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VOLUME 7

SYNTHESIS OF CALCULATIONAL METHODS FOR THE DESIGN AND ANALYSIS OF RADIATION SHIELDS FOR NUCLEAR ROCKET SYSTEMS

NAGS

A FORTRAN IV DATA PROCESSING PROGRAM FOR CALCULATION OF NEUTRON AND GAMMA RAY SOURCES AND NEUTRON AND GAMMA RAY HEATING IN TWO DIMENSIONAL GEOMETRIES

by

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ABSTRACT

This report is Volume 7 of the nine volumes of the final report on "Synthesis of Calculational Methods for the Design and Analysis of Radiation Shields for Nuclear Rocket Systems." Presented in this volume is a description of the Neutron Flux And Gamma Ray Source Edit (NAGS) program.

The NAGS program is a series of FORTRAN IV routines which process multigroup neutron and photon energy fluxes for two dimensional (R, Z or R, θ) geometry models. Fluxes input to the NAGS program are obtained from the ODD-K two dimensional transport program described in Volume 6 of this report. Additional required input data to the NAGS program is prepared automatically by the POINT program described in Volume 2 of this report.

The NAGS program provides: (1) neutron and photon energy sources and distributions for use in point kernel, Monte Carlo, and photon transport analyses, (2) neutron and gamma ray dose rates, and (3) energy deposition data for use in subsequent thermal analyses. Source distributions which are output from the NAGS program are employed as input to the KAP-V point kernel program (Volume 4), the ODD-K two dimensional transport program (Volume 6), and the FASTER Monte Carlo program (Volume 9).

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SECTION

1.0 INTRODUCTION

This report is Volume 7 of nine volumes of the final report on "Synthesis of Calculational Methods for the Design and Analysis of Radiation Shields for Nuclear Rocket Systems." Presented in this volume is a description of the Neutron Flux And Gamma Ray Source Edit (NAGS) program.

The NAGS program is a series of FORTRAN IV routines which process multigroup neutron and photon energy fluxes for two dimensional (R, Z or R, θ) geometry models. This program is an integral part of the "final" design method as schematically shown in Figure 1. The "final" design method is described in detail in Volume 1 of this report.

The starting point for the method is the POINT program (Volume 2) which prepares cross section and other basic data for use in the transport programs. In the "final" design method (Figure 2), the ODD-K two dimensional transport program (Volume 6) provides neutron and photon energy fluxes throughout the reactor geometry. The NAGS data processing program (Volume 7) processes these fluxes and calculates neutron and photon radiation levels and neutron and photon energy sources within the reactor system. These sources can be employed in either the KAP-V program (Volume 4) or the FASTER Monte Carlo program (Volume 9) for obtaining radiation levels at locations external to the reactor system. In addition, the FASTER program can compute heating rate distributions in the liquid hydrogen propellant (in either an on- or an off-axis tank) and the radiation level at the payload. Alternately, the DAFT program (Volume 8) can prepare neutron and photon energy and angular dependent fluxes at the reactor surface from the ODD-K program for use in the FASTER Monte Carlo code.

Fluxes input to the NAGS program are obtained from the ODD-K two dimensional transport program described in Volume 6. Additional input data needed for the NAGS program is prepared automatically by the POINT program described in Volume 2 of this report.

The need for automated data processing as a logical link in radiation and shielding methods is evident when the vast amount of data handling required in each step of a

of a complete, two dimensional radiation analysis of a reactor is considered. Particular difficult and time-consuming problems handled by the NAGS program are: (1) calculation of neutron and photon energy sources and distributions, (2) calculation of neutron and gamma ray dose rates, and (3) calculation of neutron, photon, and total energy deposition data.

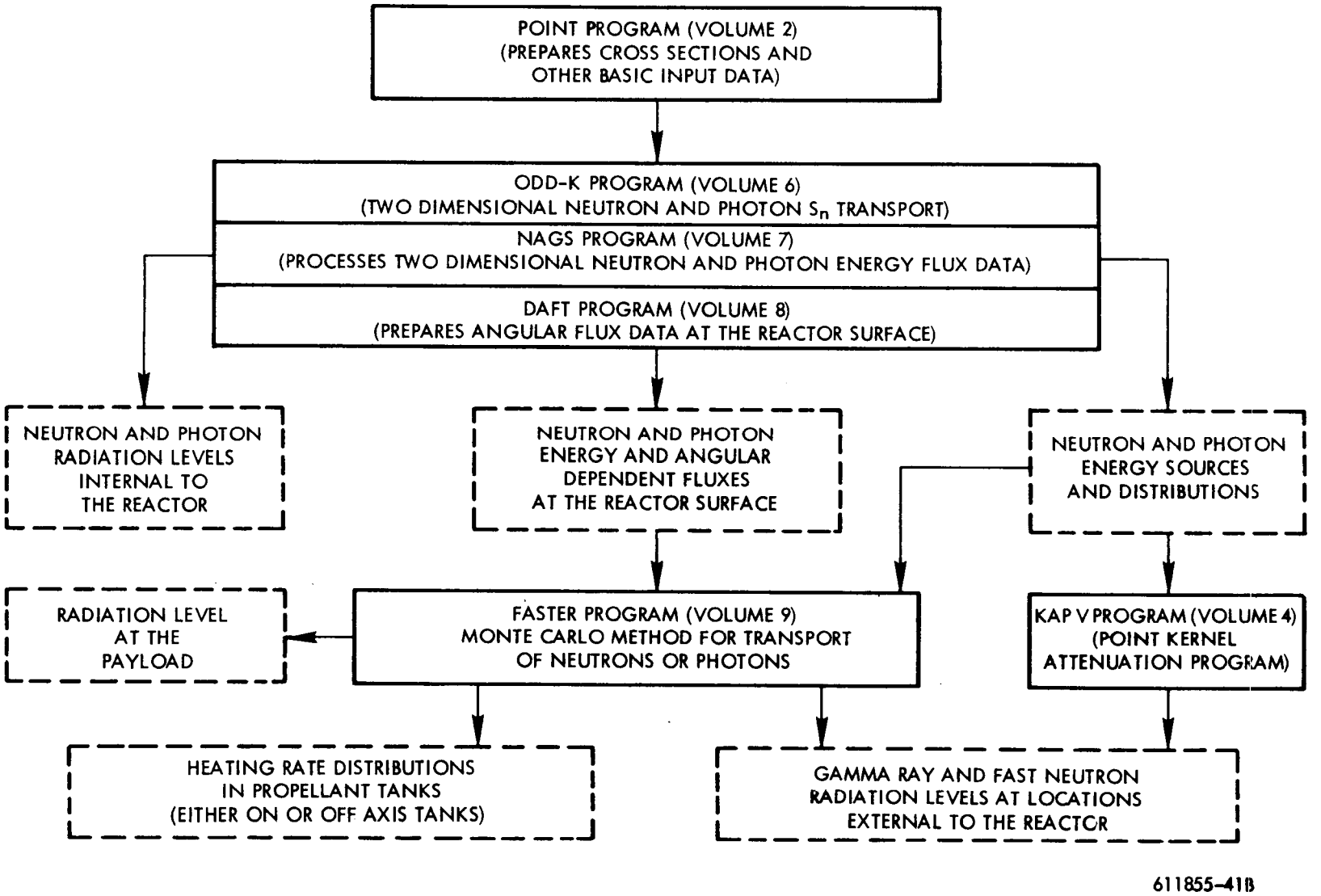

Figure 1. Schematic Diagram of the Final Design Method

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SECTION

2.0 PROGRAM DESCRIPTION

The NAGS program is a special purpose program which serves as a link between the neutron transport solution and the photon transport solution using the discrete ordinates transport program, ODD-K. In addition, this program processes neutron and photon energy flux data simultaneously to calculate total heating and heating distributions in a reactor. The program also provides source distribution data for subsequent use in point kernel or Monte Carlo analyses.

The four basic operations of the NAGS program are:

1) Normalization of multigroup neutron and photon energy fluxes to units of per fission, per watt, or a selected power level.

2) Redefinition of the mesh cell description for use in photon problems.

3) Calculation of photon and neutron sources and distribution and heating rates for each region in the problem.

4) Calculation of the total photon and neutron sources and fissions in the reactor.

These four operations are discussed in detail in subsequent sections of this report.

The FORTRAN structure of the NAGS system consists of a main control link (MAIN) and four basic calculation routines (NAGS 1 through NAGS 4) which individually perform steps in reducing the neutron and photon energy flux data into usable forms. The final output of a NAGS problem is dependent upon the route or options chosen.

A brief description of each FORTRAN routine is shown in Figure 2. A description of each routine's function is as follows:

1) The MAIN subroutine initializes the problem by clearing out (set to 0.0) all data storage and allocates data storage on the basis of input pieces of data so that a variety of problems can be handled without program changes. This routine also handles the logical flow throughout the NAGS program system.

2) The NAGS 1 routine processes all geometrical data and neutron and photon energy flux data to obtain a binary work tape containing the flux data in a usable form for subsequent use.

3) The NAGS 2 routine processes the elementwise neutron and photon reaction rate and flux data to obtain a regionwise source function and/or response function binary work tape for subsequent use.

4) The NAGS 3 routine calculates regionwise neutron and/or photon energy deposition distributions and integrals. In addition, NAGS 3 calculates neutron and photon dose rate throughout the two dimensional mesh cell array.

5) The NAGS 4 routine calculates regionwise photon source distributions and integrals for use in subsequent Monte Carlo or point kernel method analyses. The NAGS 4 routine also provides the two dimensional multigroup neutron or photon source data in each mesh cell for subsequent use in neutron or photon transport calculations.

In addition, a set of subroutines are included in the NAGS program system which calculate the region distribution data (SISET and SIR), processes neutron and photon energy flux data in the separable R and Z mesh cell directions (COLR and COLZ), and prints matrices of flux data (SCOUT). All NAGS subroutines are described more fully in Section 4.0 of this volume.

The NAGS program is an essential part of the two dimensional transport analysis system, which is shown schematically in Figure 3. As indicated in Figure 3, the POINT program prepared the macroscopic neutron and photon cross sections for use in the ODD-K program, and microscopic data for use in the NAGS program. The ODD-K neutron transport program run is the next step in the system (See Figure 3). Output from the neutron program are the neutron fluxes on cards (item A) and on tape (item B). The fluxes on cards (item A) are input to the first NAGS problem which computes the photon source data on cards for a redefined mesh (item C) and the neutron fluxes on cards (item D) for the redefined mesh. The photon source (item C) is then used in the ODD-K photon transport problem which produces photon energy fluxes on tape (item F) and on cards (item E). These photon energy fluxes (item E), and the previously computed neutron fluxes (item D), are employed in a final NAGS problem which calculates neutron and photon heating rates and dose rates.

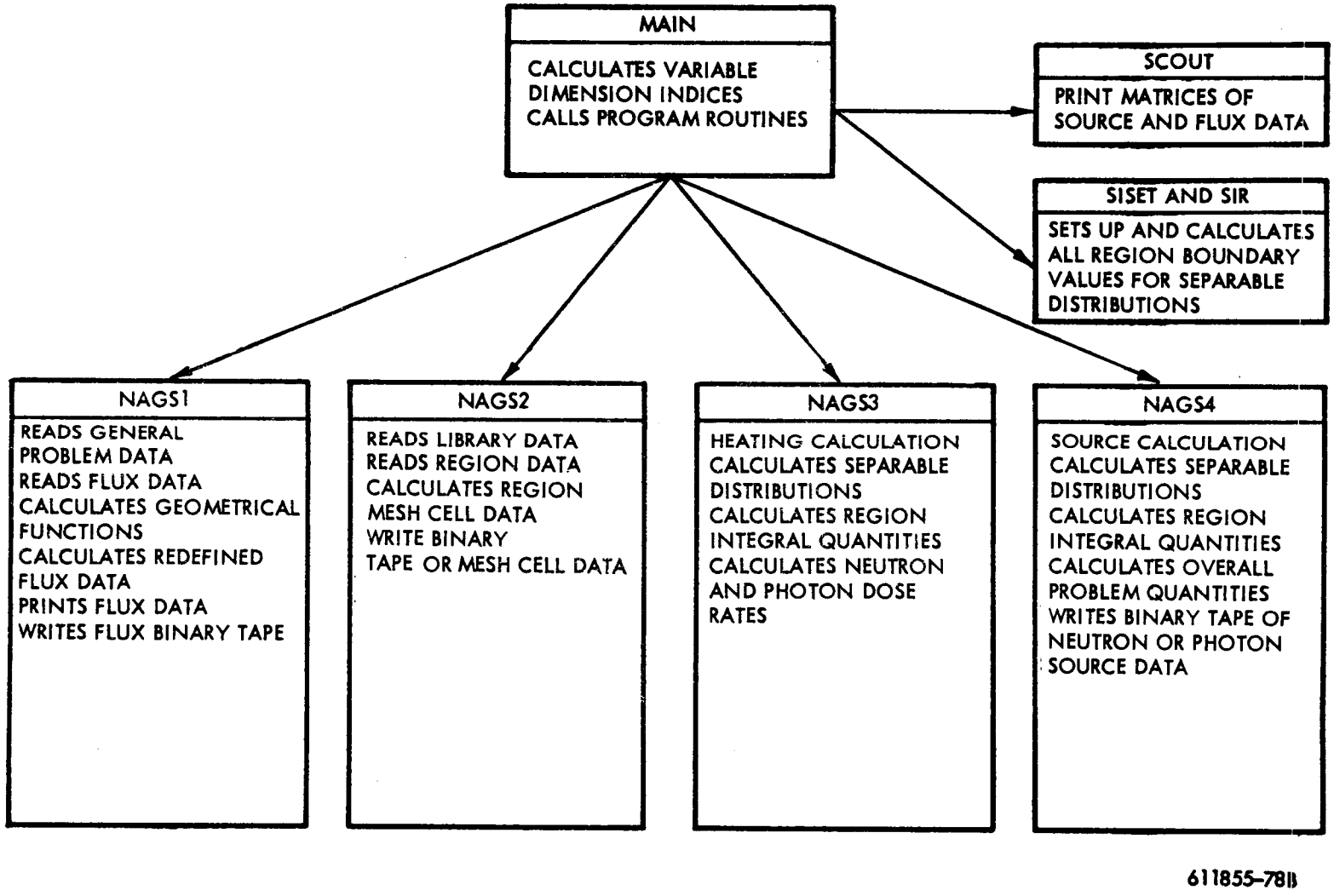

Figure 2. NAGS Basic Program Structure

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Optionally, the neutron and photon energy flux tapes (items B and F) can be input to the DAFT program which produces appropriate angular, spatial and energy fluxes for input to the FASTER Monte Carlo program.

2.1 GEOMETRY

The problem geometry is described in the NAGS system as a two dimensional reactor mockup in the R, Z or R, θ geometry. This geometry is similar to that used in the discrete ordinate transport program, ODD-K. The reactor mockup is described geometrically in NAGS as a series of rectangular or angular sector regions in a two dimensional mesh cell layout. Figure 4 illustrates the limitations of the geometry and the method by which an irregular region, D, must be described. Since the program operates on each NAGS region as a separate problem, the number of NAGS regions which can be run in a single problem is unlimited.

The integration techniques used to obtain particle fluxes, reaction rates, response rates, or particle source data are identical to the ODD-K transport method program techniques. Hence, completely consistent results are obtained in NAGS and ODD-K, i.e., the total number of neutrons and photons from the ODD-K problem is conserved. Interpolation and extrapolation techniques employed in NAGS are based on a linear variation of flux or source in the mesh cells and an exponential falloff of flux or source at the external boundaries of the reactor mockup.

2.2 MULTIGROUP FLUX OPERATIONS

Flux data for the NAGS program are the multigroup neutron and photon energy fluxes from the discrete ordinate transport method program, ODD-K, described in Volume 6 of this report. These flux data are provided by ODD-K at the center of each mesh cell and is the average flux in the mesh cell. The program will accept flux data from either the R, Z or R, θ two-dimensional geometry solutions in ODD-K. The multigroup flux data are used in the NAGS system in a manner such that the total number of neutrons and photons from the ODD-K problem is conserved.

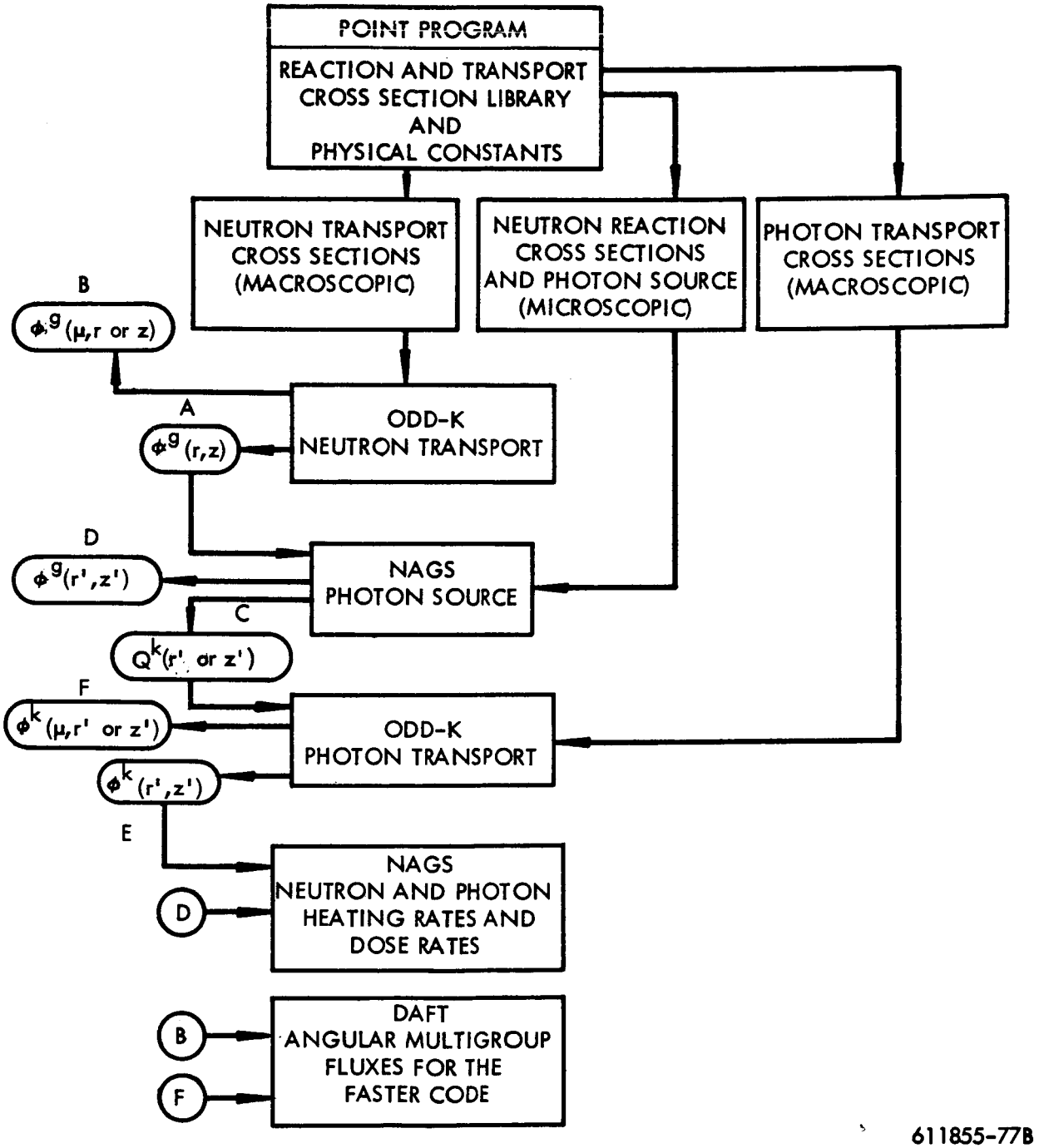


Figure 3. Schematic Diagram of the Two Dimensional Transport Analysis System

The NAGS program requires input flux data to be in either binary tape or decimal data punched card form. The input channels used for the flux data is dependent upon the type of NAGS problem (photon source or neutron and/or photon heating) to be run. A complete description of the input channels is presented in Section 5. The operations performed on the input flux data for an R, Z problem are:

1) Redefinition of radial and axial mesh cell description if required.

2) Normalization of flux data to units of per fission, per watt, or a selected power level.

3) Generation of a group dependent binary work tape containing all particle flux data in a form suitable for subsequent data processing.

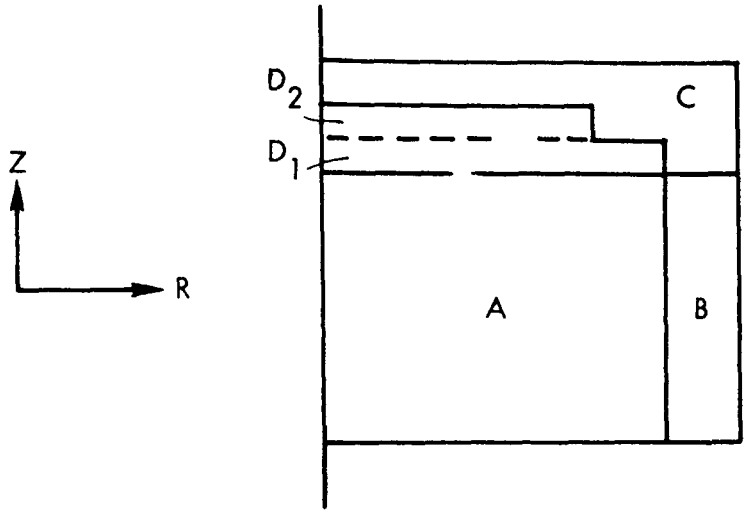
The above operations are performed in a similar manner for R, θ calculations.

2.2.1 Redefinition of Mesh Cell Data

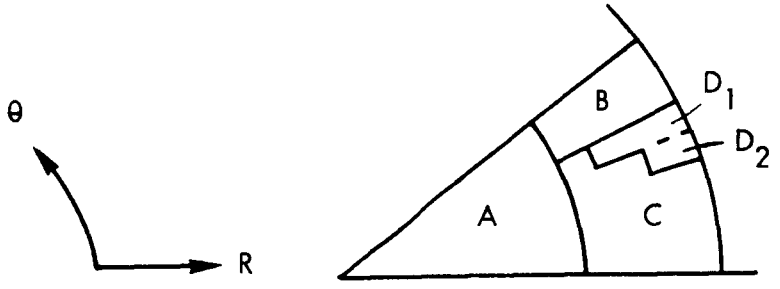
The NAGS Program is capable of redefining the radial or axial mesh cell description of the input problem geometry and fluxes. This procedure is included in order to increase the utility of the program by adjusting the mesh size in a NAGS problem to meet computer core memory limitations in subsequent problems. For example, a neutron transport problem with 16 energy groups, S_6 angular quadrature, P_o scattering cross sections, and a total of 1200 mesh cells, is an approximate maximum ODD-K neutron transport problem. This same problem in photon transport, with 13 groups, S_6 angular quadrature, but with P_1 scattering cross sections will allow only a total of 800 mesh cells. Hence, in order to run linked neutron and photon transport problems, the linking program (NAGS) must include a technique for redefinition of the neutron transport mesh cell description in either (or both) the radial or axial direction to accommodate photon transport calculations.

Redefinition of mesh cells is done in a manner to conserve mesh cell fluxes in the redefined mesh cells. This procedure is restricted to the deletion of mesh lines internal to region boundaries of the problem geometry. The user specifies in the general problem input data, the mesh cell dimensions (coordinates) of the original or input flux data solution, as

1. R-Z GEOMETRY



2. R-θ GEOMETRY



NOTE: A, B, C, D ARE MASTER REGIONS; D_1, D_2 ARE SUBREGIONS OF MASTER REGION D

REGION DESCRIPTIONS FOR A, B, C, D_1, D_2 ARE REQUIRED INPUT FOR NAGS

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Figure 4. Sample Geometries for the NAGS Code

well as the mesh cell coordinate identification nunbers which will comprise the new (or redefined) mesh cell description. The average particle flux, ϕ_{lj}, in each group in each new (redefined) radial mesh cell is computed as:*

$$\phi_{lj} = \frac{\sum_{i=i_s}^{i_f} \phi_{ij} \cdot \Delta A_i}{\sum_{i=i_s}^{i_f} \Delta A_i}$$

where ϕ_{lj} is the centered average flux in the redefined radial mesh cell, l, for each axial mesh cell, j. The quantities i_s and i_f are the input flux mesh cell coordinate indices which form the left and right boundaries of the new or redefined radial mesh cell, l. The quantity, ΔA_i is the cross sectional area, $\pi (R^2_{i+1} - R^2_i)$, of the mesh cell, i. The computed average flux data, ϕ_{lj}, is placed at the radial midpoint of the new mesh cell, $R_l = 1/2 (R_{i_s} + R_{i_f})$.

In a similar fashion, the average flux, ϕ_{lJ}, in each new axial mesh cell is obtained as:

$$\phi_{lJ} = \frac{\sum_{j=j_s}^{j_f} \phi_{lj} \cdot \Delta Z_j}{\sum_{j=j_s}^{j_f} \Delta Z_j}$$

where ϕ_{lJ} is the centered average flux in each group in the redefined mesh cell, (l, J) and ϕ_{lj} is the centered average flux previously computed in the redefined radial mesh cell, l, for each axial mesh cell, j. The quantities, j_s and j_f, are the input flux mesh cell coordinate indices which form the bottom and top boundaries of the new (or redefined) axial mesh cell, J. The quantity, ΔZ_j, is the height of each axial mesh cell, j. The computed average flux data, ϕ_{lJ}, is placed at the axial midpoint of the redefined mesh cell, $Z_J = 1/2 (Z_{j_s} + Z_{j_f})$.

*Note: The solution for the azimuthal variable, θ, in the R-θ solution is the same as for the variable Z in the R-Z solution.

The redefinition of the input flux data to a new mesh cell description is performed only if requested by the user in the general problem input data. The flux data which are processed by group are then normalized as described in the following section.

2.2.2 Flux Normalization

Normalization of the particle flux data is performed after redefinition of the mesh cell description. The constants for the calculation of the normalization factor, NF, are dependent upon the source of the flux data (i.e., neutron flux from ODD-K neutron transport, neutron flux from a previous NAGS problem, or photon flux from ODD-K). The user of NAGS has at his disposal a six parameter normalization factor. These six parameters are required input for each problem and are, also, descriptive of neutron flux normalization constants for an ODD-K problem. The normalization factor is computed as:

$$NF = \frac{\bar{\nu} \cdot K_1 \cdot P}{K_2 \cdot k_{eff} \cdot f \cdot A}$$

where:

$\bar{\nu}$ = the average number of neutrons per fission (e.g., $\bar{\nu}$ = 2.445 for a nuclear rocket flight-type reactor).

K_1 = the fissions per second per watt of power. K_1 is dependent upon the operating history, gamma ray energy production, and neutron and gamma ray energy leakage from a reactor system. For a nuclear rocket flight-type reactor with 15 minutes of full power operation, the fissions per second required to produce one watt of thermal power is calculated to be 3.21×10^{10} fissions/watt-second.

P = the total reactor power in watts. Hence $K_1 \times P$ gives the fissions per second at full reactor power.

K_2 = the parameter of radians. This parameter is 1.0 for R-Z, ODD-K problems and is included in the calculation of NF to account for symmetry in R-θ, ODD-K. In R-θ problems, the parameter K_2 is $\theta/2\pi$.

k_{eff} = the effective neutron multiplication factor (eigenvalue) of the ODD-K neutron transport problem and is used to normalize all fluxes to a critical (k_{eff} = 1.0) reactor system.

f = the fraction of fission events in the ODD-K problem which produce fission energy. This factor is included for the case when the (n, 2n) neutron interactions are included in the flux solution as pseudo-fission events. For ODD-K problems with MSFC library cross sections, beryllium (n, 2n) cross sections are not included as fission and f is input as 1.0.

A = the area (or volume) factor. This factor is required only if the neutron flux solution is normalized to some value other than the integral of fissions over the source volume. For ODD-K problems this value is always 1.0.

Hence, the normalization factor for a 5000 MW flight-type nuclear rocket reactor, in an R-Z ODD-K neutron transport problem with a multiplication factor of 1.01 is computed internally by NAGS as:

$$NF = \frac{2.445 * 3.21 \times 10^{10} * 5 \times 10^{9}}{1.0 * 1.01 * 1.0 * 1.0} = 3.89 \times 10^{20}$$

Fluxes printed out by NAGS using the above normalization constant will be in units of $\frac{neutrons}{cm^2\text{-sec}}$ at full power (5000 MW) conditions. In normalizing flux data from a photon transport problem, or a previous NAGS problem (see Figure 3), the six normalization parameters are normally set equal to 1.0 since the flux solution in the ODD-K photon transport problem is based on normalized distributed fixed source data supplied by the previous NAGS photon source problem. Also, the neutron flux data from the NAGS problem is a processed library data tape based on previously normalized flux data.

2.2.3 Generation of Particle Flux Tape

The final operation on the input flux data is the generation of a binary work tape containing the groupwise fluxes to be used in later reaction rate and response rate calculations.

This data tape can be saved for use in subsequent NAGS problems as indicated in Figure 3. For example, the neutron flux data tape used in the calculation of distributed photon sources is used as input for the combined neutron and photon energy deposition calculation. This neutron flux data tape has the same mesh cell description as the photon source data and the photon flux data.

The binary flux tape, which is generated on MSFC IBSYS Version 13 tape unit A-6, remains on this unit throughout the NAGS problem. The tape consists of a logical tape record of each group with a total of ICM (number of redefined radial mesh cells) X JCM (number of redefined axial mesh cells) pieces of data in each logical tape record.

2.3 MESH CELL OPERATIONS AND LIBRARY DATA

The computation of the neutron and photon interactions in each mesh cell of each region of a NAGS problem geometry is carried out using fluxes obtained in the redefined mesh cell description. The interaction calculations and the resultant product (neutron source, photon source, or particle energy deposition) are summed over all groups, materials, and interactions to provide total interactions, source strength, or energy deposition on an individual mesh cell basis throughout the two dimensional model. Subsequent operations on the mesh cell data provide the region integral distributions, as well as the integrals over all mesh cells and all regions. These final data processing operations are performed without alteration of mesh cell data so that all mesh cell data can be used in subsequent photon transport calculations. The procedure for obtaining particle interaction data in the program is carried out on a regionwise basis. The program requires as input, a library of physical constants and neutron and photon spectrum dependent data for each element or isotope (i.e. H, Be, U^{235}, etc.) in the reactor geometry. Library data and region data, and the interaction calculations are described in the following sections.

2.3.1 Library Data

Library data for a NAGS problem include standard neutron and photon multigroup constants as well as nuclear data for each element in the reactor geometry.

The nuclear constants required in the library for each neutron and photon energy group are:

1) Prompt fission photon energy, Γ_p^k, for each photon group, k.

2) Fission product decay photon energy, Γ_p^k, for each photon group, k, and for a specific reactor operating history (e.g., a nuclear rocket reactor with 15 minutes operation of full power).

3) Photon flux to dose rate conversion factors, K_D^k, for each photon group, k.

4) Neutron flux to dose rate conversion factors, K_D^g, for each neutron group, g.

5) Neutron multigroup parameters of,

   (a) Lethargy width, $\Delta\mu^g$, for each neutron group, g.

   (b) Energy width, ΔE^g, for each neutron group, g.

The other nuclear library data are required for each element or isotope, m, in the library and are as follows:

1) Identification number, NID_m

2) Atomic mass, A_m

3) Average energy loss per neutron scattering event, $\frac{2A_m}{(A_m+1)^2}$

4) Average energy of each alpha particle emission from neutron capture, $E(n,\alpha)$

5) Microscopic thermal neutron (2200 meter/second) absorption cross section, σ_a^{2200}

6) A six (6) character alphanumeric title (i.e., HYDROG, CARBON, etc.)

7) Inelastic neutron scattering photon energy, Γ_{sgm}^k, from an inelastic event in neutron group, g, for photon energy release in group, k.

8) Neutron elastic scattering cross sections, σ_{em}^g, for each fast neutron group, g.

9) Neutron absorption cross section for (n , α) reaction, $\sigma_{n,\alpha}^g$ for each neutron group, g.

10) Neutron elastic scattering anisotropic correction factor for neutron energy deposition, $(1-\bar{\mu}_o)_m^g$ for each neutron group, g.

11) Neutron radiative capture photon energy, Γ^{k}_{cm}, for each material and photon group, k.

12) Photon mass energy absorption coefficient $(\frac{\mu}{\rho})^{k}_{am}$ for each photon group, k.

13) Neutron fission cross sections, σ^{g}_{fm}, for each neutron group, g.

14) Neutron radiative capture cross sections, σ^{g}_{cm}, for each neutron group, g.

15) Neutron elastic scattering cross sections, σ^{g}_{em}, for each fast neutron group, g.

16) Neutron inelastic scattering cross sections, σ^{g}_{sm}, for each fast neutron group for which inelastic scattering is to be calculated.

The last four sets of cross section data (defined above) are required input only when the user employs the NAGS library option of region independent cross section data. This library option is the standard mode of input if the POINT program output with region independent cross section data (as furnished MSFC) is used.

2.3.2 Region Data

Region input data for a NAGS problem are dependent on the type of calculation being performed. The region data are processed on an individual region basis. Required data for each region are:

1) A seventy-two (72) character alphanumeric title describing the region

2) Region boundary mesh cell numbers in the redefined mesh cell description

3) The number of elements in the region, and

4) A program control word to control the reading of new region data or to proceed to the next step of the NAGS data processing.

There are two types of calculations which can be performed by NAGS. The first type is the neutron interaction calculation which results in the production of neutron and photon sources in the mesh cells. The second type is the calculation of neutron and/or photon interactions which results in energy deposition in the mesh cell.

Region input data required for a photon source calculation are dependent on the NAGS library (Refer to Section 2.3.1) used for the problem. The element microscopic cross section data described below are only required when the NAGS short library option is used. The standard MSFC mode is the NAGS long library option; element microscopic cross sections are not required. The region input data required for each element, m, follows as:

1) Element identification number, L_m,
2) Element number density, N_m,
3) Element microscopic groupwise neutron cross sections for,
   (a) fission, σ^g_{fm},
   (b) radiative capture, σ^g_{cm},
   (c) elastic scattering, σ^g_{em},
   (d) inelastic scattering, σ^g_{sm}.

The region data required for calculation of energy deposition of neutrons and photons are input for the material (e.g., fueled graphite, stainless steel, etc.) in the NAGS region. This technique is used because reactor components or structures are represented as part of a homogeneous region material in neutron and photon transport. For subsequent thermal analyses, the total heating and its distribution in these components is required. Hence, an Inconel bolt can be represented individually in a region to obtain its total heating. The input data required for the energy deposition calculation in each material, n, in each region are:

1) Material density in the region, ρ_n
2) Weight of the material in the region, W_n.

Input data for each element or constituent of the above material are required as:

1) Element identification number, L_m
2) Weight fraction, N_m of the element, L_m, in material, n.

The data are then processed on a mesh cell basis to obtain the total photon source or energy deposition in each mesh cell of a region.

An option is included in the program to eliminate repetitive input data for a NAGS region of identical composition to the previous NAGS region. This option is specified by a negative sign on the number of elements for a NAGS region. The program will then use the region element data (L_m, N_m and element cross sections) from the preceding NAGS region for all calculations in that region.

2.3.3 Mesh Cell Calculations

The mesh cell calculations are based on the redefined mesh cell description and fluxes. These fluxes are processed on a groupwise basis to obtain the total source or energy deposition in each mesh cell of a region. Mesh cell calculations are performed at both internal and external mesh cells of a region and at adjacent external mesh cells. Internal mesh cells are designated in Figure 5 by O's; external mesh cells are designated by X's.

Calculations in mesh cells, external to and adjacent to the region being calculated, provide results for use in interpolation or extrapolation of distribution values at the region boundaries. This procedure provides a calculated source or energy deposition distribution value at each boundary of a region. This calculation is described in detail in Section 2.4.3. The calculation of photon source and associated quantities at each mesh cell follow as:

1) Neutron fission density:

$$F_{IJ} = \sum_{m=1}^{NEL} \sum_{g=1}^{NGN} N_m \quad \sigma_{fm}^{g} \quad \phi_{IJ}^{g}$$

2) Fission neutron source density:

$$Q_{IJ}^{g} = \sum_{m=1}^{NEL} \sum_{g=1}^{NGN} N_m \, \nu^{g} \quad \sigma_{fm}^{g} \quad \phi_{IJ}^{g}$$

3) Photon source density in photon group, k, from neutron fission (prompt and decay):

$$Q^k_{FIJ} = \left(\Gamma^k_p + \Gamma^k_d\right) \cdot F_{IJ}$$

4) Neutron radiative capture density for element, m:

$$C_{mIJ} = \sum_{g=1}^{NGN} N_m \, \sigma^g_{cm} \phi^g_{IJ}$$

5) Photon source density in group, k, from neutron radiative capture:

$$Q^k_{CIJ} = \sum_{m=1}^{NEL} \Gamma^k_{cm} \, C_{mIJ}$$

6) Neutron inelastic scattering density for neutron group, g, and element, m:

$$S^m_{IJ} = N_m \, \sigma^g_{Sm} \, \phi^g_{IJ}$$

7) Photon source density in photon group, k, from neutron inelastic scatter:

$$Q^k_{SIJ} = \sum_{g=1}^{NI} \sum_{m=1}^{NEL} S^m_{IJ} \, \Gamma^k_{sgm}$$

8) Total photon source density in photon group, k, from all sources:

$$Q^k_{TIJ} = Q^k_{FIJ} + Q^k_{CIJ} + Q^k_{SIJ}$$

The mesh cell calculations of energy deposition are performed for neutrons and photons on a groupwise basis. The calculations follow as:

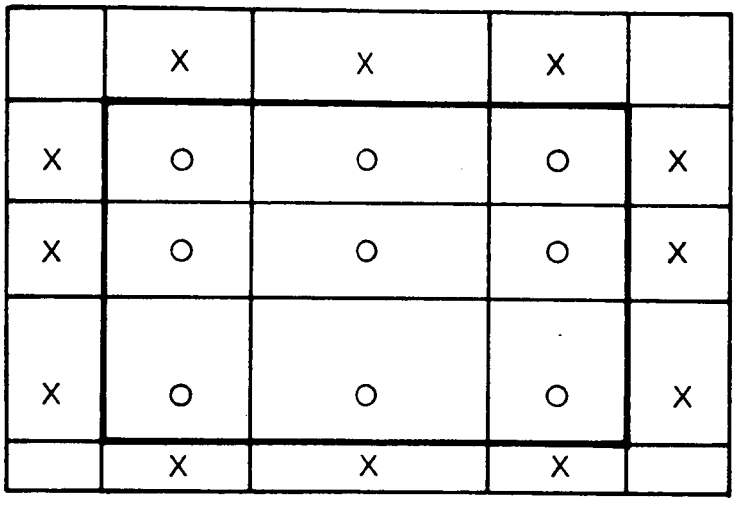


Figure 5. Region Mesh Cell Description

1) Neutron kinetic energy deposition:

$$H_{IJ} = 1.603 \times 10^{-13} \sum_{m=1}^{NEL} \sum_{g=1}^{NFAST} \sigma_{em}^{g} \left(\frac{2A_m}{(A_m+1)2}\right) (1.0 - \bar{\mu}_o)_m^g \left(\frac{N_m N_a \rho_n}{A_m}\right) \phi_{IJ}^g \cdot \frac{\Delta E^g}{\Delta \mu^g}$$

2) Photon energy deposition:

$$H_{IJ} = 1.603 \times 10^{-13} \sum_{m=1}^{NEL} \sum_{k=1}^{NGG} N_m \rho_n \left(\frac{\mu_a}{\rho}\right)_m^k \phi_{IJ}^k$$

The quantity, N_a, is Avogadro's number 0.60248×10^{24}.

2.4 REGION OPERATIONS

Region dependent quantities are calculated from the internal and external mesh cell data described in the previous section. These data are processed on a single region basis to obtain the total mesh cell photon source for photon transport, or the region source integral and energy, or spatial distribution data required for point kernel and/or Monte Carlo input, or region energy deposition integrals and distributions. The calculation of the photon source data and particle energy deposition data is discussed separately in the following sections. The region boundary mesh cell numbers I_S, I_F, J_S, and J_F define the NAGS region in the total mesh cell description. These values determine the limits of integration to be used in NAGS region calculations.

2.4.1 Photon Source

The photon source mesh cell data, described in the previous section, are processed in conjunction with the region and mesh cell dimensions to obtain final region quantities of:

1) Total region volume.
2) Total region weight.
3) Region integrals of:
   a) photon source
   b) neutron induced fissions
   c) neutron source
   d) photon energy spectrum including volume averaged spectrum
4) Region separable radial and axial distributions for photon source, neutron induced fission, and neutron source.

Intermediate and final region data are calculated from the internal and external mesh cells as shown in Figure 5. The region boundary values calculated from these data are shown in Figure 6.

The initial operation to obtain region source or fission distributions separable in the radial and axial directions with values at the top, bottom, left, and right boundaries defining the exterior boundary of a region are as follows:

1) External mesh cell values

a) Top External

$$S_t = \sum_{I=I_S}^{I_F} \sum_{k=1}^{NGG} S_{tI}^k \Delta A_I$$

b) Bottom External

$$S_b = \sum_{I=I_S}^{I_F} \sum_{k=1}^{NGG} S_{bI}^k \Delta A_I$$

c) Left External

$$S_l = \sum_{J=J_S}^{J_F} \sum_{k=1}^{NGG} S_{lJ}^k \Delta Z_J$$

d) Right External

$$S_r = \sum_{J=J_S}^{J_F} \sum_{k=1}^{NGG} S_{rJ}^k \Delta Z_J$$

2) Internal mesh values

a) Radial

$$S_I = \sum_{J=J_S}^{J_F} \sum_{k=1}^{NGG} S_{IJ}^k \Delta Z_J$$

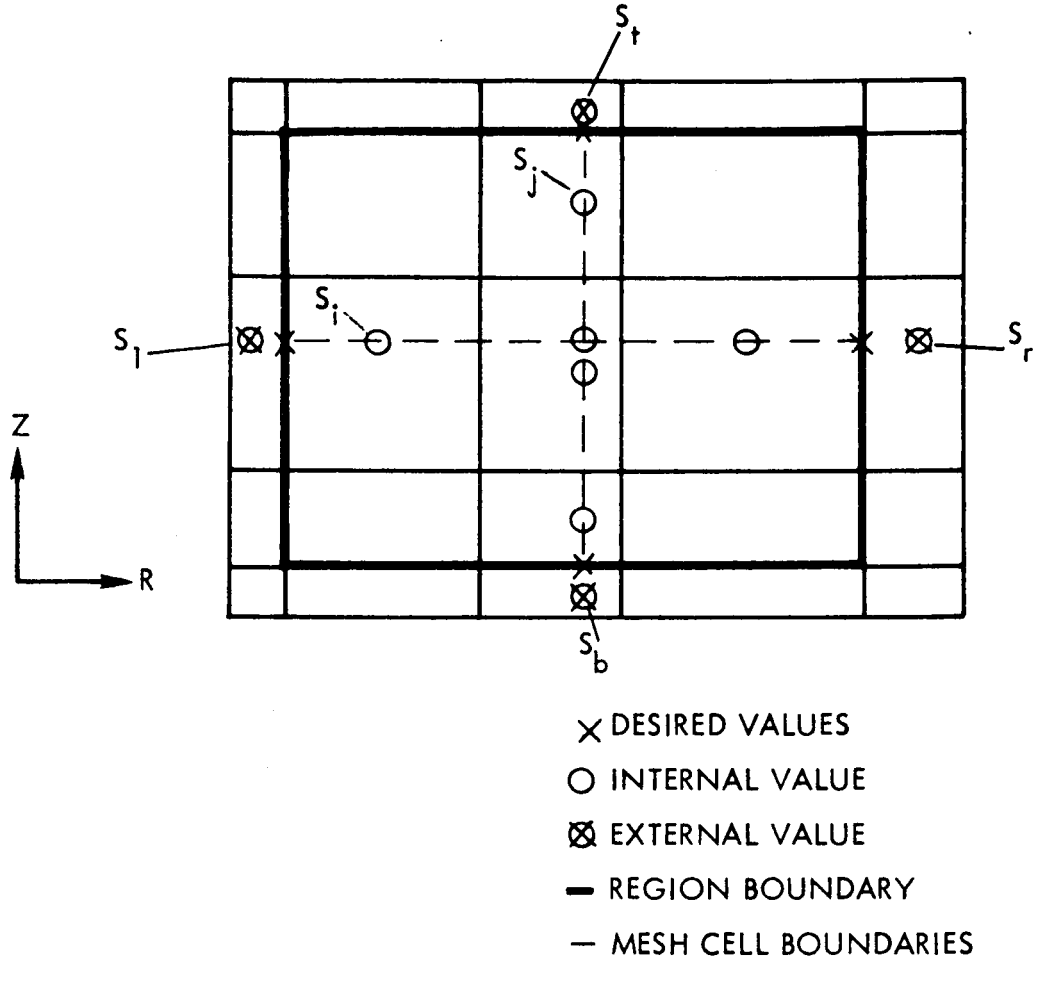


Figure 6. Region Separable Distribution Description

b) Axial

$$S_J = \sum_{I=I_S}^{I_F} \sum_{k=1}^{NGG} S_{IJ}^k \Delta A_I$$

3) Region areas and volumes

$$\Delta A = \sum_{I=I_S}^{I_F} \Delta A_I$$

$$\Delta Z = \sum_{J=J_S}^{J_F} \Delta Z_J$$

$$V_R = \Delta A \cdot \Delta Z$$

4) Region integral values

$$S_T = \sum_{I=I_S}^{I_F} \sum_{J=J_S}^{J_F} \sum_{k=1}^{NGG} S_{IJ}^k \Delta A_I \Delta Z_J$$

5) Normalized distribution values

a) Internal

S_I (normalized radial) $= S_I \Delta A/S_T$

S_J (normalized axial) $= S_J \Delta Z/S_T$

b) External

$$S_{t,b} = S_{t,b} \Delta A/S_T$$

$$S_{l,r} = S_{l,r} \Delta Z/S_T$$

The normalization operation is performed as above for photon source, neutron induced fission, and neutron source. The values S_I, S_J, S_t, S_b, S_i and S_r are used to calculate boundary values shown in Figure 6 using the techniques described in Section 2.4.3.

The remaining region quantities are obtained as follows:

1) Region Weight

$$W_R = V \cdot \sum_{m=1}^{NEL} \frac{N_m A_m}{N_a}$$

2) Region photon source

a) Total Integrated Spectrum

$$Q_T^k = \sum_{J=J_S}^{J_F} \sum_{I=I_S}^{I_F} \sum_{k=1}^{NGG} Q_{TIJ}^k \, \Delta A_I \, \Delta Z_J$$

b) Average Spectrum

$$Q_T^k = Q_T^k / V_R$$

c) Total

$$Q_T^k = \sum_{k=1}^{NGG} Q_T^k$$

3) Region neutron induced fission

$$F = \sum_{J=J_S}^{J_F} \sum_{I=I_S}^{I_F} F_{IJ} \, \Delta A_I \, \Delta Z_J$$

4) Region neutron source

$$Q_T = \sum_{J=J_S}^{J_F} \sum_{I=I_S}^{I_F} \sum_{g=1}^{NGN} Q_{IJ}^g \, \Delta A_I \, \Delta Z_J$$

2.4.2 Energy Deposition

The energy deposition mesh cell data described in Section 2.3.3 is used in a fashion similar to that described for processing of photon source data. The final region quantities calculated are:

1) Element or constituent quantities
   a) Density in region in gms/cc
   b) Total energy deposition in kilowatts
2) Region quantities for each material in the region
   a) Density in lbs/in.^{3}
   b) Weight in lbs
   c) Total energy deposition in kilowatts
   d) Photon energy deposition in kilowatts
   e) Neutron energy deposition in kilowatts
   f) Total energy deposition in Btu/hour, watts/gram, watts/cm^3 in the solid material, Btu/lb-hour, and Btu/in.^{3}-hour in the solid material
3) Region separable radial and axial energy deposition distributions (relative to a region volume average of 1.0 and region average energy deposition in Btu/in.^{3}-hour).
4) Region mesh cell total energy deposition in Btu/in.^{3}-hour.

These distribution quantities are calculated using the same techniques described for the photon source calculation. Region integrals are obtained as the summation of neutron and photon energy deposition or as separate quantities. The integrals are multiplied by appropriate conversion factors to obtain either metric or English units.

2.4.3 Interpolation and Extrapolation Procedure

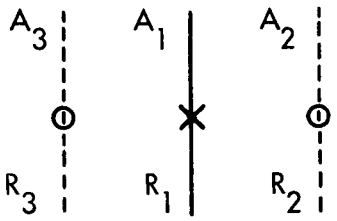
The procedures for calculating the end (or boundary) points of a radial or axial source or response distribution in a NAGS region are described in this section. The techniques are discussed in general terminology because the calculation of boundary values for neutron or photon source, fission, or energy deposition distributions are the same.

As defined earlier, a NAGS region is a set of adjacent mesh cells having the same material composition and a rectangular outer boundary. The separable radial and axial distributions are calculated at the midpoints of the redefined mesh cells of a region. These data are used for all interpolation or extrapolation operations. The additional data used in these operations are the external boundary sources (or response values) calculated with material properties of the region, but with particle fluxes at the mesh cells external and immediately adjacent to the region, as shown in Figure 6. Dependent upon the position of the region in the reactor geometry, the calculation of the boundary value assumes one of five types of interpolation or extrapolation techniques, as shown in Figure 7. The mesh cell data (internal and external to the NAGS region) are denoted by the dashed lines and the open O's. The boundary values to be calculated are denoted by the solid lines and by X's. The special case where the mesh cell lies at the reactor centerline, outer radius, top boundary, or bottom boundary of the reactor geometry requires special techniques to obtain the boundary value. In addition, the calculation of the boundary values of a region of only one mesh cell in width (or height) is based on the value at that mesh cell and at the two adjacent external mesh cell values. All values of external mesh cell data are calculated with the nuclear properties of the NAGS region and are relative to the internal mesh cell values.

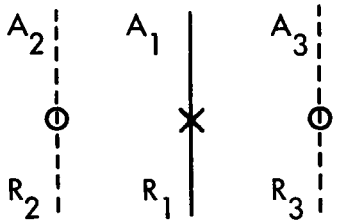
RADIAL OPERATIONS

Condition 1: Linear Interpolation at Internal Boundaries, $R_1 \neq 0.0$ or $\neq$ Outer Radius of Reactor Geometry

The value at the radial boundaries R_1 is found by linear interpolation of adjacent mesh cell values as shown below



Left Radial Region Boundary



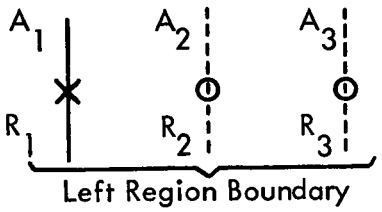
Right Radial Region Boundary

$$A_1 = \frac{\left[A_2 R_2 + \frac{(A_3 R_3 - A_2 R_2)(R_1 - R_2)}{R_3 - R_2}\right]}{R_1}$$

where: A_1, A_2, and A_3 are the values of the flux at the radial positions R_1, R_2, and R_3, respectively.

Condition 2: Parabolic Extrapolation of Reactor Centerline, $R_1 = 0.0$

The derivative of the distribution, S_l, must be zero at $R_1 = 0.0$ (i.e., $\delta S_l / \delta_r = 0.0$). The geometry with the two mesh cell values internal to the geometry used for parabolic extrapolations is as follows:



$$A_1 = \frac{A_3 R_2^2 - A_2 R_3^2}{R_2^2 - R_3^2}$$

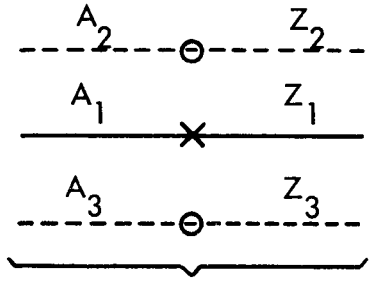
Figure 7. Distribution Interpolation and Extrapolation Techniques

(1 of 3 Sheets)

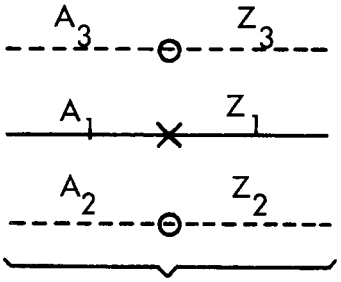
AXIAL OPERATIONS

Condition 1: Linear Interpolation Applies at Internal Boundaries, $Z_1 \neq$ Bottom or Top of Reactor Geometry

The value at the boundary Z_1 is found by linear interpolation of adjacent mesh cell values as shown below:



Bottom Region Boundary



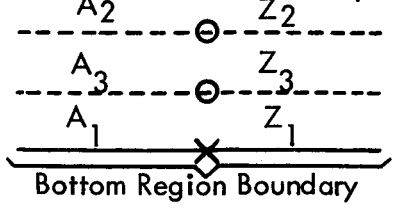
Top Region Boundary

$$A_1 = A_2 + \frac{(A_3 - A_2)(Z_1 - Z_2)}{(Z_3 - Z_2)}$$

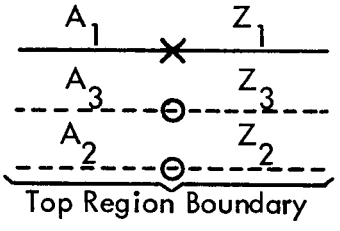
where: A_1, A_2, and A_3 are the values of the flux at the axial positions Z_1, Z_2, and Z_3, respectively.

Condition 2: Logarithmic Extrapolation at External Boundaries $Z_1 =$ Bottom or Top of Reactor Geometry

The value at the boundary Z_1 is found by extrapolation from the two adjacent mesh cells internal to the boundary as shown below.



Bottom Region Boundary



Top Region Boundary

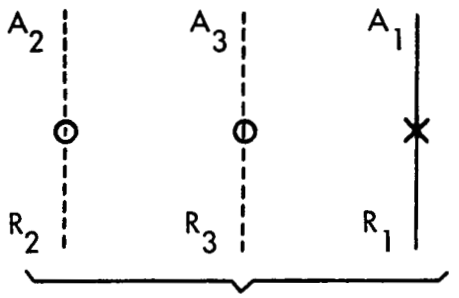
$$A_1 = A_3 \exp\left[\frac{(Z_1 - Z_3)\frac{A_3}{A_2}}{Z_3 - Z_2}\right]$$

Figure 7. (Continued) (2 of 3 Sheets)

Condition 3: Logarithmic Extrapolation at the External Boundary,

R_1 = Outer Radius of Reactor Geometry

The value at the boundary R_1 is found by logarithmic extrapolation from the two adjacent mesh cells internal to the boundary as shown below.



Right Region Boundary

$$A_1 = A_3 \frac{R_3}{R_1} \exp \left[\frac{(R_1 - R_3) \frac{A_3 R_3}{A_2 R_2}}{R_3 - R_2} \right]$$

Figure 7. (Continued) (3 of 3 Sheets)

2.5 OVERALL PROBLEM OPERATIONS

At the completion of the region data processing, the NAGS program performs calculations and operations for all mesh cells in the reactor geometry. These final operations are dependent upon whether the neutron or photon source or energy deposition calculation option is used.

2.5.1 Neutron or Photon Source

The overall reactor geometry neutron and photon source calculations yield the integral photon source, neutron source, and fissions in the reactor. These integrations follow:

1) Total photon source

$$Q_{Total} = \sum_{J=1}^{JCM} \sum_{I=1}^{ICM} \sum_{k=1}^{NGG} Q_{TIJ}^{k} \Delta A_I \Delta Z_J$$

2) Total fissions

$$F_{Total} = \sum_{J=1}^{JCM} \sum_{I=1}^{ICM} F_{IJ} \Delta A_I \Delta Z_J$$

3) Total neutron source

$$Q_{Total} = \sum_{J=1}^{JCM} \sum_{I=1}^{ICM} \sum_{g=1}^{NGN} Q_{IJ}^{g} \Delta A_I \Delta Z_J$$

In addition, the NAGS program will prepare a group dependent neutron or photon source binary tape. This tape will contain either neutron, total photon, or fission product decay photon source for all mesh cells in the reactor geometry. These data (with minor intermediate processing to generate a tape with one logical record instead of NGN or NGG logical records) are compatible with distributed fixed source input requirements of the ODD-K discrete ordinate transport program. The options available to the NAGS user are controlled by input integer NPUN (Card Type 3). The program prepares a binary tape containing one of

the following sets of mesh cell data:

1) Total photon source for each group, k,

$$Q^{k}_{TIJ}$$

2) Fission product decay photon source for each group, k,

$$Q^{k}_{DIJ} = \Gamma^{k}_{d} \; F_{IJ}$$

3) Total neutron source for each group, g,

$$Q^{g}_{IJ} = \chi^{g} \; Q_{IJ}$$

Special features are included in the NAGS program for the generation of a binary tape of source data. The user can increase the size of the mesh cell source data of a reactor geometry by placing zeros on the tape to the left, right, or top of the reactor geometry. This option, which positions the NAGS calculated source data in a larger mesh cell description, is included to permit, for example, a detailed neutron source calculation in the reactor core for use in a subsequent coarse reactor geometry. The detailed source calculation in the coarse geometry may not be possible in NAGS because of limited memory core storage; hence, this option can be used to reduce the flux data and then expand the source data. Further, this option, in conjunction with the mesh cell and flux redefining options, provides the user with considerable flexibility in running a linked neutron and photon transport problem using the ODD-K discrete ordinate transport program.

2.5.2 Neutron or Gamma Ray Dose Rates

At the completion of a NAGS mesh cell energy deposition calculation, the flux data at each mesh cell in the reactor geometry are used to calculate the neutron and photon dose rate at each of the mesh cells. This calculation of the neutron and photon dose rate follows:

1) Neutron dose rate

$$D_{NIJ} = \sum_{g=1}^{NGN} K_D^g \phi_{IJ}^g$$

2) Photon dose rate

$$D_{PIJ} = \sum_{k=1}^{NGG} K_D^k \phi_{IJ}^k$$

Since this operation is essentially a response function calculation, and is not stored in memory, the NAGS user can substitute other conversion factors in place of K_D^g or K_D^k, in the library to obtain mesh cell data as desired.

SECTION

3.0 INPUT DATA DESCRIPTION

The input data for a NAGS problem are subdivided into four sets of data. These four sets, which are the general, flux, library, and region data, are described in the following sections. A description of each set of data input and the routine (in parentheses) which reads this data is as follows:

1) General problem data - integer data pertaining to data or array dimensions (i.e., number of mesh, number of groups, etc.), problem title information, integer control words, flux normalization parameters, neutron fission parameters, and mesh cell specifications. (Subroutine MAIN and NAGS 1).

2) Flux data - input flux data required for NAGS operation including mode of input. (Subroutine NAGS 1).

3) Library data - neutron and photon multigroup quantities, and for each element: identification, physical constants and groupwise nuclear data. (Subroutine NAGS 2).

4) Region data - region title information, region composition by element or material, and depending upon the library option or type of calculation, region dependent multigroup neutron cross sections. (Subroutine NAGS 2).

A detailed description of the overall deck setup and input data requirements for a NAGS problem is included in the following sections:

3.1 GENERAL DATA

The initial data input to the NAGS program specifies: (1) the data array sizes of all input quantities, (2) the program input/output control options, (3) the flux normalization constants, (4) the fission neutron spectrum and the number of neutrons per fission event, and (5) the mesh cell dimensions of the problem geometry. These data are input as described in the following table:

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
1	2413	ICT	Number of radial mesh intervals in the input flux solution.
		ICM	Number of redefined radial mesh intervals to be used in all calculations and output data.
		JCT	Number of axial* mesh intervals in the input flux solution.
		JCM	Number of redefined axial mesh intervals to be used in all calculations.
		NGN	Total number of neutron groups NOTE: If NTYPE = 3, then NGN is input as NGG since only photon fluxes are required input to the NAGS program when NTYPE = 3.
		NFAST	Number of fast neutron groups (Neutron kinetic energy is calculated for NFAST groups).
		N I	Number of fast neutron groups for photon productions from neutron inelastic scatter.
		NGG	Number of photon energy groups to be calculated
		NEL	Number of elements in the library data
		NTYPE	Program control word for the type of calculation to be performed. NTYPE = 1: Photon or neutron source calculation.

* Azimuthal coordinates in radians (R-θ input flux solutions) can be substituted for axial coordinates in centimeters (R-Z input flux solutions) without any program changes. All further references to axial will also imply azimuthal.

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
			NTYPE = 2: Combined neutron and photon energy deposition calculation. NTYPE = 3: Photon energy deposition calculation only (i.e., fission product decay heating).
2	12A6	TITLE	Overall problem title (72 alphanumeric characters).
3	2413	NCD	Not presently used by the program. NCD = 0.
		NBIN	Input flux data control word which specifies input mode of flux data for different types of calculations (refer to Section 3.2 for details).
		NLIB	Library data option. NLIB = 0: Short library data option with region dependent neutron cross section data included with region input for each element, m, (refer to Section 3.3 for details). NLIB = 1: Standard MSFC option. Long library data option with region independent neutron cross section data included in the library for each element, m. (Refer to Section 3.3 for details on library.)
		NEX NEX1	Source positioning indices in the radial direction for all calculated results. (See Section 2.5.1 for details.) These indices are provided to enable the user to perform a NAGS calculation on a section of a reactor geometry and then position this section of data in a different reactor or problem geometry.

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
		NEX	The number of zero entries to the right of the NAGS calculated sources in each radial row.
		NEX1	The number of zero entries to the left of the NAGS calculated results in each radial row.
		ISTART	Starting radial mesh cell number in the NAGS input fluxes to be used in the redefinition of flux data. If in storage allocation, a flux edit is possible or desired for only a section of the input flux data then the user may specify ISTART≠1. ISTART is equal to the left mesh cell number of a section of the reactor geometry. The NAGS program redefines the flux data such that this left mesh cell number flux data will be the first mesh cell of the section. The mesh coordinates of the cells are altered to agree with the new mesh cell description.
		JSTART	Starting axial mesh cell number in the NAGS input to be used in redefinition of flux data. The discussion of ISTART is applicable to JSTART.
		NPUN	Binary tape output control word. Neutron or photon source data is placed on logical tape unit 9 which is MSFC IBSYS Version 13, Unit B-5. The tape contains NGN or NGG logical records each of size, ((NEX1 + ICM + NEX)*JCO). NPUN = 0: No binary data tape of sources is to be prepared. NPUN = 1: Neutron distributed source (Q^{g}_{IJ}) is to be placed on the binary tape of unit B-5. NPUN = 2: Total photon distributed source (Q^{k}_{TIJ}) is to be placed on the binary unit B-5.

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
			NPUN = 3: Fission product decay photon distributed source ($Q_{D_{IJ}}^{k}$) is to be placed on the binary tape on unit B-5.
		JCO	Source positioning index in axial direction for all calculated results. (Refer to Section 2.5.1 for details.) This index is similar in operation to the NEX index in that the program generated B-5 binary tape has logical records of size ((NEX1 + ICM + NEX)*JCO) where the last (NEX1 + ICM + NEX) * (JCO - JCM) pieces of data in each logical record are 0.0's.
4	(E12.5)	ZREF	Reference plane distance in inches from Z = 0.0. This input quantity adjusts all axial dimensions by Z_i = ZREF - .3936 *Z_T so that energy deposition and source data can be printed relative to a Z plane other than at 0.0.
5	(6E12.5)	ENU	Average number of neutrons released per fission event, ν 9. For photon flux input, ENU = 1.0.
		EFF	Fraction of fissions due to neutron fission events, EFF = 1.0, except where cross section data represents, (n, 2n) reactions by pseudo-fission. For ODD-K photon flux data, EFF = 1.0. For MSFC neutron cross section library data, EFF = 1.0.
		EFK	Multiplication factor, K_{eff}, of the ODD-K problem which provides input flux data. For photon flux data EFK = 1.0.
		VOLC	Volume of fissionable regions. For R-Z ODD-K input flux data, VOLC = 1.0.
		CONV	Conversion factor for input flux data in units of fissions per second.

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
		PK	Area factors to account for partial geometrical solutions in ODD-K transport problems (i.e., PK = 1.0 for R-Z geometry but for R-θ problems, PK = $\frac{\theta}{2\pi}$.)
6	6E12.5	CHI	The fission neutron spectrum, χ^g (i.e., the fraction of a fission neutron born in each group, g). $\sum_{g=1}^{NGN} \chi^g \equiv 1.0$ NGN Values.
7	6E12.5	UNU	Neutron release (No. of neutrons) per neutron fission event by group, ν^g. NGN Values.
8	2413	IC	Mesh coordinate number of the right radial mesh coordinate of each redefined mesh cell. (e.g., if no redefining or reduction of mesh cell description is required, IC = 2, 3, 4, 5, 10, 11, 12, . . ICT; or, if a reduction of two mesh intervals must be made, IC = 2, 4, 5, . . . 10, 12, . . ICT, where 3 and 11 are removed.) There are ICM required values of IC.
9	2413	JC	Mesh coordinate number of the top mesh coordinate of each redefined mesh cell. The discussion of IC is applicable to JC. There are JCM required values of JC.
10	6E12.5	R	Radial mesh coordinate (line) dimensions for the input flux data (ICT + 1 values).
11	6E12.5	Z	Axial mesh coordinate (line) dimensions for the input flux data (JCT + 1 values).

3.2 FLUX DATA

Input flux data for the NAGS program are input as, either a FORTAN IV binary tape, or, as punched decimal data cards. The two modes, tape and cards, cannot be intermixed for combined neutron and photon calculations. Therefore, the user must provide the input flux data in a consistent form. Since there are three types of calculations which can be performed by the NAGS program and two flux input data modes, there exist five combinations of input control word combinations. The input control words NTYPE and NBIN which are input in the general problem data (Refer to Section 3.1.) determine the binary tape unit locations or punched data cards for each type of NAGS problem.

The input flux data for either binary tape or decimal data cards are assumed to be group dependent such that:

1) A logical tape record is ICT x JCT long and there are NGN (NTYPE = 1), NGG (NTYPE = 2 or 3), or NGN + NGG (NTYPE = 2) records on the binary tape, or

2) each neutron group or photon group is a set of punched decimal data cards and each new group begins on a new card.

The flux input data and the conditions of input mode are as follows:

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
12	6E12.5 or FORTRAN IV Binary Tape	SC	Input flux data NOTE: If the binary tape input mode is used, then card type 12, flux data, is deleted from the NAGS problem deck and binary tape (or tapes) must be submitted with the problem. Conditions on input mode (which were input under general data) NTYPE = 1: NBIN = 1: Neutron flux data as binary tape data on logical tape 11 which is MSFC IBSYS Version 13 unit B-6 NTYPE = 2: NBIN = 1: Neutron flux data as binary tape on logical tape 11. Photon flux data as binary tape data on logical tape 12 which is MSFC IBSYS Version 13 unit A-9.

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
			NTYPE = 3: NBIN = 1: Photon flux data as binary tape data on logical tape 11. NTYPE = 2: NBIN = 2: Neutron and photon flux data as binary tape data on logical tape 11. NTYPE = 1, 2, or 3: NBIN = 3: Neutron and photon flux data as punched decimal data cards with each group of neutron or photon data starting on a new card (card type 12).

3.3 LIBRARY DATA

The library data for the NAGS program are a compilation of the nuclear and radiation data for the reactor geometry and for the elements in the reactor. These library data, which are assumed to be region independent, are obtained as a complete punched decimal data deck from the POINT program (Refer to Volume 2,) or can be input by the user.

The data are divided into two sections: referred to as general data and element data. The general data include neutron and photon group dependent quantities required for photon energy release from fission, neutron dose rate, neutron kinetic heating, and photon dose rate calculations. The element data are required for each element in the problem.

Each input data card is described in this section. Section 3.5 summarizes in table form, the order in which the general data, the element data, and the region data (Section 3.4) are input to the NAGS problem depending on the control word NLIB, and whether a source or energy deposition calculation is to be performed.

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
Data Cards 13 - 19 are the General Library Data			
13	13	NEL	Number of elements in the library
14	6E12.5	SFPS	Prompt fission photon spectrum for each photon energy group (Mev/fission) NGG values

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
15	6E12.5	SFDS	Fission product decay photon spectrum for each photon energy group (Mev/fission) NGG values
16	6E12.5	DKG	Photon dose conversion factors for each photon energy group (Dose rate/Mev-cm^{-2} sec^{-1}) NGG values
17	6E12.5	DK	Neutron dose conversion factors for each neutron group (Dose rate/n cm^{-2}-sec^{-1}) NGN values
18	6E12.5	DU	Letharge width ($\Delta \mu$) of each neutron group NGN values
19	6E12.5	DE	Energy width (ΔE) of each neutron group (Mev) NGN values
Data Cards 20 - 26 are Required for Each Element			
20	I3,4E12.5, 10X, A6	NID	Element or nuclide identification number (a table of element identification numbers for the MSFC library are presented in volume 2 of this report.)
		AMU	Atomic weight of element (grams/gram-atom)
		ESS	Average fractional energy loss of a neutron elastic scattering event (isotropic scattering)
		ENA	Energy of charged particle (alpha) emission with neutron absorption (Mev/absorption)
		SA2200	Neutron absorption cross sections for thermal neutrons (2200 meter/second)
		LABEL	A six character descriptive title for the element
21	6E12.5	SINS	Neutron inelastic scatter photon energy spectra for each photon energy group arising from neutron inelastic scatter events occuring in the fast neutron groups (Mev/event)

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
			NGG values for each of NI neutron groups with each NGG value defining a set of data starting on a new card
22	6E12.5	SS	Microscopic neutron elastic scatter cross sections for neutron kinetic energy deposition calculations. NFAST values
23	6E12.5	SNA	Microscopic neutron absorption cross sections for charged particle (alpha) emission NGN values
24	6E12.5	ECOS	Anisotropic correction factors for the NGN neutron energy groups to be used in neutron kinetic energy heating calculations. The factors account for anisotropy of elastic scattering as a fractional energy deposition per elastic scatter event ($0.0 \leq ECOS^{g}_{m} \leq 1.0$) NFAST values
25	6E12.5	SAS	Neutron radiative capture gamma ray spectra for gamma ray groups (Mev/capture). NGG values
26	6E12.5	SAG	Microscopic gamma ray mass energy absorption coefficients for gamma ray groups. ($cm^2/gram$). NGG values
The Following Data for each Element is Entered Only if: NLIB = 1			
26A	6E12.5	SF	Microscopic neutron fission cross sections, σ^{g}_{fm}. NGN values

Card Type	FORTRAN Format	FORTRAN Variable	Meaning
26B	6E12.5	SA	Microscopic neutron absorption cross sections (radiative capture), σ^{g}_{cm}. NGN values
26C	6E12.5	SS	Microscopic neutron elastic scatter cross sections, σ^{g}_{em}. NFAST values
26D	6E12.5	SIN	Microscopic neutron inelastic scatter cross sections for production of photons, σ^{g}_{sm}. NI values

End of Element Data, Repeat From Card Type 20 for Each Element in the Library.

3.4 REGION* DATA

The final input to a NAGS problem are the region data which: (1) titles the region input and calculation data, (2) defines the location of the region in the two dimensional mesh cell description, (3) defines the number of elements in the region, (4) provides a program control word, and (5) depending on the type of NAGS problem (source or energy deposition), provides the material density and weight in the region, the element identification numbers, the element weight fractions or atom densities, and microscopic cross section data.

The description of a region in R, Z or R, θ geometry and the specification of the region external boundaries for a region are illustrated in Figure 8. These regions may be parts of a larger irregular region. The user must describe irregular regions as a composite of NAGS regions. The user must exercise caution in specifying regions so that region mesh overlays are avoided for photon source calculations since the NAGS region calculations are always initialized (all values set to 0.0) for each region and in photon source calculations the source data are saved for all mesh cells, for subsequent reactor geometry integrals, and for photon transport problems.

The input data cards for each region and each type of calculation are described below: These data cards are repeated for each NAGS region calculation in the problem. In addition, Section 3.5 summarizes in table form, the order in which the region data are input depending on the control word, NLIB, and whether a source or energy deposition calculation is to be performed.

---

*A region in the NAGS Code is defined as a rectangular (R, Z) or annular sector (R, θ) as illustrated in Figure 8.

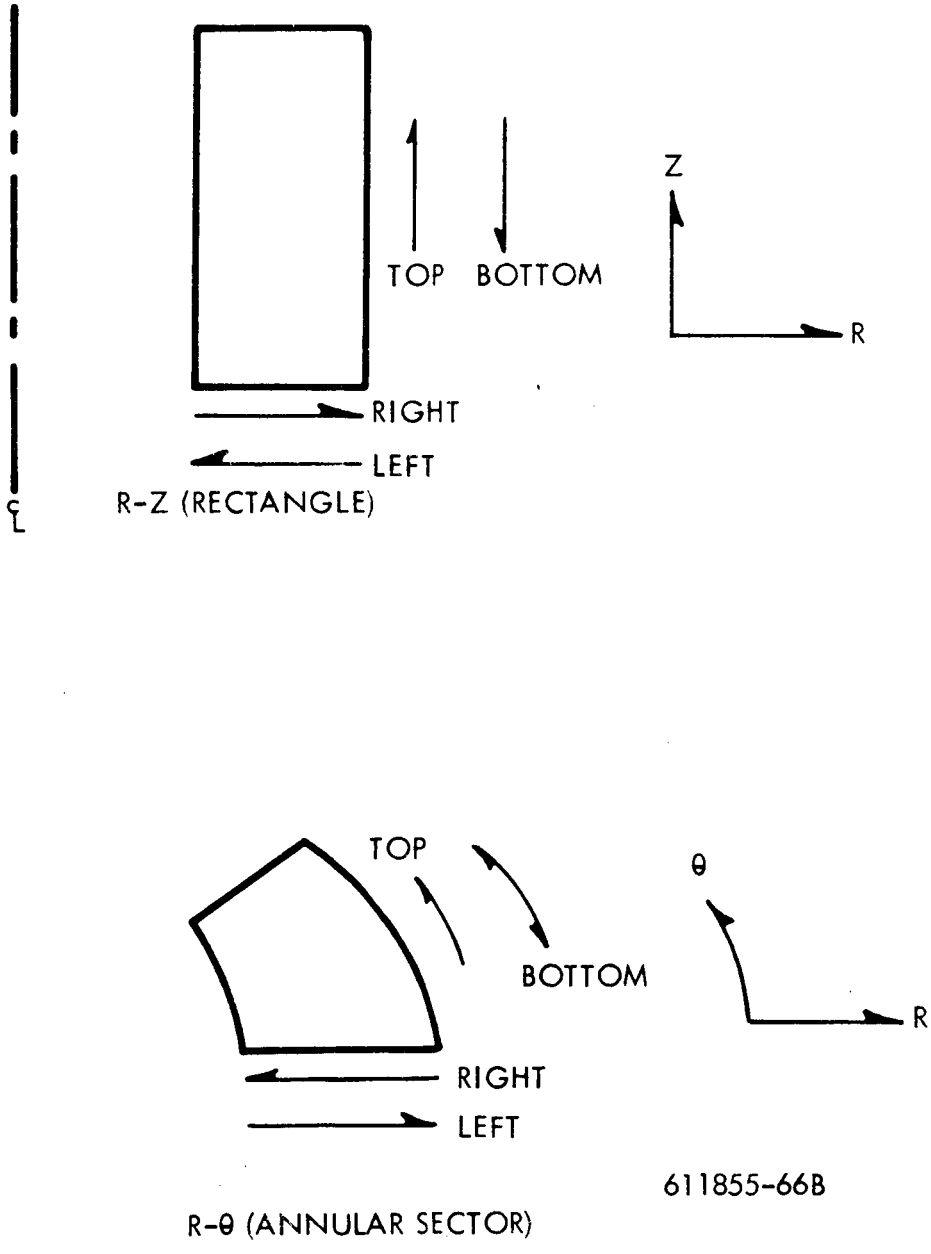


Figure 8. NAGS Region Geometry and Boundary Specification

Card Type	FORTRAN Format	FORTRAN Symbol	Meaning
27	(12A6)	ID	A 72 character title or description of the region
28	(613)	IS	IS is the radial mesh line number corresponding to the left boundary of the region (See Figure 8)
		IF	IF is the radial mesh line number corresponding to the right boundary of the region (See Figure 8)
		JS	JS is the axial (or angular)mesh line number corresponding to the bottom boundary of the region (See Figure 8)
		JF	JF is the axial (or angular) mesh line number corresponding to the top boundary of the region (See Figure 8)
		IEL	Number of elements in the region NOTE: If IEL is entered as a negative number, the program assumes that this region is identical in composition to the preceeding region and the microscopic data cards (Card Types 26-28D) are deleted from the deck. The next data card will be the title card (CARD TYPE 27 of the next subregion)
		IND	Control word. This data controls the sequence of operations which are to be performed at the completion of each region calculation. If, IND = 1, the program assumes another region follows and will return to read data (cards 27-28D) after calculations for the present region are completed. If, IND=2,

Card Type	FORTRAN Format	FORTRAN Symbol	Meaning
			the program assumes that this is the last region and when calculations are complete the program transfers control to the next NAGS operation, which is the calculation of region integrals and distributions.

The Following Set of Data (Card Types 29 and 30) Are Required Region Input Only for a NAGS Energy Deposition Calculation: NTYPE=1.

29	2E12.5	DGM	Density of the material (i.e., stainless steel, inconel, fueled graphite, beryllium) in the NAGS region (grams/cm^3 of the solid material)
		WTGM	Weight of the material in the NAGS region (kilograms)

There Are IEL (no. of Elements in Region) Required Data Cards Containing NLM, DNM:

30	I3, E12.5	NLM	Element identification number corresponding to the library element identification numbers NID.
		DNM	Weight fraction of the element NLM in the material described by DGM and WTGM (e.g., the weight fraction of Fe in stainless steel).

The Following Set of Data (Card Type 31) are Required Region Input Only For a NAGS Source Calculation: NTYPE = 1.

There are IEL (no. of elements in region)required sets of data (cards 28, 28A, 28B, 28C, 28D).

31	I3, E12.5	NLM	Element identification number corresponding to the library element identification number NID.
		DNM	Atom density of element in region ($X10^{-24}$)

Card Type	FORTRAN Format	FORTRAN Symbol	Meaning
The Following Neutron Cross Section Data are Input Only When NLIB = 0			
31A	6E12.5	SF	Microscopic neutron fission cross section, σ^{g}_{fm}. NGN values
31B	6E12.5	SA	Microscopic neutron absorption cross sections (radiative capture), $\sigma^{g}_{\epsilon m}$. NGN values
31C	6E12.5	SS	Microscopic neutron elastic scatter cross sections, σ^{g}_{em} NFAST values
31D	6E12.5	SIN	Microscopic neutron inelastic scatter cross sections for production of photons, σ^{g}_{sm}. NI values

3.5 SUMMARY OF LIBRARY AND REGION DATA

This section summarizes the three types of library and region data required as input to the NAGS program. The input is dependent on the controls NLIB and NTYPE. The three types of input discussed in Section 3.3 and 3.4 are: general library, element library and region input data. Table 1 and Figure 9 clarify the order in which these data are entered into the NAGS program.

TABLE 1

ORDER OF LIBRARY AND REGION INPUT DATA

If NLIB = 1 (Standard MSFC set-up), data are entered as follows:

Source Calculation (NTYPE = 1)

Cards 13 - 19 (general data)
Cards 20 - 26D (data for element 1)
Cards 20 - 26D (data for element 2)
etc.
Cards 27 - 28 (data for region 1)
Card 31 (data for element 1, region 1)
Card 31 (data for element 2, region 1)
etc.
Cards 27 - 28 (data for region 2)
Card 31 (data for element 1, region 2)
Card 31 (data for element 2, region 2)
etc.

Heating Calculation (NTYPE = 2 or 3)

Cards 13 - 19 (general data)
Cards 20 - 26D (data for element 1)
etc.
Cards 27 - 28 (data for region 1)
Card 29* (data for region 1)
Card 30* (data for element 1, region 1)
Card 30* (data for element 2, region 1)
etc.
Cards 27 - 28 (data for region 2)
Card 29* (data for region 2)
Card 30* (data for element 1, region 2)
Card 30* (data for element 2, region 2)
etc.

If NLIB = 0, data are entered as follows:

Source Calculation (NTYPE = 1)

Cards 13 - 19 (general data)
Cards 20 - 26 (data for element 1)
Cards 20 - 26 (data for element 2)
etc.
Cards 27 - 28 (data for region 1)
Cards 31 - 31D (data for element 1, region 1)
Cards 31 - 31D (data for element 2, region 1)
etc.
Cards 27 - 28 (data for region 2)
Cards 31 - 31D (data for element 1, region 2)
Cards 31 - 31D (data for element 2, region 2)
etc.

Heating Calculation (NTYPE = 2 or 3)

Cards 13 - 19 (general data)
Cards 20 - 26 (data for element 1)
Cards 20 - 26 (data for element 2)
etc.
Cards 27 - 28 (data for region 1)
Card 29* (data for region 1)
Card 30* (data for element 1, region 1)
Card 30* (data for element 2, region 1)
etc.
Cards 27 - 28 (data for region 2)
Card 29* (data for region 2)
Card 30* (data for element 1, region 2)
Card 30* (data for element 2, region 2)
etc.

NOTE: Refer to Sections 3.3 and 3.4 for description of each data card.

*Cards marked with an asterisk must be inserted "by hand" at the proper location. All other data cards are punched as output from the POINT code.

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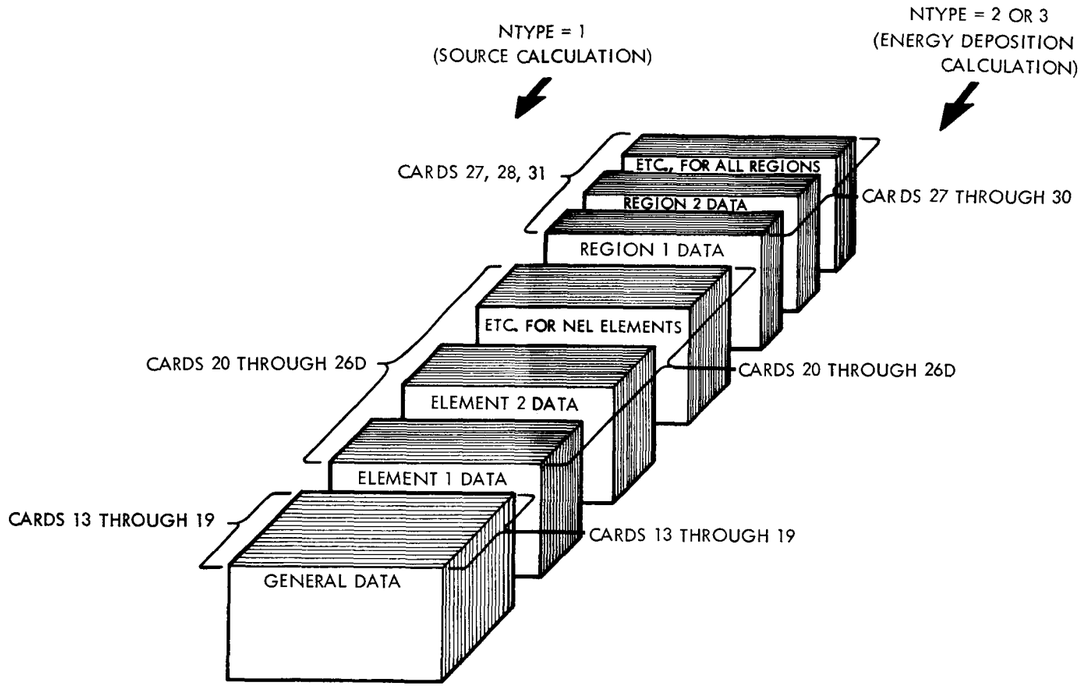
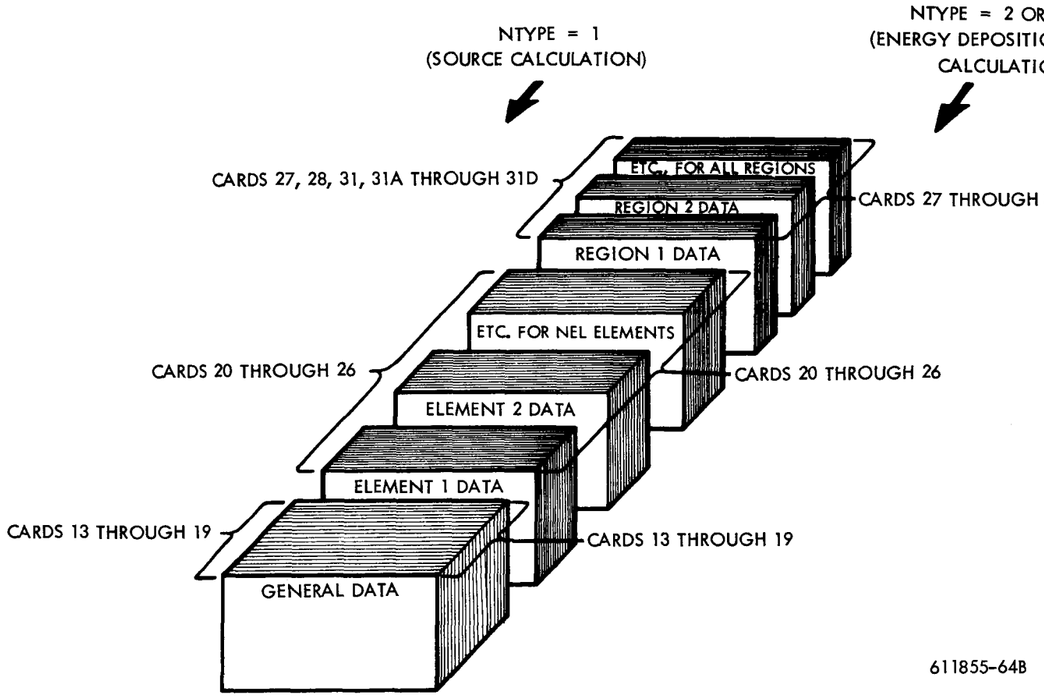
IF NLIB = 1: LONG LIBRARY OPTION (STANDARD MSFC OPTION)



NOTE: REFER TO SECTIONS 3.3 AND 3.4 FOR DESCRIPTION OF EACH DATA CARD. FOR NTYPE = 2 OR 3 CARDS 27 THROUGH 30 MUST BE INSERTED "BY HAND" AT THE PROPER LOCATION. ALL OTHER DATA CARDS ARE STANDARD PUNCHED OUTPUT FROM THE POINT PROGRAM.

Figure 9. Deck Order of Library and Region Input

IF NLIB = 0: SHORT LIBRARY OPTION



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SECTION

4.0 PROGRAM STRUCTURE AND LOGIC

The NAGS program consists of five major routines and five minor routines written in FORTRAN IV. The program is structured for the IBM 7094 Model II IBSYS Version 13 monitor system using the overlay mode. Overlay is employed in the program to achieve maximum memory core storage for data without severe penalties in program logic or running time. In addition, the NAGS program uses the variable dimensioning capability in FORTRAN IV to "pack" data into a single data vector, hence, maximizing the program's utility by allowing a wide variety of problems. The program structure is illustrated in Figure 10 with the overlay levels A and B shown. A brief description of the operations performed in each routine are included in the figure to illustrate the structure of the program with respect to the data processing functions performed.

The logical flow of the NAGS program is presented in Figure 11. Simplified flow diagrams are included for the major routines only, since the minor routines are straight forward calculations or operations. The logical flow through NAGS is controlled by the MAIN routine. The NAGS1 through NAGS4 routines return to the MAIN routine for the next NAGS step.

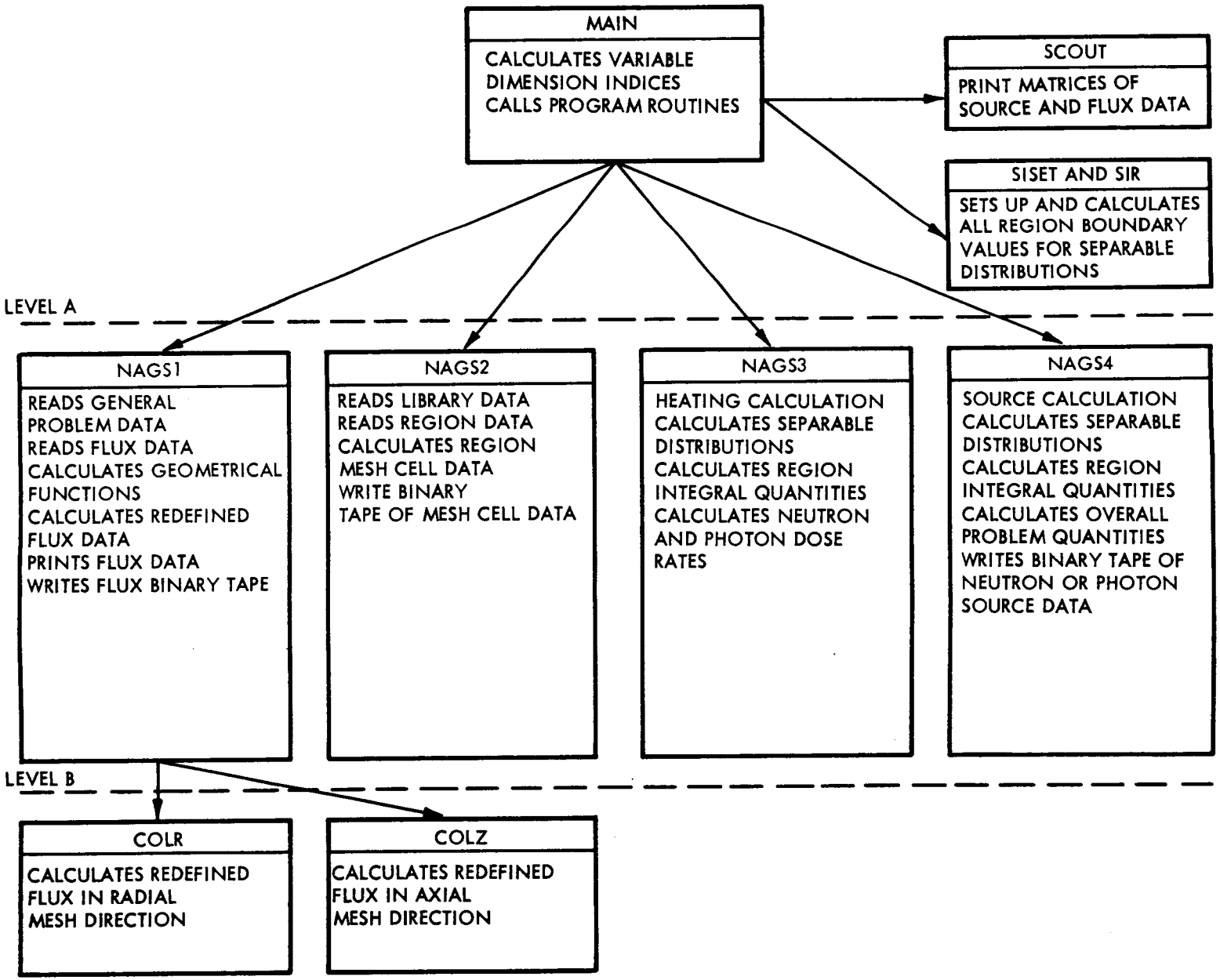

Figure 10. NAGS Program Structure

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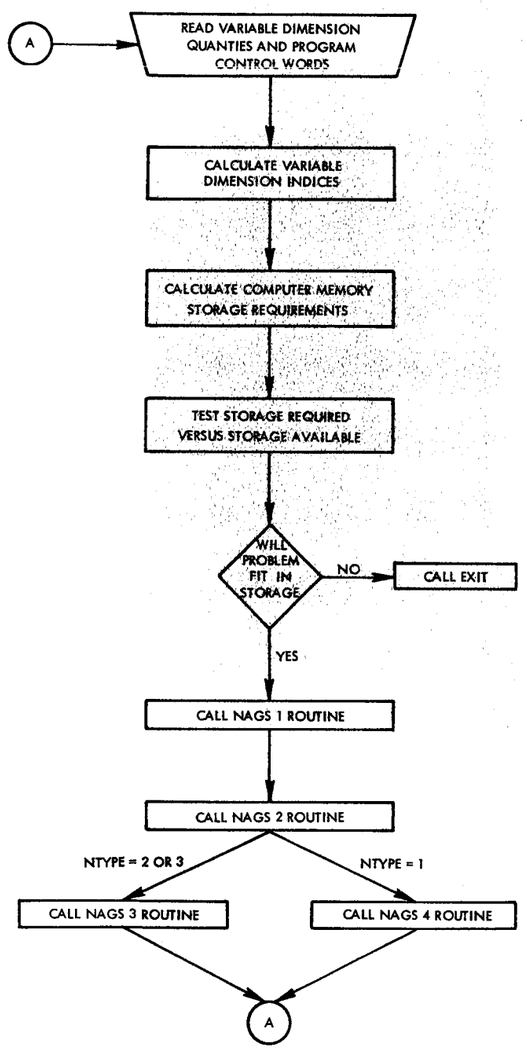
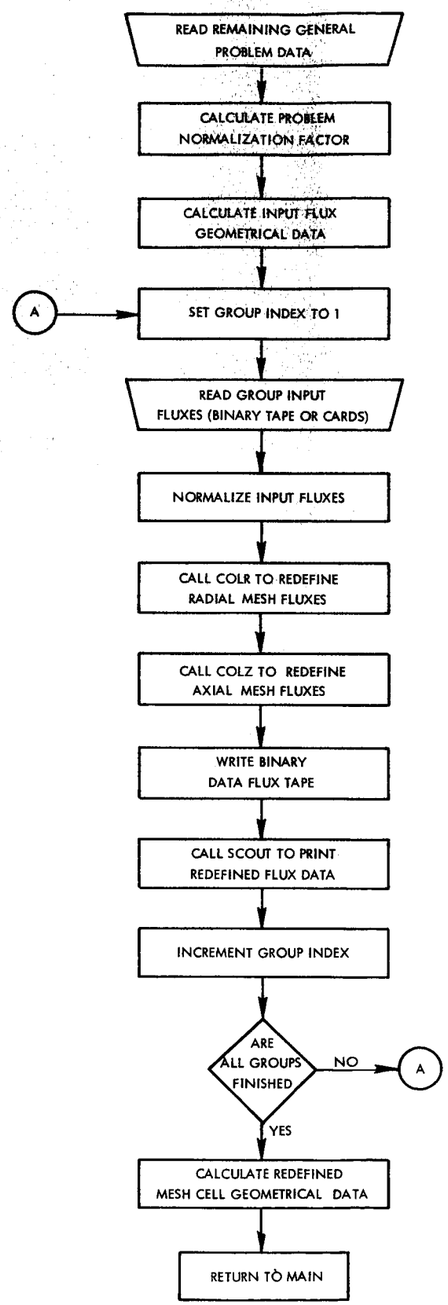
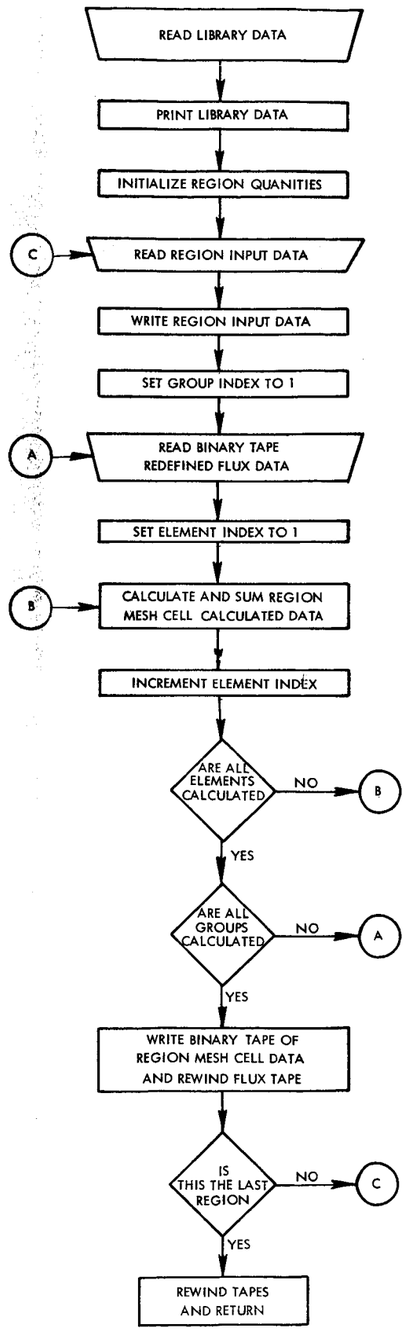
NAGS PROGRAM LOGIC
(MAIN ROUTINE)



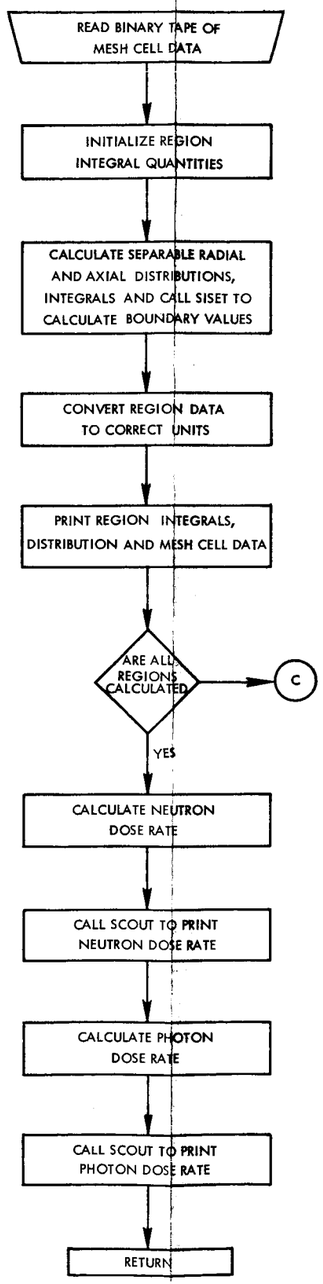
NAGS PROGRAM LOGIC
(NAGS 1 ROUTINE)



NAGS PROGRAM LOGIC
(NAGS 2 ROUTINE)



NAGS PROGRAM LOGIC
(NAGS 3 ROUTINE)



NAGS PROGRAM LOGIC
(NAGS 4 ROUTINE)

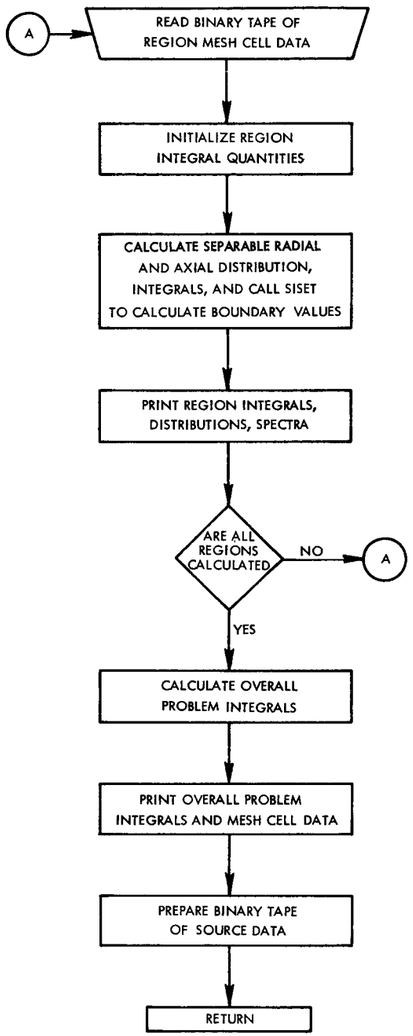


Figure 11. NAGS Program Logic

SECTION

5.0 OPERATING INSTRUCTIONS

The operating instructions and card deck setup for NAGS problems are similar to any production problem to be run under IBM IBSYS (Version 13) FORTRAN IV Monitor System. Problems may be run using either the binary object or source deck. The binary object deck is the preferred mode since compilation time is saved and the probability of damage for the source deck is eliminated. The deck setup for a binary object deck is described below and the deck setup with source decks is identical except the FORTRAN compiler card ($IBFTC in columns 1 - 6) and program source decks are substituted for binary object decks.

NAGS PROGRAM DECK SETUP

1. An accounting card (dependent on computer installation)
2. A job card, $JØB in columns 1 - 4.
3. A pause card, $PAUSE in columns 1 - 6. (This card is required to permit the IBM 7094 operator to mount the required input tapes; hence, if no tapes are input, this card is not required.)
4. An execute card, $EXECUTE, in columns 1 - 8 and IBJØB in columns 16 - 20.
5. An IBSYS job card, $IBJØB, in columns 1 - 6 and GO, FIØCS, MAP in columns 16 - 27.
6. MAIN subroutine binary object deck (A FORTRAN loader card, $IBLDR, in columns 1 - 6 is included in the punched binary object deck from the FORTRAN IV compiler).
7. SISET subroutine binary object deck.
8. SIR subroutine binary object deck.
9. SCØUT subroutine binary object deck.
10. An overlay origin card, $ØRIGIN, in columns 1 - 7 and ALPHA, SYSUT3, REW in columns 16 - 31.
11. NAGS1 subroutine binary object deck.
12. An overlay origin card, $ORIGIN, in columns 1 - 7 and BETA, SYSUT3, REW in columns 16 - 31.

13. CØLZ subroutine binary object deck.
14. Same as card 12.
15. CØLR subroutine binary object deck.
16. Same as card 10.
17. NAGS2 subroutine binary object deck.
18. Same as card 10.
19. NAGS3 subroutine binary object deck.
20. Same as card 10.
21. NAGS4 subroutine binary object deck.
22. An entry control card, $ENTRY, in columns 1 - 6.
23. A data control card, $DATA, in columns 1 - 5.
24. NAGS Problem deck.
25. Appropriate end of file cards to end job.

This deck is then written off-line (card to tape) on an IBM Model 1401 or IBM Model 360/30 to manufacture a standard system input tape. Once the input has been written on tape, the machine operation is standard and the only operator action required is the tape mounting at the beginning of the job and tape dismounting at the completion of the job. The tapes used by NAGS are the following:

All BCD input	Logical Tape 5, MSFC IBSYS Version 13 A-2
All BCD output	Logical Tape 6, MSFC IBSYS Version 13 B-1
Flux Input Binary Tape	Logical Tape 11, MSFC IBSYS Version 13 B-6
Flux Input Binary Tape	Logical Tape 12, MSFC IBSYS Version 13 A-9
Redefined Flux Binary Work Tape	Logical Tape 10, MSFC IBSYS Version 13 A-6
Intermediate Binary Work Tape	Logical Tape 9, MSFC IBSYS Version 13 B-5
Overlay Tape	Logical Tape 3, MSFC IBSYS Version 13 A-4

The binary tapes always to be mounted at the beginning of a job are the input (5), work (9), work (10), and overlay (3) tapes. The standard save tape is the normal system BCD output (6) and tapes dependent on calculation type.

The binary tapes to be mounted and saved should be clearly labeled so that these tapes may be recalled for subsequent use as input tapes. The suggested tape labels for NAGS tapes are in parentheses in the following discussions. If the calculation is a source calculation, NTYPE=1, and the flux input mode is binary tape, NBIN=1, then a binary tape generated by the ØDD-K neutron transport problem is a required input on logical tape 11. The save tapes from this source calculation are the binary tapes from logical tape 9 (NAGS SOURCE DATA) and logical tape 10 (NAGS REDEFINED FLUX DATA). If the calculation is an energy deposition calculation, NTYPE=2 or 3, and the flux input mode is binary tape, then three flux input modes exist. The first input mode (NBIN=1 for NTYPE=2) requires the binary tape (NAGS REDEFINED FLUX DATA)saved from logical tape 10 on the prior NAGS source calculation as a required input tape on logical tape 11. In addition, a second binary tape generated by the ØDD-K photon transport problem is a required input on logical tape 13. The second input mode, NBIN=1 for NTYPE=3, requires the binary tape generated by the ØDD-K photon transport problem as required input on logical tape 11. The third input mode, NBIN=2 for NTYPE=2, requires the binary tape (NAGS REDEFINED FLUX DATA)saved from logical tape 10 on the prior NAGS energy deposition, NTYPE=2, as a required input tape on logical tape 11.

The save tape from the energy deposition calculations is the binary tape from logical tape 10 (NAGS REDEFINED FLUX DATA).

When the deck and tape mounting and dismounting requests are set up in the preceding manner, the NAGS program will operate under normal IBSYS Version 13 Monitor SYSTEM control.

APPENDIX A

NAGS STORAGE ALLOCATION

The NAGS program uses the variable dimension capability of the FORTRAN IV programming language to allocate data storage in the program. This variable dimensioning, which occurs when input data is loaded, provides flexibility in using the program for a variety of problems without recompilation of the source program. There are 18,050 core locations available for input and calculated data. The total data storage locations required for a particular NAGS problem can be determined from the 7 input quantities on card 1 of the input data and the following four equations:

1. $X_1 = 2^* \left[(ICT^*JCT) + (ICT + JCT + 1)\right]$
2. $X_2 = \left[(ICM^*JCM)^*(NGG + 2)\right] + \left[(ICM + JCM)^*10\right]$, for NTYPE = 1

   or

   $X_2 = \left[(ICM^*JCM)^*3\right] + \left[(ICM + JCM)^*10\right]$, for NTYPE = 2 or 3
3. $X_3 = \left[NEL^*NGN^*3\right] + \left[(NI + 2)^*NGG\right] + \left[(NFAST^*2) + NI\right] + 9$
4. $X_4 = \left[5^*NGG\right] + \left[4^*NGN\right]$

The summation of X's yields the total storage locations for a particular problem which must be less than 18,050. If this limit is exceeded, an error print is returned by the NAGS program and the problem is terminated.

APPENDIX B

PROGRAM SOURCE LISTING

```
$IBSYS
$JOB
$EXECUTE        IBJOB
$IBJOB          GO,NOMAP,FIOCS
$IBFTC MAIN     NOLIST,  DECK,NODD,M94/2,XR7                                    MAIN    1
C      MAIN PROGRAM FOR VARIABLE DIMENSION NAGS                                 MAIN    2
       COMMON ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,IND,NTYPE                    MAIN    3
       COMMON NCD,NBIN,NLIB,NEX,NEXI,ISTART,JSTART,NPUN  ,ZREF,JCO              MAIN    4
       DIMENSION X(18050),IX(100)
    2  READ(5,1010)  ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,NTYPE                MAIN    6
C THE QUANITY NMAXRS IS THE MAXIMUM REAL STORAGE ALLOCATION FOR THE DATAMAIN    7
C VECTOR X AND IT=S VALUE MUST CORRESPOND TO THE DIMENSION OF X                 MAIN    8
C THE QUANITY NMAXIS IF THE MAXIMUM INTGER STORAGE ALLOCATION FOR THE           MAIN    9
C DATA VECTOR IX AND IT=S VALUE MUST CORRESPOND TO THE DIMENSION OF IX          MAIN   10
       NMAXRS=18050
       NMAXIS = 100
       I1 = ICT                                                                 MAIN   13
       I2 = ICM                                                                 MAIN   14
       I3 = JCT                                                                 MAIN   15
       I4 = JCM                                                                 MAIN   16
       I5 = NGN                                                                 MAIN   17
       I6 = NFAST                                                               MAIN   18
       I7 = NI                                                                  MAIN   19
       I8 = NGG                                                                 MAIN   20
       I9 = NEL                                                                 MAIN   21
       I10 = ICT+1                                                              MAIN   22
       I11 = ICT                                                                MAIN   23
       I12 = JCT+1                                                              MAIN   24
       I13 = ICM                                                                MAIN   25
       I14 = JCM                                                                MAIN   26
       I15 = I1*I3                                                              MAIN   27
       I16 = I1*I3                                                              MAIN   28
       I17 = NGG + 2                                                            MAIN   29
       IF(NTYPE.GT.1) I17 = 3                                                   MAIN   30
C                                                                               MAIN   31
C                                                                               MAIN   32
C THE FOLLOWING FORTRAN STATEMENTS ARE THE VARIABLE DIMENSION SIZING            MAIN   33
C                                                                               MAIN   34
       J1 = 1                                                                   MAIN   35
C R(ICT+1)
       J2  = J1  + I10                                                          MAIN   37
C Z(JCT+1)                                                                      MAIN   38
```

```
      J3  = J2  + I12                                                   MAIN  39
C RSF(ICM)                                                              MAIN  40
      J4=J3+I2                                                          MAIN  41
C ZSF(JCM)                                                              MAIN  42
      J5= J4+I4                                                         MAIN  43
C RS(ICM)                                                               MAIN  44
      J6=J5+I2                                                          MAIN  45
C ZS(JCM)                                                               MAIN  46
      J7=J6+I4                                                          MAIN  47
C VOLR(ICT)                                                             MAIN  48
      J8  = J7  + I1                                                    MAIN  49
C VOLZ(JCT)                                                             MAIN  50
      J9  = J8  + I3                                                    MAIN  51
C SC(ICT,JCT)                                                           MAIN  52
      J10=J9+I1*I3                                                      MAIN  53
C TEMP(ICT,JCT)                                                         MAIN  54
      J11=J10+I1*I3                                                     MAIN  55
C SG(ICM,JCM,NGG+2) OR SG(ICM,JCM,3)                                    MAIN  56
      J12=J11+I2*I4*I17                                                 MAIN  57
C UNU(NGN)                                                              MAIN  58
      J13 = J12 + I5                                                    MAIN  59
C CHI(NGN)                                                              MAIN  60
      J14 = J13 + I5                                                    MAIN  61
C SFPS(NGG)                                                             MAIN  62
      J15 = J14 + I8                                                    MAIN  63
C SFDS(NGG)                                                             MAIN  64
      J16 = J15 + I8                                                    MAIN  65
C DNM(NEL)                                                              MAIN  66
      J17 = J16 + I9                                                    MAIN  67
C SA(NGN,NEL)                                                           MAIN  68
      J18 = J17 + I5*I9                                                 MAIN  69
C SF(NGN,NEL)                                                           MAIN  70
      J19 = J18 + I5*I9                                                 MAIN  71
C SIN(NI,NEL)                                                           MAIN  72
      J20 = J19 + I7*I9                                                 MAIN  73
C SS(NFAST,NEL)                                                         MAIN  74
      J21 = J20 + I6*I9                                                 MAIN  75
C SAS(NGG,NEL)                                                          MAIN  76
      J22 = J21 + I8*I9                                                 MAIN  77
C SINS(NGG,NI,NEL)                                                      MAIN  78
      J23 = J22 + I8*I7*I9                                              MAIN  79
C AMU(NEL)                                                              MAIN  80
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```
      J24 = J23 + I9
C ESS(NEL)
      J25 = J24 + I9
C ENA(NEL)
      J26 = J25 + I9
C SA2200(NEL)
      J27 = J26 + I9
C LABEL(NEL)
      J28 = J27 + I9
C SNA(NGN,NEL)
      J29 = J28 + I5*I9
C ECOS(NFAST,NEL)
      J30 = J29 + I6*I9
C DK(NGN)
      J31=J30+I5
C DE(NGN)
      J32 = J31 + I5
C DU(NGN)
      J33 = J32 + I5
C SAG(NGG,NEL)
      J34 = J33 + I8*I9
C TSG(NGG)
      J35 = J34 + I8
C RI(ICM)
      J36 = J35 + I2
C ZI(ICM)
      J37 = J36 + I4
C SGB(ICM*3)
      J38 = J37 + I2*3
C SGT(ICM*3)
      J39 = J38 + I2*3
C SGR(JCM*3)
      J40 = J39 + I4*3
C SGL(JCM*3)
      J41 = J40 + I4*3
C RSN(ICM)
      J42=J41+I2
C ZSN(JCM)
      J43=J42+I4
C DKG(NGG)
      J44 = J43 + I8
C STC(NEL)
```

```
MAIN   81
MAIN   82
MAIN   83
MAIN   84
MAIN   85
MAIN   86
MAIN   87
MAIN   88
MAIN   89
MAIN   90
MAIN   91
MAIN   92
MAIN   93
MAIN   94
MAIN   95
MAIN   96
MAIN   97
MAIN   98
MAIN   99
MAIN  100
MAIN  101
MAIN  102
MAIN  103
MAIN  104
MAIN  105
MAIN  106
MAIN  107
MAIN  108
MAIN  109
MAIN  110
MAIN  111
MAIN  112
MAIN  113
MAIN  114
MAIN  115
MAIN  116
MAIN  117
MAIN  118
MAIN  119
MAIN  120
MAIN  121
MAIN  122
```


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```
      J45 = J44 + I9                                                    MAIN 123
      J46= J45+I9                                                       MAIN 125
C STI(M)                                                                MAIN 126
      J47 =J46 +I9                                                      MAIN 127
      J49= J47                                                          MAIN 128
      J50 =   1                                                         MAIN 129
C IC(ICM)                                                               MAIN 130
      J51 = J50 + I2                                                    MAIN 131
C JC(JCM)                                                               MAIN 132
      J52 = J51 + I4                                                    MAIN 133
C NID(NEL)                                                              MAIN 134
      J53 = J52 + I9                                                    MAIN 135
C NLM(NEL)                                                              MAIN 136
      J54 = J53 + I9                                                    MAIN 137
C                                                                       MAIN 138
      NTEST = J49                                                       MAIN 139
      NTEST2= J54                                                       MAIN 140
C                                                                       MAIN 141
      NTEST1 = NTEST - NMAXRS                                           MAIN 142
      NTEST3 = NTEST2 - NMAXIS                                          MAIN 143
      WRITE(6,1000)I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,I11,I12,I13,I14,I15,  MAIN 144
     1I16,I17,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10,J11,J12,J13,J14,J15,J16,   MAIN 145
     2J17,J18,J19,J20,J21,J22,J23,J24,J25,J26,J27,J28,J29,J30,J31,J32,   MAIN 146
     3J33,J34,J35,J36,J37,J38,J39,J40,J41,J42,J43,J44,                   MAIN 147
     4J49,J50,J51,J52,J53,J54                                           MAIN 148
 1000 FORMAT(70H1THE STORAGE REQUIREMENTS ARE DETERMINED FROM THE I ARRAMAIN 149
     1Y AS FOLLOWS  //(17I6),/79H AND THE STARTING LOCATIONS OF EACH    MAIN 150
     2VARIABLE ARE DETERMINED FROM THE J ARRAY //(17I6)    )           MAIN 151
      IF(NTEST1.LE.0) GO TO 6                                           MAIN 152
    4 WRITE (6,1002) NTEST1                                             MAIN 153
 1002 FORMAT (31H DIMENSION ERROR.  OVERFLOW OF ,I5, 10H LOCATIONS)     MAIN 154
      CALL EXIT                                                         MAIN 155
    6 IF(NTEST3.LE.0) GO TO 10                                          MAIN 156
    8 WRITE (6,1004) NTEST3                                             MAIN 157
 1004 FORMAT (31H FIXED POINT DIMENSION ERROR   ,I5, 10H LOCATIONS)     MAIN 158
      CALL EXIT                                                         MAIN 159
   10 WRITE(6,1006) NTEST,NMAXRS,NTEST2,NMAXIS                          MAIN 160
 1006 FORMAT(1H1,///,6X,31H YOUR NAGS IV PROBLEM HAS USED I5,27H LOCATIOMAIN 161
     1NS OF THE AVAILABLEI6,31H REAL NUMBER STORAGE LOCATIONS //,6X,10H MAIN 162
     2AND USED I5,27H LOCATIONS OF THE AVAILABLEI4,33H INTEGER NUMBER STMAIN 163
     3ORAGE LOCATIONS    )                                              MAIN 164
      NLINK=1                                                           MAIN 165
```


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```
      WRITE(6,1008) NLINK                                                MAIN 166
      CALL NAG1(                                                         MAIN 167
     1 X(J1 ) , X(J2 ) , X(J3 ) , X(J4 ) , X(J5 ) , X(J6 ) , X(J7 ),     MAIN 168
     1 X(J8 ) , X(J9 ) , X(J10) , X(J11) , X(J12) , X(J13) , X(J14),     MAIN 169
     1 X(J15) , X(J16) , X(J17) , X(J18) , X(J19) , X(J20) , X(J21),     MAIN 170
     1 X(J22) , X(J23) , X(J24) , X(J25) , X(J26) , X(J27) , X(J28),     MAIN 171
     1 X(J29) , X(J30) , X(J31) , X(J32) , X(J33) , X(J34) , X(J35),     MAIN 172
     1 X(J36) , X(J37) , X(J38) , X(J39) , X(J40) , X(J41) , X(J42) ,    MAIN 173
     1 X(J43) , X(J44) , X(J45) , X(J46) ,                               MAIN 174
     1 IX(J50), IX(J51), IX(J52), IX(J53) ,                              MAIN 175
     1 I1  , I2  , I3  , I4  , I5  , I6  , I7  , I8  , I9  , I10 , I11 ,MAIN 176
     1 I12 , I13 , I14 , I15 , I16 , I17 )                               MAIN 177
  12 NLINK=2                                                             MAIN 178
      WRITE(6,1008) NLINK                                                MAIN 179
      CALL NAG2(                                                         MAIN 180
     1 X(J1 ) , X(J2 ) , X(J3 ) , X(J4 ) , X(J5 ) , X(J6 ) , X(J7 ),     MAIN 181
     1 X(J8 ) , X(J9 ) , X(J10) , X(J11) , X(J12) , X(J13) , X(J14),     MAIN 182
     1 X(J15) , X(J16) , X(J17) , X(J18) , X(J19) , X(J20) , X(J21),     MAIN 183
     1 X(J22) , X(J23) , X(J24) , X(J25) , X(J26) , X(J27) , X(J28),     MAIN 184
     1 X(J29) , X(J30) , X(J31) , X(J32) , X(J33) , X(J34) , X(J35),     MAIN 185
     1 X(J36) , X(J37) , X(J38) , X(J39) , X(J40) , X(J41) , X(J42) ,    MAIN 186
     1 X(J43) , X(J44) , X(J45) , X(J46) ,                               MAIN 187
     1 IX(J50), IX(J51), IX(J52), IX(J53) ,                              MAIN 188
     1 I1  , I2  , I3  , I4  , I5  , I6  , I7  , I8  , I9  , I10 , I11 ,MAIN 189
     1 I12 , I13 , I14 , I15 , I16 , I17 )                               MAIN 190
      IF (NTYPE.EQ.1) GO TO 14                                           MAIN 191
      NLINK=3                                                            MAIN 192
      WRITE(6,1008) NLINK                                                MAIN 193
      CALL NAG3(                                                         MAIN 194
     1 X(J1 ) , X(J2 ) , X(J3 ) , X(J4 ) , X(J5 ) , X(J6 ) , X(J7 ),     MAIN 195
     1 X(J8 ) , X(J9 ) , X(J10) , X(J11) , X(J12) , X(J13) , X(J14),     MAIN 196
     1 X(J15) , X(J16) , X(J17) , X(J18) , X(J19) , X(J20) , X(J21),     MAIN 197
     1 X(J22) , X(J23) , X(J24) , X(J25) , X(J26) , X(J27) , X(J28),     MAIN 198
     1 X(J29) , X(J30) , X(J31) , X(J32) , X(J33) , X(J34) , X(J35),     MAIN 199
     1 X(J36) , X(J37) , X(J38) , X(J39) , X(J40) , X(J41) , X(J42) ,    MAIN 200
     1 X(J43) , X(J44) , X(J45) , X(J46) ,                               MAIN 201
     1 IX(J50), IX(J51), IX(J52), IX(J53) ,                              MAIN 202
     1 I1  , I2  , I3  , I4  , I5  , I6  , I7  , I8  , I9  , I10 , I11 ,MAIN 203
     1 I12 , I13 , I14 , I15 , I16 , I17 )                               MAIN 204
  14 IF (NTYPE.GT.1) GO TO 16                                            MAIN 205
      NLINK=4                                                            MAIN 206
      WRITE(6,1008) NLINK                                                MAIN 207
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      CALL NAG4(                                                          MAIN 208
     1 X(J1 ) , X(J2 ) , X(J3 ) , X(J4 ) , X(J5 ) , X(J6 ) , X(J7 ),      MAIN 209
     1 X(J8 ) , X(J9 ) , X(J10) , X(J11) , X(J12) , X(J13) , X(J14),      MAIN 210
     1 X(J15) , X(J16) , X(J17) , X(J18) , X(J19) , X(J20) , X(J21),      MAIN 211
     1 X(J22) , X(J23) , X(J24) , X(J25) , X(J26) , X(J27) , X(J28),      MAIN 212
     1 X(J29) , X(J30) , X(J31) , X(J32) , X(J33) , X(J34) , X(J35),      MAIN 213
     1 X(J36) , X(J37) , X(J38) , X(J39) , X(J40) , X(J41) , X(J42) ,     MAIN 214
     1 X(J43) , X(J44) , X(J45) , X(J46) ,                                MAIN 215
     1 IX(J50), IX(J51), IX(J52), IX(J53) ,                               MAIN 216
     1 I1  , I2  , I3  , I4  , I5  , I6  , I7  , I8  , I9  , I10 , I11 ,MAIN 217
     1 I12 , I13 , I14 , I15 , I16 , I17 )                                MAIN 218
   16 GO TO 2
 1008 FORMAT(//17H PROBLEM IN LINK I3)                                    MAIN 221
 1010 FORMAT(24I3)                                                        MAIN 222
      END                                                                 MAIN 223
$IBFTC SISETR  NOLIST,  DECK,NODD,M94/2,XR7                              SISET  1
      SUBROUTINE SISET(SGLT,SGRT,SGBT,SGTP,R,RI,Z,ZI,I1,I2,I3,I4,I10,    SISET  2
     1I12,I13,I14,IRS,IR1,IZS,IZ1,K,RS,ZS )                              SISET  3
      DIMENSION SGLT(3),SGRT(3),SGBT(3),SGTP(3)                          SISET  4
      DIMENSION R(I10),RI(I2),Z(I12),ZI(I4),RS(I2),ZS(I4)                SISET  5
      DIMENSION A(3),X(3)                                                SISET  6
      IRF1 = IR1 + 1                                                     SISET  7
      IRS1 = IRS + 1                                                     SISET  8
      IRF2 = IR1 - 1                                                     SISET  9
      IRS2 = IRS - 1                                                     SISET 10
      III = IR1 - IRS + 1                                                SISET 11
      NT = 1                                                             SISET 12
      NK = 1                                                             SISET 13
      A(2) = RS(IRS)                                                     SISET 14
      A(3) = SGLT(K)                                                     SISET 15
      X(1) = R(IRS)                                                      SISET 16
      X(2) = RI(IRS)                                                     SISET 17
      X(3) = RI(IRS2)                                                    SISET 18
      IF(SGLT(K).GT.0.0) GO TO 2                                         SISET 19
      NK = 3                                                             SISET 20
      A(3) = RS(IRS1)                                                    SISET 21
      X(3) = RI(IRS1)                                                    SISET 22
      IF(III.EQ.1) A(3) = SGRT(K)                                        SISET 23
    2 GO TO 14                                                           SISET 24
    4 SGLT(K) = A(1)                                                     SISET 25
      NT = 2                                                             SISET 26
      NK=1                                                               SISET 27
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```
      A(2) = RS(IR1)                                                    SISET 28
      A(3) = SGRT(K)                                                    SISET 29
      X(1) = R(IRF1)                                                    SISET 30
      X(2) = RI(IR1)                                                    SISET 31
      X(3) = RI(IRF1)                                                   SISET 32
      IF(SGRT(K).GT.0.0) GO TO 6                                        SISET 33
      NK = 4                                                            SISET 34
      A(2) = RS(IRF2)                                                   SISET 35
      A(3) = RS(IR1)                                                    SISET 36
      X(2) = RI(IRF2)                                                   SISET 37
      X(3) = RI(IR1)                                                    SISET 38
      IF(III.GT.1) GO TO 6                                              SISET 39
      A(2) = SGLT(K)                                                    SISET 40
      X(2) = R(IRF2)                                                    SISET 41
    6 GO TO 14                                                          SISET 42
    8 SGRT(K) = A(1)                                                    SISET 43
      NK = 2                                                            SISET 44
      NT =3                                                             SISET 45
      IZF1 = IZ1 + 1                                                    SISET 46
      IZS1 = IZS + 1                                                    SISET 47
      IZF2 = IZ1 - 1                                                    SISET 48
      IZS2 = IZS - 1                                                    SISET 49
      III = IZ1 - IZS + 1                                               SISET 50
      A(2) = ZS(IZS)                                                    SISET 51
      A(3) = SGBT(K)                                                    SISET 52
      X(1) = Z(IZS)                                                     SISET 53
      X(2) = ZI(IZS)                                                    SISET 54
      X(3) = ZI(IZS2)                                                   SISET 55
      IF(SGBT(K).GT.0.0) GO TO 10                                       SISET 56
      NK = 5                                                            SISET 57
      A(3) = ZS(IZS)                                                    SISET 58
      A(2)=ZS(IZS )                                                     SISET 59
      X(2) = ZI(IZS1)                                                   SISET 60
      X(3) = ZI(IZS)                                                    SISET 61
      IF(III.GT.1) GO TO 10                                             SISET 62
      A(2) = SGTP(K)                                                    SISET 63
   10 GO TO 14                                                          SISET 64
   12 SGBT(K) = A(1)                                                    SISET 65
      NT =4                                                             SISET 66
      NK = 2                                                            SISET 67
      A(2) = ZS(IZ1)                                                    SISET 68
      A(3) = SGTP(K)                                                    SISET 69
```

```
      X(1) = Z(IZF1 )                                                    SISET 70
      X(2) = ZI(IZ1)                                                     SISET 71
      X(3) = ZI(IZF1)                                                    SISET 72
      IF(SGTP(K).GT.0.0) GO TO 14                                        SISET 73
      A(2) = ZS(IZF2)                                                    SISET 74
      A(3) = ZS(IZ1)                                                     SISET 75
      X(2) = ZI(IZF2)                                                    SISET 76
      X(3) = ZI(IZ1)                                                     SISET 77
      IF(III.GT.1) GO TO 14                                              SISET 78
      NK = 5                                                             SISET 79
      A(2) = SGBT(K)                                                     SISET 80
      X(2) = Z(IZ1)                                                      SISET 81
   14 CALL SIR(A(1),A(2),A(3),X(1),X(2),X(3),NK)                         SISET 82
      GO TO (4,8,12,16),NT                                               SISET 83
   16 SGTP(K) = A(1)                                                     SISET 84
      RETURN                                                             SISET 85
      END                                                                SISET 86
$IBFTC SIRR    NOLIST,  DECK,NODD,M94/2,XR7                               SIRR   1
      SUBROUTINE SIR(A1,A2,A3,X1,X2,X3,NT)                               SIRR   2
      COMMON ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,IND,NTYPE              SIRR   3
      COMMON NCD,NBIN,NLIB,NEX,NEX1,ISTART,JSTART,NPUN  ,ZREF,JCO        SIRR   4
C     A1 IS THE BOUNDARY RESULT RETURNED BY THE SIR  ROUTINE             SIRR   5
C     IF NT=1, LINEAR INTERPOLATION IN R*F(R)                            SIRR   6
C     IF NT=2, LINEAR INTERPOLATION IN Z                                 SIRR   7
C     IF NT=3, LINEAR INTERPOLATION IN R*F(R) WITH DER(F(R))/DER(R) = 0. SIRR   8
C     IF NT=4, LOGRITHAMIC EXTRAPOLATION IN R*F(R)                       SIRR   9
C     IF NT=5, LOGRITHAMIC EXTRAPOLATION IN Z                            SIRR  10
      GO TO (2,4,6,8,10),NT                                              SIRR  11
    2 A1 =  (A2*X2+((A3*X3-A2*X2)*(X1-X2))/(X3-X2))/X1                   SIRR  12
      GO TO 12                                                           SIRR  13
    4 A1 =   A2+((A3-A2)*(X1-X2))/(X3-X2)                              SIRR  14
      GO TO 12                                                           SIRR  15
    6 A1 = (A3*X2*X2-A2*X3*X3)/((X2-X3)*(X2+X3))                       SIRR  16
      GO TO 12                                                           SIRR  17
    8 A1 = A3*(X3/X1)*EXP((X1-X3)*(ALOG(A3*X3/(A2*X2)))/(X3-X2))       SIRR  18
      GO TO 12                                                           SIRR  19
   10 A1 = A3*EXP((X1-X3)*(ALOG(A3/A2))/(X3-X2))                       SIRR  20
   12 RETURN                                                           SIRR  21
      END                                                              SIRR  22
$IBFTC SCOUR   NOLIST,  DECK,NODD,M94/2,XR7                            SCOUR   1
      SUBROUTINE SCOUT(SC,RI,ZI,I1,I2,I3,I4,K,NAME)                    SCOUR   2
      DIMENSION SC(I1,I2),RI(I3),ZI(I4),NAME(3)                        SCOUR   3
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```
      WRITE (6,1006) (NAME(I),I=1,3),K                                  SCOUR  4
      DO 2 ISTAR = 1,I4,8                                               SCOUR  5
      ISTOP=ISTAR + 7                                                   SCOUR  6
      ISTOP = MINO(I4,ISTOP)                                            SCOUR  7
      WRITE(6,1004)(II,II=ISTAR,ISTOP)                                  SCOUR  8
      WRITE(6,1002) (ZI(II),II=ISTAR,ISTOP)                             SCOUR  9
      DO 2 J=1,I3                                                       SCOUR 10
    2 WRITE(6,1000) J,RI(J),(SC(J,I),I=ISTAR,ISTOP)                     SCOUR 11
 1000 FORMAT(I4,F8.2,1P8E12.4)                                          SCOUR 12
 1002 FORMAT(12X,8(2X,F8.2,2X))                                         SCOUR 13
 1004 FORMAT(4H0I/J,8X,8(I6,6X))                                        SCOUR 14
 1006 FORMAT(1H1,3A6,11H GROUP NO.=,I6)                                 SCOUR 15
      RETURN                                                            SCOUR 16
      END                                                               SCOUR 17
$ORIGIN         ALPHA,SYSUT3,REW
$IBFTC NAGS1    NOLIST,  DECK,NODD,M94/2,XR7                            NAGS   1
      SUBROUTINE  NAG1( R,Z,RSF,ZSF,RS,ZS,VOLR,VOLZ,SC,TEMP,SG,UNU,CHI,  NAGS   2
     1SFPS,SFDS,DNM,SA,SF,SIN,SS,SAS,SINS,AMU,ESS,ENA,SA2200,LABEL,SNA,  NAGS   3
     2ECOS,DK,DE,DU,SAG,TSG,RI,ZI,SGB,SGT,SGL,SGR,RSN,ZSN,DKG,STC,       NAGS   4
     2STF,STI,                                                          NAGS   5
     3IC,JC,NID,NLM,I1,I2,I3,I4,I5,I6,                                  NAGS   6
     4I7     , I8     , I9     , I10    , I11    , I12    , I13    ,    NAGS   7
     5I14    , I15    , I16    , I17    )                              NAGS   8
      COMMON ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,IND,NTYPE             NAGS   9
      COMMON NCD,NBIN,NLIB,NEX,NEX1,ISTART,JSTART,NPUN  ,ZREF,JCO       NAGS  10
      DIMENSION RSF(I13),ZSF(I14),R(I10),Z(I12),RSN(I13),ZSN(I14),      NAGS  11
     1DKG(I8),RS(I13),ZS(I14),VOLR(I1),VOLZ(I3),SC(I1,I3),TEMP(I15),    NAGS  12
     2SG(I13,I14,I17),UNU(I5),CHI(I5),SFPS(I8),SFDS(I8),DNM(I9),        NAGS  13
     3SA(I5,I9),SF(I5,I9),SIN(I7,I9),SS(I6,I9),SAS(I8,I9),              NAGS  14
     4SINS(I8,I7,I9),AMU(I9),ESS(I9),ENA(I9),SA2200(I9),LABEL(I9),      NAGS  15
     5SNA(I5,I9),ECOS(I6,I9),DK(I5),DE(I5),DU(I5),SAG(I8,I9),TSG(I8),   NAGS  16
     6RI(I2),ZI(I4),SGT(I2,3),SGB(I2,3),SGL(I4,3),SGR(I4,3),IC(I2),     NAGS  17
     7JC(I4),NID(I9),NLM(I9),ID(12),TITLE(12),BUF(27)                   NAGS  18
     8,STC(I9) , STF(I9) , STI(I9)                                      NAGS  19
    2 CONTINUE                                                          NAGS  20
      REWIND 10                                                         NAGS  21
      REWIND 11                                                         NAGS  22
      REWIND 12
      READ(5,1032)(TITLE(I),I=1,12)                                     NAGS  23
      READ  (5,1028)NCD,NBIN,NLIB,NEX,NEX1,ISTART,JSTART,NPUN,JCO       NAGS  24
      READ (5,1000) ZREF                                                NAGS  25
 1000 FORMAT(6E12.5)                                                    NAGS  26
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```
      READ  (5,1030)ENU,EFF,EFK,VOLC,CONV,PK                                  NAGS  27
      READ  (5,1030)(CHI(I),I=1,NGN)                                          NAGS  28
      READ  (5,1030)(UNU(I),I=1,NGN)                                          NAGS  29
      READ  (5,1028)(IC(I),I=1,ICM)                                           NAGS  30
      READ  (5,1028)(JC(I),I=1,JCM)                                           NAGS  31
      READ  (5,1030)(R(I),I=1,I10)                                            NAGS  32
      READ  (5,1030)(Z(I),I=1,I12)                                            NAGS  33
      WRITE(6,1008)(TITLE(I),I=1,12)                                          NAGS  34
      WRITE (6,1026)                                                          NAGS  35
      WRITE (6,1010)  ICT,ICM,JCT,JCM,NCD,NGN,NGG,NEL                         NAGS  36
      WRITE (6,1012)NBIN,NLIB,NPUN,NEX,NEX1,ISTART,JSTART                     NAGS  37
      WRITE (6,1026)                                                          NAGS  38
      WRITE (6,1014)(IC(I),I=1,ICM)                                           NAGS  39
      WRITE (6,1016)(JC(I),I=1,JCM)                                           NAGS  40
      WRITE (6,1018)(R(I),I=1,I10)                                            NAGS  41
      WRITE (6,1020)(Z(I),I=1,I12)                                            NAGS  42
      WRITE(6,1024)(I,UNU(I),CHI(I),I=1,NGN)                                  NAGS  43
      WRITE (6,1002) ZREF                                                     NAGS  44
 1002 FORMAT(1H0,10X,27HZERO REFERENCE PLANE IS AT F12.6,7H INCHES )           NAGS  45
      PNORM=ENU*CONV/(PK*EFF*EFK*VOLC)                                        NAGS  46
      WRITE(6,1022) ENU,EFF,EFK,VOLC,PK,CONV,PNORM                            NAGS  47
      DO 4 J=1,I1                                                             NAGS  48
      DO 4 I=1,I3                                                             NAGS  49
    4 SC(I,J)=0.0                                                             NAGS  50
      NGT = I5                                                                NAGS  51
      IF (NTYPE.EQ.2) NGT = I5+I8                                             NAGS  52
      IF (NTYPE.EQ.3) NGT = I8                                                NAGS  53
C CALCULATE MESH INTERVAL AREAS AND VOLUMES ON ICT * JCT MESH                 NAGS  54
      DO 6 I=1,ICT                                                            NAGS  55
    6 VOLR(I) = 3.1415927*(R(I+1)*R(I+1)-R(I)*R(I))                           NAGS  56
      DO 8 J=1,JCT                                                            NAGS  57
    8 VOLZ(J) = Z(J+1)-Z(J)                                                   NAGS  58
C CALCULATE COLLAPSED MESH INTERVAL MIDPOINTS                                 NAGS  59
      IK = ISTART                                                             NAGS  60
      DO 10 I=1,ICM                                                           NAGS  61
      IL = IC(I)                                                              NAGS  62
      RI(I) = 0.5*(R(IL)+R(IK))                                               NAGS  63
   10 IK = IC(I)                                                              NAGS  64
      J1 = JSTART                                                             NAGS  65
      DO 12 J = 1,JCM                                                         NAGS  66
      J2 = JC(J)                                                              NAGS  67
      ZI(J) = 0.5*(Z(J2)+Z(J1))                                               NAGS  68
```


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```
   12 J1 = JC(J)                                                          NAGS  69
      K=1                                                                 NAGS  70
C     WHEN ODDK PROVIDES A BINARY FLUX TAPE
   14 READ(12)((SC(I,J),I=1,J1),J=1,I3)
      PPP = PNORM                                                         NAGS 115
      IF (NTYPE.EQ.2.AND.K.GT.I5) PPP = 1.0                               NAGS 116
      IF (NTYPE.EQ.3) PPP = 1.0                                           NAGS 117
      DO 32 I=1,I1                                                        NAGS 118
      DO 32 J=1,I3                                                        NAGS 119
   32 SC(I,J)=ABS(SC(I,J))*PPP                                            NAGS 120
C CALCULATE COLLAPSED FLUXES IN AN ICM * JCM MESH FROM THE ICT * JCT      NAGS 121
C VALUES                                                                  NAGS 122
      IF(ICM.LT.ICT) CALL COLR(SC,TEMP,VOLR,VOLZ,IC,JC,I1 ,I3 ,I1,I3,I2,NAGS 123
     1I4)                                                                 NAGS 124
      IF(JCM.LT.JCT) CALL COLZ(SC,TEMP,VOLR,VOLZ,IC,JC,I1 ,I3 ,I1,I3,I2,NAGS 125
     1I4)                                                                 NAGS 126
      WRITE (10)((SC(I,J),I=1,I2),J=1,I4)                                 NAGS 127
      IF(NTYPE.LT.3.AND.K.LE.I5)                                          NAGS 128
     1CALL SCOUT(SC,RI,ZI,I1,I3,  I2,I4,K,18HNEUTRON FLUXES     )         NAGS 129
      IF(NTYPE.EQ.3)                                                      NAGS 130
     1CALL SCOUT(SC,RI,ZI,I1,I3,  I2,I4,K,18HPHOTON FLUXES      )         NAGS 131
      IF(K.GT.I5)                                                         NAGS 132
     1CALL SCOUT(SC,RI,ZI,I1,I3,  I2,I4,K,18HPHOTON FLUXES      )         NAGS 133
      K=K+1                                                               NAGS 134
      IF(K.LE.NGT) GO TO 14                                               NAGS 135
      IF(NBIN.EQ.2) NBIN=1                                                NAGS 136
      REWIND 10                                                           NAGS 137
      REWIND 11                                                           NAGS 138
      REWIND 12
C CALCULATE AREAS AND RADII OF THE COLLAPSED (ICM*JCM) PROBLEM            NAGS 139
      IK = ISTART                                                         NAGS 140
      DO 34 I = 1,ICM                                                     NAGS 141
      IL = IC(I)                                                          NAGS 142
      VOLR(I) = 3.1415927*(R(IL)*R(IL)-R(IK)*R(IK))                       NAGS 143
      R(I) = R(IK)                                                        NAGS 144
   34 IK = IC(I)                                                          NAGS 145
      R(ICM+1) = R(IL)                                                    NAGS 146
      J1 = JSTART                                                         NAGS 147
      DO 36 J = 1,JCM                                                     NAGS 148
      J2 = JC(J)                                                          NAGS 149
      VOLZ(J) = Z(J2)-Z(J1)                                               NAGS 150
      Z(J) = Z(J1)                                                        NAGS 151
```


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   36 J1 = JC(J)                                                        NAGS 152
      Z(JCM+1) = Z(J2)                                                  NAGS 153
      RETURN                                                            NAGS 154
 1008 FORMAT(1H1//  ,47X,16H PROGRAM NAGS IV //  16X,12A6//)            NAGS 155
 1010 FORMAT(30H NO.OF RADIAL MESH INTERVALS**I3,/                      NAGS 156
     1       ,30H NO.OF COL.INTERVALS (R) *****I3,/                     NAGS 157
     2       ,30H NO. OF AXIAL MESH INTERVALS**I3,/                     NAGS 158
     3       ,30H NO. OF COL. INTERVALS (Z) ***I3,/                     NAGS 159
     4       ,30H NO. OF BIN. FLUX CARDS*******I3,/                     NAGS 160
     5       ,30H NO. OF NEUTRON GROUPS********I3,/                     NAGS 161
     6       ,30H NO. OF GAMMA RAY GROUPS******I3,/                     NAGS 162
     7       ,30H NO. OF MATERIALS*************I3,/  )                  NAGS 163
 1012 FORMAT(30H BINARY CARD OPTION***********I3,/                       NAGS 164
     1       ,30H LIBRARY OPTION**************I3,/                      NAGS 165
     2       ,30H PUNCH OPTION****************I3,/                      NAGS 166
     3       ,30H NO. OF ZEROS (RT)***********I3,/                      NAGS 167
     4       ,30H NO. OF ZEROS (LT)***********I3,/                      NAGS 168
     5       ,30H STARTING INTERVAL(R)********I3,/                      NAGS 169
     6       ,30H STARTING INTERVAL(Z)********I3,/ )                    NAGS 170
 1014 FORMAT (8H0IC(I)   ,24I3,/,8X,24I3)                               NAGS 171
 1016 FORMAT (8H0JC(J)   ,24I3,/,8X,24I3)                               NAGS 172
 1018 FORMAT(6H0R(I) ,10F8.3//(6X,10F8.3/))                             NAGS 173
 1020 FORMAT(6H0Z(J) ,10F8.3//(6X,10F8.3/))                             NAGS 174
 1022 FORMAT(34H1PROBLEM NORMALIZATION PARAMETERS      ///              NAGS 175
     1        32H   EFFECTIVE NU ***************1PE14.5//              NAGS 176
     2        32H   FISSION FRACTION ***********  E14.5//              NAGS 177
     3        32H   KEFF *********************    E14.5//              NAGS 178
     4        32H   FISSION VOLUME *************  E14.5//              NAGS 179
     5        32H   CONVERSION CONSTANT ********  E14.5//              NAGS 180
     6        32H   NORMALIZATION CONSTANT ******  E14.5//             NAGS 181
     7        32H   POWER NORMALIZATION FACTOR **  E14.5)              NAGS 182
 1024 FORMAT(38H1NEUTRON FISSION PARAMETERS BY GROUP                    //NAGS 183
     1        38H   GROUP      NU              CHI                   /  NAGS 184
     2(4X,I2,5X,2E14.5/))                                               NAGS 185
 1026 FORMAT(55(2H. ))                                                  NAGS 186
 1028 FORMAT(24I3)                                                      NAGS 187
 1030 FORMAT(6E12.5)                                                    NAGS 188
 1032 FORMAT(12A6)                                                      NAGS 189
 1034 FORMAT (8X,6E10.5)                                                NAGS 190
      END                                                               NAGS 191
$ORIGIN        BETA,SYSUT3,REW
$IBFTC COLRR   NOLIST,  DECK,NODD,M94/2,XR7                             COLZR  1
```


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```
      SUBROUTINE COLR(A,B,VR,VZ,IC,JC,I1,I2,I3,I4,I5,I6)                COLZR  2
      DIMENSION A(I1,I2),B(I1,I2),VR(I3),VZ(I4),IC(I5),JC(I6)           COLZR  3
      COMMON ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,IND,NTYPE             COLZR  4
      COMMON NCD,NBIN,NLIB,NEX,NEX1,ISTART,JSTART,NPUN  ,ZREF,JCO       COLZR  5
      DO 4 J=1,I4                                                       COLZR  6
      IK = ISTART                                                       COLZR  7
      DO 4 I =1,I5                                                      COLZR  8
      IL=IC(I)-1                                                        COLZR  9
      VT = 0.0                                                          COLZR 10
      B(I,J) = 0.0                                                      COLZR 11
      IF(IL.EQ.IK) A(I,J)=A(IK,J)                                       COLZR 12
      IF(IL.EQ.IK) GO TO 4                                              COLZR 13
      DO 2 K = IK,IL                                                    COLZR 14
      VT = VT + VR(K)                                                   COLZR 15
    2 B(I,J) = B(I,J) + VR(K) * A(K,J)                                  COLZR 16
      A(I,J) = B(I,J) / VT                                              COLZR 17
    4 IK = IC(I)                                                        COLZR 18
      RETURN                                                            COLZR 19
      END                                                               COLZR 20
$ORIGIN        BETA,SYSUT3,REW
$IBFTC COLZR   NOLIST,  DECK,NODD,M94/2,XR7                             COLZ
      SUBROUTINE COLZ(A,B,VR,VZ,IC,JC,I1,I2,I3,I4,I5,I6)                COLZ
      DIMENSION A(I1,I2),B(I1,I2),VR(I3),VZ(I4),IC(I5),JC(I6)           COLZ
      COMMON ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,IND,NTYPE             COLZ
      COMMON NCD,NBIN,NLIB,NEX,NEX1,ISTART,JSTART,NPUN  ,ZREF,JCO       COLZ
      DO 20 I=1,I5                                                      COLZ
      J1 = JSTART                                                       COLZ
      DO 20 J = 1,I6                                                    COLZ
      J2=JC(J)-1                                                        COLZ
      VT = 0.0                                                          COLZ
      B(I,J) = 0.0                                                      COLZ
      IF(J1.EQ.J2) A(I,J)=A(I,J1)                                       COLZ
      IF(J1.EQ.J2) GO TO 20                                             COLZ
      DO 30 K = J1,J2                                                   COLZ
      VT = VT + VZ(K)                                                   COLZ
   30 B(I,J) = B(I,J) + VZ(K) * A(I,K)                                  COLZ
      A(I,J) = B(I,J) / VT                                              COLZ
   20 J1 = JC(J)                                                        COLZ
      RETURN                                                            COLZ
      END                                                               COLZ
$ORIGIN        ALPHA,SYSUT3,REW
$IBFTC NAGS2   NOLIST,  DECK,NODD,M94/2,XR7                             NA     1
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```
      SUBROUTINE  NAG2( R,Z,RSF,ZSF,RS,ZS,VOLR,VOLZ,SC,TEMP,SG,UNU,CHI,  NA      2
     1SFPS,SFDS,DNM,SA,SF,SIN,SS,SAS,SINS,AMU,ESS,ENA,SA2200,LABEL,SNA,  NA      3
     2ECOS,DK,DE,DU,SAG,TSG,RI,ZI,SGB,SGT,SGL,SGR,RSN,ZSN,DKG,STC,       NA      4
     2STF,STI,                                                           NA      5
     3IC,JC,NID,NLM,I1,I2,I3,I4,I5,I6,                                   NA      6
     4I7     , I8     , I9     , I10    , I11    , I12    , I13    ,     NA      7
     5I14    , I15    , I16    , I17    )                                NA      8
      COMMON ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,IND,NTYPE              NA      9
      COMMON NCD,NBIN,NLIB,NEX,NEX1,ISTART,JSTART,NPUN  ,ZREF,JCO        NA     10
      DIMENSION RSF(I13),ZSF(I14),R(I10),Z(I12),RSN(I13),ZSN(I14),       NA     11
     1DKG(I8),RS(I13),ZS(I14),VOLR(I1),VOLZ(I3),SC(I1,I3),TEMP(I15),     NA     12
     2SG(I13,I14,I17),UNU(I5),CHI(I5),SFPS(I8),SFDS(I8),DNM(I9),         NA     13
     3SA(I5,I9),SF(I5,I9),SIN(I7,I9),SS(I6,I9),SAS(I8,I9),               NA     14
     4SINS(I8,I7,I9),AMU(I9),ESS(I9),ENA(I9),SA2200(I9),LABEL(I9),       NA     15
     5SNA(I5,I9),ECOS(I6,I9),DK(I5),DE(I5),DU(I5),SAG(I8,I9),TSG(I8),    NA     16
     6RI(I2),ZI(I4),SGT(I2,3),SGB(I2,3),SGL(I4,3),SGR(I4,3),IC(I2),      NA     17
     7JC(I4),NID(I9),NLM(I9),ID(12),TITLE(12),BUF(27)                    NA     18
     8,STC(I9) , STF(I9) , STI(I9)                                       NA     19
C     READ LIBRARY CONSTANTS FROM POINT CODE                            NA     20
C      CROSS DEFINITION                          DIMENSION              NA     21
C          POINT          NAGS                                          NA     22
C          ID             NID      GAM ID NO.       (NEL)              NA     23
C          A9             AMU      ATOMIC MASS UN.  (NEL)              NA     24
C          A10            ESS      (1-ALPHA)/2.0    (NEL)              NA     25
C          A14            ENA      Q(N,ALPHA)       (NEL)              NA     26
C          A16            SA2200   SIGMA(2200 M.)   (NEL)              NA     27
C          LABEL          LABEL    NUCLIDE NAME     (NEL)              NA     28
C                                                                       NA     29
C          A2             SAS      Q(N,GAMMA)       (NGG,NEL)          NA     30
C          A6             SINS     Q(N,N#,GAMMA)    (NGG,NI,NEL)       NA     31
C          A15            SNA      SIGMA(N,ALPHA)   (NGN,NEL)          NA     32
C          A1             ECOS     1-COS(THETA)     (NFAST,NEL)        NA     33
C          A7             SFPS     PROMPT FISS. G.  (NGG)              NA     34
C          A8             SFDS     DELAY FISS. GA.  (NGG)              NA     35
C           --             DKG      GAMMA DOSE C.    (NGG)              NA     36
C          A4             DK       NEUTRON DOSE C.  (NFAST)            NA     37
C          A12            DE       ENERGY WIDTH     (NGN)              NA     38
C          A13            DU       LETHARGY WIDTH   (NGN)              NA     39
C          SIGFI          SF       SIGMA FISSION    (NGN,NEL)          NA     40
C          SIGA           SA       SIGMA ABS.       (NGN,NEL)          NA     41
C          SINELA         SIN      SIGMA INELASTIC  (NI,NEL)          NA     42
C          SSYMET         SS       SIGMA ELASTIC    (NFAST,NEL)        NA     43
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C          ***          SAG       GAMMA RAY EAC    (NGG,NEL)                    NA    44
      REWIND 9                                                                  NA    45
      REWIND 10                                                                 NA   A45
    2 READ(5,1002)NEL                                                           NA    46
      READ(5,1004)  (SFPS(K1),K1=1,NGG)                                         NA    47
      READ(5,1004)  (SFDS(K1),K1=1,NGG)                                         NA    48
      READ(5,1004)  (DKG(K1),K1=1,NGG)                                          NA    49
      READ (5,1004)  (DK(J),J=1,NGN)                                            NA    50
      READ (5,1004)  (DU(J),J=1,NGN)                                            NA    51
      READ (5,1004)  (DE(J),J=1,NGN)                                            NA    52
      DO 6 N=1,NEL                                                              NA    53
      READ (5,1006) NID(N),AMU(N),ESS(N),ENA(N),SA2200(N),LABEL(N)              NA    54
      DO 4 K=1,NI                                                               NA    55
    4 READ (5,1004)   (SINS(K1,K,N),K1=1,NGG)                                   NA    56
      READ(5,1004)(SS(K,N),K=1,NFAST)
      READ (5,1004)(SNA(K,N),K=1,NGN)                                           NA    58
      READ (5,1004)(ECOS(K,N),K=1,NFAST)                                        NA    59
      READ (5,1004)(SAS(K,N),K=1,NGG)                                           NA    60
      READ (5,1004)(SAG(K,N),K=1,NGG)                                           NA    61
      IF(NLIB.EQ.0) GO TO 6
      READ(5,1004)  (SF(K,N),K=1,NGN)
      READ(5,1004)(SA(K,N),K=1,NGN)
      READ(5,1004)(SS(K,N),K=1,NFAST)
      READ(5,1004)(SIN(K,N),K=1,NI)
    6 CONTINUE
      WRITE (6,1008)                                                            NA    62
      WRITE(6,1038)  (SFPS(K1),K1=1,NGG)                                        NA    63
      WRITE(6,1038)  (SFDS(K1),K1=1,NGG)                                        NA    64
      WRITE(6,1038)  (DKG(K1),K1=1,NGG)                                         NA    65
       WRITE(6,1044)                                                            NA    66
      WRITE(6,1038)  (DK(JK),JK=1,NGN)                                          NA    67
      WRITE(6,1046)                                                             NA    68
      WRITE(6,1038)  (DU(JK),JK=1,NGN)                                          NA    69
      WRITE(6,1048)                                                             NA    70
      WRITE(6,1038)  (DE(JK),JK=1,NGN)                                          NA    71
      DO 8 N=1,NEL                                                              NA    72
      WRITE(6,1026)N                                                            NA    73
      WRITE(6,1028)                                                             NA    74
      WRITE(6,1024)  NID(N),AMU(N),ESS(N),ENA(N),SA2200(N),LABEL(N)             NA    75
      WRITE(6,1030)                                                             NA    76
      WRITE (6,1020)  NID(N),(SAS(K1,N),K1=1,NGG)                               NA    77
      WRITE(6,1032)                                                             NA    78
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      WRITE (6,1020) NID(N),(SAG(K1,N),K1=1,NGG)                        NA     79
      WRITE(6,1034)                                                     NA     80
      DO 8 K=1,NI                                                       NA     81
    8 WRITE (6,1022) NID(N),K,(SINS(K1,K,N),K1=1,NGG)                   NA     82
   10 NPASS=0                                                           NA     83
      DO 12 I=1,I13                                                     NA     84
      DO 12 J=1,I14                                                     NA     85
      DO 12 K=1,I17                                                     NA     86
   12 SG(I,J,K)=0.0                                                     NA     87
      NPROB=0                                                           NA     88
   14 READ(5,1010) (ID(I),I=1,12)                                       NA     89
      WRITE (6,1014)(ID(I),I=1,12)                                      NA     90
      READ  (5,1002)IRS,IRF,IZS,IZF,IEL,IND                             NA     91
      WRITE (6,1016)IRS,IRF,IZS,IZF,IEL,IND                             NA     92
      IR1 = IRF + 1                                                     NA     93
      IZ1 = IZF + 1                                                     NA     94
      IF (NTYPE.GT.1) READ (5,1004) DGM,WTGM                            NA     95
      WRITE (6,1040)                                                    NA     96
C     READ IN GROUP CONSTANTS FOR MICROSCOPIC MATERIALS AND COMPUTE GAMMNA     97
C     A RAY SOURCES                                                     NA     98
      NSKIP=0                                                           NA     99
      IF(IEL.GT.0)GO TO 16                                              NA    100
      NSKIP=1                                                           NA    101
      IEL=-IEL                                                          NA    102
   16 DO 28 M=1,IEL                                                     NA    103
      STC(M)  = 0.0                                                     NA    104
      STI(M) = 0.0                                                      NA    105
      STF(M) = 0.0                                                      NA    106
      IF(NSKIP.EQ.1)GO TO 18                                            NA    107
      READ(5,1042) NLM(M),DNM(M)                                        NA    108
      IF (NTYPE.GT.1) GO TO 18                                          NA    109
      IF(NLIB.GT.0) GO TO 18
      READ (5,1004)(SF(K,M),K=1,NGN)                                    NA    110
      READ (5,1004)(SA(K,M),K=1,NGN)                                    NA    111
      READ (5,1004)(SS(K,M),K=1,NFAST)                                  NA    112
      READ (5,1004)(SIN(K,M),K=1,NI)                                    NA    113
   18 NL = NLM(M)                                                       NA    114
      DO 20 JJ=1,NEL                                                    NA    115
      IF (NL.EQ.NID(JJ)) GO TO 22                                       NA    116
   20 CONTINUE                                                          NA    117
      WRITE (6,1000) NL                                                 NA    118
      GO TO 28                                                          NA    119
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   22 ID1=LABEL(JJ)                                                    NA   120
   24 WRITE(6,1018) NLM(M),DNM(M),ID1                                  NA   121
      IF (NTYPE.GT.1) GO TO 26                                         NA   122
      MJ=M
      IF(NLIB.GT.0) MJ=JJ
      WRITE (6,1038)(SF(K,MJ),K=1,NGN)
      WRITE (6,1038)( SA(K,MJ),K=1,NGN)
      WRITE (6,1038)(SIN(K,MJ),K=1,NI)
   26 WRITE (6,1038)(SS(K,MJ),K=1,NFAST)
      WRITE (6,1038)(SAG(K,JJ),K=1,NGG)                                NA   127
   28 WRITE(6,1040)                                                    NA   128
      NGT = I5                                                         NA   129
      IF(NTYPE.EQ.2) NGT=I5 + I8                                       NA   130
      IF(NTYPE.EQ.3) NGT=I8                                            NA   131
      DO 32 L = 1,3                                                    NA   132
      DO 30 J=IZS,IZ1                                                  NA   133
      SGL(J,L) = 0.0                                                   NA   134
   30 SGR(J,L) = 0.0                                                   NA   135
      DO 32 I=IRS,IR1                                                  NA   136
      SGT(I,L) = 0.0                                                   NA   137
   32 SGB(I,L) = 0.0                                                   NA   138
      DO 68 K=1,NGT                                                    NA   139
      READ (10)((SC(I,J),I=1,I2),J=1,I4)                               NA   140
      DO 66 M=1,IEL                                                    NA   141
      NL = NLM(M)                                                      NA   142
      DO 34 JJ=1,NEL                                                   NA   143
      IF (NL.EQ.NID(JJ)) GO TO 36                                      NA   144
   34 CONTINUE                                                         NA   145
      WRITE (6,1000) NL                                                NA   146
      GO TO  66                                                        NA   147
   36 KLB = K - I5                                                     NA   148
      MJ=M
      IF(NLIB.GT.0) MJ=JJ
      IF(NTYPE.EQ.2.AND.K.GT.NFAST.AND.K.LE.I5) GO TO 68               NA   149
      IF (NTYPE.NE.1) GO TO 38                                         NA   150
      SAC = SA(K,MJ)*DNM(M)
      SFC = SF(K,MJ)*DNM(M)
      SIC = 0.0                                                        NA   153
      IF(K.LE.NI) SIC = SIN(K,MJ)*DNM(M)
      GO TO 42                                                         NA   155
   38 IF (NTYPE.GT.2) GO TO 40                                         NA   156
      IF (K.GT.I5) SAC = SAG(KLB,JJ)*1.603E-13*DNM(M)*DGM              NA   157
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      IF (K.LE.NFAST) SAC = SS(K,JJ)*DE(K)*ESS(JJ)*ECOS(K,JJ)*1.603E-13*NA    158
     10.60248*DNM(M)*DGM/(AMU(JJ)*DU(K))
      SFC=0.0
      GO TO 42                                                               NA    160
   40 SAC = SAG(K,JJ)*1.603E-13*DNM(M)*DGM                                   NA    161
      SFC=0.0
   42 NGF=I17-1
      DO 48 I = IRS,IR1                                                      NA    163
      DO 48 J = IZS,IZ1                                                      NA    164
      SCV = SC(I,J)*VOLR(I)*VOLZ(J)                                          NA    165
      STI(M) = STI(M) + SIC*SCV                                              NA    166
      STC(M) = STC(M) + SAC*SCV                                              NA    167
      STF(M) = STF(M) + SFC*SCV                                              NA    168
      IF(NTYPE.GT.1) GO TO 46                                                NA    169
      DO 44 KG = 1,NGG                                                       NA    170
      SG(I,J,KG) = SG(I,J,KG) + SC(I,J) * (SAC*SAS(KG,JJ)+SFC*(SFPS(KG)+NA    171
     1SFDS(KG)))                                                             NA    172
      IF(K.LE.NI) SG(I,J,KG) = SG(I,J,KG) + SIC*SINS(KG,K,JJ) *SC(I,J)       NA    173
   44 CONTINUE                                                               NA    174
      SG(I,J,NGF) = SG(I,J,NGF) + SFC   *SC(I,J)                             NA    175
      SG(I,J,I17) = SG(I,J,I17) + SFC* UNU(K)   *SC(I,J)                     NA    176
      GO TO 48                                                               NA    177
   46 IF(NTYPE.EQ.2.AND.K.GT.I5) SG(I,J,1) = SG(I,J,1)+SAC*SC(I,J)           NA    178
      IF(NTYPE.EQ.3) SG(I,J,1) = SG(I,J,1)+SAC*SC(I,J)                       NA    179
      IF(NTYPE.EQ.2.AND.K.LE.NFAST) SG(I,J,2)=SG(I,J,2)+SAC*SC(I,J)          NA    180
      SG(I,J,I17) = SG(I,J,I17) + SAC *SC(I,J)                               NA    181
   48 CONTINUE                                                               NA    182
      SGARB=0.0                                                              NA    183
      DO 50 KG=1,NGG                                                         NA    184
   50 SGARB =(SAC*SAS(KG,JJ)+SFC*(SFPS(KG)+SFDS(KG))+SIC*SINS(KG,K,JJ))      NA    185
     1 +SGARB                                                                NA    186
      DO 56 J = IZS,IZ1                                                      NA    187
      IF(NTYPE.GT.1) GO TO 54                                                NA    188
      IF(IRS.EQ.1) GO TO 52                                                  NA    189
      SGL(J,1) = SGL(J,1)+ SGARB * SC(IRS-1,J)                               NA    190
      SGL(J,2) = SGL(J,2) + SFC*SC(IRS-1,J)                                  NA    191
      SGL(J,3) = SGL(J,3) + SFC*SC(IRS-1,J)*UNU(K)                           NA    192
   52 IF(IR1.EQ.I2) GO TO 56                                                 NA    193
      SGR(J,1) = SGR(J,1) + SGARB*SC(IR1+1,J)                                NA    194
      SGR(J,2) = SGR(J,2) + SFC*SC(IR1+1,J)                                  NA    195
      SGR(J,3) = SGR(J,3) + SFC*SC(IR1+1,J)*UNU(K)                           NA    196
      GO TO 56                                                               NA    197
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   54 IF(IRS.GT.1) SGL(J,1) = SGL(J,1) + SAC*SC(IRS-1,J)                    NA   198
      IF(IR1.LT.I2) SGR(J,1) = SGR(J,1) + SAC*SC(IR1+1,J)                   NA   199
   56 CONTINUE                                                              NA   200
      DO 64 I = IRS,IR1                                                     NA   201
      IF(NTYPE.GT.1) GO TO 62                                               NA   202
      IF(IZS.EQ.1) GO TO 58                                                 NA   203
      SGB(I,1) = SGB(I,1)+ SGARB * SC(I,IZS-1)                              NA   204
      SGB(I,2) = SGB(I,2)+ SFC   * SC(I,IZS-1)                              NA   205
      SGB(I,3) = SGB(I,3)+ SFC   * SC(I,IZS-1)*UNU(K)                       NA   206
   58 IF(IZ1.EQ.I3) GO TO 64                                                NA   207
      SGT(I,1) = SGT(I,1)+SGARB*SC(I,IZ1+1)                                 NA   208
      SGT(I,2) = SGT(I,2)+SFC  *SC(I,IZ1+1)                                 NA   209
      SGT(I,3) = SGT(I,3)+SFC  *SC(I,IZ1+1)*UNU(K)                          NA   210
   60 GO TO 64                                                              NA   211
   62 IF(IZS.GT.1) SGB(I,1) = SGB(I,1) + SAC*SC(I,IZS-1)                    NA   212
      IF(IZ1.LT.I4) SGT(I,1) = SGT(I,1) + SAC*SC(I,IZ1+1)                   NA   213
   64 CONTINUE                                                              NA   214
   66 CONTINUE                                                              NA   215
   68 CONTINUE                                                              NA   216
      REWIND 10                                                             NA   217
      WRITE(9) IRS,IRF,IZS,IZF, IEL,IND,DGM,WTGM,(NLM(M),DNM(M),M=1,IEL)    NA   218
     1,(ID(I),I=1,12)                                                       NA   219
      WRITE (9) (((SG(I,J,K),I=IRS,IR1),J=IZS,IZ1),K=1,I17), ((SGL(J,L),    NA   220
     1SGR(J,L),J=IZS,IZ1),L=1,3),((SGB(I,L),SGT(I,L),I=IRS,IR1),L=1,3)      NA   221
     2,(STC(M),STF(M),STI(M),M=1,NEL)                                       NA   222
      DO 70 I=IRS,IR1                                                       NA   223
      DO 70 J=IZS,IZ1                                                       NA   224
      DO 70 K=1,I17                                                         NA   225
   70 SG(I,J,K) = 0.0                                                       NA   226
      NPROB=NPROB+1                                                         NA   227
      IF (IND.EQ.1) GO TO 14                                                NA   228
      WRITE(6,1050) NPROB                                                   NA   229
      REWIND 9                                                              NA   230
      RETURN                                                                NA   231
 1000 FORMAT(13H0ELEMENT NO. I3,18H IS NOT IN LIBRARY)                      NA   232
 1002 FORMAT(24I3)                                                          NA   233
 1004 FORMAT(6E12.5)                                                        NA   234
 1006 FORMAT(I3,4E12.5,10X,A6)                                              NA   235
 1008 FORMAT (/74H1PROMPT FISSION AND FISSION PROD. DECAY SPECTRA AND GANA   236
     1GAMMA DOSE CONSTANTS)                                                 NA   237
 1010 FORMAT(12A6)                                                          NA   238
 1012 FORMAT (8X,6E10.5)                                                    NA   239
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 1014 FORMAT(14H1REGION OUTPUT//55(2H .)/19X12A6/55(2H .)/)                    NA   240
 1016 FORMAT(52H0REGION PARAMETERS(IS,IF,JS,JF,NO. OF ELEM.,CONTROL)//6INA   241
     14)                                                                      NA   242
 1018 FORMAT(13H0ELEMENT NO.=I4,13H NO. DENSITY=1PE12.4,13H ELEMENT ID  NA   243
     1A6//71H CROSS SECTIONS(ELASTIC SCATTER AND GAMMA RAY ENERGY ABSORPNA   244
     1TION)          )                                                        NA   245
 1020 FORMAT(I4,4X,1P8E12.4/(8X,8E12.4 ))                                     NA   246
 1022 FORMAT(2I4,1P8E12.4/(8X,8E12.4 ))                                       NA   247
 1024 FORMAT(I4,4X,1P4E12.4,2X,A6)                                            NA   248
 1026 FORMAT(30H1LIBRARY DATA FOR ELEMENT NO. I3 /)                           NA   249
 1028 FORMAT( 4H GAM6X6HA.M.U.6X9H(1.-AL)/23X8H(Q(N,AL)4X19HSIGMA ABS.  NA   250
     1ELEMENT/4H ID 43X16H(2200 M)     NAME)                                  NA   251
 1030 FORMAT(1H09X10HQ(N,GAMMA))                                              NA   252
 1032 FORMAT(1H09X27HMASS ABSORPTION COEFFICIENT/)                            NA   253
 1034 FORMAT(1H0,5X,17HGRP Q(N,N*,GAMMA))                                     NA   254
 1036 FORMAT(I4,4X,3E12.4/)                                                   NA   255
 1038 FORMAT(/(8X,1P8E12.4))                                                  NA   256
 1040 FORMAT(55(2H. ))                                                        NA   257
 1042 FORMAT(I3,E12.4)                                                        NA   258
 1044 FORMAT(1H01X22HNEUTRON DOSE CONSTANTS)                                  NA   259
 1046 FORMAT(1H01X23HLETHARGY WIDTH BY GROUP)                                 NA   260
 1048 FORMAT(1H01X21HENERGY WIDTH BY GROUP)                                   NA   261
 1050 FORMAT(23H1NAGS IV HAS PROCESSED I5, 25H SEPERATE REGION PROBLEMS)NA   262
      END                                                                     NA   263
$ORIGIN         ALPHA,SYSUT3,REW
$IBFTC NAGS3    NOLIST,  DECK,NODD,M94/2,XR7                                 NAG    1
       SUBROUTINE  NAG3( R,Z,RSF,ZSF,RS,ZS,VOLR,VOLZ,SC,TEMP,SG,UNU,CHI,  NAG    2
      1SFPS,SFDS,DNM,SA,SF,SIN,SS,SAS,SINS,AMU,ESS,ENA,SA2200,LABEL,SNA,  NAG    3
      2ECOS,DK,DE,DU,SAG,TSG,RI,ZI,SGB,SGT,SGL,SGR,RSN,ZSN,DKG,STC,       NAG    4
      2STF,STI,                                                           NAG    5
      3IC,JC,NID,NLM,I1,I2,I3,I4,I5,I6,                                   NAG    6
      4I7     , I8     , I9     , I10    , I11    , I12    , I13    ,     NAG    7
      5I14    , I15    , I16    , I17    )                                NAG    8
       COMMON ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,IND,NTYPE               NAG    9
       COMMON NCD,NBIN,NLIB,NEX,NEX1,ISTART,JSTART,NPUN  ,ZREF,JCO         NAG   10
       DIMENSION RSF(I13),ZSF(I14),R(I10),Z(I12),RSN(I13),ZSN(I14),        NAG   11
      1DKG(I8),RS(I13),ZS(I14),VOLR(I1),VOLZ(I3),SC(I1,I3),TEMP(I15),     NAG   12
      2SG(I13,I14,I17),UNU(I5),CHI(I5),SFPS(I8),SFDS(I8),DNM(I9),         NAG   13
      3SA(I5,I9),SF(I5,I9),SIN(I7,I9),SS(I6,I9),SAS(I8,I9),               NAG   14
      4SINS(I8,I7,I9),AMU(I9),ESS(I9),ENA(I9),SA2200(I9),LABEL(I9),       NAG   15
      5SNA(I5,I9),ECOS(I6,I9),DK(I5),DE(I5),DU(I5),SAG(I8,I9),TSG(I8),    NAG   16
      6RI(I2),ZI(I4),SGT(I2,3),SGB(I2,3),SGL(I4,3),SGR(I4,3),IC(I2),      NAG   17
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     7JC(I4),NID(I9),NLM(I9),ID(12),TITLE(12),BUF(27)                    NAG   18
     A,STC(I9) , STF(I9) , STI(I9)                                       NAG   19
      DIMENSION SGLT(3),SGRT(3),SGBT(3),SGTP(3)                          NAG   20
    2 READ (9) IRS,IRF,IZS,IZF, IEL,IND,DGM,WTGM,(NLM(M),DNM(M),M=1,IEL) NAG   21
     1,(ID(I),I=1,12)                                                    NAG   22
      IR1 = IRF - 1                                                      NAG   23
      IZ1 = IZF - 1                                                      NAG   24
      READ  (9) (((SG(I,J,K),I=IRS,IR1),J=IZS,IZ1),K=1,I17), ((SGL(J,L),NAG   25
     1SGR(J,L),J=IZS,IZ1),L=1,3),((SGB(I,L),SGT(I,L),I=IRS,IR1),L=1,3)   NAG   26
     2,(STC(M),STF(M),STI(M),M=1,NEL)                                    NAG   27
      VOLT =0.0                                                          NAG   28
      TSG(1)=0.0                                                         NAG   29
      TSG(2)=0.0                                                         NAG   30
      SGLT(1)=0.                                                         NAG   31
      SGRT(1)=0.                                                         NAG   32
      SGTP(1)=0.                                                         NAG   33
      SGBT(1)=0.                                                         NAG   34
      TS = 0.0                                                           NAG   35
      DO 4 I = IRS,IR1                                                   NAG   36
      SGTP(1)=SGTP(1)+SGT(I,1)*VOLR(I)                                   NAG   37
      SGBT(1)=SGBT(1)+SGB(I,1)*VOLR(I)                                   NAG   38
      RSF(I) = RI(I)/2.54                                                NAG   39
    4 RS(I)=0.0                                                          NAG   40
      DO 6 J = IZS,IZ1                                                   NAG   41
      SGRT(1)=SGRT(1)+SGR(J,1)*VOLZ(J)                                   NAG   42
      SGLT(1)=SGLT(1)+SGL(J,1)*VOLZ(J)                                   NAG   43
      ZSF(J) = ZREF -ZI(J)/2.54                                          NAG   44
    6 ZS(J)=0.0                                                          NAG   45
      DO 8 J = IZS,IZ1                                                   NAG   46
      DO 8 I = IRS,IR1                                                   NAG   47
    8 RS(I) = RS(I) + SG(I,J,3)*VOLZ(J)                                  NAG   48
      DO 10 I = IRS,IR1                                                  NAG   49
      DO 10 J = IZS,IZ1                                                  NAG   50
   10 ZS(J)=ZS(J)+ SG(I,J,3) *VOLR(I)                                    NAG   51
      VOLT = 0.0                                                         NAG   52
      DO 12 I=IRS,IR1                                                    NAG   53
      DO 12 J=IZS,IZ1                                                    NAG   54
      VOLI = VOLR(I)*VOLZ(J)                                             NAG   55
      VOLT = VOLT + VOLI                                                 NAG   56
      DO 12 K=1,2                                                        NAG   57
   12 TSG(K) = TSG(K) + SG(I,J,K)*VOLI                                   NAG   58
      TS = TSG(1) + TSG(2)                                               NAG   59
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      VOLTR=0.0                                                          NAG   60
      DO 14 I=IRS,IR1                                                    NAG   61
   14 VOLTR=VOLTR+VOLR(I)                                                NAG   62
      VOLTZ=0.0                                                          NAG   63
      DO 16 J=IZS,IZ1                                                    NAG   64
   16 VOLTZ=VOLTZ+VOLZ(J)                                                NAG   65
      DO 18 I=IRS,IR1                                                    NAG   66
   18 RS(I) =RS(I) *VOLTR/TS                                             NAG   67
      DO 20 J=IZS,IZ1                                                    NAG   68
   20 ZS(J)=ZS(J)*VOLTZ/TS                                               NAG   69
      TSA = TS/VOLT                                                      NAG   70
      SGLT(1)=SGLT(1)/(TSA*VOLTZ)                                        NAG   71
      SGRT(1)=SGRT(1)/(TSA*VOLTZ)                                        NAG   72
      SGBT(1)=SGBT(1)/(TSA*VOLTR)                                        NAG   73
      SGTP(1)=SGTP(1)/(TSA*VOLTR)                                        NAG   74
      CALL SISET(SGLT(1),SGRT(1),SGBT(1),SGTP(1),R,RI,Z,ZI,I1,I2,I3,I4,  NAG   75
     2I10,I12,I13,I14,IRS,IR1,IZS,IZ1,1,RS,ZS)                           NAG   76
C THE FOLLOWING SECTION IS THE CALCULATION OF ALL QUANITIES IN METRIC     NAG   77
C AND MIXED ENGLISH UNITS                                                NAG   78
C TSG(1),THE INTEGRATED PHOTON HEATING IN THE REGION                     NAG   79
C TSG(2),THE TOTAL INTEGRATED NEUTRON HEATING IN THE REGION              NAG   80
C TS  IS THE TOTAL NEUTRON PLUS PHOTON INTEGRATED HEATING IN THE REGION  NAG   81
C VOLTR IS THE RADIAL CROSS SECTIONAL AREA OF THE REGION                 NAG   82
C VOLTZ IS THE HEIGHT OF THE REGION                                      NAG   83
C RSF  IS THE RADIAL MESH LINE DIMENSION IN INCHES                       NAG   84
C ZSF  IS THE AXIAL  MESH LINE DIMENSION IN INCHES                       NAG   85
C     DGM IS THE DENSITY OF MATERIAL IN GMS/CC                           NAG   86
C     WTGM IS THE WEIGHT OF MATERIAL IN KILOGRAMS                        NAG   87
C     DLB IS THE DENSITY IN LBS/IN**3                                    NAG   88
C     WTLB IS THE WEIGHT IN LBS                                          NAG   89
C     VOLTI IS THE VOLUME OF THE REGION IN CUBIC INCHES                  NAG   90
C     TSWC IS THE TOTAL HEATING RATE IN WATTS/CC                         NAG   91
      L=3                                                                NAG   92
      DO 22 I=IRS,IR1                                                    NAG   93
      DO 22 J=IZS,IZ1                                                    NAG   94
   22 SG(I,J,L) = SG(I,J,L) * 55.9616                                    NAG   95
      DLB = DGM * 0.03613                                                NAG   96
      WTLB = WTGM * 2.205                                                NAG   97
      VOLTI = VOLT / 16.387                                              NAG   98
      TSWC = TS / VOLT                                                   NAG   99
      TSW =  TSWC * WTGM / DGM                                           NAG  100
      TSG(1) = TSG(1) * WTGM / (DGM*VOLT)                                NAG  101
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      TSG(2) = TSG(2) * WTGM / (DGM*VOLT)                                NAG  102
      TSB = TSW * 3.415E+03                                              NAG  103
      TSWG = TSWC / DGM                                                  NAG  104
      TSBI = TSWC * 55.9616                                              NAG  105
      TSBL = TSBI / DLB                                                  NAG  106
      WRITE (6,1032) (ID(I),I=1,12)                                      NAG  107
      WRITE(6,1016) IRS,R(IRS),IRF,R(IRF),IZS,Z(IZS),IZF,Z(IZF)          NAG  108
      WRITE(6,1018) IEL                                                  NAG  109
      WRITE (6,1020)                                                     NAG  110
      DO 28 M=1,IEL                                                      NAG  111
      DO 24 N=1,NEL                                                      NAG  112
      IF(NID(N)-NLM(M))24,26,24                                          NAG  113
   24 CONTINUE                                                           NAG  114
      GO TO 28                                                           NAG  115
   26 RHO=DNM(M)*DGM                                                     NAG  116
      WT = RHO*VOLT                                                      NAG  117
      WRITE(6,1022) NLM(M),LABEL(N),DNM(M),RHO,STC(M)                    NAG  118
   28 CONTINUE                                                           NAG  119
      WRITE (6,1026) DGM,DLB,WTGM,WTLB,TSW                               NAG  120
      WRITE (6,1030) TSG(1),TSG(2),TSB,TSWG,TSWC,TSBL,TSBI               NAG  121
      WRITE (6,1032) (ID(I),I=1,12)                                      NAG  122
      WRITE (6,1034)                                                     NAG  123
      IRT=IR1-IRS+1                                                      NAG  124
      IZT=IZ1-IZS+1                                                      NAG  125
      ISTOP= MIN0(IRT,IZT)                                               NAG  126
      ISTOP1=MAX0(IRT,IZT)                                               NAG  127
      SNL=SGLT(1)*TSBI                                                   NAG  128
      SNR=SGRT(1)*TSBI                                                   NAG  129
      SNB=SGBT(1)*TSBI                                                   NAG  130
      SNT= SGTP(1)*TSBI                                                  NAG  131
      RIN = R(IRS)/2.54                                                  NAG  132
      ZIN = ZREF - Z(IZS)/2.54                                           NAG  133
      WRITE(6,1040) R(IRS),RIN,SGLT(1),SNL,Z(IZS),ZIN,SGBT(1),SNB        NAG  134
      RIN = R(IRF)/2.54                                                  NAG  135
      ZIN = ZREF - Z(IZF)/2.54                                           NAG  136
      DO 30 IP=1,ISTOP                                                   NAG  137
      I=IP+IRS-1                                                         NAG  138
      J = IP+IZS-1                                                       NAG  139
      RSK = RS(I) * TSBI                                                 NAG  140
      ZSK = ZS(J) * TSBI                                                 NAG  141
   30 WRITE (6,1040) RI(I),RSF(I),RS(I),RSK,ZI(J),ZSF(J),ZS(J),ZSK       NAG  142
      I=I+1                                                              NAG  143
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      J=J+1                                                                  NAG  144
      IP = IP+1                                                              NAG  145
      IF(ISTOP.EQ.ISTOP1) GO TO 42                                           NAG  146
      IF(ISTOP.EQ.IRT) GO TO 36                                              NAG  147
      RSK = RS(I) * TSBI                                                     NAG  148
      WRITE(6,1040) RI(I),RSF(I),RS(I),RSK,Z(IZF),ZIN,SGTP(1),SNT            NAG  149
      IP=IP+1                                                                NAG  150
      I=I+1                                                                  NAG  151
      IF(IP.GT.ISTOP1) GO TO 34                                              NAG  152
       DO 32 IS=IP,ISTOP1                                                    NAG  153
      RSK = RS(I) * TSBI                                                     NAG  154
      WRITE(6,1040) RI(I),RSF(I),RS(I),RSK                                   NAG  155
   32 I=I+1                                                                  NAG  156
   34 WRITE(6,1040) R(IRF),RIN,SGRT(1),SNR                                   NAG  157
      GO TO 44                                                               NAG  158
   36 ZSK=ZS(J)*TSBI                                                         NAG  159
      WRITE(6,1040) R(IRF),RIN,SGRT(1),SNR,ZI(J),ZSF(J),ZS(J),ZSK            NAG  160
      IP =IP+1                                                               NAG  161
      J=J+1                                                                  NAG  162
      IF(IP.GT.ISTOP1) GO TO 40                                              NAG  163
      DO 38 J5=IP,ISTOP1                                                     NAG  164
      ZSK=ZS(J)*TSBI                                                         NAG  165
      WRITE(6,1042) ZI(J),ZSF(J),ZS(J),ZSK                                   NAG  166
   38 J=J+1                                                                  NAG  167
   40 WRITE(6,1042) Z(IZF),ZIN,SGTP(1),SNT                                   NAG  168
      GO TO 44                                                               NAG  169
   42 WRITE(6,1040) R(IRF),RIN,SGRT(1),SNR,Z(IZF),ZIN,SGTP(1),SNT            NAG  170
   44 CONTINUE                                                               NAG  171
      WRITE (6,1032) (ID(I),I=1,12)                                          NAG  172
      WRITE (6,1038)                                                         NAG  173
      DO 46 ISTAR=IRS,IR1,6                                                  NAG  174
      ISTOP=ISTAR+5                                                          NAG  175
      ISTOP= MIN0(ISTOP,IR1)                                                 NAG  176
      WRITE (6,1012) (ICP,ICP=ISTAR,ISTOP)                                   NAG  177
      DO 46 J=IZS,IZ1                                                        NAG  178
   46 WRITE(6,1008) J, (SG(I,J,3),I=ISTAR,ISTOP)                             NAG  179
      DO 50 I=IRS,IR1                                                        NAG  180
      DO 50 J=IZS,IZ1                                                        NAG  181
      DO 48 K=1,3                                                            NAG  182
   48 SG(I,J,K) = 0.0                                                        NAG  183
   50 CONTINUE                                                               NAG  184
      IF(IND.EQ.1) GO TO 2                                                   NAG  185
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      IF(NTYPE.EQ.3) GO TO 58                                          NAG  186
      DO 52 I=1,I2                                                     NAG  187
      DO 52 J=1,I4                                                     NAG  188
   52 SC(I,J) = 0.0                                                    NAG  189
      DO 56 K=1,I5                                                     NAG  190
      READ(10) ((SG(I,J,1),I=1,I2),J=1,I4)                             NAG  191
      IF(K.GT.I6) GO TO 56                                             NAG  192
      DO 54 I=1,I2                                                     NAG  193
      DO 54 J=1,I4                                                     NAG  194
   54 SC(I,J)=SC(I,J)+SG(I,J,1)*DK(K)                                  NAG  195
   56 CONTINUE                                                         NAG  196
      CALL SCOUT(SC,RI,ZI,I1,I3,I2,I4,K,18HNEUTRON DOSE          )     NAG  197
   58 IF (NTYPE.EQ.1) GO TO 64                                         NAG  198
      DO 60 I = 1,I2                                                   NAG  199
      DO 60 J= 1,I4                                                    NAG  200
   60 SC(I,J) = 0.0                                                    NAG  201
      DO 62 K=1,I8                                                     NAG  202
      READ(10) ((SG(I,J,1),I=1,I2),J=1,I4)                             NAG  203
      DO 62 I=1,I2                                                     NAG  204
      DO 62 J=1,I4                                                     NAG  205
   62 SC(I,J)=SC(I,J)+SG(I,J,1)*DKG(K)                                 NAG  206
      CALL SCOUT(SC,RI,ZI,I1,I3,I2,I4,K,18HGAMMA DOSE            )     NAG  207
 1000 FORMAT (17H0REGION VOLUME = 1PE15.5)                            NAG  208
 1002 FORMAT(12A6)                                                    NAG  209
 1004 FORMAT(44H0REGION AVERAGE SOURCE SPECTRUM (S(E,AVE.))     )     NAG  210
 1006 FORMAT(3X,I3,2X,F8.3,F10.5,F11.5,10X,I3,2X,F8.3,F10.5,F11.5)    NAG  211
 1008 FORMAT(I3,1X,1P8E13.5)                                          NAG  212
 1010 FORMAT(47H0REGION PHOTON SOURCE AND FISSION DISTRIBUTIONS //    NAG  213
     1        39H  RADIAL  RADIAL  RELATIVE DISTRIBUTION,5X           NAG  214
     2        39H  AXIAL   AXIAL   RELATIVE DISTRIBUTION/            NAG  215
     3        37H   MESH   DIMEN.   SOURCE     FISSION  ,7X          NAG  216
     4        37H   MESH   DIMEN.   SOURCE     FISSION  /)          NAG  217
 1012 FORMAT(1H0,4X,8(4X,I3,6X) )                                     NAG  218
 1014 FORMAT(42H0REGION INTEGRAL SOURCE SPECTRUM (S(E))         )     NAG  219
 1016 FORMAT(1H02X,23H REGION MESH BOUNDARIES//4X8HLEFT....I3,10X,F13.5/NAG  220
     1                                         4X8HRIGHT...I3,10X,F13.5/NAG  221
     1                                         4X8HBOTTOM..I3,10X,F13.5/NAG  222
     1                                         4X8HTOP.....I3,10X,F13.5/NAG  223
     2)                                                               NAG  224
 1018 FORMAT(1H02X,19H NO. OF ELEMENTS...I3/)                         NAG  225
 1020 FORMAT(1H03X,61HELEMENT NO.  NAME  WEIGHT FRACTION   DENSITY    NAG  226
     1    HEAT     /  6X,8H(GAM ID)/)                                 NAG  227
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 1022 FORMAT(7X,I3,6X,A6,5X,1P3E13.5)                                          NAG  228
 1020 FORMAT(14H1REGION OUTPUT//55(2H .)/19X12A6/55(2H .)//)                   NAG  229
 1026 FORMAT(1H03X18HMATERIAL DENSITY    F10.6,2X,11HGM/CM**3     ,/          NAG  230
     1       ,22X,                       F10.6,2X,11HLBS/IN**3    ,//         NAG  231
     2       , 3X,17H MATERIAL WEIGHT   1PE14.6,2X,11HKILOGRAMS   ,/          NAG  232
     3       ,20X,                      1PE14.6,2X,11HPOUNDS      ,//         NAG  233
     4       , 3X,19H HEATING DATA      1PE14.6,2X,11HKILOWATTS   ,/ )        NAG  234
 1028 FORMAT(52H0REGION PARAMETERS(IS,IF,JS,JF,NO. OF ELEM.,CONTROL)//6INAG  235
     14)                                                                       NAG  236
 1030 FORMAT(22X,                        1PE14.6,2X,17HKILOWATTS(PHOTON),/NAG  237
     1       ,22X,                       E14.6,2X,18HKILOWATTS(NEUTRON),NAG  238
     2      /,22X,                       E14.6,2X,11HBTU/HOUR     ,/         NAG  239
     3       ,22X,                       E14.6,2X,11HWATTS/GM     ,/         NAG  240
     4       ,22X,                       E14.6,2X,11HWATTS/CM**3  ,/         NAG  241
     5       ,22X,                       E14.6,2X,11HBTU/LB-HOUR  ,/         NAG  242
     6       ,22X,                       E14.6,2X,14HBTU/IN**3-HOUR,//)      NAG  243
 1032 FORMAT(1H1,2X,12A6/)                                                     NAG  244
 1034 FORMAT(32H0RELATIVE HEATING DISTRIBUTIONS  ,//                           NAG  245
     147H  AXIAL DIMENSION IN INCHES IS FROM CORE INLET  //                    NAG  246
     254H   RADIAL DIMENSIONS     RELATIVE       ABSOLUTE        ,            NAG  247
     354H   AXIAL DIMENSIONS      RELATIVE       ABSOLUTE        /            NAG  248
     454H                      DISTRIBUTION   DISTRIBUTION      ,            NAG  249
     554H                      DISTRIBUTION   DISTRIBUTION      /            NAG  250
     654H   (CM.)  (INCHES)        F(R)           KF(R)         ,            NAG  251
     754H   (CM.)  (INCHES)        F(Z)           KF(Z)         // )          NAG  252
 1036 FORMAT(34H0REGION INTEGRAL GAMMA RAY SOURCE=1PE15.5/27H0REGION INTNAG  253
     1EGRAL FISSIONS =E15.5)                                                   NAG  254
 1038 FORMAT(44H0HEATING DISTRIBUTION  (BTU/IN**3-HOUR)      )                 NAG  255
 1040 FORMAT(F10.4,2X,F10.4,2X,F10.4,4X,F12.3,4X,                              NAG  256
     1       F10.4,2X,F10.4,2X,F10.4,4X,F12.3 )                                NAG  257
 1042 FORMAT(54X,F10.4,2X,F10.4,2X,F10.4,4X,F12.3 )                            NAG  258
 1044 FORMAT(/(8X,1P8E12.4))                                                   NAG  259
 1046 FORMAT(55(2H. ))                                                         NAG  260
   64 RETURN                                                                   NAG  261
      END                                                                      NAG  262
$ORIGIN         ALPHA,SYSUT3,RE*
$IBFTC NAGS4    NOLIST,  DECK,NODD,M94/2,XR7                                  NAGS   1
       SUBROUTINE  NAG4( R,Z,RSF,ZSF,RS,ZS,VOLR,VOLZ,SC,TEMP,SG,UNU,CHI,     NAGS   2
      1SFPS,SFDS,DNM,SA,SF,SIN,SS,SAS,SINS,AMU,ESS,ENA,SA2200,LABEL,SNA,     NAGS   3
      2ECOS,DK,DE,DU,SAG,TSG,RI,ZI,SGH,SGT,SGL,SGR,RSN,ZSN,DKG,STC,          NAGS   4
      2STF,STI,                                                              NAGS   5
      3IC,JC,NID,NLM,I1,I2,I3,I4,I5,I6,                                      NAGS   6
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     4I7     , I8     , I9     , I10    , I11    , I12    , I13    ,     NAGS    7
     5I14    , I15    , I16    , I17    )                                NAGS    8
      COMMON ICT,ICM,JCT,JCM,NGN,NFAST,NI,NGG,NEL,IND,NTYPE              NAGS    9
      COMMON NCD,NBIN,NLIB,NEX,NEX1,ISTART,JSTART,NPUN  ,ZREF,JCO        NAGS   10
      DIMENSION RSF(I13),ZSF(I14),R(I10),Z(I12),RSN(I13),ZSN(I14),       NAGS   11
     1DKG(I8),RS(I13),ZS(I14),VOLR(I1),VOLZ(I3),SC(I1,I3),TEMP(I15),     NAGS   12
     2SG(I13,I14,I17),UNU(I5),CHI(I5),SFPS(I8),SFDS(I8),DNM(I9),         NAGS   13
     3SA(I5,I9),SF(I5,I9),SIN(I7,I9),SS(I6,I9),SAS(I8,I9),               NAGS   14
     4SINS(I8,I7,I9),AMU(I9),ESS(I9),ENA(I9),SA2200(I9),LABEL(I9),       NAGS   15
     5SNA(I5,I9),ECOS(I6,I9),DK(I5),DE(I5),DU(I5),SAG(I8,I9),TSG(I8),    NAGS   16
     6RI(I2),ZI(I4),SGT(I2,3),SGB(I2,3),SGL(I4,3),SGR(I4,3),IC(I2),      NAGS   17
     7JC(I4),NID(I9),NLM(I9),ID(12),TITLE(12),BUF(27)                    NAGS   18
     8,STC(I9) , STF(I9) , STI(I9)                                       NAGS   19
      DIMENSION SGLT(3),SGRT(3),SGBT(3),SGTP(3)                          NAGS   20
   2 READ (9) IRS,IRF,IZS,IZF, IEL,IND,DGM,WTGM,(NLM(M),DNM(M),M=1,IEL)  NAGS   21
     1,(ID(I),I=1,12)                                                    NAGS   22
      IR1 = IRF - 1                                                      NAGS   23
      IZ1 = IZF - 1                                                      NAGS   24
      READ  (9) (((SG(I,J,K),I=IRS,IR1),J=IZS,IZ1),K=1,I17), ((SGL(J,L),NAGS   25
     1SGR(J,L),J=IZS,IZ1),L=1,3),((SGB(I,L),SGT(I,L),I=IRS,IR1),L=1,3)   NAGS   26
     2,(STC(M),STF(M),STI(M),M=1,NEL)                                    NAGS   27
      VOLT =0.0                                                          NAGS   28
      DO 4 I=1,NGG                                                       NAGS   29
   4 TSG(I)=0.0                                                          NAGS   30
      DO 6 I = 1,3                                                       NAGS   31
      SGLT(I) = 0.0                                                      NAGS   32
      SGRT(I) = 0.0                                                      NAGS   33
      SGTP(I) = 0.0                                                      NAGS   34
   6 SGBT(I) = 0.0                                                       NAGS   35
      TS = 0.0                                                           NAGS   36
      TSF= 0.0                                                           NAGS   37
      TSN= 0.0                                                           NAGS   38
      DO 10 I = IRS,IR1                                                  NAGS   39
      DO 8 K = 1,3                                                       NAGS   40
      SGTP(K) = SGTP(K) + SGT(I,K) * VOLR(I)                             NAGS   41
   8 SGBT(K) = SGBT(K) + SGB(I,K) * VOLR(I)                              NAGS   42
      RSN(I)=0.0                                                         NAGS   43
      RSF(I)=0.0                                                         NAGS   44
  10 RS(I) = 0.0                                                         NAGS   45
      DO 14 J = IZS,IZ1                                                  NAGS   46
      DO 12 K = 1,3                                                      NAGS   47
      SGLT(K) = SGLT(K) + SGL(J,K) * VOLZ(J)                             NAGS   48
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12 SGRT(K) = SGRT(K) + SGR(J,K) * VOLZ(J)                          NAGS  49
   ZSN(J)=0.0                                                      NAGS  50
   ZSF(J)=0.0                                                      NAGS  51
14 ZS(J) = 0.0                                                     NAGS  52
   DO 20 K=1,NGG                                                   NAGS  53
   DO 16 J = IZS,IZ1                                               NAGS  54
   DO 16 I = IRS,IR1                                               NAGS  55
   IF (K.NE.NGG) GO TO 16                                          NAGS  56
   RSF(I) = RSF(I) + SG(I,J,K+1) * VOLZ(J)                         NAGS  57
   RSN(I) = RSN(I) + SG(I,J,K+2) * VOLZ(J)                         NAGS  58
16 RS(I) = RS(I) + SG(I,J,K)*VOLZ(J)                               NAGS  59
   DO 18 I = IRS,IR1                                               NAGS  60
   DO 18 J = IZS,IZ1                                               NAGS  61
   IF (K.NE.NGG) GO TO 18                                          NAGS  62
   ZSF(J) = ZSF(J) + SG(I,J,K+1) * VOLR(I)                         NAGS  63
   ZSN(J) = ZSN(J) + SG(I,J,K+2) * VOLR(I)                         NAGS  64
18 ZS(J) = ZS(J) + SG(I,J,K) * VOLR(I)                             NAGS  65
   VOLT = 0.0                                                      NAGS  66
   DO 20 I=IRS,IR1                                                 NAGS  67
   DO 20 J=IZS,IZ1                                                 NAGS  68
   VOLI = VOLR(I)*VOLZ(J)                                          NAGS  69
   VOLT = VOLT + VOLI                                              NAGS  70
   IF (K.NE.NGG) GO TO 20                                          NAGS  71
   TSF = TSF + SG(I,J,K+1) * VOLI                                  NAGS  72
   TSN = TSN + SG(I,J,K+2) * VOLI                                  NAGS  73
20 TSG(K) = TSG(K) + SG(I,J,K)*VOLI                                NAGS  74
   DO 22 K=1,NGG                                                   NAGS  75
22 TS = TS + TSG(K)                                                NAGS  76
   VOLTR=0.0                                                       NAGS  77
   DO 24 I=IRS,IR1                                                 NAGS  78
24 VOLTR=VOLTR+VOLR(I)                                             NAGS  79
   VOLTZ=0.0                                                       NAGS  80
   DO 26 J=IZS,IZ1                                                 NAGS  81
26 VOLTZ=VOLTZ+VOLZ(J)                                             NAGS  82
   DO 28 I=IRS,IR1                                                 NAGS  83
   IF(TSF.LE.0.0) GO TO 28                                         NAGS  84
   RSF(I)=RSF(I)*VOLTR/TSF                                         NAGS  85
   RSN(I)=RSN(I)*VOLTR/TSN                                         NAGS  86
28 RS(I) =RS(I) *VOLTR/TS                                          NAGS  87
   DO 30 J=IZS,IZ1                                                 NAGS  88
   IF(TSF.LE.0.0) GO TO 30                                         NAGS  89
   ZSF(J) = ZSF(J) * VOLTZ / TSF                                   NAGS  90
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      ZSN(J) = ZSN(J) * VOLTZ / TSN                                          NAGS  91
   30 ZS(J)=ZS(J)*VOLTZ/TS                                                   NAGS  92
      DO 32 K=1,3                                                            NAGS  93
      IF(K.EQ.1) TSA = TS /VOLT                                              NAGS  94
      IF(K.EQ.2) TSA = TSF/VOLT                                              NAGS  95
      IF(K.EQ.3) TSA = TSN/VOLT                                              NAGS  96
      SGLT(K)=SGLT(K)/(TSA*VOLTZ)                                            NAGS  97
      SGRT(K)=SGRT(K)/(TSA*VOLTZ)                                            NAGS  98
      SGBT(K)=SGBT(K)/(TSA*VOLTR)                                            NAGS  99
      SGTP(K)=SGTP(K)/(TSA*VOLTR)                                            NAGS 100
   32 CONTINUE                                                               NAGS 101
      CALL SISET(SGLT,SGRT,SGBT,SGTP,R,RI,Z,ZI,I1,I2,I3,I4,I10,I12,I13,     NAGS 102
     1I14,IRS,IR1,IZS,IZ1,1,RS ,ZS )                                         NAGS 103
      IF(TSF.LE.0.0) GO TO 34                                                NAGS 104
      CALL SISET(SGLT,SGRT,SGBT,SGTP,R,RI,Z,ZI,I1,I2,I3,I4,I10,I12,I13,     NAGS 105
     1I14,IRS,IR1,IZS,IZ1,2,RSF,ZSF)                                         NAGS 106
      CALL SISET(SGLT,SGRT,SGBT,SGTP,R,RI,Z,ZI,I1,I2,I3,I4,I10,I12,I13,     NAGS 107
     1I14,IRS,IR1,IZS,IZ1,3,RSN,ZSN)                                         NAGS 108
C THE FOLLOWING SECTION IS THE CALCULATION OF ALL PERTINENT SOURCE DATA      NAGS 109
C AND THE PRINTING OF SUCH                                                   NAGS 110
   34 WRITE (6,1000) (ID(I),I=1,12)                                          NAGS 111
 1000 FORMAT(1H1,2X,12A6/)                                                   NAGS 112
      WRITE(6,1002) IRS,R(IRS),IRF,R(IRF),IZS,Z(IZS),IZF,Z(IZF)              NAGS 113
 1002 FORMAT(1H02X,23H REGION MESH BOUNDARIES//4X8HLEFT....I3,10X,F13.5/NAGS 114
     1                                        4X8HRIGHT...I3,10X,F13.5/NAGS 115
     1                                        4X8HBOTTOM..I3,10X,F13.5/NAGS 116
     1                                        4X8HTOP.....I3,10X,F13.5/NAGS 117
     2)                                                                      NAGS 118
      WRITE(6,1004) IEL                                                      NAGS 119
 1004 FORMAT(1H02X,19H NO. OF ELEMENTS...I3/)                                NAGS 120
      WRITE (6,1006)                                                         NAGS 121
 1006 FORMAT(1H03x, 102HELEMENT NO. NAME      ATOM DENSITY    DENSITY       NAGS 122
     1   WEIGHT       CAPTURES     FISSIONS     IN.SCATTER  /6X,8H(GAM INAGS 123
     2D)/)                                                                   NAGS 124
      WTT = 0.                                                               NAGS 125
      DO 40 M=1,IEL                                                          NAGS 126
      DO 36 N=1,NEL                                                          NAGS 127
      IF(NID(N)-NLM(M))36,38,36                                              NAGS 128
   36 CONTINUE                                                               NAGS 129
      GO TO 40                                                               NAGS 130
   38 RHO = AMU(N)*DNM(M)/0.60248                                            NAGS 131
      WT = VOLT * RHO                                                        NAGS 132
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      WRITE(6,1008) NLM(M),LABEL(N),DNM(M), RHO,WT,STC(M),STF(M),STI(M)  NAGS 133
      WTT = WTT+ WT                                                     NAGS 134
 1008 FORMAT(7X,I3,6X,A6,5X,1P6E13.5)                                   NAGS 135
   40 CONTINUE                                                          NAGS 136
      WRITE(6,1010) VOLT,WTT                                            NAGS 137
 1010 FORMAT(1H0,2X,19H REGION VOLUME.....1PE14.5/                      NAGS 138
     1        1H0,2X,19H REGION WEIGHT.....  E14.5)                    NAGS 139
      WRITE(6,1012) TS,TSF,TSN                                          NAGS 140
 1012 FORMAT(1H0,2X,18H REGION INTEGRATED//4X18H PHOTON SOURCE....1PE14 NAGS 141
     1.5,/4X18H FISSIONS.........E14.5,/4X18H NEUTRON SOURCE...E14.5,/4XNAGS 142
     247H PHOTON SOURCE BY GROUP(INTEGRATED AND AVERAGE))               NAGS 143
       DO 42 K=1,NGG                                                    NAGS 144
      TST=TSG(K)/VOLT                                                   NAGS 145
   42 WRITE(6,1014) K,TSG(K),TST                                        NAGS 146
 1014 FORMAT(19X,I3,1P2E14.5)                                           NAGS 147
      WRITE (6,1000) (ID(I),I=1,12)                                     NAGS 148
      WRITE (6,1022)                                                    NAGS 149
      IRT=IR1-IRS+1                                                     NAGS 150
      IZT=IZ1-IZS+1                                                     NAGS 151
      ISTOP= MIN0(IRT,IZT)                                              NAGS 152
      ISTOP1=MAX0(IRT,IZT)                                              NAGS 153
      WRITE(6,1024) R(IRS),(SGLT(K),K=1,3),Z(IZS),(SGBT(K),K=1,3)       NAGS 154
      DO 44 IP = 1,ISTOP                                                NAGS 155
      I = IP + IRS - 1                                                  NAGS 156
      J = IP + IZS - 1                                                  NAGS 157
   44 WRITE(6,1024) RI(I),RS(I),RSF(I),RSN(I),ZI(J),ZS(J),ZSF(J),ZSN(J) NAGS 158
      I = I + 1                                                         NAGS 159
      IP = IP + 1                                                       NAGS 160
      J  = J  + 1                                                       NAGS 161
      IF(ISTOP.EQ.ISTOP1) GO TO 56                                      NAGS 162
      IF(ISTOP.EQ.IRT) GO TO 50                                         NAGS 163
      WRITE(6,1024) RI(I),RS(I),RSF(I),RSN(I),Z(IZF),(SGTP(K),K=1,3)    NAGS 164
      IP = IP + 1                                                       NAGS 165
      I  = I + 1                                                        NAGS 166
      IF(IP.GT.ISTOP1) GO TO 48                                         NAGS 167
      DO 46 IS = IP,ISTOP1                                              NAGS 168
      WRITE(6,1024) RI(I),RS(I),RSF(I),RSN(I)                           NAGS 169
   46 I = I+1                                                           NAGS 170
   48 WRITE(6,1024) R(IRF),(SGRT(K),K=1,3)                              NAGS 171
      GO TO 58                                                          NAGS 172
   50 WRITE(6,1024) R(IRF),(SGRT(K),K=1,3),ZI(J),ZS(J),ZSF(J),ZSN(J)    NAGS 173
      IP = IP + 1                                                       NAGS 174
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      J  = J  + 1                                                        NAGS 175
      IF(IP.GT.ISTOP1) GO TO 54                                          NAGS 176
      DO 52 JS = IP,ISTOP1                                               NAGS 177
      WRITE(6,1026) ZI(J),ZS(J),ZSF(J),ZSN(J)                            NAGS 178
   52 J = J + 1                                                          NAGS 179
   54 WRITE(6,1026) Z(IZF),(SGTP(K),K=1,3)                               NAGS 180
      GO TO 58                                                           NAGS 181
   56 WRITE(6,1024) R(IRF),(SGRT(K),K=1,3),Z(IZF),(SGTP(K),K=1,3)        NAGS 182
   58 CONTINUE                                                           NAGS 183
      IF(IND.EQ.1) GO TO 2                                               NAGS 184
      SNT = 0.0                                                          NAGS 185
      SPT=0.0                                                            NAGS 186
      SFT = 0.0                                                          NAGS 187
      DO 60 I= 1,I2                                                      NAGS 188
      DO 60 J = 1 ,I4                                                    NAGS 189
      VOLI = VOLR(I)*VOLZ(J)                                             NAGS 190
      SNT =            SNT  + SG(I,J,NGG+2)*VOLI                         NAGS 191
      SFT =          SFT+SG(I,J,NGG+1)*VOLI                              NAGS 192
      DO 60 K=1,NGG                                                      NAGS 193
   60 SPT = SPT+ SG(I,J,K)*VOLI                                          NAGS 194
      WRITE(6,1016) SPT,SFT,SNT                                          NAGS 195
 1016 FORMAT(1H1,2X,23H TOTAL PHOTON SOURCE...1PE14.5,/,                 NAGS 196
     1       1H0,2X,23H TOTAL FISSIONS.......  E14.5,/,                 NAGS 197
     2       1H0,2X,23H TOTAL NEUTRON SOURCE..  E14.5,/)                NAGS 198
      REWIND 9                                                           NAGS 199
      CALL SCOUT (SG(1,1,NGG+2),RI,ZI,I2,I4,I2,I4,K,18HNEUTRON SOURCE    NAGS 200
     1                    )                                            NAGS 201
      CALL SCOUT ( SG(1,1,NGG+1),RI,ZI,I2,I4,I2,I4,K,18HFISSION DENSITY  NAGS 202
     1                    )                                            NAGS 203
      IF(NPUN.EQ.0) GO TO 72                                             NAGS 204
      IRMAX = NEX + NEX1 + I2                                            NAGS 205
      IZMAX = JCO                                                        NAGS 206
      NTEST = IRMAX*IZMAX-2*I1*I3                                        NAGS 207
      IF(NTEST.GT.0) WRITE(6,1020) NTEST                                 NAGS 208
      DO 62 I=1,IRMAX                                                    NAGS 209
      DO 62 J=1,IZMAX                                                    NAGS 210
   62 SC(I,J) = 0.0                                                      NAGS 211
      KKK = 1                                                            NAGS 212
      IF(NPUN.EQ.1) NGPUN = NGN                                          NAGS 213
      IF(NPUN.GE.2) NGPUN = NGG                                          NAGS 214
      WRITE (9) IRMAX,IZMAX,I2,I4,NEX1,NGPUN                             NAGS 215
      DO 70 K = 1,NGPUN                                                  NAGS 216
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      IF(NPUN.EQ.1) GO TO 64                                                NAGS 217
      IF(NPUN.EQ.2) FMPY = 1.0                                              NAGS 218
      IF(NPUN.EQ.2) NGT = K                                                 NAGS 219
      IF(NPUN.EQ.2) GO TO 66                                                NAGS 220
      NGT = NGG+1                                                           NAGS 221
      FMPY  = SFDS(K)                                                       NAGS 222
      GO TO 66                                                              NAGS 223
   64 NGT = NGG+2                                                           NAGS 224
      FMPY = CHI(K)                                                         NAGS 225
   66 DO 68 I = 1,I2                                                        NAGS 226
      DO 68 J = 1,I4                                                        NAGS 227
      IJ = I+ NEX1                                                          NAGS 228
   68 SC(IJ,J)=SG(I,J,NGT)*FMPY                                             NAGS 229
      IF(NPUN.GT.1) CALL SCOUT(SC,R1,Z1,I1,I3,I2,I4,K,18HPHOTON SOURCE     NAGS 230
     1                        )                                           NAGS 231
      IF(NPUN.EQ.1) CALL SCOUT(SC,R1,Z1,I1,I3,I2,I4,K,18HNEUTRON SOURCE    NAGS 232
     1                        )                                           NAGS 233
   70 WRITE (9) ((SC(I,J),I=1,IRMAX),J=1,IZMAX)                             NAGS 234
      REWIND 9                                                              NAGS 235
      WRITE (6, 1018)                                                       NAGS 236
 1018  FORMAT(65H THE FIXED SOURCE  JCO BY (NEX1,ICM,NEX) HAS BEEN WRITTNAGS 237
     1EN ON TAPE)                                                           NAGS 238
 1020 FORMAT(52H GEOMETRY FOR TAPE WRITE IS TO LARGE FOR STORAGE BY I5)     NAGS 239
 1022 FORMAT(42H0RELATIVE SOURCE AND FISSION DISTRIBUTIONS   ,//            NAGS 240
     254H  RADIUS  PHOTON          FISSION         NEUTRON                  NAGS 241
     354H  HEIGHT  PHOTON          FISSION         NEUTRON           ,//    NAGS 242
     522X,13HDISTRIBUTIONS,19X,22X,13HDISTRIBUTIONS //                      NAGS 243
     654H    (CM.)     F(R)             F(R)             F(R)              NAGS 244
     754H    (CM.)     F(Z)             F(Z)             F(Z)          //)NAGS 245
 1024 FORMAT(F10.4,2X,F10.4,2X,F10.4,4X,F12.4,4X,                           NAGS 246
     1       F10.4,2X,F10.4,2X,F10.4,4X,F12.4 )                             NAGS 247
 1026 FORMAT(54X,F10.4,2X,F10.4,2X,F10.4,4X,F12.4 )                         NAGS 248
 1028 FORMAT(/(8X,1P8E12.4))                                                NAGS 249
 1030 FORMAT(55(2H. ))                                                      NAGS 250
   72 RETURN                                                                NAGS 251
      END                                                                   NAGS 252
$ENTRY
$DATA
```

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