HEAVY WATER ORGANIC COOLED
REACTOR

THREDES
ATOMICS INTERNATIONAL
THERMAL REACTOR DESIGN SYSTEM

ATOMICS INTERNATIONAL—COMBUSTION ENGINEERING

A Joint Venture for Heavy Water Organic Cooled Reactors

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THERMAL REACTOR DESIGN SYSTEM

By

R. A. BLAINE

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ATOMICS INTERNATIONAL—COMBUSTION ENGINEERING

A Joint Venture for Heavy Water Organic Cooled Reactors

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ABSTRACT

THREDES is a scientific applications programming system written in the FORTRAN IV language for the IBM 7094/360 computers.

Incorporated in this system are the necessary modules to perform parametric design studies of thermal reactors including the thermal cell homogenization (BAM), the fast spectrum calculation (FØRM), reactor diffusion theory (FØG), and zero dimensional burn-up (KINDLE) calculations.

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Finally, I want to acknowledge the fact that sections of this document are reproduced (with minor changes) from References 1, 2, 3, and 4. These are sections II-B, II-C, and II-D on the options in BAM, FORM, and FOG, and sections III-E, III-F, and III-G describing the addressable data.

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I INTRODUCTION

THREDES is a scientific applications programming system written in the FORTRAN IV language for the IBM 7094/IBM 360 computers. Incorporated in this system are the necessary modules to perform parametric design studies of thermal reactors, including the thermal cell homogenization, the fast spectrum calculation, reactor diffusion theory, and zero dimensional burn-up calculations.

THREDES combines BAM¹, FORM^{2,3}, FOG⁴, and KINDLE⁵ into an integrated system minimizing both data input and the time required to complete a reactor design study. The choice of the above codes is a compromise between the accuracy required in parametric studies and computer running time. Other (more or less accurate) codes can be substituted, and additional codes can be added.

In what follows, it is assumed that the reader is familiar with the theory of the individual codes as this document is intended primarily as a user's manual. Section II-A discusses the overall operation of THREDES, i.e., how information passes from one code to another, and makes frequent reference to a flow diagram. The remainder of Section II describes the individual codes discussing various options, and how these affect the overall operation of the system. Section III contains detailed information on data input and discusses the multiple case feature. Section IV contains operating instructions. Information on the library is contained in Appendix A, and sample data and output are in Appendices B and C.

II DISCUSSION

A. System Operation

This section presents first an overall view of the manner in which information from one code is transmitted to later codes and a discussion of the available options of the individual codes. The intent of THREDES is to provide complete processing of data starting with BAM and ending with FOG or KINDLE. However, it is possible to use any code or combination of codes; this feature will be clarified in what follows.

It is appropriate at this point to review the main features of the individual codes to provide a basis for the discussion of the overall system. This review will be brief but will mention (1) the purpose, (2) input, and (3) output of each code and their relationship.

BAM

Purpose - BAM computes basically the thermal flux distribution by assuming separability of space and energy in the Boltzmann equation and iterating to convergence between an infinite medium spectrum code, TEMPEST II⁶, and an S_4 cylindrical cell code⁷. From the converged space-energy flux, the averaged group constants can be calculated.

Output - BAM computes (1) the thermal group constants; the diffusion coefficient, D ; the absorption, fission, and transport cross sections, (2) the volume-flux weighted number densities, (3) the volume-weighted number densities, (4) the flux disadvantage factor, (5) the microscopic absorption, fission, and transport cross sections by element, and other cell averaged quantities as thermal utilization. The thermal group constants are saved for use in FOG or KINDLE, and the volume-weighted number densities and their identification numbers are stored for input to FORM and KINDLE. In addition, microscopic cross sections and the flux disadvantage factor are saved for KINDLE.

Input - The main items of input are (1) element identification numbers and number densities by region, (2) radii and the number of mesh points by region, (3) options controlling the model used in the spectrum calculation, convergence criteria, printing options, etc.

FORM

Purpose - FORM computes the high energy flux spectrum by solving the (space independent) Fourier transformed Boltzmann equation and averages the required cross sections over that spectrum.

Output - FORM computes the fast group micro- and macroscopic cross sections as well as certain other physics data. The group constants are used by FOG or KINDLE and the microscopic cross sections by KINDLE.

Input - The input consists of (1) element identification numbers and volume weighted number densities, and (2) control information pertaining to edits, calculation options, and group structure. The first data are available from BAM or can be supplied directly.

FOG

Purpose - FOG solves the few group diffusion theory equations for the fluxes and eigenvalue (Keff) allowing for searches on poison concentrations, boundaries, and transverse buckling.

Output - Real and adjoint flux, source, eigenvalues, and data edits containing flux integrals, neutron ballane tables, and peak to average power.

Input - Macroscopic group cross sections by region* or material, reactor geometry and control information. Group constants are available from BAM and FORM or can be supplied directly.

*This feature can be used, but all data handling in THREDES is by material.

KINDLE

Purpose - KINDLE solves the zero dimensional two-group reactor burn-up equations allowing for variable self-shielding of the plutonium resonance integrals and variation of the thermal flux disadvantage factor.

Output - The output consists of reactivity, conversion ratio, isotope concentration, fissile and fertile mass and certain other physics data as functions of exposure and time.

Input - Input for KINDLE consists of volume weighted number densities and their identification numbers, two-group micro- and macroscopic cross sections, and the thermal flux disadvantage factor. In addition, certain control information is required. All physics data is available from BAM and FORM.

The discussion that follows refers to the overall flow diagram of THREDES and is intended to explain the various options in the use of the overall system. Options referring to the individual codes are discussed in later sections. Each "box" on the flow diagram is identified, e.g., A3, B5, D6, and in general "boxes" identified by the letters A, B, C, and D refer to BAM, FORM, FOG, and KINDLE, respectively.

A1 - A card is read containing the numbers to be assigned to the materials processed by BAM, MBAM(I). The term material here is used to refer to the physics data (cross sections, number densities, fluxes, etc.) resulting from the BAM calculation for a particular cell (lattice, enrichment, etc). The numbers must be in ascending numerical order and must be consecutive if KINDLE is to be used, i.e., 1, 2, 3, ... but need not be consecutive if FOG is to be used, i.e., 2, 4, 5, 6, 10. The number of materials to be computed is determined by the number of entries to be computed and may be greater or equal to zero. In the latter case, no BAM calculations will be done.

A2 - A card is read containing the numbers to be assigned to the materials processed by FORM, MFORM(I). The same comments apply to there as above. Note that it is possible to bypass both BAM and FORM.

A3 - A card is read containing the word "FOG" or "KINDLE." Note that one code or the other will be used; it is not possible to intermix their use. A test is made to verify the choice and an error message is printed in the event that "FØG" or "KINDLE" does not appear.

A4 - At this point a test is made to determine if the BAM and FORM material numbers, MBAM(I) and MFORM(I) are in ascending order. If so, the number of cases to be run on each code is counted. If not, processing continues for those materials which were specified correctly; e.g., if MBAM(I) contained the numbers 1, 2, 3, 5, 4, 6,...material 5 would be the last one processed.

If no BAM cases are to be processed the program proceeds to B1; otherwise control passes to A5.

A5 - At this point the TEMPEST library is read from file 1 of tape 9. If an incorrect tape was mounted, an error message is printed and the job is terminated.

A6 - Provision is made for reading changes or additions to the TEMPEST library.

A7 - The counter, I, is set equal to 1. This counter indicates the number of the material, MBAM(I), which is currently being calculated.

A8 - At this point control passes to the BAM code and the thermal group data are computed. Some differences exist between BAM IV and the version incorporated herein; these are described in a later section.

A9 - The results of the BAM calculation are saved on tape 2 for later processing. This data includes MBAM(I), the material number; NØG, the number assigned to the thermal group (1,4 for FOG - must be 2 for KINDLE); B_{th}^2 , the thermal group buckling; Σ_1^{th} , the macroscopic absorption cross section; D^{th} , the thermal group diffusion coefficient; $\nu \Sigma_f^{th}$, the thermal group neutron production cross section; the volume-flux weighted number densities by element; and the microscopic cross sections - absorption, fission and transport by element.

A10 - At this point a test is made to determine if a FORM calculation is to be done for the current material. If so control passes to A11; otherwise, to A12.

A11 - The data required for a FORM calculation is saved on tape 2 for later processing. These data include MBAM(I), the material number; IP, the number of elements; the "MUFT" identification numbers; and the volume-weighted number densities. The "MUFT" identification numbers are the library numbers of the elements with possibly a minus and/or 400 or 700 added as required by FORM.

A12 - At this point the material counter, I, is increased by 1 so that processing of the next material can take place.

A13 - At this point a test is made to see how many materials are the same as the previous material, MBAM(I-1). Data Location 30 (DATA(30)) contains this number. If zero, control passes to A14. If non-zero, DATA(30) is reduced by one and the program transfers to A9. When DATA(30) has been reduced to zero control passes to A14. This feature allows several materials to have the same thermal group data without recomputation and is useful for doppler coefficient studies or in general any time only the fast group properties change.

A14 - If all required materials have been processed by BAM, control passes to B1; otherwise to A8.

B1 - The counter, I, is set equal to 1. This counter is the number of the material which is currently being processed and always runs from 1 to the highest material number indicated for BAM or FORM.

B2 - A test is made to determine if any FORM calculations are to be performed. If not, control passes to C1 - otherwise to B4.

B4 - If BAM data was computed for the current material, I, the thermal group constants, volume-flux weighted number densities and microscopic cross section are transferred from tape 2 to tape 8. Otherwise control passes directly to B5.

B5 - A test is made to determine if a FORM calculation is to be performed for material I. If not control passes to B9 - otherwise to B6.

B6 - If a BAM calculation was done for material I, the volume-weighted number densities and "MUFT" identification numbers are picked up from tape 2 - otherwise control passes directly to B7.

B7 - At this point control passes to the FORM program and the fast group data are computed. Some differences exist between the normal FORM code and the version contained herein. These are discussed in a later section.

B8 - The fast group data are written on tape 8 for use by FOG or KINDLE. This data includes the macroscopic group removal, absorption, fission and production cross sections; the diffusion coefficients, the fraction of the fission spectrum in each group; the volume-weighted number densities, their identification numbers, microscopic absorption, fission and production cross sections by element.

B9 - The material number, I, is increased by 1.

B10 - The same kind of test is made here as in BAM at A13, with the indicator in L(629). This location is reduced by 1 until zero.

B11 - If all required materials have been processed by FORM control passes to C1 - if not, to B4.

C1 - A test is made to determine whether FOG or KINDLE computations are to be performed and control passes to C2 or D1 accordingly.

C2 - If FOG computations are to be performed, the fast and thermal group constants are picked up from tape 8 for all materials processed. The remainder of the data is discarded.

C3 - The addresses of the group constants are computed for each material and stored in the proper location for FOG input. If material numbers are skipped or fast but not thermal group constants are provided (vice versa) the corresponding locations are set to zero and must be supplied by the user if needed.

C4 - At this point control passes to the FOG Code. Any number and variety of FOG calculations can be performed.

C5 - Problem Termination occurs when no more FOG cases are found.

D1 - On initial entry to KINDLE the cross sections and other built-in data are initialized and the material counter, I, is set equal to 1. Note that KINDLE expects the materials numbers in consecutive, ascending order; i.e., 1, 2, 3, If no materials have been processed, control passes directly to D3.

D2 - The macro- and microscopic information for material number I is read from tape 8. It is assumed that both FORM and BAM data are available and are groups 1 and 2 respectively. If not, an error message is printed and the job is terminated. The macroscopic group constants are stored in the input array and each element from BAM and FORM is tested to determine if it is used by KINDLE.

If the element is "UNIT A", number 55, then Unit-A, UA, is set equal to the thermal absorption Cross-Section. If the element is not used, the next element is tested. For each element used by KINDLE the following is done: (1) store the volume-weighted number density (as used in FORM), (2) store any non-zero fast and thermal absorption and fission cross-sections into the input array, and

(3) compute the average thermal flux, fuel disadvantage factor by forming the ratio of the sum of volume-flux weighted number densities (from BAM) to the volume-weighted number densities (from FORM). Zero cross-sections arise only if the element was not on the BAM or FORM library tape and are skipped so as to retain the built-in data.

D3 - The KINDLE data is read and may modify any quantity in core, such as Unit-A, any cross-section, etc. The thermal cross-sections are then tested and if any one is zero; i.e., not supplied by BAM BUILT-IN, or input, then the value is taken to be the 2200 m/s value times Unit-A. Unit-A in turn is determined by input, BAM (if element 55 is available) or by the built-in value.

Normal problem termination occurs when no more KINDLE data is found.

D4 - At this point control is turned over to the KINDLE code for a normal calculation.

D5 - A test is made to determine if the next case will use the same material; if so, a transfer is made to D3 - otherwise to D6. The last of a set of cases should indicate that the same material is to be used so that normal problem termination will occur.

D6 - If a new material is to be used in the following case, the material number, I, is incremented and control is passed to D2.

OVERALL FLOW DIAGRAM FOR THREDES

B. Thermal Group Calculations (BAM)

The original BAM code was written jointly by ORNL and Atomics International to serve the needs of nuclear engineers at both AEC installations. The code will compute the thermal group constants Σ_a , Σ_{tr} , D , Σ_f , $\nu\Sigma_f$, L^2 and η for a heterogeneous cell, as well as the energy and spatial distributions. There is nothing new about the method used in BAM. One assumes separability of the space and energy variables in the Boltzmann Equation in the thermal region and iterates between the two distributions until convergence is reached. Although this technique is not as accurate as more sophisticated methods⁸, the method is commonly used and leads to reasonable, accurate results in short times. No essential modification was made to the version of BAM incorporated in THREDES.

The S_4 Cylindrical Cell Code⁷, was chosen for the calculation of the spatial distribution in the cell and the TEMPEST II⁶ code for the energy spectrum calculation. Modifications were made to both codes, and so the input will be discussed in a later section. It is assumed that the user of this document is thoroughly familiar with the use and theory of both TEMPEST II and the S_4 Cylindrical Cell Code in what follows.

The input necessary to operate BAM is essentially the geometry of the cell, the element identification numbers and densities for each element of each region, and the various options. Much of the data needed (convergence criteria, extrapolation parameters, etc.) are built into BAM. If the FORM code is to be used then all element identification numbers should be entered in the first case. These numbers may include the information required by FORM as to the resonance scatter or option (plus or minus) and the edit number (400+ID).

The calculational procedure is as follows: First, the TEMPEST II library is read in, followed by any additional binary and/or decimal libraries and a card with the word "DATA" to signify that all libraries have been read. Next, the title card is read, followed by the case data which is entered by means of the FREAD subroutine, described in Section III A.

The element number densities are volume-flux weighted over the entire cell for use by TEMPEST II. The volume fractions are calculated using the region boundaries, and the initial flux guess is specified by an option as being flat, input, or available from the previous case. These densities are used in TEMPEST II to compute the first approximation to the spectrum and the microscopic element-wise cross-sections are obtained.

The macroscopic cross-sections necessary for a spatial calculation are formed for each region, and a diffusion theory* calculation is made to provide a guess for the S_n calculation, which in turn provides a second guess at the disadvantage factors for each region. The element densities are again volume-flux weighted and used in TEMPEST II to recompute the spectrum.

This procedure continues until the absorption cross-section in each region converges on two successive iterations to within a specified tolerance. Thus the minimum number of calculations is one S_n and two TEMPEST II runs.

The results are printed according to one of several printing options allowing a record of every iteration, the final results or no printing at all. In conjunction with this option the flux distribution can be printed.

The thermal group constants, flux disadvantage factor, volume-weighted number densities, element identification numbers, and microscopic cross-sections are written on tape for use by FORM and FOG or KINDLE.

*On successive cases an option is available to use the converged distribution from the previous case as the starting point for the S_n calculation.

AVAILABLE OPTIONS

1. Four theories are available for the spectrum calculations:
 - A. ITYPE = 1 The Wilkins Approximation.
 - B. ITYPE = 2 The Wigner-Wilkins Approximation.
 - C. ITYPE = 5 The Wilkins Approximation is used from $E_{\min}$ to E_{trans} , and the Wigner-Wilkins Approximation is used from E_{trans} to $E_{\max}$.
 - D. ITYPE = 6 Converse of above (ITYPE = 5).

If ITYPE takes on any other value, the job will be deleted.
2. Mode of Hydrogen Binding. This option permits the user to select the hydrogen transport cross-section for use in the diffusion coefficient calculation from among any element in the 200 series. The quantity "KHY" in the input is the number chosen; e.g., free gas, water, 1,3 Butadiene, etc. See equation 15 in reference 6. If hydrogen (element 1) is not present, ignore this option.
3. Option to print the TEMPEST II library. If a printout of the library is desired, set LIB = 1 in the first case. LIB will be reset to 0 on the second case.
4. Option to perform a diffusion theory calculation. A diffusion theory calculation is performed to provide a guess for the S_n calculation for Iteration 1 of Case 1, regardless of the value of IOP. All successive iterations in Case 1 use the converged S_n flux from the last iteration of the previous case.
5. Option to provide a flux disadvantage factor guess for the first iteration. This option has three choices:
 - A. KFLUX = 0 The flux is assumed flat.
 - B. KFLUX = 1 A guess is supplied for each region.
 - C. KFLUX = 2 The final distribution from the previous case is used.

It is strongly suggested that for similar cases $KFLUX = 1$ for Case 1 and $KFLUX = 2$ in Case 2 and thereafter.

6. All elements are assumed to be moderators.
7. Printing Options - For use in THREDES, it is possible to bypass all BAM printing. If any printing is requested, the volume, volume fractions, element, element densities will be printed by region for every case as before. The printout of homogenized density has been corrected so as to be volume-averaged only. The remainder of the printing is under the control of several options which print the TEMPEST and SN input and results on every iteration or for the final iteration only. An independent option is provided to print the SN flux distribution. Printing of the angular SN fluxus or TEMPEST spectrum is no longer available.

C. Fast Group Calculations (FORM)

FORM, FORTRAN MUFT, solves the Fourier transform of the Boltzmann equation using either the B1 or P1 approximation. Either the Selengut-Goertzel or exact treatment can be used for hydrogen slowing down with a conventional or self-consistent age assumption for the heavy element slowing down. The equations are derived and discussed fully Refs. 9, 10, and 11.

The FORTRAN IV version of FORM incorporated herein was modified to read certain of the input data from tape (if computed by BAM) before reading data from cards. In addition the input formats for both floating point and integer data were modified to use the FREAD and IREAD Subroutines as described in Section III-A. One restriction was imposed: only one "few group" output scheme can be obtained. A modification was made to the fast fission correction factor: this factor now applies to both the capture and fission cross-sections. Modifications to the tape handling resulted in a factor of two reduction in running time from the FORTRAN II version.

The output consisting of 1, 2, or 3 fast group constants and microscopic cross-sections is written on tape for further processing by FOG or KINDLE. Note that the microscopic cross-sections are available only for those elements for which edit 4 is requested.

The remainder of this section discusses code options and output.

1. OPTIONS IN THE CODE

a. Slowing Down Approximations

Either the B1 or the P1 approximation may be used in the solution of the slowing down equations. In effect, the B1 approximation provides an expansion of the flux into an infinite series of Legendre polynomials and an expansion of the scattering kernel into the first two Legendre polynomials. In the P1 approximation, the infinite expansion is used for the scattering kernel and the finite expansion for the flux. For large systems, the fluxes obtained by the two methods are almost identical. For small systems the B1 approximation should be used if the scattering kernel is more nearly isotropic than the flux; the P1 approximation should be used if the converse is true. No generalizations can be made about the relative accuracy of the two approximations on a given system. For safety both should be tried and the one found to agree more closely with experiment used in future calculations for similar systems. For parameter survey calculations where a high degree of accuracy is not desired and it is necessary to choose one approximation, the B1 approximation will more often give more accurate answers.

b. Age Approximations

Either the conventional or self-consistent age approximations may be selected. The self-consistent ages recognize the energy loss - scattering angle correlation in elastic scattering with heavy elements while the conventional age approximation does not. Since no extra machine time is involved in using the self-consistent age treatment, it is recommended that this be used for normal calculations.

c. Selengut-Goertzel Approximation

An exact treatment of hydrogen slowing down is obtained by selecting the "no Selengut-Goertzel" option. The Selengut-Goertzel approximation neglects the energy loss - scattering angle correlation in elastic collisions with hydrogen and has been shown to yield incorrect values for the age in hydrogen." Since negligible additional machine time is involved in choosing the "no Selengut-Goertzel" approximation, it is recommended that this option be selected.

d. Source Option

At present 11 sources appear on the library tape. They are arranged as follows:

- (1) Prompt U-235 Fission Source
- (2) Monoenergetic Source in Group 11
- (3) Monoenergetic Source in Group 12
- (4) Monoenergetic Source in Group 13
- (5) Monoenergetic Source in Group 14
- (6) Monoenergetic Source in Group 15
- (7) Delayed U-235 Neutron Fission Source
- (8) Monoenergetic Source in Group 16
- (9) Leakage Source from Piqua OMR
- (10) Complete U-235 Fission Source
- (11) Monoenergetic Source in Group 21

The monoenergetic sources are those supplied with the original Westinhouse MUFT-4 library and are used in special cases, such as the representation of certain delayed neutron groups.

e. Output Few Group Schemes

Only one output scheme is allowed.

f. Resonance Scatterer Option

Only specified elements are treated as resonance scatterers. Note that if hydrogen is present it is always a resonance scatterer.

The manner in which a resonance scatterer is specified is by making the sign of the element identification number (after 0,300, 400, or 700 is added for the edit) negative. Only elements with negative signs will be included as resonance scatterers (with the exception of hydrogen) unless no element has a negative identification in which event, all elements are resonance scatterers). If no element other than hydrogen is a resonance scatterer, then hydrogen must have a negative identification number. Those elements which are resonance scatters are indicated on the first page of output.

g. Fast Fission Factor Option

FORM treats fast fission as a homogeneous effect, so that the fast fissions which occur in the fuel cluster are not treated correctly and an erroneous fast fission cross-section results. This error in theory can be corrected by modifying the fission and capture cross-sections so that for every group cross section

$$\begin{aligned}\sigma_m^f &\longrightarrow FF \cdot \sigma_m^f \\ \sigma_m^c &\longrightarrow FF \cdot \sigma_m^c\end{aligned}$$

(1)

where FF is the correction factor, and the absorption is accordingly changed.

The reader is referred to references 12 and 13 for the details of calculating the correction factor.

The specification of this option is as follows:

Data location 627, IFF, indicates the position of the element to which the fast fission correction factor is to be applied; i.e., if U238 is the 5th element in the list of element identification numbers (regardless of edit number and/or sign) then IFF = 5.

The fast fission correction factor, FF, is entered in data location 74 of the floating point data. This correction factor is used in all succeeding cases unless re-specified.

Note that the use of this option has been changed from the prior use in FORM to agree with the normal usage of addressable data. If $FF \neq 1$ a message is printed indicating FF, and the identification number, IFF, of the element involved.

h. Printing Option for Edit 3

The 54 group element-wise intermediate integrals can be obtained by entering a 1 in L (628); otherwise only the element-wise few group data appears in the output.

i. Specification of Edit 3 and 4

It is no longer possible to obtain edit 4 without edit 3. So that by adding 400 to an element identification number, both edits 3 and 4 are obtained. Note that addition of 700 is now equivalent to addition of 400 and is also acceptable.

j. Edit 4 for Elements not in Media

If the number density of any element is zero and edit 4 is requested, the microscopic cross-sections are given in edit 4; edit 3 will not be printed as it is a macroscopic edit. The resonance calculation assume a number density of 10^{14} atoms/cm³, so that infinitely dilute resonance integrals are obtained. Note that L factors must be specified. The presence of these elements in no way affects the spectrum calculation or edit 1 and 2. The removal cross-section will not be calculated.

k. Cross-Section Addition at Execution Time

Microscopic cross-sections, resonance parameters, and inelastic scattering matrices may be replaced at execution time by the use of subroutine ADD. The only restriction is that the elements presently appear on the library tape and have parameters of the kind that are to be replaced. Cross-sections of a new element may be read in by calling a blank element from the tape having parameters of the kind to be replaced. Several blank elements now exist on the tape for this purpose. Details of coding for this option are included in Section III F 5.

2. OUTPUT EDITS

In addition to the three edit formats offered by MUFT-4, FORM has an edit (edit 4) which prints few group element-wise microscopic data. Since only minor changes have been made in the output format, this report will only list the quantities in each edit and call attention to any differences from MUFT-4.

a. Edit 1: Prints $\Sigma_a, \Sigma_R, \Sigma_f, \nu\Sigma_f, \rho, \tau, D$

for the specified few group schemes. The age as printed is the actual age of the entire source to the bottom of the particular group concerned, and should not be confused with the "T" printed by MUFT-4, which was merely the age of neutrons born in that group to the bottom of that group.

b. Edit 2: Prints edit 1 and prints a 54 group edit of flux, current, and slowing down densities.

Prints for each output few group scheme the following integrals:

$$\begin{aligned} & \int \Sigma_a \phi(u) du \\ & \int \phi(u) du \\ & \int \Sigma_f \phi(u) du \\ & \int \nu \Sigma_f \phi(u) du \\ & \int \chi(u) du \\ & \int J(u) du \end{aligned}$$

c. Edit 3: Prints edit 2 and prints a 54 group edit of fission, nu-fission, smooth absorption, and resonance absorption for elements selected. Prints Σ_a , smooth; Σ_a , resonance; Σ_f and $\nu\Sigma_f$ for few-group schemes for elements selected.

d. Edit 4: Prints for each element selected edit 3 and microscopic element-wise data required for KINDLE.

The following cross-sections appear:

$$\sigma_{tr}, \xi\sigma_s, \sigma_a, \bar{\sigma}_f, \nu\sigma_f, \sigma_R$$

where

$$\sigma_{tr} = \sigma_a + \nu\sigma_f - (1 - \beta)\sigma_s$$

σ_a is the total absorption cross-section; i.e., smooth + resonance capture and fission

σ_{tr} is the total inelastic scattering cross-section

$\xi\sigma_s$ is the elastic microscopic slowing down power

$\bar{\sigma}_f$ is the smooth plus resonance fission cross-section (as modified by a fast fission correction factor)

$\nu\sigma_f$ is the average number of neutrons per fission times the fission cross-section

σ_R is the removal cross-section to the next lower group; i.e., $\sigma_{i \rightarrow i+1}$ and includes both elastic and inelastic transfers.

Elastic Removal

Hydrogen: The elastic removal is given by:

$$\sigma_R = \frac{\eta(j_i)}{NH \int_i \phi du} \quad (2)$$

where η is the hydrogen slowing down density

j_i is the last multigroup belonging to the i^{th} few group

$\int_i \phi du$ is the i^{th} few group flux.

For few group calculations the above is an adequate definition. Since no over-scatter is allowed, this cross-section should not be used when the $i+1^{st}$ group is small.

Heavy Scatterer: For the k^{th} element

$$\sigma_R^k = \left[\frac{\xi_{cs}^k}{\sum_l \xi_{cs}^l} \right] \cdot \frac{\rho(j_i)}{\phi(u, u)} \cdot \frac{1}{1-k} \quad (3)$$

where $\rho(j_i)$ is the heavy element slowing down density and

$$\left[\frac{\xi_{cs}^k}{\sum_l \xi_{cs}^l} \right]$$

is the fraction of the slowing down density attributed to the k^{th} element and the sum over l excludes hydrogen.

Inelastic Removal

Hydrogen

None

Heavy Elements

If an inelastic matrix is in the library the inelastic removal is found as follows:

Let $\pi_{i \rightarrow j}^{i^{th}}$ = The probability for inelastic removal from the i^{th} to the j^{th} multigroup.
 σ_{IN}^i = The inelastic scattering cross-section of the i^{th} group.

$$\text{Thus } \sigma_{i \rightarrow j}^{IN} = \sigma_{IN}^i \cdot \pi_{i \rightarrow j} \quad (4)$$

Then the inelastic contribution is given by:

$$\sigma_{R, IN}^I = \frac{\sum_{i \in I} \phi_i \Delta u_i \sum_{j \in I+1} \sigma_{i \rightarrow j}}{\sum_{i \in I} \phi_i \Delta u_i} \quad (5)$$

Where the symbol $\left(\sum_{i \in I} \right)$ is understood to mean a sum over all i multigroups belonging to the I^{th} few group.

It must be pointed out that the present FORM library tape allows for inelastic scatter in the top 25 groups. So that the inelastic removal term will be in error if there are three or more few groups above multigroup 25 as "overscatter" is not accounted for.

Energy Deposition

The equations are the same as in reference 20 with the exception of the calculation of the average energy loss per elastic collision. No additional input is required for this calculation; it has been made a normal part of Edit 4. The calculation is as follows:

Following Duncan, the energy deposition due to inelastic collisions with a given element is calculated as follows (see equation A-1 in the reference).

$$E_{IN} = N \sum_{i=1}^{24} \Gamma_i \sum_{j=i+1}^{25} \sigma_{i \rightarrow j} (\bar{E}_i - \bar{E}_j) \quad (6)$$

where

E_{IN} = Energy deposition by inelastic scattering with the given element (Mev)

N = Number density of given element (atoms/cm³-barn)

Γ_i = Neutron flux in ith group (n/cm²-sec)

$\sigma_{i \rightarrow j}$ = Cross-section for inelastic scattering from group i to group j (barn)

$\bar{E}_i$ = Average Energy of group i

and the limits on the sums correspond to the fact that only the first 25 groups in the FORM library have inelastic scattering data.

The average energy of group i is computed as

$$\begin{aligned} \bar{E}_1 &= 10 \exp(-\Delta u_1^2) \\ \bar{E}_i &= \bar{E}_{i-1} \exp\left(-\frac{\Delta u_i^2 + \Delta u_{i-1}^2}{2}\right) \end{aligned} \quad (7)$$

where Δu_i is the lethargy width of group i. (This equation is the same as (A-2) but has been reformulated for computational ease.)

The fast neutron energy deposition due to elastic collisions with a given element is (see equation A-3 in the reference):

$$E_{el} = N \sum_{i=1}^{54} \Gamma_i \sigma_i \overline{\Delta E_i}$$

(8)

where

E_{el} = Energy deposition by elastic scattering with the given element (Mev)

σ_i = Microscopic elastic scattering cross-section of the given element in group i (barns)

$\overline{\Delta E_i}$ = Average energy loss of neutrons due to elastic scattering with the given element in group i.

The computation of $\overline{\Delta E_i}$ has been improved somewhat, and as a result, eliminates the requirement for supplying the atomic weights as part of the input. The new formulation is as follows:

Since ξ_i is defined to be the average logarithmic energy loss per elastic collision with a given element in group i, we can write approximately,

$$E_f^i / E_i = \exp(-\xi_i)$$

(9)

where E_f^i is the average final energy due to an elastic scattering collision in group i and where we assume for this calculation that all elastic collisions in group i occur at energy E_i , the average energy.

Thus, the average elastic energy loss is given by:

$$\overline{\Delta E_i} = E_i - E_f^i = E_i (1 - \exp(-\xi_i))$$

(10)

which is the equation used in the code. Hydrogen is assumed to lose half of its energy per collision.

The above formulation accounts for anisotropic scattering through the calculation of the $\bar{\sigma}$ which are part of the library.

The normalization used in the calculation is that of the source; e.g., 2 Mev for a fission source. However, the sum of inelastic and elastic energy deposition in all elements present in the medium may not sum to the source energy due to additional energy losses as absorption and leakage.

In the case of elements with zero number density, the elastic and inelastic energy deposition has been normalized to

$$1 \frac{\text{atom}}{\text{cm}^3\text{-barn}} .$$

D. Diffusion Theory Reactor Calculation (FØG)

The version of FOG⁴ used in THREDES will handle from one to four energy groups, up to 239 space points, and up to 40 regions. Neutrons are permitted to scatter only from a given group to a next lower group. The principal options available are:

- a. Choice of three geometries,
- b. Calculation of the fluxes and multiplication factor,
- c. "One-iteration" problems,
- d. Choice of one of nine possible sets of boundary conditions for homogeneous calculations or of eight possible sets for non-homogeneous calculations,
- e. Criticality searches on the transverse buckling, homogeneous poison, critical radius, location of a poison boundary, and location of a fuel boundary,
- f. Calculation of the adjoint flux,
- g. CRT display of source and fluxes.

The cross-section data is assumed to be group and region dependent and is supplied by material from BAM and FORM calculations or directly by input.

The few group diffusion equation as solved by FOG is:

$$-\nabla^2 \phi^i(r) + \Sigma_T^i \phi^i(r) = \sum_{j=1}^{NOG} \nu \Sigma_f^j \phi^j(r) + \sum_{j=i+1}^i \Sigma_{s,j \rightarrow i} \phi^j(r) \quad (11)$$

for $1 \leq i \leq NOG$. The symbols are defined as

$\phi^i(r)$ = neutron flux in i^{th} group at radius r ,

D^i = diffusion constant for the i^{th} group,

Σ_T^i = total removal from the i^{th} group,

$$(\Sigma_T^i = D^i (B^2)^i + \Sigma_a^i + t^i \Sigma_p^{th} + \Sigma_{s,i \rightarrow i+1})$$

$(B^2)^i$ = transverse buckling for the i^{th} group,

Σ_a^i = absorption cross for the i^{th} group,

Σ_p^{th} = poison cross-section in the thermal group,

t^i = ratio of poison cross-section in group i to thermal poison cross-section,

NOG = number of groups,

$\Sigma_{s,i \rightarrow j}$ = scattering or transfer coefficient from group i to group j ,

χ_i = the integral of the fission spectrum over the lethargy range represented by group i ,

r = distance measured from the origin,

$\nabla^2 = \frac{d^2}{dr^2} + \frac{P}{r} \frac{d}{dr}$ ($P=0$ in plane geometry; $P=1$ in cylindrical geometry; $P=2$ in spherical geometry),

and

S = normalized source density.

The normalized source density $S(r)$ is given by

$$S(r) = \sum_{i=1}^{NOG} \frac{(\nu \Sigma_f)^i \phi^i(r)}{\lambda} \quad (12)$$

where

$$\begin{aligned} \nu \Sigma_f^i &= \text{the production cross-section in the } i^{\text{th}} \text{ group,} \\ \lambda &= \text{the eigenvalue, which is related to the multiplication factor.} \end{aligned}$$

The diffusion equation is solved by writing finite difference equations for each group and solving the resulting system by forward elimination and backward substitution proceeding from group 1 to group NOG and then recomputing the source until the convergence criterion is met. A detailed derivation of the finite difference equations is given in reference 14 with a less detailed presentation in reference 4.

The remainder of this section discusses the available options in FOG. Additional features are described in Section III G.

1. Homogeneous Boundary Conditions

These boundary conditions are:

- a. $\phi^i = 0$ (inner and/or outer boundary),
- b. $d\phi^i/dr = 0$ (inner and/or outer boundary),
- c. $\phi^i + \omega^i d\phi/dr = 0$ (inner boundary), and
- d. $\phi^i + \omega_1^i d\phi/dr = 0$ (outer boundary).

1) Values for ω^i and ω_1^i may be given as input. In this case, ω^i must be non-positive and ω_1^i must be non-negative.

2) Values for ω^i and ω_1^i may be computed by formulae contained in the code. The formulae are:

$$\omega^i = -3D^i \left[\frac{0.7710466 + 1.080417 \frac{3LD^i}{2r_1}}{1.0 + 0.8103127 \cdot \frac{3LD^i}{2r_1}} \right] \quad (13)$$

and

$$\omega_1^i = 3D^i \left[\frac{0.710466}{1 + 0.710466 \frac{3LD^i}{2r_N}} \right] \quad (14)$$

In the above formulae,

$L = 0$ for plane geometry

$L = 1$ for cylindrical geometry

$L = 2$ for spherical geometry.

The above formulae are derived in reference 15.

3) Values for ω^i and ω_1^i are computed from the formulae (2) above except $L = 0$ for all geometries.

2. Non-homogeneous Boundary Conditions

These conditions are:

a. $\phi^i = \sigma^i$ (inner boundary)

b. $\phi^i = \sigma_1^i$ (outer boundary)

These boundary conditions may be used in combination with the homogeneous boundary conditions. If these boundary conditions are used, we no longer have an eigenvalue problem unless all of the ϕ^i and σ^i are zero. The use of this boundary condition is discussed further under one-iteration problems.

Note that in this code (in contrast to AIM-5) r_1 is not necessarily assumed to be zero.

3. Convergence Criteria

These conditions are:

a. Eigenvalue convergence criterion

This criterion is

$$\left| \frac{\lambda_j - \lambda_{j-1}}{\lambda_j} \right| \leq \epsilon_1, \quad (15)$$

where λ_j is the value of λ after the j^{th} iteration and ϵ_1 is a given input quantity. Since λ_0 is set equal to zero, and since this criterion must be satisfied for two successive iterations, a minimum of three iterations will, in general, be required.

b. Point-wise convergence criterion

This criterion is

$$\left| \frac{\lambda_{\max} - \lambda_{\min}}{\lambda_{\max}} \right| \leq 1, \quad (16)$$

where

$$\lambda_{\max} = \max_n \frac{G_{n,j}}{S_{n,j-1}} \quad (17)$$

and

$$\lambda_{\min} = \min_n \frac{G_{n,j}}{S_{n,j-1}}, \quad (18)$$

for the j^{th} iteration; $\lambda_{\min}$ is forced to be non-zero. Again, this criterion must be satisfied for two consecutive iterations, and the minimum number of iterations is two. This criterion is a stronger convergence criterion than the eigenvalue convergence criterion. It might be noted at this point that in some cases where this criterion is used, the difference in the values for the approximations to the eigenvalues may differ quite appreciably even though the

the convergence criterion is met. This has been noticed when the convergence criterion is met on the first two iterations, and is due to the normalization. The final value for the eigenvalue is correct.

4. Extrapolation

Three options are provided. The first two options are based upon a linear extrapolation on the source:

If $S_{n,j-1}$ is the value of the source at point n after the $j-1$ st iteration, and $S'_{n,j}$ the value after the j th iteration,

$$S_{n,j} = S'_{n,j} (1 + \theta) - \theta \cdot S_{n,j-1} \quad (0 < \theta < 1) \quad (19)$$

The options are

- a. $\theta = 0.8$ is used in the above formula
- b. θ is given as input and used in the above formula
- c. A sequence of extrapolation factors is computed by the code. This method is based upon the use of Chebyshev polynomials, and is similar to that used in the WANDA-4 code¹⁶. In theory, this method is superior to the use of a fixed extrapolation factor. In practice, however, it seems to be advantageous only in those calculations which require a rather large number of iterations using a fixed extrapolation factor.

5. Source Guess

As AIM-5, FOG is specifically designed to facilitate the so-called "survey calculations" in which many cases are run at the same time, a given case differing from the preceding one only by a few constants. If a given case is specified, and the following case has input data in common with the preceding case, this common information need not be specified.

If the case following a given case differs very little from this case, one would expect that the source would differ only slightly. For this reason, there is an option in the code to use, as the source guess, the source computed in the last case. The judicious ordering of a sequence of problems may save a significant amount of computer time.

Additionally, one may specify a source guess region-by-region or point-by-point.

6. Buckling

Options are provided to enter the transverse buckling as one value for all groups and all regions, one value for each region in all groups, one value for each group in all regions, or one value for each group and each region.

7. Printing and CRT Options

In all cases, the input options chosen are printed. Optionally, a complete listing of the input data may be obtained.

In all cases, the eigenvalue is printed, and one may obtain in addition a listing and/or CRT display of the normalized source density and fluxes. All groups, or only specified groups, may be printed, and the flux at all points or only at every other point may be printed.

8. Data Edit

One may obtain some editing and checking of the computations. By the use of the first option, one obtains the following:

- a. The volume of each region.
- b. Integrated fluxes for each region and each group.

c. If the adjoint flux is also computed, the integrated product of the flux and the adjoint flux is obtained for each region and each group.

d. The leakage and removal for each region and each group.

$$- \int D^i \nabla^2 \phi^i dv_p \quad (\text{Leakage}) \quad (20)$$

$$\int \left[\sum_T^i \phi^i - \chi^i s - \sum_{s, i-1 \rightarrow i} \phi^{i-1} \right] dv_p \quad (\text{Removal}) \quad (21)$$

In contrast to AIM-5, note that the geometric factor is included. If it were not for the finite-length of the computer word, the sum of the two quantities above would be zero for a fully converged problem. The best agreement obtained in check runs in geometries other than slab has been to eight significant figures. These quantities have also differed by a factor of 10^4 in calculations involving the simulation of a void. The calculation of the removal is in general quite accurate, but the calculation of the leakage may be faulty for the above reason.

e. For each region, the following quantities are

$$\text{computed:} \quad \bar{L} = \sum_{i=1}^{NOG} \int D^i \nabla^2 \phi^i dv_p \quad (22)$$

$$\bar{A} = \sum_{i=1}^{NOG} \int \sum_a^i \phi^i dv_p \quad (23)$$

$$\overline{DB^2} = \sum_{i=1}^{NOG} \int D_B^{2i} \phi^i dv_p \quad (24)$$

$$\bar{F}/\lambda = \int S dv_p / \lambda \quad (25)$$

In each region, in the ideal calculation,

$$\bar{L} + \bar{A} + \overline{DB^2} = \bar{F}/\lambda. \quad (26)$$

By use of another option, one may obtain, in addition to the above, the following:

- a. For each fuel region in the thermal group, the peak-to-average flux and peak-to-average source

$$\frac{\phi_m}{\int_F \phi dv_p / V_F} \quad \text{and} \quad \frac{S_m}{\int_F S dv_p / V_F} \quad (27)$$

where ϕ_m is the maximum value of the thermal flux in the fuel region and S_m is the maximum value for the source in the fuel regions. The symbol F refers to the fuel regions.

- b. For the entire reactor, the overall peak-to-average ratios

$$\frac{\phi_M}{\sum_F \int_F \phi dv_p} \quad \text{and} \quad \frac{S_M}{\sum_F \int_F S dv_p} \quad (28)$$

where ϕ_M is the maximum value of the thermal flux in all fuel regions and S_M is the corresponding value of the source.

9. "One-Iteration" Problems

By setting MICT=0 (MICT is the maximum number of iterations), certain problems involving non-homogeneous boundary conditions may be solved. These include particular problems in shielding, one-group all calculations, and some simple heat transfer problems. In all cases, at least one value of the source must be positive, although all values of λ may be zero.

If this option is selected, a notation is made that a one-iteration problem is being done. The source values which are used as input are printed out under the title "Normalized Source" along with the values for the flux.

For one-iteration calculations, set MICT=0, $N_4=0$, and $N_5=0$.

10. Adjoint Flux Calculation

Options are provided to do only an adjoint flux calculation or to do an adjoint flux calculation in addition to other calculations such as a criticality search on a homogeneous poison. If both the flux and the adjoint flux are calculated, an additional option is provided to obtain punched card output of some of the data required for the auxiliary code called PERT¹⁷.

11. Criticality Searches

Five different types of criticality searches may be made using this program. These are:

- a. Search on the buckling,
- b. Search on a homogeneous poison,
- c. Search on dimension,
- d. Search on the position of a poison boundary, and
- e. Search on fuel loading.

Unless a non-zero value is entered into λ_2 (EIGEN 2) the search is carried out for an eigenvalue of unity ($\lambda_2 = 1$). This value will be printed out. For all searches, the convergence criterion

$$|\lambda_2 - \lambda| - \epsilon_2 \lambda_2$$

(29)

must be satisfied. Additionally, one may require for the first three searches that the relative difference between the values of the search quantity on two successive iterations be less

than the prescribed quantity ϵ_3 . For example, if $N_{20} = -1$, then both of the following criteria must be satisfied at the final iteration j :

$$\left| \frac{\lambda_2 - \lambda^j}{\lambda^j} \right| \leq \epsilon_2 \quad (30)$$

and

$$\left| \frac{(B^2)^j - (B^2)^{j-1}}{(B^2)^j} \right| \leq \epsilon_3. \quad (31)$$

The maximum number of iterations or "trials" is governed by MICT 2. The code sets this value as 10; however, this may be changed by placing another value in MICT 2. If the number of iterations exceeds this value, the message, "MAXIMUM NUMBER OF TRIALS EXCEEDED" is printed, and the final edit is made. The code then proceeds to the next case, if any. The criticality search is also terminated in the same manner if the value for MICT is exceeded at any stage of the calculation. Finally, the criticality search is also terminated in other ways as noted under the particular searches.

In all searches, the final result of the calculation is inserted into the corresponding place in the input data so that, if desired, cases using the results of these searches may be run. However, note the remark in the section on the buckling search.

a. Buckling Search

A search may be made in particular regions or over the entire reactor. It is assumed that the value for the buckling is the same in all of these regions and does not depend upon the group. A search will be made through both positive and negative values of the buckling.

If it is desired to use the result of the search in the next calculation, it is important to note the various options on the buckling. For example, it is possible to enter a single value for the buckling at the beginning of the search. The code then "spreads out" this value as if the buckling were both space and energy-dependent. If the search is carried out in only one region, then at the conclusion of the search, we have a space-dependent buckling. The single number resulting from the search is replaced in the original position. If one does not change the buckling options for the next calculation, then this single value will be used throughout the reactor. If it is desired to use the space-dependent bucklings obtained, then one must select the space and energy-dependent options.

Corresponding remarks may be made of the other buckling options.

b. Homogeneous Poison Search

A search may be made in particular regions or over the entire reactor. It should be noted that values for t^i may be specified for all groups, and that the search is made only for these specified values. The search is terminated if the total removal becomes negative.

c. Dimension Search

A search may be made in particular regions or over the entire reactor. The value of Δr in each of these regions must be the same. The total size of the reactor is not fixed. The search is terminated if the value of Δr becomes non-positive or if the value of Δr exceeds 100.

In each of the above searches, the initial (non-zero) guess for B^2 , $\sum_p$, or Δr is input as if no search were being made. The mathematical method is the same as that used in the GNU-11 code³⁸. It is as follows:

Let λ^i be the eigenvalue determined by the i^{th} pass, V_i be the interpolation factor, and let G be the initial (non-zero) guess. Assuming that λ^1 has been determined using the initial guess, then for the second guess if

$$\lambda^1 < \lambda_2, \quad V_2 = 1 + 10(\lambda_2 - \lambda^1)/\lambda^1 \quad (32)$$

$$\lambda_2 < \lambda^1 < 1.25\lambda_2, \quad V_2 = 1/(1+10w) \quad (33)$$

$$\lambda^1 > 1.25\lambda_2, \quad V_2 = 1/(1-2.26w+50w^2). \quad (34)$$

In the above formulae, $w = (\lambda^1 - \lambda_2)/\lambda_2$. For the third guess,

$$\ln V_3 = \frac{\lambda^1 - \lambda_2}{\lambda^1 - \lambda^2} \ln V_2. \quad (35)$$

For fourth and subsequent guesses, V_i is taken as the solution of

$$(V_i - a)(\lambda_2 - b) = c \quad (36)$$

where a , b , and c are determined by solving the system

$$(V_{i-3} - a)(\lambda^{i-3} - b) = c \quad (37)$$

$$(V_{i-2} - a)(\lambda^{i-2} - b) = c \quad (38)$$

$$(V_{i-1} - a)(\lambda^{i-1} - b) = c. \quad (39)$$

If V_i does not lie on the same branch of the hyperbola determined by Equation (36) as does V_{i-1} , then a linear extrapolation is performed.

It has been observed that the code may over-extrapolate, and produce a negative value for the poison or mesh width. If this occurs, the code begins a new cycle of extrapolation. If it occurs again, a notation is made that the poison or mesh width is negative, and the search is terminated.

In all cases, the new guess is then given by $G \cdot Z$. If the search is on a homogeneous poison or buckling $Z = 1/V_1$. In the dimension search, for the first iteration, it is assumed that $Z = V_1$. If the change in the eigenvalue in the next iteration is not in the proper direction, the code then assumes for successive iterations that $Z = 1/V_1$. Another way of stating the above is that the code assumes for the first iteration that an increase in the size of the search region will increase the magnitude of the eigenvalue. If this is not the case, the code then makes the opposite assumption.

d. and e. Boundary Searches

The last two searches are searches for the position of an interface between two regions which may have entirely different parameters. The only requirement is that both regions have the same value for Δr . Given an initial position of the interface, the interface moves to the right or left depending upon the value of the eigenvalue. In the "poison boundary" search, it moves to the right if the reactor is overcritical, while in the "fuel loading" search the position of the interface moves to the left. The interface moves to the right or left in steps of $2 \Delta r$. If it is impossible to meet the convergence criterion

$$|\lambda_2 - \lambda| / \lambda < \epsilon_2$$

then that position for which $|\lambda_2 - \lambda| / \lambda$ is a minimum is selected.

The initial guess for the position of the interface coincides with one of the region boundaries specified in the input, and is indicated by entering in PG1 the number (in floating point form) of the region to the left of the interface. It is assumed that the regions are numbered from 1 to M and the left-hand boundary point of region number 1 is the origin. Limitations on the position of the boundary are imposed by lower and upper bounds for the position of the interface. These lower and upper bounds are expressed in terms of distance from the origin, and the lower bound must be greater than the distance to the origin of the left-hand interface of the region to the left. The upper bound must be less than the distance to the origin of the right-hand boundary of the region to the right of the initial guess.

A second guess for the position of the boundary is required. This again is expressed in terms of distance from the origin, and should lie between the upper and lower bounds. This guess will be ignored if it would cause the boundary to move in a direction opposite to that indicated as a result of the first calculation.

Thus, the input for these criticality searches are:

- PG1: Region number of the region to the left of the initial guess,
- PG2: Lower bound,
- PG3: Second guess, and
- PG4: Upper bound.

In the "poison boundary" search, if the reactor is still subcritical when the boundary is at the lower bound, the poison is removed from the remainder of the core, and a final calculation is made.

It is apparent that these last two searches may be used for other types of searches.

E. Zero Dimensional Burnup Calculations (KINDLE)

KINDLE II⁵ solves the zero dimensional, two group diffusion equations by assuming constant spatial buckling (it may be group dependent). The basic quantities obtained are Keff and the fast-to-thermal flux ratio:

$$K_{eff} = \frac{1}{(DB^2)_1 + (\Sigma_a)_1 + \Sigma_R} \cdot \left[(\nu \Sigma_f)_1 + \frac{(\nu \Sigma_f)_2 \Sigma_R}{(\Sigma_a)_2 + (DB^2)_2} \right] \quad (40)$$

$$\left[\phi_1 / \phi_2 \right] = \frac{(\nu \Sigma_f)_2}{(DB^2)_1 + (\Sigma_a)_1 + \Sigma_R - (\nu \Sigma_f)_1} \quad (41)$$

where symbols are conventional.

From the latter quantity, the fast and thermal flux amplitudes are determined as:

$$\Phi_2 = \frac{P}{KV} \cdot \frac{1}{(\Sigma_f)_2 + [\phi_1 / \phi_2] (\Sigma_f)_1} \quad (42)$$

and

$$\Phi_1 = \Phi_2 \cdot [\phi_1 / \phi_2] \quad (43)$$

where P = Power (watts)

V = Core Volume (cm³)

K = Watts/fission - sec.

(note that P/V is the specific power)

These relations are derived in Reference 19.

In addition, the time dependant isotope equations are solved by a method as described in Reference 18.

The calculational procedure is as follows:

1. Obtain the initial macroscopic group constants, number densities and microscopic cross-sections from the BAM and FORM calculation as supplemented by input. (The details of the handling of microscopic cross-sections are presented in a following section.)
2. Calculate information which remains constant.
3. Solve for K_{eff} , $[\phi_1/\phi_2]$, Φ_1 and Φ_2 .
4. Assuming Φ_1 and Φ_2 are constant, solve the isotope equations for an elapsed time Δt .
5. Recompute the macroscopic group constants from the microscopic cross-sections and the newly formed number densities.
6. If desired, form certain physics data for the edit.
7. Print results every n^{th} time; i.e., for an interval $n \Delta t$.
8. Return to step 4 until all calculations have been performed.
9. Return to step 1 for the next case.

The thermal flux disadvantage factor in fuel is allowed to vary with burn-up according to the formula:

$$g(X)_{fuel} = GAO + GA1 (S2FUEL) + GA2 (S2FUEL)^2 \quad (44)$$

where GAO, GA1 and GA2 are fitting constants
and

$$S2FUEL = \left(\sum_{a_{fuel}} \right) = \sum_{fuel} N^i \sigma_a^i \quad (45)$$

A discussion of this quantity is to be found in Appendix C of Reference 19.

Normally the code calculates a constant value for g as

$$\begin{aligned}
 \text{GAO} &= \frac{\text{Average Flux in Fuel}}{\text{Average Flux in Cell}} \\
 &= \frac{\left[\sum_i \int_F N^i(r) Q(r) d\bar{r} \right]}{\left[\sum_i \int_F N^i(r) d\bar{r} \right]} \bigg/ \bar{\Phi}_{\text{cell}}
 \end{aligned} \tag{46}$$

where F defines the regions containing fuel.

Since BAM computes volume flux weighted number densities and FORM computes volume weighted number densities, it is easily shown that the above expression can be rewritten as:

$$\text{GAO} = \frac{\sum_i N_{\text{BAM}}^i}{\sum_i N_{\text{FORM}}^i} \tag{47}$$

GA1 and GA2 are normally taken to be zero.

The thermal flux disadvantage factor for non-burnable isotopes is given by the formula

$$g_{\text{non}}(X) = \text{GBO} + \text{GB1} \cdot X + \text{GB2} \cdot X^2 \tag{48}$$

where GBO is normally taken to be 1 and GB1 = GB2 = 0

The removal cross-section is computed according to option $\gamma 7$ as follows:

If $\gamma 7 = 0$

This option allows the removal cross-section to vary according to

$$\Sigma_R(X) = \Sigma_{R_0} \cdot \left[R_0 + R_1 \cdot X + R_2 \cdot X^2 \right] \tag{49}$$

where R_0 is the initial value obtained from FORM and X was previously defined.

If Y7 = 1

This option assumes that the sum of fast absorption and removal is constant with burn-up, viz,

$$\Sigma_{a1}(X) + \Sigma_R(X) = (\Sigma_{a1} + \Sigma_R)_{\text{initial}} \quad (50)$$

Thus given $\Sigma_{a1}(X)$, $\Sigma_R(X)$ is found as follows:

$$\Sigma_R(X) = (\Sigma_{a1} + \Sigma_R)_{\text{initial}} - \Sigma_{a1}(X) \quad (51)$$

To account for self-shielding, the fast cross-sections of certain isotopes are computed from the formula:

$$\sigma_{a1}^i = \frac{\sigma_{a1}^i(0)}{[1 + N^i A^i] X^i} \quad (52)$$

where $\sigma_{a1}^i(0)$ is the initial value of the fast absorption cross-section of isotope i as obtained from FORM or input

N^i is the time dependant number density of isotope i

and A^i, X^i are fitting constants

The isotopes treated in this manner are:

<u>i</u>	<u>isotope</u>
1	Th232
5	U234
7	U236
8	U238
11	Pu240
13	Pu242

Some additional discussion follows on the treatment of the microscopic cross-sections from BAM and FORM. The letters "A," "B," etc., refer to points marked on the flow diagram in this section. It must be pointed out that although duplicate cross-sections exist on the THREDES library, KINDLE uses only those indicated in Section III H. These correspond in each case to the best available data.

A - This point corresponds to the point marked D2 on the overall flow diagram in Section II A. The micro and macroscopic data computed by BAM and FORM are read from tape and stored in temporary locations. The macroscopic data are moved to the proper data locations as given in Section III H.

B - The microscopic thermal absorption cross-sections, DATA(401) - DATA(500) are set equal to zero. Thus, if these are supplied by the user, they must be read in for each case.

C - The element identification numbers are scanned for those used by KINDLE (see the table in Section III H). The corresponding volume-weighted number densities from FORM are stored in the data block and the four microscopic cross-sections (σ_a' , σ_f' , σ_a^2 and σ_f^2) for each are placed in the data block if non-zero. Cross-sections which are zero either were not in the library for BAM or FORM or edit 4 was not taken.

D - If an identification number 55 is found, the thermal absorption cross-section is stored in Unit A (DATA(943)).

E - The thermal flux disadvantage factor in fuel is computed and placed into DATA(910).

F - The data is read according to the format described in Section III H.

G - A test is again made to determine if the current case uses new cross-section data. If not, the program continues from the point marked D4. If new cross-sections are to be used, the program transfers to H.

H-L - This section of coding tests to see if the thermal absorption cross-section of any elements are zero. If so, they are set equal to the product of Unit A and the 2200 M/S value, S2200.

D4 - At this point the normal KINDLE calculation is begun.

Output

The output from KINDLE consists of the following:

1. Printout of the element library microscopic cross-sections, yields and decay constants.
2. Initial macroscopic data.
3. Additional input data.
4. Physics data for each time step.

a. Gross Properties

Mwd/MT - Megawatt-days per metric ton of initial heavy elements (U, Pu and Th isotopes)

Uranium enrichment in weight percent

Beta - Ratio of uranium mass at time t to the initial uranium mass

Fissile and total GMSPU per KG Fuel - based on the initial mass of fuel

Percent Fissile Pu - actually the fraction of fissile plutonium.

Other items are self-explanatory - Keff, Conversion Ratio.

b. Isotope Densities (atoms/cm³)

c. Macroscopic Group Constants by Group

Absorption - $(\Sigma_a)_1$ and $(\Sigma_a)_2$

Fission - $(\Sigma_f)_1$ and $(\Sigma_f)_2$

Production - $(\nu \Sigma_f)_1$ and $(\nu \Sigma_f)_2$

Removal - Σ_R

P* - $\Sigma_R / (\Sigma_a + \Sigma_R + DB^*)_1$

K1 - $\nu \Sigma_f / (\Sigma_a + \Sigma_R + DB^*)_1$

SIGMA-P - $(\Sigma_P)_1$ and fast and thermal group poison

Z20 - $(\Sigma_P)_1 / (\Sigma_P)_2$

K2 = ρ_{eff}

ETA-F = $(\nu \Sigma_f)_2 / [(\Sigma_a + \Sigma_R + DB^*)_2]$

* Removal in printout

S2FUEL - Thermal absorption - see equation 45
GEE2 - Thermal fuel disadvantage factor - see equation 44
GNF2 - Thermal disadvantage factor for non-burnable
isotopes in fuel region
PHI-1 - Normalized Fast Flux - see equation 43
PHI-2 - Normalized Thermal Flux - see equation 42
PHI1/PHI2 - Fast-to-thermal flux ratio - see equation 41
NVT-1 - Integrated flux-time group 1
NVT-2 - Integrated flux-time group 2
NVT-2(Fuel) - Integrated flux-time group 2 times GEE2
Delta-K-Xenon - Ke worth
Delta-K-Sm - Sm worth
Delta-K-Xe Override - Peak Xenon worth
Fraction of Power by isotope

5. Neutron Economy at selected time steps

Fractional absorption, fission and production by isotope and
group -- Normalized to 1 fission neutron.

III DATA PREPARATION

A. General Information

The input to the various modules* of THREDES has been
Standardized so as to use two addressable data routines patterned after
the NAA DECRD subroutine. The use of addressable data allows the running
of multiple cases with only changes in data indicated; i.e., within a
given component any data entered remains in core until changed. Note
that in the case of FORM certain of the data may be transmitted from
a prior BAM calculation (these data are indicated in the detailed data
description). Thus, certain of the addressable data may be changed.

Two input formats are used: FREAD for floating data and IREAD
for integer data. The use of these routines is as follows:

* BAM, FORM, FOG and KINDLE

Each card contains the following information:

Column 1 - Blank unless final card of data set in which case any BCD character is used - 1,X,T, etc.

Columns 9-12 - Contain the relative address of the first piece of data on this card (right-adjusted). All data following the first are stored consecutively; however, if any data field is left blank, no change is made to the corresponding data in core. Thus, if this field contains the number 23, then the five pieces of data on this card will be stored in relative addresses 23-27, respectively. If this field is negative or blank a message is printed and the job will be terminated.

Columns 13-24 These five fields contain the data to stored starting
25-36 at the address indicated above. If the value from
37-48 the previous case is to be retained, the corresponding
49-60 field should be left blank.
61-72

Integer Data (IREAD)

Data must be right-adjusted

Floating Data (FREAD)

Floating data should be written with a decimal point. If an exponent is used, it should be right-adjusted.

Examples of acceptable data are:

1.0	
	3.5
.7	-05
4.77	+14
.0001	
0.0	

One must be careful to write the number zero as "0.0" or "0." as ".0" will be taken to be a blank.

Data input will be described according to seven types. Types 1, 2, and 3 are mandatory and determine which of the remainder are present. Types 4 through 7 are subdivided as title card, integer data, floating data and possibly others. Appendix B contains the data sheets used to run the problem in Appendix C. Examples of data types 1-6 are illustrated.

B. Type 1 Data (Mandatory)

Type 1 data consists of one card containing the list of "material numbers" to be processed by BAM. This array is referred to as MBAM(I), $I = 1, 2, \dots$. The number of "material numbers" written on this card indicates how many sets of thermal group constants will be placed on tape. The number of sets of Type 4(BAM) data may be less than this number if the option to repeat results is used (see discussion under BAM DATA(30)). If this card is blank, no BAM calculations will be performed.

For use with FOG, material numbers need not be consecutive; e.g., 2, 3, 5, 6 but must be increasing. For use with KINDLE, material numbers must be consecutive starting at 1 and increasing; e.g. 1, 2, 3, The format for this card is 36I2.

C. Type 2 Data (Mandatory)

Type 2 data consists of one card containing the list of "material numbers" to be processed by FORM. This array is referred to as MFØRM(I), $I = 1, 2, 3, \dots$. The number of "material numbers" written on this card indicates how many sets of fast group constants will be placed on tape. The number of sets of Type 5 (FORM) data may be less than this number if the option to repeat results is used (see discussion under FØRM - integer location 629. If this card is blank, no FORM calculations will be performed.

For use with FOG material numbers need not be consecutive; e.g., 2, 5, 10 but must be increasing. Matches between FORM and BAM "material numbers" will result in the availability of volume-weighted number densities and identification numbers to FORM.

For use with KINDLE, material numbers must be consecutive, increasing and agree with those for BAM.

The format of this card is 36I2.

D. Type 3 Data (Mandatory)

This card must contain one of the words FOG or KINDLE and indicate which of the two codes will be used. An error message will be printed if one of these words is not found and the job will be terminated. If neither code is desired than the lack of the data cards (after BAM and/or FORM data) will terminate the job.

The format of this card is A6.

E. Type 4 Data (BAM)

BAM Data is present if a non-zero material number is indicated on the Type 1 data card (MBAM). The number of sets of BAM data will be less than or equal to the number of entries in the Type 1 data (see the discussion under DATA(30)). If no BAM cases are to be run, skip this section and proceed to Section III F.

Three types of data must be supplied if any BAM cases are to be run. These are library changes, a title card and floating point data. The latter two are repeated for each case.

1. Decimal or Binary Library Changes

Although the TEMPEST library resides on tape, column binary and/or decimal library changes may be supplied at execution time. Any such changes must occur before the first case and will be used for all BAM cases. (see Appendix B of reference 6 for the details of preparing these changes and for further discussion of their use. A card containing the word "DATA" in columns 1-4 must be present to signify the end of the library changes.)

If no library changes are to be made then only the card containing the word "DATA" will be used.

2. Title Card

Any ALPHANUMERIC card containing up to 72 columns of information.

3. Floating Point Data

Floating point data is specified according to the FREAD format described in Section III A. Any non-blank character in column 1 terminates reading of data for that case.

In specifying data for multiple cases only changes are required.

<u>DATA</u>	<u>SYMBOL</u>	<u>MEANING</u>
1	PROB	Problem number.
2	FIMI	Number of intervals ≤ 100 .
3	RM	Number of regions ≤ 10 .
4	NFR	Number of regions containing fuel (for thermal utilization calculations).
5	RNORM	Radius for flux normalization.
6	EPS	Convergence for $\sum_A$ in each region $(.001)^*$.
7	WNU	0*, sums over all regions. 1, sums over specified regions.
8	IOP	0*, diffusion theory guess at iteration = 0. 1, flux from previous case
10	LAN	Total number of regions in sums (not needed if WNU = 0).
11	EP	Convergence in angular and total flux $(.01)^*$.
12	FITMAX	Maximum iterations on total flux $(10)^*$.
13	FPNMAX	N1 half the number of angular flux sweeps per iteration $\leq 50 (5)^*$.
14	B1	+0.95*
15	B2	-10.0*
16	KFLUX	0*, flux disadvantage factor guess is flat. 1, flux disadvantage factor guess is input by region. 2, distribution from previous case.

* These values are built in and will be used for all cases unless changed

<u>DATA</u>	<u>SYMBOL</u>	<u>MEANING</u>
17	LIB	0**, do not list library. 1, do list library.
19	TEMP	Temperature (°K)
20	EMIN	Minimum energy (ev)
21	EMAX	Maximum energy (ev)
22	B ²	Total Thermal Buckling (cm ²)
23	ETRANS	Transition energy (see reference 6).
24	ITYPE	1, Wilkins approximation. 2, Wigner-Wilkins approximation. 5, option 1 from E _{min} to E _{trans} . 6, option 2 from E _{min} to E _{trans} .
25	KHY	Mode of hydrogen bonding (see Section II B).
26	NP	Number of elements (need not be entered).
27	FLUXP	0*, do not print Sn flux distribution. 1, print Sn flux distribution.
28	POPT	0, no printing. 1*, print final values only. 2, print every iteration.
29	NOG	Number of thermal group 2-4 for FOG. Must be 2 for KINDLE.
30	NTBAM	Number of times material is to be repeated. This location is set to zero by program. See the discussion of "A13" on the flow chart in Section II A. As an example, assume the Type 1 data, MBAM(I), contains the numbers 1, 2, 3, 5, ... and in the first BAM case DATA(30) contains 2, then materials 1, 2 and 3 are identical. Thus, the second set of BAM data refers to material 5 and only one set of data is required for materials 1, 2, and 3.

* These values are built in and will be used for all cases unless changed.

** This value is built in and reset at the start of each case.

NOTE: IOP refers to the pointwise flux guess used to initiate the Sn iterations. KFLUX refers to the regionwise flux guess used to volume-flux weight the atom densities for the first TEMPEST calculation.

Element ID Numbers

These may be the MUFT numbers; e.g., -704 to indicate that edits 3 and 4 are desired and that element 4 is a resonance scatterer or the TEMPEST numbers; i.e., 4, in which case the other information must be entered for every FORM case. See Appendix A for information on the library. If FORM cases are to follow, the first BAM case must list all element ID numbers to be used in this job.

Data 100-119	First Region
Data 120-139	Second Region
.	.
.	.
.	.
Data 280-299	Tenth Region

Element Densities for Cell (atoms/BARN-cm³)

Data 400-419	First Region
Data 420-439	Second Region
.	.
.	.
.	.
Data 580-599	Tenth Region

Source and Geometry

Data 300-309	BR	Region Boundaries (CM).
Data 310-319	AJIMI	Number of intervals in each region.
Data 320-329	SACT	Source in each region.
Data 330-339	IFRO	ID of fuel regions.
Data 340-349	LAND	List of Regions in sum (not needed if WNV = 0)
Data 350-359	FLUX disadvantage guess by region	

The last card of each case must have any non-blank character in column 1.

Repeat the title card and FREAD data for each case.

F. Type 5 Data (FORM)

FORM data is present if a non-zero material number is indicated on the Type 2 data card (MFORM). The number of sets of FORM data will be less than or equal to the number of entries in the Type 2 data (see the discussion under NDATA(629)). If no FORM cases are to be run skip this section and proceed to Section III G.

Five types of data may be supplied for each FORM case. The first three are mandatory, whereas the last two are optional. These are a title card, integer data, floating point data, "L" factors and library changes (first case only).

1. Title Card

Any alphanumeric card containing up to 72 columns of information.

2. Integer Data

Integer data is specified according to the IREAD format described in Section III A. Any non-blank character in column 1 terminates the reading of integer data. Several restrictions are pointed out in what follows.

If BAM data is available, then the number of elements L(2), and the element ID numbers L(7) through L(24), will be read into core before any data is read. Thus, it is not necessary to supply these unless the ID numbers are to be changed; e.g., to append edit information. If care is used elements can be inserted or deleted; however, since the ID numbers must be in ascending order, the number densities from BAM would fall into the wrong locations and consequently would have to be supplied for the first and subsequent cases.

In general, it would be best to indicate all elements in the first BAM case using zero number densities where required and append the edit information therein.

Fixed-point Relative Addresses

L(1) = NSD	Number of source desired (may not be changed after case 1)
L(2) = IP	Number of elements in case. Elements having zero number densities are included. This number cannot be changed from case to case, and should agree with the number of elements in BAM. Normally supplied by BAM.
L(3) = N ₁	Slowing down approximation
N ₁ = 0	P1 approximation
N ₁ = 1	B1 approximation
L(4) = NED	Number of highest edit desired. (1-4) Fast group microscopic cross-sections are passed on to KINDLE only for elements for which edit 4 was taken.
L(5) = N ₂	Selengut-Goertzel Approximation
N ₂ = 0	Approximation used
N ₂ = 1	Approximation not used
L(6) = N ₃	Age approximation
N ₃ = 0	Conventional Age
N ₃ = 1	Self-consistent age
L(7) → L(24)	List of elements in case. There must be IP numbers included in first case, arranged in ascending order. These should not be changed for subsequent cases. If a Type - 3 edit is desired for a particular element, 300 should be added to the element's identification number. These additions should not influence the arranging of the elements in sequence. For example, 701 comes before 2 in the listing. Although the elements themselves may not be changed in subsequent cases, the additions (300, 400, 700) to each element may be changed. These numbers are normally supplied by BAM.

L(25) = NOS		Number of few group output schemes. Only 1 output scheme may be obtained.
L(26)		Number of groups in output scheme. Must be 1 for KINDLE or 1-3 for FOG.
L(51)→L(53)		The breakpoints for the few group output scheme. The last break point must be 54.
L(627) = IFF	{ 0	No fast fission factor.
	{ 70	Fast fission factor will be used and IFF is the position of the element in the list to which it is applied.
L(678)	{ 0	54 group element-wise intermediate integrals do not print.
	{ 1	54 group element-wise intermediate integrals will print.
L(629) = NTFØRM		Number of times material is to be repeated. This location is set to zero by the program. See the discussion of B10 on the flow chart in Section II A. As an example, assume the Type 1 data, MFORM(I) contains the numbers 1, 2, 3, 5, ... and that in the first FORM case, L(629) contains 0; the second, L(629) contains 1; the third, L(629) contains 0; etc. Then the first set of FORM data defines material 1; the second set defines materials 2 and 3; the third set defines material 5; etc. Thus, only one set of data is required for materials 2 and 5.
L(630)→L(648)		Not used at present.
L(649) = N ₄		ADD option
N ₄ = 0		No cross-sections to be added at execution time.
N ₄ = 1 or 11		Cross-sections to be read in to replace specified cross-section from library. This option may be used only on the first case of any series. See discussion under Section III F 5.

$L(650) = N_5$	L - factor option
$N_5 = 0$	No L - factors to be changed for this case.
$N_5 = 1$	Some or all of the L-factors to be changed.

The first case always expects at least one L-factor. This card is not necessary for the first case. See the section on L-factor input in Section III F 4.

3. Floating Point Data

Floating point data is specified according to the FREAD format described in Section III A. Any non-blank character in column 1 terminates reading of floating point data.

If BAM data is available, then the number densities, A(2)-A(19), will be read into core before any data is read. Thus, it is not necessary to supply those unless the number densities are to be changed.

A(1)	= B^2	Total Fast Buckling (cm^2)
A(2)-A(19)		Number densities (atoms/barn- cm^2)
		IP number densities are listed in the same order as the element ID numbers.
		May be supplied by BAM.
A(74)	= FF	Fast fission correction factor.
		Note the change from the earlier version of FORM.

4. Resonance Self-Shielding (L-factor) Information

L-factor information must be supplied under the following circumstances:

- a. For the first case.
- b. Whenever fixed point location 650 has a 1 entered.

The subroutine which is called expects to find at least one card under these circumstances.

L-factors may be supplied either by element or by resonance.
The card format is as follows:

Column 1	-	Contains the number of L-factors listed on the card. All L-factors on a card must belong to the same element.
Column 2	-	Contains a 1 if the L-factors are being specified by element or if that card is the last card for a group in specification by individual resonances.
Column 3	-	Contains a zero unless that card is the last card of L-factor information for the case, in which case it contains a one.
Column 10	-	Contains a zero if the L-factors are being specified by resonance for that element. If that element has only one L-factor, the column contains a one.
Columns 11-12	-	List the number of the position in which the resonance absorber appears in the list of resonance absorbers in the problem. For example, if the problem had niobium (element 8) and U-238 (element 20) as resonance absorbers, niobium would be designated as resonance absorber 1 and U-238 as resonance absorber 2 and these numbers would appear in column 12 on their respective cards.
Columns 13-72	-	Lists the L-factors, one to a line. The number of L-factors on the card must agree with the number punched in column 1.

It should be remembered that the first case always expects a resonance absorber. If none exists for that case, enter a zero (or any other number) for resonance absorber 1. Since there are actually no resonance absorbers in the problem, the code will ignore that number.

If the L-factors are to be entered by resonance, at least one card must appear for every group from 25 to 54 (30 in all). A number of L-factors corresponding to the number of resonances in a group must be punched on the card for that group. If there are more than five resonances in the group, two cards must be used. A 1 must appear in column 2 of the last card for every group.

If, after the first case, a zero appears in fixed point location 650, no L-factor cards need be included for that case.

5. ADD Option

ADD was written primarily for the checkout of new cross-sections rather than for production usage, although it may find limited use on production runs. ADD is called by putting a 1 or 11 in fixed point location 649. It is called only for the first case of a series and the cross-sections it calls remain in effect through the entire series. The data format has been modified to accept either "excess 50" notation or normal FORTRAN notation.

ADD replaces cross-sections called from the library with cross-sections read in at execution time. If the element desired is not presently on tape, one of the blank elements having the proper parameters in the library may be called in (see Appendix A).

Because of storage problems it is not possible to change all parameters with one calling of ADD. Therefore, ADD may be called twice during the first case. The first time it is called, microscopic cross-sections, r - m factors, and alpha factors may be changed. The second time it is called, inelastic scattering matrices may be changed.

ADD is called the first time by placing a 1 in fixed point location 649. If a 1 appears ADD will not be called the second time. If an 11 appears in fixed point location 649, ADD will be called twice. Under the present coding scheme, it is not possible to call ADD only for the second time without calling it for the first. Therefore, a dummy element must be read in the first time so that ADD is satisfied.

Each time that ADD is called, a control card must precede the data. This control card is punched as follows, using FORTRAN Fixed 10 Digit Decimal Data sheets.

1. Column 12 - Number of parameters on card.
2. Columns 13-72 - ID number of elements to changed, one per line.

The data is then stacked behind the control cards. All the data for an element is grouped together, preceded by an element control card indicating what kind of parameters are to be read in for that element. This element control card has a format as follows:

1. Column 12 - Zero for no microscopic cross-sections, 1 for microscopic cross-sections.
2. Column 24 - Zero for no r - m deck, 1 for r - m deck.
3. Column 36 - Zero for no alpha factors, 1 for alpha factors.
4. Column 48 - Zero for no inelastic scattering matrix, 1 for inelastic scattering matrix.
5. Column 52 - $\left\{ \begin{array}{l} 0 \text{ Card format is normal floating point notation 10.} \\ 1 \text{ Card format is Westinghouse Excess 50 notation.} \end{array} \right.$

Since the subroutine cannot read in inelastic scattering matrices the first time it is called, the element control card must have a zero in column 48 for the first deck of data.

Similarly, columns 12, 24, and 36 must contain a zero for the second read-in of data since ADD cannot read in these parameters the second time it is called.

The first deck of ADD data is inserted between the floating point data and the L-factor data. The second deck of ADD data is inserted after the L-factor data.

Example: It is desired to check out a new set of Pu - 239 alpha factors, a new set of Pu - 239 inelastic scattering parameters, new microscopic cross-section data for U-238, and new r - m resonance data for U-238. The ADD data decks are shown on the following pages. All of the parameters may merely replace the existing ones on tape, except for the Pu - 239 inelastic matrix, for which no parameters now exist. It is therefore necessary to call in a blank element which has an inelastic scattering matrix.

Always remember to call for the blank element in the fixed point data section and to enter its number density in the floating point data section.

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 1 of 3 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	2	ADD data deck 1 Control Card
13	2 0	I.D. number for U-238
25	2 1	I.D. number for Pu-239
37		
49	73 80	
61	1	
1	1	X-sections to be read. (Element control card for U-238)
13	1	r - m deck to be read
25	0	No alpha factors to be read
37	0	No inelastic matrix to be read (always 0 for deck 1)
49	0 73 80	Normal floating point notation
61	2	
1		After the U-238 control cards should come the data for U-238.
13		This consists of, in this case, 54 cross-section cards,
25		followed by 60 resonance parameter cards.
37		
49	73 80	
61	3 - 1 1 6	
1	0	No X-sections to be read. (Element control card for Pu-239)
13	0	No r - m deck to be read
25	1	Alpha factors to be read
37	0	No inelastic matrix to be read. (Always 0 for deck 1)
49	73 80	
61	1 1 7	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 2 of 3 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1		After the Pu-239 control card should come the data for Pu-239.
13		This consists of, in this case, 30 alpha factor card.
25		This concludes Deck 1
37		
49	73	80
61	1 1 8 - 1 4 7	
1		Normal L-factor cards from case being run are inserted here.
13		
25		
37		
49	73	80
61		
1	1	ADD data deck 2 Control Card
13	5 0	I.D. of blank element to be used to hold
25		Pu-239 inelastic scattering data
37		
49	73	80
61	1	
1	0	} Pu-239 element control card Always 0 for deck 2
13	0	
25	0	
37	1	Inelastic matrix to be read
49	73	80
61	2	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 3 of 3 JOB NO. _____

NUMBER		IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1			Pu-239 inelastic matrix data cards (55 in all)
13			
25			
37			End of 2nd ADD data check
49		73 80	
61		3 - 5 7	
1			The next card is the first card of the next case if additional
13			cases are being run.
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			

G. Type 6 Data (FØG)

FØG data is present if the word "FOG" was specified on the Type 3 data card. If KINDLE was specified, skip this section and proceed to Section III H.

Three types of data must be supplied for each FOG case. These are a title card, integer data and floating point data.

1. Title Card

Any alphanumeric card containing up to 72 columns of information.

2. Integer Data

Integer data is specified according to the IREAD format described in Section III A. Any non-blank character in column 1 terminates the reading of integer data.

No integer data is available from BAM or FORM.

L(1) = NOG	<u>Number of groups.</u> Restriction: NOG ≤ 4 .
L(2) = N ₁	<u>Geometry</u>
N ₁ = 1	Plane
= 2	Cylinder
= 3	Sphere
L(3) = N ₂	<u>Boundary Condition at Origin</u>
N ₂ = 0	$d\phi^i/dr = 0$
= 1	$\phi^i = 0$
= 2	$\phi^i = \omega^i$
= 3	$\phi^i + \omega^i$ $d\phi^i/dr = 0$, ω^i input data
= 4	$\phi^i + \omega^i$ $d\phi^i/dr = 0$, ω^i computed by code
= 5	$\phi^i + \omega^i$ $d\phi^i/dr = 0$, $\omega^i = -2.131338D^i$, computed by code

L(4) = N ₃	<u>Boundary Condition at Outer Boundary</u>
N ₃ = 0	$\phi^1 = 0$
= 1	$d\phi^1/dr = 0$
= 2	$\phi^1 = \omega_1^1$
= 3	$\phi^1 + \omega_1^1 d\phi^1/dr = 0, \omega_1^1$ input data
= 4	$\phi^1 + \omega_1^1 d\phi^1/dr = 0, \omega_1^1$ computed by code
= 5	$\phi^1 + \omega_1^1 d\phi^1/dr = 0, \omega_1^1 = -2.131338D^1$, computed by code.
L(5) = N ₄	<u>Convergence</u>
N ₄ = 0	Eigenvalue convergence
= 1	Pointwise convergence
L(6) = N ₅	<u>Extrapolation</u>
N ₅ = 0	Single extrapolation factor - built in
= 1	Single extrapolation factor - read in
= 2	Extrapolation factors computed
L(7) = M	<u>Number of regions.</u> <u>Restrictions:</u> $M \leq 40$
L(8) = LM(I),	I = 1, ..., M
	LM(I) is the number of intervals in region I.
	<u>Restriction:</u> Total number of intervals must be less than or equal to 238.
L(48) = N ₆	<u>Source</u>
N ₆ = 0	Source specified by region
= 1	Source specified by point
= 2	Source specified by previous case
L(49) = N ₇	<u>Transverse buckling by region</u>
N ₇ = 0	Constant buckling, all regions
= 1	Region dependent
L(50) = N ₈	<u>Transverse buckling by group</u>
N ₈ = 0	Group independent
= 1	Group dependent

L(51) = N_9	<u>X option</u>
$N_9 = 0$	Specified by group (supplied by FORM, region independent from last FORM case)
$= 1$	Specified by region and group
	<u>Output Edit Options</u> (apply to flux and/or adjoint calculation)
L(52) = N_{10}	Output format
$N_{10} = 0$	Print eigenvalue and fluxes, as modified by N_{11} , N_{12} , N_{13} , N_{14}
$= 1$	Print only eigenvalue
$= -1$	Print $\lambda + \phi$ as modified by N_{11} , N_{12} , N_{13} and N_{14} and provide CRT of source and fluxes.
L(53) = N_{11}	<u>Flux Print</u>
$N_{11} = 0$	Print every point
$= 1$	Print every other point
L(54) = N_{12}	<u>Group Data Print</u>
$N_{12} = 0$	Print input data
$= 1$	Do not print input data
L(55) = N_{13}	<u>Flux Multiplication</u>
$N_{13} = 0$	Option not used
$= 1$	Multiply all fluxes by number entered in A(6)
L(56) = N_{14}	<u>Flux Normalization</u>
$N_{14} = 0$	No normalization (that is, only source normalized fluxes)
$= 1$	Point normalization. Flux at every point is divided by the flux at point N_{15} in group N_{16} .
$= 2$	Normalization to maximum flux. Flux at every point is divided by the largest value of the flux at all points and in all groups
L(57) = N_{15}	Point number for normalization
L(58) = N_{16}	Group number for normalization
L(59) = N_{17}	Group print
$N_{17} = 0$	Print all groups
$= L$	Print L groups, $0 < L \leq 3$. See L(60), L(61) and L(62)

L(60),L(61),L(62) Group numbers for print. These numbers must be in ascending order. There are N_{17} numbers entered here.

L(63) = N_{18}

Checks

$N_{18} = 0$

Do not compute and print checks

$= 1$

Compute and print checks

$= 2$

Also compute peak-to-average ratios

Auxiliary Options and Calculations

L(65) = N_{20}

Criticality Search

$N_{20} = 0$

Option not used

$/N_{20}/ = 1$

Buckling search

$/N_{20}/ = 2$

Poison search

$/N_{20}/ = 3$

Dimension search

$N_{20} = 4$

Poison boundary search

$N_{20} = 5$

Fuel loading search

Note: $/N_{20}/$ is used for those searches for which an optional convergence option is available. If $N_{20} > 0$, convergence is on the desired eigenvalue only. If $N_{20} < 0$, convergence is on the search quantity as well.

L(66) = N_{21}

Control Regions

$N_{21} = 0$

Search in all regions.

$= L$

Search in L regions. See L(67).

L(67)

Control Region Numbers

Note: Enter here in ascending order N_{21} region numbers. Region number 1 is the region whose left-hand boundary point is the origin.

L(107) = N_{22} Adjoint Flux Calculation
 $N_{22} = 0$ Option not used
 $= 1$ Compute adjoint fluxes in addition to other calculations
 $= 2$ Compute only adjoint fluxes

L(108) = N_{23} Adjoint Flux Punched Card Output
 $N_{23} = 0$ Option not used
 $= 1$ Punched cards for PERT code

L(109) = MA Data by Materials
 MA = 0 Data input by regions - may be used if additional data
 is supplied.
 $= L > 0$ Data input by materials. Here L represents the number
 of materials. Restriction: $MA \leq 20$ (Normal Option)

L(110) Material Numbers
 Note: For each region, specify a non-zero material
 number.

L(130) MICT - Maximum number of iterations in the flux
 calculations; i.e., the maximum number of iterations
 for a particular reactor configuration.
 Note 1: MICT is initially set equal to 35. It is,
 however, not reset after the completion of the first
 case in a series. Hence, if MICT is changed by the
 reading into memory of another number, MICT will
 have this value for successive cases unless a new
 value is read into memory.
 Note 2: For one iteration problems, set MICT = 0.

L(151) MICT2 - Maximum number of iterations in a criticality
 search or buckling iteration; i.e., the maximum
 number of reactor configurations.

3. Floating Point Data

Floating point data is specified according to the FREAD format described in Section III A. Any non-blank character in column 1 terminates the reading of floating point data.

Normally, group data is available by material from BAM and FORM and is read into locations 2000-2600 for those materials calculated. In addition, the Chi's are read into locations 395-399.

A(1) = ϵ_1	Convergence criterion for flux calculations.
A(2) = ϵ_2	Convergence criterion for criticality search calculations.
A(3) = EIGEN2	The value of the eigenvalue to be searched for in criticality search. If this value is unity, it need not be entered.
A(4) = ϵ_3	Convergence criterion for criticality search calculation.
A(5) = 0	Extrapolation factor is entered here if $N_5 = 1$.
A(6) = FMUL	If $N_{13} = 1$, all fluxes will be multiplied by FMUL.
A(7) = R(1)	Value of radius at the origin.
A(8) = RW	M non-zero values for the width of each region are entered here.
A(50) = B^2	One, M, or NOG values of the transverse buckling are entered here according to the values of N_7 and N_8 . If the buckling is both group-dependent and region-dependent, the values are entered below.
A(90) = S_i	If $N_6 = 0$, M values for the initial source guess are entered here. If $N_6 = 1$, $N + M - 1$ values are entered. The two values of the source at the interface between the regions are entered consecutively.
A(395) = χ^i	If $N_9 = 0$, the NOG values for χ^i are entered here. If $N_9 \neq 0$, the values are entered below. (Available from FORM)

If $MA = 0$, then the values for Σ_a , D , $\nu \Sigma_f$, and Σ_s , $i \rightarrow j$ are entered as given in locations 400-1280. If $MA \neq 0$, then these values are entered into locations 2000-2600. The latter is the normal case for THREDES.

$A(400) = B_{i,j}^2$	M x NOG numbers. See discussion below in Note 1.
$A(600) = \sum_{s,i \rightarrow j}$	M x (NOG-1) numbers. $\sum_{s,1 \rightarrow 2}$ for region 1 is entered in A(600). The remaining numbers are entered as discussed in Note 1.
$A(800) = (\nu \sum_f)_{i,j}$	M x NOG numbers. See Note 1.
$A(1000) = (\sum_a)_{i,j}$	M x NOG numbers. See Note 1.
$A(1200) = D_{i,j}$	M x NOG numbers. See Note 1.
$A(1400) = \chi_{i,j}$	If $N_g \neq 0$, M x NOG numbers are entered here as discussed in Note 1.
$A(1600) = \omega^i$	NOG numbers
$A(1604) = \omega_1^i$	NOG numbers
$A(1608) = t^i$	NOG numbers
$A(1612) = \sum_p$	M numbers are entered here.
$A(1652) = PG1$	Region number of the region to the left of the interface (See Section II D 11 d.)
$A(1653) = PG2$	Lower bound (See Section II D 11 d.)
$A(1654) = PG3$	Second Guess (See Section II D 11 d.)
$A(1655) = PG4$	Upper bound (See Section II D 11 d.)

If the values for $\sum_a$, $\nu \sum_f$, etc., are entered by material, the relative addresses are as follows:

$A(2000) = B^2$	NOG numbers (not required if previously entered).
$A(2005) = \sum_{s,i \rightarrow j}$	NOG-1 numbers. See discussion under Note 2.
$A(2010) = \sum_a$	NOG numbers.
$A(2015) = D$	NOG numbers
$A(2020) = \nu \sum_f$	NOG numbers.

To get the relative addresses for the nth material, add (n-1) . 30 to the corresponding address above.

NOTES:

1. Two-dimensional arrays. Example: In the symbol $D_{i,j}$, the subscripts i and j refer to region and group, respectively. These must be written in the following order:
 $D_{1,1}; D_{2,1}; D_{3,1}; \dots; D_{40,1}; D_{1,2}; D_{2,2}; \dots; D_{1,4}; \dots; D_{40,4}$. Note that for group 1, 40 positions are taken up. If, for example, there are only 5 regions ($M=5$) and 4 groups ($NOG=4$), then the following relative addresses must be used:

$$A(1200) - D_{1,1}$$

$$A(1240) - D_{1,2}$$

$$A(1280) - D_{1,3}$$

$$A(1320) - D_{1,4}$$

The values for $D_{i,j}$ ($2 \leq i \leq 5, i \leq j \leq 4$) are entered in order following $D_{1,j}$, and no values need be entered following $D_{5,j}$.

2. If data are input by material rather than by region, the order is somewhat changed. Note that, for example, in each material, 4 positions are provided for the diffusion coefficient D . This is entered with the value of D for the highest energy group in $A(2015)$. Note that the transfer coefficients $\Sigma_{s,i \rightarrow j}$ are handled in the following way:

$$A(2005) - \Sigma_{s,1 \rightarrow 2}$$

$$A(2006) - \Sigma_{s,2 \rightarrow 3}$$

$$A(2007) - \Sigma_{s,3 \rightarrow 4}$$

H. Type 7 Data (KINDLE)

KINDLE data is present, if the word "KINDLE" was specified on the Type 3 data card.

Two types of data must be supplied for each case. These are a title card and floating point data.

1. Title Card

Any alphanumeric card containing up to 72 columns of information.

2. Floating Point Data

Floating point data is specified according to the FREAD format described in Section III A. Any non-blank character in column 1 terminates the reading of floating point data.

Normally microscopic cross-sections, volume-weighted number densities, Unit A and the flux disadvantage factor are available from BAM and FORM. In addition 2200m/s values of the cross-sections and both the fast and thermal values of ν are built into the code.

Provision is made for 100 isotopes in the data blocks. At present KINDLE is coded to treat the following 35 isotopes (only 16 of which are in the THREDES Library):

ISOTOPE ID		ISOTOPE	ISOTOPE ID		ISOTOPE	ISOTOPE ID		ISOTOPE
KINDLE	THREDES		KINDLE	THREDES		KINDLE	THREDES	
1	62	Th232	13	-	Pu242	25	-	FP34
2	-	Th233	14	90	FP11	26	26	Sm149
3	65	Pa233	15	91	FP21	27	27	Xe135
4	64	U233	16	92	FP31	28	-	Nd147
5	63	U234	17	-	FP12	29	-	Pm147
6	85	U235	18	-	FP13	30	-	Pm148
7	83	U236	19	-	FP14	31	-	Pm148m
8	28	U238	20	-	FP22	32	-	Pm149
9	-	Np239	21	-	FP23	33	-	I135
10	80	Pu239	22	-	FP24	34	-	U-237
11	81	Pu240	23	-	FP32	35	52	Np-237
12	82	Pu241	24	-	FP33	-	55	UNIT-A

To locate any piece of data add the isotope ID number minus one to the starting location of the data block.

FP11 represents a single fission product for U235 and U236.

FP21 represents a single fission product for Pu239, Pu240, Pu241 and U238.

FP31 represents a single fission product for U233.

FP12 represents the second of a 4 isotope fission product scheme for U235 and U236.

FP13 represents the third of a 4 isotope fission product scheme for U235 and U236.

FP14 represents the fourth of a 4 isotope fission product scheme for U235 and U236.

FP22 represents the second of a 4 isotope fission product scheme for Pu239, Pu240, Pu241 and U238.

FP23 represents the third of a 4 isotope fission product scheme for Pu239, Pu240, Pu241 and U238.

FP24 represents the fourth of a 4 isotope fission produce scheme for Pu239, Pu240, Pu241 and U238.

FP32 represents the second of a 4 isotope fission product scheme for U233.
 FP33 represents the third of a 4 isotope fission product scheme for U233.
 FP34 represents the fourth of a 4 isotope fission product scheme for U233.
 UNIT A is the value of a 1/v absorber having unit cross-section at
 2200 M/S averaged over the thermal spectrum.

The relative addresses for the various data are as follows:

<u>DATA LOCATIONS</u>	<u>SYMBOL</u>	<u>EXPLANATION</u>
1-100	EN	Volume-weighted number densities (from FORM)
101-200*	σ_a'	Fast group absorption cross-sections (from FORM)
201-300	σ_f'	Fast group fission cross-sections (from FORM)
301-400	ν'	Number of neutrons produced per fast fission (Built into code - See Section II E)
401-500*	σ_a^2	Thermal group absorption cross-sections (from BAM - See Section II E)
501-600	σ_f^2	Thermal group fission cross-sections (from BAM)
601-700	ν^2	Number of neutrons produced per thermal fission (Built into code - See Section II E)
701-800	λ	Decay constants (built in)
801-825	γ	Fission yield (built in) first 25 isotopes
850	Il35	Yield from U235
851	Il35	Yield from Pu239
852	Il35	Yield from U233
853	Xel35	Yield from U235
854	Xel35	Yield from Pu239
855	Xel35	Yield from U233
856	Nd147	Yield from U235
857	Nd147	Yield from Pu239
858	Nd147	Yield from U233
859	Pm149	Yield from U239
860	Pm149	Yield from Pu239
861	Pm149	Yield from U233

* DATA(128) and DATA(428) are exceptions to the isotope numbering scheme - these locations are used for the Pm147 $\rightarrow$ Pm148 reaction. The cross-sections for Nd147 are zero. DATA(129) and DATA(429) are the Pm147 $\rightarrow$ Pm148m reaction.

<u>DATA LOCATIONS</u>	<u>SYMBOL</u>	<u>EXPLANATION</u>
900	Σ_R^0	Removal cross-section (from FORM)
901	D^1	Fast group diffusion constant, D^1 (from FORM)
902	D^2	Thermal group diffusion constant, D^2 (from BAM)
903	$(B^1)^2$	Fast group total buckling, $(B^1)^2$ (from FORM)
904	$(B^2)^2$	Thermal group total buckling, $(B^2)^2$ (from BAM)
905	R_0	Fitting constant for variation of removal cross-section with burnup - See Section II E (1.0) ⁺
906	R_1	Fitting constant for variation of removal cross-section with burnup - See Section II E (0.0) ⁺
907	R_2	Fitting constant for variation of removal cross-section with burnup - See Section II E (0.0) ⁺
908	Σ_a^1	Fast group macroscopic absorption cross-section (from FORM)
909	Σ_a^2	Thermal group macroscopic absorption cross-section (from BAM)
910	GAO	Thermal flux disadvantage factor in fuel (from BAM) (1.0) ⁺
911	GA1	Fitting constant for variation of thermal flux disadvantage factor in fuel with burnup - See Section II E (0.0) ⁺
912	GA2	Fitting constant for variation of thermal flux disadvantage factor in fuel with burnup - See Section II E (0.0) ⁺
913	GB0	Thermal flux disadvantage factor for non-burnables. (1.0) ⁺
914	GB1	Fitting constant for variation of thermal disadvantage factor of non-burnables with burn-up - See Section II E (0.0) ⁺
915	GB2	Fitting constant for variation of thermal disadvantage factor of non-burnables with burn-up - See Section II E (0.0) ⁺

⁺These values are built into the code; data not built-in are zero at the start of the first case.

<u>DATA LOCATIONS</u>	<u>SYMBOL</u>	<u>EXPLANATION</u>
916	EMWDT	Initial exposure in MWD/T (0.0) ⁺
917	MEVF	Energy per fission in Mev (200.0) ⁺
918	ATh232	Fitting constant for resonance cross-section - See Section II E for Th232 (0.0) ⁺
919	AU234	Fitting constant for resonance cross-section - See Section II E for U234 (0.0) ⁺
920	AU236	Fitting constant for resonance cross-section - See Section II E for U236 (0.0) ⁺
921	AU238	Fitting constant for resonance cross-section - See Section II E for U238 (0.0) ⁺
922	APu240	Fitting constant for resonance cross-section - See Section II E for Pu240 (0.0) ⁺
923	APu242	Fitting constant for resonance cross-section - See Section II E for Pu242 (0.0) ⁺
924	XTh232	Fitting constant for resonance cross-section - See Section II E for Th232 (0.5) ⁺
925	XU234	Fitting constant for resonance cross-section - See Section II E for U234 (0.5) ⁺
926	XU236	Fitting constant for resonance cross-section - See Section II E for U236 (0.5) ⁺
927	XU238	Fitting constant for resonance cross-section - See Section II E for U238 (0.5) ⁺
928	XPu240	Fitting constant for resonance cross-section - See Section II E for Pu240 (0.5) ⁺
929	XPu242	Fitting constant for resonance cross-section - See Section II E for Pu242 (0.5) ⁺
930	Y1	0.0 ⁺ - omit Th chain 1.0 - include Th chain

⁺These values are built into the code; data not built-in are zero at the start of the first case.

<u>DATA LOCATION</u>	<u>SYMBOL</u>	<u>EXPLANATION</u>
931	Y2	0.0 ⁺ - Print all physics data 1.0 - Print summary and neutron economy only
932	Y3	Minimum Keff (terminates case) (1.0) ⁺
933	Y4	Number of timesteps ≤ 70 (35) ⁺
934	Y5	Fraction of epithermal poison (0.3) ⁺
935	Y6	0.0 ⁺ - Do not print neutron economy Print neutron economy every Y6 time steps
936	Y7	0.0 ⁺ - Use fitting scheme for variation of the removal cross-section with burn-up 1.0 - Sum of fast group removal and absorption cross-section is constant
937	Y8	Number of calculated time steps per print step (10) ⁺
938	Y9	0.0 ⁺ - Calculate fast to thermal flux ratio 1.0 - enter fast to thermal flux ratio in DATA(940). Hold constant thereafter. 2.0 - Calculate for initial time and hold constant thereafter.
939	Y10	0.0 ⁺ - use 3 fission product scheme 1.0 - use 1 fission product scheme - 1.0 - use 12 fission product scheme
940	$[\phi_1/\phi_2]$	Fast to thermal flux ratio (see Y9)
941	SP	Specific Power (KW/KG)
942	Δ MWDT	Time step (MWD/T) (1000.) ⁺
943	UNIT A	Unit - A - See Section II E (1.0) ⁺ (from BAM)
1000	IXEC	0.0 - Next case will use the same BAM/FORM material data as the present case 1.0 ⁺ - Next case will use a new material

⁺These values are built into the code; data not built-in are zero at the start of the first case.

The table of built-in data follows:

ELEMENT	KINDLE ID	FAST DATA		THERMAL DATA	
		σ^{-1}	v^1	σ 2200 M/S	v'^2
Th232	1	0	2.406	7.56	0
Th233	2	0	0	1580	0
Pa233	3	0	2.72	0	0
U233	4	0	2.51	0	2.5
U234	5	0	2.58	105	0
U235	6	0	2.43	0	2.43
U236	7	0	2.8	7.0	0
U238	8	0	2.75	2.71	0
Np239	9	0	0	67.7	0
Pu239	10	0	2.89	0	2.89
Pu240	11	0	3.31	0	0
Pu241	12	0	3.06	0	3.06
Pu242	13	0	0	25	0
FP11	14	0	0	43	0
FP21	15	0	0	54	0
FP31	16	0	0	37	0
Sml49	26	205	0	0	0
Xel35	27	273.95	0	0	0
Pml47 → Pml48	28	102.5	0	124	0
Pml47 → Pml48m	29	94.24	0	108	0
Pml48	30	2652	0	1500	0
Pml48m	31	1929	0	27000	0
Pml49	32	0	0	0	0
Il35	33	0	0	0	0
U237	34	0	0	0	0
Np237	35	0	0	196	0

IV Operating Instructions

The instructions below are specifically for the operation of THREDES on the stand-alone IBM 7094 at Los Angeles Division (LAD). The program can be operated elsewhere but requires different operating instructions. The CRT option in FOG requires an SC-4020 graphical display device.

A. Timing and Output

Timing is estimated by adding the time required by each program used as follows:

<u>Code</u>	<u>Time/Case (Min)</u>
BAM	1.0
FORM	0.4
FOG	0.3
KINDLE	0.1

These times are averages based on large numbers of cases; may vary by 50% or more and are based on the built-in or suggested convergence criterion.

Output varies with the options chosen but can be estimated from the following table:

<u>CODE</u>	<u>LOW</u> - (lines)	<u>HIGH</u> - (lines)
BAM	200	500
FORM	200	500
FOG	300	600
KINDLE	100	500

If the CRT option in FOG is exercised one frame is generated per case (two frames - if the adjoint of fluxes are calculated).

B. Deck Set-Up

THREDES resides on a program tape and consequently requires only a starter deck. This deck is filed in D/792 as 4W-016. The job card should appear as follows:

EDPM JOB REQUEST		RA 31/11/11		795	503	1-12-66	
XXXX - XX		H10		DEPT. 1	GROUP 1741	DATE SUBMITTED 1000	
JOB NUMBER		FACILITY		BLDG. 5	FLOOR	PHONE	

<div style="writing-mode: vertical-rl; transform: rotate(180deg);">EXPECT.</div>	TOT. TIME 7 FRAMES SIZE FRAMES SIZE	☒ FORTRAN ☐ ISOS, MD NO. ☒ NAANSYS (Other) ☐ CHECKOUT ☒ PRODUCTION ☐ PROGRAMMER PRESENT ☐ SPEC. INSTR. ATTACHED ☐ _____ ☐ _____	☐ DECK IS SET UP <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2"></th> <th rowspan="2">ON FILE</th> <th rowspan="2">ENCLOSED</th> <th rowspan="2">KP (PAGES)</th> <th rowspan="2">DECK NO.</th> <th rowspan="2">INTERP. KP</th> <th colspan="2">SORT</th> <th rowspan="2">INSERT AT FLAG</th> </tr> <tr> <th>KP ONLY</th> <th>ALL CARDS</th> </tr> </thead> <tbody> <tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>2</td><td></td><td>X</td><td></td><td>DATA</td><td></td><td></td><td></td><td></td></tr> <tr><td>1</td><td>X</td><td></td><td></td><td>4W016</td><td></td><td></td><td></td><td></td></tr> </tbody> </table>		ON FILE	ENCLOSED	KP (PAGES)	DECK NO.	INTERP. KP	SORT		INSERT AT FLAG	KP ONLY	ALL CARDS	5									4									3									2		X		DATA					1	X			4W016				
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LIMITS	TIME 480	PRINTING	CARDS
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BOX	Date	Time	By
RECEIVED			
KEYPUNCH			
VERIFY			
READY			
COMPLETE			

PRIORITY

Lines 2, 3, 4, and 5 can be used as usual to specify the data deck setup. The PRINTING LIMIT is the expected output expressed in hundreds of lines.

C. Special Instructions

All special instructions are indicated on the form on the following page.

Tape 20B is the THREDES program tape and 20N and 26B are the library tapes based on the standard FORM library tape 12M and the HWOCR FORM library tape 12H, respectively.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

AI-CE-MEMO 11
page 88

EDPM JOB REQUEST SUPPLEMENT

PHONE _____ JOB NUMBER _____

NAME _____ DEPT. _____ GROUP _____ DATE SUBMITTED _____

SPECIAL INSTRUCTIONS TO DEPT. 792 (Atomics International)

Send _____ blank tape(s) to D/592 (Rocketdyne) with this job

PRINT OUTPUT _____ TIMES ON _____ PART _____ PAPER

(continue on reverse side)

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

EDPM JOB REQUEST SUPPLEMENT

NAME R A BLAINE PHONE 1741 JOB NUMBER XXXX XX
795 503 1-12-66
DEPT. GROUP DATE SUBMITTED

SPECIAL INSTRUCTIONS TO DEPT. 592 (Rocketdyne)

FORTRAN ☒

OTHER NAASYS

Tapes to be mounted from library, used and refiled. **Ring Out, Hi-Density Assumed**

Use Tape from Rack 20 File B On Unit B1

Use Tape from Rack 20 File N On Unit A6

Use Tape from Rack _____ File _____ On Unit _____

Blank tapes to be mounted on Unit _____, _____, _____. **Ring In, Hi-Density Assumed**

OPERATING INSTRUCTIONS (if necessary)

File Tape on Unit _____ In Rack _____ File _____ with the enclosed label

(continue on reverse side)

List of Error Stops

MAIN PROGRAM

1. USER DID NOT REQUEST FØG OR KINDLE ON CARD 3 OR NAME IS MISSPELLED OR NOT LEFT ADJUSTED - JOB DELETED.

FREAD/IREAD

1. ADDRESS ZERO OR NEGATIVE ON CARD AFTER ADDRESS = XXXXX - JOB DELETED.

BAM

1. ERROR IN READING TEMPEST LIBRARY - JOB TERMINATED - (PROBABLY WRONG TAPE MOUNTED).
2. ERROR FLAG SET IN TEMPEST - NFLAG = X - TRY NEXT CASE.
3. ERROR IN READING BINARY LIBRARY FOR XXXXX - JOB DELETED.
4. ERROR IN INPUT. BINARY LIBRARY CARD, DECIMAL LIBRARY CARD OR DATA CARD IS MISSING - JOB DELETED.
5. THERE ARE MORE THAN 300 ELEMENTS IN THE LIBRARY - JOB DELETED.
6. THERE ARE MORE THAN 5000 TABULATED CROSS-SECTIONS IN THE LIBRARY - JOB DELETED.
7. ITYPE IS 3 OR 4 - JOB DELETED.
8. TRANSITION ENERGY OF LESS THAN 0.0007 EV HAS BEEN SPECIFIED. THE PROGRAM CANNOT HANDLE THIS CASE.
9. STARTING SERIES FAILED TO CONVERGE IN 30 ITERATIONS.
10. UPPER LIMIT OF INTEGRATION = XXXXX IS OUTSIDE OF THE DOMAIN - FUNCTION QD.
11. ARGUMENT OUTSIDE DOMAIN IN TERP. ARG = XXXX. FIRST FUNCTION VALUE = XXXXX.

FØG

1. ERROR IN PROCESSING MATERIAL XX. MATERIAL NUMBER ON TAPE 8
IS XX. IN SR MACRO FOR (BAM)
(FORM)*
2. ERROR, NUMBER OF REGIONS IS TOO LARGE (>40).
3. ERROR, NO INTERVAL IN REGION.
4. ERROR, NUMBER OF POINTS IS TOO LARGE (>238).
5. ERROR, NUMBER OF GROUPS IS TOO LARGE (>4).
6. ERROR, VALUE FOR EPSILON 1 (EPSILON 2, EPSILON 3)
IS TOO SMALL ($<10^{-7}$).
7. ERROR, R(1) MUST BE POSITIVE IF EXTRAPOLATED BOUNDARY IS USED.
8. ERROR, ALL SOURCE TERMS ARE ZERO.
9. ERROR, ZERO VALUE FOR DELTA R.
10. ERROR, DIFFUSION COEFFICIENT IS ZERO.
11. ERROR, VALUE FOR OMEGA IS NON-NEGATIVE.
12. ERROR, VALUE FOR OMEGA 1 IS NOT POSITIVE.

KINDLE

1. FORM MATERIAL NUMBER DOES NOT AGREE WITH BAM MATERIAL NUMBER.
BAM - XX. FORM - XX. - JOB DELETED.
2. ERROR IN BAM OR FORM GROUP NUMBER - FORM GROUP = XX.
BAM GROUP = XX. - JOB DELETED.

IBSYS

All system arithmetic , IO and tape redundancy messages.

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APPENDIX A

LIBRARY INFORMATION

The THREDES library consists of a tape containing two files the TEMPEST library and the FORM library. A brief discussion of the origin of the various elements will be given with specific references wherever possible.

The user should become familiar with the individual cross-sections in order to use the library properly. Within AI, the user can obtain a copy from the writer. Externally, the library can be obtained by means of the THREDES Library Program²¹ which is capable of providing a listing from the binary library tape. In addition, this program is capable of constructing a new tape, updating, converting an existing tape from FORTRAN 2 to FORTRAN 4 and combinations.

TEMPEST

The TEMPEST Library was based on the SOFOCATE Library²² but was largely updated from Reference 23. The element ID numbers were made to correspond to those on the FORM Library. The table of elements in this Appendix indicates four possible types of cross-sections. These are:

A	-	Absorption Cross-Section	-	σ_a
F	-	Fission Cross-Section	-	σ_f
X	-	Transport* Cross-Section	-	$(1-\bar{\mu})\sigma_s$
M	-	Moderating Cross-Section	-	$\xi\sigma_s$

An "X" indicated the presence of the particular cross-section with "1/v" cross-sections in the case of absorption and fission or constant in the case of the transport or moderating cross-sections. The symbol "XT" indicates the presence of tabular values.

* Note the nonstandard definition used here.

Certain of the isotope from the TEMPEST Library are special or require further explanation; these are:

H_{wa} (ID = 25)

This isotope represents the cross-section per atom of hydrogen bound in water. The absorption cross-section is the same as for H gas. The scattering cross-section was deduced from the total cross-section of water based on Reference 23 with the exception of the range 0.3 to 0.64 ev. Here the values were faired-in to a plot of the total cross-section calculated from the free atom cross-sections of hydrogen and oxygen. Oxygen was assumed to have a constant total cross-section of 4.8 barns while hydrogen absorption was assumed to follow

$$(\sigma_a)_H = \frac{0.05282}{\sqrt{E}} .$$

The scattering cross-section was then computed from

$$(\sigma_s(E))_{H_{wa}} = \frac{(\sigma_T)_{\text{water}}(E) - 4.8 - 2(\sigma_a)_H}{2}$$

The transport cross-section is computed as

$$(\sigma_{TR}(E))_{H_{wa}} = \sigma_s(E) (1 - \bar{\mu}(E))$$

where

$$\bar{\mu}(E) = \frac{2}{3M_{\text{eff}}(E)}$$

and $M_{\text{eff}}(E)$ was calculated from the Radkowsky prescription:

$$\frac{M_{\text{eff}}(E)}{1 + M_{\text{eff}}(E)} = \sqrt{\frac{(\sigma_s(E))_{H_{wa}}}{80}} .$$

H_{bu} (ID = 32)

This isotope represents the cross-section per atom of hydrogen bound in 1,3 Butadiene. The absorption cross-section is the same as for H gas. The scattering cross-section was deduced from the total cross-section of hydrogen in 1,3 Butadiene²⁴ as follows

$$\left(\sigma_s(E)\right)_{H_{bu}} = \left(\sigma_T(E)\right)_{H_{bu}} - \left(\sigma_a(E)\right)_H$$

The transport cross-section was computed in an analogous manner to that for hydrogen in water.

304SS (ID = 34)

This isotope represents the cross-section of type 304 stainless steel and was computed by forming the macroscopic cross-sections and then dividing by a number density computed using the density of type 304 stainless steel and the atomic weight of iron.

D (ID = 38)

This isotope is deuterium. The transport cross was obtained in a manner analogous to H_{wa} from heavy water data. The moderating cross-section is based on the free atom value.

B_e 7 (ID = 39)

Origin is unknown.

Unit - A (ID = 55)

This isotope has an absorption cross-section of one barn at 0.0253ev which varies as 1/v.

Unit-D (ID = 70)

Origin is unknown.

O (ID = 72)

Oxygen - Same cross-sections as ID = 2.

Zr (ID = 73)

Zirconium - Same cross-sections as ID = 3.

C (ID = 74)

Carbon - Same cross-sections as ID = 4.

FORM

The FORM Library was based on the MUFT libraries^{25,26} but has been considerably updated at AI particularly in the case of fuel isotopes. The table of elements in this Appendix indicates four possible types of cross-sections. There are:

XSEC - Cross-sections including elastic and inelastic scattering, capture, fission, MUBAR x SCATTER, PSI x SCATTER, NU and age numbers.

RES - Resonance parameters.

ALPHA- Capture to fission ratios.

INEL - Inelastic scattering matrix.

In addition, a reference is given under "REF" for each isotope. An "X" indicates the presence of the particular data. Additional notes are given for many of the isotopes in what follows:

UO₂, UC ID = 12

This isotope is used in conjunction with U238 (ID = 20 or 28) to account for the additional resonance absorption due to UO₂ or UC and is used as follows:

For UO₂ set the number density of element 12 equal to that of U238 (ID = 20 or 28).

For UC set the number density of element 12 equal to 0.62 times that of U238.

(C) ID = 16

This isotope has constant values for certain of the cross-sections equal to the low energy values of carbon. These are:

$$\begin{aligned}\sigma_S &= 4.7, \text{ Age Number} = 0.1095, \bar{\mu} \sigma_S = .26322, \\ \Sigma \sigma_S &= .74716. \text{ All other cross-sections are zero.}\end{aligned}$$

(Th) ID = 17

This isotope is used to account for the difference in resonance absorption due to the ThO_2 and is used as follows:

For Th metal set the number density of element 17 equal to that of ThO_2 (ID = 62).

U235, U238, Pu239, Pu240 and Pu241 (ID = 18, 20, 21, 22, 23)

Obsoleted by 85, 28 or 88, 80, 81, and 82 respectively.

U238 (ID = 28)

This isotope represents U metal. The resonance parameters are adjusted to fit Hellstrand's data:

$$RI_U = 3.91 + 24.7 L \text{ with } L_U = \sqrt{S/M_U}.$$

For UO_2 Hellstrand's formula is $RI_{\text{UO}_2} = 5.25 + 26.6 L_{\text{UO}_2}$

$$\text{with } L_{\text{UO}_2} = \sqrt{S/M_{\text{UO}_2}}.$$

Thus one sets $L_{28} = \frac{26.6}{24.7} \cdot \sqrt{S/M_{\text{UO}_2}}$ and adds an amount of element 12 equal to element 28.

For UC Hellstrand's formula is

$$RI_{\text{UC}} = 4.74 + 25.9 L_{\text{UC}}$$

$$\text{with } L_{\text{UC}} = \sqrt{S/M_{\text{UC}}}.$$

Thus one sets $L_{28} = \frac{25.9}{24.7} \cdot \sqrt{S/M_{\text{UC}}}$ and adds an amount of element 12 given by 0.62* times the amount of element 28.

$$* \frac{4.74 - 3.91}{5.25 - 3.91} = 0.62$$

B10 (ID = 29)

Absorption cross-section normalized to 2200M/S value of 4010 barns.

Unit-M (ID = 30)

Pseudo isotope with

$\sigma_s = 1.0$, $\mu\sigma_s = 1.0$, $\xi\sigma_s = 0$. Other cross-sections are zero.

Unit-S (ID = 31)

Pseudo isotope with

$\sigma_s = 1.0$, all other cross-sections are zero.

304SS (ID = 34)

Composite isotope representing type 304 stainless steel. The number density for use with this isotope is obtained using the density of stainless steel and the atomic weight of iron.

B-10 (ID = 35)

Absorption cross-section normalized to a 2200M/S value of 3813 barns.

Blank (ID = 50)

This is an isotope having zero values of cross-sections, resonance parameters, alpha and inelastic scattering to permit a new isotope to be added at execution time via the add option.

Unit-A (ID = 55)

This isotope has an absorption cross-section normalized to a 2200M/S value of 1 barn. All other cross-sections are zero.

ThO₂ (ID = 62)

This isotope represents ThO₂. The resonance parameters are adjusted to fit Hellstrand's data:

$$RI_{UO_2} = 6.27 + 15.6 L_{ThO_2}$$

$$\text{with } L_{ThO_2} = \sqrt{S/M_{UO_2}}.$$

For Thorium metal (Th232) Hellstrand's formula is:

$$RI_{Th} = 4.52 + 16.1 L_{Th}$$

$$\text{with } L_{Th} = \sqrt{S/M_{Th}}.$$

Thus one sets the number density of element 17 equal to that of element 62 and

$$L_{62} = \frac{16.1}{15.6} \sqrt{S/M_{Th}}.$$

Pu239, Pu240, Pu241, U236 (ID = 80, 81, 82 and 83)

Resonance data determined by use of the ARES code³⁵. Self-shielding factors (L) must be obtained by means of a prescription given in Reference 33.

U235 (ID = 85)

Resonance self-shielding factor (L) must be obtained by means of a prescription given in Reference 36.

U238 (ID = 88)

For use in homogeneous calculations.

THREDES LIBRARY TAPE 20N

ID	ISOTOPE	TEMPEST				FORM				
		A	F	X	M	XSEC	RES	ALPHA	INEL	REF
01	H Gas	X		XT	X	X				25
02	O	X		X	X	X				25
03	Zr	X		X		X			X	23,28
04	C	X		X	X	X				23,27
05	Mo	X		X		X	X			23,27
06	Fe	X		X		X			X	23,28
07	Ni	X		X		X			X	23,28
08	Nb	X		X		X	X		X	25
09	Al	X		X		X			X	23,28
10	Sn	X		X						
11	Cr	X		X		X			X	23,28
12	(UC,UO ₂)					X				27
13	Cd	XT		X		X	X		X	26
14	Hf	XT		X		X	X		X	26
15	Mn	X		X						
16	(c)					X				28
17	(Th)					X				28
18	U-235					X				26
19	Mg					X			X	28,30
20	U-238					X	X		X	25,27
21	Pu-239					X	X	X		27
22	Pu-240					X	X			27
23	Pu-241					X	X	X		26
24	In	XT		X						
25	Hwa	X		XT	XT					
26	Sm-149	XT								23
27	Xe-135	XT		X						23
28	U-238	X		X		X	X		X	23,28
29	B-10					X				25
30	UNIT-M					X				26

THREDES LIBRARY TAPE 20N

ID	ISOTOPE	TEMPEST				FORM				
		A	F	X	M	XSEC	RES	ALPHA	INEL	REF
31	MMIT-S					X				26
32	HBU			XT						
33										
34	304SS	X		X		X			X	23,29
35	B-10	X		X		X				26
36										
37	W	X		X						
38	D	X		XT	X	X				27
39	Be7	X		X	X					
40	Be	X		X	X	X				27
41	F	X		X						
42	Cl	X		X						
43	Eu151	XT		X						
44	Gd	XT		X						
45	P	X		X						
46	Na	X		X		X			X	28,30
47	S	X		X						
48	Pb	X		XT		X			X	26
49	Y89	X		X						
50	BLANK					X	X	X	X	
51										
52	Np237	XT								

THREDES LIBRARY TAPE 20N

ID	ISOTOPE	TEMPEST				FORM				
		A	F	X	M	XSEC	RES	ALPHA	INEL	REF
53	Ag	X		X		X	X		X	26
54	Hf177	X		X						
55	UNIT-A	X				X				28
56	Au	X		X		X	X			27,28
57	Ti					X				28
58										
59										
60	Dy	X		X		X	X		X	31
61	Ir					X	X		X	31
62	ThO ₂	X		X		X	X		X	28
63	U234	X	X			X	X		X	28
64	U233	XT	XT	X		X				32
65	Pa233					X				32
66										
67										
68										
69										
70	UNIT-D			XT						
71										
72	O	X		X	X	X			X	26
73	Zr	X		X		X	X		X	26

THREDES LIBRARY TAPE 20N

[illegible]

THREDES LIBRARY TAPE 20N

ID	ISOTOPE	<u>TEMPEST</u>				<u>FØRM</u>				
		A	F	X	M	XSEC	RES	ALPHA	INEL	REF
95										
96										
97										
98										
99										

THREDES LIBRARY TAPE 26B

A library tape has been prepared with the cross-sections of certain elements weighted over a spectrum typical of the Heavy Water Organic Cooled Reactor (HWOCR). The TEMPEST cross-sections are the same as on the 20N library tape. The FØRM cross-sections are those of the 12H library tape for the HWOCR³⁹.

APPENDIX B

SAMPLE DATA SHEETS

The sample cases were taken from reference 37 and illustrate the use of BAM, FORM, and FOG.

Two BAM cases were run; one for the 8-inch lattice and a second for the 12-inch lattice. These calculations determine the thermal properties of materials 1 and 2 respectively. Note that the element ID numbers indicate that Edit 4 will be obtained by FORM. Only changes were indicated in the second BAM case.

Three FORM cases were run for the 8-inch lattice, the 12-inch lattice, and the reflector (graphite). These three calculations determine the fast group properties of materials 1, 2 and 6 respectively. Note that the volume-weighted number densities and ID numbers of materials 1 and 2 were obtained from the corresponding BAM cases. Also, note that it was necessary to "zero-out" the number densities of all elements but carbon in the third case.

Two FOG cases were run using first material 1 in region 1 (the core) and then material 2. Material 6 was in region 2 (reflector) in both cases. Note that the thermal group constants of material 6 were read in. Note that the material group constants and fission spectrum were obtained from BAM and FORM.

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO DATA

PROGRAMMER RA Blave

DATE 7-1-65

PAGE 1 of 16

JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 1 2		MBAM(I)
13		
25		
37		
49	73 80	
61	1 0	
1 1 2 6		MFPRM(I)
13		
25		
37		
49	73 80	
61	2 0	
1 FGG		
13		
25		
37		
49	73 80	
61	3 0	
1 DATA		NO LIBRARY CHANGES
13		
25		
37		
49	73 80	
61	4 0	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____

 PROGRAMMER Blaine

DATE _____

 PAGE 2 of 16

JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 SGR CRITICA		FIRST BAM CASE
13 2 S-NAA-SR-ME		
25 M ϕ -7891		
37 MATERIAL 1 -		
49 8 IN. LATTIC	73 80	
61 E BAM	50	
1		
13 1.		PZ ϕ B
25 26.		NUMBER OF INTERVALS
37 4.		NUMBER OF REGIONS
49 1.	73 80	NUMBER OF FUEL REGIONS
61 1.0 - 7	60	RADIUS FOR FLUX NORMALIZATION
1		
13 1.		KFLUX
25		
37		
49 293.	73 80	TEMPERATURE
61 0.	70	
1		
13 .625		EMAX
25 1.61. - 0.6		B ²
37		
49	73 80	
61	80	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 3 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 2.4		
13 1.		ITYPE
25		KHY
37 6.		
49	73 80	
61 90		
1 29		
13 4.		NUMBER OF THERMAL GROUP (FOR FOG)
25		
37		
49	73 80	
61 100		
1 100		FORM ID NUMBERS BY REGION
13 407.		
25		
37		
49	73 80	
61 110		
1 120		
13 428.		
25 480.		
37 485.		
49	73 80	
61 120		

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER B/line DATE _____ PAGE 4 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 13 25 37 49 61	1.40 407. 409. 73 80 1.30	
1 13 25 37 49 61	160 404. 73 80 1.40	
1 13 25 37 49 61	400 .0010206 73 80 1.50	ELEMENT NUMBER DENSITIES
1 13 25 37 49 61	420 .04738 0.0 .0009609 73 80 1.60	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 5 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 440		
13 .002488		
25 .02326		
37		
49	73 80	
61	170	
1 460		
13 .08429		
25		
37		
49	73 80	
61	180	
1 300		REGION BOUNDARIES
13 1.303		
25 2.1971		
37 2.46		
49 10.7	73 80	
61	190	
1 310		INTERVALS PER REGION
13 2.		
25 4.		
37 4.		
49 16.	73 80	
61	200	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____

PROGRAMMER

Blaine

DATE _____

PAGE 6 of 16

JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 3.20		SOURCE PER REGION
13 0.		
25 0.		
37 0.		
49 -001	73 80	
61 210		
1 330		FUEL REGION NUMBER
13 2.		
25		
37		
49	73 80	
61 220		
1 X 350		FLUX DISADVANTAGE FACTOR
13 .4		GUESS BY REGION
25 .38		
37 .6		
49 1.	73 80	
61 230		X IS COLUMN 1 INDICATES LAST CARD
1 SGR CRITICAL		SECOND BAM CASE
13 LS-NAA-SR-ME		ONLY CHANGES ARE INDICATED
25 MΦ-7891		
37 MATERIAL 2 -		
49 12 IN. LATTI	73 80	
61 CE BAM 240		

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Dave DATE _____ PAGE 7 of 16 JOB NO. _____

NUMBER		IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1			
13	2.		PRΦB
25	34.		NUMBER OF INTERVALS
37			
49			
61	16.	250	RADIUS FOR FLUX NORMALIZATION
1			
13	16.		CHANGE OUTER RADIUS
25			
37			
49			
61		260	
1			
13	24.		INTERVALS IN OUTER REGION
25			
37			
49			
61		270	
1	X		
13	.28		FLUX DISADVANTAGE FACTOR GUESS
25	.3		
37	.5		
49	1.01		
61		280	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blois DATE _____ PAGE 8 of 10 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	SGR CRITICA	FIRST FORM PAGE
13	LS NAA-S2-ME	VOLUME WEIGHED NUMBER DEVICES
25	MO-7801	IN ELEMENT ID NUMBER DONE
37	MATERIAL 1 -	FROM THE FIRST FORM PAGE
49	8 IN. LATTIC	
61	E FORM 290	
1	1	
13	1	U235 FISSION SOURCE
25		
37	0	P1 APPROXIMATION
49	4	EDIT NUMBER
61	1 3.00	NO SELENGUT-GERTZEL APPROXIMATION
1	6	
13	1	SELF CONSISTENT AGE APPROXIMATION
25		
37		
49		
61	3.10	
1	26	
13	3	THREE GROUP EDIT
25		
37		
49		
61	320	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 9 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 ☒ 51		GROUP BREAKPOINTS
13 10		
25 25		
37 54		
49	73 80	
61	330	X in column 1 indicates last of integer data
1 ☒ 1		
13 1.61 -06		B ²
25		
37		
49	73 80	
61	340	X in column 1 indicates last of floating data
1 110 10.1		L FACTOR FOR ELEMENT 28
13 .275		
25		
37		
49	73 80	
61	350	
1 110 10.2		L FACTOR FOR ELEMENT 80
13 1.0		
25		
37		
49	73 80	
61	360	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 10 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 11 103		L FACTOR FOR ELEMENT 85
13 1.0		
25		
37		
49		
61	73 80 370	
1 SGR CRITICA		SECOND FORM CASE
13 LS NAA-SR-ME		VOLUME WEIGHTED NUMBER DENSITIES
25 Mφ-7891		AND FILAMENT ID NUMBERS COME
37 MATERIAL 6 -		FROM THE SECOND BAM CASE.
49 12 IN. LATI	73 80	OPTIONS ARE THOSE SPECIFIED
61 CE FORM 3.80		IN THE FIRST FORM CASE.
1 X 4		AT LEAST ONE CARD OF EACH
13 4		TYPE MUST BE PRESENT
25		
37		
49		
61	73 80 3.90	
1 X 1		AT LEAST ONE CARD OF EACH
13 161. -06		TYPE MUST BE PRESENT
25		
37		
49		
61	73 80 4.00	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 11 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	SGR CRITICA	THIRD FORM CASE
13	LS NAA-SR-ME	
25	Mφ-7891	
37	MATERIAL 6(G	
49	R REFLECTφZ)	
61	FφRM 410	
1	4	
13	4	
25		
37		
49		
61	420	
1	7	DELETE EDIT 4 FOR ALL ELEMENTS BUT 4.
13	40.4	
25	7	
37	9	
49	28	
61	80 430	
1	X 12	
13	85	
25		
37		
49		
61	440	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.

PROGRAMMER

Blarve

DATE _____

PAGE

12 of 16

JOB NO.

NUMBER		IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	2		
13	0.084		
25	0.0		ZERO OUT ALL NUMBER DENSITIES EXCEPT
37	0.0		FOR ELEMENT 4
49	0.0	73 80	
61	0.0	4.50	
1	X 7		
13	0.0		
25			
37			
49		73 80	
61		4.60	
1	S&R CRITICAL		FIRST FOG CASE
13	LS - 8 IN LA		USES 8 INCH LATTICE DATA FROM
25	TICE		FIRST BAM AND FORM CASES
37			
49		73 80	
61	F&G	4.20	
1	1		
13	4		N & G
25	2		CYL. GEOMETRY
37	0		BD. COND. AT ORIGIN
49	4	73 80	BD. COND. AT OUTSIDE
61	0	4.80	CONVERGENCE

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 13 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	6	
13	0	EXTRAPOLATION
25	2	NUMBER OF REGIONS
37	20	INTERVALS IN REGION 1
49	60	INTERVALS IN REGION 2
61	490	
1	53	
13	1	PRINT EVERY OTHER POINT
25		
37		
49		
61	500	
1	63	
13	2	COMPUTE CHECKS AND PEAK-TO-AV. FLUX
25		
37		
49		
61	510	
1	X 109	DATA INPUT BY MATERIAL
13	6	6 IS HIGHEST MATERIAL NUMBER
25	1	MATERIAL 1 (8 IN. LATTICE) IN REGION 1
37	6	MATERIAL 6 (6 IN. LATTICE) IN REGION 2
49		
61	520	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 14 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1	
13	.001	ϵ_1
25		
37		
49		
61	73 80 530	
1	8	
13	51.	WIDTH OF REGION 1
25	134.	WIDTH OF REGION 2
37		
49		
61	73 80 540	
1	50	
13	161. -06	TRANSVERSE BUCKLING
25		
37		
49		
61	73 80 550	
1	90	
13	1. -04	SOURCE GUESS BY REGION
25		
37		
49		
61	73 80 560	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 15 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	2163	
13	.00032	Σ^4 for material 6 (GRAPHITE)
25		
37		
49		
61	570	
1	X 2168	
13	.0872	D ⁴ for material 6 (Graphite)
25		
37		
49		
61	580	
1	SGR CRITICAL	SECOND FOG CASE
13	LS - 12 IN L	USES 12 INCH LATTICE
25	ATTICE	DATA FROM SECOND
37		BAM AND FORM CASES
49		
61	590	
1	8	
13	40	CHANGE INTERVALS IN REGION 1 and 2
25	40	
37		
49		
61	600	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER Blaine DATE _____ PAGE 16 of 16 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 ☒ 1.10		
13 2		MATERIAL 2 IN REGION 1
25		
37		
49	73 80	
61	6.10	
1 ☒ 8		
13 7.0.		CHANGE WIDTH OF REGIONS 1 and 2
25 1.15.		
37		
49	73 80	
61	6.20	
1		JOB IS TERMINATED WHEN NO
13		MORE DATA IS FOUND ON THE
25		INPUT TAPE (SYSIN)
37		
49	73 80	
61		
1		
13		
25		
37		
49	73 80	
61		

APPENDIX C

SAMPLE OUTPUT

AI THERMAL REACTOR DESIGN SYSTEM - THREDES
BAM-FORM-FOG-KINDLE

THE FOLLOWING MATERIAL PROPERTIES WILL BE CALCULATED FOR USE IN FOG

CODE	MATERIAL NUMBERS
BAM	1 2
FORM	1 2 6

VOLUME IN EACH REGION, SN

1 0.16978090E 01 2 0.31294393E 01 3 0.12243515E 01 4 0.10843839E 03

VOLUME FRACTION IN EACH REGION

1 0.14829321E-01 2 0.27333736E-01 3 0.10693960E-01 4 0.94714298E 00

VOLUME SUMMED OVER ALL REGIONS IS 0.11448999E 03

ELEMENT AND ATOM DENSITY, BY REGION, INPUT

REGION 1

407 0.10206000E-02

REGION 2

428 0.47380000E-01 480 0. 485 0.96089999E-03

REGION 3

407 0.24879999E-02 409 0.23260000E-01

REGION 4

404 0.84289999E-01

ELEMENT AND HOMOGENIZED DENSITY

4 0.79834681E-01 7 0.41741379E-04 9 0.24874151E-03 28 0.12950724E-02 80 0.
85 0.26264986E-04

SGR CRITICALS-NAA-SR-MEMO-7891 MATERIAL 1 -8 IN. LATTICE BAM
THIS CASE HAS CONVERGED IN, 2 ITERATIONS/O

FINAL VALUES IN EACH REGION

SIGT

1	0.21063523E-01	2	0.94143028E 00	3	0.88697998E-01	4	0.38236512E-00
---	----------------	---	----------------	---	----------------	---	----------------

SIGS

1	0.17658676E-01	2	0.39181303E-00	3	0.75420706E-01	4	0.38213711E-00
---	----------------	---	----------------	---	----------------	---	----------------

SIGA

1	0.34048471E-02	2	0.54961724E 00	3	0.13277292E-01	4	0.22801012E-03
---	----------------	---	----------------	---	----------------	---	----------------

INPUT

4 REGIONS
26 INTERVALS

CONVERGENCE = 1.00E-02
BOUNDARY GUESS = 2.00E-01

ITMAX = 10 NMAX = 5 B1 = 0.9500 B2 = -10.0000

I	R	Q	SIGTI	SIGSI
1	1.3030000	0.	2.10635E-02	1.76587E-02
2	2.1971000	0.	9.41430E-01	3.91813E-01
3	2.4600000	0.	8.86980E-02	7.54207E-02
4	10.6999999	10.00000E-04	3.82365E-01	3.82137E-01

REG	OUTER BOUNDARY	AVERAGE FLUX	AV.FLUX IN REGION TO AV.FLUX IN CELL
1	1.303000	5.7675290E-02	0.3607002
2	2.197100	6.2521276E-02	0.3910069
3	2.460000	9.4528598E-02	0.5911801
4	10.700000	1.6504691E-01	1.0322003
CELL	10.700000	1.5989813E-01	

SIGMA A AVG= 6.19919735E-03 SIGMA S AVG= 3.78351867E-01 SIGMA TR AVG= 3.84551063E-01

D= 8.66811621E-01 L SQUARE= 1.39826427E 02 F= 9.47563493E-01
SGR CRITICALS-NAA-SR-MEMO-7891 MATERIAL 1 -8 IN. LATTICE BAM

TEMPEST DATA

HEAVY MODERATOR

TEMPERATURE	E MIN	E MAX	H1 SCATTERER	BUCKLING
0.2930E 03	0.	0.6250E 00	NONE	0.1610E-03

ISOTOPE	NUMBER	DENSITY
C A	4	0.8241E-01
NI A	7	0.2119E-04

2SAL A	9	0.1471E-03
U238	28	0.5064E-03
PU239A	80	0.
U235 A	85	0.1027E-04

MODERATOR	NUMBER	DENSITY
CARBON	304	0.8241E-01

AVERAGE TRANSPORT
CROSS SECTION
0.3846E-00

DIFFUSION CONSTANT
D AVERAGED
0.8669E 00

MACRO ABSORPTION
CROSS SECTION
0.6199E-02

TOTAL FLUX
0.1815E 01

XI SIGMA S
0.6242E-01

NU SIGMA F
0.1008E-01

ELEMENT	ID NUMBER	MICRO CROSS SECTION
C A	4	0.2705E-02
C X	204	0.4534E 01
NI A	7	0.3336E 01
NI X	207	0.1730E 02
2SAL A	9	0.2140E-00
2SAL X	209	0.1392E 01
U238	28	0.1966E 01
U238 X	228	0.8067E 01
PU239A	80	0.1082E 04
PU239F	180	0.7344E 03
PU239X	280	0.9573E 01
U235 A	85	0.4750E 03
U235 F	185	0.4040E 03
U235 X	285	0.9972E 01

SGR CRITICALS-NAA-SR-MEMO-7891

MATERIAL 2 -12 IN. LATTICE

BAM

VOLUME IN EACH REGION, SN

1 0.16978090E 01 2 0.31294393E 01 3 0.12243515E 01 4 0.24994840E 03

VOLUME FRACTION IN EACH REGION

1 0.66320662E-02 2 0.12224372E-01 3 0.47826231E-02 4 0.97636093E 00

VOLUME SUMMED OVER ALL REGIONS IS 0.25600000E 03

ELEMENT AND ATOM DENSITY, BY REGION, INPUT

REGION 1

407 0.10206000E-02

REGION 2

428 0.47380000E-01 480 0. 485 0.96089999E-03

REGION 3

407 0.24879999E-02 409 0.23260000E-01

REGION 4

404 0.84289999E-01

ELEMENT AND HOMOGENIZED DENSITY

4 0.82297461E-01 7 0.18667853E-04 9 0.11124381E-03 28 0.57919075E-03 80 0.
85 0.11746399E-04

SGR CRITICALS-NAA-SR-MEMO-7891 MATERIAL 2 -12 IN. LATTICE BAM
THIS CASE HAS CONVERGED IN, 3 ITERATIONS/0

FINAL VALUES IN EACH REGION

SIGT

1	0.21475543E-01	2	0.10136671E 01	3	0.90304685E-01	4	0.38239274E-00
---	----------------	---	----------------	---	----------------	---	----------------

SIGS

1	0.17658675E-01	2	0.39181303E-00	3	0.75420707E-01	4	0.38213713E-00
---	----------------	---	----------------	---	----------------	---	----------------

SIGA

1	0.38168675E-02	2	0.62185417E 00	3	0.14883977E-01	4	0.25560334E-03
---	----------------	---	----------------	---	----------------	---	----------------

INPUT

4 REGIONS
34 INTERVALS

CONVERGENCE = 1.00E-02

BOUNDARY GUESS = 4.58E-01

ITMAX = 10

NMAX = 5

B1 = 0.9500

B2 = -10.0000

I	R	Q	SIGTI	SIGSI
1	1.3030000	0.	2.14755E-02	1.76587E-02
2	2.1971000	0.	1.01367E 00	3.91813E-01
3	2.4600000	0.	9.03047E-02	7.54207E-02
4	16.0000000	10.00000E-04	3.82393E-01	3.82137E-01

REG	OUTER BOUNDARY	AVERAGE FLUX	AV.FLUX IN REGION TO AV.FLUX IN CELL
1	1.303000	1.1208375E-01	0.2811074
2	2.197100	1.2433390E-01	0.3118310
3	2.460000	1.9796948E-01	0.4965099
4	16.000000	4.0508794E-01	1.0159656
CELL	16.000000	3.9872210E-01	

SIGMA A AVG= 2.66647464E-03 SIGMA S AVG= 3.80766174E-01 SIGMA TR AVG= 3.83432651E-01

D= 8.69339967E-01 L SQUARE= 3.26025963E 02 F= 8.88990080E-01
SGR CRITICALS-NAA-SR-MEMO-7891 MATERIAL 2 -12 IN. LATTICE BAM

TEMPEST DATA

HEAVY MODERATOR

TEMPERATURE
0.2930E 03

E MIN
0.

E MAX
0.6250E 00

H1 SCATTERER
NONE

BUCKLING
0.1610E-03

ISOTOPE	NUMBER	DENSITY
C A	4	0.8361E-01
NI A	7	0.7811E-05

2SAL A	9	0.5523E-04
U238	28	0.1806E-03
PU239A	80	0.
U235 A	85	0.3663E-05

MODERATOR	NUMBER	DENSITY
CARBON	304	0.8361E-01

AVERAGE TRANSPORT
CROSS SECTION
0.3834E-00

DIFFUSION CONSTANT
D AVERAGED
0.8694E 00

MACRO ABSORPTION
CROSS SECTION
0.2666E-02

TOTAL FLUX
0.1271E 01

XI SIGMA S
0.6333E-01

NU SIGMA F
0.4081E-02

ELEMENT	ID NUMBER	MICRO CROSS SECTION
C A	4	0.3032E-02
C X	204	0.4534E 01
NI A	7	0.3740E 01
NI X	207	0.1730E 02
2SAL A	9	0.2399E-00
2SAL X	209	0.1392E 01
U238	28	0.2204E 01
U238 X	228	0.8067E 01
PU239A	80	0.1023E 04
PU239F	180	0.7173E 03
PU239X	280	0.9573E 01
U235 A	85	0.5385E 03
U235 F	185	0.4585E 03
U235 X	285	0.9972E 01

A.I. FOURIER TRANSFORM FAST SPECTRUM CODE

SGR CRITICALS NAA-SR-MEMO-7891

MATERIAL 1 -8 IN. LATTICE

FORM

INPUT DATA

NUMBER OF ELEMENTS 6	SOURCE 1	APPROXIMATION P1	SELENGUT-GOERTZEL NO, DELTA 1=1	AGE APPROXIMATION SELF-CONSISTENT DELTA 2=1	BUCKLING 0.00016100
	ELEMENT	NUMBER DENSITY	TYPE 3 EDIT	TYPE 4 EDIT	RESONANCE SCATTERER
	4	0.0798347	X	X	X
	7	0.0000417	X	X	X
	9	0.0002487	X	X	X
	28	0.0012951	X	X	X
	80	0.	X	X	X
	85	0.0000263	X	X	X

OUTPUT SCHEME 1 NO.GROUPS= 3 BREAKPOINTS= 10 25 54

RESONANCE SELFSHIELDING FACTORS

ELEMENT	L
28	0.275000
80	1.000000
85	1.000000

OUTPUT DATA

OVERALL FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SIGMA-A	SIGMA-R	SIGMA-F	NU SIGMA-F	P	AGE	DIFF.COEF.
1 OF 3	1 TO 10	0.000536	0.026274	0.000454	0.001202	0.980007	61.005	2.171448
2 OF 3	11 TO 25	0.000473	0.011000	0.000051	0.000126	0.958756	149.096	1.010893
3 OF 3	26 TO 54	0.002232	0.005254	0.000647	0.001589	0.701805	270.214	0.906714

INTERMEDIATE INTEGRALS

OUTPUT GROUP	MUFT GROUPS	ABSORPTION	FLUX	FISSION	NU-FISSION	SOURCE	CURRENT
1 OF 3	1 TO 10	0.014865	27.732661	0.012589	0.033326	0.753199	0.764107
2 OF 3	11 TO 25	0.039660	83.811487	0.004261	0.010524	0.246610	1.075033
3 OF 3	26 TO 54	0.269718	120.823210	0.078129	0.192042	0.000190	1.390060

54 GROUP EDIT

GROUP	FLUX	CURRENT	ETA	RHO	Q
1	0.435883	0.025530	0.	0.	0.005627
2	1.652272	0.096430	0.	0.	0.020603
3	4.116018	0.212128	0.	0.	0.055037
4	4.853142	0.135400	0.	0.	0.118199
5	7.488105	0.184605	0.	0.	0.205995
6	15.587914	0.496988	0.	0.	0.302750
7	16.974424	0.498030	0.	0.	0.404581
8	19.776696	0.534091	0.	0.	0.508866
9	20.298167	0.475831	0.	0.	0.601619
10	19.748024	0.397393	0.	0.	0.682512
11	19.682916	0.356650	0.	0.	0.755140
12	19.427479	0.322859	0.	0.	0.810974
13	18.688239	0.283489	0.	0.	0.853120
14	18.134114	0.257056	0.	0.	0.883695
15	17.719750	0.238773	0.	0.	0.905731
16	17.156037	0.219439	0.	0.	0.920874
17	16.767503	0.206656	0.	0.	0.930704
18	16.622527	0.201801	0.	0.	0.936762
19	16.498360	0.197558	0.	0.	0.939909
20	16.401998	0.194867	0.	0.	0.940858
21	16.249220	0.190973	0.	0.	0.938608
22	16.082199	0.187503	0.	0.	0.936552
23	15.767821	0.180492	0.	0.	0.932770
24	15.533754	0.176032	0.	0.	0.928626
25	15.440525	0.175493	0.	0.	0.921948
26	15.300840	0.173750	0.	0.	0.913235
27	15.166958	0.172730	0.	0.	0.905197
28	15.057183	0.172415	0.	0.	0.898711
29	14.969531	0.172772	0.	0.	0.893491
30	14.887427	0.172211	0.	0.	0.888591
31	14.732461	0.169893	0.	0.	0.877792
32	14.511936	0.167364	0.	0.	0.863645
33	14.358399	0.165676	0.	0.	0.858076
34	14.158525	0.163419	0.	0.	0.845672
35	14.045091	0.162135	0.	0.	0.839268
36	13.883548	0.160290	0.	0.	0.829368
37	13.803543	0.159336	0.	0.	0.824931
38	13.683323	0.157587	0.	0.	0.817550
39	13.248155	0.153298	0.	0.	0.790265
40	13.108257	0.151553	0.	0.	0.783245
41	12.629516	0.145896	0.	0.	0.753159

42	12.521001	0.144508	0.	0.	0.748342
43	12.348326	0.142372	0.	0.	0.737674
44	12.117037	0.139598	0.	0.	0.723652
45	11.402406	0.131306	0.	0.	0.678942
46	11.251643	0.129548	0.	0.	0.672405
47	11.203458	0.128981	0.	0.	0.669777
48	11.114389	0.127943	0.	0.	0.664264
49	11.082260	0.127556	0.	0.	0.662592
50	11.040194	0.127053	0.	0.	0.660018
51	11.009340	0.126678	0.	0.	0.658211
52	10.870198	0.125054	0.	0.	0.649513
53	10.747881	0.123064	0.	0.	0.641621
54	10.629409	0.121776	0.	0.	0.634782

ELEMENT NUMBER 4

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.	0.	0.	0.
2 OF 3	11 TO 25	0.00000014	0.	0.	0.
3 OF 3	26 TO 54	0.00000966	0.	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	1.9432818	0.3248148	0.	0.	0.	0.3075425
2 OF 3	11 TO 25	4.0216140	0.6772429	0.0000018	0.	0.	0.1373127
3 OF 3	26 TO 54	4.4368994	0.7471600	0.0001210	0.	0.	0.0656456

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 1.8605E 00
INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=0.

ELEMENT NUMBER 7

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.00000017	0.	0.	0.
2 OF 3	11 TO 25	0.00000416	0.	0.	0.
3 OF 3	26 TO 54	0.00001353	0.	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	2.4275988	0.0648177	0.0042397	0.	0.	0.1631242
2 OF 3	11 TO 25	11.3890305	0.3834312	0.0996718	0.	0.	0.0777416
3 OF 3	26 TO 54	18.0427384	0.6036152	0.3242825	0.	0.	0.0530338

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 2.2075E-04
INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=1.0196E-03

ELEMENT NUMBER 9

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.00000085	0.	0.	0.
2 OF 3	11 TO 25	0.00000104	0.	0.	0.
3 OF 3	26 TO 54	0.00000285	0.	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	2.0110972	0.1272823	0.0034181	0.	0.	0.2347470
2 OF 3	11 TO 25	3.3307786	0.2464419	0.0042163	0.	0.	0.0499667
3 OF 3	26 TO 54	1.3787238	0.1012361	0.0114525	0.	0.	0.0088946

FAST NEUTRON ENERGY DEPOSITION
 NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
 OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 2.3894E-03
 INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=3.1848E-03

ELEMENT NUMBER 28

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.00050226	0.	0.00042453	0.00112159
2 OF 3	11 TO 25	0.00040186	0.	0.00000025	0.00000060
3 OF 3	26 TO 54	0.00028334	0.00093820	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	4.4716034	0.0198450	0.3878249	0.3278117	0.8660458	1.2529594
2 OF 3	11 TO 25	10.4247574	0.0829136	0.3103044	0.0001953	0.0004688	0.0168109
3 OF 3	26 TO 54	9.7502548	0.0740089	0.9432212	0.	0.	0.0065024

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 2.2561E-03

INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=1.0728E-01

ELEMENT NUMBER 80

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	1.9645629	0.	1.9645629	1.9235106	6.0210232	1.2341696
2 OF 3	11 TO 25	2.5323746	0.	2.5323746	1.9233834	5.6300379	0.
3 OF 3	26 TO 54	42.4079337	0.	42.4079337	23.8957489	69.7280197	0.

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM) = -0.

INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM) = 8.2840E 01

ELEMENT NUMBER 85

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.00003271	0.	0.00002940	0.00008009
2 OF 3	11 TO 25	0.00006599	0.	0.00005058	0.00012495
3 OF 3	26 TO 54	0.00041651	0.00057248	0.00064664	0.00158944

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	5.2973730	0.0391650	1.2455014	1.1196225	3.0493380	1.2653006
2 OF 3	11 TO 25	12.6105783	0.0939235	2.5124711	1.9261064	4.7576977	0.0190432
3 OF 3	26 TO 54	45.9421558	0.0703620	37.6545272	24.6199188	60.5156450	0.0061820

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 8.3236E-05
INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=1.9725E-03

A.I. FOURIER TRANSFORM FAST SPECTRUM CODE

SGR CRITICALS NAA-SR-MEMO-7891

MATERIAL 6 -12 IN. LATTICE

FORM

INPUT DATA

NUMBER OF ELEMENTS 6	SOURCE 1	APPROXIMATION P1	SELENGUT-GOERTZEL NO, DELTA 1=1	AGE APPROXIMATION SELF-CONSISTENT DELTA 2=1	BUCKLING 0.00016100
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ELEMENT	NUMBER DENSITY	TYPE 3 EDIT	TYPE 4 EDIT	RESONANCE SCATTERER
4	0.0822975	X	X	X
7	0.0000187	X	X	X
9	0.0001112	X	X	X
28	0.0005792	X	X	X
80	0.	X	X	X
85	0.0000117	X	X	X

OUTPUT SCHEME 1 NO.GROUPS= 3 BREAKPOINTS= 10 25 54

RESONANCE SELFSHIELDING FACTORS

ELEMENT	L
28	0.275000
80	1.000000
85	1.000000

OUTPUT DATA

OVERALL FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SIGMA-A	SIGMA-R	SIGMA-F	NU SIGMA-F	P	AGE	DIFF.COEF.
1 OF 3	1 TO 10	0.000240	0.025846	0.000204	0.000539	0.990793	62.450	2.162861
2 OF 3	11 TO 25	0.000212	0.011406	0.000023	0.000056	0.981766	148.996	1.005627
3 OF 3	26 TO 54	0.001029	0.006110	0.000298	0.000733	0.855921	274.802	0.898140

INTERMEDIATE INTEGRALS

OUTPUT GROUP	MUFT GROUPS	ABSORPTION	FLUX	FISSION	NU-FISSION	SOURCE	CURRENT
1 OF 3	1 TO 10	0.006843	28.493444	0.005799	0.015349	0.753199	0.781964
2 OF 3	11 TO 25	0.017678	83.455568	0.001899	0.004691	0.246610	1.064891
3 OF 3	26 TO 54	0.134446	130.709198	0.038989	0.095834	0.000190	1.489578

54 GROUP EDIT

GROUP	FLUX	CURRENT	ETA	RHO	Q
1	0.442852	0.026278	0.	0.	0.005888
2	1.696716	0.100302	0.	0.	0.021791
3	4.252037	0.221258	0.	0.	0.058533
4	4.962080	0.137434	0.	0.	0.124472
5	7.641870	0.186781	0.	0.	0.216517
6	16.087989	0.512410	0.	0.	0.321690
7	17.594784	0.514541	0.	0.	0.431741
8	20.373711	0.545518	0.	0.	0.539444
9	20.807092	0.483044	0.	0.	0.634526
10	20.114645	0.400288	0.	0.	0.715217
11	19.848305	0.355529	0.	0.	0.783109
12	19.449317	0.319550	0.	0.	0.835179
13	18.615356	0.279260	0.	0.	0.874277
14	18.003796	0.252596	0.	0.	0.902731
15	17.551281	0.234359	0.	0.	0.923203
16	16.978241	0.215608	0.	0.	0.937487
17	16.597386	0.203590	0.	0.	0.947120
18	16.440379	0.198423	0.	0.	0.953428
19	16.336299	0.194866	0.	0.	0.957261
20	16.251043	0.192339	0.	0.	0.959275
21	16.145477	0.189471	0.	0.	0.959878
22	16.006114	0.186257	0.	0.	0.959385
23	15.724710	0.179862	0.	0.	0.957579
24	15.523673	0.175723	0.	0.	0.955351
25	15.475470	0.175409	0.	0.	0.951853
26	15.405578	0.174547	0.	0.	0.947371
27	15.337440	0.174000	0.	0.	0.943151
28	15.279424	0.173762	0.	0.	0.939608
29	15.230920	0.173818	0.	0.	0.936629
30	15.184755	0.173463	0.	0.	0.933789
31	15.106018	0.172328	0.	0.	0.928238
32	14.997500	0.171096	0.	0.	0.921105
33	14.921056	0.170262	0.	0.	0.918216
34	14.825492	0.169193	0.	0.	0.912122
35	14.768889	0.168559	0.	0.	0.908812
36	14.689907	0.167667	0.	0.	0.903836
37	14.648166	0.167176	0.	0.	0.901428
38	14.587577	0.166316	0.	0.	0.897607
39	14.377862	0.164268	0.	0.	0.884085
40	14.306662	0.163394	0.	0.	0.880347
41	14.071042	0.160643	0.	0.	0.865122

42	14.013644	0.159922	0.	0.	0.862409
43	13.921934	0.158804	0.	0.	0.856582
44	13.800215	0.157362	0.	0.	0.848990
45	13.435013	0.153167	0.	0.	0.825495
46	13.352619	0.152216	0.	0.	0.821690
47	13.322730	0.151868	0.	0.	0.819985
48	13.271519	0.151277	0.	0.	0.816733
49	13.249819	0.151020	0.	0.	0.815529
50	13.222799	0.150702	0.	0.	0.813834
51	13.201459	0.150447	0.	0.	0.812537
52	13.123202	0.149542	0.	0.	0.807523
53	13.052740	0.148426	0.	0.	0.802833
54	12.983318	0.147672	0.	0.	0.798696

ELEMENT NUMBER 4

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.	0.	0.	0.
2 OF 3	11 TO 25	0.00000014	0.	0.	0.
3 OF 3	26 TO 54	0.00001073	0.	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	1.9415239	0.3245105	0.	0.	0.	0.3046933
2 OF 3	11 TO 25	4.0207499	0.6770974	0.0000018	0.	0.	0.1383811
3 OF 3	26 TO 54	4.4369087	0.7471600	0.0001304	0.	0.	0.0741690

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 1.9504E 00
INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=0.

ELEMENT NUMBER 7

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.00000007	0.	0.	0.
2 OF 3	11 TO 25	0.00000186	0.	0.	0.
3 OF 3	26 TO 54	0.00000617	0.	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	2.4274157	0.0647731	0.0042326	0.	0.	0.1626677
2 OF 3	11 TO 25	11.4006042	0.3838161	0.0999972	0.	0.	0.0784420
3 OF 3	26 TO 54	18.0155087	0.6024734	0.3305689	0.	0.	0.0598062

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 1.0010E-04
INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=4.6909E-04

ELEMENT NUMBER 9

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.00000037	0.	0.	0.
2 OF 3	11 TO 25	0.00000046	0.	0.	0.
3 OF 3	26 TO 54	0.00000133	0.	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	2.0099222	0.1271649	0.0034138	0.	0.	0.2337310
2 OF 3	11 TO 25	3.3261862	0.2461014	0.0042176	0.	0.	0.0502967
3 OF 3	26 TO 54	1.3791229	0.1012267	0.0119800	0.	0.	0.0100485

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 1.0853E-03

INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=1.4639E-03

ELEMENT NUMBER 28

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.00022507	0.	0.00019037	0.00050285
2 OF 3	11 TO 25	0.00017980	0.	0.00000011	0.00000027
3 OF 3	26 TO 54	0.00012697	0.00042699	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	4.4713936	0.0198177	0.3886113	0.3286824	0.8682030	1.2540731
2 OF 3	11 TO 25	10.4226552	0.0828975	0.3104375	0.0001975	0.0004741	0.0169421
3 OF 3	26 TO 54	9.7526462	0.0739178	0.9564634	0.	0.	0.0073377

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO,ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 1.0215E-03

INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=4.9315E-02

ELEMENT NUMBER 80

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	1.9647052	0.	1.9647052	1.9238186	6.0222260	1.2354656
2 OF 3	11 TO 25	2.5334721	0.	2.5334721	1.9240351	5.6320093	0.
3 OF 3	26 TO 54	43.3508587	0.	43.3508587	24.6049633	71.7944183	0.

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM) = -0.

INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM) = 8.5144E 01

ELEMENT NUMBER 85

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.00001463	0.	0.00001315	0.00003582
2 OF 3	11 TO 25	0.00002954	0.	0.00002264	0.00005593
3 OF 3	26 TO 54	0.00018486	0.00027236	0.00029828	0.00073318

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A.	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	5.2966948	0.0391481	1.2455245	1.1196987	3.0496949	1.2648667
2 OF 3	11 TO 25	12.6121181	0.0938980	2.5150291	1.9278658	4.7620693	0.0191903
3 OF 3	26 TO 54	47.1529322	0.0698490	38.9257307	25.3938274	62.4179101	0.0069338

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 3.7875E-05

INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=9.0535E-04

A.I. FOURIER TRANSFORM FAST SPECTRUM CODE

SGR CRITICALS NAA-SR-MEMO-7891

MATERIAL 6(GR REFLECTOR)

FORM

INPUT DATA

NUMBER OF ELEMENTS 6	SOURCE 1	APPROXIMATION P1	SELENGUT-GOERTZEL NO, DELTA 1=1	AGE APPROXIMATION SELF-CONSISTENT DELTA 2=1	BUCKLING 0.00016100
	ELEMENT	NUMBER DENSITY	TYPE 3 EDIT	TYPE 4 EDIT	RESONANCE SCATTERER
	4	0.0840000	X	X	X
	7	0.			X
	9	0.			X
	28	0.			X
	80	0.			X
	85	0.			X

OUTPUT SCHEME 1 NO.GROUPS= 3 BREAKPOINTS= 10 25 54

RESONANCE SELFSHIELDING FACTORS

ELEMENT	L
28	0.275000
80	1.000000
85	1.000000

OUTPUT DATA

OVERALL FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SIGMA-A	SIGMA-R	SIGMA-F	NU	SIGMA-F	P	AGE	DIFF.COEF.
1 OF 3	1 TO 10	0.	0.025409	0.	0.	1.000000		64.133	2.163519
2 OF 3	11 TO 25	0.000000	0.011690	0.	0.	0.999987		150.076	1.004925
3 OF 3	26 TO 54	0.000012	0.006827	0.	0.	0.998305		280.864	0.894372

INTERMEDIATE INTEGRALS

OUTPUT GROUP	MUFT GROUPS	ABSORPTION	FLUX	FISSION	NU-FISSION	SOURCE	CURRENT
1 OF 3	1 TO 10	0.	29.241829	0.	0.	0.753199	0.802746
2 OF 3	11 TO 25	0.000013	83.495579	0.	0.	0.246610	1.064658
3 OF 3	26 TO 54	0.001621	139.823332	0.	0.	0.000190	1.586759

54 GROUP EDIT

GROUP	FLUX	CURRENT	ETA	RHO	Q
1	0.450161	0.027092	0.	0.	0.006104
2	1.739877	0.104298	0.	0.	0.022793
3	4.382241	0.230625	0.	0.	0.061512
4	5.072458	0.140152	0.	0.	0.129787
5	7.799261	0.189969	0.	0.	0.225394
6	16.566387	0.529033	0.	0.	0.337776
7	18.182138	0.532144	0.	0.	0.454928
8	20.954193	0.559137	0.	0.	0.565524
9	21.316670	0.492728	0.	0.	0.662551
10	20.503933	0.405807	0.	0.	0.743014
11	20.070755	0.357443	0.	0.	0.806780
12	19.552637	0.319420	0.	0.	0.855596
13	18.637398	0.278067	0.	0.	0.892054
14	17.975862	0.250996	0.	0.	0.918658
15	17.489753	0.232638	0.	0.	0.937750
16	16.905483	0.214184	0.	0.	0.951250
17	16.527734	0.202658	0.	0.	0.960658
18	16.360088	0.197203	0.	0.	0.967112
19	16.270272	0.194146	0.	0.	0.971456
20	16.192790	0.191720	0.	0.	0.974298
21	16.122628	0.189626	0.	0.	0.977163
22	16.003727	0.186582	0.	0.	0.977918
23	15.746561	0.180623	0.	0.	0.977699
24	15.570199	0.176700	0.	0.	0.977015
25	15.556669	0.176547	0.	0.	0.976101
26	15.540848	0.176368	0.	0.	0.975077
27	15.523959	0.176176	0.	0.	0.974003
28	15.506494	0.175977	0.	0.	0.972898
29	15.488766	0.175776	0.	0.	0.971783
30	15.470970	0.175574	0.	0.	0.970665
31	15.453022	0.175370	0.	0.	0.969535
32	15.434977	0.175165	0.	0.	0.968402
33	15.421404	0.175011	0.	0.	0.967833
34	15.412322	0.174907	0.	0.	0.967263
35	15.403213	0.174804	0.	0.	0.966691
36	15.394073	0.174700	0.	0.	0.966118
37	15.384898	0.174595	0.	0.	0.965542
38	15.375681	0.174490	0.	0.	0.964963
39	15.366418	0.174385	0.	0.	0.964381
40	15.357099	0.174279	0.	0.	0.963796
41	15.347719	0.174172	0.	0.	0.963207

42	15.338268	0.174064	0.	0.	0.962614
43	15.328736	0.173955	0.	0.	0.962015
44	15.319113	0.173845	0.	0.	0.961411
45	15.309383	0.173734	0.	0.	0.960800
46	15.299534	0.173621	0.	0.	0.960181
47	15.289549	0.173507	0.	0.	0.959554
48	15.279409	0.173390	0.	0.	0.958917
49	15.269092	0.173272	0.	0.	0.958269
50	15.258575	0.173151	0.	0.	0.957608
51	15.247748	0.173026	0.	0.	0.956922
52	15.236745	0.172899	0.	0.	0.956241
53	15.224372	0.172756	0.	0.	0.955387
54	15.210615	0.172597	0.	0.	0.954536

ELEMENT NUMBER 4

ELEMENTWISE FEW GROUP DATA

OUTPUT GROUP	MUFT GROUPS	SMOOTH SIGMA-A	RESONANCE SIGMA-A	SIGMA-F	NU SIGMA-F
1 OF 3	1 TO 10	0.	0.	0.	0.
2 OF 3	11 TO 25	0.00000015	0.	0.	0.
3 OF 3	26 TO 54	0.00001159	0.	0.	0.

TYPE 4 EDIT

OUTPUT GROUP	MUFT GROUPS	SIGMA-TR	XI SIGMA-S	SIGMA-A	SIGMA-F	NU-SIGMA-F	SIGMA-R
1 OF 3	1 TO 10	1.9401728	0.3242771	0.	0.	0.	0.3024913
2 OF 3	11 TO 25	4.0199017	0.6769546	0.0000018	0.	0.	0.1391721
3 OF 3	26 TO 54	4.4369162	0.7471600	0.0001380	0.	0.	0.0812706

FAST NEUTRON ENERGY DEPOSITION

NOTE - IF NUMBER DENSITY IS ZERO, ENERGY IS IN UNITS - MEV/ATOM
OTHERWISE THE UNITS ARE - MEV

ELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)= 2.0265E 00
INELASTIC ENERGY DEPOSITION (MEV OR MEV/ATOM)=0.

SGR CRITICALS - 8 IN LATTICE

FOG

INPUT OPTIONS

GEOMETRY N1=2 BOUNDARY CONDITION AT ORIGIN N2=0 OUTER BOUNDARY CONDITION N3=4
CONVERGENCE N4=0 EXTRAPOLATION FACTOR N5=0 SOURCE N6=0
BUCKLING BY REGION N7=0 BUCKLING BY GROUP N8=0 CHI OPTION N9=0
OUTPUT FORMAT N10=0 FLUX PRINT N11=1 GROUP DATA PRINTOUT N12=0
FLUX MULTIPLICATION N13=0 FLUX NORMALIZATION N14=0 N15= 0 N16=0
GROUP PRINT N17=0 CHECKS N18=2 BUCKLING ITERATION N19=0
CRITICALITY SEARCH N20= 0 ADJOINT FLUX N22=0 ADJOINT FLUX OUTPUT N23=0

INPUT OPTIONS

GEOMETRY N1=0 BOUNDARY CONDITION AT ORIGIN N2=

DIMENSIONS

NO. OF REGIONS M= 2 NO. OF POINTS N= 81 NO. OF GROUPS NOG= 4
NO. OF GROUPS FROM WHICH THERE IS SCATTERING NDS= 1

2 NO. OF INTERVALS IN REGIONS

LM= 20 60

EIGENVALUE CONVERGENCE EPS1= 0.99999999E-03

EXTRAPOLATION FACTOR

THETA= 0.80000000E 00

R(1)= 0.

2 DELTA R

DELR= 0.25500000E 01 0.22333333E 01

DATA FOR GROUP 1

T= 0.
OMEG1= 0.45544299E 01

	REGION 1	REGION 2
CHI	0.75319940E 00	0.75319940E 00
SIGMA POISON	0.	0.
BUCKLING	0.16100000E-03	0.16100000E-03
SIGMA ABSORPTION	0.53600165E-03	0.
TOTAL REMOVAL	0.27159289E-01	0.25757601E-01
DIFFUSION COEFFICIENT	0.21714480E 01	0.21635190E 01
NU SIGMA FISSION	0.12016828E-02	0.

DATA FOR GROUP 2

T= 0.
OMEG1= 0.21295085E 01

	REGION 1	REGION 2
CHI	0.24660961E-00	0.24660961E-00
SIGMA POISON	0.	0.
BUCKLING	0.16100000E-03	0.16100000E-03
SIGMA ABSORPTION	0.47320970E-03	0.15198905E-06
TOTAL REMOVAL	0.11636218E-01	0.11852403E-01
DIFFUSION COEFFICIENT	0.10108933E 01	0.10049254E 01
NU SIGMA FISSION	0.12556793E-03	0.
TRANSFER COEFFICIENTS	0.26273685E-01	0.25409275E-01

DATA FOR GROUP 3

T= 0.
OMEG1= 0.18964390E 01

	REGION 1	REGION 2
CHI	0.18998235E-03	0.18998235E-03
SIGMA POISON	0.	0.
BUCKLING	0.16100000E-03	0.16100000E-03
SIGMA ABSORPTION	0.22323330E-02	0.11590312E-04
TOTAL REMOVAL	0.76321240E-02	0.69823221E-02
DIFFUSION COEFFICIENT	0.90671398E 00	0.89437213E 00
NU SIGMA FISSION	0.15894426E-02	0.
TRANSFER COEFFICIENTS	0.11000255E-01	0.11690458E-01

DATA FOR GROUP 4

T= 0.

OMEG1= 0.18492379E 01

	REGION 1	REGION 2
CHI	0.	0.
SIGMA POISON	0.	0.
BUCKLING	0.16100000E-03	0.16100000E-03
SIGMA ABSORPTION	0.61991999E-02	0.31999999E-03
TOTAL REMOVAL	0.63387719E-02	0.46039199E-03
DIFFUSION COEFFICIENT	0.86690629E 00	0.87199999E 00
NU SIGMA FISSION	0.10081650E-01	0.
TRANSFER COEFFICIENTS	0.52538100E-02	0.68267379E-02

UNDRFLOW AT 30511 IN MQ

EIGENVALUES

NO. OF ITERATIONS

LAMBDA (J) = 0.99740829E 00
 LAMBDA (J-1)= 0.99717882E 00

J= 4

RADIUS	NORMALIZED SOURCE	SOURCE NORMALIZED FLUXES			
		GROUP 1	GROUP 2	GROUP 3	GROUP 4
0.	0.13461224E-03	0.35796681E-02	0.10377087E-01	0.13714821E-01	0.10599434E-01
0.50999999E 01	0.13411536E-03	0.35668699E-02	0.10335029E-01	0.13646600E-01	0.10563082E-01
0.10200000E 02	0.13265224E-03	0.35287438E-02	0.10208267E-01	0.13440702E-01	0.10456914E-01
0.15300000E 02	0.13031229E-03	0.34659572E-02	0.99945740E-02	0.13093304E-01	0.10290331E-01
0.20400000E 02	0.12726592E-03	0.33790382E-02	0.96886538E-02	0.12597939E-01	0.10081214E-01
0.25500000E 02	0.12380116E-03	0.32671457E-02	0.92795813E-02	0.11945786E-01	0.98596835E-02
0.30599999E 02	0.12038366E-03	0.31254864E-02	0.87469914E-02	0.11127113E-01	0.96741678E-02
0.35699999E 02	0.11774900E-03	0.29401309E-02	0.80563008E-02	0.10135242E-01	0.96005841E-02
0.40799999E 02	0.11703786E-03	0.26779334E-02	0.71544524E-02	0.89751226E-02	0.97556154E-02
0.45899999E 02	0.11998418E-03	0.22674306E-02	0.59707357E-02	0.76793215E-02	0.10315069E-01
-0.50999999E 02	0.12916122E-03	0.15634370E-02	0.44341761E-02	0.63340528E-02	0.11538122E-01
-0.50999999E 02	0.	0.15634370E-02	0.44341761E-02	0.63340528E-02	0.11538122E-01
0.55466665E 02	0.	0.92343388E-03	0.31023391E-02	0.51595169E-02	0.12554461E-01
0.59933332E 02	0.	0.54707371E-03	0.21248145E-02	0.40665848E-02	0.12843876E-01
0.64399999E 02	0.	0.32495008E-03	0.14328335E-02	0.31259158E-02	0.12629340E-01
0.68866666E 02	0.	0.19345076E-03	0.95485236E-03	0.23561364E-02	0.12084492E-01
0.73333332E 02	0.	0.11539494E-03	0.63045785E-03	0.17481452E-02	0.11339404E-01
0.77799999E 02	0.	0.68955040E-04	0.41319043E-03	0.12804092E-02	0.10488160E-01
0.82266665E 02	0.	0.41269092E-04	0.26915647E-03	0.92780533E-03	0.95964835E-02
0.86733332E 02	0.	0.24733931E-04	0.17444688E-03	0.66624573E-03	0.87085424E-02
0.91199999E 02	0.	0.14842627E-04	0.11258186E-03	0.47474714E-03	0.78526099E-02
0.95666665E 02	0.	0.89171560E-05	0.72392064E-04	0.33605370E-03	0.70455493E-02
0.10013333E 03	0.	0.53628455E-05	0.46403151E-04	0.23651354E-03	0.62962480E-02
0.10460000E 03	0.	0.32283360E-05	0.29662931E-04	0.16562314E-03	0.56081752E-02
0.10906667E 03	0.	0.19451031E-05	0.18916276E-04	0.11546983E-03	0.49812402E-02
0.11353333E 03	0.	0.11728892E-05	0.12037402E-04	0.80190398E-04	0.44131151E-02
0.11799999E 03	0.	0.70777498E-06	0.76455147E-05	0.55497426E-04	0.39001556E-02
0.12246666E 03	0.	0.42739903E-06	0.48477837E-05	0.38289773E-04	0.34380283E-02
0.12693333E 03	0.	0.25825617E-06	0.30691303E-05	0.26344608E-04	0.30221264E-02
0.13140000E 03	0.	0.15614477E-06	0.19403734E-05	0.18080817E-04	0.26478370E-02
0.13586666E 03	0.	0.94459541E-07	0.12251960E-05	0.12381095E-04	0.23107041E-02
0.14033332E 03	0.	0.57172650E-07	0.77271278E-06	0.84603184E-05	0.20065212E-02
0.14479999E 03	0.	0.34620668E-07	0.48679923E-06	0.57694668E-05	0.17313769E-02
0.14926666E 03	0.	0.20972976E-07	0.30633792E-06	0.39262195E-05	0.14816703E-02
0.15373333E 03	0.	0.12709036E-07	0.19253512E-06	0.26652754E-05	0.12541050E-02
0.15820000E 03	0.	0.77016205E-08	0.12080106E-06	0.18030430E-05	0.10456739E-02

0.16266666E 03 0.	0.46643713E-08	0.75563451E-07	0.12126931E-05	0.85363504E-03
0.16713333E 03 0.	0.28185815E-08	0.46960255E-07	0.80660878E-06	0.67548619E-03
0.17159999E 03 0.	0.16919706E-08	0.28732172E-07	0.52406794E-06	0.50893696E-03
0.17606666E 03 0.	0.99694105E-09	0.16877531E-07	0.32259016E-06	0.35188181E-03
0.18053333E 03 0.	0.55663870E-09	0.87881096E-08	0.17181695E-06	0.20237391E-03
-0.18499999E 03 0.	0.25964230E-09	0.26836000E-08	0.49107182E-07	0.58600532E-04

REGION	VOLUME	LBAR	ABAR	DBSQRD	FBAR/EIGEN
1	0.81712823E 04	0.22158889E-00	0.73670138E 00	0.41863337E-01	0.09999999E 01
2	0.99349721E 05	-0.18941414E-00	0.12391786E-00	0.65496089E-01	0.

INTEGRATED FLUXES

REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4
1	0.22970337E 02	0.63630941E 02	0.81960232E 02	0.82480956E 02
2	0.50223212E 01	0.20025205E 02	0.44217565E 02	0.38563227E 03

VOLUME-AVERAGED FLUXES

REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4
1	0.28111055E-02	0.77871426E-02	0.10030277E-01	0.10094003E-01
2	0.50551940E-04	0.20156276E-03	0.44506983E-03	0.38815636E-02

REGIONAL CHECKS

REGION	GROUP 1		GROUP 2	
	LEAKAGE	REMOVAL	LEAKAGE	REMOVAL
1	0.12938281E-00	-0.12934137E-00	0.10974124E-00	-0.10970146E-00
2	-0.12936302E-00	0.12936295E-00	-0.10973334E-00	0.10973326E-00

REGION	GROUP 3		GROUP 4	
	LEAKAGE	REMOVAL	LEAKAGE	REMOVAL
1	0.74664412E-01	-0.74615926E-01	-0.92199633E-01	0.92224475E-01
2	-0.74637493E-01	0.74637459E-01	0.12431972E-00	-0.12431972E-00

FUEL REGION	PEAK TO AVERAGE THERMAL FLUX IN FUEL	PEAK TO AVERAGE SOURCE
1	0.11430669E 01	0.10999545E 01

OVERALL AVG. FLUX= 0.11430669E 01 OVERALL AVG. SOURCE= 0.10999545E 01

SGR CRITICALS - 12 IN LATTICE

INPUT OPTIONS

GEOMETRY N1=2 BOUNDARY CONDITION AT ORIGIN N2=0 OUTER BOUNDARY CONDITION N3=4
CONVERGENCE N4=0 EXTRAPOLATION FACTOR N5=0 SOURCE N6=0
BUCKLING BY REGION N7=0 BUCKLING BY GROUP N8=0 CHI OPTION N9=0
OUTPUT FORMAT N10=0 FLUX PRINT N11=1 GROUP DATA PRINTOUT N12=0
FLUX MULTIPLICATION N13=0 FLUX NORMALIZATION N14=0 N15= 0 N16=0
GROUP PRINT N17=0 CHECKS N18=2 BUCKLING ITERATION N19=0
CRITICALITY SEARCH N20= 0 ADJOINT FLUX N22=0 ADJOINT FLUX OUTPUT N23=0

INPUT OPTIONS

GEOMETRY N1=0 BOUNDARY CONDITION AT ORIGIN N2=

DIMENSIONS

NO. OF REGIONS M= 2 NO. OF POINTS N= 81 NO. OF GROUPS NOG= 4
NO. OF GROUPS FROM WHICH THERE IS SCATTERING NDS= 1

2 NO. OF INTERVALS IN REGIONS

LM= 40 40

EIGENVALUE CONVERGENCE EPS1= 0.99999999E-03

EXTRAPOLATION FACTOR

THETA= 0.80000000E 00

R(1)= 0.

2 DELTA R

DELR= 0.17500000E 01 0.28749999E 01

DATA FOR GROUP 1

T= 0.

OMEG1= 0.4554429E 01

	REGION 1	REGION 2
CHI	0.75319940E 00	0.75319940E 00
SIGMA POISON	0.	0.
BUCKLING	0.16100000E-03	0.16100000E-03
SIGMA ABSORPTION	0.24016929E-03	0.
TOTAL REMOVAL	0.26434129E-01	0.25757601E-01
DIFFUSION COEFFICIENT	0.21628612E 01	0.21635190E 01
NU SIGMA FISSION	0.53867809E-03	0.

DATA FOR GROUP 2

T= 0.

OMEG1= 0.21295085E 01

	REGION 1	REGION 2
CHI	0.24660961E-00	0.24660961E-00
SIGMA POISON	0.	0.
BUCKLING	0.16100000E-03	0.16100000E-03
SIGMA ABSORPTION	0.21182960E-03	0.15198905E-06
TOTAL REMOVAL	0.11779246E-01	0.11852403E-01
DIFFUSION COEFFICIENT	0.10056265E 01	0.10049254E 01
NU SIGMA FISSION	0.56211737E-04	0.
TRANSFER COEFFICIENTS	0.25845739E-01	0.25409275E-01

DATA FOR GROUP 3

T= 0.

OMEG1= 0.18964390E 01

	REGION 1	REGION 2
CHI	0.18998235E-03	0.18998235E-03
SIGMA POISON	0.	0.
BUCKLING	0.16100000E-03	0.16100000E-03
SIGMA ABSORPTION	0.10285896E-02	0.11590312E-04
TOTAL REMOVAL	0.72836755E-02	0.69823221E-02
DIFFUSION COEFFICIENT	0.89814021E 00	0.89437213E 00
NU SIGMA FISSION	0.73318569E-03	0.
TRANSFER COEFFICIENTS	0.11405510E-01	0.11690458E-01

DATA FOR GROUP 4

T= 0.

OMEG1= 0.18492379E 01

	REGION 1	REGION 2
CHI	0.	0.
SIGMA POISON	0.	0.
BUCKLING	0.16100000E-03	0.16100000E-03
SIGMA ABSORPTION	0.26664761E-02	0.31999999E-03
TOTAL REMOVAL	0.28064424E-02	0.46039199E-03
DIFFUSION COEFFICIENT	0.86935566E 00	0.87199999E 00
NU SIGMA FISSION	0.40814556E-02	0.
TRANSFER COEFFICIENTS	0.61104853E-02	0.68267379E-02

UNDRFLOW AT 30511 IN MQ

EIGENVALUES

NO. OF ITERATIONS

LAMBDA (J) = C.99787895E 00
 LAMBDA (J-1)= C.99777558E 00

J= 6

RADIUS	NORMALIZED SOURCE	SOURCE NORMALIZED FLUXES			
		GROUP 1	GROUP 2	GROUP 3	GROUP 4
0.	0.84133010E-04	0.23100618E-02	0.65667717E-02	0.96855108E-02	0.18434544E-01
0.34999999E 01	0.84012502E-04	0.23067903E-02	0.65573210E-02	0.96706188E-02	0.18408318E-01
0.70000000E 01	0.83651733E-04	0.22969934E-02	0.65289948E-02	0.96259362E-02	0.18329823E-01
0.1050C000E 02	0.83053005E-04	0.22807247E-02	0.64818696E-02	0.95514380E-02	0.18199618E-01
0.13999999E 02	0.82220238E-04	0.22580719E-02	0.64160610E-02	0.94470695E-02	0.18018659E-01
0.1750C000E 02	0.81159097E-04	0.22291540E-02	0.63317045E-02	0.93127272E-02	0.17788330E-01
0.20999999E 02	0.79877183E-04	0.21941159E-02	0.62289263E-02	0.91482317E-02	0.17510504E-01
0.2450C000E 02	0.78384329E-04	0.21531194E-02	0.61078004E-02	0.89532983E-02	0.17187611E-01
0.27999999E 02	0.76692963E-04	0.21063279E-02	0.59682897E-02	0.87275042E-02	0.16822746E-01
0.31500000E 02	0.74818633E-04	0.20538818E-02	0.58101654E-02	0.84702599E-02	0.16419800E-01
0.34999999E 02	0.72780685E-04	0.19958575E-02	0.56329013E-02	0.81807953E-02	0.15983638E-01
0.3850C000E 02	0.70603123E-04	0.19322050E-02	0.54355386E-02	0.78581694E-02	0.15520319E-01
0.41999999E 02	0.68315719E-04	0.18626489E-02	0.52165210E-02	0.75013274E-02	0.15037369E-01
0.4550C0C0E 02	0.65955380E-04	0.17865369E-02	0.49735025E-02	0.71092343E-02	0.14544114E-01
0.48999999E 02	0.63567777E-04	0.17026095E-02	0.47031465E-02	0.66811197E-02	0.14052074E-01
0.5250C000E 02	0.61209274E-04	0.16086522E-02	0.44009522E-02	0.62168874E-02	0.13575397E-01
0.55999999E 02	0.58949058E-04	0.15009762E-02	0.40611834E-02	0.57177490E-02	0.13131350E-01
0.5950C000E 02	0.56871370E-04	0.13736451E-02	0.36770427E-02	0.51871458E-02	0.12740786E-01
0.6300C000E 02	0.55077581E-04	0.12173358E-02	0.32413353E-02	0.46320140E-02	0.12428575E-01
0.6650C000E 02	0.53687716E-04	0.10176636E-02	0.27480517E-02	0.40644003E-02	0.12223878E-01
-0.70000000E 02	0.52840771E-04	0.75273498E-03	0.21955771E-02	0.35033359E-02	0.12160171E-01
-0.7000C000E 02	0.	0.75273498E-03	0.21955771E-02	0.35033359E-02	0.12160171E-01
0.75750000E 02	0.	0.38782411E-03	0.13911345E-02	0.26313552E-02	0.11884498E-01
0.81500000E 02	0.	0.20036148E-03	0.85335253E-03	0.18938927E-02	0.11170807E-01
0.87249999E 02	0.	0.10375813E-03	0.51183359E-03	0.13202762E-02	0.10218354E-01
0.93000000E 02	0.	0.53843082E-04	0.30198980E-03	0.89799714E-03	0.91664553E-02
0.9875C000E 02	0.	0.27991860E-04	0.17596640E-03	0.59899875E-03	0.81057349E-02
0.1045C000E 03	0.	0.14576037E-04	0.10153501E-03	0.39332791E-03	0.70906358E-02
0.11025000E 03	0.	0.76011410E-05	0.58128576E-04	0.25497109E-03	0.61504127E-02
0.11600000E 03	0.	0.39690501E-05	0.33065130E-04	0.16352313E-03	0.52977186E-02
0.12175000E 03	0.	0.20749551E-05	0.18707946E-04	0.10393435E-03	0.45348398E-02
0.1275C000E 03	0.	0.10859210E-05	0.10537060E-04	0.65556759E-04	0.38579875E-02
0.13325000E 03	0.	0.56887114E-06	0.59119998E-05	0.41079091E-04	0.32601240E-02
0.13900000E 03	0.	0.29827563E-06	0.33059251E-05	0.25593506E-04	0.27327460E-02
0.14475000E 03	0.	0.15652022E-06	0.18431390E-05	0.15863013E-04	0.22669584E-02
0.1505C000E 03	0.	0.82189386E-07	0.10247225E-05	0.97822572E-05	0.18540813E-02

0.15625000E 03	0.	0.43174729E-07	0.56795644E-06	0.59969740E-05	0.14859609E-02
0.16200000E 03	0.	0.22669552E-07	0.31330992E-06	0.36432570E-05	0.11550982E-02
0.16774999E 03	0.	0.11863636E-07	0.17099103E-06	0.21726695E-05	0.85467082E-03
0.17349999E 03	0.	0.61263245E-08	0.90396886E-07	0.12366004E-05	0.57849272E-03
0.17924999E 03	0.	0.30067538E-08	0.42668568E-07	0.61027142E-06	0.32094496E-03
-0.18499999E 03	0.	0.11792612E-08	0.10628176E-07	0.14244694E-06	0.76891956E-04

REGION	VOLUME	LBAR	ABAR	DBSQRD	FBAR/EIGEN
1	0.15393803E 05	0.21689194E-00	0.71721444E 00	0.65937915E-01	0.09999999E 01
2	0.92127203E 05	-0.17465734E-00	0.11614069E-00	0.58516562E-01	0.

INTEGRATED FLUXES

REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4
1	0.25312935E 02	0.70255937E 02	0.10155207E 03	0.22193987E 03
2	0.32642319E 01	0.13180657E 02	0.30912755E 02	0.36181376E 03

VOLUME-AVERAGED FLUXES

REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4
1	0.16443586E-02	0.45639100E-02	0.65969446E-02	0.14417480E-01
2	0.35431791E-04	0.14307020E-03	0.33554427E-03	0.39273281E-02

REGIONAL CHECKS

REGION	GROUP 1		GROUP 2	
	LEAKAGE	REMOVAL	LEAKAGE	REMOVAL
1	0.84082514E-01	-0.84073998E-01	0.73287567E-01	-0.73279150E-01
2	-0.84078813E-01	0.84078785E-01	-0.73280744E-01	0.73280701E-01

REGION	GROUP 3		GROUP 4	
	LEAKAGE	REMOVAL	LEAKAGE	REMOVAL
1	0.61832988E-01	-0.61822511E-01	-0.23111418E-02	0.23290068E-02
2	-0.61754897E-01	0.61754891E-01	0.44457104E-01	-0.44457123E-01

FUEL REGION	PEAK TO AVERAGE THERMAL FLUX IN FUEL	PEAK TO AVERAGE SOURCE
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1	0.12786245E 01	0.12951270E 01
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OVERALL AVG. FLUX=	0.12786245E 01	OVERALL AVG. SOURCE=	0.12951270E 01
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1R A BLAINE		H05	12-49-21				
PRINTING	PUNCHING	CRT-35	CRT-9	COMPILE	ASSEMBLY	LOADING	EXECUTION
000000	000001	00000	00000	00000.0	00000.0	00006.6	00099.4