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THE 1107 MANUAL FOR PHYSICS CHAIN, A REACTOR ANALYSIS CODE

E. L. KELLEY, JR.

D. R. MARR

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A REACTOR ANALYSIS CODE

By

E. L. Kelley, Jr.

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Theoretical Physics
FFTF Reactor Physics Section

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TABLE OF CONTENTS

SECTION I	1
Introduction	1
Computer Codes Involved	1
Chain Link Identification	2
Tape Usage	2
Input Instructions	3
Running Time	3
SECTION II	5
Auxiliary Programs for the PCT	5
STARTER	5
KONV	5
COMPAX	5
SCHWAC	5
COMBO	6
SIGMA-3H and SIGMA-3C	9
SECTION III	10
Type Runs Available	10
TYPE I - PSPL	10
TYPE II - Single or Multiple TEMPEST, HRG, or GAM Non-Chain Cases Using COMBO	10
TYPE III - Single Pass Physics Chain Run-Using COMBO	11
TYPE IV - Multiple Pass Physics Chain Runs- Using COMBO	13
TYPE V - Single Pass Physics Chain Runs-Not Using COMBO	15
TYPE VI - Multiple Pass Physics Chain Runs-Not Using COMBO	15
SECTION IV	18
Input Instructions for Programs Used on the PCT	18
STARTER Input Instructions	19
COMBO Input Instructions	20
SIGMA-3H Input Instructions	27
HFN Input Instructions (PCT Version)	30
SCHWAC Input	43
TEMPEST Input Instructions	44
HRG and GAM Input Instructions	46
SIGMA-3C Input Instructions	54
Input Instructions for CALX	59
APPENDIX I	66
Table 1 - Chain Link Identification	66
Table 2 - Group Energy Boundaries for CALX	67
Table 3 - Input Location for Isotopes of the JBURN and DBURN Array	68
REFERENCES	70

THE 1107 MANUAL FOR PHYSICS CHAIN,
A REACTOR ANALYSIS CODE

E. L. Kelley
D. R. Marr

SECTION I

Introduction to the Physics Chain

PHYSICS CHAIN is an automated collection of codes that first prepare cross sections and then use those cross sections to do a 0-d burnup or a 1-d multigroup, multiregion diffusion calculation.

PHYSICS CHAIN enables the user to analyze a reactor or cell type problem. This is accomplished in three steps: (1) A neutron flux spectrum for the reactor (cell), or perhaps a separate spectrum for each region of the reactor (cell), is generated from a reference set of cross sections on a relatively fine energy mesh, and a set of microscopic group cross sections is averaged over this spectrum; (2) These data group cross sections are used as input to special programs that generate data tapes; (3) these data tapes are used by the computer programs that solve multigroup, multiregion diffusion or burnup problems. These three major steps are accomplished with one computer pass. Those familiar with computer use can readily appreciate the drastic reduction of man hours and machine time from that ordinarily involved in running each program separately to accomplish its portion of the problem, in addition to the reduction of errors due to excessive card handling and input conversion. At the time of this printing there exist two separate Physics Chains--one for the IBM 7090, see HW-80968, and one for the UNIVAC 1107. This document describes the UNIVAC 1107 Physics Chain.

Computer Codes Involved

The programs on the Physics Chain Tape (PCT) used to generate spectrum averaged isotope cross section data by

energy groups are TEMPEST,⁽¹⁾ HRG,⁽²⁾ and GAM,⁽³⁾ with TEMPEST calculating cross sections for the thermal group (energies up to 2.0 eV) and HRG or GAM calculating cross sections for the epithermal groups (energies from 0.414 eV to 10 MeV). Cross sections generated by these programs are written to a separate tape and make up the TAM Library which is used by the programs SIGMA-3H and SIGMA-3C.

Upon completion of the TAM Library, control is shifted to either SIGMA-3H or SIGMA-3C. If SIGMA-3H is called it will read the TAM Library along with regular input and make up an HFN Data Tape. Upon completion of the HFN Data Tape, SIGMA-3H calls program HFN⁽⁴⁾ as the next link of the chain. HFN reads the data tape produced by SIGMA-3H along with regular input information and performs the necessary diffusion theory calculations. The HFN program in this case is the final link of the chain, and when the desired calculations are completed the problem is terminated. If SIGMA-3C is called the same procedure follows except that a CALX Data Tape is made and Program CALX⁽⁵⁾ is called as the next chain link rather than HFN. In this case there are additional options which depend on the type problems being run with CALX.

Chain Link Identification

The chain link identification number for any program that might be used on a Physics Chain run may be found on Table 1, Appendix I, of this manual.

Tape Usage

Various library and data tapes are used when running the Physics Chain and are referred to throughout this manual. It is felt that information here as to their usage might eliminate later confusion.

A Composite Library Tape (CLT) is used by the PCT and contains the basic cross section libraries that were mentioned previously. There are three of these cross section libraries on a particular CLT, two in binary form and one in decimal. The first, a binary, is used by program TEMPEST and contains basic isotope cross section information for use in calculating the spectrum for the thermal group. The second, also binary, is used by HRG or GAM and contains basic isotope cross section information for use in calculating the spectrum for the epithermal energies. The third, a decimal library, is used by SIGMA-3H or SIGMA-3C for coordinating and analyzing information from TEMPEST and HRG or GAM output that is written to the TAM Library. More detailed description is found in the SIGMA-3 Library document.⁽⁷⁾

As mentioned previously, the TAM Library tape generated by programs TEMPEST and GAM or TEMPEST and HRG contains the spectrum averaged isotopic group cross sections for the problem or region of the problem being analyzed. Information is read from this library and used by codes SIGMA-3H or SIGMA-3C for making up the HFN or CALX Data Tapes. As their names imply these data tapes contain input data for programs HFN and CALX.

Input Instructions

Specific input instructions for each program that is to be used when running a PCT may be found in Section IV of this manual. Information concerning input flow and tapes required for a given type problem may be found in Section III.

Running Time

Running time for the 1107 PHYSICS CHAIN is approximately 10% less than that of the 7090 PHYSICS CHAIN. However, since the EXEC MONITOR provides for simultaneous operation of

parasites (printer, card reader, typewriter, punch, data line),
running times may vary as much as 20% under adverse conditions.

SECTION II

Auxiliary Programs for the PCT

This section deals with programs that take care of the chain "housekeeping," and other necessities such as permitting operation with standardized input, controlling type run to be made and monitoring when particular links are to be called. Program use of these codes is described in this section, with instructions when and when not to use them.

Program STARTER

The purpose of this code is to copy the appropriate libraries onto drum from which files can be more readily accessed in multiple pass problems. STARTER also determines the nature of the run, whether a simulated chain run or a PSPL (Pseudo Special Procedures Library) run, and arranges the I/O table accordingly.

Program KONV

Program KONV converts HRG or GAM type CLTs from the IBM 7090 format to the UNIVAC 1107 format.

Program COMPAX

This program compacts the records on a CLT into 5000 word records consequently reducing the tape to drum time from approximately 1 minute to approximately 8 seconds. Program COMPAX is kept in absolute form in the first file of the program tape. It requires no card input. The CLT to be compacted should be mounted on logical tape A and a tape on which the compacted version can be written should be mounted on logical tape B.

Program SCHWAC

Program SCHWAC is an auxiliary program to be used with HFN to reduce the number of regions through homogenization. SCHWAC

is called into memory after an HFN run which generates the necessary average fluxes for the many region problem. SCHWAC then flux weight averages the HFN neutron parameters for the desired configuration.

$$\bar{\xi}_j = \frac{\sum_{i=NI}^{NN} \bar{\phi}_{ij} V_i \xi_{ij}}{\sum_{i=NI}^{NN} \bar{\phi}_{ij} V_i} = \frac{\sum_{i=NI}^{NN} \int_{V_i} \xi_{ij} \phi_{ij}(r) dV}{\sum_{i=NI}^{NN} \int_{V_i} \phi_{ij}(r) dV}$$

where

ξ parameter to be averaged in the j^{th} group
 NI index of region at which to start average
 NN index of last region to be put in average
 V_i volume of the i^{th} region

$\bar{\phi}_i$ is the average flux in the i^{th} region.

Rerunning of HFN with the above homogenized parameters is permitted.

Program COMBO

Introduction

Program COMBO is a computer code which has been written primarily to simplify input to the PHYSICS CHAIN. Subroutine LISTIV⁽⁶⁾ is used as a means of getting input into the TEMPEST and HRG or GAM codes now used on the PHYSICS CHAIN Tapes. By using this program one may eliminate most of the input redundancy due to former input requirements, at the same time letting the program take care of some of the "bookkeeping" that is presently required by HRG and GAM.

Isotopes used in calculating the spectrum need only be referred to by their SIGMA-3 Library⁽⁷⁾ identification numbers and may be listed in random order. COMBO will take these isotopes, assign corresponding TEMPEST and HRG or GAM identification numbers to the isotopes, and arrange the numbers in ascending order as required by HRG and GAM.

After all the input data for TEMPEST and HRG or GAM have been read and modified to meet the requirements of these programs, COMBO then writes these data to the Chain Data Tape (special drum location) in record order corresponding to the program for which the data are used. This process is followed for as many passes through TEMPEST and HRG or GAM as desired by the user. Further information on multiple pass procedures may be found in this section under the heading Code Restrictions, or in Section III for the particular type problem being run.

When all COMBO data for the run have been read and written to the Chain Data Tape or drum, the tape or drum is rewound and COMBO calls the next link on the chain as specified by input (see COMBO Input Instructions).

Options Available

Modifications have been made to this program that enable the user to run single or multiple cases of individual codes using the LISTIV input formats. This means that COMBO is available not only for complete chain runs, but may be used for HRG, TEMPEST, or GAM runs only.

In making runs for a single code it is necessary to supply only the input pertinent to that code. A column labeled CODE has been added to the COMBO input instructions. In this column, for each input location, there will be either a T or an H, both a T and an H, or neither. All input is necessary for normal chain runs. However, for single or multiple TEMPEST runs, only those entries that have a T under the CODE column are necessary.

For single or multiple HRG or GAM runs, only the entries that have an H are necessary.

Code Restrictions

1. Library Sources

When making a run of any type that employs the use of COMBO, a CLT must be mounted that contains the Library or Libraries for that particular type run. Example: If an HRG case is to be run, a CLT containing the HRG Library must be used—a regular HRG Library Tape is not sufficient.

2. Link Specification

The user must specify the link to call after COMBO has finished arranging input according to the program to be run. This is necessary when running a single TEMPEST, HRG, or GAM case as well as with regular Chain Runs. See Location 15 of COMBO Input Instructions.

3. Multi-region Reactor Type Problems

When running a reactor type problem involving more than one region, it is usually necessary to make a pass through TEMPEST and HRG or GAM for each region of the problem. By means of input, COMBO monitors the passes to be made and expects a separate input case for each pass.

Advantages in Using Program COMBO

Listed below are certain conveniences that are available when using a PCT that contains program COMBO.

1. Program COMBO uses input formats as specified by subroutine LISTIV.
2. COMBO does not clear memory with each case, therefore multiple TEMPEST and HRG and GAM passes may be made with changes being made only to input that differs from case to case.

3. The SIGMA-3 Library isotope identification number is sufficient for identifying isotopes used in spectrum calculations by TEMPEST and HRG or GAM. COMBO has an isotope Identification Number Library and will select the proper TEMPEST and HRG or GAM number corresponding to the SIGMA-3 number.
4. The isotope identification numbers need not be arranged in any particular order. COMBO will select the proper HRG or GAM identification numbers and arrange these numbers in ascending order as is specified by these programs.
5. The same set of isotope densities may be used for both TEMPEST and HRG or GAM isotopes unless otherwise specified.

Program SIGMA-3H and SIGMA-3C

Programs SIGMA-3H and SIGMA-3C are used on the Physics Chain to generate cross section data tapes for programs HFN and CALX. These programs read the group microscopic cross sections calculated by the thermal and epi-thermal spectrum codes and generate the HFN or CALX data tape for a particular problem.

Options are available in SIGMA-3H or SIGMA-3C that allow the user to mix isotopes and enter on the HFN or CALX data tape a mixture that may be treated as an isotope. There are provisions for generating up to 10 mixtures.

SECTION III

This section describes the type problems that can be run on the PHYSICS CHAIN. Listed below are the types permitted at present:

TYPE I PSPL
 TYPE II Single or Multiple TEMPEST, HRG, or GAM non-chain cases using COMBO
 TYPE III Single pass chain—with COMBO
 TYPE IV Multiple pass chain—with COMBO
 TYPE V Single pass chain—without COMBO
 TYPE VI Multiple pass chain—without COMBO

Further information concerning control flow and tapes needed for these various type runs follows in this section of the manual.

TYPE I - PSPL

PSPL (Pseudo SPL) is an attempt to provide users with codes, the input to which is compatible with input to SPL codes on the IBM 7090. In each case only the specific library is copied from the CLT (if used) to the drum. The user is thus warned that even though the code will possibly transfer to another link, the library may not be available for that link.

Input should be in the following order:

<u>Input to:</u>	<u>Comments:</u>
STARTER	Use Type 2 STARTER Input.
Applicable Code	Standard SPL or IBM 7090 deck input.

TYPE II - Single or Multiple TEMPEST, HRG, or GAM Non-Chain Cases Using COMBO

This type problem allows the user to make TEMPEST, GAM or HRG runs using the convenient LISTIN input formats. Input is submitted in accordance with COMBO input instructions. A COMBO Data Case is needed for each pass through TEMPEST, HRG, or GAM.

Input flow should be in the following order:

<u>Input to:</u>	<u>Comments:</u>
STARTER	Use Starter's type 2 input formats. (See STARTER Input Instructions.)
COMBO	If single or multiple TEMPEST runs are being made use COMBO input for only those entries that have a "T" under the code column. If HRG or GAM is being run use only those entries that have an "H" under the code column.

TYPE III - Single Pass Physics Chain Run - Using COMBO

This type problem calls for one pass through the Physics Chain, using COMBO to generate input for TEMPEST and HRG or GAM. Program TEMPEST reads this input, along with a basic cross section library as contained on a CLT, and does a spectrum calculation for the thermal energy group. A set of thermal group cross sections are then written by TEMPEST to a TAM library and the next link, HRG or GAM, is called. Programs HRG or GAM read their COMBO generated input, along with cross sections from a Basic Library, and perform calculations for the epithermal energy groups. The epithermal group cross sections are then written to the TAM Library and the next link is called, this being either Program SIGMA-3H or SIGMA-3C. The function of these programs on the chain is to make up data tapes for programs HFN or CALX.

These data tapes consist of cross section data that has been read from the TAM Library and modified by the SIGMA-3H or SIGMA-3C codes. Upon completion of these data tapes control is passed to HFN or CALX, whichever the case might be. These programs read their input along with their respective data tapes and perform the desired calculations.

Input flow should be in the following order:

<u>Input to:</u>	<u>Comments:</u>
STARTER	Uses STARTER's type 1 input formats. (See STARTER Input Instructions.)
COMBO (TEMPEST and HRG or GAM)	Prepares input for TEMPEST and HRG or GAM in proper record order and calls TEMPEST. TEMPEST analyzes input and writes the thermal output to the printer and to the TAM Library. TEMPEST then calls the epithermal program GAM or HRG (as specified by input). HRG or GAM analyzes input and writes output to the printer and to the TAM Library. The following link is then called.
SIGMA-3H or SIGMA-3C	This link reads regular input plus the cross section data from the TAM Library as generated by the thermal and epithermal codes. Data is correlated and output written to printer and to an HFN or a CALX data tape. If SIGMA-3H was used HFN is called. If SIGMA-3C was used CALX is called.
HFN or CALX	Reads regular input and the HFN or CALX data tape as generated by SIGMA-3H or SIGMA-3C and performs the desired calculations.

Type IV - Multiple Pass Physics Chain Runs - Using COMBO

This type run is the same as the Type III run except for the multiple pass feature. It is often desirable, especially when using HFN to analyze data for a multiregion reactor type problem, to make multiple spectrum calculations each requiring a separate pass through TEMPEST and HRG or GAM. For this type problem the thermal and epithermal codes make up a TAM Library, which is a set of thermal and epithermal cross sections for a particular spectrum. For the first region from input supplied by the first COMBO case, read the second set of input supplied by COMBO and make a second TAM Library, this one for the second region, and so on until there exists a TAM Library for each region in this problem. These TAM Libraries are stacked one behind the other on the Drum or a tape if so desired. When the last TAM Library has been written, the Drum or Tape is rewound and the next link, SIGMA-3H or SIGMA-3C, is called. There should be a SIGMA-3H or SIGMA-3C case for each TAM Library to be analyzed. This link makes up the HFN or CALX data tape from the cross sections furnished by the TAM Libraries. This data tape contains sequentially ordered sets of cross sections, one for each TAM Library, that will be used by HFN or CALX for final calculations in the problem. When the last SIGMA-3H or SIGMA-3C case has been run control is passed to HFN or CALX, whichever the case may be. HFN or CALX reads the data tape along with regular input and performs the desired calculations. If necessary, more than one case of HFN and CALX may be run using this data tape.

In some instances when HFN is being used to analyze cells in a reactor it is desirable to combine or homogenize the cells and analyze the reactor as a whole. To accomplish this HFN analyzes each cell as a separate case and calls another link, SCHWAC. SCHWAC averages the cross section for each cell and writes the flux weight averaged cross sections to the HFN data tape as a new material.

When each cell has been averaged or homogenized the final case of HFN does a reactor analysis using these new averaged cross sections.

Input flow for this type problem should be in the following order:

<u>Input for:</u>	<u>Comments</u>
STARTER	Uses STARTER's Type 1 input formats. (See STARTER Input Instructions.)
COMBO (TEMPEST and HRG or GAM	Data for first TEMPEST and HRG pass is read in and arranged in proper record order for these codes and written to Drum or a specified tape. Data for second TEMPEST and HRG pass is read in and analyzed in proper record order for these codes and written to the Drum, or a specified tape, behind the first set of data. This process is followed for each region of the problem. When data for the last region have been written, the Drum or specified tape is rewound and control is given to TEMPEST and HRG or GAM. A TAM Library is made for each set of data and these are stacked one behind the other on the TAM Library tape. Next link is called.
SIGMA-3H or SIGMA-3C	This program makes an HFN or CALX Data Tape for each region using the corresponding TAM Library and regular input. There must be a separate SIGMA-3H or SIGMA-3C case for each TAM Library. When the last set of cross section data has been written to the HFN or CALX Data Tape, the link containing HFN or CALX is called.
HFN or CALX	This program reads regular input along with the data tape as generated by SIGMA-3H or SIGMA-3C and performs the desired calculations.

TYPE V - Single Pass Physics Chain Runs - Not Using COMBO

This type run is essentially the same as the Type III run except for the input formats. When making this type chain run COMBO is not used, therefore, input must be in the formats as required by TEMPEST and HRG or GAM. See TEMPEST and HRG or GAM input instructions.

Input flow should be in the following order:

<u>Input for:</u>	<u>Comments</u>
STARTER	Uses STARTER's type 1 input formats. (See STARTER Input Instructions.)
TEMPEST	TEMPEST reads input and from a basic cross section library generates thermal cross sections which are written to the TAM Library. Calls next link.
HRG or GAM	HRG or GAM reads its input and from its basic cross section library generates a set of epithermal cross sections for the problem and writes them to the TAM Library. Calls next link.
SIGMA-3H or SIGMA-3C	This link reads the TAM Library cross sections along with normal input and prepares a data tape for either HFN or CALX. Control is transferred to next link.
HFN or CALX	Reads regular input along with the data tape as generated by SIGMA-3H or SIGMA-3C and performs the desired calculations.

TYPE VI - Multiple Pass Physics Chain Runs - Not Using COMBO

This type run is the same as the Type IV run with the exception of input formats. COMBO is not employed and therefore, input must be according to the specifications of the thermal and epithermal codes used. Since multiple passes are being made, separate input for

each region is necessary for the thermal code (TEMPEST) and the epithermal code (HRG or GAM) in a given order for each region to be analyzed. TEMPEST input for Region 1 is followed by HRG or GAM input for the same region. Next comes TEMPEST input for Region 2, followed by HRG or GAM input for Region 2 and so on until input has been furnished for all regions or spectrums to be analyzed. TAM Libraries are generated for each spectrum and are available for later use in the chain.

Remaining input to a Type VI Physics Chain Run is the same as for a Type IV Run. There must be a SIGMA-3H or SIGMA-3C input set for each TAM Library to be analyzed.

Input flow should be in the following order:

<u>Input for:</u>	<u>Comment</u>
STARTER	Uses STARTER's type 1 input formats. (See STARTER Input Instructions.)
TEMPEST	TEMPEST reads input and its basic cross section library and generates a set of thermal cross sections for the first region or spectrum. These cross sections are written to the TAM Library tape. Calls next link.
HRG or GAM	Reads input and a basic cross section library and generates a set of epithermal cross sections for the first region or spectrum. These cross sections are written behind the thermal cross sections on the TAM Library to complete the first TAM Library. Next link is called.
TEMPEST	Reads input for Region 2 and generates a new set of cross sections which are written to the TAM Library tape behind the first Library.

HRG or GAM

Reads input for Region 2 and generates epithermal cross sections which are written to the TAM Library tape to complete the second Library. Calls next link.

Note: This process is continued for each region or spectrum to be analyzed by the problem, after which the TAM Library tape is rewound and the next Link on the Physics Chain is called.

SIGMA-3H or
SIGMA-3C

This link analyzes the TAM Library for each region of the problem and makes up a HFN or CALX data tape. There must be a set of input for each TAM Library to be analyzed. After all the TAM Libraries have been analyzed and HFN or CALX data tapes written, the data tapes are rewound and HFN or CALX is called.

HFN or CALX

Reads regular input and the HFN or CALX data tape as generated by SIGMA-3H or SIGMA-3C and performs the desired calculations.

SECTION IVInput Instructions for Programs Used on the PCT

This section of the Physics Chain manual contains specific input instructions for all auxiliary and working programs for the chain. It should be noted that programs COMBO, SIGMA-3H, SIGMA-3C, HFN and CALX use subroutine LISTIV as a means of getting input into program storage. For information concerning use of this subroutine consult the LISTIV document, BNWL-41.

STARTER INPUT INSTRUCTIONS

STARTER input consists of one card only. It must be one of the following two types:

TYPE 1 - Chain Type (5I3 Format)

<u>Column</u>	<u>Entry</u>
1 - 3	Logical unit for composite library tape. Suggested input: 1 (Logical Unit A).
4 - 6	Link to call after STARTER.
7 - 9	1 for HFN data tape on Logical Unit B. 0 for HFN data in a drum file.
10 - 12	1 for TAM Library on Logical Unit D. 0 for TAM Library in a drum file.

(5I3 Format)

13 - 15	1 for CLT interlock inhibition, just rewinds when through. 0 for CLT rewind <u>and</u> interlock when through reading.
---------	---

TYPE 2 - Pseudo Special Procedures Library (PSPL)

Input consists of the following words in a Free Field format.

RUN XX....X

Where the word XX....X is one of the following:

TEMPEST	SIGMA-3C
GAM	CALX
HRG	COMBO-TEMPEST
HFN	COMBO-GAM
SIGMA-3H	COMBO-HRG

GAM, HRG, and TEMPEST will expect a specific library tape on logical unit A and SIGMA-3H and SIGMA-3C will expect a card library. If the words [WITH] CLT are added, STARTER will copy the appropriate library from the CLT (which should be on logical unit A) to the area of the drum which the code accesses. COMBO-TEMPEST, COMBO-GAM, and COMBO-HRG type runs require a CLT and hence the words [WITH] CLT are not required.

COMBO INPUT INSTRUCTIONS

<u>Code</u>	<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Remarks</u>
T,H	2	1-12	BCD	Any case identification desired by the user.
T,H	1	13	NCASE	(This entry for first COMBO case <u>only</u> .) Number of COMBO cases to be run.
T,H	1	14	NSET**	Type data being run on the chain. 1 - TEMPEST and GAM 2 - TEMPEST and HRG 3 - TEMPEST only 4 - GAM only 5 - HRG only
T,H	1	15	LINK	Link we call after <u>last</u> case of COMBO data has been read in.
	1	18	ISAME	Are TEMPEST and HRG (or GAM) isotope densities the same? 0 - Yes 1 - No
T,H	1	19	NGP	Total number of Groups. (Including the thermal group if NSET < 3.)
T,H	1	20	NISO	Total number of isotopes used to determine the spectrum. (Maximum - 50)
T,H	1	21-70	ISO	SIGMA-3 Number for each isotope used to determine the spectrum.
T,H	0	71-120	DEN*	Densities of the isotopes used to determine the spectrum. (If TEMPEST and GAM densities are different put TEMPEST concentrations in TCON array.)
	0	4401-4450	TCON	If ISAME = 1 enter TEMPEST isotope densities here. If ISAME = 0 no entry necessary.
T	0	121	TEMP	Temperature (TEMPEST input temperature) (If cell-neutron temperature; if reactor-core temperature)

* See footnote on page 29.

** See footnote on page 29.

Code	Format	Location	Name	Remarks
T	0	122	EMIN	Minimum energy for averaging thermal group.
T	0	123	EMAX	Maximum energy for averaging thermal group.
T	0	124	BUCK	Buckling (B^2 for thermal group only).
T	1	125	LIST	Enter a non-zero number here to get a Library listing from TEMPEST.
T	1	126	MTYPE	Type of moderation (thermal) 1 - Heavy 2 - Light 3 - Maxwellian
T	1	128	NMOD	Number of moderator isotopes.
T,H	1	129	DUM2(1)**	Should COMBO data tape be rewound? 0 or blank - No. 1 - Yes.
T	1	131-180	IMOD	SIGMA-3 numbers for moderator isotopes. (Maximum - 50)
T	0	181-230	DMOD	Densities of the moderator isotopes in corresponding order with IMOD array.
H	0	282	GAMID	The HRG or GAM Tape Identification Number is entered here in an E10.0 format.
H	1	283	ICALC	Type calculation 1 - Pl calc. is being used. 2 - Bl calc. is being used. 3 - Spectra is to be read in.
H	1	284	ISRCE	Source: 0 or Blank - Unit source in one group. 1 - U-233 fission spectrum 2 - U-235 fission spectrum 3 - Pu-239 fission spectrum 4 - Pu-241 fission spectrum 5 - Cf-252 fission spectrum 6 - Po-Be (Whitmore - Baker) 7 - Po-Be (Cochrane - Henry) 8 - Ra-Be (Hill)

** See footnote on page 26.

<u>Code</u>	<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Remarks</u>
H	1	285	ISGPN	If unit source in one group, specify group number here. (IF ISRCE=0)
H	1	286	IOUT	1 - Output to A3 and B7 (TAM LIBE.) 0 - Output to A3 only 1 - Output to B7 (TAM LIBE.) only
H	1	287	IAGE	Should age calculation be made? 0 - No 1 - Yes
H	1	288	MICRO	Should microscopic cross sections be calculated? 0 - No 1 - Yes
H	1	289	IGEOM	Type geometry for resonance calculation 1 - Slab 2 - Cylinder 3 - Sphere (not available for CALX)
H	0	290	STEMP	System temperature in degrees Kelvin for resonance integral calculation
H	1	291	ITO**	Output control, additional data: (For HRG only) 0 - Normal output + N - An additional one-group average of σ_a , σ_c , and σ_f over the top N broad group is pro- vided for each nuclide. - N - Broad group cross sections are punched as specified below. -1- Program S-XIII with dummy thermal in-group values. -2- Program S-XIII with thermal in-group read in. -3- HFN, zero diagonal transfer matrix. -4- HFN, non-zero transfer matrix. -5- DTF/2DF, F format -6- DTF/2DF, E format.

** See footnote on page 26.

<u>Code</u>	<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Remarks</u>
H	1	292	JTO**	Output Control, additional data: (HRG only) 0 - Normal output 1 - Fine group Flux written to logical unit 4 at end of case. -1 - Five group fluxes and currents are punched, 6 per card, for future HRG input.
H	1	293	NTO**	Output Control (HRG only) a) As a data suppressor: 0 - Normal output 1 - Suppress printing of transfer matrices b) As punch control: (Used only if -3 or -4 of ITO input is used.) 0 - Punch macroscopic cross sections for HFN. -1 - Punch nuclide cross sections for HFN N - Number of groups to which down- scattering occurs when punching cross sections for DTF/2DF. (E10)
H	0	301-368	ENERGY	Boundary energies for each <u>epithermal</u> group. (From lower boundary of highest energy to lower boundary of lowest energy. Lower boundary of lowest energy should equal EMAX.)
H	0	401-468	FLUX	Flux for each group. (This entry necessary only if Location 283 contains a 3).
H	1	501-550	ISEL*	Is there self shielding for this isotope of the ISO array? 0 - No self shielding for this isotope 1 - There are self shielding factors for this isotope
H	1	551-600	ITGP*	0 - Self shielding is by broad group 1 - Self shielding is by fine group

* See footnote on page 26.

** See footnote on page 26.

<u>Code</u>	<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Remarks</u>
H	0	601-4000	SFACT*	Self shielding factors for isotopes as specified by the ISEL array. <u>NOTE:</u> This is a two-dimension array and is indexed by group number and isotope number. Ex.: SFACT (Ngp,Iso) Factors for each group for a particular isotope are read in, then factors for each group for the next specified isotope are read in, etc.
H	1	4001-4050	IRESSS*	Enter a 1 here for isotopes of the ISO array that require resonance parameters.
H	0	4051-4300	SIGMA*	(Necessary only for those isotopes requiring resonance self shielding. One card for each isotope.)
H		4051-4055		Parameters for first isotope of the ISO array.
		4051	SIGMA-M	Moderator cross section per absorber atom.
		4052	SIGMA-P	Total scatter cross section per absorber atom
		4053	SIGMA-Eff	Effective cross section for unresolved resonance calculation
		4054		Lumped nucli density per barn-cm
		4055	LBAR	LBAR in cm
		4056-4060		Parameters for second isotope of the ISO array
		4061-4065		Parameters for third isotope of the ISO array
		4066-4101		Etc.

* See footnote on page 26.

<u>Code</u>	<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Remarks</u>
H	1	4301	IP1	Necessary only if P1 calculation is being made 0 - Leakage by broad group 1 - Leakage by fine group
H	0	4302	BK1	Necessary for B ₁ calculations only. Enter B (not B ²) for epithermal groups only. (one entry)
H	1	4303	IB1	Necessary only if B1 calculation is being made. 0 - B1 approximation 1 - P1 fourier transform method (α_n set to 1.0)
H	0	4304-4371	PLEAK	Necessary only if P1 calculation is being made. PLEAK is leakage factor for groups 1, 2, 3, ... NGP. In case of fine group structure PLEAK entries for 1-68 groups are necessary. <u>NOTE:</u> If leakage factors are zero, put a 0.0 entry in location 4304 and the program will automatically assign leakage factors of -1.0×10^{-10} to each group.
H	1	4372	NEXT	NEXT is the link number that HGR or GAM should call after each TAM Library has been made. <u>NOTE:</u> If NEXT is positive, the TAM Library will be rewound. If NEXT is negative the TAM Library will <u>not</u> be rewound, thus allowing the Libraries to be stacked.
H	1	4373	NCHAIN	Tape number that Link NEXT is on.

- * These variables are dimensioned to 50 in accord with the ISO array. Entries in these arrays must pertain to a particular isotope and therefore must correspond in position to the ISO array. Example: If ZR is the 5th isotope in the ISO array, then the density of ZR must be entered in the 5th position of the DEN array. Also, if there are self shielding factors for, say U-238, for ISEL(2), and a 1 or 0 for ITGP(2), depending on type Group. The SIGMA array is handled similarly except there are five items entered for each isotope.
- ** Different from input as found in USER'S MANUAL FOR HFN AND CALX CHAIN⁽⁸⁾

SIGMA-3H INPUT INSTRUCTIONS

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Remarks</u>
2	1	KBCD	KBCD will be second half of HFN name.
2	2-12	KBCD(2-12)	66 character heading.
1	14	NGROUP	No. of groups. Max: 20
1	15	NTHERM	No. of thermal groups (1).
1	16	ISO	No. of isotopes for which cross sections are wanted (does not include gross fission products generated in SIGMA-3H).
1	17	IMIX	No. of mixtures to mix (max. 10 counting GFP's).
1	18	NMIX	Total number of mixture components.
1	19	LINK	Chain link number to call next 0 - rewinds Tam Library before next case. (-) - does not rewind Tam library before next case. (+) - goes on to next link.
1	20	ITAPE	Chain tape number on which LINK is located. If zero, calls exit rather than next link.
1	24-28	NFP	Gross fission product control for each of the five GFP tables on the SIGMA-3 Library. 0 - No. GFP from this fission table. 1 - Mix. GFP for this fission table excluding isotopes specified in NISO array. -1 - same as +1 except exclude mixture components also.
1	39-138	NISO	SIGMA-3 isotope numbers for those isotopes for which cross sections are wanted.
1	139-338	MIX	SIGMA-3 isotope numbers for all mixture components.
1	429	MISC(91)	Non-zero to add this set of cross sections to an existing data tape. Automatically set to zero every case.

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Remarks</u>
1	430	MISC(92)	Number of HFN data tape binary output is to be written to if other than B6.
0	494-513	BSQ	Buckling. One for each group.
0	574-673	DENS	Concentrations of the ISO isotopes named in the NISO array. (Needed only when shielding calculation is done.)
0	674-2673	FRAC	Volume fractions or concentrations of the mixture components of each mixture. (Each mixture occupies 200 successive locations)
	674-873		Volume fractions or concentrations of each component of mixture one. (Named 001MIX.)
	874-1073		Volume fractions or concentrations of mixture two. (Named 002MIX.)
	1074-1273		Etc. for specified number of mixtures.
			<u>NOTE:</u> Volume fractions give microscopic cross sections.
			NMIX
			$\sigma = \sum_{i=1} \text{FRAC}_i * \sigma_i$
			Concentrations give macroscopic cross sections.
0	20418-20421		Gammas used in calculation of shielding factor for thermal group.
	20418	GAMMA ₁ *	
	20419	GAMMA ₂	
	20420	GAMMA ₃	
	20421	GAMMA ₄	
			$f_{th} = \frac{\gamma_1 + \gamma_2 \sum_a^{th}}{1.0 + \gamma_3 \sum_a^{th} + \gamma_4 \left(\sum_a^{th} \right)^2}$

*GAMMA₁ and GAMMA₅ are set to 1.0 after each case.

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Remarks</u>
0	20422-20425		Gammas used in calculation of shielding factor for Pu-240 isotope.
	20422	GAMMA ₅ *	$f_{240} = \frac{\gamma_5 + \gamma_6 N_{240}}{1.0 + \gamma_7 N_{240} + \gamma_8 (N_{240})^2}$
	20423	GAMMA ₆	
	20424	GAMMA ₇	
	20425	GAMMA ₈	
			Where N_{240} is Atomic Density of Pu-240.
0	20426	GDUM(1)	Used only for special type shielding factor calculation for Pu-240. Not applicable for normal SIGMA-3H runs.
	20427	GDUM(2)	
	20428	GDUM(3)	
	20429	GDUM(4)	
0	20431-20630	FACT	<p>Fraction of the calculated shielding factor that you wish to use to shield thermal cross sections.</p> <p>To find FACT input locations for particular isotopes, add their SIGMA-3 numbers to 20430.</p> <p>EXAMPLE: SIGMA-3 number for Pu-239 is 33. 20430 + 33 = 20463 At location 20463 enter the FACT value.</p>

*GAMMA₁ and GAMMA₅ are set to 1.0 after each case.

HFN INPUT INSTRUCTIONS (PCT VERSION)

1. MISCELLANEOUS CONTROL AND TAPE INFORMATION

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
1	1	$20 \leq N_1 > 1$	Number energy groups
1	2	$N_2 = 0$	Scattering transfer can only take neutrons from a group to the next lower energy (higher indexed) group
		$N_1 \geq N_2 > 0$	Neutrons may be scattered from any group into any lower energy group. In addition, neutrons may be upscattered from any lower energy group into group number N_1 , $N_1 \geq N_2$, (i.e., N_2 is index of first thermal group)

Example: In a five group calculation, with two thermal groups,
 $N_1 = 5$ and $N_2 = 4$.

1	3	$N_3 = 0$	All information on external sources will be input, by space points, into locations 17882 through 19981. This option includes the case where no external source is present.
		$N_3 = 1$	The external source to the right of each space point, SP_i , is input for all points. The program will set the source to the left of the point, SM_i , equal to SP_i unless a non-zero value for SM_i is input.
		$N_3 = 2$	The external source is constant within each region. The regional values of the external source are input to locations 20195 through 20244.
1	4	$N_4 = 0$	All cross section data is input from cards, and no data tape is to be generated.
		$N_4 > 0$	Use the cross section data which is in the library at the end of this input record to update the data tape. In case data for a given group are found both on the old data tape (if any) and in the card input, the data

<u>Format</u>	<u>Location</u>	<u>Entry</u>
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which was read from cards will replace the data from the library tape. Sixty Hollerith characters should be entered into locations 101 through 110 (at six per location using format two) giving the reference for data for first material. The reference for the second material should go into locations 111 through 120, etc.

$N_4 = 0$

Scan the data tape mounted on unit IT1 (Location 5) pulling off data for those materials (with correct group structures) which have been listed as being in the incore library. N_4 will be set to zero, after data is successfully read, to reduce unnecessary tape handling.

1	5	IT1 = 0
		IT1 > 0

No data tape is input.

Data tape is mounted on tape until IT1. This tape will be searched, if $N_4 < 0$, for cross section data. If $N_4 > 0$, the data on this tape will be merged with that which was input on cards, to make a new data tape on unit number IT2. Suggested entry: 6 for CHAIN RUNS.

1	6	IT2 = 0
		IT2 > 0

No new data tape will be generated.

If data tape updating (using old tape on IT1) or data tape generation (using the in-core library, with IT1 = 0) has been specified, the resultant tape will be on unit IT2.

NOTE: After an updating pass has been completed, the contents of locations 5 and 6 are interchanged. Thus, in the absence of input to the contrary, successive updating passes will result in the latest data tape alternating between the two tape units. In this way, the tape may be updated and used on the input pass immediately following the last updating pass, with HFN keeping track of the most up-to-date tape. IT2 and IT1 should always be between 5 and 10, inclusive.

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
1	7	$100 \geq N_7 > 0^{**}$	Indicates that during the tape updating process, data for N_7 materials are to be detected. The material names are entered into the locations starting at 3752. The numbers of groups to which the effected data apply are given starting in Location 3952. The group coupling schemes (equivalent of N_2) are given starting in Location 4052.
1	8	$N_8 = 0^{**}$	Normally
		$N_8 = 1$	List, in a compressed form, the data which is being added to the new data tape as it is added.

NOTE: The names, numbers of groups, group coupling schemes, and references for all materials encountered on each tape update pass are always listed on the output. N_8 controls listing of the actual cross sections on the tape.

1	47	N_{47}^{**}	Link to call next. If zero reads more input.
1	10	$N_{10} = 0$	No effect
		$N_{10} \neq 0$	After getting cross section from library tape, return for more input before running case. Thus, individual neutron parameters from the tape may be changed before use. N_{10} will be reset to zero.
1	11	$N_{11} = 0$	No effect
		$N_{11} \neq 0$	Clear all data from core immediately, then read input. Any input read in the same input record with this entry (before the next 9 card) will also be destroyed.
1	12	$N_{12} = 0$	Save fluxes and fission densities computed for this case as a starting for the next case.
		$N_{12} = 1$	After this case is run, clear fluxes, fission densities, and pointwise external sources. Following cases start from flat (or input) flux guess.

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
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2. CASE SPECIFICATION

1	13	$N_{13} = 0$	Slab geometry
		$= 1$	Cylindrical geometry
		$= 2$	Spherical geometry
1	14	$50 \geq NR > 0$	Number of homogeneous regions
1	15	$N_{15} = 0$	Compute direct flux
		$= 1$	Compute adjoint function
		$N_{15} = 2$	Compute direct, adjoint functions and their gradients at each point. Also, compute volume integrals of the form. $\int \nabla \phi_i + \nabla \phi_i dV$; and $\int \phi_i \phi_j dV$ N_{15} will be set to 0 at the end of this sequence.
1	28	$N_{28} = 0$	No effect
		$N_{28} = 1$	Compute gradients of the converged (direct or adjoint) fluxes. If $N_{15} = 2$, this entry is not needed.
1	35	$N_{35} = 1$	A true power density calculation will be performed using the fission cross sections located where the in-scattering cross sections normally are.
		$N_{35} \leq 0$	A fission neutron production calculation will be performed using $\nu \Sigma_f$.

(Data tapes made up by SIGMA-3H will have the fission cross sections in their appropriate place.)

3. CRITICALITY SEARCH CONTROL

When this option is exercised, HFN varies a single specified parameter in an attempt to attain a pre-specified multiplication. Each calculation involving a new value of the parameter looks, in the output, like a separate case. The difference is that, in contrast with the running of separate cases, no input is read between calculations.

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
1	16	$N_{16} = 0$	For no search, ignore Locations 17-21
		$N_{16} = LOC > 0$	Location of variable parameter
1	17	$N_{17} = 0$	No effect
		$N_{17} > 0$	Remake any material mixtures each time the parameter is varied.
1	18	$N_{18} > 2$	Maximum number of calculations to be performed in the attempt reproduce the desired multiplication.
0	19	k	Desired multiplication
0	20	dk	Accuracy to which k must be reproduced on a successful criticality search
0	21	$(\Delta k)^{-1}$	Estimate of parameter change necessary to <u>increase</u> the calculated k by 1%. This number is used only to form an estimate of the parameter, for use in the second calculation, using the results of the first.

4. DETECTOR TRAVERSE CALCULATION

1	29	$N_{29} = 0$	Do not normalize computed activities.
		$N_{29} > 0$	Normalize each traverse to 1.0 at HFN mesh point Number N_{29} .
		$-N'_{29} < 0$	Normalize all traverses so that the activity for traverse Number 1 is unity at mesh point Number N_{29} . The same normalizing factor will be used on all traverses.
1	30	Not used	
1	31	$N_{31} \geq 0$	Number of traverses $N_{31} \leq 10$; also $N_{31} * (\text{No. groups}) \leq 100$.

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
1	32	$N_{32} = 0$	Traverse ratios, for first traverse, will not be computed.
		$N_{32} > 0$	At each mesh point, compute the activity ratio for Traverse 1: $\frac{A_1}{A_{N_{32}}}$ (before normalization)
		$-N_{32} < 0$	At each mesh point, compute the activity fraction for Traverse 1: $\frac{A_1}{A_{N_{32}}} - 1$ (before normalization)
1	33	N_{33}	Same logic as Location 32, except pertains to traverse Number 2.
1	34		etc.
2	13852	DETECT ₁	12 Hollerith name for first detector material
2	13854	DETECT ₂	12 Hollerith name for second detector material
	etc.		
0	13752	ACTCRS _{1,1}	Group one activation cross section for detector type one.
0	13753	ACTCRS _{1,2}	Group two activation cross section for detector type one.
	etc.		
0	13752+	ACTCRS _{2,1}	Group one activation cross section for detector type two.
	(no. grps)		

5. OUTPUT CONTROL OPTIONS

Flux and Power Normalization

0	42	$A = 0.0$	Normalize "power" (fission neutron production rate) so that average over <u>core</u> region(s) is 1.0, for output listing.
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<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
		A > 0	Normalize core power to total output of A megawatts (for purpose of converting from neutrons to MW, HFN assumes $\nu = 2.46$, with 200 MeV per fission).
1	43	$N_{43} = 0$	Normalize fluxes, for output, to be consistent with the power
		$N_{43} > 0$	Normalize flux, group N_{43} , to unity at spatial mesh point number N_{44} .
1	44	N_{44}	Mesh point number for flux normalization.
6. <u>ITERATION CONTROLS</u>			
1	53	LMAX	Maximum number of iterations allowed. Set to 100 if not input. Suggested input: none.
0	57	EPSK	Convergence criterion. The problem is assumed to have converged if the fractional difference between system eigenvalues on two successive iterations is less than EPSK. Set to 10^{-7} if no input. If set negative, this convergence test is bypassed forcing HFN to try for flux convergence. Suggested input: none.
0	58	EPSPHI	Convergence criterion. The maximum fractional change in flux at any point, in any group, on two successive iterations must be less than EPSPHI for convergence. Set to 10^{-4} if no input. If set negative, this convergence test is bypassed forcing HFN to try for eigenvalue convergence. Suggested input: none.

7. OUTPUT LIST SUPPRESSION

Suppress Selected Portions of Output by Entering
a Non-zero Number in Locations Indicated

<u>Format</u>	<u>Location</u>	<u>Meaning</u>
1	62	Transfer matrices
1	63	Few group parameters
1	64	Pointwise flux and fission density
1	65	Calculated reactivity as a function of iteration, except final iteration (neg. entry suppresses all reactivities).
1	66	Average fluxes, fission densities, and leakage cross sections computed therefrom.
1	67	Pointwise gradient
1	68	Perturbation integrals
1	69	Direct-adjoint flux gradient product (point- and group-wise).
1	70	Direct-adjoint flux product (point- and group-wise).
1	71	All traverse output
1	72	Flux adjoint product traverse only
1	73	Average traverse activity
1	74	Unnormalized traverse activity
1	75	Normalized traverse activity
1	76	Traverse ratio data
1	77	Albedoes, region radii, calculation description

8. INITIAL GUESSES FOR FLUX, FISSION DENSITY

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
0	10602	FLUX ₁ **	Estimate of group one flux, at first mesh point
0	10603	FLUX ₂	Estimate of group one flux at second mesh point
		etc.	

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
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NOTE: If a total of N mesh intervals have been specified in the HFN input, then group one flux estimates are input to locations 10602 through $10602 + (N + 3) - 1$. ($N + 3$ points are used, after insertion of an extra point at each outside boundary.) Group two fluxes go from locations $10602 + (N + 3)$ through $10602 + (N + 3) - 1$. Flux estimates for other groups follow, in a similar manner.

0	1151	FP_1	Estimate of fission neutron production to right of mesh point 1.
0	1152	FP_2	
	etc.		
0	2202	FM_2	Estimate of fission neutron production to left of mesh point 2.
0	2203	FM_3	
	etc.		

NOTE: If initial guesses are not made for all quantities for all points, HFN ordinarily sets those values of the fission density and flux, which are zero, to unity. This particular feature may be bypassed by setting location 26 to unity (format 1).

9. JOB AND MATERIALS IDENTIFICATION

2	13872	18 Hollerith - user's name (6 Hollerith/location)
2	13875	18 Hollerith - date
2	13878	18 Hollerith - case identification
2	17381	12 Hollerith - name of first material in (in-core) cross section library
2	17383	12 Hollerith - name of second material in (in-core) cross section library.

NOTE: The maximum allowable number of materials in the in-core library is always less than 101, and varies below 100, depending on group structure. The exact dependence is discussed in detail in the HFN document HW-71543, which describes the actual entry of cross section data, from card input, into the in-core library.

10. REGION SPECIFICATIONS

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
0	17781	R_0	Inside radius of inner region
0	17782	R_1	Outside radius, region 1
0	17783	R_2	Outside radius, region 2, etc.
0	17731	*EN_1	Number of mesh intervals in region 1. This does not include the extra mesh interval inserted near left boundary.
0	17732	*EN_2	Number of mesh intervals in region 2.
0	17733	*EN_3	etc. (Number of space points $\times N_1 \leq 2100$)

NOTE: A region, j , is specified as being a portion of the core (for core power calculation purposes) by entering $-EN_j < 0$, in which case the number of mesh intervals in region j is taken equal to EN_j .

2	17581	REG_1	12 letter BCD giving name of material in region 1.
2	17583	REG_2	Material name for region 2.
2	17585	REG_3	etc.

NOTE: Region material names must, ordinarily, correspond exactly to the material names used in the cross section library. The only exception occurs when the material in a region is mixture of one or more materials in the library. In this case, a distinct name, which will be assigned to the mixture, should be used. If the name of an existing material is used for a mixture, the cross section data for that material will be replaced by the data computed for the mixture. If two or more regions are composed of a mixture, the mixture need only be specified once.

1	20245	$N47_1 = 0$	Region one material is already in library (either from data tape, input cards, or a previous mixing).
		$N47_1 > 0$	Material in region one is to be manufactured from a mixture of $N47_1$ materials, the names and proportions of which are specified elsewhere. Material library storage will be set aside, and cleared for a new material, with the name REG_1 , if none already

exist. After clearing this area of the library, the mixture cross sections are computed as

$$j = j_1 + N47_1 - 1$$

$$\Sigma(\text{mixture}) = \sum_{j=j_1}^{j=j_1 + N47_1 - 1} \text{VOL}(j) * \Sigma(j) \quad N47 > 0$$

where $\text{VOL}(j)$ is the volume fraction of the j -th mixture component specified, (which is in the library with name PART_1) Σ denotes a typical cross section and $(j_1 - 1)$ materials have been used in making up mixtures for regions which are closer to the origin than the one for which mixing is presently being performed. $j_1 = 0$ for region 1, and for region j ,

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
		$j_1 = \sum_{i=1}^{j-1} N47_i$	$j > 1$
1	20245	$N47_1 < 0$	The same logic applies as for a positive entry, except that the data area set aside for the "mixture" is not cleared before use.
		$\Sigma(\text{mixture}) = \Sigma'(\text{mixture}) - \sum_{i=j_1}^{j=j_1 - N47_1 - 1} \text{VOL}(j) * \Sigma(j), N47 < 0$	
1	20246	$N47_2$	Same logic as above, but applied to region 2.
		etc.	

NOTE: $N47$ entries are not set to zero by the program. In order to save redundant mixing, they should be set to zero, via input, after being used.

2	20295	PART_1	12 letter name of material, already specified as part of library, which is first component of first mixture.
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<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
2	20297	PART ₂ etc.	Name of second mixture component
0	20495	VOL ₁	Volume fraction of first mixture component in first mixture
0	20496	VOL ₂	Volume fraction of second mixture component

Examples: See HFN Document HW-71545.

11. BOUNDARY CONDITIONS

0	20022	Left exterior boundary albedo for Group 1
0	20023	Left exterior boundary albedo for Group 2 etc.
0	20042	Right exterior boundary albedo for Group 1
0	20043	Right exterior boundary albedo for Group 2

NOTE: An albedo of 1.0 denotes a center of symmetry. A zero albedo is used at the physical boundary of a reactor, and an albedo of -1.0 should be used on cases where the dimensions read into HFN are extrapolated dimensions.

0	20062	Left exterior boundary surface source for Group 1
0	20063	Left exterior boundary surface source for Group 2 etc.
0	20082	Right exterior boundary surface source for Group 1
0	20083	Right exterior boundary surface source for Group 2 etc.

NOTE: If Location 27 is set to unity (format 1) then the "albedo" entry is interpreted as being a fixed extrapolation distance, in cm. Equation (13) of HW-71545 becomes:

$$\nabla \phi_0 = \frac{\phi_0}{A^-} + \frac{J_{in}^-}{D_0}$$

<u>Format</u>	<u>Location</u>	<u>Entry</u>	<u>Meaning</u>
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NOTE: If Location 27 is set to -1, then Cohen's formula for the extrapolation distance from a curved surface is used to compute the right exterior boundary (only) condition:

$$l = \frac{A^+}{1 + 1.065669 \left(\frac{\mu_{NR}^D}{R_{NR}} \right)}$$

where the right "albedo" is the extrapolation distance, in transport mean free paths, from a plane boundary (equals 2/3 according to diffusion theory).

12. EXTERNAL SOURCE SPECIFICATIONS

0	17882	SP ₁	External source to right of HFN mesh point Number 1
0	17883	SP ₂	External source to right of HFN mesh point Number 2.

NOTE: Input to SP array destroyed if N₃ = 2, specifying a region-wise constant source

0	18933	SM ₂	External source to left of HFN mesh point Number 2
0	18934	SM ₃	External source to left of HFN mesh point Number 3

etc.

NOTE: Input to SM array is destroyed if N₃ = 1, specifying SM_i = SP_i, or if N₃ = 2.

0	20195	SOURCE ₁	Strength of spatially constant source in Region 1.
0	20196	SOURCE ₂	

etc.

NOTE: The SOURCE array is ignored unless N₃ = 2.

SCHWAC INPUT

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Input</u>
1	20597	IT2	Tens and unit digit give output tape unit No. If hundreds digit, N, is nonzero average material will be added to already existing tape. SCHWAC looks through tape for last material; stops in error if it cannot find it within the first 100 N materials.
1	21138	LINK	Next link to call. If zero, calls HFN with no HFN data clearing.
1	21139	NAVE	No. of averages (10 or less). If zero, do one.
2	21140	NAME	12 Hollerith name for result of 1st ave.
2	21142		12 Hollerith name for result of 2nd ave.
2	21144		etc., up to 10 names.
1	21160	NREG	If zero, averages all regions into one.
1	21160,21161		Indices of first, last regions of 1st average.
1	21162,21163		Indices of first, last regions of 2nd average.
1	21164,21165		etc.

NOTE: SCHWAC does not disturb the data arrays loaded into HFN via LISTIV input, so change cases may be run on HFN after returning from SCHWAC. The above SCHWAC input is unfortunately clobbered so SCHWAC needs a complete new set each case.

TEMPEST INPUT INSTRUCTIONS

<u>Card</u>	<u>Cols.</u>	<u>Format</u>	
1	1-14	H	BINARY LIBRARY (must be these exact letters.)
	70-72	I	Logical Tape Unit for Cross Section Library. (If negative expects a CLT).
2	1-4	H	DATA (must be these exact letters).
3	1-72	H	Title cards (up to 12) BCD.
4	1-6	H	X-LAST (must be these exact characters.) Signifies end of title cards.
5	1-12	E	Temperature (TEMP).
	13-24	E	Minimum energy for averaging. (EMIN)
	25-36	E	Maximum energy for averaging. (EMAX)
	37-48	E	Buckling.
	49-60	E	EBRAKE (Leave Blank)
6	1-12	I	Type of moderation (MTYPE) 1 = heavy approximation 2 = light approximation 3 = Maxwellian distribution
	13-24	I	Mode of hydrogen bonding. (MOHB) 201 = free gas 230 = water 232 = Butylene
	25-36	I	Total number of absorption isotope that determine the spectrum (NISO)
	37-48	I	Number of moderators. (NMOD)
	49-60	I	Nonzero number to get library listing. (LIST)
7	1-3	I	Isotope number used in spectrum determina- tion. (ISO)
	4-12	E	Density of above Isotope. (DEN)
	13-15	I	Isotope number of second isotope used in spectrum determination.
	16-24	E	Corresponding density.
	etc.		Until all isotopes listed (6 per card).
8			Needed only if nonzero number of moderators and Maxwellian distribution not used.
	1-13	I	Number of first moderator. (IMOD)
	4-12	E	Density of first moderator. (DMOD)

<u>Card</u>	<u>Cols.</u>	<u>Format</u>	<u>Input</u>
	13-15	I	Number of second moderator.
	16-24	E	Density of second moderator.
	etc.		(6 per card).
9	1-12	I	Number of isotopes to be averaged (if negative, will average all isotopes in library in which case no further cards are needed. Negative also causes average cross section to be written B7.) (NAVE)
	13-24	I	ITLNK. Link to call after each TEMPEST CASE
10	1-12	I	Number of first isotope to average (NUMA(I)
	13-24	I	Number of second isotope to average
	etc.		(6 per card).

HRG AND GAM INPUT INSTRUCTIONS

The format for input HRG is described below. The differences between HRG input and GAM-I input as described in GA-1850 are such that GAM-I data can be used by HRG with at most minor modifications. These modifications are: a) the Card 0 formats differ (the Card 0 format is not described in GA-1850 but the data are nevertheless needed) and b) input data for those nuclides requiring resonance integral calculations in HRG but not in GAM-I must also include a Card 8.

HRG AND GAM INPUT INSTRUCTIONS

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>Code Mnemonic</u>	<u>Input</u>
Card 0 is needed only in starting a run.				
0	1-6	I6	NOID	HRG Library Tape identification number.
Sufficient Cards 1-11 are needed with each case for a complete specification.				
1	1-72	12A6	BXCX(I)	Case title card. This information is printed as heading on each page of output.
2	1-12	E12	WTP (MTP)	Type of problem: 1.0 - P1 2.0 - B1 3.0 - Fine group fluxes to be read in; fine group currents zeroed internally. 4.0 - Find group fluxes and currents and P1 leakage terms to be read in. (HRG only). 5.0 - Fine group fluxes and currents and B1 transform parameter to be read in (HRG only).
	13-24	E12	WSTU (MSTU)	Source: 0.0 - Unit source in one fine group. 1.0 - U ²³³ fission spectrum. 2.0 - U ²³⁵ fission spectrum. 3.0 - Pu ²³⁹ fission spectrum. 4.0 - Pu ²⁴¹ fission spectrum. 5.0 - Cf ²⁵² fission spectrum. 6.0 - Po-Be (Whitmore-Baker) 7.0 - Po-Be (Cochrane-Henry) 8.0 - Ra-Be (Hill)

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>Code Mnemoic</u>	<u>Input</u>
	25-36	E12	WGHUS (MGHUS)	Unit source specification: (Needed only if 0.0 in cols. 13-24) Group number of fine group having the unit source.
	37-48	E12	STEMP	System temperature, °K for resonance integral calcula- tion (Used only by GAM).
	49-60	E12	XBCD	Output control, broad group microscopic cross sections: 0.0 - Normal output. -1.0 - Output to TAM Library only. 1.0 - Normal plus output to TAM Library.
	61-63	I3	ITO	Output control, additional data: (HRG only) 0 - Normal output +N - An additional one-group average of σ_a , σ_c , and σ_f over the top N broad group is provided for each nuclide. -N - Broad group cross sec- tions are punched as specified below. -1 - Program S-XIII with dummy thermal in- group values. -2 - Program S-XIII with thermal in-group read in. -3 - HFN, zero diagonal transfer matrix. -4 - HFN, non-zero diagonal transfer matrix. -5 - DTF/2DF, F format -6 - DTF/2DF, E format

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>Code Mnemoic</u>	<u>Input</u>
	64-66	I3	JTO	Output control, additional data: (HGR only) 0 - Normal output 1 - Fine group fluxes written to logical unit 4 at end of the case. -1 - Fine group fluxes and currents are punched, 6 per card, for future HGR input.
	67-69	I3	NT0	Output control, additional data: (HGR only) (used only if -3 thru -6 in cols. 61-63) 0 - Punch macroscopic cross sections for HFN -1 - Punch nuclide cross sections for HFN. N - Number of groups to which down-scattering occurs when punching cross section for DTF/2DF (≤ 10).
3	1-12	E12	POI (NOI)	Number of nuclides
	13-24	E12	PNOAG (NOAG)	Number of broad groups (≤ 33)
	25-36	E12	PMAGE (MAGE)	Age calculation option: 0.0 - No 1.0 - Yes
	37-48	E12	PMICR	Microscopic cross section to be averaged over broad groups: 0.0 - No 1.0 - Yes
	49-60	E12	SJGM (JGM)	Geometry specification for resonance integral calculation: 0.0 - None 1.0 - Slab 2.0 - Cylinder 3.0 - Sphere

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>Code Mnemonic</u>	<u>Input</u>
4	1-72	6E12	CEG(I)	Broad group energy boundaries: Lower energy boundary, in electron volts and in decreasing magnitude, 6 values per card for as many broad groups as given by PNOAG, Cols. 13-24 of Card 3.
5A	1-72	6E12	AJ(I)	Fine group currents: (HRG only) (Needed only if 4.0 or 5.0 in cols. 1-12 of Card 2). Fine group currents to be read in, 6 per card, 68 total.
5B	1-72	6E12	APHI(I)	Fine group fluxes: (Needed only if 3.0 4.0, or 5.0 in cols. 1-12 of Card 2). Fine group fluxes to be read in, 6 per card, 68 total.

Nuclide Data Cards. A set of cards 6-8 must be supplied in order, as needed, for each nuclide; the sets must be arranged in ascending order of nuclide identification numbers.

6	1-12	E12	PMANU (MANU)	Nuclide identification number (see attached list)
	13-24	E12	ADEN	Nuclide density per barn-cm. A negative value indicates nuclide cross sections should be converted to macroscopic form (multiplied by ADEN) before being written and punched as output.
	25-36	E12	SSON	Self-shielding factor input specification: 0.0 - No 1.0 - Yes

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>Code Mnemonic</u>	<u>Input</u>
6 (cont)	37-48	E12	HATSS	Self-shielding factor type specification: (Needed only if 1.0 in cols. 25-36) 0.0 - Broad group 1.0 - Fine group
7	1-72	6E12	PSFS(I)	Self-shielding factors: (Needed only if 1.0 in cols. 25-36 of Card 6). Self-shielding factors to be read in, 6 per card, for a total of: PNOAG values (cols. 13-24 in Card 3) if 0.0 in cols. 37-48 in Card 6; 68 values if 1.0 in cols. 37-48 in Card 6.
8				Resonance integral calculation data: (Needed only if nuclide requires a resonance integral calculation. Such nuclides are indicated by an asterisk in the list of identification numbers).
	1-12	E12	SIG(1,1)	σ_m , admixed moderator scattering cross section per atom of this nuclide ($\sigma_m = 0.0$ for pure metal), used in IM approximation.
	13-24	E12	SIG(2,1)	σ_p , total off-resonance scattering cross section per atom of this nuclide ($\sigma_p = \sigma_m = \sigma_{\text{potential}}$), used in NR approximation.
	25-36	E12	SIGU(1)	σ_m , eff, effective total off-resonance scattering cross section per absorber atom of this nuclide, based on Wigner's rational approximation, used in unresolved resonance calculation.

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>Code Mnemonic</u>	<u>Input</u>
8 (cont)	37-48	E12	AR(1)	Nuclide density of resonance absorber in single equivalent "fuel lump", per barn-cm.
	49-60	E12	RBAR	Mean chord length, $\bar{\ell}$, of single equivalent "fuel lump" in cm.
	61-72	E12	T(1)	Temperature of "fuel lump" in °K (HRG only).
<u>P1 Calculation</u> (Cards 9 and 10 needed only if 1.0 or 4.0 in cols 1-12 of Card 2).				
9	1-12	E12	HATLT	Input control, leakage factors: 0.0 - Broad group 1.0 - Fine group
10		6E12	AL1(I)	Leakage factors: Leakage factors to be read in, 6 per card for a total of PNOAG values (cols 13-24 in Card 3) if 0.0 in cols 1-12 of Card 9, 68 values if 1.0 in cols 1-12 of Card 9.
<u>B1 Calculation</u> (Card 11 needed only if 2.0 or 5.0 in cols 1-12 of Card 2).				
11	1-12	E12	TKN	Fourier transform parameter, k, the square root of the buckling.
	13-24	E12	WAG	Control parameter: 0.0 - B1 method 1.0 - P1 Fourier transform method ($\alpha_n = 1.0$).

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>Code Mnemonic</u>	<u>Input</u>
12				Thermal cross sections for punch option: (HRG only). This card is necessary only if cols 61-63 of Card Type 2 (ITO) contain -2. One card of this type is then required for each nuclide in this case (the number in cols 1-12 of Card Type 3). These cards appear directly behind the regular HRG input for this case.
	1-5	I5	ISO	HRG nuclide identification number.
	6-63	4E14	SNSG(I)	Thermal group cross sections for this nuclide as follows: $v\sigma_f$ P0(th-th) σ_{tot} P1(th-th)
13	1-3	I3	ILINK	Link number to call next. If this entry is <u>negative</u> the TAM Library will not be rewound.
	4-6	I3	ITAPE	(Not used on 1107 Runs)

NOTE: If making a TYPE I run (PSPL), card 13 is not used and should be omitted.

SIGMA-3C INPUT INSTRUCTIONS

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Input</u>
2	1	KBCD	72 character Hollerith headings will be used for CALX data tape identification.
1	14	NGROUP	Total number of groups (= 9 for CALX)
1	15	NTHERM	Number of thermal groups (= 1 for CALX)
1	16	ISO	Number of non-fuel burnable isotopes treated separately from gross fission products in burnup analysis; maximum 100
1	17	IMIX	Number of mixtures. These mixtures become the base materials in CALX and neither burn nor contain fuels. Presently either 1 or 2 for CALX.
1	18	NMIX	Number of mixture components; maximum 200
1	19	LINK	> 0 Chain link number to call next = 0 Rewind TAM tape, start another case. < 0 Start another case analyzing next TAM case.
1	20	ITAPE	= 0 Calls exit when through > 0 Chain tape number on which next link is located (3 for CALX system)
1	21	JXE	Set to unity to keep Xe-135, Sm-149, and I-135 at current equilibrium value during course of burnup.
1	24	KBND	Boundary conditions in CALX = 0 for cell = 1 for symmetric half reactors = 2 for homogeneous single region
1	25	KGO	Geometry control for CALX = 0 for slab = 1 for cylinder = 2 for sphere (currently unavailable)
1	26	NFP ₁	Set to unity to mix a gross fission product from table number 1.

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Input</u>
1	27	NFP ₂	Unity to mix GFP from Table 2
1	28	NFP ₃	Unity to mix GFP from Table 3
1	29	NFP ₄	Unity to mix GFP from Table 4
1	30	NFP ₅	Unity to mix GFP from Table 5
1	32	KDUMP ₂	Non-zero to dump thermal absorption cross section and TEMPEST data from which computed
1	33	KDUMP ₃	Non-zero to dump thermal fission information
1	34	KDUMP ₄	Non-zero to dump thermal transport information
1	35	KDUMP ₅	Non-zero to dump thermal scatter information
1	36	KDUMP ₆	Non-zero to dump fuel accounting data
1	37	KDUMP ₇	Dump NGROUP cross sections and GAM and TEMPEST isotope numbers for first KDUMP ₇ SIGMA-3 isotopes. If negative dump information only for SIGMA-3 isotope KDUMP ₇ .
1	38	KDUMP ₈	Non-zero to dump fission product yields, mixture components, and fractions
1	41-200	JBURN	The fuel isotopes of interest are specified in this array. See Table 3, Appendix I, for input locations for each isotope with reference to its particular owner.
1	201-300	NISO	SIGMA-3 numbers of the non-fuel isotopes of interest
	201	NISO ₁	SIGMA-3 number of first non-fuel isotope
	202	NISO ₂	SIGMA-3 number of second
	203	NISO ₃	Etc., for all non-fuel isotopes

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Input</u>
1	301-500	MIX	SIGMA-3 isotope numbers of mixture components
	301	MIX ₁	SIGMA-3 number of first-mixture isotope
	302	MIX ₂	SIGMA-3 number of second
	303	MIX ₃	Etc., for all mixture components
1	591	MISC ₉₁	A non-zero entry here will suppress writing of logical record number 1 on the CALX data tape (Suggested entry: None.)
1	592	MISC ₉₂	Non-zero will suppress writing of logical Record 2
1	593	MISC ₉₃	Non-zero will suppress logical Record 3
1	594	MISC ₉₄	Non-zero will suppress logical Record 4
1	595	MISC ₉₅	Non-zero will suppress logical Record 5
1	596	MISC ₉₆	Non-zero will suppress logical Record 6
1	597	MISC ₉₇	Non-zero to suppress logical Record 7. (If not type III problem, enter a 1 here)
2	601-640	KALL	Name of SIGMA-3 fuel isotope. A name must be entered for each fuel isotope used in the problem. To find the proper location for this name in the KALL array, add the isotope's SIGMA-3 number to 600. <u>Example:</u> If U-235 and U-238 are used, enter <u>b</u> U-235 in location 620 and <u>b</u> U-238 in location 623. (b indicates blank)
0	641	HEIGHT	Reactor or cell "height" When multiplied by thickness or radius gives volume for slab and spherical geometry, and gives cross section area for cylindrical geometry.
0	643	DXE	Starting guess at equilibrium Xe-135 density if location 21 is unity

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Input</u>
0	645	DI	I-135 equilibrium density guess
0	646	DENFP ₁	Initial concentration of GFP ₁
0	647	DENFP ₂	Initial concentration of GFP ₂
0	648	DENFP ₃	Initial concentration of GFP ₃
0	649	DENFP ₄	Initial concentration of GFP ₄
0	650	DENFP ₅	Initial concentration of GFP ₅
0	651	R ₁	Outer radius of first region (cm)
0	652	R ₂	Outer radius of second region (cm)
0	661-669	BSQ	Perpendicular buckling for each group to get effect of finite size on neutron spectrum (Enter a B ² value for each of 9 groups in successive locations)
0	741-900	DBURN	Initial concentrations for fuel isotopes as entered in the JBURN array for the fuel isotope being used. See Table 3, Appendix I. Example: 4.0×10^{-4} entered in location 830 would be the concentration of that portion of U-238 that belonged to owner two.
0	901-1000	DENS	Initial densities of the individual non-fuel isotopes
	901		Initial density of first non-fuel isotopes
	902		Initial density of second non-fuel isotopes
	903		Etc., for number of specified non-fuels
0	1001-1200	FRAC _{I,1}	Concentrations of each MIX in the first mixture (Base for region Number 1)
0	1001	FRAC _{1,1}	Concentrations of first mixture component (MIX ₁) in first mixture

<u>Format</u>	<u>Location</u>	<u>Name</u>	<u>Input</u>
	1002	FRAC _{2,1}	Concentrations of second component of first mixture
	1003	FRAC _{3,1}	Etc., for all components of mixture one
0	1201-1400	FRAC _{I,2}	Concentrations of each MIX in the second mixture (Base for Region 2)
	1201	FRAC _{1,2}	Concentrations of first component in second mixture
	1202	FRAC _{2,2}	Concentrations of second component in second mixture
	1203	FRAC _{3,2}	Etc., for all components of the second mixture

INPUT INSTRUCTIONS FOR CALX1. CONTROL INPUT FOR CALX

<u>Format</u>	<u>Location</u>	<u>Array</u> <u>Size</u>	<u>Name</u>	<u>Comments</u>
1	16		ITAPE(1)	This is the control for the binary input tape made up from SIGMA-3C (CALX data tape). 1-DO NOT READ TAPE 0-READ TAPE -1-REWIND AND READ (automatically set to unity after tape is read.)
1	5942		KM	OUTPUT TAPE NUMBER
1	5943		N1	Link number to call next.
1	5944		JNP	Number of lines of extra heading to be copied to output tape. (Set to zero after reading.) JNP cards of Hollerith information follow tape specification cards.
1	5948		NUMBER	CALX case number.Updated by Program.
1	5949		N6	Case control 1-NOT LAST CASE (automatically set to 1 for first case.) 0-LAST CASE-CALLS EXIT -1-CALLS NEXT CHAIN LINK (if N6 = -1 link # is needed in N1)
1	5953		ITIME	Set non-zero to run internal timing routine.
1	5962		N5	=1 for constant power burnup =2 for constant fluc burnup
0	5963		PWI**	Value of the constant power density in watts per unit volume or the constant flux in n/barn-cm. (Exception: If XK = 0 when N5 = 1, PWI units are megawatts/metric ton.)
0	5988		TMAX	Time limit on exposure run, in seconds.
0	5989		BMULT**	Limit on irradiation
0	5990		EAE	Allowed differences between BMULT and end point if NS6 = 2.
0	5965		DENS**	Core fuel density, gm/cc.

<u>Format</u>	<u>Location</u>	<u>Array Size</u>	<u>Name</u>	<u>Comments</u>
1	8863		NPUT2	Non-zero if more input is to be read in after data tape has been read. (This is for changing input from tape.) Automatically set to zero after second input.
1	8864		NWRIT	=1-input 9 group cross sections will be written out (automatically set to zero after writing). =0-input 9 group cross sections will <u>not</u> be written out.
0	5099	90	SHIELD	Constant linear, quadratic shield factor (3 per fuel)(presently unused).
0	5189	300	SHIELD	Self-shielding factor (3/non-fuel).
1	5489	30	INREG	Fuel region number (currently all fuels must be in Region 1). If not input, CALX puts all fuels in Region 1.
0	6023		AKRACY**	(k) (k-1) $\frac{\phi_i - \phi_{i-1}}{\phi_i} \leq \text{AKRACY for convergence}$ on k th iteration of spectrum calculation. If zero, uses 0.0001.
1	6024		NITER**	Maximum number of iterations in spectrum calculation. If zero, uses 50.
1	6025		NMI**	Number of mesh intervals in Region 1. If zero, uses 24.
1	6026		NM2**	Number of mesh intervals in Region 2. If zero, uses 23.
1	6027		IC4**	if = 0 uses equal mesh spacing ≠ 0 uses equal volume spacing
0	12313		TYME**	Starting time for burnup.
1	5519	100	INREG	Non-fuel region number (currently all non-fuels must be in Region 1). If not input CALX puts all non-fuels in Region 1.

<u>Format</u>	<u>Location</u>	<u>Array Size</u>	<u>Name</u>	<u>Comments</u>
1	5649	30	IREC	Fuel recycle product number. If not input fuels recycle into same isotope. Used to change owners of fuels during downtime.
1	12311		IFMWNT	Number of tapes to mount. IFMWNT tape specification cards follow first 9 card (automatically set to zero after mounting tapes).
1	5975	N17		<p>N17 = 0 - no initialization.</p> <p>1 - Add mixture specified to get CMULT desired. TOT is constant.</p> <p>2 - Add mixture specified to get PERFIS desired. TOT is constant.</p> <p>3 - Add poison mixture specified to get CMULT desired. TOT may or may not be constant.</p> <p>4 - Add specified mixture and individual isotope N18 to get PERFIS, TOT, and CUMULT.</p> <p>NOTE: If N17 is negative CALX uses the results of a burnup and chemical processing as the enrichment or poison mixture. The beginning of this array is located at 5679. In order to have a cycle case started using this option, the initial enrichment mixture should start at 5679.</p>
1	5976	N18		Accounting number of individual isotope to use when N17 = 4.
1	5977	N19		Maximum number of initialization iterations.
1	5979	CMULT		Initial XMULT desired.
0	5980	CMATCH		Accuracy required in CMULT.
0	5981	TOT		Total fuel density. If this entry is not specified the program will use the TOT of the input concentrations.

<u>Format</u>	<u>Location</u>	<u>Array Size</u>	<u>Name</u>	<u>Comments</u>
0	5982		PERFIS	Fissile atom fraction
0	5809	130	YAA	Enrichment or poison composition. Concentration of accounting isotope one goes in 5809, etc.

3. INPUT FOR RECYCLE CASE

0	6008		DEL	Days of AEC charge period and startup
0	6009		DDAYS1	Days from discharge to processing
0	6010		DDAYS	Days from fabrication to fabrication- recharge; use only on graded cycle.
1	6013		NPASS	Maximum number of recycle passes
0	156	30	PERSAV	Recovery efficiency of fuel chemical reprocessing. If negative adds fuel (initial concentrations) to recycle mix.
0	186	100	PERSAV	Recovery efficiency of non-fuel chemical reprocessing. If negative adds fuel (initial concentrations) to recycle mix.
0	6012		DEXP	Maximum fractional difference in exposure, for two successive passes, for equilibrium. Recycle will stop when this limit is reached.

4. INPUT FOR GRADED CASE ONLY

To run a graded case a constant power burnup must be set up with the following additions:

0	6011		RMATCH	Maximum positive fractional case dif- ference. Non-zero number here starts graded run.
1	6017		N57	Maximum number of graded cycles per fuel lifetime.

5. INPUT FOR ECONOMICS CASE

1	6014		N2	Tape unit number for economics output.
1	6018		IDENT	Economics case number
1	6019		NSTEP	Non-zero positive to get economics output.
1	6021		PERIOD	Time between economics output, days.

CALX INPUT - READ IN FROM CALX DATA TAPE

<u>Format</u>	<u>Location</u>	<u>Array Size</u>	<u>Name</u>	<u>Comments</u>
2	1	12	BCD	Case identification - 72 characters.
1	13		KPAGE	Current page number
0	14	2	RADIUS	Region radii
1	16	10	ITAPE	Binary tape control 0 - TO READ +1 - TO NOT READ
0	26	30	C	Fuel isotopic concentrations
0	56	100	C	Non-fuel isotopic concentrations
0	286	9	BSQ	System geometric buckling
0	295	9	EDGE	Fluxes at edge of cell (for continuous irradiation)
0	304	30	KPHYS	Physical fuel isotope numbers
1	334	30	NPFYT	Accounting fuel fission product yield table number
1	364	15	NRFYT	Actual fuel fission product yield table number
0	379	9	FIS	Fraction of fission neutrons born into group
0	388	15	Q	Energy per fission, joules
1	403	30	KCP	Fuel capture product index
1	433	30	KDP	Fuel decay product index
1	463	100	KDP	Non-fuel decay product index
0	563	30	GLAM	Fuel radioactive decay constants, sec ⁻¹
0	593	100	GLAM	Non-fuel radioactive decay constants, sec ⁻¹
0	693	200	CF	Capture transmutation fraction (2/non-fuel)
0	893	100	YIELD	Fission product yield table number 1
0	993	100	YIELD	Fission product yield table number 2
0	1093	100	YIELD	Fission product yield table number 3
0	1193	100	YIELD	Fission product yield table number 4
0	1293	100	YIELD	Fission product yield table number 5

<u>Format</u>	<u>Location</u>	<u>Array Size</u>	<u>Name</u>	<u>Comments</u>
0	1393	135	SIGNUL	Fuel $\nu\alpha_f$ (9/physical fuel)
0	1528	135	SIGFL	Fuel σ_f (9/physical fuel)
0	1663	135	SIGRL	Fuel σ_r (9/physical fuel)
0	1798	900	SIGRL	Non-fuel σ_r .
0	2698	120	SIGSDL	Fuel $\sigma_{j \rightarrow j+1}$ (8/physical fuel)
0	2818	800	SIGSDL	Non-fuel $\sigma_{j \rightarrow j+1}$
0	3618	135	SIGTRL	Fuel σ_{tr} (9/physical fuel)
0	3753	900	SIGTRL	Non-fuel σ_{tr}
0	4653	18	SBTRL	Base σ_{tr} (9/region)
0	4671	18	SBAL	Base σ_a
0	4689	18	SBTRL	Base σ_{tr}
0	4707	72	SIGBL	Base transfer matrix (36/region)
0	4779	30	BSIGAL	Fuel $\bar{\sigma}_a$ (input only with non-operative SIGMA)
0	3809	100	BSIGAL	Non-fuel $\bar{\sigma}_a$ (input only with non-operative SIGMA)
0	4909	30	BSIGFL	Fuel $\bar{\sigma}_f$ (input only with non-operative SIGMA)
0	4939	30	BSINUL	Fuel $\bar{\nu}\sigma_f$ (input only with non-operative SIGMA)
2	4969	30	NAME	Fuel isotope name (six characters)
2	4999	100	NAME	Non-fuel isotope name (six characters)
1	5940		NMAX2	30 plus index of last isotope
1	5950		II	Iodine-135 index
1	5951		IXE	Xenon-135 index
1	5952		ISM	Samarium-149 index
1	5954		KGEOM	Geometry. 0 = Slab 1 = Cylinder
1	5955		NBND	Boundary condition 0 = Cell 1 = Reactor 2 = Infinite Homo.
1	5956		IREG	Number of regions (1 or 2)
1	5957		NG	Number of groups (1-9) (must be 9 presently)

<u>Format</u>	<u>Location</u>	<u>Array Size</u>	<u>Name</u>	<u>Comments</u>
1	5958		NACTF	Number of actual fuel (1-15)
1	5959		NACTI	Number of numerically analyzed non-fuels + 15
1	5960		NFUEL	Number of accounting fuels (1-30)
1	5961		NMAX	NACTI + 15
0	5964		HEIGHT	Reactor "Height"

APPENDIX ITABLE 1CHAIN LINK IDENTIFICATION

<u>Chain Link</u>	<u>Program Name</u>
1	COMBO
2	GAM-2 (Second Link of Program GAM)
3	TEMPEST
4	GAM-1 (First Link of Program GAM)
5	HFN
6	SIGMA-3H
7	SIGMA-3C
8	CALX
9	KONROL
10	SLOPE
11	SCHWAC
12	HRG-2 (Second Link of Program HRG)
14	HRG-1 (First Link of Program HRG)

TABLE 2GROUP ENERGY BOUNDARIES FOR CALX

<u>Group No.</u>	<u>Boundary Energies (ev)</u>		<u>Remarks</u>
	<u>(Lower)</u>	<u>(Upper)</u>	
9	0.0	0.683	Thermal Group
8	0.683	2.38	Epithermal Group
7	2.38	10.68	"
6	10.68	1.01×10^2	"
5	1.01×10^2	1.23×10^3	"
4	1.23×10^3	1.17×10^4	"
3	1.17×10^4	1.11×10^5	"
2	1.11×10^5	1.05×10^6	"
1	1.05×10^6	10.0 MeV	"

TABLE 3INPUT LOCATIONS FOR ISOTOPES OF THE JBURN ARRAY

Each isotope of the JBURN array of CALX occupies four locations, one for each of four owners. An entry (1,2,3, or 4) in either of these four locations will signify that this isotope is to be used in the burnup calculation. The magnitude of the entry specifies which of the four owners will get the decay and capture products of this isotope. The location that this entry occupies indicates which owner owns the isotope.

Example: A 3 entered in Location 130 indicates that Owner 2 owns the isotope U²³⁸, and that Owner 3 will get the capture and decay products.

NOTE: For DBURN array add 700 to the input locations in this table.

<u>Isotope Name</u>	<u>Owner 1 Location No.</u>	<u>Owner 2 Location No.</u>	<u>Owner 3 Location No.</u>	<u>Owner 4 Location No.</u>
--	41	42	43	44
Th-227	45	46	47	48
Th-228	49	50	51	52
Th-229	53	54	55	56
Th-230	57	58	59	60
Th-231	61	62	63	64
Th-232	65	66	67	68
Th-234	69	70	71	72
Pa-229	73	74	75	76
Pa-230	77	78	79	80
Pa-231	81	82	83	84
Pa-232	85	86	87	88
Pa-233	89	90	91	92
Pa-234	93	94	95	96

TABLE 3 (cont)

<u>Isotope Name</u>	<u>Owner 1 Location No.</u>	<u>Owner 2 Location No.</u>	<u>Owner 3 Location No.</u>	<u>Owner 4 Location No.</u>
U-230	97	98	99	100
U-231	101	102	103	104
U-232	105	106	107	108
U-233	109	110	111	112
U-234	113	114	115	116
U-235	117	118	119	120
U-236	121	122	123	124
U-237	125	126	127	128
U-238	129	130	131	132
Np-234	133	134	135	136
Np-235	137	138	139	140
Np-236	141	142	143	144
Np-237	145	146	147	148
Np-238	149	150	151	152
Np-239	153	154	155	156
Pu-236	157	158	159	160
Pu-237	161	162	163	164
Pu-238	165	166	167	168
Pu-239	169	170	171	172
Pu-240	173	174	175	176
Pu-241	177	178	179	180
Pu-242	181	182	183	184
Am-240	185	186	187	188
Am-241	189	190	191	192
Am-242	193	194	195	196
Am-243	197	198	199	200

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