A Combined P3 Vitamin-C, MACK-IV, Coupled 25 Neutron-21 Gamma Group Cross Section Library - The U.W. Cross Section Library

R.T. Perry and G.A. Moses

December 1980

UWFDM-390

FUSION TECHNOLOGY INSTITUTE

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A Combined P3 Vitamin-C, MACK-IV, Coupled 25 Neutron-21 Gamma Group Cross Section Library - The U.W. Cross Section Library

R.T. Perry and G.A. Moses

Fusion Technology Institute
University of Wisconsin
1500 Engineering Drive
Madison, WI 53706

http://fti.neep.wisc.edu

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R.T. Perry

G.A. Moses

Fusion Engineering Program
Nuclear Engineering Department
University of Wisconsin
Madison, WI 53706

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A Combined P3, VITAMIN-C, MACKLIB-IV, Coupled 25 Neutron - 21 Gamma Group Cross Section Library - The UW Cross Section Library

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We have combined the 25 neutron group - 21 gamma energy group, P_3 expansion, DLC-41B/VITAMIN-C cross section library[1] (see Appendix I - memo of T. Wu) with the DLC-60/MACKLIB-IV[2] response library (see Appendix II - memo of T. Wu) into a single library. This results in a library that is convenient for use in ANISN[3] and facilitates export of the library to other installations.

A listing of the contents of the library is given in Table 1. The cross section ID numbers are listed in column 4 of Table 1.

The contents of the cross section sets are listed in Table 2. Their position would be an input parameter to ANISN should activity calculations be desired. Note that not all library entries have DLC MACKLIB-IV response functions and some sets have no gamma data.

In Table 3 some important ANISN input control parameters for this library are listed.

Table 1 Contents of UW Cross Section Library

46	96	0	100	H-1	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	101	H-1	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	102	H-1	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	103	H-1	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	200	H-2	P0	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	201	H-2	P1	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	202	H-2	P2	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	203	H-2	P3	25N GP-NO GAMMA--DLC41/B LIB. ONLY	********
46	96	0	300	H-3	P0	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	301	H-3	P1	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	302	H-3	P2	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	303	H-3	P3	25N GP-NO GAMMA--DLC41/B LIB. ONLY	********
46	96	0	400	HE-3	P0	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	401	HE-3	P1	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	402	HE-3	P2	25N GP-NO GAMMA--DLC41/B LIB, ONLY	********
46	96	0	403	HE-3	P3	25N GP-NO GAMMA--DLC41/B LIB. ONLY	********
46	96	0	500	HE-4	P0	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	501	HE-4	P1	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	502	HE-4	P2	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	503	HE-4	P3	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	600	LI-6	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	601	LI-6	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	602	LI-6	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	603	LI-6	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	700	LI-7	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	701	LI-7	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	702	LI-7	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	703	LI-7	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	800	BE	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	801	BE	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	802	BE	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	803	BE	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********

46	96	0	900	B-10	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	901	B-10	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	902	B-10	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	903	B-10	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	1000	B-11	P0	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	1001	B-11	P1	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	1002	B-11	P2	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	1003	B-11	P3	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	1100	C-12	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1101	C-12	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1102	C-12	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1103	C-12	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	1200	N-14	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1201	N-14	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1202	N-14	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1203	N-14	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	1300	O-16	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1301	O-16	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1302	O-16	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1303	O-16	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	1400	F	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1401	F	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1402	F	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1403	F	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	1500	NA	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1501	NA	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1502	NA	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1503	NA	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	1600	MG	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1601	MG	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1602	MG	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1603	MG	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********

46	96	0	1700	AL27	P0	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1701	AL27	P1	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1702	AL27	P2	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1703	AL27	P3	25N=21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	1800	SI	P0	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1801	SI	P1	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1802	SI	P2	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1803	SI	P3	25N=21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	1900	K	P0	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1901	K	P1	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1902	K	P2	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	1903	K	P3	25N=21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	2000	CA	P0	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2001	CA	P1	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2002	CA	P2	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2003	CA	P3	25N=21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	2100	TI	P0	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2101	TI	P1	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2102	TI	P2	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2103	TI	P3	25N=21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	2200	V	P0	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2201	V	P1	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2202	V	P2	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2203	V	P3	25N=21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	2300	CR	P0	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2301	CR	P1	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2302	CR	P2	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2303	CR	P3	25N=21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	2400	MN55	P0	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2401	MN55	P1	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2402	MN55	P2	25N=21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	2403	MN55	P3	25N=21G GP. DLC41/B & DLC60 LIB.	********

46	96	0	2500	FE	P0	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2501	FE	P1	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2502	FE	P2	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2503	FE	P3	25N-21G GP. DLC41/B & DLC60 LIB.	*******
46	96	0	2600	NI	P0	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2601	NI	P1	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2602	NI	P2	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2603	NI	P3	25N-21G GP. DLC41/B & DLC60 LIB.	*******
46	96	0	2700	CU	P0	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2701	CU	P1	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2702	CU	P2	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2703	CU	P3	25N-21G GP. DLC41/B & DLC60 LIB.	*******
46	96	0	2800	ZR	P0	25N-21G GP, DLC41/B LIB, ONLY	*******
46	96	0	2801	ZR	P1	25N-21G GP, DLC41/B LIB, ONLY	*******
46	96	0	2802	ZR	P2	25N-21G GP, DLC41/B LIB, ONLY	*******
46	96	0	2803	ZR	P3	25N-21G GP. DLC41/B LIB. ONLY	*******
46	96	0	2900	NB93	P0	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2901	NB93	P1	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2902	NB93	P2	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	2903	NB93	P3	25N-21G GP. DLC41/B & DLC60 LIB.	*******
46	96	0	3000	MO	P0	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	3001	MO	P1	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	3002	MO	P2	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	3003	MO	P3	25N-21G GP. DLC41/B & DLC60 LIB.	*******
46	96	0	3100	SN	P0	25N-21G GP, DLC41/B LIB, ONLY	*******
46	96	0	3101	SN	P1	25N-21G GP, DLC41/B LIB, ONLY	*******
46	96	0	3102	SN	P2	25N-21G GP, DLC41/B LIB, ONLY	*******
46	96	0	3103	SN	P3	25N-21G GP. DLC41/B LIB. ONLY	*******
46	96	0	3200	TA181	P0	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	3201	TA181	P1	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	3202	TA181	P2	25N-21G GP, DLC41/B & DLC60 LIB,	*******
46	96	0	3203	TA181	P3	25N-21G GP. DLC41/B & DLC60 LIB.	*******

46	96	0	3300	W-182	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3301	W-182	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3302	W-182	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3303	W-182	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	3400	W-183	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3401	W-183	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3402	W-183	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3403	W-183	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	3500	W-184	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3501	W-184	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3502	W-184	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3503	W-184	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	3600	W-186	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3601	W-186	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3602	W-186	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3603	W-186	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	3700	PB	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3701	PB	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3702	PB	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	3703	PB	P3	25N-21G GP. DLC41/B & DLC60 LIB.	********
46	96	0	3800	TH232	P0	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	3801	TH232	P1	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	3802	TH232	P2	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	3803	TH232	P3	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	3900	U-233	P0	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	3901	U-233	P1	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	3902	U-233	P2	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	3903	U-233	P3	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	4000	U-234	P0	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	4001	U-234	P1	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	4002	U-234	P2	25N GP=NO GAMMA=DLC41/B AND DLC60	********
46	96	0	4003	U-234	P3	25N GP=NO GAMMA=DLC41/B AND DLC60	********

46	96	0	4100	U-235	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4101	U-235	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4102	U-235	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4103	U-235	P3	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4200	U-236	P0	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4201	U-236	P1	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4202	U-236	P2	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4203	U-236	P3	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4300	U-238	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4301	U-238	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4302	U-238	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4303	U-238	P3	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4400	PU-238	P0	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4401	PU-238	P1	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4402	PU-238	P2	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4403	PU-238	P3	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4500	PU-239	P0	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4501	PU-239	P1	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4502	PU-239	P2	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4503	PU-239	P3	25N-21G GP, DLC41/B & DLC60 LIB,	********
46	96	0	4600	PU-241	P0	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4601	PU-241	P1	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4602	PU-241	P2	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4603	PU-241	P3	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4700	PU-242	P0	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4701	PU-242	P1	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4702	PU-242	P2	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4703	PU-242	P3	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4800	AM-241	P0	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4801	AM-241	P1	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4802	AM-241	P2	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	0	4803	AM-241	P3	25N GP-NO GAMMA-DLC41/B AND DLC60	********
46	96	7	0	END DATA			********

Table 2 Cross Section Set Format

(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	(n,2n) cross section
36	(n,3n) cross section
37	Total fission cross section
38	$(n,n')\alpha$ cross section
39	$(n,2n)\alpha$ cross section
40	Inelastic continuum
41	(n,γ) cross section
42	(n,p) cross section
43	(n,d) cross section
44	(n,t) cross section
45	$(n,^{3}He)$ cross section

(Table 2 - Continued)

Position	Content
46	(n,α) cross section
47	ν
48	Absorption cross section
49	ν x fission cross section
50	Total cross section
51-96	Group transfer cross sections

Note 1 - 34 are from MACKLIB
35 - 96 are from VITAMIN-C

Table 3 - ANISN Control Parameters

ISCT	Maximum order of scatter - 3
IGM	Number of energy groups in the calculation - 46
IHT	Position of σ_{total} in the cross section table - 50
IHS	Position of σ_s^{g-g} in the cross section table - 51
IHM	Cross section table length - 96

In Table 4, the neutron energy group structure is given and in Table 5, the energy group structure for the gamma cross sections are given.

In the following sections, we discuss in more detail the cross section sets - their use and data retrieval programs. We refer to this library as the UW Cross Section Library.

Cross Section Sets

The cross section sets are a combination of response functions from the DLC-60/MACK IV Library and response functions and transport cross sections from the DLC-41B/VITAMIN-C Library. Both the DLC-60 and DLC-41B Library was created from ENDF/B-IV[4] files. The neutron and gamma transport cross sections are coupled by the use of gamma production cross sections. The neutron and gamma scattering cross sections are approximated by Legendre polynomials in a P_3 expansion.

The structure of the cross section sets are such that in a single ANISN run, both space and energy dependent neutron and gamma fluxes may be calculated. In the same run, the fluxes may be used with the response functions to determine various reaction rates such as tritium production, heating, and dpa rates.

In recapitulation, the library contains, for many elements and isotopes, the following cross sections:

- Gamma response functions
- Neutron response functions
- Gamma production cross sections
- Neutron transport cross sections
- Gamma transport cross sections
- Legendre expansions of the neutron and gamma scattering cross sections

Table 4

Neutron 25 Energy Group Structure in eV

Group Limits

Group	E(Top)	E(Low)	E(Mid Point)
1	1.4918 (+7)	1.3499 (+7)	1.4208 (+7)
2	1.3499 (+7)	1.2214 (+7)	1.2856 (+7)
3	1.2214 (+7)	1.1052 (+7)	1.1633 (+7)
4	1.1052 (+7)	1.0000 (+7)	1.0526 (+7)
5	1.0000 (+7)	9.0484 (+6)	9.5242 (+6)
6	9.0484 (+6)	8.1873 (+6)	8.6178 (+6)
7	8.1873 (+6)	7.4082 (+6)	7.7979 (+6)
8	7.4082 (+6)	6.7032 (+6)	7.0557 (+6)
9	6.7032 (+6)	6.0653 (+6)	6.3843 (+6)
10	6.0653 (+6)	5.4881 (+6)	5.7787 (+6)
11	5.4881 (+6)	4.4933 (+6)	4.9907 (+6)
12	4.4933 (+6)	3.6788 (+6)	4.0860 (+6)
13	3.6788 (+6)	3.0119 (+6)	3.3453 (+6)
14	3.6119 (+6)	2.4660 (+6)	2.7390 (+6)
15	2.4660 (+6)	1.3534 (+6)	1.9097 (+6)
16	1.3534 (+6)	7.4274 (+5)	1.0481 (+6)
17	7.4274 (+5)	4.0762 (+5)	5.7518 (+5)
18	4.0762 (+5)	1.6573 (+5)	2.8667 (+5)
19	1.6573 (+5)	3.1828 (+4)	9.8779 (+4)
20	3.1828 (+4)	3.3546 (+3)	1.7591 (+4)
21	3.3546 (+3)	3.5358 (+2)	1.8541 (+3)
22	3.5358 (+2)	3.7267 (+1)	1.9542 (+2)
23	3.7267 (+1)	3.9279 (+0)	2.0597 (+1)
24	3.9279 (+0)	4.1399 (-1)	2.1718 (+0)
25	4.1399 (-1)	2.200 (-2)	2.1800 (-1)

Table 5 Gamma 21 Multigroup Structure in MeV Group Boundaries

Group	E(Top)	E(Low)	E(Mid-Point)
1	14.0	12.0	13.0
2	12.0	10.0	11.0
3	10.0	8.0	9.00
4	8.0	7.5	7.75
5	7.5	7.0	7.25
6	7.0	6.5	6.75
7	6.5	6.0	6.25
8	6.0	5.5	5.75
9	5.5	5.0	5.25
10	5.0	4.5	4.75
11	4.5	4.0	6.25
12	4.0	3.5	3.75
13	3.5	3.0	3.25
14	3.0	2.5	2.75
15	2.5	2.0	2.25
16	2.0	1.5	1.75
17	1.5	1.0	1.25
18	1.0	0.4	0.7
19	0.4	0.2	0.3
20	0.2	0.1	0.15
21	0.1	0.01	0.055

Each cross section set is a matrix 96 elements long by 46 elements wide. There are 4 distinct cross section sets per element/isotope. Thus, for example, if a problem required Fe, Cr, Ni, Li^6, Li^7, O and H^1, a total of seven elements and isotopes, the total number of cross section sets read into ANISN would be (4x7) or 28. The number 28 would be input into ANISN. This results from the fact that each element/isotope has a P_3 Legendre expansion. The P_0 and the remaining expansions P_1, P_2, P_3 each comprise a distinct set, each set being a matrix 96 elements long and 46 elements wide. If S_j^i represents the jth expansion of the ith element/isotope matrix, we can describe the matrix arrangement on tape by:

$$S_0^1\ S_1^1\ S_2^1\ S_3^1\ S_0^2\ S_1^2\ \cdots\ S_3^{K-1}\ S_0^K\ S_1^K\ S_2^K\ S_3^K\ S_0^{K+1}\ \cdots\ S_3^{N-1}\ S_0^N\ S_1^N\ S_2^N\ S_3^N\ .$$

The P_0 set for each element/isotope contains the response functions, gamma production cross sections and the P_0 component of the scattering cross sections. The P_1, P_2 and P_3 set for each element/isotope contains the respective component of the Legendre expansion of the scattering cross sections. All other locations of these matrices are filled with zeros.

For the purpose of illustration, a P_0 cross section set for a fictitious element is described in Figure 1. For this example we are assuming that the set has 4 neutron groups and 3 gamma energy groups. In addition the set has three response functions: kerma factors, displacement cross sections, and hydrogen production cross sections. The set contains the gamma production cross sections. In addition, the standard absorption, fission total and scattering cross sections are noted. The nomenclature for the elements of the matrix are:

	COL. 1	COL. 2	COL. 3	COL. 4	COL. 5	COL. 6	COL. 7
ROW 1	${}_n\sigma_K^1$	${}_n\sigma_K^2$	${}_n\sigma_K^3$	${}_n\sigma_K^4$	${}_\gamma\sigma_K^1$	${}_\gamma\sigma_K^2$	${}_\gamma\sigma_K^3$
ROW 2	${}_n\sigma_p^1$	${}_n\sigma_p^2$	${}_n\sigma_p^3$	${}_n\sigma_p^4$	0	0	0
ROW 3	${}_n\sigma_{dpa}^1$	${}_n\sigma_{dpa}^2$	${}_n\sigma_{dpa}^3$	${}_n\sigma_{dpa}^4$	0	0	0
ROW 4	${}_n\sigma_a^1$	${}_n\sigma_a^2$	${}_n\sigma_a^3$	${}_n\sigma_a^4$	${}_\gamma\sigma_a^1$	${}_\gamma\sigma_a^2$	${}_\gamma\sigma_a^3$
ROW 5	${}_n\nu\sigma_f$	${}_n\nu\sigma_f$	${}_n\nu\sigma_f$	${}_n\nu\sigma_f$	0	0	0
ROW 6	${}_n\sigma_t^1$	${}_n\sigma_t^2$	${}_n\sigma_t^3$	${}_n\sigma_t^4$	${}_\gamma\sigma_t^1$	${}_\gamma\sigma_t^2$	${}_\gamma\sigma_t^3$
ROW 7	${}_n\sigma_s^{1-1}$	${}_n\sigma_s^{2-2}$	${}_n\sigma_s^{3-3}$	${}_n\sigma_s^{4-4}$	${}_\gamma\sigma_s^{1-1}$	${}_\gamma\sigma_s^{2-2}$	${}_\gamma\sigma_s^{3-3}$
ROW 8	0	${}_n\sigma_s^{1-2}$	${}_n\sigma_s^{2-3}$	${}_n\sigma_s^{3-4}$	${}_n\sigma_\gamma^{4-1}$	${}_\gamma\sigma_s^{1-2}$	${}_\gamma\sigma_s^{2-3}$
ROW 9	0	0	${}_n\sigma_s^{1-3}$	${}_n\sigma_s^{2-4}$	${}_n\sigma_\gamma^{3-1}$	${}_n\sigma_\gamma^{4-2}$	${}_\gamma\sigma_s^{1-3}$
ROW 10	0	0	0	${}_n\sigma_s^{1-4}$	${}_n\sigma_\gamma^{2-1}$	${}_n\sigma_\gamma^{3-2}$	${}_n\sigma_\gamma^{4-3}$
ROW 11	0	0	0	0	${}_n\sigma_\gamma^{1-1}$	${}_n\sigma_\gamma^{2-2}$	${}_n\sigma_\gamma^{3-3}$
ROW 12	0	0	0	0	0	${}_n\sigma_\gamma^{1-2}$	${}_n\sigma_\gamma^{2-3}$
ROW 13	0	0	0	0	0	0	${}_n\sigma_\gamma^{1-3}$

FIGURE 1 Po CROSS SECTION SET FOR FICTICIOUS ELEMENT. THIS SET HAS A 4NEUTRON – 3GAMMA ENERGY GROUP STRUCTURE.

${}_n\sigma_K^i$, ${}_\gamma\sigma_K^i$ is the kerma factor for the ith neutron and gamma group, respectively,

${}_n\sigma_p^i$ is the hydrogen production cross section for the ith neutron group,

${}_n\sigma_{dpa}^i$ is the displacement cross section for the ith neutron group,

${}_n\sigma_a^i$, ${}_\gamma\sigma_a^i$ is the absorption cross section for the ith neutron and gamma group, respectively,

${}_n\nu_n\sigma_f^i$ is ν times the fission cross section for the ith neutron group,

${}_n\sigma_t^i$, ${}_\gamma\sigma_t^i$ is the total cross section for the ith neutron and gamma group, respectively,

${}_n\sigma_s^{i-j}$, ${}_\gamma\sigma_s^{i-j}$ is the scattering cross section from neutron group i to neutron group j and the scattering cross section from gamma group i to gamma group j,

${}_n\sigma_\gamma^{i-j}$ is the gamma production cross section which produces a gamma in energy group j, from a reaction of a neutron in energy group i.

In this example, it is assumed that the gamma displacement cross sections, hydrogen production cross sections and fission cross sections are either unknown or zero as indicated by zeros in the matrix (Figure 1). In a P_1, P_2 or P_3 set associated with this element, all locations except the scattering cross sections will be zero; however, the matrix size would remain the same.

An examination of the matrix shown in Figure 1 reveals several distinct areas and forms. These are shown in Figure 2.

Note that the columns are associated with the energy groups. In this example column 1 to column 4 represents neutron energy groups one to four while columns 5, 6, and 7 represent gamma energy groups 1, 2 and 3. The table width is 7, the sum of the two, and if this fictitious set were used in ANISN, 7 would be input as the number of energy groups.

The rows are associated with the various reaction cross sections. For example, row 6 contains the total cross section and row 7 the self-scattering cross section. Again if this set were used in ANISN, 6 would be input as the location of the total cross section and 7 would be input as the location of σ^{g-g}. The cross section table length would be 13. If activity calculations for heating, hydrogen production, and dpa were desired, their locations would be described by positions 1, 2 and 3, respectively.

The cross section sets in the UW Library are identical in form to that described in Figure 1. The sets are simply much larger and contain many more response functions. The matrix as noted earlier is 96 elements long by 46 elements wide. The cross section table length, 96, is input into ANISN. The number of energy groups, 46, is also input into ANISN. The number 46 is the sum of the number of neutron groups, 25, and the number of gamma groups, 21. The

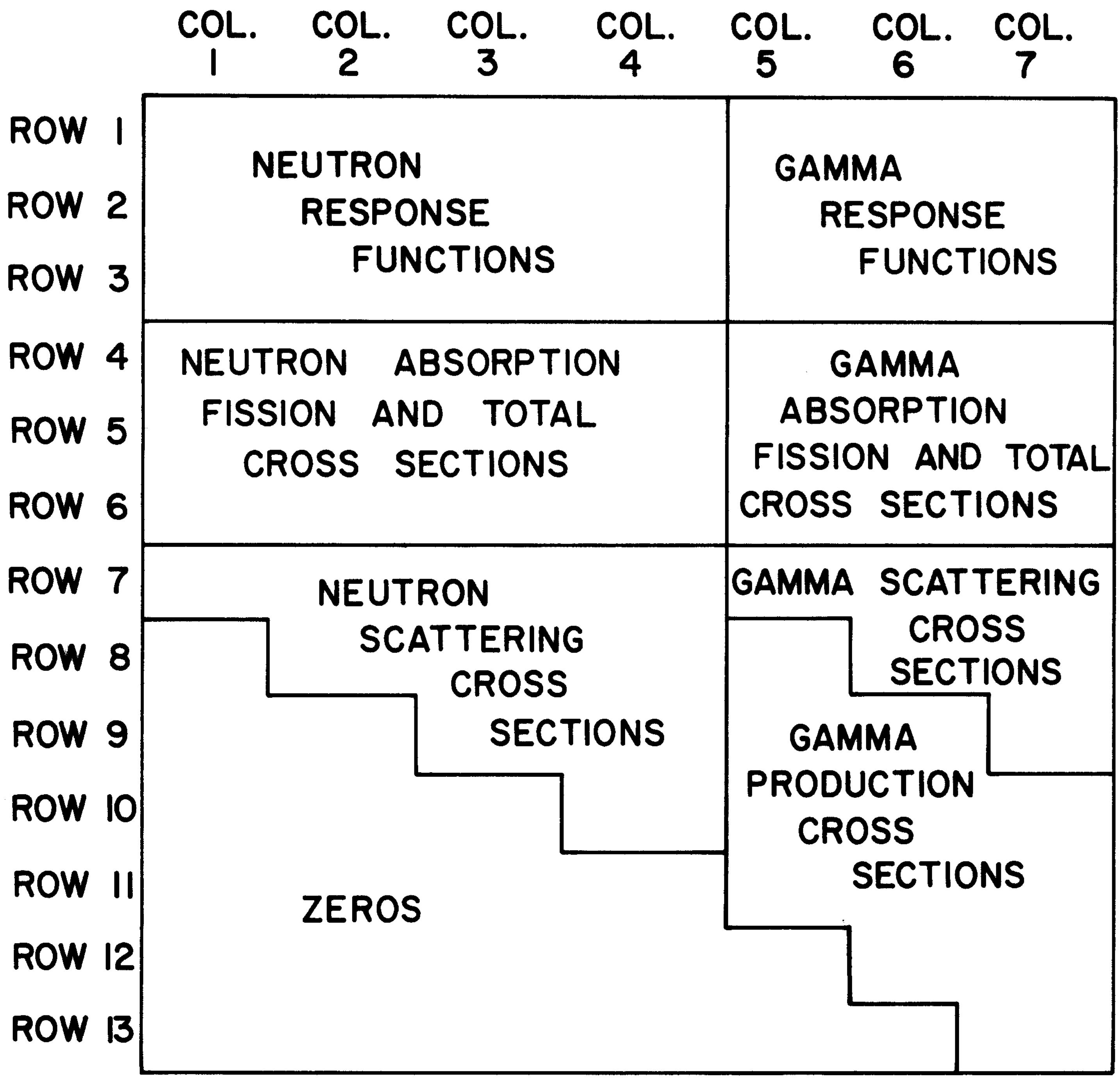

FIGURE 2 Po COUPLED CROSS SECTION SET

location of the total cross section is row 50 and of the self scattering cross section is row 51. These numbers are also ANISN input. As noted earlier the P_1, P_2 and P_3 sets follow the P_0 set for each element. The response functions are found in rows 1 through 47. (The cross sections, σ_a, $\nu\sigma_f$, σ_t and σ_s - rows 48, 49, 50, and 51 may also be considered response functions of activities if these reactions are desired.) A list of the various reactions were given in Table 2. The first 34 rows are from the DLC-60/MACK-IV Library. The remaining cross sections are from the DLC/41B/VITAMIN-C Library. Note that many of the response functions from the two libraries overlap. In these cases, it is recommended that the DLC-41B/VITAMIN-C Library be used, since the transport calculationswere made with cross sections from this library. Although both cross section sets were created from ENDF/B-IV files, the processing codes were different and discrepancies between the two sets may be found.

As noted earlier, not all sets are complete and in some sets various reactions may be missing. Errors may also be present that resulted from processing or transmission. It is strongly recommended that prior to use a set should be printed out and inspected. Check to see if the reaction cross sections desired are present. Compare a few values from the transport matrix with values from the literature. These acts are a major part in insuring the validity of your calculations.

Data Retrieval Programs

The cross sections are transmitted between installations in a card image format. The cross sections are in a FIDO[5] format, i.e. (I2,1A1,F9.0) and repeats are used. Each set is preceded by an ID card in a (4I4,16A4) format and these ID cards were listed in Table 1. The first location gives the table length, the second location gives the table width and the fourth location is the set's ID number. The remaining locations are text describing the data. The last card in the entire library is an ID card with the number 7 in the third location, which is normally zero. This card is used for data control.

The normal flow of data into ANISN or TAPEMAKER[6] (described later) is through ANISN binary cross section sets, as shown in Figure 3.

Thus, a small program, DRP-III, a data retrieval program, has been written to create the ANISN binary tape. It would normally be used only once as it converts all of the cross sections on the tape that are in a card image into the binary tape. The code and its input are described in Appendix III.

TAPEMAKER

Although ANISN can read and search the ANISN binary tape for cross sections, this is often inconvenient because the cross sections will quickly use up available core storage. To overcome this problem a code TAPEMAKER[6] has been written which reads the ANISN binary tape and places the cross sections of choice on a group independent tape.

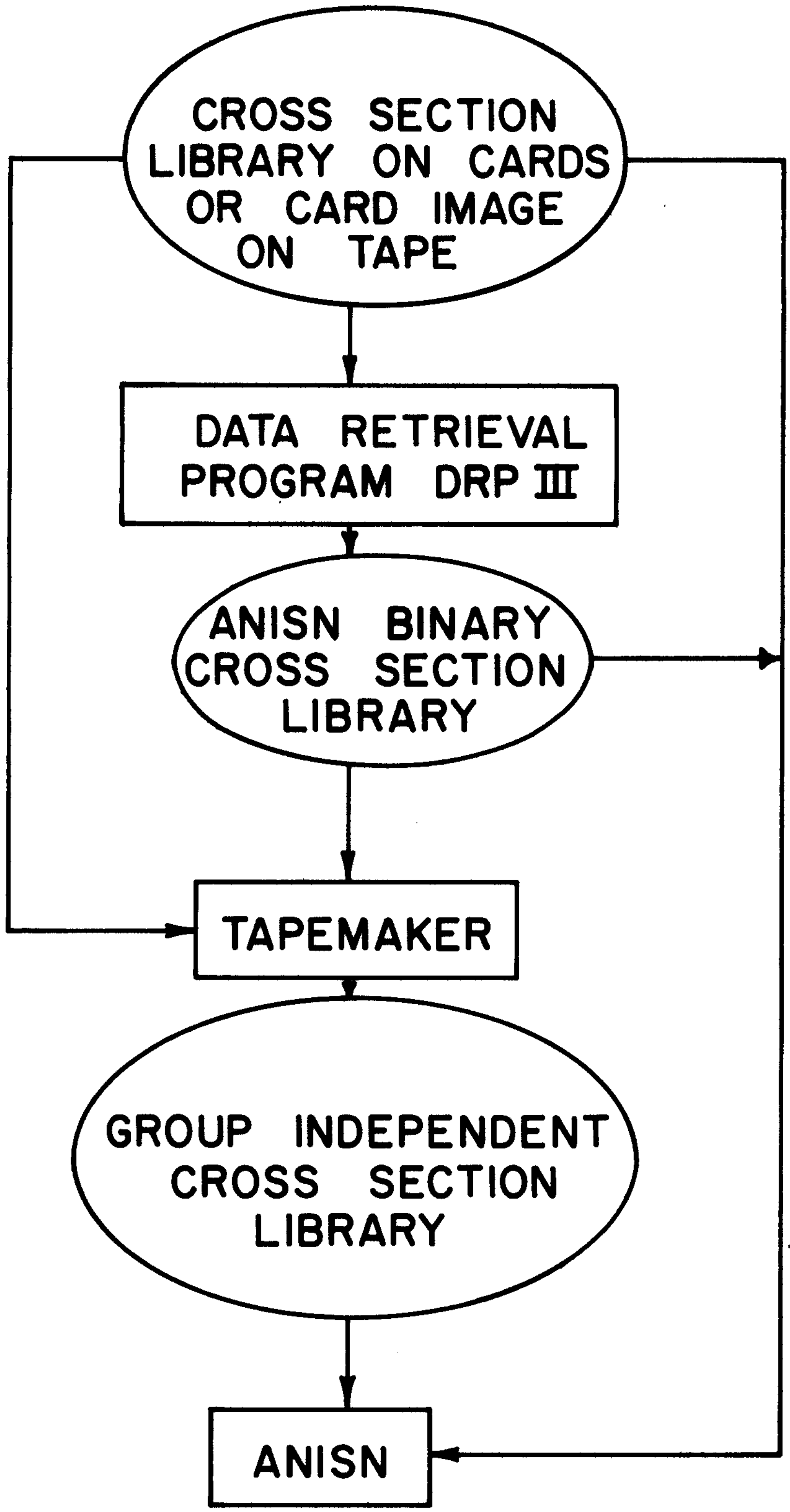

FIGURE 3 DATA FLOW INTO ANISN

This group independent tape is read by ANISN and only one energy group at a time is in the core. The code is described in CCC-254 ANISN ORNL, pg. 69, but the input is repeated here for convenience in Appendix IV.

Although cross sections may be mixed in TAPEMAKER, we have found that this is more easily accomplished in ANISN. Thus, we create a group independent tape containing only microscopic cross sections. We do this by reading in the cross sections of choice and transferring only one set, by use of the mixing tables, to each of the "mixtures" specified. The number of mixtures is, of course, the number of sets read.

To use the group independent tape in ANISN set: ID2=1, IDATA1=1, MCR=0, and MTP = the total number of sets on the group independent tape. Do <u>not</u> enter a 13$ array (Library ID numbers). Note that all cross sections on the group independent tape will be read by ANISN.

Conclusion

Use of the cross section sets is best facilitated by experience. As a starting point, however, for further study, we recommend the following documents.

CCC 254 ANISN ORNL
CCC 255 ANISN W
CCC 303 INDRA

They are available from the Radiation Shielding Information Center - Oak Ridge National Laboratory, Oak Ridge, Tennessee.

References

1. RSIC Data Library Collection, "VITAMIN-C, 171 Neutron, 36 Gamma-Ray Group Cross Sections Library in AMPX Interface Format for Fusion Neutronics Studies", DLC-41, ORNL.

2. RSIC Data Library Collection, "MACKLIB-IV, 171 Neutron, 36 Gamma-Ray Group Kerma Factor Library", DLC-60, ORNL.

3. W.W. Engle, Jr., "ANISN, A 1-D Discrete Ordinates Transport Code With Anisotropic Scattering", ORNL-K-1693 (1973).

4. D. Garber, "END 201, ENDF/B Summary Documentation", BNL-17561 (ENDF-201), 2nd ed., BNL (1975).

5. RSIC Computer Code Collection, "ANISN-ORNL", CCC-254, ORNL, pg. 8.

6. PSIC Computer Code Collection, "ANISN-ORNL", CCC-254, ORNL, pg. 69.

Appendix I

A new 25 neutron and 21 gamma group coupled ANISN-formatted data library has been created recently from the RSIC DLC-41B/VITAMIN-C AMPX master interface library by AMPX modules AIM, CHOX, MALOCS, and NITAWL. It has 48 materials with a P_3 expansion. The standard weighting spectrum (evaporation + 1/E + fission + 1/E + Maxwellian) is used in neutron group collapsing. It contains neutron data only for materials from ID = 141 to the end due to the lack of gamma production data in ENDF/B-IV files. There are 13 extra activity cross sections included in this library above the normal $3(\sigma_a, \nu\sigma_f, \sigma_t)$.

Appendix II

Recently we have received the RSIC distribution of DLC-60, the MACKLIB-IV library, which includes most of the nuclear response functions for 49 nuclides presently of interest in fusion and fusion-fission hybrid applications. The library is in the new format of the "MACK-Activity Table" which uses a fixed position for each specific response function. A more convenient library, 25 neutron and 21 gamma groups, was created by group collapsing from the original CTR structure of 171 neutron and 36 gamma groups with the standard weighting spectrum (evaporation + 1/E + fission + 1/E + Maxwellian) and flat spectrum for neutron and gamma respectively.

Appendix III

DRP-III

DRP-III Data Retrieval Program

DRP-III is a data retrieval program. It reads an ANISN formatted cross section tape and creates an ANISN binary cross section tape. The binary tape may be read by ANISN or TAPEMAKER. All cross sections on the formatted tape will be read and transferred to the binary tape. It is programmed for a cross section matrix size of (96,46).

The title card for the cross sections sets have a 4I6, 14A4 format on the formatted tape and a 4I6, 12A4 structure on the ANISN binary tape. The cross section ID number is the fourth number on the ID card. The third number is a control number. It is normally zero. If it is equal to 7, it is the last card on the tape and the program terminates. (This card is also written on the binary tape.)

The cross sections are written on the binary tape using the following statement.

WRITE(NOUT) [(CS(I,J),I=1,96),J=1,46] CS(I,J) is the cross section matrix. NOUT is the logical unit on which the cross sections are to be written. NIN is the logical unit on which the formatted cross sections are read.

The code requires one card of input in a 2I4,18A4 format. The input control parameters are: NIN, NOUT, and a title of the user's choice.

```
C
C          DRPIII  -  DATA RETRIEVAL PROGRAM
C
C     DRPIII IS A DATA RETRIEVAL PROGRAM.  IT READS AN ANISN FORMATTED
C     CROSS SECTION TAPE AND CREATES AN ANISN BINARY CROSS SECTION
C     TAPE.  THE BINARY TAPE MAY BE READ BY ANISN OR TAPEMAKER.  ALL
C     CROSS SECTION SETS ON THE FORMATTED TAPE WILL BE READ AND TRANS-
C     FERED TO THE BINARY TAPE.  IT IS PROGRAMED FOR A CROSS SECTION
C     MATRIX SIZE OF (96,46). THE TITLE CARD FOR THE CROSS SECTION SETS
C     HAVE A 4I6,14A4 FORMAT ON THE FORMATTED TAPE AND A 4I6,12A4
C     STRUCTURE ON THE ANISN BINARY TAPE.  THE CROSS SECTION ID NUMBER
C     IS THE FOURTH NUMBER ON THE TITLE CARD.  THE THIRD NUMBER IS A
C     CONTROL NUMBER.  IT IS NORMALLY ZERO.  IF IT IS EQUAL TO 7,
C     IT IS THE LAST CARD ON THE TAPE, AND THE PROGRAM TERMINATES.
C     NIN IS THE UNIT NUMBER ON WHICH THE FORMATTED CROSS SECTIONS
C     ARE TO BE READ.  NOUT IS THE UNIT NUMBER ON WHICH THE BINARY
C     CROSS SECTIONS ARE OUTPUT.  THE CODE REQUIRES ONE CARD OF INPUT
C     IN A 2I4,18A4 FORMAT.  THE INPUT CONTROL PARAMETERS ARE NIN,NOUT,
C     AND A TITLE OF THE USERS CHOICE.
C     R.T.PERRY --  UNIVERSITY OF WISCONSIN--  MAY 1980
C
      DIMENSION CS(96,46),NI(18),NO(16),T(18)
      READ(5,1)NIN,NOUT,T
    1 FORMAT(2I4,18A4)
      WRITE(6,2)T,NIN,NOUT
    2 FORMAT(1H1,1X,18A4,/,1X,'FORMATTED CROSS SECTIONS READ ON UNIT',I4
     1,/,1X,'ANISN BINARY CROSS SECTIONS WRITTEN ON UNIT',I4,/,1X,
     2'THE SETS TRANSFERED ARE...',//)
      REWIND NIN
      REWIND NOUT
      NGP=46
      NGP4 = 96
      NCOUNT=NGP*NGP4
      K=0
      L=0
    7 READ(NIN,3)NI
    3 FORMAT(4I6,14A4)
      DO 4 I=1,16
    4 NO(I)=NI(I)
      WRITE(6,5)NI
    5 FORMAT(1X,4I6,14A4)
      WRITE(NOUT)NO
      K = K+1
      IF(K.EQ.4)WRITE(6,6)
    6 FORMAT(/)
      IF(K.EQ.4)L=L+1
      IF(K.EQ.4)K=0
      IF(L.EQ.8)WRITE(6,9)
    9 FORMAT(1H1,////)
      IF(L.EQ.8)L=0
      IF(NO(3).EQ.7)GO TO 10
      CALL FETCH(CS,NCOUNT,NGP,NGP4,NIN)
      WRITE(NOUT)((CS(I,J),I=1,96),J=1,46)
      GO TO 7
   10 CONTINUE
      END FILE NOUT
```

```
      WRITE(6,9)
      STOP
      END
      SUBROUTINE FETCH(XN1,NCOUNT,NGP,NGP4,N5)
      DIMENSION XN1(NCOUNT),IN(6),KK(6),V(6),W(12)
      EQUIVALENCE(IBLANK,XBLANK)
      DATA IBLANK/1H /
      KNT = NGP*NGP4
      J=0
  622 READ  (N5,8)(IN(I),KK(I),V(I),I=1,6),(W(I),I=1,12)
    8 FORMAT(6(I2,A1,F9.0),T1,6(4X,2A4))
      DO 635 I=1,6
      IF(KK(I)-IBLANK) 700,810,700
C     NO REPEATS
  810 IF(W(2*I-1).EQ.XBLANK .AND. W(2*I).EQ.XBLANK)GO TO 800
  801 J=J+1
      XN1(J)=V(I)
      GO TO 800
C     REPEAT
  700 L=IN(I)
      DO 809 M=1,L
      J=J+1
  809 XN1(J)=V(I)
  800 IF(J-  KNT ) 635,24,24
  635 CONTINUE
      GO TO 622
   24 RETURN
      END
```

Appendix IV

TAPEMAKER

TAPEMAKER

A Routine to Prepare a "Group Independent" Cross Section Tape for ANISN

If it is desired to use ANISN for a computation involving several different elements for which a fine group, high order P expansion, cross section library is available, it is possible that the resulting input cross section matrix will exceed the storage capacity of the computer.

This problem can be overcome by using a "group independent" cross section tape[1]. When this tape is used, rather than storing the entire matrix, only the cross section data for a single group are stored in the memory while the calculations for that group are performed. Data for the next group are read from the group independent tape (replacing the data stored for the previous group) before calculations for that group are performed.

The TAPEMAKER routine produces the group independent tape from cross section data on cards and/or an ANISN library (binary) tape.

Input for TAPEMAKER:

1. LIM1 card - format (6X, I6)

LIM1	dimension of DUMY in main program. (TAPEMAKER is most efficient when LIM1 and DUMY dimensions are as large as computer storage allows)

2. Integer parameters - format (12I6)

IGM	number of energy groups
IHT	position of σ_t in cross-section table
IHS	position of σ_{gg} in cross-section table
IHM	length of cross-section table
MS	mixing table length
MCR	number of cross-section sets to be read from cards
MTP	number of cross-section sets to be read from tape
MT	number of <u>mixtures</u>** (note change from ANISN definition)
ITH	0 - forward solution 1 - adjoint solution
IPRT	0 - do not print cross-sections 1 - print mixture cross-sections 2 - print all cross-sections

3. Mixing table (ANISN format)
   10$, 11$, 12* arrays (MS entries, each array)
   ANISN binary library tape ID numbers (ANISN format)
   13$ array with library ID numbers (MTP values, MTP > 0)
   NOTE: The data in this section followed by a T

4. Cross sections from cards (note change from ANISN procedure)
   14* array followed by a T, one material at a time
   NOTE: A 14* array followed by a T is required for each of the MCR materials (MCR > 0)

**NOTE: There are MCR + MTP + MT materials. Only the last MT materials (as mixed in the 10$, 11$, 12* mixing tables) are written on Logical 3.

LOGICAL TAPE NUMBERS

1 - scratch
2 - scratch
4 - scratch
8 - "group independent" tape
9 - ANISN binary library tape
5 - input
6 - output

A sample problem is included to illustrate the use of the IBM 360 TAPEMAKER routine. A 27 group, P-2 expansion, set of cross section data (on cards) for hydrogen and oxygen are used to generate a group independent tape containing a 27 group P-2 expansion, set of cross sections for water. The input data required for the sample problem are shown below.

```
         75000
      27     3     4     30     9     6     0     3     0     2
10$            117.0           9.1      117.0         9.1        117.0
       9.1
11$            3R0.0       4I1.0         6.1
12*            3R0.0       3R0.0688    3R0.0334
  T
14*
(Data for Hydrogen P-0, 810 values)
  T
14*
(Data for Hydrogen P-1, 810 values)
  T
14*
(Data for Hydrogen P-2, 810 values)
  T
14*
(Data for Oxygen P-0, 810 values)
  T
14*
(Data for Oxygen P-1, 810 values)
```

T
14*
(Data for Oxygen P-2, 810 values)
T

The above data is for the 360 version of Tapemaker. For the 7090 version, LIM1 should be 23000 rather than 75000.

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[1]Ward W. Engle, Jr., "A User's Manual for ANISN", K-1693 (1967).