	5.8567E-04	5.7744E-04
35	1.9404E-04	1.9741E-04	1.8948E-04	1.9098E-04	1.8829E-04
36	6.3142E-05	6.4238E-05	6.1657E-05	6.2145E-05	6.1269E-05
37	2.5761E-05	2.6208E-05	2.5155E-05	2.5354E-05	2.4997E-05
38	3.1715E-06	3.2263E-06	3.0973E-06	3.1218E-06	3.0779E-06
39	1.0416E-06	1.0595E-06	1.0175E-06	1.0254E-06	1.0111E-06
40	4.0087E-07	4.0781E-07	3.9198E-07	3.9498E-07	3.8960E-07
41	1.0808E-07	1.0989E-07	1.0590E-07	9.6708E-08	1.0517E-07
42	4.7007E-09	0	1.0349E-08	1.9397E-11	1.5776E-08
43	2.6106E-09	0	5.5918E-09	1.0701E-11	8.6067E-09
44	6.6295E-10	0	1.6994E-09	3.3430E-12	2.6035E-09
45	1.2831E-10	0	1.0556E-09	2.1628E-12	1.6126E-09
46	3.1175E-11	0	1.0958E-09	2.3672E-12	1.4742E-09
47	1.0398E-11	0	3.4341E-10	7.8650E-13	5.1255E-10

Table 3.15 Neutron response functions collapsed using 1/4T PV weighting

Grp	Upper Energy	U-235 χ	Li-6 He-4 prd	B-10 (n,α)	Th-232 (n,f)	U-235 (n,f)
1	1.7332E+01	5.0179E-05	4.7963E-01	4.3304E-02	4.1263E-01	2.0793E+00
2	1.4191E+01	2.0166E-04	5.2033E-01	4.2292E-02	3.2291E-01	1.9005E+00
3	1.2214E+01	1.1460E-03	5.6430E-01	4.5450E-02	3.1036E-01	1.7302E+00
4	1.0000E+01	2.5222E-03	6.3704E-01	5.8503E-02	3.2450E-01	1.7632E+00
5	8.6071E+00	5.6568E-03	7.0908E-01	8.1864E-02	3.6337E-01	1.7415E+00
6	7.4082E+00	1.6147E-02	7.7621E-01	1.1414E-01	2.8465E-01	1.3812E+00
7	6.0653E+00	3.0712E-02	8.0527E-01	1.2289E-01	1.4362E-01	1.0547E+00
8	4.9659E+00	8.0512E-02	7.6989E-01	2.6597E-01	1.4229E-01	1.1115E+00
9	3.6788E+00	7.6758E-02	5.9559E-01	3.0350E-01	1.3947E-01	1.1732E+00
10	3.0119E+00	4.4010E-02	3.9400E-01	3.7024E-01	1.2694E-01	1.2155E+00
11	2.7253E+00	4.6685E-02	2.8708E-01	3.1883E-01	1.2045E-01	1.2429E+00
12	2.4660E+00	2.0028E-02	2.5191E-01	2.8484E-01	1.1507E-01	1.2553E+00
13	2.3653E+00	4.0262E-03	2.4746E-01	2.9288E-01	1.1585E-01	1.2592E+00
14	2.3457E+00	2.4344E-02	2.4244E-01	3.0943E-01	1.2625E-01	1.2639E+00
15	2.2313E+00	7.3547E-02	2.3398E-01	4.1198E-01	1.2262E-01	1.2702E+00
16	1.9205E+00	7.1946E-02	2.1936E-01	5.0046E-01	9.0122E-02	1.2587E+00
17	1.6530E+00	8.9495E-02	2.1293E-01	3.0573E-01	7.9563E-02	1.2313E+00
18	1.3534E+00	1.1503E-01	2.2060E-01	2.1747E-01	7.4847E-03	1.1995E+00
19	1.0026E+00	6.2685E-02	2.3907E-01	2.5540E-01	6.8938E-04	1.1491E+00
20	8.2085E-01	2.7239E-02	2.5661E-01	3.2158E-01	1.2548E-04	1.1110E+00
21	7.4274E-01	4.6851E-02	2.8569E-01	4.4379E-01	3.0226E-05	1.1163E+00
22	6.0810E-01	3.7615E-02	3.3667E-01	6.6124E-01	6.1021E-06	1.1273E+00
23	4.9787E-01	4.1771E-02	5.0774E-01	8.4596E-01	0	1.1818E+00
24	3.6883E-01	2.1390E-02	1.0316E+00	9.5540E-01	0	1.2263E+00
25	2.9721E-01	3.0048E-02	2.4743E+00	1.2692E+00	0	1.3005E+00
26	1.8316E-01	1.5408E-02	9.2442E-01	1.6988E+00	0	1.4392E+00
27	1.1109E-01	7.4251E-03	6.5419E-01	2.1377E+00	0	1.6230E+00
28	6.7379E-02	3.5461E-03	7.1681E-01	2.6075E+00	0	1.8074E+00
29	4.0868E-02	9.9806E-04	8.2512E-01	3.1168E+00	0	1.9647E+00
30	3.1828E-02	5.6977E-04	9.2476E-01	3.5436E+00	0	2.1159E+00
31	2.6058E-02	1.7337E-04	9.6822E-01	3.7275E+00	0	2.1833E+00
32	2.4176E-02	2.0305E-04	1.0055E+00	3.8859E+00	0	2.2787E+00
33	2.1875E-02	5.4037E-04	1.1194E+00	4.3576E+00	0	2.3874E+00
34	1.5034E-02	4.8419E-04	1.4356E+00	5.6653E+00	0	2.8722E+00
35	7.1017E-03	1.5746E-04	2.1471E+00	8.5862E+00	0	4.0917E+00
36	3.3546E-03	5.1156E-05	3.1235E+00	1.2574E+01	0	5.6289E+00
37	1.5846E-03	2.0827E-05	5.1337E+00	2.0786E+01	0	9.7895E+00
38	4.5400E-04	2.5484E-06	8.6613E+00	3.5175E+01	0	1.7137E+01
39	2.1445E-04	8.2729E-07	1.2394E+01	5.0427E+01	0	2.0795E+01
40	1.0130E-04	3.0899E-07	1.9260E+01	7.8415E+01	0	3.3782E+01
41	3.7266E-05	5.9997E-08	3.3837E+01	1.3784E+02	0	4.9377E+01
42	1.0677E-05	5.4050E-12	5.5363E+01	2.2573E+02	0	5.0104E+01
43	5.0435E-06	0	8.5475E+01	3.4851E+02	0	1.6088E+01
44	1.8554E-06	0	1.3211E+02	5.3872E+02	0	4.1541E+01
45	8.7643E-07	0	1.9350E+02	7.8921E+02	0	7.1080E+01
46	4.1399E-07	0	3.3917E+02	1.3835E+03	0	1.8975E+02
47	1.0000E-07	0	6.5472E+02	2.6707E+03	0	3.8385E+02

Table 3.15 cont'd

Grp	U-238 (n,f)	Np-237 (n,f)	Pu-239 (n,f)	Al-27 (n,p)	Al-27 (n,α)	S-32 (n,p)
1	1.2030E+00	2.2008E+00	2.3765E+00	6.2573E-02	1.0490E-01	1.9969E-01
2	1.0345E+00	2.0821E+00	2.3068E+00	7.9970E-02	1.2276E-01	3.2156E-01
3	9.8468E-01	2.1055E+00	2.2293E+00	8.8438E-02	1.0298E-01	3.8190E-01
4	9.9501E-01	2.1753E+00	2.2746E+00	8.3652E-02	7.4884E-02	3.4015E-01
5	9.9114E-01	2.2387E+00	2.2572E+00	7.1603E-02	3.9600E-02	3.1792E-01
6	8.3063E-01	1.9568E+00	1.9941E+00	5.3171E-02	9.8424E-03	3.0655E-01
7	5.5979E-01	1.4918E+00	1.6976E+00	3.6185E-02	4.3048E-04	2.4861E-01
8	5.4637E-01	1.5311E+00	1.7483E+00	1.1581E-02	1.4240E-06	2.7668E-01
9	5.2528E-01	1.6098E+00	1.8170E+00	4.2962E-03	0	1.8625E-01
10	5.2327E-01	1.6507E+00	1.8563E+00	6.1154E-04	0	9.9629E-02
11	5.3272E-01	1.6634E+00	1.8914E+00	1.1766E-04	0	6.8769E-02
12	5.3690E-01	1.6606E+00	1.9187E+00	1.2562E-05	0	7.2381E-02
13	5.3770E-01	1.6697E+00	1.9292E+00	8.2121E-06	0	6.6468E-02
14	5.3831E-01	1.6826E+00	1.9451E+00	3.2145E-06	0	6.1091E-02
15	5.3011E-01	1.6822E+00	1.9614E+00	1.4984E-07	0	2.1233E-02
16	4.7447E-01	1.6462E+00	1.9358E+00	6.8493E-10	0	3.8002E-03
17	3.1627E-01	1.5854E+00	1.9111E+00	0	0	5.7213E-04
18	4.0979E-02	1.4719E+00	1.7939E+00	0	0	5.5013E-05
19	1.2280E-02	1.3383E+00	1.6980E+00	0	0	1.4370E-07
20	3.7513E-03	1.1930E+00	1.6640E+00	0	0	0
21	1.4174E-03	9.2466E-01	1.6254E+00	0	0	0
22	6.2319E-04	6.1302E-01	1.5857E+00	0	0	0
23	2.7669E-04	2.5960E-01	1.5581E+00	0	0	0
24	1.5361E-04	9.2568E-02	1.5462E+00	0	0	0
25	7.8551E-05	4.5624E-02	1.5098E+00	0	0	0
26	1.0790E-04	2.3415E-02	1.5009E+00	0	0	0
27	3.6617E-05	1.4606E-02	1.5333E+00	0	0	0
28	9.1652E-05	1.1885E-02	1.5305E+00	0	0	0
29	2.9046E-05	1.0686E-02	1.5803E+00	0	0	0
30	5.0866E-05	1.0129E-02	1.6106E+00	0	0	0
31	2.4468E-05	9.9113E-03	1.5930E+00	0	0	0
32	2.5441E-05	9.7705E-03	1.5729E+00	0	0	0
33	1.4497E-04	9.5449E-03	1.7021E+00	0	0	0
34	5.2671E-04	9.1381E-03	1.8880E+00	0	0	0
35	1.2822E-05	8.8064E-03	2.3236E+00	0	0	0
36	5.9145E-09	9.3350E-03	3.6339E+00	0	0	0
37	1.0459E-03	1.3684E-02	7.1712E+00	0	0	0
38	1.1502E-05	2.6078E-02	1.2940E+01	0	0	0
39	1.7070E-05	3.0845E-02	1.9213E+01	0	0	0
40	2.8886E-05	6.2512E-02	4.7642E+01	0	0	0
41	1.4284E-04	2.4718E-02	7.0557E+01	0	0	0
42	7.5663E-05	8.1492E-03	3.7043E+01	0	0	0
43	1.7359E-06	3.8741E-03	1.0280E+01	0	0	0
44	1.8881E-06	9.8116E-03	2.6609E+01	0	0	0
45	2.5594E-06	1.0235E-02	1.4963E+02	0	0	0
46	4.3150E-06	5.5072E-03	1.2060E+03	0	0	0
47	8.2184E-06	1.1981E-02	5.6228E+02	0	0	0

Table 3.15 cont'd

Grp	Ti-46 (n,p)	Ti-47 (n,p)	T-47 (n,n'p)	Ti-48 (n,p)	Ti-48 (n,n'p)	Mn-55 (n,2n)
1	2.3995E-01	1.0628E-01	9.5268E-02	6.0033E-02	1.7129E-02	7.9549E-01
2	2.6649E-01	1.2894E-01	1.8970E-02	6.0176E-02	3.1087E-03	5.4918E-01
3	2.6092E-01	1.3818E-01	1.1391E-03	3.9626E-02	7.1408E-05	8.3715E-02
4	2.3599E-01	1.3057E-01	0	2.2626E-02	0	0
5	2.0458E-01	1.1750E-01	0	1.2786E-02	0	0
6	1.5493E-01	1.0466E-01	0	4.7766E-03	0	0
7	9.7555E-02	8.9539E-02	0	6.2458E-04	0	0
8	4.0019E-02	7.3311E-02	0	1.6195E-05	0	0
9	5.2546E-03	5.1029E-02	0	1.0858E-08	0	0
10	4.6436E-04	3.5028E-02	0	0	0	0
11	6.8561E-06	3.0686E-02	0	0	0	0
12	1.0704E-06	3.1236E-02	0	0	0	0
13	3.7716E-07	3.0536E-02	0	0	0	0
14	3.4221E-07	2.5869E-02	0	0	0	0
15	2.3325E-07	1.8011E-02	0	0	0	0
16	7.9544E-08	9.4769E-03	0	0	0	0
17	8.3607E-10	3.9493E-03	0	0	0	0
18	0	1.7975E-03	0	0	0	0
19	0	1.7179E-07	0	0	0	0
20	0	2.5278E-09	0	0	0	0
21	0	1.4882E-09	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0

Table 3.15 cont'd

Grp	Fe-54 (n,p)	Fe-56 (n,p)	Co-59 (n,2n)	Co-59 (n,α)	Ni-58 (n,p)	Ni-58 (n,2n)
1	2.6161E-01	9.8795E-02	7.6839E-01	2.7669E-02	2.6005E-01	4.5404E-02
2	4.0412E-01	1.1344E-01	5.0631E-01	2.7497E-02	4.7045E-01	7.1034E-03
3	4.6969E-01	8.0985E-02	5.5171E-02	1.8838E-02	5.9230E-01	0
4	4.8225E-01	5.6807E-02	0	1.2748E-02	6.2312E-01	0
5	4.8234E-01	4.0851E-02	0	7.4824E-03	6.2541E-01	0
6	4.7815E-01	2.3050E-02	0	2.4431E-03	6.0484E-01	0
7	4.3395E-01	5.3423E-03	0	4.2660E-04	5.0885E-01	0
8	3.1282E-01	1.7492E-04	0	1.3715E-05	3.8149E-01	0
9	1.9322E-01	1.2560E-07	0	0	2.4454E-01	0
10	1.3264E-01	6.5572E-10	0	0	1.7101E-01	0
11	7.8693E-02	0	0	0	1.2494E-01	0
12	5.6558E-02	0	0	0	9.6566E-02	0
13	5.1201E-02	0	0	0	8.8545E-02	0
14	4.4937E-02	0	0	0	7.9112E-02	0
15	2.9322E-02	0	0	0	5.0612E-02	0
16	8.8809E-03	0	0	0	2.7833E-02	0
17	2.9013E-03	0	0	0	1.4619E-02	0
18	7.3438E-04	0	0	0	5.6316E-03	0
19	8.6749E-05	0	0	0	1.2936E-03	0
20	6.5240E-06	0	0	0	8.9192E-04	0
21	2.6735E-07	0	0	0	5.2509E-04	0
22	0	0	0	0	1.7505E-04	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0

Table 3.15 cont'd

Grp	Ni-60 (n,p)	Cu-63 (n,α)	Cu-65 (n,2n)	In-115 (n,n')	I-127 (n,2n)	Sc-45 (n,γ)
1	1.2079E-01	3.5414E-02	9.9088E-01	6.0775E-02	1.4904E+00	1.8647E-04
2	1.4392E-01	4.3376E-02	7.1928E-01	9.4242E-02	1.3091E+00	2.7480E-04
3	1.1530E-01	3.6377E-02	1.3852E-01	2.0363E-01	6.8610E-01	3.6019E-04
4	8.7169E-02	2.6793E-02	0	2.7085E-01	3.7525E-02	4.2423E-04
5	6.4115E-02	1.8050E-02	0	2.9518E-01	0	4.7437E-04
6	3.6653E-02	9.8682E-03	0	3.2385E-01	0	5.2590E-04
7	1.5024E-02	3.2531E-03	0	3.3120E-01	0	5.7136E-04
8	2.1857E-03	5.7499E-04	0	3.1565E-01	0	7.6261E-04
9	2.6605E-05	4.4528E-05	0	3.3133E-01	0	1.1118E-03
10	7.5317E-08	8.1371E-06	0	3.3553E-01	0	1.3425E-03
11	4.2871E-08	2.9891E-06	0	3.3299E-01	0	1.5084E-03
12	2.7871E-08	9.3951E-07	0	3.2342E-01	0	1.6305E-03
13	2.3077E-08	8.1765E-07	0	3.1936E-01	0	1.6702E-03
14	1.7439E-08	6.7433E-07	0	3.1200E-01	0	1.7179E-03
15	2.8724E-09	2.4661E-07	0	2.7317E-01	0	2.0534E-03
16	0	1.3777E-08	0	2.0943E-01	0	2.6590E-03
17	0	0	0	1.6695E-01	0	3.2249E-03
18	0	0	0	9.1255E-02	0	4.7217E-03
19	0	0	0	4.8357E-02	0	5.5782E-03
20	0	0	0	2.5038E-02	0	6.0335E-03
21	0	0	0	1.2610E-02	0	6.7752E-03
22	0	0	0	3.8445E-03	0	7.7021E-03
23	0	0	0	1.7160E-03	0	9.1569E-03
24	0	0	0	9.8680E-05	0	1.1074E-02
25	0	0	0	0	0	1.6641E-02
26	0	0	0	0	0	2.4224E-02
27	0	0	0	0	0	4.0092E-02
28	0	0	0	0	0	4.4335E-02
29	0	0	0	0	0	6.1241E-02
30	0	0	0	0	0	6.6394E-02
31	0	0	0	0	0	2.6464E-02
32	0	0	0	0	0	5.1904E-02
33	0	0	0	0	0	1.1192E-01
34	0	0	0	0	0	1.6540E-01
35	0	0	0	0	0	2.2394E-01
36	0	0	0	0	0	1.9068E-01
37	0	0	0	0	0	7.9567E-02
38	0	0	0	0	0	1.1496E-01
39	0	0	0	0	0	2.3184E-01
40	0	0	0	0	0	4.5753E-01
41	0	0	0	0	0	9.1400E-01
42	0	0	0	0	0	1.5591E+00
43	0	0	0	0	0	2.4415E+00
44	0	0	0	0	0	3.7992E+00
45	0	0	0	0	0	5.5780E+00
46	0	0	0	0	0	9.7899E+00
47	0	0	0	0	0	1.8905E+01

Table 3.15 cont'd

Grp	Na-24 (n,γ)	Fe-58 (n,γ)	Co-59 (n,γ)	Cu-63 (n,γ)	In-115 (n,γ)	Au-197 (n,γ)
1	2.2780E-04	8.8452E-04	7.6760E-04	2.5967E-03	1.1764E-03	8.4765E-04
2	1.9769E-04	7.2902E-04	8.3882E-04	2.8383E-03	1.1811E-03	1.6664E-03
3	1.7883E-04	6.4592E-04	6.6332E-04	3.0989E-03	1.3019E-03	1.6206E-03
4	1.7381E-04	6.3253E-04	6.3928E-04	3.3571E-03	1.8651E-03	1.1514E-03
5	1.6998E-04	6.4590E-04	7.2544E-04	3.6240E-03	2.9262E-03	9.2362E-04
6	1.6664E-04	6.7785E-04	9.3983E-04	3.9654E-03	5.4862E-03	3.2508E-03
7	1.6332E-04	7.2857E-04	1.1809E-03	4.2730E-03	1.1955E-02	6.1630E-03
8	1.6076E-04	8.3222E-04	1.5558E-03	4.8199E-03	2.6466E-02	1.0797E-02
9	1.6825E-04	1.0191E-03	2.0650E-03	5.4150E-03	5.3519E-02	2.0036E-02
10	1.7466E-04	1.2847E-03	2.3459E-03	5.7234E-03	7.7247E-02	2.7127E-02
11	1.7922E-04	1.6653E-03	2.5345E-03	5.9647E-03	9.7497E-02	3.1767E-02
12	1.8263E-04	1.9246E-03	2.6952E-03	6.1279E-03	1.1511E-01	3.5724E-02
13	1.8379E-04	2.0081E-03	2.7590E-03	6.1801E-03	1.2038E-01	3.7626E-02
14	1.8522E-04	2.1063E-03	2.8340E-03	6.2415E-03	1.2630E-01	4.0115E-02
15	1.9006E-04	2.3992E-03	3.0759E-03	6.4755E-03	1.4773E-01	4.9445E-02
16	1.9798E-04	2.5605E-03	3.5721E-03	7.6256E-03	1.7765E-01	6.0544E-02
17	2.0709E-04	2.6107E-03	4.3255E-03	9.1770E-03	2.0701E-01	6.7959E-02
18	2.2118E-04	2.6701E-03	6.0633E-03	1.2004E-02	2.2871E-01	7.5400E-02
19	2.4052E-04	2.7774E-03	6.4531E-03	1.3735E-02	2.2834E-01	8.4188E-02
20	2.8979E-04	2.8829E-03	6.5386E-03	1.3879E-02	2.1778E-01	9.0905E-02
21	3.4349E-04	2.9793E-03	6.7456E-03	1.3956E-02	2.0376E-01	9.9826E-02
22	3.1500E-04	3.0714E-03	7.1082E-03	1.4452E-02	1.9304E-01	1.2011E-01
23	4.7207E-04	2.5704E-03	7.8925E-03	1.6482E-02	1.8416E-01	1.5276E-01
24	6.7499E-04	3.7513E-03	8.9361E-03	1.9068E-02	1.9240E-01	1.8594E-01
25	9.6344E-04	3.9281E-03	1.0985E-02	2.3634E-02	2.3081E-01	2.3639E-01
26	8.8136E-04	8.3676E-03	1.5588E-02	2.8126E-02	3.1209E-01	2.7570E-01
27	2.1005E-05	1.1688E-02	1.6484E-02	3.1992E-02	4.2859E-01	3.3597E-01
28	1.2692E-03	1.6521E-02	1.8361E-02	3.9214E-02	5.5954E-01	4.2258E-01
29	5.0278E-03	1.4026E-02	2.6823E-02	5.9238E-02	6.8791E-01	5.3125E-01
30	2.1495E-05	2.3575E-02	1.9079E-02	6.6841E-02	7.8493E-01	6.0518E-01
31	2.1730E-05	3.8909E-03	7.3953E-02	8.8066E-02	8.2005E-01	6.2974E-01
32	2.2830E-05	2.3009E-03	2.4979E-02	9.9647E-02	8.4224E-01	6.5276E-01
33	3.2405E-05	1.5402E-02	4.2320E-02	1.1701E-01	8.9657E-01	7.6081E-01
34	3.4576E-04	6.4938E-02	6.9534E-02	1.6607E-01	1.0617E+00	1.1359E+00
35	5.4134E-03	3.0468E-02	2.2509E-01	2.7849E-01	1.3207E+00	1.9042E+00
36	8.9861E-02	6.1198E-03	7.1167E-02	5.0290E-01	1.6739E+00	3.3284E+00
37	6.7412E-03	7.0740E-03	4.6695E-02	1.6247E+00	2.5923E+00	1.0047E+01
38	6.1315E-03	9.5115E-01	3.0590E-01	2.5636E-02	6.8658E+00	1.5778E+01
39	7.7703E-03	1.6447E-02	7.5687E+01	3.4651E-02	6.6567E+00	1.1854E+01
40	1.1334E-02	2.3906E-02	2.9283E+00	6.9568E-02	9.4425E+00	3.7457E+01
41	1.9345E-02	4.1751E-02	1.7686E+00	1.4532E-01	8.7672E+00	8.5093E-01
42	3.1273E-02	6.8186E-02	2.3957E+00	2.5305E-01	6.0661E+01	2.4411E+02
43	4.8144E-02	1.0511E-01	3.5060E+00	3.9940E-01	8.5999E+01	1.4055E+03
44	7.4226E-02	1.6228E-01	5.3008E+00	6.2361E-01	4.3378E+03	2.4922E+01
45	1.0859E-01	2.3742E-01	7.7021E+00	9.1676E-01	1.3022E+02	2.5758E+01
46	1.9031E-01	4.1544E-01	1.3434E+01	1.6102E+00	9.9532E+01	3.8143E+01
47	3.6731E-01	8.0050E-01	2.5886E+01	3.1103E+00	1.5289E+02	6.9515E+01

Table 3.15 cont'd

Grp	Th-232 (n,γ)	U-238 (n,γ)	Sqr-root E-mid	N flux Total	U-234 (n,f)	U-236 (n,f)
1	1.4790E-03	6.4392E-04	3.9701E+00	1.0000E+00	2.1243E+00	1.7614E+00
2	1.6238E-03	1.4941E-03	3.6335E+00	1.0000E+00	1.9976E+00	1.5447E+00
3	1.8947E-03	1.4748E-03	3.3327E+00	1.0000E+00	1.9862E+00	1.4851E+00
4	2.7070E-03	1.0507E-03	3.0502E+00	1.0000E+00	2.1284E+00	1.5634E+00
5	4.0695E-03	1.3898E-03	2.8298E+00	1.0000E+00	2.1207E+00	1.5136E+00
6	6.6778E-03	2.5462E-03	2.5955E+00	1.0000E+00	1.7112E+00	1.2401E+00
7	1.0620E-02	4.7626E-03	2.3485E+00	1.0000E+00	1.3284E+00	8.8201E-01
8	1.6806E-02	8.9747E-03	2.0790E+00	1.0000E+00	1.4104E+00	8.6300E-01
9	2.6300E-02	1.5954E-02	1.8290E+00	1.0000E+00	1.5008E+00	8.8032E-01
10	3.3291E-02	2.1468E-02	1.6937E+00	1.0000E+00	1.5196E+00	8.6631E-01
11	3.9771E-02	2.6326E-02	1.6111E+00	1.0000E+00	1.5359E+00	8.8603E-01
12	4.5810E-02	3.0776E-02	1.5542E+00	1.0000E+00	1.5159E+00	8.7592E-01
13	4.8360E-02	3.2635E-02	1.5348E+00	1.0000E+00	1.5188E+00	8.7113E-01
14	5.1360E-02	3.4822E-02	1.5128E+00	1.0000E+00	1.5307E+00	8.6609E-01
15	6.1088E-02	4.3022E-02	1.4408E+00	1.0000E+00	1.5483E+00	8.1232E-01
16	8.1592E-02	5.6798E-02	1.3367E+00	1.0000E+00	1.5500E+00	7.5144E-01
17	9.9072E-02	7.1608E-02	1.2261E+00	1.0000E+00	1.3821E+00	6.9390E-01
18	1.2076E-01	1.0482E-01	1.0854E+00	1.0000E+00	1.2288E+00	5.5251E-01
19	1.4687E-01	1.2345E-01	9.5484E-01	1.0000E+00	1.2342E+00	2.7293E-01
20	1.6077E-01	1.2000E-01	8.8419E-01	1.0000E+00	1.2716E+00	1.2292E-01
21	1.6477E-01	1.1633E-01	8.2184E-01	1.0000E+00	1.0033E+00	4.2210E-02
22	1.5822E-01	1.1025E-01	7.4363E-01	1.0000E+00	7.2377E-01	1.3613E-02
23	1.4499E-01	1.1117E-01	6.5829E-01	1.0000E+00	3.9427E-01	4.8559E-03
24	1.4407E-01	1.1408E-01	5.7708E-01	1.0000E+00	1.7573E-01	2.6372E-03
25	1.5540E-01	1.2078E-01	4.9009E-01	1.0000E+00	9.3501E-02	2.4193E-03
26	1.9138E-01	1.4611E-01	3.8357E-01	1.0000E+00	4.6117E-02	2.2765E-03
27	2.5519E-01	2.0335E-01	2.9872E-01	1.0000E+00	2.2565E-02	4.8303E-03
28	3.6677E-01	3.0785E-01	2.3265E-01	1.0000E+00	1.7139E-02	6.3810E-03
29	4.2970E-01	4.0514E-01	1.9065E-01	1.0000E+00	1.8523E-02	7.6946E-03
30	4.6875E-01	4.5814E-01	1.7013E-01	1.0000E+00	1.4103E-02	8.7761E-03
31	4.9106E-01	4.8049E-01	1.5848E-01	1.0000E+00	1.2794E-02	9.2142E-03
32	5.1104E-01	4.9979E-01	1.5174E-01	1.0000E+00	1.3062E-02	9.6188E-03
33	5.6682E-01	5.5439E-01	1.3585E-01	1.0000E+00	1.4161E-02	1.0669E-02
34	7.0555E-01	6.5620E-01	1.0520E-01	1.0000E+00	1.6210E-02	1.3323E-02
35	1.0024E+00	9.1636E-01	7.2306E-02	1.0000E+00	1.1799E-02	1.8628E-02
36	1.8266E+00	1.4946E+00	4.9695E-02	1.0000E+00	6.8199E-03	2.7069E-02
37	3.1005E+00	2.7798E+00	3.1927E-02	1.0000E+00	1.1589E-01	6.0000E-02
38	8.9247E+00	4.8413E+00	1.8282E-02	1.0000E+00	2.8272E-02	1.0106E-01
39	1.4875E+01	1.9972E+01	1.2565E-02	1.0000E+00	7.1025E-02	1.7177E-01
40	1.6910E+01	1.3292E+01	8.3236E-03	1.0000E+00	1.0092E-02	7.0006E-01
41	3.4172E+01	8.8834E+01	4.8961E-03	1.0000E+00	5.0782E-03	5.0277E-02
42	2.7011E-01	1.7288E+02	2.8036E-03	1.0000E+00	2.9539E-01	4.1479E+00
43	4.4074E-01	6.9953E-01	1.8573E-03	1.0000E+00	2.7662E-02	5.0252E-02
44	8.2018E-01	4.8826E-01	1.1687E-03	1.0000E+00	2.6115E-02	1.0558E-02
45	1.3462E+00	6.1803E-01	8.0325E-04	1.0000E+00	5.8819E-02	1.1691E-02
46	2.5617E+00	1.0088E+00	5.0695E-04	1.0000E+00	1.4247E-01	1.7926E-02
47	5.1114E+00	1.9007E+00	2.2362E-04	1.0000E+00	3.1384E-01	3.3079E-02

Table 3.15 cont'd

Grp	Pu-240 (n,f)	Pu-241 (n,f)	Pu-242 (n,f)	Rh-103 (n,n')	Silicon dspl kerma	U-238 χ
1	2.2869E+00	2.0882E+00	2.0216E+00	0	1.7146E+05	2.5568E-05
2	2.1259E+00	2.1069E+00	1.8931E+00	0	1.6748E+05	1.3895E-04
3	2.1703E+00	1.9866E+00	1.8684E+00	0	1.6183E+05	9.2397E-04
4	2.2169E+00	1.9734E+00	1.9047E+00	0	1.6216E+05	2.3012E-03
5	2.2078E+00	1.9228E+00	1.9415E+00	0	1.6794E+05	5.3971E-03
6	1.9140E+00	1.6484E+00	1.6679E+00	0	1.4848E+05	1.5970E-02
7	1.5338E+00	1.3506E+00	1.2709E+00	4.5084E-03	1.4741E+05	3.1340E-02
8	1.5648E+00	1.3604E+00	1.2491E+00	1.7834E-02	1.3828E+05	8.3571E-02
9	1.6655E+00	1.4723E+00	1.3270E+00	4.8251E-02	1.1529E+05	7.8777E-02
10	1.6998E+00	1.5344E+00	1.3710E+00	7.0618E-02	1.1518E+05	4.4513E-02
11	1.6943E+00	1.5636E+00	1.3958E+00	8.9124E-02	1.2594E+05	4.6779E-02
12	1.6997E+00	1.6012E+00	1.4099E+00	1.0270E-01	1.0218E+05	1.9959E-02
13	1.7089E+00	1.6171E+00	1.4137E+00	1.0726E-01	1.0711E+05	4.0056E-03
14	1.7225E+00	1.6342E+00	1.4178E+00	1.1281E-01	1.0266E+05	2.4181E-02
15	1.7421E+00	1.6704E+00	1.4275E+00	1.3098E-01	1.1001E+05	7.2808E-02
16	1.6745E+00	1.7151E+00	1.4242E+00	1.5320E-01	1.0670E+05	7.1180E-02
17	1.5901E+00	1.7171E+00	1.3988E+00	1.7466E-01	1.1399E+05	8.8822E-02
18	1.5513E+00	1.6031E+00	1.4801E+00	1.8903E-01	7.6490E+04	1.1438E-01
19	1.4045E+00	1.5429E+00	1.2134E+00	2.0017E-01	9.8719E+04	6.2108E-02
20	1.1361E+00	1.5250E+00	8.4401E-01	2.0251E-01	1.0147E+05	2.6880E-02
21	8.8037E-01	1.4886E+00	5.5391E-01	1.8025E-01	5.6072E+04	4.6032E-02
22	5.9801E-01	1.5008E+00	3.3375E-01	1.6167E-01	7.7138E+04	3.6806E-02
23	2.6574E-01	1.5553E+00	1.4970E-01	1.3651E-01	5.2612E+04	4.1012E-02
24	1.5384E-01	1.6609E+00	8.5572E-02	1.1515E-01	4.9920E+04	2.1221E-02
25	1.0712E-01	1.8218E+00	4.7447E-02	7.8643E-02	7.1116E+04	3.0246E-02
26	7.3759E-02	2.0001E+00	2.0957E-02	3.5324E-02	2.0548E+04	1.5802E-02
27	8.1279E-02	2.1845E+00	1.4084E-02	1.0335E-02	6.0896E+03	7.7209E-03
28	9.2942E-02	2.3323E+00	1.2421E-02	2.0034E-03	8.1329E+03	3.7220E-03
29	9.7818E-02	2.5033E+00	1.1891E-02	3.9986E-07	3.1274E+03	1.0529E-03
30	9.7431E-02	2.7278E+00	1.1636E-02	0	2.4776E+03	6.0240E-04
31	9.7050E-02	2.8118E+00	1.1553E-02	0	2.2856E+03	1.8351E-04
32	9.6448E-02	2.9058E+00	1.1492E-02	0	2.1536E+03	2.1506E-04
33	9.4444E-02	3.1289E+00	1.1356E-02	0	1.8185E+03	5.7311E-04
34	8.6061E-02	3.6112E+00	1.3728E-02	0	1.1711E+03	5.1466E-04
35	7.8052E-02	5.2537E+00	1.7349E-02	0	5.6494E+02	1.6766E-04
36	2.2479E-01	7.4550E+00	1.2987E-02	0	2.7317E+02	5.4512E-05
37	2.3603E-01	1.1347E+01	3.9105E-02	0	1.1140E+02	2.2199E-05
38	4.5207E-02	2.4495E+01	2.2766E-02	0	3.8626E+01	2.7146E-06
39	4.4463E-02	2.4942E+01	6.3503E-02	0	5.8015E+00	8.8031E-07
40	6.7299E-02	3.9029E+01	5.6856E-02	0	2.0193E+00	3.2884E-07
41	1.5526E-01	1.0578E+02	7.7708E-05	0	3.5524E+00	7.9696E-08
42	7.2570E-04	2.4131E+02	7.3019E-05	0	5.7866E+00	9.5563E-09
43	3.0673E-03	1.0551E+02	1.0133E-04	0	8.9381E+00	2.6717E-09
44	1.9322E+00	2.7918E+01	1.5029E-04	0	1.3818E+01	2.1631E-11
45	8.9031E-02	4.9580E+01	2.1711E-04	0	2.0267E+01	0
46	3.3213E-02	8.6876E+02	3.7721E-04	0	3.5567E+01	0
47	4.7023E-02	7.4286E+02	7.2617E-04	0	6.8352E+01	0

Table 3.15 cont'd

Grp	Pu-239 χ	N flux > 1.0 MeV	N flux > 0.1 MeV	N flux < 0.414 eV	Midpoint energy	Energy width
1	5.6208E-05	1.0000E+00	1.0000E+00	0	1.5762E+01	3.1410E+00
2	2.2677E-04	1.0000E+00	1.0000E+00	0	1.3203E+01	1.9770E+00
3	1.2921E-03	1.0000E+00	1.0000E+00	0	1.1107E+01	2.2140E+00
4	2.9394E-03	1.0000E+00	1.0000E+00	0	9.3035E+00	1.3929E+00
5	6.4700E-03	1.0000E+00	1.0000E+00	0	8.0077E+00	1.1989E+00
6	1.8109E-02	1.0000E+00	1.0000E+00	0	6.7368E+00	1.3429E+00
7	3.4016E-02	1.0000E+00	1.0000E+00	0	5.5156E+00	1.0994E+00
8	8.7792E-02	1.0000E+00	1.0000E+00	0	4.3224E+00	1.2871E+00
9	8.1231E-02	1.0000E+00	1.0000E+00	0	3.3454E+00	6.6690E-01
10	4.5561E-02	1.0000E+00	1.0000E+00	0	2.8686E+00	2.8660E-01
11	4.7656E-02	1.0000E+00	1.0000E+00	0	2.5956E+00	2.5930E-01
12	2.0272E-02	1.0000E+00	1.0000E+00	0	2.4156E+00	1.0070E-01
13	4.0474E-03	1.0000E+00	1.0000E+00	0	2.3555E+00	1.9600E-02
14	2.4523E-02	1.0000E+00	1.0000E+00	0	2.2885E+00	1.1440E-01
15	7.3440E-02	1.0000E+00	1.0000E+00	0	2.0759E+00	3.1080E-01
16	7.1233E-02	1.0000E+00	1.0000E+00	0	1.7867E+00	2.6750E-01
17	8.8012E-02	1.0000E+00	1.0000E+00	0	1.5032E+00	2.9960E-01
18	1.1158E-01	1.0000E+00	1.0000E+00	0	1.1780E+00	3.5080E-01
19	5.9861E-02	1.3000E-02	1.0000E+00	0	9.1172E-01	1.8175E-01
20	2.5776E-02	0	1.0000E+00	0	7.8180E-01	7.8110E-02
21	4.3929E-02	0	1.0000E+00	0	6.7542E-01	1.3464E-01
22	3.4950E-02	0	1.0000E+00	0	5.5299E-01	1.1023E-01
23	3.8841E-02	0	1.0000E+00	0	4.3335E-01	1.2904E-01
24	2.0200E-02	0	1.0000E+00	0	3.3302E-01	7.1620E-02
25	2.8665E-02	0	1.0000E+00	0	2.4018E-01	1.1405E-01
26	1.5048E-02	0	1.0000E+00	0	1.4713E-01	7.2070E-02
27	7.4971E-03	0	2.1034E-01	0	8.9235E-02	4.3711E-02
28	3.5511E-03	0	0	0	5.4123E-02	2.6511E-02
29	9.9694E-04	0	0	0	3.6348E-02	9.0400E-03
30	5.6378E-04	0	0	0	2.8943E-02	5.7700E-03
31	1.7409E-04	0	0	0	2.5117E-02	1.8820E-03
32	2.1284E-04	0	0	0	2.3025E-02	2.3010E-03
33	5.3012E-04	0	0	0	1.8454E-02	6.8410E-03
34	5.1937E-04	0	0	0	1.1068E-02	7.9323E-03
35	1.5779E-04	0	0	0	5.2282E-03	3.7471E-03
36	5.3309E-05	0	0	0	2.4696E-03	1.7700E-03
37	2.1981E-05	0	0	0	1.0193E-03	1.1306E-03
38	2.6501E-06	0	0	0	3.3423E-04	2.3955E-04
39	8.6276E-07	0	0	0	1.5787E-04	1.1315E-04
40	3.1417E-07	0	0	0	6.9283E-05	6.4034E-05
41	6.1447E-08	0	0	0	2.3971E-05	2.6589E-05
42	2.1765E-11	0	0	0	7.8602E-06	5.6335E-06
43	8.2907E-12	0	0	0	3.4495E-06	3.1881E-06
44	6.8575E-13	0	0	0	1.3659E-06	9.7897E-07
45	0	0	0	0	6.4521E-07	4.6244E-07
46	0	0	0	1.0000E+00	2.5700E-07	3.1399E-07
47	0	0	0	1.0000E+00	5.0005E-08	9.9990E-08

Table 3.15 cont'd

Grp	Lethargy width	Pu-238 (n,f)	U-234 ν	U-235 ν	U-236 ν	U-238 ν
1	1.9995E-01	2.6617E+00	4.4121E+00	4.5834E+00	4.3161E+00	4.6415E+00
2	1.5002E-01	2.6810E+00	4.1089E+00	4.2507E+00	4.0219E+00	4.3056E+00
3	2.0000E-01	2.7096E+00	3.8156E+00	3.9511E+00	3.7373E+00	3.9754E+00
4	1.5000E-01	2.7066E+00	3.5959E+00	3.7255E+00	3.5240E+00	3.7281E+00
5	1.5000E-01	2.6675E+00	3.4239E+00	3.5422E+00	3.3572E+00	3.5379E+00
6	2.0000E-01	2.4947E+00	3.2473E+00	3.3385E+00	3.1858E+00	3.3438E+00
7	1.9999E-01	2.2194E+00	3.0914E+00	3.1278E+00	3.0346E+00	3.1718E+00
8	3.0001E-01	2.2436E+00	2.9324E+00	2.9376E+00	2.8803E+00	2.9647E+00
9	2.0002E-01	2.2816E+00	2.7986E+00	2.8040E+00	2.7504E+00	2.7767E+00
10	9.9993E-02	2.2468E+00	2.7385E+00	2.7505E+00	2.6920E+00	2.6985E+00
11	9.9981E-02	2.2258E+00	2.7023E+00	2.7178E+00	2.6569E+00	2.6770E+00
12	4.1693E-02	2.2117E+00	2.6778E+00	2.6961E+00	2.6332E+00	2.6641E+00
13	8.3210E-03	2.2071E+00	2.6700E+00	2.6892E+00	2.6256E+00	2.6600E+00
14	4.9999E-02	2.2018E+00	2.6608E+00	2.6812E+00	2.6166E+00	2.6551E+00
15	1.5000E-01	2.1852E+00	2.6321E+00	2.6559E+00	2.5888E+00	2.6400E+00
16	1.4999E-01	2.1603E+00	2.5916E+00	2.6199E+00	2.5495E+00	2.6186E+00
17	1.9997E-01	2.1230E+00	2.5540E+00	2.5871E+00	2.5130E+00	2.5989E+00
18	3.0002E-01	2.0752E+00	2.5095E+00	2.5496E+00	2.4699E+00	2.5755E+00
19	2.0001E-01	2.0057E+00	2.4745E+00	2.5216E+00	2.4360E+00	2.5568E+00
20	9.9994E-02	1.9112E+00	2.4574E+00	2.5078E+00	2.4194E+00	2.5478E+00
21	2.0001E-01	1.7346E+00	2.4419E+00	2.4962E+00	2.4043E+00	2.5396E+00
22	2.0000E-01	1.5358E+00	2.4270E+00	2.4859E+00	2.3898E+00	2.5317E+00
23	3.0000E-01	1.2256E+00	2.4100E+00	2.4739E+00	2.3733E+00	2.5227E+00
24	2.1590E-01	1.0257E+00	2.3968E+00	2.4643E+00	2.3604E+00	2.5157E+00
25	4.8408E-01	8.5052E-01	2.3843E+00	2.4552E+00	2.3483E+00	2.5091E+00
26	5.0002E-01	7.1674E-01	2.3718E+00	2.4429E+00	2.3362E+00	2.5025E+00
27	5.0001E-01	6.1173E-01	2.3635E+00	2.4290E+00	2.3281E+00	2.4981E+00
28	4.9999E-01	6.2584E-01	2.3593E+00	2.4233E+00	2.3240E+00	2.4959E+00
29	2.5000E-01	6.7409E-01	2.3569E+00	2.4236E+00	2.3218E+00	2.4946E+00
30	2.0002E-01	7.0514E-01	2.3558E+00	2.4258E+00	2.3206E+00	2.4941E+00
31	7.4964E-02	7.2035E-01	2.3554E+00	2.4267E+00	2.3203E+00	2.4939E+00
32	1.0002E-01	7.3186E-01	2.3551E+00	2.4275E+00	2.3200E+00	2.4937E+00
33	3.7503E-01	6.6131E-01	2.3545E+00	2.4291E+00	2.3194E+00	2.4934E+00
34	7.4998E-01	8.0131E-01	2.3535E+00	2.4327E+00	2.3185E+00	2.4929E+00
35	7.5000E-01	1.4456E+00	2.3527E+00	2.4338E+00	2.3177E+00	2.4924E+00
36	7.5000E-01	1.6742E+00	2.3523E+00	2.4338E+00	2.3173E+00	2.4923E+00
37	1.2500E+00	2.4197E+00	2.3521E+00	2.4338E+00	2.3171E+00	2.4921E+00
38	7.5002E-01	3.4140E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
39	7.4999E-01	6.4419E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
40	1.0000E+00	1.3774E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
41	1.2500E+00	1.2830E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
42	7.4999E-01	2.2068E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
43	1.0000E+00	1.1979E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
44	7.5000E-01	2.1490E-01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
45	7.5002E-01	7.1934E-01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
46	1.4207E+00	3.2742E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
47	9.2103E+00	1.0439E+01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00

Table 3.15 cont'd

Grp	Pu-238 ν	Pu-239 ν	Pu-240 ν	Pu-241 ν	Pu-242 ν	U-234 χ
1	5.1526E+00	5.1106E+00	5.1200E+00	5.2385E+00	5.2142E+00	1.5159E-04
2	4.8200E+00	4.8080E+00	4.7787E+00	4.8917E+00	4.8601E+00	4.6489E-04
3	4.4983E+00	4.5098E+00	4.4485E+00	4.5561E+00	4.5175E+00	2.0914E-03
4	4.2571E+00	4.2733E+00	4.2010E+00	4.3044E+00	4.2606E+00	4.0422E-03
5	4.0683E+00	4.0731E+00	4.0073E+00	4.1075E+00	4.0596E+00	7.9523E-03
6	3.8745E+00	3.8693E+00	3.8087E+00	3.9063E+00	3.8535E+00	2.0119E-02
7	3.7047E+00	3.6822E+00	3.6343E+00	3.7309E+00	3.6724E+00	3.4986E-02
8	3.5311E+00	3.4989E+00	3.4562E+00	3.5517E+00	3.4874E+00	8.4943E-02
9	3.3847E+00	3.3552E+00	3.3058E+00	3.3964E+00	3.3313E+00	7.6300E-02
10	3.3187E+00	3.2973E+00	3.2382E+00	3.3256E+00	3.2612E+00	4.2488E-02
11	3.2790E+00	3.2576E+00	3.1974E+00	3.2830E+00	3.2189E+00	4.4430E-02
12	3.2522E+00	3.2316E+00	3.1698E+00	3.2541E+00	3.1903E+00	1.8922E-02
13	3.2436E+00	3.2238E+00	3.1610E+00	3.2449E+00	3.1812E+00	3.7965E-03
14	3.2335E+00	3.2149E+00	3.1506E+00	3.2340E+00	3.1705E+00	2.2916E-02
15	3.2021E+00	3.1866E+00	3.1184E+00	3.2002E+00	3.1370E+00	6.9064E-02
16	3.1577E+00	3.1425E+00	3.0728E+00	3.1525E+00	3.0897E+00	6.7814E-02
17	3.1164E+00	3.0963E+00	3.0304E+00	3.1082E+00	3.0458E+00	8.5334E-02
18	3.0676E+00	3.0423E+00	2.9803E+00	3.0557E+00	2.9938E+00	1.1157E-01
19	3.0293E+00	3.0043E+00	2.9409E+00	3.0145E+00	2.9530E+00	6.1607E-02
20	3.0106E+00	2.9866E+00	2.9217E+00	2.9944E+00	2.9331E+00	2.6932E-02
21	2.9935E+00	2.9703E+00	2.9042E+00	2.9760E+00	2.9149E+00	4.6550E-02
22	2.9772E+00	2.9549E+00	2.8874E+00	2.9585E+00	2.8975E+00	3.7658E-02
23	2.9585E+00	2.9395E+00	2.8683E+00	2.9457E+00	2.8777E+00	4.2494E-02
24	2.9440E+00	2.9288E+00	2.8534E+00	2.9453E+00	2.8623E+00	2.2243E-02
25	2.9304E+00	2.9191E+00	2.8393E+00	2.9453E+00	2.8477E+00	3.2067E-02
26	2.9167E+00	2.9088E+00	2.8253E+00	2.9453E+00	2.8331E+00	1.6963E-02
27	2.9076E+00	2.9024E+00	2.8159E+00	2.9453E+00	2.8234E+00	8.3563E-03
28	2.9030E+00	2.8992E+00	2.8112E+00	2.9453E+00	2.8185E+00	4.0490E-03
29	2.9004E+00	2.8976E+00	2.8085E+00	2.9453E+00	2.8157E+00	1.1485E-03
30	2.8991E+00	2.8968E+00	2.8072E+00	2.9453E+00	2.8144E+00	6.5783E-04
31	2.8987E+00	2.8965E+00	2.8068E+00	2.9453E+00	2.8140E+00	2.0051E-04
32	2.8984E+00	2.8963E+00	2.8065E+00	2.9453E+00	2.8136E+00	2.3506E-04
33	2.8977E+00	2.8958E+00	2.8058E+00	2.9453E+00	2.8129E+00	6.2681E-04
34	2.8967E+00	2.8952E+00	2.8047E+00	2.9453E+00	2.8118E+00	5.6349E-04
35	2.8957E+00	2.8948E+00	2.8038E+00	2.9453E+00	2.8108E+00	1.8373E-04
36	2.8953E+00	2.8945E+00	2.8034E+00	2.9453E+00	2.8104E+00	5.9785E-05
37	2.8951E+00	2.8886E+00	2.8031E+00	2.9453E+00	2.8101E+00	2.4392E-05
38	2.8950E+00	2.8631E+00	2.8030E+00	2.9453E+00	2.8100E+00	3.0037E-06
39	2.8950E+00	2.8702E+00	2.8030E+00	2.9453E+00	2.8100E+00	9.8697E-07
40	2.8950E+00	2.8630E+00	2.8030E+00	2.9453E+00	2.8100E+00	3.8048E-07
41	2.8950E+00	2.8615E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.0297E-07
42	2.8950E+00	2.8644E+00	2.8030E+00	2.9453E+00	2.8100E+00	9.1138E-09
43	2.8950E+00	2.8772E+00	2.8030E+00	2.9453E+00	2.8100E+00	5.0382E-09
44	2.8950E+00	2.8783E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.5297E-09
45	2.8950E+00	2.8692E+00	2.8030E+00	2.9453E+00	2.8100E+00	7.9147E-10
46	2.8950E+00	2.8630E+00	2.8030E+00	2.9453E+00	2.8100E+00	4.3746E-10
47	2.8950E+00	2.8758E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.8584E-10

Table 3.15 cont'd

Grp	U-236 χ	Pu-238 χ	Pu-240 χ	Pu-241 χ	Pu-242 χ
1	1.0898E-04	8.0233E-05	1.0673E-04	9.9677E-05	1.1131E-04
2	3.5098E-04	2.8002E-04	3.5394E-04	3.3529E-04	3.6640E-04
3	1.6611E-03	1.4154E-03	1.7054E-03	1.6360E-03	1.7532E-03
4	3.3451E-03	2.9768E-03	3.4603E-03	3.3494E-03	3.5386E-03
5	6.7995E-03	6.2305E-03	7.0470E-03	6.8657E-03	7.1773E-03
6	1.7797E-02	1.6736E-02	1.8416E-02	1.8057E-02	1.8681E-02
7	3.1944E-02	3.0672E-02	3.2916E-02	3.2452E-02	3.3263E-02
8	8.0131E-02	7.8339E-02	8.1967E-02	8.1247E-02	8.2519E-02
9	7.3775E-02	7.2970E-02	7.4920E-02	7.4551E-02	7.5211E-02
10	4.1592E-02	4.1353E-02	4.2059E-02	4.1931E-02	4.2163E-02
11	4.3812E-02	4.3685E-02	4.4185E-02	4.4099E-02	4.4256E-02
12	1.8748E-02	1.8727E-02	1.8873E-02	1.8850E-02	1.8893E-02
13	3.7676E-03	3.7654E-03	3.7902E-03	3.7865E-03	3.7936E-03
14	2.2782E-02	2.2785E-02	2.2903E-02	2.2886E-02	2.2918E-02
15	6.9061E-02	6.9211E-02	6.9262E-02	6.9270E-02	6.9262E-02
16	6.8334E-02	6.8659E-02	6.8309E-02	6.8393E-02	6.8248E-02
17	8.6641E-02	8.7260E-02	8.6317E-02	8.6519E-02	8.6166E-02
18	1.1426E-01	1.1537E-01	1.1337E-01	1.1378E-01	1.1306E-01
19	6.3535E-02	6.4276E-02	6.2828E-02	6.3116E-02	6.2606E-02
20	2.7870E-02	2.8221E-02	2.7513E-02	2.7653E-02	2.7405E-02
21	4.8306E-02	4.8948E-02	4.7619E-02	4.7880E-02	4.7416E-02
22	3.9204E-02	3.9757E-02	3.8583E-02	3.8811E-02	3.8404E-02
23	4.4378E-02	4.5037E-02	4.3602E-02	4.3879E-02	4.3384E-02
24	2.3290E-02	2.3651E-02	2.2851E-02	2.3005E-02	2.2730E-02
25	3.3658E-02	3.4196E-02	3.2980E-02	3.3213E-02	3.2796E-02
26	1.7848E-02	1.8144E-02	1.7465E-02	1.7594E-02	1.7363E-02
27	8.8057E-03	8.9545E-03	8.6096E-03	8.6750E-03	8.5576E-03
28	4.2707E-03	4.3438E-03	4.1735E-03	4.2057E-03	4.1478E-03
29	1.2120E-03	1.2328E-03	1.1841E-03	1.1933E-03	1.1768E-03
30	6.9430E-04	7.0627E-04	6.7824E-04	6.8355E-04	6.7402E-04
31	2.1165E-04	2.1530E-04	2.0674E-04	2.0836E-04	2.0545E-04
32	2.4813E-04	2.5242E-04	2.4237E-04	2.4427E-04	2.4086E-04
33	6.6174E-04	6.7317E-04	6.4634E-04	6.5142E-04	6.4229E-04
34	5.9501E-04	6.0531E-04	5.8109E-04	5.8567E-04	5.7744E-04
35	1.9404E-04	1.9741E-04	1.8948E-04	1.9098E-04	1.8829E-04
36	6.3142E-05	6.4238E-05	6.1657E-05	6.2145E-05	6.1269E-05
37	2.5761E-05	2.6208E-05	2.5155E-05	2.5354E-05	2.4997E-05
38	3.1715E-06	3.2263E-06	3.0973E-06	3.1218E-06	3.0779E-06
39	1.0416E-06	1.0595E-06	1.0175E-06	1.0254E-06	1.0111E-06
40	4.0087E-07	4.0781E-07	3.9198E-07	3.9498E-07	3.8960E-07
41	1.0808E-07	1.0989E-07	1.0590E-07	9.6708E-08	1.0517E-07
42	4.7007E-09	0	1.0349E-08	1.9397E-11	1.5776E-08
43	2.6106E-09	0	5.5918E-09	1.0701E-11	8.6067E-09
44	6.6295E-10	0	1.6994E-09	3.3430E-12	2.6035E-09
45	1.2831E-10	0	1.0556E-09	2.1628E-12	1.6126E-09
46	3.1175E-11	0	1.0958E-09	2.3672E-12	1.4742E-09
47	1.0398E-11	0	3.4341E-10	7.8650E-13	5.1255E-10

columns and 279 rows. The row positions of the responses are the same as for the broad-group responses (listed in Table 3.13) with the exception of the additional 16 responses. These extra 16 responses start with ion 56. The fine-group responses will be useful for users who may need to generate broad-group responses with different weighting spectra. Be aware that certain of these "responses" are not averaged but rather are summed to give the broad-group values, e.g. χ's, weighting spectra, etc.

The kerma factors are also represented as cross-section tables with ANISN IDs of 8001 - 8004. The 8001 and 8002 sets contain the neutron-only kerma factors for the 120 nuclides in BUGLE-93, while the 8003 and 8004 sets contain the gamma-ray-only kerma factors. It should be noted that the gamma-ray kerma factors are the same for all isotopes of a given element. The row positions for these data sets are listed in Tables 3.16 and 3.17. The kerma factors were collapsed from VITAMIN-B6 using the concrete weighting spectrum. Ten nuclides were observed to have negative neutron kerma factors when processed by NJOY, which is apparently due to problems in the ENDF/B-VI evaluation rather than the processing. These nuclides include: ^{197}Au (MAT 7925), ^{138}Ba (MAT 5649), ^{209}Bi (MAT 8325), ^{151}Eu (MAT 6325), Mo (MAT 4200), ^{93}Nb (MAT 4125), ^{181}Ta (MAT 7328), Ti (MAT 2200), W-Nat (MAT 7400), and ^{183}W (MAT 7434). These nuclides are included in the BUGLE-96 kerma data sets but contain only zeros.

Table 3.16 Row positions for neutron kerma factor data set 1 (ID=8001) and gamma-ray kerma factor data set 1 (ID=8003).[a] Kermas are in units of eV·b

Row	Nuclide	Row	Nuclide	Row	Nuclide
1	Ag-107	21	Cm-242	41	Fe-54
2	Ag-109	22	Cm-243	42	Fe-56
3	Al-27	23	Cm-244	43	Fe-57
4	Am-241	24	Cm-245	44	Fe-58
5	Am-242	25	Cm-246	45	Ga
6	Am-242m	26	Cm-247	46	H-1 (H2O)
7	Am-243	27	Cm-248	47	H-1 (CH2)
8	Au-197[b]	28	Co-59	48	H-2 (D2O)
9	B-10	29	Cr-50	49	H-3
10	B-11	30	Cr-52	50	He-3
11	Ba-138[b]	31	Cr-53	51	He-4
12	Be-9	32	Cr-54	52	Hf-174
13	Be-9 (Thermal)	33	Cu-63	53	Hf-176
14	Bi-209[b]	34	Cu-65	54	Hf-177
15	C	35	Eu-151[b]	55	Hf-178
16	C (Graphite)	36	Eu-152	56	Hf-179
17	Ca	37	Eu-153	57	Hf-180
18	Cd-Nat	38	Eu-154	58	In-Nat
19	Cl-Nat	39	Eu-155	59	K
20	Cm-241	40	F-19	60	Li-6

[a] Gamma-ray kerma factors are the same for all isotopes of each element.
[b] Neutron kerma factors are set to zero.

Table 3.17 Row positions for neutron kerma factor data set 2 (ID=8002) and gamma-ray kerma factor data set 2 (ID=8004).[a] Kermas are in units of eV·b

Row	Nuclide	Row	Nuclide	Row	Nuclide
1	Li-7	21	Pa-233	41	Ta-182
2	Mg	22	Pb-206	42	Th-230
3	Mn-55	23	Pb-207	43	Th-232
4	Mo[b]	24	Pb-208	44	Ti[b]
5	N-14	25	Pu-236	45	U-232
6	N-15	26	Pu-237	46	U-233
7	Na-23	27	Pu-238	47	U-234
8	Nb-93[b]	28	Pu-239	48	U-235
9	Ni-58	29	Pu-240	49	U-236
10	Ni-60	30	Pu-241	50	U-237
11	Ni-61	31	Pu-242	51	U-238
12	Ni-62	32	Pu-243	52	V
13	Ni-64	33	Pu-244	53	W-Nat[b]
14	Np-237	34	Re-185	54	W-182
15	Np-238	35	Re-187	55	W-183[b]
16	Np-239	36	S	56	W-184
17	O-16	37	S-32	57	W-186
18	O-17	38	Si	58	Y-89
19	P-31	39	Sn-Nat	59	Zr
20	Pa-231	40	Ta-181[b]	60	Zr (Zirc-2)

[a] Gamma-ray kerma factors are the same for all isotopes of each element.
[b] Neutron kerma factors are set to zero.

4 LIBRARY VERIFICATION AND VALIDATION

The preceding BUGLE-93 cross-section library was extensively verified and validated using three levels of testing, which included: (1) automatic diagnostic software to check for internal consistency of the data files, (2) numerical and graphical comparisons with other cross-section data, and (3) computational analysis of more than 30 integral benchmark experiments. The benchmark testing was a significant effort and included many CSEWG-approved benchmarks[22] and several non-CSWEG benchmarks which have been generally accepted as being suitable for testing nuclear data. The benchmark testing not only served to verify the processing of the multigroup cross sections, but also to validate the library for use for LWR pressure vessel dosimetry and shielding applications. Additionally, it helped to demonstrate the impact of changes in the ENDF/B-VI data for this application.

Verification of BUGLE-96 was accomplished using the first two levels of testing described above, i.e. automated software checking and comparisons with other cross-section data. The first step in the data verification process made use of diagnostic modules in the AMPX-77 system. Also, data were compared with BUGLE-93 results at several steps during the processing. These periodic comparisons were an important step in the processing, since it frequently happens that even minor changes to the processing codes, which are intended to fix one specific problem, may cause unexpected changes in other portions of the processed data files.

For BUGLE-96, resources were not available to repeat the extensive set of benchmark analyses that were performed for BUGLE-93. However, much of the benchmark testing of BUGLE-93 remains valid for BUGLE-96, especially for those applications which are sensitive to only data above the thermal energy range. Therefore, the results of the BUGLE-93 data testing are provided in this section. It is expected that with time, some of these benchmarks will be rerun with the actual BUGLE-96 data and that further validation results will be contributed by the user community.

4.1 Processing Methods

The first level of data testing made use of diagnostic modules in the AMPX-77 system. An example of cross-section checks performed by one of these modules, RADE, is provided in Table 4.1. In addition, pointwise and/or multigroup data were graphically plotted and compared with ENDF/B-V results for key reactions. At each step of the processing, the files were compared with previous results and differences were identified and resolved or justified. This was an important step in the processing, since even minor changes to the processing codes, which were intended to fix a specific problem, often caused changes in other portions of the processed data files.

4.2 Thermal and Fast Reactor Data Testing Benchmarks

The calculation of criticality benchmarks help to establish the reliability of the resulting fine-group cross-section library and the cross-section processing methods for fuel and moderator materials. The

Table 4.1 Cross section checks performed by RADE on AMPX master interface files [a]

1. $\sigma_t = \sigma_a + \sigma_s$
2. $\sigma_{in} = \sum \sigma_{in}(\text{partial})$
3. $\sigma_a = \sigma_c + \sigma_f$
4. $\sigma_c = \sigma_{ng} + \sigma_{n\alpha} + \sigma_{np} + \sigma_{nd} + \ldots$
5. $\sigma_{el}(g) = \sum_{g'} \sigma_{el,o}(g \rightarrow g')$ (for all processes with scattering matrix).
6. $\sigma_o(g \rightarrow g') > 0$
7. $\sigma_t, \sigma_a, \sigma_f, \sigma_{n\alpha}, \sigma_{np}, \ldots > 0$
8. $-1 \leq \{ \mu(g \rightarrow g') = \sigma_l(g \rightarrow g')/(2l+1)\sigma_o(g \rightarrow g') \} \leq 1$, for all odd l.[b]

[a] Deviations between the right- and left-hand sides of the above relationships are printed if greater than a user supplied tolerance.
[b] For even l, the left-hand side of this inequality is given by the table:

l	$\mu(g \rightarrow g')$
2	-0.5
4	-0.433
6	-0.419
8	-0.414

testing included the calculation of several CSEWG fast and thermal critical experiments. A few additional non-CSEWG benchmarks which had ENDF/B-V results available were also analyzed. Table 4.2 lists the physics benchmarks used in this project. Because of the removal of thermal-neutron upscatter in the BUGLE-93 data and relatively poor energy resolution at lower energies, only the VITAMIN-B6 data were used to analyze the thermal and fast reactor benchmarks. Furthermore, BUGLE-93 is intended primarily for shielding applications and is not expected to perform well for reactor physics analyses.

4.2.1 Thermal Reactor Physics Benchmarks

The XSDRNPM module of the SCALE system[19] was used to calculate a total of 23 thermal reactor benchmarks. Calculated eigenvalue and reaction rate ratios were compared to results obtained with the SCALE LAW-238 library (238 groups) based on ENDF/B-V data.[23] In some cases, results were compared with those obtained by researchers at other organizations using ENDF/B-VI. These comparisons help to further assure the correctness of the analysis methods.

4.2.1.1 ORNL Series: The first set of thermal reactor benchmarks are for the ORNL critical solution spheres: ORNL-1, -2, -3, -4, and -10. These are unreflected spheres of ^{235}U as uranyl nitrate and H_2O solutions. The benchmarks are especially useful for testing H_2O fast-neutron scattering data, ^{235}U absorption data, and hydrogen neutron capture data. The calculated k_{eff} values are given in Table 4.3. ENDF/B-VI data appear to yield k_{eff} values which are 0.3 to 0.6% low relative to the experiments and are about 0.4% lower than the corresponding average value obtained using the LAW-238 library. Although not listed in Table 4.3, other ENDF/B-VI-based results calculated elsewhere and presented at the October 1993 CSEWG meeting are in good agreement with the VITAMIN-B6 results.

4.2.1.2 L Series: Calculated values of k_{eff} for the L-Series benchmarks (L-7, -8, -9, -10, and -11) are given in Table 4.4. These benchmarks are similar to the ORNL series above except that they include both reflected and unreflected spheres of ^{235}U as uranyl fluoride and H_2O solutions. The L-Series benchmarks are significantly improved with ENDF/B-VI. As seen in Table 4.4, the average k_{eff} with VITAMIN-B6 is 1.0022, which is about 0.5% lower than the ENDF/B-V results. When k_{eff} is plotted as a function of leakage from the spheres, as shown in Fig. 4.1, one can see that not only does the VITAMIN-B6 data yield values closer to unity, but they also appear to reduce the positive trend of k_{eff} with increasing leakage.

4.2.1.3 TRX and BABL Series: Two series of H_2O-moderated uranium lattice experiments were analyzed including TRX-1 and -2 and BAPL-1, -2, and -3. These lattices directly test ^{235}U resonance fission integrals and thermal fission cross sections. Also, ^{238}U shielded resonance capture and thermal neutron capture are tested. The benchmarks are sensitive to the ^{235}U fission spectrum and the ^{238}U fast fission and inelastic scattering cross sections. Calculated values of k_{eff} for these benchmarks are given in Table 4.5. In the case of TRX-1 and -2, the VITAMIN-B6 results are 0.2 to 0.4% lower than ENDF/B-V results, which were already significantly below unity. However, the VITAMIN-B6 results compare well with other ENDF/B-VI-based calculations performed elsewhere.

Table 4.2 CSEWG reactor physics benchmarks used for data testing

Thermal reactor benchmarks:	
ORNL-1,-2 -3,-4,-10	Unreflected spheres of ^{235}U (as uranyl nitrate) in H_2O
L-7,-8,-9 -10,-11	Reflected and unreflected spheres of ^{235}U (as uranyl fluoride) in H_2O.
TRX-1,-2	H_2O moderated uranium lattices
BAPL-1,-2,-3	H_2O moderated uranium oxide critical lattices
PNL-1,-3R, -4R,-5R, -6B,-8A	Unreflected spheres of plutonium nitrate in H_2O
PNL-7A,-12A,	Reflected spheres of plutonium nitrate in H_2O
Fast reactor benchmarks:	
JEZEBEL	Bare sphere of plutonium metal
JEZEBEL-PU	Bare sphere of plutonium metal containing 20.1% ^{240}Pu
JEZEBEL-23	Bare sphere of uranium metal (98.13 atom-% ^{233}U)
GODIVA	Bare sphere of enriched uranium metal
FLATTOP-25	Reflected sphere of enriched uranium metal
FLATTOP-PU	Reflected sphere of plutonium metal
FLATTOP-23	Reflected sphere of uranium metal (98.13 atom-% ^{233}U)
BIG TEN	Reflected cylinder of uranium containing 10% ^{235}U
ZPR-3/11	Fertile to fission uranium metal ratio of 7:1 with ^{238}U reflector
ZPR-3/12	Uranium-fueled assembly with uranium-to-graphite ratio of 4:1 and ^{238}U reflector
ZPR-6/6A	Uranium oxide fueled fast critical assembly with depleted uranium reflector
ZPR-6/7	Large plutonium oxide fueled fast critical assembly with depleted uranium reflector

Table 4.3 ORNL critical solution spheres

Benchmark	k-effective	
	LAW-238 ENDF/B-V	VITAMIN-B6 ENDF/B-VI
ORNL-1	1.0007	0.9965
ORNL-2	1.0005	0.9964
ORNL-3	0.9975	0.9935
ORNL-4	0.9989	0.9950
ORNL-10	0.9993	0.9961
Average	0.9994	0.9955

Table 4.4 L-Series critical solution spheres

Benchmark	Leakage[a]	k-effective	
		LAW-238 ENDF/B-V	VITAMIN-B6 ENDF/B-VI
L-9	0.174	1.0052	1.0011
L-11	0.202	1.0035	0.9988
L-8	0.239	1.0088	1.0042
L-10	0.463	1.0090	1.0030
L-7	0.469	1.0082	1.0037
Average		1.0069	1.0022

[a] Based on LAW-238 calculations.

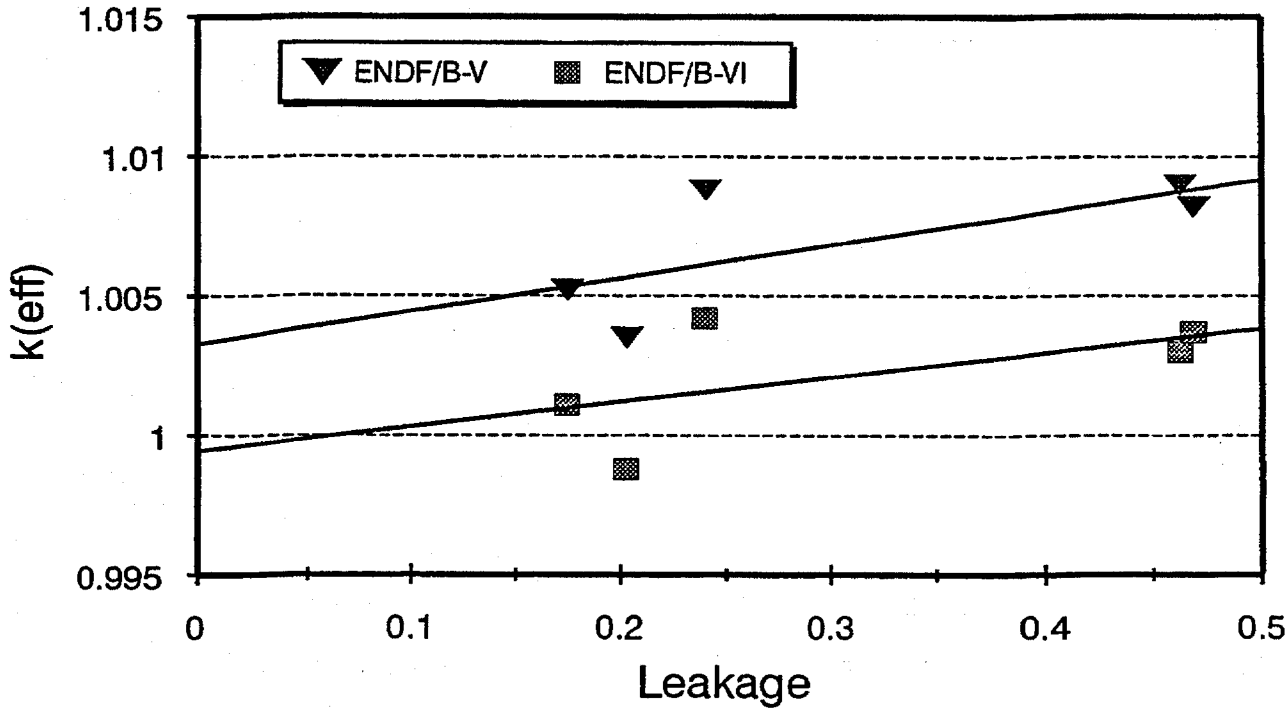


Fig. 4.1 Comparison of calculated k_{eff} values for L-Series thermal reactor benchmarks using the LAW-238 (ENDF/B-V) and VITAMIN-B6 (ENDF/B-VI) libraries. Lines represent linear regression fits to the data

Table 4.5 Thermal reactor lattices

Benchmark	Pitch (cm)	k-effective LAW-238 ENDF/B-V	k-effective VITAMIN-B6 ENDF/B-VI
TRX-1	1.806	0.9915	0.9894
TRX-2	2.174	0.9959	0.9915
Average		0.9937	0.9905
BAPL-1	1.5578	0.9947	0.9975
BAPL-2	1.6523	0.9965	0.9971
BAPL-3	1.8057	0.9987	0.9972
Average		0.9966	0.9973

The BAPL-1, -2, and -3 benchmarks appear much more favorable for ENDF/B-VI. The average k_{eff} for the three lattices is slightly higher and closer to unity for VITAMIN-B6 calculations relative to ENDF/B-V. More importantly, the marked trend in the eigenvalue as a function of lattice pitch is essentially eliminated with ENDF/B-VI data. This is shown graphically in Fig. 4.2.

4.2.1.4 PNL Series: Finally, the PNL series of plutonium nitrate spheres were analyzed using VITAMIN-B6. These critical assemblies include $H/^{239}Pu$ atom ratios ranging from 131 to 1204 and are useful for testing the H_2O scattering data, cross sections for thermal-neutron capture and fission by ^{239}Pu, and the ^{239}Pu fission spectrum and nubar (average number of neutrons per fission). The CSEWG benchmark specifications for PNL-3, -4, and -5 were determined to be inaccurate. Specifically, the radii given in the published specifications[22] were not adjusted to specify critical sizes for solutions without stainless steel walls. For this analysis, we have corrected the specifications to include the stainless steel vessel in the calculations. These revised benchmarks are designated PNL-3R, -4R, and -5R. The impact of the stainless steel vessel was to increase k_{eff} by 0.4 to 0.5% as compared to previous calculations with no vessel. The results for the PNL benchmarks are listed in Table 4.6 ordered by increasing H/Pu ratio. The neutron production-to-absorption ratio and the k_{eff} for each benchmark is given based on VITAMIN-B6 calculations. These results are plotted in Fig. 4.3. Because of the scatter in the results, it is probably meaningless to conclude a trend in the eigenvalue as a function of hydrogen content.

4.2.2 Fast Reactor Physics Benchmarks

As indicated in Table 4.2, 12 CSEWG fast reactor benchmarks were used to test VITAMIN-B6. Calculated eigenvalue and reaction rate ratios were compared to results obtained with the VITAMIN-E library (174 groups) based on ENDF/B-V data. These k_{eff} results are summarized in Table 4.7. One apparent trend is that ENDF/B-VI data yield slightly lower values of k_{eff} for the relatively simple benchmarks, but yield significantly higher values for the larger mockups. A summary of the calculated-to-experiment ratios for various reaction rate ratios are given in Table 4.8 for the VITAMIN-B6 calculations. Note that the reaction rate ratios for ZPR-6/7 are given relative to ^{239}Pu fission while those for the other benchmarks are given relative to ^{235}U fission.

In order to give further assurance that the cross-section processing and the computational methods used to analyze the benchmarks were done correctly, we performed extensive comparisons with benchmark analyses performed at LANL. The LANL results, also based on ENDF/B-VI data are listed in Table 4.8 for the CSEWG fast reactor benchmarks. While some benchmarks agree well, others show significant differences relative to the VITAMIN-B6 results. These differences need to be investigated further, but appear to be primarily due to the different energy group structures (80 groups used by LANL compared to 199 groups for VITAMIN-B6) and modest differences in the computational methods.

Four additional non-CSEWG benchmarks were also analyzed: H2OX-1, UH3-UR, HISS(HUG), and HISS(HPG). H2OX-1 is a highly enriched uranium metal sphere reflected by water and has a radius slightly smaller than the GODIVA assembly. The UH3-UR benchmark is a sphere of enriched uranium hydride (approximately UH_3) with a natural uranium reflector.

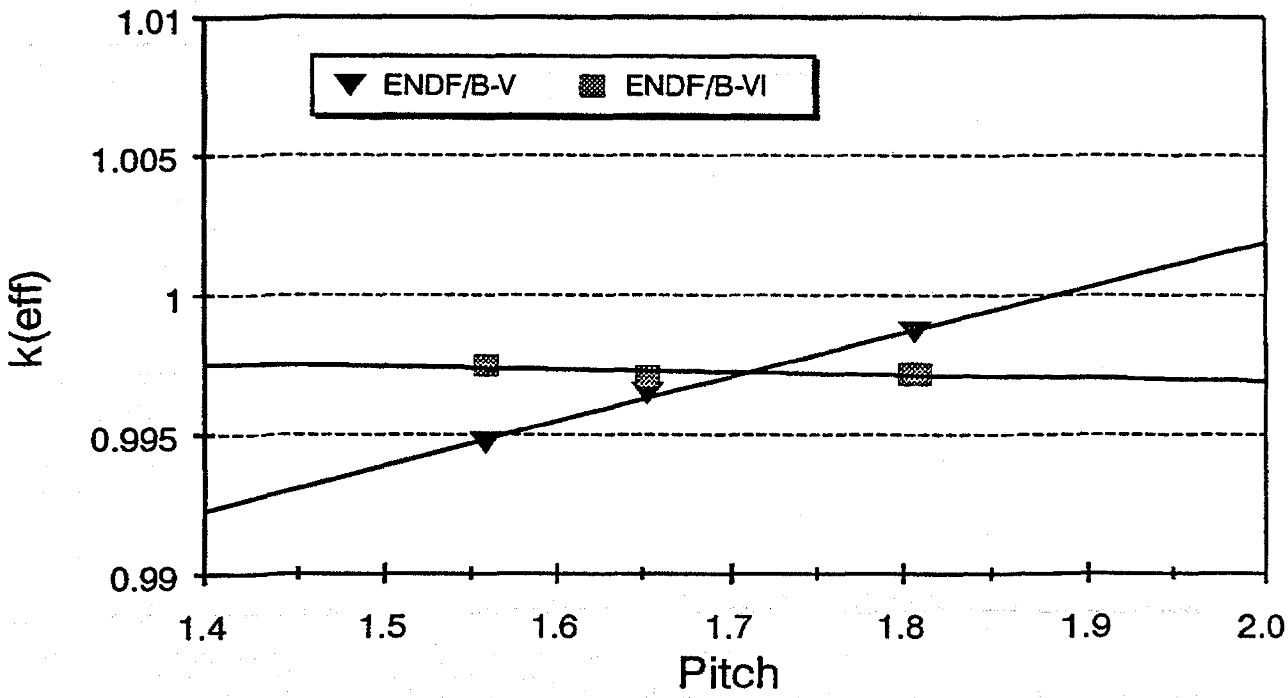


Fig. 4.2 Comparison of calculated k_{eff} values for BAPL Series thermal reactor benchmarks using the LAW-238 (ENDF/B-V) and VITAMIN-B6 (ENDF/B-VI) libraries. Lines represent linear regression fits to the data

Table 4.6 PNL series calculated using VITAMIN-B6

Benchmark	$H/^{239}Pu$ Ratio	Prod/Abs Ratio	k_{eff} ENDF/B-VI
PNL-6B	131	1.6642	1.0025
PNL-5R	578	1.5949	1.0065
PNL-1	700	1.6043	1.0089
PNL-8A	795	1.5487	1.0066
PNL-4R	911	1.4809	1.0013
PNL-7A	985	1.0126	1.0052
PNL-12A	1118	1.0294	1.0066
PNL-3R	1204	1.4531	0.9942

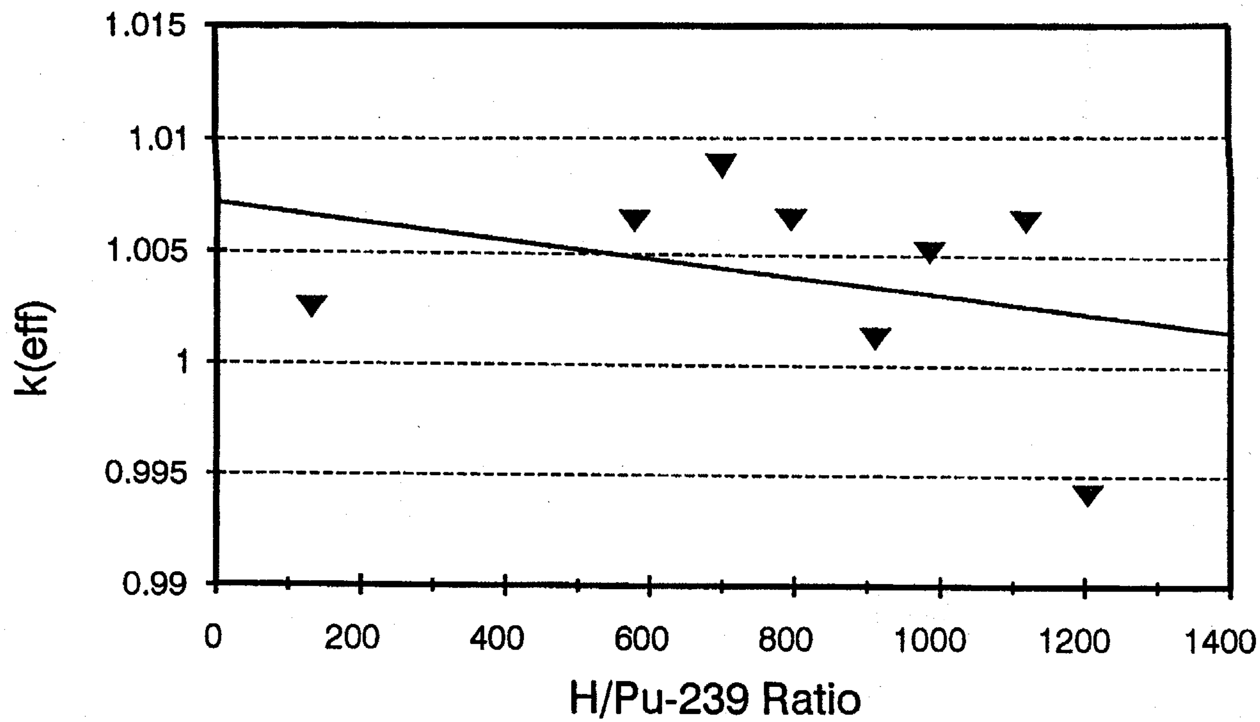


Fig. 4.3 Calculated k_{eff} values for PNL Series thermal reactor benchmarks using the VITAMIN-B6 library. Line represents linear regression fits to the data

Table 4.7 Summary of fast reactor benchmark results

Benchmark	k-effective VITAMIN-E ENDF/B-V	k-effective VITAMIN-B6 ENDF/B-VI	Δk/k (%)	k-effective LANL ENDF/B-VI
JEZEBEL	0.9983	0.9970	-0.13	0.9989
JEZEBEL-23	0.9935	0.9934	-0.01	0.9940
JEZEBEL-PU	1.0021	0.9980	-0.41	0.9981
FLATTOP-23	--	1.0032	--	1.0041
FLATTOP-PU	--	1.0029	--	1.0055
GODIVA	0.9966	0.9960	-0.06	0.9983
FLATTOP-25	1.0047	1.0018	-0.29	1.0030
ZPR-3/12	1.0047	1.0109	0.62	--
ZPR-3/11	1.0126	1.0141	0.15	--
BIGTEN	1.0144	1.0171	0.27	1.0105
ZPR-6/6A	0.9921	1.0110	1.90	1.0063
ZPR-6/7	1.0037	1.0150	1.13	1.0070
Average[a]	1.0023	1.0054	0.31	--
Average[b]	--	1.0035	--	1.0026

[a] Excludes FLATTOP-23 and FLATTOP-PU.
[b] Excludes ZPR-3/11 and ZPR-3/12.

Table 4.8 Calculated-to-experiment ratios calculated using VITAMIN-B6

Benchmark	Central Reaction Rate Ratios[a]				
	F28/F25	F37/F25	F23/F25	F49/F25	C28/F25
JEZEBEL	0.964	0.969	1.000	0.975	--
JEZEBEL-23	1.011	0.990	--	--	--
JEZEBEL-PU	0.964	1.000	--	--	--
FLATTOP-23	1.000	0.996	--	--	--
FLATTOP-PU	0.973	0.985	--	--	--
GODIVA	0.963	0.961	1.001	0.978	--
FLATTOP-25	0.970	0.979	0.990	0.984	--
ZPR-3/12	1.061	--	1.031	0.995	0.950
ZPR-3/11	1.068	--	1.035	0.994	--
BIGTEN	1.044	1.044	0.996	0.988	0.946
ZPR-6/6A	0.958	--	--	--	0.991
	F28/F49	F37/F49	F23/F49	F25/F49	C28/F49
ZPR-6/7	1.012	--	--	1.033	1.038

[a] Nomenclature: F = fission; C = capture
23 = ^{233}U; 25 = ^{235}U; 28 = ^{238}U; 37 = ^{237}Np; 49 = ^{239}Pu

Table 4.9 Summary results for non-CSEWG fast reactor benchmarks

Benchmark	k-effective LAW-238 ENDF/B-V	k-effective VITAMIN-B6 ENDF/B-VI
H2OX-1	1.0047	1.0001
UH3-UR	1.0098	1.0222
HISS(HUG)	1.0254	1.0293
HISS(HPG)	0.9968	1.0055
Average	1.0092	1.0143

HISS(HUG) is a homogeneous uranium-graphite assembly and HISS(HPG) is a homogeneous plutonium-graphite assembly; both HISS benchmarks contain large amounts of boron. The fission rates for the UH3-UR and the HISS benchmarks peak in the resolved resonance range and thus are sensitive to the fission and capture cross sections in that energy range.

Calculated values of k_{eff} for the four benchmarks are given in Table 4.9 compared to calculations using the LAW-238 library. Excepting for H2OX-1, ENDF/B-VI data appear to give 0.5 to 1.0% higher eigenvalues than ENDF/B-V data. It has been observed that the evaluated capture resonance integral for ^{235}U in ENDF/B-VI is about 8% lower than the measured value. The high values of the calculated k_{eff} values for UH3-UR and HISS(HUG) using ENDF/B-VI cross sections tend to support the need to increase the ^{235}U capture resonance integral.

4.3 Shielding Benchmarks

Several integral shielding benchmarks were identified as useful for testing the VITAMIN-B6 and BUGLE-93 cross-section libraries. These benchmarks are listed in Table 4.10. Unlike the reactor physics benchmarks, even the relatively simple shielding benchmarks tend to have complex source descriptions and geometry models which often require multidimensional analyses. Also, several of the benchmark experiments contain multiple configurations involving different materials and multiple types of detector responses. Hence, analysis of the shielding benchmarks can require a substantial effort. For this project, only a limited set of configurations and measurements were evaluated.

Table 4.10 Shielding benchmarks used for data testing

Cross Section Evaluation Working Group Benchmarks:

"Broomstick" Experiments for Iron, Oxygen, Nitrogen, Sodium, and Stainless Steel. (SDT1-5)

Secondary Gamma-ray Production for Thermal Neutron Spectrum. (SB2)

Secondary Gamma-ray Production for Fast Neutron Spectrum. (SB3)

ORNL Benchmark for Iron and Stainless Steel. (SDT-11)

Nuclear Energy Agency Committee on Reactor Physics Benchmarks:

Winfrith Iron Benchmark Experiment.

Winfrith Water Benchmark Experiment.

PWR Shielding Benchmark (Computational).

LMFBR Shielding Benchmark (Computational).

Other Relevant Benchmarks:

University of Illinois Iron Sphere Benchmarks (14 MeV and ^{252}Cf).

Pool Critical Assembly (PCA) Blind Test Benchmark.

Winfrith NESDIP2 Radial Shield Experiment.

LWR Shielding Benchmark (Computational).

It should be noted also that calculated-to-measured results for many of the benchmarks could have been substantially improved with further refinements in the methodology, such as additional spatial weighting of the cross sections. Since the intent here is primarily to compare the various cross-section data sets rather than analyze the benchmarks to the fullest extent, the emphasis was placed on using data sets which were processed in a consistent manner. The impact of using more refined processing of the cross sections was demonstrated for a few selected benchmarks configurations.

As shown in Table 4.10, the benchmarks are divided into three categories. The first two categories represent benchmarks which have been reviewed and accepted by either the Cross Section Evaluation Working Group (CSEWG) or the Nuclear Energy Agency Committee on Reactor Physics (NEACRP) for the purpose of testing nuclear data and numerical methods. The third category represents additional benchmarks which have been generally accepted and are especially relevant in assessing the quality and adequacy of the BUGLE-93 library. For most of the benchmarks, three types of comparisons were made: (1) results based on VITAMIN-E and VITAMIN-B6 data to demonstrate the impact of using ENDF/B-VI data, (2) results based on VITAMIN-B6 and BUGLE-93 data to demonstrate the impact of using broad-group cross sections, and (3) results based on BUGLE-80 and BUGLE-93 data to show the combined impact of the new broad-group library.

4.3.1 Cross Section Evaluation Working Group Benchmarks

4.3.1.1 SDT1-4: The first set of CSEWG shielding benchmarks used for this project are the "Broomstick" experiments, which were actually analyzed shortly after the release of ENDF/B-VI and have been reported earlier.[23] These experiments, which give a direct measurement of the total cross section, can be analyzed without processing of the evaluated data except to extract the pointwise total cross-section values and to group the cross-section values into the energy bins prescribed in the benchmark specifications reports. Five Broomsticks were analyzed: two iron samples,[24] oxygen,[25] nitrogen,[26] and sodium.[27] Originally, these tests were valuable for improving the total cross section for numerous materials; however, their value has diminished in recent years due to the relatively coarse energy resolution of the measurements and the relative stability in the total cross section for these materials. The Broomsticks do continue to be useful as a check against format errors in the evaluated files. As such, ENDF/B-VI successfully passed these tests. Only minor differences were observed between the Version VI and Version V results.

4.3.1.2 SB2: The second set of CSEWG shielding benchmarks consists of measurements of the gamma-ray spectra arising from thermal-neutron capture in several samples of pure materials.[28] The measured capture spectrum from each sample was summed over 0.5-MeV bins and converted to a production cross section based on the tabulated radiative capture cross section at 0.0253 eV. No transport calculations are needed to analyze the experiments; instead, calculations consist of binning the thermal-neutron capture gamma-ray spectra into the same energy groups in which the measurements were reported. This was done for the VITAMIN-B6 group number 193, which ranges from 0.021 to 0.03 eV (E_{mid} = 0.0255 eV).

Comparisons of measured and calculated gamma-ray production cross sections are given in Tables 4.11 and 4.12. The reported accuracy in the measurements is 15%. There is considerable spread in the results, which could be due to several factors, including: (1) the accuracy of the 0.0253-eV radiative capture cross section used to normalize the measurements, (2) the manner in which gamma-ray lines on or near the group boundaries are treated, and (3) the width of the thermal-neutron group used to generate the calculated production cross sections. Further investigation is needed to resolve the differences.

4.3.1.3 SB3: The third set of CSEWG shielding benchmarks is similar to the SB2 benchmarks except that the secondary gamma-ray spectra were measured for a fast-neutron incident spectrum.[29] Comparisons of measured and calculated gamma-ray production cross sections are given in Tables 4.13 and 4.14. As with the thermal-neutron-induced data, the fast-neutron-induced results show tremendous variation. However, for groups which contain significant numbers of secondary gamma rays, the agreement between the measured and calculated cross sections is generally within the 30% accuracy quoted for the measurements.

4.3.1.4 SDT11: The fourth and final CSEWG shielding benchmark used in this project is the ORNL iron and stainless steel experiment.[30] As with the preceding benchmarks, the SDT11 experiment was performed at the Tower Shielding Facility (TSF) and included measurements of both the neutron fluence and neutron spectra behind thick slabs of iron and stainless steel. Various thicknesses of iron or stainless steel were placed in the collimated beam, but only the 30-cm-thick samples were analyzed here. The analysis was performed using the GRTUNCL,[31] code to compute the first collision source from the reactor, the DORT code to transport the neutrons through the shield samples, and the FALSTF[32] code to calculate the detector responses at distant locations from the shield samples. Comparisons were made for several detectors and for measurements made both on the beam centerline and off-centerline. When comparing calculated spectra with measured NE-213 or Benjamin counter spectra, the calculated spectra were smoothed with the approximate energy resolution of the detectors.

The measured fast-neutron spectrum behind a 30-cm-thick iron slab is compared in Fig. 4.4 to results calculated with VITAMIN-E and VITAMIN-B6 data. The VITAMIN-B6 data yield slightly better agreement with the measurement between 3.5 and 5.5 MeV. Figure 4.5 compares BUGLE-93 and BUGLE-80 results to the same measurement, which shows a somewhat greater improvement with the newer data. The dominant feature of the comparisons, however, is the significant underprediction of the measurement below 4 MeV. It is felt that this is due to an underprediction of the uncollided flux resulting from the narrow, deep windows in the iron total cross section. This conclusion is supported by several observations, including comparisons of the neutron spectrum off-centerline, in which the uncollided flux is relatively unimportant. Figure 4.6 shows that excellent agreement was achieved between the fine-group calculations and the measured spectrum at the off-centerline location. These results suggest that even the fine-group cross sections may be inadequate for deep penetration in iron, especially for highly directed sources.

Comparisons of measurements and calculations for several integral detectors are given in Table 4.15 for both the 30-cm-thick iron slab and the 30-cm-thick stainless steel slab. Both on-centerline and

Table 4.11 Calculated-to-experiment ratios for gamma-ray production cross sections from thermal-neutron capture in Fe, SS, N, Na, Al, and Cu

Gamma-ray Energy (MeV)	Iron	Stainless Steel	Nitrogen	Sodium	Aluminum	Copper
1.5 - 2.0	0.87	1.08	0.86	0.63	0.74	0.60
2.0 - 2.5	1.65	1.15	--	0.92	0.82	0.57
2.5 - 3.0	1.59	1.76	0.92	0.91	1.02	0.37
3.0 - 3.5	1.29	1.18	--	1.20	1.16	0.54
3.5 - 4.0	0.94	0.98	0.89	1.08	1.06	0.68
4.0 - 4.5	1.25	1.17	--	0.44	1.08	1.07
4.5 - 5.0	1.41	1.29	0.92	0.19	1.20	0.77
5.0 - 5.5	1.86	0.86	0.89	0.42	1.10	1.36
5.5 - 6.0	0.96	0.78	0.86	1.06	1.04	1.03
6.0 - 6.5	0.90	0.96	0.94	1.04	0.99	0.99
6.5 - 7.0	0.93	0.55	--		0.56	1.24
7.0 - 7.5	0.93	0.99	0.95		--	0.94
7.5 - 8.0	1.04	1.02	--		1.07	0.96
8.0 - 10.0	1.05[a]	1.09	0.88			
> 10.0			0.90			

[a] For energies > 8.0 MeV.

Table 4.12 Calculated-to-experiment ratios for gamma-ray production cross sections from thermal-neutron capture in Ti, Ca, K, Si, Ni, and S

Gamma-ray Energy (MeV)	Titanium	Calcium	Potassium	Silicon	Nickel	Sulfur
1.5 - 2.0	0.82	1.01[b]	1.09	--	1.49	1.03
2.0 - 2.5	1.19	--	0.57	1.17	0.90	1.03
2.5 - 3.0	0.70	0.64	0.84	0.35	0.38	1.03
3.0 - 3.5	1.31	0.15	1.05	0.49	0.53	1.03
3.5 - 4.0	1.26	0.83	0.66	1.00	0.60	1.02
4.0 - 4.5	1.30	1.02	0.95	--	0.78	1.03
4.5 - 5.0	1.21	0.98	0.58	0.94	0.68	1.03
5.0 - 5.5	2.68	0.12	0.86	0.80	0.49	1.03
5.5 - 6.0	1.58	0.70	0.96	--	0.33	1.03
6.0 - 6.5	1.09	1.32	--	1.19	0.50	1.03
6.5 - 7.0	1.04		--	1.67	0.32	1.03
7.0 - 7.5	0.37		6.11	0.97	1.95	1.03
7.5 - 8.0	—		1.10	--	1.25	1.03
8.0 - 10.0	0.40[a]			1.40[a]	1.09	1.03
> 10.0						

[a] For energies > 8.0 MeV.
[b] For energy range 1.5 - 2.5 MeV.

Table 4.13 Calculated-to-experiment ratios for gamma-ray production cross sections from fast-neutron capture in Fe, SS, O, Na, Al, and Cu

Gamma-ray Energy (MeV)	Iron	Stainless Steel	Oxygen	Sodium	Aluminum	Copper
1.5 - 2.0	0.59	0.63	--	0.78	0.73	0.68
2.0 - 2.5	0.78	0.86	--	0.90	0.95	0.97
2.5 - 3.0	0.86	1.03	--	0.73	1.23	0.86
3.0 - 3.5	0.74	0.77	--	0.74	0.99	0.99
3.5 - 4.0	0.96	1.09	--	0.76	0.77	0.79
4.0 - 4.5	1.31	1.27	--	1.03	0.85	0.70
4.5 - 5.0	1.42	1.28	--	0.49	1.01	0.73
5.0 - 5.5	1.26	0.88	--	0.98	0.68	0.64
5.5 - 6.0	1.16	0.87	--	0.87	1.39	>0.57
6.0 - 6.5	>0.77	>0.59	1.66[a]	0.40	>0.64	>0.31
6.5 - 7.0	>1.62	>0.30	1.60[b]	0.89	>0.72	
7.0 - 7.5	>0.38				>1.42	

[a] For 6.13 MeV gamma ray.
[b] For 6.92 + 7.12 MeV gamma rays.

Table 4.14 Calculated-to-experiment ratios for gamma-ray production cross sections from fast-neutron capture in Ti, Ca, K, Si, Ni, and S

Gamma-ray Energy (MeV)	Titanium	Calcium	Potassium	Silicon	Nickel	Sulfur
1.5 - 2.0	0.95	0.54	0.13	0.89	0.46	0.21
2.0 - 2.5	0.85	1.55	0.15	0.66	0.73	0.98
2.5 - 3.0	1.03	0.69	0.98	1.26	0.79	0.51
3.0 - 3.5	1.37	0.92	1.03	1.05	1.12	0.19
3.5 - 4.0	0.94	1.76	1.30	0.14	0.84	0.99
4.0 - 4.5	1.11	0.69	0.37	2.57	0.72	0.78
4.5 - 5.0	1.02	0.54	1.68	0.37	1.02	0.18
5.0 - 5.5	>0.66	2.17	0.51	1.54	>0.61	0.37
5.5 - 6.0	>0.56	>0.91	0.32	0.41	>0.51	>0.11
6.0 - 6.5	>0.39	>0.15	>0.08	>0.39	>0.33	>0.37
6.5 - 7.0		>0.49	>0.06	>0.51		>0.16
7.0 - 7.5			>0.02	>0.35		>0.24

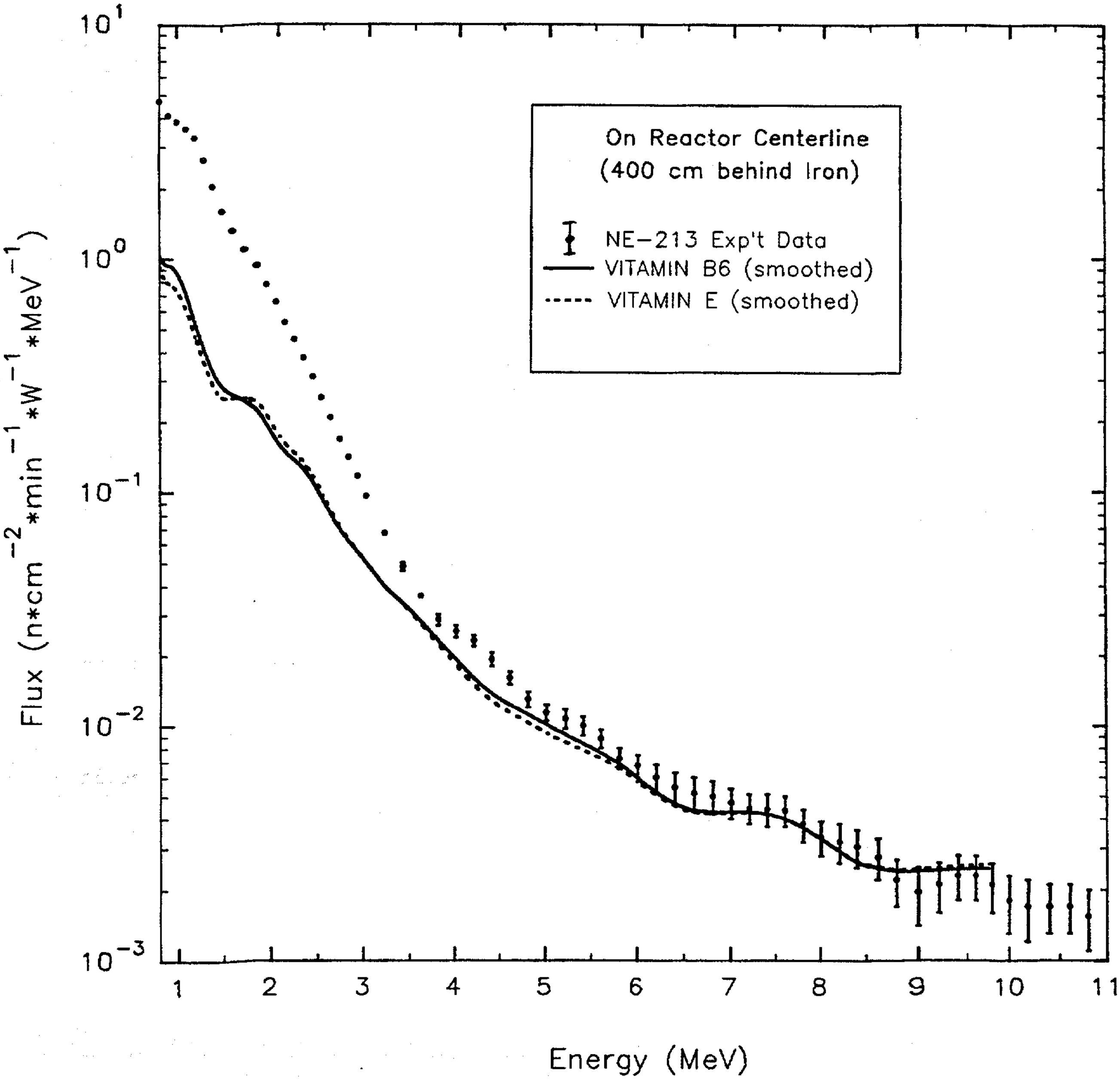


Fig. 4.4 VITAMIN-B6 and VITAMIN-E calculations compared to measured fast neutron spectrum on reactor beam centerline behind 30.5 cm iron slab in SDT11 shielding benchmark. Calculations (solid and dotted lines) have been smoothed with detector resolution

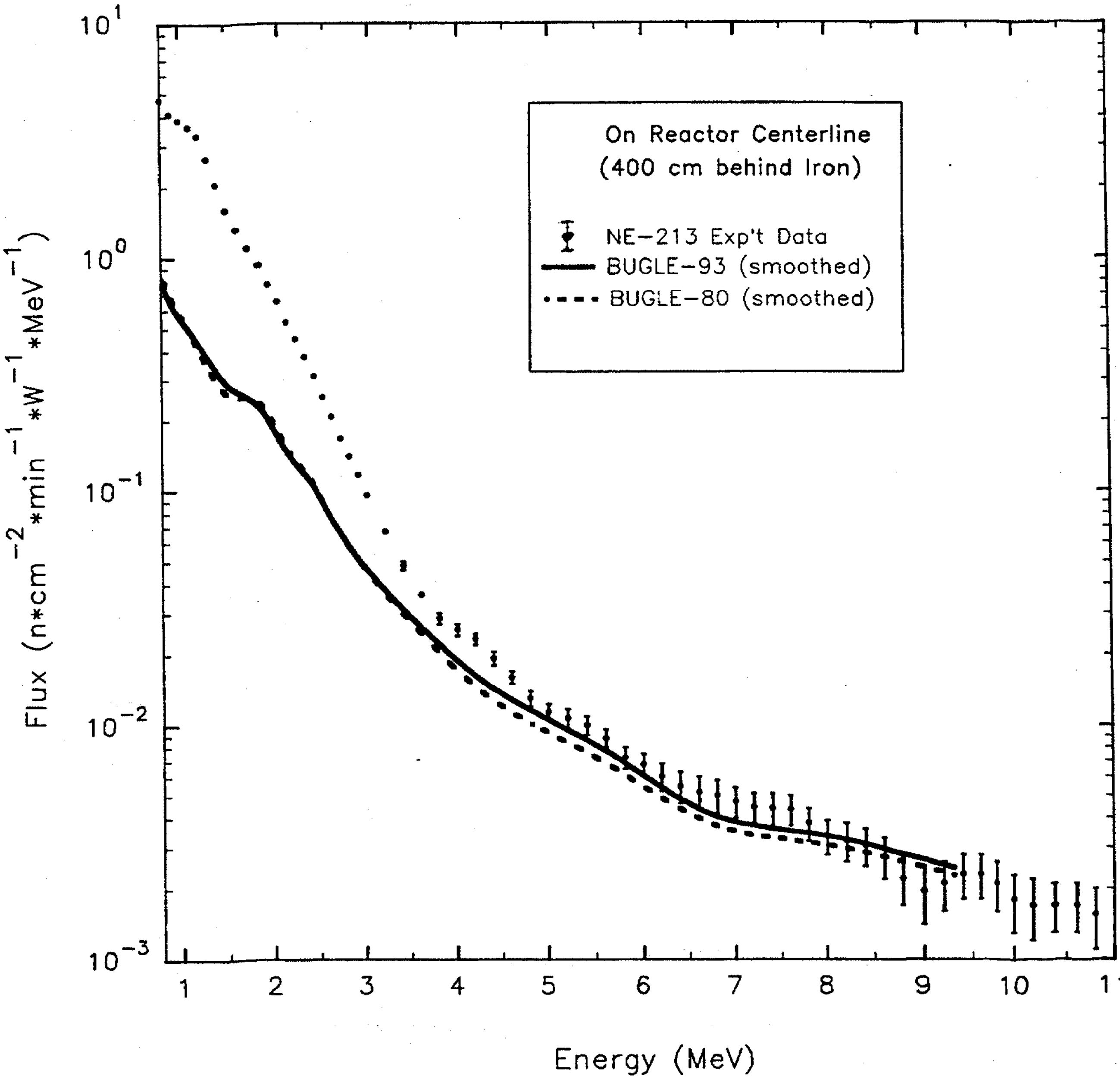


Fig. 4.5 BUGLE-93 and BUGLE-80 calculations compared to measured fast neutron spectrum on reactor beam centerline behind 30.5 cm iron slab in SDT11 shielding benchmark. Calculations (solid and dotted lines) have been smoothed with detector resolution

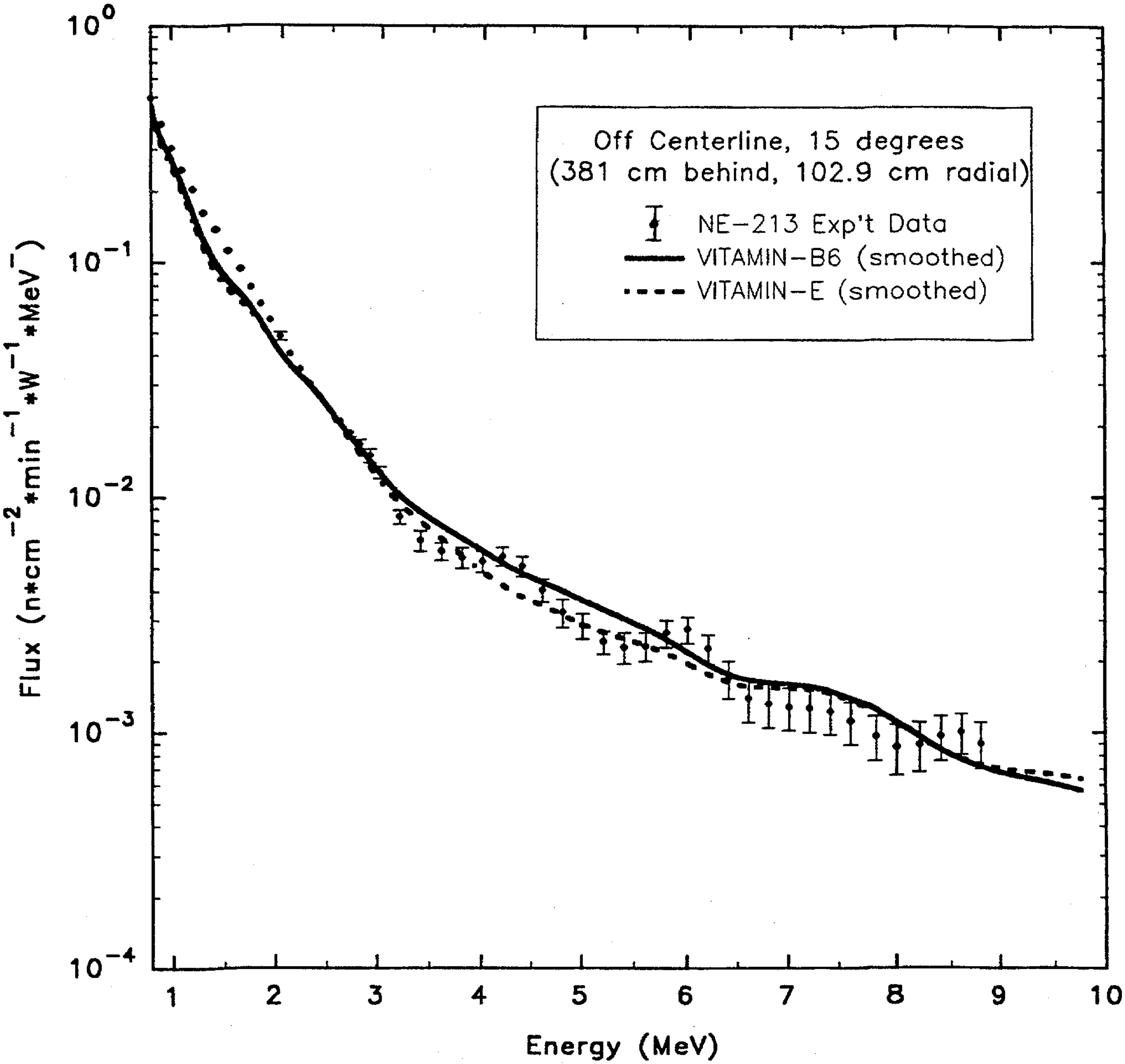


Fig. 4.6 VITAMIN-B6 and VITAMIN-E calculations compared to measured fast neutron spectrum off-centerline behind 30.5 cm iron slab in SDT11 shielding benchmark. Calculations (solid and dotted lines) have been smoothed with detector resolution.

Table 4.15 Calculated-to-experiment ratios for various detectors behind 30 cm iron from SDT11 benchmark

Location	Cross-Section Set			
	BUGLE-80	BUGLE-93	VITAMIN-E	VITAMIN-B6
Integrated NE-213:				
Fe, 15° OC[a]	0.71	0.82	0.73	0.81
Integrated Benjamin Counter:				
Fe, CL[b]	0.80	0.80	0.83	0.76
Fe, 15° OC	1.00	1.00	1.05	0.95
SS, CL	1.04	1.04	0.94	0.98
SS, 15° OC	0.94	1.09	1.11	1.03
3" Bonner Ball:				
Fe, CL	0.38	0.66	0.47	0.40
Fe, 15° OC	0.87	0.85	0.91	0.90
SS, CL	0.57	0.58	0.61	0.62
SS, 15° OC	0.82	0.83	0.85	0.88
6" Bonner Ball:				
Fe, CL	0.29	0.33	0.35	0.32
Fe, 15° OC	0.92	0.89	0.94	0.94
SS, CL	0.54	0.53	0.57	0.57
SS, 15° OC	0.96	0.94	0.96	0.98
10" Bonner Ball:				
Fe, CL	0.22	0.23	0.25	0.25
Fe, 15° OC	0.52	0.52	0.52	0.54
SS, CL	0.43	0.43	0.44	0.45
SS, 15° OC	0.82	0.81	0.80	0.83

[a] Off-centerline.
[b] On beam centerline.

off-centerline measurements are compared to calculations using four different cross-section sets. It is interesting to note that all four data sets yield nearly the same result for all cases except the integrated NE-213 spectrum. In some cases, the older ENDF/B-IV and -V data give slightly larger C/Es. This is due to two changes in the ENDF/B-VI iron cross section relative to the older versions: (1) the reduced continuum inelastic cross section between 3 and 10 MeV results in greater penetration of neutrons in this energy range, and (2) the larger total cross section just below the deep window in the cross section at 24 keV results in a reduced penetration of neutrons in the energy range of 10 to 24 keV. Only the former change is relevant to the NE-213 spectrum since it has a threshold of approximately 1 MeV.

4.3.2 Nuclear Energy Agency Committee on Reactor Physics Benchmarks

4.3.2.1 Winfrith Iron Experiment: The Winfrith Iron Experiment[34] measured fission neutron transmission through a thick iron shield. The shield consisted of 24 5.08-cm-thick iron plates spaced 6.35 mm apart. Fission neutrons were produced in a natural uranium converter plate which preceded the shield and was powered by graphite-moderated neutrons from the NESTOR reactor. Neutron spectra were measured at four locations using NE-213 detectors placed in 5.08-cm-wide by 105.5-cm-deep slots cut in special iron plates. In addition, activation foil measurements were made in the gaps between the iron plates.

Calculations for the experiment were performed with DORT using infinitely dilute, standard weighted fine- and broad-group cross sections. Additional calculations were performed using self-shielded, fine-group cross sections and broad-group cross sections which were collapsed using calculated fine-group spectra at several internal zones within the iron shield. Calculated and measured neutron spectra at 76.2 cm into the shield are presented in Fig. 4.7 for the fine-group calculations and Fig. 4.8 for the broad-group calculations.

As expected, the calculated results obtained using the self-shielded, VITAMIN-B6 fine-group and the zone-weighted, BUGLE-93 broad-group cross sections are in better agreement with the measured spectrum than are those obtained using the infinitely dilute cross sections. Integrals of the calculated neutron spectra at four locations are compared with integrals of the measured spectra in Table 4.16. At 20.32 cm depth into the shield, the broad-group libraries and the self-shielded, VITAMIN-B6 library gave calculated integral fluxes about 30% higher than measured, while the standard-weighted, fine-group libraries (VITAMIN-E and VITAMIN-B6) overpredicted the measurement by about 10%. All libraries underpredict the measured result at greater distances into the shield by an increasing amount. At 101.6 cm into the shield, the concrete-weighted BUGLE-93 library underpredicted the measured integral flux by greater than a factor of 6. Self-shielding and zone-weighting the cross sections reduced this underprediction to about a factor of 2, thus showing the importance of proper processing for deep penetration problems.

Calculated and measured activations are compared in Table 4.17. The high-energy $^{32}S(n,p)$ reaction is affected less by self-shielding than are the $^{103}Rh(n,n')$ and $^{115}In(n,n')$ reactions. For the latter two reactions, whose response functions span the iron resonance regions, self-shielding has a large effect on results at deep penetrations. The

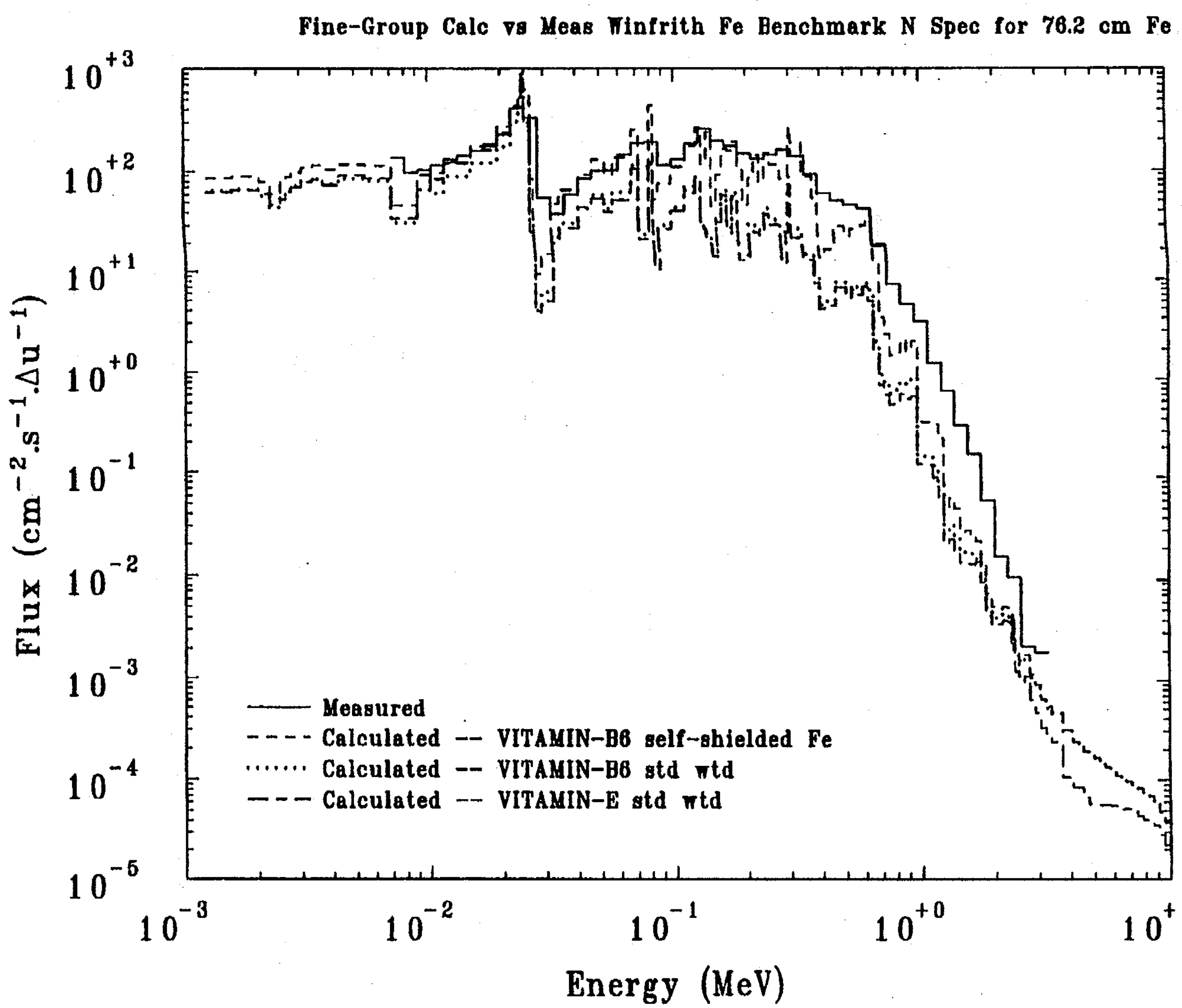


Fig. 4.7 Fine-group calculations compared to measured neutron spectrum for an iron thickness of 76.2 cm in the Winfrith Iron Experiment

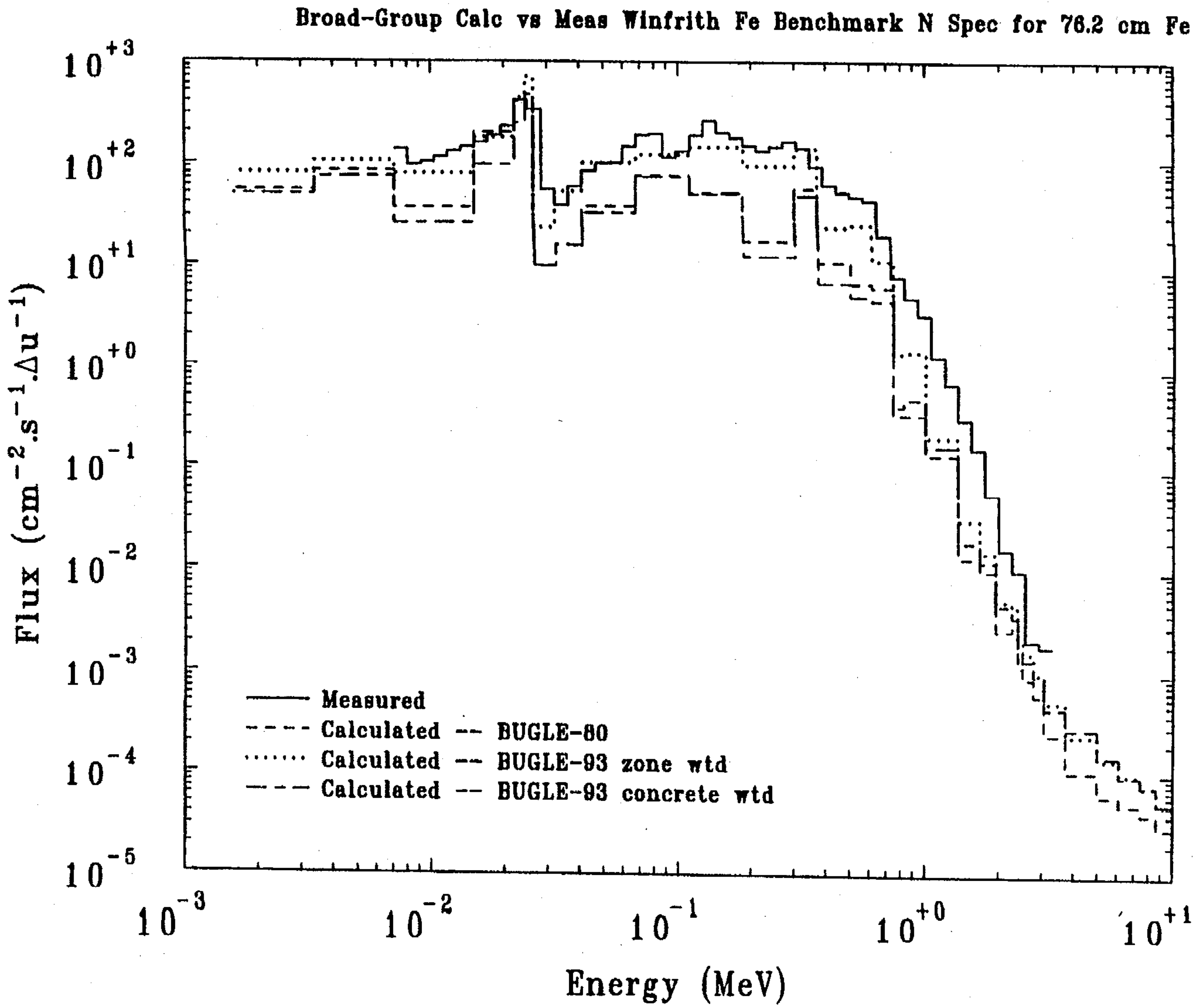


Fig. 4.8 Broad-group calculations compared to measured neutron spectrum for an iron thickness of 76.2 cm in the Winfrith Iron Experiment

Table 4.16 Calculated-to-experiment ratios for integrated neutron flux[a] from Winfrith Iron Benchmark

Cross section set	Iron Thickness (cm)			
	20.32	50.8	76.2	101.6
BUGLE-80 (concrete weighted)	1.28	0.73	0.46	0.24
BUGLE-93 (concrete weighted)	1.30	0.62	0.34	0.15
BUGLE-93 (spatial weighted)	1.28	0.95	0.80	0.52
VITAMIN-E (standard weighted)	1.09	0.69	0.48	0.29
VITAMIN-B6 (standard weighted)	1.12	0.65	0.42	0.21
VITAMIN-B6 (Fe self-shielded)	1.28	0.98	0.87	0.62

[a] Energy range: 52.5 keV < E < 4.72 MeV at 20.32 cm
7.1 keV < E < 4.72 MeV at 50.8 cm
7.1 keV < E < 3.25 MeV at 76.2 cm
9.1 keV < E < 1.97 MeV at 101.6 cm

Table 4.17 Calculated-to-experiment ratios for dosimeter reactions from Winfrith Iron Benchmark

Cross section set	Iron Thickness (cm)			
	20.32	35.56	50.8	60.96
$^{32}S(n,p)$:				
BUGLE-80 (concrete weighted)	0.88	0.80	0.60	0.51
BUGLE-93 (concrete weighted)	1.06	1.06	0.89	0.79
BUGLE-93 (spatial weighted)	1.06	1.09	0.92	0.84
VITAMIN-E (standard weighted)	0.87	0.79	0.60	0.51
VITAMIN-B6 (standard weighted)	1.04	1.04	0.86	0.76
VITAMIN-B6 (Fe self-shielded)	1.06	1.08	0.91	0.82
	Iron Thickness (cm)			
	20.32	50.8	76.2	101.6
$^{103}Rh(n,n')$:				
BUGLE-80 (concrete weighted)	1.03	0.63	0.27	0.09
BUGLE-93 (concrete weighted)	1.04	0.58	0.23	0.07
BUGLE-93 (spatial weighted)	1.18	1.09	0.73	0.39
VITAMIN-E (standard weighted)	0.93	0.48	0.18	0.05
VITAMIN-B6 (standard weighted)	0.96	0.52	0.20	0.06
VITAMIN-B6 (Fe self-shielded)	1.17	1.11	0.79	0.45
	Iron Thickness (cm)			
	20.32	30.48	45.72	55.88
$^{115}In(n,n')$:				
BUGLE-80 (concrete weighted)	0.86	0.77	0.49	0.37
BUGLE-93 (concrete weighted)	0.91	0.81	0.48	0.34
BUGLE-93 (spatial weighted)	1.00	0.99	0.75	0.65
VITAMIN-E (standard weighted)	0.81	0.68	0.38	0.26
VITAMIN-B6 (standard weighted)	0.87	0.75	0.43	0.31
VITAMIN-B6 (Fe self-shielded)	0.99	0.96	0.71	0.62

calculated $^{115}In(n,n')$ activation shows a greater underprediction than do the $^{103}Rh(n,n')$ results.

4.3.2.2 Winfrith Water Experiment: The Winfrith Water Experiment[35] measured fission neutron transmission through varying thicknesses of iron. The configuration consisted of one, two, four, or eight small ^{252}Cf sources suspended in a water tank at seven distances from the centerline of a voided 7.51-cm-OD, 0.404-cm-thick stainless steel tube. Neutron spectra were measured within the tube at the axial midplane of the sources. Also, $^{32}S(n,p)$ activities were measured along the tube centerline at the source axial midplane and at 15 and 30 cm above and below the midplane.

Two-dimensional calculations were performed using DORT with an R-Z geometry model. The calculational model provided in Ref. 34 was used, which modeled the source as a 1.9-cm-thick by 0.46-cm-high smeared ring centered at the source radius. The initial set of calculations using each of the various cross-section libraries used a P_3 Legendre expansion and a symmetric S_{16} angular quadrature. However, it was observed that the nearly point nature of the source generated ray effects and caused the responses at the axial midplane to be artificially depressed. A recalculation using the BUGLE-80 and BUGLE-93 cross-section libraries and a biased 240-angle quadrature resulted in a substantial improvement in the comparisons, both on and off the axial midplane. Tables 4.18 and 4.19 show comparisons of calculated and measured fast-neutron fluxes and $^{32}S(n,p)$ activities at the radial center of the axial midplane. As mentioned, calculations using the S_{16} quadrature underestimate the integrated flux by 20 to 30%. Using the biased quadrature, the underestimation is reduced to 10-20%. In the case of sulfur activation, the biased quadrature yielded excellent results, overpredicting the measurements by only 0-5%.

Figure 4.9 compares the measured neutron flux with calculations based on BUGLE-80 and BUGLE-93 data and using the biased 240-angle quadrature. In this comparison, the source is at a radius of 30.48 cm. The calculated results appear to underpredict the measured results below 5 MeV and generally overpredict the measurement above 6 MeV. The two data sets are in close agreement, although the BUGLE-93 results appear to be a slight improvement, especially below 5 MeV.

4.3.3 Other Relevant Benchmarks

4.3.3.1 Univ. of Illinois Iron Sphere: Two benchmark experiments were conducted at the University of Illinois using a large sphere of iron.[36-37] The 38.1-cm-radius sphere had a 7.65-cm-radius cavity at the center, in which was placed either an encapsulated californium (^{252}Cf) fission source or a deuterium-tritium (D-T) fusion source. The fast neutron leakage from the 30.5-cm-thick iron shell was measured using a NE-213 proton recoil spectrometer at 200 cm from the center of the sphere. The measured leakage spectrum from the ^{252}Cf source is compared to calculated one-dimensional results in Fig. 4.10 for the fine-group cross sections and Fig. 4.11 for the broad-group cross sections. As shown in Fig.4.10, there is a general improvement using the VITAMIN-B6 library relative to VITAMIN-E for energies above 3 MeV. Similarly, the BUGLE-93 results in Fig. 4.11 show an increase over BUGLE-80 in the calculated flux for energies above 1 MeV, which more closely matches the experimental results. Improvements in the calculated spectra are even more noticeable with the D-T fusion source, as shown in Figs. 4.12 and 4.13.

Table 4.18 Calculated-to-experiment ratios for integral neutron flux (0.9 MeV > E > 10 MeV) for the Winfrith Water Experiment

Source Radius (cm)	Cross-Section Set				
	BUGLE-80[a]	BUGLE-93[a]	VITAMIN-E[a]	VITAMIN-B6[a]	BUGLE-93[b]
10.16	0.80	0.83	0.81	0.83	0.93
15.24	0.69	0.72	0.69	0.72	0.92
20.32	0.68	0.72	0.68	0.71	0.89
25.40	0.67	0.70	0.66	0.70	0.84
30.48	0.69	0.71	0.67	0.71	0.82
35.56	0.73	0.76	0.72	0.75	0.84
50.80	0.78	0.78	0.76	0.78	0.79

[a] With symmetric S_{16} (160 angle) quadrature and P_3 Legendre expansion.
[b] With biased 240-angle quadrature and P_5 Legendre expansion.

Table 4.19 Calculated-to-experiment ratios for $^{32}S(n,p)$ activity for the Winfrith Water Experiment

Source Radius (cm)	Cross-Section Set				
	BUGLE-80[a]	BUGLE-93[a]	VITAMIN-E[a]	VITAMIN-B6[a]	BUGLE-93[b]
10.16	0.82	0.87	0.81	0.86	1.00
15.24	0.65	0.69	0.64	0.68	1.05
25.40	0.69	0.72	0.66	0.70	1.06
30.48	0.71	0.73	0.69	0.72	1.01
35.56	0.75	0.77	0.73	0.75	0.99

[a] With symmetric S_{16} (160 angle) quadrature and P_3 Legendre expansion.
[b] With biased 240-angle quadrature and P_5 Legendre expansion.

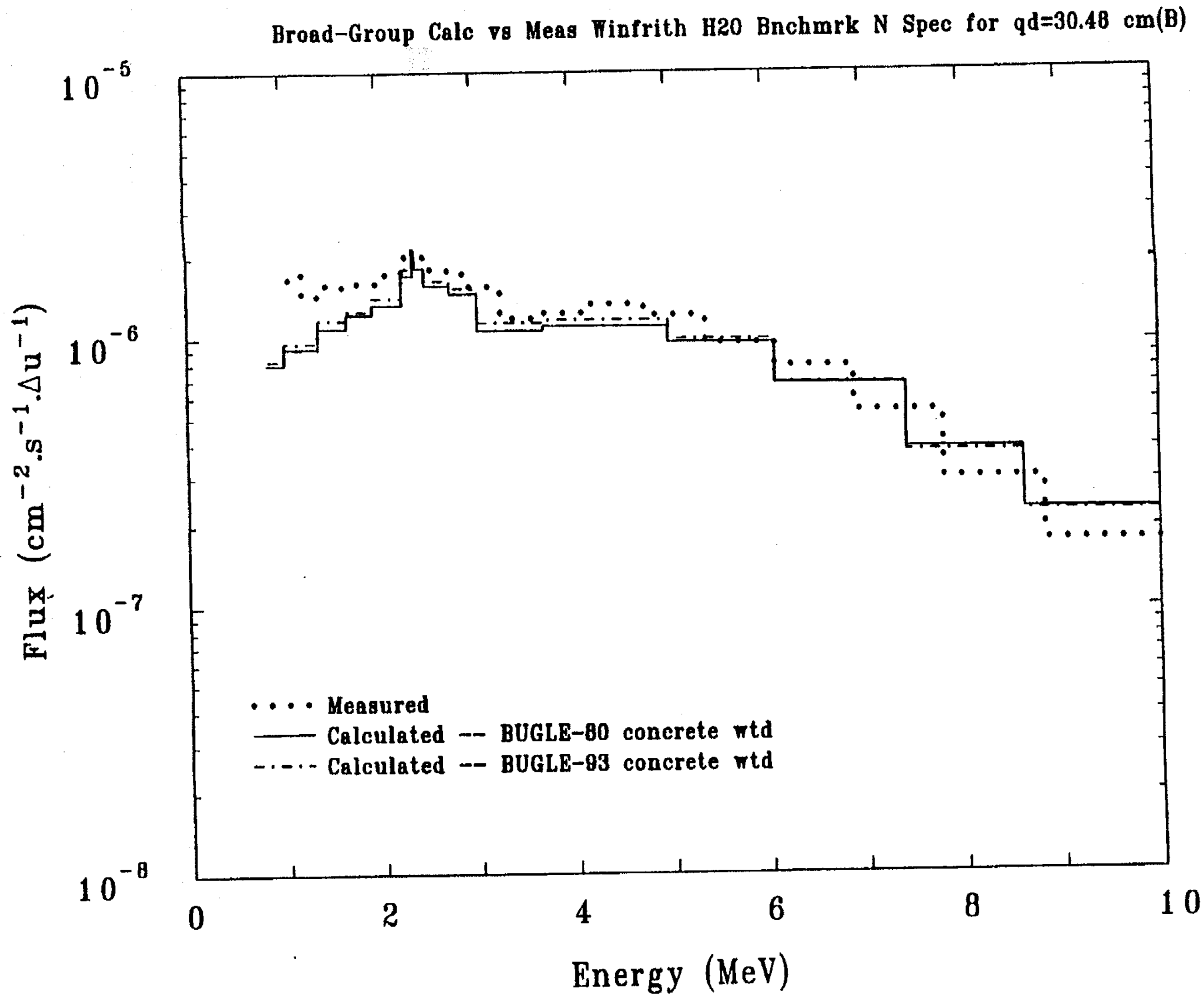


Fig. 4.9 Comparison of broad-group calculated flux spectra and measured flux spectrum due to ^{252}Cf point sources at 30.48 cm radius in the Winfrith Water Experiment.

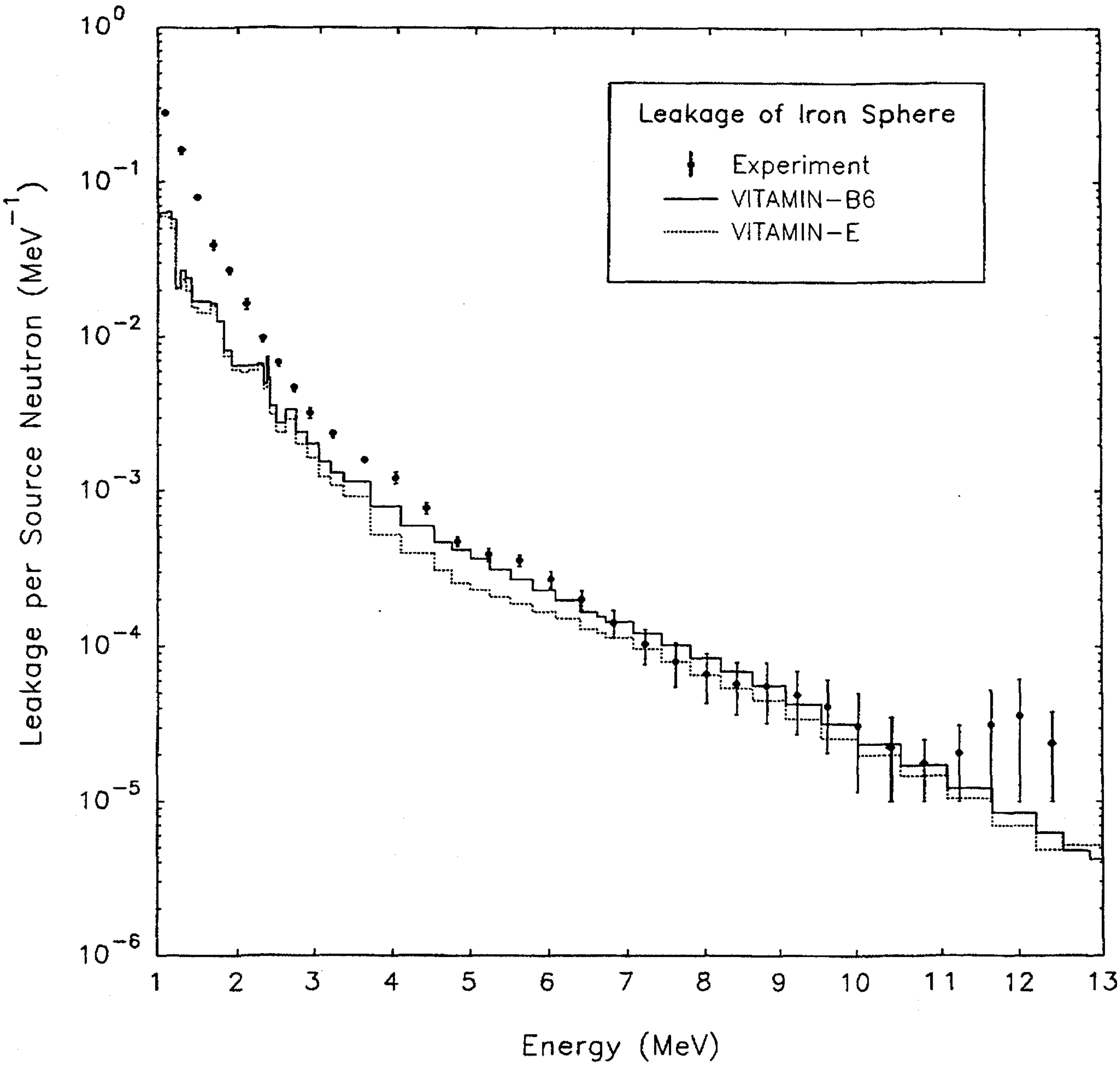


Fig. 4.10 Fine-group calculations compared to measured neutron leakage from ^{252}Cf fission source in the Univ. of Ill. iron sphere

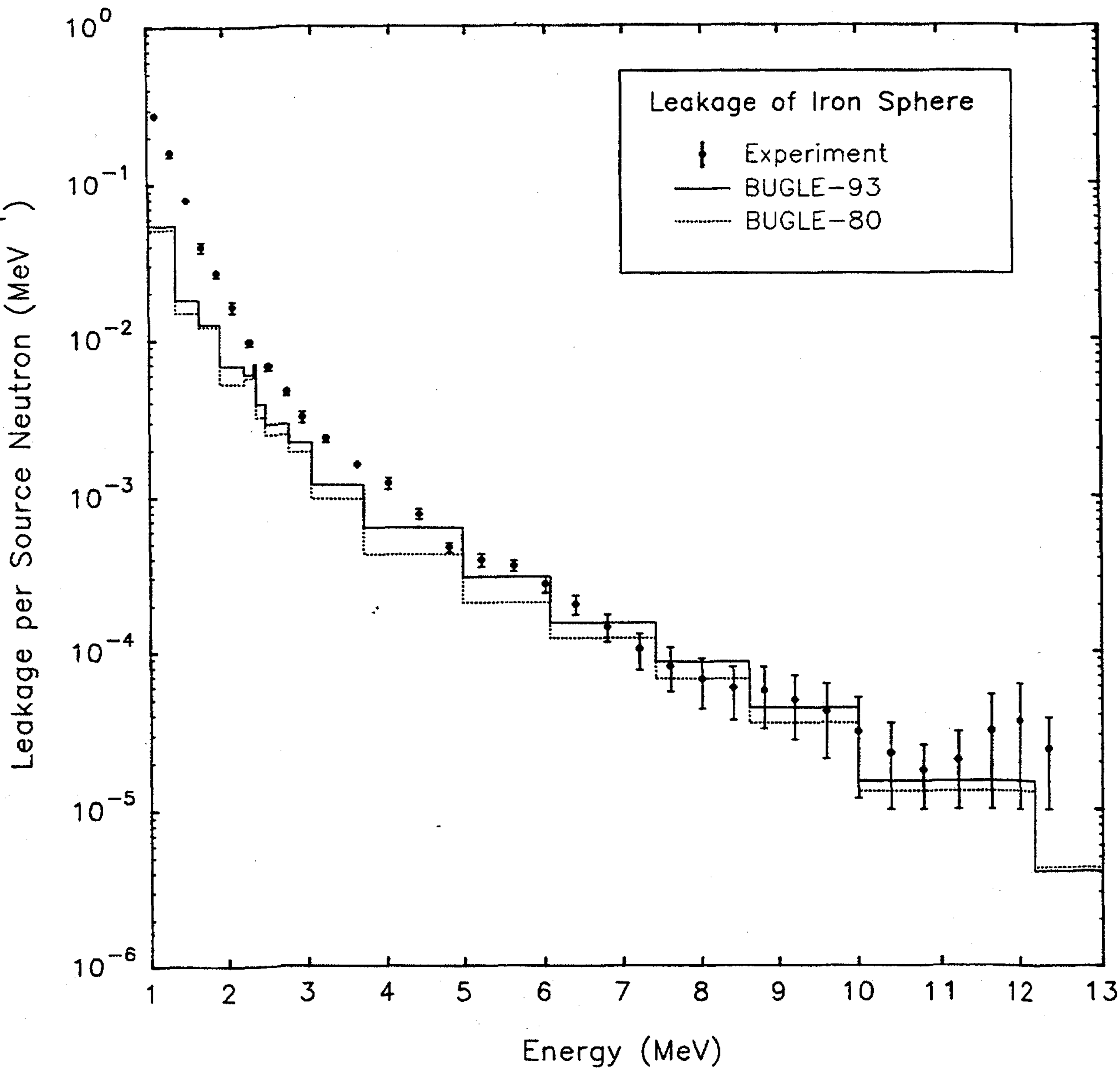


Fig. 4.11 Broad-group calculations compared to measured neutron leakage from ^{252}Cf fission source in the Univ. of Ill. iron sphere

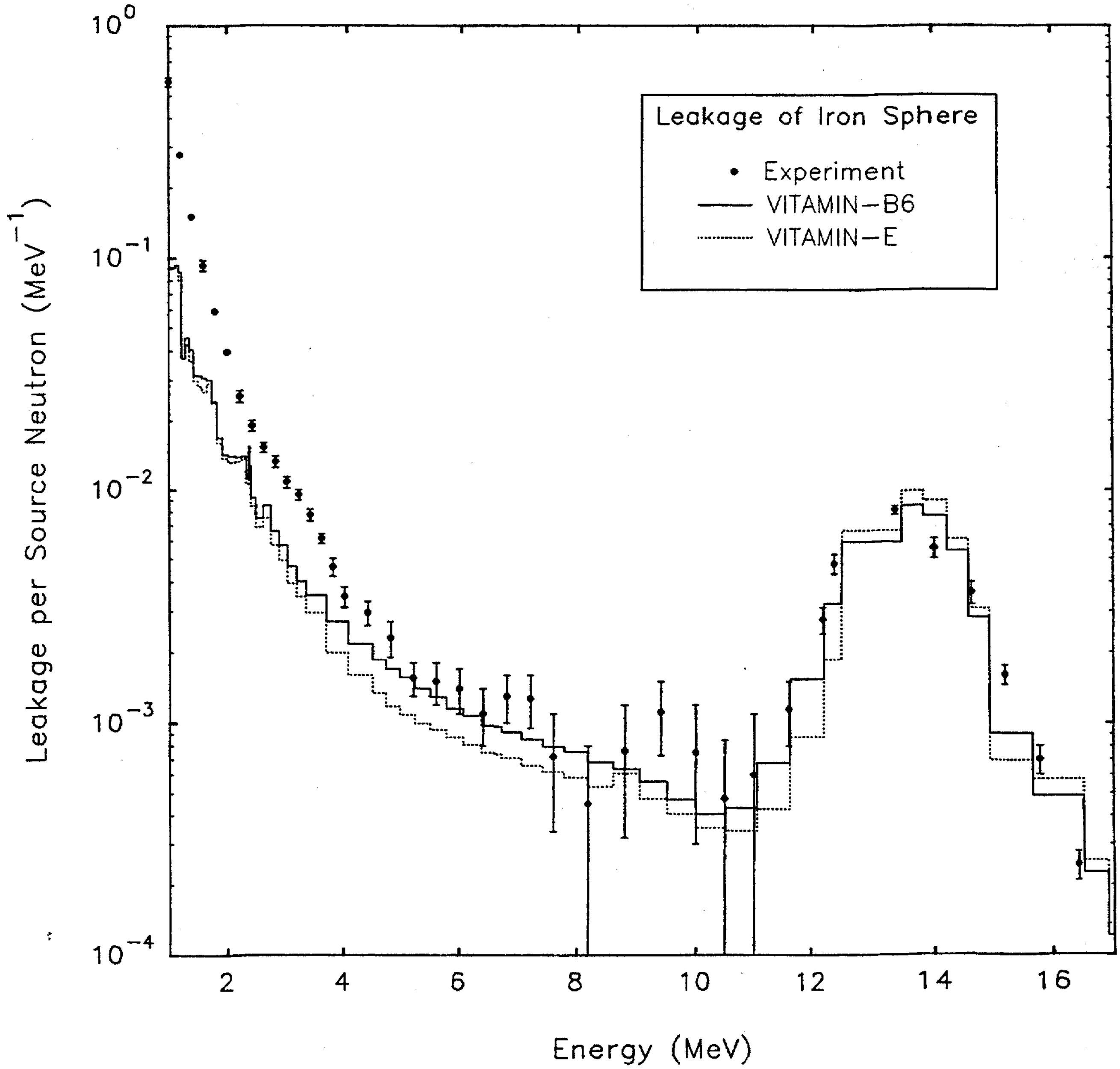


Fig. 4.12 Fine-group calculations compared to measured neutron leakage from D-T fusion source in the Univ. of Ill. iron sphere

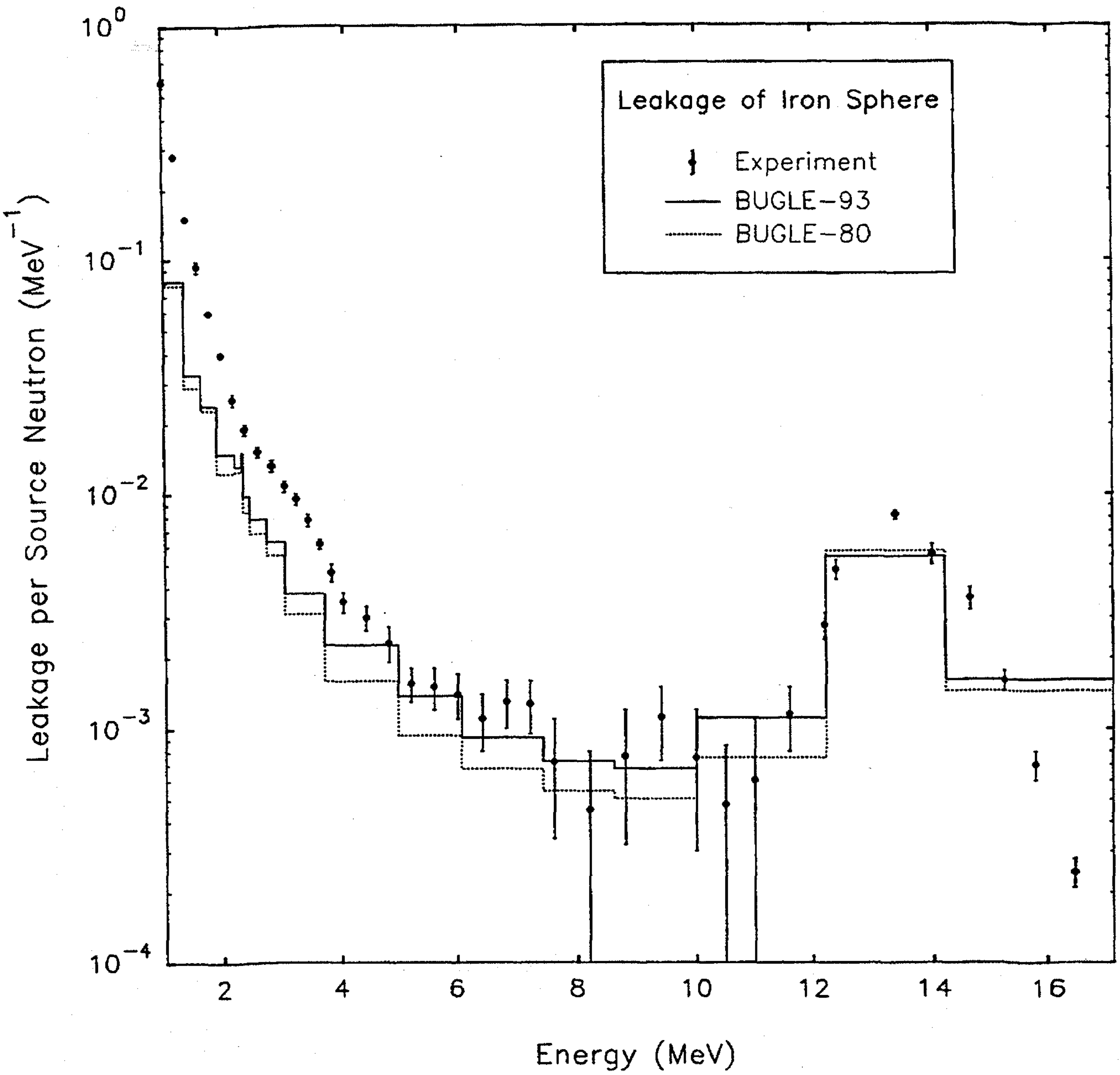


Fig. 4.13 Broad-group calculations compared to measured neutron leakage from D-T fusion source in the Univ. of Ill. iron sphere

4.3.3.2 PCA Blind Test: The Pool Critical Assembly (PCA) Blind Test Benchmark[37] was designed to provide measured data against which shielding methods and data from several international installations could be tested. The benchmark was so named because participants were given only the geometry and source description; calculations were performed without knowledge of the measured data. The geometry represents the radial regions of a typical light water reactor. Several configurations were studied, each being named according to the width (in centimeters) of the water layers preceding and following the thermal shield. Extensive neutron measurements were made for the 8/7 and 12/13 configurations, and gamma-ray measurements were made for the 4/12 configuration.

While the PCA geometry was parallelepipedal, calculations were performed using DORT with a cylindrical geometry model. For the PCA 4/12 configuration, the gamma-ray spectrum at one location and gamma-ray heating at several locations were calculated. Figure 4.14 shows a comparison of the calculated and measured gamma-ray spectra for gamma-ray energies between 0.248 and 2.731 MeV. Ratios of the calculated-to-measured flux integrals range from 0.52 to 0.55, so the results from all libraries are comparable. Energy self-shielding and spatial weighting would likely improve these ratios. Table 4.20 compares calculated and measured gamma-ray heating results. The calculated gamma-ray heating was obtained by using gamma-ray sensitivities for a CaF_2 thermoluminescent dosimeter (TLD). The reported measured results were corrected for neutron contributions to the TLD response. In general, the calculated results agree well with the measured results, the broad-group libraries showing somewhat better agreement. Ratios of gamma-ray heating to the fast-neutron flux at the same locations were also in good agreement with measured values, as shown in Table 4.21. These results are somewhat inconsistent with the fact that the calculated integrals of the gamma-ray flux significantly underpredict the measured integrals.

4.3.4 Conclusions from Shielding Data Testing

The BUGLE-93 and VITAMIN-B6 libraries have been tested using several shielding benchmarks, both experimental and computational. Results were reported for the experimental benchmarks and all show that the new libraries are consistent with previous libraries and in some cases better. Changes to the iron data above 3.0 MeV were observed to improve the prediction of the fast-neutron transmission through thick iron regions. Also, the effect of increasing the iron total cross section near the 24 keV window was observed indirectly. In general, the results showed that for shields containing thick iron regions, problem-specific self-shielded libraries should be used for accurate predictions of neutron transmission through the shield. Also, the potential inadequacy of even the fine-group cross sections in cases where the uncollided flux is dominant was demonstrated. Collectively, the integral testing was invaluable for helping to "shake down" the new libraries and qualify them for use in LWR shielding applications.

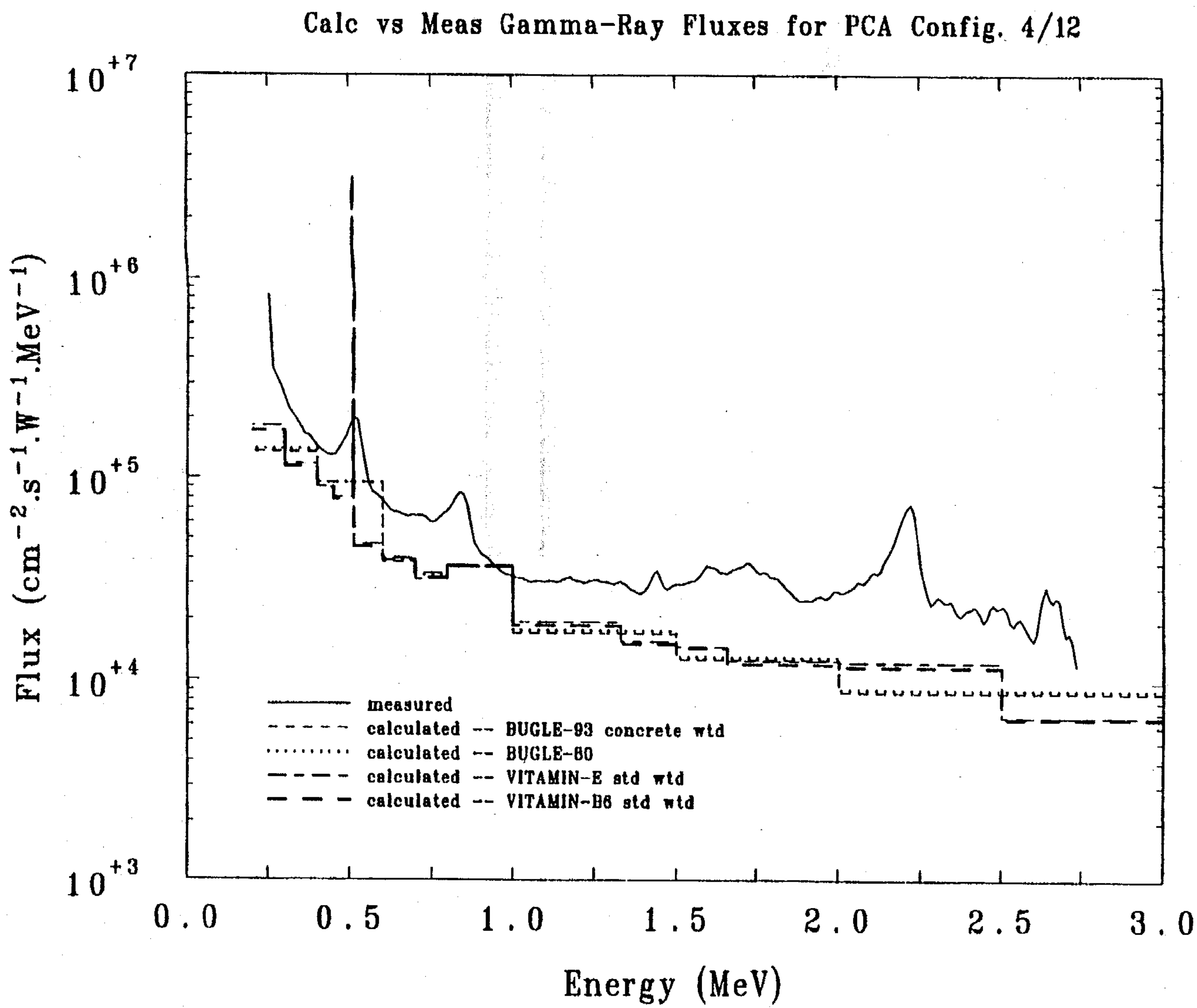


Fig. 4.14 Comparison of measured and calculated gamma-ray spectrum in the PCA Blind Test configuration 4/12

Table 4.20 Calculated-to-experiment ratios for gamma-ray energy deposition in steel from PCA Blind Test configuration 4/12

Location	Cross-Section Set BUGLE-80	BUGLE-93	VITAMIN-E	VITAMIN-B6
SSC[a]	1.02	1.01	1.03	1.02
1/4 PV Thickness	1.08	1.07	1.11	1.11
1/2 PV Thickness	1.03	1.03	1.06	1.06
3/4 PV Thickness	1.00	1.02	1.04	1.03

[a] Simulated surveillance capsule preceding PV mockup.

Table 4.21 Calculated-to-experiment ratios for ratio of gamma-ray energy deposition in steel to neutron equivalent fission fluxes from PCA Blind Test configuration 4/12

Location	Cross-Section Set BUGLE-80	BUGLE-93	VITAMIN-E	VITAMIN-B6
SSC[a]	0.89	0.84	0.85	0.86
1/4 PV Thickness	1.09	0.96	0.98	1.01
1/2 PV Thickness	1.12	0.94	0.96	1.00
3/4 PV Thickness	1.10	0.92	0.91	0.95

[a] Simulated surveillance capsule preceding PV mockup.

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APPENDIX A

INPUT LISTINGS FOR KEY PROCESSING STEPS

Table A.1 Sample NJOY Processing Job For Generating Neutron PENDF File

```
echo 'getting endf tape for u235'
rm tape21
echo 'running njoy'
cat>input <<EOF
 0
 6/
 *reconr*
  21 22
 *pendf tape for u-235, mat 9228, mod1 evaluation*/
 9228 3 0
 .002 0. 7 /
 *u-235, mod1 evaluation*/
 *processed by the njoy system*/
 *r.q. wright,  9-28-93*/
 0/
 *broadr*
 22 23
 9228 4 0 1 0.0
 .002/
 300. 600. 1000. 2100.
 0/
 *heatr*
 21 23 24
 9228/
 *unresr*
 21 24 25
 9228 4 7 1
 300. 600. 1000. 2100.
 1.e10 1.e6 1.e5 1.e4 1.e3 100. 50.
 0/
 *thermr*
 0 25 26
 0 9228 8 4 1 0 1 221 0
 300. 600. 1000. 2100.
 .01 5.0435
 *stop*
EOF
xnjoy94m<input
echo 'njoy run is finished'
```

Table A.2 Sample NJOY Processing Job For Generating Neutron GENDF File

```
echo 'getting endf  tape'
rm tape21
rm tape23
echo 'running njoy'
cat>input <<EOF
 0
 6/
 *groupr*
  21  23  0  24
  9228 1 1 4 5 4 7 1
 *  u-235  mod1  evaluation, mat 9228*/
 300. 600. 1000. 2100.
 1.e10  1.e6 1.e5 1.e4 1.e3 1.e2  50.
 199
 1.0000e-05 5.0000e-04 2.0000e-03 5.0000e-03 1.0000e-02 1.4500e-02
 2.1000e-02 3.0000e-02 4.0000e-02 5.0000e-02 7.0000e-02 1.0000e-01
 1.2500e-01 1.5000e-01 1.8400e-01 2.2500e-01 2.7500e-01 3.2500e-01
 3.6680e-01 4.1399e-01 5.0000e-01 5.3158e-01 6.2506e-01 6.8256e-01
 8.0000e-01 8.7643e-01
 1.0000e+00 1.0400e+00 1.0800e+00 1.1253e+00 1.3000e+00 1.4450e+00
 1.8554e+00 2.3824e+00 3.0590e+00 3.9279e+00 5.0435e+00 6.4760e+00
 8.3153e+00 1.0677e+01 1.3710e+01 1.7604e+01 2.2603e+01 2.9023e+01
 3.7266e+01 4.7851e+01 6.1442e+01 7.8893e+01 1.0130e+02 1.3007e+02
 1.6702e+02 2.1445e+02 2.7536e+02 3.5357e+02 4.5400e+02 5.8295e+02
 7.4852e+02 9.6112e+02 1.2341e+03 1.5846e+03 2.0347e+03 2.2487e+03
 2.4852e+03 2.6126e+03 2.7465e+03 3.0354e+03 3.3546e+03 3.7074e+03
 4.3074e+03 5.5308e+03 7.1017e+03 9.1188e+03 1.0595e+04 1.1709e+04
 1.5034e+04 1.9305e+04 2.1875e+04 2.3579e+04 2.4176e+04 2.4788e+04
 2.6058e+04 2.7000e+04 2.8501e+04 3.1828e+04 3.4307e+04 4.0868e+04
 4.6309e+04 5.2475e+04 5.6562e+04 6.7379e+04 7.1998e+04 7.9499e+04
 8.2503e+04 8.6517e+04 9.8037e+04 1.1109e+05 1.1679e+05 1.2277e+05
 1.2907e+05 1.3569e+05 1.4264e+05 1.4996e+05 1.5764e+05 1.6573e+05
 1.7422e+05 1.8316e+05 1.9255e+05 2.0242e+05 2.1280e+05 2.2371e+05
 2.3518e+05 2.4724e+05 2.7324e+05 2.8725e+05 2.9452e+05 2.9721e+05
 2.9849e+05 3.0197e+05 3.3373e+05 3.6883e+05 3.8774e+05 4.0762e+05
 4.5049e+05 4.9787e+05 5.2340e+05 5.5023e+05 5.7844e+05 6.0810e+05
 6.3928e+05 6.7206e+05 7.0651e+05 7.4274e+05 7.8082e+05 8.2085e+05
 8.6294e+05 9.0718e+05 9.6164e+05 1.0026e+06 1.1080e+06 1.1648e+06
 1.2246e+06 1.2874e+06 1.3534e+06 1.4227e+06 1.4957e+06 1.5724e+06
 1.6530e+06 1.7377e+06 1.8268e+06 1.9205e+06 2.0190e+06 2.1225e+06
 2.2313e+06 2.3069e+06 2.3457e+06 2.3653e+06 2.3852e+06 2.4660e+06
 2.5924e+06 2.7253e+06 2.8651e+06 3.0119e+06 3.1664e+06 3.3287e+06
 3.6788e+06 4.0657e+06 4.4933e+06 4.7237e+06 4.9659e+06 5.2205e+06
 5.4881e+06 5.7695e+06 6.0653e+06 6.3763e+06 6.5924e+06 6.7032e+06
 7.0469e+06 7.4082e+06 7.7880e+06 8.1873e+06 8.6071e+06 9.0484e+06
 9.5123e+06 1.0000e+07 1.0513e+07 1.1052e+07 1.1618e+07 1.2214e+07
```

```
 1.2523e+07 1.2840e+07 1.3499e+07 1.3840e+07 1.4191e+07 1.4550e+07
 1.4918e+07 1.5683e+07 1.6487e+07 1.6905e+07 1.7332e+07 1.9640e+07
 42
 1.0000e+03 1.0000e+04 2.0000e+04 3.0000e+04 4.0000e+04 4.5000e+04
 6.0000e+04 7.0000e+04 7.5000e+04 1.0000e+05 1.5000e+05 2.0000e+05
 3.0000e+05 4.0000e+05 4.5000e+05 5.1000e+05 5.1200e+05 6.0000e+05
 7.0000e+05 8.0000e+05 1.0000e+06 1.3300e+06 1.3400e+06 1.5000e+06
 1.6600e+06 2.0000e+06 2.5000e+06 3.0000e+06 3.5000e+06 4.0000e+06
 4.5000e+06 5.0000e+06 5.5000e+06 6.0000e+06 6.5000e+06 7.0000e+06
 7.5000e+06 8.0000e+06 1.0000e+07 1.2000e+07 1.4000e+07 2.0000e+07
 3.0000e+07
 0.125 0.025 8.2085e+5 1.2730e+6
 3/
 3 221 *thrsct*/
 3 251 *mubar*/
 3 252 *xi*/
 3 253 *gamma*/
 3 452 *nubar*/
 6/
 6 18 *fission*/
 6 221 *thrsct*/
 16/
 0/
 3 1 *total*/
 3 2 *elastic*/
 3 18 *fission*/
 3 102 *capture*/
 6 221 *thrsct*/
 0/
 3 1 *total*/
 3 2 *elastic*/
 3 18 *fission*/
 3 102 *capture*/
 6 221 *thrsct*/
 0/
 3 1 *total*/
 3 2 *elastic*/
 3 18 *fission*/
 3 102 *capture*/
 6 221 *thrsct*/
 0/
 0/
 *stop*
EOF
xnjoy94m<input
echo 'njoy run completed'
```

Table A.3 Sample NJOY Processing Job For Generating Gamma-Ray GENDF File.

```
echo 'running njoy'
cat>input <<EOF
 0
 6
 *reconr*
 20 21
 *gendf tape - photon interaction cross sections from t706*/
 9200 1 0
 .001/
 *92-uranium*/
 0/
 *gaminr*
 20 21 0 23
 9200 1 3 5 1
 *42 group photon interaction library*/
 42
 1.0e+3 1.0e+4 2.0e+4 3.0e+4 4.0e+4 4.5e+4 6.0e+4 7.0e+4 7.5e+4 1.0e+5
 1.50e+5 2.00e+5 3.00e+5 4.00e+5 4.50e+5 5.10e+5 5.12e+5 6.00e+5
 7.00e+5 8.00e+5 1.00e+6
 1.33e+6 1.34e+6 1.50e+6 1.66e+6 2.00e+6 2.50e+6 3.00e+6 3.50e+6
 4.00e+6 4.50e+6 5.00e+6 5.50e+6 6.00e+6 6.50e+6 7.00e+6 7.50e+6
 8.00e+6 1.00e+7 1.20e+7 1.40e+7 2.00e+7 3.00e+7
 -1 0/
 0/
 *stop*
EOF
xnjoy93m<input
echo 'njoy run completed'
```

Table A.4 Sample SMILER Processing Job For Converting From GENDF Format to AMPX Master Format

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/jib/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#smiler
-1$$ 450000 e
0$$ 75 70 0 71  e
1$$ 92235 e  6$$ 900 2000 t
 u235    v94.10 standard wgt e649228vb60003092095
end
#rade
-1$$ 450000 e
1$$ 75 e  2$$ a2 100 1 e t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi         scampi
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade           rade
if ( ! ( -e smiler ) )   ln -s $PGM_DIR/smiler         smiler
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable               qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases               aliases
if ( ! ( -e ft70f001 ) ) ln -s /u2/jew/gendf/u235.g             ft70f001
if ( ! ( -e ft71f001 ) ) ln -s /u2/jew/b6gam/u.gg93m           ft71f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft75f001 /u2/jew/b6ampx/ampx.u235
```

Table A.5 Processing Job For Generating Self-Shielded BWR/PWR Nuclides

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA ) ) setenv SCA /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
' get data needed for collapsing off of the master tape
0$$ 65 60 e        1$$ 1 t
2$$ 60 27 t
3$$ 1001 5010 8016 24050 24052 24053 24054 26054 26056 26057 26058
    28058 28060 28061 28062 28064 40000 92235 92238 25055 6012
    11023 12000 13027 14000 19000 20000
  t
end
#bonami
'     pwr fuel cell from resar..westinghouse plant            Feb '96
0$$ 65 0 18 81
1$$ 2 3 20 1 1 2  2** 0.001 1.0 t
3$$ 3r3 14r2 3r1
4$$ 1001 5010 8016 24050 24052 24053 24054 26054 26056 26057 26058
    28058 28060 28061 28062 28064 40000 92235 92238 8016
5** 4.714-2 4.2-6 2.357-2
   3.3196-6 6.40156-5 7.258-6 1.8069-6 8.555-6 1.32994-4 3.045-6 4.06-7
   5.98728-4 2.28897-4 9.91-6 3.1484-5 7.981-6 4.27-2
   6.325-4 2.166-2 4.465-2
6$$ 1 2 3
7** 0.41783 0.47498 0.71079
8** 921 672 583
10$$ 100113 501013 801613 2405012 2405212 2405312 2405412
 2605412 2605612 2605712 2605812 2805812 2806012 2806112
 2806212 2806412 4000012 9223511 9223811 801611
11$$ 0 1 1  t
end
#bonami
'    bwr fuel cell from gesar 238 general electric            Feb '96
0$$ 65 0 18 82
1$$ 2 3 19 1 1 2  2** 0.001 1.0 t
3$$ 2r3 14r2 3r1
4$$ 1001 8016 24050 24052 24053 24054 26054 26056 26057 26058
    28058 28060 28061 28062 28064 40000 92235 92238 8016
```

```
5** 2.475-2 1.2375-2
   3.3196-6 6.40156-5 7.258-6 1.8069-6 8.555-6 1.32994-4 3.045-6 4.06-7
   5.98728-4 2.28897-4 9.91-6 3.1484-5 7.981-6 4.27-2
   4.959-4 2.177-2 4.455-2
6$$ 1 2 3
7** 0.53213 0.6134 0.9174
8** 921 672 551
10$$ 100123 801623 2405022 2405222 2405322 2405422 2605422
 2605622 2605722 2605822 2805822 2806022 2806122 2806222
 2806422 4000022 9223521 9223821 801621
11$$ 0 1 1  t
end
#bonami
'    infinite medium collapse for iron-water mixture          Feb '96
0$$ 65 0 18 83
1$$ 0 1 16 1 1 0 t
3$$ f1
4$$ 1001 8016 24050 24052 24053 24054 26054 26056 26057 26058
    28058 28060 28061 28062 28064 25055
5** 1.1785-2 5.8925-3
    5.67-4 1.09346-2 1.2398-3 3.086-4 2.5798-3 4.01046-2 9.182-4
    1.224-4 4.3778-3 1.67366-3 7.246-5 2.3021-4 5.835-5 1.14-3
6$$ 1
7** 10.0
8** 590.
10$$ 100131 801631 2405031 2405231 2405331 2405431 2605431
  2605631 2605731 2605831 2805831 2806031 2806131 2806231
  2806431 2505531
11$$ 1 t
end
#bonami
'    infinite medium collapse for concrete type 04            Feb '96
0$$ 65 0 18 84
1$$ 0 1 13 1 1 0 t
3$$ f1
4$$ 1001 8016 26054 26056 26057 26058 6012 11023 12000 13027 14000
    19000 20000
5** 8.6-3 4.33-2
    2.0355-5 3.16434-4 7.245-6 9.66-7
    1.15-4 9.64-4 1.24-4 1.74-4 1.66-3 4.6-4 1.5-3
6$$ 1
7** 100.0
8** 300.0
10$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041
11$$ 1 t
end
```

```
#bonami
' self-shield carbon steel (1) & stainless steel (2)            Feb '96
0$$   65 0  18  85 e
1$$   1  2 30  2r0   0
2**   0.001  0.0        t
3$$   15r1 15r2
4$$ 26054 26056 26057 26058 24050 24052 24053 24054 28058 28060
    28061 28062 28064 25055 6012
    26054 26056 26057 26058 24050 24052 24053 24054 28058 28060
    28061 28062 28064 25055 6012
5**   4.75-3 7.518-2 1.72-3 2.457-4
      5.518-6 1.06413-4 1.2065-5 3.004-6
      3.03119-4 1.15884-4 5.017-6 1.594-5 4.04-6   1.12-3 9.81-4
      3.381-3 5.352-2 1.224-3 1.749-4
      7.56-4 1.45795-2 1.653-3 4.115-4
      5.83709-3 2.23155-3 9.662-5 3.0695-4 7.781-5  1.52-3 2.37-4
6$$   1  2
7**    10.0 20.0
8**   f600.0            9**   f0.0
10$$  2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
      2805851 2806051 2806151 2806251 2806451 2505551 601251
      2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
      2805852 2806052 2806152 2806252 2806452 2505552 601252
11$$ 1 t
end
#ajax
0$$ 75 81 e  1$$ 5 t
2$$ 81 20 t
3$$ 100113 501013 801613 2405012 2405212 2405312 2405412
 2605412 2605612 2605712 2605812 2805812 2806012 2806112
 2806212 2806412 4000012 9223511 9223811 801611  t
2$$ 82 19 t
3$$ 100123 801623 2405022 2405222 2405322 2405422 2605422
 2605622 2605722 2605822 2805822 2806022 2806122 2806222
 2806422 4000022 9223521 9223821 801621  t
2$$ 83 16 t
3$$ 100131 801631 2405031 2405231 2405331 2405431 2605431
  2605631 2605731 2605831 2805831 2806031 2806131 2806231
  2806431 2505531 t
2$$ 84 13 t
3$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041  t
2$$ 85 30 t
3$$   2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
      2805851 2806051 2806151 2806251 2806451 2505551 601251
      2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
      2805852 2806052 2806152 2806252 2806452 2505552 601252  t
end
```

```
#nitawl
' xsdrn library will be produced on unit 76                       Feb '96
0$$   75 a4 76   e     1$$ a2 98 a11 -1 e t
2$$ 100113 501013 801613 2405012 2405212 2405312 2405412
    2605412 2605612 2605712 2605812 2805812 2806012 2806112
    2806212 2806412 4000012 9223511 9223811 801611
    100123 801623 2405022 2405222 2405322 2405422 2605422
    2605622 2605722 2605822 2805822 2806022 2806122 2806222
    2806422 4000022 9223521 9223821 801621
    100131 801631 2405031 2405231 2405331 2405431 2605431
    2605631 2605731 2605831 2805831 2806031 2806131 2806231
    2806431 2505531
    100141 801641 2605441 2605641 2605741 2605841 601241 1102341
    1200041 1302741 1400041 1900041 2000041
    2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
    2805851 2806051 2806151 2806251 2806451 2505551 601251
    2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
    2805852 2806052 2806152 2806252 2806452 2505552 601252
4** 17r600. 3r1000. 16r600. 3r1000. 16r600. 13r300. 30r600. t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scale ) )    ln -s $PGM_DIR/scampi          scampi
if ( ! ( -e bonami ) )   ln -s $PGM_DIR/bonami          bonami
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl          nitawl
if ( ! ( -e xsdrn ) )    ln -s $PGM_DIR/xsdrn           xsdrn
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                 qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                 aliases
if ( ! ( -e ft60f001 ) ) ln -s /rsic/data/lmplib/vitaminb6.r3    ft60f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv $tmpdir/ft75f001 /u5/jew/bug96/ampx.vitb6r3.bonami
mv $tmpdir/ft76f001 /u5/jew/bug96/xsdrn.wklib.vb6r3
```

Table A.6 Processing Job For Calculating BWR Weighting Spectrum

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA ) ) setenv SCA /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR  $SCA/bin
cat >input <<'EOF'
#xsdrnpm
epri np-152  bwr case  3579 mwt gesar 238" core midplane 50% void Feb '96
-1$$ 2000000
1$$  2  7   154  1   0
     5  57  8  3  0
    40 100  0  0  3
2$$ -2  33  0 3z -1 1  e
3$$  1  1  0  0  0
     0  0  1  0  0
     0  0
4$$  0  67  41  -2  3
     4  70  -1  0
5**  0.00001  0.00001  7.46419+17  2z
     1.420892   4z
     0.001   0.75   t
13$$    10r1     2r2      16r3  16r4      13r5
'    fuel     water    ss304  a533b    concrete
14$$ 100123 801623 4000022 2605422 2605622 2605722 2605822
      9223521 9223821 801621
     100123 801631
     601252 1400041 2405052 2405252 2405352 2405452 2505552
      2605452 2605652 2605752 2605852 2805852 2806052 2806152
      2806252 2806452
     601251 1400041 2405051 2405251 2405351 2405451 2505551
      2605451 2605651 2605751 2605851 2805851 2806051 2806151
      2806251 2806451
     100141 601241 801641 1102341 1200041 1302741 1400041
      1900041 2000041 2605441 2605641 2605741 2605841
15** 1.5354-2 7.677-3  5.7645-3
     1.1818-6 1.83715-5  4.206-7  5.61-8
     1.2125-4 5.322-3 1.0884-2
     4.950-2           2.475-2 2.37-4  8.93-4
     7.5603-4 1.457946-2 1.653-3 4.1151-4 1.52-3
     3.4397-3 5.347276-2 1.2243-3 1.6324-4
     5.837085-3 2.23155-3 9.6615-5 3.06945-4 7.7805-5
     9.81-4  3.71-4
```

```
     5.51815-6 1.064133-4 1.2065-5 3.00355-6 1.12-3
     4.832094-3 7.5118588-2 1.719898-3 2.2932-4
     3.031188-4 1.15884-4 5.0172-6 1.59396-5 4.0404-6
     7.77-3  1.15-4  4.38-2 1.05-3 1.48-4 2.39-3 1.58-2 6.93-4 2.92-3
     1.8467-5 2.870836-4 6.573-6 8.764-7
     t
30$$  64r1  f0
'  lwr source spectrum for 199-group structure
31**
944991-14 408572-11 410082-11 1407-8 2346-8 1676-8 212-7 2669-8 3318-8
9212-8 689696-10 689304-10 2022-7 2892-7 4059-7 5583-7 7525-7 9963-7
1297-6 166-5 2092-6 2597-6 3179-6 3839-6 144-5 3137-6 539-5 6274-6
7224-6 8229-6 9282-6 1037-5 1148-5 2632-5 3072-5 3482-5 188-4 1965-5
203858-7 210743-7 2164-5 2212-5 1496-5 3787-6 3769-6 758-5 1523-5 23-3
231-4 2312-5 2306-5 229-4 2266-5 2237-5 2202-5 2162-5 2111-5 20628-6
200921-7 1953-5 189-4 3591-5 1422-5 1912-5 1568-5 1503-5 1438-5 1373-5
131-4 1248-5 1188-5 1128-5 1071-5 1015-5 9643-6 9099-6 1672-5 1488-5
6804-6 6405-6 1168-5 1031-5 111318-8 408612-9 857096-9 2305-6 4395-6
7978-6 3614-6 3382-6 3164-6 296-5 2765-6 2584-6 2417-6 2253-6 2107-6
1962-6 1834-6 1708-6 1595-6 1487-6 1383-6 1291-6 2853-6 2386-6 800687-9
588195-9 142617-8 846046-9 1879-6 6696-7 9652-7 8036-7 9037-7 3215-7
412869-9 179031-9 11-5 1452-7 6873-8 6624-8 1846-7 2654-7 4036-7 2781-7
766153-10 114985-9 1319-7 9077-8 6245-8 2768-8 1528-8 1316-8 1132-8
5056-9 4693-9 8395-9 7227-9 1397-8 9602-9 6601-9 4538-9 3119-9 2144-9
147411-11 101289-11 6962-10 4784-10 329-9 226-9 1553-10 1067-10 7339-11
504437-13 345483-13 23938-12 163763-13 112537-13 7737-12 5317-12 3654-12
2512-12 1727-12 1186-12 813315-15 562685-15 385-12 112103-15 152962-15
299068-16 274697-16 285471-16 960036-16 45626-15 793822-16 302382-16
556619-16 144778-16 446222-16 97115-16 970882-17 13405-15 161026-16
161422-16 163938-16 146302-16 179059-16 596373-18 562593-18 373104-18
481014-18 596373-18 619278-18 621267-18 115897-17 153207-17 231793-17
654104-17                 f0
  t
33** f0
  t
35** 49i 0 3i 200 4i 210  4i  225  14i   235.15  2i  253.75
    19i  258.83  25i  302.26 317.5 8i 318 345 4i 347.22  9i 357 390
36$$ 64r1 15r2 3r3 20r4 26r5 11r6 15r7
38**  128r1  11r  1.0-10  f1
39$$  1 2 3 2 4 2 5
40$$   f3
51$$
 0 6r1 5r2 4r3 3r4 3r5 5r6 4r7 4r8 3r9 2r10 2r11 2r12 13 2r14 3r15
 3r16 4r17 5r18 4r19 2r20 4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28
 2r29 3r30 2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40 5r41
 3r42 4r43 7r44 6r45 8r46 11r47 2z 2r48 49 2r50 2r51 2r52 2r53  2r54
 2r55 2r56 3r57 58 59 60 4r61 2r62 2r63 3r64 3r65 66 67 0
  t
end
'EOF'
```

Table A.6 (Cont'd)

```
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi        scampi
if ( ! ( -e bonami ) )   ln -s $PGM_DIR/bonami        bonami
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl        nitawl
if ( ! ( -e xsdrn ) )    ln -s $PGM_DIR/xsdrn         xsdrn
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax          ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable              qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases              aliases
if ( ! ( -e ft04f001 ) ) ln -s /u5/jew/bug96/xsdrn.wklib.vb6r3  ft04f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv $tmpdir/ft33f001 /u5/jew/bug96/xsdrn.scalar.bwr
mv $tmpdir/ft03f001 /u5/jew/bug96/ft03wk.bwr
```

Table A.7 Processing Job For Calculating PWR Weighting Spectra

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA ) ) setenv SCA /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR  $SCA/bin
cat >input <<'EOF'
#xsdrnpm
 epri  np-152 pwr problem no pads 3425 mwt flat power dist. Feb '96
-1$$ 2000000
1$$  2  8  119  1  0
     5  59  8  3  0
    40 100  0  0  3
2$$ -2  33  0 3z -1 1  e
3$$  1  1  0  0  0
     0  0  1  0  0
     0  0
4$$  0  67  41  -2  3
     4  70  -1  0
5**  0.00001  0.00001  7.2676e+17  2z
     1.420892   4z
     0.001   0.75   t
13$$     11r1     3r2      16r3   16r4      13r5
'    fuel     water    ss304  a533b    concrete
14$$ 100113 501013 801613 4000012 2605412 2605612 2605712 2605812
     9223511 9223811 801611
     100113 501013 801631
     601252 1400041 2405052 2405252 2405352 2405452 2505552
      2605452 2605652 2605752 2605852 2805852 2806052 2806152
      2806252 2806452
     601251 1400041 2405051 2405251 2405351 2405451 2505551
      2605451 2605651 2605751 2605851 2805851 2806051 2806151
      2806251 2806451
     100141 601241 801641 1102341 1200041 1302741 1400041
      1900041 2000041 2605441 2605641 2605741 2605841
15** 2.768-2  2.466-6  1.384-2  4.257-3
     8.5196-7 1.3244368-5 3.0324-7 4.0432-8
     1.903-4  6.515-3 1.343-2
     4.714-2  4.200-6  2.357-2 2.37-4  8.93-4
     7.5603-4 1.457946-2 1.653-3 4.1151-4 1.52-3
     3.4397-3 5.347276-2 1.2243-3 1.6324-4
     5.837085-3 2.23155-3 9.6615-5 3.06945-4 7.7805-5
     9.81-4  3.71-4
     5.51815-6 1.064133-4 1.2065-5 3.00355-6 1.12-3
     4.832094-3 7.5118588-2 1.719898-3 2.2932-4
```

```
     3.031188-4 1.15884-4 5.0172-6 1.59396-5 4.0404-6
     7.77-3  1.15-4  4.38-2 1.05-3 1.48-4 2.39-3 1.58-2 6.93-4 2.92-3
     1.8467-5 2.870836-4 6.573-6 8.764-7
     t
30$$  46r1  f0
'  pwr source spectrum for 199-group structure
31**
944991-14 408572-11 410082-11 1407-8 2346-8 1676-8 212-7 2669-8 3318-8      1   1
9212-8 689696-10 689304-10 2022-7 2892-7 4059-7 5583-7 7525-7 9963-7        1   2
1297-6 166-5 2092-6 2597-6 3179-6 3839-6 144-5 3137-6 539-5 6274-6          1   3
7224-6 8229-6 9282-6 1037-5 1148-5 2632-5 3072-5 3482-5 188-4 1965-5        1   4
203858-7 210743-7 2164-5 2212-5 1496-5 3787-6 3769-6 758-5 1523-5 23-3      1   5
231-4 2312-5 2306-5 229-4 2266-5 2237-5 2202-5 2162-5 2111-5 20628-6        1   6
200921-7 1953-5 189-4 3591-5 1422-5 1912-5 1568-5 1503-5 1438-5 1373-5      1   7
131-4 1248-5 1188-5 1128-5 1071-5 1015-5 9643-6 9099-6 1672-5 1488-5        1   8
6804-6 6405-6 1168-5 1031-5 111318-8 408612-9 857096-9 2305-6 4395-6        1   9
7978-6 3614-6 3382-6 3164-6 296-5 2765-6 2584-6 2417-6 2253-6 2107-6        1  10
1962-6 1834-6 1708-6 1595-6 1487-6 1383-6 1291-6 2853-6 2386-6 800687-9     1  11
588195-9 142617-8 846046-9 1879-6 6696-7 9652-7 8036-7 9037-7 3215-7        1  12
412869-9 179031-9 11-5 1452-7 6873-8 6624-8 1846-7 2654-7 4036-7 2781-7     1  13
766153-10 114985-9 1319-7 9077-8 6245-8 2768-8 1528-8 1316-8 1132-8         1  14
5056-9 4693-9 8395-9 7227-9 1397-8 9602-9 6601-9 4538-9 3119-9 2144-9       1  15
147411-11 101289-11 6962-10 4784-10 329-9 226-9 1553-10 1067-10 7339-11     1  16
504437-13 345483-13 23938-12 163763-13 112537-13 7737-12 5317-12 3654-12    1  17
2512-12 1727-12 1186-12 813315-15 562685-15 385-12 112103-15 152962-15      1  18
299068-16 274697-16 285471-16 960036-16 45626-15 793822-16 302382-16        1  19
556619-16 144778-16 446222-16 97115-16 970882-17 13405-15 161026-16         1  20
161422-16 163938-16 146302-16 179059-16 596373-18 562593-18 373104-18       1  21
481014-18 596373-18 619278-18 621267-18 115897-17 153207-17 231793-17       1  22
654104-17                f0                                                 1  23
  t
33** f0
  t
35**  29i 0  9i  120  5i  151.66  2i  168.51  7i  171.40
  4i 187.96  4i 193.68  9i 200.66  14i 219.71  241.62
    4i242  259.5  8i 260  10i 275  300
36$$ 46r1  3r2  8r3  5r4  15r5  15r6  7r7  20r8
38**  92r  1  7r  1.0-10  f1
39$$   1  3  2  3  2  4  2  5
40$$      f3
51$$
 0 6r1 5r2 4r3 3r4 3r5 5r6 4r7 4r8 3r9 2r10 2r11 2r12 13 2r14 3r15
 3r16 4r17 5r18 4r19 2r20 4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28
 2r29 3r30 2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40 5r41
 3r42 4r43 7r44 6r45 8r46 11r47 2z 2r48 49 2r50 2r51 2r52 2r53 2r54
 2r55 2r56 3r57 58 59 60 4r61 2r62 2r63 3r64 3r65 66 67 0
  t
end
'EOF'
```

Table A.7 (Cont'd)

```
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )    ln -s $PGM_DIR/scampi        scampi
if ( ! ( -e bonami ) )   ln -s $PGM_DIR/bonami        bonami
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl        nitawl
if ( ! ( -e xsdrn ) )    ln -s $PGM_DIR/xsdrn         xsdrn
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax          ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable              qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases              aliases
if ( ! ( -e ft04f001 ) ) ln -s /u5/jew/bug96/xsdrn.wklib.vb6r3  ft04f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv $tmpdir/ft33f001 /u5/jew/bug96/xsdrn.scalar.pwr
mv $tmpdir/ft03f001 /u5/jew/bug96/ft03wk.pwr
```

Table A.8a Processing Job For Collapsing BWR Core Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 10 t
3$$ 100123 801623 4000022 2605422 2605622 2605722 2605822
    9223521 9223821 801621  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for bwr core (int #57)              Mar '96
 7.60143e+05 2.90634e+08 3.27643e+08 1.08799e+09 1.78948e+09 1.27953e+09
 1.62123e+09 2.02030e+09 2.49749e+09 6.85701e+09 5.05334e+09 5.17907e+09
 1.43870e+10 2.04008e+10 3.02041e+10 4.02078e+10 5.44518e+10 7.40053e+10
 9.38160e+10 1.17843e+11 1.53420e+11 1.89306e+11 2.27723e+11 2.88589e+11
 1.09607e+11 2.42843e+11 4.19346e+11 4.71693e+11 5.32827e+11 6.43324e+11
 6.98187e+11 8.18274e+11 8.68133e+11 1.97883e+12 2.10514e+12 2.36048e+12
 1.42728e+12 1.71759e+12 1.72329e+12 1.83347e+12 2.00608e+12 2.02076e+12
 1.39901e+12 3.81191e+11 3.91890e+11 7.70352e+11 1.38789e+12 1.94868e+12
 1.90020e+12 1.85231e+12 1.79866e+12 2.14296e+12 2.08624e+12 2.03031e+12
 2.11954e+12 2.23346e+12 2.19462e+12 1.82537e+12 2.25984e+12 2.27227e+12
 2.11976e+12 3.47177e+12 1.35233e+12 2.24613e+12 2.15271e+12 2.49667e+12
 2.78663e+12 2.63796e+12 2.44973e+12 2.36574e+12 2.30676e+12 2.24061e+12
 2.16740e+12 2.09230e+12 2.02307e+12 1.96015e+12 3.21529e+12 2.46432e+12
 1.43952e+12 1.44394e+12 3.28625e+12 3.34269e+12 3.69863e+11 1.35776e+11
 2.85285e+11 7.74687e+11 1.52601e+12 2.89730e+12 1.37983e+12 1.34084e+12
 1.31041e+12 1.27469e+12 1.23302e+12 1.19292e+12 1.16266e+12 1.13338e+12
 1.11270e+12 1.08494e+12 1.06379e+12 1.03963e+12 1.01808e+12 9.95902e+11
 9.71912e+11 9.53669e+11 2.29887e+12 2.19548e+12 8.13572e+11 6.19403e+11
 1.61449e+12 1.07654e+12 2.72592e+12 1.12235e+12 1.80796e+12 1.73158e+12
 2.44770e+12 1.00943e+12 1.46214e+12 7.01129e+11 4.58286e+11 6.42107e+11
 3.12091e+11 3.13661e+11 9.52447e+11 1.52359e+12 3.06792e+12 2.95603e+12
 1.15761e+12 1.71170e+12 2.79970e+12 2.80830e+12 2.73063e+12 1.62588e+12
```

```
 1.08376e+12 1.06987e+12 1.04420e+12 5.09300e+11 5.76884e+11 1.04666e+12
 1.07292e+12 2.59086e+12 2.58660e+12 2.56748e+12 2.52283e+12 2.49421e+12
 2.46115e+12 2.44183e+12 2.42955e+12 2.36810e+12 2.36087e+12 2.31931e+12
 2.12917e+12 2.31714e+12 2.20101e+12 2.19805e+12 2.09320e+12 2.06189e+12
 2.07766e+12 1.75099e+12 1.96469e+12 1.93991e+12 1.88498e+12 1.40758e+12
 1.53680e+12 1.75269e+12 1.75774e+12 1.79627e+12 1.81003e+12 1.82828e+12
 7.83721e+11 1.05850e+12 2.95255e+11 2.76228e+11 2.94520e+11 9.88026e+11
 6.94970e+11 1.20945e+12 7.12704e+11 1.30767e+12 5.19128e+11 1.63906e+12
 1.15275e+12 1.24436e+12 1.92642e+12 2.74006e+12 3.24911e+12 3.68464e+12
 3.43253e+12 4.10335e+12 5.77353e+12 4.11199e+12 2.05434e+12 1.84338e+12
 1.40112e+12 7.99235e+11 4.14250e+11 3.03532e+11 9.07528e+10 1.70774e+10
 1.21898e+09
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
      2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for bwr core (int #57)              Mar '96
             1.95474e+02 7.34404e+03 5.42148e+04 7.31863e+05 3.40538e+09
 1.61277e+10 3.35803e+10 6.07724e+10 1.44246e+11 2.51910e+11 3.31486e+11
 4.31915e+11 1.30983e+12 1.82483e+12 2.79593e+12 5.24077e+12 9.96501e+12
 9.02074e+12 5.16624e+12 6.09643e+12 4.16807e+11 1.56718e+13 1.18219e+13
 6.65880e+12 7.49228e+12 6.52617e+12 3.64557e+12 4.37527e+12 3.28651e+12
 5.44538e+12 3.34478e+12 6.27510e+11 2.84651e+11 1.18804e+11 1.13728e+10
 1.37233e+10 2.84362e+10 4.68689e+09 3.23285e+09 1.51357e+09 1.16855e+09
 3.95740e+07
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 10   a11 -1 e t
2$$ 100123 801623 4000022 2605422 2605622 2605722 2605822
    9223521 9223821 801621
4** 7r600. 3r1000. e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
```

Table A.8a (Cont'd)

```
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi          scampi
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs          malocs
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade            rade
if ( ! ( -e alpo    ) )  ln -s $PGM_DIR/alpo            alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl          nitawl
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.bcore.binr3
```

Table A.8b Fortran source code used to create the ANISN files in the portable BCD format

```
c
c     convert binary anisn data to a bcd fixed-field format
c
      dimension  c(10000),name(14)
      open(unit=7,file='ft07',status='new',form='formatted')
      open(unit=10,file='ft10',status='new',form='formatted')
      open(unit=1,file='ft01',status='old',form='unformatted')
      n1=1
      n6=6
      n7=7
c
      n10=10
      rewind n1
1     continue
    3 read(n1,end=2) neg,ntl,icon,idt,name
      if(icon.eq.7)go to 2
      len=neg*ntl
      read(n1) (c(k),k=1,len)
      write(n7,20) neg,ntl,icon,idt,name
      write(n10,20) neg,ntl,icon,idt,name
   20 format(1x,i5,3i6,14a4)
      call punsh(c,len)
      write(n6,20) neg,ntl,icon,idt,name
      go to 1
    2 continue
      idum=7
      write(n7,20) idum,idum,idum,idum
      stop
      end
      subroutine punsh(x,n)                                          ansn2808
c   *** clever set of subroutines which punch cards in anisn format  ansn2809
c   *** punsh sets up each card punched by dtfpun utilizing repeats  ansn2810
      dimension etr(6),nn(6),r(6),x(1)                               ansn2811
      data bb,rr/'    ','r   '/                                      ansn2812
      ncard=1                                                        ansn2813
      i6=0                                                           ansn2814
      k=0                                                            ansn2815
      itrip=0                                                        ansn2816
      ii=n+1                                                         ansn2817
      do 1 i=2,ii                                                    ansn2818
      if(itrip.le.0)go to 2                                          ansn2819
      if(i.eq.ii.and.i6.eq.0)go to 1                                 feb 1970
      itrip=0                                                        ansn2820
      go to 3                                                        ansn2821
    2 if(i.ge.ii)go to 4                                             ansn2822
```

```
      if(x(i).ne.x(i-1))go to 4                                         ansn2823
      k=k+1                                                             ansn2824
      if(k.lt.98)go to 1                                                ansn2825
      itrip=1                                                           ansn2826
    4 i6=i6+1                                                           ansn2827
      nn(i6)=0                                                          ansn2828
      r(i6)=bb                                                          ansn2829
      if(k.le.0)go to 5                                                 ansn2830
      nn(i6)=k+1                                                        ansn2831
      r(i6)=rr                                                          ansn2832
      k=0                                                               ansn2833
    5 etr(i6)=x(i-1)                                                    ansn2834
      if(i6.ge.6)go to 6                                                ansn2835
    3 if(i.lt.ii)go to 1                                                ansn2836
    6 call dtfpun(etr,nn,r,i6,ncard)                                    ansn2837
      ncard=ncard +1                                                    ansn2838
      i6=0                                                              ansn2839
    1 continue                                                          ansn2840
      return                                                            ansn2841
      end                                                               ansn2842
      subroutine dtfpun(e,nn,r,isum,ncard)                              ansn2843
c   *** dtfpun uses variabe format to punch and number cards            ansn2844
      dimension e(6),nn(6),r(6),ie(6),iexp(6),s1(6),s2(6)               ansn2845
      dimension fmt(26),fbt(4),fet(2)                                   ansn2846
      data pos,xneg/'+   ','-   '/                                      ansn2847
      data fmt(1),fmt(26),fet(1),fet(2)/'(   ','i8) ','t73,','i8) '/    ansn2848
      data fbt(1),fbt(2) ,fbt(3),fbt(4)/'i2,2','a1,i','5,a1',',i2,'/    ansn2849
      do 2 j=1,6                                                        ansn2850
      k=(j-1)*4 + 1                                                     ansn2851
      do 3 i=1,4                                                        ansn2852
      l=k+i                                                             ansn2853
    3 fmt(l)=fbt(i)                                                     ansn2854
    2 continue                                                          ansn2855
      if(isum.eq.6)go to 4                                              ansn2856
      k=isum*4 + 2                                                      ansn2857
      fmt(k)=fet(1)                                                     ansn2858
      fmt(k+1)=fet(2)                                                   ansn2859
    4 do 1 i=1,isum                                                     ansn2860
      s1(i)=pos                                                         ansn2861
      if(e(i).lt.0.0)s1(i)=xneg                                         ansn2862
      call fltfx(e(i),ie(i),iexp(i))                                    ansn2863
      s2(i)=xneg                                                        ansn2864
      if(iexp(i).ge.0)s2(i)=pos                                         ansn2865
      iexp(i)=iabs(iexp(i))                                             ansn2866
    1 continue                                                          ansn2867
```

```
      write (7,fmt) (nn(i),r(i),s1(i),ie(i),s2(i),iexp(i),i=1,isum)
     1,ncard
      return
      end
      subroutine fltfx(e1,ne1,n1)
c    *** fltfx converts floating number to integer
      n=-4
      e=abs(e1)
      if(e.ne.0.0)go to 1
      n=0
      ne=0
      go to 6
    3 e=e*10.0
      n=n-1
    1 if(e.ge.1.0)go to 4
      go to 3
    5 e=e/10.0
      n=n+1
    4 if(e.ge.10.0)go to 5
      e=e*10000.0
    2 ne=e
      e=e-float(ne)
      if(e.lt.0.5)go to 6
      if(ne.ne.99999)go to 7
      n=n+1
      ne=10000
      go to 6
    7 ne=ne+1
    6 ne1=ne
      n1=n
      return
      end
```

Table A.9 Processing Job For Collapsing PWR Core Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scale job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 20 t
3$$ 100113 501013 801613 2405012 2405212 2405312 2405412
 2605412 2605612 2605712 2605812 2805812 2806012 2806112
 2806212 2806412 4000012 9223511 9223811 801611  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting spectrum for pwr mid-core (int #37)      Mar '96
 1.18569e+06 4.44299e+08 5.06194e+08 1.67311e+09 2.74417e+09 1.96180e+09
 2.48586e+09 3.09280e+09 3.81923e+09 1.04620e+10 7.69466e+09 7.89203e+09
 2.17256e+10 3.06929e+10 4.58104e+10 6.05589e+10 8.19191e+10 1.11443e+11
 1.40281e+11 1.75241e+11 2.28628e+11 2.80991e+11 3.36246e+11 4.28487e+11
 1.62756e+11 3.61051e+11 6.22579e+11 6.95059e+11 7.80393e+11 9.46492e+11
 1.01740e+12 1.19555e+12 1.25790e+12 2.84664e+12 2.97639e+12 3.30436e+12
 1.99850e+12 2.41813e+12 2.40488e+12 2.54923e+12 2.78330e+12 2.78702e+12
 1.92623e+12 5.27521e+11 5.42589e+11 1.05934e+12 1.88068e+12 2.62297e+12
 2.54514e+12 2.46853e+12 2.38193e+12 2.83562e+12 2.72677e+12 2.63967e+12
 2.74706e+12 2.87447e+12 2.80168e+12 2.31657e+12 2.87304e+12 2.85670e+12
 2.64854e+12 4.33302e+12 1.68634e+12 2.78322e+12 2.63744e+12 3.01844e+12
 3.32231e+12 3.12345e+12 2.88702e+12 2.77609e+12 2.69602e+12 2.61244e+12
 2.52675e+12 2.44394e+12 2.36438e+12 2.27797e+12 3.79303e+12 2.95327e+12
 1.72592e+12 1.72178e+12 3.86696e+12 3.88260e+12 4.29115e+11 1.57695e+11
 3.31585e+11 9.01151e+11 1.76722e+12 3.35764e+12 1.60126e+12 1.55458e+12
 1.51589e+12 1.47589e+12 1.43327e+12 1.39199e+12 1.35773e+12 1.32392e+12
 1.29833e+12 1.26603e+12 1.24134e+12 1.21331e+12 1.18968e+12 1.16512e+12
 1.13835e+12 1.11830e+12 2.69934e+12 2.57966e+12 9.54430e+11 7.30951e+11
 1.90973e+12 1.25908e+12 3.20042e+12 1.32469e+12 2.14632e+12 2.07340e+12
 2.86656e+12 1.19258e+12 1.72830e+12 8.33077e+11 5.43326e+11 7.60420e+11
 3.74458e+11 3.75009e+11 1.12693e+12 1.83115e+12 3.63262e+12 3.52834e+12
 1.38683e+12 2.05739e+12 3.38095e+12 3.35791e+12 3.29508e+12 1.96518e+12
```

```
 1.31016e+12 1.29889e+12 1.28318e+12 6.32145e+11 6.73976e+11 1.27364e+12
 1.29863e+12 3.16874e+12 3.15895e+12 3.14372e+12 3.10215e+12 3.07554e+12
 3.04843e+12 3.03314e+12 3.02048e+12 2.96543e+12 2.95795e+12 2.92033e+12
 2.72967e+12 2.91763e+12 2.79907e+12 2.79925e+12 2.70229e+12 2.65131e+12
 2.68277e+12 2.32392e+12 2.56828e+12 2.53435e+12 2.47600e+12 1.93851e+12
 2.11725e+12 2.36001e+12 2.36451e+12 2.41543e+12 2.43760e+12 2.46489e+12
 1.05858e+12 1.43256e+12 4.01745e+11 3.75070e+11 3.98828e+11 1.34272e+12
 9.45318e+11 1.65368e+12 9.67802e+11 1.78668e+12 7.09187e+11 2.25321e+12
 1.59535e+12 1.74063e+12 2.73440e+12 3.95822e+12 4.77304e+12 5.48771e+12
 5.16659e+12 6.22772e+12 8.82304e+12 6.32026e+12 3.16449e+12 2.85268e+12
 2.17551e+12 1.24483e+12 6.46810e+11 4.75035e+11 1.42377e+11 2.68474e+10
 1.91611e+09

6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
       2r16 3r17 3r18 19 20 0
7**
' photon weighting spectrum for pwr mid-core (int #37)       Mar '96
             1.56551e+02 5.78821e+03 5.36244e+04 1.60647e+07 1.94149e+09
 2.04060e+10 6.40015e+10 1.19179e+11 2.81762e+11 4.95520e+11 6.52351e+11
 8.34889e+11 2.32033e+12 3.31156e+12 5.09403e+12 9.40590e+12 1.78914e+13
 1.59802e+13 9.30442e+12 1.10960e+13 7.62175e+11 2.85726e+13 2.14723e+13
 1.20755e+13 1.33643e+13 1.15110e+13 6.50410e+12 8.26396e+12 5.79812e+12
 9.50287e+12 5.73402e+12 1.06108e+12 4.53652e+11 1.90297e+11 1.82731e+10
 2.21555e+10 3.90794e+10 6.59067e+09 4.87415e+09 2.27160e+09 1.73293e+09
 6.90986e+07
  t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 20   a11 -1 e t
2$$ 100113 501013 801613 2405012 2405212 2405312 2405412
 2605412 2605612 2605712 2605812 2805812 2806012 2806112
 2806212 2806412 4000012 9223511 9223811 801611
4** 17r600. 3r1000.  e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
```

Table A.9 (Cont'd)

```
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi        scampi
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs        malocs
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade          rade
if ( ! ( -e alpo   ) )   ln -s $PGM_DIR/alpo          alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl        nitawl
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax          ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable              qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases              aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.pcore.binr3
```

Table A.10 Processing Job For Collapsing PWR Downcomer Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA    ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e    1$$ 1 t
2$$ 85 17 t
3$$ 100131 801631
    2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
    2805852 2806052 2806152 2806252 2806452 2505552 601252  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for downcomer (pwr int # 69)        Mar '96
 1.39915e+04 3.54372e+06 5.18817e+06 1.60383e+07 2.43561e+07 1.69080e+07
 2.11815e+07 2.56302e+07 3.07903e+07 8.03502e+07 5.60907e+07 5.97414e+07
 1.41298e+08 1.86232e+08 2.97667e+08 3.61070e+08 4.72567e+08 6.38921e+08
 7.36351e+08 8.34712e+08 1.07576e+09 1.24101e+09 1.36028e+09 1.78428e+09
 6.69262e+08 1.49223e+09 2.52511e+09 2.54710e+09 2.60240e+09 3.25652e+09
 3.07945e+09 3.63869e+09 3.56835e+09 7.24468e+09 6.27365e+09 6.19037e+09
 3.69762e+09 4.91689e+09 4.99987e+09 5.21449e+09 5.69261e+09 5.52907e+09
 4.13321e+09 1.28138e+09 1.42532e+09 2.45442e+09 4.21172e+09 5.54678e+09
 5.23457e+09 5.02601e+09 4.62360e+09 5.74029e+09 5.41086e+09 5.07163e+09
 5.29273e+09 5.33738e+09 5.24055e+09 4.06970e+09 5.14046e+09 5.29298e+09
 4.81191e+09 7.49563e+09 2.82735e+09 4.74389e+09 4.36514e+09 4.84229e+09
 5.04403e+09 4.73117e+09 4.54659e+09 4.41987e+09 4.37375e+09 4.26280e+09
 4.18452e+09 4.05442e+09 3.92548e+09 3.77005e+09 6.42492e+09 5.17460e+09
 3.00309e+09 3.00124e+09 6.41753e+09 6.30699e+09 7.02080e+08 2.58802e+08
 5.44835e+08 1.48098e+09 2.89938e+09 5.57163e+09 2.68692e+09 2.62080e+09
 2.56455e+09 2.50752e+09 2.45258e+09 2.40299e+09 2.35757e+09 2.30563e+09
 2.26717e+09 2.21809e+09 2.17812e+09 2.13831e+09 2.10744e+09 2.07275e+09
 2.03182e+09 2.00219e+09 4.85708e+09 4.67856e+09 1.73389e+09 1.34508e+09
 3.51120e+09 2.30397e+09 5.90408e+09 2.46297e+09 4.02920e+09 3.93460e+09
 5.37383e+09 2.26377e+09 3.28835e+09 1.59677e+09 1.05075e+09 1.47450e+09
 7.34569e+08 7.30041e+08 2.17712e+09 3.58561e+09 7.07411e+09 6.99859e+09
```

```
 2.77672e+09 4.13796e+09 6.86644e+09 6.85077e+09 6.83678e+09 4.11127e+09
 2.74721e+09 2.75060e+09 2.75364e+09 1.37655e+09 1.37670e+09 2.75515e+09
 2.76516e+09 6.93215e+09 6.94795e+09 6.96166e+09 6.99919e+09 7.04239e+09
 7.08511e+09 7.11887e+09 7.17530e+09 7.21707e+09 7.25652e+09 7.29909e+09
 7.33766e+09 7.37986e+09 7.42400e+09 7.46781e+09 7.51122e+09 7.55318e+09
 7.59531e+09 7.63461e+09 7.67576e+09 7.71536e+09 7.75140e+09 7.78692e+09
 7.82080e+09 8.08726e+09 8.19244e+09 8.35176e+09 8.52544e+09 8.66854e+09
 3.75896e+09 5.19911e+09 1.49831e+09 1.38750e+09 1.46322e+09 4.95747e+09
 3.50260e+09 6.25927e+09 3.70424e+09 7.33383e+09 3.19930e+09 1.25192e+10
 1.21165e+10 1.76488e+10 3.78424e+10 7.34719e+10 1.09734e+11 1.46207e+11
 1.52214e+11 1.98356e+11 3.03079e+11 2.31049e+11 1.20067e+11 1.11586e+11
 8.74983e+10 5.12889e+10 2.71373e+10 2.02161e+10 6.13389e+09 1.16196e+09
 8.24701e+07
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
      2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for downcomer (pwr int # 69)         Mar '96
             9.07865e+03 4.64029e+05 2.97633e+06 3.40422e+07 1.08686e+11
 1.61151e+11 5.23443e+10 2.55963e+10 4.86437e+10 5.08230e+10 3.67259e+10
 4.41619e+10 6.31741e+10 6.35878e+10 8.99862e+10 1.11188e+11 5.49328e+11
 1.85319e+11 1.00367e+11 1.16212e+11 8.28716e+09 2.81188e+11 2.51682e+11
 1.44918e+11 1.71906e+11 1.82161e+11 1.10502e+11 3.79878e+11 2.06617e+11
 5.40032e+11 9.11408e+11 7.40802e+11 1.07902e+12 8.06000e+11 1.78515e+11
 3.40832e+11 5.07365e+11 1.16649e+11 1.07556e+11 1.05784e+10 7.80633e+07
 3.49827e+03
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 17   a11 -1 e t
2$$ 100131 801631
    2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
    2805852 2806052 2806152 2806252 2806452 2505552 601252  t
4** 16r600. 300. e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
```

Table A.10. (Cont'd)

```
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi          scampi
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs          malocs
if ( ! ( -e rade  ) )    ln -s $PGM_DIR/rade            rade
if ( ! ( -e alpo    ) )  ln -s $PGM_DIR/alpo            alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl          nitawl
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.pdown.binr3
```

Table A.11 Processing Job For Collapsing Pressure Vessel Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 15 t
3$$ 2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
    2805851 2806051 2806151 2806251 2806451 2505551 601251  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for pwr 1/4 t (int # 82)           Mar '96
 2.03215e+03 4.18056e+05 6.81865e+05 2.08922e+06 3.02157e+06 2.04763e+06
 2.54330e+06 3.03800e+06 3.59299e+06 9.18082e+06 6.23205e+06 6.71812e+06
 1.50512e+07 1.89521e+07 3.05225e+07 3.69878e+07 4.76357e+07 6.29950e+07
 7.09828e+07 7.72222e+07 9.58409e+07 1.08454e+08 1.15445e+08 1.48532e+08
 5.53087e+07 1.22804e+08 2.07669e+08 2.04994e+08 2.01628e+08 2.43334e+08
 2.26654e+08 2.54045e+08 2.58444e+08 5.06374e+08 4.59876e+08 4.59142e+08
 2.54035e+08 3.21448e+08 3.74510e+08 4.04206e+08 4.63800e+08 4.40535e+08
 3.45104e+08 1.06835e+08 1.21513e+08 1.97142e+08 4.15481e+08 5.79737e+08
 5.53014e+08 5.35248e+08 5.40172e+08 6.68888e+08 7.24571e+08 6.83830e+08
 7.17674e+08 6.96118e+08 7.44846e+08 7.69783e+08 7.01744e+08 1.05792e+09
 9.93141e+08 1.63592e+09 6.50915e+08 1.22615e+09 8.73979e+08 9.54807e+08
 8.47164e+08 8.70091e+08 1.21457e+09 1.42394e+09 1.91549e+09 2.07707e+09
 1.49149e+09 1.26944e+09 1.17421e+09 1.04716e+09 2.26682e+09 1.50290e+09
 6.65211e+08 1.58189e+09 3.12159e+09 3.26339e+09 4.25648e+08 1.39922e+08
 2.22958e+08 3.50825e+08 6.75385e+08 1.69728e+09 9.84263e+08 5.61228e+08
 8.98116e+08 5.76868e+08 3.44429e+08 7.90226e+08 1.08735e+09 8.24752e+08
 8.06347e+08 4.74128e+08 2.48667e+08 1.02195e+09 5.61371e+08 9.30994e+08
 6.06883e+08 5.64584e+08 9.54252e+08 6.89646e+08 1.89188e+08 8.65162e+08
 6.85223e+08 8.54640e+08 1.23261e+09 3.72389e+08 8.53077e+08 6.08219e+08
 6.20878e+08 2.05786e+08 1.04499e+08 3.19190e+07 1.70755e+08 1.17856e+09
 5.74779e+08 3.01447e+08 6.74028e+08 6.41245e+08 9.04405e+08 8.44766e+08
 3.20065e+08 3.54901e+08 3.64416e+08 9.58778e+08 1.00082e+09 5.43613e+08
 3.94439e+08 3.70119e+08 3.26757e+08 1.43042e+08 1.17488e+08 1.70699e+08
```

```
 2.52204e+08 8.34092e+08 8.46457e+08 6.88845e+08 6.79808e+08 6.70325e+08
 6.44457e+08 3.84890e+08 5.74520e+08 6.11877e+08 6.26343e+08 6.33040e+08
 6.35565e+08 6.35521e+08 6.33173e+08 6.28578e+08 6.21589e+08 6.12049e+08
 5.99986e+08 5.84983e+08 5.67397e+08 5.46951e+08 5.23508e+08 4.97454e+08
 4.68932e+08 4.47222e+08 4.15622e+08 3.82848e+08 3.49625e+08 3.17941e+08
 1.27342e+08 1.63889e+08 4.36622e+07 3.97262e+07 4.14360e+07 1.27715e+08
 7.52922e+07 1.18850e+08 6.65624e+07 1.15791e+08 4.45780e+07 1.36196e+08
 9.94780e+07 1.07402e+08 1.61617e+08 2.11647e+08 2.20140e+08 2.17164e+08
 1.78275e+08 1.88484e+08 2.35810e+08 1.49982e+08 6.88905e+07 5.26549e+07
 3.23228e+07 1.43354e+07 5.74911e+06 3.11617e+06 6.51680e+05 9.16805e+04
 5.55381e+03
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
      2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for pwr 1/4 t (int #82)                Mar '96
             1.36280e+03 5.04155e+04 3.11115e+05 3.37501e+06 9.41338e+09
 1.44768e+10 5.33314e+09 3.25443e+09 5.30716e+09 5.74850e+09 4.82593e+09
 5.69622e+09 7.58842e+09 8.20490e+09 1.06041e+10 1.30938e+10 2.63421e+10
 1.87301e+10 1.02051e+10 1.14511e+10 7.66627e+08 2.88382e+10 2.55198e+10
 1.40042e+10 1.65787e+10 1.73677e+10 2.28301e+10 1.93786e+10 1.83964e+10
 4.62153e+10 6.99706e+10 4.42136e+10 3.15168e+10 5.53679e+09 3.13010e+08
 2.31786e+08 2.69633e+07 1.51193e+06 1.46105e+06 5.17695e+05 4.01734e+05
 2.64739e+04
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 15   a11 -1 e t
2$$ 2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
    2805851 2806051 2806151 2806251 2806451 2505551 601251
4**  14r600. 300.  e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi          scampi
```

Table A.11 (Cont'd)

```
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs          malocs
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade            rade
if ( ! ( -e alpo    ) )  ln -s $PGM_DIR/alpo            alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl          nitawl
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.pp14t.binr3
```

Table A.12 Processing Job For Collapsing Concrete Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA    ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 13 t
3$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for concrete (int #106)             Mar '96
 7.49089e+01 1.17450e+04 2.18856e+04 6.65186e+04 9.03011e+04 5.93865e+04
 7.23383e+04 8.52154e+04 9.96951e+04 2.49934e+05 1.67743e+05 1.83308e+05
 3.86282e+05 4.75843e+05 7.91253e+05 9.09275e+05 1.16524e+06 1.57593e+06
 1.72816e+06 1.78897e+06 2.15954e+06 2.34602e+06 2.45418e+06 3.22437e+06
 1.22696e+06 2.76014e+06 4.67362e+06 4.52275e+06 4.50172e+06 5.87379e+06
 5.38154e+06 6.16163e+06 6.05195e+06 1.27683e+07 1.08807e+07 1.04539e+07
 6.70057e+06 9.28986e+06 1.04109e+07 1.19418e+07 1.44194e+07 1.42482e+07
 1.27614e+07 4.07382e+06 5.22988e+06 8.73649e+06 1.48167e+07 1.84750e+07
 1.72498e+07 1.45772e+07 1.35677e+07 2.34182e+07 2.12228e+07 1.95332e+07
 2.31932e+07 2.59998e+07 2.70471e+07 1.87577e+07 2.73080e+07 3.19539e+07
 3.16101e+07 3.94638e+07 1.27634e+07 2.60949e+07 3.16730e+07 3.68396e+07
 4.45387e+07 4.94233e+07 5.39156e+07 5.97974e+07 6.91957e+07 8.02057e+07
 8.07039e+07 7.36781e+07 8.07989e+07 7.78520e+07 1.20683e+08 7.17608e+07
 4.16483e+07 4.34337e+07 1.16100e+08 1.38926e+08 1.60702e+07 6.05129e+06
 1.26130e+07 3.40802e+07 6.98310e+07 1.38240e+08 6.80422e+07 6.73782e+07
 6.16487e+07 5.96601e+07 5.51216e+07 5.32484e+07 6.15963e+07 7.68394e+07
 8.74831e+07 8.20728e+07 7.54146e+07 7.52664e+07 8.30361e+07 8.44216e+07
 7.42002e+07 7.55824e+07 1.78796e+08 1.56690e+08 5.85381e+07 5.11802e+07
 1.32931e+08 8.63812e+07 2.06913e+08 7.91847e+07 1.68920e+08 1.49037e+08
 1.86957e+08 8.65092e+07 1.29518e+08 6.03404e+07 4.16963e+07 5.94854e+07
 2.99593e+07 2.95727e+07 8.79286e+07 1.43873e+08 2.84526e+08 2.81089e+08
 1.11444e+08 1.63558e+08 2.76291e+08 2.73184e+08 2.74347e+08 1.61861e+08
 9.94352e+07 9.52323e+07 6.94481e+07 4.24177e+07 5.56387e+07 1.25215e+08
```

NUREG/CR-6214, Rev. 1
ORNL/TM-6795/R1

Production and Testing of the Revised VITAMIN-B6 Fine-Group and the BUGLE-93 Broad-Group Neutron/Photon Cross-Section Libraries Derived From ENDF/B-VI.3 Nuclear Data

Oak Ridge National Laboratory

Los Alamos National Laboratory

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Production and Testing of the Revised VITAMIN-B6 Fine-Group and the BUGLE-93 Broad-Group Neutron/Photon Cross-Section Libraries Derived From ENDF/B-VI.3 Nuclear Data

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ABSTRACT

A revised multigroup cross-section library based on Release 3 of ENDF/B-VI data has been produced and tested for light-water-reactor shielding and reactor pressure vessel dosimetry applications. This new broad-group library, which is designated BUGLE-96, represents an improvement over the BUGLE-93 data library released in February 1994 and replaces the data package for BUGLE-93 in the Radiation Safety Information Computational Center (formerly RSIC). The processing methodology is the same as that used for producing BUGLE-93 and is consistent with ANSI/ANS 6.1.2. The ENDF data were first processed into a fine-group, pseudo-problem-independent format and then collapsed into the final broad-group format. The fine-group library, which is designated VITAMIN-B6, contains 120 nuclides. The BUGLE-96 47-neutron-group/20-gamma-ray-group library contains the same 120 nuclides processed as infinitely dilute and collapsed using a weighting spectrum typical of a concrete shield. Additionally, nuclides processed with resonance self-shielding and weighted using spectra specific to BWR and PWR material compositions and reactor models are available. As an added feature of BUGLE-96, cross-section sets having upscatter data for four thermal neutron groups are included. The upscattering data should improve the application of BUGLE-96 to the calculation of more accurate thermal fluences, although more computer time will be required. Several new dosimetry response functions and kerma factors for all 120 nuclides are also included in the library. The incorporation of feedback from users has resulted in a data library that addresses a wider spectrum of user needs.

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FOREWORD

Since the January 1995 publication of NUREG/CR-6214, "Production of the VITAMIN-B6 Fine Group and the BUGLE-93 Broad-Group Neutron/Photon Cross-Section Libraries Derived from ENDF/B-VI Nuclear Data," additional enhancements have been made to the multigroup constants used by the worldwide light-water-reactor (LWR) community. Whereas, the initial BUGLE-93 report documented the development of multigroup data derived from Release 2 of ENDF/B-VI, the objective of this revised report is to document the BUGLE-96 data library, which is based on Release 3 of ENDF/B-VI reference data.

The documentation of BUGLE-93 improved on the standard for LWR cross-section data development with highly detailed descriptions of both the data development and data testing components of the original task. New reference evaluated data for several important nuclides combined with a need to improve the self-shielding for the materials in the reactor pressure vessel, and a need to provide better data for LWR applications sensitive to the thermal flux, motivated continued work toward improving the BUGLE-93 product. Sponsorship of the current work to help meet the ANSI/ANS 6.1.2 requirements for updating the standard on nuclear radiation protection calculations for nuclear power plants was provided by the U.S. Nuclear Regulatory Commission.

This revision to NUREG/CR-6214 represents an attempt to reduce confusion, and hopefully errors, in usage caused by the anticipated burden on readers switching between an addendum and the original report in order to obtain the correct data for nuclear engineering analysis. In part, the approach taken in preparing this revision was to integrate work performed during the past 2 ½ years with the original work and rewrite the data preparation sections of NUREG/CR-6214. For completeness, the section of the original report describing the data testing program is included. Although new data testing activity was not supported in the present effort, a few selected CSEWG benchmarks were calculated with BUGLE-96 to gain some confidence in the performance of the new Release 3 evaluations. No expected differences were observed in the performance parameters for the benchmarks checked.

ACKNOWLEDGMENTS

The authors are grateful to all individuals who helped directly or indirectly with developing the library specifications, processing the cross-section data, or analyzing the benchmark experiments. We wish to explicitly acknowledge our gratitude to Professor Mark Williams of Louisiana State University for valuable discussions and contributions in the processing and data testing activities, and to Mike Mayfield and Carolyn Fairbanks of the U.S. Nuclear Regulatory Commission for their sponsorship of this project.

1 INTRODUCTION

The generation of multigroup cross-section libraries with broad energy group structures is primarily for reasons of economy. Despite the impressive performance of modern supercomputers, it is still often impractical to perform two- and three-dimensional radiation transport analyses using pointwise data or finely structured multigroup data, especially if fine resolution is needed for the space or angular meshes. Even for one-dimensional analyses, it is often more efficient to use few-group data to perform the initial scoping analysis, and then advance to finer group data as accuracy requirements become more stringent. The establishment of reference broad-group libraries is desirable to avoid duplication of effort, both in terms of the library generation and verification, and to assure a common database for comparisons among program participants.

A revised multigroup cross-section library based on Release 3 of ENDF/B-VI data[1] has been produced and tested for light-water-reactor shielding and reactor pressure vessel dosimetry applications. The broad-group library, which is designated BUGLE-96, represents an improvement over the BUGLE-93 data library (D. T. Ingersoll et al., NUREG/CR-6214, 1995), which was released in February 1994 as a replacement for the outdated BUGLE-80[2] and SAILOR[3] libraries. The data were initially prepared by processing the ENDF data into a fine-group, pseudo-problem-independent format using the NJOY processing system[4] and then by collapsing the fine-group data into the final broad-group format using the AMPX code system.[5] The fine-group library is designated VITAMIN-B6 and is modeled after the earlier VITAMIN-C[6] and VITAMIN-E[7] libraries. BUGLE-93 is available in a format for direct use in radiation transport codes such as ANISN,[8] DORT,[9] TORT,[10] MORSE,[11] and other similar multigroup codes. It is expected that the general nature of BUGLE-96, and especially VITAMIN-B6, will make these libraries useful for other shielding applications and potentially for reactor physics analyses.

1.1 Background

In 1974, the Cross-Section Evaluation Working Group (CSEWG) released Version 4 of the Evaluated Nuclear Data Files (ENDF/B-IV).[12] Subsequently, several independent efforts were undertaken to develop multigroup cross-section libraries based on these improved data files. At the same time, the ANS 6.1 Working Group was working to develop a standardized approach for generating multigroup cross sections to be used in radiation protection and shielding analyses for nuclear power plants. Their goal was to establish the recommended methodology for generating a problem-dependent cross-section library and also to select a reference library utilizing this methodology as an industry standard.

The recommended methodology adopted by ANS 6.1 consists of a two-stage process: (1) the processing of ENDF files into a fine-group, pseudo-problem-independent library, followed by (2) the collapsing of the fine-group library into the desired broad-group, problem-dependent library. The library generated in the first stage is considered pseudo-problem-independent if it has been prepared with enough detail in energy, temperatures, and resonance self-shielding so as to be applicable to a wide range of specific problems. The problem-dependent library is then derived from the fine-group library by applying temperature and resonance self-shielding information and collapsing to a smaller number of groups. This approach removes from the end user the need to deal with the complex and tedious task of producing a group-averaged library from the ENDF files, which contain a mix of point and functional data. This approach also reduces the user's responsibility to the operation of a finite number of well-defined processing codes. Hence, a higher level of standardization is achieved, along with a higher level of reliability since the user can focus on only those features that are special to his application.

The activities of the ANS 6.1 Working Group motivated the development and generation of a broad-group library, designated BUGLE, specifically tailored for power reactor radiation shielding analyses. The library, which was derived from the ENDF/B-IV-based VITAMIN-C fine-group library,[6] contained 45 neutron energy groups and 16 gamma-ray energy groups. However, initial experience with the BUGLE library indicated specific deficiencies, especially with respect to the group structure and the energy weighting function. As a result, the library specifications were modified and a new library was prepared and designated as BUGLE-80.[2] In parallel to the BUGLE-80 effort was an independent project to analyze fluence levels at the pressure vessel location in specific light-water power reactors. This project culminated in the production of a broad-group cross-section library, designated SAILOR.[3] The SAILOR library is similar to BUGLE-80, using the same 47 neutron energy groups and 20 gamma-ray energy groups, but differs in the weighting spectra used to collapse from the VITAMIN-C data. Whereas BUGLE-80 uses only a single energy weighting, which corresponds to the spectrum within the concrete shield of an LWR, SAILOR uses five different spectra corresponding to specific core, downcomer, and pressure vessel locations within specific PWR and BWR models.

At the completion of their effort, the ANS 6.1 Working Group issued a standard describing the methodology for producing multigroup cross sections for nuclear power plant shielding analyses. This standard, ANSI/ANS 6.1.2,[13] explicitly mentions the fine-group VITAMIN-C cross-section library and the derived broad-group BUGLE-80 library as satisfying the preferred processing methodology. The SAILOR library also employs the same methodology and is cited in the standard. These libraries, derived from ENDF/B-IV, have been used extensively in the LWR shielding community, but were in need of updating with more modern and accurate nuclear data. Because of this, the U.S. Nuclear Regulatory Commission (NRC) supported an effort to update the BUGLE-80 and SAILOR libraries. In the initial phase of the project, specifications for the new library were developed[14] and extensively reviewed. The driving constraints for the project were to construct a cross-section library that was based on the best available nuclear data and which was "plug compatible" with the previous libraries to facilitate its rapid implementation by the LWR community.

The project resulted in the production of a new fine-group library, designated VITAMIN-B6, and a new broad-group library, designated BUGLE-93.[38] The BUGLE-93 library was released for general distribution in February 1994, and was quickly implemented by the LWR shielding community. Feedback from the user community indicated the need for a few further improvements to the data library. Specifically, it is desirable for some users to have the new data provided in a format which is <u>exactly</u> compatible with the previous SAILOR library, (i.e. the nuclides should be premixed into compound materials having the same nuclide densities and material identifiers as SAILOR. More significantly, accuracy issues related to the treatment of thermal scattering reactions were studied by users at Louisiana State University (LSU). Conclusions from the LSU study indicated that for some problems of interest, it is important to retain neutron "upscatter" reactions in the multigroup data. For these reasons, and because revised versions of the ENDF/B-VI data had been released subsequent to the generation of BUGLE-93, a project was undertaken to produce a revised multigroup library, which is designated as BUGLE-96 and is described in this report.

1.2 Evaluated Nuclear Data Files

Version VI of the U.S. Evaluated Nuclear Data File (ENDF/B-VI)[1] was released for open distribution in 1990 after an extensive measurement and evaluation effort spanning nearly 10 years. The multilaboratory project was coordinated by CSEWG, which is operated through the National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. Seventy-four of the 320 evaluations contained in the library are new for Version VI. Most of the new evaluations represent relatively important nuclides throughout the mass range, and many of them include substantial changes to the cross-section data. Subsequent to the initial release of ENDF/B-VI in 1991, revisions to some of the evaluations and additional new evaluations were prepared and released. The latest of these major releases is Release 3, which was distributed in May 1995. The BUGLE-96 library reported herein is derived from this release of ENDF.

ENDF/B-VI contains numerous significant changes relative to earlier versions. Improved experimental data and model predictions are included, and several format changes were made to provide for better representation of the underlying physics and the extension to higher energies. Some of the more significant changes include:

- new resonance region evaluation for ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu (first update since ENDF/B-III)
- simultaneous evaluation of several neutron standard cross sections
- addition of sublibraries in File 1 for charged particle reactions
- File 6 formats for angle-energy correlations of recoil and secondary particles
- Reich-Moore formalism for resonance region
- representation separate isotopic evaluations for structural elements

Note that even though the format changes were well-intended and thoroughly reviewed before implementation, they have adversely affected the timely utilization of Version VI data since processing codes must be correspondingly altered to treat the new formats. Unfortunately, the steady decline in funding support for work of this type during the past decade has caused most of the processing code systems to become out of date. Currently, only the NJOY code system developed by Los Alamos National Laboratory is available to process ENDF/B-VI.

Of special interest for LWR shielding analyses are improvements to the iron evaluation. For more than a decade, it had been widely observed in integral benchmark experiments that neutron transmission through thick iron was consistently underpredicted in the energy range of 3 to 10 MeV. It became apparent that at least a portion of the discrepancies were due to the continuum inelastic scattering cross section for ^{56}Fe. Specifically, ENDF/B-V (and previous versions) treat the continuum inelastic cross section as isotropic for the outgoing neutrons; however, differential data indicate that the angular distribution for outgoing neutrons is in fact forward directed, which if incorporated into the cross-section data, would increase the transmission of neutrons through iron. To test this theory, a preliminary version of ENDF/B-VI iron data[15] was prepared and used to analyze several benchmarks. The new iron data showed significant improvements in the calculated-to-experiment ratios for those benchmarks.

An especially important result was obtained from dosimetry data taken from the reactor cavity region of Arkansas Nuclear One Unit-1 (ANO-1). The original analysis of ANO-1 was performed using two-dimensional (2-D) transport methods incorporating ENDF/B-IV data and showed a consistent underprediction of the pressure vessel dosimetry.[16] Since the reactor included a thick iron thermal shield and an iron pressure vessel, it was expected that the discrepancies might be due to the iron data. A reanalysis of ANO-1 using scaled one-dimensional (1-D) methods and preliminary Version 6 iron data showed significant improvements in the agreement with the measured dosimeter data.[17]

Because of these observations and other known improvements contained in ENDF/B-VI, it became clear that use of these data will substantially benefit light-water-reactor shielding applications. Our processing of ENDF/B-VI into multigroup format for use in radiation transport calculations now provides analysts with the most currently available nuclear data, which will help to reduce design biases and uncertainties.

1.3 Cross-Section Processing and Testing

The calculational approach used to produce a new ENDF/B-VI library is consistent with the ANS 6.1.2 standard. Specifically, the ENDF data were first processed into a fine-group set similar to the VITAMIN-C and VITAMIN-E libraries and then collapsed into a broad-group set similar to BUGLE-80. Although the overall methodology is the same, a different set of processing codes were used to perform the initial phase of the processing. The earlier VITAMIN-C and VITAMIN-E libraries were created from ENDF/B-IV and ENDF/B-V using a combination of the AMPX code system and the MINX code. However, these codes were not kept current with the format changes in ENDF/B-VI, and it was prohibitively expensive to make the required changes to the codes for this project. Instead, the selected approach employs both the NJOY modular code system and the AMPX code system.

Several modules of NJOY were used to process the neutron interaction, gamma-ray production, and gamma-ray interaction data from the ENDF/B-VI formats to a group-averaged format. The SMILER module in the AMPX code system was then used to translate the intermediate NJOY file into the AMPX master format for the fine-group library. A detailed description of the VITAMIN-B6 fine-group library and the processing system is given in Chapter 2. Additional modules from the AMPX system were then used to perform the computations and manipulations needed to produce the final broad-group library. The specifications and processing methods used to generate the BUGLE-96 broad-group library are described in Chapter 3.

Finally, the BUGLE-96 verification and validation effort described in Chapter 4 includes the results of a thorough benchmark testing effort for the preceding BUGLE-93 library.

2 FINE-GROUP LIBRARY SPECIFICATIONS

2.1 Name

The fine-group pseudo-problem-independent library is designated as VITAMIN-B6. This continues the "VITAMIN" naming convention initially started with the ENDF/B-IV-based VITAMIN-C library and the follow-on ENDF/B-V-based VITAMIN-E library. The "B6" designation conveniently reflects the origin of the evaluated data, but also was chosen since vitamin B_6 represents an element of broad nutritional value -- something that we feel will characterize this new library.

2.2 Materials, Temperatures and Background Cross Sections

The set of 120 nuclides processed for VITAMIN-B6 are listed in Table 2.1, which also indicates the ENDF/B-VI MAT number and tape number. The nuclides that underwent major revisions for Version 6 of ENDF are flagged in the table, along with the nuclides which are contained in BUGLE-80. Even though all nuclides contain neutron interaction and photon interaction data, only some of the nuclides contain gamma-ray production data, as indicated in the table. Two of the nuclides, tin and Zirc-2, were not available from ENDF/B-VI and were obtained elsewhere. Tin was obtained from the Livermore Evaluated Nuclear Data Library (LENDL-V),[18] and Zirc-2 was obtained from Version IV of ENDF. Seven additional nuclides that contain only a limited number of specific reactions were also processed. These nuclides are important for dosimetry applications and are listed in Table 2.2. It is expected that additional materials beyond those listed in Tables 2.1 and 2.2 will be processed and added to the library as needed for future analysis projects.

The Bondarenko (f-factor) method is used for handling resonance self-shielding and temperature effects. All materials were processed at temperatures of 300, 600, 1000, and 2100 K, and most materials were processed with 6 to 8 values of the background cross section, σ_0. These parameters are summarized in Table 2.3. As seen in Table 2.3, nearly all materials are processed with the following values of σ_0: 1, 10, 10^2, 10^3, 10^4, and 10^{10} barns. Even though these values of σ_0 appear adequate for most circumstances, additional values were added to this library to improve the accuracy of the cross-section interpolation between σ_0 values. These additional values are based on experience obtained in the utilization of VITAMIN-E. Consistent with most other libraries, we elected to use infinitely dilute cross sections for nuclides with Z less than 7, with the exception of ^{11}B. Hence, only a background cross section of 10^{10} barns was used for these nuclides. The thermal scattering law data for graphite, polyethylene, beryllium metal, heavy water, and light water were processed at all temperatures available on the ENDF tape.

Table 2.1 ENDF/B-VI nuclides processed for the VITAMIN-B6 library

Z	Nuclide	MAT	ENDF[a] tape	New for Ver. 6	BUGLE-80 nuclides	Gamma-ray production
1	H-1 (H_2O)	125/1	120/118	X	X	X
	H-1 (CH_2)	125/37	120/118	X		X
	H-2 (D_2O)	128/11	134/118[b]	X		X
	H-3	131	101		X	
2	He-3	225	120	X		
	He-4	228	101		X	
3	Li-6	325	120	X	X	X
	Li-7	328	100	X	X	X
4	Be-9	425	100	X	X	X
	Be-9 (Thermal)	425/26	100/118	X		X
5	B-10	525	120	X	X	X
	B-11	528	100	X	X	X
6	C	600	120	X	X	X
	C (Graphite)	600/31	120/118[b]	X		X
7	N-14	725	134	X	X	X
	N-15	728	116	X		X
8	O-16	825	116	X	X	X
	O-17	828	101			
9	F-19	925	115	X	X	X
11	Na-23	1125	120		X	X
12	Mg	1200	101		X	X
13	Al-27	1325	134		X	X
14	Si	1400	116		X	X
15	P-31	1525	101		X	X
16	S	1600	101		X	X
	S-32	1625	101			X
17	Cl	1700	101			X
19	K	1900	101		X	X
20	Ca	2000	101		X	X
22	Ti	2200	102		X	X
23	V	2300	103	X	X	X
24	Cr-50	2425	122	X	X	X
	Cr-52	2431	122	X	X	X
	Cr-53	2434	122	X	X	X
	Cr-54	2437	122	X	X	X
25	Mn-55	2525	114	X	X	X
26	Fe-54	2625	123	X	X	X
	Fe-56	2631	123	X	X	X
	Fe-57	2634	123	X	X	X
	Fe-58	2637	123	X	X	X
27	Co-59	2725	129	X	X	X
28	Ni-58	2825	124	X	X	X
	Ni-60	2831	124	X	X	X
	Ni-61	2834	124	X	X	X
	Ni-62	2837	124	X	X	X
	Ni-64	2843	124	X	X	X
29	Cu-63	2925	129	X	X	X
	Cu-65	2931	129	X	X	X

Table 2.1 cont'd

Z	Nuclide	MAT	ENDF tape	New for Ver. 6	BUGLE-80 nuclides	Gamma-ray production
31	Ga	3100	102			X
39	Y-89	3925	103	X		X
40	Zr	4000	120		X	
40	Zirc-2	1284	411[c]		X	
41	Nb-93	4125	120	X	X	X
42	Mo	4200	104		X	X
47	Ag-107	4725	104		X	
	Ag-109	4731	104		X	
48	Cd	4800	104		X	
49	In	4900	116	X		X
50	Sn	7850	---[d]		X	X
56	Ba-138	5649	134		X	X
63	Eu-151	6325	103	X	X	X
	Eu-152	6328	103	X	X	
	Eu-153	6331	103	X	X	X
	Eu-154	6334	103	X	X	
	Eu-155	6337	120	X		
72	Hf-174	7225	127	X		
	Hf-176	7231	127	X		
	Hf-177	7234	127	X		
	Hf-178	7237	127	X		
	Hf-179	7240	127	X		
	Hf-180	7243	127	X		
73	Ta-181	7328	106		X	X
	Ta-182	7331	106			
74	W	7400	120			X
	W-182	7431	107		X	X
	W-183	7434	107		X	X
	W-184	7437	107		X	X
	W-186	7443	107		X	X
75	Re-185	7525	115	X		
	Re-187	7531	115	X		
79	Au-197	7925	120	X		X
82	Pb-206	8231	115	X	X	X
	Pb-207	8234	120	X	X	X
	Pb-208	8237	115	X	X	X
83	Bi-209	8325	108	X		X
90	Th-230	9034	110			
	Th-232	9040	109		X	X
91	Pa-231	9131	109			
	Pa-233	9137	110			
92	U-232	9219	109			
	U-233	9222	109		X	X
	U-234	9225	109		X	
	U-235	9228	135	X	X	X
	U-236	9231	108	X	X	
	U-237	9234	129			X
	U-238	9237	128	X	X	X

Table 2.1 cont'd

Z	Nuclide	MAT	ENDF tape	New for Ver. 6	BUGLE-80 nuclides	Gamma-ray production
93	Np-237	9346	121	X		X
	Np-238	9349	128			
	Np-239	9352	108	X		
94	Pu-236	9428	110			
	Pu-237	9431	110			
	Pu-238	9434	109		X	
	Pu-239	9437	128	X	X	X
	Pu-240	9440	128	X	X	X
	Pu-241	9443	135	X	X	X
	Pu-242	9446	109		X	X
	Pu-243	9449	129			X
	Pu-244	9452	110			
95	Am-241	9543	135	X	X	X
	Am-242	9546	121			
	Am-242m	9547	121			X
	Am-243	9549	108	X		X
96	Cm-241	9628	110			
	Cm-242	9631	109			X
	Cm-243	9634	110			X
	Cm-244	9637	110			X
	Cm-245	9640	129			X
	Cm-246	9643	129			X
	Cm-247	9646	129			X
	Cm-248	9649	110			X

[a] Tapes 100-119 are from initial release of ENDF/B-VI (April 1991);
Tapes 120-126 are from Revision 1 of ENDF/B-VI (August 1992);
Tapes 127-129 are from Revision 2 of ENDF/B-VI (June 1993);
Tapes 132-135 are from Revision 3 of ENDF/B-VI (May 1995).
[b] Incorporates improved thermal scattering law data from ORNL.
[c] From Revision 1 of ENDF/B-IV.
[d] From LENDL-V.

Table 2.2 ENDF/B-VI nuclides processed for dosimetry reactions only

Z	Nuclide	MAT	ENDF tape
21	Sc-45	2125	127[a]
22	Ti-46	2225	102
	Ti-47	2228	102
	Ti-48	2231	102
45	Rh-103	4525	104
49	In-115	4931	116
53	I-127	5325	127[a]

[a] Revision 2 of ENDF/B-VI (June 1993).

Table 2.3 Background cross-section values at which Bondarenko factors are tabulated in the VITAMIN-B6 library. All nuclides were processed at four temperatures: 300, 600, 1000, and 2100 K

Nuclide	Background cross sections (barns)										Legendre order
	10+10[a]	10+6	10+5	10+4	1000	300	100	50	10	1	
H-1	X										7
H-2	X										7
H-3	X										7
He-3	X										7
He-4	X										7
Li-6	X										7
Li-7	X										7
Be-9	X										7
B-10	X										7
B-11	X				X		X		X	X	7
C	X										7
N-14	X				X		X		X	X	7
N-15	X				X		X		X	X	7
O-16	X				X		X		X	X	7
O-17	X				X		X		X	X	7
F-19	X				X		X		X	X	7
Na-23	X				X	X	X	X	X	X	7
Mg	X		X	X	X		X		X	X	7
Al-27	X			X	X		X	X	X	X	7
Si	X		X	X	X		X		X	X	7
P-31	X			X	X		X		X	X	7
S	X			X	X		X		X	X	7
S-32	X			X	X		X		X	X	7
Cl	X			X	X		X		X	X	7
K	X			X	X		X		X	X	7
Ca	X		X	X	X		X		X	X	7
Ti	X		X	X	X		X		X	X	7
V	X			X	X		X		X	X	7
Cr-50	X		X	X	X		X		X	X	7
Cr-52	X		X	X	X		X		X	X	7
Cr-53	X		X	X	X		X		X	X	7
Cr-54	X		X	X	X		X		X	X	7
Mn-55	X		X	X	X		X		X	X	7
Fe-54	X		X	X	X		X		X	X	7
Fe-56	X		X	X	X		X	X	X	X	7
Fe-57	X		X	X	X		X		X	X	7
Fe-58	X		X	X	X		X		X	X	7
Co-59	X		X	X	X		X		X	X	7
Ni-58	X		X	X	X		X	X	X	X	7
Ni-60	X		X	X	X		X	X	X	X	7
Ni-61	X		X	X	X		X		X	X	7
Ni-62	X		X	X	X		X		X	X	7
Ni-64	X		X	X	X		X		X	X	7
Cu-63	X		X	X	X		X		X	X	7
Cu-65	X		X	X	X		X		X	X	7
Ga	X		X	X	X		X		X	X	5

Table 2.3 cont'd

Nuclide	Background cross sections (barns)										Legendre order
	10+10[a]	10+6	10+5	10+4	1000	300	100	50	10	1	
Y-89	X		X	X	X		X		X	X	5
Zr	X		X	X	X		X		X	X	5
Zirc2	X		X	X	X		X		X	X	5
Nb-93	X		X	X	X		X		X	X	5
Mo	X		X	X	X		X				5
Ag-107	X		X	X	X		X		X	X	5
Ag-109	X		X	X	X		X		X	X	5
Cd	X		X	X	X		X		X	X	5
In	X		X	X	X		X		X	X	5
Sn	X		X	X	X		X		X	X	5
Ba-138	X		X	X	X		X		X	X	5
Eu-151	X		X	X	X		X	X			5
Eu-152	X	X	X	X	X		X				5
Eu-153	X		X	X	X		X	X			5
Eu-154	X	X	X	X	X		X				5
Eu-155	X	X	X	X	X		X				5
Hf-174	X		X	X	X		X		X	X	5
Hf-176	X		X	X	X		X		X	X	5
Hf-177	X		X	X	X		X	X			5
Hf-178	X		X	X	X		X		X	X	5
Hf-179	X		X	X	X		X	X			5
Hf-180	X		X	X	X		X		X	X	5
Ta-181	X		X	X	X		X	X			5
Ta-182	X		X	X	X		X	X			5
W	X		X	X	X		X		X	X	5
W-182	X		X	X	X		X		X	X	5
W-183	X		X	X	X		X	X			5
W-184	X		X	X	X		X		X	X	5
W-186	X		X	X	X		X		X	X	5
Re-185	X	X	X	X	X		X				5
Re-187	X	X	X	X	X		X				5
Au-197	X		X	X	X		X		X	X	5
Pb-206	X		X	X	X		X		X	X	5
Pb-207	X		X	X	X		X		X	X	5
Pb-208	X		X	X	X		X		X	X	5
Bi-209	X		X	X	X		X		X	X	5
Th-230	X	X	X	X	X		X				5
Th-232	X			X	X	X	X	X	X	X	5
Pa-231	X		X	X	X		X	X			5
Pa-233	X		X	X	X		X	X			5
U-232	X		X	X	X		X	X			5
U-233	X		X	X	X		X	X			5
U-234	X		X	X	X		X		X	X	5
U-235	X	X	X	X	X		X	X			5
U-236	X		X	X	X		X		X	X	5
U-237	X		X	X	X		X	X			5
U-238	X			X	X	X	X	X	X	X	5

Table 2.3 cont'd

Nuclide	Background cross sections (barns)										Legendre order
	10+10[a]	10+6	10+5	10+4	1000	300	100	50	10	1	
Np-237	X		X	X	X		X		X	X	5
Np-238	X		X	X	X		X	X			5
Np-239	X		X	X	X		X	X			5
Pu-236	X		X	X	X		X		X	X	5
Pu-237	X		X	X	X		X	X			5
Pu-238	X		X	X	X		X		X	X	5
Pu-239	X		X	X	X		X	X			5
Pu-240	X		X	X	X		X		X	X	5
Pu-241	X		X	X	X		X	X			5
Pu-242	X		X	X	X		X		X	X	5
Pu-243	X		X	X	X		X	X			5
Pu-244	X		X	X	X		X		X	X	5
Am-241	X		X	X	X		X	X			5
Am-242	X		X	X	X		X	X			5
Am-242m	X		X	X	X						5
Am-243	X		X	X	X		X	X			5
Cm-241	X		X	X	X		X	X			5
Cm-242	X		X	X	X		X	X			5
Cm-243	X		X	X	X		X	X			5
Cm-244	X		X	X	X		X	X			5
Cm-245	X		X	X	X		X	X			5
Cm-246	X		X	X	X		X	X			5
Cm-247	X		X	X	X		X	X			5
Cm-248	X		X	X	X		X	X			5

[a] Read as 1×10^{10}

2.3 Energy-Group Structure

Feedback from users of previous VITAMIN libraries, which were developed primarily for "fast" neutron applications, indicated that the neutron energy group structure appears adequate at higher energies, but that refining the neutron group structure in the thermal energy range would greatly expand the usefulness of the fine-group library for a broader range of applications. On the other hand, experience with a 27-neutron-group library from the SCALE system,[19] which was developed primarily for criticality safety and for out-of-core shielding applications, has been favorable in terms of the number of thermal energy groups, but has indicated inadequate resolution in the high energy range (E > 0.1 MeV). Hence, the VITAMIN-B6 neutron energy group structure was constructed as a compromise and improvement over the 174 neutron group structure used for VITAMIN-E and the 27-neutron-group structure used for SCALE.

The VITAMIN-B6 thermal energy range (i.e., the range of groups which include upscatter) contains 36 groups and has 5.043 eV as the uppermost boundary. The group boundaries are listed in Table 2.4, which also labels corresponding boundaries from the VITAMIN-E and the 27-group libraries. Figure 2.1 provides a graphical comparison of the neutron group boundaries below 5.043 eV for the VITAMIN-B6, VITAMIN-E, SCALE, and BUGLE-96 group structures. By combining the best features of the VITAMIN and 27-group neutron energy grids, we have maximized our options for creating the best problem-independent energy grid for a variety of reactor designs including thermal (water- or graphite- moderated) and fast reactor systems. Consequently, problem-dependent libraries can be easily derived from VITAMIN-B6 without having to repeat the multigroup averaging directly from the ENDF files.

The full VITAMIN-B6 neutron energy group structure is given in Table 2.5. The 199-group boundaries are based on the 175 groups in VITAMIN-J (a European library based on the VITAMIN-C and VITAMIN-E structures) with an expanded number of thermal groups as discussed above. At higher energies, the boundaries are almost identical with the earlier VITAMIN libraries, which consist of a basic 100-group-mesh of equal lethargy width plus numerous additional boundaries to resolve resonance minima that are important for shielding calculations.

The photon energy group structure is given in Table 2.6. It is based on a combination of the 42 gamma-ray groups in VITAMIN-J and the 18 groups in the SCALE shielding library. The top energy group extends to 30 MeV, which allows proper representation of high-energy gamma rays from neutron capture at high energies. Although the cross section for capture at neutron energies between 20 and 30 MeV is small, such a reaction in some materials can produce gamma rays with energies between 20 and 30 MeV.

2.4 Weighting Function

The neutron weighting function is of the form typically chosen for fission reactor shielding problems (i.e., it consists of a smoothly varying combination of a Maxwellian thermal spectrum, a fission spectrum, and a "1/E" slowing-down spectrum). This corresponds to an IWT=4 option in the GROUPR module of NJOY. The breakpoint energies for

Table 2.4 VITAMIN-B6 thermal neutron energy range

Group	Upper energy (eV)	Lethargy Width	Group	Upper energy (eV)	Lethargy Width
164	5.0435*	0.250	182	0.36680	0.121
165	3.9279*	0.250	183	0.3250#	0.167
166	3.0590*	0.250	184	0.2750	0.201
167	2.3824*	0.250	185	0.2250#	0.210
168	1.8554*	0.250	186	0.1840	0.204
169	1.4450*	0.106	187	0.1500	0.182
170	1.3000#	0.144	188	0.1250	0.223
171	1.1253*	0.041	189	0.1000*#	0.357
172	1.0800	0.038	190	0.0700	0.366
173	1.0400	0.039	191	0.0500#	0.223
174	1.0000#	0.132	192	0.0400	0.288
175	0.87643*	0.091	193	0.0300#	0.357
176	0.8000#	0.159	194	0.0210	0.370
177	0.68256*	0.088	195	0.0145	0.372
178	0.62506	0.162	196	0.0100#	0.693
179	0.53158*	0.061	197	0.0050	0.916
180	0.5000	0.188	198	0.0020	1.386
181	0.41399*	0.121	199	0.0005	3.912
				0.00001*#	

* VITAMIN-E boundary.
\# 27-group SCALE boundary.

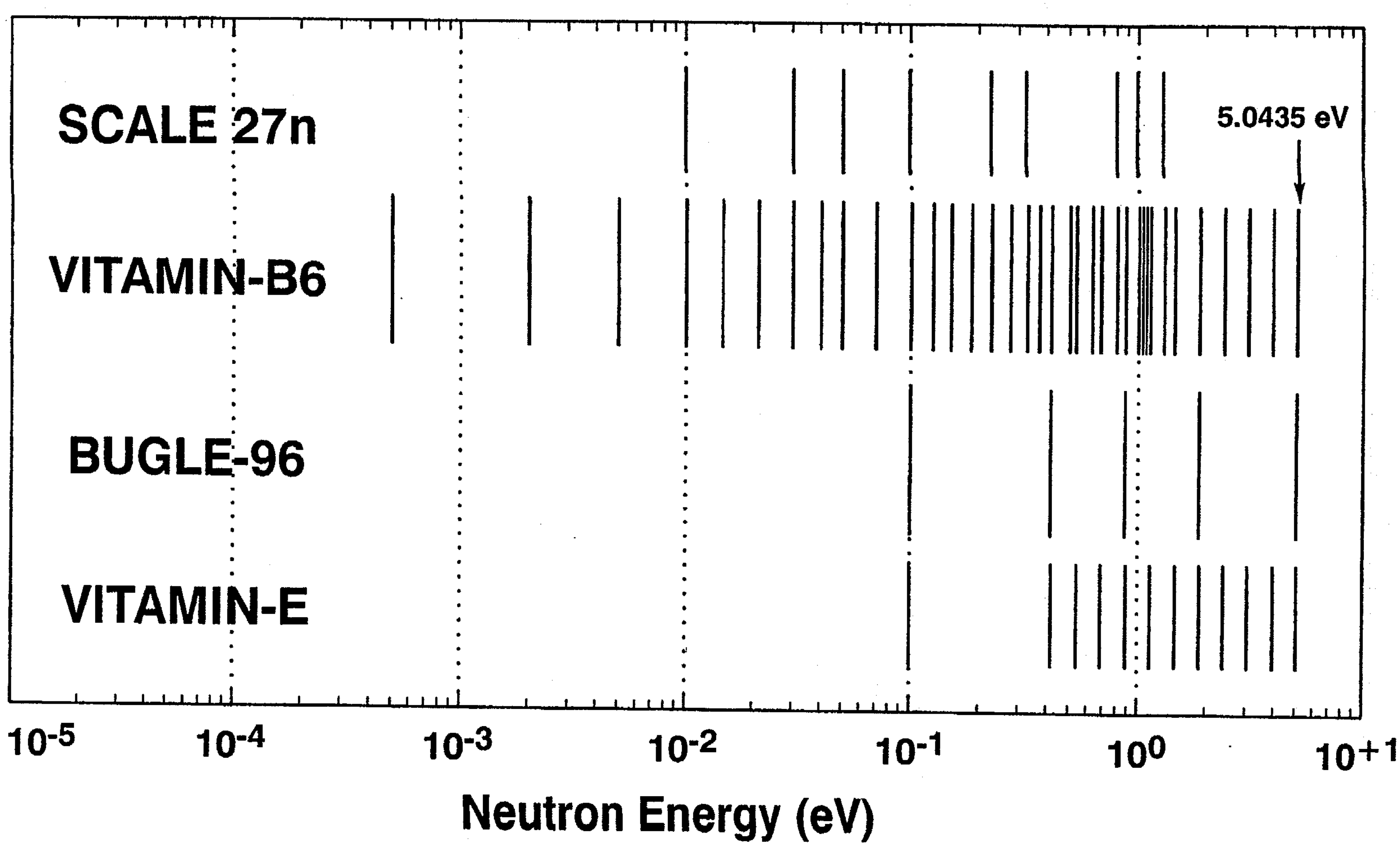


Fig. 2.1 Graphical display of neutron group boundaries below 5.0435 eV for several related cross-section libraries

Table 2.5 Neutron group energy boundaries for VITAMIN-B6

Fine group	Upper energy (eV)	Upper lethargy	Fine group	Upper energy (eV)	Upper lethargy
1	1.9640E+07	-6.7498E-01	48	2.2313E+06	1.5000E+00
2	1.7332E+07	-5.4997E-01	49	2.1225E+06	1.5500E+00
3	1.6905E+07	-5.2502E-01	50	2.0190E+06	1.6000E+00
4	1.6487E+07	-5.0000E-01	51	1.9205E+06	1.6500E+00
5	1.5683E+07	-4.5000E-01	52	1.8268E+06	1.7000E+00
6	1.4918E+07	-3.9998E-01	53	1.7377E+06	1.7500E+00
7	1.4550E+07	-3.7501E-01	54	1.6530E+06	1.8000E+00
8	1.4191E+07	-3.5002E-01	55	1.5724E+06	1.8500E+00
9	1.3840E+07	-3.2498E-01	56	1.4957E+06	1.9000E+00
10	1.3499E+07	-3.0003E-01	57	1.4227E+06	1.9500E+00
11	1.2840E+07	-2.4998E-01	58	1.3534E+06	2.0000E+00
12	1.2523E+07	-2.2498E-01	59	1.2874E+06	2.0500E+00
13	1.2214E+07	-2.0000E-01	60	1.2246E+06	2.1000E+00
14	1.1618E+07	-1.4997E-01	61	1.1648E+06	2.1500E+00
15	1.1052E+07	-1.0003E-01	62	1.1080E+06	2.2000E+00
16	1.0513E+07	-5.0028E-02	63	1.0026E+06	2.3000E+00
17	1.0000E+07	0.0000E+00	64	9.6164E+05	2.3417E+00
18	9.5123E+06	5.0000E-02	65	9.0718E+05	2.4000E+00
19	9.0484E+06	9.9997E-02	66	8.6294E+05	2.4500E+00
20	8.6071E+06	1.5000E-01	67	8.2085E+05	2.5000E+00
21	8.1873E+06	2.0000E-01	68	7.8082E+05	2.5500E+00
22	7.7880E+06	2.5000E-01	69	7.4274E+05	2.6000E+00
23	7.4082E+06	3.0000E-01	70	7.0651E+05	2.6500E+00
24	7.0469E+06	3.5000E-01	71	6.7206E+05	2.7000E+00
25	6.7032E+06	4.0000E-01	72	6.3928E+05	2.7500E+00
26	6.5924E+06	4.1667E-01	73	6.0810E+05	2.8000E+00
27	6.3763E+06	4.5000E-01	74	5.7844E+05	2.8500E+00
28	6.0653E+06	5.0000E-01	75	5.5023E+05	2.9000E+00
29	5.7695E+06	5.5000E-01	76	5.2340E+05	2.9500E+00
30	5.4881E+06	6.0000E-01	77	4.9787E+05	3.0000E+00
31	5.2205E+06	6.5000E-01	78	4.5049E+05	3.1000E+00
32	4.9659E+06	7.0000E-01	79	4.0762E+05	3.2000E+00
33	4.7237E+06	7.5000E-01	80	3.8774E+05	3.2500E+00
34	4.4933E+06	8.0000E-01	81	3.6883E+05	3.3000E+00
35	4.0657E+06	9.0000E-01	82	3.3373E+05	3.4000E+00
36	3.6788E+06	1.0000E+00	83	3.0197E+05	3.5000E+00
37	3.3287E+06	1.1000E+00	84	2.9849E+05	3.5116E+00
38	3.1664E+06	1.1500E+00	85	2.9721E+05	3.5159E+00
39	3.0119E+06	1.2000E+00	86	2.9452E+05	3.5250E+00
40	2.8651E+06	1.2500E+00	87	2.8725E+05	3.5500E+00
41	2.7253E+06	1.3000E+00	88	2.7324E+05	3.6000E+00
42	2.5924E+06	1.3500E+00	89	2.4724E+05	3.7000E+00
43	2.4660E+06	1.4000E+00	90	2.3518E+05	3.7500E+00
44	2.3852E+06	1.4333E+00	91	2.2371E+05	3.8000E+00
45	2.3653E+06	1.4417E+00	92	2.1280E+05	3.8500E+00
46	2.3457E+06	1.4500E+00	93	2.0242E+05	3.9000E+00
47	2.3069E+06	1.4667E+00	94	1.9255E+05	3.9500E+00

Table 2.5 cont'd

Fine group	Upper energy (eV)	Upper lethargy	Fine group	Upper energy (eV)	Upper lethargy
95	1.8316E+05	4.0000E+00	142	1.2341E+03	9.0000E+00
96	1.7422E+05	4.0500E+00	143	9.6112E+02	9.2500E+00
97	1.6573E+05	4.1000E+00	144	7.4852E+02	9.5000E+00
98	1.5764E+05	4.1500E+00	145	5.8295E+02	9.7500E+00
99	1.4996E+05	4.2000E+00	146	4.5400E+02	1.0000E+01
100	1.4264E+05	4.2500E+00	147	3.5357E+02	1.0250E+01
101	1.3569E+05	4.3000E+00	148	2.7536E+02	1.0500E+01
102	1.2907E+05	4.3500E+00	149	2.1445E+02	1.0750E+01
103	1.2277E+05	4.4000E+00	150	1.6702E+02	1.1000E+01
104	1.1679E+05	4.4500E+00	151	1.3007E+02	1.1250E+01
105	1.1109E+05	4.5000E+00	152	1.0130E+02	1.1500E+01
106	9.8037E+04	4.6250E+00	153	7.8893E+01	1.1750E+01
107	8.6517E+04	4.7500E+00	154	6.1442E+01	1.2000E+01
108	8.2503E+04	4.7975E+00	155	4.7851E+01	1.2250E+01
109	7.9499E+04	4.8346E+00	156	3.7266E+01	1.2500E+01
110	7.1998E+04	4.9337E+00	157	2.9023E+01	1.2750E+01
111	6.7379E+04	5.0000E+00	158	2.2603E+01	1.3000E+01
112	5.6562E+04	5.1750E+00	159	1.7604E+01	1.3250E+01
113	5.2475E+04	5.2500E+00	160	1.3710E+01	1.3500E+01
114	4.6309E+04	5.3750E+00	161	1.0677E+01	1.3750E+01
115	4.0868E+04	5.5000E+00	162	8.3153E+00	1.4000E+01
116	3.4307E+04	5.6750E+00	163	6.4760E+00	1.4250E+01
117	3.1828E+04	5.7500E+00	164	5.0435E+00	1.4500E+01
118	2.8501E+04	5.8604E+00	165	3.9279E+00	1.4750E+01
119	2.7000E+04	5.9145E+00	166	3.0590E+00	1.5000E+01
120	2.6058E+04	5.9500E+00	167	2.3824E+00	1.5250E+01
121	2.4788E+04	6.0000E+00	168	1.8554E+00	1.5500E+01
122	2.4176E+04	6.0250E+00	169	1.4450E+00	1.5750E+01
123	2.3579E+04	6.0500E+00	170	1.3000E+00	1.5856E+01
124	2.1875E+04	6.1250E+00	171	1.1253E+00	1.6000E+01
125	1.9305E+04	6.2500E+00	172	1.0800E+00	1.6041E+01
126	1.5034E+04	6.5000E+00	173	1.0400E+00	1.6079E+01
127	1.1709E+04	6.7500E+00	174	1.0000E+00	1.6118E+01
128	1.0595E+04	6.8500E+00	175	8.7643E-01	1.6250E+01
129	9.1188E+03	7.0000E+00	176	8.0000E-01	1.6341E+01
130	7.1017E+03	7.2500E+00	177	6.8256E-01	1.6500E+01
131	5.5308E+03	7.5000E+00	178	6.2506E-01	1.6588E+01
132	4.3074E+03	7.7500E+00	179	5.3158E-01	1.6500E+01
133	3.7074E+03	7.9000E+00	180	5.0000E-01	1.6811E+01
134	3.3546E+03	8.0000E+00	181	4.1399E-01	1.7000E+01
135	3.0354E+03	8.1000E+00	182	3.6680E-01	1.7121E+01
136	2.7465E+03	8.2000E+00	183	3.2500E-01	1.7242E+01
137	2.6126E+03	8.2500E+00	184	2.7500E-01	1.7409E+01
138	2.4852E+03	8.3000E+00	185	2.2500E-01	1.7610E+01
139	2.2487E+03	8.4000E+00	186	1.8400E-01	1.7811E+01
140	2.0347E+03	8.5000E+00	187	1.5000E-01	1.8015E+01
141	1.5846E+03	8.7500E+00	188	1.2500E-01	1.8198E+01

Table 2.5 cont'd

Fine group	Upper energy (eV)	Upper lethargy	Fine group	Upper energy (eV)	Upper lethargy
189	1.0000E-01	1.8421E+01	195	1.4500E-02	2.0352E+01
190	7.0000E-02	1.8777E+01	196	1.0000E-02	2.0723E+01
191	5.0000E-02	1.9114E+01	197	5.0000E-03	2.1416E+01
192	4.0000E-02	1.9337E+01	198	2.0000E-03	2.2333E+01
193	3.0000E-02	1.9625E+01	199	5.0000E-04	2.3719E+01
194	2.1000E-02	1.9981E+01		1.0000E-05	2.7631E+01

Table 2.6 Photon group energy boundaries for VITAMIN-B6

Fine group	Upper energy (eV)	Fine group	Upper energy (eV)
1	3.0000E+07	23	1.0000E+06
2	2.0000E+07	24	8.0000E+05
3	1.4000E+07	25	7.0000E+05
4	1.2000E+07	26	6.0000E+05
5	1.0000E+07	27	5.1200E+05
6	8.0000E+06	28	5.1000E+05
7	7.5000E+06	29	4.5000E+05
8	7.0000E+06	30	4.0000E+05
9	6.5000E+06	31	3.0000E+05
10	6.0000E+06	32	2.0000E+05
11	5.5000E+06	33	1.5000E+05
12	5.0000E+06	34	1.0000E+05
13	4.5000E+06	35	7.5000E+04
14	4.0000E+06	36	7.0000E+04
15	3.5000E+06	37	6.0000E+04
16	3.0000E+06	38	4.5000E+04
17	2.5000E+06	39	4.0000E+04
18	2.0000E+06	40	3.0000E+04
19	1.6600E+06	41	2.0000E+04
20	1.5000E+06	42	1.0000E+04
21	1.3400E+06		1.0000E+03
22	1.3300E+06		

the 3-region spectrum are similar to those used in VITAMIN-C. The breakpoint energy between the Maxwellian and 1/E shapes is 0.125 eV. The fission temperature has been adjusted to better reflect the neutron spectrum in a thermal reactor (σ_0 = 1.273 MeV versus σ_0 = 1.41 MeV for VITAMIN-E). The use of a large number of energy groups should make the exact functional form and energy break points less important compared with generating a broad-group library directly from ENDF/B data. The functional form of the weighting spectrum is given by the following:

Functional form	Energy limits	Groups
1. Maxwellian Thermal Spectrum (kT = 0.025 eV)		
$W_1(E) = C_1Ee^{-E/kT}$	10^{-5} eV to 0.125 eV	188-199
2. "1/E" slowing-Down Spectrum		
$W_2(E) = C_2/E$	0.125 eV to 820.8 keV	167-187
3. Fission Spectrum (θ= 1.273 MeV)		
$W_3(E) = C_3E^{1/2}e^{-E/\theta}$	820.8 keV to 20 MeV	1-66

A continuous weighting spectrum is achieved with the following constants: $C_1 = 9498.4\ eV^{-2}$; $C_2 = 1.0$; and $C_3 = 2.5625\ MeV^{-1.5}$. The neutron weighting function is shown in Fig. 2.2 and listed in Table 2.7 in a 199-group form.

The photon weighting spectrum consists of a 1/E spectrum with a "roll-off" of the spectrum at lower energies to represent photoelectric absorption and a similar drop-off of the spectrum at higher energies corresponding to the Q-value for neutron capture. This corresponds to the IWT=3 input option in the GAMINR module of NJOY. The gamma-ray weighting function is shown in Fig. 2.3 and listed in Table 2.8 in a 42-group form.

2.5 Legendre Order of Scattering

The order of scattering used for both neutrons and photons is P_7 for nuclides with Z=1 through Z=29 (copper) and P_5 for the remainder of the nuclides. Most calculations are likely to be done with P_3 scattering, but for some problems (e.g., when single scatter events dominate), higher orders may be required.

2.6 Convergence Parameters

The fractional error tolerances are input parameters to NJOY and were chosen based on our experience with the VITAMIN libraries and the experience of NJOY users. Specifically, the resolved resonance reconstruction tolerance was chosen to be 0.2% for all nuclides. The other tolerances were chosen to be: 0.2% for linearization, 0.2% for thinning, and 0.1% for integration.

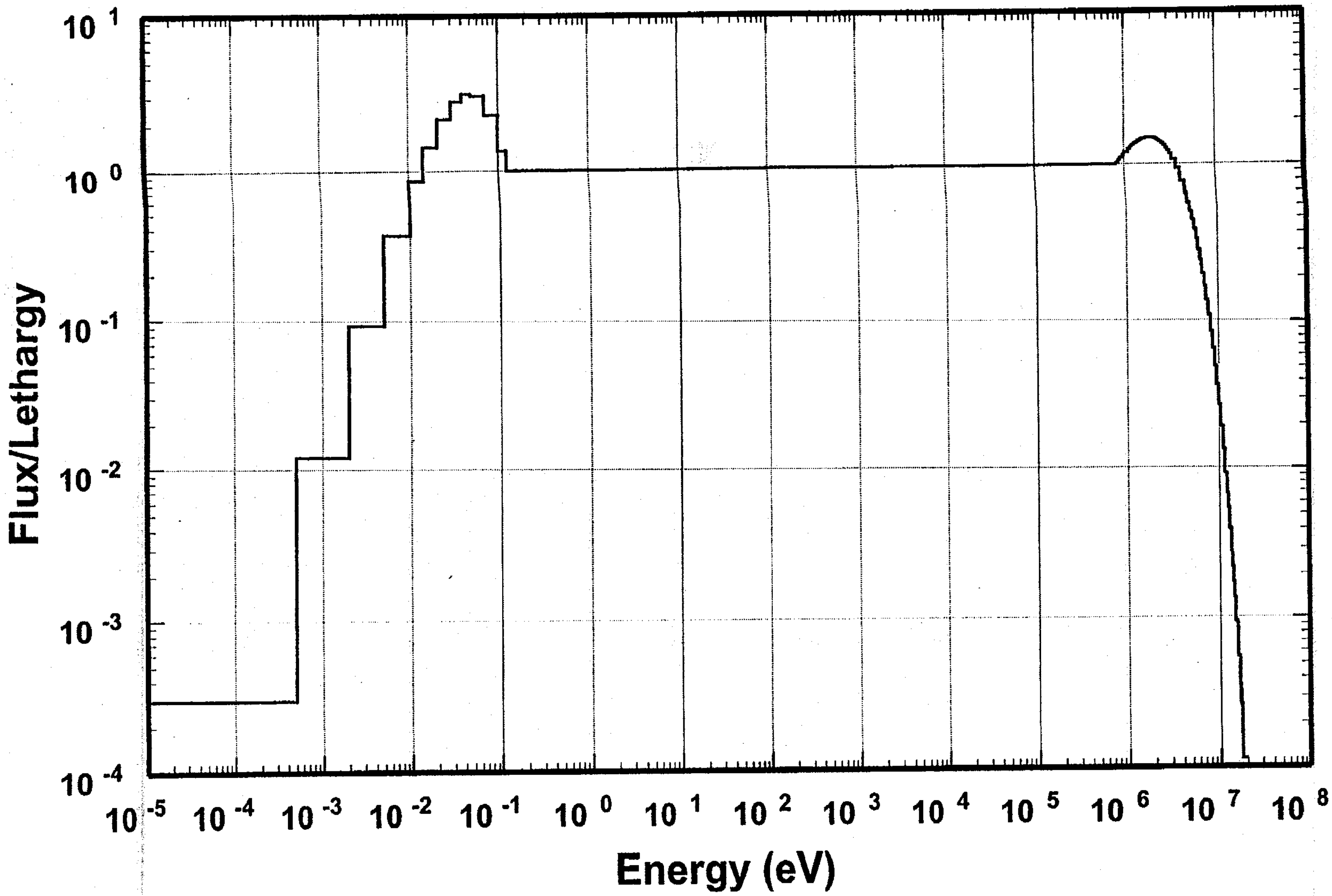


Fig. 2.2 199-Group representation of standard weighting spectrum used to create VITAMIN-B6 neutron cross sections from ENDF/B-VI pointwise data

Table 2.7 Neutron energy weighting spectrum for VITAMIN-B6

Group	Weight	Group	Weight	Group	Weight
1	1.423E-05	48	7.440E-02	95	5.004E-02
2	6.578E-06	49	7.503E-02	96	4.996E-02
3	8.861E-06	50	7.539E-02	97	5.005E-02
4	2.733E-05	51	7.543E-02	98	4.995E-02
5	4.690E-05	52	7.516E-02	99	5.004E-02
6	3.419E-05	53	7.461E-02	100	4.995E-02
7	4.380E-05	54	7.389E-02	101	5.002E-02
8	5.590E-05	55	7.295E-02	102	5.004E-02
9	7.036E-05	56	7.181E-02	103	4.994E-02
10	1.991E-04	57	7.031E-02	104	5.004E-02
11	1.368E-04	58	6.888E-02	105	1.250E-01
12	1.684E-04	59	6.723E-02	106	1.250E-01
13	4.576E-04	60	6.552E-02	107	4.751E-02
14	6.684E-04	61	6.354E-02	108	3.709E-02
15	9.574E-04	62	1.211E-01	109	9.911E-02
16	1.342E-03	63	4.809E-02	110	6.631E-02
17	1.843E-03	64	6.474E-02	111	1.750E-01
18	2.482E-03	65	5.321E-02	112	7.500E-02
19	3.285E-03	66	5.108E-02	113	1.250E-01
20	4.272E-03	67	5.000E-02	114	1.250E-01
21	5.465E-03	68	5.000E-02	115	1.750E-01
22	6.882E-03	69	5.001E-02	116	7.500E-02
23	8.540E-03	70	4.999E-02	117	1.104E-01
24	1.045E-02	71	5.001E-02	118	5.410E-02
25	3.951E-03	72	5.000E-02	119	3.551E-02
26	8.659E-03	73	5.000E-02	120	4.997E-02
27	1.503E-02	74	5.000E-02	121	2.500E-02
28	1.769E-02	75	4.999E-02	122	2.500E-02
29	2.058E-02	76	5.001E-02	123	7.501E-02
30	2.368E-02	77	1.000E-01	124	1.250E-01
31	2.697E-02	78	1.000E-01	125	2.501E-01
32	3.041E-02	79	5.000E-02	126	2.500E-01
33	3.397E-02	80	5.000E-02	127	9.998E-02
34	7.885E-02	81	1.000E-01	128	1.500E-01
35	9.338E-02	82	1.000E-01	129	2.500E-01
36	1.073E-01	83	1.159E-02	130	2.500E-01
37	5.848E-02	84	4.297E-03	131	2.500E-01
38	6.148E-02	85	9.092E-03	132	1.500E-01
39	6.413E-02	86	2.499E-02	133	1.000E-01
40	6.666E-02	87	5.000E-02	134	9.999E-02
41	6.879E-02	88	9.999E-02	135	1.000E-01
42	7.065E-02	89	5.001E-02	136	4.998E-02
43	4.797E-02	90	5.000E-02	137	4.999E-02
44	1.216E-02	91	5.000E-02	138	1.000E-01
45	1.212E-02	92	5.001E-02	139	1.000E-01
46	2.439E-02	93	4.999E-02	140	2.500E-01
47	4.909E-02	94	5.000E-02	141	2.500E-01

Table 2.7 cont'd

Group	Weight	Group	Weight	Group	Weight
142	2.500E-01	162	2.500E-01	182	1.210E-01
143	2.500E-01	163	2.500E-01	183	1.671E-01
144	2.500E-01	164	2.500E-01	184	2.007E-01
145	2.500E-01	165	2.500E-01	185	2.012E-01
146	2.500E-01	166	2.500E-01	186	2.043E-01
147	2.500E-01	167	2.500E-01	187	1.823E-01
148	2.500E-01	168	2.500E-01	188	3.037E-01
149	2.500E-01	169	1.057E-01	189	8.282E-01
150	2.500E-01	170	1.443E-01	190	1.038E+00
151	2.500E-01	171	4.109E-02	191	7.060E-01
152	2.500E-01	172	3.774E-02	192	8.174E-01
153	2.500E-01	173	3.922E-02	193	7.820E-01
154	2.500E-01	174	1.319E-01	194	5.360E-01
155	2.500E-01	175	9.125E-02	195	3.194E-01
156	2.500E-01	176	1.588E-01	196	2.614E-01
157	2.500E-01	177	8.800E-02	197	8.601E-02
158	2.500E-01	178	1.620E-01	198	1.684E-02
159	2.500E-01	179	6.125E-02	199	1.171E-03
160	2.500E-01	180	1.888E-01		
161	2.500E-01	181	1.210E-01		

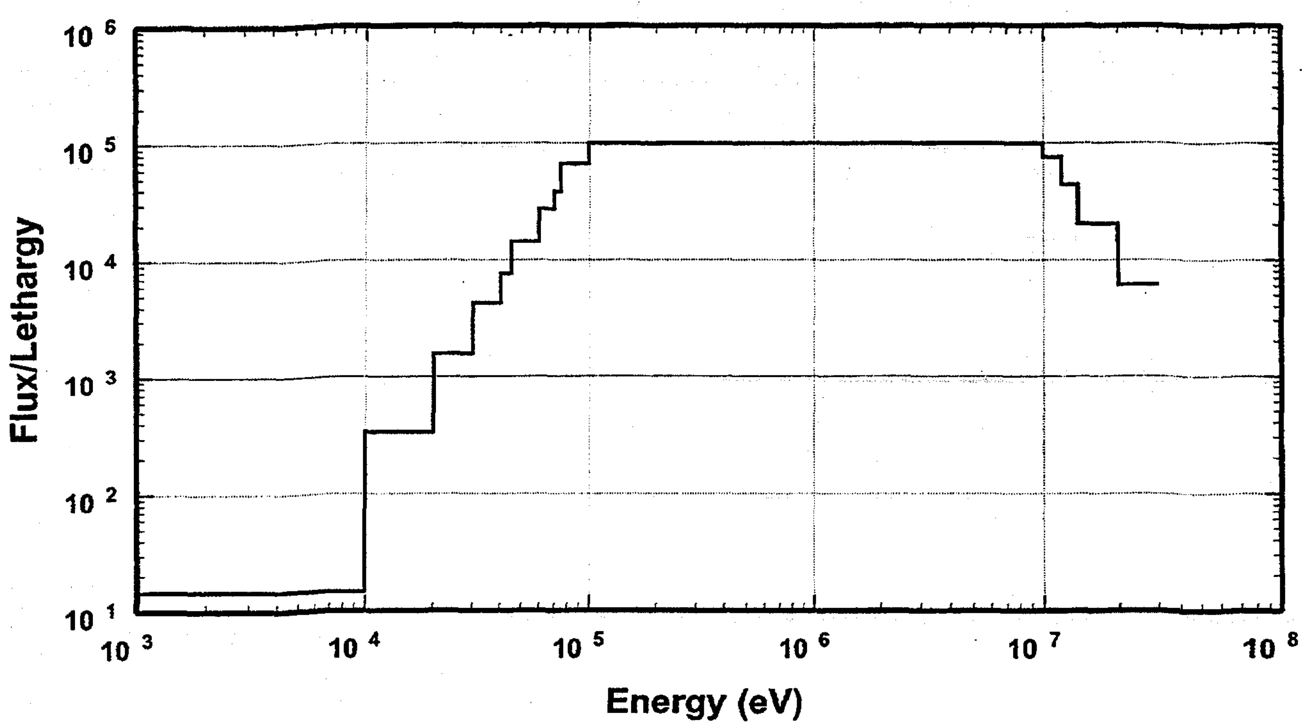


Fig. 2.3 42-Group representation of standard weighting spectrum used to create VITAMIN-B6 gamma-ray cross sections from ENDF/B-VI pointwise data

Table 2.8 Photon energy weighting spectrum for VITAMIN-B6

Group	Weight	Group	Weight	Group	Weight
1	2.498E+03	15	1.542E+04	29	1.178E+04
2	7.298E+03	16	1.824E+04	30	2.877E+04
3	6.824E+03	17	2.232E+04	31	4.055E+04
4	1.387E+04	18	1.864E+04	32	2.877E+04
5	2.232E+04	19	1.014E+04	33	4.055E+04
6	6.455E+03	20	1.128E+04	34	1.927E+04
7	6.901E+03	21	7.491E+02	35	2.629E+03
8	7.413E+03	22	2.852E+04	36	4.233E+03
9	8.006E+03	23	2.232E+04	37	4.163E+03
10	8.703E+03	24	1.335E+04	38	9.042E+02
11	9.534E+03	25	1.542E+04	39	1.233E+03
12	1.054E+04	26	1.586E+04	40	6.333E+02
13	1.178E+04	27	3.914E+02	41	2.333E+02
14	1.336E+04	28	1.252E+04	42	3.330E+01

2.7 Processing Codes and Procedures

The NJOY91.94M processing system[4] was used on a Cray Y-MP/864 to produce the point data and to produce multigroup averaged data in GENDF format for ENDF/B-VI.2 evaluations. NJOY94.15 was needed to correctly process the ENDF/B-VI.3 nuclides. Specifically, the RECONR, BROADR, UNRESR, HEATR, THERMR, GROUPR, and GAMINR modules were used in the fine-group processing task. Only those evaluations which contain unresolved resonance parameters were processed through the UNRESR module. The SMILER code from the AMPX-77 code system[5] was used to translate the multigroup data into the AMPX master library format. The RADE code, also from AMPX-77, was used to check and screen the data for internal consistency and "sanity," (i.e., the data values are physical and within expected bounds). These modules are described in Table 2.9. A schematic diagram illustrating the VITAMIN-B6 processing procedure is given in Fig. 2.4. Listings of the NJOY input for the three job steps used to process ^{235}U are given in Tables A.1-A.3, and the corresponding SMILER input listing is given in Table A.4 in Appendix A.

Table 2.9 Modules from the NJOY91/NJOY94 and the AMPX-77 nuclear cross-section processing systems used to process VITAMIN-B6

Module	Function
NJOY91/NJOY94 System:	
RECONR	Reconstruct pointwise cross sections from ENDF/B resonance parameters and interpolation schemes.
BROADR	Doppler broaden and thin pointwise cross sections.
UNRESR	Compute effective pointwise self-shielded cross sections in the unresolved energy range.
HEATR	Generates pointwise heat production cross sections (kerma factors) and radiation-damage-production cross sections.
THERMR	Generate neutron scattering cross sections and point-to-point scattering kernels in the thermal range for free or bound atoms.
GROUPR	Generate self-shielded multigroup cross sections and group-to-group scattering and photon production matrices in GENDF format.
GAMINR	Compute multigroup photon interaction cross sections, scattering matrices, and heat production in GENDF format.
AMPX-77 System:	
SMILER	Translate GENDF files produced by NJOY into AMPX master interface format.
RADE	Perform sanity and consistency tests on multigroup libraries.

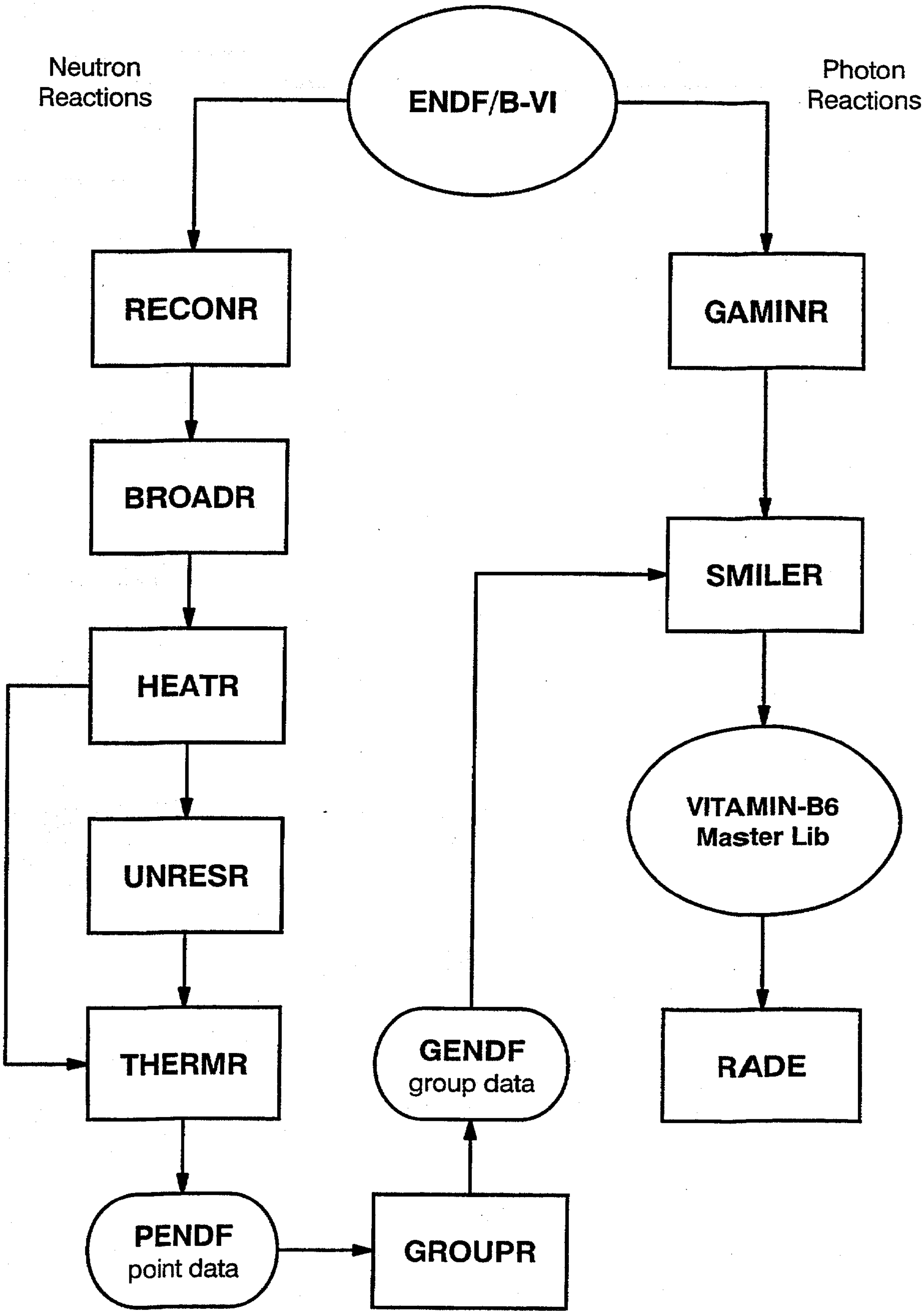


Fig. 2.4 Procedure for generating VITAMIN-B6 library from ENDF/B-VI.

3 BROAD-GROUP LIBRARY SPECIFICATIONS

3.1 Name

The problem-dependent broad-group cross-section library derived from VITAMIN-B6 is designated as BUGLE-96. The name was chosen to be consistent with the earlier BUGLE libraries and indicates its year of production.

3.2 Materials and Energy Group Structure

BUGLE-96 contains all nuclides available in the VITAMIN-B6 fine-group library as listed in Table 2.1. Some nuclides appear multiple times due to the inclusion of different resonance self-shielding and energy weighting options for key fuel and structural materials. Both the neutron and the gamma-ray group structures are identical with the previously developed BUGLE-80 library. The energy boundaries for the 47 neutron groups are given in Table 3.1 along with the corresponding VITAMIN-B6 groups numbers which were collapsed to form the BUGLE-96 groups. Similarly, the 20 gamma-ray group structure is given in Table 3.2.

3.3 Weighting Spectra

The accuracy of results from a radiation transport calculation that uses broad-group cross-section data can be significantly affected by the energy-dependent weighting spectrum used to collapse the data from pointwise or fine-group data. It is important to use a weighting spectrum which is sufficiently prototypical to provide the desired accuracy. In general, a broad-group library is useful only for the range of problems represented by the specific weighting functions. For BUGLE-96, this range includes in-vessel and reactor cavity analyses for light-water-cooled reactors (PWR and BWR). For other applications, the validity of BUGLE-96 data will need to be explicitly demonstrated. Even for LWR applications, it is important that the proper data sets be used for specific regions of the reactor geometry to ensure sufficiently accurate results.

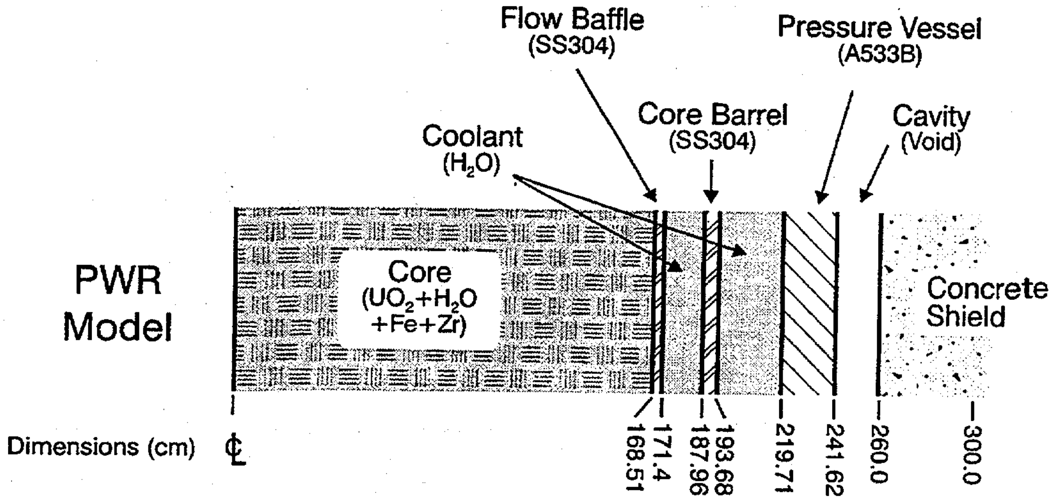
BUGLE-93 was produced by collapsing the VITAMIN-B6 fine-group library with the same methodology and reactor models used for the earlier BUGLE and SAILOR libraries. Specifically, five separate sets of broad-group cross sections were generated using five different weighting spectra. To determine the spectra, 1-D calculations were performed for two specific reactor models: one representing a typical PWR plant and one representing a BWR plant. These models, which correspond exactly to the models listed in the SAILOR report, are shown in Fig. 3.1. Number densities for the various regions are given in Table 3.3. [Note: The corresponding table (Table A.3) in the SAILOR report[3] contained errors in the number densities for the BWR and PWR core mixtures. These errors have been corrected in Table 3.3.] Flux spectra from five specific locations within these models were then selected corresponding to: (1) off-center in the BWR core region, (2) off-center in the PWR core region, (3) the downcomer region in the PWR model, (4) within the pressure vessel at a depth of one-fourth the total thickness, and (5) within the concrete shield surrounding the reactor vessel.

Table 3.1. Neutron group energy boundaries for BUGLE-96

Broad group	Upper energy (eV)	Upper lethargy	VITAMIN-B6 groups
1	1.7332E+07	-5.4997E-01	2-7
2	1.4191E+07	-3.5002E-01	8-12
3	1.2214E+07	-2.0000E-01	13-16
4	1.0000E+07	0.0000E+00	17-19
5	8.6071E+06	1.5000E-01	20-22
6	7.4082E+06	3.0000E-01	23-27
7	6.0653E+06	5.0000E-01	28-31
8	4.9659E+06	7.0000E-01	32-35
9	3.6788E+06	1.0000E+00	36-38
10	3.0119E+06	1.2000E+00	39-40
11	2.7253E+06	1.3000E+00	41-42
12	2.4660E+06	1.4000E+00	43-44
13	2.3653E+06	1.4417E+00	45
14	2.3457E+06	1.4500E+00	46-47
15	2.2313E+06	1.5000E+00	48-50
16	1.9205E+06	1.6500E+00	51-53
17	1.6530E+06	1.8000E+00	54-57
18	1.3534E+06	2.0000E+00	58-62
19	1.0026E+06	2.3000E+00	63-66
20	8.2085E+05	2.5000E+00	67-68
21	7.4274E+05	2.6000E+00	69-72
22	6.0810E+05	2.8000E+00	73-76
23	4.9787E+05	3.0000E+00	77-80
24	3.6883E+05	3.3000E+00	81-84
25	2.9721E+05	3.5159E+00	85-94
26	1.8316E+05	4.0000E+00	95-104
27	1.1109E+05	4.5000E+00	105-110
28	6.7379E+04	5.0000E+00	111-114
29	4.0868E+04	5.5000E+00	115-116
30	3.1828E+04	5.7500E+00	117-119
31	2.6058E+04	5.9500E+00	120-121
32	2.4176E+04	6.0250E+00	122-123
33	2.1875E+04	6.1250E+00	124-125
34	1.5034E+04	6.5000E+00	126-129
35	7.1017E+03	7.2500E+00	130-133
36	3.3546E+03	8.0000E+00	134-140
37	1.5846E+03	8.7500E+00	141-145
38	4.5400E+02	1.0000E+01	146-148
39	2.1445E+02	1.0750E+01	149-151
40	1.0130E+02	1.1500E+01	152-155
41	3.7266E+01	1.2500E+01	156-160
42	1.0677E+01	1.3750E+01	161-163
43	5.0435E+00	1.4500E+01	164-167
44	1.8554E+00	1.5500E+01	168-174
45	8.7643E-01	1.6250E+01	175-180
46	4.1399E-01	1.7000E+01	181-188
47	1.0000E-01	1.8421E+01	189-199
	1.0000E-05	2.7631E+01	

Table 3.2 Photon group energy boundaries for BUGLE-96

Broad group	Upper energy (eV)	VITAMIN-B6 groups
1	1.4000E+07	3-4
2	1.0000E+07	5
3	8.0000E+06	6-7
4	7.0000E+06	8-9
5	6.0000E+06	10-11
6	5.0000E+06	12-13
7	4.0000E+06	14-15
8	3.0000E+06	16-17
9	2.0000E+06	18-19
10	1.5000E+06	20-22
11	1.0000E+06	23
12	8.0000E+05	24
13	7.0000E+05	25
14	6.0000E+05	26-29
15	4.0000E+05	30-31
16	2.0000E+05	32-33
17	1.0000E+05	34-36
18	6.0000E+04	37-39
19	3.0000E+04	40
20	2.0000E+04	41
	1.0000E+04	



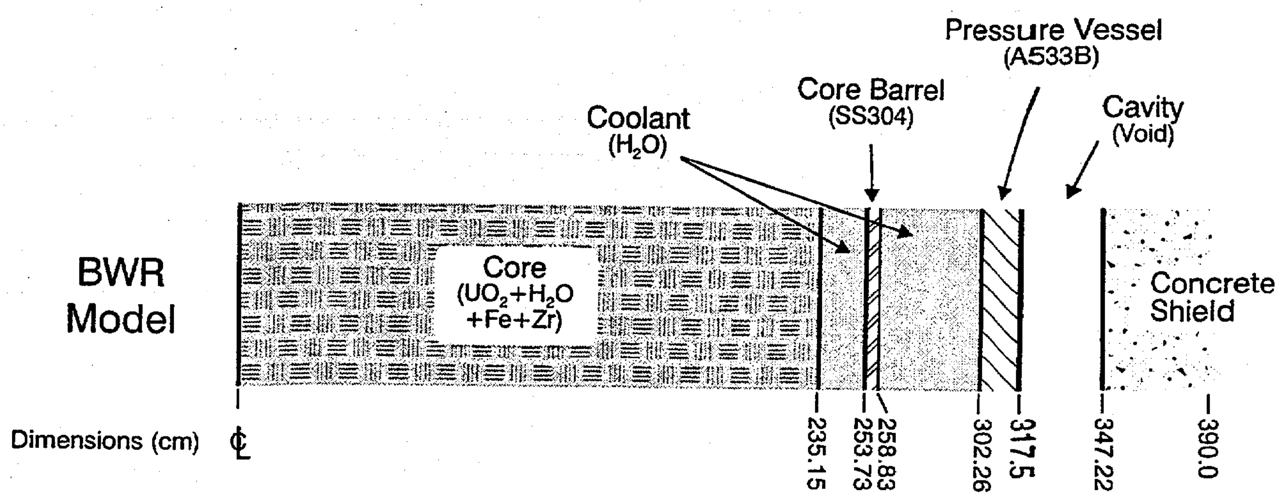


Fig. 3.1 One-dimensional models used to calculate the specific flux spectra for collapsing BUGLE-96 cross sections from VITAMIN-B6

Table 3.3 Number densities[a] and natural abundances used in BWR and PWR models

	HOMOGENEOUS CORES		COOLANT	
	BWR	PWR	BWR	PWR
Hydrogen	1.535-2[b]	2.768-2	4.950-2	4.714-2
Oxygen	7.677-3	1.384-2	2.475-2	2.357-2
Boron-10	0	2.466-6	0	4.200-6
Zirconium	5.765-3	4.257-3		
Iron	2.003-5	1.444-5		
U-235	1.213-4	1.903-4		
U-238	5.322-3	6.515-3		
Fuel Oxygen	1.088-2	1.343-2		

	STEELS	
	SS-304	A533-B
Carbon	2.37-4	9.81-4
Silicon	8.93-4	3.71-4
Chromium	1.74-2	1.27-4
Manganese	1.52-3	1.12-3
Iron	5.83-2	8.19-2
Nickel	8.55-3	4.44-4

CONCRETE	
	Type 04
Hydrogen	7.77-3
Carbon	1.15-4
Oxygen	4.38-2
Sodium	1.05-3
Magnesium	1.48-4
Aluminum	2.39-3
Silicon	1.58-2
Potassium	6.93-4
Calcium	2.29-3
Iron	3.13-4

NATURAL ABUNDANCES (%)

Cr-50	4.345	Fe-54	5.9	Ni-58	68.27
Cr-52	83.79	Fe-56	91.72	Ni-60	26.10
Cr-53	9.5	Fe-57	2.1	Ni-61	1.13
Cr-54	2.365	Fe-58	0.28	Ni-62	3.59
				Ni-64	0.91

[a] In units of $b^{-1} \cdot cm^{-1}$.
[b] Read as 1.535×10^{-2}.

The calculated neutron flux spectra are compared in Fig. 3.2 and listed in Table 3.4. The corresponding gamma-ray flux spectra are compared graphically in Fig. 3.3 and listed in Table 3.5.

The specific nuclides contained within the various PWR and BWR regions were resonance self-shielded, corrected for temperature effects, and collapsed using the corresponding flux spectrum. In the core region, the nuclides were self-shielded using a fuel-clad-moderator pin model. The key parameters for the BWR and PWR pin cell models are given in Table 3.6. In the pressure vessel, the constituents of steel were self-shielded for carbon steel and stainless steel (type 304) using the number densities given in Table 3.7 and collapsed using the quarter-thickness (1/4T) flux spectrum. The SAILOR approach used in preparing BUGLE-93, which resulted in self-shielding the steel constituents for a 50-50 mixture of water and stainless steel, was abandoned in favor of a self-shielding approach that contained only steel. A reanalysis of ANO-1 using scaled 1-D methods and ENDF/B-VI iron cross sections prepared using this approach showed significant improvements in the agreement with measured dosimeter data. Finally, all nuclides in VITAMIN-B6 were collapsed to 47 neutron groups and 20 gamma-ray groups using the flux spectrum calculated within the concrete shield. These nuclides are infinitely dilute (i.e., they have not been energy self-shielded).

3.4 Processing Codes and Procedures

All computational tools used to self-shield, temperature-correct, and collapse the fine-group library into the broad-group format were modules of the SCAMPI code package operational on an IBM/RISC 6000 workstation cluster. The development of the SCAMPI package was stimulated by the need for access to tested operational modules to perform the above mentioned tasks in a workstation environment. The names and a brief description of the primary modules are given in Table 3.8. The names and functionality of the SCAMPI modules are the same as the modules in AMPX-77 operational on the Hitachi AS/EX60 mainframe.

The first portion of the collapsing procedure is given in Fig. 3.4, which diagrams the sequence of steps needed to select and self-shield specific sets of cross sections and perform the PWR and BWR 1-D transport calculations. The results of this procedure are the five flux spectra calculated using the XSDRNPM module (Tables 3.4 and 3.5). Complete input listings for the BONAMI case and the two XSDRNPM cases are given in Tables A.5-7 in Appendix A. The second portion of the collapsing procedure is diagramed in Fig. 3.5. In this sequence, the MALOCS module was used to perform the group collapsing of the cross sections which were previously self-shielded. Complete input listings for the five MALOCS cases are given in Tables A.8-12 in Appendix A. In MALOCS, the ANISN methodology was selected for removal of the upscatter transfer matrix in the thermal energy range. Removing upscatter is done for purposes of economy, since it eliminates the need to perform outer (source) iterations during flux convergence. However, removing the upscatter terms does require a nonphysical adjustment to the cross sections, since in reality, low-energy neutrons can increase their kinetic energy by scattering off low-Z nuclei such as hydrogen. For most shielding problems, this is an acceptable approximation because the leading shielding issues are frequently dominated by the transport of higher-energy neutrons and accurate transport of the thermal neutrons is relatively unimportant.

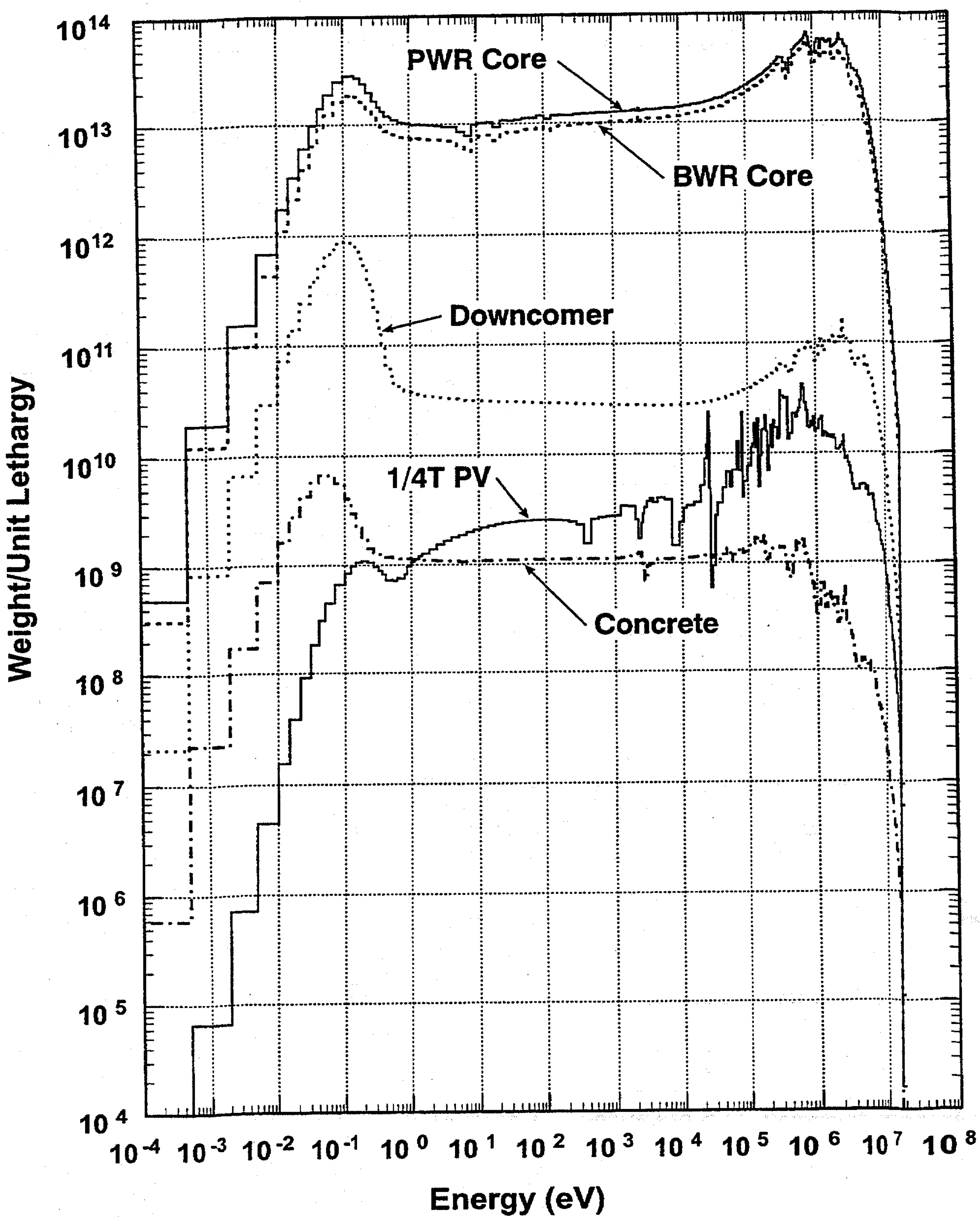


Fig. 3.2 Comparison of five BWR- and PWR-specific neutron flux spectra

Table 3.4 Neutron weighting spectra from PWR/BWR models

Fine group	BWR Core (Int#57) [a]	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
1	7.6014E+05	1.1857E+06	1.3992E+04	2.0322E+03	7.4909E+01
2	2.9063E+08	4.4430E+08	3.5437E+06	4.1806E+05	1.1745E+04
3	3.2764E+08	5.0619E+08	5.1882E+06	6.8186E+05	2.1886E+04
4	1.0879E+09	1.6731E+09	1.6038E+07	2.0892E+06	6.6519E+04
5	1.7894E+09	2.7442E+09	2.4356E+07	3.0216E+06	9.0301E+04
6	1.2795E+09	1.9618E+09	1.6908E+07	2.0476E+06	5.9386E+04
7	1.6212E+09	2.4859E+09	2.1181E+07	2.5433E+06	7.2338E+04
8	2.0203E+09	3.0928E+09	2.5630E+07	3.0380E+06	8.5215E+04
9	2.4974E+09	3.8192E+09	3.0790E+07	3.5930E+06	9.9695E+04
10	6.8570E+09	1.0462E+10	8.0350E+07	9.1808E+06	2.4993E+05
11	5.0533E+09	7.6947E+09	5.6091E+07	6.2320E+06	1.6774E+05
12	5.1790E+09	7.8920E+09	5.9741E+07	6.7181E+06	1.8331E+05
13	1.4387E+10	2.1726E+10	1.4130E+08	1.5051E+07	3.8628E+05
14	2.0400E+10	3.0693E+10	1.8623E+08	1.8952E+07	4.7584E+05
15	3.0204E+10	4.5810E+10	2.9767E+08	3.0523E+07	7.9125E+05
16	4.0207E+10	6.0559E+10	3.6107E+08	3.6988E+07	9.0927E+05
17	5.4451E+10	8.1919E+10	4.7257E+08	4.7636E+07	1.1652E+06
18	7.4005E+10	1.1144E+11	6.3892E+08	6.2995E+07	1.5759E+06
19	9.3816E+10	1.4028E+11	7.3635E+08	7.0983E+07	1.7282E+06
20	1.1784E+11	1.7524E+11	8.3471E+08	7.7222E+07	1.7890E+06
21	1.5342E+11	2.2863E+11	1.0758E+09	9.5841E+07	2.1595E+06
22	1.8930E+11	2.8099E+11	1.2410E+09	1.0845E+08	2.3460E+06
23	2.2772E+11	3.3625E+11	1.3603E+09	1.1545E+08	2.4542E+06
24	2.8858E+11	4.2849E+11	1.7843E+09	1.4853E+08	3.2244E+06
25	1.0960E+11	1.6276E+11	6.6926E+08	5.5309E+07	1.2270E+06
26	2.4284E+11	3.6105E+11	1.4922E+09	1.2280E+08	2.7601E+06
27	4.1934E+11	6.2258E+11	2.5251E+09	2.0767E+08	4.6736E+06
28	4.7169E+11	6.9506E+11	2.5471E+09	2.0499E+08	4.5228E+06
29	5.3282E+11	7.8039E+11	2.6024E+09	2.0163E+08	4.5017E+06
30	6.4332E+11	9.4649E+11	3.2565E+09	2.4333E+08	5.8738E+06
31	6.9818E+11	1.0174E+12	3.0795E+09	2.2665E+08	5.3815E+06
32	8.1827E+11	1.1956E+12	3.6387E+09	2.5404E+08	6.1616E+06
33	8.6813E+11	1.2579E+12	3.5684E+09	2.5844E+08	6.0520E+06
34	1.9788E+12	2.8466E+12	7.2447E+09	5.0637E+08	1.2768E+07
35	2.1051E+12	2.9764E+12	6.2737E+09	4.5988E+08	1.0881E+07
36	2.3604E+12	3.3044E+12	6.1904E+09	4.5914E+08	1.0454E+07
37	1.4272E+12	1.9985E+12	3.6976E+09	2.5404E+08	6.7006E+06
38	1.7175E+12	2.4181E+12	4.9169E+09	3.2145E+08	9.2899E+06
39	1.7232E+12	2.4049E+12	4.9999E+09	3.7451E+08	1.0411E+07
40	1.8334E+12	2.5492E+12	5.2145E+09	4.0421E+08	1.1942E+07
41	2.0060E+12	2.7833E+12	5.6926E+09	4.6380E+08	1.4419E+07
42	2.0207E+12	2.7870E+12	5.5291E+09	4.4053E+08	1.4248E+07
43	1.3990E+12	1.9262E+12	4.1332E+09	3.4510E+08	1.2761E+07
44	3.8119E+11	5.2752E+11	1.2814E+09	1.0683E+08	4.0738E+06
45	3.9189E+11	5.4259E+11	1.4253E+09	1.2151E+08	5.2299E+06
46	7.7035E+11	1.0593E+12	2.4544E+09	1.9714E+08	8.7365E+06
47	1.3878E+12	1.8807E+12	4.2117E+09	4.1548E+08	1.4817E+07

Table 3.4 cont'd

Fine group	BWR Core (Int#57)	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
48	1.9486E+12	2.6230E+12	5.5468E+09	5.7974E+08	1.8475E+07
49	1.9002E+12	2.5451E+12	5.2346E+09	5.5301E+08	1.7250E+07
50	1.8523E+12	2.4685E+12	5.0260E+09	5.3525E+08	1.4577E+07
51	1.7986E+12	2.3819E+12	4.6236E+09	5.4017E+08	1.3568E+07
52	2.1429E+12	2.8356E+12	5.7403E+09	6.6889E+08	2.3418E+07
53	2.0862E+12	2.7268E+12	5.4109E+09	7.2457E+08	2.1223E+07
54	2.0303E+12	2.6397E+12	5.0716E+09	6.8383E+08	1.9533E+07
55	2.1195E+12	2.7471E+12	5.2927E+09	7.1767E+08	2.3193E+07
56	2.2334E+12	2.8745E+12	5.3374E+09	6.9612E+08	2.6000E+07
57	2.1946E+12	2.8017E+12	5.2406E+09	7.4485E+08	2.7047E+07
58	1.8253E+12	2.3166E+12	4.0697E+09	7.6978E+08	1.8758E+07
59	2.2598E+12	2.8730E+12	5.1405E+09	7.0174E+08	2.7308E+07
60	2.2722E+12	2.8567E+12	5.2930E+09	1.0579E+09	3.1954E+07
61	2.1197E+12	2.6485E+12	4.8119E+09	9.9314E+08	3.1610E+07
62	3.4717E+12	4.3330E+12	7.4956E+09	1.6359E+09	3.9464E+07
63	1.3523E+12	1.6863E+12	2.8273E+09	6.5092E+08	1.2763E+07
64	2.2461E+12	2.7832E+12	4.7439E+09	1.2262E+09	2.6095E+07
65	2.1527E+12	2.6374E+12	4.3651E+09	8.7398E+08	3.1673E+07
66	2.4966E+12	3.0184E+12	4.8423E+09	9.5481E+08	3.6840E+07
67	2.7866E+12	3.3223E+12	5.0440E+09	8.4716E+08	4.4539E+07
68	2.6379E+12	3.1234E+12	4.7312E+09	8.7009E+08	4.9423E+07
69	2.4497E+12	2.8870E+12	4.5466E+09	1.2146E+09	5.3916E+07
70	2.3657E+12	2.7761E+12	4.4199E+09	1.4239E+09	5.9797E+07
71	2.3067E+12	2.6960E+12	4.3737E+09	1.9155E+09	6.9196E+07
72	2.2406E+12	2.6124E+12	4.2628E+09	2.0771E+09	8.0206E+07
73	2.1674E+12	2.5268E+12	4.1845E+09	1.4915E+09	8.0704E+07
74	2.0923E+12	2.4439E+12	4.0544E+09	1.2694E+09	7.3678E+07
75	2.0230E+12	2.3644E+12	3.9255E+09	1.1742E+09	8.0799E+07
76	1.9601E+12	2.2780E+12	3.7700E+09	1.0472E+09	7.7852E+07
77	3.2152E+12	3.7930E+12	6.4249E+09	2.2668E+09	1.2068E+08
78	2.4643E+12	2.9533E+12	5.1746E+09	1.5029E+09	7.1761E+07
79	1.4395E+12	1.7259E+12	3.0031E+09	6.6521E+08	4.1648E+07
80	1.4439E+12	1.7218E+12	3.0012E+09	1.5819E+09	4.3434E+07
81	3.2862E+12	3.8670E+12	6.4175E+09	3.1216E+09	1.1610E+08
82	3.3426E+12	3.8826E+12	6.3070E+09	3.2634E+09	1.3893E+08
83	3.6986E+11	4.2912E+11	7.0208E+08	4.2565E+08	1.6070E+07
84	1.3577E+11	1.5770E+11	2.5880E+08	1.3992E+08	6.0513E+06
85	2.8528E+11	3.3159E+11	5.4483E+08	2.2296E+08	1.2613E+07
86	7.7468E+11	9.0115E+11	1.4810E+09	3.5082E+08	3.4080E+07
87	1.5260E+12	1.7672E+12	2.8994E+09	6.7539E+08	6.9831E+07
88	2.8973E+12	3.3576E+12	5.5716E+09	1.6973E+09	1.3824E+08
89	1.3798E+12	1.6013E+12	2.6869E+09	9.8426E+08	6.8042E+07
90	1.3408E+12	1.5546E+12	2.6208E+09	5.6123E+08	6.7378E+07
91	1.3104E+12	1.5159E+12	2.5645E+09	8.9812E+08	6.1649E+07
92	1.2746E+12	1.4759E+12	2.5075E+09	5.7687E+08	5.9660E+07
93	1.2330E+12	1.4333E+12	2.4526E+09	3.4443E+08	5.5122E+07
94	1.1929E+12	1.3920E+12	2.4030E+09	7.9023E+08	5.3248E+07

Table 3.4 cont'd

Fine group	BWR Core (Int#57)	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
95	1.1626E+12	1.3577E+12	2.3576E+09	1.0874E+09	6.1596E+07
96	1.1333E+12	1.3239E+12	2.3056E+09	8.2475E+08	7.6839E+07
97	1.1127E+12	1.2983E+12	2.2672E+09	8.0635E+08	8.7483E+07
98	1.0849E+12	1.2660E+12	2.2181E+09	4.7413E+08	8.2073E+07
99	1.0637E+12	1.2413E+12	2.1781E+09	2.4867E+08	7.5415E+07
100	1.0396E+12	1.2133E+12	2.1383E+09	1.0220E+09	7.5266E+07
101	1.0180E+12	1.1897E+12	2.1074E+09	5.6137E+08	8.3036E+07
102	9.9590E+11	1.1651E+12	2.0728E+09	9.3099E+08	8.4422E+07
103	9.7191E+11	1.1383E+12	2.0318E+09	6.0688E+08	7.4200E+07
104	9.5366E+11	1.1183E+12	2.0022E+09	5.6458E+08	7.5582E+07
105	2.2988E+12	2.6993E+12	4.8571E+09	9.5425E+08	1.7880E+08
106	2.1954E+12	2.5797E+12	4.6786E+09	6.8965E+08	1.5669E+08
107	8.1357E+11	9.5443E+11	1.7339E+09	1.8919E+08	5.8538E+07
108	6.1940E+11	7.3095E+11	1.3451E+09	8.6516E+08	5.1180E+07
109	1.6144E+12	1.9097E+12	3.5112E+09	6.8522E+08	1.3293E+08
110	1.0765E+12	1.2591E+12	2.3040E+09	8.5464E+08	8.6381E+07
111	2.7259E+12	3.2004E+12	5.9041E+09	1.2326E+09	2.0691E+08
112	1.1223E+12	1.3247E+12	2.4630E+09	3.7239E+08	7.9185E+07
113	1.8079E+12	2.1463E+12	4.0292E+09	8.5308E+08	1.6892E+08
114	1.7315E+12	2.0734E+12	3.9346E+09	6.0822E+08	1.4904E+08
115	2.4477E+12	2.8666E+12	5.3738E+09	6.2088E+08	1.8696E+08
116	1.0094E+12	1.1926E+12	2.2638E+09	2.0579E+08	8.6509E+07
117	1.4621E+12	1.7283E+12	3.2884E+09	1.0450E+08	1.2952E+08
118	7.0112E+11	8.3308E+11	1.5968E+09	3.1919E+07	6.0340E+07
119	4.5828E+11	5.4333E+11	1.0508E+09	1.7075E+08	4.1696E+07
120	6.4210E+11	7.6042E+11	1.4745E+09	1.1786E+09	5.9485E+07
121	3.1209E+11	3.7446E+11	7.3457E+08	5.7478E+08	2.9959E+07
122	3.1366E+11	3.7501E+11	7.3004E+08	3.0145E+08	2.9573E+07
123	9.5244E+11	1.1269E+12	2.1771E+09	6.7403E+08	8.7929E+07
124	1.5235E+12	1.8312E+12	3.5856E+09	6.4125E+08	1.4387E+08
125	3.0679E+12	3.6326E+12	7.0741E+09	9.0441E+08	2.8453E+08
126	2.9560E+12	3.5283E+12	6.9986E+09	8.4477E+08	2.8109E+08
127	1.1576E+12	1.3868E+12	2.7767E+09	3.2006E+08	1.1144E+08
128	1.7117E+12	2.0574E+12	4.1380E+09	3.5490E+08	1.6356E+08
129	2.7997E+12	3.3810E+12	6.8664E+09	3.6442E+08	2.7629E+08
130	2.8083E+12	3.3579E+12	6.8508E+09	9.5878E+08	2.7318E+08
131	2.7306E+12	3.2951E+12	6.8368E+09	1.0008E+09	2.7435E+08
132	1.6258E+12	1.9652E+12	4.1113E+09	5.4361E+08	1.6186E+08
133	1.0837E+12	1.3102E+12	2.7472E+09	3.9444E+08	9.9435E+07
134	1.0698E+12	1.2989E+12	2.7506E+09	3.7012E+08	9.5232E+07
135	1.0442E+12	1.2832E+12	2.7536E+09	3.2676E+08	6.9448E+07
136	5.0930E+11	6.3214E+11	1.3766E+09	1.4304E+08	4.2418E+07
137	5.7688E+11	6.7398E+11	1.3767E+09	1.1749E+08	5.5639E+07
138	1.0466E+12	1.2736E+12	2.7552E+09	1.7070E+08	1.2521E+08
139	1.0729E+12	1.2986E+12	2.7652E+09	2.5220E+08	1.2185E+08
140	2.5908E+12	3.1687E+12	6.9321E+09	8.3409E+08	2.9225E+08
141	2.5866E+12	3.1590E+12	6.9480E+09	8.4646E+08	2.8320E+08

Table 3.4 cont'd

Fine group	BWR Core (Int#57)	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
142	2.5674E+12	3.1437E+12	6.9617E+09	6.8885E+08	2.7938E+08
143	2.5228E+12	3.1021E+12	6.9992E+09	6.7981E+08	2.7845E+08
144	2.4942E+12	3.0755E+12	7.0424E+09	6.7033E+08	2.7836E+08
145	2.4611E+12	3.0484E+12	7.0851E+09	6.4446E+08	2.7846E+08
146	2.4418E+12	3.0331E+12	7.1189E+09	3.8489E+08	2.7805E+08
147	2.4295E+12	3.0205E+12	7.1753E+09	5.7452E+08	2.7810E+08
148	2.3681E+12	2.9654E+12	7.2171E+09	6.1188E+08	2.7799E+08
149	2.3608E+12	2.9580E+12	7.2565E+09	6.2634E+08	2.7773E+08
150	2.3193E+12	2.9203E+12	7.2991E+09	6.3304E+08	2.7749E+08
151	2.1291E+12	2.7297E+12	7.3377E+09	6.3556E+08	2.7699E+08
152	2.3171E+12	2.9176E+12	7.3799E+09	6.3552E+08	2.7652E+08
153	2.2010E+12	2.7991E+12	7.4240E+09	6.3317E+08	2.7603E+08
154	2.1980E+12	2.7992E+12	7.4678E+09	6.2858E+08	2.7546E+08
155	2.0932E+12	2.7023E+12	7.5112E+09	6.2159E+08	2.7481E+08
156	2.0618E+12	2.6513E+12	7.5532E+09	6.1205E+08	2.7404E+08
157	2.0776E+12	2.6828E+12	7.5953E+09	5.9999E+08	2.7322E+08
158	1.7509E+12	2.3239E+12	7.6346E+09	5.8498E+08	2.7225E+08
159	1.9646E+12	2.5683E+12	7.6758E+09	5.6740E+08	2.7129E+08
160	1.9399E+12	2.5343E+12	7.7154E+09	5.4695E+08	2.7021E+08
161	1.8849E+12	2.4760E+12	7.7514E+09	5.2351E+08	2.6894E+08
162	1.4075E+12	1.9385E+12	7.7869E+09	4.9745E+08	2.6759E+08
163	1.5368E+12	2.1172E+12	7.8208E+09	4.6893E+08	2.6615E+08
164	1.7526E+12	2.3600E+12	8.0873E+09	4.4722E+08	2.7198E+08
165	1.7577E+12	2.3645E+12	8.1924E+09	4.1562E+08	2.7048E+08
166	1.7962E+12	2.4154E+12	8.3518E+09	3.8285E+08	2.7243E+08
167	1.8100E+12	2.4376E+12	8.5254E+09	3.4962E+08	2.7446E+08
168	1.8282E+12	2.4649E+12	8.6685E+09	3.1794E+08	2.7502E+08
169	7.8372E+11	1.0586E+12	3.7590E+09	1.2734E+08	1.1746E+08
170	1.0585E+12	1.4326E+12	5.1991E+09	1.6389E+08	1.6134E+08
171	2.9525E+11	4.0175E+11	1.4983E+09	4.3662E+07	4.5576E+07
172	2.7622E+11	3.7507E+11	1.3875E+09	3.9726E+07	4.2030E+07
173	2.9452E+11	3.9883E+11	1.4632E+09	4.1436E+07	4.4357E+07
174	9.8802E+11	1.3427E+12	4.9575E+09	1.2771E+08	1.5065E+08
175	6.9497E+11	9.4532E+11	3.5026E+09	7.5292E+07	1.0270E+08
176	1.2094E+12	1.6537E+12	6.2593E+09	1.1885E+08	1.8035E+08
177	7.1270E+11	9.6780E+11	3.7042E+09	6.6562E+07	1.0179E+08
178	1.3076E+12	1.7867E+12	7.3338E+09	1.1579E+08	1.8845E+08
179	5.1912E+11	7.0919E+11	3.1993E+09	4.4578E+07	7.3052E+07
180	1.6390E+12	2.2532E+12	1.2519E+10	1.3620E+08	2.2386E+08
181	1.1527E+12	1.5953E+12	1.2117E+10	9.9478E+07	1.4981E+08
182	1.2443E+12	1.7406E+12	1.7649E+10	1.0740E+08	1.5278E+08
183	1.9264E+12	2.7344E+12	3.7842E+10	1.6162E+08	2.1853E+08
184	2.7400E+12	3.9582E+12	7.3472E+10	2.1165E+08	2.8535E+08
185	3.2491E+12	4.7730E+12	1.0973E+11	2.2014E+08	3.4177E+08
186	3.6846E+12	5.4877E+12	1.4621E+11	2.1716E+08	4.5240E+08
187	3.4325E+12	5.1666E+12	1.5221E+11	1.7828E+08	5.4530E+08
188	4.1033E+12	6.2277E+12	1.9836E+11	1.8848E+08	9.1237E+08

Table 3.4 cont'd

Fine group	BWR Core (Int#57)	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
189	5.7735E+12	8.8230E+12	3.0308E+11	2.3581E+08	2.0281E+09
190	4.1119E+12	6.3203E+12	2.3105E+11	1.4998E+08	2.2419E+09
191	2.0543E+12	3.1645E+12	1.2007E+11	6.8890E+07	1.5004E+09
192	1.8433E+12	2.8527E+12	1.1159E+11	5.2655E+07	1.6613E+09
193	1.4011E+12	2.1755E+12	8.7498E+10	3.2323E+07	1.5405E+09
194	7.9923E+11	1.2448E+12	5.1289E+10	1.4335E+07	1.0340E+09
195	4.1425E+11	6.4681E+11	2.7137E+10	5.7491E+06	6.0430E+08
196	3.0353E+11	4.7504E+11	2.0216E+10	3.1162E+06	4.8835E+08
197	9.0752E+10	1.4238E+11	6.1339E+09	6.5168E+05	1.5854E+08
198	1.7077E+10	2.6847E+10	1.1620E+09	9.1680E+04	3.1176E+07
199	1.2189E+09	1.9161E+09	8.2470E+07	5.5538E+03	2.2896E+06

[a] Spatial mesh interval number from PWR or BWR model.

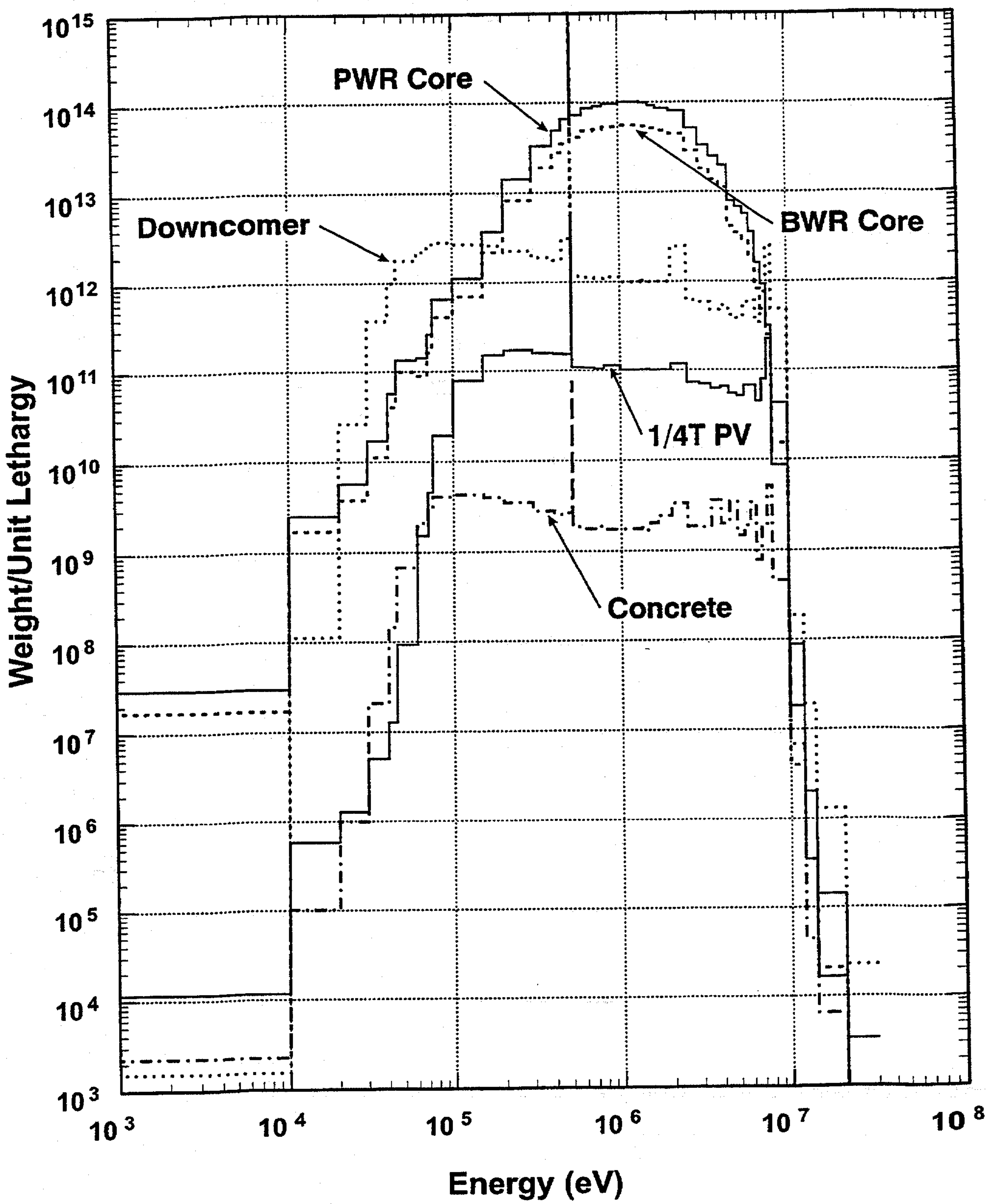


Fig. 3.3 Comparison of five BWR- and PWR-specific gamma-ray flux spectra

Table 3.5 Photon weighting spectra from PWR/BWR models

Fine group	BWR Core (Int#57)[a]	PWR Core (Int#37)	Downcomer (Int#69)	1/4T PV (Int#82)	Concrete (Int#106)
1	1.9547E+02	1.5655E+02	9.0787E+03	1.3628E+03	7.4294E+01
2	7.3440E+03	5.7882E+03	4.6403E+05	5.0416E+04	2.3094E+03
3	5.4214E+04	5.3624E+04	2.9763E+06	3.1112E+05	6.8232E+03
4	7.3186E+05	1.6065E+07	3.4042E+07	3.3750E+06	1.2494E+06
5	3.4053E+09	1.9415E+09	1.0869E+11	9.4134E+09	1.0352E+08
6	1.6127E+10	2.0406E+10	1.6115E+11	1.4477E+10	3.2567E+08
7	3.3580E+10	6.4002E+10	5.2344E+10	5.3331E+09	1.2039E+08
8	6.0772E+10	1.1918E+11	2.5596E+10	3.2544E+09	5.8387E+07
9	1.4424E+11	2.8176E+11	4.8644E+10	5.3072E+09	2.6821E+08
10	2.5191E+11	4.9552E+11	5.0823E+10	5.7485E+09	1.6168E+08
11	3.3148E+11	6.5235E+11	3.6726E+10	4.8259E+09	1.3763E+08
12	4.3191E+11	8.3489E+11	4.4162E+10	5.6962E+09	3.6002E+08
13	1.3098E+12	2.3203E+12	6.3174E+10	7.5884E+09	2.2969E+08
14	1.8248E+12	3.3116E+12	6.3588E+10	8.2049E+09	4.7275E+08
15	2.7959E+12	5.0940E+12	8.9986E+10	1.0604E+10	2.7411E+08
16	5.2407E+12	9.4059E+12	1.1119E+11	1.3094E+10	3.3173E+08
17	9.9650E+12	1.7891E+13	5.4933E+11	2.6342E+10	7.3526E+08
18	9.0207E+12	1.5980E+13	1.8532E+11	1.8730E+10	4.4644E+08
19	5.1662E+12	9.3044E+12	1.0037E+11	1.0205E+10	2.0131E+08
20	6.0964E+12	1.1096E+13	1.1621E+11	1.1451E+10	1.8789E+08
21	4.1680E+11	7.6217E+11	8.2872E+09	7.6663E+08	1.3326E+07
22	1.5671E+13	2.8573E+13	2.8119E+11	2.8838E+10	4.9424E+08
23	1.1821E+13	2.1472E+13	2.5168E+11	2.5520E+10	3.8663E+08
24	6.6588E+12	1.2076E+13	1.4492E+11	1.4004E+10	2.4889E+08
25	7.4922E+12	1.3364E+13	1.7191E+11	1.6579E+10	2.6908E+08
26	6.5261E+12	1.1511E+13	1.8216E+11	1.7368E+10	2.9002E+08
27	3.6455E+12	6.5041E+12	1.1050E+11	2.2830E+10	2.8719E+08
28	4.3752E+12	8.2640E+12	3.7988E+11	1.9379E+10	3.3261E+08
29	3.2865E+12	5.7981E+12	2.0662E+11	1.8396E+10	2.9771E+08
30	5.4453E+12	9.5029E+12	5.4003E+11	4.6215E+10	7.9939E+08
31	3.3447E+12	5.7340E+12	9.1141E+11	6.9971E+10	1.3968E+09
32	6.2751E+11	1.0611E+12	7.4080E+11	4.4214E+10	1.1394E+09
33	2.8465E+11	4.5365E+11	1.0790E+12	3.1517E+10	1.7201E+09
34	1.1880E+11	1.9030E+11	8.0600E+11	5.5368E+09	1.1588E+09
35	1.1372E+10	1.8273E+10	1.7852E+11	3.1301E+08	2.1005E+08
36	1.3723E+10	2.2156E+10	3.4083E+11	2.3179E+08	3.1880E+08
37	2.8436E+10	3.9079E+10	5.0736E+11	2.6963E+07	1.9505E+08
38	4.6868E+09	6.5907E+09	1.1665E+11	1.5119E+06	1.7075E+07
39	3.2328E+09	4.8742E+09	1.0756E+11	1.4611E+06	6.0232E+06
40	1.5135E+09	2.2716E+09	1.0578E+10	5.1770E+05	4.0161E+05
41	1.1685E+09	1.7329E+09	7.8063E+07	4.0173E+05	7.0674E+04
42	3.9574E+07	6.9099E+07	3.4983E+03	2.6474E+04	5.1938E+03

[a] Spatial mesh interval number from PWR or BWR model.

Table 3.6 Key parameters for BWR and PWR pin cells

	BWR	PWR
Inner radius clad (cm)	0.53213	0.41783
Outer radius clad (cm)	0.6134	0.47498
Outer radius cell (cm)	0.9174	0.71079
Region temperature (K)		
Pellet	921	921
Clad	672	672
Moderator	583	551
Pellet nuclear density ($b^{-1}\cdot cm^{-1}$)		
U-235	4.959-4[a]	6.325-4
U-238	2.177-2	2.166-2
Oxygen	4.455-2	4.465-2
Moderator density ($b^{-1}\cdot cm^{-1}$)		
Hydrogen	2.475-2	4.714-2
Oxygen	1.238-2	2.357-2
Boron-10	0	4.200-6
Zircalloy-4 density ($b^{-1}\cdot cm^{-1}$)		
Chromium	7.64-5	
Iron	1.45-4	
Nickel	8.77-4	
Zirconium	4.27-2	

[a] Read as 4.959×10^{-4}.

Table 3.7 Number densities[a] used for steel constituents

	Stainless Steel	Carbon Steel
Carbon	2.37-4[b]	9.81-4
Chromium	1.74-2	1.27-4
Manganese	1.52-3	1.12-3
Iron	5.83-2	8.19-2
Nickel	8.55-3	4.44-4

[a] In units of $b^{-1}\cdot cm^{-1}$.
[b] Read as 2.37×10^{-4}.

Table 3.8 Processing codes from AMPX-77 used to produce BUGLE-96.

Module	Function
AJAX	Merge and delete nuclides from master libraries.
AIM	BCD-to-binary (or vice-versa) conversion of master libraries.
ALE	Display information contained in either an AMPX master or working library.
ALPO	Produce ANISN library from AMPX working library format.
BONAMI-S	Perform interpolation on Bondarenko factors to self-shield reaction cross sections.
MALOCS	Collapse energy group structure of master library.
NITAWL	Convert master library to working library format.
WORKER	Prepare working libraries for use in transport calculations. Interpolate thermal scattering matrices; particularly useful for nuclides with upscattering.
XSDRNPM	Perform a one-dimensional discrete-ordinates or diffusion theory calculation using cross sections in an AMPX working library. Also, perform spatial cross-section weighting.

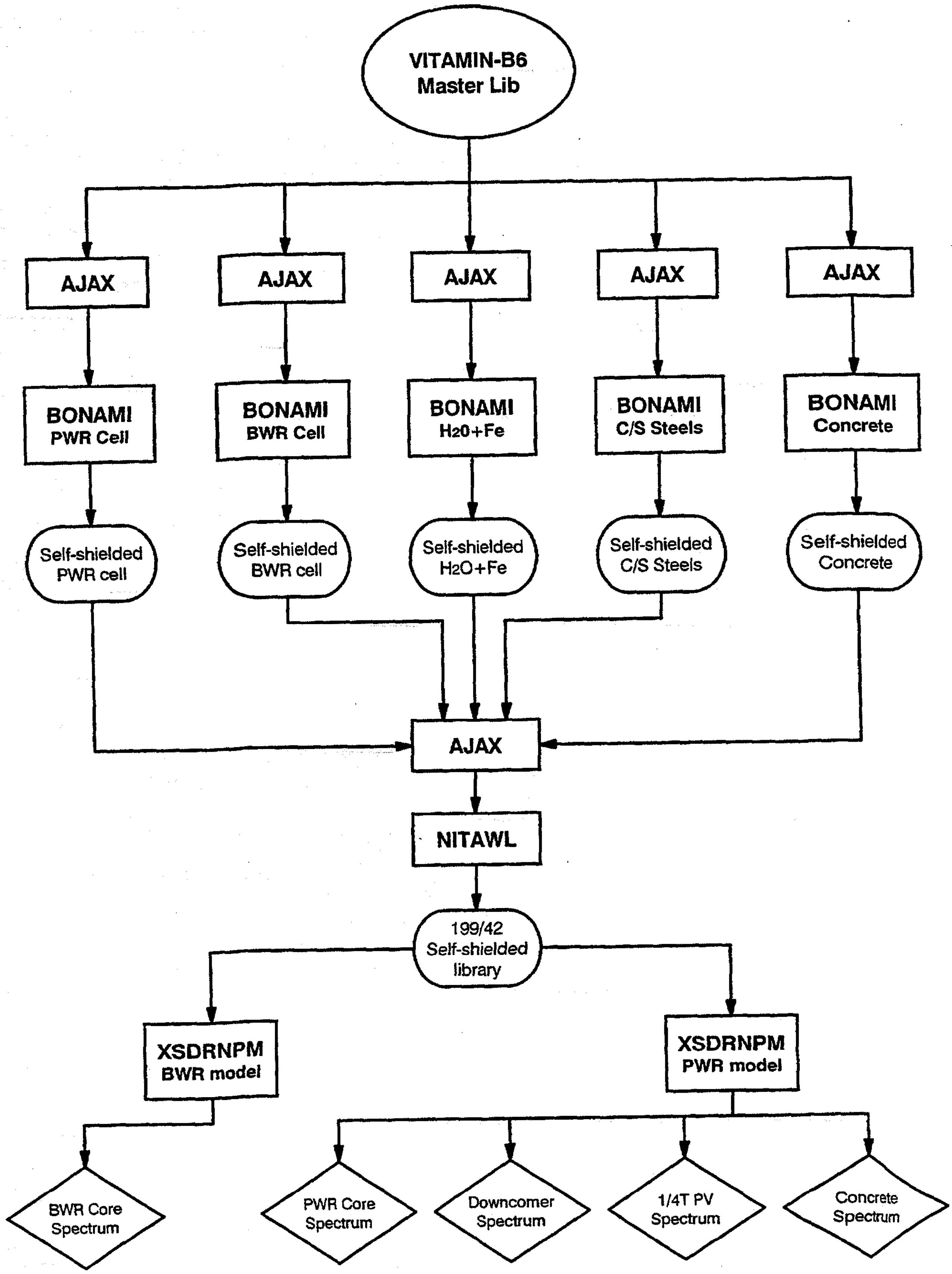


Fig. 3.4 Procedure for calculating BWR- and PWR-specific flux spectra

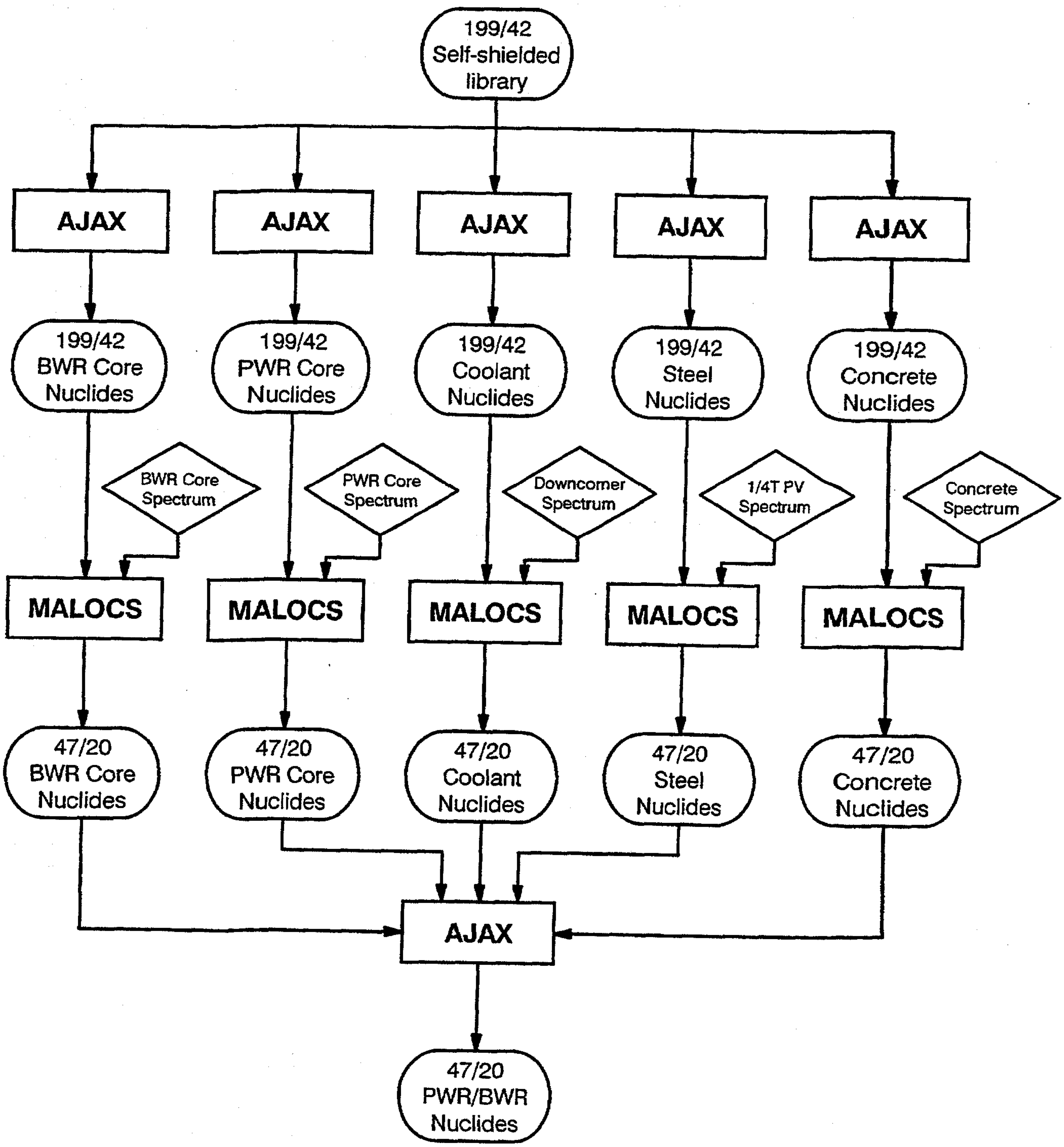


Fig. 3.5 Procedure for collapsing fine-group cross sections using BWR- and PWR-specific flux spectra

The approach used for removing the upscatter terms in BUGLE-96 is the same as implemented in the ANISN code. Conceptually, the upscatter between two groups is set to zero and the downscatter is reduced an equivalent amount to preserve the net transfer reaction rate between the two groups. The within-group scatter terms of both groups are increased a corresponding amount to preserve the total scatter reaction rate. Although this yields an acceptable solution in most circumstances, it can cause the generation of negative downscatter terms if the upscatter is greater than the downscatter between two groups. This highlights the importance of using a particular cross-section set only in the type of application for which it was intended.

The final processing sequence is diagramed in Fig. 3.6, which is the process used to generate a full set of infinitely dilute cross sections collapsed with a concrete weighting spectrum. Nuclides from this set can be used for general purposes and for cases where the problem-specific self-shielded/weighted data sets are not appropriate. The complete BUGLE-96 library is actually contained in three distinct data sets: (1) the full set of general nuclides just described, (2) the set of self-shielded and energy weighted nuclides specific to BWR and PWR models, and (3) a set of response functions and kerma factors.

NOTE: The preceding BUGLE-93 library contained an additional processing sequence for generating data sets specific to the constituents of carbon steel and stainless steel and self-shielded at a temperature of 300 K. For BUGLE-96, these data sets were included in the BWR/PWR-specific processing sequences, so that a separate processing step was not needed. However, this approach results in data sets for carbon steel and stainless steel which are self-shielded at a temperature of 600 K rather than the earlier 300 K.

3.5 Library Format and Content

The BUGLE-96 data library package consists of four major parts:

BUGLE-96	-	complete replacement for all files previously contained in BUGLE-93.
BUGLE-96T	-	the same cross sections as BUGLE-96 with the thermal upscattering cross sections retained in the thermal region.
SAILOR-96	-	the same cross sections as BUGLE-96 with the ANISN identifiers arranged to be plug compatible with DLC-76/SAILOR.
SAILOR-96T	-	the same cross sections as BUGLE-96T with the ANISN identifiers arranged to be plug compatible with DLC-76/SAILOR.

The BUGLE-96 broad-group data library package is available in ANISN card image format.[8] For BUGLE-96 and SAILOR-96, the table width is 67 (number of groups) and the table length is 70 (number of groups plus 3). For BUGLE-96T and SAILOR-96T, the table width is 67 (number of groups) and the table length is 74 (number of groups plus 3 plus 4 upscatter groups).

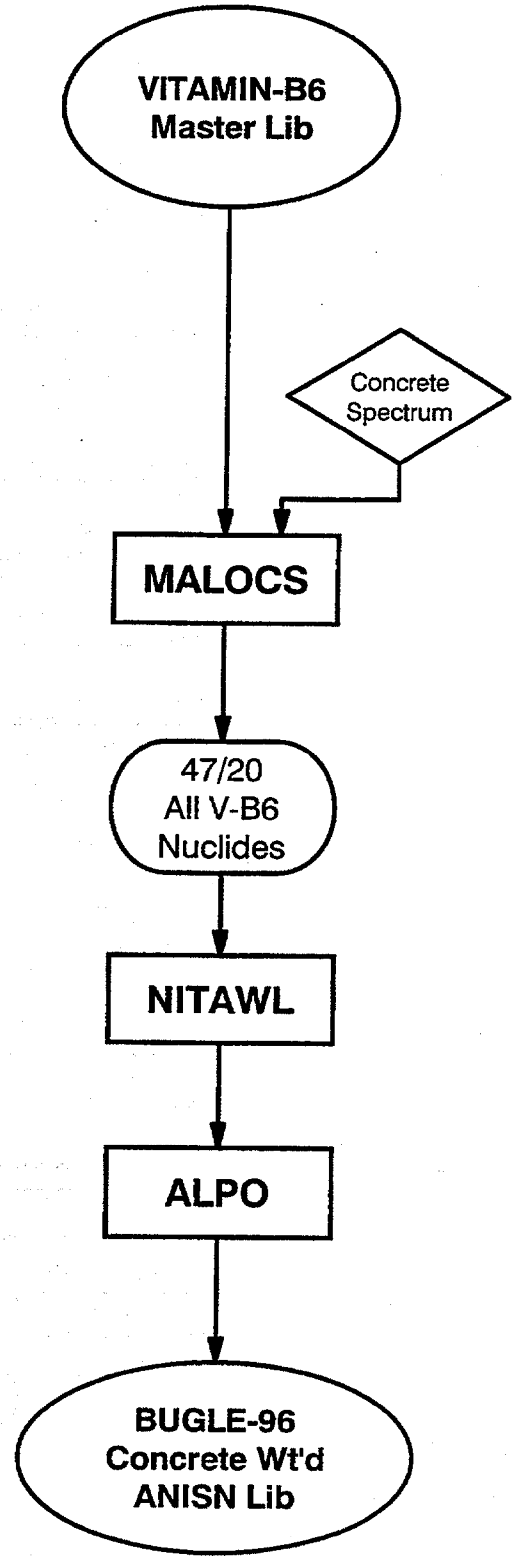


Fig. 3.6 Procedure for generating complete infinitely dilute BUUGLE-96 library using concrete flux spectrum

Table positions 1 through 4 are defined as:

1. absorption cross section (σ_a),

2. fission cross section times the number of neutrons produced per fission ($\nu\sigma_f$),

3. total cross section (σ_T), and

4. within-group scattering cross section (σ_{g-g}).

These positions are followed by the standard down-scatter transfer matrix. As mentioned in the previous section, the upscatter transfer matrix was removed using the ANISN methodology option in MALOCS for BUGLE-96 and SAILOR-96.

Each cross-section matrix is preceded by a title card containing four integer parameters, an alpha/numeric descriptor, and a Pedigree Identification Code. The integer parameters (4I6 format) include: (1) the number of columns in the cross-section table (total number of energy groups), (2) the number of rows in the table (normally equals the number of columns plus 3), (3) a control code, which is generally not used, and (4) a unique identification number. The 36-character descriptor field (36H format) can contain any pertinent information, but usually includes the order of P_L expansion, the specific isotope or element, and special processing treatments such as self-shielding or energy weighting.

On the first pass, the collapsing procedure outlined in Fig. 3.5 regenerated the files needed to replace BUGLE-93 (no thermal upscattering data). The collapsing procedure was then repeated for the five MALOCS cases to produce self-shielded cross sections with upscattering data. On this second pass, a new library with upscattering data designated as BUGLE-96T was created. The difference between the production of the collapsed data for BUGLE-96 and BUGLE-96T is a single parameter in the MALOCS module.

Starting with BUGLE-93 and continuing with BUGLE-96, we added to the title record a 20-character Pedigree Identification Code (PIC) in the final 20 columns of the card (20H format). As the name suggests, the intent of the PIC is to put into a compact form information which is pertinent to the original source and ancestry of the data. The format and content of the PIC is given in Table 3.9. As an example, the PIC for ^{56}Fe is "E622631B96VB63020194." Most BUGLE-96 nuclides have this same PIC except for the nuclide MAT number and, in some cases, the ENDF/B-VI MOD number. This information is typically well understood at the time of the initial release of a library, but experience has shown us that the pedigree information can become vague or lost entirely as the library evolves. Frequently, the library grows with the addition of data sets based on later revisions to the evaluated data or processing options, or with the addition of data processed from alternative evaluations. Many analyses have gone amuck because of confusions regarding the actual nature and pedigree of a particular data set. The PIC is an attempt to avoid this problem. It is hoped that future libraries will adopt the same PIC format so that a standard will emerge.

Listings of the library contents for BUGLE-96 are given in Tables 3.10-3.12. Table 3.10 lists all materials which comprise the "standard weighted" library (i.e., the collection of all materials which were

Table 3.9 Pedigree Indentification Code [a]

Field(s)	Parameter	Comments/Options	
1	Evaluated File	B=BROND C=CENDL D=EFF E=ENDF	F=FENDL G=JENDL J=JEFF L=LENDL
2	Evaluation Version		
3	Evaluation "MOD"		
4-7	Material identifer	e.g., MAT number for ENDF	
8-10	Library designation	B93=BUGLE-93 B96=BUGLE-96 S96=SAILOR-96	VNC=VITAMIN-C VNE=VITAMIN-E VB6=VITAMIN-B6
11-13	Parent library	For derived libraries. Use "000" if no parent library.	
14	Data completeness	0=response fcts 1=neutron only 2=photon only	3=neutron+photon 4=(3)+delayed photons 5=thermal upscatter
15-20	Date of processing	"mmddyy" for month, day, and year	

[a] Appears in columns 61-80 of P_0 cross-section title cards.

Table 3.10 Nuclides in BUGLE-96 which are infinitely dilute and weighted with a concrete flux spectrum

Entry	Nuclide	ANISN-ID	Entry	Nuclide	ANISN-ID
1	Ag-107	1-6	46	H-1 (H2O)	313-320
2	Ag-109	7-12	47	H-1 (CH2)	321-328
3	Al-27	13-20	48	H-2 (D2O)	329-336
4	Am-241	21-26	49	H-3	337-344
5	Am-242	27-32	50	He-3	345-352
6	Am-242m	33-38	51	He-4	353-360
7	Am-243	39-44	52	Hf-174	361-366
8	Au-197	45-50	53	Hf-176	367-372
9	B-10	51-58	54	Hf-177	373-378
10	B-11	59-66	55	Hf-178	379-384
11	Ba-138	67-72	56	Hf-179	385-390
12	Be-9	73-80	57	Hf-180	391-396
13	Be-9 (Thermal)	81-88	58	In-Nat	397-402
14	Bi-209	89-94	59	K	403-410
15	C	95-102	60	Li-6	411-418
16	C (Graphite)	103-110	61	Li-7	419-426
17	Ca	111-118	62	Mg	427-434
18	Cd-Nat	119-124	63	Mn-55	435-442
19	Cl-Nat	125-132	64	Mo	443-448
20	Cm-241	133-138	65	N-14	449-456
21	Cm-242	139-144	66	N-15	457-464
22	Cm-243	145-150	67	Na-23	465-472
23	Cm-244	151-156	68	Nb-93	473-478
24	Cm-245	157-162	69	Ni-58	479-486
25	Cm-246	163-168	70	Ni-60	487-494
26	Cm-247	169-174	71	Ni-61	495-502
27	Cm-248	175-180	72	Ni-62	503-510
28	Co-59	181-188	73	Ni-64	511-518
29	Cr-50	189-196	74	Np-237	519-524
30	Cr-52	197-204	75	Np-238	525-530
31	Cr-53	205-212	76	Np-239	531-536
32	Cr-54	213-220	77	O-16	537-544
33	Cu-63	221-228	78	O-17	545-552
34	Cu-65	229-236	79	P-31	553-560
35	Eu-151	237-242	80	Pa-231	561-566
36	Eu-152	243-248	81	Pa-233	567-572
37	Eu-153	249-254	82	Pb-206	573-578
38	Eu-154	255-260	83	Pb-207	579-584
39	Eu-155	261-266	84	Pb-208	585-590
40	F-19	267-274	85	Pu-236	591-596
41	Fe-54	275-282	86	Pu-237	597-602
42	Fe-56	283-290	87	Pu-238	603-608
43	Fe-57	291-298	88	Pu-239	609-614
44	Fe-58	299-306	89	Pu-240	615-620
45	Ga	307-312	90	Pu-241	621-626

Table 3.10 cont'd

Entry	Nuclide	ANISN-ID	Entry	Nuclide	ANISN-ID
91	Pu-242	627-632	106	U-233	725-730
92	Pu-243	633-638	107	U-234	731-736
93	Pu-244	639-644	108	U-235	737-742
94	Re-185	645-650	109	U-236	743-748
95	Re-187	651-656	110	U-237	749-754
96	S	657-664	111	U-238	755-760
97	S-32	665-672	112	V	761-768
98	Si	673-680	113	W-Nat	769-774
99	Sn-Nat	681-686	114	W-182	775-780
100	Ta-181	687-692	115	W-183	781-786
101	Ta-182	693-698	116	W-184	787-792
102	Th-230	699-704	117	W-186	793-798
103	Th-232	705-710	118	Y-89	799-804
104	Ti	711-718	119	Zr	805-810
105	U-232	719-724	120	Zr (Zirc-2)	811-816

Table 3.11a Nuclides in BUGLE-96 which are self-shielded and weighted with BWR- and PWR-specific flux spectra

Nuclide	ANISN-ID	Description
B-10	1001-1008	PWR core coolant
Cr-50	1009-1016	PWR core clad
Cr-52	1017-1024	PWR core clad
Cr-53	1025-1032	PWR core clad
Cr-54	1033-1040	PWR core clad
Fe-54	1041-1048	PWR core clad
Fe-56	1049-1056	PWR core clad
Fe-57	1057-1064	PWR core clad
Fe-58	1065-1072	PWR core clad
H-1(H2O)	1073-1080	PWR core coolant
Ni-58	1081-1088	PWR core clad
Ni-60	1089-1096	PWR core clad
Ni-61	1097-1104	PWR core clad
Ni-62	1105-1112	PWR core clad
Ni-64	1113-1120	PWR core clad
O-16	1121-1128	PWR core coolant
O-16	1129-1136	PWR core fuel
U-235	1137-1142	PWR core fuel
U-238	1143-1148	PWR core fuel
Zr	1149-1154	PWR core clad
H-1(H2O)	2001-2008	PWR downcomer
O-16	2009-2016	PWR downcomer
C	2017-2024	PWR downcomer
Cr-50	2025-2032	PWR downcomer
Cr-52	2033-2040	PWR downcomer
Cr-53	2041-2048	PWR downcomer
Cr-54	2049-2056	PWR downcomer
Fe-54	2057-2064	PWR downcomer
Fe-56	2065-2072	PWR downcomer
Fe-57	2073-2080	PWR downcomer
Fe-58	2081-2088	PWR downcomer
Mn-55	2089-2096	PWR downcomer
Ni-58	2097-2104	PWR downcomer
Ni-60	2105-2112	PWR downcomer
Ni-61	2113-2120	PWR downcomer
Ni-62	2121-2128	PWR downcomer
Ni-64	2129-2136	PWR downcomer
C	3001-3008	PWR 1/4 T in Pressure Vessel
Cr-50	3009-3016	PWR 1/4 T in Pressure Vessel
Cr-52	3017-3024	PWR 1/4 T in Pressure Vessel
Cr-53	3025-3032	PWR 1/4 T in Pressure Vessel
Cr-54	3033-3040	PWR 1/4 T in Pressure Vessel
Fe-54	3041-3048	PWR 1/4 T in Pressure Vessel
Fe-56	3049-3056	PWR 1/4 T in Pressure Vessel

Table 3.11a cont'd

Nuclide	ANISN-ID	Description
Fe-57	3057-3064	PWR 1/4 T in Pressure Vessel
Fe-58	3065-3072	PWR 1/4 T in Pressure Vessel
Mn-55	3073-3080	PWR 1/4 T in Pressure Vessel
Ni-58	3081-3088	PWR 1/4 T in Pressure Vessel
Ni-60	3089-3096	PWR 1/4 T in Pressure Vessel
Ni-61	3097-3104	PWR 1/4 T in Pressure Vessel
Ni-62	3105-3112	PWR 1/4 T in Pressure Vessel
Ni-64	3113-3120	PWR 1/4 T in Pressure Vessel
Al-27	4001-4008	Concrete type 04
C	4009-4016	Concrete type 04
Ca	4017-4024	Concrete type 04
Fe-54	4025-4032	Concrete type 04
Fe-56	4033-4040	Concrete type 04
Fe-57	4041-4048	Concrete type 04
Fe-58	4049-4056	Concrete type 04
H-1(H2O)	4057-4064	Concrete type 04
K	4065-4072	Concrete type 04
Mg	4073-4080	Concrete type 04
Na-23	4081-4088	Concrete type 04
O-16	4089-4096	Concrete type 04
Si	4097-4104	Concrete type 04
C	5001-5008	Carbon steel
C	5009-5016	Stainless steel
Cr-50	5017-5024	Carbon steel
Cr-50	5025-5032	Stainless steel
Cr-52	5033-5040	Carbon steel
Cr-52	5041-5048	Stainless steel
Cr-53	5049-5056	Carbon steel
Cr-53	5057-5064	Stainless steel
Cr-54	5065-5072	Carbon steel
Cr-54	5073-5080	Stainless steel
Fe-54	5081-5088	Carbon steel
Fe-54	5089-5096	Stainless steel
Fe-56	5097-5104	Carbon steel
Fe-56	5105-5112	Stainless steel
Fe-57	5113-5120	Carbon steel
Fe-57	5121-5128	Stainless steel
Fe-58	5129-5136	Carbon steel
Fe-58	5137-5144	Stainless steel
Mn-55	5145-5152	Carbon steel
Mn-55	5153-5160	Stainless steel
Ni-58	5161-5168	Carbon steel

Table 3.11a cont'd

Nuclide	ANISN-ID	Description
Ni-58	5169-5176	Stainless steel
Ni-60	5177-5185	Carbon steel
Ni-60	5186-5192	Stainless steel
Ni-61	5193-5200	Carbon steel
Ni-61	5201-5208	Stainless steel
Ni-62	5209-5216	Carbon steel
Ni-62	5217-5224	Stainless steel
Ni-64	5225-5232	Carbon steel
Ni-64	5233-5240	Stainless steel
Fe-54	6001-6008	BWR core clad
Fe-56	6009-6016	BWR core clad
Fe-57	6017-6024	BWR core clad
Fe-58	6025-6032	BWR core clad
H-1(H2O)	6033-6040	BWR core coolant
O-16	6041-6048	BWR core coolant
O-16	6049-6056	BWR core fuel
U-235	6057-6062	BWR core fuel
U-238	6063-6068	BWR core fuel
Zr	6069-6074	BWR core clad

Table 3.11b Nuclides in SAILOR-96 which are self-shielded and weighted with BWR- and PWR-specific flux spectra

Nuclide	ANISN-ID	Description
BUGLE-96	1	RESPONSE FUNCTIONS 1-55(FLAT WTNG)
BUGLE-96	2	RESPONSE FUNCTIONS 1-55(1/4T PV WTNG)
H-1 (H2O)	3-6	PWR core coolant
B-10	7-10	PWR core coolant
O-16	11-14	PWR core coolant
Cr	15-18	PWR core clad
Fe	19-22	PWR core clad
Ni	23-26	PWR core clad
Zr	27-30	PWR core clad
U-235	31-34	PWR core fuel
U-238	35-38	PWR core fuel
O-16	39-42	PWR core fuel
U-235	43-46	BWR core fuel
U-238	47-50	BWR core fuel
O-16	51-54	BWR core fuel
H-1 (H2O)	55-58	PWR downcomer
O-16	59-62	PWR downcomer
Cr	63-66	PWR downcomer
Mn-55	67-70	PWR downcomer
Fe	71-74	PWR downcomer
Ni	75-78	PWR downcomer
C	79-82	PWR downcomer
H1(h2o)	83-86	Concrete type 04
C	87-90	Concrete type 04
O-16	91-94	Concrete type 04
Na-23	95-98	Concrete type 04
Mg	99-102	Concrete type 04
Al-27	103-106	Concrete type 04
Si	107-110	Concrete type 04
K	111-114	Concrete type 04
Ca	115-118	Concrete type 04
Fe	119-122	Concrete type 04
Cr	123-126	PWR 1/4 T in PV
Mn-55	127-130	PWR 1/4 T in PV
Fe	131-134	PWR 1/4 T in PV
Ni	135-138	PWR 1/4 T in PV
C	139-142	PWR 1/4 T in PV

Table 3.12 Data Sets in BUGLE-96 which contain response functions or kerma factors

ANISN-ID	Description
1	199/42-group response functions
7001	Response functions (first 55 responses) with flat weighting
7002	Response functions (last 16 responses) with flat weighting
7003	Response functions (first 55 responses) with 1/4T PV weighting
7004	Response functions (last 16 responses) with 1/4T PV weighting
8001	Neutron kerma factors for first 60 nuclides (^{107}Ag - ^{6}Li)
8002	Neutron kerma factors for last 60 nuclides (^{7}Li - Zirc-2)
8003	Gamma-ray kerma factors for first 60 nuclides (^{107}Ag - ^{6}Li)
8004	Gamma-ray kerma factors for last 60 nuclides (^{7}Li - Zirc-2)

processed as infinitely dilute and collapsed using the concrete flux spectrum). Table 3.11a lists the "special weighted" library (i.e., the collection of materials which were processed with specific self-shielding compositions and collapsed using the PWR and BWR flux spectra). The range of ANISN IDs for each nuclide are for the P_0 through P_L components, where "L" is either 5 or 7. Table 11.b lists the SAILOR-96 nuclides which have exactly the same ANISN identifiers as the earlier SAILOR data based on ENDF/B-VI. Note that the maximum order of Legendre scattering components for SAILOR-96 cross sections is P_3 which is less than BUGLE-96. Finally, Table 3.12 lists the ANISN IDs for the response functions and kerma factors data sets provided with the library. These responses and kerma factors are described in the following section.

3.6 Response Functions

We have continued the practice of including with the cross-section library additional data sets consisting of selected response functions which are expected to be of use to the user community. The following response functions are included with BUGLE-96:

- Dosimetry reaction cross sections based on ENDF/B-VI evaluations, including the 45 neutron responses in the SAILOR library.
- Neutron group boundaries, midpoint energy values, energy intervals, lethargy intervals, etc.
- Silicon displacement kerma.
- Total kerma factors for neutrons and photons calculated with the HEATR (neutron) and GAMINR (photons) modules of NJOY.

A list of the 55 original response functions included in BUGLE-93 and 16 additional response functions is given in Table 3.13 All but three of the responses are from the ENDF/B-VI evaluations. The ^6Li helium production cross section, the $^{32}S(n,p)$ cross section, and the Si displacement kerma, were obtained from Sandia National Laboratories compendium of dosimetry data.[20] The broad-group responses were prepared for two different energy weightings: a flat (uniform) weighting spectrum and the 1/4T pressure vessel weighting spectrum (listed in Table 3.4). The response functions are included in the library as "pseudo cross sections," i.e., they appear as normal 67-by-70 cross-section matrices. Within a matrix, each row represents a different response function. The row positions of the various response functions are given in Table 3.13. The group-wise responses are listed in Tables 3.14 and 3.15. The ANISN IDs of the four response tables are 7001-7002 for the flat-weighted responses and 7003-7004 for the 1/4T-weighted responses.

Even though the different weightings resulted in only a few percent change for most of the group-wise responses, differences of 20 to 30% were observed for several group constants, especially near reaction thresholds, and a maximum difference of 60% was observed for Group 30 of the ^{28}Fe (n,γ) reaction. Because of the observed sensitivity of the broad-group responses to the weighting function, a fine-group set of responses was prepared and is included in the BUGLE-96 package. The fine-group response matrix has an ANISN ID of 1 and contains 241

Table 3.13. Neutron response functions included with BUGLE-96 indicating row positions in data sets 7001-7004

Row	Response	Row	Response
	Data Sets 7001 and 7003		
1	Group upper energy (MeV)	29	I-127 (n,2n)
2	U-235 fission spectrum (χ)	30	Sc-45 (n,γ)
3	Li-6 (n,x) He-4	31	Na-23 (n,γ)
4	B-10 (n,α)	32	Fe-58 (n,γ)
5	Th-232 (n,fission)	33	Co-59 (n,γ)
6	U-235 (n,fission)	34	Cu-63 (n,γ)
7	U-238 (n,fission)	35	In-115 (n,γ)
8	Np-237 (n,fission)	36	Au-197 (n,γ)
9	Pu-239 (n,fission)	37	Th-232 (n,γ)
10	Al-27 (n,p)	38	U-238 (n,γ)
11	Al-27 (n,α)	39	Square-root(E_{mid}) ($MeV^{1/2}$)
12	S-32 (n,p)	40	Total neutron flux
13	Ti-46 (n,p)	41	U-234 (n,fission)
14	Ti-47 (n,p)	42	U-236 (n,fission)
15	Ti-47 (n,n'p)	43	Pu-240 (n,fission)
16	Ti-48 (n,p)	44	Pu-241 (n,fission)
17	Ti-48 (n,n'p)	45	Pu-242 (n,fission)
18	Mn-55 (n,2n)	46	Rh-103 (n,n')
19	Fe-54 (n,p)	47	Si displacement kerma (eV·b)
20	Fe-56 (n,p)	48	U-238 fission spectrum (χ)
21	Co-59 (n,2n)	49	Pu-239 fission spectrum (χ)
22	Co-59 (n,α)	50	E > 1.0 MeV neutron flux
23	Ni-58 (n,p)	51	E > 0.1 MeV neutron flux
24	Ni-58 (n,2n)	52	E < 0.414 eV neutron flux
25	Ni-60 (n,p)	53	Midpoint energy (MeV)
26	Cu-63 (n,α)	54	Group energy width (MeV)
27	Cu-65 (n,2n)	55	Group lethargy width
28	In-115 (n,n')		
	Data Sets 7002 and 7004		
1	Pu-238 (n,fission)	9	Pu-241 neutrons per fission (ν)
2	U-234 neutrons per fission (ν)	10	Pu-242 neutrons per fission (ν)
3	U-235 neutrons per fission (ν)	11	U-234 fission spectrum (χ)
4	U-236 neutrons per fission (ν)	12	U-236 fission spectrum (χ)
5	U-238 neutrons per fission (ν)	13	Pu-238 fission spectrum (χ)
6	Pu-238 neutrons per fission (ν)	14	Pu-240 fission spectrum (χ)
7	Pu-239 neutrons per fission (ν)	15	Pu-241 fission spectrum (χ)
8	Pu-240 neutrons per fission (ν)	16	Pu-242 fission spectrum (χ)

Table 3.14 Neutron response functions collapsed using flat weighting

Grp	Upper Energy	U-235 χ	Li-6 He-4 prd	B-10 (n,α)	Th-232 (n,f)	U-235 (n,f)
1	1.7332E+01	5.0179E-05	4.7232E-01	4.2156E-02	4.3136E-01	2.0735E+00
2	1.4191E+01	2.0166E-04	5.1684E-01	4.2619E-02	3.2663E-01	1.9282E+00
3	1.2214E+01	1.1460E-03	5.5853E-01	4.4402E-02	3.0836E-01	1.7293E+00
4	1.0000E+01	2.5222E-03	6.3289E-01	5.7616E-02	3.2388E-01	1.7612E+00
5	8.6071E+00	5.6568E-03	7.0577E-01	8.0408E-02	3.6062E-01	1.7464E+00
6	7.4082E+00	1.6147E-02	7.7178E-01	1.1269E-01	3.0408E-01	1.4230E+00
7	6.0653E+00	3.0712E-02	8.0511E-01	1.2197E-01	1.4357E-01	1.0552E+00
8	4.9659E+00	8.0512E-02	7.7062E-01	2.6313E-01	1.4232E-01	1.1106E+00
9	3.6788E+00	7.6758E-02	6.0925E-01	3.0406E-01	1.3969E-01	1.1703E+00
10	3.0119E+00	4.4010E-02	3.9611E-01	3.6913E-01	1.2703E-01	1.2150E+00
11	2.7253E+00	4.6685E-02	2.8706E-01	3.1882E-01	1.2045E-01	1.2429E+00
12	2.4660E+00	2.0028E-02	2.5208E-01	2.8462E-01	1.1507E-01	1.2552E+00
13	2.3653E+00	4.0262E-03	2.4746E-01	2.9288E-01	1.1585E-01	1.2592E+00
14	2.3457E+00	2.4344E-02	2.4252E-01	3.0917E-01	1.2609E-01	1.2638E+00
15	2.2313E+00	7.3547E-02	2.3399E-01	4.1159E-01	1.2266E-01	1.2702E+00
16	1.9205E+00	7.1946E-02	2.2020E-01	5.0278E-01	9.1294E-02	1.2595E+00
17	1.6530E+00	8.9495E-02	2.1291E-01	3.0979E-01	8.1353E-02	1.2321E+00
18	1.3534E+00	1.1503E-01	2.2016E-01	2.1852E-01	8.6693E-03	1.2003E+00
19	1.0026E+00	6.2685E-02	2.3861E-01	2.5376E-01	7.1248E-04	1.1517E+00
20	8.2085E-01	2.7239E-02	2.5648E-01	3.2103E-01	1.2603E-04	1.1110E+00
21	7.4274E-01	4.6851E-02	2.8261E-01	4.3035E-01	3.4442E-05	1.1157E+00
22	6.0810E-01	3.7615E-02	3.3814E-01	6.6683E-01	5.8520E-06	1.1278E+00
23	4.9787E-01	4.1771E-02	4.9376E-01	8.4399E-01	0	1.1797E+00
24	3.6883E-01	2.1390E-02	1.0122E+00	9.5140E-01	0	1.2260E+00
25	2.9721E-01	3.0048E-02	2.4377E+00	1.2647E+00	0	1.2984E+00
26	1.8316E-01	1.5408E-02	9.2165E-01	1.6957E+00	0	1.4372E+00
27	1.1109E-01	7.4251E-03	6.5334E-01	2.0955E+00	0	1.6021E+00
28	6.7379E-02	3.5461E-03	7.1593E-01	2.6030E+00	0	1.8105E+00
29	4.0868E-02	9.9806E-04	8.2619E-01	3.1216E+00	0	1.9686E+00
30	3.1828E-02	5.6977E-04	9.0935E-01	3.4799E+00	0	2.1196E+00
31	2.6058E-02	1.7337E-04	9.6818E-01	3.7273E+00	0	2.1831E+00
32	2.4176E-02	2.0305E-04	1.0067E+00	3.8907E+00	0	2.2818E+00
33	2.1875E-02	5.4037E-04	1.1233E+00	4.3737E+00	0	2.3938E+00
34	1.5034E-02	4.8419E-04	1.4537E+00	5.7400E+00	0	2.8863E+00
35	7.1017E-03	1.5746E-04	2.1032E+00	8.4066E+00	0	3.9988E+00
36	3.3546E-03	5.1156E-05	3.0547E+00	1.2293E+01	0	5.5154E+00
37	1.5846E-03	2.0827E-05	4.8963E+00	1.9816E+01	0	9.1358E+00
38	4.5400E-04	2.5484E-06	8.3350E+00	3.3846E+01	0	1.5618E+01
39	2.1445E-04	8.2729E-07	1.2133E+01	4.9359E+01	0	2.0654E+01
40	1.0130E-04	3.0899E-07	1.8549E+01	7.5517E+01	0	3.1806E+01
41	3.7266E-05	5.9997E-08	3.2034E+01	1.3049E+02	0	5.0522E+01
42	1.0677E-05	5.4050E-12	5.4477E+01	2.2211E+02	0	5.5389E+01
43	5.0435E-06	0	8.3285E+01	3.3957E+02	0	1.5699E+01
44	1.8554E-06	0	1.3057E+02	5.3243E+02	0	3.8833E+01
45	8.7643E-07	0	1.8991E+02	7.7447E+02	0	6.8464E+01
46	4.1399E-07	0	3.1296E+02	1.2766E+03	0	1.7917E+02
47	1.0000E-07	0	9.1977E+02	3.7523E+03	0	5.6297E+02

Table 3.14 cont'd

Grp	U-238 (n,f)	Np-237 (n,f)	Pu-239 (n,f)	Al-27 (n,p)	Al-27 (n,α)	S-32 (n,p)
1	1.2234E+00	2.2132E+00	2.3625E+00	5.8405E-02	9.7543E-02	1.7951E-01
2	1.0486E+00	2.0859E+00	2.3204E+00	7.8881E-02	1.2293E-01	3.1087E-01
3	9.8453E-01	2.0992E+00	2.2254E+00	8.7649E-02	1.0656E-01	3.8390E-01
4	9.9428E-01	2.1700E+00	2.2727E+00	8.4350E-02	7.6501E-02	3.4238E-01
5	9.9215E-01	2.2408E+00	2.2611E+00	7.2316E-02	4.1129E-02	3.1792E-01
6	8.5700E-01	1.9945E+00	2.0237E+00	5.4283E-02	1.1752E-02	3.0879E-01
7	5.6212E-01	1.4976E+00	1.6988E+00	3.7175E-02	4.8068E-04	2.5253E-01
8	5.4633E-01	1.5300E+00	1.7474E+00	1.1781E-02	1.5439E-06	2.7643E-01
9	5.2636E-01	1.6067E+00	1.8144E+00	4.7024E-03	0	1.9069E-01
10	5.2305E-01	1.6503E+00	1.8558E+00	6.2519E-04	0	1.0029E-01
11	5.3272E-01	1.6634E+00	1.8915E+00	1.1762E-04	0	6.8771E-02
12	5.3687E-01	1.6604E+00	1.9184E+00	1.2707E-05	0	7.2443E-02
13	5.3770E-01	1.6697E+00	1.9292E+00	8.2121E-06	0	6.6468E-02
14	5.3830E-01	1.6825E+00	1.9449E+00	3.2863E-06	0	6.1205E-02
15	5.3017E-01	1.6822E+00	1.9615E+00	1.5040E-07	0	2.1312E-02
16	4.7751E-01	1.6480E+00	1.9371E+00	8.5882E-10	0	4.1410E-03
17	3.2418E-01	1.5871E+00	1.9115E+00	0	0	5.9892E-04
18	4.3223E-02	1.4768E+00	1.8000E+00	0	0	6.0849E-05
19	1.2452E-02	1.3441E+00	1.6990E+00	0	0	1.8438E-07
20	3.7815E-03	1.1943E+00	1.6642E+00	0	0	0
21	1.5308E-03	9.5046E-01	1.6287E+00	0	0	0
22	6.1396E-04	6.0631E-01	1.5850E+00	0	0	0
23	2.8064E-04	2.6755E-01	1.5585E+00	0	0	0
24	1.5625E-04	9.3890E-02	1.5465E+00	0	0	0
25	7.9030E-05	4.6082E-02	1.5103E+00	0	0	0
26	1.0871E-04	2.3472E-02	1.5002E+00	0	0	0
27	3.3874E-05	1.5002E-02	1.5312E+00	0	0	0
28	9.1657E-05	1.1899E-02	1.5312E+00	0	0	0
29	3.0299E-05	1.0679E-02	1.5819E+00	0	0	0
30	9.9116E-05	1.0210E-02	1.6082E+00	0	0	0
31	2.4563E-05	9.9114E-03	1.5928E+00	0	0	0
32	2.7250E-05	9.7667E-03	1.5685E+00	0	0	0
33	1.5467E-04	9.5391E-03	1.7034E+00	0	0	0
34	4.5649E-04	9.1165E-03	1.9090E+00	0	0	0
35	1.6245E-05	8.7492E-03	2.2946E+00	0	0	0
36	4.4009E-09	9.2726E-03	3.5612E+00	0	0	0
37	9.2651E-04	1.3921E-02	6.6004E+00	0	0	0
38	9.9456E-06	2.4388E-02	1.1588E+01	0	0	0
39	1.9059E-05	3.2385E-02	1.8998E+01	0	0	0
40	3.2121E-05	4.3443E-02	4.9683E+01	0	0	0
41	1.4170E-04	3.4089E-02	5.2670E+01	0	0	0
42	7.3600E-05	7.3561E-03	3.6908E+01	0	0	0
43	1.7630E-06	3.9811E-03	9.8234E+00	0	0	0
44	1.8730E-06	1.0127E-02	2.5775E+01	0	0	0
45	2.5176E-06	8.5747E-03	1.3269E+02	0	0	0
46	3.9946E-06	5.1855E-03	1.3889E+03	0	0	0
47	1.1524E-05	1.7418E-02	7.5572E+02	0	0	0

Table 3.14 cont'd

Grp	Ti-46 (n,p)	Ti-47 (n,p)	T-47 (n,n'p)	Ti-48 (n,p)	Ti-48 (n,n'p)	Mn-55 (n,2n)
1	2.3185E-01	1.0126E-01	1.1057E-01	5.7867E-02	2.2238E-02	8.0975E-01
2	2.6548E-01	1.2747E-01	2.3093E-02	6.1081E-02	3.5666E-03	5.8141E-01
3	2.6304E-01	1.3799E-01	1.7344E-03	4.2421E-02	1.2965E-04	1.2730E-01
4	2.3755E-01	1.3120E-01	0	2.3314E-02	0	0
5	2.0627E-01	1.1822E-01	0	1.3187E-02	0	0
6	1.5952E-01	1.0506E-01	0	5.3056E-03	0	0
7	9.9284E-02	9.0214E-02	0	6.7628E-04	0	0
8	4.0704E-02	7.3510E-02	0	1.7157E-05	0	0
9	5.8083E-03	5.2088E-02	0	1.2844E-08	0	0
10	4.8186E-04	3.5199E-02	0	0	0	0
11	6.8546E-06	3.0687E-02	0	0	0	0
12	1.1050E-06	3.1258E-02	0	0	0	0
13	3.7716E-07	3.0536E-02	0	0	0	0
14	3.4272E-07	2.5942E-02	0	0	0	0
15	2.3359E-07	1.8030E-02	0	0	0	0
16	8.5452E-08	9.8049E-03	0	0	0	0
17	9.3494E-10	3.9990E-03	0	0	0	0
18	0	1.9598E-03	0	0	0	0
19	0	2.1140E-07	0	0	0	0
20	0	2.5346E-09	0	0	0	0
21	0	1.5774E-09	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0

Table 3.14 cont'd

Grp	Fe-54 (n,p)	Fe-56 (n,p)	Co-59 (n,2n)	Co-59 (n,α)	Ni-58 (n,p)	Ni-58 (n,2n)
1	2.3759E-01	9.1463E-02	7.8082E-01	2.5970E-02	2.2483E-01	5.1877E-02
2	3.9440E-01	1.1418E-01	5.4103E-01	2.7977E-02	4.5434E-01	9.4648E-03
3	4.6660E-01	8.5175E-02	8.9558E-02	1.9845E-02	5.8459E-01	0
4	4.8187E-01	5.7662E-02	0	1.2993E-02	6.2224E-01	0
5	4.8244E-01	4.1566E-02	0	7.7581E-03	6.2576E-01	0
6	4.7882E-01	2.4502E-02	0	2.7350E-03	6.0747E-01	0
7	4.3636E-01	5.7549E-03	0	4.5752E-04	5.1342E-01	0
8	3.1456E-01	1.8636E-04	0	1.4630E-05	3.8294E-01	0
9	1.9525E-01	1.4495E-07	0	0	2.4987E-01	0
10	1.3386E-01	6.9837E-10	0	0	1.7178E-01	0
11	7.8687E-02	0	0	0	1.2493E-01	0
12	5.6738E-02	0	0	0	9.6834E-02	0
13	5.1201E-02	0	0	0	8.8545E-02	0
14	4.5028E-02	0	0	0	7.9250E-02	0
15	2.9369E-02	0	0	0	5.0693E-02	0
16	9.5342E-03	0	0	0	2.8424E-02	0
17	2.9663E-03	0	0	0	1.4874E-02	0
18	7.8443E-04	0	0	0	5.9147E-03	0
19	9.0086E-05	0	0	0	1.3076E-03	0
20	6.6386E-06	0	0	0	8.9429E-04	0
21	3.9069E-07	0	0	0	5.5658E-04	0
22	0	0	0	0	1.6795E-04	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0

Table 3.14 cont'd

Grp	Ni-60 (n,p)	Cu-63 (n,α)	Cu-65 (n,2n)	In-115 (n,n')	I-127 (n,2n)	Sc-45 (n,γ)
1	1.0970E-01	3.2358E-02	1.0154E+00	5.9912E-02	1.5110E+00	1.6777E-04
2	1.4476E-01	4.3444E-02	7.5293E-01	8.8137E-02	1.3317E+00	2.6797E-04
3	1.1942E-01	3.7670E-02	2.0051E-01	1.9048E-01	7.9571E-01	3.5059E-04
4	8.8511E-02	2.7224E-02	0	2.6858E-01	4.8966E-02	4.2128E-04
5	6.5210E-02	1.8464E-02	0	2.9499E-01	0	4.7210E-04
6	3.8780E-02	1.0490E-02	0	3.1974E-01	0	5.2193E-04
7	1.5557E-02	3.3924E-03	0	3.3184E-01	0	5.7001E-04
8	2.2826E-03	5.9165E-04	0	3.1564E-01	0	7.5871E-04
9	3.0367E-05	4.8528E-05	0	3.3119E-01	0	1.0959E-03
10	7.6355E-08	8.2245E-06	0	3.3545E-01	0	1.3400E-03
11	4.2868E-08	2.9883E-06	0	3.3299E-01	0	1.5084E-03
12	2.8031E-08	9.4358E-07	0	3.2355E-01	0	1.6292E-03
13	2.3077E-08	8.1765E-07	0	3.1936E-01	0	1.6702E-03
14	1.7521E-08	6.7643E-07	0	3.1211E-01	0	1.7172E-03
15	2.8931E-09	2.4778E-07	0	2.7333E-01	0	2.0518E-03
16	0	1.6179E-08	0	2.1137E-01	0	2.6434E-03
17	0	0	0	1.6837E-01	0	3.2035E-03
18	0	0	0	9.3883E-02	0	4.6661E-03
19	0	0	0	4.9097E-02	0	5.5650E-03
20	0	0	0	2.5136E-02	0	6.0290E-03
21	0	0	0	1.3610E-02	0	6.7108E-03
22	0	0	0	3.7611E-03	0	7.7269E-03
23	0	0	0	1.7964E-03	0	9.0921E-03
24	0	0	0	1.0768E-04	0	1.1026E-02
25	0	0	0	0	0	1.6553E-02
26	0	0	0	0	0	2.4130E-02
27	0	0	0	0	0	4.1520E-02
28	0	0	0	0	0	4.4403E-02
29	0	0	0	0	0	6.1024E-02
30	0	0	0	0	0	6.3981E-02
31	0	0	0	0	0	2.6273E-02
32	0	0	0	0	0	4.5354E-02
33	0	0	0	0	0	1.1275E-01
34	0	0	0	0	0	1.6751E-01
35	0	0	0	0	0	2.0048E-01
36	0	0	0	0	0	2.0606E-01
37	0	0	0	0	0	6.7725E-02
38	0	0	0	0	0	1.0632E-01
39	0	0	0	0	0	2.2321E-01
40	0	0	0	0	0	4.3439E-01
41	0	0	0	0	0	8.5889E-01
42	0	0	0	0	0	1.5330E+00
43	0	0	0	0	0	2.3777E+00
44	0	0	0	0	0	3.7547E+00
45	0	0	0	0	0	5.4741E+00
46	0	0	0	0	0	9.0321E+00
47	0	0	0	0	0	2.6560E+01

Table 3.14 cont'd

Grp	Na-24 (n,γ)	Fe-58 (n,γ)	Co-59 (n,γ)	Cu-63 (n,γ)	In-115 (n,γ)	Au-197 (n,γ)
1	2.3070E-04	9.1567E-04	6.8770E-04	2.5623E-03	1.1155E-03	6.8982E-04
2	2.0005E-04	7.3968E-04	8.5053E-04	2.8175E-03	1.1891E-03	1.6116E-03
3	1.7988E-04	6.5168E-04	6.8172E-04	3.0696E-03	1.2659E-03	1.6731E-03
4	1.7403E-04	6.3263E-04	6.3552E-04	3.3421E-03	1.8208E-03	1.1750E-03
5	1.7014E-04	6.4504E-04	7.1898E-04	3.6106E-03	2.8639E-03	9.1819E-04
6	1.6691E-04	6.7390E-04	9.2215E-04	3.9385E-03	5.1798E-03	3.0070E-03
7	1.6343E-04	7.2704E-04	1.1725E-03	4.2639E-03	1.1665E-02	6.0744E-03
8	1.6076E-04	8.3040E-04	1.5502E-03	4.8109E-03	2.6232E-02	1.0718E-02
9	1.6781E-04	1.0115E-03	2.0452E-03	5.3953E-03	5.2041E-02	1.9549E-02
10	1.7459E-04	1.2784E-03	2.3427E-03	5.7193E-03	7.6962E-02	2.7051E-02
11	1.7922E-04	1.6654E-03	2.5345E-03	5.9647E-03	9.7501E-02	3.1768E-02
12	1.8259E-04	1.9218E-03	2.6931E-03	6.1262E-03	1.1492E-01	3.5664E-02
13	1.8379E-04	2.0081E-03	2.7590E-03	6.1801E-03	1.2038E-01	3.7626E-02
14	1.8519E-04	2.1048E-03	2.8329E-03	6.2406E-03	1.2621E-01	4.0078E-02
15	1.9004E-04	2.3984E-03	3.0750E-03	6.4744E-03	1.4765E-01	4.9414E-02
16	1.9765E-04	2.5584E-03	3.5505E-03	7.5680E-03	1.7647E-01	6.0164E-02
17	2.0684E-04	2.6095E-03	4.2985E-03	9.1289E-03	2.0634E-01	6.7846E-02
18	2.2063E-04	2.6680E-03	5.9988E-03	1.1900E-02	2.2849E-01	7.5082E-02
19	2.3988E-04	2.7737E-03	6.4521E-03	1.3725E-02	2.2849E-01	8.3994E-02
20	2.8913E-04	2.8823E-03	6.5376E-03	1.3879E-02	2.1788E-01	9.0859E-02
21	3.4120E-04	2.9711E-03	6.7224E-03	1.3950E-02	2.0476E-01	9.8884E-02
22	3.1318E-04	3.0732E-03	7.1180E-03	1.4474E-02	1.9281E-01	1.2062E-01
23	4.9395E-04	2.7341E-03	7.8534E-03	1.6377E-02	1.8393E-01	1.5151E-01
24	5.9582E-04	3.7273E-03	8.9120E-03	1.9019E-02	1.9209E-01	1.8524E-01
25	8.5059E-04	3.8525E-03	1.0952E-02	2.3569E-02	2.3042E-01	2.3561E-01
26	1.0398E-03	9.3131E-03	1.5506E-02	2.8106E-02	3.1100E-01	2.7524E-01
27	1.8591E-05	1.2589E-02	1.7452E-02	3.2226E-02	4.1669E-01	3.2856E-01
28	1.4633E-03	1.6917E-02	1.8170E-02	3.9129E-02	5.5833E-01	4.2178E-01
29	4.8595E-03	1.3672E-02	2.7343E-02	5.9252E-02	6.8908E-01	5.3222E-01
30	2.1801E-05	1.4391E-02	3.0530E-02	5.7142E-02	7.7226E-01	5.9594E-01
31	2.1729E-05	3.8969E-03	7.4013E-02	8.8300E-02	8.2002E-01	6.2972E-01
32	2.2866E-05	2.2993E-03	2.5812E-02	9.8415E-02	8.4271E-01	6.5357E-01
33	3.2827E-05	1.4997E-02	4.3350E-02	1.1565E-01	8.9870E-01	7.6550E-01
34	4.2580E-04	6.2677E-02	6.9895E-02	1.7697E-01	1.0695E+00	1.1601E+00
35	4.3323E-03	3.7572E-02	2.1806E-01	2.8514E-01	1.3063E+00	1.8692E+00
36	1.0226E-01	6.2123E-03	7.9458E-02	5.1503E-01	1.6452E+00	3.1238E+00
37	7.0401E-03	6.7240E-03	4.5000E-02	1.0560E+00	2.4899E+00	9.3400E+00
38	6.0157E-03	1.3475E+00	2.4559E-01	2.8621E-02	6.3837E+00	1.5854E+01
39	7.6425E-03	1.6327E-02	6.8796E+01	3.3434E-02	7.2317E+00	1.1622E+01
40	1.0955E-02	2.3040E-02	3.2785E+00	6.5824E-02	8.8408E+00	3.2960E+01
41	1.8351E-02	3.9539E-02	1.7355E+00	1.3611E-01	9.2816E+00	6.6678E-01
42	3.0776E-02	6.7097E-02	2.3647E+00	2.4869E-01	7.1728E+01	1.9950E+02
43	4.6918E-02	1.0243E-01	3.4231E+00	3.8882E-01	8.2452E+01	1.7419E+03
44	7.3364E-02	1.6040E-01	5.2409E+00	6.1624E-01	4.6433E+03	2.5042E+01
45	1.0657E-01	2.3303E-01	7.5609E+00	8.9960E-01	1.3505E+02	2.5533E+01
46	1.7562E-01	3.8345E-01	1.2401E+01	1.4854E+00	9.7434E+01	3.5695E+01
47	5.1603E-01	1.1251E+00	3.6358E+01	4.3703E+00	2.0867E+02	9.6877E+01

Table 3.14 cont'd

Grp	Th-232 (n,γ)	U-238 (n,γ)	Sqr-root E-mid	N flux Total	U-234 (n,f)	U-236 (n,f)
1	1.4711E-03	5.3381E-04	3.9701E+00	1.0000E+00	2.1363E+00	1.7831E+00
2	1.6025E-03	1.4080E-03	3.6335E+00	1.0000E+00	2.0083E+00	1.5576E+00
3	1.8642E-03	1.5809E-03	3.3327E+00	1.0000E+00	1.9630E+00	1.4867E+00
4	2.6395E-03	1.0527E-03	3.0502E+00	1.0000E+00	2.1259E+00	1.5594E+00
5	3.9834E-03	1.3611E-03	2.8298E+00	1.0000E+00	2.1237E+00	1.5170E+00
6	6.4657E-03	2.4189E-03	2.5955E+00	1.0000E+00	1.7644E+00	1.2776E+00
7	1.0451E-02	4.6746E-03	2.3485E+00	1.0000E+00	1.3307E+00	8.8677E-01
8	1.6721E-02	8.9088E-03	2.0790E+00	1.0000E+00	1.4087E+00	8.6255E-01
9	2.5906E-02	1.5632E-02	1.8290E+00	1.0000E+00	1.4985E+00	8.8156E-01
10	3.3183E-02	2.1387E-02	1.6937E+00	1.0000E+00	1.5197E+00	8.6630E-01
11	3.9772E-02	2.6327E-02	1.6111E+00	1.0000E+00	1.5359E+00	8.8603E-01
12	4.5724E-02	3.0714E-02	1.5542E+00	1.0000E+00	1.5159E+00	8.7609E-01
13	4.8360E-02	3.2635E-02	1.5348E+00	1.0000E+00	1.5188E+00	8.7113E-01
14	5.1316E-02	3.4790E-02	1.5128E+00	1.0000E+00	1.5306E+00	8.6616E-01
15	6.1054E-02	4.2993E-02	1.4408E+00	1.0000E+00	1.5483E+00	8.1253E-01
16	8.0735E-02	5.6288E-02	1.3367E+00	1.0000E+00	1.5533E+00	7.5492E-01
17	9.8678E-02	7.1126E-02	1.2261E+00	1.0000E+00	1.3866E+00	6.9303E-01
18	1.1984E-01	1.0332E-01	1.0854E+00	1.0000E+00	1.2338E+00	5.6177E-01
19	1.4631E-01	1.2356E-01	9.5484E-01	1.0000E+00	1.2293E+00	2.7796E-01
20	1.6073E-01	1.2002E-01	8.8419E-01	1.0000E+00	1.2729E+00	1.2361E-01
21	1.6466E-01	1.1688E-01	8.2184E-01	1.0000E+00	1.0312E+00	4.6719E-02
22	1.5789E-01	1.1021E-01	7.4363E-01	1.0000E+00	7.1936E-01	1.3408E-02
23	1.4506E-01	1.1104E-01	6.5829E-01	1.0000E+00	4.0382E-01	4.9630E-03
24	1.4402E-01	1.1404E-01	5.7708E-01	1.0000E+00	1.7843E-01	2.6411E-03
25	1.5519E-01	1.2069E-01	4.9009E-01	1.0000E+00	9.4149E-02	2.4220E-03
26	1.9093E-01	1.4577E-01	3.8357E-01	1.0000E+00	4.6307E-02	2.2758E-03
27	2.4693E-01	1.9617E-01	2.9872E-01	1.0000E+00	2.3625E-02	4.6449E-03
28	3.6550E-01	3.0660E-01	2.3265E-01	1.0000E+00	1.7090E-02	6.3696E-03
29	4.3004E-01	4.0574E-01	1.9065E-01	1.0000E+00	1.8465E-02	7.7069E-03
30	4.6127E-01	4.5034E-01	1.7013E-01	1.0000E+00	1.4649E-02	8.6163E-03
31	4.9104E-01	4.8046E-01	1.5848E-01	1.0000E+00	1.2794E-02	9.2138E-03
32	5.1166E-01	5.0036E-01	1.5174E-01	1.0000E+00	1.3076E-02	9.6306E-03
33	5.6866E-01	5.5622E-01	1.3585E-01	1.0000E+00	1.4194E-02	1.0705E-02
34	7.1318E-01	6.5641E-01	1.0520E-01	1.0000E+00	1.6265E-02	1.3460E-02
35	9.8950E-01	9.0722E-01	7.2306E-02	1.0000E+00	1.2172E-02	1.8299E-02
36	1.7641E+00	1.4524E+00	4.9695E-02	1.0000E+00	6.4100E-03	2.6387E-02
37	2.8651E+00	2.6019E+00	3.1927E-02	1.0000E+00	8.0287E-02	5.4766E-02
38	7.7534E+00	4.1837E+00	1.8282E-02	1.0000E+00	3.1568E-02	1.0906E-01
39	1.4214E+01	1.7907E+01	1.2565E-02	1.0000E+00	6.4810E-02	1.7891E-01
40	1.7431E+01	1.4532E+01	8.3236E-03	1.0000E+00	1.2787E-02	5.8900E-01
41	3.6855E+01	1.0186E+02	4.8961E-03	1.0000E+00	7.2656E-03	7.3626E-02
42	2.6913E-01	1.6854E+02	2.8036E-03	1.0000E+00	2.3900E-01	3.3532E+00
43	4.2428E-01	7.4634E-01	1.8573E-03	1.0000E+00	3.1591E-02	5.8630E-02
44	8.0707E-01	4.8598E-01	1.1687E-03	1.0000E+00	2.5390E-02	1.0576E-02
45	1.3155E+00	6.0912E-01	8.0325E-04	1.0000E+00	5.6768E-02	1.1566E-02
46	2.3457E+00	9.3643E-01	5.0695E-04	1.0000E+00	1.2756E-01	1.6726E-02
47	7.2285E+00	2.6611E+00	2.2362E-04	1.0000E+00	4.5017E-01	4.6180E-02

Table 3.14 cont'd

Grp	Pu-240 (n,f)	Pu-241 (n,f)	Pu-242 (n,f)	Rh-103 (n,n')	Silicon dspl kerma	U-238 χ
1	2.2815E+00	2.0603E+00	2.0296E+00	0	1.7344E+05	2.5568E-05
2	2.1344E+00	2.1270E+00	1.9071E+00	0	1.6731E+05	1.3895E-04
3	2.1609E+00	1.9857E+00	1.8646E+00	0	1.6249E+05	9.2397E-04
4	2.2159E+00	1.9749E+00	1.9025E+00	0	1.6207E+05	2.3012E-03
5	2.2112E+00	1.9257E+00	1.9413E+00	0	1.6748E+05	5.3971E-03
6	1.9505E+00	1.6897E+00	1.7055E+00	0	1.4984E+05	1.5970E-02
7	1.5387E+00	1.3549E+00	1.2780E+00	4.3283E-03	1.4845E+05	3.1340E-02
8	1.5634E+00	1.3593E+00	1.2483E+00	1.7584E-02	1.3904E+05	8.3571E-02
9	1.6622E+00	1.4678E+00	1.3236E+00	4.6854E-02	1.1339E+05	7.8777E-02
10	1.6997E+00	1.5338E+00	1.3706E+00	7.0324E-02	1.1449E+05	4.4513E-02
11	1.6943E+00	1.5636E+00	1.3958E+00	8.9127E-02	1.2594E+05	4.6779E-02
12	1.6995E+00	1.6007E+00	1.4098E+00	1.0254E-01	1.0160E+05	1.9959E-02
13	1.7089E+00	1.6171E+00	1.4137E+00	1.0726E-01	1.0711E+05	4.0056E-03
14	1.7223E+00	1.6339E+00	1.4177E+00	1.1272E-01	1.0253E+05	2.4181E-02
15	1.7421E+00	1.6703E+00	1.4274E+00	1.3093E-01	1.0992E+05	7.2808E-02
16	1.6785E+00	1.7137E+00	1.4248E+00	1.5239E-01	1.0911E+05	7.1180E-02
17	1.5919E+00	1.7179E+00	1.3992E+00	1.7411E-01	1.1614E+05	8.8822E-02
18	1.5513E+00	1.6078E+00	1.4744E+00	1.8893E-01	7.7796E+04	1.1438E-01
19	1.4110E+00	1.5435E+00	1.2242E+00	1.9972E-01	9.8770E+04	6.2108E-02
20	1.1379E+00	1.5251E+00	8.4627E-01	2.0256E-01	1.0260E+05	2.6880E-02
21	9.0043E-01	1.4900E+00	5.7579E-01	1.8343E-01	5.6951E+04	4.6032E-02
22	5.9099E-01	1.5016E+00	3.2958E-01	1.6137E-01	7.7366E+04	3.6806E-02
23	2.7018E-01	1.5513E+00	1.5223E-01	1.3692E-01	5.2779E+04	4.1012E-02
24	1.5493E-01	1.6583E+00	8.6297E-02	1.1553E-01	4.9906E+04	2.1221E-02
25	1.0764E-01	1.8201E+00	4.7899E-02	7.9194E-02	7.0893E+04	3.0246E-02
26	7.3462E-02	1.9989E+00	2.0971E-02	3.5464E-02	1.8165E+04	1.5802E-02
27	7.9696E-02	2.1701E+00	1.4350E-02	1.1422E-02	5.8684E+03	7.7209E-03
28	9.2867E-02	2.3309E+00	1.2428E-02	2.0690E-03	8.9068E+03	3.7220E-03
29	9.7825E-02	2.5058E+00	1.1888E-02	3.8639E-07	3.1172E+03	1.0529E-03
30	9.7560E-02	2.6975E+00	1.1668E-02	0	2.5502E+03	6.0240E-04
31	9.7050E-02	2.8117E+00	1.1553E-02	0	2.2858E+03	1.8351E-04
32	9.6430E-02	2.9086E+00	1.1490E-02	0	2.1499E+03	2.1506E-04
33	9.4366E-02	3.1356E+00	1.1352E-02	0	1.8075E+03	5.7311E-04
34	8.5520E-02	3.6408E+00	1.4205E-02	0	1.1483E+03	5.1466E-04
35	7.7704E-02	5.1444E+00	1.7569E-02	0	5.8705E+02	1.6766E-04
36	1.9789E-01	7.3033E+00	1.3134E-02	0	2.8353E+02	5.4512E-05
37	2.5020E-01	1.0762E+01	3.8552E-02	0	1.2074E+02	2.2199E-05
38	4.7740E-02	2.3305E+01	2.1200E-02	0	4.1562E+01	2.7146E-06
39	4.4803E-02	2.6230E+01	7.2759E-02	0	6.9815E+00	8.8031E-07
40	6.8179E-02	4.0447E+01	5.1272E-02	0	1.9451E+00	3.2884E-07
41	1.4532E-01	9.5972E+01	8.2924E-05	0	3.3620E+00	7.9696E-08
42	7.1568E-04	2.3536E+02	7.2308E-05	0	5.6956E+00	9.5563E-09
43	2.6864E-03	1.2366E+02	9.9111E-05	0	8.7047E+00	2.6717E-09
44	1.7088E+00	2.7696E+01	1.4864E-04	0	1.3654E+01	2.1631E-11
45	9.7596E-02	4.6301E+01	2.1317E-04	0	1.9892E+01	0
46	3.3352E-02	8.1545E+02	3.4837E-04	0	3.2798E+01	0
47	6.3706E-02	1.0225E+03	1.0197E-03	0	9.6064E+01	0

Table 3.14 cont'd

Grp	Pu-239 χ	N flux > 1.0 MeV	N flux > 0.1 MeV	N flux < 0.414 eV	Midpoint energy	Energy width
1	5.6208E-05	1.0000E+00	1.0000E+00	0	1.5762E+01	3.1410E+00
2	2.2677E-04	1.0000E+00	1.0000E+00	0	1.3203E+01	1.9770E+00
3	1.2921E-03	1.0000E+00	1.0000E+00	0	1.1107E+01	2.2140E+00
4	2.9394E-03	1.0000E+00	1.0000E+00	0	9.3035E+00	1.3929E+00
5	6.4700E-03	1.0000E+00	1.0000E+00	0	8.0077E+00	1.1989E+00
6	1.8109E-02	1.0000E+00	1.0000E+00	0	6.7368E+00	1.3429E+00
7	3.4016E-02	1.0000E+00	1.0000E+00	0	5.5156E+00	1.0994E+00
8	8.7792E-02	1.0000E+00	1.0000E+00	0	4.3224E+00	1.2871E+00
9	8.1231E-02	1.0000E+00	1.0000E+00	0	3.3454E+00	6.6690E-01
10	4.5561E-02	1.0000E+00	1.0000E+00	0	2.8686E+00	2.8660E-01
11	4.7656E-02	1.0000E+00	1.0000E+00	0	2.5956E+00	2.5930E-01
12	2.0272E-02	1.0000E+00	1.0000E+00	0	2.4156E+00	1.0070E-01
13	4.0474E-03	1.0000E+00	1.0000E+00	0	2.3555E+00	1.9600E-02
14	2.4523E-02	1.0000E+00	1.0000E+00	0	2.2885E+00	1.1440E-01
15	7.3440E-02	1.0000E+00	1.0000E+00	0	2.0759E+00	3.1080E-01
16	7.1233E-02	1.0000E+00	1.0000E+00	0	1.7867E+00	2.6750E-01
17	8.8012E-02	1.0000E+00	1.0000E+00	0	1.5032E+00	2.9960E-01
18	1.1158E-01	1.0000E+00	1.0000E+00	0	1.1780E+00	3.5080E-01
19	5.9861E-02	1.3000E-02	1.0000E+00	0	9.1172E-01	1.8175E-01
20	2.5776E-02	0	1.0000E+00	0	7.8180E-01	7.8110E-02
21	4.3929E-02	0	1.0000E+00	0	6.7542E-01	1.3464E-01
22	3.4950E-02	0	1.0000E+00	0	5.5299E-01	1.1023E-01
23	3.8841E-02	0	1.0000E+00	0	4.3335E-01	1.2904E-01
24	2.0200E-02	0	1.0000E+00	0	3.3302E-01	7.1620E-02
25	2.8665E-02	0	1.0000E+00	0	2.4018E-01	1.1405E-01
26	1.5048E-02	0	1.0000E+00	0	1.4713E-01	7.2070E-02
27	7.4971E-03	0	2.1034E-01	0	8.9235E-02	4.3711E-02
28	3.5511E-03	0	0	0	5.4123E-02	2.6511E-02
29	9.9694E-04	0	0	0	3.6348E-02	9.0400E-03
30	5.6378E-04	0	0	0	2.8943E-02	5.7700E-03
31	1.7409E-04	0	0	0	2.5117E-02	1.8820E-03
32	2.1284E-04	0	0	0	2.3025E-02	2.3010E-03
33	5.3012E-04	0	0	0	1.8454E-02	6.8410E-03
34	5.1937E-04	0	0	0	1.1068E-02	7.9323E-03
35	1.5779E-04	0	0	0	5.2282E-03	3.7471E-03
36	5.3309E-05	0	0	0	2.4696E-03	1.7700E-03
37	2.1981E-05	0	0	0	1.0193E-03	1.1306E-03
38	2.6501E-06	0	0	0	3.3423E-04	2.3955E-04
39	8.6276E-07	0	0	0	1.5787E-04	1.1315E-04
40	3.1417E-07	0	0	0	6.9283E-05	6.4034E-05
41	6.1447E-08	0	0	0	2.3971E-05	2.6589E-05
42	2.1765E-11	0	0	0	7.8602E-06	5.6335E-06
43	8.2907E-12	0	0	0	3.4495E-06	3.1881E-06
44	6.8575E-13	0	0	0	1.3659E-06	9.7897E-07
45	0	0	0	0	6.4521E-07	4.6244E-07
46	0	0	0	1.0000E+00	2.5700E-07	3.1399E-07
47	0	0	0	1.0000E+00	5.0005E-08	9.9990E-08

Table 3.14 cont'd

Grp	Lethargy width	Pu-238 (n,f)	U-234 ν	U-235 ν	U-236 ν	U-238 ν
1	1.9995E-01	2.6638E+00	4.4762E+00	4.6543E+00	4.3783E+00	4.7063E+00
2	1.5002E-01	2.6787E+00	4.1324E+00	4.2759E+00	4.0447E+00	4.3320E+00
3	2.0000E-01	2.7064E+00	3.8486E+00	3.9841E+00	3.7694E+00	4.0125E+00
4	1.5000E-01	2.7080E+00	3.6060E+00	3.7362E+00	3.5339E+00	3.7394E+00
5	1.5000E-01	2.6711E+00	3.4317E+00	3.5505E+00	3.3647E+00	3.5465E+00
6	2.0000E-01	2.5139E+00	3.2609E+00	3.3563E+00	3.1990E+00	3.3588E+00
7	1.9999E-01	2.2263E+00	3.0960E+00	3.1339E+00	3.0391E+00	3.1769E+00
8	3.0001E-01	2.2412E+00	2.9344E+00	2.9398E+00	2.8822E+00	2.9675E+00
9	2.0002E-01	2.2842E+00	2.8030E+00	2.8079E+00	2.7547E+00	2.7830E+00
10	9.9993E-02	2.2472E+00	2.7391E+00	2.7510E+00	2.6926E+00	2.6990E+00
11	9.9981E-02	2.2258E+00	2.7023E+00	2.7178E+00	2.6569E+00	2.6770E+00
12	4.1693E-02	2.2118E+00	2.6781E+00	2.6963E+00	2.6334E+00	2.6642E+00
13	8.3210E-03	2.2071E+00	2.6700E+00	2.6892E+00	2.6256E+00	2.6600E+00
14	4.9999E-02	2.2019E+00	2.6609E+00	2.6813E+00	2.6168E+00	2.6552E+00
15	1.5000E-01	2.1852E+00	2.6322E+00	2.6560E+00	2.5889E+00	2.6400E+00
16	1.4999E-01	2.1615E+00	2.5932E+00	2.6213E+00	2.5510E+00	2.6194E+00
17	1.9997E-01	2.1240E+00	2.5549E+00	2.5879E+00	2.5139E+00	2.5993E+00
18	3.0002E-01	2.0769E+00	2.5110E+00	2.5509E+00	2.4714E+00	2.5763E+00
19	2.0001E-01	2.0078E+00	2.4750E+00	2.5221E+00	2.4365E+00	2.5571E+00
20	9.9994E-02	1.9126E+00	2.4575E+00	2.5078E+00	2.4195E+00	2.5479E+00
21	2.0001E-01	1.7486E+00	2.4432E+00	2.4971E+00	2.4056E+00	2.5403E+00
22	2.0000E-01	1.5305E+00	2.4267E+00	2.4857E+00	2.3895E+00	2.5315E+00
23	3.0000E-01	1.2346E+00	2.4106E+00	2.4743E+00	2.3739E+00	2.5230E+00
24	2.1590E-01	1.0286E+00	2.3970E+00	2.4645E+00	2.3606E+00	2.5159E+00
25	4.8408E-01	8.5123E-01	2.3844E+00	2.4553E+00	2.3485E+00	2.5092E+00
26	5.0002E-01	7.1708E-01	2.3719E+00	2.4431E+00	2.3363E+00	2.5026E+00
27	5.0001E-01	6.2535E-01	2.3640E+00	2.4299E+00	2.3287E+00	2.4984E+00
28	4.9999E-01	6.2532E-01	2.3593E+00	2.4233E+00	2.3241E+00	2.4960E+00
29	2.5000E-01	6.7442E-01	2.3569E+00	2.4236E+00	2.3217E+00	2.4946E+00
30	2.0002E-01	6.9956E-01	2.3559E+00	2.4255E+00	2.3208E+00	2.4942E+00
31	7.4964E-02	7.2033E-01	2.3554E+00	2.4267E+00	2.3203E+00	2.4939E+00
32	1.0002E-01	7.3218E-01	2.3551E+00	2.4275E+00	2.3200E+00	2.4937E+00
33	3.7503E-01	6.5599E-01	2.3545E+00	2.4291E+00	2.3194E+00	2.4933E+00
34	7.4998E-01	8.5059E-01	2.3535E+00	2.4327E+00	2.3184E+00	2.4929E+00
35	7.5000E-01	1.4380E+00	2.3527E+00	2.4338E+00	2.3177E+00	2.4925E+00
36	7.5000E-01	1.6541E+00	2.3523E+00	2.4338E+00	2.3173E+00	2.4923E+00
37	1.2500E+00	2.3178E+00	2.3521E+00	2.4338E+00	2.3171E+00	2.4922E+00
38	7.5002E-01	3.3753E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
39	7.4999E-01	6.5745E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
40	1.0000E+00	1.7268E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
41	1.2500E+00	1.1965E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
42	7.4999E-01	2.6274E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
43	1.0000E+00	1.0651E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
44	7.5000E-01	2.0749E-01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
45	7.5002E-01	6.7838E-01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
46	1.4207E+00	2.7370E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
47	9.2103E+00	1.6171E+01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00

Table 3.14 cont'd

Grp	Pu-238 ν	Pu-239 ν	Pu-240 ν	Pu-241 ν	Pu-242 ν	U-234 χ
1	5.2231E+00	5.1730E+00	5.1923E+00	5.3119E+00	5.2892E+00	1.5159E-04
2	4.8457E+00	4.8321E+00	4.8051E+00	4.9186E+00	4.8875E+00	4.6489E-04
3	4.5344E+00	4.5426E+00	4.4856E+00	4.5938E+00	4.5560E+00	2.0914E-03
4	4.2682E+00	4.2850E+00	4.2124E+00	4.3160E+00	4.2724E+00	4.0422E-03
5	4.0768E+00	4.0819E+00	4.0160E+00	4.1164E+00	4.0687E+00	7.9523E-03
6	3.8894E+00	3.8857E+00	3.8239E+00	3.9216E+00	3.8693E+00	2.0119E-02
7	3.7097E+00	3.6875E+00	3.6394E+00	3.7361E+00	3.6777E+00	3.4986E-02
8	3.5333E+00	3.5013E+00	3.4585E+00	3.5540E+00	3.4898E+00	8.4943E-02
9	3.3895E+00	3.3594E+00	3.3108E+00	3.4016E+00	3.3365E+00	7.6300E-02
10	3.3194E+00	3.2979E+00	3.2389E+00	3.3263E+00	3.2619E+00	4.2488E-02
11	3.2790E+00	3.2576E+00	3.1974E+00	3.2829E+00	3.2189E+00	4.4430E-02
12	3.2525E+00	3.2319E+00	3.1701E+00	3.2544E+00	3.1907E+00	1.8922E-02
13	3.2436E+00	3.2238E+00	3.1610E+00	3.2449E+00	3.1812E+00	3.7965E-03
14	3.2337E+00	3.2151E+00	3.1508E+00	3.2342E+00	3.1706E+00	2.2916E-02
15	3.2022E+00	3.1867E+00	3.1185E+00	3.2003E+00	3.1371E+00	6.9064E-02
16	3.1594E+00	3.1443E+00	3.0745E+00	3.1544E+00	3.0915E+00	6.7814E-02
17	3.1174E+00	3.0975E+00	3.0315E+00	3.1093E+00	3.0469E+00	8.5334E-02
18	3.0693E+00	3.0441E+00	2.9820E+00	3.0576E+00	2.9956E+00	1.1157E-01
19	3.0299E+00	3.0049E+00	2.9416E+00	3.0152E+00	2.9537E+00	6.1607E-02
20	3.0107E+00	2.9867E+00	2.9218E+00	2.9945E+00	2.9333E+00	2.6932E-02
21	2.9949E+00	2.9717E+00	2.9057E+00	2.9776E+00	2.9165E+00	4.6550E-02
22	2.9768E+00	2.9546E+00	2.8871E+00	2.9581E+00	2.8972E+00	3.7658E-02
23	2.9591E+00	2.9400E+00	2.8690E+00	2.9457E+00	2.8784E+00	4.2494E-02
24	2.9443E+00	2.9290E+00	2.8536E+00	2.9453E+00	2.8625E+00	2.2243E-02
25	2.9305E+00	2.9192E+00	2.8395E+00	2.9453E+00	2.8479E+00	3.2067E-02
26	2.9168E+00	2.9088E+00	2.8254E+00	2.9453E+00	2.8332E+00	1.6963E-02
27	2.9082E+00	2.9029E+00	2.8165E+00	2.9453E+00	2.8241E+00	8.3563E-03
28	2.9030E+00	2.8992E+00	2.8112E+00	2.9453E+00	2.8185E+00	4.0490E-03
29	2.9004E+00	2.8976E+00	2.8085E+00	2.9453E+00	2.8157E+00	1.1485E-03
30	2.8993E+00	2.8969E+00	2.8074E+00	2.9453E+00	2.8146E+00	6.5783E-04
31	2.8987E+00	2.8965E+00	2.8068E+00	2.9453E+00	2.8140E+00	2.0051E-04
32	2.8984E+00	2.8963E+00	2.8065E+00	2.9453E+00	2.8136E+00	2.3506E-04
33	2.8977E+00	2.8958E+00	2.8058E+00	2.9453E+00	2.8129E+00	6.2681E-04
34	2.8966E+00	2.8951E+00	2.8047E+00	2.9453E+00	2.8117E+00	5.6349E-04
35	2.8958E+00	2.8948E+00	2.8038E+00	2.9453E+00	2.8108E+00	1.8373E-04
36	2.8954E+00	2.8945E+00	2.8034E+00	2.9453E+00	2.8104E+00	5.9785E-05
37	2.8951E+00	2.8903E+00	2.8031E+00	2.9453E+00	2.8102E+00	2.4392E-05
38	2.8950E+00	2.8651E+00	2.8030E+00	2.9453E+00	2.8100E+00	3.0037E-06
39	2.8950E+00	2.8718E+00	2.8030E+00	2.9453E+00	2.8100E+00	9.8697E-07
40	2.8950E+00	2.8668E+00	2.8030E+00	2.9453E+00	2.8100E+00	3.8048E-07
41	2.8950E+00	2.8632E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.0297E-07
42	2.8950E+00	2.8643E+00	2.8030E+00	2.9453E+00	2.8100E+00	9.1138E-09
43	2.8950E+00	2.8770E+00	2.8030E+00	2.9453E+00	2.8100E+00	5.0382E-09
44	2.8950E+00	2.8784E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.5297E-09
45	2.8950E+00	2.8700E+00	2.8030E+00	2.9453E+00	2.8100E+00	7.9147E-10
46	2.8950E+00	2.8615E+00	2.8030E+00	2.9453E+00	2.8100E+00	4.3746E-10
47	2.8950E+00	2.8768E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.8584E-10

Table 3.14 cont'd

Grp	U-236 χ	Pu-238 χ	Pu-240 χ	Pu-241 χ	Pu-242 χ
1	1.0898E-04	8.0233E-05	1.0673E-04	9.9677E-05	1.1131E-04
2	3.5098E-04	2.8002E-04	3.5394E-04	3.3529E-04	3.6640E-04
3	1.6611E-03	1.4154E-03	1.7054E-03	1.6360E-03	1.7532E-03
4	3.3451E-03	2.9768E-03	3.4603E-03	3.3494E-03	3.5386E-03
5	6.7995E-03	6.2305E-03	7.0470E-03	6.8657E-03	7.1773E-03
6	1.7797E-02	1.6736E-02	1.8416E-02	1.8057E-02	1.8681E-02
7	3.1944E-02	3.0672E-02	3.2916E-02	3.2452E-02	3.3263E-02
8	8.0131E-02	7.8339E-02	8.1967E-02	8.1247E-02	8.2519E-02
9	7.3775E-02	7.2970E-02	7.4920E-02	7.4551E-02	7.5211E-02
10	4.1592E-02	4.1353E-02	4.2059E-02	4.1931E-02	4.2163E-02
11	4.3812E-02	4.3685E-02	4.4185E-02	4.4099E-02	4.4256E-02
12	1.8748E-02	1.8727E-02	1.8873E-02	1.8850E-02	1.8893E-02
13	3.7676E-03	3.7654E-03	3.7902E-03	3.7865E-03	3.7936E-03
14	2.2782E-02	2.2785E-02	2.2903E-02	2.2886E-02	2.2918E-02
15	6.9061E-02	6.9211E-02	6.9262E-02	6.9270E-02	6.9262E-02
16	6.8334E-02	6.8659E-02	6.8309E-02	6.8393E-02	6.8248E-02
17	8.6641E-02	8.7260E-02	8.6317E-02	8.6519E-02	8.6166E-02
18	1.1426E-01	1.1537E-01	1.1337E-01	1.1378E-01	1.1306E-01
19	6.3535E-02	6.4276E-02	6.2828E-02	6.3116E-02	6.2606E-02
20	2.7870E-02	2.8221E-02	2.7513E-02	2.7653E-02	2.7405E-02
21	4.8306E-02	4.8948E-02	4.7619E-02	4.7880E-02	4.7416E-02
22	3.9204E-02	3.9757E-02	3.8583E-02	3.8811E-02	3.8404E-02
23	4.4378E-02	4.5037E-02	4.3602E-02	4.3879E-02	4.3384E-02
24	2.3290E-02	2.3651E-02	2.2851E-02	2.3005E-02	2.2730E-02
25	3.3658E-02	3.4196E-02	3.2980E-02	3.3213E-02	3.2796E-02
26	1.7848E-02	1.8144E-02	1.7465E-02	1.7594E-02	1.7363E-02
27	8.8057E-03	8.9545E-03	8.6096E-03	8.6750E-03	8.5576E-03
28	4.2707E-03	4.3438E-03	4.1735E-03	4.2057E-03	4.1478E-03
29	1.2120E-03	1.2328E-03	1.1841E-03	1.1933E-03	1.1768E-03
30	6.9430E-04	7.0627E-04	6.7824E-04	6.8355E-04	6.7402E-04
31	2.1165E-04	2.1530E-04	2.0674E-04	2.0836E-04	2.0545E-04
32	2.4813E-04	2.5242E-04	2.4237E-04	2.4427E-04	2.4086E-04
33	6.6174E-04	6.7317E-04	6.4634E-04	6.5142E-04	6.4229E-04
34	5.9501E-04	6.0531E-04	5.8109E-04	5.8567E-04	5.7744E-04
35	1.9404E-04	1.9741E-04	1.8948E-04	1.9098E-04	1.8829E-04
36	6.3142E-05	6.4238E-05	6.1657E-05	6.2145E-05	6.1269E-05
37	2.5761E-05	2.6208E-05	2.5155E-05	2.5354E-05	2.4997E-05
38	3.1715E-06	3.2263E-06	3.0973E-06	3.1218E-06	3.0779E-06
39	1.0416E-06	1.0595E-06	1.0175E-06	1.0254E-06	1.0111E-06
40	4.0087E-07	4.0781E-07	3.9198E-07	3.9498E-07	3.8960E-07
41	1.0808E-07	1.0989E-07	1.0590E-07	9.6708E-08	1.0517E-07
42	4.7007E-09	0	1.0349E-08	1.9397E-11	1.5776E-08
43	2.6106E-09	0	5.5918E-09	1.0701E-11	8.6067E-09
44	6.6295E-10	0	1.6994E-09	3.3430E-12	2.6035E-09
45	1.2831E-10	0	1.0556E-09	2.1628E-12	1.6126E-09
46	3.1175E-11	0	1.0958E-09	2.3672E-12	1.4742E-09
47	1.0398E-11	0	3.4341E-10	7.8650E-13	5.1255E-10

Table 3.15 Neutron response functions collapsed using 1/4T PV weighting

Grp	Upper Energy	U-235 χ	Li-6 He-4 prd	B-10 (n,α)	Th-232 (n,f)	U-235 (n,f)
1	1.7332E+01	5.0179E-05	4.7963E-01	4.3304E-02	4.1263E-01	2.0793E+00
2	1.4191E+01	2.0166E-04	5.2033E-01	4.2292E-02	3.2291E-01	1.9005E+00
3	1.2214E+01	1.1460E-03	5.6430E-01	4.5450E-02	3.1036E-01	1.7302E+00
4	1.0000E+01	2.5222E-03	6.3704E-01	5.8503E-02	3.2450E-01	1.7632E+00
5	8.6071E+00	5.6568E-03	7.0908E-01	8.1864E-02	3.6337E-01	1.7415E+00
6	7.4082E+00	1.6147E-02	7.7621E-01	1.1414E-01	2.8465E-01	1.3812E+00
7	6.0653E+00	3.0712E-02	8.0527E-01	1.2289E-01	1.4362E-01	1.0547E+00
8	4.9659E+00	8.0512E-02	7.6989E-01	2.6597E-01	1.4229E-01	1.1115E+00
9	3.6788E+00	7.6758E-02	5.9559E-01	3.0350E-01	1.3947E-01	1.1732E+00
10	3.0119E+00	4.4010E-02	3.9400E-01	3.7024E-01	1.2694E-01	1.2155E+00
11	2.7253E+00	4.6685E-02	2.8708E-01	3.1883E-01	1.2045E-01	1.2429E+00
12	2.4660E+00	2.0028E-02	2.5191E-01	2.8484E-01	1.1507E-01	1.2553E+00
13	2.3653E+00	4.0262E-03	2.4746E-01	2.9288E-01	1.1585E-01	1.2592E+00
14	2.3457E+00	2.4344E-02	2.4244E-01	3.0943E-01	1.2625E-01	1.2639E+00
15	2.2313E+00	7.3547E-02	2.3398E-01	4.1198E-01	1.2262E-01	1.2702E+00
16	1.9205E+00	7.1946E-02	2.1936E-01	5.0046E-01	9.0122E-02	1.2587E+00
17	1.6530E+00	8.9495E-02	2.1293E-01	3.0573E-01	7.9563E-02	1.2313E+00
18	1.3534E+00	1.1503E-01	2.2060E-01	2.1747E-01	7.4847E-03	1.1995E+00
19	1.0026E+00	6.2685E-02	2.3907E-01	2.5540E-01	6.8938E-04	1.1491E+00
20	8.2085E-01	2.7239E-02	2.5661E-01	3.2158E-01	1.2548E-04	1.1110E+00
21	7.4274E-01	4.6851E-02	2.8569E-01	4.4379E-01	3.0226E-05	1.1163E+00
22	6.0810E-01	3.7615E-02	3.3667E-01	6.6124E-01	6.1021E-06	1.1273E+00
23	4.9787E-01	4.1771E-02	5.0774E-01	8.4596E-01	0	1.1818E+00
24	3.6883E-01	2.1390E-02	1.0316E+00	9.5540E-01	0	1.2263E+00
25	2.9721E-01	3.0048E-02	2.4743E+00	1.2692E+00	0	1.3005E+00
26	1.8316E-01	1.5408E-02	9.2442E-01	1.6988E+00	0	1.4392E+00
27	1.1109E-01	7.4251E-03	6.5419E-01	2.1377E+00	0	1.6230E+00
28	6.7379E-02	3.5461E-03	7.1681E-01	2.6075E+00	0	1.8074E+00
29	4.0868E-02	9.9806E-04	8.2512E-01	3.1168E+00	0	1.9647E+00
30	3.1828E-02	5.6977E-04	9.2476E-01	3.5436E+00	0	2.1159E+00
31	2.6058E-02	1.7337E-04	9.6822E-01	3.7275E+00	0	2.1833E+00
32	2.4176E-02	2.0305E-04	1.0055E+00	3.8859E+00	0	2.2787E+00
33	2.1875E-02	5.4037E-04	1.1194E+00	4.3576E+00	0	2.3874E+00
34	1.5034E-02	4.8419E-04	1.4356E+00	5.6653E+00	0	2.8722E+00
35	7.1017E-03	1.5746E-04	2.1471E+00	8.5862E+00	0	4.0917E+00
36	3.3546E-03	5.1156E-05	3.1235E+00	1.2574E+01	0	5.6289E+00
37	1.5846E-03	2.0827E-05	5.1337E+00	2.0786E+01	0	9.7895E+00
38	4.5400E-04	2.5484E-06	8.6613E+00	3.5175E+01	0	1.7137E+01
39	2.1445E-04	8.2729E-07	1.2394E+01	5.0427E+01	0	2.0795E+01
40	1.0130E-04	3.0899E-07	1.9260E+01	7.8415E+01	0	3.3782E+01
41	3.7266E-05	5.9997E-08	3.3837E+01	1.3784E+02	0	4.9377E+01
42	1.0677E-05	5.4050E-12	5.5363E+01	2.2573E+02	0	5.0104E+01
43	5.0435E-06	0	8.5475E+01	3.4851E+02	0	1.6088E+01
44	1.8554E-06	0	1.3211E+02	5.3872E+02	0	4.1541E+01
45	8.7643E-07	0	1.9350E+02	7.8921E+02	0	7.1080E+01
46	4.1399E-07	0	3.3917E+02	1.3835E+03	0	1.8975E+02
47	1.0000E-07	0	6.5472E+02	2.6707E+03	0	3.8385E+02

Table 3.15 cont'd

Grp	U-238 (n,f)	Np-237 (n,f)	Pu-239 (n,f)	Al-27 (n,p)	Al-27 (n,α)	S-32 (n,p)
1	1.2030E+00	2.2008E+00	2.3765E+00	6.2573E-02	1.0490E-01	1.9969E-01
2	1.0345E+00	2.0821E+00	2.3068E+00	7.9970E-02	1.2276E-01	3.2156E-01
3	9.8468E-01	2.1055E+00	2.2293E+00	8.8438E-02	1.0298E-01	3.8190E-01
4	9.9501E-01	2.1753E+00	2.2746E+00	8.3652E-02	7.4884E-02	3.4015E-01
5	9.9114E-01	2.2387E+00	2.2572E+00	7.1603E-02	3.9600E-02	3.1792E-01
6	8.3063E-01	1.9568E+00	1.9941E+00	5.3171E-02	9.8424E-03	3.0655E-01
7	5.5979E-01	1.4918E+00	1.6976E+00	3.6185E-02	4.3048E-04	2.4861E-01
8	5.4637E-01	1.5311E+00	1.7483E+00	1.1581E-02	1.4240E-06	2.7668E-01
9	5.2528E-01	1.6098E+00	1.8170E+00	4.2962E-03	0	1.8625E-01
10	5.2327E-01	1.6507E+00	1.8563E+00	6.1154E-04	0	9.9629E-02
11	5.3272E-01	1.6634E+00	1.8914E+00	1.1766E-04	0	6.8769E-02
12	5.3690E-01	1.6606E+00	1.9187E+00	1.2562E-05	0	7.2381E-02
13	5.3770E-01	1.6697E+00	1.9292E+00	8.2121E-06	0	6.6468E-02
14	5.3831E-01	1.6826E+00	1.9451E+00	3.2145E-06	0	6.1091E-02
15	5.3011E-01	1.6822E+00	1.9614E+00	1.4984E-07	0	2.1233E-02
16	4.7447E-01	1.6462E+00	1.9358E+00	6.8493E-10	0	3.8002E-03
17	3.1627E-01	1.5854E+00	1.9111E+00	0	0	5.7213E-04
18	4.0979E-02	1.4719E+00	1.7939E+00	0	0	5.5013E-05
19	1.2280E-02	1.3383E+00	1.6980E+00	0	0	1.4370E-07
20	3.7513E-03	1.1930E+00	1.6640E+00	0	0	0
21	1.4174E-03	9.2466E-01	1.6254E+00	0	0	0
22	6.2319E-04	6.1302E-01	1.5857E+00	0	0	0
23	2.7669E-04	2.5960E-01	1.5581E+00	0	0	0
24	1.5361E-04	9.2568E-02	1.5462E+00	0	0	0
25	7.8551E-05	4.5624E-02	1.5098E+00	0	0	0
26	1.0790E-04	2.3415E-02	1.5009E+00	0	0	0
27	3.6617E-05	1.4606E-02	1.5333E+00	0	0	0
28	9.1652E-05	1.1885E-02	1.5305E+00	0	0	0
29	2.9046E-05	1.0686E-02	1.5803E+00	0	0	0
30	5.0866E-05	1.0129E-02	1.6106E+00	0	0	0
31	2.4468E-05	9.9113E-03	1.5930E+00	0	0	0
32	2.5441E-05	9.7705E-03	1.5729E+00	0	0	0
33	1.4497E-04	9.5449E-03	1.7021E+00	0	0	0
34	5.2671E-04	9.1381E-03	1.8880E+00	0	0	0
35	1.2822E-05	8.8064E-03	2.3236E+00	0	0	0
36	5.9145E-09	9.3350E-03	3.6339E+00	0	0	0
37	1.0459E-03	1.3684E-02	7.1712E+00	0	0	0
38	1.1502E-05	2.6078E-02	1.2940E+01	0	0	0
39	1.7070E-05	3.0845E-02	1.9213E+01	0	0	0
40	2.8886E-05	6.2512E-02	4.7642E+01	0	0	0
41	1.4284E-04	2.4718E-02	7.0557E+01	0	0	0
42	7.5663E-05	8.1492E-03	3.7043E+01	0	0	0
43	1.7359E-06	3.8741E-03	1.0280E+01	0	0	0
44	1.8881E-06	9.8116E-03	2.6609E+01	0	0	0
45	2.5594E-06	1.0235E-02	1.4963E+02	0	0	0
46	4.3150E-06	5.5072E-03	1.2060E+03	0	0	0
47	8.2184E-06	1.1981E-02	5.6228E+02	0	0	0

Table 3.15 cont'd

Grp	Ti-46 (n,p)	Ti-47 (n,p)	T-47 (n,n'p)	Ti-48 (n,p)	Ti-48 (n,n'p)	Mn-55 (n,2n)
1	2.3995E-01	1.0628E-01	9.5268E-02	6.0033E-02	1.7129E-02	7.9549E-01
2	2.6649E-01	1.2894E-01	1.8970E-02	6.0176E-02	3.1087E-03	5.4918E-01
3	2.6092E-01	1.3818E-01	1.1391E-03	3.9626E-02	7.1408E-05	8.3715E-02
4	2.3599E-01	1.3057E-01	0	2.2626E-02	0	0
5	2.0458E-01	1.1750E-01	0	1.2786E-02	0	0
6	1.5493E-01	1.0466E-01	0	4.7766E-03	0	0
7	9.7555E-02	8.9539E-02	0	6.2458E-04	0	0
8	4.0019E-02	7.3311E-02	0	1.6195E-05	0	0
9	5.2546E-03	5.1029E-02	0	1.0858E-08	0	0
10	4.6436E-04	3.5028E-02	0	0	0	0
11	6.8561E-06	3.0686E-02	0	0	0	0
12	1.0704E-06	3.1236E-02	0	0	0	0
13	3.7716E-07	3.0536E-02	0	0	0	0
14	3.4221E-07	2.5869E-02	0	0	0	0
15	2.3325E-07	1.8011E-02	0	0	0	0
16	7.9544E-08	9.4769E-03	0	0	0	0
17	8.3607E-10	3.9493E-03	0	0	0	0
18	0	1.7975E-03	0	0	0	0
19	0	1.7179E-07	0	0	0	0
20	0	2.5278E-09	0	0	0	0
21	0	1.4882E-09	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0

Table 3.15 cont'd

Grp	Fe-54 (n,p)	Fe-56 (n,p)	Co-59 (n,2n)	Co-59 (n,α)	Ni-58 (n,p)	Ni-58 (n,2n)
1	2.6161E-01	9.8795E-02	7.6839E-01	2.7669E-02	2.6005E-01	4.5404E-02
2	4.0412E-01	1.1344E-01	5.0631E-01	2.7497E-02	4.7045E-01	7.1034E-03
3	4.6969E-01	8.0985E-02	5.5171E-02	1.8838E-02	5.9230E-01	0
4	4.8225E-01	5.6807E-02	0	1.2748E-02	6.2312E-01	0
5	4.8234E-01	4.0851E-02	0	7.4824E-03	6.2541E-01	0
6	4.7815E-01	2.3050E-02	0	2.4431E-03	6.0484E-01	0
7	4.3395E-01	5.3423E-03	0	4.2660E-04	5.0885E-01	0
8	3.1282E-01	1.7492E-04	0	1.3715E-05	3.8149E-01	0
9	1.9322E-01	1.2560E-07	0	0	2.4454E-01	0
10	1.3264E-01	6.5572E-10	0	0	1.7101E-01	0
11	7.8693E-02	0	0	0	1.2494E-01	0
12	5.6558E-02	0	0	0	9.6566E-02	0
13	5.1201E-02	0	0	0	8.8545E-02	0
14	4.4937E-02	0	0	0	7.9112E-02	0
15	2.9322E-02	0	0	0	5.0612E-02	0
16	8.8809E-03	0	0	0	2.7833E-02	0
17	2.9013E-03	0	0	0	1.4619E-02	0
18	7.3438E-04	0	0	0	5.6316E-03	0
19	8.6749E-05	0	0	0	1.2936E-03	0
20	6.5240E-06	0	0	0	8.9192E-04	0
21	2.6735E-07	0	0	0	5.2509E-04	0
22	0	0	0	0	1.7505E-04	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	0	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0

Table 3.15 cont'd

Grp	Ni-60 (n,p)	Cu-63 (n,α)	Cu-65 (n,2n)	In-115 (n,n')	I-127 (n,2n)	Sc-45 (n,γ)
1	1.2079E-01	3.5414E-02	9.9088E-01	6.0775E-02	1.4904E+00	1.8647E-04
2	1.4392E-01	4.3376E-02	7.1928E-01	9.4242E-02	1.3091E+00	2.7480E-04
3	1.1530E-01	3.6377E-02	1.3852E-01	2.0363E-01	6.8610E-01	3.6019E-04
4	8.7169E-02	2.6793E-02	0	2.7085E-01	3.7525E-02	4.2423E-04
5	6.4115E-02	1.8050E-02	0	2.9518E-01	0	4.7437E-04
6	3.6653E-02	9.8682E-03	0	3.2385E-01	0	5.2590E-04
7	1.5024E-02	3.2531E-03	0	3.3120E-01	0	5.7136E-04
8	2.1857E-03	5.7499E-04	0	3.1565E-01	0	7.6261E-04
9	2.6605E-05	4.4528E-05	0	3.3133E-01	0	1.1118E-03
10	7.5317E-08	8.1371E-06	0	3.3553E-01	0	1.3425E-03
11	4.2871E-08	2.9891E-06	0	3.3299E-01	0	1.5084E-03
12	2.7871E-08	9.3951E-07	0	3.2342E-01	0	1.6305E-03
13	2.3077E-08	8.1765E-07	0	3.1936E-01	0	1.6702E-03
14	1.7439E-08	6.7433E-07	0	3.1200E-01	0	1.7179E-03
15	2.8724E-09	2.4661E-07	0	2.7317E-01	0	2.0534E-03
16	0	1.3777E-08	0	2.0943E-01	0	2.6590E-03
17	0	0	0	1.6695E-01	0	3.2249E-03
18	0	0	0	9.1255E-02	0	4.7217E-03
19	0	0	0	4.8357E-02	0	5.5782E-03
20	0	0	0	2.5038E-02	0	6.0335E-03
21	0	0	0	1.2610E-02	0	6.7752E-03
22	0	0	0	3.8445E-03	0	7.7021E-03
23	0	0	0	1.7160E-03	0	9.1569E-03
24	0	0	0	9.8680E-05	0	1.1074E-02
25	0	0	0	0	0	1.6641E-02
26	0	0	0	0	0	2.4224E-02
27	0	0	0	0	0	4.0092E-02
28	0	0	0	0	0	4.4335E-02
29	0	0	0	0	0	6.1241E-02
30	0	0	0	0	0	6.6394E-02
31	0	0	0	0	0	2.6464E-02
32	0	0	0	0	0	5.1904E-02
33	0	0	0	0	0	1.1192E-01
34	0	0	0	0	0	1.6540E-01
35	0	0	0	0	0	2.2394E-01
36	0	0	0	0	0	1.9068E-01
37	0	0	0	0	0	7.9567E-02
38	0	0	0	0	0	1.1496E-01
39	0	0	0	0	0	2.3184E-01
40	0	0	0	0	0	4.5753E-01
41	0	0	0	0	0	9.1400E-01
42	0	0	0	0	0	1.5591E+00
43	0	0	0	0	0	2.4415E+00
44	0	0	0	0	0	3.7992E+00
45	0	0	0	0	0	5.5780E+00
46	0	0	0	0	0	9.7899E+00
47	0	0	0	0	0	1.8905E+01

Table 3.15 cont'd

Grp	Na-24 (n,γ)	Fe-58 (n,γ)	Co-59 (n,γ)	Cu-63 (n,γ)	In-115 (n,γ)	Au-197 (n,γ)
1	2.2780E-04	8.8452E-04	7.6760E-04	2.5967E-03	1.1764E-03	8.4765E-04
2	1.9769E-04	7.2902E-04	8.3882E-04	2.8383E-03	1.1811E-03	1.6664E-03
3	1.7883E-04	6.4592E-04	6.6332E-04	3.0989E-03	1.3019E-03	1.6206E-03
4	1.7381E-04	6.3253E-04	6.3928E-04	3.3571E-03	1.8651E-03	1.1514E-03
5	1.6998E-04	6.4590E-04	7.2544E-04	3.6240E-03	2.9262E-03	9.2362E-04
6	1.6664E-04	6.7785E-04	9.3983E-04	3.9654E-03	5.4862E-03	3.2508E-03
7	1.6332E-04	7.2857E-04	1.1809E-03	4.2730E-03	1.1955E-02	6.1630E-03
8	1.6076E-04	8.3222E-04	1.5558E-03	4.8199E-03	2.6466E-02	1.0797E-02
9	1.6825E-04	1.0191E-03	2.0650E-03	5.4150E-03	5.3519E-02	2.0036E-02
10	1.7466E-04	1.2847E-03	2.3459E-03	5.7234E-03	7.7247E-02	2.7127E-02
11	1.7922E-04	1.6653E-03	2.5345E-03	5.9647E-03	9.7497E-02	3.1767E-02
12	1.8263E-04	1.9246E-03	2.6952E-03	6.1279E-03	1.1511E-01	3.5724E-02
13	1.8379E-04	2.0081E-03	2.7590E-03	6.1801E-03	1.2038E-01	3.7626E-02
14	1.8522E-04	2.1063E-03	2.8340E-03	6.2415E-03	1.2630E-01	4.0115E-02
15	1.9006E-04	2.3992E-03	3.0759E-03	6.4755E-03	1.4773E-01	4.9445E-02
16	1.9798E-04	2.5605E-03	3.5721E-03	7.6256E-03	1.7765E-01	6.0544E-02
17	2.0709E-04	2.6107E-03	4.3255E-03	9.1770E-03	2.0701E-01	6.7959E-02
18	2.2118E-04	2.6701E-03	6.0633E-03	1.2004E-02	2.2871E-01	7.5400E-02
19	2.4052E-04	2.7774E-03	6.4531E-03	1.3735E-02	2.2834E-01	8.4188E-02
20	2.8979E-04	2.8829E-03	6.5386E-03	1.3879E-02	2.1778E-01	9.0905E-02
21	3.4349E-04	2.9793E-03	6.7456E-03	1.3956E-02	2.0376E-01	9.9826E-02
22	3.1500E-04	3.0714E-03	7.1082E-03	1.4452E-02	1.9304E-01	1.2011E-01
23	4.7207E-04	2.5704E-03	7.8925E-03	1.6482E-02	1.8416E-01	1.5276E-01
24	6.7499E-04	3.7513E-03	8.9361E-03	1.9068E-02	1.9240E-01	1.8594E-01
25	9.6344E-04	3.9281E-03	1.0985E-02	2.3634E-02	2.3081E-01	2.3639E-01
26	8.8136E-04	8.3676E-03	1.5588E-02	2.8126E-02	3.1209E-01	2.7570E-01
27	2.1005E-05	1.1688E-02	1.6484E-02	3.1992E-02	4.2859E-01	3.3597E-01
28	1.2692E-03	1.6521E-02	1.8361E-02	3.9214E-02	5.5954E-01	4.2258E-01
29	5.0278E-03	1.4026E-02	2.6823E-02	5.9238E-02	6.8791E-01	5.3125E-01
30	2.1495E-05	2.3575E-02	1.9079E-02	6.6841E-02	7.8493E-01	6.0518E-01
31	2.1730E-05	3.8909E-03	7.3953E-02	8.8066E-02	8.2005E-01	6.2974E-01
32	2.2830E-05	2.3009E-03	2.4979E-02	9.9647E-02	8.4224E-01	6.5276E-01
33	3.2405E-05	1.5402E-02	4.2320E-02	1.1701E-01	8.9657E-01	7.6081E-01
34	3.4576E-04	6.4938E-02	6.9534E-02	1.6607E-01	1.0617E+00	1.1359E+00
35	5.4134E-03	3.0468E-02	2.2509E-01	2.7849E-01	1.3207E+00	1.9042E+00
36	8.9861E-02	6.1198E-03	7.1167E-02	5.0290E-01	1.6739E+00	3.3284E+00
37	6.7412E-03	7.0740E-03	4.6695E-02	1.6247E+00	2.5923E+00	1.0047E+01
38	6.1315E-03	9.5115E-01	3.0590E-01	2.5636E-02	6.8658E+00	1.5778E+01
39	7.7703E-03	1.6447E-02	7.5687E+01	3.4651E-02	6.6567E+00	1.1854E+01
40	1.1334E-02	2.3906E-02	2.9283E+00	6.9568E-02	9.4425E+00	3.7457E+01
41	1.9345E-02	4.1751E-02	1.7686E+00	1.4532E-01	8.7672E+00	8.5093E-01
42	3.1273E-02	6.8186E-02	2.3957E+00	2.5305E-01	6.0661E+01	2.4411E+02
43	4.8144E-02	1.0511E-01	3.5060E+00	3.9940E-01	8.5999E+01	1.4055E+03
44	7.4226E-02	1.6228E-01	5.3008E+00	6.2361E-01	4.3378E+03	2.4922E+01
45	1.0859E-01	2.3742E-01	7.7021E+00	9.1676E-01	1.3022E+02	2.5758E+01
46	1.9031E-01	4.1544E-01	1.3434E+01	1.6102E+00	9.9532E+01	3.8143E+01
47	3.6731E-01	8.0050E-01	2.5886E+01	3.1103E+00	1.5289E+02	6.9515E+01

Table 3.15 cont'd

Grp	Th-232 (n,γ)	U-238 (n,γ)	Sqr-root E-mid	N flux Total	U-234 (n,f)	U-236 (n,f)
1	1.4790E-03	6.4392E-04	3.9701E+00	1.0000E+00	2.1243E+00	1.7614E+00
2	1.6238E-03	1.4941E-03	3.6335E+00	1.0000E+00	1.9976E+00	1.5447E+00
3	1.8947E-03	1.4748E-03	3.3327E+00	1.0000E+00	1.9862E+00	1.4851E+00
4	2.7070E-03	1.0507E-03	3.0502E+00	1.0000E+00	2.1284E+00	1.5634E+00
5	4.0695E-03	1.3898E-03	2.8298E+00	1.0000E+00	2.1207E+00	1.5136E+00
6	6.6778E-03	2.5462E-03	2.5955E+00	1.0000E+00	1.7112E+00	1.2401E+00
7	1.0620E-02	4.7626E-03	2.3485E+00	1.0000E+00	1.3284E+00	8.8201E-01
8	1.6806E-02	8.9747E-03	2.0790E+00	1.0000E+00	1.4104E+00	8.6300E-01
9	2.6300E-02	1.5954E-02	1.8290E+00	1.0000E+00	1.5008E+00	8.8032E-01
10	3.3291E-02	2.1468E-02	1.6937E+00	1.0000E+00	1.5196E+00	8.6631E-01
11	3.9771E-02	2.6326E-02	1.6111E+00	1.0000E+00	1.5359E+00	8.8603E-01
12	4.5810E-02	3.0776E-02	1.5542E+00	1.0000E+00	1.5159E+00	8.7592E-01
13	4.8360E-02	3.2635E-02	1.5348E+00	1.0000E+00	1.5188E+00	8.7113E-01
14	5.1360E-02	3.4822E-02	1.5128E+00	1.0000E+00	1.5307E+00	8.6609E-01
15	6.1088E-02	4.3022E-02	1.4408E+00	1.0000E+00	1.5483E+00	8.1232E-01
16	8.1592E-02	5.6798E-02	1.3367E+00	1.0000E+00	1.5500E+00	7.5144E-01
17	9.9072E-02	7.1608E-02	1.2261E+00	1.0000E+00	1.3821E+00	6.9390E-01
18	1.2076E-01	1.0482E-01	1.0854E+00	1.0000E+00	1.2288E+00	5.5251E-01
19	1.4687E-01	1.2345E-01	9.5484E-01	1.0000E+00	1.2342E+00	2.7293E-01
20	1.6077E-01	1.2000E-01	8.8419E-01	1.0000E+00	1.2716E+00	1.2292E-01
21	1.6477E-01	1.1633E-01	8.2184E-01	1.0000E+00	1.0033E+00	4.2210E-02
22	1.5822E-01	1.1025E-01	7.4363E-01	1.0000E+00	7.2377E-01	1.3613E-02
23	1.4499E-01	1.1117E-01	6.5829E-01	1.0000E+00	3.9427E-01	4.8559E-03
24	1.4407E-01	1.1408E-01	5.7708E-01	1.0000E+00	1.7573E-01	2.6372E-03
25	1.5540E-01	1.2078E-01	4.9009E-01	1.0000E+00	9.3501E-02	2.4193E-03
26	1.9138E-01	1.4611E-01	3.8357E-01	1.0000E+00	4.6117E-02	2.2765E-03
27	2.5519E-01	2.0335E-01	2.9872E-01	1.0000E+00	2.2565E-02	4.8303E-03
28	3.6677E-01	3.0785E-01	2.3265E-01	1.0000E+00	1.7139E-02	6.3810E-03
29	4.2970E-01	4.0514E-01	1.9065E-01	1.0000E+00	1.8523E-02	7.6946E-03
30	4.6875E-01	4.5814E-01	1.7013E-01	1.0000E+00	1.4103E-02	8.7761E-03
31	4.9106E-01	4.8049E-01	1.5848E-01	1.0000E+00	1.2794E-02	9.2142E-03
32	5.1104E-01	4.9979E-01	1.5174E-01	1.0000E+00	1.3062E-02	9.6188E-03
33	5.6682E-01	5.5439E-01	1.3585E-01	1.0000E+00	1.4161E-02	1.0669E-02
34	7.0555E-01	6.5620E-01	1.0520E-01	1.0000E+00	1.6210E-02	1.3323E-02
35	1.0024E+00	9.1636E-01	7.2306E-02	1.0000E+00	1.1799E-02	1.8628E-02
36	1.8266E+00	1.4946E+00	4.9695E-02	1.0000E+00	6.8199E-03	2.7069E-02
37	3.1005E+00	2.7798E+00	3.1927E-02	1.0000E+00	1.1589E-01	6.0000E-02
38	8.9247E+00	4.8413E+00	1.8282E-02	1.0000E+00	2.8272E-02	1.0106E-01
39	1.4875E+01	1.9972E+01	1.2565E-02	1.0000E+00	7.1025E-02	1.7177E-01
40	1.6910E+01	1.3292E+01	8.3236E-03	1.0000E+00	1.0092E-02	7.0006E-01
41	3.4172E+01	8.8834E+01	4.8961E-03	1.0000E+00	5.0782E-03	5.0277E-02
42	2.7011E-01	1.7288E+02	2.8036E-03	1.0000E+00	2.9539E-01	4.1479E+00
43	4.4074E-01	6.9953E-01	1.8573E-03	1.0000E+00	2.7662E-02	5.0252E-02
44	8.2018E-01	4.8826E-01	1.1687E-03	1.0000E+00	2.6115E-02	1.0558E-02
45	1.3462E+00	6.1803E-01	8.0325E-04	1.0000E+00	5.8819E-02	1.1691E-02
46	2.5617E+00	1.0088E+00	5.0695E-04	1.0000E+00	1.4247E-01	1.7926E-02
47	5.1114E+00	1.9007E+00	2.2362E-04	1.0000E+00	3.1384E-01	3.3079E-02

Table 3.15 cont'd

Grp	Pu-240 (n,f)	Pu-241 (n,f)	Pu-242 (n,f)	Rh-103 (n,n')	Silicon dspl kerma	U-238 χ
1	2.2869E+00	2.0882E+00	2.0216E+00	0	1.7146E+05	2.5568E-05
2	2.1259E+00	2.1069E+00	1.8931E+00	0	1.6748E+05	1.3895E-04
3	2.1703E+00	1.9866E+00	1.8684E+00	0	1.6183E+05	9.2397E-04
4	2.2169E+00	1.9734E+00	1.9047E+00	0	1.6216E+05	2.3012E-03
5	2.2078E+00	1.9228E+00	1.9415E+00	0	1.6794E+05	5.3971E-03
6	1.9140E+00	1.6484E+00	1.6679E+00	0	1.4848E+05	1.5970E-02
7	1.5338E+00	1.3506E+00	1.2709E+00	4.5084E-03	1.4741E+05	3.1340E-02
8	1.5648E+00	1.3604E+00	1.2491E+00	1.7834E-02	1.3828E+05	8.3571E-02
9	1.6655E+00	1.4723E+00	1.3270E+00	4.8251E-02	1.1529E+05	7.8777E-02
10	1.6998E+00	1.5344E+00	1.3710E+00	7.0618E-02	1.1518E+05	4.4513E-02
11	1.6943E+00	1.5636E+00	1.3958E+00	8.9124E-02	1.2594E+05	4.6779E-02
12	1.6997E+00	1.6012E+00	1.4099E+00	1.0270E-01	1.0218E+05	1.9959E-02
13	1.7089E+00	1.6171E+00	1.4137E+00	1.0726E-01	1.0711E+05	4.0056E-03
14	1.7225E+00	1.6342E+00	1.4178E+00	1.1281E-01	1.0266E+05	2.4181E-02
15	1.7421E+00	1.6704E+00	1.4275E+00	1.3098E-01	1.1001E+05	7.2808E-02
16	1.6745E+00	1.7151E+00	1.4242E+00	1.5320E-01	1.0670E+05	7.1180E-02
17	1.5901E+00	1.7171E+00	1.3988E+00	1.7466E-01	1.1399E+05	8.8822E-02
18	1.5513E+00	1.6031E+00	1.4801E+00	1.8903E-01	7.6490E+04	1.1438E-01
19	1.4045E+00	1.5429E+00	1.2134E+00	2.0017E-01	9.8719E+04	6.2108E-02
20	1.1361E+00	1.5250E+00	8.4401E-01	2.0251E-01	1.0147E+05	2.6880E-02
21	8.8037E-01	1.4886E+00	5.5391E-01	1.8025E-01	5.6072E+04	4.6032E-02
22	5.9801E-01	1.5008E+00	3.3375E-01	1.6167E-01	7.7138E+04	3.6806E-02
23	2.6574E-01	1.5553E+00	1.4970E-01	1.3651E-01	5.2612E+04	4.1012E-02
24	1.5384E-01	1.6609E+00	8.5572E-02	1.1515E-01	4.9920E+04	2.1221E-02
25	1.0712E-01	1.8218E+00	4.7447E-02	7.8643E-02	7.1116E+04	3.0246E-02
26	7.3759E-02	2.0001E+00	2.0957E-02	3.5324E-02	2.0548E+04	1.5802E-02
27	8.1279E-02	2.1845E+00	1.4084E-02	1.0335E-02	6.0896E+03	7.7209E-03
28	9.2942E-02	2.3323E+00	1.2421E-02	2.0034E-03	8.1329E+03	3.7220E-03
29	9.7818E-02	2.5033E+00	1.1891E-02	3.9986E-07	3.1274E+03	1.0529E-03
30	9.7431E-02	2.7278E+00	1.1636E-02	0	2.4776E+03	6.0240E-04
31	9.7050E-02	2.8118E+00	1.1553E-02	0	2.2856E+03	1.8351E-04
32	9.6448E-02	2.9058E+00	1.1492E-02	0	2.1536E+03	2.1506E-04
33	9.4444E-02	3.1289E+00	1.1356E-02	0	1.8185E+03	5.7311E-04
34	8.6061E-02	3.6112E+00	1.3728E-02	0	1.1711E+03	5.1466E-04
35	7.8052E-02	5.2537E+00	1.7349E-02	0	5.6494E+02	1.6766E-04
36	2.2479E-01	7.4550E+00	1.2987E-02	0	2.7317E+02	5.4512E-05
37	2.3603E-01	1.1347E+01	3.9105E-02	0	1.1140E+02	2.2199E-05
38	4.5207E-02	2.4495E+01	2.2766E-02	0	3.8626E+01	2.7146E-06
39	4.4463E-02	2.4942E+01	6.3503E-02	0	5.8015E+00	8.8031E-07
40	6.7299E-02	3.9029E+01	5.6856E-02	0	2.0193E+00	3.2884E-07
41	1.5526E-01	1.0578E+02	7.7708E-05	0	3.5524E+00	7.9696E-08
42	7.2570E-04	2.4131E+02	7.3019E-05	0	5.7866E+00	9.5563E-09
43	3.0673E-03	1.0551E+02	1.0133E-04	0	8.9381E+00	2.6717E-09
44	1.9322E+00	2.7918E+01	1.5029E-04	0	1.3818E+01	2.1631E-11
45	8.9031E-02	4.9580E+01	2.1711E-04	0	2.0267E+01	0
46	3.3213E-02	8.6876E+02	3.7721E-04	0	3.5567E+01	0
47	4.7023E-02	7.4286E+02	7.2617E-04	0	6.8352E+01	0

Table 3.15 cont'd

Grp	Pu-239 χ	N flux > 1.0 MeV	N flux > 0.1 MeV	N flux < 0.414 eV	Midpoint energy	Energy width
1	5.6208E-05	1.0000E+00	1.0000E+00	0	1.5762E+01	3.1410E+00
2	2.2677E-04	1.0000E+00	1.0000E+00	0	1.3203E+01	1.9770E+00
3	1.2921E-03	1.0000E+00	1.0000E+00	0	1.1107E+01	2.2140E+00
4	2.9394E-03	1.0000E+00	1.0000E+00	0	9.3035E+00	1.3929E+00
5	6.4700E-03	1.0000E+00	1.0000E+00	0	8.0077E+00	1.1989E+00
6	1.8109E-02	1.0000E+00	1.0000E+00	0	6.7368E+00	1.3429E+00
7	3.4016E-02	1.0000E+00	1.0000E+00	0	5.5156E+00	1.0994E+00
8	8.7792E-02	1.0000E+00	1.0000E+00	0	4.3224E+00	1.2871E+00
9	8.1231E-02	1.0000E+00	1.0000E+00	0	3.3454E+00	6.6690E-01
10	4.5561E-02	1.0000E+00	1.0000E+00	0	2.8686E+00	2.8660E-01
11	4.7656E-02	1.0000E+00	1.0000E+00	0	2.5956E+00	2.5930E-01
12	2.0272E-02	1.0000E+00	1.0000E+00	0	2.4156E+00	1.0070E-01
13	4.0474E-03	1.0000E+00	1.0000E+00	0	2.3555E+00	1.9600E-02
14	2.4523E-02	1.0000E+00	1.0000E+00	0	2.2885E+00	1.1440E-01
15	7.3440E-02	1.0000E+00	1.0000E+00	0	2.0759E+00	3.1080E-01
16	7.1233E-02	1.0000E+00	1.0000E+00	0	1.7867E+00	2.6750E-01
17	8.8012E-02	1.0000E+00	1.0000E+00	0	1.5032E+00	2.9960E-01
18	1.1158E-01	1.0000E+00	1.0000E+00	0	1.1780E+00	3.5080E-01
19	5.9861E-02	1.3000E-02	1.0000E+00	0	9.1172E-01	1.8175E-01
20	2.5776E-02	0	1.0000E+00	0	7.8180E-01	7.8110E-02
21	4.3929E-02	0	1.0000E+00	0	6.7542E-01	1.3464E-01
22	3.4950E-02	0	1.0000E+00	0	5.5299E-01	1.1023E-01
23	3.8841E-02	0	1.0000E+00	0	4.3335E-01	1.2904E-01
24	2.0200E-02	0	1.0000E+00	0	3.3302E-01	7.1620E-02
25	2.8665E-02	0	1.0000E+00	0	2.4018E-01	1.1405E-01
26	1.5048E-02	0	1.0000E+00	0	1.4713E-01	7.2070E-02
27	7.4971E-03	0	2.1034E-01	0	8.9235E-02	4.3711E-02
28	3.5511E-03	0	0	0	5.4123E-02	2.6511E-02
29	9.9694E-04	0	0	0	3.6348E-02	9.0400E-03
30	5.6378E-04	0	0	0	2.8943E-02	5.7700E-03
31	1.7409E-04	0	0	0	2.5117E-02	1.8820E-03
32	2.1284E-04	0	0	0	2.3025E-02	2.3010E-03
33	5.3012E-04	0	0	0	1.8454E-02	6.8410E-03
34	5.1937E-04	0	0	0	1.1068E-02	7.9323E-03
35	1.5779E-04	0	0	0	5.2282E-03	3.7471E-03
36	5.3309E-05	0	0	0	2.4696E-03	1.7700E-03
37	2.1981E-05	0	0	0	1.0193E-03	1.1306E-03
38	2.6501E-06	0	0	0	3.3423E-04	2.3955E-04
39	8.6276E-07	0	0	0	1.5787E-04	1.1315E-04
40	3.1417E-07	0	0	0	6.9283E-05	6.4034E-05
41	6.1447E-08	0	0	0	2.3971E-05	2.6589E-05
42	2.1765E-11	0	0	0	7.8602E-06	5.6335E-06
43	8.2907E-12	0	0	0	3.4495E-06	3.1881E-06
44	6.8575E-13	0	0	0	1.3659E-06	9.7897E-07
45	0	0	0	0	6.4521E-07	4.6244E-07
46	0	0	0	1.0000E+00	2.5700E-07	3.1399E-07
47	0	0	0	1.0000E+00	5.0005E-08	9.9990E-08

Table 3.15 cont'd

Grp	Lethargy width	Pu-238 (n,f)	U-234 ν	U-235 ν	U-236 ν	U-238 ν
1	1.9995E-01	2.6617E+00	4.4121E+00	4.5834E+00	4.3161E+00	4.6415E+00
2	1.5002E-01	2.6810E+00	4.1089E+00	4.2507E+00	4.0219E+00	4.3056E+00
3	2.0000E-01	2.7096E+00	3.8156E+00	3.9511E+00	3.7373E+00	3.9754E+00
4	1.5000E-01	2.7066E+00	3.5959E+00	3.7255E+00	3.5240E+00	3.7281E+00
5	1.5000E-01	2.6675E+00	3.4239E+00	3.5422E+00	3.3572E+00	3.5379E+00
6	2.0000E-01	2.4947E+00	3.2473E+00	3.3385E+00	3.1858E+00	3.3438E+00
7	1.9999E-01	2.2194E+00	3.0914E+00	3.1278E+00	3.0346E+00	3.1718E+00
8	3.0001E-01	2.2436E+00	2.9324E+00	2.9376E+00	2.8803E+00	2.9647E+00
9	2.0002E-01	2.2816E+00	2.7986E+00	2.8040E+00	2.7504E+00	2.7767E+00
10	9.9993E-02	2.2468E+00	2.7385E+00	2.7505E+00	2.6920E+00	2.6985E+00
11	9.9981E-02	2.2258E+00	2.7023E+00	2.7178E+00	2.6569E+00	2.6770E+00
12	4.1693E-02	2.2117E+00	2.6778E+00	2.6961E+00	2.6332E+00	2.6641E+00
13	8.3210E-03	2.2071E+00	2.6700E+00	2.6892E+00	2.6256E+00	2.6600E+00
14	4.9999E-02	2.2018E+00	2.6608E+00	2.6812E+00	2.6166E+00	2.6551E+00
15	1.5000E-01	2.1852E+00	2.6321E+00	2.6559E+00	2.5888E+00	2.6400E+00
16	1.4999E-01	2.1603E+00	2.5916E+00	2.6199E+00	2.5495E+00	2.6186E+00
17	1.9997E-01	2.1230E+00	2.5540E+00	2.5871E+00	2.5130E+00	2.5989E+00
18	3.0002E-01	2.0752E+00	2.5095E+00	2.5496E+00	2.4699E+00	2.5755E+00
19	2.0001E-01	2.0057E+00	2.4745E+00	2.5216E+00	2.4360E+00	2.5568E+00
20	9.9994E-02	1.9112E+00	2.4574E+00	2.5078E+00	2.4194E+00	2.5478E+00
21	2.0001E-01	1.7346E+00	2.4419E+00	2.4962E+00	2.4043E+00	2.5396E+00
22	2.0000E-01	1.5358E+00	2.4270E+00	2.4859E+00	2.3898E+00	2.5317E+00
23	3.0000E-01	1.2256E+00	2.4100E+00	2.4739E+00	2.3733E+00	2.5227E+00
24	2.1590E-01	1.0257E+00	2.3968E+00	2.4643E+00	2.3604E+00	2.5157E+00
25	4.8408E-01	8.5052E-01	2.3843E+00	2.4552E+00	2.3483E+00	2.5091E+00
26	5.0002E-01	7.1674E-01	2.3718E+00	2.4429E+00	2.3362E+00	2.5025E+00
27	5.0001E-01	6.1173E-01	2.3635E+00	2.4290E+00	2.3281E+00	2.4981E+00
28	4.9999E-01	6.2584E-01	2.3593E+00	2.4233E+00	2.3240E+00	2.4959E+00
29	2.5000E-01	6.7409E-01	2.3569E+00	2.4236E+00	2.3218E+00	2.4946E+00
30	2.0002E-01	7.0514E-01	2.3558E+00	2.4258E+00	2.3206E+00	2.4941E+00
31	7.4964E-02	7.2035E-01	2.3554E+00	2.4267E+00	2.3203E+00	2.4939E+00
32	1.0002E-01	7.3186E-01	2.3551E+00	2.4275E+00	2.3200E+00	2.4937E+00
33	3.7503E-01	6.6131E-01	2.3545E+00	2.4291E+00	2.3194E+00	2.4934E+00
34	7.4998E-01	8.0131E-01	2.3535E+00	2.4327E+00	2.3185E+00	2.4929E+00
35	7.5000E-01	1.4456E+00	2.3527E+00	2.4338E+00	2.3177E+00	2.4924E+00
36	7.5000E-01	1.6742E+00	2.3523E+00	2.4338E+00	2.3173E+00	2.4923E+00
37	1.2500E+00	2.4197E+00	2.3521E+00	2.4338E+00	2.3171E+00	2.4921E+00
38	7.5002E-01	3.4140E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
39	7.4999E-01	6.4419E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
40	1.0000E+00	1.3774E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
41	1.2500E+00	1.2830E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
42	7.4999E-01	2.2068E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
43	1.0000E+00	1.1979E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
44	7.5000E-01	2.1490E-01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
45	7.5002E-01	7.1934E-01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
46	1.4207E+00	3.2742E+00	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00
47	9.2103E+00	1.0439E+01	2.3520E+00	2.4338E+00	2.3170E+00	2.4921E+00

Table 3.15 cont'd

Grp	Pu-238 ν	Pu-239 ν	Pu-240 ν	Pu-241 ν	Pu-242 ν	U-234 χ
1	5.1526E+00	5.1106E+00	5.1200E+00	5.2385E+00	5.2142E+00	1.5159E-04
2	4.8200E+00	4.8080E+00	4.7787E+00	4.8917E+00	4.8601E+00	4.6489E-04
3	4.4983E+00	4.5098E+00	4.4485E+00	4.5561E+00	4.5175E+00	2.0914E-03
4	4.2571E+00	4.2733E+00	4.2010E+00	4.3044E+00	4.2606E+00	4.0422E-03
5	4.0683E+00	4.0731E+00	4.0073E+00	4.1075E+00	4.0596E+00	7.9523E-03
6	3.8745E+00	3.8693E+00	3.8087E+00	3.9063E+00	3.8535E+00	2.0119E-02
7	3.7047E+00	3.6822E+00	3.6343E+00	3.7309E+00	3.6724E+00	3.4986E-02
8	3.5311E+00	3.4989E+00	3.4562E+00	3.5517E+00	3.4874E+00	8.4943E-02
9	3.3847E+00	3.3552E+00	3.3058E+00	3.3964E+00	3.3313E+00	7.6300E-02
10	3.3187E+00	3.2973E+00	3.2382E+00	3.3256E+00	3.2612E+00	4.2488E-02
11	3.2790E+00	3.2576E+00	3.1974E+00	3.2830E+00	3.2189E+00	4.4430E-02
12	3.2522E+00	3.2316E+00	3.1698E+00	3.2541E+00	3.1903E+00	1.8922E-02
13	3.2436E+00	3.2238E+00	3.1610E+00	3.2449E+00	3.1812E+00	3.7965E-03
14	3.2335E+00	3.2149E+00	3.1506E+00	3.2340E+00	3.1705E+00	2.2916E-02
15	3.2021E+00	3.1866E+00	3.1184E+00	3.2002E+00	3.1370E+00	6.9064E-02
16	3.1577E+00	3.1425E+00	3.0728E+00	3.1525E+00	3.0897E+00	6.7814E-02
17	3.1164E+00	3.0963E+00	3.0304E+00	3.1082E+00	3.0458E+00	8.5334E-02
18	3.0676E+00	3.0423E+00	2.9803E+00	3.0557E+00	2.9938E+00	1.1157E-01
19	3.0293E+00	3.0043E+00	2.9409E+00	3.0145E+00	2.9530E+00	6.1607E-02
20	3.0106E+00	2.9866E+00	2.9217E+00	2.9944E+00	2.9331E+00	2.6932E-02
21	2.9935E+00	2.9703E+00	2.9042E+00	2.9760E+00	2.9149E+00	4.6550E-02
22	2.9772E+00	2.9549E+00	2.8874E+00	2.9585E+00	2.8975E+00	3.7658E-02
23	2.9585E+00	2.9395E+00	2.8683E+00	2.9457E+00	2.8777E+00	4.2494E-02
24	2.9440E+00	2.9288E+00	2.8534E+00	2.9453E+00	2.8623E+00	2.2243E-02
25	2.9304E+00	2.9191E+00	2.8393E+00	2.9453E+00	2.8477E+00	3.2067E-02
26	2.9167E+00	2.9088E+00	2.8253E+00	2.9453E+00	2.8331E+00	1.6963E-02
27	2.9076E+00	2.9024E+00	2.8159E+00	2.9453E+00	2.8234E+00	8.3563E-03
28	2.9030E+00	2.8992E+00	2.8112E+00	2.9453E+00	2.8185E+00	4.0490E-03
29	2.9004E+00	2.8976E+00	2.8085E+00	2.9453E+00	2.8157E+00	1.1485E-03
30	2.8991E+00	2.8968E+00	2.8072E+00	2.9453E+00	2.8144E+00	6.5783E-04
31	2.8987E+00	2.8965E+00	2.8068E+00	2.9453E+00	2.8140E+00	2.0051E-04
32	2.8984E+00	2.8963E+00	2.8065E+00	2.9453E+00	2.8136E+00	2.3506E-04
33	2.8977E+00	2.8958E+00	2.8058E+00	2.9453E+00	2.8129E+00	6.2681E-04
34	2.8967E+00	2.8952E+00	2.8047E+00	2.9453E+00	2.8118E+00	5.6349E-04
35	2.8957E+00	2.8948E+00	2.8038E+00	2.9453E+00	2.8108E+00	1.8373E-04
36	2.8953E+00	2.8945E+00	2.8034E+00	2.9453E+00	2.8104E+00	5.9785E-05
37	2.8951E+00	2.8886E+00	2.8031E+00	2.9453E+00	2.8101E+00	2.4392E-05
38	2.8950E+00	2.8631E+00	2.8030E+00	2.9453E+00	2.8100E+00	3.0037E-06
39	2.8950E+00	2.8702E+00	2.8030E+00	2.9453E+00	2.8100E+00	9.8697E-07
40	2.8950E+00	2.8630E+00	2.8030E+00	2.9453E+00	2.8100E+00	3.8048E-07
41	2.8950E+00	2.8615E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.0297E-07
42	2.8950E+00	2.8644E+00	2.8030E+00	2.9453E+00	2.8100E+00	9.1138E-09
43	2.8950E+00	2.8772E+00	2.8030E+00	2.9453E+00	2.8100E+00	5.0382E-09
44	2.8950E+00	2.8783E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.5297E-09
45	2.8950E+00	2.8692E+00	2.8030E+00	2.9453E+00	2.8100E+00	7.9147E-10
46	2.8950E+00	2.8630E+00	2.8030E+00	2.9453E+00	2.8100E+00	4.3746E-10
47	2.8950E+00	2.8758E+00	2.8030E+00	2.9453E+00	2.8100E+00	1.8584E-10

Table 3.15 cont'd

Grp	U-236 χ	Pu-238 χ	Pu-240 χ	Pu-241 χ	Pu-242 χ
1	1.0898E-04	8.0233E-05	1.0673E-04	9.9677E-05	1.1131E-04
2	3.5098E-04	2.8002E-04	3.5394E-04	3.3529E-04	3.6640E-04
3	1.6611E-03	1.4154E-03	1.7054E-03	1.6360E-03	1.7532E-03
4	3.3451E-03	2.9768E-03	3.4603E-03	3.3494E-03	3.5386E-03
5	6.7995E-03	6.2305E-03	7.0470E-03	6.8657E-03	7.1773E-03
6	1.7797E-02	1.6736E-02	1.8416E-02	1.8057E-02	1.8681E-02
7	3.1944E-02	3.0672E-02	3.2916E-02	3.2452E-02	3.3263E-02
8	8.0131E-02	7.8339E-02	8.1967E-02	8.1247E-02	8.2519E-02
9	7.3775E-02	7.2970E-02	7.4920E-02	7.4551E-02	7.5211E-02
10	4.1592E-02	4.1353E-02	4.2059E-02	4.1931E-02	4.2163E-02
11	4.3812E-02	4.3685E-02	4.4185E-02	4.4099E-02	4.4256E-02
12	1.8748E-02	1.8727E-02	1.8873E-02	1.8850E-02	1.8893E-02
13	3.7676E-03	3.7654E-03	3.7902E-03	3.7865E-03	3.7936E-03
14	2.2782E-02	2.2785E-02	2.2903E-02	2.2886E-02	2.2918E-02
15	6.9061E-02	6.9211E-02	6.9262E-02	6.9270E-02	6.9262E-02
16	6.8334E-02	6.8659E-02	6.8309E-02	6.8393E-02	6.8248E-02
17	8.6641E-02	8.7260E-02	8.6317E-02	8.6519E-02	8.6166E-02
18	1.1426E-01	1.1537E-01	1.1337E-01	1.1378E-01	1.1306E-01
19	6.3535E-02	6.4276E-02	6.2828E-02	6.3116E-02	6.2606E-02
20	2.7870E-02	2.8221E-02	2.7513E-02	2.7653E-02	2.7405E-02
21	4.8306E-02	4.8948E-02	4.7619E-02	4.7880E-02	4.7416E-02
22	3.9204E-02	3.9757E-02	3.8583E-02	3.8811E-02	3.8404E-02
23	4.4378E-02	4.5037E-02	4.3602E-02	4.3879E-02	4.3384E-02
24	2.3290E-02	2.3651E-02	2.2851E-02	2.3005E-02	2.2730E-02
25	3.3658E-02	3.4196E-02	3.2980E-02	3.3213E-02	3.2796E-02
26	1.7848E-02	1.8144E-02	1.7465E-02	1.7594E-02	1.7363E-02
27	8.8057E-03	8.9545E-03	8.6096E-03	8.6750E-03	8.5576E-03
28	4.2707E-03	4.3438E-03	4.1735E-03	4.2057E-03	4.1478E-03
29	1.2120E-03	1.2328E-03	1.1841E-03	1.1933E-03	1.1768E-03
30	6.9430E-04	7.0627E-04	6.7824E-04	6.8355E-04	6.7402E-04
31	2.1165E-04	2.1530E-04	2.0674E-04	2.0836E-04	2.0545E-04
32	2.4813E-04	2.5242E-04	2.4237E-04	2.4427E-04	2.4086E-04
33	6.6174E-04	6.7317E-04	6.4634E-04	6.5142E-04	6.4229E-04
34	5.9501E-04	6.0531E-04	5.8109E-04	5.8567E-04	5.7744E-04
35	1.9404E-04	1.9741E-04	1.8948E-04	1.9098E-04	1.8829E-04
36	6.3142E-05	6.4238E-05	6.1657E-05	6.2145E-05	6.1269E-05
37	2.5761E-05	2.6208E-05	2.5155E-05	2.5354E-05	2.4997E-05
38	3.1715E-06	3.2263E-06	3.0973E-06	3.1218E-06	3.0779E-06
39	1.0416E-06	1.0595E-06	1.0175E-06	1.0254E-06	1.0111E-06
40	4.0087E-07	4.0781E-07	3.9198E-07	3.9498E-07	3.8960E-07
41	1.0808E-07	1.0989E-07	1.0590E-07	9.6708E-08	1.0517E-07
42	4.7007E-09	0	1.0349E-08	1.9397E-11	1.5776E-08
43	2.6106E-09	0	5.5918E-09	1.0701E-11	8.6067E-09
44	6.6295E-10	0	1.6994E-09	3.3430E-12	2.6035E-09
45	1.2831E-10	0	1.0556E-09	2.1628E-12	1.6126E-09
46	3.1175E-11	0	1.0958E-09	2.3672E-12	1.4742E-09
47	1.0398E-11	0	3.4341E-10	7.8650E-13	5.1255E-10

columns and 279 rows. The row positions of the responses are the same as for the broad-group responses (listed in Table 3.13) with the exception of the additional 16 responses. These extra 16 responses start with ion 56. The fine-group responses will be useful for users who may need to generate broad-group responses with different weighting spectra. Be aware that certain of these "responses" are not averaged but rather are summed to give the broad-group values, e.g. χ's, weighting spectra, etc.

The kerma factors are also represented as cross-section tables with ANISN IDs of 8001 - 8004. The 8001 and 8002 sets contain the neutron-only kerma factors for the 120 nuclides in BUGLE-93, while the 8003 and 8004 sets contain the gamma-ray-only kerma factors. It should be noted that the gamma-ray kerma factors are the same for all isotopes of a given element. The row positions for these data sets are listed in Tables 3.16 and 3.17. The kerma factors were collapsed from VITAMIN-B6 using the concrete weighting spectrum. Ten nuclides were observed to have negative neutron kerma factors when processed by NJOY, which is apparently due to problems in the ENDF/B-VI evaluation rather than the processing. These nuclides include: ^{197}Au (MAT 7925), ^{138}Ba (MAT 5649), ^{209}Bi (MAT 8325), ^{151}Eu (MAT 6325), Mo (MAT 4200), ^{93}Nb (MAT 4125), ^{181}Ta (MAT 7328), Ti (MAT 2200), W-Nat (MAT 7400), and ^{183}W (MAT 7434). These nuclides are included in the BUGLE-96 kerma data sets but contain only zeros.

Table 3.16 Row positions for neutron kerma factor data set 1 (ID=8001) and gamma-ray kerma factor data set 1 (ID=8003).[a] Kermas are in units of eV·b

Row	Nuclide	Row	Nuclide	Row	Nuclide
1	Ag-107	21	Cm-242	41	Fe-54
2	Ag-109	22	Cm-243	42	Fe-56
3	Al-27	23	Cm-244	43	Fe-57
4	Am-241	24	Cm-245	44	Fe-58
5	Am-242	25	Cm-246	45	Ga
6	Am-242m	26	Cm-247	46	H-1 (H2O)
7	Am-243	27	Cm-248	47	H-1 (CH2)
8	Au-197[b]	28	Co-59	48	H-2 (D2O)
9	B-10	29	Cr-50	49	H-3
10	B-11	30	Cr-52	50	He-3
11	Ba-138[b]	31	Cr-53	51	He-4
12	Be-9	32	Cr-54	52	Hf-174
13	Be-9 (Thermal)	33	Cu-63	53	Hf-176
14	Bi-209[b]	34	Cu-65	54	Hf-177
15	C	35	Eu-151[b]	55	Hf-178
16	C (Graphite)	36	Eu-152	56	Hf-179
17	Ca	37	Eu-153	57	Hf-180
18	Cd-Nat	38	Eu-154	58	In-Nat
19	Cl-Nat	39	Eu-155	59	K
20	Cm-241	40	F-19	60	Li-6

[a] Gamma-ray kerma factors are the same for all isotopes of each element.
[b] Neutron kerma factors are set to zero.

Table 3.17 Row positions for neutron kerma factor data set 2 (ID=8002) and gamma-ray kerma factor data set 2 (ID=8004).[a] Kermas are in units of eV·b

Row	Nuclide	Row	Nuclide	Row	Nuclide
1	Li-7	21	Pa-233	41	Ta-182
2	Mg	22	Pb-206	42	Th-230
3	Mn-55	23	Pb-207	43	Th-232
4	Mo[b]	24	Pb-208	44	Ti[b]
5	N-14	25	Pu-236	45	U-232
6	N-15	26	Pu-237	46	U-233
7	Na-23	27	Pu-238	47	U-234
8	Nb-93[b]	28	Pu-239	48	U-235
9	Ni-58	29	Pu-240	49	U-236
10	Ni-60	30	Pu-241	50	U-237
11	Ni-61	31	Pu-242	51	U-238
12	Ni-62	32	Pu-243	52	V
13	Ni-64	33	Pu-244	53	W-Nat[b]
14	Np-237	34	Re-185	54	W-182
15	Np-238	35	Re-187	55	W-183[b]
16	Np-239	36	S	56	W-184
17	O-16	37	S-32	57	W-186
18	O-17	38	Si	58	Y-89
19	P-31	39	Sn-Nat	59	Zr
20	Pa-231	40	Ta-181[b]	60	Zr (Zirc-2)

[a] Gamma-ray kerma factors are the same for all isotopes of each element.
[b] Neutron kerma factors are set to zero.

4 LIBRARY VERIFICATION AND VALIDATION

The preceding BUGLE-93 cross-section library was extensively verified and validated using three levels of testing, which included: (1) automatic diagnostic software to check for internal consistency of the data files, (2) numerical and graphical comparisons with other cross-section data, and (3) computational analysis of more than 30 integral benchmark experiments. The benchmark testing was a significant effort and included many CSEWG-approved benchmarks[22] and several non-CSWEG benchmarks which have been generally accepted as being suitable for testing nuclear data. The benchmark testing not only served to verify the processing of the multigroup cross sections, but also to validate the library for use for LWR pressure vessel dosimetry and shielding applications. Additionally, it helped to demonstrate the impact of changes in the ENDF/B-VI data for this application.

Verification of BUGLE-96 was accomplished using the first two levels of testing described above, i.e. automated software checking and comparisons with other cross-section data. The first step in the data verification process made use of diagnostic modules in the AMPX-77 system. Also, data were compared with BUGLE-93 results at several steps during the processing. These periodic comparisons were an important step in the processing, since it frequently happens that even minor changes to the processing codes, which are intended to fix one specific problem, may cause unexpected changes in other portions of the processed data files.

For BUGLE-96, resources were not available to repeat the extensive set of benchmark analyses that were performed for BUGLE-93. However, much of the benchmark testing of BUGLE-93 remains valid for BUGLE-96, especially for those applications which are sensitive to only data above the thermal energy range. Therefore, the results of the BUGLE-93 data testing are provided in this section. It is expected that with time, some of these benchmarks will be rerun with the actual BUGLE-96 data and that further validation results will be contributed by the user community.

4.1 Processing Methods

The first level of data testing made use of diagnostic modules in the AMPX-77 system. An example of cross-section checks performed by one of these modules, RADE, is provided in Table 4.1. In addition, pointwise and/or multigroup data were graphically plotted and compared with ENDF/B-V results for key reactions. At each step of the processing, the files were compared with previous results and differences were identified and resolved or justified. This was an important step in the processing, since even minor changes to the processing codes, which were intended to fix a specific problem, often caused changes in other portions of the processed data files.

4.2 Thermal and Fast Reactor Data Testing Benchmarks

The calculation of criticality benchmarks help to establish the reliability of the resulting fine-group cross-section library and the cross-section processing methods for fuel and moderator materials. The

Table 4.1 Cross section checks performed by RADE on AMPX master interface files [a]

1.	$\sigma_t = \sigma_a + \sigma_s$
2.	$\sigma_{in} = \sum \sigma_{in}(\text{partial})$
3.	$\sigma_a = \sigma_c + \sigma_f$
4.	$\sigma_c = \sigma_{ng} + \sigma_{n\alpha} + \sigma_{np} + \sigma_{nd} + \ldots$
5.	$\sigma_{el}(g) = \sum_{g'} \sigma_{el,o}(g \to g')$ (for all processes with scattering matrix).
6.	$\sigma_o(g \to g') > 0$
7.	$\sigma_t, \sigma_a, \sigma_f, \sigma_{n\alpha}, \sigma_{np}, \ldots > 0$
8.	$-1 \le \{ \mu(g \to g') = \sigma_l(g \to g')/(2l+1)\sigma_o(g \to g') \} \le 1$, for all odd l.[b]

[a] Deviations between the right- and left-hand sides of the above relationships are printed if greater than a user supplied tolerance.

[b] For even l, the left-hand side of this inequality is given by the table:

l	$\mu(g \to g')$
2	-0.5
4	-0.433
6	-0.419
8	-0.414

testing included the calculation of several CSEWG fast and thermal critical experiments. A few additional non-CSEWG benchmarks which had ENDF/B-V results available were also analyzed. Table 4.2 lists the physics benchmarks used in this project. Because of the removal of thermal-neutron upscatter in the BUGLE-93 data and relatively poor energy resolution at lower energies, only the VITAMIN-B6 data were used to analyze the thermal and fast reactor benchmarks. Furthermore, BUGLE-93 is intended primarily for shielding applications and is not expected to perform well for reactor physics analyses.

4.2.1 Thermal Reactor Physics Benchmarks

The XSDRNPM module of the SCALE system[19] was used to calculate a total of 23 thermal reactor benchmarks. Calculated eigenvalue and reaction rate ratios were compared to results obtained with the SCALE LAW-238 library (238 groups) based on ENDF/B-V data.[23] In some cases, results were compared with those obtained by researchers at other organizations using ENDF/B-VI. These comparisons help to further assure the correctness of the analysis methods.

4.2.1.1 ORNL Series: The first set of thermal reactor benchmarks are for the ORNL critical solution spheres: ORNL-1, -2, -3, -4, and -10. These are unreflected spheres of ^{235}U as uranyl nitrate and H_2O solutions. The benchmarks are especially useful for testing H_2O fast-neutron scattering data, ^{235}U absorption data, and hydrogen neutron capture data. The calculated k_{eff} values are given in Table 4.3. ENDF/B-VI data appear to yield k_{eff} values which are 0.3 to 0.6% low relative to the experiments and are about 0.4% lower than the corresponding average value obtained using the LAW-238 library. Although not listed in Table 4.3, other ENDF/B-VI-based results calculated elsewhere and presented at the October 1993 CSEWG meeting are in good agreement with the VITAMIN-B6 results.

4.2.1.2 L Series: Calculated values of k_{eff} for the L-Series benchmarks (L-7, -8, -9, -10, and -11) are given in Table 4.4. These benchmarks are similar to the ORNL series above except that they include both reflected and unreflected spheres of ^{235}U as uranyl fluoride and H_2O solutions. The L-Series benchmarks are significantly improved with ENDF/B-VI. As seen in Table 4.4, the average k_{eff} with VITAMIN-B6 is 1.0022, which is about 0.5% lower than the ENDF/B-V results. When k_{eff} is plotted as a function of leakage from the spheres, as shown in Fig. 4.1, one can see that not only does the VITAMIN-B6 data yield values closer to unity, but they also appear to reduce the positive trend of k_{eff} with increasing leakage.

4.2.1.3 TRX and BABL Series: Two series of H_2O-moderated uranium lattice experiments were analyzed including TRX-1 and -2 and BAPL-1, -2, and -3. These lattices directly test ^{235}U resonance fission integrals and thermal fission cross sections. Also, ^{238}U shielded resonance capture and thermal neutron capture are tested. The benchmarks are sensitive to the ^{235}U fission spectrum and the ^{238}U fast fission and inelastic scattering cross sections. Calculated values of k_{eff} for these benchmarks are given in Table 4.5. In the case of TRX-1 and -2, the VITAMIN-B6 results are 0.2 to 0.4% lower than ENDF/B-V results, which were already significantly below unity. However, the VITAMIN-B6 results compare well with other ENDF/B-VI-based calculations performed elsewhere.

Table 4.2 CSEWG reactor physics benchmarks used for data testing

Thermal reactor benchmarks:

ORNL-1,-2 -3,-4,-10	Unreflected spheres of ^{235}U (as uranyl nitrate) in H_2O
L-7,-8,-9 -10,-11	Reflected and unreflected spheres of ^{235}U (as uranyl fluoride) in H_2O.
TRX-1,-2	H_2O moderated uranium lattices
BAPL-1,-2,-3	H_2O moderated uranium oxide critical lattices
PNL-1,-3R, -4R,-5R, -6B,-8A	Unreflected spheres of plutonium nitrate in H_2O
PNL-7A,-12A,	Reflected spheres of plutonium nitrate in H_2O

Fast reactor benchmarks:

JEZEBEL	Bare sphere of plutonium metal
JEZEBEL-PU	Bare sphere of plutonium metal containing 20.1% ^{240}Pu
JEZEBEL-23	Bare sphere of uranium metal (98.13 atom-% ^{233}U)
GODIVA	Bare sphere of enriched uranium metal
FLATTOP-25	Reflected sphere of enriched uranium metal
FLATTOP-PU	Reflected sphere of plutonium metal
FLATTOP-23	Reflected sphere of uranium metal (98.13 atom-% ^{233}U)
BIG TEN	Reflected cylinder of uranium containing 10% ^{235}U
ZPR-3/11	Fertile to fission uranium metal ratio of 7:1 with ^{238}U reflector
ZPR-3/12	Uranium-fueled assembly with uranium-to-graphite ratio of 4:1 and ^{238}U reflector
ZPR-6/6A	Uranium oxide fueled fast critical assembly with depleted uranium reflector
ZPR-6/7	Large plutonium oxide fueled fast critical assembly with depleted uranium reflector

Table 4.3 ORNL critical solution spheres

Benchmark	k-effective LAW-238 ENDF/B-V	k-effective VITAMIN-B6 ENDF/B-VI
ORNL-1	1.0007	0.9965
ORNL-2	1.0005	0.9964
ORNL-3	0.9975	0.9935
ORNL-4	0.9989	0.9950
ORNL-10	0.9993	0.9961
Average	0.9994	0.9955

Table 4.4 L-Series critical solution spheres

Benchmark	Leakage[a]	k-effective LAW-238 ENDF/B-V	k-effective VITAMIN-B6 ENDF/B-VI
L-9	0.174	1.0052	1.0011
L-11	0.202	1.0035	0.9988
L-8	0.239	1.0088	1.0042
L-10	0.463	1.0090	1.0030
L-7	0.469	1.0082	1.0037
Average		1.0069	1.0022

[a] Based on LAW-238 calculations.

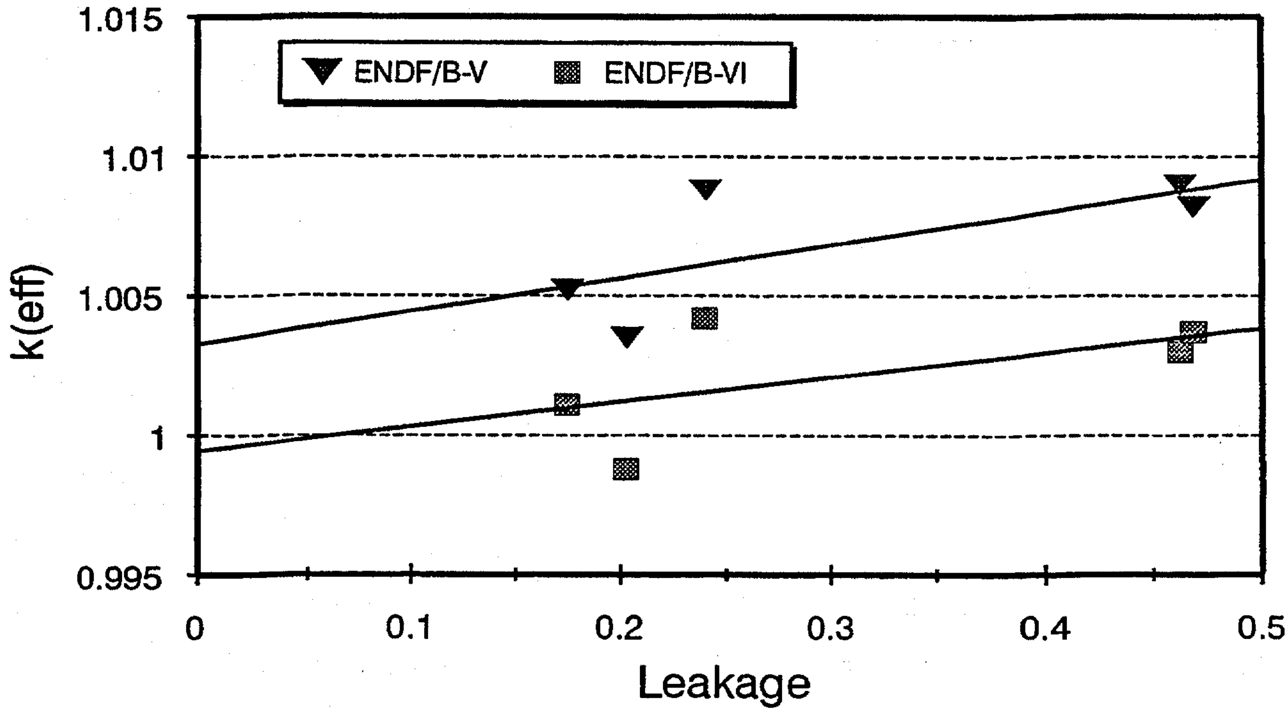


Fig. 4.1 Comparison of calculated k_{eff} values for L-Series thermal reactor benchmarks using the LAW-238 (ENDF/B-V) and VITAMIN-B6 (ENDF/B-VI) libraries. Lines represent linear regression fits to the data

Table 4.5 Thermal reactor lattices

Benchmark	Pitch (cm)	k-effective LAW-238 ENDF/B-V	k-effective VITAMIN-B6 ENDF/B-VI
TRX-1	1.806	0.9915	0.9894
TRX-2	2.174	0.9959	0.9915
Average		0.9937	0.9905
BAPL-1	1.5578	0.9947	0.9975
BAPL-2	1.6523	0.9965	0.9971
BAPL-3	1.8057	0.9987	0.9972
Average		0.9966	0.9973

The BAPL-1, -2, and -3 benchmarks appear much more favorable for ENDF/B-VI. The average k_{eff} for the three lattices is slightly higher and closer to unity for VITAMIN-B6 calculations relative to ENDF/B-V. More importantly, the marked trend in the eigenvalue as a function of lattice pitch is essentially eliminated with ENDF/B-VI data. This is shown graphically in Fig. 4.2.

4.2.1.4 PNL Series: Finally, the PNL series of plutonium nitrate spheres were analyzed using VITAMIN-B6. These critical assemblies include $H/^{239}Pu$ atom ratios ranging from 131 to 1204 and are useful for testing the H_2O scattering data, cross sections for thermal-neutron capture and fission by ^{239}Pu, and the ^{239}Pu fission spectrum and nubar (average number of neutrons per fission). The CSEWG benchmark specifications for PNL-3, -4, and -5 were determined to be inaccurate. Specifically, the radii given in the published specifications[22] were not adjusted to specify critical sizes for solutions without stainless steel walls. For this analysis, we have corrected the specifications to include the stainless steel vessel in the calculations. These revised benchmarks are designated PNL-3R, -4R, and -5R. The impact of the stainless steel vessel was to increase k_{eff} by 0.4 to 0.5% as compared to previous calculations with no vessel. The results for the PNL benchmarks are listed in Table 4.6 ordered by increasing H/Pu ratio. The neutron production-to-absorption ratio and the k_{eff} for each benchmark is given based on VITAMIN-B6 calculations. These results are plotted in Fig. 4.3. Because of the scatter in the results, it is probably meaningless to conclude a trend in the eigenvalue as a function of hydrogen content.

4.2.2 Fast Reactor Physics Benchmarks

As indicated in Table 4.2, 12 CSEWG fast reactor benchmarks were used to test VITAMIN-B6. Calculated eigenvalue and reaction rate ratios were compared to results obtained with the VITAMIN-E library (174 groups) based on ENDF/B-V data. These k_{eff} results are summarized in Table 4.7. One apparent trend is that ENDF/B-VI data yield slightly lower values of k_{eff} for the relatively simple benchmarks, but yield significantly higher values for the larger mockups. A summary of the calculated-to-experiment ratios for various reaction rate ratios are given in Table 4.8 for the VITAMIN-B6 calculations. Note that the reaction rate ratios for ZPR-6/7 are given relative to ^{239}Pu fission while those for the other benchmarks are given relative to ^{235}U fission.

In order to give further assurance that the cross-section processing and the computational methods used to analyze the benchmarks were done correctly, we performed extensive comparisons with benchmark analyses performed at LANL. The LANL results, also based on ENDF/B-VI data are listed in Table 4.8 for the CSEWG fast reactor benchmarks. While some benchmarks agree well, others show significant differences relative to the VITAMIN-B6 results. These differences need to be investigated further, but appear to be primarily due to the different energy group structures (80 groups used by LANL compared to 199 groups for VITAMIN-B6) and modest differences in the computational methods.

Four additional non-CSEWG benchmarks were also analyzed: H2OX-1, UH3-UR, HISS(HUG), and HISS(HPG). H2OX-1 is a highly enriched uranium metal sphere reflected by water and has a radius slightly smaller than the GODIVA assembly. The UH3-UR benchmark is a sphere of enriched uranium hydride (approximately UH_3) with a natural uranium reflector.

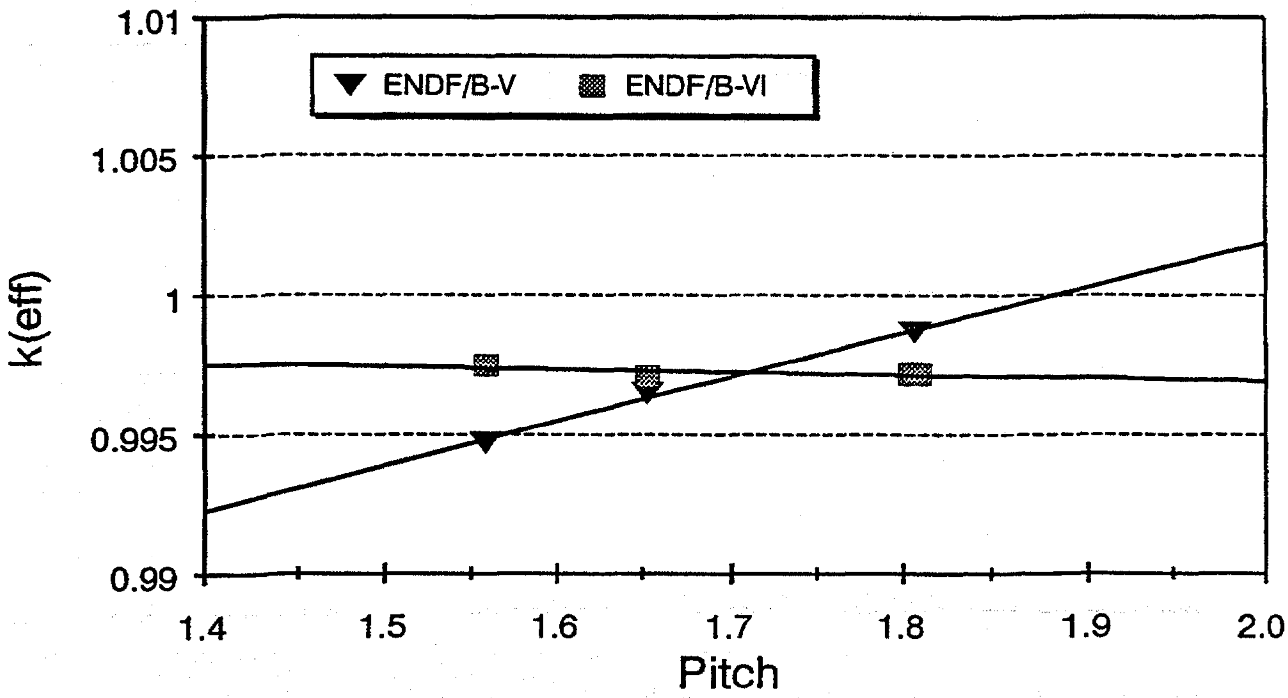


Fig. 4.2 Comparison of calculated k_{eff} values for BAPL Series thermal reactor benchmarks using the LAW-238 (ENDF/B-V) and VITAMIN-B6 (ENDF/B-VI) libraries. Lines represent linear regression fits to the data

Table 4.6 PNL series calculated using VITAMIN-B6

Benchmark	$H/^{239}Pu$ Ratio	Prod/Abs Ratio	k_{eff} ENDF/B-VI
PNL-6B	131	1.6642	1.0025
PNL-5R	578	1.5949	1.0065
PNL-1	700	1.6043	1.0089
PNL-8A	795	1.5487	1.0066
PNL-4R	911	1.4809	1.0013
PNL-7A	985	1.0126	1.0052
PNL-12A	1118	1.0294	1.0066
PNL-3R	1204	1.4531	0.9942

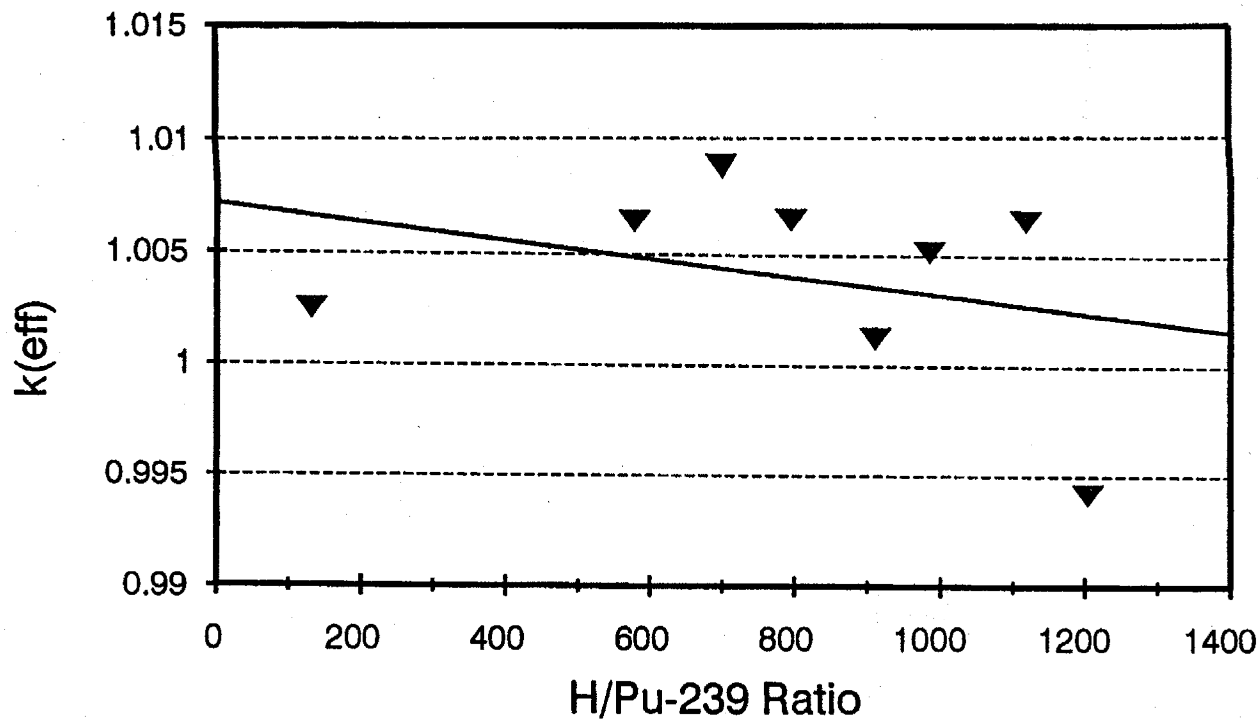


Fig. 4.3 Calculated k_{eff} values for PNL Series thermal reactor benchmarks using the VITAMIN-B6 library. Line represents linear regression fits to the data

Table 4.7 Summary of fast reactor benchmark results

Benchmark	k-effective VITAMIN-E ENDF/B-V	k-effective VITAMIN-B6 ENDF/B-VI	Δk/k (%)	k-effective LANL ENDF/B-VI
JEZEBEL	0.9983	0.9970	-0.13	0.9989
JEZEBEL-23	0.9935	0.9934	-0.01	0.9940
JEZEBEL-PU	1.0021	0.9980	-0.41	0.9981
FLATTOP-23	--	1.0032	--	1.0041
FLATTOP-PU	--	1.0029	--	1.0055
GODIVA	0.9966	0.9960	-0.06	0.9983
FLATTOP-25	1.0047	1.0018	-0.29	1.0030
ZPR-3/12	1.0047	1.0109	0.62	--
ZPR-3/11	1.0126	1.0141	0.15	--
BIGTEN	1.0144	1.0171	0.27	1.0105
ZPR-6/6A	0.9921	1.0110	1.90	1.0063
ZPR-6/7	1.0037	1.0150	1.13	1.0070
Average[a]	1.0023	1.0054	0.31	--
Average[b]	--	1.0035	--	1.0026

[a] Excludes FLATTOP-23 and FLATTOP-PU.
[b] Excludes ZPR-3/11 and ZPR-3/12.

Table 4.8 Calculated-to-experiment ratios calculated using VITAMIN-B6

Benchmark	Central Reaction Rate Ratios[a]				
	F28/F25	F37/F25	F23/F25	F49/F25	C28/F25
JEZEBEL	0.964	0.969	1.000	0.975	--
JEZEBEL-23	1.011	0.990	--	--	--
JEZEBEL-PU	0.964	1.000	--	--	--
FLATTOP-23	1.000	0.996	--	--	--
FLATTOP-PU	0.973	0.985	--	--	--
GODIVA	0.963	0.961	1.001	0.978	--
FLATTOP-25	0.970	0.979	0.990	0.984	--
ZPR-3/12	1.061	--	1.031	0.995	0.950
ZPR-3/11	1.068	--	1.035	0.994	--
BIGTEN	1.044	1.044	0.996	0.988	0.946
ZPR-6/6A	0.958	--	--	--	0.991
	F28/F49	F37/F49	F23/F49	F25/F49	C28/F49
ZPR-6/7	1.012	--	--	1.033	1.038

[a] Nomenclature: F = fission; C = capture
23 = ^{233}U; 25 = ^{235}U; 28 = ^{238}U; 37 = ^{237}Np; 49 = ^{239}Pu

Table 4.9 Summary results for non-CSEWG fast reactor benchmarks

Benchmark	k-effective LAW-238 ENDF/B-V	k-effective VITAMIN-B6 ENDF/B-VI
H2OX-1	1.0047	1.0001
UH3-UR	1.0098	1.0222
HISS(HUG)	1.0254	1.0293
HISS(HPG)	0.9968	1.0055
Average	1.0092	1.0143

HISS(HUG) is a homogeneous uranium-graphite assembly and HISS(HPG) is a homogeneous plutonium-graphite assembly; both HISS benchmarks contain large amounts of boron. The fission rates for the UH3-UR and the HISS benchmarks peak in the resolved resonance range and thus are sensitive to the fission and capture cross sections in that energy range.

Calculated values of k_{eff} for the four benchmarks are given in Table 4.9 compared to calculations using the LAW-238 library. Excepting for H2OX-1, ENDF/B-VI data appear to give 0.5 to 1.0% higher eigenvalues than ENDF/B-V data. It has been observed that the evaluated capture resonance integral for ^{235}U in ENDF/B-VI is about 8% lower than the measured value. The high values of the calculated k_{eff} values for UH3-UR and HISS(HUG) using ENDF/B-VI cross sections tend to support the need to increase the ^{235}U capture resonance integral.

4.3 Shielding Benchmarks

Several integral shielding benchmarks were identified as useful for testing the VITAMIN-B6 and BUGLE-93 cross-section libraries. These benchmarks are listed in Table 4.10. Unlike the reactor physics benchmarks, even the relatively simple shielding benchmarks tend to have complex source descriptions and geometry models which often require multidimensional analyses. Also, several of the benchmark experiments contain multiple configurations involving different materials and multiple types of detector responses. Hence, analysis of the shielding benchmarks can require a substantial effort. For this project, only a limited set of configurations and measurements were evaluated.

Table 4.10 Shielding benchmarks used for data testing

<u>Cross Section Evaluation Working Group Benchmarks</u>:
"Broomstick" Experiments for Iron, Oxygen, Nitrogen, Sodium, and Stainless Steel. (SDT1-5)
Secondary Gamma-ray Production for Thermal Neutron Spectrum. (SB2)
Secondary Gamma-ray Production for Fast Neutron Spectrum. (SB3)
ORNL Benchmark for Iron and Stainless Steel. (SDT-11)
<u>Nuclear Energy Agency Committee on Reactor Physics Benchmarks</u>:
Winfrith Iron Benchmark Experiment.
Winfrith Water Benchmark Experiment.
PWR Shielding Benchmark (Computational).
LMFBR Shielding Benchmark (Computational).
<u>Other Relevant Benchmarks</u>:
University of Illinois Iron Sphere Benchmarks (14 MeV and ^{252}Cf).
Pool Critical Assembly (PCA) Blind Test Benchmark.
Winfrith NESDIP2 Radial Shield Experiment.
LWR Shielding Benchmark (Computational).

It should be noted also that calculated-to-measured results for many of the benchmarks could have been substantially improved with further refinements in the methodology, such as additional spatial weighting of the cross sections. Since the intent here is primarily to compare the various cross-section data sets rather than analyze the benchmarks to the fullest extent, the emphasis was placed on using data sets which were processed in a consistent manner. The impact of using more refined processing of the cross sections was demonstrated for a few selected benchmarks configurations.

As shown in Table 4.10, the benchmarks are divided into three categories. The first two categories represent benchmarks which have been reviewed and accepted by either the Cross Section Evaluation Working Group (CSEWG) or the Nuclear Energy Agency Committee on Reactor Physics (NEACRP) for the purpose of testing nuclear data and numerical methods. The third category represents additional benchmarks which have been generally accepted and are especially relevant in assessing the quality and adequacy of the BUGLE-93 library. For most of the benchmarks, three types of comparisons were made: (1) results based on VITAMIN-E and VITAMIN-B6 data to demonstrate the impact of using ENDF/B-VI data, (2) results based on VITAMIN-B6 and BUGLE-93 data to demonstrate the impact of using broad-group cross sections, and (3) results based on BUGLE-80 and BUGLE-93 data to show the combined impact of the new broad-group library.

4.3.1 Cross Section Evaluation Working Group Benchmarks

4.3.1.1 SDT1-4: The first set of CSEWG shielding benchmarks used for this project are the "Broomstick" experiments, which were actually analyzed shortly after the release of ENDF/B-VI and have been reported earlier.[23] These experiments, which give a direct measurement of the total cross section, can be analyzed without processing of the evaluated data except to extract the pointwise total cross-section values and to group the cross-section values into the energy bins prescribed in the benchmark specifications reports. Five Broomsticks were analyzed: two iron samples,[24] oxygen,[25] nitrogen,[26] and sodium.[27] Originally, these tests were valuable for improving the total cross section for numerous materials; however, their value has diminished in recent years due to the relatively coarse energy resolution of the measurements and the relative stability in the total cross section for these materials. The Broomsticks do continue to be useful as a check against format errors in the evaluated files. As such, ENDF/B-VI successfully passed these tests. Only minor differences were observed between the Version VI and Version V results.

4.3.1.2 SB2: The second set of CSEWG shielding benchmarks consists of measurements of the gamma-ray spectra arising from thermal-neutron capture in several samples of pure materials.[28] The measured capture spectrum from each sample was summed over 0.5-MeV bins and converted to a production cross section based on the tabulated radiative capture cross section at 0.0253 eV. No transport calculations are needed to analyze the experiments; instead, calculations consist of binning the thermal-neutron capture gamma-ray spectra into the same energy groups in which the measurements were reported. This was done for the VITAMIN-B6 group number 193, which ranges from 0.021 to 0.03 eV (E_{mid} = 0.0255 eV).

Comparisons of measured and calculated gamma-ray production cross sections are given in Tables 4.11 and 4.12. The reported accuracy in the measurements is 15%. There is considerable spread in the results, which could be due to several factors, including: (1) the accuracy of the 0.0253-eV radiative capture cross section used to normalize the measurements, (2) the manner in which gamma-ray lines on or near the group boundaries are treated, and (3) the width of the thermal-neutron group used to generate the calculated production cross sections. Further investigation is needed to resolve the differences.

4.3.1.3 SB3: The third set of CSEWG shielding benchmarks is similar to the SB2 benchmarks except that the secondary gamma-ray spectra were measured for a fast-neutron incident spectrum.[29] Comparisons of measured and calculated gamma-ray production cross sections are given in Tables 4.13 and 4.14. As with the thermal-neutron-induced data, the fast-neutron-induced results show tremendous variation. However, for groups which contain significant numbers of secondary gamma rays, the agreement between the measured and calculated cross sections is generally within the 30% accuracy quoted for the measurements.

4.3.1.4 SDT11: The fourth and final CSEWG shielding benchmark used in this project is the ORNL iron and stainless steel experiment.[30] As with the preceding benchmarks, the SDT11 experiment was performed at the Tower Shielding Facility (TSF) and included measurements of both the neutron fluence and neutron spectra behind thick slabs of iron and stainless steel. Various thicknesses of iron or stainless steel were placed in the collimated beam, but only the 30-cm-thick samples were analyzed here. The analysis was performed using the GRTUNCL,[31] code to compute the first collision source from the reactor, the DORT code to transport the neutrons through the shield samples, and the FALSTF[32] code to calculate the detector responses at distant locations from the shield samples. Comparisons were made for several detectors and for measurements made both on the beam centerline and off-centerline. When comparing calculated spectra with measured NE-213 or Benjamin counter spectra, the calculated spectra were smoothed with the approximate energy resolution of the detectors.

The measured fast-neutron spectrum behind a 30-cm-thick iron slab is compared in Fig. 4.4 to results calculated with VITAMIN-E and VITAMIN-B6 data. The VITAMIN-B6 data yield slightly better agreement with the measurement between 3.5 and 5.5 MeV. Figure 4.5 compares BUGLE-93 and BUGLE-80 results to the same measurement, which shows a somewhat greater improvement with the newer data. The dominant feature of the comparisons, however, is the significant underprediction of the measurement below 4 MeV. It is felt that this is due to an underprediction of the uncollided flux resulting from the narrow, deep windows in the iron total cross section. This conclusion is supported by several observations, including comparisons of the neutron spectrum off-centerline, in which the uncollided flux is relatively unimportant. Figure 4.6 shows that excellent agreement was achieved between the fine-group calculations and the measured spectrum at the off-centerline location. These results suggest that even the fine-group cross sections may be inadequate for deep penetration in iron, especially for highly directed sources.

Comparisons of measurements and calculations for several integral detectors are given in Table 4.15 for both the 30-cm-thick iron slab and the 30-cm-thick stainless steel slab. Both on-centerline and

Table 4.11 Calculated-to-experiment ratios for gamma-ray production cross sections from thermal-neutron capture in Fe, SS, N, Na, Al, and Cu

Gamma-ray Energy (MeV)	Iron	Stainless Steel	Nitrogen	Sodium	Aluminum	Copper
1.5 - 2.0	0.87	1.08	0.86	0.63	0.74	0.60
2.0 - 2.5	1.65	1.15	--	0.92	0.82	0.57
2.5 - 3.0	1.59	1.76	0.92	0.91	1.02	0.37
3.0 - 3.5	1.29	1.18	--	1.20	1.16	0.54
3.5 - 4.0	0.94	0.98	0.89	1.08	1.06	0.68
4.0 - 4.5	1.25	1.17	--	0.44	1.08	1.07
4.5 - 5.0	1.41	1.29	0.92	0.19	1.20	0.77
5.0 - 5.5	1.86	0.86	0.89	0.42	1.10	1.36
5.5 - 6.0	0.96	0.78	0.86	1.06	1.04	1.03
6.0 - 6.5	0.90	0.96	0.94	1.04	0.99	0.99
6.5 - 7.0	0.93	0.55	--		0.56	1.24
7.0 - 7.5	0.93	0.99	0.95		--	0.94
7.5 - 8.0	1.04	1.02	--		1.07	0.96
8.0 - 10.0	1.05[a]	1.09	0.88			
> 10.0			0.90			

[a] For energies > 8.0 MeV.

Table 4.12 Calculated-to-experiment ratios for gamma-ray production cross sections from thermal-neutron capture in Ti, Ca, K, Si, Ni, and S

Gamma-ray Energy (MeV)	Titanium	Calcium	Potassium	Silicon	Nickel	Sulfur
1.5 - 2.0	0.82	1.01[b]	1.09	--	1.49	1.03
2.0 - 2.5	1.19	--	0.57	1.17	0.90	1.03
2.5 - 3.0	0.70	0.64	0.84	0.35	0.38	1.03
3.0 - 3.5	1.31	0.15	1.05	0.49	0.53	1.03
3.5 - 4.0	1.26	0.83	0.66	1.00	0.60	1.02
4.0 - 4.5	1.30	1.02	0.95	--	0.78	1.03
4.5 - 5.0	1.21	0.98	0.58	0.94	0.68	1.03
5.0 - 5.5	2.68	0.12	0.86	0.80	0.49	1.03
5.5 - 6.0	1.58	0.70	0.96	--	0.33	1.03
6.0 - 6.5	1.09	1.32	--	1.19	0.50	1.03
6.5 - 7.0	1.04		--	1.67	0.32	1.03
7.0 - 7.5	0.37		6.11	0.97	1.95	1.03
7.5 - 8.0	—		1.10	--	1.25	1.03
8.0 - 10.0	0.40[a]			1.40[a]	1.09	1.03
> 10.0						

[a] For energies > 8.0 MeV.
[b] For energy range 1.5 - 2.5 MeV.

Table 4.13 Calculated-to-experiment ratios for gamma-ray production cross sections from fast-neutron capture in Fe, SS, O, Na, Al, and Cu

Gamma-ray Energy (MeV)	Iron	Stainless Steel	Oxygen	Sodium	Aluminum	Copper
1.5 - 2.0	0.59	0.63	--	0.78	0.73	0.68
2.0 - 2.5	0.78	0.86	--	0.90	0.95	0.97
2.5 - 3.0	0.86	1.03	--	0.73	1.23	0.86
3.0 - 3.5	0.74	0.77	--	0.74	0.99	0.99
3.5 - 4.0	0.96	1.09	--	0.76	0.77	0.79
4.0 - 4.5	1.31	1.27	--	1.03	0.85	0.70
4.5 - 5.0	1.42	1.28	--	0.49	1.01	0.73
5.0 - 5.5	1.26	0.88	--	0.98	0.68	0.64
5.5 - 6.0	1.16	0.87	--	0.87	1.39	>0.57
6.0 - 6.5	>0.77	>0.59	1.66[a]	0.40	>0.64	>0.31
6.5 - 7.0	>1.62	>0.30	1.60[b]	0.89	>0.72	
7.0 - 7.5	>0.38				>1.42	

[a] For 6.13 MeV gamma ray.
[b] For 6.92 + 7.12 MeV gamma rays.

Table 4.14 Calculated-to-experiment ratios for gamma-ray production cross sections from fast-neutron capture in Ti, Ca, K, Si, Ni, and S

Gamma-ray Energy (MeV)	Titanium	Calcium	Potassium	Silicon	Nickel	Sulfur
1.5 - 2.0	0.95	0.54	0.13	0.89	0.46	0.21
2.0 - 2.5	0.85	1.55	0.15	0.66	0.73	0.98
2.5 - 3.0	1.03	0.69	0.98	1.26	0.79	0.51
3.0 - 3.5	1.37	0.92	1.03	1.05	1.12	0.19
3.5 - 4.0	0.94	1.76	1.30	0.14	0.84	0.99
4.0 - 4.5	1.11	0.69	0.37	2.57	0.72	0.78
4.5 - 5.0	1.02	0.54	1.68	0.37	1.02	0.18
5.0 - 5.5	>0.66	2.17	0.51	1.54	>0.61	0.37
5.5 - 6.0	>0.56	>0.91	0.32	0.41	>0.51	>0.11
6.0 - 6.5	>0.39	>0.15	>0.08	>0.39	>0.33	>0.37
6.5 - 7.0		>0.49	>0.06	>0.51		>0.16
7.0 - 7.5			>0.02	>0.35		>0.24

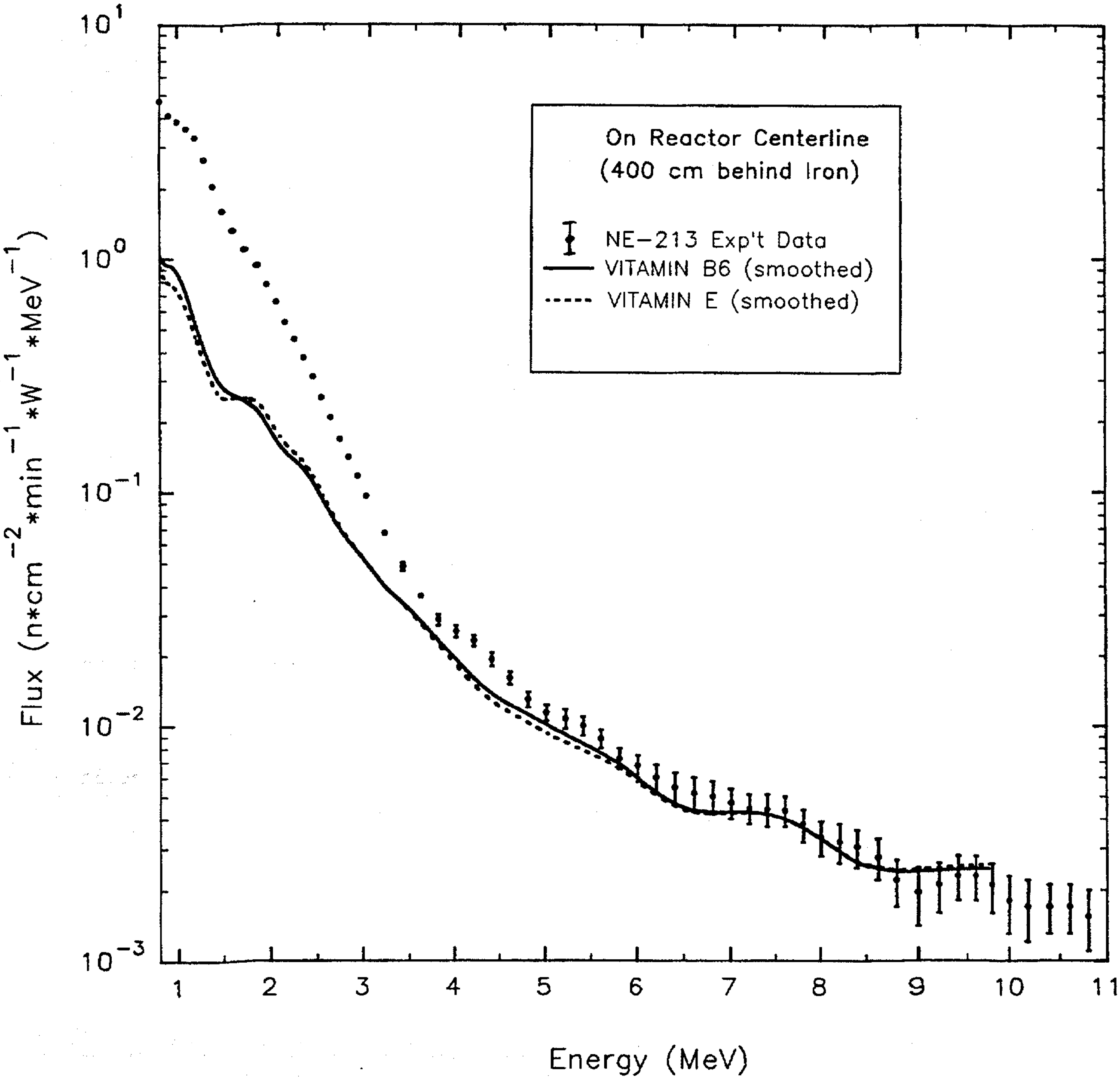


Fig. 4.4 VITAMIN-B6 and VITAMIN-E calculations compared to measured fast neutron spectrum on reactor beam centerline behind 30.5 cm iron slab in SDT11 shielding benchmark. Calculations (solid and dotted lines) have been smoothed with detector resolution

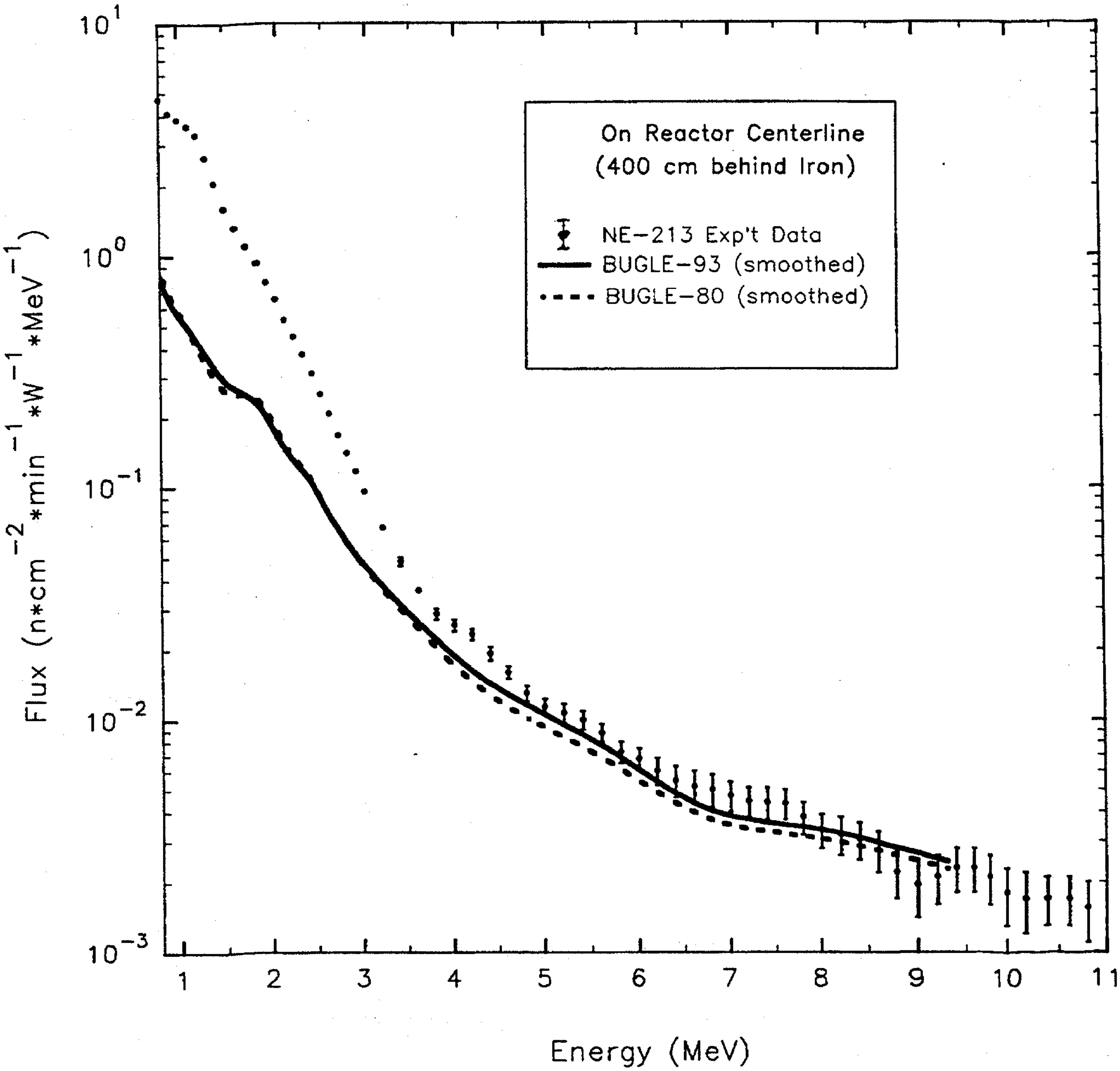


Fig. 4.5 BUGLE-93 and BUGLE-80 calculations compared to measured fast neutron spectrum on reactor beam centerline behind 30.5 cm iron slab in SDT11 shielding benchmark. Calculations (solid and dotted lines) have been smoothed with detector resolution

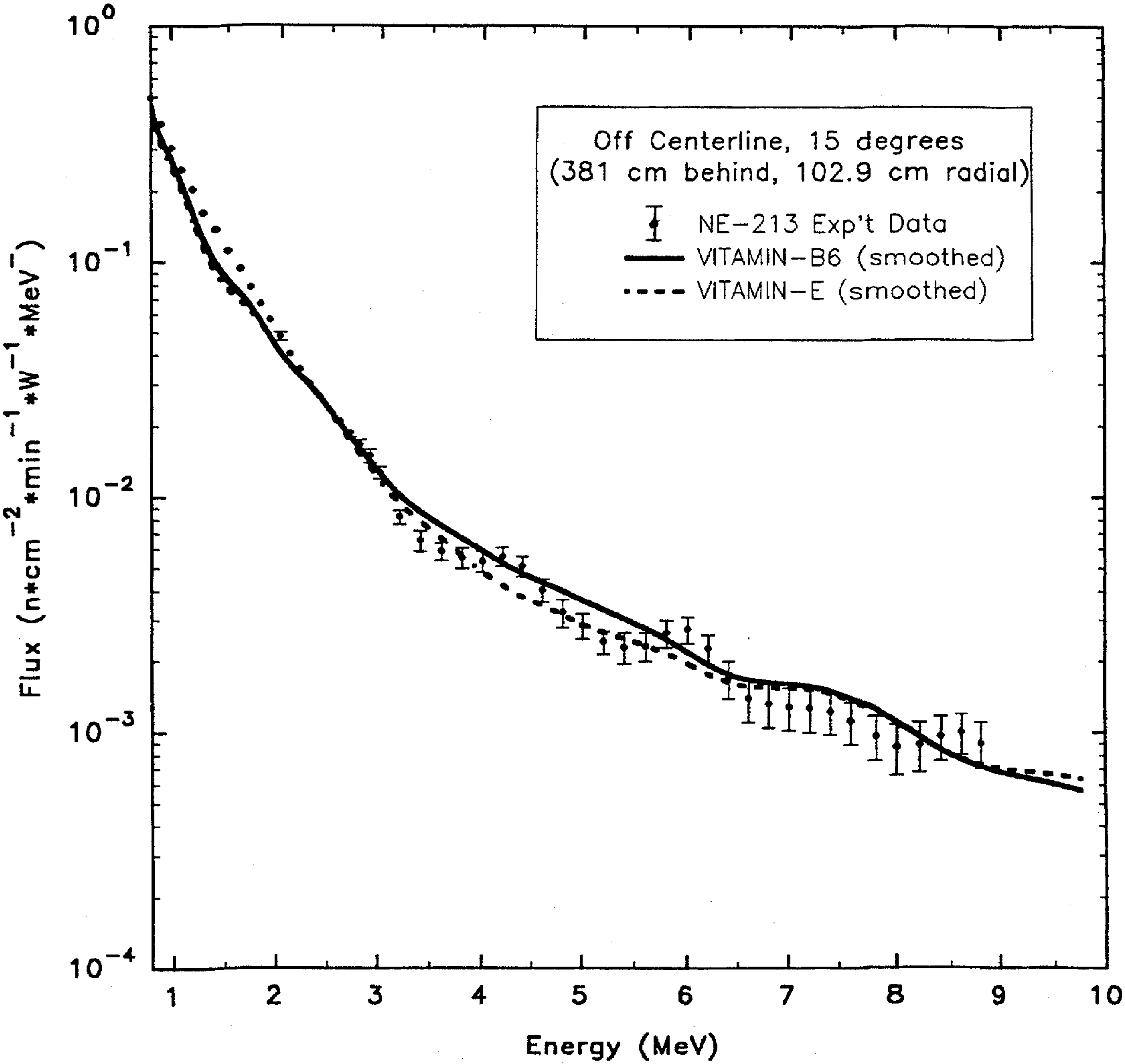


Fig. 4.6 VITAMIN-B6 and VITAMIN-E calculations compared to measured fast neutron spectrum off-centerline behind 30.5 cm iron slab in SDT11 shielding benchmark. Calculations (solid and dotted lines) have been smoothed with detector resolution

Table 4.15 Calculated-to-experiment ratios for various detectors behind 30 cm iron from SDT11 benchmark

Location	Cross-Section Set BUGLE-80	BUGLE-93	VITAMIN-E	VITAMIN-B6
Integrated NE-213:				
Fe, 15° OC[a]	0.71	0.82	0.73	0.81
Integrated Benjamin Counter:				
Fe, CL[b]	0.80	0.80	0.83	0.76
Fe, 15° OC	1.00	1.00	1.05	0.95
SS, CL	1.04	1.04	0.94	0.98
SS, 15° OC	0.94	1.09	1.11	1.03
3" Bonner Ball:				
Fe, CL	0.38	0.66	0.47	0.40
Fe, 15° OC	0.87	0.85	0.91	0.90
SS, CL	0.57	0.58	0.61	0.62
SS, 15° OC	0.82	0.83	0.85	0.88
6" Bonner Ball:				
Fe, CL	0.29	0.33	0.35	0.32
Fe, 15° OC	0.92	0.89	0.94	0.94
SS, CL	0.54	0.53	0.57	0.57
SS, 15° OC	0.96	0.94	0.96	0.98
10" Bonner Ball:				
Fe, CL	0.22	0.23	0.25	0.25
Fe, 15° OC	0.52	0.52	0.52	0.54
SS, CL	0.43	0.43	0.44	0.45
SS, 15° OC	0.82	0.81	0.80	0.83

[a] Off-centerline.
[b] On beam centerline.

off-centerline measurements are compared to calculations using four different cross-section sets. It is interesting to note that all four data sets yield nearly the same result for all cases except the integrated NE-213 spectrum. In some cases, the older ENDF/B-IV and -V data give slightly larger C/Es. This is due to two changes in the ENDF/B-VI iron cross section relative to the older versions: (1) the reduced continuum inelastic cross section between 3 and 10 MeV results in greater penetration of neutrons in this energy range, and (2) the larger total cross section just below the deep window in the cross section at 24 keV results in a reduced penetration of neutrons in the energy range of 10 to 24 keV. Only the former change is relevant to the NE-213 spectrum since it has a threshold of approximately 1 MeV.

4.3.2 Nuclear Energy Agency Committee on Reactor Physics Benchmarks

4.3.2.1 Winfrith Iron Experiment: The Winfrith Iron Experiment[34] measured fission neutron transmission through a thick iron shield. The shield consisted of 24 5.08-cm-thick iron plates spaced 6.35 mm apart. Fission neutrons were produced in a natural uranium converter plate which preceded the shield and was powered by graphite-moderated neutrons from the NESTOR reactor. Neutron spectra were measured at four locations using NE-213 detectors placed in 5.08-cm-wide by 105.5-cm-deep slots cut in special iron plates. In addition, activation foil measurements were made in the gaps between the iron plates.

Calculations for the experiment were performed with DORT using infinitely dilute, standard weighted fine- and broad-group cross sections. Additional calculations were performed using self-shielded, fine-group cross sections and broad-group cross sections which were collapsed using calculated fine-group spectra at several internal zones within the iron shield. Calculated and measured neutron spectra at 76.2 cm into the shield are presented in Fig. 4.7 for the fine-group calculations and Fig. 4.8 for the broad-group calculations.

As expected, the calculated results obtained using the self-shielded, VITAMIN-B6 fine-group and the zone-weighted, BUGLE-93 broad-group cross sections are in better agreement with the measured spectrum than are those obtained using the infinitely dilute cross sections. Integrals of the calculated neutron spectra at four locations are compared with integrals of the measured spectra in Table 4.16. At 20.32 cm depth into the shield, the broad-group libraries and the self-shielded, VITAMIN-B6 library gave calculated integral fluxes about 30% higher than measured, while the standard-weighted, fine-group libraries (VITAMIN-E and VITAMIN-B6) overpredicted the measurement by about 10%. All libraries underpredict the measured result at greater distances into the shield by an increasing amount. At 101.6 cm into the shield, the concrete-weighted BUGLE-93 library underpredicted the measured integral flux by greater than a factor of 6. Self-shielding and zone-weighting the cross sections reduced this underprediction to about a factor of 2, thus showing the importance of proper processing for deep penetration problems.

Calculated and measured activations are compared in Table 4.17. The high-energy $^{32}S(n,p)$ reaction is affected less by self-shielding than are the $^{103}Rh(n,n')$ and $^{115}In(n,n')$ reactions. For the latter two reactions, whose response functions span the iron resonance regions, self-shielding has a large effect on results at deep penetrations. The

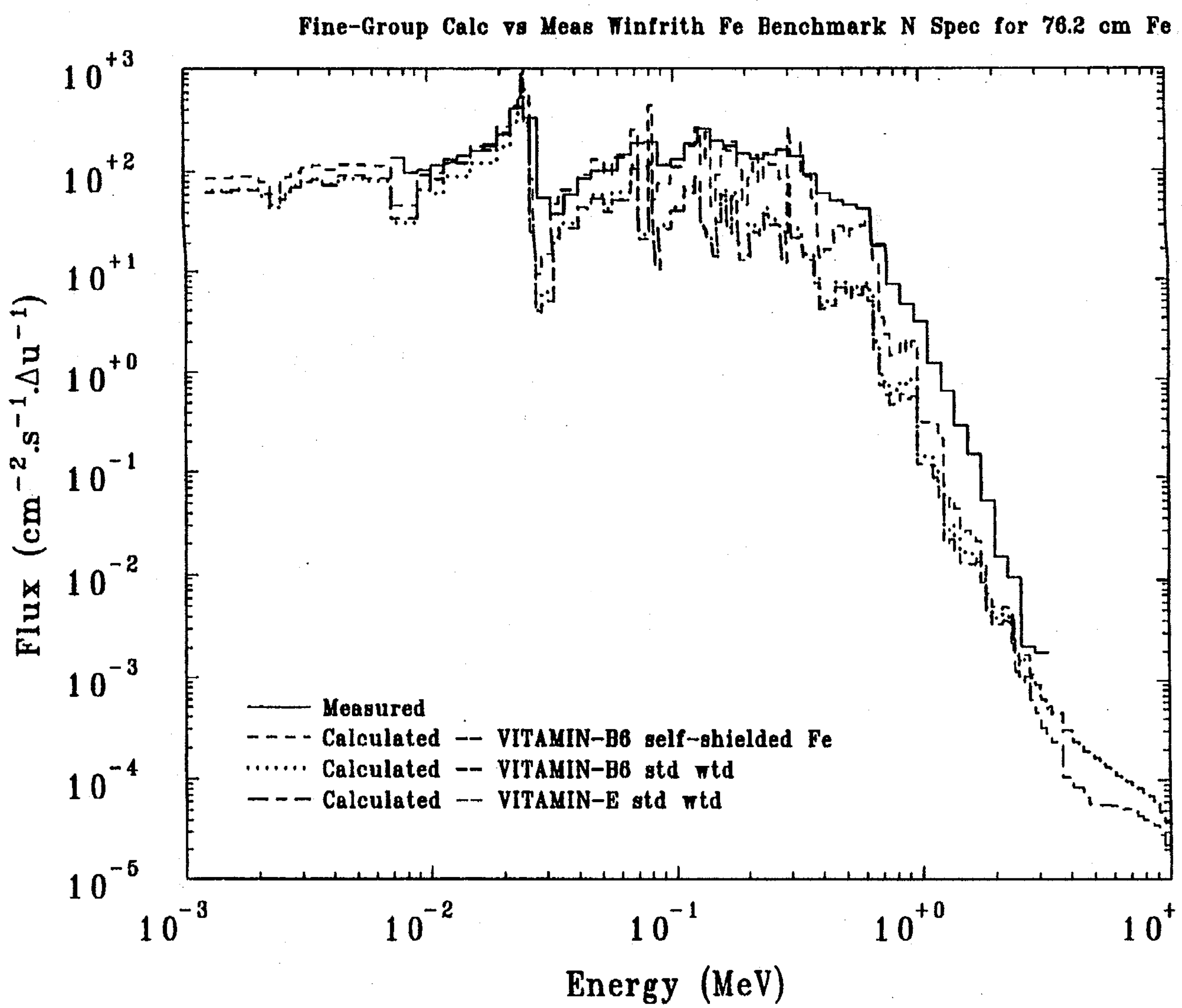


Fig. 4.7 Fine-group calculations compared to measured neutron spectrum for an iron thickness of 76.2 cm in the Winfrith Iron Experiment

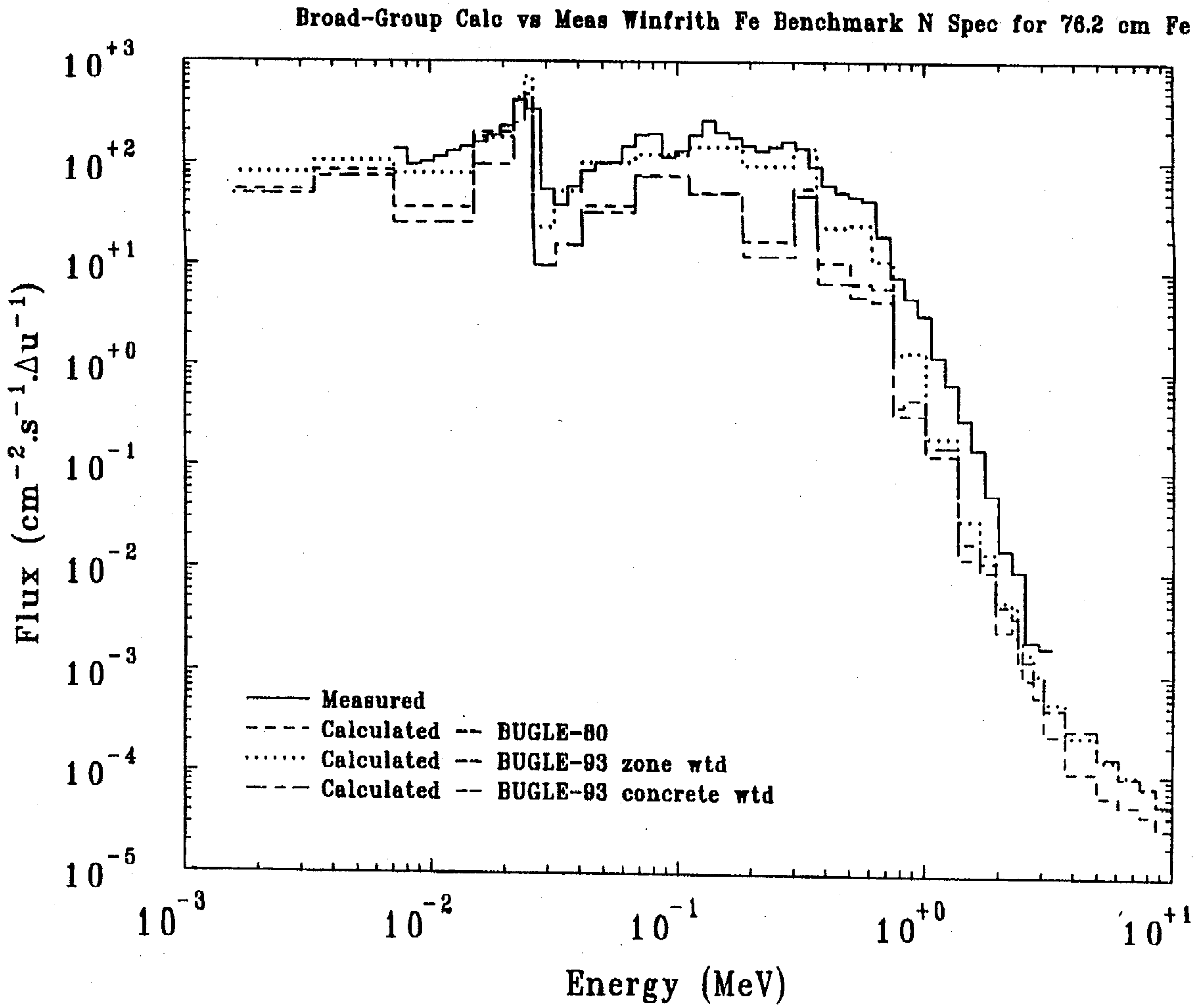


Fig. 4.8 Broad-group calculations compared to measured neutron spectrum for an iron thickness of 76.2 cm in the Winfrith Iron Experiment

Table 4.16 Calculated-to-experiment ratios for integrated neutron flux[a] from Winfrith Iron Benchmark

Cross section set	Iron Thickness (cm) 20.32	50.8	76.2	101.6
BUGLE-80 (concrete weighted)	1.28	0.73	0.46	0.24
BUGLE-93 (concrete weighted)	1.30	0.62	0.34	0.15
BUGLE-93 (spatial weighted)	1.28	0.95	0.80	0.52
VITAMIN-E (standard weighted)	1.09	0.69	0.48	0.29
VITAMIN-B6 (standard weighted)	1.12	0.65	0.42	0.21
VITAMIN-B6 (Fe self-shielded)	1.28	0.98	0.87	0.62

[a] Energy range: 52.5 keV < E < 4.72 MeV at 20.32 cm
7.1 keV < E < 4.72 MeV at 50.8 cm
7.1 keV < E < 3.25 MeV at 76.2 cm
9.1 keV < E < 1.97 MeV at 101.6 cm

Table 4.17 Calculated-to-experiment ratios for dosimeter reactions from Winfrith Iron Benchmark

Cross section set	Iron Thickness (cm)			
	20.32	35.56	50.8	60.96
$^{32}S(n,p)$:				
BUGLE-80 (concrete weighted)	0.88	0.80	0.60	0.51
BUGLE-93 (concrete weighted)	1.06	1.06	0.89	0.79
BUGLE-93 (spatial weighted)	1.06	1.09	0.92	0.84
VITAMIN-E (standard weighted)	0.87	0.79	0.60	0.51
VITAMIN-B6 (standard weighted)	1.04	1.04	0.86	0.76
VITAMIN-B6 (Fe self-shielded)	1.06	1.08	0.91	0.82
	Iron Thickness (cm)			
	20.32	50.8	76.2	101.6
$^{103}Rh(n,n')$:				
BUGLE-80 (concrete weighted)	1.03	0.63	0.27	0.09
BUGLE-93 (concrete weighted)	1.04	0.58	0.23	0.07
BUGLE-93 (spatial weighted)	1.18	1.09	0.73	0.39
VITAMIN-E (standard weighted)	0.93	0.48	0.18	0.05
VITAMIN-B6 (standard weighted)	0.96	0.52	0.20	0.06
VITAMIN-B6 (Fe self-shielded)	1.17	1.11	0.79	0.45
	Iron Thickness (cm)			
	20.32	30.48	45.72	55.88
$^{115}In(n,n')$:				
BUGLE-80 (concrete weighted)	0.86	0.77	0.49	0.37
BUGLE-93 (concrete weighted)	0.91	0.81	0.48	0.34
BUGLE-93 (spatial weighted)	1.00	0.99	0.75	0.65
VITAMIN-E (standard weighted)	0.81	0.68	0.38	0.26
VITAMIN-B6 (standard weighted)	0.87	0.75	0.43	0.31
VITAMIN-B6 (Fe self-shielded)	0.99	0.96	0.71	0.62

calculated $^{115}In(n,n')$ activation shows a greater underprediction than do the $^{103}Rh(n,n')$ results.

4.3.2.2 Winfrith Water Experiment: The Winfrith Water Experiment[35] measured fission neutron transmission through varying thicknesses of iron. The configuration consisted of one, two, four, or eight small ^{252}Cf sources suspended in a water tank at seven distances from the centerline of a voided 7.51-cm-OD, 0.404-cm-thick stainless steel tube. Neutron spectra were measured within the tube at the axial midplane of the sources. Also, $^{32}S(n,p)$ activities were measured along the tube centerline at the source axial midplane and at 15 and 30 cm above and below the midplane.

Two-dimensional calculations were performed using DORT with an R-Z geometry model. The calculational model provided in Ref. 34 was used, which modeled the source as a 1.9-cm-thick by 0.46-cm-high smeared ring centered at the source radius. The initial set of calculations using each of the various cross-section libraries used a P_3 Legendre expansion and a symmetric S_{16} angular quadrature. However, it was observed that the nearly point nature of the source generated ray effects and caused the responses at the axial midplane to be artificially depressed. A recalculation using the BUGLE-80 and BUGLE-93 cross-section libraries and a biased 240-angle quadrature resulted in a substantial improvement in the comparisons, both on and off the axial midplane. Tables 4.18 and 4.19 show comparisons of calculated and measured fast-neutron fluxes and $^{32}S(n,p)$ activities at the radial center of the axial midplane. As mentioned, calculations using the S_{16} quadrature underestimate the integrated flux by 20 to 30%. Using the biased quadrature, the underestimation is reduced to 10-20%. In the case of sulfur activation, the biased quadrature yielded excellent results, overpredicting the measurements by only 0-5%.

Figure 4.9 compares the measured neutron flux with calculations based on BUGLE-80 and BUGLE-93 data and using the biased 240-angle quadrature. In this comparison, the source is at a radius of 30.48 cm. The calculated results appear to underpredict the measured results below 5 MeV and generally overpredict the measurement above 6 MeV. The two data sets are in close agreement, although the BUGLE-93 results appear to be a slight improvement, especially below 5 MeV.

4.3.3 Other Relevant Benchmarks

4.3.3.1 Univ. of Illinois Iron Sphere: Two benchmark experiments were conducted at the University of Illinois using a large sphere of iron.[36-37] The 38.1-cm-radius sphere had a 7.65-cm-radius cavity at the center, in which was placed either an encapsulated californium (^{252}Cf) fission source or a deuterium-tritium (D-T) fusion source. The fast neutron leakage from the 30.5-cm-thick iron shell was measured using a NE-213 proton recoil spectrometer at 200 cm from the center of the sphere. The measured leakage spectrum from the ^{252}Cf source is compared to calculated one-dimensional results in Fig. 4.10 for the fine-group cross sections and Fig. 4.11 for the broad-group cross sections. As shown in Fig.4.10, there is a general improvement using the VITAMIN-B6 library relative to VITAMIN-E for energies above 3 MeV. Similarly, the BUGLE-93 results in Fig. 4.11 show an increase over BUGLE-80 in the calculated flux for energies above 1 MeV, which more closely matches the experimental results. Improvements in the calculated spectra are even more noticeable with the D-T fusion source, as shown in Figs. 4.12 and 4.13.

Table 4.18 Calculated-to-experiment ratios for integral neutron flux (0.9 MeV > E > 10 MeV) for the Winfrith Water Experiment

Source Radius (cm)	Cross-Section Set				
	BUGLE-80[a]	BUGLE-93[a]	VITAMIN-E[a]	VITAMIN-B6[a]	BUGLE-93[b]
10.16	0.80	0.83	0.81	0.83	0.93
15.24	0.69	0.72	0.69	0.72	0.92
20.32	0.68	0.72	0.68	0.71	0.89
25.40	0.67	0.70	0.66	0.70	0.84
30.48	0.69	0.71	0.67	0.71	0.82
35.56	0.73	0.76	0.72	0.75	0.84
50.80	0.78	0.78	0.76	0.78	0.79

[a] With symmetric S_{16} (160 angle) quadrature and P_3 Legendre expansion.
[b] With biased 240-angle quadrature and P_5 Legendre expansion.

Table 4.19 Calculated-to-experiment ratios for $^{32}S(n,p)$ activity for the Winfrith Water Experiment

Source Radius (cm)	Cross-Section Set				
	BUGLE-80[a]	BUGLE-93[a]	VITAMIN-E[a]	VITAMIN-B6[a]	BUGLE-93[b]
10.16	0.82	0.87	0.81	0.86	1.00
15.24	0.65	0.69	0.64	0.68	1.05
25.40	0.69	0.72	0.66	0.70	1.06
30.48	0.71	0.73	0.69	0.72	1.01
35.56	0.75	0.77	0.73	0.75	0.99

[a] With symmetric S_{16} (160 angle) quadrature and P_3 Legendre expansion.
[b] With biased 240-angle quadrature and P_5 Legendre expansion.

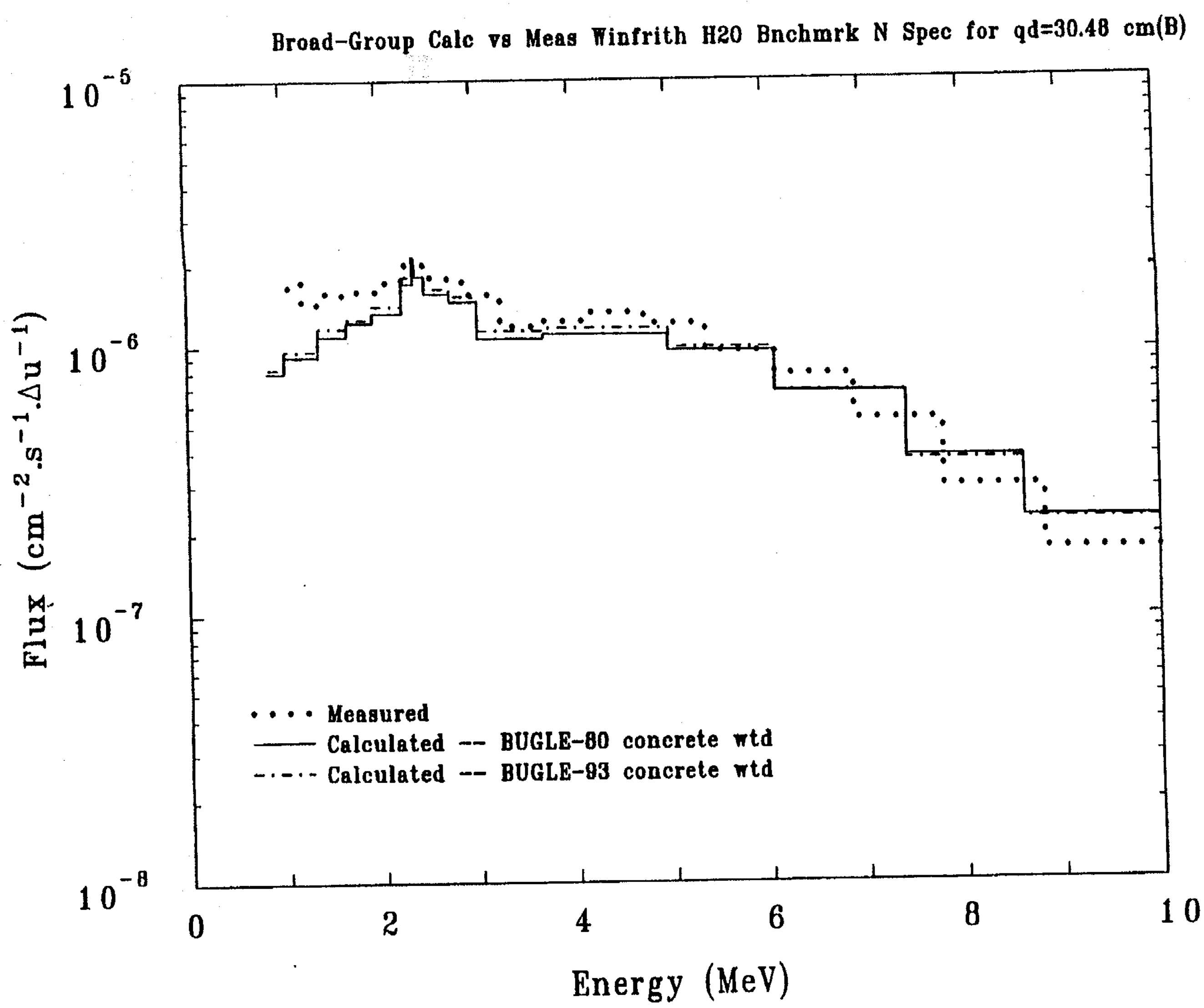


Fig. 4.9 Comparison of broad-group calculated flux spectra and measured flux spectrum due to ^{252}Cf point sources at 30.48 cm radius in the Winfrith Water Experiment.

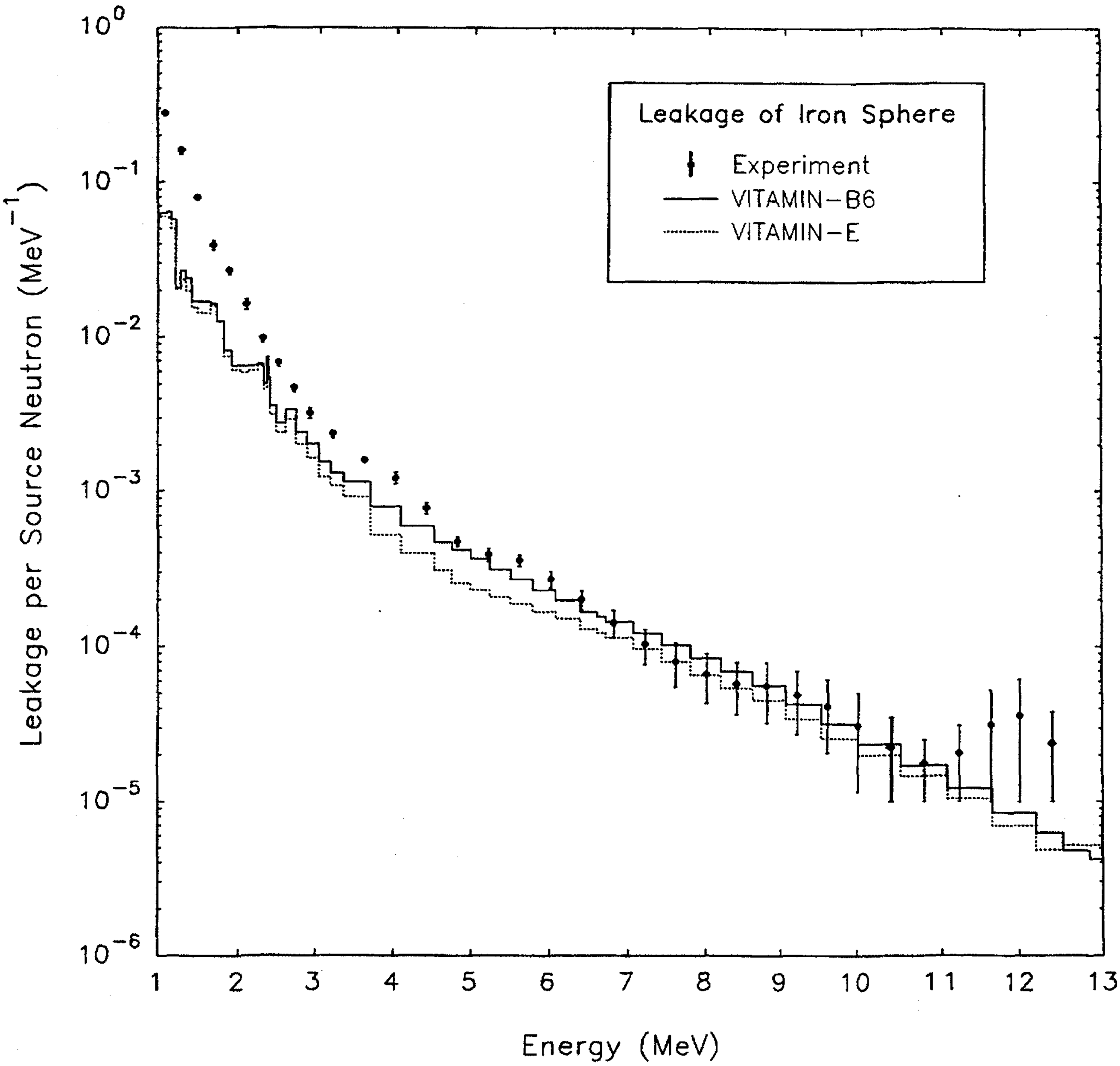


Fig. 4.10 Fine-group calculations compared to measured neutron leakage from ^{252}Cf fission source in the Univ. of Ill. iron sphere

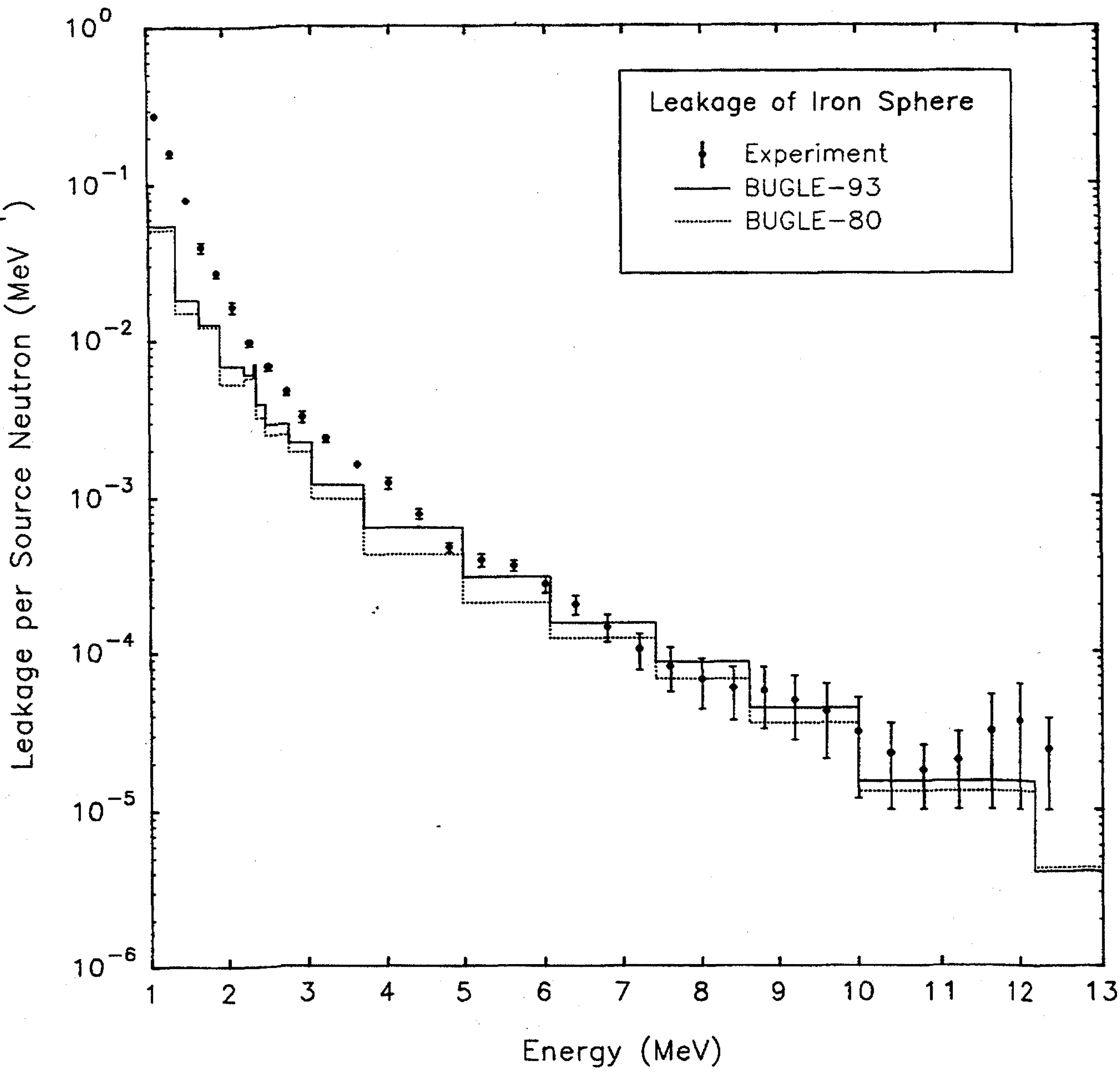


Fig. 4.11 Broad-group calculations compared to measured neutron leakage from ^{252}Cf fission source in the Univ. of Ill. iron sphere

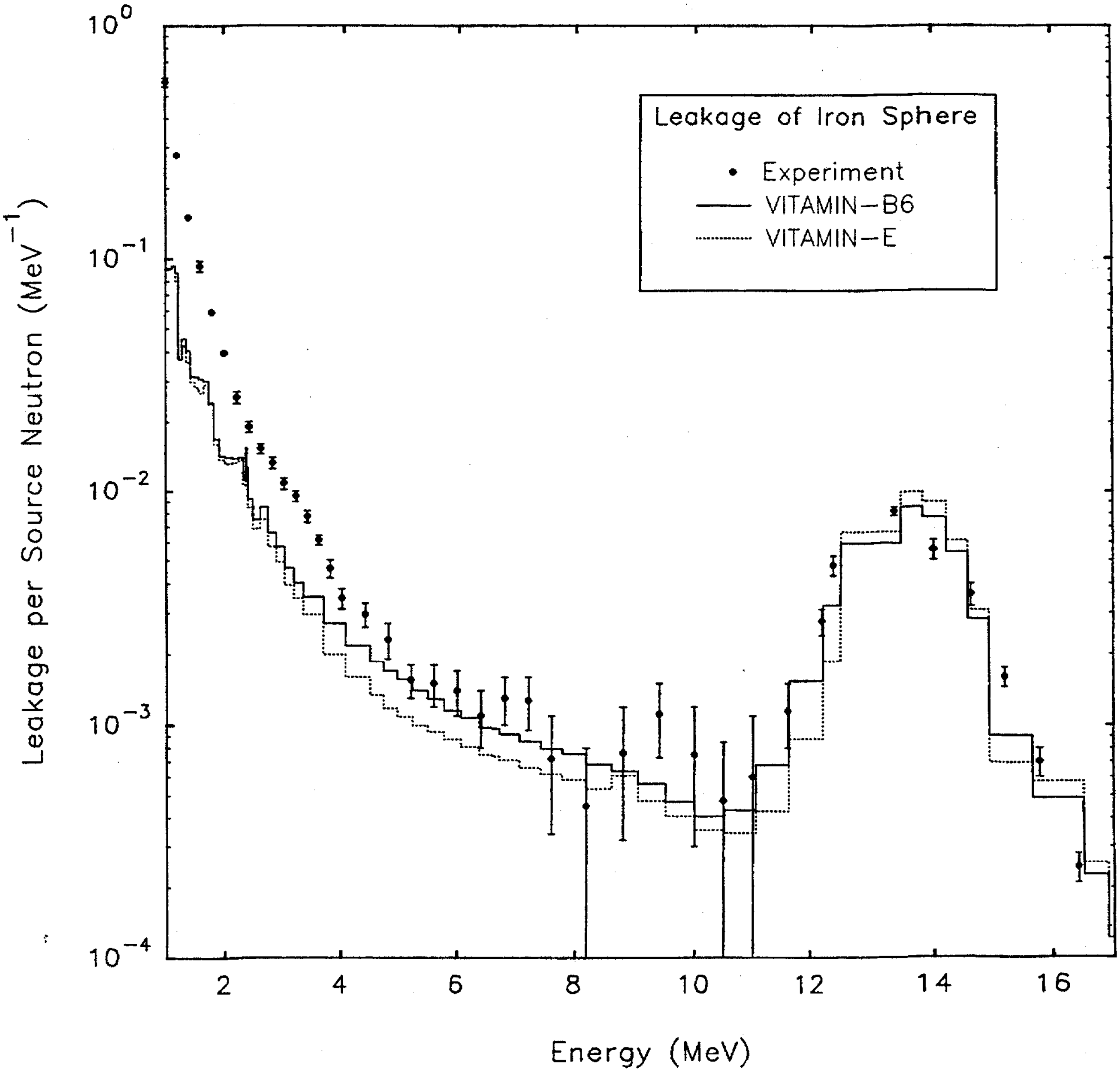


Fig. 4.12 Fine-group calculations compared to measured neutron leakage from D-T fusion source in the Univ. of Ill. iron sphere

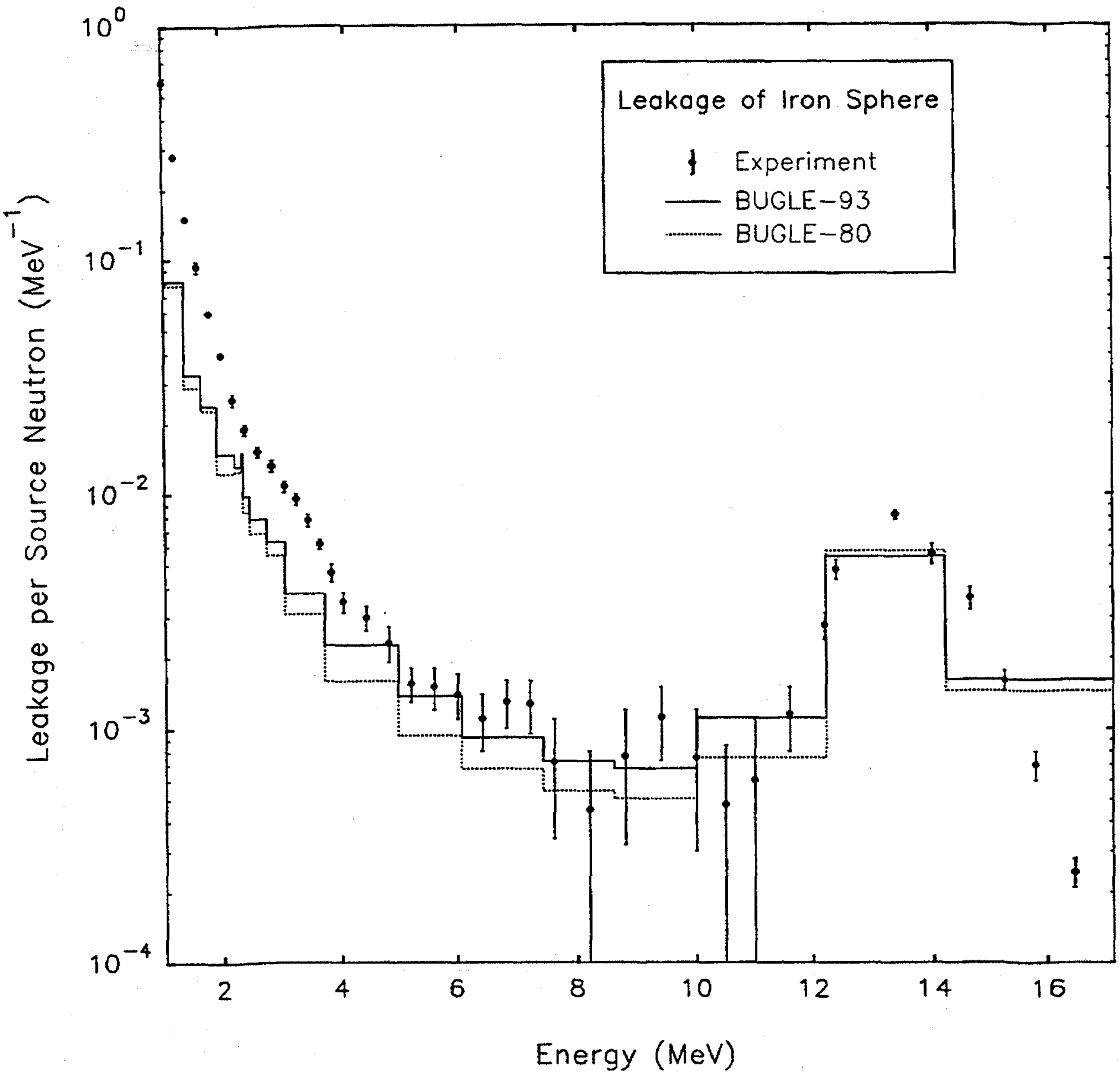


Fig. 4.13 Broad-group calculations compared to measured neutron leakage from D-T fusion source in the Univ. of Ill. iron sphere

4.3.3.2 PCA Blind Test: The Pool Critical Assembly (PCA) Blind Test Benchmark[37] was designed to provide measured data against which shielding methods and data from several international installations could be tested. The benchmark was so named because participants were given only the geometry and source description; calculations were performed without knowledge of the measured data. The geometry represents the radial regions of a typical light water reactor. Several configurations were studied, each being named according to the width (in centimeters) of the water layers preceding and following the thermal shield. Extensive neutron measurements were made for the 8/7 and 12/13 configurations, and gamma-ray measurements were made for the 4/12 configuration.

While the PCA geometry was parallelepipedal, calculations were performed using DORT with a cylindrical geometry model. For the PCA 4/12 configuration, the gamma-ray spectrum at one location and gamma-ray heating at several locations were calculated. Figure 4.14 shows a comparison of the calculated and measured gamma-ray spectra for gamma-ray energies between 0.248 and 2.731 MeV. Ratios of the calculated-to-measured flux integrals range from 0.52 to 0.55, so the results from all libraries are comparable. Energy self-shielding and spatial weighting would likely improve these ratios. Table 4.20 compares calculated and measured gamma-ray heating results. The calculated gamma-ray heating was obtained by using gamma-ray sensitivities for a CaF_2 thermoluminescent dosimeter (TLD). The reported measured results were corrected for neutron contributions to the TLD response. In general, the calculated results agree well with the measured results, the broad-group libraries showing somewhat better agreement. Ratios of gamma-ray heating to the fast-neutron flux at the same locations were also in good agreement with measured values, as shown in Table 4.21. These results are somewhat inconsistent with the fact that the calculated integrals of the gamma-ray flux significantly underpredict the measured integrals.

4.3.4 Conclusions from Shielding Data Testing

The BUGLE-93 and VITAMIN-B6 libraries have been tested using several shielding benchmarks, both experimental and computational. Results were reported for the experimental benchmarks and all show that the new libraries are consistent with previous libraries and in some cases better. Changes to the iron data above 3.0 MeV were observed to improve the prediction of the fast-neutron transmission through thick iron regions. Also, the effect of increasing the iron total cross section near the 24 keV window was observed indirectly. In general, the results showed that for shields containing thick iron regions, problem-specific self-shielded libraries should be used for accurate predictions of neutron transmission through the shield. Also, the potential inadequacy of even the fine-group cross sections in cases where the uncollided flux is dominant was demonstrated. Collectively, the integral testing was invaluable for helping to "shake down" the new libraries and qualify them for use in LWR shielding applications.

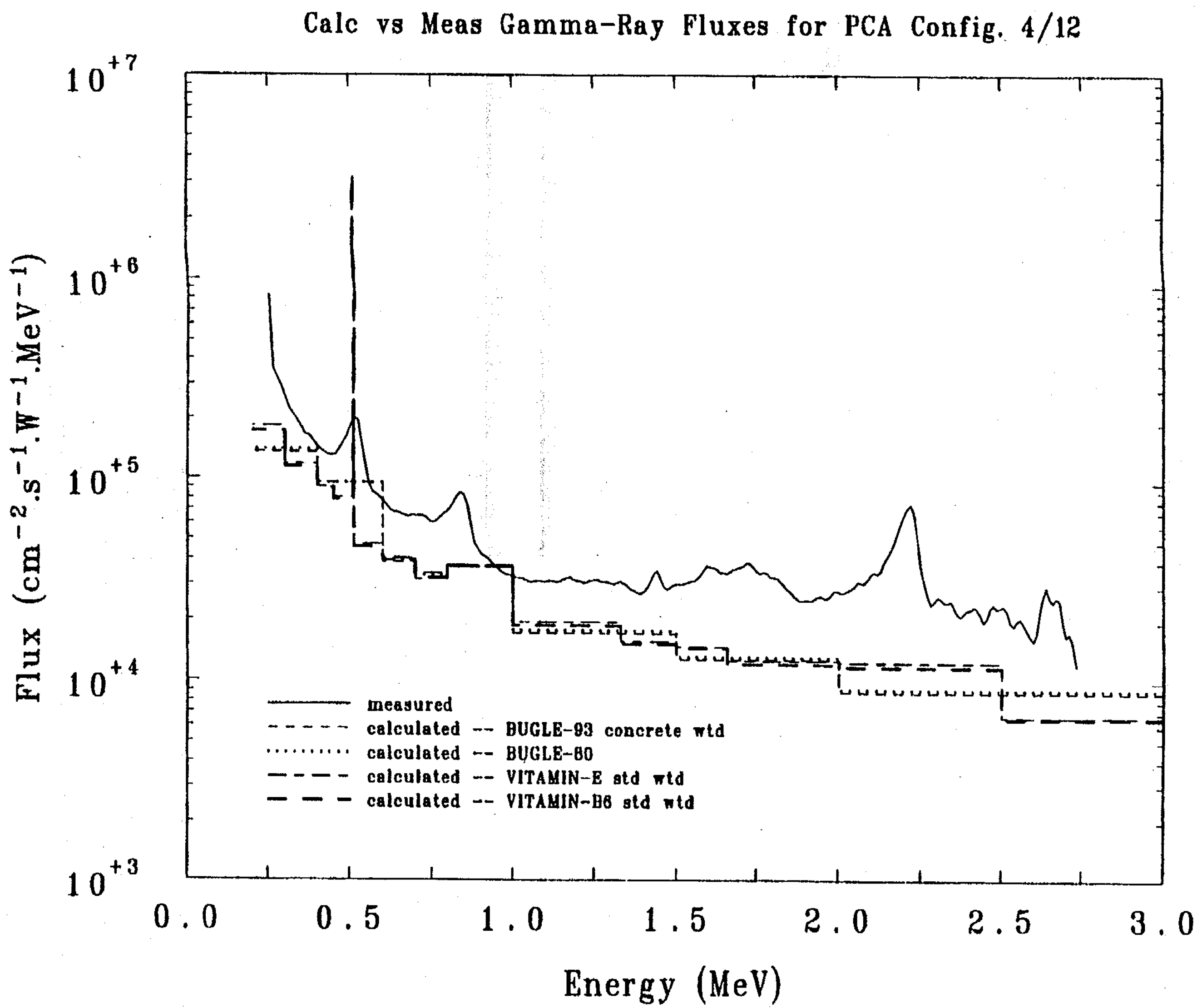


Fig. 4.14 Comparison of measured and calculated gamma-ray spectrum in the PCA Blind Test configuration 4/12

Table 4.20 Calculated-to-experiment ratios for gamma-ray energy deposition in steel from PCA Blind Test configuration 4/12

Location	Cross-Section Set BUGLE-80	BUGLE-93	VITAMIN-E	VITAMIN-B6
SSC[a]	1.02	1.01	1.03	1.02
1/4 PV Thickness	1.08	1.07	1.11	1.11
1/2 PV Thickness	1.03	1.03	1.06	1.06
3/4 PV Thickness	1.00	1.02	1.04	1.03

[a] Simulated surveillance capsule preceding PV mockup.

Table 4.21 Calculated-to-experiment ratios for ratio of gamma-ray energy deposition in steel to neutron equivalent fission fluxes from PCA Blind Test configuration 4/12

Location	Cross-Section Set BUGLE-80	BUGLE-93	VITAMIN-E	VITAMIN-B6
SSC[a]	0.89	0.84	0.85	0.86
1/4 PV Thickness	1.09	0.96	0.98	1.01
1/2 PV Thickness	1.12	0.94	0.96	1.00
3/4 PV Thickness	1.10	0.92	0.91	0.95

[a] Simulated surveillance capsule preceding PV mockup.

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APPENDIX A

INPUT LISTINGS FOR KEY PROCESSING STEPS

Table A.1   Sample NJOY Processing Job For Generating Neutron PENDF File

```
echo 'getting endf tape for u235'
rm tape21
echo 'running njoy'
cat>input <<EOF
 0
 6/
 *reconr*
  21 22
 *pendf tape for u-235, mat 9228, mod1 evaluation*/
 9228 3 0
 .002 0. 7 /
 *u-235, mod1 evaluation*/
 *processed by the njoy system*/
 *r.q. wright,  9-28-93*/
 0/
 *broadr*
 22 23
 9228 4 0 1 0.0
 .002/
 300. 600. 1000. 2100.
 0/
 *heatr*
 21 23 24
 9228/
 *unresr*
 21 24 25
 9228 4 7 1
 300. 600. 1000. 2100.
 1.e10 1.e6 1.e5 1.e4 1.e3 100. 50.
 0/
 *thermr*
 0 25 26
 0 9228 8 4 1 0 1 221 0
 300. 600. 1000. 2100.
 .01 5.0435
 *stop*
EOF
xnjoy94m<input
echo 'njoy run is finished'
```

Table A.2 Sample NJOY Processing Job For Generating Neutron GENDF File

```
echo 'getting endf  tape'
rm tape21
rm tape23
echo 'running njoy'
cat>input <<EOF
 0
 6/
 *groupr*
  21  23  0  24
  9228 1 1 4 5 4 7 1
 *  u-235  mod1  evaluation, mat 9228*/
 300. 600. 1000. 2100.
 1.e10  1.e6 1.e5 1.e4 1.e3 1.e2  50.
 199
 1.0000e-05 5.0000e-04 2.0000e-03 5.0000e-03 1.0000e-02 1.4500e-02
 2.1000e-02 3.0000e-02 4.0000e-02 5.0000e-02 7.0000e-02 1.0000e-01
 1.2500e-01 1.5000e-01 1.8400e-01 2.2500e-01 2.7500e-01 3.2500e-01
 3.6680e-01 4.1399e-01 5.0000e-01 5.3158e-01 6.2506e-01 6.8256e-01
 8.0000e-01 8.7643e-01
 1.0000e+00 1.0400e+00 1.0800e+00 1.1253e+00 1.3000e+00 1.4450e+00
 1.8554e+00 2.3824e+00 3.0590e+00 3.9279e+00 5.0435e+00 6.4760e+00
 8.3153e+00 1.0677e+01 1.3710e+01 1.7604e+01 2.2603e+01 2.9023e+01
 3.7266e+01 4.7851e+01 6.1442e+01 7.8893e+01 1.0130e+02 1.3007e+02
 1.6702e+02 2.1445e+02 2.7536e+02 3.5357e+02 4.5400e+02 5.8295e+02
 7.4852e+02 9.6112e+02 1.2341e+03 1.5846e+03 2.0347e+03 2.2487e+03
 2.4852e+03 2.6126e+03 2.7465e+03 3.0354e+03 3.3546e+03 3.7074e+03
 4.3074e+03 5.5308e+03 7.1017e+03 9.1188e+03 1.0595e+04 1.1709e+04
 1.5034e+04 1.9305e+04 2.1875e+04 2.3579e+04 2.4176e+04 2.4788e+04
 2.6058e+04 2.7000e+04 2.8501e+04 3.1828e+04 3.4307e+04 4.0868e+04
 4.6309e+04 5.2475e+04 5.6562e+04 6.7379e+04 7.1998e+04 7.9499e+04
 8.2503e+04 8.6517e+04 9.8037e+04 1.1109e+05 1.1679e+05 1.2277e+05
 1.2907e+05 1.3569e+05 1.4264e+05 1.4996e+05 1.5764e+05 1.6573e+05
 1.7422e+05 1.8316e+05 1.9255e+05 2.0242e+05 2.1280e+05 2.2371e+05
 2.3518e+05 2.4724e+05 2.7324e+05 2.8725e+05 2.9452e+05 2.9721e+05
 2.9849e+05 3.0197e+05 3.3373e+05 3.6883e+05 3.8774e+05 4.0762e+05
 4.5049e+05 4.9787e+05 5.2340e+05 5.5023e+05 5.7844e+05 6.0810e+05
 6.3928e+05 6.7206e+05 7.0651e+05 7.4274e+05 7.8082e+05 8.2085e+05
 8.6294e+05 9.0718e+05 9.6164e+05 1.0026e+06 1.1080e+06 1.1648e+06
 1.2246e+06 1.2874e+06 1.3534e+06 1.4227e+06 1.4957e+06 1.5724e+06
 1.6530e+06 1.7377e+06 1.8268e+06 1.9205e+06 2.0190e+06 2.1225e+06
 2.2313e+06 2.3069e+06 2.3457e+06 2.3653e+06 2.3852e+06 2.4660e+06
 2.5924e+06 2.7253e+06 2.8651e+06 3.0119e+06 3.1664e+06 3.3287e+06
 3.6788e+06 4.0657e+06 4.4933e+06 4.7237e+06 4.9659e+06 5.2205e+06
 5.4881e+06 5.7695e+06 6.0653e+06 6.3763e+06 6.5924e+06 6.7032e+06
 7.0469e+06 7.4082e+06 7.7880e+06 8.1873e+06 8.6071e+06 9.0484e+06
 9.5123e+06 1.0000e+07 1.0513e+07 1.1052e+07 1.1618e+07 1.2214e+07
```

```
1.2523e+07 1.2840e+07 1.3499e+07 1.3840e+07 1.4191e+07 1.4550e+07
1.4918e+07 1.5683e+07 1.6487e+07 1.6905e+07 1.7332e+07 1.9640e+07
42
1.0000e+03 1.0000e+04 2.0000e+04 3.0000e+04 4.0000e+04 4.5000e+04
6.0000e+04 7.0000e+04 7.5000e+04 1.0000e+05 1.5000e+05 2.0000e+05
3.0000e+05 4.0000e+05 4.5000e+05 5.1000e+05 5.1200e+05 6.0000e+05
7.0000e+05 8.0000e+05 1.0000e+06 1.3300e+06 1.3400e+06 1.5000e+06
1.6600e+06 2.0000e+06 2.5000e+06 3.0000e+06 3.5000e+06 4.0000e+06
4.5000e+06 5.0000e+06 5.5000e+06 6.0000e+06 6.5000e+06 7.0000e+06
7.5000e+06 8.0000e+06 1.0000e+07 1.2000e+07 1.4000e+07 2.0000e+07
3.0000e+07
0.125 0.025 8.2085e+5 1.2730e+6
3/
3 221 *thrsct*/
3 251 *mubar*/
3 252 *xi*/
3 253 *gamma*/
3 452 *nubar*/
6/
6 18 *fission*/
6 221 *thrsct*/
16/
0/
3 1 *total*/
3 2 *elastic*/
3 18 *fission*/
3 102 *capture*/
6 221 *thrsct*/
0/
3 1 *total*/
3 2 *elastic*/
3 18 *fission*/
3 102 *capture*/
6 221 *thrsct*/
0/
3 1 *total*/
3 2 *elastic*/
3 18 *fission*/
3 102 *capture*/
6 221 *thrsct*/
0/
0/
*stop*
EOF
xnjoy94m<input
echo 'njoy run completed'
```

Table A.3 Sample NJOY Processing Job For Generating Gamma-Ray GENDF File.

```
echo 'running njoy'
cat>input <<EOF
 0
 6
 *reconr*
 20 21
 *gendf tape - photon interaction cross sections from t706*/
 9200 1 0
 .001/
 *92-uranium*/
 0/
 *gaminr*
 20 21 0 23
 9200 1 3 5 1
 *42 group photon interaction library*/
 42
 1.0e+3 1.0e+4 2.0e+4 3.0e+4 4.0e+4 4.5e+4 6.0e+4 7.0e+4 7.5e+4 1.0e+5
 1.50e+5 2.00e+5 3.00e+5 4.00e+5 4.50e+5 5.10e+5 5.12e+5 6.00e+5
 7.00e+5 8.00e+5 1.00e+6
 1.33e+6 1.34e+6 1.50e+6 1.66e+6 2.00e+6 2.50e+6 3.00e+6 3.50e+6
 4.00e+6 4.50e+6 5.00e+6 5.50e+6 6.00e+6 6.50e+6 7.00e+6 7.50e+6
 8.00e+6 1.00e+7 1.20e+7 1.40e+7 2.00e+7 3.00e+7
 -1 0/
 0/
 *stop*
EOF
xnjoy93m<input
echo 'njoy run completed'
```

Table A.4 Sample SMILER Processing Job For Converting From GENDF Format to AMPX Master Format

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA    ) ) setenv SCA   /rsic/jib/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#smiler
-1$$ 450000 e
0$$ 75 70 0 71  e
1$$ 92235 e   6$$ 900 2000 t
 u235    v94.10 standard wgt e649228vb60003092095
end
#rade
-1$$ 450000 e
1$$ 75 e  2$$ a2 100 1 e t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi          scampi
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade            rade
if ( ! ( -e smiler ) )   ln -s $PGM_DIR/smiler          smiler
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft70f001 ) ) ln -s /u2/jew/gendf/u235.g              ft70f001
if ( ! ( -e ft71f001 ) ) ln -s /u2/jew/b6gam/u.gg93m            ft71f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft75f001 /u2/jew/b6ampx/ampx.u235
```

Table A.5 Processing Job For Generating Self-Shielded BWR/PWR Nuclides

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA ) ) setenv SCA /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
' get data needed for collapsing off of the master tape
0$$ 65 60 e       1$$ 1 t
2$$ 60 27 t
3$$ 1001 5010 8016 24050 24052 24053 24054 26054 26056 26057 26058
    28058 28060 28061 28062 28064 40000 92235 92238 25055 6012
    11023 12000 13027 14000 19000 20000
  t
end
#bonami
'     pwr fuel cell from resar..westinghouse plant              Feb '96
0$$ 65 0 18 81
1$$ 2 3 20 1 1 2  2** 0.001 1.0 t
3$$ 3r3 14r2 3r1
4$$ 1001 5010 8016 24050 24052 24053 24054 26054 26056 26057 26058
    28058 28060 28061 28062 28064 40000 92235 92238 8016
5** 4.714-2 4.2-6 2.357-2
   3.3196-6 6.40156-5 7.258-6 1.8069-6 8.555-6 1.32994-4 3.045-6 4.06-7
   5.98728-4 2.28897-4 9.91-6 3.1484-5 7.981-6 4.27-2
   6.325-4 2.166-2 4.465-2
6$$ 1 2 3
7** 0.41783 0.47498 0.71079
8** 921 672 583
10$$ 100113 501013 801613 2405012 2405212 2405312 2405412
 2605412 2605612 2605712 2605812 2805812 2806012 2806112
 2806212 2806412 4000012 9223511 9223811 801611
11$$ 0 1 1  t
end
#bonami
'    bwr fuel cell from gesar 238 general electric              Feb '96
0$$ 65 0 18 82
1$$ 2 3 19 1 1 2  2** 0.001 1.0 t
3$$ 2r3 14r2 3r1
4$$ 1001 8016 24050 24052 24053 24054 26054 26056 26057 26058
    28058 28060 28061 28062 28064 40000 92235 92238 8016
```

```
5** 2.475-2 1.2375-2
   3.3196-6 6.40156-5 7.258-6 1.8069-6 8.555-6 1.32994-4 3.045-6 4.06-7
   5.98728-4 2.28897-4 9.91-6 3.1484-5 7.981-6 4.27-2
   4.959-4 2.177-2 4.455-2
6$$ 1 2 3
7** 0.53213 0.6134 0.9174
8** 921 672 551
10$$ 100123 801623 2405022 2405222 2405322 2405422 2605422
 2605622 2605722 2605822 2805822 2806022 2806122 2806222
 2806422 4000022 9223521 9223821 801621
11$$ 0 1 1  t
end
#bonami
'    infinite medium collapse for iron-water mixture          Feb '96
0$$ 65 0 18 83
1$$ 0 1 16 1 1 0 t
3$$ f1
4$$ 1001 8016 24050 24052 24053 24054 26054 26056 26057 26058
    28058 28060 28061 28062 28064 25055
5** 1.1785-2 5.8925-3
    5.67-4 1.09346-2 1.2398-3 3.086-4 2.5798-3 4.01046-2 9.182-4
    1.224-4 4.3778-3 1.67366-3 7.246-5 2.3021-4 5.835-5 1.14-3
6$$ 1
7** 10.0
8** 590.
10$$ 100131 801631 2405031 2405231 2405331 2405431 2605431
  2605631 2605731 2605831 2805831 2806031 2806131 2806231
  2806431 2505531
11$$ 1 t
end
#bonami
'    infinite medium collapse for concrete type 04            Feb '96
0$$ 65 0 18 84
1$$ 0 1 13 1 1 0 t
3$$ f1
4$$ 1001 8016 26054 26056 26057 26058 6012 11023 12000 13027 14000
    19000 20000
5** 8.6-3 4.33-2
    2.0355-5 3.16434-4 7.245-6 9.66-7
    1.15-4 9.64-4 1.24-4 1.74-4 1.66-3 4.6-4 1.5-3
6$$ 1
7** 100.0
8** 300.0
10$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041
11$$ 1 t
end
```

```
#bonami
' self-shield carbon steel (1) & stainless steel (2)          Feb '96
0$$   65 0  18  85 e
1$$   1  2 30  2r0   0
2**   0.001  0.0         t
3$$   15r1 15r2
4$$ 26054 26056 26057 26058 24050 24052 24053 24054 28058 28060
    28061 28062 28064 25055 6012
    26054 26056 26057 26058 24050 24052 24053 24054 28058 28060
    28061 28062 28064 25055 6012
5**   4.75-3 7.518-2 1.72-3 2.457-4
      5.518-6 1.06413-4 1.2065-5 3.004-6
      3.03119-4 1.15884-4 5.017-6 1.594-5 4.04-6   1.12-3 9.81-4
      3.381-3 5.352-2 1.224-3 1.749-4
      7.56-4 1.45795-2 1.653-3 4.115-4
      5.83709-3 2.23155-3 9.662-5 3.0695-4 7.781-5  1.52-3 2.37-4
6$$   1  2
7**    10.0 20.0
8**   f600.0              9**   f0.0
10$$  2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
      2805851 2806051 2806151 2806251 2806451 2505551 601251
      2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
      2805852 2806052 2806152 2806252 2806452 2505552 601252
11$$ 1 t
end
#ajax
0$$ 75 81 e  1$$ 5 t
2$$ 81 20 t
3$$ 100113 501013 801613 2405012 2405212 2405312 2405412
 2605412 2605612 2605712 2605812 2805812 2806012 2806112
 2806212 2806412 4000012 9223511 9223811 801611  t
2$$ 82 19 t
3$$ 100123 801623 2405022 2405222 2405322 2405422 2605422
 2605622 2605722 2605822 2805822 2806022 2806122 2806222
 2806422 4000022 9223521 9223821 801621  t
2$$ 83 16 t
3$$ 100131 801631 2405031 2405231 2405331 2405431 2605431
  2605631 2605731 2605831 2805831 2806031 2806131 2806231
  2806431 2505531 t
2$$ 84 13 t
3$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041  t
2$$ 85 30 t
3$$   2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
      2805851 2806051 2806151 2806251 2806451 2505551 601251
      2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
      2805852 2806052 2806152 2806252 2806452 2505552 601252  t
end
```

```
#nitawl
' xsdrn library will be produced on unit 76                    Feb '96
0$$   75 a4 76   e     1$$ a2 98 a11 -1 e t
2$$ 100113 501013 801613 2405012 2405212 2405312 2405412
    2605412 2605612 2605712 2605812 2805812 2806012 2806112
    2806212 2806412 4000012 9223511 9223811 801611
    100123 801623 2405022 2405222 2405322 2405422 2605422
    2605622 2605722 2605822 2805822 2806022 2806122 2806222
    2806422 4000022 9223521 9223821 801621
    100131 801631 2405031 2405231 2405331 2405431 2605431
    2605631 2605731 2605831 2805831 2806031 2806131 2806231
    2806431 2505531
    100141 801641 2605441 2605641 2605741 2605841 601241 1102341
    1200041 1302741 1400041 1900041 2000041
    2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
    2805851 2806051 2806151 2806251 2806451 2505551 601251
    2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
    2805852 2806052 2806152 2806252 2806452 2505552 601252
4** 17r600. 3r1000. 16r600. 3r1000. 16r600. 13r300. 30r600. t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scale ) )    ln -s $PGM_DIR/scampi         scampi
if ( ! ( -e bonami ) )   ln -s $PGM_DIR/bonami         bonami
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl         nitawl
if ( ! ( -e xsdrn ) )    ln -s $PGM_DIR/xsdrn          xsdrn
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax           ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft60f001 ) ) ln -s /rsic/data/lmplib/vitaminb6.r3   ft60f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv $tmpdir/ft75f001 /u5/jew/bug96/ampx.vitb6r3.bonami
mv $tmpdir/ft76f001 /u5/jew/bug96/xsdrn.wklib.vb6r3
```

Table A.6   Processing Job For Calculating BWR Weighting Spectrum

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA ) ) setenv SCA /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR  $SCA/bin
cat >input <<'EOF'
#xsdrnpm
epri np-152  bwr case  3579 mwt gesar 238" core midplane 50% void Feb '96
-1$$ 2000000
1$$  2  7   154  1   0
     5  57  8  3  0
    40 100  0  0  3
2$$ -2  33  0 3z -1 1  e
3$$  1  1  0  0  0
     0  0  1  0  0
     0  0
4$$  0  67  41  -2  3
     4  70  -1  0
5**  0.00001  0.00001  7.46419+17  2z
     1.420892   4z
     0.001   0.75   t
13$$    10r1     2r2      16r3  16r4      13r5
'    fuel      water    ss304  a533b    concrete
14$$ 100123 801623 4000022 2605422 2605622 2605722 2605822
      9223521 9223821 801621
     100123 801631
     601252 1400041 2405052 2405252 2405352 2405452 2505552
      2605452 2605652 2605752 2605852 2805852 2806052 2806152
      2806252 2806452
     601251 1400041 2405051 2405251 2405351 2405451 2505551
      2605451 2605651 2605751 2605851 2805851 2806051 2806151
      2806251 2806451
     100141 601241 801641 1102341 1200041 1302741 1400041
      1900041 2000041 2605441 2605641 2605741 2605841
15** 1.5354-2 7.677-3  5.7645-3
     1.1818-6 1.83715-5  4.206-7  5.61-8
     1.2125-4 5.322-3 1.0884-2
     4.950-2            2.475-2 2.37-4  8.93-4
     7.5603-4 1.457946-2 1.653-3 4.1151-4 1.52-3
     3.4397-3 5.347276-2 1.2243-3 1.6324-4
     5.837085-3 2.23155-3 9.6615-5 3.06945-4 7.7805-5
     9.81-4  3.71-4
```

```
     5.51815-6 1.064133-4 1.2065-5 3.00355-6 1.12-3
     4.832094-3 7.5118588-2 1.719898-3 2.2932-4
     3.031188-4 1.15884-4 5.0172-6 1.59396-5 4.0404-6
     7.77-3  1.15-4  4.38-2 1.05-3 1.48-4 2.39-3 1.58-2 6.93-4 2.92-3
     1.8467-5 2.870836-4 6.573-6 8.764-7
     t
30$$  64r1  f0
'  lwr source spectrum for 199-group structure
31**
944991-14 408572-11 410082-11 1407-8 2346-8 1676-8 212-7 2669-8 3318-8     1   1
9212-8 689696-10 689304-10 2022-7 2892-7 4059-7 5583-7 7525-7 9963-7       1   2
1297-6 166-5 2092-6 2597-6 3179-6 3839-6 144-5 3137-6 539-5 6274-6         1   3
7224-6 8229-6 9282-6 1037-5 1148-5 2632-5 3072-5 3482-5 188-4 1965-5       1   4
203858-7 210743-7 2164-5 2212-5 1496-5 3787-6 3769-6 758-5 1523-5 23-3     1   5
231-4 2312-5 2306-5 229-4 2266-5 2237-5 2202-5 2162-5 2111-5 20628-6       1   6
200921-7 1953-5 189-4 3591-5 1422-5 1912-5 1568-5 1503-5 1438-5 1373-5     1   7
131-4 1248-5 1188-5 1128-5 1071-5 1015-5 9643-6 9099-6 1672-5 1488-5       1   8
6804-6 6405-6 1168-5 1031-5 111318-8 408612-9 857096-9 2305-6 4395-6       1   9
7978-6 3614-6 3382-6 3164-6 296-5 2765-6 2584-6 2417-6 2253-6 2107-6       1  10
1962-6 1834-6 1708-6 1595-6 1487-6 1383-6 1291-6 2853-6 2386-6 800687-9    1  11
588195-9 142617-8 846046-9 1879-6 6696-7 9652-7 8036-7 9037-7 3215-7       1  12
412869-9 179031-9 11-5 1452-7 6873-8 6624-8 1846-7 2654-7 4036-7 2781-7    1  13
766153-10 114985-9 1319-7 9077-8 6245-8 2768-8 1528-8 1316-8 1132-8        1  14
5056-9 4693-9 8395-9 7227-9 1397-8 9602-9 6601-9 4538-9 3119-9 2144-9      1  15
147411-11 101289-11 6962-10 4784-10 329-9 226-9 1553-10 1067-10 7339-11    1  16
504437-13 345483-13 23938-12 163763-13 112537-13 7737-12 5317-12 3654-12   1  17
2512-12 1727-12 1186-12 813315-15 562685-15 385-12 112103-15 152962-15     1  18
299068-16 274697-16 285471-16 960036-16 45626-15 793822-16 302382-16       1  19
556619-16 144778-16 446222-16 97115-16 970882-17 13405-15 161026-16        1  20
161422-16 163938-16 146302-16 179059-16 596373-18 562593-18 373104-18      1  21
481014-18 596373-18 619278-18 621267-18 115897-17 153207-17 231793-17      1  22
654104-17                 f0                                               1  23
  t
33** f0
  t
35** 49i 0 3i 200 4i 210  4i  225  14i   235.15  2i  253.75
    19i  258.83  25i  302.26 317.5 8i 318 345 4i 347.22  9i 357 390
36$$ 64r1 15r2 3r3 20r4 26r5 11r6 15r7
38**  128r1  11r  1.0-10  f1
39$$  1 2 3 2 4 2 5
40$$   f3
51$$
 0 6r1 5r2 4r3 3r4 3r5 5r6 4r7 4r8 3r9 2r10 2r11 2r12 13 2r14 3r15
 3r16 4r17 5r18 4r19 2r20 4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28
 2r29 3r30 2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40 5r41
 3r42 4r43 7r44 6r45 8r46 11r47 2z 2r48 49 2r50 2r51 2r52 2r53 2r54
 2r55 2r56 3r57 58 59 60 4r61 2r62 2r63 3r64 3r65 66 67 0
  t
end
'EOF'
```

```
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi           scampi
if ( ! ( -e bonami ) )   ln -s $PGM_DIR/bonami           bonami
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl           nitawl
if ( ! ( -e xsdrn ) )    ln -s $PGM_DIR/xsdrn            xsdrn
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax             ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                 qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                 aliases
if ( ! ( -e ft04f001 ) ) ln -s /u5/jew/bug96/xsdrn.wklib.vb6r3  ft04f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv $tmpdir/ft33f001 /u5/jew/bug96/xsdrn.scalar.bwr
mv $tmpdir/ft03f001 /u5/jew/bug96/ft03wk.bwr
```

Table A.7 Processing Job For Calculating PWR Weighting Spectra

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA ) ) setenv SCA /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR  $SCA/bin
cat >input <<'EOF'
#xsdrnpm
 epri  np-152 pwr problem no pads 3425 mwt flat power dist. Feb '96
-1$$ 2000000
1$$  2  8  119  1  0
     5  59  8  3  0
    40 100  0  0  3
2$$ -2  33  0 3z -1 1  e
3$$  1  1  0  0  0
     0  0  1  0  0
     0  0
4$$  0  67  41  -2  3
     4  70  -1  0
5**  0.00001  0.00001  7.2676e+17  2z
     1.420892   4z
     0.001   0.75   t
13$$    11r1     3r2      16r3   16r4      13r5
'    fuel     water     ss304  a533b    concrete
14$$ 100113 501013 801613 4000012 2605412 2605612 2605712 2605812
     9223511 9223811 801611
     100113 501013 801631
     601252 1400041 2405052 2405252 2405352 2405452 2505552
      2605452 2605652 2605752 2605852 2805852 2806052 2806152
      2806252 2806452
     601251 1400041 2405051 2405251 2405351 2405451 2505551
      2605451 2605651 2605751 2605851 2805851 2806051 2806151
      2806251 2806451
     100141 601241 801641 1102341 1200041 1302741 1400041
      1900041 2000041 2605441 2605641 2605741 2605841
15** 2.768-2  2.466-6  1.384-2  4.257-3
     8.5196-7 1.3244368-5 3.0324-7 4.0432-8
     1.903-4  6.515-3 1.343-2
     4.714-2  4.200-6  2.357-2 2.37-4  8.93-4
     7.5603-4 1.457946-2 1.653-3 4.1151-4 1.52-3
     3.4397-3 5.347276-2 1.2243-3 1.6324-4
     5.837085-3 2.23155-3 9.6615-5 3.06945-4 7.7805-5
     9.81-4  3.71-4
     5.51815-6 1.064133-4 1.2065-5 3.00355-6 1.12-3
     4.832094-3 7.5118588-2 1.719898-3 2.2932-4
```

```
     3.031188-4 1.15884-4 5.0172-6 1.59396-5 4.0404-6
     7.77-3  1.15-4  4.38-2 1.05-3 1.48-4 2.39-3 1.58-2 6.93-4 2.92-3
     1.8467-5 2.870836-4 6.573-6 8.764-7
     t
30$$  46r1  f0
'  pwr source spectrum for 199-group structure
31**
944991-14 408572-11 410082-11 1407-8 2346-8 1676-8 212-7 2669-8 3318-8       1   1
9212-8 689696-10 689304-10 2022-7 2892-7 4059-7 5583-7 7525-7 9963-7         1   2
1297-6 166-5 2092-6 2597-6 3179-6 3839-6 144-5 3137-6 539-5 6274-6           1   3
7224-6 8229-6 9282-6 1037-5 1148-5 2632-5 3072-5 3482-5 188-4 1965-5         1   4
203858-7 210743-7 2164-5 2212-5 1496-5 3787-6 3769-6 758-5 1523-5 23-3       1   5
231-4 2312-5 2306-5 229-4 2266-5 2237-5 2202-5 2162-5 2111-5 20628-6         1   6
200921-7 1953-5 189-4 3591-5 1422-5 1912-5 1568-5 1503-5 1438-5 1373-5       1   7
131-4 1248-5 1188-5 1128-5 1071-5 1015-5 9643-6 9099-6 1672-5 1488-5         1   8
6804-6 6405-6 1168-5 1031-5 111318-8 408612-9 857096-9 2305-6 4395-6         1   9
7978-6 3614-6 3382-6 3164-6 296-5 2765-6 2584-6 2417-6 2253-6 2107-6         1  10
1962-6 1834-6 1708-6 1595-6 1487-6 1383-6 1291-6 2853-6 2386-6 800687-9      1  11
588195-9 142617-8 846046-9 1879-6 6696-7 9652-7 8036-7 9037-7 3215-7         1  12
412869-9 179031-9 11-5 1452-7 6873-8 6624-8 1846-7 2654-7 4036-7 2781-7      1  13
766153-10 114985-9 1319-7 9077-8 6245-8 2768-8 1528-8 1316-8 1132-8          1  14
5056-9 4693-9 8395-9 7227-9 1397-8 9602-9 6601-9 4538-9 3119-9 2144-9        1  15
147411-11 101289-11 6962-10 4784-10 329-9 226-9 1553-10 1067-10 7339-11      1  16
504437-13 345483-13 23938-12 163763-13 112537-13 7737-12 5317-12 3654-12     1  17
2512-12 1727-12 1186-12 813315-15 562685-15 385-12 112103-15 152962-15       1  18
299068-16 274697-16 285471-16 960036-16 45626-15 793822-16 302382-16         1  19
556619-16 144778-16 446222-16 97115-16 970882-17 13405-15 161026-16          1  20
161422-16 163938-16 146302-16 179059-16 596373-18 562593-18 373104-18        1  21
481014-18 596373-18 619278-18 621267-18 115897-17 153207-17 231793-17        1  22
654104-17                f0                                                  1  23
  t
33** f0
  t
35**  29i 0  9i  120  5i  151.66  2i  168.51  7i  171.40
  4i 187.96  4i 193.68  9i 200.66  14i 219.71  241.62
    4i242  259.5  8i 260  10i 275  300
36$$ 46r1  3r2  8r3  5r4  15r5  15r6  7r7  20r8
38**  92r  1  7r  1.0-10  f1
39$$   1  3  2  3  2  4  2  5
40$$     f3
51$$
 0 6r1 5r2 4r3 3r4 3r5 5r6 4r7 4r8 3r9 2r10 2r11 2r12 13 2r14 3r15
 3r16 4r17 5r18 4r19 2r20 4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28
 2r29 3r30 2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40 5r41
 3r42 4r43 7r44 6r45 8r46 11r47 2z 2r48 49 2r50 2r51 2r52 2r53 2r54
 2r55 2r56 3r57 58 59 60 4r61 2r62 2r63 3r64 3r65 66 67 0
  t
end
'EOF'
```

Table A.7 (Cont'd)

```
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi         scampi
if ( ! ( -e bonami ) )   ln -s $PGM_DIR/bonami         bonami
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl         nitawl
if ( ! ( -e xsdrn ) )    ln -s $PGM_DIR/xsdrn          xsdrn
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax           ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable               qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases               aliases
if ( ! ( -e ft04f001 ) ) ln -s /u5/jew/bug96/xsdrn.wklib.vb6r3 ft04f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv $tmpdir/ft33f001 /u5/jew/bug96/xsdrn.scalar.pwr
mv $tmpdir/ft03f001 /u5/jew/bug96/ft03wk.pwr
```

Table A.8a Processing Job For Collapsing BWR Core Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 10 t
3$$ 100123 801623 4000022 2605422 2605622 2605722 2605822
    9223521 9223821 801621  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for bwr core (int #57)              Mar '96
 7.60143e+05 2.90634e+08 3.27643e+08 1.08799e+09 1.78948e+09 1.27953e+09
 1.62123e+09 2.02030e+09 2.49749e+09 6.85701e+09 5.05334e+09 5.17907e+09
 1.43870e+10 2.04008e+10 3.02041e+10 4.02078e+10 5.44518e+10 7.40053e+10
 9.38160e+10 1.17843e+11 1.53420e+11 1.89306e+11 2.27723e+11 2.88589e+11
 1.09607e+11 2.42843e+11 4.19346e+11 4.71693e+11 5.32827e+11 6.43324e+11
 6.98187e+11 8.18274e+11 8.68133e+11 1.97883e+12 2.10514e+12 2.36048e+12
 1.42728e+12 1.71759e+12 1.72329e+12 1.83347e+12 2.00608e+12 2.02076e+12
 1.39901e+12 3.81191e+11 3.91890e+11 7.70352e+11 1.38789e+12 1.94868e+12
 1.90020e+12 1.85231e+12 1.79866e+12 2.14296e+12 2.08624e+12 2.03031e+12
 2.11954e+12 2.23346e+12 2.19462e+12 1.82537e+12 2.25984e+12 2.27227e+12
 2.11976e+12 3.47177e+12 1.35233e+12 2.24613e+12 2.15271e+12 2.49667e+12
 2.78663e+12 2.63796e+12 2.44973e+12 2.36574e+12 2.30676e+12 2.24061e+12
 2.16740e+12 2.09230e+12 2.02307e+12 1.96015e+12 3.21529e+12 2.46432e+12
 1.43952e+12 1.44394e+12 3.28625e+12 3.34269e+12 3.69863e+11 1.35776e+11
 2.85285e+11 7.74687e+11 1.52601e+12 2.89730e+12 1.37983e+12 1.34084e+12
 1.31041e+12 1.27469e+12 1.23302e+12 1.19292e+12 1.16266e+12 1.13338e+12
 1.11270e+12 1.08494e+12 1.06379e+12 1.03963e+12 1.01808e+12 9.95902e+11
 9.71912e+11 9.53669e+11 2.29887e+12 2.19548e+12 8.13572e+11 6.19403e+11
 1.61449e+12 1.07654e+12 2.72592e+12 1.12235e+12 1.80796e+12 1.73158e+12
 2.44770e+12 1.00943e+12 1.46214e+12 7.01129e+11 4.58286e+11 6.42107e+11
 3.12091e+11 3.13661e+11 9.52447e+11 1.52359e+12 3.06792e+12 2.95603e+12
 1.15761e+12 1.71170e+12 2.79970e+12 2.80830e+12 2.73063e+12 1.62588e+12
```

```
 1.08376e+12 1.06987e+12 1.04420e+12 5.09300e+11 5.76884e+11 1.04666e+12
 1.07292e+12 2.59086e+12 2.58660e+12 2.56748e+12 2.52283e+12 2.49421e+12
 2.46115e+12 2.44183e+12 2.42955e+12 2.36810e+12 2.36087e+12 2.31931e+12
 2.12917e+12 2.31714e+12 2.20101e+12 2.19805e+12 2.09320e+12 2.06189e+12
 2.07766e+12 1.75099e+12 1.96469e+12 1.93991e+12 1.88498e+12 1.40758e+12
 1.53680e+12 1.75269e+12 1.75774e+12 1.79627e+12 1.81003e+12 1.82828e+12
 7.83721e+11 1.05850e+12 2.95255e+11 2.76228e+11 2.94520e+11 9.88026e+11
 6.94970e+11 1.20945e+12 7.12704e+11 1.30767e+12 5.19128e+11 1.63906e+12
 1.15275e+12 1.24436e+12 1.92642e+12 2.74006e+12 3.24911e+12 3.68464e+12
 3.43253e+12 4.10335e+12 5.77353e+12 4.11199e+12 2.05434e+12 1.84338e+12
 1.40112e+12 7.99235e+11 4.14250e+11 3.03532e+11 9.07528e+10 1.70774e+10
 1.21898e+09
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
      2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for bwr core (int #57)                Mar '96
             1.95474e+02 7.34404e+03 5.42148e+04 7.31863e+05 3.40538e+09
 1.61277e+10 3.35803e+10 6.07724e+10 1.44246e+11 2.51910e+11 3.31486e+11
 4.31915e+11 1.30983e+12 1.82483e+12 2.79593e+12 5.24077e+12 9.96501e+12
 9.02074e+12 5.16624e+12 6.09643e+12 4.16807e+11 1.56718e+13 1.18219e+13
 6.65880e+12 7.49228e+12 6.52617e+12 3.64557e+12 4.37527e+12 3.28651e+12
 5.44538e+12 3.34478e+12 6.27510e+11 2.84651e+11 1.18804e+11 1.13728e+10
 1.37233e+10 2.84362e+10 4.68689e+09 3.23285e+09 1.51357e+09 1.16855e+09
 3.95740e+07
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 10   a11 -1 e t
2$$ 100123 801623 4000022 2605422 2605622 2605722 2605822
    9223521 9223821 801621
4** 7r600. 3r1000. e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
```

Table A.8a (Cont'd)

```
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi          scampi
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs          malocs
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade            rade
if ( ! ( -e alpo   ) )   ln -s $PGM_DIR/alpo            alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl          nitawl
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.bcore.binr3
```

Table A.8b Fortran source code used to create the ANISN files in the portable BCD format

```
c
c     convert binary anisn data to a bcd fixed-field format
c
      dimension  c(10000),name(14)
      open(unit=7,file='ft07',status='new',form='formatted')
      open(unit=10,file='ft10',status='new',form='formatted')
      open(unit=1,file='ft01',status='old',form='unformatted')
      n1=1
      n6=6
      n7=7
c
      n10=10
      rewind n1
1     continue
    3 read(n1,end=2) neg,ntl,icon,idt,name
      if(icon.eq.7)go to 2
      len=neg*ntl
      read(n1)  (c(k),k=1,len)
      write(n7,20) neg,ntl,icon,idt,name
      write(n10,20) neg,ntl,icon,idt,name
   20 format(1x,i5,3i6,14a4)
      call punsh(c,len)
      write(n6,20) neg,ntl,icon,idt,name
      go to 1
    2 continue
      idum=7
      write(n7,20) idum,idum,idum,idum
      stop
      end
      subroutine punsh(x,n)                                             ansn2808
c    *** clever set of subroutines which punch cards in anisn format    ansn2809
c    *** punsh sets up each card punched by dtfpun utilizing repeats    ansn2810
      dimension etr(6),nn(6),r(6),x(1)                                  ansn2811
      data bb,rr/'    ','r   '/                                         ansn2812
      ncard=1                                                           ansn2813
      i6=0                                                              ansn2814
      k=0                                                               ansn2815
      itrip=0                                                           ansn2816
      ii=n+1                                                            ansn2817
      do 1 i=2,ii                                                       ansn2818
      if(itrip.le.0)go to 2                                             ansn2819
      if(i.eq.ii.and.i6.eq.0)go to 1                                    feb 1970
      itrip=0                                                           ansn2820
      go to 3                                                           ansn2821
    2 if(i.ge.ii)go to 4                                                ansn2822
```

```
      if(x(i).ne.x(i-1))go to 4                                       ansn2823
      k=k+1                                                           ansn2824
      if(k.lt.98)go to 1                                              ansn2825
      itrip=1                                                         ansn2826
    4 i6=i6+1                                                         ansn2827
      nn(i6)=0                                                        ansn2828
      r(i6)=bb                                                        ansn2829
      if(k.le.0)go to 5                                               ansn2830
      nn(i6)=k+1                                                      ansn2831
      r(i6)=rr                                                        ansn2832
      k=0                                                             ansn2833
    5 etr(i6)=x(i-1)                                                  ansn2834
      if(i6.ge.6)go to 6                                              ansn2835
    3 if(i.lt.ii)go to 1                                              ansn2836
    6 call dtfpun(etr,nn,r,i6,ncard)                                  ansn2837
      ncard=ncard +1                                                  ansn2838
      i6=0                                                            ansn2839
    1 continue                                                        ansn2840
      return                                                          ansn2841
      end                                                             ansn2842
      subroutine dtfpun(e,nn,r,isum,ncard)                            ansn2843
c   *** dtfpun uses variabe format to punch and number cards          ansn2844
      dimension e(6),nn(6),r(6),ie(6),iexp(6),s1(6),s2(6)             ansn2845
      dimension fmt(26),fbt(4),fet(2)                                 ansn2846
      data pos,xneg/'+   ','-   '/                                    ansn2847
      data fmt(1),fmt(26),fet(1),fet(2)/'(   ','i8) ','t73,','i8) '/  ansn2848
      data fbt(1),fbt(2) ,fbt(3),fbt(4)/'i2,2','a1,i','5,a1',',i2,'/  ansn2849
      do 2 j=1,6                                                      ansn2850
      k=(j-1)*4 + 1                                                   ansn2851
      do 3 i=1,4                                                      ansn2852
      l=k+i                                                           ansn2853
    3 fmt(l)=fbt(i)                                                   ansn2854
    2 continue                                                        ansn2855
      if(isum.eq.6)go to 4                                            ansn2856
      k=isum*4 + 2                                                    ansn2857
      fmt(k)=fet(1)                                                   ansn2858
      fmt(k+1)=fet(2)                                                 ansn2859
    4 do 1 i=1,isum                                                   ansn2860
      s1(i)=pos                                                       ansn2861
      if(e(i).lt.0.0)s1(i)=xneg                                       ansn2862
      call fltfx(e(i),ie(i),iexp(i))                                  ansn2863
      s2(i)=xneg                                                      ansn2864
      if(iexp(i).ge.0)s2(i)=pos                                       ansn2865
      iexp(i)=iabs(iexp(i))                                           ansn2866
    1 continue                                                        ansn2867
```

```
      write (7,fmt) (nn(i),r(i),s1(i),ie(i),s2(i),iexp(i),i=1,isum)      ansn2868
     1,ncard                                                              ansn2869
      return                                                              ansn2870
      end                                                                 ansn2871
      subroutine fltfx(e1,ne1,n1)                                         ansn2872
c    *** fltfx converts floating number to integer                        ansn2873
      n=-4                                                                ansn2874
      e=abs(e1)                                                           ansn2875
      if(e.ne.0.0)go to 1                                                 ansn2876
      n=0                                                                 ansn2877
      ne=0                                                                ansn2878
      go to 6                                                             ansn2879
    3 e=e*10.0                                                            ansn2880
      n=n-1                                                               ansn2881
    1 if(e.ge.1.0)go to 4                                                 ansn2882
      go to 3                                                             ansn2883
    5 e=e/10.0                                                            ansn2884
      n=n+1                                                               ansn2885
    4 if(e.ge.10.0)go to 5                                                ansn2886
      e=e*10000.0                                                         ansn2887
    2 ne=e                                                                ansn2888
      e=e-float(ne)                                                       ansn2889
      if(e.lt.0.5)go to 6                                                 ansn2890
      if(ne.ne.99999)go to 7                                              ansn2891
      n=n+1                                                               ansn2892
      ne=10000                                                            ansn2893
      go to 6                                                             ansn2894
    7 ne=ne+1                                                             ansn2895
    6 ne1=ne                                                              ansn2896
      n1=n                                                                ansn2897
      return                                                              ansn2898
      end                                                                 ansn2899
```

Table A.9 Processing Job For Collapsing PWR Core Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scale job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 20 t
3$$ 100113 501013 801613 2405012 2405212 2405312 2405412
 2605412 2605612 2605712 2605812 2805812 2806012 2806112
 2806212 2806412 4000012 9223511 9223811 801611  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting spectrum for pwr mid-core (int #37)      Mar '96
 1.18569e+06 4.44299e+08 5.06194e+08 1.67311e+09 2.74417e+09 1.96180e+09
 2.48586e+09 3.09280e+09 3.81923e+09 1.04620e+10 7.69466e+09 7.89203e+09
 2.17256e+10 3.06929e+10 4.58104e+10 6.05589e+10 8.19191e+10 1.11443e+11
 1.40281e+11 1.75241e+11 2.28628e+11 2.80991e+11 3.36246e+11 4.28487e+11
 1.62756e+11 3.61051e+11 6.22579e+11 6.95059e+11 7.80393e+11 9.46492e+11
 1.01740e+12 1.19555e+12 1.25790e+12 2.84664e+12 2.97639e+12 3.30436e+12
 1.99850e+12 2.41813e+12 2.40488e+12 2.54923e+12 2.78330e+12 2.78702e+12
 1.92623e+12 5.27521e+11 5.42589e+11 1.05934e+12 1.88068e+12 2.62297e+12
 2.54514e+12 2.46853e+12 2.38193e+12 2.83562e+12 2.72677e+12 2.63967e+12
 2.74706e+12 2.87447e+12 2.80168e+12 2.31657e+12 2.87304e+12 2.85670e+12
 2.64854e+12 4.33302e+12 1.68634e+12 2.78322e+12 2.63744e+12 3.01844e+12
 3.32231e+12 3.12345e+12 2.88702e+12 2.77609e+12 2.69602e+12 2.61244e+12
 2.52675e+12 2.44394e+12 2.36438e+12 2.27797e+12 3.79303e+12 2.95327e+12
 1.72592e+12 1.72178e+12 3.86696e+12 3.88260e+12 4.29115e+11 1.57695e+11
 3.31585e+11 9.01151e+11 1.76722e+12 3.35764e+12 1.60126e+12 1.55458e+12
 1.51589e+12 1.47589e+12 1.43327e+12 1.39199e+12 1.35773e+12 1.32392e+12
 1.29833e+12 1.26603e+12 1.24134e+12 1.21331e+12 1.18968e+12 1.16512e+12
 1.13835e+12 1.11830e+12 2.69934e+12 2.57966e+12 9.54430e+11 7.30951e+11
 1.90973e+12 1.25908e+12 3.20042e+12 1.32469e+12 2.14632e+12 2.07340e+12
 2.86656e+12 1.19258e+12 1.72830e+12 8.33077e+11 5.43326e+11 7.60420e+11
 3.74458e+11 3.75009e+11 1.12693e+12 1.83115e+12 3.63262e+12 3.52834e+12
 1.38683e+12 2.05739e+12 3.38095e+12 3.35791e+12 3.29508e+12 1.96518e+12
```

```
 1.31016e+12 1.29889e+12 1.28318e+12 6.32145e+11 6.73976e+11 1.27364e+12
 1.29863e+12 3.16874e+12 3.15895e+12 3.14372e+12 3.10215e+12 3.07554e+12
 3.04843e+12 3.03314e+12 3.02048e+12 2.96543e+12 2.95795e+12 2.92033e+12
 2.72967e+12 2.91763e+12 2.79907e+12 2.79925e+12 2.70229e+12 2.65131e+12
 2.68277e+12 2.32392e+12 2.56828e+12 2.53435e+12 2.47600e+12 1.93851e+12
 2.11725e+12 2.36001e+12 2.36451e+12 2.41543e+12 2.43760e+12 2.46489e+12
 1.05858e+12 1.43256e+12 4.01745e+11 3.75070e+11 3.98828e+11 1.34272e+12
 9.45318e+11 1.65368e+12 9.67802e+11 1.78668e+12 7.09187e+11 2.25321e+12
 1.59535e+12 1.74063e+12 2.73440e+12 3.95822e+12 4.77304e+12 5.48771e+12
 5.16659e+12 6.22772e+12 8.82304e+12 6.32026e+12 3.16449e+12 2.85268e+12
 2.17551e+12 1.24483e+12 6.46810e+11 4.75035e+11 1.42377e+11 2.68474e+10
 1.91611e+09

6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
       2r16 3r17 3r18 19 20 0
7**
' photon weighting spectrum for pwr mid-core (int #37)       Mar '96
             1.56551e+02 5.78821e+03 5.36244e+04 1.60647e+07 1.94149e+09
 2.04060e+10 6.40015e+10 1.19179e+11 2.81762e+11 4.95520e+11 6.52351e+11
 8.34889e+11 2.32033e+12 3.31156e+12 5.09403e+12 9.40590e+12 1.78914e+13
 1.59802e+13 9.30442e+12 1.10960e+13 7.62175e+11 2.85726e+13 2.14723e+13
 1.20755e+13 1.33643e+13 1.15110e+13 6.50410e+12 8.26396e+12 5.79812e+12
 9.50287e+12 5.73402e+12 1.06108e+12 4.53652e+11 1.90297e+11 1.82731e+10
 2.21555e+10 3.90794e+10 6.59067e+09 4.87415e+09 2.27160e+09 1.73293e+09
 6.90986e+07
  t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 20   a11 -1 e t
2$$ 100113 501013 801613 2405012 2405212 2405312 2405412
 2605412 2605612 2605712 2605812 2805812 2806012 2806112
 2806212 2806412 4000012 9223511 9223811 801611
4** 17r600. 3r1000.  e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
```

Table A.9 (Cont'd)

```
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi          scampi
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs          malocs
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade            rade
if ( ! ( -e alpo   ) )   ln -s $PGM_DIR/alpo            alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl          nitawl
if ( ! ( -e ajax ) )     ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.pcore.binr3
```

Table A.10 Processing Job For Collapsing PWR Downcomer Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA    ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e    1$$ 1 t
2$$ 85 17 t
3$$ 100131 801631
    2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
    2805852 2806052 2806152 2806252 2806452 2505552 601252  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for downcomer (pwr int # 69)        Mar '96
 1.39915e+04 3.54372e+06 5.18817e+06 1.60383e+07 2.43561e+07 1.69080e+07
 2.11815e+07 2.56302e+07 3.07903e+07 8.03502e+07 5.60907e+07 5.97414e+07
 1.41298e+08 1.86232e+08 2.97667e+08 3.61070e+08 4.72567e+08 6.38921e+08
 7.36351e+08 8.34712e+08 1.07576e+09 1.24101e+09 1.36028e+09 1.78428e+09
 6.69262e+08 1.49223e+09 2.52511e+09 2.54710e+09 2.60240e+09 3.25652e+09
 3.07945e+09 3.63869e+09 3.56835e+09 7.24468e+09 6.27365e+09 6.19037e+09
 3.69762e+09 4.91689e+09 4.99987e+09 5.21449e+09 5.69261e+09 5.52907e+09
 4.13321e+09 1.28138e+09 1.42532e+09 2.45442e+09 4.21172e+09 5.54678e+09
 5.23457e+09 5.02601e+09 4.62360e+09 5.74029e+09 5.41086e+09 5.07163e+09
 5.29273e+09 5.33738e+09 5.24055e+09 4.06970e+09 5.14046e+09 5.29298e+09
 4.81191e+09 7.49563e+09 2.82735e+09 4.74389e+09 4.36514e+09 4.84229e+09
 5.04403e+09 4.73117e+09 4.54659e+09 4.41987e+09 4.37375e+09 4.26280e+09
 4.18452e+09 4.05442e+09 3.92548e+09 3.77005e+09 6.42492e+09 5.17460e+09
 3.00309e+09 3.00124e+09 6.41753e+09 6.30699e+09 7.02080e+08 2.58802e+08
 5.44835e+08 1.48098e+09 2.89938e+09 5.57163e+09 2.68692e+09 2.62080e+09
 2.56455e+09 2.50752e+09 2.45258e+09 2.40299e+09 2.35757e+09 2.30563e+09
 2.26717e+09 2.21809e+09 2.17812e+09 2.13831e+09 2.10744e+09 2.07275e+09
 2.03182e+09 2.00219e+09 4.85708e+09 4.67856e+09 1.73389e+09 1.34508e+09
 3.51120e+09 2.30397e+09 5.90408e+09 2.46297e+09 4.02920e+09 3.93460e+09
 5.37383e+09 2.26377e+09 3.28835e+09 1.59677e+09 1.05075e+09 1.47450e+09
 7.34569e+08 7.30041e+08 2.17712e+09 3.58561e+09 7.07411e+09 6.99859e+09
```

```
 2.77672e+09 4.13796e+09 6.86644e+09 6.85077e+09 6.83678e+09 4.11127e+09
 2.74721e+09 2.75060e+09 2.75364e+09 1.37655e+09 1.37670e+09 2.75515e+09
 2.76516e+09 6.93215e+09 6.94795e+09 6.96166e+09 6.99919e+09 7.04239e+09
 7.08511e+09 7.11887e+09 7.17530e+09 7.21707e+09 7.25652e+09 7.29909e+09
 7.33766e+09 7.37986e+09 7.42400e+09 7.46781e+09 7.51122e+09 7.55318e+09
 7.59531e+09 7.63461e+09 7.67576e+09 7.71536e+09 7.75140e+09 7.78692e+09
 7.82080e+09 8.08726e+09 8.19244e+09 8.35176e+09 8.52544e+09 8.66854e+09
 3.75896e+09 5.19911e+09 1.49831e+09 1.38750e+09 1.46322e+09 4.95747e+09
 3.50260e+09 6.25927e+09 3.70424e+09 7.33383e+09 3.19930e+09 1.25192e+10
 1.21165e+10 1.76488e+10 3.78424e+10 7.34719e+10 1.09734e+11 1.46207e+11
 1.52214e+11 1.98356e+11 3.03079e+11 2.31049e+11 1.20067e+11 1.11586e+11
 8.74983e+10 5.12889e+10 2.71373e+10 2.02161e+10 6.13389e+09 1.16196e+09
 8.24701e+07
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
      2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for downcomer (pwr int # 69)        Mar '96
             9.07865e+03 4.64029e+05 2.97633e+06 3.40422e+07 1.08686e+11
 1.61151e+11 5.23443e+10 2.55963e+10 4.86437e+10 5.08230e+10 3.67259e+10
 4.41619e+10 6.31741e+10 6.35878e+10 8.99862e+10 1.11188e+11 5.49328e+11
 1.85319e+11 1.00367e+11 1.16212e+11 8.28716e+09 2.81188e+11 2.51682e+11
 1.44918e+11 1.71906e+11 1.82161e+11 1.10502e+11 3.79878e+11 2.06617e+11
 5.40032e+11 9.11408e+11 7.40802e+11 1.07902e+12 8.06000e+11 1.78515e+11
 3.40832e+11 5.07365e+11 1.16649e+11 1.07556e+11 1.05784e+10 7.80633e+07
 3.49827e+03
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 17   a11 -1 e t
2$$ 100131 801631
    2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
    2805852 2806052 2806152 2806252 2806452 2505552 601252  t
4** 16r600. 300. e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
```

```
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi        scampi
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs        malocs
if ( ! ( -e rade  ) )    ln -s $PGM_DIR/rade          rade
if ( ! ( -e alpo    ) )  ln -s $PGM_DIR/alpo          alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl        nitawl
if ( ! ( -e ajax  ) )    ln -s $PGM_DIR/ajax          ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable              qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases              aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.pdown.binr3
```

Table A.11 Processing Job For Collapsing Pressure Vessel Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 15 t
3$$ 2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
    2805851 2806051 2806151 2806251 2806451 2505551 601251  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for pwr 1/4 t (int # 82)            Mar '96
 2.03215e+03 4.18056e+05 6.81865e+05 2.08922e+06 3.02157e+06 2.04763e+06
 2.54330e+06 3.03800e+06 3.59299e+06 9.18082e+06 6.23205e+06 6.71812e+06
 1.50512e+07 1.89521e+07 3.05225e+07 3.69878e+07 4.76357e+07 6.29950e+07
 7.09828e+07 7.72222e+07 9.58409e+07 1.08454e+08 1.15445e+08 1.48532e+08
 5.53087e+07 1.22804e+08 2.07669e+08 2.04994e+08 2.01628e+08 2.43334e+08
 2.26654e+08 2.54045e+08 2.58444e+08 5.06374e+08 4.59876e+08 4.59142e+08
 2.54035e+08 3.21448e+08 3.74510e+08 4.04206e+08 4.63800e+08 4.40535e+08
 3.45104e+08 1.06835e+08 1.21513e+08 1.97142e+08 4.15481e+08 5.79737e+08
 5.53014e+08 5.35248e+08 5.40172e+08 6.68888e+08 7.24571e+08 6.83830e+08
 7.17674e+08 6.96118e+08 7.44846e+08 7.69783e+08 7.01744e+08 1.05792e+09
 9.93141e+08 1.63592e+09 6.50915e+08 1.22615e+09 8.73979e+08 9.54807e+08
 8.47164e+08 8.70091e+08 1.21457e+09 1.42394e+09 1.91549e+09 2.07707e+09
 1.49149e+09 1.26944e+09 1.17421e+09 1.04716e+09 2.26682e+09 1.50290e+09
 6.65211e+08 1.58189e+09 3.12159e+09 3.26339e+09 4.25648e+08 1.39922e+08
 2.22958e+08 3.50825e+08 6.75385e+08 1.69728e+09 9.84263e+08 5.61228e+08
 8.98116e+08 5.76868e+08 3.44429e+08 7.90226e+08 1.08735e+09 8.24752e+08
 8.06347e+08 4.74128e+08 2.48667e+08 1.02195e+09 5.61371e+08 9.30994e+08
 6.06883e+08 5.64584e+08 9.54252e+08 6.89646e+08 1.89188e+08 8.65162e+08
 6.85223e+08 8.54640e+08 1.23261e+09 3.72389e+08 8.53077e+08 6.08219e+08
 6.20878e+08 2.05786e+08 1.04499e+08 3.19190e+07 1.70755e+08 1.17856e+09
 5.74779e+08 3.01447e+08 6.74028e+08 6.41245e+08 9.04405e+08 8.44766e+08
 3.20065e+08 3.54901e+08 3.64416e+08 9.58778e+08 1.00082e+09 5.43613e+08
 3.94439e+08 3.70119e+08 3.26757e+08 1.43042e+08 1.17488e+08 1.70699e+08
```

```
 2.52204e+08 8.34092e+08 8.46457e+08 6.88845e+08 6.79808e+08 6.70325e+08
 6.44457e+08 3.84890e+08 5.74520e+08 6.11877e+08 6.26343e+08 6.33040e+08
 6.35565e+08 6.35521e+08 6.33173e+08 6.28578e+08 6.21589e+08 6.12049e+08
 5.99986e+08 5.84983e+08 5.67397e+08 5.46951e+08 5.23508e+08 4.97454e+08
 4.68932e+08 4.47222e+08 4.15622e+08 3.82848e+08 3.49625e+08 3.17941e+08
 1.27342e+08 1.63889e+08 4.36622e+07 3.97262e+07 4.14360e+07 1.27715e+08
 7.52922e+07 1.18850e+08 6.65624e+07 1.15791e+08 4.45780e+07 1.36196e+08
 9.94780e+07 1.07402e+08 1.61617e+08 2.11647e+08 2.20140e+08 2.17164e+08
 1.78275e+08 1.88484e+08 2.35810e+08 1.49982e+08 6.88905e+07 5.26549e+07
 3.23228e+07 1.43354e+07 5.74911e+06 3.11617e+06 6.51680e+05 9.16805e+04
 5.55381e+03
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
       2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for pwr 1/4 t (int #82)                  Mar '96
             1.36280e+03 5.04155e+04 3.11115e+05 3.37501e+06 9.41338e+09
 1.44768e+10 5.33314e+09 3.25443e+09 5.30716e+09 5.74850e+09 4.82593e+09
 5.69622e+09 7.58842e+09 8.20490e+09 1.06041e+10 1.30938e+10 2.63421e+10
 1.87301e+10 1.02051e+10 1.14511e+10 7.66627e+08 2.88382e+10 2.55198e+10
 1.40042e+10 1.65787e+10 1.73677e+10 2.28301e+10 1.93786e+10 1.83964e+10
 4.62153e+10 6.99706e+10 4.42136e+10 3.15168e+10 5.53679e+09 3.13010e+08
 2.31786e+08 2.69633e+07 1.51193e+06 1.46105e+06 5.17695e+05 4.01734e+05
 2.64739e+04
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 15   a11 -1 e t
2$$ 2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
    2805851 2806051 2806151 2806251 2806451 2505551 601251
4**  14r600. 300.  e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi         scampi
```

Table A.11 (Cont'd)

```
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs          malocs
if ( ! ( -e rade )  )    ln -s $PGM_DIR/rade            rade
if ( ! ( -e alpo    ) )  ln -s $PGM_DIR/alpo            alpo
if ( ! ( -e nitawl  ) )  ln -s $PGM_DIR/nitawl          nitawl
if ( ! ( -e ajax )  )    ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.pp14t.binr3
```

Table A.12 Processing Job For Collapsing Concrete Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA    ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 13 t
3$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for concrete (int #106)             Mar '96
 7.49089e+01 1.17450e+04 2.18856e+04 6.65186e+04 9.03011e+04 5.93865e+04
 7.23383e+04 8.52154e+04 9.96951e+04 2.49934e+05 1.67743e+05 1.83308e+05
 3.86282e+05 4.75843e+05 7.91253e+05 9.09275e+05 1.16524e+06 1.57593e+06
 1.72816e+06 1.78897e+06 2.15954e+06 2.34602e+06 2.45418e+06 3.22437e+06
 1.22696e+06 2.76014e+06 4.67362e+06 4.52275e+06 4.50172e+06 5.87379e+06
 5.38154e+06 6.16163e+06 6.05195e+06 1.27683e+07 1.08807e+07 1.04539e+07
 6.70057e+06 9.28986e+06 1.04109e+07 1.19418e+07 1.44194e+07 1.42482e+07
 1.27614e+07 4.07382e+06 5.22988e+06 8.73649e+06 1.48167e+07 1.84750e+07
 1.72498e+07 1.45772e+07 1.35677e+07 2.34182e+07 2.12228e+07 1.95332e+07
 2.31932e+07 2.59998e+07 2.70471e+07 1.87577e+07 2.73080e+07 3.19539e+07
 3.16101e+07 3.94638e+07 1.27634e+07 2.60949e+07 3.16730e+07 3.68396e+07
 4.45387e+07 4.94233e+07 5.39156e+07 5.97974e+07 6.91957e+07 8.02057e+07
 8.07039e+07 7.36781e+07 8.07989e+07 7.78520e+07 1.20683e+08 7.17608e+07
 4.16483e+07 4.34337e+07 1.16100e+08 1.38926e+08 1.60702e+07 6.05129e+06
 1.26130e+07 3.40802e+07 6.98310e+07 1.38240e+08 6.80422e+07 6.73782e+07
 6.16487e+07 5.96601e+07 5.51216e+07 5.32484e+07 6.15963e+07 7.68394e+07
 8.74831e+07 8.20728e+07 7.54146e+07 7.52664e+07 8.30361e+07 8.44216e+07
 7.42002e+07 7.55824e+07 1.78796e+08 1.56690e+08 5.85381e+07 5.11802e+07
 1.32931e+08 8.63812e+07 2.06913e+08 7.91847e+07 1.68920e+08 1.49037e+08
 1.86957e+08 8.65092e+07 1.29518e+08 6.03404e+07 4.16963e+07 5.94854e+07
 2.99593e+07 2.95727e+07 8.79286e+07 1.43873e+08 2.84526e+08 2.81089e+08
 1.11444e+08 1.63558e+08 2.76291e+08 2.73184e+08 2.74347e+08 1.61861e+08
 9.94352e+07 9.52323e+07 6.94481e+07 4.24177e+07 5.56387e+07 1.25215e+08
```

```
 1.21848e+08 2.92248e+08 2.83198e+08 2.79382e+08 2.78449e+08 2.78364e+08
 2.78459e+08 2.78046e+08 2.78095e+08 2.77993e+08 2.77735e+08 2.77491e+08
 2.76995e+08 2.76522e+08 2.76032e+08 2.75460e+08 2.74811e+08 2.74043e+08
 2.73221e+08 2.72252e+08 2.71294e+08 2.70215e+08 2.68945e+08 2.67590e+08
 2.66153e+08 2.71976e+08 2.70484e+08 2.72429e+08 2.74460e+08 2.75021e+08
 1.17465e+08 1.61344e+08 4.55757e+07 4.20303e+07 4.43568e+07 1.50652e+08
 1.02698e+08 1.80353e+08 1.01786e+08 1.88451e+08 7.30516e+07 2.23860e+08
 1.49807e+08 1.52780e+08 2.18535e+08 2.85348e+08 3.41771e+08 4.52399e+08
 5.45297e+08 9.12370e+08 2.02815e+09 2.24190e+09 1.50043e+09 1.66125e+09
 1.54048e+09 1.03403e+09 6.04299e+08 4.88353e+08 1.58541e+08 3.11761e+07
 2.28965e+06
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
       2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for concrete (int #106)             Mar '96
             7.42941e+01 2.30936e+03 6.82316e+03 1.24943e+06 1.03523e+08
 3.25671e+08 1.20393e+08 5.83873e+07 2.68211e+08 1.61678e+08 1.37631e+08
 3.60019e+08 2.29686e+08 4.72749e+08 2.74113e+08 3.31726e+08 7.35257e+08
 4.46441e+08 2.01309e+08 1.87887e+08 1.33262e+07 4.94239e+08 3.86628e+08
 2.48890e+08 2.69078e+08 2.90021e+08 2.87195e+08 3.32608e+08 2.97708e+08
 7.99392e+08 1.39680e+09 1.13935e+09 1.72007e+09 1.15885e+09 2.10047e+08
 3.18797e+08 1.95052e+08 1.70746e+07 6.02324e+06 4.01610e+05 7.06744e+04
 5.19384e+03
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 13   a11 -1 e t
2$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041  t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi        scampi
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs        malocs
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade          rade
if ( ! ( -e alpo   ) )   ln -s $PGM_DIR/alpo          alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl        nitawl
```

Table A.12 (Cont'd)

```
if ( ! ( -e ajax  ) )     ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                 qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                 aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.pconc.binr3
```

Table A.13 Processing Job For Collapsing Carbon/Stainless Steel Nuclides Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1  t
2$$ 85 30 t
3$$    2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
       2805851 2806051 2806151 2806251 2806451 2505551 601251
       2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
       2805852 2806052 2806152 2806252 2806452 2505552 601252  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for pwr 1/4 t (int # 82)            Mar '96
 2.03215e+03 4.18056e+05 6.81865e+05 2.08922e+06 3.02157e+06 2.04763e+06
 2.54330e+06 3.03800e+06 3.59299e+06 9.18082e+06 6.23205e+06 6.71812e+06
 1.50512e+07 1.89521e+07 3.05225e+07 3.69878e+07 4.76357e+07 6.29950e+07
 7.09828e+07 7.72222e+07 9.58409e+07 1.08454e+08 1.15445e+08 1.48532e+08
 5.53087e+07 1.22804e+08 2.07669e+08 2.04994e+08 2.01628e+08 2.43334e+08
 2.26654e+08 2.54045e+08 2.58444e+08 5.06374e+08 4.59876e+08 4.59142e+08
 2.54035e+08 3.21448e+08 3.74510e+08 4.04206e+08 4.63800e+08 4.40535e+08
 3.45104e+08 1.06835e+08 1.21513e+08 1.97142e+08 4.15481e+08 5.79737e+08
 5.53014e+08 5.35248e+08 5.40172e+08 6.68888e+08 7.24571e+08 6.83830e+08
 7.17674e+08 6.96118e+08 7.44846e+08 7.69783e+08 7.01744e+08 1.05792e+09
 9.93141e+08 1.63592e+09 6.50915e+08 1.22615e+09 8.73979e+08 9.54807e+08
 8.47164e+08 8.70091e+08 1.21457e+09 1.42394e+09 1.91549e+09 2.07707e+09
 1.49149e+09 1.26944e+09 1.17421e+09 1.04716e+09 2.26682e+09 1.50290e+09
 6.65211e+08 1.58189e+09 3.12159e+09 3.26339e+09 4.25648e+08 1.39922e+08
 2.22958e+08 3.50825e+08 6.75385e+08 1.69728e+09 9.84263e+08 5.61228e+08
 8.98116e+08 5.76868e+08 3.44429e+08 7.90226e+08 1.08735e+09 8.24752e+08
 8.06347e+08 4.74128e+08 2.48667e+08 1.02195e+09 5.61371e+08 9.30994e+08
 6.06883e+08 5.64584e+08 9.54252e+08 6.89646e+08 1.89188e+08 8.65162e+08
 6.85223e+08 8.54640e+08 1.23261e+09 3.72389e+08 8.53077e+08 6.08219e+08
 6.20878e+08 2.05786e+08 1.04499e+08 3.19190e+07 1.70755e+08 1.17856e+09
 5.74779e+08 3.01447e+08 6.74028e+08 6.41245e+08 9.04405e+08 8.44766e+08
```

```
 3.20065e+08 3.54901e+08 3.64416e+08 9.58778e+08 1.00082e+09 5.43613e+08
 3.94439e+08 3.70119e+08 3.26757e+08 1.43042e+08 1.17488e+08 1.70699e+08
 2.52204e+08 8.34092e+08 8.46457e+08 6.88845e+08 6.79808e+08 6.70325e+08
 6.44457e+08 3.84890e+08 5.74520e+08 6.11877e+08 6.26343e+08 6.33040e+08
 6.35565e+08 6.35521e+08 6.33173e+08 6.28578e+08 6.21589e+08 6.12049e+08
 5.99986e+08 5.84983e+08 5.67397e+08 5.46951e+08 5.23508e+08 4.97454e+08
 4.68932e+08 4.47222e+08 4.15622e+08 3.82848e+08 3.49625e+08 3.17941e+08
 1.27342e+08 1.63889e+08 4.36622e+07 3.97262e+07 4.14360e+07 1.27715e+08
 7.52922e+07 1.18850e+08 6.65624e+07 1.15791e+08 4.45780e+07 1.36196e+08
 9.94780e+07 1.07402e+08 1.61617e+08 2.11647e+08 2.20140e+08 2.17164e+08
 1.78275e+08 1.88484e+08 2.35810e+08 1.49982e+08 6.88905e+07 5.26549e+07
 3.23228e+07 1.43354e+07 5.74911e+06 3.11617e+06 6.51680e+05 9.16805e+04
 5.55381e+03
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
      2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for pwr 1/4 t (int #82)              Mar '96
             1.36280e+03 5.04155e+04 3.11115e+05 3.37501e+06 9.41338e+09
 1.44768e+10 5.33314e+09 3.25443e+09 5.30716e+09 5.74850e+09 4.82593e+09
 5.69622e+09 7.58842e+09 8.20490e+09 1.06041e+10 1.30938e+10 2.63421e+10
 1.87301e+10 1.02051e+10 1.14511e+10 7.66627e+08 2.88382e+10 2.55198e+10
 1.40042e+10 1.65787e+10 1.73677e+10 2.28301e+10 1.93786e+10 1.83964e+10
 4.62153e+10 6.99706e+10 4.42136e+10 3.15168e+10 5.53679e+09 3.13010e+08
 2.31786e+08 2.69633e+07 1.51193e+06 1.46105e+06 5.17695e+05 4.01734e+05
 2.64739e+04
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 30   a11 -1 e t
2$$   2605451 2605651 2605751 2605851 2405051 2405251 2405351 2405451
      2805851 2806051 2806151 2806251 2806451 2505551 601251
      2605452 2605652 2605752 2605852 2405052 2405252 2405352 2405452
      2805852 2806052 2806152 2806252 2806452 2505552 601252
4**  14r600. 300. 14r600. 300.  e t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
```

Table A.13 (Cont'd)

```
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi  ) )  ln -s $PGM_DIR/scampi          scampi
if ( ! ( -e malocs  ) )  ln -s $PGM_DIR/malocs          malocs
if ( ! ( -e rade )  )    ln -s $PGM_DIR/rade            rade
if ( ! ( -e alpo    ) )  ln -s $PGM_DIR/alpo            alpo
if ( ! ( -e nitawl  ) )  ln -s $PGM_DIR/nitawl          nitawl
if ( ! ( -e ajax )  )    ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )  ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )  ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft85f001 ) ) ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.steel.binr3
```

Table A.14 Processing Job For Collapsing All VITAMIN-B6 Nuclides With Concrete Weighting Spectrum Without Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#malocs
1$$ 199 47 42 20 e   2$$ 1 81 3$$ 0 0 1 1  a7 2 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12   13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for concrete (feb'96 xsdrnpm pwr calc int #106)
 7.49089e+01 1.17450e+04 2.18856e+04 6.65186e+04 9.03011e+04 5.93865e+04
 7.23383e+04 8.52154e+04 9.96951e+04 2.49934e+05 1.67743e+05 1.83308e+05
 3.86282e+05 4.75843e+05 7.91253e+05 9.09275e+05 1.16524e+06 1.57593e+06
 1.72816e+06 1.78897e+06 2.15954e+06 2.34602e+06 2.45418e+06 3.22437e+06
 1.22696e+06 2.76014e+06 4.67362e+06 4.52275e+06 4.50172e+06 5.87379e+06
 5.38154e+06 6.16163e+06 6.05195e+06 1.27683e+07 1.08807e+07 1.04539e+07
 6.70057e+06 9.28986e+06 1.04109e+07 1.19418e+07 1.44194e+07 1.42482e+07
 1.27614e+07 4.07382e+06 5.22988e+06 8.73649e+06 1.48167e+07 1.84750e+07
 1.72498e+07 1.45772e+07 1.35677e+07 2.34182e+07 2.12228e+07 1.95332e+07
 2.31932e+07 2.59998e+07 2.70471e+07 1.87577e+07 2.73080e+07 3.19539e+07
 3.16101e+07 3.94638e+07 1.27634e+07 2.60949e+07 3.16730e+07 3.68396e+07
 4.45387e+07 4.94233e+07 5.39156e+07 5.97974e+07 6.91957e+07 8.02057e+07
 8.07039e+07 7.36781e+07 8.07989e+07 7.78520e+07 1.20683e+08 7.17608e+07
 4.16483e+07 4.34337e+07 1.16100e+08 1.38926e+08 1.60702e+07 6.05129e+06
 1.26130e+07 3.40802e+07 6.98310e+07 1.38240e+08 6.80422e+07 6.73782e+07
 6.16487e+07 5.96601e+07 5.51216e+07 5.32484e+07 6.15963e+07 7.68394e+07
 8.74831e+07 8.20728e+07 7.54146e+07 7.52664e+07 8.30361e+07 8.44216e+07
 7.42002e+07 7.55824e+07 1.78796e+08 1.56690e+08 5.85381e+07 5.11802e+07
 1.32931e+08 8.63812e+07 2.06913e+08 7.91847e+07 1.68920e+08 1.49037e+08
 1.86957e+08 8.65092e+07 1.29518e+08 6.03404e+07 4.16963e+07 5.94854e+07
 2.99593e+07 2.95727e+07 8.79286e+07 1.43873e+08 2.84526e+08 2.81089e+08
 1.11444e+08 1.63558e+08 2.76291e+08 2.73184e+08 2.74347e+08 1.61861e+08
 9.94352e+07 9.52323e+07 6.94481e+07 4.24177e+07 5.56387e+07 1.25215e+08
 1.21848e+08 2.92248e+08 2.83198e+08 2.79382e+08 2.78449e+08 2.78364e+08
 2.78459e+08 2.78046e+08 2.78095e+08 2.77993e+08 2.77735e+08 2.77491e+08
 2.76995e+08 2.76522e+08 2.76032e+08 2.75460e+08 2.74811e+08 2.74043e+08
 2.73221e+08 2.72252e+08 2.71294e+08 2.70215e+08 2.68945e+08 2.67590e+08
 2.66153e+08 2.71976e+08 2.70484e+08 2.72429e+08 2.74460e+08 2.75021e+08
 1.17465e+08 1.61344e+08 4.55757e+07 4.20303e+07 4.43568e+07 1.50652e+08
```

```
 1.02698e+08 1.80353e+08 1.01786e+08 1.88451e+08 7.30516e+07 2.23860e+08
 1.49807e+08 1.52780e+08 2.18535e+08 2.85348e+08 3.41771e+08 4.52399e+08
 5.45297e+08 9.12370e+08 2.02815e+09 2.24190e+09 1.50043e+09 1.66125e+09
 1.54048e+09 1.03403e+09 6.04299e+08 4.88353e+08 1.58541e+08 3.11761e+07
 2.28965e+06
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
     2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for concrete (feb'96 xsdrnpm pwr calc int #106)
             7.42941e+01 2.30936e+03 6.82316e+03 1.24943e+06 1.03523e+08
 3.25671e+08 1.20393e+08 5.83873e+07 2.68211e+08 1.61678e+08 1.37631e+08
 3.60019e+08 2.29686e+08 4.72749e+08 2.74113e+08 3.31726e+08 7.35257e+08
 4.46441e+08 2.01309e+08 1.87887e+08 1.33262e+07 4.94239e+08 3.86628e+08
 2.48890e+08 2.69078e+08 2.90021e+08 2.87195e+08 3.32608e+08 2.97708e+08
 7.99392e+08 1.39680e+09 1.13935e+09 1.72007e+09 1.15885e+09 2.10047e+08
 3.18797e+08 1.95052e+08 1.70746e+07 6.02324e+06 4.01610e+05 7.06744e+04
 5.19384e+03
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 120   all -1 e t
2$$ 47107 47109 13027 95241 95242 95601 95243 79197 5010 5011 56138
     4009 4309 83209 6012 6312 20000 48000 17000 96241 96242 96243
    96244 96245 96246 96247 96248 27059 24050 24052 24053 24054
    29063 29065 63151 63152 63153 63154 63155 9019 26054 26056 26057
    26058 31000 1001  1901  1002  1003 2003 2004 72174 72176 72177
    72178 72179 72180 49000 19000 3006 3007 12000 25055 42000 7014
    7015  11023 41093 28058 28060 28061 28062 28064 93237 93238 93239
    8016 8017 15031 91231 91233 82206 82207 82208 94236 94237 94238
    94239 94240 94241 94242 94243 94244 75185 75187 16000 16032 14000
    50000 73181 73182 90230 90232 22000 92232 92233 92234 92235 92236
    92237 92238 23000 74000 74182 74183 74184 74186 39089 40000 40302
  t
end
#alpo
0$$ 87 4 1$$ 1 3 4 70 7 -1 -1 e t
2$$  4 0 t
end
#rade
1$$ 0 4 e  2$$ a2 100 1 e t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
```

Table A.14 (Cont'd)

```
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )  ln -s $PGM_DIR/scampi              scampi
if ( ! ( -e malocs ) )  ln -s $PGM_DIR/malocs              malocs
if ( ! ( -e rade ) )    ln -s $PGM_DIR/rade                rade
if ( ! ( -e alpo   ) )  ln -s $PGM_DIR/alpo                alpo
if ( ! ( -e nitawl ) )  ln -s $PGM_DIR/nitawl              nitawl
if ( ! ( -e qatable ) ) ln -s $DATA_DIR/qatable                    qatable
if ( ! ( -e aliases ) ) ln -s $DATA_DIR/aliases                    aliases
if ( ! ( -e ft01f001 ) ) ln -s /rsic/data/lmplib/vitaminb6.r3m ft01f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print >> $1
cat $tmpdir/_prt* >> $1
cat $tmpdir/_out* >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.binr3
```

Table A.15 Processing Job For Collapsing PWR Concrete Nuclides With Upscattering Cross Sections

```
#!/bin/csh
# shell script to execute a scampi job
setenv RTNDIR `pwd`
if ( ! ( $?SCA   ) ) setenv SCA   /rsic/codes/Scampi
setenv DATA_DIR $SCA/data
setenv PGM_DIR $SCA/bin
cat >input <<'EOF'
#ajax
0$$ 82 85 e  1$$ 1 t
2$$ 85 13 t
3$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041  t
end
#malocs
1$$ 199 47 42 20 e   2$$ 82 81 3$$ 0 0 1 1  a7 0 f0 t
4$$
    0 6r1  5r2  4r3  3r4  3r5  5r6  4r7  4r8  3r9  2r10
   2r11 2r12  13 2r14 3r15 3r16 4r17 5r18 4r19  2r20
   4r21 4r22 4r23 4r24 10r25 10r26 6r27 4r28 2r29 3r30
   2r31 2r32 2r33 4r34 4r35 7r36 5r37 3r38 3r39 4r40
   5r41 3r42 4r43 7r44 6r45 8r46 11r47
5**
' neutron weighting flux for concrete (int #106)           Mar '96
 7.49089e+01 1.17450e+04 2.18856e+04 6.65186e+04 9.03011e+04 5.93865e+04
 7.23383e+04 8.52154e+04 9.96951e+04 2.49934e+05 1.67743e+05 1.83308e+05
 3.86282e+05 4.75843e+05 7.91253e+05 9.09275e+05 1.16524e+06 1.57593e+06
 1.72816e+06 1.78897e+06 2.15954e+06 2.34602e+06 2.45418e+06 3.22437e+06
 1.22696e+06 2.76014e+06 4.67362e+06 4.52275e+06 4.50172e+06 5.87379e+06
 5.38154e+06 6.16163e+06 6.05195e+06 1.27683e+07 1.08807e+07 1.04539e+07
 6.70057e+06 9.28986e+06 1.04109e+07 1.19418e+07 1.44194e+07 1.42482e+07
 1.27614e+07 4.07382e+06 5.22988e+06 8.73649e+06 1.48167e+07 1.84750e+07
 1.72498e+07 1.45772e+07 1.35677e+07 2.34182e+07 2.12228e+07 1.95332e+07
 2.31932e+07 2.59998e+07 2.70471e+07 1.87577e+07 2.73080e+07 3.19539e+07
 3.16101e+07 3.94638e+07 1.27634e+07 2.60949e+07 3.16730e+07 3.68396e+07
 4.45387e+07 4.94233e+07 5.39156e+07 5.97974e+07 6.91957e+07 8.02057e+07
 8.07039e+07 7.36781e+07 8.07989e+07 7.78520e+07 1.20683e+08 7.17608e+07
 4.16483e+07 4.34337e+07 1.16100e+08 1.38926e+08 1.60702e+07 6.05129e+06
 1.26130e+07 3.40802e+07 6.98310e+07 1.38240e+08 6.80422e+07 6.73782e+07
 6.16487e+07 5.96601e+07 5.51216e+07 5.32484e+07 6.15963e+07 7.68394e+07
 8.74831e+07 8.20728e+07 7.54146e+07 7.52664e+07 8.30361e+07 8.44216e+07
 7.42002e+07 7.55824e+07 1.78796e+08 1.56690e+08 5.85381e+07 5.11802e+07
 1.32931e+08 8.63812e+07 2.06913e+08 7.91847e+07 1.68920e+08 1.49037e+08
 1.86957e+08 8.65092e+07 1.29518e+08 6.03404e+07 4.16963e+07 5.94854e+07
 2.99593e+07 2.95727e+07 8.79286e+07 1.43873e+08 2.84526e+08 2.81089e+08
 1.11444e+08 1.63558e+08 2.76291e+08 2.73184e+08 2.74347e+08 1.61861e+08
 9.94352e+07 9.52323e+07 6.94481e+07 4.24177e+07 5.56387e+07 1.25215e+08
```

```
 1.21848e+08 2.92248e+08 2.83198e+08 2.79382e+08 2.78449e+08 2.78364e+08
 2.78459e+08 2.78046e+08 2.78095e+08 2.77993e+08 2.77735e+08 2.77491e+08
 2.76995e+08 2.76522e+08 2.76032e+08 2.75460e+08 2.74811e+08 2.74043e+08
 2.73221e+08 2.72252e+08 2.71294e+08 2.70215e+08 2.68945e+08 2.67590e+08
 2.66153e+08 2.71976e+08 2.70484e+08 2.72429e+08 2.74460e+08 2.75021e+08
 1.17465e+08 1.61344e+08 4.55757e+07 4.20303e+07 4.43568e+07 1.50652e+08
 1.02698e+08 1.80353e+08 1.01786e+08 1.88451e+08 7.30516e+07 2.23860e+08
 1.49807e+08 1.52780e+08 2.18535e+08 2.85348e+08 3.41771e+08 4.52399e+08
 5.45297e+08 9.12370e+08 2.02815e+09 2.24190e+09 1.50043e+09 1.66125e+09
 1.54048e+09 1.03403e+09 6.04299e+08 4.88353e+08 1.58541e+08 3.11761e+07
 2.28965e+06
6$$ 2z 2r1 2 2r3 2r4 2r5 2r6 2r7 2r8 2r9 3r10 11 12 13 4r14 2r15
       2r16 3r17 3r18 19 20 0
7**
' photon weighting flux for concrete (int #106)              Mar '96
             7.42941e+01 2.30936e+03 6.82316e+03 1.24943e+06 1.03523e+08
 3.25671e+08 1.20393e+08 5.83873e+07 2.68211e+08 1.61678e+08 1.37631e+08
 3.60019e+08 2.29686e+08 4.72749e+08 2.74113e+08 3.31726e+08 7.35257e+08
 4.46441e+08 2.01309e+08 1.87887e+08 1.33262e+07 4.94239e+08 3.86628e+08
 2.48890e+08 2.69078e+08 2.90021e+08 2.87195e+08 3.32608e+08 2.97708e+08
 7.99392e+08 1.39680e+09 1.13935e+09 1.72007e+09 1.15885e+09 2.10047e+08
 3.18797e+08 1.95052e+08 1.70746e+07 6.02324e+06 4.01610e+05 7.06744e+04
 5.19384e+03
 t
end
#nitawl
6$$ a3 500 1000 e
0$$ 81 e 1$$ 0 13   a11 -1 e t
2$$ 100141 801641 2605441 2605641 2605741 2605841 601241 1102341
 1200041 1302741 1400041 1900041 2000041  t
end
#alpo
0$$ 87 4 1$$ 1 3 8 74 7 -1 -1 e t
2$$  4 0 t
end
'EOF'
setenv TMPDIR /rsic/tmp/$USER.$$
mkdir $TMPDIR
set tmpdir=$TMPDIR
cp input $tmpdir/sysin
cd $tmpdir
if ( ! ( -e scampi ) )   ln -s $PGM_DIR/scampi         scampi
if ( ! ( -e malocs ) )   ln -s $PGM_DIR/malocs         malocs
if ( ! ( -e rade ) )     ln -s $PGM_DIR/rade           rade
if ( ! ( -e alpo   ) )   ln -s $PGM_DIR/alpo           alpo
if ( ! ( -e nitawl ) )   ln -s $PGM_DIR/nitawl         nitawl
```

Table A.15 (Cont'd)

```
if ( ! ( -e ajax ) )      ln -s $PGM_DIR/ajax            ajax
if ( ! ( -e qatable ) )   ln -s $DATA_DIR/qatable                qatable
if ( ! ( -e aliases ) )   ln -s $DATA_DIR/aliases                aliases
if ( ! ( -e ft85f001 ) )  ln -s /u5/jew/bug96/ampx.vitb6r3.bonami ft85f001
rm print _prt* _out*
scampi
cd $RTNDIR
cat $tmpdir/print  >> $1
cat $tmpdir/_prt*  >> $1
cat $tmpdir/_out*  >> $1
mv  $tmpdir/ft87f001 /u2/jew/d185/bugle96.pconc.tbinr3
```

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C. Fairbanks, NRC Project Manager

11. ABSTRACT *(200 words or less)*

A Revised multigroup cross-section library based on Released 3 of ENDF/B-VI data has been produced and tested for light-water reactor shielding and reactor pressure vessel dosimetry applications. This new broad-group library, which is designated BUGLE-96, represents an improvement over the BUGLE-93 data library released in February 1994 and replaces the data package for BUGLE-93 in the Radiation Safety Information Computational Center (formerly RSIC). The processing methodology is the same as that used for producing BUGLE-93 and is consistent with ANSI/ANS 6.1.2. The ENDF data were first processed into a fine-group, pseudo-problem-independent format and then collapsed into the final broad-group format. The fine-group library, which is designated VITAMIN-B6, contains 120 nuclides. The BUGLE-96 47-neutron-group/20-gamma-ray-group library contains the same 120 nuclides processed as infinitely dilute and collapsed using a weighting spectrum typical of a concrete shield. Additionally, nuclides processed with resonance self-shielding and weighted using spectra specific to BWR and PWR material compositions and reactor models are available. As an added feature of BUGLE-96, cross section sets having upscatter data for four thermal neutron groups are included.

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reactor pressure vessel, reactor dosimetry, reactor shielding, nuclear data, cross ections, ENDF/B-VI

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