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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

HEROIC
A NEW METHOD FOR CLUSTER-TYPE FUELLED LATTICE CELL CALCULATIONS

by

R. CUNIBERTI and Cl. DAOLIO

1970

Joint Nuclear Research Center
Ispra Establishment - Italy

Reactor Physics Department
Reactor Theory and Analysis

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The machine time on the IBM-360 is typically of the order of 10 minutes.

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ABSTRACT

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KEYWORDS

CODES
INTEGRALS
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MEASUREMENTS
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H E R O I C

A NEW METHOD FOR CLUSTER-TYPE FUELLED LATTICE CELL CALCULATIONS*)

INTRODUCTION

The fuel elements used in most of the heavy water moderated power reactors are characterized by a markedly heterogeneous structure which requires a very refined description of the spatial distribution of neutron events.

Since 1962 an important program at Ispra has been devoted to the assessment of calculational methods for solving the eigenvalue problem in such a reactor cell. The results of this work have been reported by Amyot et al.(1).

Several calculational methods have been set-up and checked against experimental results. Two lattice calculation codes PLUTHARCO(2) and PINOCCHIO(3) are being used and continuously developed.

The first code PLUTHARCO, intended for survey studies, is based on correlation techniques and a phenomenological description.

With the second code, PINOCCHIO, an attempt has been made to set-up a model which gives a detailed description of the neutron physics in the cell without having to make adjustments in the broad group data in order to achieve the desired agreement.

Essentially, PINOCCHIO solves the eigenvalue problem for the infinite lattice in a multigroup energy structure. A limited number of well defined cluster geometries can be treated by the code, which uses the first flight collision probabilities approach in the integral transport equation applied to the cell

*) Manuscript received on 18 September 1969.

homogenized in annular regions with a cylindrical outer boundary. The HEROIC code, which is described in this report, is substantially based on the PINOCCHIO scheme, but it uses a generalized cylindrical cell geometry treatment so that clusters can be treated without any homogenization. Furthermore, the code is no longer limited to the description of a restricted number of fixed cluster geometries. Radial and azimuthal subdivisions of both the pins and the coolant are allowed.

Collision probabilities are calculated by means of the CLUCOP subroutine developed by Carlvik (4) which deals with a two-dimensional cluster geometry.

Due to the fact that in the thermal region it is not obvious how the cluster geometry can be simplified and the fact that homogenization always introduces additional sources of errors, the main interest of the HEROIC calculational scheme is in the prediction of thermal events, and, consequently, it can be used as a reference for the test of homogenization procedures. The results of the code are compared with fine structure measurements performed at Ispra and elsewhere, and it is shown that thermal activation distributions are well reproduced.

1. GENERAL

The HEROIC code is a multi-energy group program solving the eigenvalue problem in a reactor cell with a cylindrical outer boundary. The rest of the cell geometry is generally cylindrical so that the cluster geometry can be treated without any intervening homogenization. The program is subdivided in four major parts.

In the first part, the calculation of macroscopic cross sections

from input and library data is done. This part includes the evaluation of Dancoff coefficients and resonance integrals. The energy group structure is fixed, and the limits of the groups are given in table 1.

In the second part, the collision probability matrix is set-up. The eigenvalue equations are solved in the third part, producing the flux distribution in space and energy. In the final part, this flux distribution is used to calculate region-averaged macroscopic reaction rates in each group and in three standard sets of groups: "fast","epithermal" and "thermal". Macroscopic reaction rates for fissile and fertile isotopes and for individual isotopes specified by the user are also calculated.

Intensive and extensive parameters of the cell, few group parameters for the homogenized cell, and all the parameters which are generally compared with experiments are calculated in this last section.

2. DATA LIBRARY AND RESONANCE CROSS SECTIONS

The library of HEROIC is exactly the same library available to the PINOCCHIO code. Cell cross section data, except for the resonance integrals, are taken from the GAM-II (5) library for the fast and epithermal region and the GATHER-II (5) library for the thermal range. However, the 2200 m/s constants for U-233, U-235, Pu-239 and Pu-241 have been extracted from the 1965 study of Westcott (6). To construct the HEROIC library in the group structure described in table 1, an energy condensation was performed with the help of GGC-II(5) (for an ideal homogeneous system consisting of D_2O and natural uranium).

Table 1

Energy group structure

Group n.	High energy (eV)	Low energy (eV)
1	$1.49.10^{7}$	$1.35.10^{6}$
2	$1.35.10^{6}$	$1.11.10^{5}$
3	$1.11.10^{5}$	$3.18.10^{4}$
4	$3.18.10^{4}$	961
5	961	130
6	130	47.8
7	47.8	29
8	29	10.7
9	10.7	2.38
10	2.38	1.5
11	1.5	1.3
12	1.3	1.2
13	1.2	1.15
14	1.15	1.11
15	1.11	1.09
16	1.09	1.07
27	1.07	1.05
28	1.05	1.025
19	1.025	1
20	1	0.97
21	0.97	0.91
22	0.91	0.7
23	0.7	0.5
24	0.5	0.414
25	0.414	0.35
26	0.35	0.31
27	0.31	0.27
28	0.27	0.22
29	0.22	0.16
30	0.16	0.1
31	0.1	0.085
32	0.085	0.06
33	0.06	0.04
34	0.04	0.03
35	0.03	0.025
36	0.025	0.015
37	0.015	0.01
38	0.01	0.005
39	0.005	0.0

Diagonal transport corrections are included. Energy exchange between thermal groups in heavy water, light water and graphite is accounted for through the Nelkin - Honeck, the Nelkin and the Parks kernels, respectively. A kernel developed at Ispra (7) describes the interactions with the hydrogen atoms bound in the organic molecule. As in PINOCCHIO, resonance cross sections in a given group are defined simply as being equal to the resonance integrals in the group divided by the lethargy width of the group.
Resonance integrals are average values for the cluster obtained by a best fit (8) (9) of the results of the ZUT and TUZ Nordheim's method in the form $I = A + B\sqrt{Seff/M}$.
In the case of Uranium-235, a slightly more complicated correlation has been developed (10). No attempt has been made to distribute resonance capture in different pins, i.e., inner pins are given a resonance integral equal to that of outer pins.
As suggested by Levine the effective surface is calculated as

$$\frac{S_{eff}}{M} = \frac{1-C}{1+0.1\,C}\,\frac{2}{r\rho}$$

where ρ is the fuel density, r the rod radius and C the Dancoff coefficient.
The Dancoff coefficient can be obtained from the fuel to fuel collision probabilities in the limit of black fuel as proposed by Leslie (11) and is defined as

$$C = \frac{4V_f}{S_f}\Big/\overline{L_f}$$

where V_f and S_f are the total fuel volume and surface and $\overline{L_f}$ is determined by the asymptotic expansion of P(f,f,) for large values of the total macroscopic cross section.

P(f,f) is calculated by the CLUCOP subroutine assuming a total cross-section, $\Sigma_f = \frac{1000}{2r}$ for the fuel where r is the radius of a pin.

3. NEUTRON TRANSPORT AND EIGENVALUE PROBLEM

Neutron transport is described by means of first flight collision probabilities. The program is limited to isotropic scattering in the laboratory system (transport corrections are made when preparing the data library).

The method used for calculating the collision probabilities is that described by Carlvik (4) and is included in the CLUCOP code. It is similar to the one used in the PIJ routine (12).

The equations for the method of collision probabilities have been formulated by Amyot et al. in ref. (3) where the eigenvalue problem has been discussed.

The space-energy distribution of the flux for the infinite lattice is calculated with reference to one neutron produced by fission occuring below a given energy limit.

The collision probability equations for the thermal energy groups are solved with the iterative scheme proposed by Honeck (13) (ITER subroutine of the THERMOS code).

The infinite multiplication factor is defined in the framework of a four factor formula, corrected to allow for epithermal fissions

$$K_\infty = \varepsilon \left[p \eta f_{th} + (1-p) \eta f_{epi} \right]$$

Cell-averaged cross sections are then produced. The cell averaged diffusion coefficients are calculated by the Benoist (14)formula.

Assuming that the buckling remains constant as a function of energy, the criticality equations are solved in the form

$$\sum_m \alpha_{mn} \phi_m = B^2 \phi_n$$

where

$$\alpha_{mn} = D_n^{-1} C_{mn} \Sigma_m \quad (m \neq n)$$
$$\alpha_{nn} = D_n^{-1} \left[C_{nn} \Sigma_n - \Sigma_{rn} \right]$$

C_{mn} is the number of neutrons appearing in group n at each collision in group m; Σ_n is the cell-averaged collision cross-section; Σ_{rn} the cell averaged removal cross-section. D_n the cell averaged diffusion coefficient.

Once the material buckling and the flux spectrum have been obtained, the Keff of the system can be defined as

$$K_{eff} = \frac{\sum_n (\nu \Sigma_f)_n \phi_n}{\sum_n (\Sigma_{an} + D_n B^2) \phi_n}$$

where all reaction rates are referred to one neutron existing (or produced in) the system.

4. COMPARISON WITH EXPERIMENTAL RESULTS

4.1. Thermal Fine Structure Measurements

The HEROIC code has been tested on thermal fine structure measurements of the neutron density.

Tables 2 and 3 give the results for the seven rod cluster fuel element (carbide fuelled, diphyl cooled) and for the 19 rod cluster ECO fuel element (U metal fuelled and diphyl cooled). Fig. I gives the layout of the 19 rod cluster and subdivisions used in the calculation. Table 4 gives the results for the CIRENE 19 rod cluster (UO_2 fuelled, polystirene cooled D_2O moderated) and table 5 gives the comparison of the fine structure of the thermal neutron density for the Marviken 37 rod cluster (UO_2

fuelled, D_2O cooled and moderated) (Fig. II).
For this case the theoretical results obtained by the CLEF Swedish code (18) are also given.

4.2. Neutron Balance Measurements

The HEROIC code has been used for the comparative analysis of substitution and zero-reactivity measurements performed at Ispra, on ECO and at Montecuccolino, on RB-1, respectively.
In fact, the comparison between substitution and zero reactivity techniques is not straight-forward because the measured quantity is the material buckling in the former type of experiment and in K-inf in the latter type.
In table 6 the results of such a comparison in terms of K-inf are given with leakage calculations performed by the two lattices codes PINOCCHIO and HEROIC.
From the comparison given in table 6 it appears that, when a particular accuracy is needed for the interpretation of neutron balance measurements, the more refined code HEROIC gives very satisfactory results.

Table 2

Fine structure of thermal neutron densities Comparison HEROIC-experiments (fuel element UC/7/25.2 Diphyl)

	ISPRA(15) experimental results	Canadian(16) experimental results	HEROIC
Central pin	0.6738	0.691	0.699
Central can	0.7883	-	0.813
Exter. pins	1.0544	1.052	1.048
Exter. cans	1.2618	-	1.288

Table 3

Fine structure of thermal neutron densities Comparison HEROIC-experiments (fuel element U/19/12 Diphyl)

Region	ISPRA(17) experimental results	HEROIC
A	1.	1.
B	1.163	1.176
C	1.792	1.759
1A	2.686	2.620
2	1.561	1.581
3	1.585	1.581
4	1.132	1.159

Fig. I - Details of the detector arrangement in the ECO clustered fuel element for the average flux measurements (dimensions in mm)

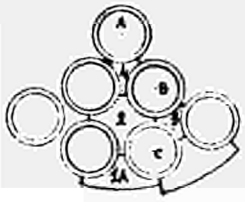


Table 4

Fine structure of thermal neutron densities
Comparison HEROIC–experiments CIRENE (fuel element UO_2/19/0.35 D_2O 99.7% pitch 30.2 cm)

	Experimental results(19)	HEROIC
Central pin	0.666	0.669
Internal pins	0.773	0.775
External pins	1.141	1.140
Pressure tube	1.778	1.762
Calandria tube	1.801	1.839
Moderator	2.518	2.506

Fig. II – Marviken boiler test element.
Subdivisions used in the calculations

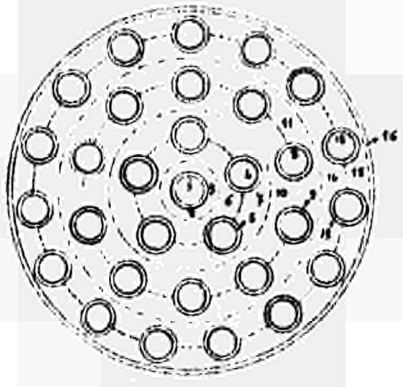


Table 5

Cu-63 activation distribution for the Marviken boiler test element (37 rod cluster, D_2O mod. and cooled, pitch 24.04 cm).
Comparison HEROIC-experiments

Region	Experimental results	HEROIC	CLEF (18) results
1	0.781	0.776	0.784
2	-	0.824	0.845
3	0.892	0.861	0.874
4	0.824	0.817	0.828
5	-	0.877	0.879
6 + 7	0.942	0.934	0.943
8	0.928	0.928	0.929
9	-	0.996	1.006
10+11	1.056	1.055	1.060
12	1.121	1.124	1.119
13	-	1.212	1.203
14+15	1.229	1.251	1.245
16	1.385	1.405	1.393
Moderator	1.829	1.750	1.780

Table 6

A comparison of leakage calculations performed by HEROIC and PINOCCHIO in terms of K-inf from different experimental techniques

fuel element type	Pitch (cm)	K-inf RB-1	K-inf ECO PINOCCHIO	K-inf ECO HEROIC
U/19/12	18.8	1.0902	1.0906	1.0905
	23.5	1.1279	1.1314	1.1288
	26.7	1.1334	1.1412	1.1373
UC/7/25.2	23.5	1.0953	1.0927	1.0939
	26.7	1.1090	1.1034	—

Part II

CODE DESCRIPTION

5. SPECIFICATION OF THE CELL GEOMETRY

The composition of the materials which constitute the cell is expressed in the HEROIC input in terms of atomic densities (nuclei/barn cm.). A maximum of ten materials can be considered. If one of the materials is the void (atomic density equal zero) the corresponding macroscopic cross sections is defined by the code as equal to $0.9.10^5$.

The following rules should be followed for the subdivision of the cell in regions.

a) The fuel pins include fuel and canning, and may be subdivided by concentric circles and by diameters.

a) The coolant and the moderator may be subdivided by concentric circles and by radial lines between these circles.

c) Region numbers in the pin should start in the innermost annulus.

d) If an annulus is further subdivided by diameters, these diameters should be specified by giving their angles (in positive orientation) with the line through the cell centre and the pin centre. In this case the numbering of the sectors in the annulus starts in that sector which has the smallest (in degrees) specified diameter as its lower boundary (zero included).

e) The regions numbering inside a pin is always immediately precedent at the number of the coolant region in which the centre of the pin is placed.

f) In the coolant and moderator zones, region numbers start at the innermost regions.

g) If an annulus in the coolant or moderator zones is subdivided by radii, the numbering is done in a recurrent sector in positive orientation.

Fig. III gives an example or regions numbering.

6. ISOTOPES AND LIBRARY

A list of the isotopes that are included in the present version of the code library is given in table 7. Each isotope is identified by two identification numbers (ex. 14002 40). The seven numbers (xyzzz cc) which compose the identification are chosen in the following way:

x = 0 : microscopic thermal cross-sections do not depend on temperature (non-moderator isotope)

= 1 : microscopic thermal cross-sections depend on temperature, that is, the isotope is present in the library at several temperatures (moderator isotopes)

y = $0 \leq y \leq 9$: identifies the model used in the scattering kernel at thermal energies. If x = 0, y = 0 or blank

zzz : identifies the isotope

cc : isotope temperature in (°C).(=27 for the isotopes in ambient temperature). This number is not given in input for each isotope, but it is assigned to each material, as it is clear that all isotopes which belong to the same material are at the same temperature. Special attention must be paid in the control if these isotopes are included in the library at the asked temperature. For x = 0, cc is always assumed, by the code, equal to 27°C.

The number zzz is also used by the code for the identification of the resonance isotopes in the fuel. For these isotopes (defined resonant in the input data) the coefficients for the resonance integrals calculation are read from library (see section III of the table 7). Through the resonance integrals the microscopic scattering and capture epithermal cross sections are obtained.

Therefore, the HEROIC library is divided into 3 sections:

a) thermal cross sections

b) fast and epithermal cross sections

c) resonance integrals coefficients

The total number of isotopes present in the cluster must be ≤ 50 : in the evaluation of this total number, both the identification numbers have to be considered, that is to say for example that (12001 27) and (12001 70) will be considered by the code as two isotopes.

7. FEW-GROUP PARAMETERS

Few-group macroscopic cross sections for use in diffusion calculation and three groups heterogeneous parameters for use in the SOS code are calculated by HEROIC.

The parameters are averaged values for channel (fuel element and tubes), moderator and cell: they are calculated only if the calculation of the three-groups macroscopic cross sections is requested (see Input Data, word AVE, card 2). Broad group limits for few-group parameters calculations must be given in input by following this rule: from high to low energy, for each group, the lower energy limit must be specified in the

input data, by giving the ordinal number corresponding to the lower HEROIC fine group in the broad group (see table 1).

8. CODE LANGUAGE AND SYSTEM

HEROIC, written in FORTRAN IV, can be run on a normal IBM 360/65 following the O.S. nominator, in the HASP system, with overlay organisation. The total number of bytes occupied is ~ 284.000, including library subroutines and special functions. The compiler used is FORTRAN H (level zero).

9. EXECUTION TIME

The mean time for a typical cell calculation mainly depends on the accuracy asked for the collision probabilities calculation. The input data parameters for this accuracy, are the number of integration lines and angles (directions) (see input data,word ACC,card 2). Besides, for the same number of lines and directions, the execution time is proporzional to the regions number (see input data,word GEO , card 2). Table 8 shows the approximate times of execution for several numbers of lines and angles. As example, the execution time for the sample case is about of 7.3 minutes. In this case the execution time necessary for the collision probabilities calculation (39 groups, 14 regions, 10 lines, 2 angles) is about 5 minutes. The HEROIC code gives, for this, the progressive times, in seconds, at the end of the subroutines INDAT, INLIB, REGION, AREA, GEOM, BOUND, GLUCOP, RISON, GROUPS, BOUND1, COLLIS, MAIN (see flow-diagram).

The execution time is slightly reduced in the cases after the first if the word MAT (see input data) is not changed. In fact in this case, the library tape must be read completely only once to locate the isotopes of interest (see flow-diagram).

10. INPUT DATA SPECIFICATION

The HEROIC INPUT is controlled by directive words defining different data blocks.

The directive words are the following: TIT, GEO, MAT, ASS, ACC, ALB, AVE, STA, END.

These words are punched starting in card column 1.

The data blocks must be given in the same order as the directive words in the list and, besides, for successive cases, is not necessary to repeat all the input data, but only the directive words, with the corresponding data block, that are to change.

10.1. Title Card (TIT)

Card 1 FORMAT (A3)

cols. 1 - 3 Specify the word TIT, which defines the data block

Card 2 FORMAT (18A4)

cols. 1 - 72 Alpha-numeric text (not $ or '). Should always introduce a new data case.

10.2. Geometry Cards (GEO)

Card 1 FORMAT (A3)

cols. 1 - 3 Specify the word GEO which defines the block

Card 2 FORMAT (6I5)

cols. 1 - 5 NRG, the number of regions in the cell. NRG $\leq$ 30.

cols. 6 - 10 NDR, the number of different pin-types with regard to radial subdivision (by concentric circles). $1 \leq NDR \leq 20$.

cols. 11 - 15 NDS, the number of different pin-types with regard to sectorial subdivision (by diameters). Set zero if no subdivision of this kind is wanted $0 \leq NDS \leq 20$

Cols. 16 - 20 NP, the number of pin-rings. A pin-ring is a number of pins of the same type and nuclear composition which are equally spaced on a circle around the cell centre. Analogous parts in the different pins of pin-ring have the same region numbers. $1 \leq NP \leq 20$.

cols. 21 - 25 NCORA, the number of radii concentric with the cell boundary (subdivision in radial zones of the coolant and moderator zone). $1 \leq NCORA \leq 30$

cols. 26 - 30 IKYL, the number of annuli in which subdivision by radial lines is wanted. An annulus of this kind may consist of one or several annuli formed by the CORA; (see card 7). $0 \leq IDYL \leq 20$.

Card 3 FORMAT (8E10.0)

- $PIRAI_{ij}$, $j=1.....K_i$, the radii of the pin-type i. The radii must be given in increasing order and the last will be the pin radius or the external radius of the canning, if there is. The radius $PIRAI_{i(K_i+1)}$ equal to zero or blank indicates the end of the set. $K_i \leq 30$.

Card 3 is repeated NDR times (see Card 2)

Card 4 FORMAT (8E10.0)

- $VINGI_{ij}$, $j=1.....L_i$, the diameters dividing the pin-type i in sectors. The diameters must be given in degrees in positive orientation from the line through the cell centre and the pin centre. The diameter $WINGI_{i(l_i+1)}$ equal zero or blank indicates the end of the set. $L_i \leq 30$.

Card 4 is repeated NDS times (see Card 2)

Card 5 FORMAT (5I5)

cols. 1 - 5 $NPAN_i$, the number of pins in the pin-ring i.

cols. 6 -10 $NPIS_i$, the type of pin with respect to radial subdivision in the pin-ring i. Specify a number 1 to NDR (see Card 2)

cols. 11 -15 $NPID_i$, the type of pin with respect to sectorial subdivision in the pin-ring i. Specify a number 0 to NDS (see Card 2). Zero means no subdivision of this kind (NDS = 0).

cols. 16 -20 NS_i

Value	Meaning
0	The pins of pin-ring i have not the same region numbers as a pin-ring K(K<i), i.e. the ring introduces new region numbers.
1	The pins of pin-ring i have the same region numbers as a pin-ring K (K<i).

2 The pins of pin-ring i have the same region numbers as a pin-ring K ($K < i$) but reflected in a line through the cell centre and the pin centre.

cols. 21 - 25 NF_i, the pin-ring $K(K < i)$ (see NS_i) is the $(i-NF_i)$th Specify only if $NS_i \neq 0$.

Card 6 FORMAT (3E10.0)

cols. 1 - 10 $RIRA_i$, the radius of the pin-ring i. Different pin-rings may have the same radius

cols. 11 - 20 PIP_i, the position of a pin in the pin-ring i. Specify in degrees from the boundary of the integration sector, which must be a symmetry axis of the cell.

cols. 21 - 30 RHO_i, the fuel density in the pin- ring i (gr/cm^3).

Cards 5 and 6 are repeated NP times (see Card 2), starting in the cell centre.

Card 7 FORMAT (8E10.0)

- $CORA_i$, i = 1.....NCORA (see Card 2), the radii concentric with the cell boundary, starting in the centre. Avoid exact coincidence with the radii $RIRA_i$ (see Card 6).

Card 8 FORMAT (3I5)

Only if IKYL > 0 (see Card 2)

cols. 1 - 5 $NDEL_i$, the number recurrent sectors of the annulus i.

cols. 6 - 10 $IDEL_i$, the recurrent sector is divided in $IDEL_i$ subsectors. $2 \leq IDEL_i \leq 20$

cols. 11 - 15 $ISYM_i$

Value	Meaning
1	The regions of the recurrent sector are all different (no symmetry)
2	The sector is symmetric (see Fig. III)

Card 9 FORMAT (3E10.0)

Only if IKYL>0 (see Card 2)

cols. 1 - 10 $RADA_i$, the inner radius of the annulus i.

cols. 11 - 20 $RADB_i$, the outer radius of the annulus i. $RADA_i$ and $RADB_i$ must coincide with the $CORA_i$ (see Card 7)

cols. 21 - 30 AIN_i, the starting position for a recurrent sector. Specify the lower angular boundary in degrees.

Card 10 FORMAT (8E10.0)

Only if IKYL>0 (see Card 2)

$ANGLE_{ij}$, j=2.....$IDEL_i$ (see Card 8), the inner angular boundaries in the recurrent sector of annulus i. Restriction: $ANGLE_{ij}$ and the sector boundaries must not intersect the pins but through the pin centre

Cards 8, 9 and 10 are repeated for IKYL times (see Card 2) starting in the centre.

Card 11 FORMAT (2E10.0)

cols. 1 - 10 G, the integration angle (in degrees). 45° for a quadratic cell, 30° for an hexagonal cell

cols. 11 - 20 B2EX, the experimental buckling to be used in the Keff calculation (leakage terms).

10.3 Isotopes and Materials Cards (MAT)

Card 1 FORMAT (A3)

cols. 1 - 3 Specify the word MAT, which defines the data block

Card 2 FORMAT (12I5)

cols. 1 - 5 NMAT, the number of materials. NMAT $\leq$ 10

cols. 6 -10 NE, the number of isotopes present in the cell NE $\leq$ 50

- IEM_j, j=1....NMAT, the temperatures of the materials. IEM_j is the second identification number (cc) for the isotopes belong to the material j (see Isotopes and Library)

Card 3 FORMAT (13I5)

cols. 1 - 5 $ISTBA_i$, the first identification number (xyzzz) for the isotope i (see Isotopes and Library)

cols. 6 -10 IRIS,

Value	Meaning
0	The isotope do not require a resonance integral calculation
1	The isotope requires a resonance integral calculation

cols. 11 -15 ICON,

Value	Meaning
0	The fission (if there is) and absorption reaction rate for the isotope i are not calculated and printed
1	The fission (if there is) and absorption reaction rate for the isotope i are calculated and printed.

for $232 \leq ISTBA \leq 242$ the reactions are alway calculated.

For NOP = 0 (see word ACC, Card 2) put always ICON = 0.

- $ISMAT_j$, j=1....NMA, the material code number (see ASS, Card 2); NMA is the number of the materials in which the isotope j is present. $ISMAT_j \leq NMAT$

Card 4 FORMAT (8E10.0)

$DENS_j$, j=1.....NMA, the density (nuclei/barn cm) of the isotope i in the materials in which it is present. NMA is defined in the preceding card.

Card 3 and 4 are repeated for NE times (see Card 2)

10.4 The Assigning of Materials to Space Regions (ASS)

Card 1 FORMAT (A3)

cols. 1 - 3 Specify the word ASS, which defines the data block

Card 2 FORMAT (I2, I3, 15I5)

cols. 1 - 2 IMA, optional data; this number can be used to identify the material but it is not read by the program. In fact the n^{th} card of this type corresponds to n^{th} material (n=1.....NMAT).

- $NREG_j$, the region numbers associated with the material code number IMA; - 1 indicates the end of the set

Card 2 is repeated NMAT times (see word MAT, Card 2)

10.5 Accuracy of Integration (ACC)

Card 1 FORMAT (A3)

cols. 1 - 3 Specify the word ACC, which defines the data block

Card 2 FORMAT (9I5)

cols. 1 - 5 NIG, the types number of integration intervals over the cluster (generally = 1) NIG $\leq$ 5

- $NINT_i$, i = 1.....NIG, the number of integration lines drawn for each type of integration interval i.
- INTG, the number of Gauss-points in each annulus of the moderator. INTG $\leq$ 4
- NANG, the number of integration angles (directions).
- NOP, the output indicator

Value	Meaning
0	Reduced output (see flow-diagram)
1	Complete output

Card 3 FORMAT (5E10.0)

- $BINT_i$, i = 1.....NIG, the outer radial boundary for each type of integration interval i (see Card 2). $BINT_i$ must coincide with one of the $CORA_i$ (see word GEO, Card 7).

10.6 Albedo Value (ALB)

Card 1 FORMAT (A3)

cols. 1 - 3 Specify the word ALB, which defines the data block

Card 2 FORMAT (2E10.0)

cols. 1 -10 ALBEDO, the albedo for the cell boundary, i.e. the probability that a neutron, which has crossed the cell boundary, will return.

cols. 11 -20 EPS, the convergence criterion for the neutron density in the thermal flux calculation. If

EPS = 0 or blank the standard option EPS = 10^{-4} is used by the code

10.7 Few-group Parameters (AVE)

Card 1	FORMAT (A3)
cols. 1 - 3	Specify the word AVE, which defines the data block
Card 2	FORMAT (12I5)
cols. 1 - 5	NRC, the number of the outermost region of the channel (fuel element and tubes). Generally NRC = NRG-NMOD. NRG = total regions number (see word GEO, Card 2). NMOD=radial and sectorial regions number in the moderator zone.
cols. 6 -10	NRCM, the few-group number wanted. NRCM $\leq$ 10
-	$NGRP_i$, i=1.....NRCM, the few-groups limits (see few-group parameters)

10.8 Start Directive (STA)

Card 1	FORMAT (A3)
cols. 1 - 3	Specify the word STA, which causes the computation to start

10.9 End Directive (END)

Card 1	FORMAT (A3)
cols. 1 - 3	Specify the word END, which causes the computation to end. This card should be the last data card.

11. CODE DIAGNOSTICS

The HEROIC code gives several diagnostic as output, for some input errors. Some diagnostics are self-explanatory. The list is following:

a) ILLEGAL DIRECTIVE IN DATA : (Subr. INDAT)
   A non-existent directive word is given.

b) PROGRAM ERROR STOP 1000: (Subr. INDAT and INLIB)
   A moderator isotope asked, is not included in the thermal library or is not included for the temperature asked.

c) PROGRAM ERROR STOP 1001: (Subr. INLIB)
   An isotope asked is not included in the fast and epithermal library.

d) PROGRAM ERROR STOP 1002: (Subr. INLIB)
   An isotope asked as resonant (IRIS = 1, see word MAT Card 3) is not included in the resonance integrals coefficients library.

e) PROGRAM ERROR STOP 1003: (Subr. INLIB)
   The density gives for the U238 (see word MAT Card 4) es equal to zero.

f) ALL REGIONS ARE NOT ASSIGNED A MATERIAL: (Subr. CLUCOP)
   A control is necessary for the data block ASS.

g) NEGATIVE VOLUME NOT PERMITTED: (Subr. CLUCOP)
   A control is necessary for the data block GEO.

h) ERROR IN GEOMETRY SPECIFICATION: (Subr. GEOM)
   As for the preceding diagnostic.

i) PROGRAM ERROR STOP 1004: (Subr. RISON)
   As for the STOP 1002.

l) PROGRAM ERROR STOP 1005: (Subr. RISON)
   As for the STOP 1002

m) **** THERMAL FLUX SPECTRUM CALCULATION HAS NOT CONVERGED.
   PLEASE TRY WITH A GREATER VALUE OF EPS****(see word ALB Card 2)

If some diagnostic is printed out, the calculation is stoped for the present case, but the code starts the successive case, if there is.

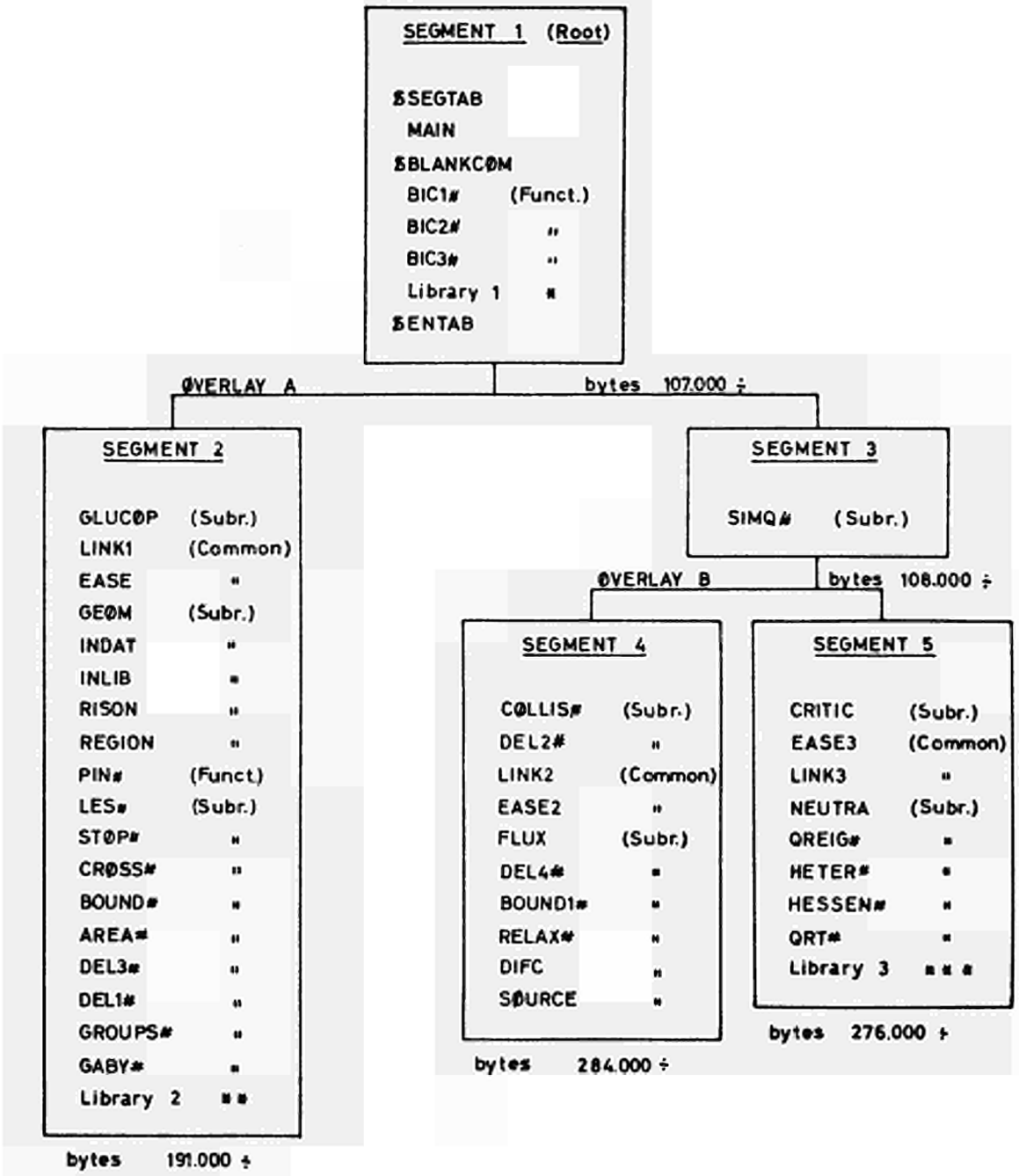
12. OUTPUT LIST

If NOP = 1 (see word ACC Card 2) a complete output is given (about 6000 lines).

If NOP = 0 a reduced output is given (about 1000 lines).

See the flow-diagram for the contents of two output types, which is, in any case, self-explanatory.

13. OVERLAY ORGANISATION

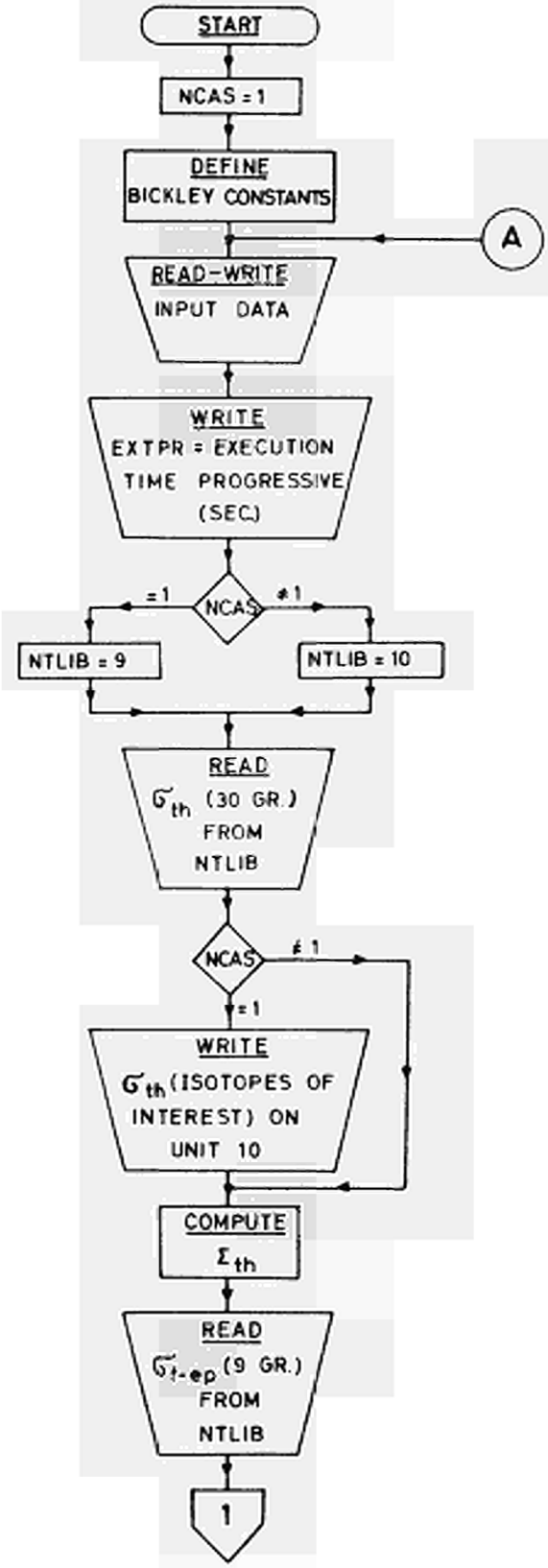


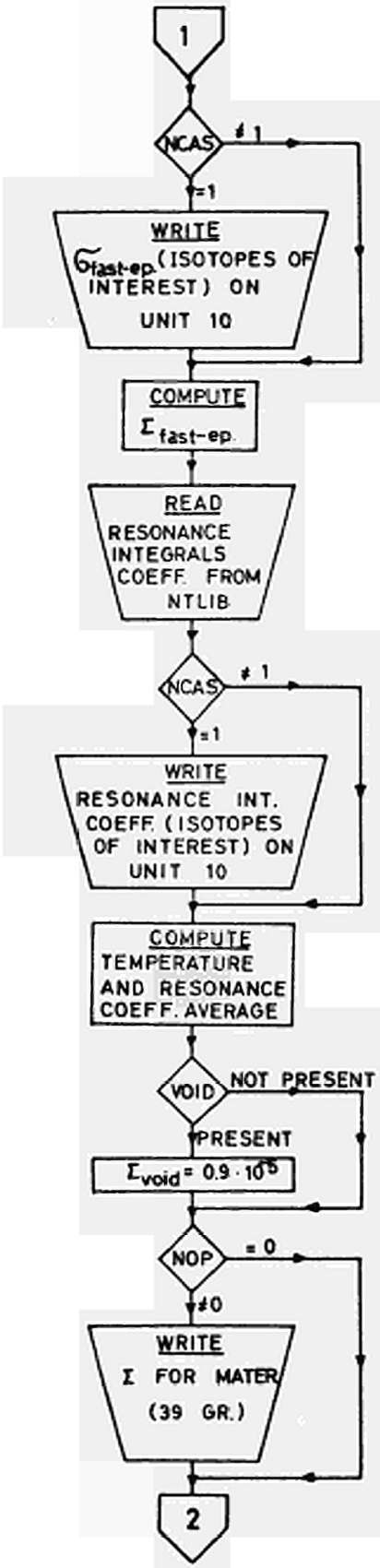
\# Library 1 – STCLØK, IHCFCVTH, IHCFCØMH, IHCUØPT, IHCTRCH, IHCSLØG, IHCSEXP, IHCFRXPR, IHCFRXPI, IHCSSORT, IHCFIØSH, IHCUATBL, IHCFINTH

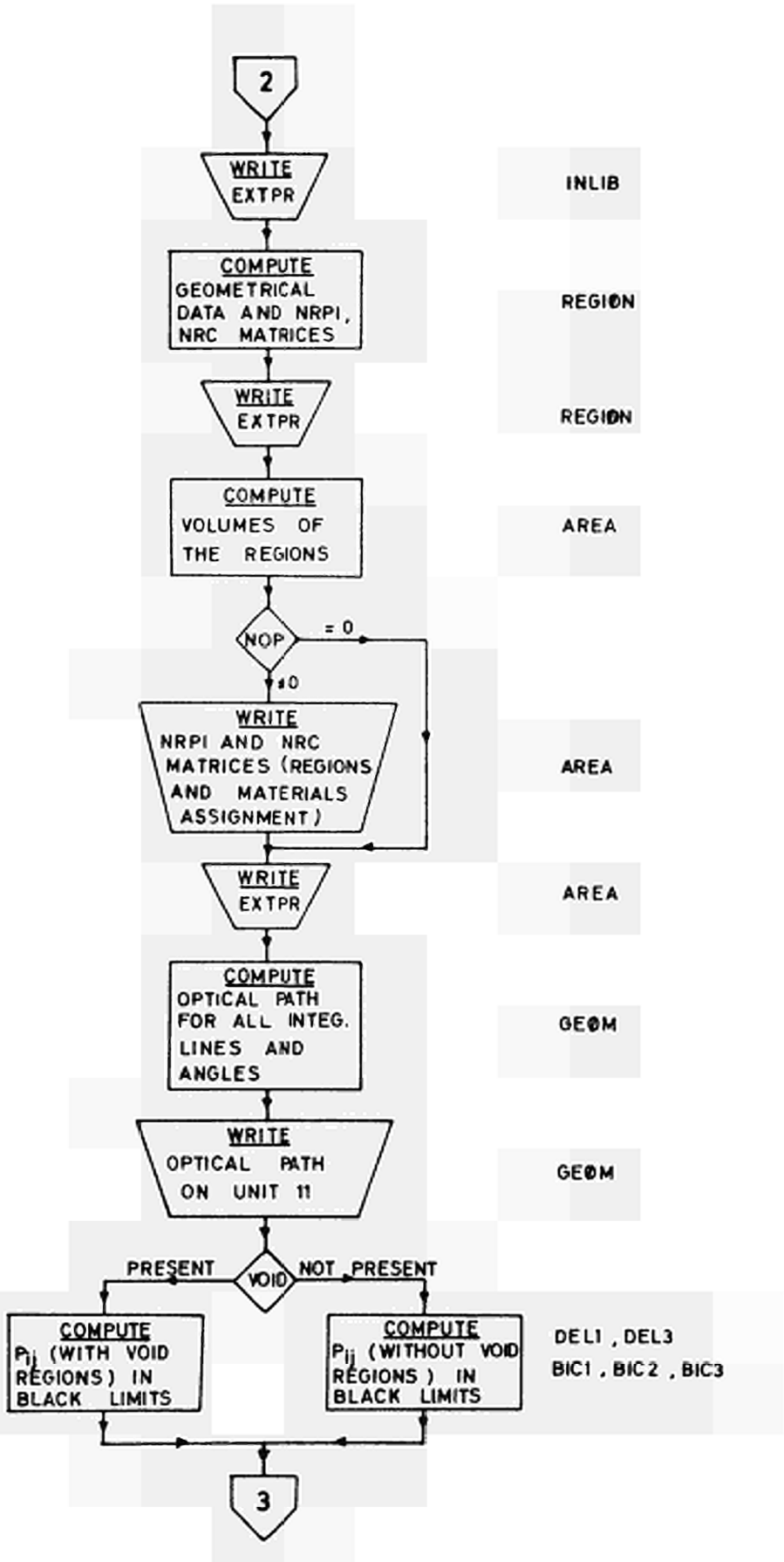
\# # Library 2 – IHCFEXIT, IHCSSCN, IHCSATN2, IHCFSLIT, IHCSASCN

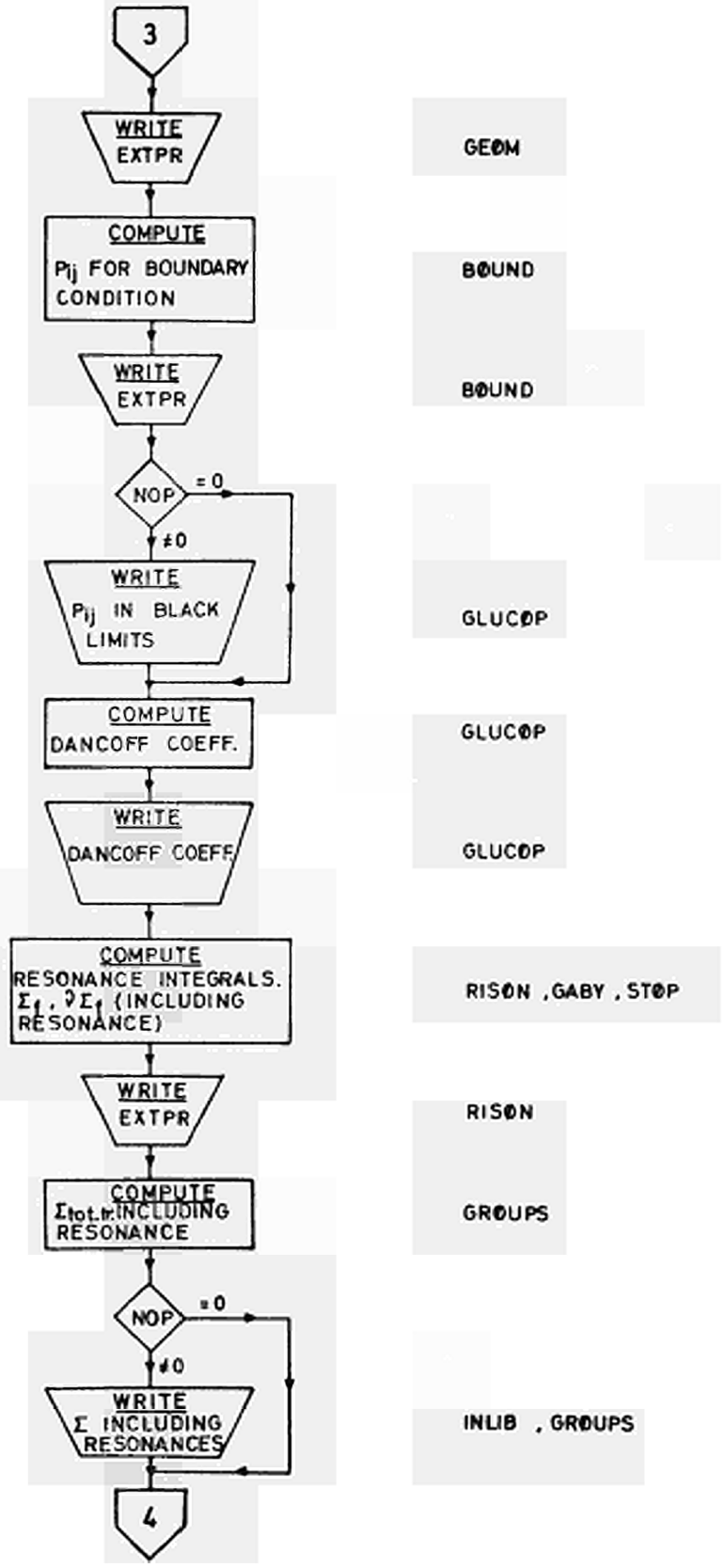
\# # # Library 3 – BESI#, BESK#, BIØ#, BI1#, BKØ#, BK1#

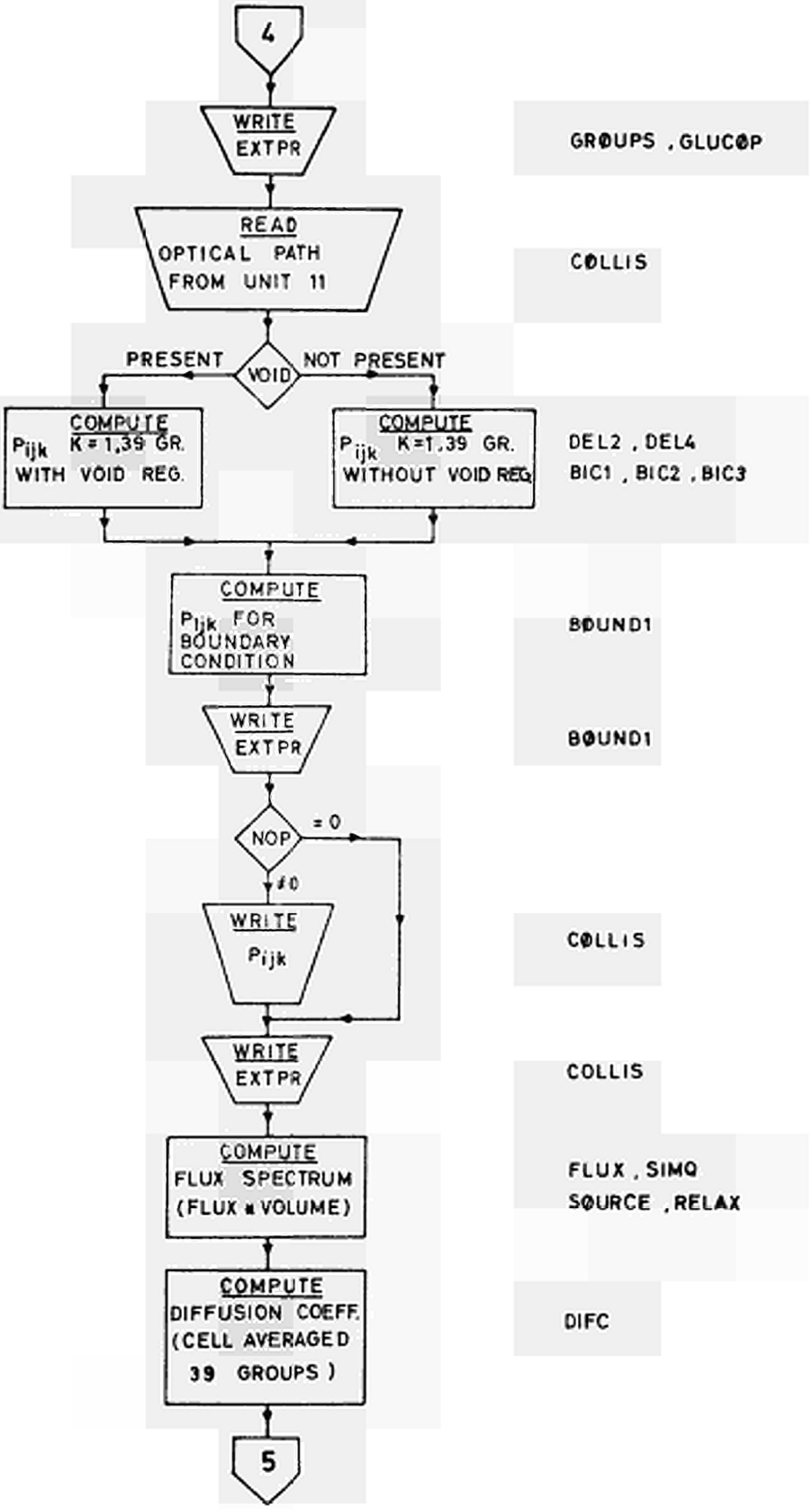
14. FLOW DIAGRAM

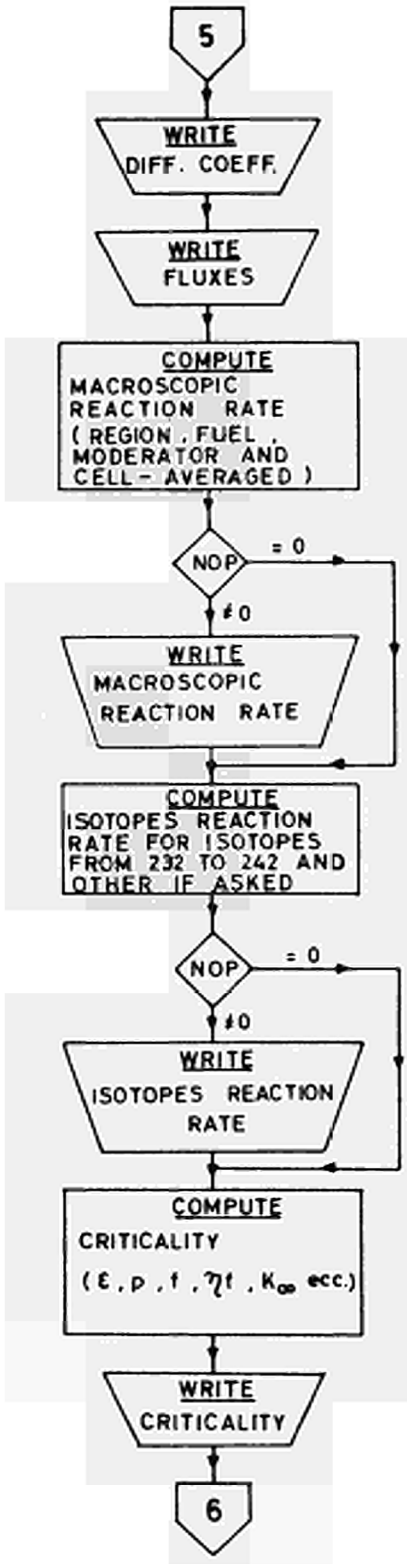


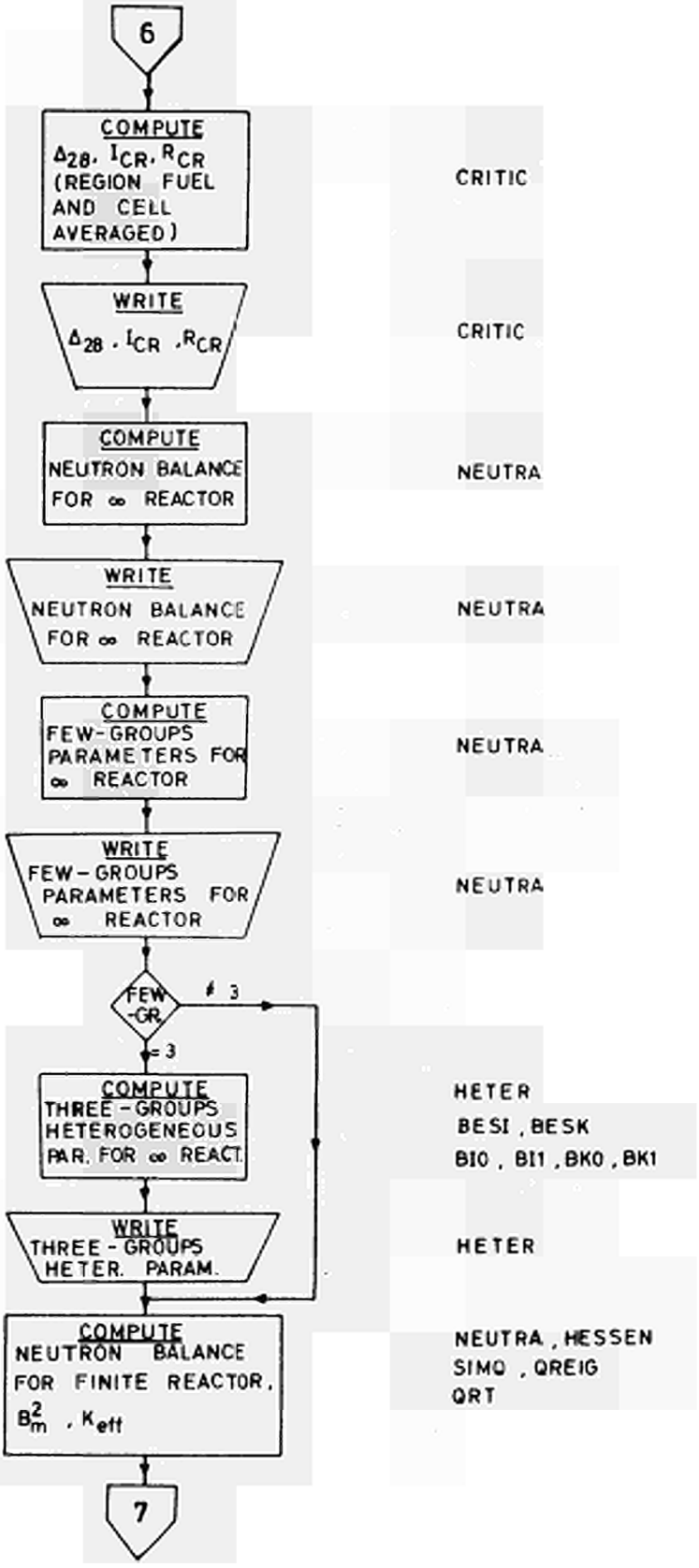

1
NCAS
≠ 1
=1
WRITE σ fast-ep (ISOTOPES OF INTEREST) ON UNIT 10
INLIB
COMPUTE Σ fast-ep
INLIB
READ RESONANCE INTEGRALS COEFF. FROM NTLIB
INLIB , STØP
NCAS
≠ 1
=1
WRITE RESONANCE INT. COEFF. (ISOTOPES OF INTEREST) ON UNIT 10
INLIB
COMPUTE TEMPERATURE AND RESONANCE COEFF. AVERAGE
INLIB , STØP , PIN
VOID
NOT PRESENT
PRESENT
Σ void = 0.9 · 10^-5
INLIB
NOP
= 0
≠0
WRITE Σ FOR MATER (39 GR.)
INLIB , CRØSS
2

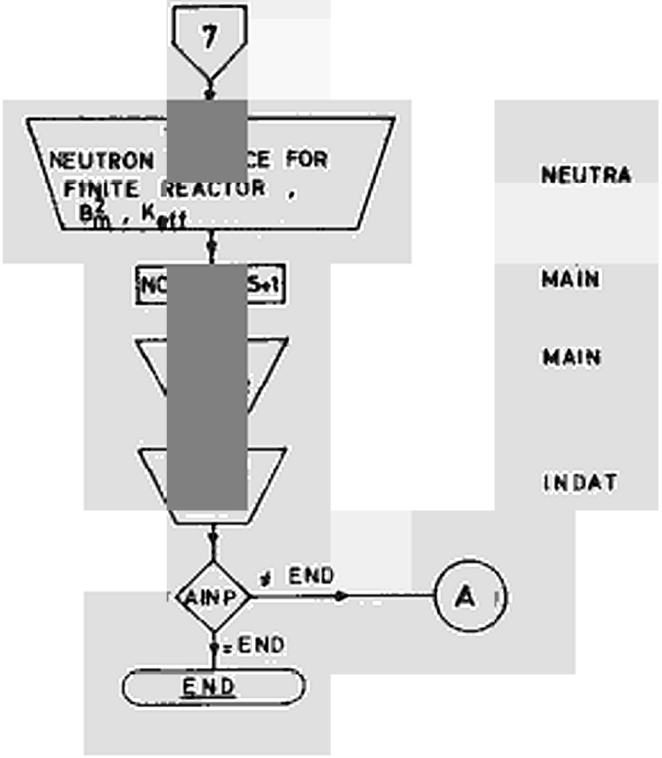

2
WRITE EXTPR
INLIB
COMPUTE GEOMETRICAL DATA AND NRPI, NRC MATRICES
REGION
WRITE EXTPR
REGION
COMPUTE VOLUMES OF THE REGIONS
AREA
NOP
= 0
≠0
WRITE NRPI AND NRC MATRICES (REGIONS AND MATERIALS ASSIGNMENT)
AREA
WRITE EXTPR
AREA
COMPUTE OPTICAL PATH FOR ALL INTEG. LINES AND ANGLES
GEOM
WRITE OPTICAL PATH ON UNIT 11
GEOM
PRESENT
VOID
NOT PRESENT
COMPUTE Pij (WITH VOID REGIONS) IN BLACK LIMITS
COMPUTE Pij (WITHOUT VOID REGIONS) IN BLACK LIMITS
DEL1 , DEL3
BIC1 , BIC2 , BIC3
3


3
WRITE EXTPR
GEØM
COMPUTE Pij FOR BOUNDARY CONDITION
BØUND
WRITE EXTPR
BØUND
NOP
= 0
≠0
WRITE Pij IN BLACK LIMITS
GLUCØP
COMPUTE DANCOFF COEFF.
GLUCØP
WRITE DANCOFF COEFF.
GLUCØP
COMPUTE RESONANCE INTEGRALS. Σf , ϑΣf (INCLUDING RESONANCE)
RISØN , GABY , STØP
WRITE EXTPR
RISØN
COMPUTE Σtot.tr. INCLUDING RESONANCE
GRØUPS
NOP
= 0
≠0
WRITE Σ INCLUDING RESONANCES
INLIB , GRØUPS
4


4
WRITE EXTPR
GROUPS , GLUCOP
READ OPTICAL PATH FROM UNIT 11
COLLIS
PRESENT
VOID
NOT PRESENT
COMPUTE Pijk K = 1,39 GR. WITH VOID REG.
COMPUTE Pijk K=1,39 GR. WITHOUT VOID REG.
DEL2 , DEL4
BIC1 , BIC2 , BIC3
COMPUTE Pijk FOR BOUNDARY CONDITION
BOUND1
WRITE EXTPR
BOUND1
NOP
= 0
≠ 0
WRITE Pijk
COLLIS
WRITE EXTPR
COLLIS
COMPUTE FLUX SPECTRUM (FLUX x VOLUME)
FLUX , SIMQ
SOURCE , RELAX
COMPUTE DIFFUSION COEFF. (CELL AVERAGED 39 GROUPS)
DIFC
5


5
WRITE
DIFF. COEFF.
FLUX
WRITE
FLUXES
FLUX
COMPUTE
MACROSCOPIC
REACTION RATE
(REGION , FUEL ,
MODERATOR AND
CELL - AVERAGED)
CRITIC
NOP
= 0
≠0
WRITE
MACROSCOPIC
REACTION RATE
CRITIC
COMPUTE
ISOTOPES REACTION
RATE FOR ISOTOPES
FROM 232 TO 242 AND
OTHER IF ASKED
CRITIC
NOP
= 0
≠0
WRITE
ISOTOPES REACTION
RATE
CRITIC
COMPUTE
CRITICALITY
(ε , p , f , η f , K∞ ecc.)
CRITIC
WRITE
CRITICALITY
CRITIC
6


6
COMPUTE
Δ_{28}, I_{CR}, R_{CR} (REGION FUEL AND CELL AVERAGED)
CRITIC
WRITE
Δ_{28} , I_{CR} , R_{CR}
CRITIC
COMPUTE
NEUTRON BALANCE FOR ∞ REACTOR
NEUTRA
WRITE
NEUTRON BALANCE FOR ∞ REACTOR
NEUTRA
COMPUTE
FEW-GROUPS PARAMETERS FOR ∞ REACTOR
NEUTRA
WRITE
FEW-GROUPS PARAMETERS FOR ∞ REACTOR
NEUTRA
FEW -GR.
≠ 3
= 3
COMPUTE
THREE-GROUPS HETEROGENEOUS PAR. FOR ∞ REACT.
HETER
BESI , BESK
BI0 , BI1 , BK0 , BK1
WRITE
THREE-GROUPS HETER. PARAM.
HETER
COMPUTE
NEUTRON BALANCE FOR FINITE REACTOR, B_m^2 , K_{eff}
NEUTRA , HESSEN
SIMQ , QREIG
QRT
7


7
NEUTRON
FINITE REACTOR ,
NEUTRA
MAIN
MAIN
INDAT
AINP
≠ END
A
= END
END

15. SAMPLE CASE INPUT (see Fig.IV)

```
1  TIT
2  UC/7 /25.2      D20 /  D20 99.73 /  PASS0 20 CM.
3  GE0
4          14          1          0          2          10          0
5  1.26                1.375
6              1          1          0          0          0
7  0.0                 0.0                   13.54
8              6          1          0          0          0
9  2.95                0.0                   13.54
10 1.5489              3.0                   4.4                   4.55                  4.75                  5.05                  5.20                  7.20
11 9.2                 11.2838
12 30.0                0.0003992
13 MAT
14         4          8          27         27         27         27
15 120001              0          0          4
16 1.7932  -04         4
17 10012               0          0          1
18 3.2620  -02         2
19         235         1          1          1
20 2.3662  -04         4
21         238         1          1          1
22 3.2383  -02         2
23 10016               0          0          2          4
24 3.3876  -03         3.3208     -02        2
25             27          0          0          2
```

```
   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
26 5 . 8 9 4 8   - 0 2
27 1 2 0 0 2       0     4
28 6 . 6 2 3 6   - 0 2
29       6 3       0     1     2       3     4
30 1 .           - 0 9 1 .       - 0 9 1 .       - 0 9 1 .       - 0 9
31 A S S
32 1       1       4     - 1
33 2       2       5     9     1 1     - 1
34 3     1 0       - 1
35 4       3       6     7     8     1 2     1 3     1 4     - 1
36 A C C
37         1       1 0   2     2     0
38 4 . 5 5
39 A L B
40 1 .                 0 .
41 A V E
42       1 1       2     9     3 9
43 S T A
44 E N D
```

```
285I    SYS1.CMPLIB                                          PASSED
285I    VOL SER NOS= EURSY0.
285I    SYSOUT                                               SYSOUT
285I    VOL SER NOS=      .
285I    SYS1.FORTLIB                                         KEPT
285I    VOL SER NOS= EURSY0.
285I    SYS1.LIB                                             KEPT
285I    VOL SER NOS= EURSY2.
285I    SYS1.SSPLIB                                          KEPT
285I    VOL SER NOS= EURSY2.
285I    SYS69101.T125507.RP001.PINOCCHI.R0000290             DELETED
285I    VOL SER NOS= EURSY0.
285I    SYS69101.T125507.RP001.PINOCCHI.GOSET                PASSED
285I    VOL SER NOS= EURSY3.
285I    SYS69101.T125507.RP001.PINOCCHI.GOSET                PASSED
285I    VOL SER NOS= EURSY3.
 LKED       DATE=69.04.11  BEG.T.=17.024  DURATION=0.007  N.OPER=463
)          EXEC PGM=*.+STEL.LKED.SYSLMOD,COND=(+GL,LT,+STEL.LKED)          00032120
[05F001      DD DDNAME=SYSIN                                               00032130
[06F001      DD SYSOUT=A                                                   00032140
[07F001      DD UNIT=SYSCP,LABEL=(,NL),DISP=(MOD,PASS),DSNAME=PUNCH1,     C00032150
             VOLUME=SER=PUNCH1                                             00032160
(SUDUMP      DD SYSOUT=A                                                   00032170
).FT09F001 DD DSNAME=LIBE,UNIT=L91,DISP=(OLD,DELETE),LABEL=(1,SL),        C
             VOLUME=(PRIVATE,SER=LIBPIN),                                 C
             DCB=(,RECFM=VB,LRECL=800,BLKSIZE=804,DEN=2)
).FT10F001 DD DSNAME=+LIBPIN,UNIT=2314,SPACE=(CYL,(2,1)),                 C
             VOLUME=SER=EURSY1
).FT11F001 DD DSNAME=+AVSIND,UNIT=2314,SPACE=(CYL,(5,11)),                C
             VOLUME=SER=EURSY2
).SYSIN      DD *
236I ALLOC. FOR PINOCCHI GO       B
237I JOBLIB    ON 1C0
237I PGM=*.DD ON 232
237I FT05F001 ON 00C
237I FT07F001 ON 00D
237I FT09F001 ON 383
237I FT10F001 ON 230
237I FT11F001 ON 231
```

***** H E R O I C HETEROGENEOUS REACTOR ON INITIAL COLLISION CALCULATION *****

'/25.2 D20 / D20 99.73 / PASSO 20 CM.

1BER OF REGIONS = 14

)IAL SUB-DIVISIONS OF RODS
) TYPE) RADII 1.26000 1.37500

) CIRCLE RADIUS START POS. NR OF RODS ROD TYPES NS NF RHO
1 0.0 0.0 1 1 0 0 0 13.54000
2 2.95000 0.0 6 1 0 0 0 13.54000

3-DIVISIONS(ANNULI) IN COOLANT ZONE AND MODERATOR ZONE
)II 1.54890 3.00000 4.40000 4.55000 4.75000 5.05000 5.20000 7.20000 9.20000 11.28380

TEGRATION SECTOR = 30.00

>ERIMENTAL BUCKLING = 3.9200E-04

1PERATURES AND ATOMIC DENSITIES OF PURE MATERIALS

TERIAL 1 2 3 4

1.(C) 27 27 27 27
)01 0.0 0.0 0.0 1.7932E-04
)12 3.2620E-02 0.0 0.0 0.0
235 2.3662E-04 0.0 0.0 0.0
238 3.2383E-02 0.0 0.0 0.0
)16 0.0 3.3876E-03 0.0 3.3208E-02
27 0.0 5.8948E-02 0.0 0.0
)02 0.0 0.0 0.0 6.6236E-02
63 1.0000E-09 1.0000E-09 1.0000E-09 1.0000E-09

TPUT INDICATOR(COLL) = 0

CURACY OF INTEGRATION
INTERVAL 0.0 - 4.55000 10 INTEGRATION LINES

1BER OF GAUSSPOINTS = 2

1BER OF INTEGRATION ANGLES 2

3EDO BETA = 1.00000

JTRON DENSITY CONVERGENCE CRITERION FOR THERMAL FLUX CALCULATION = 0.00010

1CTION RATES ARE REQUESTED FOR FOLLOWING COMBINATIONS OF REGIONS

1BINATION 1 REG. 1-11
1BINATION 2 REG. 12-14

1-GROUP PARAMETERS ARE REQUESTED FOR FOLLOWING COMBINATIONS AND GROUPS

1BINATION 1 GROUPS 1- 9
1BINATION 2 GROUPS 10-39

3RESSIVE TIME(SEC.) AT THE END OF INDAT = 1.480

```
GRESSIVE TIME(SEC.) AT THE END OF REGION =    22.840
GRESSIVE TIME(SEC.) AT THE END OF AREA =    22.840
GRESSIVE TIME(SEC.) AT THE END OF GEOM =    27.300
GRESSIVE TIME(SEC.) AT THE END OF BOUND =    27.320
NCOFF COEFFICIENT FOR THE FUEL IN THE CLUSTER     =   3.9092E-01
UARE ROOT S/M  =  2.6214E-01
GRESSIVE TIME(SEC.) AT THE END OF RISON =    27.640
GRESSIVE TIME(SEC.) AT THE END OF GROUPS =    27.740
GRESSIVE TIME(SEC.) AT THE END OF GLUCOP =    27.760
GRESSIVE TIME(SEC.) AT THE END OF BOUND1 =   312.800
GRESSIVE TIME(SEC.) AT THE END OF COLLIS =   313.180
FFUSION COEFFICIENTS(CELL-AVERAGED)

  2.3607E 00
  1.1690E 00
  1.1873E 00
  1.2454E 00
  1.2335E 00
  1.2328E 00
  1.2269E 00
  1.2306E 00
  1.2296E 00
  1.1721E 00
  1.1738E 00
  1.1751E 00
  1.1715E 00
  1.1708E 00
  1.1720E 00
  1.1719E 00
  1.1726E 00
  1.1722E 00
  1.1701E 00
  1.1681E 00
  1.1652E 00
  1.1603E 00
  1.1507E 00
  1.1442E 00
  1.1362E 00
  1.1281E 00
  1.1128E 00
  1.0847E 00
  1.0468E 00
  9.9539E-01
  9.5530E-01
  9.2458E-01
  8.9146E-01
  8.2436E-01
  7.6871E-01
  7.0512E-01
  6.3264E-01
```

5.6655E-01
4.6005E-01

)X SPECTRUM(FLUX*VOLUME)

)UP 1

)138E-01 5.0394E-02 8.5985E-02 1.6171E 00 2.4617E-01 1.9419E-01 4.6372E-01 1.1686E-01 1.5226E-01 2.2257E-01
.058E-01 1.2923E 00 1.1648E 00 1.3281E 00

)UP 2

)787E-01 1.0043E-01 1.6765E-01 2.9795E 00 4.8753E-01 3.8792E-01 9.9686E-01 2.6003E-01 3.4406E-01 5.1352E-01
)071E-01 3.2905E 00 3.1423E 00 3.5252E 00

)UP 3

)899E-01 3.1969E-02 5.3865E-02 9.1167E-01 1.6959E-01 1.2912E-01 3.9013E-01 1.0978E-01 1.4840E-01 2.2830E-01
(781E-01 1.7552E 00 1.9930E 00 2.3925E 00

)UP 4

)036E-01 5.5624E-02 9.4749E-02 1.7327E 00 3.2816E-01 2.2999E-01 8.1774E-01 2.4861E-01 3.4542E-01 5.4331E-01
)429E-01 4.5002E 00 5.7431E 00 7.3210E 00

)UP 5

)143E-01 2.7438E-02 4.6135E-02 8.6952E-01 1.6959E-01 1.1235E-01 4.1730E-01 1.2899E-01 1.7916E-01 2.8388E-01
)869E-01 2.4202E 00 3.2044E 00 4.1573E 00

)UP 6

)107E-02 1.2535E-02 2.1085E-02 4.0160E-01 7.9265E-02 5.1588E-02 1.9707E-01 6.1563E-02 8.5663E-02 1.3605E-01
(335E-02 1.1722E 00 1.5743E 00 2.0564E 00

)UP 7

)694E-02 5.1971E-03 8.7809E-03 1.6944E-01 3.5018E-02 2.1882E-02 9.0212E-02 2.8817E-02 4.0274E-02 6.4260E-02
)781E-02 5.6542E-01 7.7196E-01 1.0138E 00

)UP 8

)520E-02 1.0472E-02 1.7623E-02 3.4342E-01 6.9737E-02 4.3605E-02 1.7725E-01 5.6485E-02 7.8877E-02 1.2580E-01
)102E-02 1.1045E 00 1.5131E 00 1.9923E 00

)UP 9

(859E-02 1.4397E-02 2.4226E-02 4.7625E-01 9.7526E-02 6.0124E-02 2.4955E-01 8.0063E-02 1.1193E-01 1.7877E-01
)991E-02 1.5795E 00 2.1814E 00 2.8830E 00

)UP 10

8871E-02 3466E-02	4.6190E-03 4.3761E-01	7.7320E-03 5.9825E-01	1.5055E-01 7.8927E-01	2.9435E-02	1.8832E-02	7.2536E-02	2.2795E-02	3.1735E-02	5.0469E-02
IUP 11									
1750E-03 1464E-03	1.8015E-03 1.6365E-01	3.0126E-03 2.2268E-01	5.8245E-02 2.9339E-01	1.1290E-02	7.3063E-03	2.7553E-02	8.5984E-03	1.1951E-02	1.8984E-02
IUP 12									
1099E-03 1527E-03	9.6740E-04 8.9849E-02	1.6226E-03 1.2234E-01	3.1286E-02 1.6119E-01	6.0985E-03	3.9474E-03	1.5032E-02	4.7055E-03	6.5471E-03	1.0402E-02
IUP 13									
3195E-03 3916E-03	4.9236E-04 4.7961E-02	8.2772E-04 6.5554E-02	1.5955E-02 8.6440E-02	3.1628E-03	2.0263E-03	7.8940E-03	2.4867E-03	3.4638E-03	5.5121E-03
IUP 14									
1782E-03 2991E-03	4.2623E-04 4.1500E-02	7.1539E-04 5.6745E-02	1.3803E-02 7.4830E-02	2.7438E-03	1.7515E-03	6.8254E-03	2.1494E-03	2.9927E-03	4.7643E-03
IUP 15									
1188E-03 1889E-03	2.1904E-04 2.1401E-02	3.6780E-04 2.9266E-02	7.0982E-03 3.8595E-02	1.4110E-03	9.0085E-04	3.5165E-03	1.1082E-03	1.5435E-03	2.4570E-03
IUP 16									
1376E-03 2125E-03	2.2274E-04 2.1790E-02	3.7407E-04 2.9801E-02	7.2206E-03 3.9301E-02	1.4352E-03	9.1635E-04	3.5793E-03	1.1283E-03	1.5717E-03	2.5019E-03
IUP 17									
1579E-03 2375E-03	2.2672E-04 2.2199E-02	3.8084E-04 3.0360E-02	7.3524E-03 4.0038E-02	1.4607E-03	9.3303E-04	3.6460E-03	1.1496E-03	1.6017E-03	2.5494E-03
IUP 18									
1886E-03 2531E-03	3.0065E-04 2.9076E-02	5.0425E-04 3.9735E-02	9.7359E-03 5.2393E-02	1.9303E-03	1.2335E-03	4.7927E-03	1.5083E-03	2.1001E-03	3.3423E-03
IUP 19									
1769E-03 2893E-03	3.0791E-04 2.9667E-02	5.1623E-04 4.0533E-02	9.9690E-03 5.3443E-02	1.9744E-03	1.2623E-03	4.8955E-03	1.5399E-03	2.1438E-03	3.4116E-03
IUP 20									

405E-03 3.7863E-04 6.3485E-04 1.2260E-02 2.4248E-03 1.5518E-03 6.0116E-03 1.8905E-03 2.6321E-03 4.1879E-03
965E-03 3.6397E-02 4.9716E-02 6.5547E-02

UP 21

909E-03 7.7930E-04 1.3081E-03 2.5259E-02 4.9965E-03 3.2000E-03 1.2429E-02 3.9124E-03 5.4496E-03 8.6703E-03
481E-03 7.5359E-02 1.0296E-01 1.3575E-01

UP 22

670E-02 3.4481E-03 5.7839E-03 1.1160E-01 2.2055E-02 1.4139E-02 5.4685E-02 1.7188E-02 2.3929E-02 3.8067E-02
964E-02 3.3062E-01 4.5131E-01 5.9489E-01

UP 23

370E-02 4.3793E-03 7.3496E-03 1.4176E-01 2.8129E-02 1.7995E-02 6.9930E-02 2.2006E-02 3.0644E-02 4.8766E-02
579E-02 4.2420E-01 5.7941E-01 7.6379E-01

UP 24

905E-02 2.5402E-03 4.2662E-03 8.2383E-02 1.6465E-02 1.0475E-02 4.1146E-02 1.2988E-02 1.8096E-02 2.8818E-02
121E-02 2.5147E-01 3.4413E-01 4.5383E-01

UP 25

222E-02 2.2293E-03 3.7484E-03 7.2610E-02 1.4695E-02 9.2476E-03 3.7052E-02 1.1762E-02 1.6406E-02 2.6159E-02
735E-02 2.2961E-01 3.1543E-01 4.1641E-01

UP 26

049E-03 1.6228E-03 2.7310E-03 5.3118E-02 1.0867E-02 6.7659E-03 2.7613E-02 8.8120E-03 1.2303E-02 1.9640E-02
317E-02 1.7327E-01 2.3892E-01 3.1576E-01

UP 27

473E-03 1.8626E-03 3.1360E-03 6.1262E-02 1.2638E-02 7.7938E-03 3.2297E-02 1.0353E-02 1.4466E-02 2.3115E-02
148E-02 2.0483E-01 2.8348E-01 3.7513E-01

UP 28

567E-02 2.9377E-03 4.9381E-03 9.7120E-02 2.0095E-02 1.2281E-02 5.1312E-02 1.6495E-02 2.3054E-02 3.6870E-02
379E-02 3.2796E-01 4.5604E-01 6.0473E-01

UP 29

143E-02 5.9136E-03 9.9323E-03 1.9845E-01 4.1512E-02 2.4807E-02 1.0682E-01 3.4688E-02 4.8571E-02 7.7840E-02
946E-02 6.9941E-01 9.8528E-01 1.3142E 00

UP 30

229E-02 1.6848E-02 2.8312E-02 5.8143E-01 1.2355E-01 7.1287E-02 3.2352E-01 1.0687E-01 1.5022E-01 2.4141E-01

716E-01 2.1999E 00 3.1600E 00 4.2528E 00

UP 31

680E-02 8.2320E-03 1.3867E-02 2.8913E-01 6.2565E-02 3.5202E-02 1.6671E-01 5.5747E-02 7.8595E-02 1.2655E-01
728E-02 1.1648E 00 1.6910E 00 2.2854E 00

UP 32

377E-02 2.0025E-02 3.3725E-02 7.1494E-01 1.5758E-01 8.6243E-02 4.2420E-01 1.4327E-01 2.0237E-01 3.2648E-01
227E-01 3.0340E 00 4.4456E 00 6.0297E 00

UP 33

111E-01 2.1745E-02 3.6700E-02 7.9403E-01 1.8108E-01 9.5099E-02 4.9720E-01 1.7040E-01 2.4133E-01 3.9037E-01
620E-01 3.6744E 00 5.4416E 00 7.4081E 00

UP 34

015E-02 1.1466E-02 1.9438E-02 4.2918E-01 1.0129E-01 5.1076E-02 2.8454E-01 9.8999E-02 1.4071E-01 2.2814E-01
062E-01 2.1749E 00 3.2555E 00 4.4481E 00

UP 35

773E-02 5.1077E-03 8.6936E-03 1.9476E-01 4.7085E-02 2.3071E-02 1.3447E-01 4.7287E-02 6.7397E-02 1.0944E-01
894E-02 1.0526E 00 1.5871E 00 2.1739E 00

UP 36

396E-02 9.3219E-03 1.5976E-02 3.6519E-01 9.1829E-02 4.3045E-02 2.6870E-01 9.5926E-02 1.3724E-01 2.2332E-01
823E-01 2.1742E 00 3.3088E 00 4.5451E 00

UP 37

645E-02 3.0668E-03 5.3262E-03 1.2473E-01 3.3543E-02 1.4691E-02 1.0184E-01 3.7120E-02 5.3380E-02 8.7108E-02
162E-02 8.6163E-01 1.3254E 00 1.8261E 00

UP 38

282E-03 1.8181E-03 3.2218E-03 7.6355E-02 2.2341E-02 9.1098E-03 7.0614E-02 2.6252E-02 3.7934E-02 6.2070E-02
919E-02 6.2309E-01 9.6647E-01 1.3342E 00

UP 39

626E-03 6.2040E-04 1.1468E-03 2.6176E-02 8.8095E-03 3.3236E-03 2.9359E-02 1.1138E-02 1.6168E-02 2.6548E-02
081E-02 2.7180E-01 4.2449E-01 5.8657E-01

TICALITY

MULTIPLICATION FACTOR 1.041061E 00
NANCE ESCAPE PROBABILITY 8.337727E-01

RMAL UTILISATION FACTOR 9.477757E-01
RMAL FISSION FACTOR 1.307422E 00
RMAL MULTIPLICATION FACTOR 1.239142E 00
THERMAL MULTIPLICATION FACT. 9.284109E-02

INITE MULTIPLICATION FACTOR 1.091651E 00

TA-28,INITIAL CONVERSION RATIO AND RELATIVE CONVERSION RATIO

	DELTA-28	ICR	RCR
. 1	1.1301E-01	1.1853E 00	6.1022E-05
. 2	0.0	0.0	0.0
. 3	0.0	0.0	0.0
. 4	7.7379E-02	1.0551E 00	5.5043E-04
. 5	0.0	0.0	0.0
. 6	0.0	0.0	0.0
. 7	0.0	0.0	0.0
. 8	0.0	0.0	0.0
. 9	0.0	0.0	0.0
.10	0.0	0.0	0.0
.11	0.0	0.0	0.0
.12	0.0	0.0	0.0
.13	0.0	0.0	0.0
.14	0.0	0.0	0.0
L	8.1297E-02	1.0694E 00	4.8606E-04
ER.	0.0	0.0	0.0
L	8.1297E-02	1.0694E 00	4.8606E-04

'RON BALANCE FOR INFINITE REACTOR

	LEAKAGE	ABSOR.	PROD.	SCATT.OUT	FLUX	FLUX*VOL.
	6.7889E-03	3.8604E-02	1.0176E-01	6.3289E-01	1.8341E-02	7.3364E 00
	7.8010E-03	2.0470E-02	4.6419E-03	1.0174E 00	4.2560E-02	1.7024E 01
	4.0027E-03	1.1702E-02	0.0	9.3424E-01	2.1501E-02	8.6003E 00
	1.1002E-02	3.7659E-02	0.0	9.9130E-01	5.6338E-02	2.2535E 01
	5.9507E-03	2.4328E-02	0.0	9.6171E-01	3.0766E-02	1.2306E 01
	2.8921E-03	1.6866E-02	0.0	7.7941E-01	1.4962E-02	5.9848E 00
	1.3825E-03	1.7612E-02	2.1528E-03	5.2159E-01	7.1864E-03	2.8746E 00
	2.7265E-03	2.4931E-02	6.9115E-03	7.4320E-01	1.4130E-02	5.6518E 00
	3.9056E-03	3.9956E-02	7.0021E-03	8.2105E-01	2.0256E-02	8.1025E 00
	1.0403E-03	3.0514E-03	1.6232E-03	4.1358E-01	5.6604E-03	2.2642E 00
	3.9009E-04	1.5446E-03	7.8025E-04	2.1230E-01	2.1194E-03	8.4778E-01
	2.1395E-04	9.5836E-04	8.1135E-04	1.2528E-01	1.1611E-03	4.6445E-01
	1.1352E-04	7.4036E-04	8.3887E-04	7.1776E-02	6.1797E-04	2.4719E-01
	9.8181E-05	7.2052E-04	8.6532E-04	6.0877E-02	5.3481E-04	2.1392E-01
	5.0672E-05	3.5101E-04	4.1651E-04	3.2701E-02	2.7573E-04	1.1029E-01
	5.1585E-05	3.4359E-04	4.0788E-04	3.3376E-02	2.8073E-04	1.1229E-01
	5.2583E-05	3.3574E-04	3.9907E-04	3.4074E-02	2.8598E-04	1.1439E-01
	6.8897E-05	4.2208E-04	4.9896E-04	4.4320E-02	3.7486E-04	1.4994E-01
	7.0189E-05	4.0463E-04	4.6540E-04	4.5415E-02	3.8257E-04	1.5303E-01
	8.5976E-05	4.6227E-04	4.9840E-04	5.5248E-02	4.6942E-04	1.8777E-01
	1.7750E-04	9.3375E-04	9.6399E-04	1.0787E-01	9.7152E-04	3.8861E-01
	7.7563E-04	4.1691E-03	4.1186E-03	3.3405E-01	4.2634E-03	1.7053E 00
	9.8620E-04	6.2680E-03	6.3273E-03	3.9863E-01	5.4658E-03	2.1863E 00
	5.8066E-04	4.6410E-03	5.1571E-03	2.8627E-01	3.2366E-03	1.2946E 00
	5.2568E-04	5.1149E-03	6.1882E-03	2.7243E-01	2.9508E-03	1.1803E 00
	3.9352E-04	4.6003E-03	5.9097E-03	2.2177E-01	2.2246E-03	8.8984E-01
	4.5878E-04	5.9862E-03	7.7160E-03	2.5315E-01	2.6294E-03	1.0518E 00
	7.1763E-04	9.4843E-03	1.1605E-02	3.6400E-01	4.2195E-03	1.6878E 00
	1.4844E-03	2.0152E-02	2.3660E-02	6.9231E-01	9.0439E-03	3.6175E 00
	4.4738E-03	7.1917E-02	8.6036E-02	2.0622E 00	2.8664E-02	1.1466E 01
	2.2784E-03	4.1188E-02	5.0041E-02	1.7281E 00	1.5211E-02	6.0843E 00
	5.7576E-03	1.1840E-01	1.4603E-01	3.4042E 00	3.9714E-02	1.5886E 01
	6.7302E-03	1.6304E-01	2.0439E-01	4.1214E 00	4.8148E-02	1.9259E 01
	3.6891E-03	1.0679E-01	1.3507E-01	3.3902E 00	2.8540E-02	1.1416E 01
	1.6669E-03	5.4607E-02	6.9193E-02	2.0636E 00	1.3829E-02	5.5316E 00
	3.1613E-03	1.2201E-01	1.5496E-01	3.3330E 00	2.8593E-02	1.1437E 01
	1.1241E-03	5.3311E-02	6.7684E-02	1.8141E 00	1.1332E-02	4.5328E 00
	7.2698E-04	4.2347E-02	5.3470E-02	1.3352E 00	8.1834E-03	3.2734E 00
	2.5651E-04	2.3730E-02	2.9488E-02	6.4395E-01	3.5560E-03	1.4224E 00
2	1.4590E-02	5.9074E-02	9.8888E-02	1.6503E 00	6.0901E-02	2.4360E 01
9	3.1862E-02	1.7305E-01	1.6066E-02	5.7525E 00	1.6514E-01	6.6056E 01
39	3.8201E-02	8.6803E-01	1.0756E 00	2.7955E 01	2.7294E-01	1.0918E 02
39	8.4652E-02	1.1002E 00	1.1906E 00	3.5358E 01	4.9898E-01	1.9959E 02

-GROUPS PARAMETERS FOR INFINITE REACTOR

-AVERAGED

AD GROUP	FINE GROUPS	DIFF.COEFF.	ABSORPTION	PRODUCTION	SCATT.OUT
1	1- 9	1.3460E 00	9.2736E-03	4.8012E-03	2.4874E-03
2	10-39	1.0197E 00	5.3564E-02	6.6893E-02	0.0

NSFER KERNEL BETWEEN BROAD GROUPS

FROM	1	2
1	2.7565E-01	
2	2.4874E-03	3.0522E-01

ERATOR-AVERAGED

AD GROUP	FINE GROUPS	DIFF.COEFF.	ABSORPTION	PRODUCTION	SCATT.OUT
1	1- 9	1.2972E 00	3.5712E-05	5.3444E-05	1.2285E-02
2	10-39	8.7066E-01	7.2370E-05	0.0	0.0

NSFER KERNEL BETWEEN BROAD GROUPS

FROM	1	2
1	2.5150E-01	
2	1.2285E-02	3.9848E-01

L-AVERAGED

AD GROUP	FINE GROUPS	DIFF.COEFF.	ABSORPTION	PRODUCTION	SCATT.OUT
1	1- 9	1.3106E 00	2.5673E-03	1.3545E-03	9.6003E-03
2	10-39	8.9261E-01	7.9507E-03	9.8521E-03	0.0

NSFER KERNEL BETWEEN BROAD GROUPS

FROM	1	2
1	2.5812E-01	
2	9.6003E-03	3.8474E-01

'RON BALANCE FOR FINITE REACTOR

	LEAKAGE	ABSOR.	PROD.	SCATT.OUT	FLUX	FLUX*VOL.
	2.2954E 00	1.3052E 01	3.4407E 01	2.1398E 02	6.2012E 00	2.4805E 03
	2.8028E 00	7.3545E 00	1.6678E 00	3.6554E 02	1.5291E 01	6.1166E 03
	1.4340E 00	4.1922E 00	0.0	3.3470E 02	7.7028E 00	3.0811E 03
	3.9008E 00	1.3352E 01	0.0	3.5147E 02	1.9975E 01	7.9899E 03
	2.0972E 00	8.5739E 00	0.0	3.3893E 02	1.0843E 01	4.3371E 03
	1.0156E 00	5.9226E 00	0.0	2.7370E 02	5.2541E 00	2.1016E 03
	4.8463E-01	6.1739E 00	7.5468E-01	1.8284E 02	2.5192E 00	1.0077E 03
	9.5339E-01	8.7178E 00	2.4168E 00	2.5988E 02	4.9408E 00	1.9763E 03
	1.3603E 00	1.3917E 01	2.4388E 00	2.8597E 02	7.0553E 00	2.8221E 03
	4.2343E-01	1.2420E 00	6.6068E-01	1.6833E 02	2.3039E 00	9.2156E 02
	1.5050E-01	5.9591E-01	3.0103E-01	8.1907E 01	8.1770E-01	3.2708E 02
	8.0164E-02	3.5908E-01	3.0400E-01	4.6940E 01	4.3505E-01	1.7402E 02
	4.1983E-02	2.7381E-01	3.1024E-01	2.6545E 01	2.2854E-01	9.1418E 01
	3.6039E-02	2.6448E-01	3.1763E-01	2.2346E 01	1.9631E-01	7.8525E 01
	1.8509E-02	1.2821E-01	1.5213E-01	1.1945E 01	1.0071E-01	4.0285E 01
	1.8779E-02	1.2508E-01	1.4848E-01	1.2150E 01	1.0220E-01	4.0879E 01
	1.9078E-02	1.2181E-01	1.4479E-01	1.2362E 01	1.0376E-01	4.1503E 01
	2.4948E-02	1.5284E-01	1.8067E-01	1.6048E 01	1.3574E-01	5.4295E 01
	2.5317E-02	1.4595E-01	1.6787E-01	1.6381E 01	1.3799E-01	5.5198E 01
	3.0880E-02	1.6603E-01	1.7901E-01	1.9843E 01	1.6860E-01	6.7441E 01
	6.3303E-02	3.3301E-01	3.4380E-01	3.8473E 01	3.4649E-01	1.3859E 02
	2.7090E-01	1.4561E 00	1.4385E 00	1.1667E 02	1.4891E 00	5.9562E 02
	3.3820E-01	2.1495E 00	2.1698E 00	1.3670E 02	1.8744E 00	7.4976E 02
	1.9818E-01	1.5839E 00	1.7601E 00	9.7703E 01	1.1046E 00	4.4185E 02
	1.7942E-01	1.7458E 00	2.1121E 00	9.2985E 01	1.0072E 00	4.0286E 02
	1.3456E-01	1.5731E 00	2.0208E 00	7.5835E 01	7.6070E-01	3.0428E 02
	1.5730E-01	2.0525E 00	2.6455E 00	8.6797E 01	9.0152E-01	3.6061E 02
	2.4660E-01	3.2591E 00	3.9878E 00	1.2508E 02	1.4500E 00	5.7998E 02
	5.0474E-01	6.8524E 00	8.0453E 00	2.3540E 02	3.0752E 00	1.2301E 03
	1.4986E 00	2.4090E 01	2.8819E 01	6.9076E 02	9.6013E 00	3.8405E 03
	7.5978E-01	1.3735E 01	1.6687E 01	5.7628E 02	5.0722E 00	2.0289E 03
	1.9150E 00	3.9379E 01	4.8568E 01	1.1322E 03	1.3209E 01	5.2836E 03
	2.2346E 00	5.4134E 01	6.7864E 01	1.3684E 03	1.5987E 01	6.3946E 03
	1.2239E 00	3.5431E 01	4.4812E 01	1.1248E 03	9.4687E 00	3.7875E 03
	5.5286E-01	1.8112E 01	2.2950E 01	6.8446E 02	4.5868E 00	1.8347E 03
	1.0483E 00	4.0460E 01	5.1387E 01	1.1053E 03	9.4817E 00	3.7927E 03
	3.7272E-01	1.7677E 01	2.2442E 01	6.0149E 02	3.7574E 00	1.5030E 03
	2.4105E-01	1.4041E 01	1.7729E 01	4.4272E 02	2.7134E 00	1.0854E 03
	8.5057E-02	7.8688E 00	9.7781E 00	2.1353E 02	1.1791E 00	4.7166E 02
2	5.0982E 00	2.0407E 01	3.6075E 01	5.7952E 02	2.1493E 01	8.5970E 03
9	1.1246E 01	6.0849E 01	5.6103E 00	2.0275E 03	5.8290E 01	2.3316E 04
9	1.2895E 01	2.8951E 02	3.5843E 02	9.3803E 03	9.1796E 01	3.6718E 04
9	2.9238E 01	3.7076E 02	4.0011E 02	1.1987E 04	1.7158E 02	6.8631E 04

:RIAL BUCKLING - EIGENVALUE = 3.9349E-04

:CTIVE MULTIPLICATION FACTOR = 1.0003E 00

;RESSIVE TIME(SEC.) AT THE END OF MAIN = 382.490

```
285I    SYS1.CMPLIB                                          PASSED
285I    VOL SER NOS= EURSY0.
285I    SYS69101.T125507.RP001.PINOCCHI.GOSET                PASSED
285I    VOL SER NOS= EURSY3.
285I    SYSOUT                                               SYSOUT
285I    VOL SER NOS=      .
285I    PUNCH1                                               PASSED
285I    VOL SER NOS= PUNCH1.
285I    LIRE                                                 DELETED
285I    VOL SER NOS= LIBPIN.
285I    SYS69101.T125507.RP001.PINOCCHI.LIBPIN               DELETED
285I    VOL SER NOS= EURSY1.
285I    SYS69101.T125507.RP001.PINOCCHI.AVSIND               DELETED
285I    VOL SER NOS= EURSY2.
280I K 383,LIBPIN,PINOCCHI
 GO        DATE=69.04.11   BEG.T.=17.031   DURATION=0.108   N.OPER=463
285I    SYS69101.T125507.RP001.PINOCCHI.GOSET                DELETED
285I    VOL SER NOS= EURSY3.
285I    SYS1.CMPLIB                                          KEPT
285I    VOL SER NOS= EURSY0.
 PINOCCHI  DATE=69.04.11   BEG.T.=17.018   DURATION=0.121   N.OPER=463


 S P  JOB STATISTICS --  1,735 CARDS READ --      965 LINES PRINTED --      0 CARDS PUNCHED --   7.31 MINUTES EXECUTION TIME
```

Table 7

Isotope in HEROIC Library

Thermal cross sections

ELEM.	1st IDENT.	2nd IDENT.	MODEL
H	10001	27	FREE GAS
	10001	40	" "
	10001	50	" "
	10001	60	" "
	10001	70	" "
	10001	80	" "
	10001	90	" "
	12001	27	H in H_2O without transp.correction
	14001	27	H in H_2O with transp.correction
	12001	70	H in H_2O
	12001	150	" "
	12001	250	" "
	12001	350	" "
	13001	27	ARDENTE MODEL
	13001	100	" "
	13001	150	" "
	13001	200	" "
	13001	250	" "
	13001	300	" "
	13001	350	" "
	13001	400	" "
	13001	450	" "
D	10002	27	FREE GAS
	10002	50	" "
	10002	90	" "
	10002	100	" "
	10002	150	" "
	10002	200	" "
	10002	250	" "
	10002	300	" "

Thermal cross sections

ELEM.	1st IDENT.	2nd IDENT.	MODEL
D	12002	27	NELKIN MODEL
	12002	40	(from GAKER 101 groups)
	12002	50	" "
	12002	60	" "
	12002	70	" "
	12002	80	" "
	12002	90	" "
	14002	27	(from GAKER 30 groups)
	14002	40	" "
	14002	50	" "
	14002	60	" "
	14002	70	" "
	14002	80	" "
	14002	90	" "
C	10012	27	FREE GAS
	10012	100	" "
	10012	150	" "
	10012	177	" "
	10012	200	" "
	10012	250	" "
	10012	300	" "
	10012	350	" "
	10012	400	" "
	10012	450	" "
	10012	620	" "
	10012	627	" "
	10012	700	" "
	10012	720	" "
	10012	800	" "
	10012	820	" "
	10012	900	" "
	10012	928	" "
	10012	1000	" "
	10012	1100	" "
	10012	1200	" "
	10012	1300	" "
	10012	1400	" "
	10012	1500	" "
	15012	27	PARKS KERNEL

Thermal cross sections

ELEM.	Ist IDENT.	2nd IDENT.	MODEL
O	10016	27	FREE GAS
	10016	40	" "
	10016	50	" "
	10016	60	" "
	10016	70	" "
	10016	80	" "
	10016	90	" "
	10016	150	" "
	10016	177	" "
	10016	250	" "
	10016	350	" "
	10016	627	" "
	10016	700	" "
	10016	800	" "
	10016	900	" "
	10016	1000	" "
	10016	1100	" "
	10016	1200	" "
	10016	1300	" "
	10016	1400	" "
	10016	1500	" "
Fe	26	27	
Al	27	27	
Zr	40	27	
Th232	232	27	
U235	235	27	
U236	236	27	
U238	238	27	
Pu239	239	27	
Pu240	240	27	
Pu240	10240	177	Dopp. Broadened
	10240	327	" "
	10240	627	" "
	10240	927	" "
Pu241	241	27	
Xe	135	27	
Bo	10	27	
Cr	52	27	
Mn	55	27	

Thermal cross sections

ELEM.	1st IDENT.	2nd IDENT.	MODEL
Ni	58	27	
Cu	63	27	
Nb	93	27	
Cd	112	27	
Sn	119	27	
Pb	207	27	
Sm	149	27	
U233	233	27	
Pa233	533	27	
Np239	539	27	

Fast and epithermal cross sections

H	1	27	
D	2	27	
Bo	10	27	
C	12	27	
O	16	27	
Mg	24	27	
Fe	26	27	
Al	27	27	
Zr	40	27	
Cr	52	27	
Mn	55	27	
Ni	58	27	
Cu	63	27	
Nb	93	27	
Cd	112	27	
Sn	119	27	
Xe	135	27	
Sm	149	27	
Pb	207	27	
Th	232	27	
U233	233	27	
U235	235	27	
U236	236	27	
U238	238	27	
Pu239	239	27	

Fast and epithermal cross sections

ELEM.	1st IDENT.	2nd IDENT.	MODEL
Pu240	240	27	
Pu241	241	27	
Pa233	533	27	
Np239	539	27	
Resonance integral coefficients			
Th	232	27	
U235	235	27	
U238	238	27	

Table 8

HEROIC Calculation

Computing times in minutes

lines / Angles	12	16	24	32
2	7.3	8.9	12.3	17.0
4	12.1	15.4	21.9	33.0
8	21.9	28.4	41.5	65.0
16	42.0	52.0	75.0	107.1

ILLUSTRATION OF THE ASSIGNING OF REGION NUMBERS

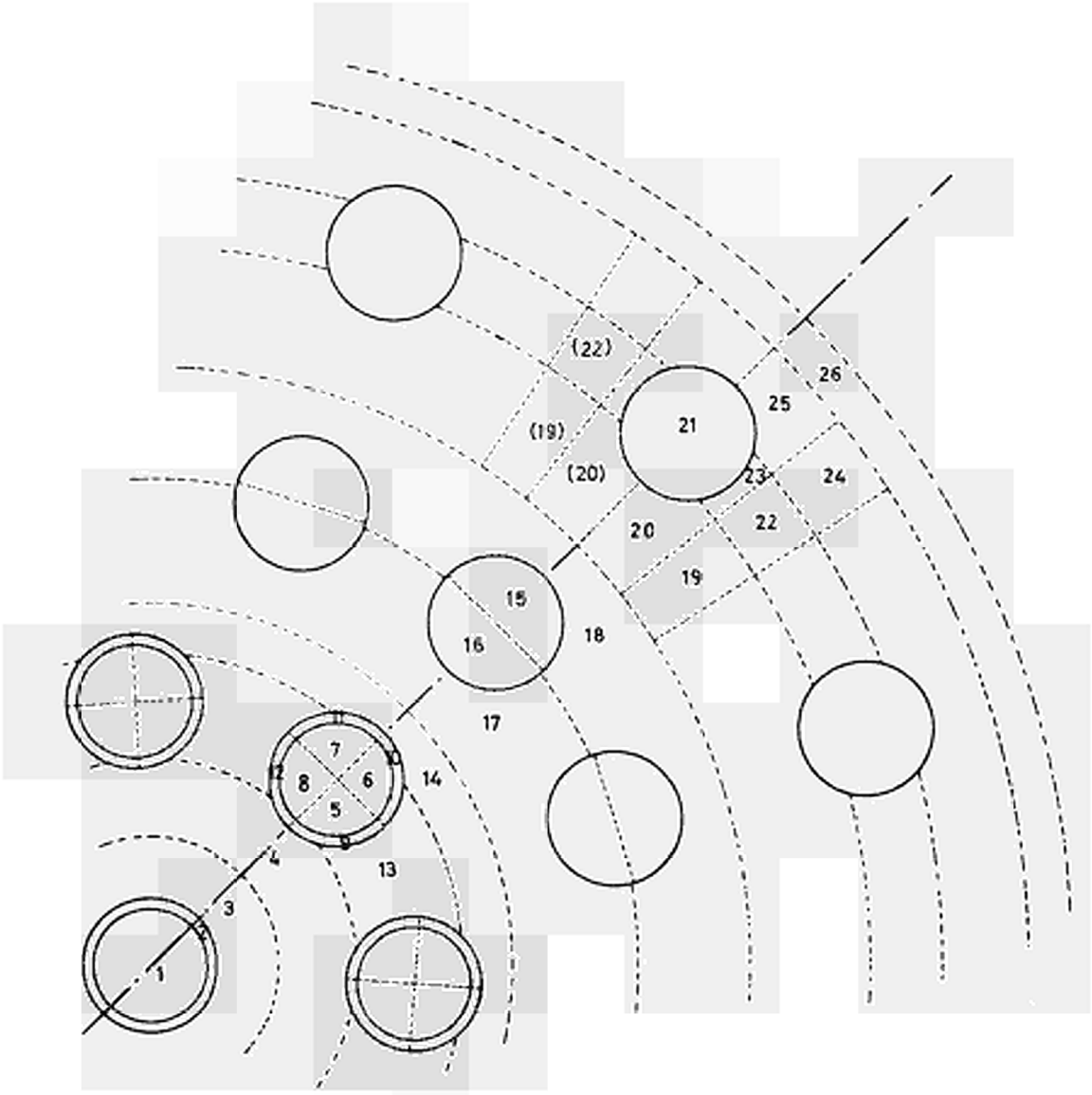


Fig. III

ASSIGNING OF REGION NUMBERS FOR SAMPLE CASE

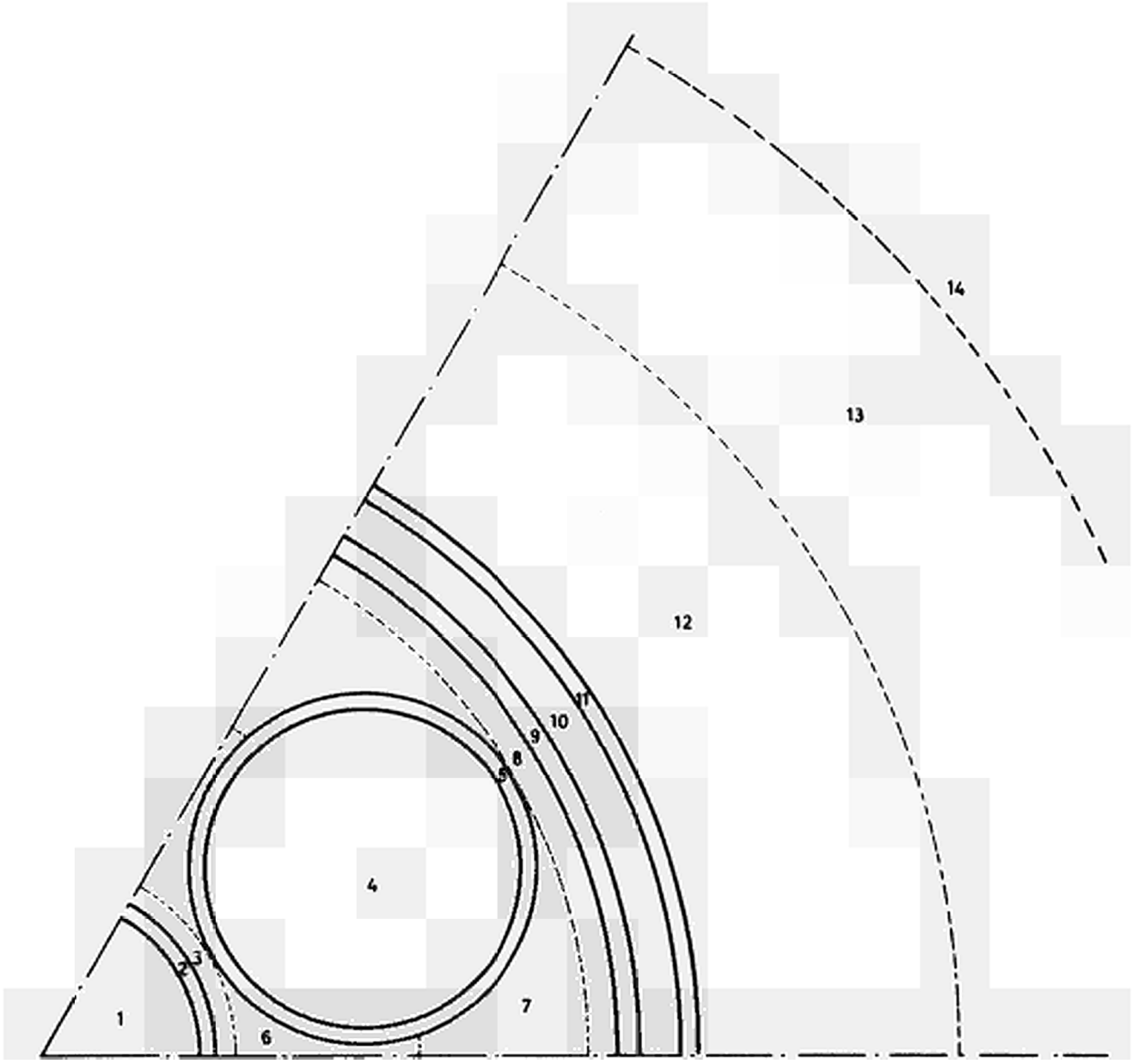


Fig. IV

References

1. AMYOT L. et al.: "Heavy Water Lattice Analyses at Ispra", BNES Int. Conf. London June 1967 on the Physics Problems in Thermal Reactor Design - Paper 15 pg. 117-125
2. DE HAAN W. et al. :"PLUTHARCO, A Plutonium, Uranium, Thorium Assembly Reactivity Code ", EUR-3141.e. (1966)
3. AMYOT L. et al.: "PINOCCHIO: A Computer Programme for Cell Reactivity Calculations" , **not available**
4. CARLVIK I.: "A Method for Calculating Collision Probabilities in General Cylindrical Geometry and Applications to Flux Distribution and Dancoff Factors", Paper P/681, Third Geneva Conf. (1964)
5. VIEWEG M.A. et al.: "GGC-II Program for Using GAM-II and GATHER-II Spectrum Codes in Preparing Multigroup Cross-section input", GA-4436 (1963)
6. WESTCOTT C.H.: "A Survey of Values of the 2200 $m/_{sec}$ Constants for Four Fissile Nuclides", Atomic Energy Review - Vol. 3 - No. 2 (1965)
7. ARDENTE V.: "Remarks on the Slow Neutron Scattering by Organic Molecules", J. de Physique, 25, 64 (1964)
8. DE HAAN W.:"Correlation of the Analytical Theory of the Results of Nordheim Numerical Resonance Integral Calculation Method", Private Communication
9. BREVI R.: "Analisi Critica del Calcolo dell'Integrale di Risonanza del Torio" -
10. DE HAAN W.et al.:"Calculation of the Absorption and Fission Resonance Integrals of U-235 by a Fitting Procedure " EUR 3936e. (1968)

11. LESLIE D.C., JONSON A.: "The Calculation of Collision Probabilities and Resonance Integrals in Cluster Type Fuel Elements", AEEW-k 384 (1964)

12. BEARDWOOD J.E. et al.: "The Solution of the Transport Equation by Collision Probability Methods", Conference on the Application of Computing Methods to Reactor Problems, ANL-7050 pp. 93-110 (1965)

13. HONECK M.C.: "A Thermalisation Transport Theory Code for Thermal Lattice Calculations", BNL-5826 (1962)

14. BENOIST P.: "Streaming Effects and Collision Probabilities in Lattices", CEA Report SPM n. 988 (1967)

15. BOEUF A., TASSAN S.: "A Measurement of the Hyperfine Structure of the Thermal Neutron Flux Distribution in Organic Cooled UC Clustered Fuel Elements in a D_2O Moderated Lattice" - Energia Nucleare Vol. 13, n. 2 (1966)

16. KAY R.E., GREEN R.E.: "Lattice Measurements with 7-rod Clusters of Natural Uranium Carbide in Heavy Water Moderator", AECL-2650 Chalk River, Ontario (1966)

17. BOEUF A., TASSAN S.: "A Measurement of the Fine Structure Distribution of the Thermal Flux in Organic Cooled Fuel Elements in a D_2O Moderated Lattice", Energia Nucleare Vol. 11, n. 10 (1964)

18. JONSSON A., PEKAREK H.: "Multigroup Collision Probability Theory in Cluster Geometry, Comparison with Experiments", Reactor Physics in the Resonance and Thermal Regions, San Diego pag. 367-393 (1966)

19. Misure di K-inf e di Parametri Dettagliati per Reticoli CIRENE ai Passi 27.4,30.2 e 32.2 cm e con Densità del Refrigerante Equivalente a 0.35 gr/cm^3 di H_2O - Doc. Int. CISE n. 279

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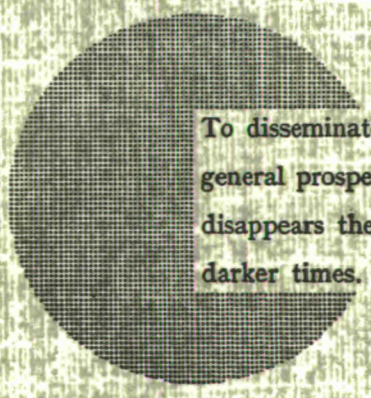

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Alfred Nobel

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