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LIB-IV, A Library of Group Constants for Nuclear Reactor Calculations

by

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A LIBRARY OF GROUP CONSTANTS
FOR NUCLEAR REACTOR CALCULATIONS

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ABSTRACT

A 50-group, 101-isotope library of multigroup constants for nuclear reactor design is described. Nuclear cross sections, self-shielding factors, transfer matrices, and delayed neutron data were generated with MINX and NJOY using evaluated data from ENDF/B-IV. The output is in the CCCC-III interface format. Test results are presented for six CSEWG benchmark critical assemblies.

I. INTRODUCTION

The purpose of this report is to document LIB-IV, a rather complete and tested multigroup library based on the latest version of the Evaluated Nuclear Data Files[1] (ENDF/B-IV) and generated using the MINX[2] nuclear cross-section processing code. This library is being issued in the CCCC-III interface format[3,4] and is intended for use by the nuclear community for fast-reactor design calculations.

The ENDF/B-IV data files are the latest result of a continuing major effort to compile, evaluate, test, and update a computer-readable repository of basic nuclear data. Because of the scope of this effort and the intensive testing of the data, these files are rapidly becoming the authoritative source of data for the preparation of multigroup constants. The MINX (Multigroup Interpretation of Nuclear Cross Sections) code is a new advanced computer program for processing ENDF/B data. It is a designer-oriented code producing pseudo-composition-independent libraries of group cross sections, self-shielding factors, and group-to-group transfer matrices in the CCCC interface format. The Committee for Computer Code Coordination (CCCC) interface system is part of an ambitious attempt by the Division of Reactor Research and Development (DRRD) of the United States Energy Research and Development Administration (ERDA) to facilitate the exchange of codes and data for reactor design among the laboratories and companies involved in the DRRD program. LIB-IV contains three CCCC-III files: ISOTXS (isotope constants, cross sections, and matrices), BRKOXS (self-shielding factors), and DLAYXS (delayed neutron yields and spectra by time group).*

The detailed specifications for the library, the processing methods, and the testing performed will be discussed in the following sections.

II. MATERIALS AND SPECIFICATIONS

Table I shows the 101 materials comprising LIB-IV. Also shown are the ENDF/B-IV material source numbers, MINX CDC-7600 timing, and the σ_0 table values. All materials

*Delayed neutron constants were generated from ENDF/B-IV using NJOY.[5]

TABLE I

LIB-IV MATERIALS

I	MATERIAL	ENDF/B MAT NO.	MINX TIMING (SEC)	SIGO VALUES (BARNS)
1	H-1	1269	133	1000,100,10,1,.1,.01
2	H-2	1120	95	1000,100,10,1,.1,.01
3	H-3	1169	165	1000,100,10,1,.1,.01
4	HE-3	1146	102	10000,1000,100,10,1,.1
5	HE-4	1270	118	10000,1000,100,10,1,.1
6	LI-6	1271	157	1000,100,10,1,.1,.01
7	LI-7	1272	159	1000,100,10,1,.1,.01
8	BE-9	1289	516	1000,100,10,1,.1,.01
9	B-10	1273	428	1000,100,10,1
10	B-11	1160	182	100000,10000,1000,100,10,1
11	C-12	1274	156	1000,100,10,1,.1
12	N-14	1275	593	1000,100,10,1,.1,.01
13	O-16	1276	590	1000,100,10,1,.1
14	F	1277	384	10000,1000,100,10,1,.1
15	NA-23	1156	667	1000,100,10,1,.1
16	MG	1280	584	10000,1000,100,10,1,.1
17	AL-27	1193	631	100000,10000,1000,100,10,1
18	SI	1194	546	10000,1000,100,10,1,.1
19	CL	1149	438	10000,1000,100,10,1,.1
20	K	1150	368	10000,1000,100,10,1,.1
21	CA	1195	542	10000,1000,100,10,1,.1
22	TI	1286	218	100000,10000,1000,100,10,1
23	V	1196	344	100000,10000,1000,100,10,1
24	CR	1191	1641	1000,100,10,1,.1
25	MN-55	1197	705	100000,10000,1000,100,10,1
26	FE	1192	1075	1000,100,10,1,.1
27	CO-59	1199	910	10000,1000,100,10,1,.1
28	NI	1190	1251	1000,100,10,1,.1
29	CU	1295	707	100000,10000,1000,100,10,1
30	CU-63	1085	451	100000,10000,1000,100,10,1
31	CU-65	1086	365	100000,10000,1000,100,10,1
32	KR-78	1181	162	10000,1000,100,10,1,.1
33	KR-80	1182	178	10000,1000,100,10,1,.1
34	KR-82	1183	176	10000,1000,100,10,1,.1
35	KR-83	1184	192	10000,1000,100,10,1,.1
36	KR-84	1185	217	10000,1000,100,10,1,.1
37	KR-86	1186	163	10000,1000,100,10,1,.1
38	ZIRC-2	1284	1273	10000,1000,100,10,1,.1
39	NB-93	1189	2975	100000,10000,1000,100,10,1
40	MO	1287	532	100000,10000,1000,100,10,1
41	TC-99	1137	325	100000,10000,1000,100,10,1
42	RH-103	1125	2403	100000,10000,1000,100,10,1
43	AG-107	1138	698	100000,10000,1000,100,10,1
44	AG-109	1139	793	100000,10000,1000,100,10,1
45	CD	1281	839	10000,1000,100,10,1,.1
46	CD-113	1282	605	10000,1000,100,10,1,.1
47	XE-124	1170	177	10000,1000,100,10,1,.1
48	XE-126	1171	146	10000,1000,100,10,1,.1
49	XE-127	1172	307	10000,1000,100,10,1,.1
50	XE-128	1173	1165	10000,1000,100,1,.1
51	XE-130	1174	290	10000,1000,100,1,.1
52	XE-131	1175	751	10000,1000,100,1,.1
53	XE-132	1176	215	10000,1000,100,1,.1
54	XE-134	1177	143	10000,1000,100,1,.1
55	XE-135	1294	154	100000,10000,1000,100,10,1
56	XE-136	1178	128	100000,10000,1000,100,10,1
57	CS-133	1141	1472	100000,10000,1000,100,10,1
58	SM-149	1027	464	100000,10000,1000,100,10,1
59	EU-151	1290	900	100000,10000,1000,100,10,1
60	EU-152	1292	713	100000,10000,1000,100,10,1
61	EU-153	1291	785	100000,10000,1000,100,10,1
62	EU-154	1293	585	100000,10000,1000,100,10,1
63	GD	1030	378	100000,10000,1000,100,10,1
64	DY-164	1031	213	100000,10000,1000,100,10,1

TABLE I (cont)

I	MATERIAL	ENDF/B MAT NO.	MINX TIMING (SEC)	SIGO VALUES (BARNS)
65	LU-175	1032	354	100000,10000,1000,100,10,1
66	LU-176	1033	389	100000,10000,1000,100,10,1
67	TA-181	1285	1092	10000,1000,100,1,.1
68	TA-182	1127	252	10000,1000,100,1,.1
69	W-182	1128	2023	100000,10000,1000,100,10,1
70	W-183	1129	1353	100000,10000,1000,100,10,1
71	W-184	1130	1352	100000,10000,1000,100,10,1
72	W-186	1131	1489	100000,10000,1000,100,10,1
73	RE-185	1083	470	100000,10000,1000,100,10,1
74	RE-187	1084	418	100000,10000,1000,100,10,1
75	AU-197	1283	1685	100000,10000,1000,100,10,1
76	PB	1288	641	10000,1000,100,1,.1
77	TH-232	1296	3859	100000,10000,1000,100,10,1
78	PA-233	1297	462	100000,10000,1000,100,10,1
79	U-233	1260	531	10000,1000,100,1,.1
80	U-234	1043	672	100000,10000,1000,100,10,1
81	U-235	1261	2832	10000,1000,100,1,.1
82	U-236	1163	780	100000,10000,1000,100,10,1
83	U-238	1262	6454	10000,1000,100,1,.1
84	NP-237	1263	2085	100000,10000,1000,100,10,1
85	PU-238	1050	1043	100000,10000,1000,100,10,1
86	PU-239	1264	3505	10000,1000,100,10,1
87	PU-240	1265	6113	100000,10000,1000,100,10,1
88	PU-241	1266	544	100000,10000,1000,100,10,1
89	PU-242	1161	664	100000,10000,1000,100,10,1
90	AM-241	1056	540	100000,10000,1000,100,10,1
91	AM-243	1057	231	100000,10000,1000,100,10,1
92	CM-244	1162	1957	100000,10000,1000,100,10,1
93	FP233N	1067	83	10000,1000,100,10,1,.1
94	FP233S	1066	98	10000,1000,100,10,1,.1
95	FP233R	1042	93	10000,1000,100,10,1,.1
96	FP235N	1069	84	10000,1000,100,10,1,.1
97	FP235S	1068	93	10000,1000,100,10,1,.1
98	FP235R	1045	95	10000,1000,100,10,1,.1
99	FP239N	1071	85	10000,1000,100,10,1,.1
100	FP239S	1070	94	10000,1000,100,10,1,.1
101	FP239R	1052	91	10000,1000,100,10,1,.1
		TOTAL	79435	

were run for 3 temperatures, 300, 900, and 2100° K. ^{63}Cu, ^{65}Cu, and the 9 lumped fission-product isotopes were obtained from ENDF/B-III in order to provide a library complete enough to allow full Cross Section Evaluation Working Group (CSEWG) benchmark testing and reactor burnup calculations.

The names of the 9 lumped fission products can be interpreted in the following manner: FP233N refers to the lumped, nonsaturating, ^{233}U fission products; "S" would stand for slowly saturating; and "R" would stand for rapidly saturating.

Delayed neutron yields and spectra for 6 time groups are included for the following 7 isotopes: ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, and ^{241}Pu. These are all of the ENDF/B-IV materials that have delayed neutron data.

Table II shows the 50-group energy structure used in LIB-IV. This structure is a subset of the 240-group structure,[6] and the widely used 26-group half-lethargy structure is a subset of the LIB-IV structure.

The library was generated using a "thermal + 1/E + fission" weight function. The thermal portion is Maxwellian with a temperature of 0.025 eV which joins 1/E at 0.10 eV. The fission spectrum joins 1/E at 820.8 keV (lower boundary of group 6) and has a characteristic temperature of 1.40 MeV.

TABLE II

LIB-IV GROUP STRUCTURE

GROUP	ENERGY RANGE (EV)		LETHARGY
01	1.5000E+07	1.0000E+07	0.692
02	1.0000E+07	6.0653E+06	0.5
03	6.0653E+06	3.6788E+06	0.5
04	3.6788E+06	2.2313E+06	0.5
05	2.2313E+06	1.3534E+06	0.5
06	1.3534E+06	8.2085E+05	0.5
07	8.2085E+05	4.9787E+05	0.5
08	4.9787E+05	3.8774E+05	0.25
09	3.8774E+05	3.0197E+05	0.25
10	3.0197E+05	2.3518E+05	0.25
11	2.3518E+05	1.8316E+05	0.25
12	1.8316E+05	1.4264E+05	0.25
13	1.4264E+05	1.1109E+05	0.25
14	1.1109E+05	8.6517E+04	0.25
15	8.6517E+04	6.7379E+04	0.25
16	6.7379E+04	5.2475E+04	0.25
17	5.2475E+04	4.0868E+04	0.25
18	4.0868E+04	3.1828E+04	0.25
19	3.1828E+04	2.4788E+04	0.25
20	2.4788E+04	1.9305E+04	0.25
21	1.9305E+04	1.5034E+04	0.25
22	1.5034E+04	1.1709E+04	0.25
23	1.1709E+04	9.1188E+03	0.25
24	9.1188E+03	7.1017E+03	0.25
25	7.1017E+03	5.5308E+03	0.25
26	5.5308E+03	4.3074E+03	0.25
27	4.3074E+03	3.3546E+03	0.25
28	3.3546E+03	2.6126E+03	0.25
29	2.6126E+03	2.0347E+03	0.25
30	2.0347E+03	1.5846E+03	0.25
31	1.5846E+03	1.2341E+03	0.25
32	1.2341E+03	9.6112E+02	0.25
33	9.6112E+02	7.4852E+02	0.25
34	7.4852E+02	5.8295E+02	0.25
35	5.8295E+02	4.5400E+02	0.25
36	4.5400E+02	3.5358E+02	0.25
37	3.5358E+02	2.7536E+02	0.25
38	2.7536E+02	1.6702E+02	0.5
39	1.6702E+02	1.0130E+02	0.5
40	1.0130E+02	6.1442E+01	0.5
41	6.1442E+01	3.7267E+01	0.5
42	3.7267E+01	2.2603E+01	0.5
43	2.2603E+01	1.3710E+01	0.5
44	1.3710E+01	8.3153E+00	0.5
45	8.3153E+00	5.0435E+00	0.5
46	5.0435E+00	3.0590E+00	0.5
47	3.0590E+00	1.8554E+00	0.5
48	1.8554E+00	1.1254E+00	0.5
49	1.1254E+00	6.8256E-01	0.5
50	6.8256E-01	1.0000E-05	11.31

The P_0, P_1, P_2, and P_3 Legendre components of the matrices were generated whenever the ENDF/B data permitted. Tolerances used in running the MINX code were as follows: resonance reconstruction 0.5%, linearization 0.2%, thinning (resolved range only) 0.2%, and adaptive integration 0.1% (except that ^{238}U, ^{103}Rh, and ^{133}Cs used a reconstruction tolerance of 1.0%).

III. LIBRARY FORMAT

The user of LIB-IV should be familiar with the format for the ISOTXS, BRKOXS, and DLAYXS files as described in Ref. 4. The amount of data in LIB-IV is so large that it is impractical to try and list it in this document. Therefore, an abbreviated listing featuring group constants for ^{239}Pu has been constructed to familiarize the reader with the kinds of data provided and the format of that data (see Appendix A). Note that scattering matrices have been sub-blocked. There is a record for each sink group containing elements from all source groups and all Legendre orders. Section IV describes the processing methods used to obtain the data in these files.

Certain manipulations may be required to update, transmit, or use CCCC data. Therefore, three utility codes are provided as described below.

CINX -- will exactly collapse fine-group data (ISOTXS, BRKOXS, AND DLAYXS) to a subset coarse-group structure, and will also change the format of the data to 1DX/PERT-V[7,8] form, if desired.

LINX -- will combine two multi-isotope CCCC files (ISOTXS or BRKOXS only) into a new composite file in CCCC format.

BINX -- will convert CCCC data (ISOTXS, BRKOXS, or DLAYXS) from binary to BCD mode or *vice versa* and selectively print the contents of the files.

These codes are completely described elsewhere.[9,10] For the convenience of the user, operating instructions for LINX, BINX, and CINX, have been included as Appendix B of this report.

LIB-IV is issued on two 7-track BCD tapes recorded at 800 bits per inch. Data are blocked into records containing 50 card images of 80 columns each. The last block (record) in each file may be short. The tapes contain six files as shown in Table III.

TABLE III

STRUCTURE OF LIB-IV TRANSMITTAL TAPE

Tape	File	Contents	No. of Cards
1	1	LINX	460
	2	BINX	872
	3	CINX	857
	4	ISOTXS	192 273
2	5	BRKOXS	80 083
	6	DLAYXS	735
		Total	275 280

IV. PROCESSING METHODS

LIB-IV features cross sections for use in the Self-Shielding Factor Method,[11,12] sometimes called the Bondarenko Method. In the region of a resonance, the neutron flux will be depressed, thereby causing a reduction in the contribution of that resonance to the reaction rate, i.e., self-shielding. The magnitude of the self-shielding depends on the temperature, composition, and geometry of the problem in a complex way, but for many problems of practical interest, accurate reaction rates can be computed using average cross sections defined by

$$\sigma^i_{x\ell g}(T,\sigma_0) = \frac{\int_g \sigma^i_x(E,T)\phi^i_\ell(E,T,\sigma_0)\,dE}{\int_g \phi^i_\ell(E,T,\sigma_0)\,dE} \qquad (1)$$

where the weight functions for material i are given by

$$\phi^i_\ell(E,T,\sigma_0) = \frac{C(E)}{\left[\sigma_0+\sigma^i_t(E,T)\right]^{\ell+1}} \quad . \qquad (2)$$

In these formulas, $\ell = 0$ refers to flux weighting, $\ell = 1$ refers to current weighting, E is the neutron energy, T is the temperature, g is the group index, C(E) is the slowly varying component of the weight function (as described in Sec. II), and $\sigma^i_t(E,T)$ is the microscopic total cross section for this material. The "background cross section per atom" σ_0 is regarded as a parameter by which composition and geometry effects can be introduced (see Ref. 12).

The flux of Eq. (2) is based on the narrow resonance approximation, the B_0 approximation for small B, and the assumption that the positions of resonances in different isotopes are not correlated. Therefore, the multigroup constants in LIB-IV are best suited for large critical systems containing some light isotopes. The data can be used in other applications with due regard to the approximations used.[13]

LIB-IV contains "infinite dilution" cross sections at 0° K $\sigma^i_{x\ell g}(o,\infty)$ evaluated by Eq. (1). Temperature and σ_0 dependent cross sections are to be obtained by interpolating in tables of "f-factors"

$$f^i_{x\ell g}(T,\sigma_0) = \frac{\sigma^i_{x\ell g}(T,\sigma_0)}{\sigma^i_{x\ell g}(0,\infty)} \quad . \tag{3}$$

The "total" f-factor in the BRKOXS file is $f^i_{t1g}(T,\sigma_0)$.

The special quantities $\bar{\mu}$ (average scattering cosine), $\bar{\xi}$ (average log decrement), and D (average fission yield) are reaction-rate averaged at T = 0 and $\sigma_0 = \infty$. For example,

$$\bar{\nu}_g = \frac{\int_g \bar{\nu}(E)\sigma_f(E)C(E)dE}{\int_g \sigma_f(E)C(E)dE} \quad . \tag{4}$$

This formula preserves the fission neutron production rate. Similar formulas apply for $\bar{\mu}$ and $\bar{\xi}$ using $\sigma_e(E)$. The transport cross section and transport f-factors are computed using

$$\sigma^i_{tr,g}(T,\sigma_0) = \sigma^i_{t1g}(T,\sigma_0) - \bar{\mu}^i_g \sigma^i_{e0g}(T,\sigma_0) \ , \tag{5}$$

where σ_e is the elastic scattering cross section. The potential scattering cross section given is based on the actual ℓ-dependent σ_p used by MINX during resonance reconstruction and may not be meaningful outside the resonance range.

Accurate, high-order, group-to-group, transfer cross sections are computed for all reactions (at infinite dilution only) using

$$\sigma^i_{x\ell;g\to g'} = \frac{\int_g dE \int_{g'} dE' \sigma^i_x(E) m^i_x F^i_{x\ell}(E\to E')C(E)}{\int_g C(E)dE} \ , \tag{6}$$

where g is the initial energy group, g' is the final energy group, m^i_x is the neutron multiplicity, and $F^i_{x\ell}(E\to E')$ is a Legendre component of the probability of scattering from E to E'. The only reaction for which significant self-shielding is expected is elastic scattering; all elements are assumed to have the same f-factor as the elastic cross section.* MINX produces matrices for all neutron scattering reactions given in ENDF/B, and all are added into the total matrix in the ISOTXS file. The "inelastic" matrix is the sum of all scattering reactions except elastic and (n,2n). The (n,2n) matrix in ISOTXS has been normalized for a neutron yield of one.

The elastic cross section was obtained by summing all final energy groups of the elastic matrix, and the elastic removal cross section was computed with

$$\sigma^i_{dg} = \sum_{g'\neq g} \sigma^i_{e0;g\to g'} \quad . \tag{7}$$

The inelastic cross section is the sum over all reactions and all final energy groups in the inelastic matrix with the (n,3n) contribution divided by three. Finally, the (n,2n) cross section was obtained by summing the (n,2n) matrix.

LIB-IV does not provide a fission chi matrix. The correct definition for the isotope chi vector is

$$\chi^i_{g'} = \frac{\int dE \int_{g'} dE' \nu^i(E)\sigma^i_f(E) g^i(E\to E')C(E)}{\int dE \nu^i(E)\sigma^i_f(E)C(E)} \ . \tag{8}$$

However, if the distribution of fission neutron secondary energies $g^i_f(E\to E')$ is a slowly varying function of E over the range of interest,

*This approximation is explicit in the original method[11] and codes using it,[7] but may not be justified for some problems.[14]

$$\chi_{g'}^{i} \cong \int_{g'} dE' g_f^i(E^* \rightarrow E') \quad , \tag{9}$$

where E* is some well-chosen energy; MINX uses E* = 1.0 MeV and processes the distribution from MT18 only. These two approximations are appropriate for reactor problems, but they will be less adequate for a fusion problem.

Values quoted for the average energy released in fission (EFISS) were inferred from data for four of the isotopes.[15] The energy released through neutron capture (ECAPT) was obtained by adding the reaction Q-values[16] to the energy released by decay to a stable isotope computed from the Table of Isotopes.[17]

V. CRITICAL ASSEMBLY CALCULATIONS

This library has been used in the calculation of several CSEWG benchmark criticals to provide a comparison with results from other labs and codes and to give an indication of how the library may perform in reactor design calculations.

The calculational procedure is shown in Fig. 1. All benchmark specifications came from Ref. 18, all DTF[19] runs used S_{16}, and the two fission source vectors used for Pu- and U-fueled assemblies are shown in Table IV. The k_{eff} results are shown in Table V and the central reaction rate ratios are shown in Table VI.

In general, only in a few cases do the current LIB-IV results increase the spread in integral results[20] already established by other codes and libraries. One is encouraged by such agreement, and the lack of any obvious anomalies further increases one's confidence in LIB-IV.

Since MINX is very similar to ETOX,[21] one can easily extrapolate from past comparisons and validations[12,22,23] of ETOX and the Shielding Factor Method, and state that LIB-IV offers a simple, reliable, accurate, fast, and directly interpretable scheme for processing nuclear data for reactor calculations.

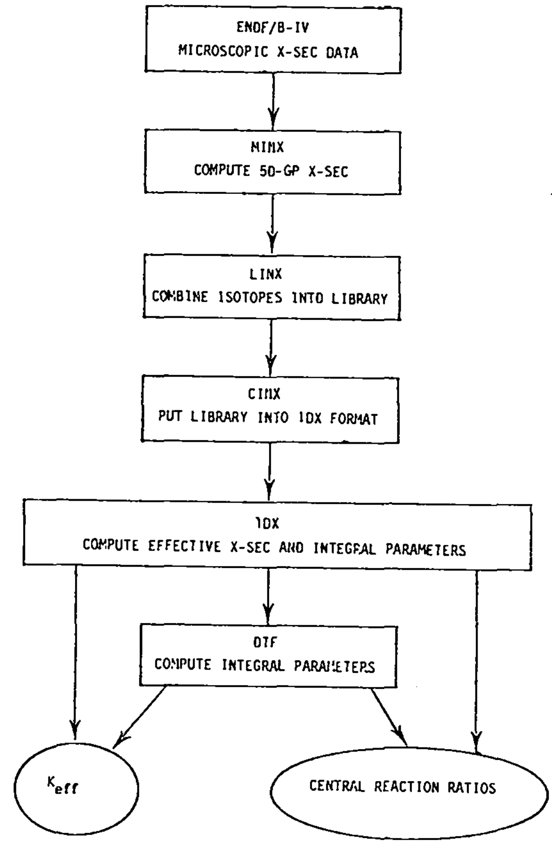

Fig. 1. Calculational procedure.

TABLE IV

FISSION SOURCE VECTORS

Group	Chi for Pu-Fueled	Chi for U-Fueled
1	2.6650000E-03	1.9820000E-03
2	3.2393000E-02	2.7500000E-02
3	1.2144500E-01	1.1217400E-01
4	2.1038100E-01	2.0520400E-01
5	2.2236700E-01	2.2451600E-01
6	1.7232300E-01	1.7777600E-01
7	1.1017300E-01	1.1517800E-01
8	3.6035000E-02	3.7930000E-02
9	2.6550000E-02	2.8033000E-02
10	1.9263000E-02	2.0388000E-02
11	1.3810000E-02	1.4644000E-02
12	9.8090000E-03	1.0416000E-02
13	6.9160000E-03	7.3530000E-03
14	4.8490000E-03	5.1600000E-03
15	3.3850000E-03	3.6050000E-03
16	2.3550000E-03	2.5090000E-03
17	1.6340000E-03	1.7410000E-03
18	1.1310000E-03	1.2060000E-03
19	7.8200000E-04	8.3400000E-04
20	5.4000000E-04	5.7600000E-04
21	3.7200000E-04	3.9700000E-04
22	2.5700000E-04	2.7400000E-04
23	1.7700000E-04	1.8900000E-04
24	1.2200000E-04	1.3000000E-04
25	8.4000000E-05	8.9000000E-05
26	5.8000000E-05	6.1000000E-05

TABLE IV (cont)

Group	Chi for Pu-Fueled	Chi for U-Fueled
27	4.0000000E-05	4.2000000E-05
28	2.7000000E-05	2.9000000E-05
29	1.9000000E-05	2.0000000E-05
30	1.3000000E-05	1.4000000E-05
31	9.0000000E-06	9.0000000E-06
32	6.0000000E-06	6.0000000E-06
33	4.0000000E-06	4.0000000E-06
34	3.0000000E-06	3.0000000E-06
35	2.0000000E-06	2.0000000E-06
36	1.0000000E-06	1.0000000E-06
37	1.0000000E-06	1.0000000E-06
38	1.0000000E-06	1.0000000E-06
39	0.	1.0000000E-06
40	0.	0.
41	0.	0.
42	0.	0.
43	0.	0.
44	0.	0.
45	0.	0.
46	0.	0.
47	0.	0.
48	0.	0.
49	0.	0.
50	0.	0.

TABLE V

CSEWG BENCHMARK EIGENVALUES

BENCHMARK	CODES USED	UNCORRECTED KEFF	HETEROGENEITY CORRECTION	$P_0 \rightarrow P_{00}$ CORRECTION	DIFF→S_8 CORRECTION	$S_{16} \rightarrow S_{00}$ CORRECTION	CORRECTED KEFF
Pu-Fueled[a]							
JEZEBEL	1DX-DTF	1.00089		-0.0032		-0.0021	0.99559
VERA-11A	1DX-DTF	0.99235				-0.002	0.99035
ZPR-6-7	1DX-DTF	0.97085	0.0166		0.0018		0.98925
U-Fueled[a]							
GODIVA	1DX-DTF	1.01184		-0.003		-0.0017	1.00714
ZPR-3-11	1DX-DTF	1.01515					1.01515
ZPR-6-6A	1DX	0.98323	0.0073		0.0013		0.99183

[a]Arranged in order of spectrum hardness.

TABLE VI

CENTRAL SPECTRAL INDICIES (CALCULATED-TO-EXPERIMENTAL)

Ratio W.R.T. U235(N,F)	Pu-Fueled[a] JEZEBEL	Pu-Fueled[a] VERA-11A	Pu-Fueled[a] ZPR-6-6	U-Fueled[a] GODIVA	U-Fueled[a] ZPR-3-11	U-Fueled[a] ZPR-6-6A
Pu240(N,F)		1.0850			1.0540	
Pu239(N,F)	0.9363	1.0836	0.9625	0.9728	0.9843	
U238(N,F)	0.9485	1.1531	0.9377	1.0861	1.0563	0.9452
U238(N,G)			1.0534	0.9925	0.9691	1.0309
NP237(N,F)	0.9448	1.1758			1.0506	
U236(N,F)					0.7851	
U234(N,F,)				0.9762	1.0405	
U233(N,F)	0.9287	0.9993		0.9241	0.9989	
Th232(N,F)				1.0758		
Au(N,G)				0.8491		

[a]Arranged in order of spectrum hardness.

APPENDIX A

SAMPLE DATA

This appendix contains abbreviated BINX listings of the LIB-IV ISOTXS, BRKOXS, and DLAYXS CCCC-III files. The ^{239}Pu multigroup constants are featured.

LIB-IV ISOTXS LISTING

```
BINX...CONVERT MODE OF CCCC FILE

MODE=1  (1 MEANS BIN TO BCD, 2 MEANS BCD TO BIN)
TYPE=1  (1 MEANS ISOTXS, 2 MEANS BRKOXS, 3 MEANS DLAYXS)
IRD=   1    1  -0  -0  -0  -0  -0  -0  -0  -0

*** FILEISOTXS -- VERSION  1 -- UNIT  3***
**USER IDENTIFICATION**T2LASL   MINX

FILE CONTROL PARAMETERS

 NGROUP    NUMBER OF ENERGY GROUPS IN SET                         50
 NISO      NUMBER OF ISOTOPES IN SET                             101
 MAXUP     MAXIMUM NUMBER OF UPSCATTER GROUPS                      0
 MAXDN     MAXIMUM NUMBER OF DOWNSCATTER GROUPS                   50
 MAXORD    MAXIMUM SCATTERING ORDER                                3
 ICHIST    SET FISSION SPECTRUM FLAG                               0
             ICHIST=1        SET VECTOR
                   =NGROUP, SET MATRIX
 NSCMAX    MAXIMUM NUMBER OF BLOCKS OF                             4
             SCATTERING DATA
 NSBLOK    BLOCKING CONTROL FOR SCATTERING DATA                   50

LIB-IV A 101-ISOTOPE 50-GROUP LIBRARY GENERATED WITH MINX FROM ENDF/B-IV

ISOTOPE               NAME
    1                   H1
    2                   H2
    3                   H3
    4                  HE3
    5                  HE4
    6                  LI6
    7                  LI7
    8                  BE9
    9                  B10
   10                  B11
   11                  C12
   12                  N14
   13                  O16
   14                    F
   15                 NA23
   16                   MG
   17                 AL27
   18                   SI
   19                   CL
   20                    K
   21                   CA
   22                   TI
   23                    V
   24                   CR
   25                 MN55
   26                   FE
   27                 CO59
   28                   NI
   29                   CU
   30                 CU63
   31                 CU65
   32                 KR78
   33                 KR80
   34                 KR82
```

35	KR83
36	KR84
37	KR86
38	ZIRC2
39	NB93
40	MD
41	TC99
42	RH103
43	AG107
44	AG109
45	CD
46	CD113
47	XE124
48	XE126
49	XE127
50	XE128
51	XE130
52	XE131
53	XE132
54	XE134
55	XE135
56	XE136
57	CS133
58	SM149
59	EU151
60	EU152
61	EU153
62	EU154
63	GD
64	DY164
65	LU175
66	LU176
67	TA181
68	TA182
69	W182
70	W183
71	W184
72	W186
73	RE185
74	RE187
75	AU197
76	PB
77	TH232
78	PA233
79	U233
80	U234
81	U235
82	U236
83	U238
84	NP237
85	PU238
86	PU239
87	PU240
88	PU241
89	PU242
90	AM241
91	AM243
92	CM244
93	FP233N
94	FP233S
95	FP233R
96	FP235N
97	FP235S
98	FP235R
99	FP239N
100	FP239S
101	FP239R

GROUP STRUCTURE

GROUP	NEUTRON VELOCITY (CM/SEC)	UPPER ENERGY (EV)
1	5.27745E+09	1.99711E+07
2	3.89009E+09	1.00000E+07
3	3.02960F+09	6.06531E+06
4	2.35946E+09	3.67879E+06
5	1.83755E+09	2.23130E+06
•		
•		
•		

NUMBER OF RECORDS TO BE SKIPPED

ISOTOPE	RECORDS
1	0
2	102
3	254
4	406
5	508
6	610
7	762
8	964
9	1116
10	1268
11	1469
12	1621
13	1822
14	1974
15	2175
16	2376
17	2578
18	2779
19	2981
20	3182
21	3383
22	3584
23	3737
24	3938
25	4140
26	4341
27	4542
28	4716
29	4918
30	5119
31	5319
32	5519
33	5720
34	5921
35	6122
36	6324
37	6525
38	6726
39	6928
40	7103
41	7251
42	7453
43	7655
44	7857
45	8059
46	8261
47	8463
48	8664
49	8865
50	9067
51	9269
52	9471
53	9673
54	9875
55	10077
56	10229
57	10431

58	10633
59	10835
60	11037
61	11239
62	11441
63	11643
64	11845
65	12047
66	12249
67	12451
68	12637
69	12839
70	13041
71	13243
72	13445
73	13647
74	13849
75	14051
76	14253
77	14455
78	14657
79	14859
80	15061
81	15263
82	15465
83	15667
84	15869
85	16071
86	16273
87	16475
88	16677
89	16879
90	17081
91	17233
92	17385
93	17587
94	17589
95	17591
96	17593
97	17595
98	17597
99	17599
100	17601
101	17603

⋮ (Skip to Pu-239 constants)

ISOTOPE 86

ISOTOPE CONTROL PARAMETERS

HABSID	ABSOLUTE ISOTOPE LABEL	PU239
HIDENT	LIBRARY IDENTIFIER	ENDFB
HMAT	ISOTOPE IDENTIFICATION	1264
AMASS	GRAM ATOMIC WEIGHT	.23905E+03
EFISS	THERMAL ENERGY/FISSION (W*SEC/FISS)	.33196E-10
ECAPT	THERMAL ENERGY/CAPTURE (W*SEC/CAPT)	.18727E-11
TEMP	ISOTOPE TEMPERATURE (DEG K)	0.
SIGPOT	AVE. POTENTIAL SCATTERING (BARNS/ATOM)	.10000E+11
ADENS	REFERENCE ATOM DENSITY (A/B*CM)	0.
K8R	ISOTOPE CLASSIFICATION	1
ICHI	FISSION SPECTRUM FLAG (0/1/N=SET CHI/VECTOR/MATRIX)	1
IFIS	(N,F) X-SEC FLAG (0/1=NO/YES)	1
IALF	(N,A) X-SEC FLAG (0/1=NO/YES)	0
INP	(N,P) X-SEC FLAG (0/1=NO/YES)	0
IN2N	(N,2N) X-SEC FLAG (0/1=NO/YES)	1
IND	(N,D) X-SEC FLAG (0/1=NO/YES)	0

INT	(N,T) X-SEC FLAG (0/1=NO/YES)	0
LTOT	NUMBER OF TOTAL X-SEC MOMENTS	1
LTRN	NUMBER OF TRANSPORT X-SEC MOMENTS	1
ISTRPD	NUMBER OF TRANSPORT X-SEC DIRECTIONS	0

SCATTERING BLOCKS

BLOCK	NAME	TYPE	ORDERS
1	INELAS	200	4
2	ELASTC	100	4
3	N2N	300	1
4	TOTAL	0	4

SCATTERING BANDWIDTH AND IN-GROUP SCATTERING POSITION

GROUP/BLOCK	1	2	3	4	1	2	3	4
1	1	1	1	1	1	1	1	1
2	2	2	2	2	1	1	1	1
3	3	2	3	3	1	1	1	1
4	4	2	4	4	1	1	1	1
5	5	2	5	5	1	1	1	1
•								
•								
•								
46	46	2	46	46	1	1	1	1
47	47	2	47	47	1	1	1	1
48	48	2	48	48	1	1	1	1
49	49	2	49	49	1	1	1	1
50	50	2	50	50	1	1	1	1

PRINCIPAL CROSS SECTIONS

GROUP	STRPL	STOTPL	SNGAM	SFIS	SNUTOT	CHISO
1	3.17961E+00	5.90003E+00	2.35022E-03	2.34036E+00	4.56771E+00	2.60560E-03
2	3.59940E+00	6.67484E+00	5.12545E-04	2.12428E+00	3.95828E+00	3.20173E-02
3	4.28234E+00	7.82359E+00	1.69466E-03	1.73533E+00	3.54253E+00	1.20766E-01
4	4.73192E+00	7.79443E+00	5.83780E-03	1.87962E+00	3.28288E+00	2.10020E-01
5	4.97238E+00	7.15870E+00	1.02738E-02	1.92340E+00	3.12277E+00	2.22541E-01
•						
•						
•						
46	1.86699E+01	1.86949E+01	6.86168E-01	9.12557E+00	2.87330E+00	2.69842E-09
47	2.57616E+01	2.57883E+01	2.16982E+00	1.41194E+01	2.87330E+00	1.27445E-09
48	4.17560E+01	4.17841E+01	7.72434E+00	2.40920E+01	2.87330E+00	6.02010E-10
49	7.75153E+01	7.75453E+01	1.89318E+01	4.79841E+01	2.87330E+00	2.84370E-10
50	1.19912E+03	1.19914E+03	3.95191E+02	7.95243E+02	2.87330E+00	2.54565E-10

BLOCK 1 INFLAS SCATTERING, ORDER 4

GROUP 1

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	2.96105E-02	1.98279E-02	1.32301E-02	7.96745E-03

GROUP 2

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	1.08118E-02	5.13291E-03	2.49375E-03	9.67350E-04
2	8.77443E-02	5.38009E-02	3.41329E-02	1.86799E-02

GROUP 3

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	6.60272E-03	6.46678E-04	1.30360E-04	1.48782E-05
2	2.92672E-02	9.20485E-03	3.14681E-03	6.96451E-04
3	2.87350E-02	1.18844E-02	5.23447E-03	1.74480E-03

GROUP 4

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	1.16116E-01	1.78123E-03	1.43991E-05	-1.57147E-06
2	8.58675E-02	5.62052E-04	6.91510E-05	3.24973E-06
3	5.47031E-02	2.20773E-03	3.24540E-04	2.10338E-05
4	3.12489E-03	0.	0.	0.

GROUP 5

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	2.64095E-01	3.79723E-03	1.84614E-05	-4.14327E-06
2	3.16531E-01	-9.91404E-04	-1.16044E-05	-2.57053E-06
3	2.70369E-01	3.26128E-05	4.64688E-06	-9.50340E-08
4	1.29825E-01	5.45655E-05	8.37585E-06	-4.21996E-07
5	9.59246E-03	0.	0.	0.

•

•

•

[POSN 1 = in-scatter
POSN 2 = I-1 to I
POSN 3 = I-2 to I
⋮]

GROUP 50

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1 TO 26	0.	0.	0.	0.
27	6.94075E-09	-1.04128E-09	-2.62626E-10	-1.08308E-10
28 TO 34	0.	0.	0.	0.
35	7.85542E-11	-2.73003E-11	-7.79106E-12	3.24110E-12
36	2.26264E-11	-8.38594E-12	-2.01697E-12	1.24661E-12
37 TO 38	0.	0.	0.	0.
39	3.42355E-11	-1.43332E-11	-2.08775E-12	2.77496E-12
40	3.10699E-11	-1.29471E-11	-2.09208E-12	2.70900E-12
41	1.22868E-11	-5.29022E-12	-7.23542E-13	1.18205E-12
42	4.35832E-12	-1.94541E-12	-1.80757E-13	4.14271E-13
43	4.73237E-11	-2.10974E-11	-2.22508E-12	4.87287E-12
44	1.46775E-11	-6.42997E-12	-6.46591E-13	1.54443E-12
45	2.87846E-12	-6.53183E-13	-9.87508E-15	1.34220E-13
46	5.41201E-12	-2.09220E-12	7.06614E-13	4.60451E-14
47	2.13792E-12	0.	0.	0.
48	4.11811E-12	-1.53820E-12	5.48818E-13	1.49964E-14
49	5.76786E-13	0.	0.	0.
50	7.97602E-14	0.	0.	0.

BLOCK 2 ELASTIC SCATTERING, ORDER 0

GROUP 1

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	3.11469E+00	2.70648E+00	2.37089E+00	2.06125E+00

GROUP 2

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	3.69097E+00	3.06739E+00	2.66260E+00	2.26742E+00
2	2.73034E-02	3.82719E-03	3.49122E-03	-6.86457E-04

GROUP 3

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	4.41146E+00	3.53767E+00	2.95272E+00	2.47075E+00
2	2.50025E-02	2.72197E-03	2.40500E-03	1.67691E-03

GROUP 4

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	4.25148E+00	3.06229E+00	2.36329E+00	1.94636E+00
2	2.53016E-02	2.65169E-03	6.79577E-04	2.87584E-03

GROUP 5

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	3.75285E+00	2.18666E+00	1.47978E+00	1.22025E+00
2	2.56240E-02	1.74833E-04	-1.95819E-03	1.96885E-03

•
•
•

```
      GROUP   50
       POSN       ORDER  1      ORDER  2      ORDER  3      ORDER  4
         1      8.70955E+00  2.44996E-02  3.10122E-05  0.
         2      1.86705E-01 -6.18474E-02 -2.33999E-04  0.


BLOCK  3      N2N SCATTERING, ORDER  1
      GROUP    1
       POSN       ORDER  1
         1      9.24084E-11
      GROUP    2
       POSN       ORDER  1
         1      0.
         2      5.72538E-06
      GROUP    3
       POSN       ORDER  1
         1      0.
         2      1.32362E-05
         3      1.17584E-03
      GROUP    4
       POSN       ORDER  1
      1 TO   2  0.
         3      1.28550E-03
         4      1.32346E-02
      GROUP    5
       POSN       ORDER  1
      1 TO   3  0.
         4      9.61054E-03
         5      4.16122E-02
         .

         .

         .

      GROUP   50
       POSN       ORDER  1
      1 TO  47  0.
        48      2.82463E-14
        49      2.79820E-13
        50      2.06193E-13

BLOCK  4    TOTAL SCATTERING, ORDER  4
      GROUP    1
       POSN       ORDER  1      ORDER  2      ORDER  3      ORDER  4
         1      3.14430E+00  2.72630E+00  2.38412E+00  2.06922E+00
      GROUP    2
       POSN       ORDER  1      ORDER  2      ORDER  3      ORDER  4
         1      3.70178E+00  3.07253E+00  2.66509E+00  2.26839E+00
         2      1.15059E-01  5.76281E-02  3.76241E-02  1.79935E-02
      GROUP    3
       POSN       ORDER  1      ORDER  2      ORDER  3      ORDER  4
         1      4.41807E+00  3.53832E+00  2.95285E+00  2.47077E+00
         2      5.42962E-02  1.19268E-02  5.55181E-03  2.37336E-03
         3      3.10867E-02  1.18844E-02  5.23447E-03  1.74480E-03
      GROUP    4
       POSN       ORDER  1      ORDER  2      ORDER  3      ORDER  4
         1      4.36759E+00  3.06407E+00  2.36330E+00  1.94636E+00
         2      1.11169E-01  3.21374E-03  7.48728E-04  2.87909E-03
         3      5.72741E-02  2.20773E-03  3.24540E-04  2.10338E-05
         4      2.95941E-02  0.           0.           0.
      GROUP    5
       POSN       ORDER  1      ORDER  2      ORDER  3      ORDER  4
         1      4.01694E+00  2.19046E+00  1.47980E+00  1.22025E+00
         2      3.42155E-01 -8.16571E-04 -1.96979E-03  1.96628E-03
         3      2.70369E-01  3.26128E-05  4.64688E-06 -9.50340E-08
         4      1.49046E-01  5.45655E-05  8.37585E-06 -4.21996E-07
         5      9.28169E-02  0.           0.           0.
         .
         .
         .
```

GROUP 50

POSN	ORDER 1	ORDER 2	ORDER 3	ORDER 4
1	8.70955E+00	2.44996E-02	3.10122E-05	0.
2	1.86705E-01	-6.18474E-02	-2.33999E-04	0.
3 TO 26	0.	0.	0.	0.
27	6.94075E-09	-1.04128E-09	-2.62626E-10	-1.08308E-10
28 TO 34	0.	0.	0.	0.
35	7.85542E-11	-2.73003E-11	-7.79106E-12	3.24110E-12
36	2.26264E-11	-8.38594E-12	-2.01697E-12	1.24601E-12
37 TO 38	0.	0.	0.	0.
39	3.42555E-11	-1.43332E-11	-2.06775E-12	2.77496E-12
40	3.10699E-11	-1.29471E-11	-2.09208E-12	2.70900E-12
41	1.22868E-11	-5.29022E-12	-7.23542E-13	1.18205E-12
42	4.35832E-12	-1.94541E-12	-1.80757E-13	4.14271E-13
43	4.73237E-11	-2.10974E-11	-2.22508E-12	4.87287E-12
44	1.46775E-11	-6.42997E-12	-6.46591E-13	1.54443E-12
45	2.87846E-12	-6.53183E-13	-9.87508E-15	1.34220E-13
46	5.41201E-12	-2.09220E-12	7.06614E-13	4.60451E-14
47	2.13792E-12	0.	0.	0.
48	4.17460E-12	-1.53820E-12	5.48818E-13	1.49964E-14
49	1.13643E-12	0.	0.	0.
50	4.92147E-13	0.	0.	0.

LIB-IV BRKOXS LISTING

```
BINX...CONVERT MODE OF CCCC FILE

MODE=1   (1 MEANS BIN TO BCD, 2 MEANS BCD TO BIN)
TYPE=2   (1 MEANS ISOTXS, 2 MEANS BRKOXS, 3 MEANS DLAYXS)
IRD=   1   1  -0  -0  -0  -0  -0  -0  -0  -0

*** FILEBRKOXS -- VERSION  1 -- UNIT   3***
**USER IDENTIFICATION**I2LASL    MINX

FILE CONTROL PARAMETERS

 NGROUP    NUMBER OF ENERGY GROUPS IN SET                      50
 NISOSH    NUMBER OF ISOTOPES WITH SELF-
             SHIELDING FACTORS                                101
 NSIGPT    TOTAL NUMBER OF VALUES OF VARIABLE X
             WHICH ARE GIVEN.  NSIGPT IS EQUAL TO
             THE SUM FROM 1 TO NISOSH OF NTABP(I)             597
 NTEMPT    TOTAL NUMBER OF VALUES OF VARIABLE T8
             WHICH ARE GIVEN.  NTEMPT IS EQUAL TO
             THE SUM FROM 1 TO NISOSH OF NTABT(I)             303

ISOTOPE          NAME
     1             H1
     2             H2
     3             H3
     4             HE3
     5             HE4
     .
     .
     .

LN(SIGPO)/LN(10) VALUES FOR ALL ISOTOPES

ISOTOPE      1ST VALUE        2ND VALUE          . . .
     1     3.00000E+00     2.00000E+00     1.00000E+00     0.             -1.00000E+00
     2     3.00000E+00     2.00000E+00     1.00000E+00     0.             -1.00000E+00
     3     3.00000E+00     2.00000E+00     1.00000E+00     0.             -1.00000E+00
     4     4.00000E+00     3.00000E+00     2.00000E+00     1.00000E+00     0.
     5     4.00000E+00     3.00000E+00     2.00000E+00     1.00000E+00     0.
     .
     .
     .
```

97	4.00000E+00	3.00000E+00	2.00000E+00	1.00000E+00	0.
98	4.00000E+00	3.00000E+00	2.00000E+00	1.00000E+00	0.
99	4.00000E+00	3.00000E+00	2.00000E+00	1.00000E+00	0.
100	4.00000E+00	3.00000E+00	2.00000E+00	1.00000E+00	0.
101	4.00000E+00	3.00000E+00	2.00000E+00	1.00000E+00	0.

TEMPERATURES (DEG C) FOR ALL ISOTOPES

ISOTOPE	1ST VALUE	2ND VALUE	. . .
1	2.68400E+01	6.26840E+02	1.82684E+03
2	2.68400E+01	6.26840E+02	1.82684E+03
3	2.68400E+01	6.26840E+02	1.82684E+03
4	2.68400E+01	6.26840E+02	1.82684E+03
5	2.68400E+01	6.26840E+02	1.82684E+03
•			
•			
•			
97	2.68400E+01	6.26840E+02	1.82684E+03
98	2.68400E+01	6.26840E+02	1.82684E+03
99	2.68400E+01	6.26840E+02	1.82684E+03
100	2.68400E+01	6.26840E+02	1.82684E+03
101	2.68400E+01	6.26840E+02	1.82684E+03

GROUP STRUCTURE

GROUP	TOP ENERGY
1	1.99711E+07
2	1.00000E+07
3	6.06531E+06
4	3.67879E+06
5	2.23130E+06
•	
•	
•	

F-FACTOR START END GROUPS AND NUMBER OF SIGPO TEMP VALUES

ISOTOPE	JBFH	JBFL	NTABP	NTABT
1	1	50	6	3
2	1	50	6	3
3	1	50	6	3
4	1	50	6	3
5	1	50	6	3
•				
•				
•				
97	1	50	6	3
98	1	50	6	3
99	1	50	6	3
100	1	50	6	3
101	1	50	6	3

•

• (Skip to Pu-239)

•

TOTAL SELF-SHIELDING FACTORS ISOTOPE 86

GROUP 1

SIGO	TEMP 1	TEMP 2	TEMP 3
1	1.00000E+00	1.00000E+00	1.00000E+00
2	9.99999E-01	9.99999E-01	9.99999E-01
3	9.99987E-01	9.99987E-01	9.99987E-01
4	9.99915E-01	9.99915E-01	9.99915E-01
5	9.99807E-01	9.99807E-01	9.99807E-01
•			
•			
•			

GROUP 38

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.80620E-01	9.89868E-01	9.97461E-01
2	8.60546E-01	9.05490E-01	9.37927E-01
3	5.79352E-01	6.49970E-01	7.19002E-01
4	4.17467E-01	4.62683E-01	5.21489E-01
5	3.82940E-01	4.19595E-01	4.70474E-01

GROUP 39

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.65823E-01	9.83015E-01	9.93999E-01
2	7.73720E-01	8.38828E-01	8.88298E-01
3	4.87762E-01	5.41770E-01	6.03890E-01
4	3.54472E-01	3.75256E-01	4.08110E-01
5	3.23443E-01	3.37560E-01	3.62546E-01

GROUP 40

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.24094E-01	9.46533E-01	9.62209E-01
2	6.50109E-01	7.00580E-01	7.49008E-01
3	3.99280E-01	4.13906E-01	4.36605E-01
4	2.95745E-01	3.00034E-01	3.08607E-01
5	2.73460E-01	2.76222E-01	2.82237E-01

⋮

CAPTURE SELF-SHIELDING FACTORS ISOTOPE 86

GROUP 1

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.99997E-01	9.99995E-01	9.99992E-01
2	9.99999E-01	9.99997E-01	9.99993E-01
3	1.00001E+00	1.00001E+00	1.00001E+00
4	1.00010E+00	1.00009E+00	1.00069E+00
5	1.00023E+00	1.00022E+00	1.00022E+00

⋮

GROUP 38

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.86848E-01	9.93318E-01	9.97398E-01
2	9.02799E-01	9.40493E-01	9.63247E-01
3	6.26682E-01	7.26080E-01	8.02844E-01
4	3.90496E-01	4.92944E-01	5.95464E-01
5	3.33294E-01	4.28300E-01	5.31542E-01

GROUP 39

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.77642E-01	9.90209E-01	9.97237E-01
2	8.16723E-01	8.78557E-01	9.19252E-01
3	4.70206E-01	5.62280E-01	6.46628E-01
4	2.72354E-01	3.34868E-01	4.07859E-01
5	2.30520E-01	2.82211E-01	3.47296E-01

GROUP 40

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.47423E-01	9.63917E-01	9.74441E-01
2	6.97018E-01	7.62031E-01	8.12995E-01
3	3.49282E-01	4.01430E-01	4.58228E-01
4	2.16035E-01	2.44308E-01	2.80531E-01
5	1.92476E-01	2.15973E-01	2.47138E-01

⋮

FISSION SELF-SHIELDING FACTORS ISOTOPE 86

GROUP 1

SIGO	TEMP 1	TEMP 2	TEMP 3
1	1.00000E+00	1.00000E+00	1.00000E+00
2	9.99998E-01	9.99998E-01	9.99998E-01
3	9.99984E-01	9.99984E-01	9.99984E-01
4	9.99895E-01	9.99895E-01	9.99895E-01
5	9.99761E-01	9.99761E-01	9.99761E-01

⋮

GROUP 38

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.90818E-01	9.95090E-01	9.98568E-01
2	9.26260E-01	9.48586E-01	9.65114E-01
3	7.00487E-01	7.57435E-01	8.09246E-01
4	4.98194E-01	5.58602E-01	6.25742E-01
5	4.43986E-01	5.02317E-01	5.71029E-01

GROUP 39

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.92413E-01	1.00120E+00	1.00700E+00
2	8.99956E-01	9.35709E-01	9.61282E-01
3	6.70508E-01	7.28228E-01	7.85334E-01
4	4.83907E-01	5.29080E-01	5.85870E-01
5	4.31637E-01	4.70627E-01	5.23424E-01

GROUP 40

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.63872E-01	9.73954E-01	9.81219E-01
2	8.00222E-01	8.33163E-01	8.62668E-01
3	5.58877E-01	5.79430E-01	6.06608E-01
4	4.21033E-01	4.31785E-01	4.49489E-01
5	3.88603E-01	3.97551E-01	4.13043E-01

⋮

TRANSPORT SELF-SHIELDING FACTORS ISOTOPE 86

GROUP 1

SIGO	TEMP 1	TEMP 2	TEMP 3
1	1.00000E+00	1.00000E+00	1.00000E+00
2	9.99998E-01	9.99998E-01	9.99998E-01
3	9.99978E-01	9.99978E-01	9.99978E-01
4	9.99853E-01	9.99853E-01	9.99853E-01
5	9.99664E-01	9.99664E-01	9.99664E-01

⋮

GROUP 38

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.80609E-01	9.89860E-01	9.97456E-01
2	8.60473E-01	9.05438E-01	9.37892E-01
3	5.79140E-01	6.49789E-01	7.18856E-01
4	4.17180E-01	4.62411E-01	5.21243E-01
5	3.82638E-01	4.19303E-01	4.70202E-01

GROUP 39

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.65807E-01	9.83007E-01	9.93995E-01
2	7.73619E-01	8.38754E-01	8.88245E-01
3	4.87552E-01	5.41576E-01	6.03716E-01
4	3.54212E-01	3.74996E-01	4.07854E-01
5	3.23171E-01	3.37285E-01	3.62272E-01

GROUP 40

SIGO	TEMP 1	TEMP 2	TEMP 3
1	9.24071E-01	9.46317E-01	9.62197E-01
2	6.50014E-01	7.00494E-01	7.48932E-01
3	3.99139E-01	4.13762E-01	4.36460E-01
4	2.95583E-01	2.99869E-01	3.08439E-01
5	2.73293E-01	2.76052E-01	2.82064E-01

⋮

ELASTIC SELF-SHIELDING FACTORS ISOTOPE 86

GROUP 1

SIGO	TEMP 1	TEMP 2	TEMP 3
1	1.00000E+00	1.00000E+00	1.00000E+00
2	1.00000E+00	1.00000E+00	1.00000E+00
3	9.99998E-01	9.99998E-01	9.99998E-01
4	9.99988E-01	9.99988E-01	9.99988E-01
5	9.99973E-01	9.99973E-01	9.99973E-01

⋮

```
GROUP     38
SIGO      TEMP    1     TEMP    2     TEMP    3
   1      9.92880E-01   9.98523E-01   1.00284E+00
   2      9.38063E-01   9.60688E-01   9.76121E-01
   3      8.06635E-01   8.43174E-01   8.75359E-01
   4      7.25028E-01   7.53948E-01   7.84325E-01
   5      7.06347E-01   7.32668E-01   7.61276E-01
GROUP     39
SIGO      TEMP    1     TEMP    2     TEMP    3
   1      9.85274E-01   9.93040E-01   9.98943E-01
   2      8.97079E-01   9.29181E-01   9.52908E-01
   3      7.44828E-01   7.79962E-01   8.16149E-01
   4      6.72602E-01   6.93847E-01   7.20367E-01
   5      6.56345E-01   6.74234E-01   6.97763E-01
GROUP     40
SIGO      TEMP    1     TEMP    2     TEMP    3
   1      9.71724E-01   9.80711E-01   9.87112E-01
   2      8.44862E-01   8.76224E-01   9.02487E-01
   3      6.86481E-01   7.07400E-01   7.31925E-01
   4      6.26071E-01   6.36671E-01   6.51044E-01
   5      6.13621E-01   6.22534E-01   6.35005E-01
   .
   .
   .
CROSS SECTIONS

GROUP          XSPO          XSIN          XSE          XSMU          XSFD
   1     4.12950E-02   1.91050E-01   3.14199E+00   8.65643E-01   2.73034E-02
   2     2.56521E-01   7.09728E-01   3.71598E+00   8.27651E-01   2.50025E-02
   3     4.00817E-01   1.64881E+00   4.43677E+00   7.98105E-01   2.53016E-02
   4     7.05782E-02   1.63394E+00   4.27710E+00   7.16033E-01   2.56240E-02
   5     4.52797E-01   1.44338E+00   3.78170E+00   5.78139E-01   2.88507E-02
   .
   .
   .
  46     1.02000E+01   0.            8.88286E+00   2.81338E-03   1.55596E-01
  47     1.02000E+01   0.            9.49873E+00   2.81338E-03   1.63643E-01
  48     1.02000E+01   0.            9.96734E+00   2.81338E-03   1.72303E-01
  49     1.02000E+01   0.            1.06288E+01   2.81338E-03   1.86705E-01
  50     1.02000E+01   0.            8.70955E+00   2.81338E-03   7.52226E-09
```

LIB-IV DLAYXS LISTING

```
BINX...CONVERT MODE OF CCCC FILE

MODE=1  (1 MEANS BIN TO BCD, 2 MEANS BCD TO BIN)
TYPE=3  (1 MEANS ISOTXS, 2 MEANS BRKOXS, 3 MEANS DLAYXS)
IRD=   1   1   1   1  -0  -0  -0  -0  -0  -0
DELAYED NEUTRON PRECURSOR DATA DLAYXS
USER IDENTIFICATION T2LASLNJOY
FILE VERSION NUMBER      1

FILE CONTROL PARAMETERS

 NGROUP     NUMBER OF NEUTRON ENERGY GROUPS IN SET            50
 NISOD      NUMBER OF ISOTOPES IN DELAYED                      7
              NEUTRON SET
 NFAM       NUMBER OF DELAYED NEUTRON FAMILIES                42
              IN SET
 IDUM       DUMMY TO MAKE UP 4-WORD RECORD                    42

FAMILY NUMBER OF K-TH YIELD VECTOR
      1          TH232
      2           U233
      3           U235
      4           U238
      5          PU239
      6          PU240
      7          PU241
```

DELAYED NEUTRON PRECURSOR DECAY CONSTANT FOR FAMILY N

FAMILY	N
1	.12370E-01
2	.33400E-01
3	.12100E+00
4	.32100E+00
5	.12100E+01
6	.32900E+01
7	.12580E-01
8	.33420E-01
9	.13100E+00
⋮	
39	.12400E+00
40	.35200E+00
41	.16100E+01
42	.34700E+01

FRACTION OF DELAYED NEUTRONS EMITTED INTO NEUTRON ENERGY GROUP FROM PRECURSOR FAMILY

GROUP	FAMILY 1	FAMILY 2	FAMILY 3	FAMILY 4	FAMILY 5	FAMILY 6
1 TO 5	0.	0.	0.	0.	0.	0.
6	4.28756E-04	3.75347E-02	5.96411E-03	1.54809E-02	5.97021E-03	1.49255E-03
7	1.01041E-03	4.92969E-02	1.82556E-02	5.19319E-02	2.00276E-02	5.00689E-03
8	1.39243E-03	3.45842E-02	1.52397E-02	3.72657E-02	1.43715E-02	3.59288E-03
9	1.67277E-03	1.88974E-02	1.56667E-02	4.73665E-02	1.82669E-02	4.56673E-03
10	3.84730E-03	2.59834E-03	1.25841E-02	5.38701E-02	2.07750E-02	5.19376E-03
⋮						

GROUP	FAMILY 37	FAMILY 38	FAMILY 39	FAMILY 40	FAMILY 41	FAMILY 42
1 TO 5	0.	0.	0.	0.	0.	0.
6	3.99911E-04	6.26830E-02	6.69352E-03	1.22245E-02	5.70477E-03	5.01519E-04
7	8.99575E-04	8.63288E-02	1.36861E-02	3.63586E-02	1.69673E-02	1.49163E-03
8	5.93667E-04	4.15176E-02	1.78613E-02	1.71662E-02	8.01090E-03	7.04255E-04
9	5.14483E-04	2.00511E-02	1.71085E-02	5.01153E-02	2.33871E-02	2.05601E-03
10	6.71926E-04	1.25352E-03	1.72034E-02	5.37707E-02	2.50930E-02	2.20598E-03

MAXIMUM ENERGY BOUND

GROUP	J
1	1.99711E+07
2	1.00000E+07
3	6.06531E+06
4	3.67879E+06
⋮	

NUMBER OF FAMILIES TO WHICH FISSION IN ISOTOPE CONTRIBUTES DELAYED NEUTRON PRECURSORS

ISOTOP/NUMBER	1
1	6
2	6
3	6
4	6
5	6
6	6
7	6

NUMBER OF RECORDS TO BE SKIPPED TO READ DATA FOR ISOTOPE

ISOTOP/NUMBER	1
1	0
2	1
3	2
4	3
5	4
6	5
7	6

(Skip to Pu-239)

NUMBER OF DELAYED NEUTRON PRECURSORS PRODUCED IN FAMILY PER FISSION IN GROUP

GROUP	FAMILY 1	FAMILY 2	FAMILY 3	FAMILY 4	FAMILY 5	FAMILY 6
1	1.63400E-04	1.20400E-03	9.28800E-04	1.41040E-03	4.42900E-04	1.50500E-04
2	1.69504E-04	1.24898E-03	9.63496E-04	1.46309E-03	4.59446E-04	1.56122E-04
3	2.28205E-04	1.68151E-03	1.29717E-03	1.96978E-03	6.18557E-04	2.10189E-04
4	2.45100E-04	1.80600E-03	1.39320E-03	2.11560E-03	6.64351E-04	2.25750E-04
5	2.45100E-04	1.80600E-03	1.39320E-03	2.11560E-03	6.64351E-04	2.25750E-04
•						
•						
•						
46	2.45100E-04	1.80600E-03	1.39320E-03	2.11560E-03	6.64351E-04	2.25750E-04
47	2.45100E-04	1.80600E-03	1.39320E-03	2.11560E-03	6.64351E-04	2.25750E-04
48	2.45100E-04	1.80600E-03	1.39320E-03	2.11560E-03	6.64351E-04	2.25750E-04
49	2.45100E-04	1.80600E-03	1.39320E-03	2.11560E-03	6.64351E-04	2.25750E-04
50	2.45100E-04	1.80600E-03	1.39320E-03	2.11560E-03	6.64351E-04	2.25750E-04

FAMILY NUMBER OF K-TH YIELD VECTOR

FAMILY/VECTOR	1	2	3	4	5	6
1	25	26	27	28	29	30

APPENDIX B

OPERATING INSTRUCTIONS FOR THE UTILITY CODES LINX, BINX, AND CINX

The CCCC utility codes used to manipulate LIB-IV are described more completely elsewhere.[9,10] However, for convenience, the operating instructions for these codes have been included in this report as Tables B-I, B-II, and B-III.

The versions of LINX, BINX, and CINX included on the LIB-IV transmittal tape are for the LASL CDC 7600. They can be easily converted to a short-word machine such as an IBM 360 by following the instructions found on the "C IBM comment" cards which will be found in the codes.

TABLE B-I

LINX OPERATION INFORMATION

Input/Output Units

3 -- primary binary input file.[a]
4 -- secondary binary input file.
8 -- final binary output file.[b]
6 -- listing of messages and diagnostics.

User's Input

None

---

[a]ISOTXS or BRKOXS only.

[b]User identification, version, and library identifier are taken from the primary input file.

TABLE B-II

BINX OPERATING INFORMATION

Input/Output Units

3 -- input binary (BCD) unit.[a]
8 -- output BCD (binary) unit.
5 -- system input for user's input.
6 -- system output for listing and diagnostics.

User's Input

One card (12I5):MODE,NTYPE,IRD(I≤10)

MODE = 1 means binary input and BCD output.
MODE = 2 means BCD input and binary output.
NTYPE = 1 means ISOTXS.
NTYPE = 2 means BRKOXS.
NTYPE = 3 means DLAYXS.
IRD(I) = 1 means print the Ith record type.

---

[a]ISOTXS, BRKOXS, or DLAYXS only.

TABLE B-III

CINX OPERATING INFORMATION

Input Files

3,4,12 -- Fine-group binary CCCC-III ISOTXS, BRKOXS, and DLAYXS files, respectively.

Output Files

8,9,13 -- Coarse-group binary CCCC-III ISOTXS, BRKOXS, and DLAYXS files, respectively.

10 -- Coarse-group lDX binary format.

System Files

5 -- Data cards.
6 -- Computer printout.
PUN -- PERT-V output on cards.

Data Cards:

1. Run Options Input Card (Format 5I6).
   - MF Major functions (0/1/2 = collapse/lDX/both).
   - NCG Number of coarse groups (omit if MF = 1).
   - ICF Collapsing flux (0/1 - thermal-Fermi-Watt/input) (omit if MF = 1).
   - NDT Number of downscattering terms (including ingroup) (omit if MF = 0).
   - NPF Neutron precursor file (0/1 = No/Yes) (- for PERT-V data).

2. Number of Fine Groups per each Coarse Group (Format 12I6) (omit if MF = 1).

3. Parameters for ICF = 0 Option (Format 4E12.5) (omit if MF = 1 or ICF $\neq$ 0).
   - TE Nuclear temperature (eV) for thermal spectrum region (0.025 used for LIB-IV).
   - EB Upper limit (eV) for thermal region (0.1 used for LIB-IV).
   - TC Nuclear temperature (eV) for WATT spectrum region (1.4×10^6 used for LIB-IV).
   - EC Lower limit (eV) for WATT region (0.8208×10^6 used for LIB-IV).

4. Input Flux (Format 6E12.5) (omit if MF = 1 or ICF = 0).

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