LAMS-2801

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LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA ○ LOS ALAMOS NEW MEXICO

A CODE FOR REDUCING MANY-GROUP
CROSS SECTIONS TO FEW GROUPS

Printed in USA. Price $ 1.25. Available from the

Office of Technical Services
U. S. Department of Commerce
Washington 25, D. C.

LAMS-2801
UC-32, MATHEMATICS AND COMPUTERS
TID-4500 (18th Ed.)

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REPORT WRITTEN: December 1962

REPORT DISTRIBUTED: February 11, 1963

A CODE FOR REDUCING MANY-GROUP CROSS SECTIONS TO FEW GROUPS*

by

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*This report supersedes LAMS-2747.

Contract W-7405-ENG. 36 with the U. S. Atomic Energy Commission

ABSTRACT

A code (ZOT) has been written which will produce few-group neutron cross sections from many-group sets based on a given flux spectrum or one computed for an infinite medium. The cross-section format is that of S_n transport theory including the possibility of upscattering in energy. The code is written in the Floco II system for use on the IBM 704 or IBM 7090.

CONTENTS

INTRODUCTION

While many-group cross sections are necessary for computing a large variety of problems with a single set of cross section parameters, it is often desirable to reduce the number of groups used for particular problems. Multidimensional S_n and diffusion codes are becoming available but are time-consuming with many energy groups. Where many S_n one-dimensional problems must be run for parameter studies, for temperature or perturbation effects, or when coupled to hydrodynamic codes, specially tailored few-group cross sections would be advantageous.

George Bell has suggested (internal memo, July 3, 1958) recipes for collapsing many-group parameters assuming a many-group flux spectrum. This can be obtained from a single many-group calculation for the system or approximated, for example by solving the infinite medium (space independent) equations.

A code (ZOT) has been written which will collapse groups according to a given flux spectrum or using a self-generated infinite medium flux. Code details and the results of several test cases are given.

CROSS SECTION INPUT

The code is designed for the standard Los Alamos S_n transport cross section format. For each energy group (denoted by subscript or superscript g and running from g = 1 for the highest energy to G for the lowest) the neutron cross sections are entered in the following order:

$$\left.\begin{array}{l}\sigma_{ac1}\\ \sigma_{ac2}\\ \cdot\\ \cdot\\ \cdot\\ \sigma_{aci}\end{array}\right\}\ \text{optional activity (ac) } \sigma\text{'s, e.g., } \sigma_{n,p}$$

$\nu\sigma_f$ ν(neutrons/fission) times the fission cross section

σ_{tr} the transport cross section (occasionally labeled σ_g)

$$\left.\begin{array}{l}\cdot\\ \cdot\\ \cdot\\ \sigma_{g+2,g}\\ \sigma_{g+1,g}\end{array}\right\}\ \begin{array}{l}\text{upscattering from groups of lower energy (higher}\\ \text{g indices) to the group g}\end{array}$$

σ_{gg} scattering within the group

$$\left.\begin{array}{l}\sigma_{g-1,g}\\ \sigma_{g-2,g}\\ \cdot\\ \cdot\\ \cdot\end{array}\right\}\ \begin{array}{l}\text{downscattering from groups of higher energy to}\\ \text{the group g}\end{array}$$

The activity σ's are not used in the solution of the transport equation, but are available for calculation of activities from the results of criticality calculations. The most commonly appearing one is σ_a (absorption).* In the solution of the transport equation the absorption is accounted for implicitly in the transport cross section σ_{tr}, which includes σ_a. Note that through error or intent, the absorption used by the transport code may be different from that which may appear as one of the activity σ's. We shall always deal with the σ_a derived from the transport and scattering σ's:

$$\sigma_a^g = \sigma_{tr}^g - \sum_{\text{all } g'} \sigma_{g',g} \tag{1}$$

where all g' includes $g' = g$. The number of activity σ's and up- and downscattering for each group will be given implicitly by noting the position in the table of σ_{tr}, σ_{gg}, and the last $\sigma_{g',g}$. If these are called h_t, h_s, and h_ℓ respectively, then:

number of activity σ's $= h_t - 2$

number of upscattering σ's $= h_s - h_t - 1$

number of downscattering σ's $= h_\ell = h_s$.

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*This one is required by the Los Alamos DTK transport code.

The ZOT code will take the many-group cross sections for elements or mixtures and reduce the number of groups to $K(K \leq G)$ by combining some of the groups according to equations given later. The new groups must have energy limits which are a subset of the many-group limits. We shall use k to denote the few-group energy index (and i for the σ position, analogous to h for the many-group set). Thus each group k will be composed of one or more of the groups g of the input σ's. For example, the first of the few-group set $(k = 1)$ might be composed of $g = 1, 2,$ and 3 of the input many-group set. Our equations will use a simple summation sign to indicate a summation over all g in a particular k group.

THE EQUATIONS FOR GROUP COLLAPSING

Fission spectrum (fraction of fission neutrons out in each energy group)

$$\chi_k = \sum_{g \text{ in } k} \chi_g \equiv \sum \chi_g \tag{2}$$

Activity and fission cross sections are weighted linearly by the flux φ

$$\sigma_{ac}^{k} = \frac{\sum \varphi_g \, \sigma_{ac}^{g}}{\sum \varphi_g} \tag{3}$$

Transport cross section

$$\sigma_{tr}^{k} \equiv \sigma_k = \frac{\sum \varphi_g}{\sum \varphi_g/\sigma_g} \tag{4}$$

or

$$\sigma_k = \sum \varphi_g \sigma_g \Big/ \sum \varphi_g \tag{5}$$

Both options (inverse and linear averaging) are available.

Transfer cross sections from group k' to group k

$$\sigma_{k',k} = \sum_{\substack{g' \text{ in } k' \\ \text{and} \\ g \text{ in } k}} \varphi_{g'} \sigma_{g',g} \Big/ \sum_{g' \text{ in } k'} \varphi_{g'} \tag{6}$$

For the many-group set, absorption cross sections (σ_a's) are found from Eq. (1) and are collapsed with linear averaging

$$\sigma_a^k = \sum \varphi_g \sigma_a^g \Big/ \sum \varphi_g \tag{7}$$

These are sufficient to define the new set. The elastic scattering σ_{kk} is determined from the other few-group constants by

$$\sigma_{kk} = \sigma_k - \left(\sum_{k' \neq k} \sigma_{k,k'} \right) - \sigma_a^k \tag{8}$$

For conciseness in annotating the code, we define

$$\varphi_k = \sum \varphi_g \tag{9}$$

Different cross sections may be computed for each region (i.e., core and reflector) separately, but a single velocity spectrum is used for a given problem, and this must be weighted by the total fluxes in each region. The region volumes are used as a measure of the total flux.

$$v_k = \frac{\left(\sum_r V_r \sum \varphi_{g,r}\right)}{\left(\sum V_r \sum \varphi_{gr}/v_g\right)} \tag{10}$$

The infinite medium fluxes (φ^o) can be generated by

$$\left(\sigma_g - \sigma_{gg}\right)\varphi_g^o = x_g + \sum_{g' \neq g} \sigma_{g' \to g}\, \varphi_{g'}^o . \tag{11}$$

These are solved successively from the highest energy group until groups with nonzero upscattering are reached, upon which the remaining equations are solved simultaneously.

GENERAL DESCRIPTION OF THE CODE

The code is written for the Floco II assembly system* (LAMS-2339) and is intended to be fully compatible with the Floco II assembled SNG routines. The code accepts multigroup cross sections and input data on atomic composition and computes collapsed group parameters for the mixtures described for each special region. An option allows collapsing the element microscopic cross sections separately. The code will accept flux spectra as input, will compute infinite medium fluxes, or can use the flux used in the previous spacial region (mixture) regardless of its source. The volumes can be given directly or can be computed from the coordinates for planes, infinite cylinders, or spheres. The code assumes there has been sufficient size allotted to the up- and downscattering in the output groups and will stop with an on-line comment if this is not true. The many-group set is divided into a few groups, each containing one or more of the original groups according to the wishes of the user. The input and output are printed off-line (on-line if sense switch #6 is down), and the output fission spectrum, velocities, and cross sections are punched on-line, suitable for direct inclusion in the new S_n codes. (They may be used in the Floco I version of SNG by placing nine punches in columns 3 and 21.) The code will normally average $(\sigma_{tr})^{-1}$ but will

*This will run on the IBM 704 or IBM 7090 with the appropriate Floco II assembly program. The standard deck is for the 704; modifications for 7090 operation are discussed in a later section.

average σ_{tr} if requested. In either case, a comment will be printed describing which was done.

CODE DETAILS

Input

The input is divided into two parts: the parameters which precede the code and the data which follow it.

The parameters determine the sizes of data storage blocks and are used in determining exits and loop lengths in the code. They consist of information on the size of the problem (e.g., number of mixtures), options such as the method of transport weighting, and the cross section table size. Parameters are put on Floco cards, following a "load parameters" pseudo-instruction (*0000S00, see LAMS-2339 and example in Appendix I). There are three sets labeled P00, G00, and K00, each requiring a load parameters instruction. All are fixed point numbers. The code was designed originally to form mixture macroscopic cross sections in a manner similar to the SNG code. This requires two tables which we shall label NO and MO. The NO table contains a fixed point identification number (ID#) for each region, followed by the ID numbers of the elements in that particular region. The elements are numbered implicitly by the order in which they are input. The MO block contains the atomic densities corresponding to the elements in each region and zeros in the positions occupied by the mixture numbers in the NO table. This is illustrated in the example (Appendix I). The lengths of the NO and MO blocks are required for input parameter P05.

One could get σ's for collapsed microscopic elements with this arrangement by placing each element in a separate region with an atom density of 1.0. However, since this is a common use of the code, an alternate way to obtain these σ's with simpler input has been built into the code. This is signaled by letting the mixture specification parameter P05 (or N) be zero. The number of regions R (P02) is put equal to the number of elements E, and P03 is input as 2E. There is no need for certain of the data blocks (NO, MO, FO), and only one set of weighting fluxes need be entered for all elements.

1. Parameters

Position	Symbol	Description
P01	PID	Problem identification number.
P02	R	Number of regions (or number of elements for element calculation).
P03	M	Number of mixtures + number of elements (or twice number of elements for element calculation).
P04	W	Volume specification, described later.
P05	N	Number of mixture specifications, i.e., length of NO and MO tables (N = 0 for element calculations).
P06	T	Transport σ averaging 0 for inverse, 1 for linear average.

Parameters, continued

Position	Symbol	Description
G01	G	Number of input groups.
G02	h_t	Position of σ_{tr} in σ table.
G03	h_s	Position of σ_{gg}.
G04	h_ℓ	Position of last σ in a group (number of σ's per group).
G05	U	Number of groups with nonzero upscattering, assumed to occur in the lowest energy groups.
K01	K	Output cross section parameters (similar to input group parameters, but may have smaller values except for i_t). The equivalent of G05 is not needed.
K02	i_t	
K03	i_s	
K04	i_ℓ	

W, Volume Specification

W	Meaning
0	Volumes are supplied in W0 data block.
1	Planar distances of regions are supplied in W0 data block; code will compute volumes $V = (r_{i+1} - r_i)$ and place them in W0 data block.
2	Cylindrical radii supplied in W0; code computes $V = (r^2_{i+1} - r^2_i)$, etc.
3	Spherical radii supplied; $V = (r^3_{i+1} - r^3_i)$, etc.
4	Volumes are not supplied; velocities are computed separately for each region.

2. Data

The data follow the code and are on Floco cards preceded by Floco "load data" pseudo-instructions (*0000S0). The order of the data blocks is immaterial. Binary cards (e.g., flux dumps) may be loaded behind a Floco "load data" card if they contain the data in the correct number and order. Binary card addresses will be ignored.

Block	Description	Type	Number of Entries
CO	Group separation, a table giving the largest value of g in each output group.	fixed	K
FO*	The flux source for each region 0 -- flux supplied 1 -- calculate ∞ medium flux 2 -- use flux from previous region.	fixed	R
F2†	The weighting fluxes for each region.	floating	GXR
NO*	The mixture specifications, similar to the SNG input. For each region there is an identifying number, followed by the labels of the elements in that region.		
MO*	The atomic densities ($x10^{-24}$) of the elements in the order given in NO. Zeros in the positions corresponding to region numbers in NO serve to delimit the regions.	floating	N
WO	Volume or radius input.	floating	R
SO	Input fission neutron spectrum.	floating	G
VO	Input group velocities.	floating	G

*Can be omitted for microscopic element calculation.

†Only one set (G entries) needed for microscopic element calculation.

Block	Description	Type	Number of Entries
PO	The input (and mixture) cross section block. The elements are numbered implicitly by the order in which they are placed in the input deck. The regions are labeled by consecutive numbers beginning with E + 1, as in the DSN code. See example (Appendix I).	floating	Input = $h_\ell \times G \times E$ Total = $h_\ell \times G \times M$

Output

The output includes off-line (on-line if sense switch #6 is down) listing of all of the input blocks, descriptively labeled and of the mixture cross sections (in the PO block) and the mixture absorption cross sections. This is followed by a print of the output fission spectrum, velocities, absorption cross sections, and mixture cross sections.

The fission spectrum, velocities, and mixture cross sections for each region are punched in that order on separate cards (or blocks of cards), ready for direct insertion into the DSN code. Cards may also be used in the Floco I SNG code by putting nine punches in columns 3 and 19. Should trouble arise, one can obtain an input print by transferring manually to $(1016)_8$ and pressing start twice. One can obtain an on-line output print by setting sense switch #6 down and transferring manually to $(1017)_8$ and pushing start twice.

When the calculation is finished, an on-line statement to that effect will be printed. Pushing start will then result in an on-line print of the storage map giving locations of all code and data blocks.

Operation

The present deck (10-30-62) has all necessary loading and transfer cards in it. The three parameter cards follow ZOT card number 001, and the data cards follow card number 076.* The ZOT deck should be preceded by an on-line identification card to identify the user on the off-line listing. ZOT card 00D calls Floco II from the Los Alamos utility tape 1, and may be replaced by a Floco II card deck.

Running time -- ≤ 1 minute per case + readin time, unless there are more than 10 upscattering groups.

Problem size -- for the 8K machine about $(4000)_{10}$ words are available for data. The largest block will be the input and mixture cross sections (PO) which will be $h_\ell \times G \times (E + R)$ numbers. Almost all problems can thus be done on an 8K 704.

Stops -- the only programmed stops are for the cases in which insufficient down- or upscattering has been allowed in the output groups. The code will print an on-line comment and stop. One can then transfer to $(1016)_8$ to obtain an input print. There is an error stop (usually insufficient space) in the matrix solver subroutine, and three possible divide checks which are described in Appendix II.

Sense switches -- setting sense switch #6 down causes on-line printing of both input and output. An on-line print of the results can be obtained by transferring manually to $(1017)_8$ and pushing start twice (with sense switch #6 down).

*This is a change from the earlier (9-09-59) deck.

Operation on IBM 7090

The ZOT deck (001 to 080) will work without modification on the 7090. However the appropriate Floco II assembly system must be used, and therefore the ZOT 000 card, which is an XX Floco 2 card for calling the 704 version from tape, must be replaced by the equivalent for the 7090. This is a set of two cards (2-FL2 01 and 2-FL2 02) for calling Floco from tape, or a master set of cards containing Floco for use if it is not already on the utility tape in the Los Alamos format. Note that header or identification cards follow the Floco II cards, making the deck arrangement

2-FL2 01 2-FL2 02	Floco II, call in from Los Alamos 7090 utility tape.
Header Card	* in column 1, followed by name, phone, etc.
ZOT 001	Initialize Input, etc., as in 704 version.

RESULTS

A series of DSN transport calculations were made to investigate the accuracy of the reduced cross section sets. Few-group results are typically within 2% of the many-group results, but each new situation should be checked, especially where the spectrum changes rapidly in space. Some typical results obtained in 1959 with S_4 SNG transport calculations are listed in Table I. Further calculations are presently under way to study the extent of application and the effects of varying the group spacing, the method of averaging the transport cross section, etc. For example, a 3 group calculation of the C/U = 2400 base sphere with different group aggregations (6, 11, 1) gave only 0.4% error using fluxes generated in an 18 group DTK transport code, compared to 2.5% error with the spacing (6, 6, 6) as listed in Table I. However, the (6, 11, 1) spacing with infinite medium fluxes appears to give a larger error (7%) although this result is difficult to understand and may be in error.

Table I

Bare U^{235} Sphere

# Groups*	Flux Source	Radius	Sign, % Error	# Iterations
6	-	8.686	-	22
2	SNG 6 group	8.732	+0.53	15
2	∞ medium	8.742	+0.65	15
1	SNG 6 group	8.776	+1.03	19
1	∞ medium	8.753	+0.75	16

Bare Graphite Sphere C/U = 300

# Groups*	Flux Source	k_{eff}	Sign, % Error	# Iterations
18	-	0.9700	-	119
6	18 group SNG	0.9634	-0.7	127
6	∞ medium	0.9778	+0.8	126
3	18 group SNG	0.9582	-1.15	136
3	∞ medium	0.9883	+1.9	122

Bare Graphite Sphere C/U = 2400

# Groups*	Flux Source	k_{eff}	Sign, % Error	# Iterations
18	-	0.967	-	51
6	18 group SNG	0.934	-3.4	77
6	∞ medium	0.950	-1.7	75
3	18 group SNG	0.943	-2.5	111
3	∞ medium	0.984	+1.7	112

*Each of the collapsed groups contained equal numbers (3 or 6) of groups of the 18 group set.

Appendix I

Example

Consider an H_2O reflected, H_2O moderated sphere, for which it is desired to reduce the Hansen-Mills 18 group cross sections to 3 groups. There are thus two regions with the following composition:

Atom density $\times 10^{-24}$	Core	Reflector
H	0.0663	0.0668
O	0.0332	0.0334
U^{235}	1.288×10^{-4}	

Assume one wishes to compute the infinite medium fluxes for the core and reflector compositions to use in weighting the 18 group cross sections and that the core and reflector radii will be supplied for weighting the velocities. The three output groups are chosen to contain 6, 9, and 3 input groups, respectively, starting from the high energy end. Parameters and data for the above problem follow on Floco coding forms and are included in the ZOT decks.

FLOCO 704

77	78	79	80	PROBLEM Example		
				PROGRAMMER	DATE	PAGE

	C	OPERATION P 2	R 3	S 4	5	ADDRESS X 6	R 7	S 8	9	REMARKS
0	9	*					P	0	0	load instruction
1	10								1	ID #
2	19								2	# regions
3	28								5	# elements and mixtures
4	37								3	volume spec.
5	46								7	mixture spec.
6	55								0	$\cdot(\sigma_{tr})^{-1}$
7	64									P 0 0
0	9	*					G	0	0	load instruction
1	10							1	8	G
2	19								2	pos. of σ_g
3	28								3	pos. of σ_{gg}
4	37								8	pos. of last $\sigma_{g'g}$
5	46								0	# upscattering
6	55									
7	64									G 0 0
0	9	*					K	0	0	
1	10								3	K
2	19								2	pos. of σ_k
3	28								3	pos. of σ_{kk}
4	37								5	last $\sigma_{k'k}$
5	46									
6	55									
7	64									K 0 0
0	9	*					C	0		"load data"
1	10								6	table of last
2	19							1	5	g in each k
3	28							1	8	
4	37									
5	46									
6	55									
7	64									0 C 0

	C	OPERATION P 2	R 3	S 4	5	ADDRESS X 6	R 7	S 8	9	REMARKS
0	9	*					N	0		
1	10								4	1st region (core)
2	19								1	H
3	28								2	O
4	37								3	U^{235}
5	46								5	2nd region (reflec.)
6	55								1	H
7	64								2	0 N 0 0
0	9	*					M	0		
1	10								0	mixture
2	19			.	0	6	6	3		N_H
3	28			.	0	3	3	2		N_O
4	37	.	0	0	0	1	2	8	8	N_U
5	46								0	mixture
6	55				.	0	6	6	8	
7	64				.	0	3	3	4	0 M 0
0	9	*					F	0		
1	10								1	fixed pt. flux-
2	19								1	source
3	28									
4	37									
5	46									
6	55									
7	64									0 F 0
0	9	*					W	0		
1	10					1	6	.		*radii
2	19		3	1		.	2	7		
3	28									
4	37		(no decimal point allowed in last column of a field)							
5	46									
6	55									
7	64									

FLOCO 704

77	78	79	80	PROBLEM		
				PROGRAMMER	DATE	PAGE

	C	OPERATION P	R	S	ADDRESS X	R	S	REMARKS
	1	2	3	4 5	6	7	8 9	
0	9	*				S	0	
1	10							
2	19	This card followed by 18 group						
3	28	fission spectrum						
4	37							
5	46							
6	55							
7	64							0 S 0
0	9	*				V	0	
1	10							
2	19							
3	28	This card followed by 18 group						
4	37	velocity set						
5	46							
6	55							
7	64							0 V 0
0	9	*				P	0	
1	10							
2	19	This card followed by 18 group						
3	28	cross sections in the order, H, O, U235						
4	37							
5	46							
6	55							
7	64							

Appendix II

ZOT Code Listings and Flow Diagrams

The coding is relatively simple and straightforward except perhaps where the transfer cross sections $\sigma_{g'g}$ are involved. Flow diagrams are given for those cases and for the master or flow code. Annotated listings are given for all code blocks, as well as summaries of the data and code blocks.

Summary of Data and Code Blocks

Data

A0 (A1)	Input absorption cross sections by region.
A2 (A3)	Output absorption cross sections by region.
C0	Separation of output groups.
F0	Flux source table.
F2 (F3)	Many-group flux by region.
F4 (F5)	Few-group flux by region.
G0	Table of the output group corresponding to each input group.
M0	Atomic density table.
M1 (M2)	Matrix for flux with upscattering.
N0	Mixture composition table.

Data (contd.)

P0 (P1, P2)	Many-group cross sections by element and mixture.
Q0 (Q1, Q2)	Output cross sections by mixture.
V0	Many-group velocities.
V1	Few-group velocities average over volume.
V2 (V3)	Few-group velocities for each region.
W0	Volume or radius table.

Code

801	Flow code (master code).
803	Data assignment.
804	Form mixture σ's.
805	Calculate many-group fluxes, φ_g.
806	Set region addresses.
807	Calculate many-group absorption σ_a^g.
810	Calculate transfer cross sections $\sigma_{k'k}$.
811	Collapse cross sections σ_{ac}, $\nu\sigma_f$, σ_{tr}, σ_a.
812	Calculate few-group self-scattering σ_{kk}.
813	Generate code constants.
814	Calculate fission spectrum χ_k.
815	Calculate velocities.
816	Input print.
817	Output print and punch.

Code (contd.)

822	Place element σ's in region blocks.
823	Set flux for element calculation.
843 - 867 and 871	Print remarks and headings.
870	Matrix solver subroutine LA-S885.

Use of Temporary Storage Block T00

T01-T07	Temporary use only.
T10	σ_t^g region base address and region index in decrement.
T11	φ_g region base address.
T12	σ_t^k region base address.
T13	φ_k region base address.
T14	v_k region base address.
T15	σ_a region base address.
T16	σ_a region base address.
T17	Not used.
T20	$h_\ell - h_s$
T21	# elements
T22	$h_s - h_t - 1$
T23	$h_s - h_t$
T24	$h_t + 1$
T25	$i_t + 1$

Error Stops

Location

Octal	Region	Symbolic	Type	Cause
5314	805	X47	divide check	$\sigma_g - \sigma_{gg} = 0$. Not allowed in calculating flux.
5427	805	Y62	halt	Matrix error. Stop, check size.
5461	805	Z14	divide check	$\varphi_k = \sum \varphi_g = 0$. Check flux input.
5617	810	X46	halt	Too few upscattering cross sections allowed in output (on-line print).
5674	810	X53	halt	Too few downscattering cross sections allowed in output (on-line print).
6304	815	X50	divide check	$\sum V_r v_k^r = 0$. Check volume and velocity inputs.

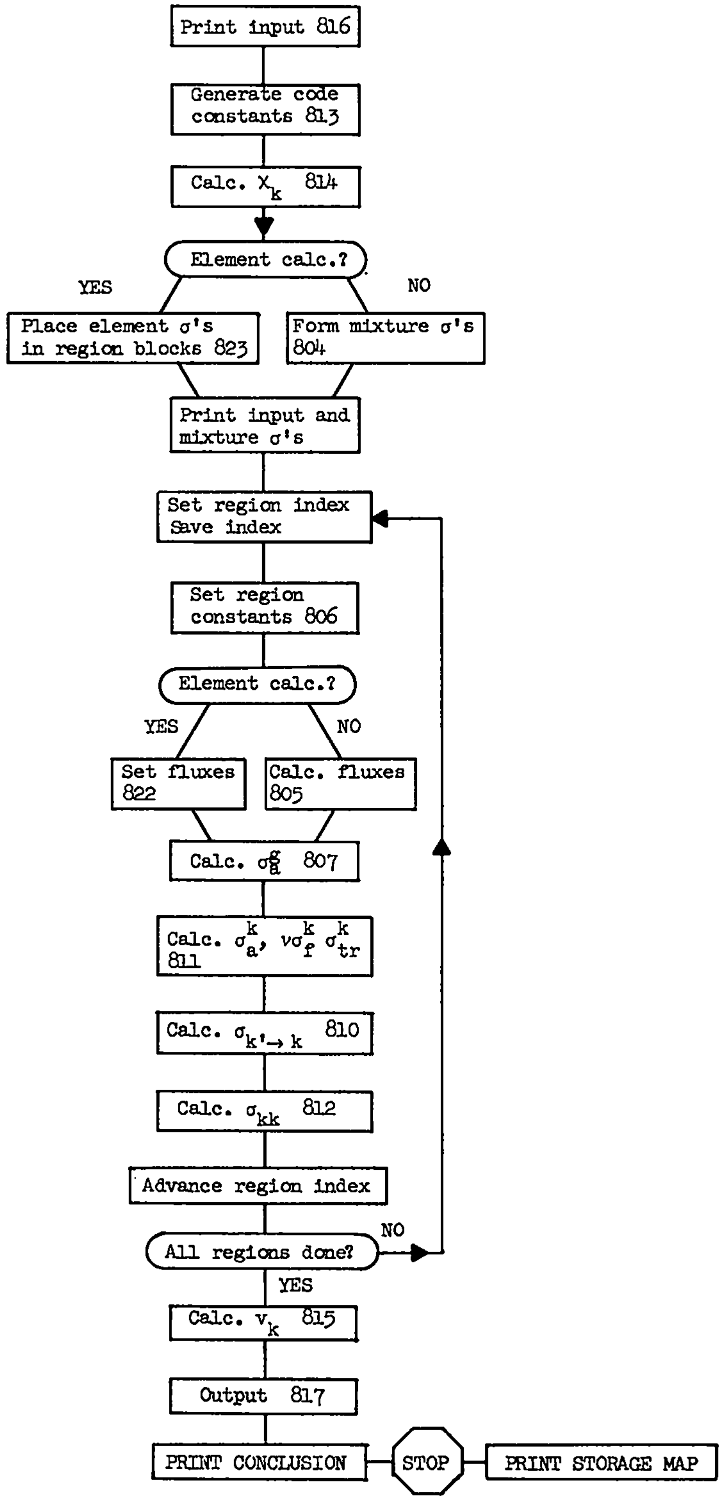
ZOT Deck

XX Floco 2 or ZOT 000	Floco II tape calling card.
ZOT 001	Initialize, allow space for parameters.
Input	Parameters P00, G00, K00 cards.
ZOT 002	Assigns temporary storage T00, 30_8 spaces.
003	Assigns formula space 100_8 for 801, 1500_8 for 804, 50_8 for 803, and 420_8 for 870.
004 to 025	Remarks for printing headings.

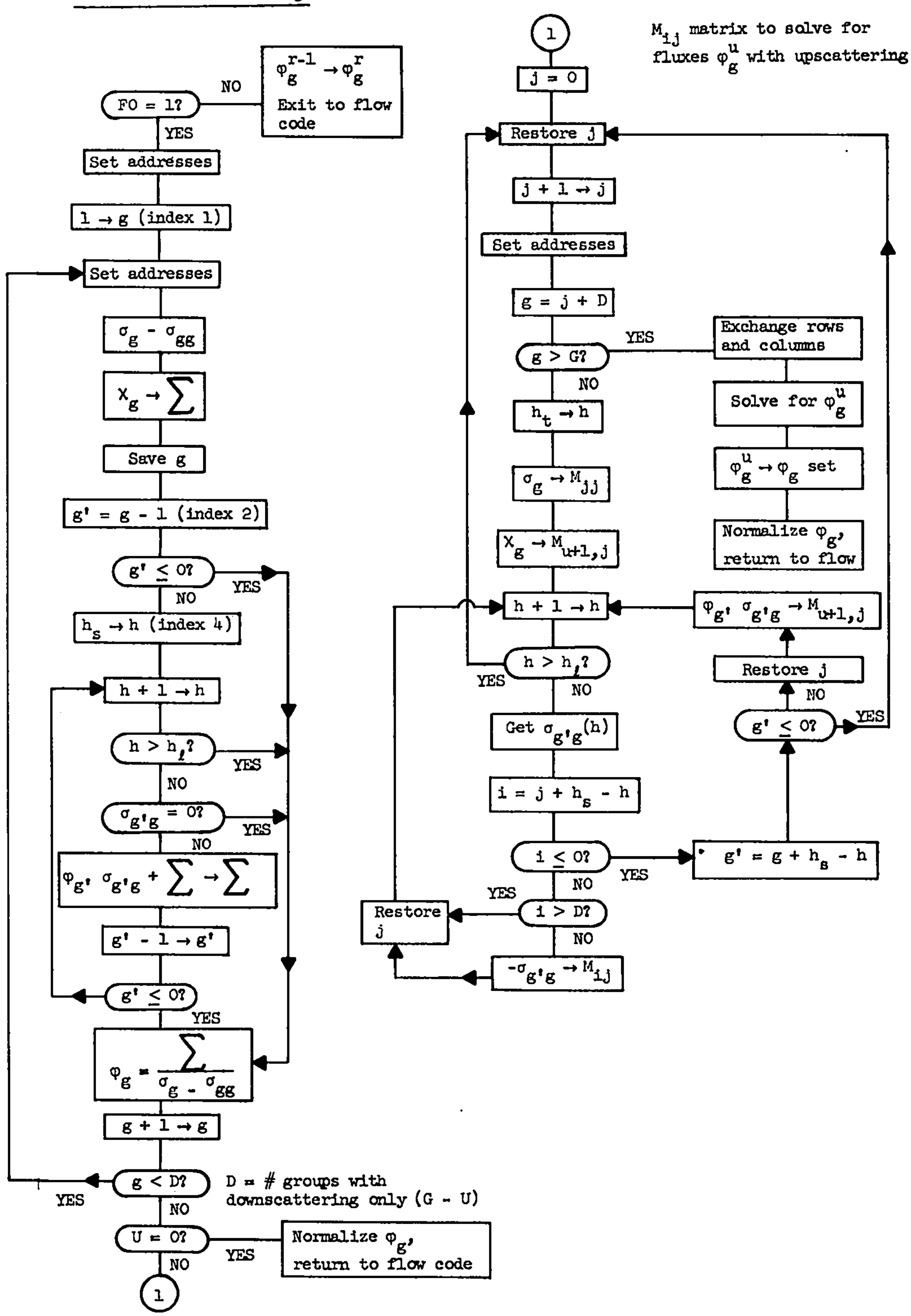
ZOT Deck, continued

026	Load data assign code (803).
027, 028	Data assign code (symbolic binary).
029	Execute data assign code.
030	Load matrix solver (870).
031 - 041	Matrix solver (binary).
042	Load formulas 804 to 823.
043 - 073	Formulas in symbolic binary.
074	Load flow code 801.
75, 76	Flow code.
Input	Data.
77	Transfer to flow code.
78, 79	Blank.

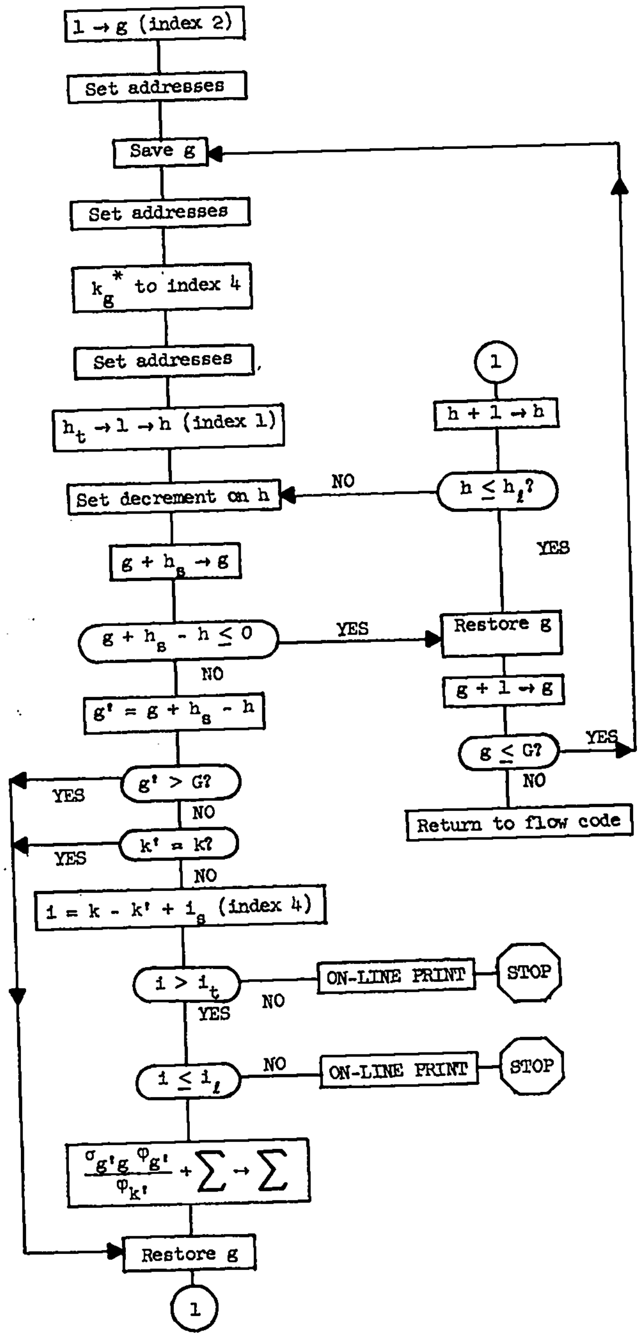
801 FLOW CODE



805 CALCULATE FLUXES φ_g



810 $\sigma_{g',g}$ COLLAPSE



*k_g is the output group corresponding to an input group g.

```
X00 8      8U1       FLOW CODE
X01  TSX4816
X02  TSX4813
X03  TSX4814
X04  CLA PC6
X05  TZE X11         Linear σtr?
X06  TSX4974
X07 40C00845
                     NO
X10  TRA X13
X11  TSX4974
X12 40C00844
X13  CLA PC5         Element calc.?
X14  TNZ X17         Transfer on "no".
X15  TSX4822
X16  TRA X20
X17  TSX48C4

X20  TSX4974         Print input and
X21 00000861         mixture sigmas.
X22 40000PC
X23  LXA24C1         1 → region index.
X24  SXD2T1C         Save.
X25  TSX48C6
X26  CLA PC5   (1)   Element calc.?
X27  TNZ X32
                     NO
X30  TSX4823
X31  TRA X35
X32  CLA2FC          Fluxes supplied?
X33  TZE X35         Transfer on "yes".
X34  TSX48C5         Calc. flux.
X35  TSX48C7         σ^g_a
X36  TSX4811         σ^k_a, νσ^k_f, σ_k
X37  TSX4810         σ_k' → k

X40  TSX4812
X41  LXD2T10
X42 10012X43         r + 1 → region.
X43 7P022X24   (1)   All regions done?
X44  TSX4815
X45  TSX4817
X46  HPR             Normal program stop.
X47  TSX4976         Print storage map.

X50 *     4801       Transfer to flow code.
```

```
X00 8     8C4     FORM MIXTURE σ's
X01  LXA14C1      1 → i
XC2  CLA1NC       Ni
X03  STA TC1      Save Ni. (2)
X04  CLA1MC       Mi atom density.
X05  TNZ X14
X06  LXA2T01      Ni → j
X07  CLA PC*
                  Set address
X10  SUB2P2       for region sigmas.
X11  STA X26
X12  STA X27
X13  TRA X31
X14  STC TC2
X15  LXA4TC1      Ni → index.
X16  CLA P0*
X17  SUB4P2       Set address.

X20  STA X24
X21  LXA2402      Put hi × G
X22  CLA2P2       in index.
X23  PAX2
X24  LDQ2CC0
X25  FMP T02      (1)
X26  FAD20CC      Form Mi × σ.
X27  STO20CC

X30 20012X24 (1)
X31 10011X32      Advance i.
X32 7P051X02 (2)
X33  LXD4457
X34  TRA4001
```

```
X00 8     BC5      CALCULATE FLUXES
X01  SUB 4C1       Use flux from previous region?
X02  TNZ Z21       YES
X03  CLA T11       NO, calc. flux.
X04  STA X42
X05  STA X50
X06  CLA GC1
X07  SUB GC5

X10  ALS 022
X11  STD X52       # of groups with only downscattering = Gd.
X12  LXA14C1       g = 1
X13  CLA T10       σr base.  ②
X14  SUB1P1
X15  STA X37       σr(g) base.
X16  SUB GC2
X17  STA X23       σg

X20  ADD GC2
X21  SUB GC3
X22  STA X24       σgg
X23  CLA OCC
X24  FSB OCC
X25  STO TC3       σg - σgg
X26  CLA1SO        Xg
X27  STO T02

X30  SXD1TC1
X31  LXD2TC1       g → index 2.
X32  20012X34      g' = g - 1
X33  TRA X46       g' = 0
X34  LXA4GC3       hs → h
X35  1C014X36      h + 1 → h
X36  3G044X46      h > hl?
X37  CLA4OCC       NO, σg' → g   ①

X40  TZE X46       σg' → g = 0?
X41  LRS 043                 NO
X42  FMP2CCO       φg' σg',g
X43  FAD T02       Σ φg' σg'g
X44  STO TC2
X45  20012X35      g' = 1 → g', g' = 0?  ①
X46  CLA TC2
X47  FDH TC3       Σ φg' σg'g / σg - σgg

X50  STQ1000       φg
X51  10011X52      g + 1 → g
X52  70C01X13      g < Gd?          NO ②
X53  CLA G05
X54  TZE Z01       Upscattering present?
X55  CLA T11       YES
X56  STA Y35       Set up matrix solution.
X57  STA Y77

X60  STZ T04       j = 0
X61  LXD1T04       Save j.  ① from Y14
X62  1C011X63      j + 1 → j
X63  CLA M1*       Set addresses on j.      ②
X64  SUB1M2                                 from Y32
X65  STA Y10
X66  STA Y23
X67  STA Y24
```

```
X70   SUB GC5
X71   SUB 4C1
X72   STA Y12
X73   STA Y36
X74   STA Y37
X75   SXD1T04
X76   LXD2TC4        j → index 2.
X77  10002YC0        g = j + Gd

Y00   SXD2T05        Save g.
Y01  3G012Z32        g > G?  Exit of matrix set.
Y02   CLA T1C        NO
Y03   SUB2P1
Y04   STA Y07
Y05   STA Y15
Y06   LXA4GC2        h = htr
Y07   CLA4C00        -

Y10   STO1C00        σg → Mjj
Y11   CLA2SC
Y12   STO CC0        Xg → Mn+1,j
Y13  1CC14Y14        h + 1 → h
Y14  3G044X61        h > hℓ?     (1) YES
Y15   CLA40C0        NO
Y16   STO TC1        σg' → g
Y17   SXD4Y21

Y20  1GC31Y21        Index i = j + hs
Y21  6C001Y27        i = j + hs - h
Y22   TRA Z34        Patch.
Y23   FAD10C0        -σg'g + Mij → Mij
Y24   STO10CC
Y25   LXD1T04        Restore j.
Y26   TRA Y13
Y27   LXD2TC5        g → index 2.

Y30   SXD4Y32
Y31  1GC32Y32        g + hs
Y32  6CC02X61        g + hs - h = g' < 0? (2)
Y33   LXD1TC4        NO, restore j.
Y34   LDQ TC1
Y35   FMP2CC0
Y36   FAD 000        φg' σg' → g + Mn+1,j → Mn+1,j
Y37   STO CC0

Y40   TRA Y13
Y41   ARS C01        From Z33
Y42   STD Y57
Y43   ARS C21
Y44   CHS
Y45   ADD M1*
Y46   STA Y64
Y47   LXA1401

Y50   LXD2M2*
Y51   CLA1M1
Y52   LDQ2M1
Y53   STO2M1       (1)
Y54   STQ1M1         Store matrix to agree
Y55  20012Y56        with subroutine input
Y56  10011Y57        requirements.
```

```
Y57 70C01Y51
Y60  LXD1457
Y61  TSX4870        Matrix solver.
Y62 OHPR            Error stop.
Y63 0G05 001
Y64 4000 CCC
Y65 9GC52Y63
Y66  SXD1457
Y67  CLA Y64

Y70  CHS
Y71  ADD G05
Y72  STA Y76
Y73  LXA1G05
Y74  LXD2X52
Y75 10012Y76
Y76  CLA1000        Store upscattering φ
Y77  STO2CC0        in regular φ block.

Z00 2C011Y75
Z01  CLA T11        Normalize φ.
Z02  STA ZC7
Z03  STA Z13
Z04  STA Z15
Z05  CLM
Z06  LXA1G01        G → index 1.
Z07  FAD1CCC        φg + Σ(g-1) φg → Σ φg

Z10 20011Z07
Z11  STO TC1        Σ(1..g) φg = Σ
Z12  LXA1G01
Z13  CLA1CC0
Z14  FDH T01        φg/Σ
Z15  STQ1CC0
Z16 20011Z13
Z17  LXD4457

Z20  TRA4CC1        Return to flow code
Z21  CLA T11        from X02.
Z22  STA Z27        Use flux from previous region.
Z23  ADD G01
Z24  STA Z26
Z25  LXA2G01
Z26  CLA20C0        φg,r-1 → φg,r
Z27  STO2000

Z30 20C12Z26
Z31  TRA Z17
Z32  CLA M2*        From matrix set.
Z33  TRA Y41
Z34 3G051Y25        i ≥ # upscattering groups?
Z35  CLS T01        NO, -σg'g
Z36  TRA Y23        Return to code.
Z37 80002X11        Patch.

Z40  STD X77
Z41  TRA X12
Z42 H0002X60        Patch.
Z43  CLA M2*
Z44  STA X64
Z45  TRA X61
```

```
X00 H     8C6        SET REGION ADDRESSES
X01  LXD2T10         r → index 2.
X02  CLA F2*         •φg base address.
X03  SUB2F3
X04  STA T11         φgr base address.
X05  PXD2
X06  PCX4
X07 1T214X10         r + E → index 4.

X10  CLA P0*         σg base address.
X11  SUB4P2          σrg base address.
X12  STA T10
X13  CLA F4*         φk
X14  SUB2F5
X15  STA T13         φkr
X16  CLA Q0*         σk
X17  SUB2Q2

X20  STA T12         σkr
X21  CLA V2*         vk
X22  SUB2V3
X23  STA T14         vkr
X24  CLA A0*         σa(g)
X25  SUB2A1
X26  STA T15         σar(g)
X27  CLA A2*
                     σa(k)
X30  SUB2A3
X31  STA T16         σar(k)
X32  LXD4457
X33  TRA4001

X34 80002X04 ┐
X35  CLA T21 │
X36  ALS 022 │       Patch to
X37  STD X07 │       get E in
             │       decrement.
X40  TRA XC5 ┘
```

X00	8 807	CALCULATE σ_g^g
X01	CLA T15	σ_a^r address base.
X02	STA X16	
X03	STA X17	
X04	STA X33	
X05	STA X34	
X06	LXA24C1	$1 \rightarrow g$
X07	SXD2T01	Save g.
X10	CLA T10	1
X11	SUB2P1	$\sigma_{(g,r)}$ address.
X12	STA X31	
X13	SUB G02	
X14	STA X15	
X15	CLA 000	σ_g
X16	FAD2000	$+\sigma_a^g \rightarrow \sigma_{ag}$
X17	STO2000	
X20	LXA1T24	$h_t + 1 \rightarrow h$
X21	SXD1X23	$i \rightarrow$ dec.
X22	1GC32X23	$g + h_s$
X23	60002X37	$g + h_s - h = g'$ 2
X24	PXD2	
X25	ARS 022	
X26	SUB G01	$g' - G$
X27	TZE X31	$g' = G$?
X30	TPL X35	NO, $g' \geq G$?
X31	CLS1000	NO $\sigma_{g'g}$
X32	TZE X35	$= 0$?
X33	FAD20C0	NO $\sigma_a - \sigma_{g'g} \rightarrow \sigma_a$
X34	STO20C0	
X35	10011X36	$h + 1 \rightarrow h$
X36	7G041X43	$h \leq h_l$
X37	LXD2TC1	Restore g.
X40	10012X41	$g + 1 \rightarrow g$
X41	7G012X07	$g \leq G$? 1
X42	TRA40C1	Return to flow code.
X43	LXD2T01	Restore g.
X44	TRA X21	2

X00	8 810	CALCULATE $\sigma_{k'} \to k$
X01	LXA2401	$1 \to g$
X02	TNO X04	Test accum. overflow.
X03	TRA XC4	
X04	CLA T11	φ_g^r address.
X05	STA X63	
X06	STZ T01	
X07	STZ TC2	
X10	CLA T13	σ_r^k address.
X11	STA X64	
X12	SXD2TC1	Save g.
X13	CLA T10	σ_r^g address.
X14	SUB2P1	
X15	STA X62	
X16	CLA2GC	
X17	STO TC2	
X20	LXA4T02	
X21	CLA T12	
X22	SUB4Q1	
X23	STA X71	σ_{tr}^k address.
X24	STA X73	
X25	STA T30	
X26	LXA1T24	$h_t + 1 \to h$
X27	SXD1X31	
X30	1G032X31	$g + h_s$
X31	60002X77	$g' = g + h_s - h$
X32	3GC12X74	$g' > G$?
X33	CLA2G0	
X34	STO TC3	$k' - k$
X35	SUB TC2	
X36	TZE X74	
X37	CHS	
X40	ADD KC3	$i = k - k' + i_s$
X41	STO TC4	
X42	LXA4TC4	$i \to$ index 4.
X43	3K024X47	$i > i_t$?
X44	TSX4975	Print.
X45	4C000847	Too few upscat.
X46	HTR Y02	
X47	3K044X51	$i \le i_\ell$
X50	TRA X54	
X51	TSX4975	Print.
X52	40000846	Too few downscat.
X53	HTR YC2	
X54	CLA T04	
X55	NCP	
X56	NOP	
X57	NOP	
X60	STO TC4	
X61	LXA4T03	$k' \to$ index 4.
X62	LDQ1000	
X63	FMP2000	$\dfrac{\varphi_{g'}\ \sigma_{g'} \to g}{\varphi_{k'}}$
X64	FDH4000	
X65	STQ T07	
X66	CLA TC7	
X67	NOP	

```
X70  LXA4TC4     Restore i.
X71  FAD40C0     ∑φg' σg' → g/φk'
X72  NOP
X73  STO40C0     σk' → k
X74  LXD2TC1     Restore g.
X75  10011X76    h + 1 → h        ①
X76  7GC41X27    h ≤ h
X77  LXD2T01     Restore g.

Y00  10012YC1    g + 1 → g
Y01  7GC12X12    g > G?       NO ②
Y02  LXD4457     Return to flow code.
Y03  TRA4C01
```

X00	8 811	CALCULATE σ_{ac}^{k}, $\nu\sigma_{f}^{k}$, σ_{tr}^{k}, v_{r}^{k}, σ_{a}^{k}
X01	LXA24C1	$1 \rightarrow g$
X02	LXA1401	$1 \rightarrow k$
X03	CLA1C0	
X04	ALS 022	3
X05	STD YC7	
X06	CLA T13	Set addresses.
X07	STA X42	φ_{r}^{k}
X10	STA X43	
X11	STA Y24	
X12	STA Y31	
X13	STA Y33	
X14	STA Y40	
X15	CLA T14	v_{r}^{k}
X16	STA X50	
X17	STA X51	
X20	CLA T15	σ_{ar}^{g}
X21	STA X52	
X22	CLA T16	σ_{ar}^{k}
X23	STA X54	
X24	STA X55	
X25	STA Y23	
X26	STA Y25	
X27	CLA T11	φ_{r}^{g}
X30	STA X40	
X31	CLA T12	σ_{r}^{k} base.
X32	SUB101	
X33	STA Y02	
X34	STA Y03	
X35	SUB K02	
X36	STA X75	
X37	STA X76	
X40	CLA20C0	φ_{r}^{g}
X41	STO TC1	
X42	FAD10C0	$\varphi_{r}^{k} = \sum \varphi_{r}^{g}$ 2
X43	STO1000	
X44	CLA T01	
X45	FDP2VC	φ_{g}/v_{g}
X46	STQ T07	
X47	CLA T07	
X50	FAD10C0	$v_{k} = \sum \varphi_{g}/v_{g}$
X51	STO1000	
X52	LDQ2000	σ_{ar}^{g}
X53	FMP T01	
X54	FAD10C0	
X55	STO10C0	$\sum \varphi_{g}^{r}\, \sigma_{ar}^{g}$
X56	CLA T10	
X57	SUB2P1	σ_{r}^{g} base.
X60	STA YC0	
X61	SUB GC2	
X62	STA X67	σ_{tr}^{g} base.
X63	STA X72	
X64	CLA PC6	Linear σ_{tr}?
X65	TZE X71	
X66	LDQ T01	YES
X67	FMP 0C0	$\varphi_{g}\, \sigma_{tr}^{g}$

X70	TRA X75	
X71	CLA TC1	Inverse σ_{tr}.
X72	FDP CC0	φ_g/σ^g_{tr}
X73	STQ T07	
X74	CLA T07	
X75	FAD 000	$\sum \varphi_g \sigma^g_{tr}$ or $\sum \varphi_g/\sigma^g_{tr}$
X76	STO CC0	
X77	LXA44C1	$1 \rightarrow$ index 4, i for $\sigma_{ac}(i)$.
Y00	LDQ4000	
Y01	FMP TC1	
Y02	FAD4000	$\sum \sigma^{g,r}_{ac}(i)\ \varphi^g_r$ 1
Y03	STO4000	
Y04	10014Y05	$i + 1 \rightarrow i$
Y05	7GC24YC0	$i > h_t - 1$ 1
Y06	10012Y07	$g + 1 \rightarrow g$
Y07	70002X40	$g >$ largest g in k? 2
Y10	10011Y11	$k + 1 \rightarrow k$
Y11	7K011X03	$k > K$? 3
Y12	LXA1401	$1 \rightarrow k$
Y13	CLA T12	
Y14	SUB1Q1	σ^r_k base. 2
Y15	STA Y37	
Y16	STA Y41	
Y17	SUB K02	$\sigma^{k,r}_{tr}$ base.
Y20	STA Y30	
Y21	STA Y34	
Y22	STA Y35	
Y23	CLA1CCC	
Y24	FDP1C00	$\sigma^k_a = \frac{\sum \varphi_g \sigma^g_a}{\varphi_k}$
Y25	STQ1000	
Y26	CLA P06	Linear σ_{tr}?
Y27	TZE Y33	
Y30	CLA 000	YES $\sigma^k_{tr} = \frac{\sum \varphi_g \sigma^g_{tr}}{\varphi_k}$
Y31	FDP1000	
Y32	TRA Y35	
Y33	CLA1CCC	Inverse $\sigma_{tr} = \varphi_k \Big/ \sum \varphi_g \Big/ \sigma^g_{tr}$
Y34	FDP 0C0	
Y35	STQ 00C	
Y36	LXA44C1	$1 \rightarrow$ index 4 (i).
Y37	CLA40C0	
Y40	FDP1000	$\sigma^k_{ac}(i) = \frac{\sum \varphi_g \sigma^g_{ac}(i)}{\varphi_k}$ 1
Y41	STQ40CC	
Y42	10014Y43	$i + 1 \rightarrow i$
Y43	7KC24Y37	$i > h_t - 1$? 1
Y44	10011Y45	$k + 1 \rightarrow k$
Y45	7K011Y13	$k > K$? 2
Y46	LXD4457	
Y47	TRA4001	Return to flow code.
Y50	90016YC5	Dec. - $1 \rightarrow$ dec. of Y05.
Y51	90016Y43	Dec. - $1 \rightarrow$ dec. of Y43.

X00	8 812	σ_{kk} CALC.
X01	STZ TC1	
X02	CLA T16	σ_a^k address.
X03	STA X20	
X04	LXA24C1	$i \to k$
X05	SXD2TC1	Save k.
X06	CLA T12	
X07	SUB2Q1	2
X10	STA X42	
X11	SUB K02	σ_k address.
X12	STA X17	
X13	ADD K02	
X14	SUB KC3	
X15	STA X21	σ_{kk} address.
X16	STA X22	
X17	CLA 000	σ_k
X20	FSB20C0	$\sigma_k - \sigma_a$
X21	FAD 0C0	$+ \sigma_{kk}$
X22	STO 000	$\to \sigma_{kk}$
X23	LXA1T25	$i_t + 1$
X24	LXD2T01	Restore k.
X25	SXD1X27	1
X26	1K032X27	$k + i_s$
X27	60002X51	$k + i_s - i = k'$
X30	3K012X47	Is $k' > K$?
X31	CLM	NO
X32	PXD2	
X33	SUB TC1	
X34	TZE X47	Is $k' = k$?
X35	CLA T12	NO,
X36	SUB2Q1	
X37	SUB K03	
X40	STA X44	
X41	STA X45	
X42	CLS1CC0	$- \sigma_{k'k}$
X43	NOP	
X44	FAD 000	$+ \sum$
X45	STO CCC	$\to \sigma_{kk}$
X46	NOP	
X47	10011X50	$i + 1 \to i$
X50	7K041X24	$i > i_t$? NO 1
X51	LXD2TC1	YES, restore k.
X52	10012X53	$k + 1 \to k$
X53	7K012X05	$k > K$? NO 2
X54	LXD4457	YES, return to flow code.
X55	TRA4CC1	

```
X00 8     813        GENERATE CODE CONSTANTS
X01  LXA24C1
X02  LXA1401
X03  CLA 4C1
X04  STO T01
X05  CLA1CC
X06  ALS 022    (2)
X07  STO X13

X10  CLA TC1         Form a table
X11  STO2G0          of k corresponding
X12 10012X13         to each g.
X13 70002X11  (1)
X14  ADD 4C1
X15 10011X16
X16 7K011X04  (2)
X17  CLA G04

X20  SUB G03
X21  STO T20         h_l - h_s
X22  CLA P03
X23  SUB PC2
X24  STO T21         E = M - R
X25  CLA C03
X26  SUB G02
X27  STO T23         h_s - h_t

X30  SUB 401
X31  STO T22         h_s - h_t - 1
X32  CLA GC2
X33  ADD 401
X34  STO T24         h_t + 1
X35  CLA K02
X36  ADD 4C1
X37  STO T25         i_t + 1    812, X23

X40  TRA4001
```

```
X00 8     814        CALC. X_k (fission spectrum)
X01  LXA2401         1 → index 2.
X02  LXA14C1         1 → index 1.
X03  CLA1C0     ②    Group limits.
X04  ALS 022
X05  STD X12
X06  CLA2SC     ①
X07  FAD1S1
X10  STO1S1
X11 10012X12    ①
X12 7C002X06
X13 10011X14    ②
X14 7K011XC3
X15  TRA4001
```

$$X_k = \sum_{k \text{ in } g} X_g$$

X00	8 815	CALC. v_k
X01	CLA PC4	Volume specification W.
X02	SUB 4C4	
X03	TZE X54	$W = 4$, calc. v for each region.
X04	CLA PC4	
X05	TZE X24	$W = 0$ volumes supplied.
X06	LXA24C1	Generate volumes, $1 \to$ index 2.
X07	STZ T02	
X10	LXA1P04	$n \to$ index $1 = i$ (region index).
X11	LDQ 421	1.0
X12	FMP2W0	r_i^n
X13	LRS 043	
X14	20011X12	
X15	STO T01	
X16	FSB T02	$r_i^n - r_{i-1}^n$
X17	STO2W0	
X20	CLA T01	
X21	STO T02	$r_i \to r_{i-1}$
X22	10012X23	$i + 1 \to i$
X23	7P022X10	
X24	LXA1K01	$K \to k$ (index 1).
X25	LXA2P02	$R \to$ index 2.
X26	STZ TC1	
X27	STZ T02	
X30	CLA F4*	φ base address.
X31	SUB2F5	
X32	STA X33	
X33	LDQ1000	φ_r^k
X34	FMP2W0	
X35	FAD T01	$\sum V_r \varphi_r^k$
X36	STO T01	
X37	CLA V2*	v base.
X40	SUB2V3	
X41	STA X42	v_r^k
X42	LDQ1000	
X43	FMP2W0	
X44	FAD T02	
X45	STO TC2	$\sum V_r v_k^r$
X46	20012X30	$r - 1 \to r$
X47	CLA T01	Regions done.
X50	FDH TC2	v^k
X51	STQ1V1	
X52	20011X25	$k - 1 \to k$
X53	TRA4001	Calc. done, return to flow code.
X54	LDQ KC1	v_k for each region.
X55	MPY P02	
X56	STQ T01	
X57	LXA1T01	$R \times K$ in index 1.
X60	CLA1F4	$\varphi_k / \sum \varphi_g / v_g$
X61	FDP1V2	
X62	STQ1V2	
X63	20011X60	
X64	TRA4001	Return to flow code.
X65	80002X15	Patch, LRS not reliable.
X66	STQ T01	
X67	CLA T01	
X70	TRA X16	

```
X00 8      816        INPUT PRINT
X01  TSX4974
X02 00000850
X03 00000851
X04 00000852
X05 00061PC0          Parameters.
X06 00000853
X07 00051G00

X10 00000854
X11 00051K00
X12 00000855
X13 00000S0           Fission spectrum.
X14 00000VC           Velocities.
X15 00000C0           Few-group spacing.
X16 00000NQ           Elements for mixtures.
X17 00000M0           Atom densities.

X20 00000856
X21 00000F0           Flux source.
X22 00000W0           Volumes or radii.
X23 00000857
X24 40000F2           Flux input.
X25  LXD4457
X26  TRA4001          Return.
```

```
X00 8      817         OUTPUT PRINT
X01   TSX4974
X02 00000862
X03 00000863
X04 C0000S1           Fission spectrum.
X05 C0000V1           Velocity spectrum.
X06 C0000871
X07 C0000F2           Fluxes used.

X10 00000864
X11 00000F4           Output fluxes.   F4
X12 C0000860
X13 00000A0           Input absorptions.
X14 00000865
X15 00000A2           Output absorption.
X16 C0000866
X17 4000000           Output sigmas.

X20   CLA P04         Print velocities
X21   SUB 404         for each region?
X22   TNZ X26
X23   TSX4974         YES
X24 C0000867
X25 40000V2
X26   TSX4973         Punch on line.
X27 C0000SL

X30 00000V1
X31 40000C0
X32   TSX4975
X33 00000843
X34 40002000
X35   LXD4457
X36   TRA4001
```

```
X00 8     822     PLACE ELEMENTS IN REGION BLOCKS
X01  LXA2P02      E → index 2.
X02 10C12X03      E + 1
X03  CLA PQ*
X04  STA X11      PO block address.
X05  SUB2P2
X06  STA X12      PO - h_ℓ × G × E
X07  CLA2P2

X10  PAX1         h_ℓ × G × E in index 1 = i.
X11  CLA1000      σ element.
X12  STO1000      σ region.
X13 20011X11      i - 1 → i   1
X14  TRA4QC1      Return.
```

```
X00 8     823      SET FLUX FOR ELEMENT CALC.
X01  LXD2T10       r = 1?
X02 70012X13       If yes, flux supplied, exit.
X03  CLA T11       NO,
X04  STA X11       Set φ^g_r address.
X05  AND GC1
X06  STA X10       φ^g_{r-1} address.
X07  LXA1G01       G → g

X10  CLA100C       Place φ^g_{r-1} → φ^g_r
X11  STO10C0                              (1)
X12 20011X10       g - 1 → g
X13  TRA4001       g = 0, return.
X14 *     801
```