DLC-75

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BUGLE-80

Coupled 47 Neutron, 20 Gamma-Ray, P_3, Cross Section Library for LWR Shielding Calculations by the ANS-6.1.2 Working Group on Multigroup Cross Sections

Contributed by

Oak Ridge National Laboratory
Oak Ridge, Tennessee

ANS-6.1.2

and

EG&G Idaho, Inc.
Idaho Falls, Idaho

RADIATION SHIELDING INFORMATION CENTER

DOCUMENTATION FOR DLC-75/BUGLE-80 CODE PACKAGE

(Total Pages 27; Updated 11/89)

1. **NAME AND TITLE OF DATA LIBRARY**
   BUGLE-80: Coupled 47 Neutron, 20 Gamma-Ray Group, P_3, Cross Section Library for LWR Shielding Calculations by the ANS-6.1.2 Working Group on Multigroup Cross Sections.

2. **NAME AND TITLE OF DATA RETRIEVAL PROGRAMS**
   BCBN: BCD to binary conversion program.

3. **CONTRIBUTORS**
   Oak Ridge National Laboratory, Oak Ridge, Tennessee.
   ANS-6.1.2.
   EG&G Idaho, Inc., Idaho Falls, Idaho.
   Battelle, Columbus, Ohio.

4. **HISTORICAL BACKGROUND AND INFORMATION**
   The 47 neutron, 20 gama-ray group, P_3, cross section library was developed at Oak Ridge National Laboratory for LWR shielding applications. It replaces the DLC-47/BUGLE library which was prepared for use by the ANS 6.1.2 Working Group on Shielding Cross Sections for concrete shielding applications. Studies by members of ANS 6.1.2 and others led to the development of BUGLE-80. Since it has a different group structure, BUGLE-80 was given a new DLC number to help minimize confusion with the earlier version.
   The current library was generated by collapse from DLC-41C/VITAMIN-C using a spectrum typical to that expected in a PWR shield. The cross sections should be useful for shielding situations where resonance self shielding and temperature effects are not important.

5. **APPLICATION OF THE DATA**
   The DLC-75/BUGLE-80 package contains microscopic coupled (47n,20g) data for 42 isotopes and 47n data for 24 isotopes (gamma-production not available on ENDF/B-IV for these 24 isotopes). In addition, sample input and output for running ANISN test cases for a concrete and LWR problem in both (47n,20g) and (171n,36g) energy structures are also provided. Kerma factors in the 47n,20g structure (based on DLC-60/MACKLIB-IV) are included as well as (47n,20g) cross sections with delayed gammas from fission for U-235, U-238, and Pu-239.

6. **SOURCE AND SCOPE OF DATA**
   The library was produced in a manner similar to that for BUGLE. The VITAMIN-C library was the starting point for the series of AMPX-II steps followed by an AXMIX run that were required to make BUGLE-80. A calculational scheme was used to produce the 19 materials used in the concrete and LWR calculations.
   BUGLE-80 is based on ENDF/B-IV evaluated data and the group structure has been tailored to represent the spectral phenomena of typical LWR shielding problems. It was derived by collapsing from DLC-41/VITAMIN-C. The evaluated data which served as sources of data for VITAMIN-C are ENDF/B-IV, LENDL, and ENDF/B-III.

47 neutron, 20 gamma-ray group, P_3, cross sections (microscopic and macroscopic cross sections used in the concrete and LWR calculations.)

^{1}H, ^{10}B, ^{16}O, Cr, ^{55}Mn, Fe, Ni, Zr, ^{235}U, ^{238}U, ^{12}C,

Si, Mo, Na, Mg, ^{27}Al, ^{32}S, K, Ca.

47 neutron 20 gamma-ray group, P_3, cross sections.

^{6}Li, ^{7}Li, ^{9}Be, ^{14}N, F, ^{31}P, Cl, Ti, V, ^{59}Co, Cu,

^{93}Nb, Sn, Ba, ^{151}Eu, ^{153}Eu, ^{181}Ta, ^{182}W, ^{183}W, ^{184}W,

^{186}W, Pb, ^{239}Pu, ^{240}Pu.

47 neutron group, P_3, cross sections (23 materials) (neutron only).

^{234}U, ^{236}U, ^{242}Pu, ^{233}Pa, Gd, ^{243}Am, ^{244}Cm, ^{241}Am,

^{238}Pu, ^{241}Pu, ^{3}H, ^{3}He, ^{4}He, $^{2}Zirc$, ^{107}Ag, ^{109}Ag,

Cd, ^{232}Th, ^{233}U, ^{237}Np, ^{2}H, ^{11}B.

47 neutron, 20 gamma-ray group kerma factors from MACKLIB-IV (49 materials).

^{1}H, ^{4}He, ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B, C, ^{14}N, ^{16}O,

F, ^{23}Na, Mg, ^{27}Al, Si, Cl, K, Ca, Ti, V, Cr, ^{55}Mn,

Fe, ^{59}Co, Ni, Cu, Nb, Mo, ^{181}Ta, ^{182}W, ^{183}W, ^{184}W,

Pb, ^{232}Th, ^{233}Pa, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U,

^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am.

47 neutron, 20 gamma-ray group, P_3, cross section with delayed gammas from fission.

^{235}U, ^{238}U, ^{239}Pu.

7. **DISCUSSION OF THE DATA RETRIEVAL PROGRAM**

BCBN is included to read formatted ANISN records and write them as unformatted records; the code is called BCD2BIN for the PC 386 and PC 486 version (B).

8. **DATA FORMAT AND COMPUTER**

Card images in ANISN format; mainframe computers with a subset distributed on diskettes; The entire package has been downloaded to diskettes for use on 386/387 personal computers.

9. **TYPICAL RUNNING TIME**

On a PC 386, the BCD2BIN program took about 4 minutes to convert XSEC1.BCD to binary form.

10. **REFERENCE**

R. W. Roussin, "BUGLE-80: A Coupled 47-Neutron, 20-Gamma-Ray Group Library for LWR Shielding Calculations," Informal Notes (June 1980).

11. **CONTENTS OF LIBRARY**

Included are the referenced documents and a reel of magnetic tape which contains cross sections, job control cards, source deck, input data, ANISN input for problems, input for AMPX modules, scalar fluxes, plus output from BCD-binary conversion program, concrete source generation program and LWR source generation program; total records 110,719. To facilitate use on personal computers, files 1 and 2 are available on one DS/HD (1.2MB) diskette in ANISN format with each of the 192 materials in separate files. The compressed file is approximately 850 KB and will expand to over 2.5 MB. The neutron data from files 1 and 2 is also available in ISOTXS format (4D isotope control and group independent data records) and is available in a single file on one DS/HD diskette. The compressed ISOTXS file is less than 1 MB and will expand to over 5.6 MB. README files on the diskettes contain instructions on accessing the compressed data files.

The PC 386/486 version (B) is available on 2 DS/HD 5.25-inch diskettes (1.2MB).

12. **DATE OF ABSTRACT**

April 1985, revised August 1989, April 1991.

KEYWORDS: ANISN FORMAT; BENCHMARK PROBLEM CROSS SECTIONS; CONCRETE CROSS SECTIONS; COUPLED NEUTRON-GAMMA-RAY CROSS SECTIONS; MICROCOMPUTER; MULTIGROUP CROSS SECTIONS; MULTIGROUP CROSS SECTIONS BASED ON ENDF/B; CCCC INTERFACE FORMAT.

Informal Notes

B U G L E - 8 0

Coupled 47-Neutron, 20-Gamma-Ray, P_3,
Cross-Section Library
for LWR Shielding Calculations

R. W. Roussin

June 1980

Oak Ridge National Laboratory
Oak Ridge, Tennessee
and
ANS-6.1.2

ACKNOWLEDGEMENT

Several persons were involved in the development of what has now been released as DLC-75/BUGLE-80.

The specifications for the original version DLC-47/BUGLE were developed with the help of C. R. Weisbin and E. M. Oblow of Oak Ridge National Laboratory. Suggestions for improvements to the original specifications came from G. L. Simmons (Science Applications, Inc.-La Jolla) and from members of the ANS 6.1.2. These include D. R. Harris, chairman (Rensselaer Polytechnic Institute), M. Battat (Los Alamos Scientific Laboratory), V. R. Cain (Science Applications, Inc.-Oak Ridge), W. Herwig (Babcock & Wilcox), B. Hopkins (Bechtel Corporation), E. Normand (Sargent and Lundy), O. Ozer (Electric Power Research Institute), S. Purohit (Consolidated Edison), P. Rose (Brookhaven National Laboratory), and W. Smith (Duke Power Company).

Calculations for the concrete and LWR problems were performed by G. De Beer (South Africa), M. Metghalchi (Iran), and J. West (ORNL).

The assistance of N. M. Greene (ORNL) in performing runs with AMPX-II to produce BUGLE-80 is appreciated.

BUGLE-80: A Coupled 47 Neutron, 20 Gamma-Ray Group Library

for LWR Shielding Calculations

R. W. Roussin

June 1980

INTRODUCTION

As a result of experience[1,2] gained with the DLC-47/BUGLE 45 neutron, 16 gamma-ray group cross section library, its specifications were altered to better satisfy the requirements of the ANS 6.1.2 Working Group on Cross Sections for recommending a standard broad group library for LWR shielding applications.[3] As indicated in Ref. 1 and 2, comparisons have been made with a variety of multigroup libraries commonly used in the radiation transport community. Feedback from ANS 6.1.2 also suggested some additions and modifications to the original BUGLE library to more adequately meet the needs of the user community.

Among the changes suggested in the comparison studies and by ANS 6.1.2 are the following:

1. Refinement of the neutron and gamma-ray group structure to allow better spectral results for a 1 meter concrete andfor a LWR[4] benchmark problem.
2. The use of a more representative spectrum for collapsing from the 171n, 36g VITAMIN-C[5] master library.
3. The inclusion of kerma factors.
4. The inclusion of delayed gamma rays from fission.
5. The inclusion of information about how the library was produced.

GROUP STRUCTURE AND COLLAPSING SPECTRUM

The original BUGLE was produced by collapsing using a group version of the original weighting function used for VITAMIN-C, which included a fusion peak at 14 MeV. The peak, in combination with a broad group spanning 10 to 13.5 MeV allowed the buildup of too many high energy neutrons above 10 MeV. This would not be acceptable for accurate fluence calculations to predict pressure vessel damage for LWRs.

The group structure around the 2.3 MeV minimum in oxygen also proved to be inadequate and additional groups were provided to allow a better calculation of spectral results for neutron transport through 1 meter of concrete. For the LWR benchmark, the pressure vessel spectrum results near the 25 keV minimum in iron indicated an inadequate representation, and the group structure was refined accordingly. In addition, the shape of pressure vessel spectrum just above 1 eV was badly modeled, and groups were added to compensate. It was found that the use of two groups in the thermal region (below 0.414eV) modeled the thermal flux better for all problems considered. Finally, to obtain a better match of gamma-ray spectra, 4 additional groups were added to the original BUGLE structure.

Some neutron groups in the original structure were deemed to be unnecessary, and the net result was the addition of 2 groups. Thus, the final structure for BUGLE-80 is 47 neutron and 20 gamma-ray groups as indicated in Table 1.

The collapsing spectrum used was taken from the VITAMIN-C calculation of a PWR model reactor.[6] The typical spectrum chosen was that in the middle of the concrete shield (beyond the pressure vessel). The values used are listed in Table 2.

Table 1. Neutron and Gamma-Ray Group Structure for BUGLE-80

GROUP	Neutron Group UPPER ENERGY	Neutron Group UPPER LETHARGY	Gamma-Ray Group UPPER ENERGY
1	1.733299E+07	-5.500267E-01	1.400000E+07
2	1.419100E+07	-3.500229E-01	1.000000E+07
3	1.221400E+07	-1.999978E-01	8.000000E+06
4	1.000000E+07	0.0	7.000000E+06
5	8.607100E+06	1.499971E-01	6.000000E+06
6	7.408200E+06	2.999975E-01	5.000000E+06
7	6.065300E+06	5.000008E-01	4.000000E+06
8	4.965900E+06	6.999902E-01	3.000000E+06
9	3.678800E+06	9.999963E-01	2.000000E+06
10	3.011900E+06	1.200013E+00	1.500000E+06
11	2.725300E+06	1.300006E+00	1.000000E+06
12	2.466000E+06	1.399987E+00	8.000000E+05
13	2.365300E+06	1.441686E+00	7.000000E+05
14	2.345700E+06	1.450001E+00	6.000000E+05
15	2.231300E+06	1.500000E+00	4.000000E+05
16	1.920500E+06	1.649999E+00	2.000000E+05
17	1.653000E+06	1.799993E+00	1.000000E+05
18	1.353400E+06	1.999965E+00	6.000000E+04
19	1.002600E+06	2.299988E+00	3.000000E+04
20	8.208500E+05	2.500000E+00	2.000000E+04
21	7.427400E+05	2.599994E+00	1.000000E+04
22	6.081000E+05	2.800000E+00	
23	4.978700E+05	3.000001E+00	
24	3.688300E+05	3.300004E+00	
25	2.972000E+05	3.515935E+00	
26	1.831600E+05	3.999980E+00	
27	1.110900E+05	4.499999E+00	
28	6.737900E+04	5.000007E+00	
29	4.086800E+04	5.499993E+00	
30	3.182800E+04	5.749994E+00	
31	2.605800E+04	5.950015E+00	
32	2.417600E+04	6.024980E+00	
33	2.187500E+04	6.124996E+00	
34	1.503400E+04	6.500026E+00	
35	7.101699E+03	7.250007E+00	
36	3.354600E+03	8.000008E+00	
37	1.584600E+03	8.750009E+00	
38	4.540000E+02	9.999999E+00	
39	2.144500E+02	1.075002E+01	
40	1.013000E+02	1.150001E+01	
41	3.726700E+01	1.249999E+01	
42	1.067700E+01	1.375000E+01	
43	5.043500E+00	1.450000E+01	
44	1.855399E+00	1.550000E+01	
45	8.764200E-01	1.625000E+01	
46	4.139900E-01	1.700000E+01	
47	9.999996E-02	1.842067E+01	
48	1.000000E-05	2.763101E+01	

Table 2. Spectrum Used for Collapsing
from the VITAMIN-C to BUGLE-80 Group Structure

Neutron Groups

FINE GROUP	UPPER ENERGY	GROUP FLUX
1	1.733299E+07	3.087000E+04
2	1.648700E+07	5.980000E+04
3	1.568300E+07	4.163000E+04
4	1.491800E+07	5.856000E+04
5	1.455000E+07	7.631000E+04
6	1.419100E+07	9.475000E+04
7	1.384000E+07	1.152000E+05
8	1.349900E+07	3.766000E+05
9	1.284000E+07	3.942000E+05
10	1.221400E+07	4.010000E+05
11	1.161800E+07	4.779000E+05
12	1.105200E+07	8.293000E+05
13	1.051300E+07	9.341000E+05
14	1.000000E+07	1.173000E+06
15	9.512300E+06	1.540000E+06
16	9.048400E+06	1.655000E+06
17	8.607100E+06	1.771000E+06
18	8.187300E+06	2.138000E+06
19	7.788000E+06	2.327000E+06
20	7.408200E+06	2.289000E+06
21	7.046900E+06	2.992000E+06
22	6.703200E+06	1.156000E+06
23	6.592400E+06	2.664000E+06
24	6.376300E+06	4.091000E+06
25	6.065300E+06	3.628000E+06
26	5.769500E+06	3.770000E+06
27	5.488100E+06	4.957000E+06
28	5.220500E+06	4.161000E+06
29	4.965900E+06	4.642000E+06
30	4.723700E+06	4.766000E+06
31	4.493300E+06	9.520000E+06
32	4.065700E+06	8.331000E+06
33	3.678800E+06	7.996000E+06
34	3.328700E+06	5.291000E+06
35	3.166400E+06	7.570000E+06
36	3.011900E+06	8.570000E+06
37	2.865000E+06	9.821000E+06
38	2.725300E+06	1.190000E+07
39	2.592400E+06	1.154000E+07
40	2.466000E+06	1.064000E+07
41	2.385200E+06	3.581000E+06
42	2.365300E+06	4.720000E+06
43	2.345700E+06	7.369000E+06
44	2.306900E+06	1.290000E+07
45	2.231300E+06	1.460000E+07
46	2.122500E+06	1.317000E+07
47	2.019000E+06	1.118000E+07
48	1.920500E+06	1.097000E+07
49	1.826800E+06	2.096000E+07
50	1.737700E+06	1.716000E+07
51	1.653000E+06	1.581000E+07
52	1.572400E+06	1.736000E+07
53	1.495700E+06	1.935000E+07
54	1.422700E+06	2.120000E+07
55	1.353400E+06	1.509000E+07
56	1.287300E+06	2.379000E+07
57	1.224000E+06	2.843000E+07
58	1.164800E+06	2.686000E+07
59	1.108000E+06	3.193000E+07

Table 2 (continued). Spectrum Used for Collapsing from the VITAMIN-C to BUGLE-80 Group Structures

Neutron Groups

Fine Group	Upper Energy	Group Flux
60	1.002000E+06	1.068000E+07
61	9.616400E+05	2.413000E+07
62	9.071800E+05	2.867000E+07
63	8.629400E+05	3.265000E+07
64	8.208500E+05	3.838000E+07
65	7.806200E+05	4.423000E+07
66	7.427400E+05	4.739000E+07
67	7.065100E+05	4.999000E+07
68	6.720000E+05	5.929000E+07
69	6.392800E+05	6.843000E+07
70	6.081000E+05	7.119000E+07
71	5.764400E+05	6.178000E+07
72	5.502300E+05	7.108000E+07
73	5.234000E+05	6.856000E+07
74	4.978700E+05	9.044000E+07
75	4.504900E+05	6.633000E+07
76	4.076200E+05	3.598000E+07
77	3.877400E+05	3.883000E+07
78	3.688300E+05	1.035000E+08
79	3.337300E+05	1.183000E+08
80	3.019700E+05	1.415000E+07
81	2.985000E+05	5.373000E+06
82	2.972000E+05	1.096000E+07
83	2.945200E+05	2.974000E+07
84	2.872500E+05	6.016000E+07
85	2.732400E+05	1.200000E+08
86	2.472400E+05	5.957000E+07
87	2.351800E+05	5.884000E+07
88	2.237100E+05	5.323000E+07
89	2.128000E+05	5.154000E+07
90	2.024200E+05	4.937000E+07
91	1.925500E+05	5.262000E+07
92	1.831600E+05	6.499000E+07
93	1.742200E+05	7.287000E+07
94	1.657300E+05	7.761000E+07
95	1.576400E+05	7.178000E+07
96	1.499600E+05	6.718000E+07
97	1.426400E+05	6.599000E+07
98	1.356900E+05	7.358000E+07
99	1.290700E+05	7.573000E+07
100	1.227700E+05	6.729000E+07
101	1.167900E+05	6.846000E+07
102	1.110900E+05	1.636000E+08
103	9.803700E+04	1.431000E+08
104	8.651700E+04	5.354000E+07
105	8.250000E+04	4.718000E+07
106	7.950000E+04	1.205000E+08
107	7.200000E+04	7.979000E+07
108	6.737900E+04	2.052000E+08
109	5.656200E+04	8.345000E+07
110	5.247500E+04	1.423000E+08
111	4.630900E+04	1.377000E+08
112	4.086800E+04	1.718000E+08
113	3.430700E+04	7.974000E+07
114	3.162600E+04	1.188000E+08
115	2.850000E+04	5.540000E+07
116	2.700000E+04	3.832000E+07
117	2.605800E+04	5.587000E+07
118	2.478800E+04	2.905000E+07
119	2.417600E+04	2.838000E+07

Table 2 (continued). Spectrum Used for Collapsing from the VITAMIN-C to BUGLE-80 Group Structures

Neutron Groups

Fine Group	Upper Energy	Group Flux
120	2.357900E+04	8.391000E+07
121	2.187500E+04	1.391000E+08
122	1.930500E+04	2.736000E+08
123	1.503400E+04	2.693998E+08
124	1.170900E+04	2.619000E+08
125	9.118797E+03	2.639000E+08
126	7.101699E+03	2.607000E+08
127	5.530797E+03	2.614000E+08
128	4.307398E+03	1.534000E+08
129	3.707400E+03	9.319000E+07
130	3.354600E+03	8.646000E+07
131	3.035400E+03	6.604000E+07
132	2.746500E+03	4.361000E+07
133	2.612600E+03	5.466000E+07
134	2.485200E+03	1.190000E+08
135	2.248700E+03	1.159000E+08
136	2.034700E+03	2.774999E+08
137	1.584500E+03	2.685998E+08
138	1.234100E+03	2.645000E+08
139	9.611199E+02	2.633000E+08
140	7.485198E+02	2.625000E+08
141	5.829500E+02	2.619000E+08
142	4.540000E+02	2.610000E+08
143	3.535798E+02	2.605000E+08
144	2.753599E+02	2.598000E+08
145	2.144500E+02	2.590000E+08
146	1.670200E+02	2.583000E+08
147	1.300700E+02	2.574000E+08
148	1.013000E+02	2.565000E+08
149	7.889299E+01	2.556000E+08
150	6.144199E+01	2.545000E+08
151	4.785100E+01	2.536000E+08
152	3.726700E+01	2.460000E+08
153	2.920299E+01	2.573000E+08
154	2.260300E+01	2.498000E+08
155	1.760300E+01	2.484000E+08
156	1.371000E+01	2.471000E+08
157	1.067700E+01	2.455000E+08
158	8.315300E+00	2.440000E+08
159	6.476000E+00	2.424000E+08
160	5.043500E+00	2.406000E+08
161	3.927899E+00	2.388000E+08
162	3.058999E+00	2.410000E+08
163	2.372399E+00	2.369000E+08
164	1.855399E+00	2.328000E+08
165	1.445000E+00	2.305000E+08
166	1.125400E+00	2.282000E+08
167	8.764200E-01	2.257000E+08
168	6.825000E-01	2.231000E+08
169	5.315600E-01	2.202000E+08
170	4.139900E-01	1.823000E+09
171	9.999996E-02	1.005000E+10
172	1.000000E-05	

Table 2 (continued). Spectrum Used for Collapsing from the VITAMIN-C to BUGLE-80 Group Structures

Gamma-Ray Groups

NE GROUP	UPPER ENERGY	GROUP FLUX
1	1.400000E+07	3.202000E+03
2	1.200000E+07	1.070000E+06
3	1.000000E+07	9.371000E+07
4	8.000000E+06	2.945999E+08
5	7.500000E+05	1.057000E+08
6	7.000000E+06	5.911000E+07
7	6.500000E+06	2.392000E+08
8	6.000000E+06	1.499000E+08
9	5.500000E+06	1.269000E+08
10	5.000000E+06	3.147999E+08
11	4.500000E+06	2.072000E+08
12	4.000000E+06	4.166999E+08
13	3.500000E+06	2.497000E+08
14	3.000000E+06	3.045000E+08
15	2.500000E+06	6.557998E+08
16	2.000000E+06	4.093998E+08
17	1.660000E+06	1.851000E+08
18	1.500000E+06	1.876000E+08
19	1.330000E+06	4.547999E+08
20	1.000000E+06	3.682998E+08
21	8.000000E+05	2.311000E+08
22	7.000000E+05	2.510000E+06
23	6.000000E+05	2.704000E+08
24	5.120000E+05	2.581000E+08
25	5.100000E+05	3.077000E+08
26	4.500000E+05	2.768000E+08
27	4.000000E+05	7.489999E+08
28	3.000000E+05	1.333000E+09
29	2.000000E+05	1.077000E+09
30	1.500000E+05	1.674000E+09
31	1.000000E+05	9.984998E+08
32	7.500000E+04	4.745999E+08
33	6.000000E+04	1.848000E+08
34	4.500000E+04	1.952000E+07
35	3.000000E+04	5.421000E+05
36	2.000000E+04	5.835000E+04
37	1.000000E+04	

CALCULATIONAL SEQUENCE TO PRODUCE BUGLE-80

The revised library was produced in a manner similar to that for BUGLE. The VITAMIN-C library was the starting point for the series of AMPX-II[7] steps followed by an AXMIX[8] run that were required to make BUGLE-80. The calculational scheme used to produce the 19 materials used in the concrete and LWR calculations is indicated in Figure 1.

It should be noted that the effect of the BONAMI self shielding run was unimportant for the problems considered. Comparisons between concrete calculations using shielded and unshielded constituents showed no differences in fluences in the thermal region.

Similar approaches were used to prepare the additional materials provided in BUGLE-80 except that BONAMI was not used for the remaining materials included in BUGLE-80.

CONTENTS OF THE BUGLE-80 PACKAGE

The revised library, to be denoted DLC-47B/BUGLE-80, is available from the Radiation Shielding Information Center (RSIC) and Oak Ridge National Laboratory. The package consists of 31 files written on a standard 2400 ft reel of magnetic tape. The various types of information included are listed below.

47n,20g Cross Sections for the Concrete and LWR Sample Problems

Cross sections in the BUGLE-80 group structure are provided for the 19 constituents of the materials needed to describe the concrete and LWR problems. In addition, the macroscopic cross sections for the 5 materials used in the two problems are also included for completeness. The elements and materials are listed in Table 3.

47n,20g Coupled Cross Sections for Other Elements

An additional 24 elements which were derived from evaluations with gamma-ray production are also provided. These are listed in Table 4.

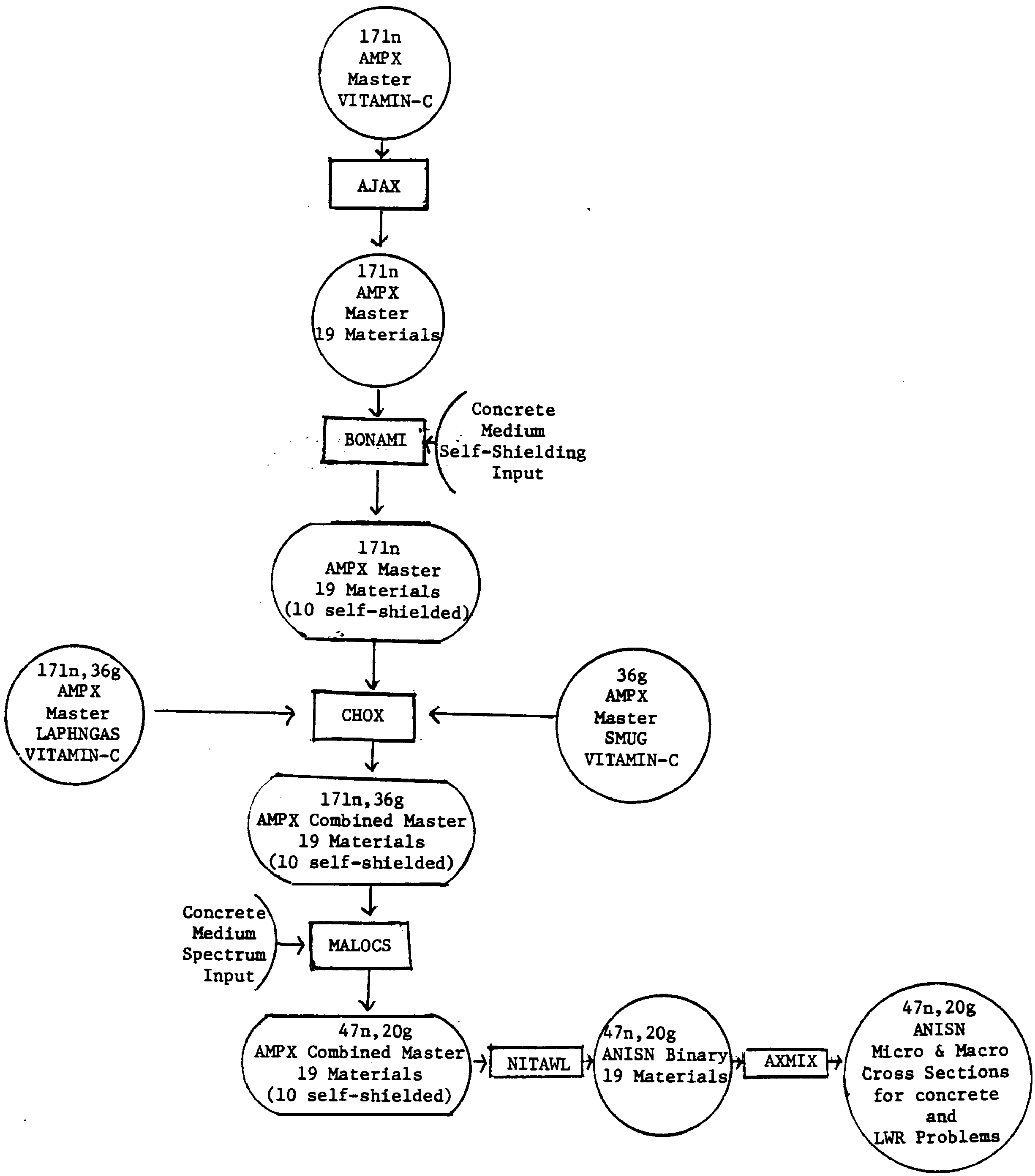

Fig. 1. Calculational Scheme to Produce the 19 Materials Cross Section Library Used in Test Runs for BUGLE-80.

Table 3. BUGLE-80 (47n,20g), P_3, Microscopic and Macroscopic Cross Sections Used in the Concrete and LWR Calculation

ID	Material	ID	Material
1-4	H-1	49-52	Mo
5-8	B-10	53-56	Na
9-12	O-16	57-60	Mg
13-16	Cr	61-64	Al-27
17-20	Mn-55	65-68	S-32
21-24	Fe	69-72	K
25-28	Ni	73-76	Ca
29-32	Zr	77-80	LWR Core
33-36	U-235	81-84	LWR Coolant
37-40	U-238	85-88	LWR Low Carbon Steel
41-44	C-12	89-92	LWR Stainless Steel
45-48	Si	93-96	Concrete

Table 4. BUGLE-80 (47n,20g), P_3, Microscopic Cross Sections for Other Materials with Gamma-Ray Production

ID	Material	ID	Material
101-104	Li-6	149-152	Sn *
105-108	Li-7	153-156	Ba
109-112	Be-9	157-160	Eu-151
113-116	N-14	161-164	Eu-153
117-720	F	165-168	Ta-181
121-124	P-31	169-172	W-182
125-128	Cl	173-176	W-183
129-132	Ti	177-180	W-184
133-136	V	181-184	W-186
137-140	Co-59	185-188	Pb
141-144	Cu	189-192	Pu-239
145-148	Nb-93	193-196	Pu-240

Table 5. BUGLE-80 47n, P_3, Microscopic Cross Sections for Materials with no Gamma-Ray Production

ID	Material	ID	Material
201-204	U-234	249-252	He-3
205-208	U-236	253-256	He-4
209-212	Pu-242	257-260	Zirc-2 *
213-216	Pa-233	261-264	Ag-107
217-220	Sm-149	265-268	Ag-109
221-224	Gd	269-272	Cd
225-228	Am-243	273-276	Th-232
229-232	Cm-244	277-280	U-233
233-236	Am-241	281-284	Np-237
237-240	Pu-238	285-288	H-2
241-244	Pu-241	289-292	B-11
245-248	H-3		

* non-ENDF

47n Cross Sections for 23 Additional Elements

Some evaluations contain only neutron data. For these, no gamma-ray production data is available, and consequently only neutron cross sections are included as part of BUGLE-80. These are listed in Table 5.

Retrieval and Source Generation Programs

A simple program for reading the BUGLE-80 card image cross sections and converting them to binary form is included as part of the package. IBM JCL, DD cards, sample input, and sample output are also provided.

A program to generate a neutron fission, fusion, or a combination fission plus fusion source for the concrete slab problem is included. IBM JCL, DD cards, sample input and output also provided.

For the LWR problem, a source generation program with JCL, DD cards, sample input and output is also included as part of BUGLE-80.

171n,36g Macroseopic Cross Sections

For completeness, the macroscopic cross sections used for the concrete and LWR calculations are included as part of the package. They are listed in Table 6.

ANISN Input and Scalar Flux Output for the Concrete and LWR Problems

To aid the BUGLE-80 user in perhaps repeating or extending some of the investigations culminating in the package, the input for ANISN for the (47n,20g) runs of the concrete and LWR problems are provided for direct comparison. These inputs include the results of running the source generation programs mentioned above. Also provided are the scalar fluxes in card image format from the 4 ANISN runs mentioned above.

AMPX-II and AXMIX Input for Producing BUGLE-80

To help demonstrate how to execute the AMPX-II modules and AXMIX in the sequence shown in Figure 1, the appropriate input data are provided in the package.

Table 6. BUGLE-80 (171n,36g), P3, Macroscopic Cross Sections for the Concrete and LWR Calculations

ID	Material	ID	Material
301-304	LWR Core	313-316	LWR Stainless Steel
305-308	LWR Coolant	317-320	Concrete
309-312	LWR Low Carbon Steel		

Table 7. BUGLE-80 (47n,20g) Kerma Factors

ID	Material	ID	Material	ID	Material	ID	Material
1269	H-1	1194	Si	1285	Ta-181	1050	Pu-238
1270	He-4	1149	Cl	1128	W-182	1264	Pu-239
1271	Li-6	1150	K	1129	W-183	1265	Pu-240
1272	Li-7	1195	Ca	1130	W-184	1266	Pu-241
1289	Be-9	1286	Ti	1131	W-186	1161	Pu-242
1273	B-10	1196	V	1288	Pb	1056	Am-241
1160	B-11	1191	Cr	1296	Th-232	1057	Am-243
1274	C	1197	Mn-55	1297	Pa-233		
1275	N-14	1192	Fe	1260	U-233		
1276	O-16	1199	Co-59	1043	U-234		
1277	F	1190	Ni	1261	U-235		
1156	Na-23	1295	Cu	1163	U-236		
1280	Mg	1189	Nb	1262	U-238		
1193	Al-27	1287	Mo	1263	Np-237		

Kerma Factors in BUGLE-80

The 47n,20g kerma factors provided were derived by collapsing from (171n,36g) MACLIB-IV[10] Kerma Factor Library, using the retrieval program provided with that code and the same weighting function as was used for the cross section collapse. Kerma factors are provided for 49 elements as listed in Table 7. The units are eV-barn/atom. See Table 11 for activities as a function of table positions.

Delayed Fission Product Gamma Rays

As a means of providing a delayed component to represent fission product gamma-ray production, some data were made available by O. W. Hermann and G. W. Morrison[11] of ORNL and later by R. LaBauve[12] of LASL. A means of incorporating the Hermann/Morrison data for U-235, U-238, and Pu-239 was devised and implemented to provide 47n,20g ANISN card image data sets with gamma-ray production both prompt as well as delayed components. These modified cross sections are included as a file on the BUGLE-80 package. A summary of data sets available for possible inclusion is given in Table 8.

Calculational Results with BUGLE-80

Results of the calculations comparing BUGLE-80 with VITAMIN-C are given in Figures 2 through 7. Results for the concrete calculations plotted in Figures 2 and 3 show very good agreement between BUGLE-80 and VITAMIN-C. For the LWR problem, the results of which are plotted in Figures 4 through 7, agreement is good in the water regions but not exceptional in the core and pressure vessel regions.

Applications of BUGLE-80

As can be seen from results plotted in Figures 2 through 7, BUGLE-80 is likely to produce acceptable results for concrete shielding problems and in certain portions of LWR shielding problems beyond the pressure vessel of the reactor. this is due to the combination of group boundary selection and spectrum choice (PWR concrete shield) for collapse to the 47n, 20g energy structure.

Table 8. Delayed Fission Gamma-Ray Data Sets
Available for Use with BUGLE-80

Element	Type	Irradiation Time	Source
U-235*	Thermal	10^{13}S	ORIGEN-ORNL
U-235	Fast	"	"
U-238*	Fast	"	"
Pu-239*	Thermal	"	"
Pu-239	Fast	"	"
U-238	Fast	{10,100,1000,3600,	"
Pu-239	Fast	10^5,10^6, and 10^8S}	"
Th-232	Fast	10^8S	CINDER-LASL
U-233	Thermal	"	"
U-235	Thermal	"	"
U-235	Fast	"	"
U-235	High-E	"	"
U-238	Fast	"	"
U-238	High-E	"	"
Pu-239	Thermal	"	"
Pu-239	Fast	"	"
Pu-241	Thermal	"	"

*47n,20g Cross Sections have been prepared which include these data sets.

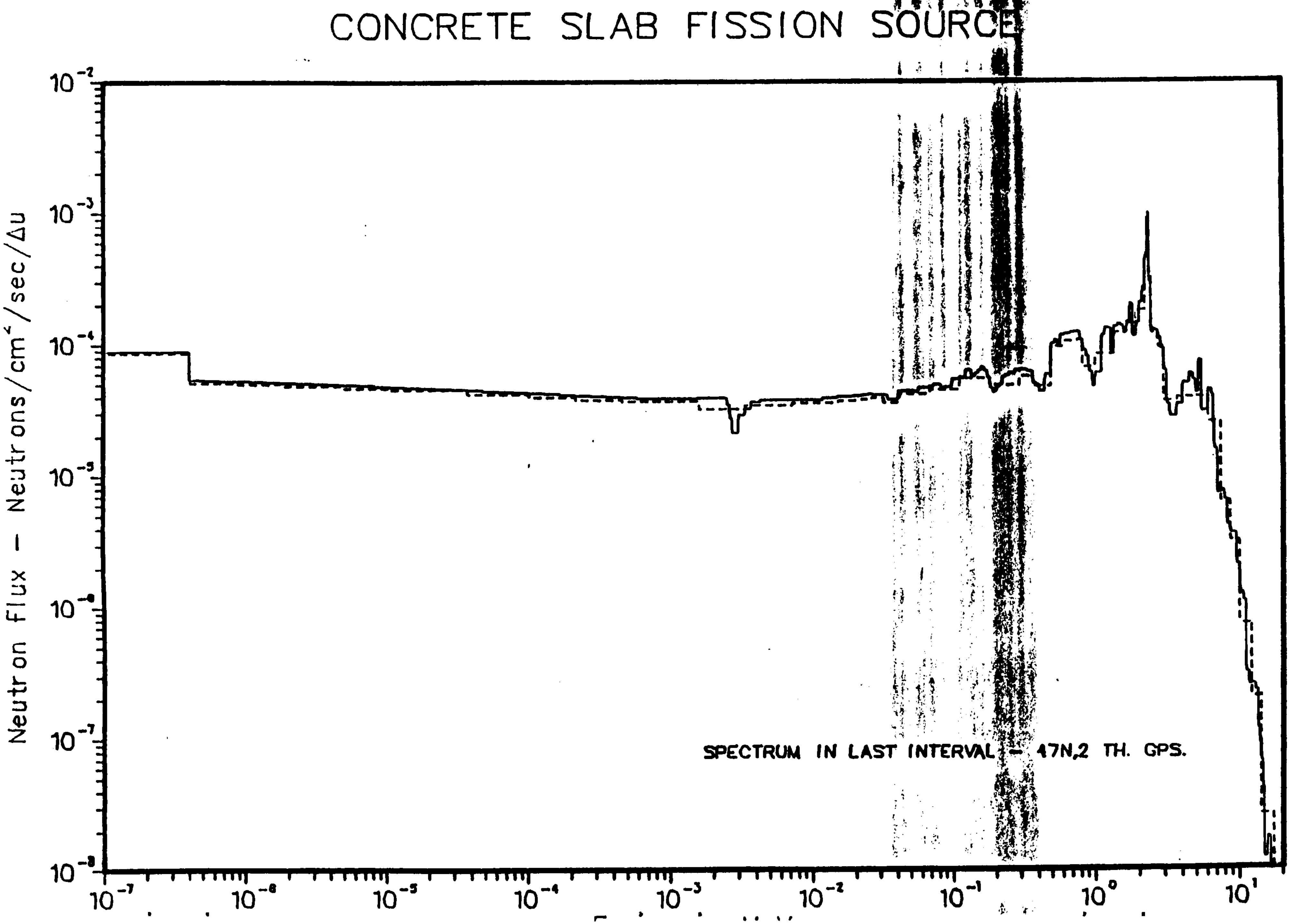

Figure 2. Neutron Spectrum in the Last Interval of a 1 Meter Concrete Slab, Fission Source.

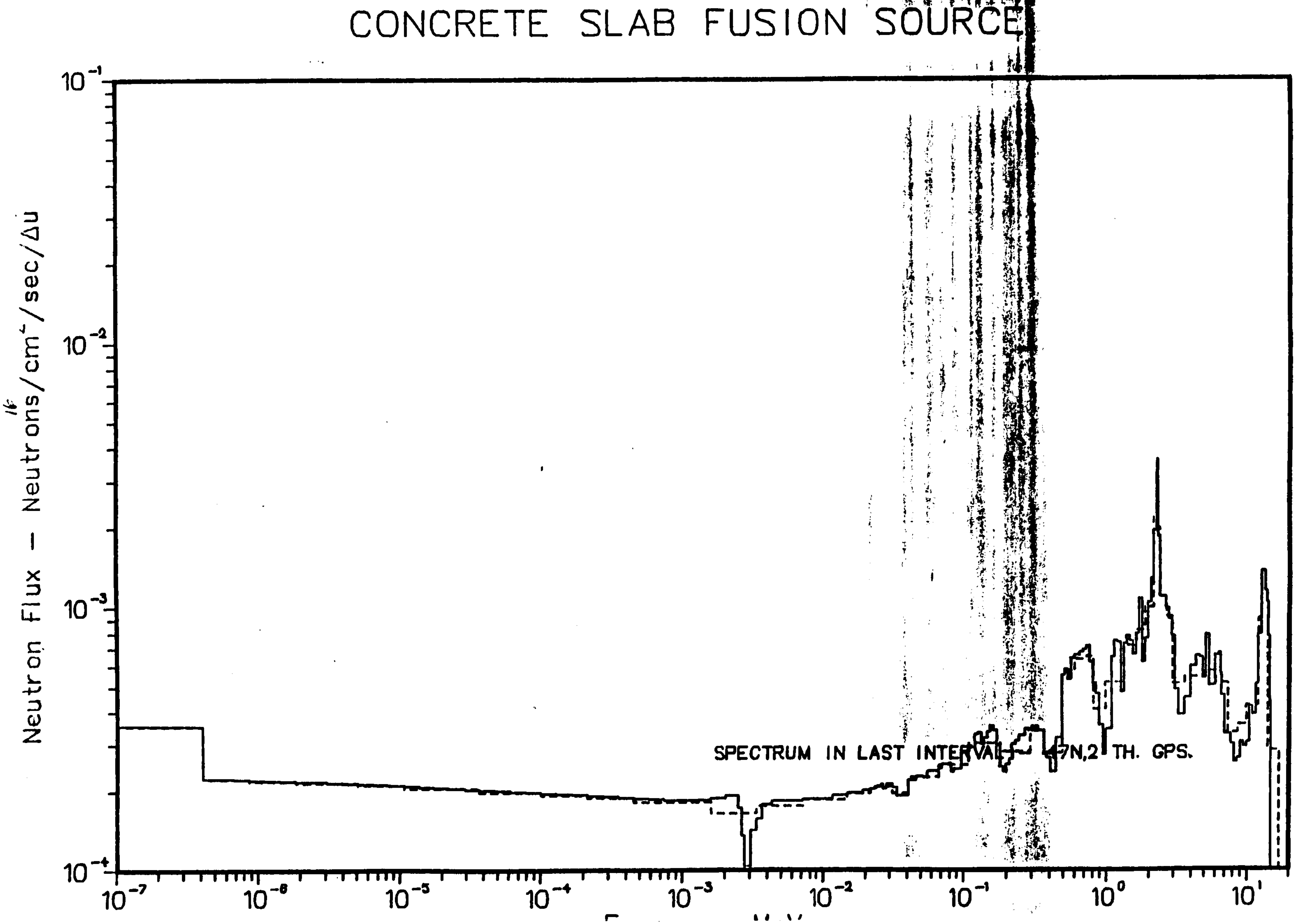

Figure 3. Neutron Spectrum in the Last Interval of a 1 Meter Concrete Slab, Fission Source.

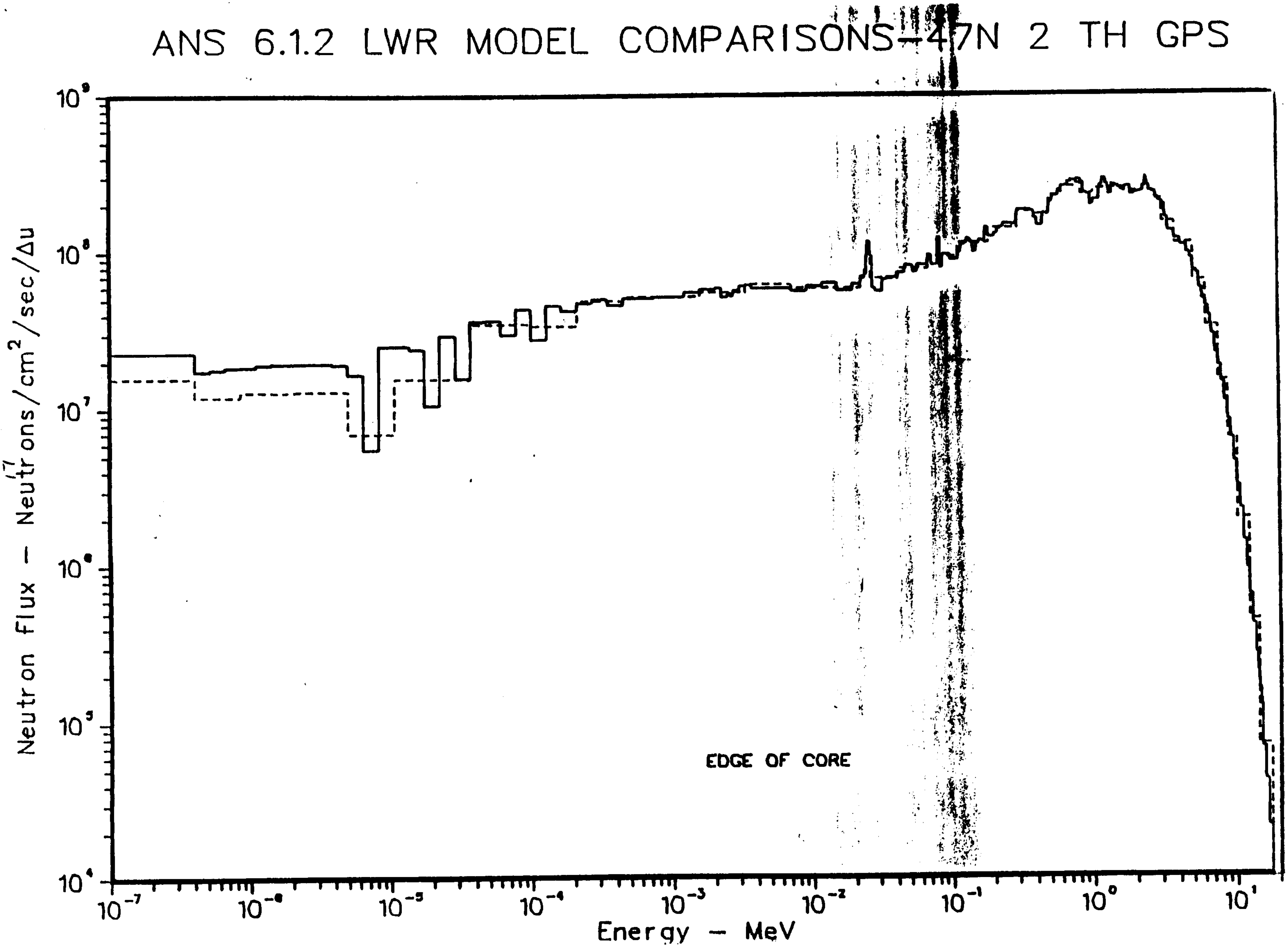

Figure 4. Neutron Spectrum at the Edge of the Core of the LWR.

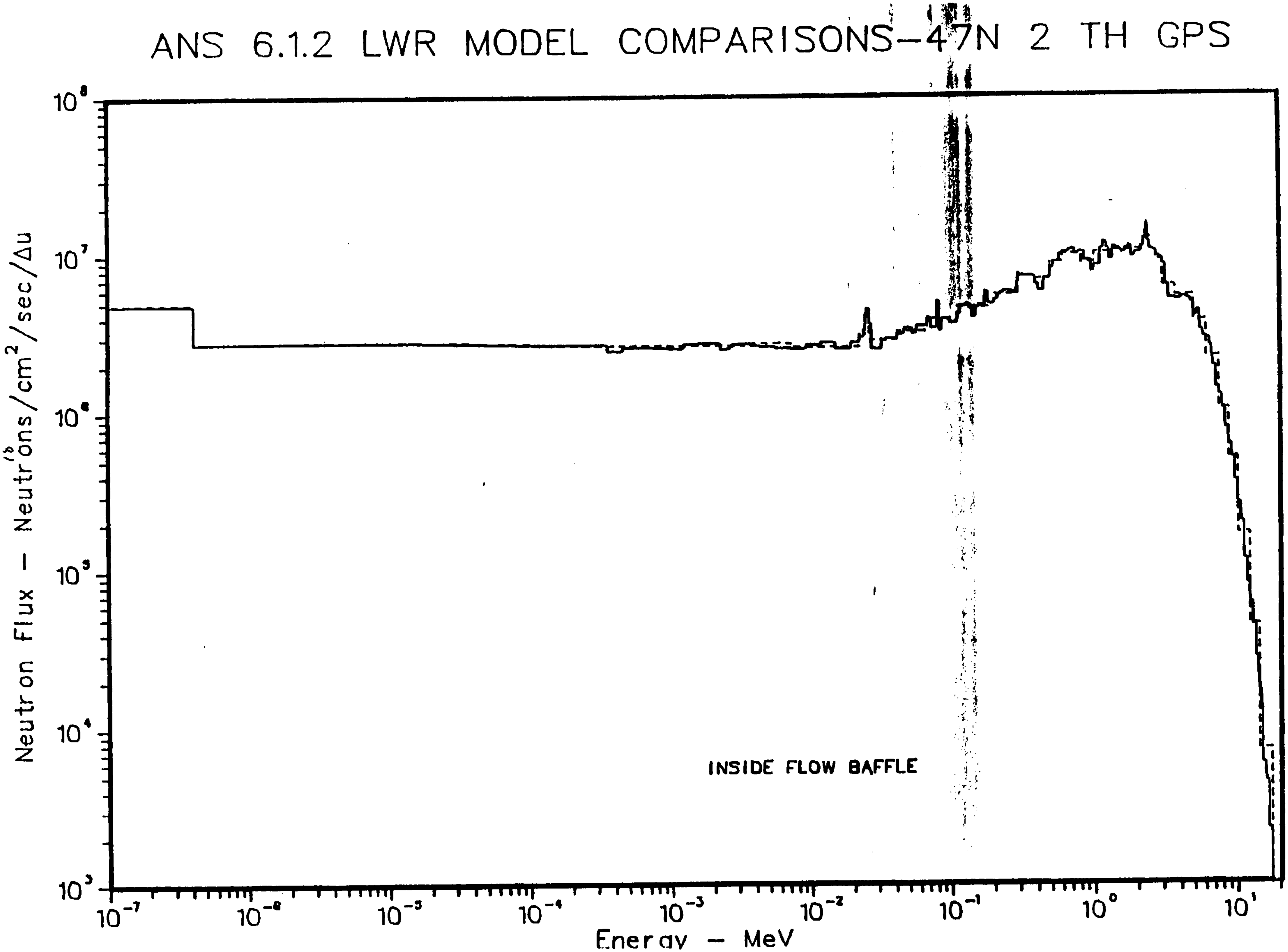

Figure 5. Neutron Spectrum in the Flow Baffle of the LWR.

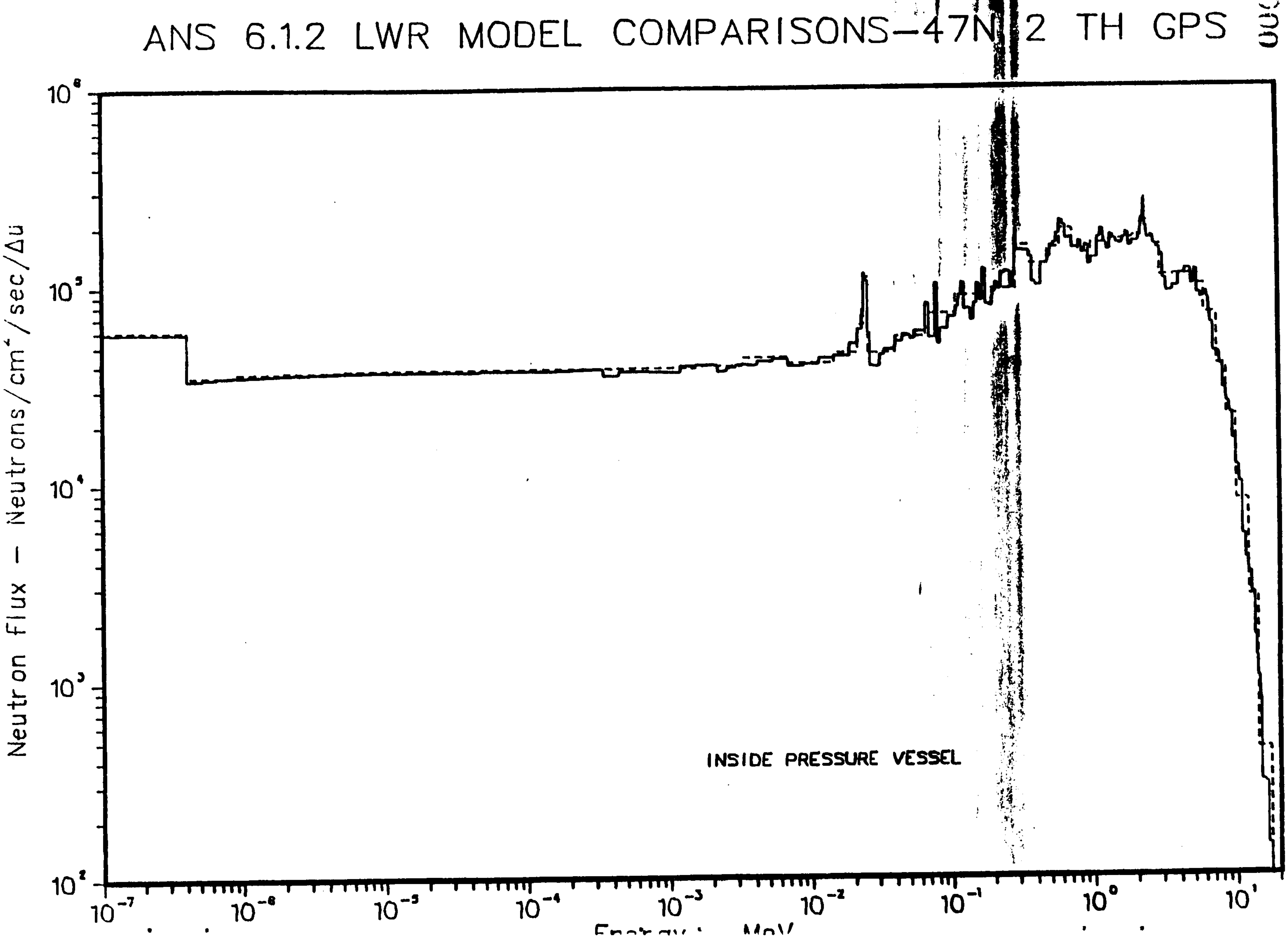

Figure 6. Neutron Spectrum Entering the Pressure Vessel of the LWR.

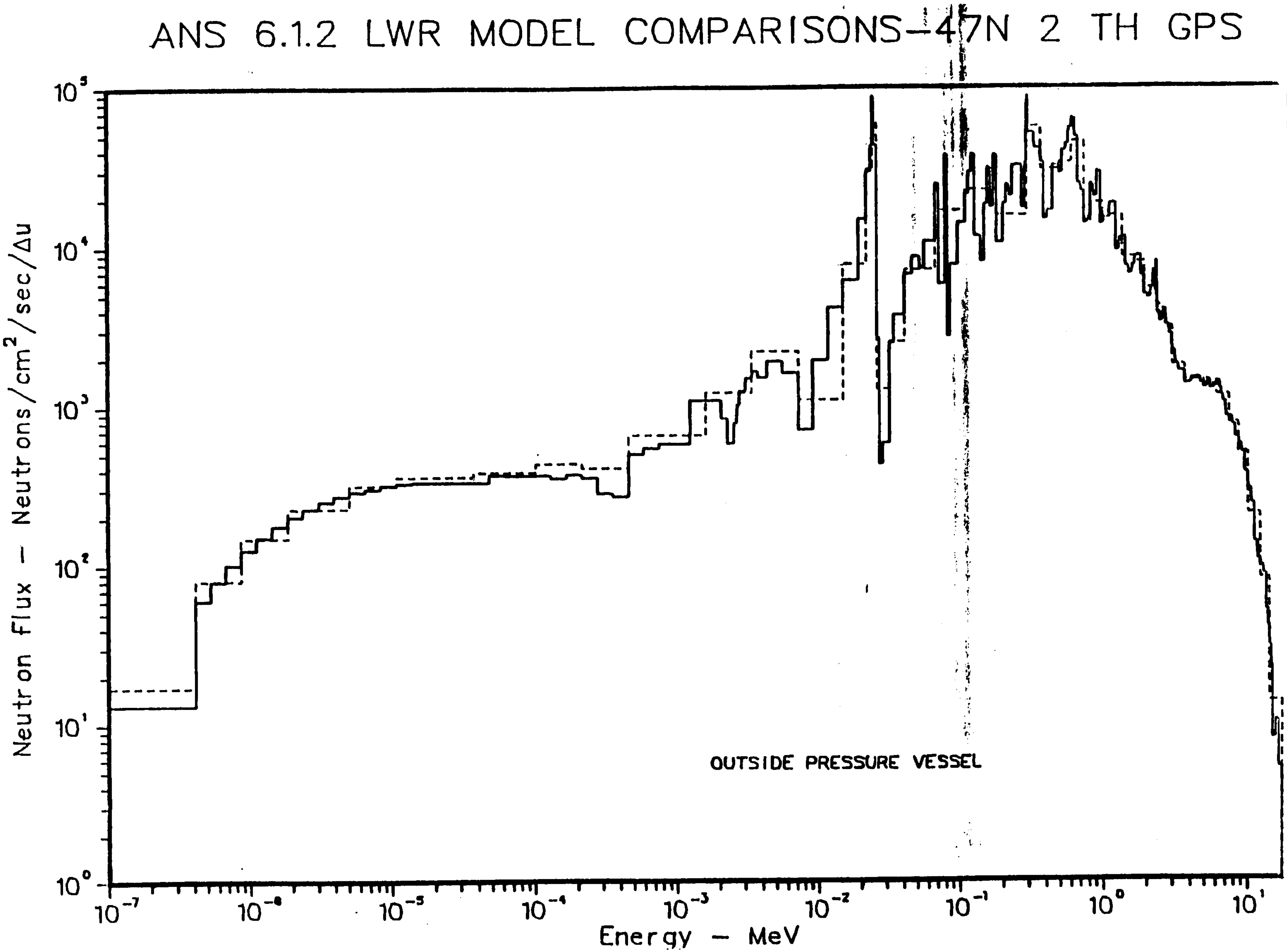

Figure 7. Neutron Spectrum Leaving the Pressure Vessel of the LWR.

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In my judgment, for a given range of LWR shielding problems, BUGLE-80 is likely to perform better than other broad group libraries currently in use, such as CASK, FEWG1, and BUGLE. The reasons for this are that BUGLE-80 is based on ENDF/B-IV evaluated data and the group structure has been tailored to represent the spectral phenomena of typical LWR shielding problems.[6]

Sources of Cross Sections for BUGLE-80

As indicated above, BUGLE-80 was derived by collapsing from DLC-41/VITAMIN-C. The evaluated data which served as sources of data for VITAMIN-C are ENDF/B-IV,[13] LENDL,[14] and ENDF/B-III.[15] The materials and their identification are given in Table 9.

Composition of Concrete and LWR Materials

The nuclear densities of the constituents of the concrete and LWR materials are listed in Table 10.

Table 9. Source of the Evaluations from which the BUGLE-80 Library was Derived

Material	MAT*	Authors	Institution
H-1	1269	L. Stewart, R. LaBauve, P. Young	LASL
H-2	1120	B. Leonard, L. Stewart	BNWL
H-3	1269	L. Stewart	LASL
He-4	1270	R. Nisley, G. Hale, P. Young	LASL
Li-6	1271	G. Hale, D. Dodder, P. Young	LASL
Li-7	1272	R. LaBauve, L. Stewart, M. Battat	LASL
Be-9	1289	R. Howerton, S. Perkins	
B-10	1273	G. Hale, R. Nisley, P. Young	LASL
B-11	1160	C. Cowan	GE
C-12	1274	F. Perey, C. Fu	ORNL
N-14	1275	P. Young, D. Foster, G. Hale	LASL
O-16	1276	P. Young, D. Foster, G. Hale	LASL
F	1277	C. Fu, D. Larson	ORNL
Na-23	1156	Paik, Pitterle	WARD
Mg	1280	M. Drake, M. Fricke	SAI
Al-27	1193	P. Young, G. Foster	LASL
Si	1194	D. Larson, F. Perey	ORNL
P	7019***	R. Howerton	LLL
S	7020***	R. Howerton	LLL
K	1150	M. Drake	GGA
Ca	1195	C. Fu, F. Perey	ORNL
Ti	1286	R. Howerton, R. Haight, S. Perkins	LLL
V	1196	S. Penny, L. Owen	ORNL
Cr	1191	A. Prince	BNL
Mn-55	1197	S. Takahashi	BNL
Fe	1192	C. Fu, F. Perey	ORNL
Co-59	1199	T. Krieger (BNL), A. Smith, D. Smith	BNL, ANL
Ni	1190	M. Bhat	BNL
Cu	1295	M. Drake, M. Fricke	SAI
Cu-63**	1085		
Cu-65**	1086		
Zr	7841***	R. Howerton	LLL
Zirc-2	1285	B. Leonard	BNWL
Nb-93	1189	R. Howerton (LLL), A. Smith, P. Gunther, J. Whalen	LLL, ANL
Mo	1287	R. Howerton	LLL
Ag-107	1138	M. Bhat, A. Prince	BNL
Ag-109	1139	M. Bhat, A. Prince	BNL
Cd	1281	S. Pearlstein	BNL
Sn	7039***	R. Howerton	LLL
Eu-151	1290	H. Takahashi	BNL

Table 9 (continued). Source of the Evaluations from which the BUGLE-80 Library was Derived

Material	MAT*	Authors	Institution
Eu-152	1292	H. Takahashi	BNL
Eu-153	1291	H. Takahashi	BNL
Eu-154	1293	H. Takahashi	BNL
Gd	7853***	R. Howerton	LLL
Ta-181	1285	R. Howerton, S. Perkins, M. MacGregor	LLL
W-182	1128	J. Otter, E. Ottewitte, P. Rose, P. Young (LASL)	AI, LASL
W-183	1129	J. Otter, E. Ottewitte, P. Rose, P. Young (LASL)	AI, LASL
W-184	1130	J. Otter, E. Ottewitte, P. Rose, P. Young (LASL)	AI, LASL
W-186	1131	J. Otter, E. Ottewitte, P. Rose, P. Young (LASL)	AI, LASL
Pb	1288	C. Fu, F. Perey	ORNL
Th-232	1296	W. Wittkopf, Roy, Z. Livolsi	B&W
U-233	1260	N. Steen	BAPL
U-234	1043	M. Drake, Nichols	GGA
U-235	1261	L. Stewart, H. Alter (AI), R. Hunter	LASL, AI
U-236	1163	J. McCrosson	SRL
U-238	1262	N. Paik	WARD
Pu-238	1050	H. Alter	AI
Pu-239	1264	B. Hutchins (GE), R. Hunter, L. Stewart	GE, LASL
Pu-240	1265	E. Pennington, H. Hummel	ANL
Pu-241	1266	H. Hummel, E. Pennington	ANL
Pu-242	1161	H. Alter, C. Dunford	AI
Am-241	1056	J. Smith, R. Grimesey	ANC

*All data generated from ENDF/B-IV unless otherwise noted.
**From ENDF/B-III
***From Livermore Evaluated Data Library

Key to Laboratory Abbreviations:

AI	Atomics International
ANC	Aerojet Nuclear Company
ANL	Argonne National Laboratory
B&W	Babcock and Wilcox
BAPL	Bettis Atomic Power Laboratory
BNL	Brookhaven National Laboratory
BNWL	Battelle Northwest Laboratory
GE	General Electric
GGA	Gulf General Atomic
LASL	Los Alamos Scientific Laboratory
LLL	Lawrence Livermore Laboratory
ORNL	Oak Ridge National Laboratory
SAI	Science Applications, Inc.
SRL	Savannah River Laboratory
WARD	Westinghouse Advanced Reactor Division

Table 10

LWR BENCHMARK NUCLEAR DENSITIES

LWR HOMOGENEOUS CORE	
Hydrogen	2.68×10^{-2}
Boron-10	7.44×10^{-7}
Oxygen	2.51×10^{-2}
Chromium	6.86×10^{-5}
Manganese	5.98×10^{-6}
Iron	2.29×10^{-4}
Nickel	3.36×10^{-5}
Zirconium	4.44×10^{-3}
Uranium-235	2.05×10^{-4}
Uranium-238	6.54×10^{-3}

LOW CARBON STEEL A533B(7.86 g/cm^2)	
Carbon	8.67×10^{-4}
Silicon	4.96×10^{-4}
Chromium	1.54×10^{-4}
Manganese	1.12×10^{-3}
Iron	8.20×10^{-2}
Nickel	5.95×10^{-4}
Molybdnum	2.71×10^{-4}

BORATED PRIMARY COOLANT	
Hydrogen	4.62×10^{-2}
Boron-10	1.28×10^{-6}
Oxygen	2.31×10^{-2}

STAINLESS STEEL-304 7.90 (g/cm^3)	
Chronium	1.74×10^{-2}
Manganese	1.52×10^{-3}
Iron	5.81×10^{-2}
Nickel	8.51×10^{-3}

CONCRETE TYPE 04	
Hydrogen	7.77×10^{-3}
Oxygen	4.39×10^{-2}
Sodium	1.05×10^{-3}
Magnesium	1.49×10^{-4}
Aluminum	2.45×10^{-3}
Silicon	1.58×10^{-2}
Sulfur	5.64×10^{-5}
Potassium	6.93×10^{-4}
Calcium	2.92×10^{-3}
Iron	3.13×10^{-4}

AIR	
Nitrogen	4.25×10^{-5}
Oxygen	1.13×10^{-5}

TABLE 11

MACK-Activity Table

(For each energy group, there are IHM entries arranged according to this table.)

Position	Content
1	Neutron and gamma kerma factors
2	Neutron kerma factor
3	Gamma kerma factor
4	Displacement cross section - A
5	Displacement cross section - B
6	Total hydrogen production cross section
7	Total tritium production cross section
8	Total helium production cross section
9	Total cross section
10	Elastic cross section
11	Total inelastic cross section
12	(n,2n) cross section
13	(n,3n) cross section
14	Total fission cross section
15	(n,n′t) cross section
16	(n,n′) continuum cross section
17	(n,γ) cross section
18	(n,p) cross section
19	(n,D) cross section
20	(n,t) cross section
21	$(n,{}^{3}He)$ cross section
22	(n,α) cross section
23	Elastic scattering kerma factor
24	(n,n′) charged particles kerma factor
25	Inelastic-level scattering kerma factor
26	(n, charged particles) kerma factor
27	(n,2n) kerma factor
28	(n,3n) kerma factor
29	Fission kerma factor
30	Inelastic continuum kerma factor
31	Radiative capture kerma factor
32	Group mid-energy for neutron and gamma
33	Group mid-energy for neutron only
34	Group mid-energy for gamma only
35 . . IHM	Positions 35-IHM are filled with cross sections for the MT reactions not given in the fixed positions 1-34.

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