

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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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

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46	96	Q	191		P1	25N-	31G	GP,	DL	¢41	18	2	DL	Č 6 Ĝ	L, I	В,	***	***
46	96	Ó	105		b5	32N-	SIG	GP	ÖL	Col	18	-	DL	C 6 G	FI	8,	**	***
46	96	0	103	H=1	P3	25N•	•21G	GP.	DL	C41	/8	8	DL	C60	LI	В.	***	***
46	94	ģ	200	HōŽ	PŌ	ŽŠN	GP=1	40 G	AMM	Ã÷	DLC	41	/B	Lİ	в'.	ONL	Y****	***
46	96	ð			21	25N	GP=I	40 G	AMM	Amm	DLC	41	/B	ĹĮ	B.		Y****	
46	96		- 502-		63	ZŠN									В	ONL	Y####	****
46	96	Ö	203		P3	25N	GP=1	40 G	AMM	Aen	DLC	41	18	L, I	В.	DNL	Y***	**************************************
46	96	ó	300	H=3	PQ	ŽŠN	GP=I	40 G	ÀMM	Ä	DLC	. <u> </u>	/B	LĪ	В	DNL	Y****	**************************************
46	96	Ó	301		ΡĪ	25N	GP=I		AMM					LI	В	ONL	Y****	***
46	96		302-		- P2	SSN	GP	10- G	AMM	A	DLC	:41	18	LI	₿.	DNL	Y####	***
46	96	Ŏ	303		P3	25N	GP=I	NO G	AMM	A	DLC	41	/8	LI	В.	ONL	Y****	由安全的
46	96	ð	400	HE-3	Ρά	ŽŠŇ	GP-	NO 6	AMM	Á÷	DLC	41	ZB	ĻÍ	В	DNL	Y****	***
46	96	Ó	401	HE-3	Pi	25N	GP	NO G	AMM	A-1	DLC	:41	18	LI	В,		Y****	
46	96	0	402	HE-3	P2-	25N											¥***	
46	96	Ò		HE-3	P3	25N											Y***	
46	96	Ó	ŠÓQ	HE-4	Po												青安安女	
46	96	0	501	HE-4	Pi		GP										青次青年	
46	96	0	- 502	HE-4	65												***	
46	96	0	503	HE-4	P3	25N	GP =	NO G	MMAS	A=C	LC	41/	8	AND	DL	.C60	***	***
46	96	Ö		L.I.	Po	25N	210	GP,	. OL	Č41	/B	t	DL	Ç60	Ľ1	В,		***
46	96	Ô.		しょう	Ρį	35N:	-\$1G	GP,	, DL	Ç41	/8	2	DL	C60	L,1	₿.	***	中中中市
96-	95-	0	74 - 7	-L3-6-	P2	25N:	-51G	-GP,	, DL,	C41	18	-t-	DL	C60	-41	B		中的命令
46	96	0	603	LI-6	P3	25%	-21G	GP.	, DL	C 4 1	/8	8	DL	C60	LI	, B _e	***	****
46	96	Õ	700	L.T.Z	Po	žšn.	-21G	GP,	, DL	Č41	/8	£		Č60				***
46	96	0	701	LI=7	Pş	\$5N-	-21G	GP,	, DL	C41	/B	8	DL	C60	LI	₿,	***	***
45	95-	0	-702-	L397-	65	25N:	-51G	GP,	, DL	C41	18	S ·	DL	C60	L.	B,-		中央中
46	96	0	703	LI=7	P3	25%	-21G	GP.	. DL	C41	18	r.	DL	C60	L. I	8.	***	****
46	96	ď	800		Pġ	ŽŠN	-21G	GP,	DL.	Ç41	/8	Ł	DL	Č60	L'1	В,	***	· · · · · · · · · · · · · · · · · · ·
46	96	Ó	801	82	Pi	SEN.	-216	GP.	. DL	C41	18		ĎΓ	C60	L ₁	В,	专商的名	***
46.	96	0	802		P2	25N	216	GP,	. DL	C41	18		DL	C60	L, 1	B.,-	***	***
46	96	0	803	BE	P3	25N	-518	GP.	, DL	C41	18	L	DL	C60	LI	₿.	***	***

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46	96	Ó		8-10	PÕ	25N-	ŽįG	GP,	ÖLÇ4	ijs	1	DLC60	L15.	*******************************
46	76	0		8-10	Pt	~ \$5N=	2 <u>1</u> G	BP,	-DLC4	11/5	- 8	DLC60	LIB.	*****
46	96	Ģ		B-10	63	25N=	21 G	GP,	DLC4	11/8	Ł	DLC60	LIB.	****
46	96		903	Beto	P3	25N-	21 G	GP.	DLC4	11/6		DLC60	LIB.	***
46	96	Ó	1000	Bejj	PÖ	ŽŠN	CP.	NG 6	ÄMMÄ	Di F	4.4	A ANR	DĹĈĠŐ	
- ŠŠ	96	- ģ		Bell	ej –		GP-	NO-6	AMMA	Dir	7 A /	RAND		****
46	96	Õ		8911	PŽ		62-	NO G	AMMA	DLC	745 41 <i>)</i>	B AND		
46	96	Ò		8-11	P3		GP-	NO G	AMMA	DLC	41/	B AND		
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45	96 96	0	1102	C-13	Pţ	52N#	210	0.5		14/17	•	DI 640	LIB,	**********
46	96	0		C-12	P2 P3	25N=	21G	GP.	DLC4	1/8	i.	DFC90	LIB,	· 中央内内中央内内内 中央中央内内内
	1.	•	· *** *** ***		<u>*</u> 8			226		** * *			*** × •	
46	95	0		N=14	PQ	35N-	21 G	GP,	OLC4	11/8	L	DLC60	LIB,	专用的内容的内容
46	96	Ŏ.		Ne.14	Pi	\$5N-	21 G	GP,	DLC4	1/8	.	DLC60	LIB,	一种教育中央的教育
96	96	Q	1505		Şģ	SSNA	21G	GP,	DLC4	1/8	L	DLC60	LIB, LIB,	***********
46	96		1203	N#14	P3	25N=	21	GF.	DLC4	1/5	8	DLC 60	rie.	*******
Ãò	96	Ģ	1300	0-16	Ρĝ	25N-	ŽįG	GP.	ĎĽČ4	178	8	DLČ60	LIB.	中央市场中央市场
46	96	Ö	1301	0-16	- Pi	25N-	2 t G	GP	DLC4	1/8	· •	DLCAO	LIB.	****
46	96	0		0-16	PŽ	25N-	21G	GP.	DLC4	1/8	Ł	DLC60	LIB.	***
46	96	0		0-16	P3	25N-	21G	GP,	DLC4	1/8	8	DLC60	LIB, LIB, LIB,	自由有有有的的有
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- 46	96	0	1401		- 6 1	ひにがっ	5 j 4 3 f G	CP	- DI 64	[4 / 17 1 / 18		ያት ሌዋሪ ማድቅዋል		**************************************
46	96	ŏ	1402	* :	ΡŽ	SKN=	216	GP.	DLC	11/8	.	DLCAO	LIB, LIB,	****
46	96	ŏ	1403	*	P3	25N=	21G	GP.	DLC4	1/8	Ł	DLC60	LIB.	***
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45	96	0-	1501	NA		2577-	JOU ŠÍM	20	0101	14 / 15	₩	していたない	LIB,	· 中国市市市市 (1977年)
46	70 96	0	1502 1503		P2 P3	25 N=	310 218	GB	DI CA		•	・ロートトゥ	LIB.	****
70	7 🛡		1303	17 P		63774	Z 1 G	Vr.	<i></i>			7660 0	LID.	**************************************
46	96	Ó	1600	MG	Põ	ŽŽN-	2 i G	GP,	DLC	i/B	Ł	DLC60	LIB.	************
46	96	0		MO	61	52N=	210	OP,	- DLC4	11/8	£	DFC90	-LIB,	
96	96	0	7905		PŞ	35N=	Şig	GP,	DLG4	11/8	L	DLC60	LIB,	***
46	96	0	1603	MG	P3	25N=	21G	GP.	DLC4	11/8	£	DFC90	LIB.	有女有有自有有有

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:	46	96	. 0	1701	ALST	- 5 <u>1</u>	25N-21G	GP.	01041/8	Ł	DLC60	LIB	****
; n	46	96	0	1702	ALZZ.	PZ	25N-21G	GP,	DLC41/B		DLC60	LIB.	***
:9 (9 (9	`46.	96	0	1703	AL27	Р3	25N-21G	GP.	DLC41/B	8	DFC90	LIB.	*****
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3	46	96	0	1801		- Pj	25N-210	GP,	DLC41/8	🚡	DLC60	LIB	***
373	46	96	Q c	1802	81	P2	25N-21G	GP.	DLC41/B		DLC60	LIB.	***
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6 : Bir Sir Sir	96	96	0	1902	K	P2	\$20-51C	GP,	DLC41/5	ે 👢	DLC60	LIB.	****
9 . 9	46.	96	0 :	1903	K:	P3	25N=21G	GP.	DLC41/B		DLC60	LIB.	*******
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5 0 5 0	46	96	Q	\$005	ÇĀ	P2	S2ñ-S1C	GP,	QLC41/B	Ł	DLC60	LIB.	****
7 (C)	46	96	0	2003	CA	P3	25N-216	GP.	DLC41/8	8.	DLC60	LIB.	青青青岩青黄青
10° +**	ā.	96	ô:	ŽĪÓO	ĬĬ	PÕ	25N=21G	GP.	DLC41/B	2	DLC60	LIB.	**************************************
	46	96		1015	TI	- 51	25N-21G	GP.	DLC41/8		DLC60	LIB.	***
	46	96	0	5105		P2	SENESIG	GP,	DLC41/B	2	DLC60	LIB.	南西大大大大大
ਲ : ਜ:	46.	96	0	2103	71	P3	25N=21G	GP.	DLC41/B	2	DLC60	LIB.	青安安安安安安(
	46	96	ő:	2200	V ,	êğ.	250-216	GP,	OLC41/8		DLC60	LIB.	************
20 20	46	95	0-	5561	- A	Pţ-	25N-21G	-GP	DLC41/8	£	DECAO	LIB.	****
ii II	46	96	Q	5505		P2	52N-51G	GP,	DLC41/8	Ł	DFC90	LIB,	中央大学中央
2	46	96	0	2203	Y	P3	25N-21G	GF.	DLC41/B	&	DLC60	LIB.	青青白白白白白
;. }	46	96	Ö	2300	ĈŘ	Pģ	25N-21G	GP.	DLC41/8	Ł	DLČ60	LIB.	**************************************
•	46	96	0	2301		P.J		~ .		-	~		
,	46	96	0	\$305		P 2	.32N-\$10	GP,	DLC41/B	Z.	DFC90	LIB,	***
; ; ;	146.	96.	0	5303	CR	Р3	25N-21G	GP.	DLC41/B	2	DLC60	LIB.	****
1.1 5.1	46	96	0	2400	MNSS	Pğ	25N=21G	GP.	DLC41/B	2	DLCAO	LTA'	
3	46	96	Ŏ	2401	MNSS	Pi	35N-S10	Q.	DLC41/B	Ĩ.	PLCOO	LIB.	一种存在存命的会
	46	96	Q	3402	MNSS	P2	25N-21G	GP,	QLC41/B		DLC60	LIB.	****
4	46	96	0	2403	MN55	P3	25N-21G	GP.	DLC41/B		DLC60		***

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	46	96	Ģ	2500		Po	25N-2	16 6	DI CATA	A CONTRACTOR	*
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		96	Q	\$600	NI	Po	25N-21	G GP	, DLC41/	B & DLC60 LIB	
	46	96	Q	5901	NI	P.1	25N-21	GGP	DECATA	B & DI CAO I TR	
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	46	96	Ó	2702		65	2EN=21	G GP	* N. C. 1 . 1	# DLC60 LIB	**********
	46	96	Ō	2703		P3	24N=21	G GP	. DLC41/!	P DICEO LIB	************
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	46	96	Õ	3000		Pộ	ŽŠN-ŽŽ	G GP	DLC41/8	LIB. ONLY	1 5 4 g g g s
	96	96		5901		PI	35N-21	G GP	QLC41/8	LIB, ONLY	*************************
	46	96 96		\$805		P2	650451	G GF	. DLC41/6	BITE ONLY	*****
The street contract c	49	70	0	2803	ZR	P3	25N=21	G GP	DLC41/8	LIB. ONLY	***
	96	96	ó	2900	NB93	Po	ŠĒN-ŠĪ	r r r			
	46	96			NB93	PĪ	26N-21	C CP	DLC41/8	& DLC60 LIB,	
	46	96			N893	PŽ	25N=21	G GP	DLC41/8	LE DECOO FIR	
	46	96	<u>.</u>	2903		P3	25N-21	G GP	DLC41/8	& DLC60 LIB.	************
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	46	-9 6			40	Pg	320-51	G GP,	DLC41/B	& DLC60 LIB,	安全会会会会会
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						F3	&216mS11	s op.	ULC41/8	& DLC60 LIB.	青年有余安司公安
	46	96	Õ:	3100	BN	Po	25N-21	s GP	DLC41/B	LIB. ONLY	* * * * * * * * * * * * * * * * * * * *
	46	96		3101		Ρį	25N-21	GP.	DECATION	LIB, ONLY	· 特殊方式会会会会
	46	96	O :		N	PŽ	25N-21	GP.	DECATION	LIB, ONLY	****
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	46	96			A181	PQ	250-216	GP,	DLC41/B	& DLC60 LIB,	****
	45	96			A181 -	P1	SAUGSIG	SP	DLC41/B	& DLC60 LIB.	专内农会会会会会
	46	96			A181	P3	SEN-SEA STREET		01.541/5	& DLC60 LIB,	费索索力会会会会
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46	96	0	3302	• ,•	P2	25N-51G	GP	QLC41/6	F DL	C60 F		***
46	96	0	3303	W=182	Р3	25N=21G	GP,	DLC41/B	S & DL	.C60 L	.IB.	有有有有有有有
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46	96	Ó	3466	W-183	Po	25N-21G	CP'	DICATIO	L L DI	řáň i	70	
46	96	ō		- W=183-	PŢ.	フロリニコー		-01-04-78		CAO-	7 # 17 # 7 D	***
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46	96	ŏ		W=183	P3	25N-316		CPP4TVD		COV L		***
40	70		3403	Mefob	P. 3	25N+216	UP.	. 06641/0) # VL	UBV: L	100	***
	£ .											
96	96	Ô	3500	W-184	Ëĝ	25N-21G	GP'	DLC4178	& DL	CAO L	TR.	**********
46	96	· • •	3901		Pi	25N-216	GP	DICATOR	1- ED	040	TR	***
46	96	Q	3502		βŽ	3EN-316	GP.	DICALAR	2 DI	C40	TR	
46	96	ŏ	3503		P3	25N#21G		DICATIO		PAR I	TAVA TA	*********
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46	96	0	3600	W-186	PO	25N-21G	GP.	DLC41/8	& DL	C60 L	18.	***
46	95	o o Ó o		W=186	P j	25N-21G	GP.	DLC41/B	& DL	C60 L	IB.	**********
46	96	ò		W-186	PŽ	25N-21G	GP.	DLC41/8	R DL	ČÁQ Í	TB.	费用农业会协会会
46	96	Õ		W=186	P3	25N=21G	GP.	DICATA	a Di	C60 L	TR.	电电声电电电电
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46	96	0	3700	P8	PO	25N-21G	GP,	DLC41/8	& DL	C60 L	IB.	***
46	96	0 :	3701	P8-	Pi	25N=210	gp.	DLC41/B	- B-DL	C60-L	IB.	***
45	96	Ō	3702		P2	55N-510	GP.	DLC41/8	& DL	C60 L	IB.	***
46	76	0	3703		P3	25N-21G	GP.	DLC41/8	& DL	C60 L	18.	*******
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# Table 2 Cross Section Set Format

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

<u>Position</u>	Content
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45	Neutron and gamma kerma factors Neutron kerma factor Gamma kerma factor Displacement cross section - A Displacement cross section - B Total hydrogen production cross section Total tritium production cross section Total helium production cross section Total cross section Elastic cross section Total inelastic cross section (n,2n) cross section (n,3n) cross section (n,n't) cross section (n,n') continuum cross section (n,n) cross section (n,a) cross section (n,a) cross section (n,a) cross section (n,an) kerma factor Inelastic scattering kerma factor (n,charged particles) kerma factor (n,charged particles) kerma factor (n,an) kerma factor Fission kerma factor

### (Table 2 - Continued)

<u>Position</u>	Content
46 47	$(n,\alpha)$ cross section
48 49	Absorption cross section ∨ x fission cross section
50 51-96	Total cross section 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 $\sigma_{\mbox{total}}$ in the cross section table - 50
IHS	Position of $\sigma_{s}^{g-g}$ 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  $S_j^1$  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.	COL.	COL.	COL.	COL. 5	COL.	COL.
ROW	1	_n σ _K ¹	no _K 2	$_{n}\sigma_{K}^{3}$	$n^{\sigma_{K}^{4}}$	rok	$_{\gamma}\sigma_{\rm K}^2$	$_{\gamma}\sigma_{K}^{3}$
ROW	2	$_{n}\sigma_{p}^{l}$	$_{n}\sigma_{p}^{2}$	$_{ m n}\sigma_{ m p}^{ m 3}$	$n^{\sigma_p^4}$	0	0	0
ROW	3	n ^o dpa	$n^{\sigma_{2}^{2}}$	$n^{\sigma_{dpa}^3}$	$n^{\sigma_{dpa}^4}$	0	0	0
ROW	4	$_{n}\sigma_{a}^{I}$	$_{n}\sigma_{a}^{2}$	$_{n}\sigma_{a}^{3}$	$n\sigma_a^4$	$r\sigma_{a}^{I}$	$_{\gamma}\sigma_{0}^{2}$	$_{\gamma}\sigma_{0}^{3}$
ROW	5	$_{\sf n} u\sigma_{\sf f}$	$_{n} u\sigma_{f}$	$_{n} u\sigma_{f}$	$_{n} u\sigma_{f}$	0	0	0
ROW	6	_n σ _t l	not ²	$_{n}\sigma_{t}^{3}$	$_{n}\sigma_{t}^{4}$	$_{\gamma}\sigma_{l}^{l}$	$_{\gamma}\sigma_{i}^{2}$	$_{\gamma}\sigma_{t}^{3}$
ROW	7	nos l-1	$_{ m n}\sigma_{ m s}^{2-2}$	$n\sigma_s^{3-3}$	$n\sigma_s^{4-4}$	$_{\gamma}\sigma_{\rm s}^{\rm I-I}$	$\gamma \sigma_{\rm s}^{2-1}$	2 $_{\gamma}\sigma_{\rm s}^{3-3}$
ROW	8	0	n 0 - 1 - 2	$n\sigma_s^{2-3}$	$n\sigma_s^{3-4}$	nσγ4-1	$\gamma \sigma_{\rm s}^{1-2}$	$ros^{2-3}$
ROW	9	0	0	$n\sigma_s^{1-3}$	n 0 s 2 - 4	$n\sigma_{\gamma}^{3-1}$	$n\sigma_{\gamma}^{4}$	2 $_{\gamma}\sigma_{\rm S}^{1-3}$
ROW	10	0	0	0	$n\sigma_s^{1-4}$	$n\sigma_{\gamma}^{2-1}$	$_{n}\sigma_{\gamma}^{3}$	2 $_{\text{N}}\sigma_{\gamma}^{-4-3}$
ROW	II	0	0	0	0	n _O y l-I	$n\sigma_{\gamma}^{2}$	2 $_{\rm n}\sigma_{\gamma}^{3-3}$
ROW	12	0	0	0	0	0	$n\sigma_{\gamma}^{1-2}$	2 $_{\rm n}\sigma_{\gamma}^{2-3}$
ROW	13	0	0	0	0	0 '	0	$ \begin{array}{c}     n\sigma_{\gamma}^{2-3} \\     n\sigma_{\gamma}^{1-3} \end{array} $

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

- i i  $n^{\sigma}K,\;\gamma^{\sigma}K\;\text{is the kerma factor for the ith neutron and gamma group,}$  respectively,
- i  $n^{\sigma}p$  is the hydrogen production cross section for the ith neutron group,
- $n^{\nu}n^{\sigma}f$  is  $\nu$  times the fission cross section for the ith neutron group,  $n^{\sigma}t$ ,  $\gamma^{\sigma}t$  is the total cross section for the ith neutron and gamma group, respectively,
- $n^{\sigma}s$ ,  $\gamma^{\sigma}s$  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,
- $n^{\sigma}\gamma$  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  $\sigma^{g-g}$ . 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

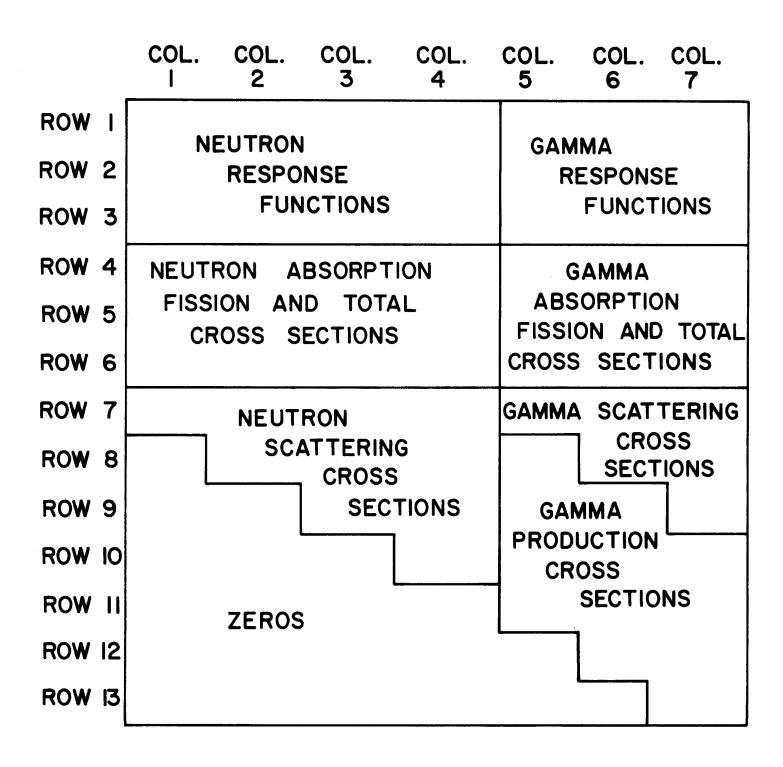


FIGURE 2 Po COUPLED CROSS SECTION SET

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,  $\sigma_a$ ,  $v\sigma_f$ ,  $\sigma_t$  and  $\sigma_s$  - 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 calculations were 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 <u>strongly recommended</u> 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.

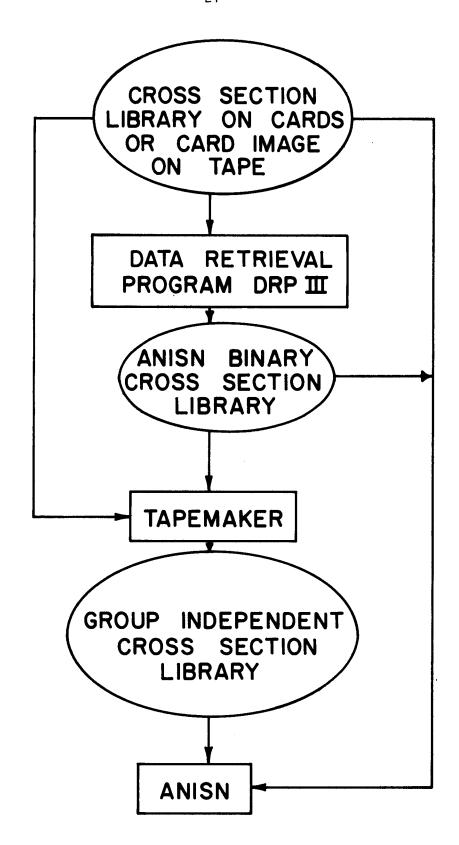


FIGURE 3 DATA FLOW INTO ANISN

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 ANISH ORNL CCC 255 ANISH 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 P₃ 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 416, 14A4 format on the formatted tape and a 416, 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.

10 CONTINUE

END FILE NOUT

#### DRPIII - DATA RETRIEVAL PROGRAM

DRPILI IS A DATA RETRIEVAL PROGRAM. IT READS AN ANISH FORMATTED CROSS SECTION TAPE AND CREATES AN ANISH BINARY CROSS SECTION THE BINARY TAPE MAY BE READ BY ANISH OR TAPEMAKER. CROSS SECTION SETS ON THE FORMATTED TAPE WILL BE READ AND TRANS-FERED TO THE BINARY TAPE. IT IS PROGRAMED FOR A CROSS SECTION MATRIX SIZE OF (96,46). THE TITLE CARD FOR THE CROSS SECTION SETS HAVE A 416,14A4 FORMAT ON THE FORMATTED TAPE AND A 416,12A4 STRUCTURE ON THE ANISH BINARY TAPE. THE CROSS SECTION ID NUMBER IS THE FOURTH NUMBER ON THE TITLE CARD. THE THIRD NUMBER IS A CONTROL NUMBER. IT IS NORMALLY TERO. IF IT IS EQUAL TO 7, IT IS THE LAST CARD ON THE TAPE, AND THE PROGRAM TERMINATES. NIN IS THE UNIT NUMBER ON WHICH THE FORMATTED CROSS SECTIONS ARE TO BE READ. NOUT IS THE UNIT NUMBER ON WHICH THE BINARY CROSS SECTIONS ARE OHTPUT. THE CODE REQUIRES ONE CARD OF INPUT IN A 214,1844 FORMAT. THE INPUT CONTROL PARAMETERS ARE NIN, NOUT, AND A TITLE OF THE USERS CHOICE. R.T. PERRY -- UNIVERSITY OF WISCONSIN--MAY 1980

DIMENSION CS(96,46), NI(18), NO(16), T(18) READ(5,1)NIN, NOUT, T 1 FORMAT(214,1844) WRITE (6,2) T. NIN, NOUT 2 FORMAT(1H1,1x.18A4,/,1x. FORMATTED CROSS SECTIONS READ ON UNIT', 14 1,/,1x, ANISH BINARY CROSS SECTIONS WRITTEN ON UNIT', 14,/,1x, 2 THE SETS TRANSFERED ARE... 1, //) REWIND NIN REWIND NOUT NGP=46 MGP4 = 96 NCOUNTENGP*NGP4 K=0 L=0 7 READ(NIN, 3)NI 3 FORMAT (416,14A4) DO 4 T=1,16 4 NO(I)=NI(I)WRITE (6,5)NI 5 FORMAT(1X,416,14A4) WRITE (NOUT) NO K = K+1 IF (K.EQ.4) WRITE(6,6) 6 FORMAT(/) TF(K.ER,4)L=L+1 IF (K.FQ.4)K=0 IF(L.EQ.A)WRITE(6.9) 9 FORMAT(1H1,////) IF(L.F9.8)L#0 TF(NO(3).EQ.7)GO TO 10 CALL FETCH (CS. NCOUNT, NGP, NGP4, NIN) WRITE(NOUT)((CS(I,J),T=1,96),J=1,46) GO TO 7

```
WRITE (6.9)
      STOP
      END
      SUBROUTINE FETCH (XN1, NCOUNT, NGP, NGP4, N5)
      DIMENSION XN1 (NCOUNT), IN(6), KK(6), V(6), W(12)
      FOUTVALENCE (IBLANK, XBLANK)
      DATA TBLANK/1H /
      KNT = NGP*NGP#
      J=0
  622 READ (N5.8) (IN(I), KK(I), V(I), I=1.6), (W(I), I=1.12)
    8 FORMAT(6(T2, 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*T).EQ. XBLANK)GO TO 800
  801 J=J+1
      XN1(J)=V(T)
      GO TO 800
      REPEAT
  700 L=IN(I)
      DO 809 M=1.L
      J=J+1
  809 XN1(J)=V(T)
  800 IF(J= KNT ) 635,24,24
  635 CONTINUE
      SS6 07 09
   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 tape¹. 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)
- Integer parameters format (1216) number of energy groups IGM position of  $\sigma_t$  in cross-section table position of  $\sigma_{qq}^t$  in cross-section table length of cross-section table IHT IHS IHM 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 mixtures** (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	l										
11\$			3R0.	.0		411.0		6.1				
12*			3R0.	.0		3R0.0688		3R0.0334				
T												
14*												
(Data T	for	Hydro	ogen	P-0,	810	values)						
14*												
(Data T	for	Hydro	gen	P-1,	810	values)						
14*												
(Data T	for	Hydro	gen	P-2,	810	values)						
14*												
(Data T	for	0xyge	en P-	0, 8	lO va	alues)						
14*												
(Data	for	0xyge	en P-	1, 8	lO va	alues)						

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

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

 $^{^{1}}$ Ward W. Engle, Jr., "A User's Manual for ANISN", K-1693 (1967).