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WANL-PR-(LL)-010

VOLUME 4

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

KAP-V

THE POINT KERNEL ATTENUATION PROGRAM

by

R. K. Disney

and

M. A. Capo

Contract No. NAS-8-20414
Contract No. DCN-16-28-0029(IF)

ACKNOWLEDGMENTS

The authors wish to express their appreciation to G. A. Graves and R. E. Malenpant at the Los Alamos Scientific Laboratory for providing the QAD program and operating instructions upon which the KAP-V program is based. Also, the authors appreciate the guidance provided by Mr. Henry E. Stern, Deputy Manager, Nuclear and Plasma Physics Division, George C. Marshall Space Flight Center, the technical monitor of the contract.

ABSTRACT

This report is Volume 4 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 and gamma ray point kernal attenuation program (KAP-V).

KAP-V is a computer program written in FORTRAN IV language. The program employs the point kernel method to calculate radiation levels at detector points located within or outside a complex radiation source geometry describable by a combination of quadratic surfaces. This program can be used, for example, to calculate gamma ray and/or fast neutron flux, dose, or heating rate. The attenuation function, or kernel, for gamma rays employs exponential attenuation along with a build-up factor. Three optional fast neutron attenuation functions are included: (1) a modified Albert-Welton function for calculating fast neutron dose rate using removal cross sections; (2) a bivariant polynomial expression for computing neutron spectra using infinite media moments data; and (3) a monovariant polynomial expression for computing neutron spectra using infinite media moments data. The program also handles either cylindrical, spherical, disc, line, or point sources. A variety of options are available for describing neutron or gamma ray source distributions in complex geometries.

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SECTION

1.0 INTRODUCTION

This report is Volume 4 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 and gamma ray kernel attentuation program (KAP-V).

The KAP-V program is an integral part of both the "early" and "final" design radiation analysis methods provided for the Marshall Space Flight Center under this contract. A simplified schematic diagram of each method is shown in Figures 1 and 2. Both methods are fully described in Volume 1 of this report. The starting point for both methods is the POINT program (Volume 2) which prepares cross section and other basic data for use in the transport programs.

In the "early" design method (Figure 1), the TAPAT program system (Volume 3) computes one dimensional neutron and photon energy fluxes in the reactor geometry. From these fluxes, neutron and photon energy sources and distributions are obtained and are used as input to the KAP-V program. The KAP-V program (Volume 4) provides gamma ray and fast neutron radiation levels at locations external to the reactor. Radiation levels from the KAP-V program at a specific radial distance from the center of the reactor can then be employed in the TIC-TOC-TOE program (Volume 5) for calculating radiation quantities of interest in an on-axis liquid hydrogen propellant tank.

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

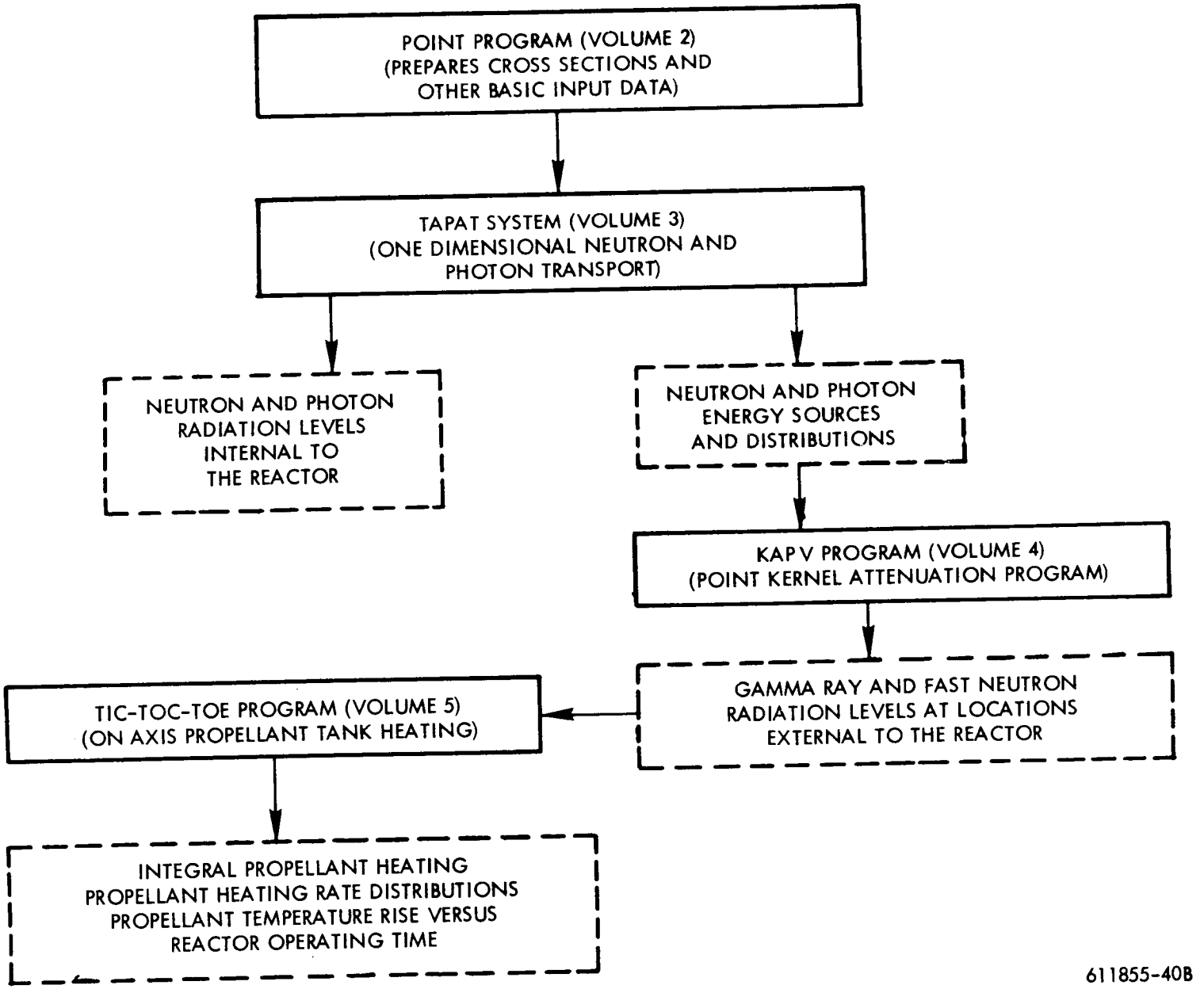

Figure 1. Schematic Diagram of the "Early" Design Method

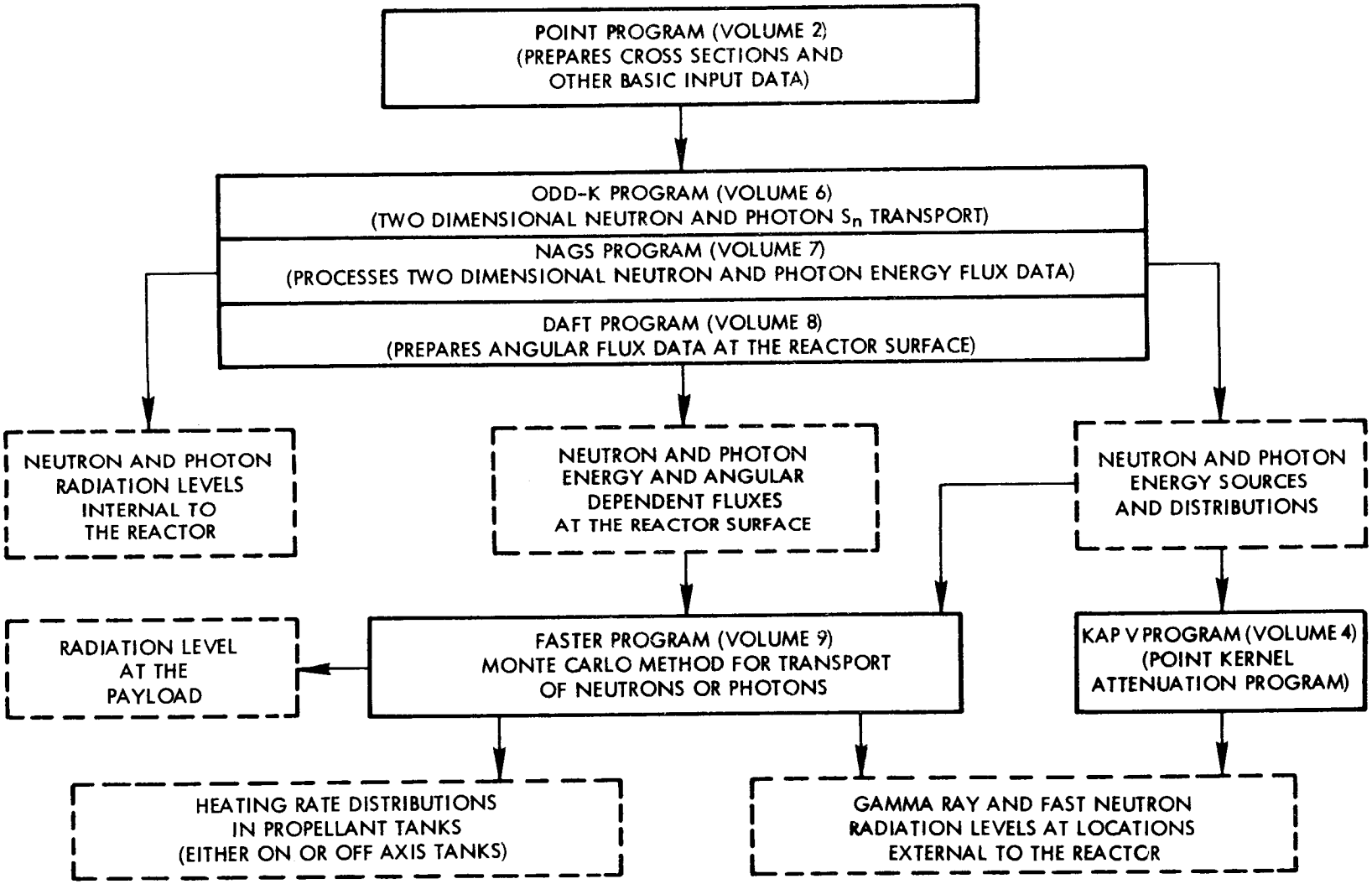

Figure 2. Schematic Diagram of the "Final" Design Method

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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.

Extensive radiation analysis at Westinghouse Astronuclear Laboratory indicated that a point kernel program was needed which included the desirable features of both the Los Alamos Scientific Laboratory QAD program series[1] and the General Electric Aircraft Nuclear Propulsion Department programs, 14-0 and 14-1[2]. This same conclusion was noted in a previous study[3] performed for MSFC. The KAP-V program was formulated initially at WANL in FORTRAN II[4], employing the QAD geometry routine as the only intact routine from the QAD IV program. Many features requested by KAP program users at WANL were incorporated in the program between 1963 and 1966, at which time work on the latest version, KAP-V, was initiated under the present contract. The entire programming effort on the KAP-V program was directed at producing a point kernel program which was a useful and efficient computer program in FORTRAN IV computer language. The present version of the KAP-V code is operational on the IBM 7094 Model II at WANL and MSFC, and on the CDC 6600 at the Westinghouse Telecomputer Center in Pittsburgh.

KAP-V is a point kernel program designed to calculate the radiation level at detector points located within or outside a complex radiation source geometry describable by a combination of quadratic surfaces. The program evaluates the material thicknesses intercepted along the line-of-sight from the source point to the detector point. These material thicknesses (or path lengths) then are employed in attenuation functions to calculate the flux, dose rate, or heating rate at the detector. The attentuation function for gamma rays employs exponential attenuation with a buildup factor. Three optional neutron attenuation functions are included: (1) a modified Albert-Welton function for calculating fast neutron dose rate using removal cross sections; (2) a bivariant polynominal expression for computing neutron spectra using infinite media moments data; and (3) a monovariant polynominal expression for computing neutron spectra using infinite media moments data.

The program also handles either cylindrical, spherical, disc, line, or point sources. Different source distributions may be employed for neutrons and gamma rays. A variety of options is available for describing the source distributions. The source distributions are assumed separable along the axis and radius of cylindrical-type source regions and independent of the azimuthal angular position for either spherical or cylindrical sources. An option is provided to describe azimuthal source density variation by specifying input data for discrete point sources.

Specific desirable features which have been incorporated in the KAP-V program are:

(1) Input data preparation has been simplified to allow minimum input for running "stacked" cases.

(2) The program uses the "point-in-region" concept to calculate the boundary surface-zone relationship ("ambiguity index") which is required as input in other point kernel codes.

(3) A routine is included in the program to calculate gamma ray mass absorption coefficients for up to twenty elements as a function of input gamma ray energy which eliminates a great deal of the previously required input data.

(4) A routine is included in the program to calculate the cubic polynominal coefficients for buildup factors as a function of input gamma ray energy from a library of bivariant polynominal data.

(5) A routine is included which will interpolate a closely-spaced source distribution (obtained from a discrete ordinate transport or diffusion theory source calculation) to a source mesh description more amenable and economic to point kernel calculations.

(6) A routine is included which calculates and normalizes point source strengths for a variety of source geometries and functional variations of source distributions.

(7) Input data are checked for consistency to eliminate many erroneous calculations that can occur if input data for a problem is incomplete.

(8) The program has the capability to calculate fluxes and/or other radiation responses such as heating rates at multiple detector points for each source region.

(9) The program has no set limit on the number of source regions which can be run in a single problem. This feature is handled as a set of stacked source region problems. The program computes the summation at each detector point of the neutron and/or photon radiation from each source region.

(10) The program allows the user to input separate source distributions for neutrons and gamma rays within the same source region.

(11) The program eliminates unnecessary response function computations by accumulating flux data as a function of detector point and group during the calculation for each source region. Calculations for up to ten response functions are performed only at the completion of each source region calculation and/or at the completion of source region problems.

(12) An option is included for calculating the flux at a detector located within a gamma ray source region. This option circumvents the numerical difficulties introduced by the "inverse square law," when a source point is too close to the detector.

The KAP-V program, with the above features, has proven to be an efficient tool for the analysis of the radiation environment produced by reactor sources. Comparisons, presented in Volume 1, between KAP calculations and NRX experimental radiation environment, and between Monte Carlo and transport calculations, give added confidence to point kernel analysis, provided that the code is judiciously employed.

The computer time required for running a "typical" problem is difficult to evaluate. The running time is dependent primarily upon the number of zones and associated boundaries along the path between each source and detector point. A complex problem run on the IBM 7094 computer required an average of 0.01 seconds per source point for each detector point. This complex geometry contained 44 zones and 32 boundaries.

Section 2 gives a more detailed description of the program, including the geometry, sources, and attenuation kernels. Section 3 briefly describes the logic of the KAP-V program. Input data instructions are presented in Section 4, and the output data is described in Section 5. A sample problem, along with an actual print-out of the results, is given in Section 6. The FORTRAN IV source program is listed in the Appendix.

SECTION

2.0 PROGRAM DESCRIPTION

2.1 GEOMETRY

The KAP-V program requires the following information in order to perform geometry and material calculations:

1) Zones (or regions) which are described by intersecting surfaces
2) Geometric surfaces which are described by various equations
3) Materials in the zones which are described by a material composition table
4) Nuclear properties of the materials.

Based on this input data, the KAP-V program calculates the "line-of-sight" distance (path length) through each material in each zone between each source point and the detector point.

Subsequent sections describe the techniques used in describing and solving geometry dependent quantities for a KAP-V problem.

2.1.1 Surfaces

The geometry of the problem can include the following types of equation surfaces:

1) Equations of a surface of revolution about any x, y, or z coordinate axis.
2) Equations of a plane normal to the x, y, or z axis of the reference system.
3) Equations of an elliptic cylinder about any z axis.
4) Equations of any quadrature surface by specifying appropriate equation coefficients.

To simplify the geometry input description, the program contains specific forms of the quadratic surface equations. Each of these equations are identified by an equation number. The equations available are as follows:

$$A(X^2) + B(Y^2) + C(Z^2) + X_0X + Y_0Y + Z_0Z - D = 0 \qquad \text{(NEQBD = 1)}$$

$$A(X-X_0)^2 + B(Y-Y_0)^2 + C(Z-Z_0)^2 - D = 0 \qquad \text{(NEQBD = 2)}$$

$$A(X-X_0)^2 + B(Y-Y_0)^2 - D = 0 \qquad \text{(NEQBD = 3)}$$

$$X - D = 0 \qquad \text{(NEQBD = 4)}$$

$$Y - D = 0 \qquad (NEQBD = 5)$$

$$Z - D = 0 \qquad (NEQBD = 6)$$

The quantities A, B, C, X_0, Y_0, Z_0, and D are input parameters for the surfaces in a problem. The surface equation number defines the necessary parameters. The user specifies the equation number, NEQBD, and only those parameters necessary to solve the respective surface equation.

The surface defined by NEQBD = 4, 5, and 6 are planes normal to each of the coordinate axes. NEQBD = 3 is the equation for a cylindric surface with its axis parallel to the Z axis. NEQBD = 2 is an elliptic surface which, by specifying the A, B, and C coefficients properly, can describe elliptical cylindric surfaces with their axis parallel to each of the coordinate axes. NEQBD = 1 is a form of the general quadratic equation. By proper manipulation of the coefficient of a quadratic equation defining a surface, one can calculate the required coefficients A, B, C, D, X_0, Y_0, and Z_0.

The equations shown above require that all parameters must be in units consistent with the nuclear properties of the zones.

The maximum number of surfaces that can be employed in a KAP-V problem is limited to 100.

2.1.2 Zones

A zone is defined as a region containing a homogeneous composition of materials and is bounded by a set of geometrical surfaces as defined by the surface equations. Geometrical surfaces described in a problem geometry are used to define the exterior boundaries of zones in a problem. Each zone is described as a volume bounded by as many as six intersecting surfaces. The boundary surfaces of a zone are designated by the geometric surface numbers.

KAP-V uses the "point-in-region" technique to assign the boundary surface-zone relationship values to each of the zone boundary numbers, since the relationship of the zone with respect to each of its boundary surfaces must be known for a KAP-V geometry calculation. This relationship is designated by the sign (plus or minus) of the zone boundary number and is called the "ambiguity index". The ambiguity index defines the position of a zone with respect to the zone

boundary surface as being an interior (+) or exterior (-) zone. In complex geometries, the assignment of ambiguity indices by the program user is difficult and time consuming. To circumvent this problem, the KAP-V program requires as input the Cartesian coordinates of a point (X_p, Y_p, Z_p) within each zone. Using these point coordinates, the designated surface numbers (LBD) for each boundary of a zone, and the equation number (NEQBD) of the surfaces, the calculation of the ambiguity index is straightforward. The surface equation and the coordinates (X_p, Y_p, Z_p) define the quantity, V, for each particular equation number (NEQBD = 1 through 6).

$$V = A(X_p - X_0)^2 + B(Y_p - Y_0)^2 + C(Z_p - Z_0)^2 + X_0X_p + Y_0Y_p + Z_0Z_p - D \quad \text{(NEQBD = 1)}$$

$$V = A(X_p - X_0)^2 + B(Y_p - Y_0)^2 + C(Z_p - Z_0)^2 - D \quad \text{(NEQBD = 2)}$$

$$V = (X_p - X_0)^2 - (Y_p - Y_0)^2 - D \quad \text{(NEQBD = 3)}$$

$$V = X_p - D \quad \text{(NEQBD = 4)}$$

$$V = Y_p - D \quad \text{(NEQBD = 5)}$$

$$V = Z_p - D \quad \text{(NEQBD = 6)}$$

The sign ($\pm$) of the quantity V determines the ambiguity index of the boundary surface of the zone. This ambiguity index is assigned to the boundary number LBD. If V is negative, the zone is internal to the boundary surface and the boundary number LBD is given a positive sign. Similarly, if V is positive, the zone is external to the boundary surface and the boundary number LBD is given a negative sign. The ambiguity index calculation is performed at the beginning of each KAP-V source region calculation, and the computed signs are used for all geometry calculations for this source region.

External zones can be described by a single boundary surface. External boundary surfaces of external zones need not be defined. An external zone is recognized by the program if the sign of the boundary is a negative number. The sign of the boundary number of an external zone must be input by the program user.

2.1.3 Geometry Calculations

The geometry calculation begins with the computed Cartesian coordinates of a source

point (X_S, Y_S, Z_S) and a detector point (X_D, Y_D, Z_D). These coordinates are computed as follows:

$$X_S = \bar{R}_i \cos \bar{\theta}_{k,i}$$
$$Y_S = \bar{R}_i \sin \bar{\theta}_{k,i}$$
$$Z_S = \bar{Z}_i$$

Cylindrical Source Point

or:

$$X_S = \bar{R}_i \cos \bar{\theta}_{k,i} \sin \bar{\phi}_i$$
$$Y_S = \bar{R}_i \sin \bar{\theta}_{k,i} \sin \bar{\phi}_i$$
$$Z_S = \bar{R}_i \cos \bar{\phi}_i$$

Spherical Source Point

$$X_D = R_D \cos \theta_D$$
$$Y_D = R_D \sin \theta_D$$
$$Z_D = Z_D$$

Detector Point

where:

$\bar{R}_i$ = the geometrical mean of the source interval bounded by the radii R_i and R_{i+1}, i.e.,

$$\bar{R}_i = \sqrt{\frac{R_{i+1}^2 + R_i^2}{2}}$$

$\bar{\theta}_{k,i}$ = the arithmetic mean of the azimuthal source interval for each radial interval, i, bounded by $\theta_{k,i}$ and $\theta_{k+1,i}$, i.e.,

$$\bar{\theta}_{k,i} = \frac{\theta_{k+1,i} + \theta_{k,i}}{2}$$

$\overline{Z}_i$ = the arithmetic mean of the axial source interval bounded by Z_i and Z_{i+1}, i.e.,

$$\overline{Z}_i = \frac{Z_{i+1} + Z_i}{2}$$

$\overline{\phi}_i$ = the arithmetic mean of the polar source interval bounded by ϕ_i and ϕ_{i+1}, i.e.,

$$\overline{\phi}_i = \frac{\phi_{i+1} + \phi_i}{2}$$

R_D = the radial coordinate of the detector point (input to the problem)

θ_D = the azimuthal coordinate of the detector point (input to the problem)

Z_D = the axial coordinate of the detector point (input to the problem)

The total "line-of-sight" distance, ρ, between a source point and a detector point, and the direction cosines (α, β, γ) are then computed as follows:

$$\rho = \sqrt{(X_D - X_S)^2 + (Y_D - Y_S)^2 + (Z_D - Z_S)^2}$$

$$\alpha = \frac{X_D - X_S}{\rho}$$

$$\beta = \frac{Y_D - Y_S}{\rho}$$

$$\gamma = \frac{Z_D - Z_S}{\rho}$$

The next step in the geometry calculation is to obtain the path length, ρ_Z, traversed in each region along the "line-of-sight". This calculation begins with the coordinates of a "pseudo-point" (X', Y', Z'), along the "line-of-sight" which is related to the original source point by the input value, FUDGE, designated by Δ. This calculation is performed as:

$$X' = X_S + \alpha\Delta$$

$$Y' = Y_S + \beta\Delta$$

$$Z' = Z_S + \gamma\Delta$$

This pseudo-point, (X', Y', Z'), is used in conjunction with input zone boundaries, surface numbers, surface equations, input surface parameters, and the source zone number to calculate the correct zone in which X', Y', and Z' lies. The actual operation performed is a cyclic calculation of the quantities, V_{bZ}, for each boundary, b, of the source zone, Z. The cyclic calculation begins in the zone specified by the input value, IZSO. The values of V_{bZ} depend on the equation number $NEQBD_b$ of boundary b, and follow as:

$$V_{bZ} = A(X_p - X_0)^2 + B(Y_p - Y_0)^2 + C(Z_p - Z_0)^2 + X_0X_p + Y_0Y_p + Z_0Z_p - D,$$

$$V_{bZ} = A(X_p - X_0)^2 + B(Y_p - Y_0)^2 + C(Z_p - Z_0)^2 - D,$$

$$V_{bZ} = (X_p - X_0)^2 - (Y_p - Y_0)^2 - D,$$

$$V_{bZ} = X_p - D,$$

$$V_{bZ} = Y_p - D,$$

$$V_{bZ} = Z_p - D.$$

If the sign of the quantity, V_{bZ}, and the sign (ambiguity index) of the boundary surface number LBD_{bZ}, are of opposite sign for all boundary surfaces, the point (X', Y', Z') lies within the region or zone, Z. If the point does not lie in the IZSO zone, the program searches the zones in a specific order as follows: IZSO + 1, IZSO + 2, ...up to the number of zones, NREG; then it begins with Zone 1, 2, etc. up to IZSO-1. If a zone is found which contains the point (X', Y', Z'), the calculation proceeds to the next geometry calculation step. If no zone can be found which contains the point, the region calculation is terminated by printing an error statement along with the results for source regions preceding that one in which the error occurred.

The next step in calculating the path length in each region involves the analytic solution of distances from the point (X', Y', Z') to each boundary surface of the zone. The solution is obtained by solving the boundary equations for the point of intersection of the "line-of-sight" and the surface in question. These distances to each boundary are sequentially tested, and the minimum distance in the correct direction is selected as the distance from the "pseudo-point", (X', Y', Z') to the correct boundary. This quantity is defined as ρ'_Z.

At this point in the calculation, the correct path length in the zone is calculated as:

$$\rho_Z = \rho'_Z + \Delta$$

The material path lengths, ρ_m, for each material, m, are immediately calculated as cumulative sums from ρ_Z, and composition material matrix values, θ_{mc}, as follows:

$$\rho_m = \rho_m + \rho_Z \cdot \theta_{m,c}$$

In the above equation, c is the specific composition of the zone, Z, (quantities, $\theta_{m,c}$, are discussed in the next section), and ρ_m is set to zero at the beginning of each source-to-detector calculation. The final operation in the source zone path length calculation is the starting point for obtaining the next zone (along the line-of-sight) path length. The input values, $NTRYZN_{bZ}$, determine the "most probable" zone entered upon crossing boundary, b, of the zone, Z. With the last calculated value of ρ_Z, a new "pseudo-point" along the line-of-sight is calculated as:

$$X' = X' + \alpha\rho_Z$$

$$Y' = Y' + \beta\rho_Z$$

$$Z' = Z' + \gamma\rho_Z$$

These current "pseudo-point" coordinates and the zone number, $NTRYZN_{bZ}$, are used in the operations described above in calculating data for the next zone traversed in the source-detector "line-of-sight". The data of:

1) the correct zone,
2) the zone path lengths,
3) the new material path lengths, and
4) the zone entered upon crossing the correct boundary

are obtained for each zone along the line-of-sight. This cyclic procedure (calculation of zone path length) continues until an "outside zone" is reached or until the detector point, (X_D, Y_D, Z_D), is reached. At this point in the program, the total material path lengths,

ρ_m, on this particular source-to-detector "line-of-sight" are known, and hence the material attenuation functions and the source point detector flux can be evaluated. This source point-to-detector point calculation is repeated for each source point in a source region until the entire source region is accounted for.

2.2 MATERIAL AND NUCLEAR PROPERTIES

The contents of the KAP-V regions are described as homogeneous mixtures of constituents (elements or materials). These elements or materials, which may be used in as many regions as desired, are defined by a matrix of numbers, $\theta_{m,c}$. The quantities, $\theta_{m,c}$, describe <u>either</u> the density <u>or</u> the volume fraction of each constituent, m, in each composition, c. The density (weight of material/region volume) is used, for example, if the mass gamma ray absorption coefficients in units of cm^2/gm are employed. Volume fractions, i.e., the fraction of the region volume occupied by an element or material in a region composition is used, for example, if linear gamma ray absorption coefficients in units of cm^{-1} are input to the program. The maximum number of compositions is limited to fifty, each consisting of a maximum of 20 constituents (elements or materials). An example of this matrix is shown in Table 1.

The data in the matrix, $\theta_{m,c}$, are used in the geometry calculation to obtain the total thickness density, gm/cm^2, if $\theta_{m,c}$ is in units of gm/cm^3, <u>or</u> total thickness, cm, if $\theta_{m,c}$ is input as volume fractions. This operation is as follows:

$$\rho_m = \sum_{\bar{Z}} \theta_{m,c} \cdot \rho_Z$$

where the composition number, c, is specified as being in zone, Z.

Values of ρ_m are used in calculating the neutron and/or groupwise gamma ray penetration depth for each source to detector path length through each element or material, m.

A "void" is defined as a composition with zero density or volume fraction for each constituent in the matrix.

Nuclear data, such as gamma ray attenuation coefficients in a KAP-V problem are required for each constituent (element or material) in the material matrix. Specifically, required nuclear properties are the groupwise gamma ray mass or linear absorption coefficients,

TABLE 1

ELEMENT OR MATERIAL COMPOSITION MATRIX ($\Theta_{M,C}$)

Element or Material Number, M →

Composition Number, C ↓	1	2	3	4	. . . . .	MAT
1	$\Theta_{1,1}$	$\Theta_{2,1}$	$\Theta_{3,1}$	$\Theta_{4,1}$	. . . . .	$\Theta_{MAT,1}$
2	$\Theta_{1,2}$	$\Theta_{2,2}$	$\Theta_{3,2}$	$\Theta_{4,2}$	. . . . .	$\Theta_{MAT,2}$
3	$\Theta_{1,3}$	$\Theta_{2,3}$	$\Theta_{3,3}$	$\Theta_{4,3}$	. . . . .	$\Theta_{MAT,3}$
.	.	.	.	.	. . . . .	.
.	.	.	.	.	. . . . .	.
.	.	.	.	.	. . . . .	.
.	.	.	.	.	. . . . .	.
.	.	.	.	.	. . . . .	.
.	.	.	.	.	. . . . .	.
.	.	.	.	.	. . . . .	.
NCOMP	$\Theta_{1,NCOMP}$	$\Theta_{2,NCOMP}$	$\Theta_{3,NCOMP}$	$\Theta_{4,NCOMP}$	. . . . .	$\Theta_{MAT,NCOMP}$

$(\mu/\rho)_m$, or μ_m, and the mass or linear neutron removal cross sections, $(\Sigma/\rho)_m$ or Σ_m. The user must input (or compile from the library as discussed in Section 2.6) these quantities in dimensions consistent with the material matrix quantities, $\theta_{m,c}$. For example, if $(\mu/\rho)_m$ and $(\Sigma/\rho)_m$ are input in units of cm^2/gram, then $\theta_{m,c}$'s must be in units of grams/cm^3.

2.3 SOURCE

The KAP-V program can employ either a cylindrical or a spherical source region, as well as the basic source geometries of a point, line, or disk. The source distribution in cylindrical or spherical geometry is assumed separable in the spatial (radial, axial, or polar, and azimuthal) coordinates. The source energy distribution is input as a separate quantity.

The source distribution can be input as unnormalized radial and/or axial source data. The program integrates and normalizes the input distribution data to obtain the source strength of the source point representing each finite source volume in the source region.

The program assumes that the azimuthal distribution of the source density is uniform. The uniform azimuthal distribution data is used within the program to properly normalize the source.

The same distribution may be assumed for the gamma ray and neutron source, or, the user may specify a different source distribution and normalization constant for gamma rays and neutrons.

2.3.1 Energy Distribution

The quantity, $\Gamma(E_n$ or $E_G)$, defines the source strength in each energy group. For the gamma ray source strength, the quantity $\Gamma(E_G)$, may represent the number of particles (or photons) of energy, E_G, or energy release (Mev) at energy E_G. The user must provide dimensionally consistent data for the total power (if source strengths are input on a per watt basis or the gamma ray source input), $A_{T,I}$, in the source region, along with the gamma ray group source strengths, $\Gamma(E_G)$.

The neutron energy distribution parameters, $\Gamma(E_n)$, for the neutron differential energy spectrum function can be input as integration factors, ΔE_n, or as parameters to convert the neutron spectra data from units of one fission source neutron to units of neutrons per fission or

per watt. Also the quantity, $\Gamma(E_n)$, allows the user to input the total power or total fission rate in order to make the spectral data dimensionally consistent. The units of $\Gamma(E_n)$ must be dimensionally consistent with the total power (or neutron source strength) input as $A_{T'2}$.

Although the Albert-Welton function computes an energy independent dose rate based on a fission spectrum source, a separate quantity, Γ_{AW}, may be input to the code to provide a "source strength" for use with this function.

2.3.2 Spatial Distribution

The spatial source in a KAP-V source region is represented as a finite number of volume elements, each of which are represented as a source point. The source density at each source point, and the location of each source point, are determined by the program from input source parameters. The program includes techniques to calculate source point densities from: (1) analytical functions (uniform or flat, cosine, exponential), or (2) pointwise source values. The unnormalized source densities for gamma rays or neutrons are defined as the separable quantities: $f(\bar{R}_i)$, $f(\bar{Z}_i)$, $f(\bar{\phi}_i)$, and $f(\bar{\theta}_{k,i})$, for the space coordinates of R (radius for cylindrical or spherical sources), Z (axial dimension for cylindrical sources), ϕ (polar angle for spherical sources), and θ (azimuthal angle for cylindrical and spherical sources), respectively.

By means of the input quantities, (ISRC, ISZC, and ISTC), the program user selectes a technique for calculating the source density variation of interest.

Analytical Functions

The KAP-V cylindrical and spherical source density functions for the variable, R (radius), are described in equations 2.4 through 2.7.

The function, $f(\bar{R}_i)$, in equations 2.4 through 2.7 defines the unnormalized source density for each radial interval. The source point is placed at $\bar{R}_i$ of each annular source interval bounded by R_i and R_{i+1}. The quantity, $\bar{R}_i$, is defined by equation 2.1.

$$\bar{R}_i = \sqrt{\frac{R_{i+1}^2 + R_i^2}{2}} \qquad (2.1)$$

The function f ($\overline{Z}_i$ or $\overline{\emptyset}_i$) in equation 2.8 through 2.11 defines the unnormalized source for each axial or polar interval. The source point is placed at the arithmetic mean, $\overline{Z}_i$, or $\overline{\emptyset}_i$, of the axial or polar source interval bounded by Z_i and Z_{i+1} or $\emptyset_i$ and $\emptyset_{i+1}$ as defined by equations 2.2 and 2.3:

$$\overline{Z}_i = \frac{Z_{i+1} + Z_i}{2} \tag{2.2}$$

$$\overline{\emptyset}_i = \frac{\emptyset_{i+1} + \emptyset_i}{2} \tag{2.3}$$

The analytical functions for the cylinder and sphere, and the <u>only</u> required input parameters, follow as:

<u>Cylinder - Uniform Source Density (ISRC = 1)</u>

$$f(\overline{R}_i) = \int_{R_i}^{R_{i+1}} R\,dR \tag{2.4}$$

where values of R_i are required input.

<u>Cylinder - Cosine Variation of Source Density (ISRC = 2)</u>

$$f(\overline{R}_i) = \int_{R_i}^{R_{i+1}} \cos\ x_1 \left[R - x_2\right] R\,dR \tag{2.5}$$

where values of x_1, x_2 and R_i are required input.

<u>Cylinder - Exponential Variation of Source Density (ISRC = 4)</u>

$$f(\overline{R}_i) = \int_{R_i}^{R_{i+1}} x_2 \cdot \exp\ \left[x_1 R\right] R\,dR \tag{2.6}$$

where values of x_1, x_2 and R_i are required input.

Sphere - Uniform Source Density (ISRC = 6)

$$f(\bar{R}_i) = \int_{R_i}^{R_{i+1}} R^2 \, dR \tag{2.7}$$

where values of R_i are required input.

Cylinder - Uniform Source Density (ISZC = 1)

$$f(\bar{Z}_i) = \int_{Z_i}^{Z_{i+1}} dZ \tag{2.8}$$

where values of Z_i are required input.

Cylinder - Cosine Variation of Source Density (ISZC = 2)

$$f(\bar{Z}_i) = \int_{Z_i}^{Z_{i+1}} \cos \; \xi_1 \left[Z - \xi_2\right] dZ \tag{2.9}$$

where values of ξ_1, ξ_2 and Z_i are required input.

Cylinder - Exponential Variation of Source Density (ISZC = 4)

$$f(\bar{Z}_i) = \int_{Z_i}^{Z_{i+1}} \xi_2 \cdot \exp\left[\xi_1 Z\right] dZ \tag{2.10}$$

where values of ξ_1, ξ_2 and Z_i are required input.

Spherical - Uniform Variation of Source Density (ISZC = 6)

$$f(\bar{\phi}_i) = \int_{\phi_i}^{\phi_{i+1}} \cos \; \phi \, d\phi \tag{2.11}$$

where values of ϕ_i are required input.

Pointwise Source Density

Pointwise source density can be specified as input point values at the spatial limits (R_i, R_{i+1} or Z_i, Z_{i+1}) of each interval in the source region, or as point values calculated from input point values at spatial points other than the desired space points.

Input point values defined as $g(R_i)$ at R_i and $g(Z_j)$ at Z_j are used directly in the program to obtain the source density parameters of $f(\bar{R}_i)$ and $f(\bar{Z}_j)$. The use of these point values are specified by the input values ISRC and ISZC. The techniques used for direct input value calculations are based on a source variation between two adjacent spatial points, i.e., R_i, R_{i+1} or Z_i, Z_{i+1}. The point value calculation for cylindrical and spherical source regions follow as:

Cylinder - Linear Variation of Source Density (ISRC = 3)

$$f(\bar{R}_i) = \int_{R_i}^{R_{i+1}} [aR + b] \; R\,dR \tag{2.12}$$

where a and b are computed internally by the program from the adjacent values $g(R_i)$ at R_i and $g(R_{i+1})$ at R_{i+1}.

Cylinder - Exponential Variation of Source Density (ISRC = 5)

$$f(\bar{R}_i) = \int_{R_i}^{R_{i+1}} x_2 \cdot \exp\left[x_1 R\right] \; R\,dR \tag{2.13}$$

where x_1 and x_2 are computed internally by the program from the adjacent values $g(R_i)$ at R_i and $g(R_{i+1})$ at R_{i+1}.

Sphere - Linear Variation of Source Density (ISRC = 7)

$$f(\bar{R}_i) = \int_{R_i}^{R_{i+1}} [aR + b] \; R^2\,dR \tag{2.14}$$

where a and b are computed internally by the program from the adjacent values $g(R_i)$ at R_i and $g(R_{i+1})$ at R_{i+1}.

Cylinder - Linear Variation of Source Density (ISZC = 3)

$$f(\bar{Z}_i) = \int_{Z_i}^{Z_{i+1}} [aZ + b] \, dZ \tag{2.15}$$

where a and b are computed internally by the program from the adjacent values $g(Z_i)$ at Z_i and $g(Z_{i+1})$ at Z_{i+1}.

Cylinder - Exponential Variation of Source Density (ISZC = 5)

$$f(\bar{Z}_i) = \int_{Z_i}^{Z_{i+1}} \xi_2 \cdot \exp\left[\xi_1 Z\right] dZ \tag{2.16}$$

where ξ_1 and ξ_2 are computed internally by the program from the adjacent values $g(Z_i)$ at Z_i and $g(Z_{i+1})$ at Z_{i+1}.

The technique of calculating point values from input point values at spatial points other than the desired space points is a very useful facet of the KAP V program. The input point values may be representative of a fine radial mesh output from a transport code problem. The fine mesh may, however, provide too many source points for economical use in a point kernel calculation. Therefore, the user of the KAP-V code can input the exact transport code output data, of $g'(R')$ versus R', and the code will interpolate new point values $g(R)$ at R, where the values of the new radial mesh, R, are selected to better represent a point kernel source point description. The point values $g(R)$ at R are used in the equations 2.12 through 2.16 described above to calculate the pointwise source density. This interpolation technique is controlled by the input quantity ISIT, and the spatial distributions of the source are input as the point values, FSIT, at RSIT and ZSIT, as described in the section on input data, Section 4.0.

Azimuthal Variation

The azimuthal distribution is assumed to be uniform in the azimuthal space variable, θ, for cylindrical and spherical source regions. The user of the KAP-V program has the option of specifying the mode in which the routine will subdivide the θ variable into intervals as shown in equations 2.17 through 2.19.

Same Number of Azimuthal Intervals in All Radial Intervals (ISTC = 1)

$$f(\bar{\theta}_{k,i}) = \int_{\theta_{k,i}}^{\theta_{k+1,i}} d\theta \qquad \text{Required input, } \theta_{k,1} \tag{2.17}$$

Variable Number of Azimuthal Intervals in Each Radial Interval (ISTC = 2)

$$f(\bar{\theta}_{k,i}) = \int_{\theta_{k,i}}^{\theta_{k+1,i}} d\theta \qquad \theta_{k,i} \text{ are required input for each radial interval} \tag{2.18}$$

Variable Number of Azimuthal Intervals in Each Radial Interval (ISTC = 3)

$$f(\bar{\theta}_{k,i}) = \frac{\int_{\theta_{k,1}}^{\theta_{k+1,i}} d\theta}{k_i} \qquad k_i \text{ is required input for radial intervals} \tag{2.19}$$

These three options allow description of the three possible variations shown in Figure 3. One additional option is available to the program user: if discrete point sources are of interest, then the quantity ISRC is input as a zero, and the source density is input as $f(\bar{R}, \bar{Z}, \bar{\theta})$. This option allows the user to describe a variable source density in the azimuthal variable, θ.

2.3.3 Normalization of Source Parameters

The source normalization routine in the KAP-V program gives the user the versatility to input the source distribution data in unnormalized form. The program normalizes the source parameters as shown in the equations which follow.

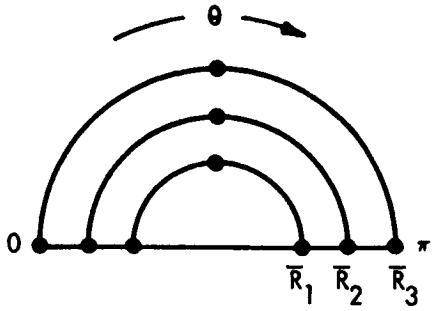
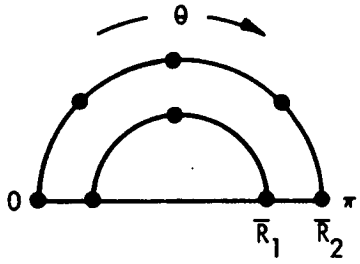
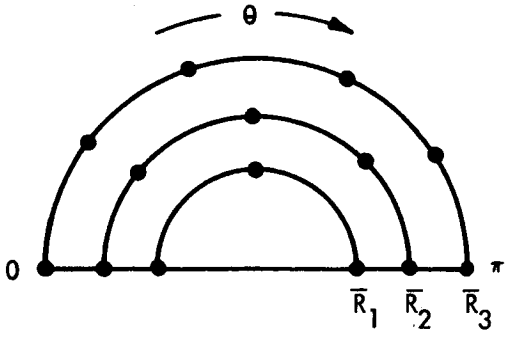
SOURCE GEOMETRY	INPUT DATA
	IF ISTC = 1, $\theta_{K,1}$ IS INPUT AS 0.0, 1.5708, 3.1416
	IF ISTC = 2, $\theta_{K,1}$ IS INPUT AS 0, 1.5708, 3.1416, $\theta_{K,2}$ IS INPUT AS 0, .7854, 1.5708, 2.3562, 3.1416
	IF ISTC = 3, K_1 IS INPUT AS 2, K_2 IS INPUT AS 4, K_3 IS INPUT AS 5

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Figure 3. Examples of Azimuthal Source Description

Cylindrical Source Region

Gamma Ray Source

$$P'_1 = \frac{A_{T,1}}{\left[\theta_{1,k+1} - \theta_{1,1}\right] \cdot \iint_{R\,Z} f_1(\bar{R}_i) \cdot f_1(\bar{Z}_i) \cdot R\,dR\,dZ} \tag{2.20}$$

$$f'_1(\bar{\theta}_{k,i}) = P'_1 \cdot f_1(\bar{\theta}_{k,i}) \tag{2.21}$$

where:

$A_{T,1}$ = the gamma ray source normalization constant which is input as ASOI(1).

$\theta_{1,k+1}$ = the upper limit of the θ variable for the gamma ray problem

$\theta_{1,1}$ = the lower limit of the θ variable for the gamma ray problem

$f_1(\bar{R}_i)$ = the unnormalized gamma ray source density at each radius, R_i

$f_1(\bar{Z}_i)$ = the unnormalized gamma ray source density at each value of Z_i

$f_1(\bar{\theta}_{k,i})$ = the unnormalized gamma ray source density at each azimuthal value θ_k for each radial position, i (i.e., $\Delta\theta_{k,i}$)

Neutron Source

If ASOI (2) is input as zero, then the program uses the gamma ray source, $A_{T,1}$, and distributions for neutrons and solves the same equation described for gamma rays. If ASOI(2) in not input as zero, then the program solves the following equations:

$$P'_2 = \frac{A_{T,2}}{\left[\theta_{1,k+1} - \theta_{1,1}\right] \cdot \iint_{R\,Z} f_2(\bar{R}_i) \cdot f_2(\bar{Z}_i)\, R\,dR\,dZ} \tag{2.22}$$

$$f'_2(\bar{\theta}_{k,i}) = P'_2 \cdot f_2(\bar{\theta}_{k,i}) \tag{2.23}$$

where all terms were previously defined and the subscript 2 refers to neutron data.

The normalized quantity, $f'(\bar{\theta}_{k,i})$, and the unnormalized quantities, $f(\bar{R}_i)$ and $f(\bar{Z}_i)$, provide the source magnitude of the source point defined at the coordinates $\bar{R}_i$, $\bar{Z}_i$, and $\bar{\theta}_{k,i}$ as $S(\bar{R}_i, \bar{Z}_i, \bar{\theta}_{k,i})$ in units of watts or particles per second.

This source parameter data is stored internally to the program and is used in the definition of the source magnitude for each source-to-detector calculation.

The user has the option of specifying the source region azimuthal parameters, $\theta_{1,k+1}$, $\theta_{1,1}$, or $\theta_{2,k+1}$, $\theta_{2,1}$ such that the source region symmetry is accounted for in the normalization. If $A_{T,1}$ or $A_{T,2}$ is total power (or source strength), and if $\theta_{1,k+1}$ and $\theta_{1,1}$ are π and 0.0, the power or source density is effectively twice that in the source region. Hence each source point source at $\theta_{1,k}$ includes its mirror image at $\theta_{1,k+\pi}$.

Spherical Source Region

Gamma Ray Source

$$P'_1 = \frac{A_{T,1}}{\left[\theta_{1,k+1} - \theta_{1,1}\right] \cdot \iint_{\phi\,R} \sin(\phi) \cdot f_1(\bar{\phi}_i) \cdot f_1(\bar{R}_i)\, R^2 dR\,d\phi} \tag{2.24}$$

$$f'_1(\bar{\theta}_{k,i}) = P'_1 \cdot f_1(\bar{\theta}_{k,i}) \tag{2.25}$$

where:

$f_1(\bar{\phi}_i)$ = the unnormalized gamma ray source density at each polar coordinate, $\bar{\phi}_i$ and all other terms are as previously defined.

Neutron Source

$$P_2' = \frac{A_{T,2}}{\left[\theta_{1,k+1} - \theta_{1,1}\right] \cdot \int_{\phi}\int_{R} \sin(\phi) \cdot f_2(\bar{\phi}_i) \cdot f_2(\bar{R}_i)\, R^2 dR d\phi} \qquad (2.26)$$

$$f'_2(\bar{\theta}_{k,i}) = P'_2 \cdot f_2(\bar{\theta}_{k,i}) \qquad (2.27)$$

where all terms are as previously defined, and the subscript 2 refers to neutron data.

2.4 MATERIAL ATTENUATION

2.4.1 Fast Neutron

The KAP V program contains three material attenuation options for obtaining the neutron response at a detector point. The user can specify the use of the modified Albert-Welton material attenuation function[2], and either a bivariant or monovariant polynomial material attenuation function for calculating differential neutron spectra employing infinite media moments data. Various conversion factors can be applied to any of these three functions, as described in Section 2.5 for conversion to different units.

Fast Neutron Dose Rate

A modification of the Albert-Welton function is used to calculate the fast neutron dose rate from fission sources in mixtures of hydrogenous and heavy materials. This function combines a theoretical hydrogen cross section with integration over the fission neutron spectrum to obtain the uncollided flux or dose. Attenuation effects of non-hydrogenous materials are included by employing exponential attenuation with effective removal cross sections.

The basic assumption in the Albert-Welton function is that all heavy materials are followed by sufficient hydrogenous materials to validate the use of neutron removal cross sections for the heavy materials. In addition, the Albert-Welton function is an integral quantity calculated from theoretical consideration of the energy dependence of neutron cross sections and the variation of neutron spectrum with penetration in hydrogen. Hence, the Albert-Welton function dose rate does not include buildup of neutrons at lower energies.

The equation coded in the program for computing the energy independent fast neutron response at the detector from each source point is:

$$D_n = \frac{\Gamma_{AW} \cdot S(\bar{R}_i, \bar{Z}_i, \bar{\theta}_k) \cdot \psi(W'_R, X_R)}{4\pi \rho^2} \tag{2.28}$$

where:

Γ_{AW} = the "source strength" for use in the Albert-Welton function.

$S(\bar{R}_i, \bar{Z}_i, \bar{\theta}_k)$ = the volume weighted source strength for the source point, located at $\bar{R}_i, \bar{Z}_i, \bar{\theta}_{k,i}$

ρ = the distance (cm) from the source point to the detector point.

$$\psi(W'_R, X_R) = \alpha_1 \cdot \left[X_R\right]^{\alpha_2} \cdot \exp\left[-\alpha_3 X_R\right]^{\alpha_4} \cdot \exp\left[-W'_R\right] \tag{2.29}$$

$$W'_R = \sum_{m=1}^{M} \Sigma'_m \rho_m \tag{2.30}$$

$$X_R = \sum_{m=1}^{M} \eta_m \rho_m \tag{2.31}$$

Σ'_m = non-hydrogenous removal cross section for all materials, m

ρ_m = the path length for each material, m

η_m = the ratio of the hydrogen density in material m to the hydrogen density in water

$\alpha_1, \alpha_2, \alpha_3$, and α_4 are constants.

The user will note that in equation 2.31 the units of X_R may be either cm or gm/cm^2 depending on the units of the path length (ρ_m). Hence, care must be exercised in applying the input quantity, η_m, to assure proper units.

Since the Albert-Welton function (equation 2.29) cannot be used to calculate the neutron dose rate for small values of X_R, the following equation (originally coded in Program 14-0) is employed in the KAP V code:

$$\Psi(W'_R, X_R) = \alpha_5 \cdot \exp\left[-\alpha_7 X_R\right] \cdot \exp\left[-W'_R\right], \text{ if } X_R < \alpha_6 \tag{2.32}$$

Values of α_5, α_6, and α_7, are input to the code. The units of α_1, (eq. 2.29) and α_5 (eq. 2.32) must be compatable to provide proper units for dose rate calculations.

Neutron Spectra

Either a monovariant or a bivariant polynomial expression can be employed to calculate the differential neutron spectrum. The monovariant polynomial data are available as sets of data representing specific differential spectrum energy points and are solved only in the variable of material depth penetration, W_R. In contrast, the bivariant polynomial data are available as sets of data which are solved as a function of initial neutron energy, E_n, as specified by the user, and material depth penetration, W_R.

The monovariant and bivariant polynomial representation of the moments method data is derived from the infinite medium moments method data such as that generated by the Nuclear Development Corporation [7]. The polynomial coefficients are applicable over specific depth penetration or energy. The user of the KAP program specifies the applicable ranges of polynomial data. Both polynomials are based on the infinite medium of the particular material (hereafter called the reference material) used in the moments method calculation. The inclusion of other materials is based on their equivalent neutron removal in comparison to the reference material; hence, extreme care must be used in selecting the removal cross section for material in non-hydrogenous media (e.g., carbon and beryllium media). The equivalent depth penetration in the reference material is calculated in the program as:

$$W_R = \sum_{m=1}^{M} \Sigma_m \rho_m / \Sigma_R \tag{2.33}$$

where, Σ_R is the neutron removal cross section for this reference material.

The user specifies a separate set of neutron removal cross sections, Σ_m, for the neutron spectra option which is not the same set that was used in the Albert-Welton function. The program then uses these cross section data in the evaluation of W_R. A restriction of the moments data evaluation in the KAP program arises when the depth penetration exceeds the range of applicability of the polynomial data. The program automatically truncates the polynomial evaluation at $W_R = 120$ gm/cm^2. However, the user is provided with the capability to input energy dependent extrapolation parameters, $\lambda(E_n)$, for extending the range of the moments data functions.

The equation coded in the program for computing the differential neutron energy response at the detector from each source point for each scattered neutron energy, E_n is:

$$D_n(E_n) = \frac{\Gamma(E_n) \cdot S(\bar{R}_i, \bar{Z}_j, \bar{\sigma}_k) \cdot \Psi(W_R, E_n)}{4\pi\rho^2} \tag{2.34}$$

where:

$\Gamma(E_n)$ = the source strength for each group, E_n, and all other parameters were previously defined except $\Psi(W_R, E_n)$ which is described below.

<u>Neutron Spectra Monovariant Polynomial</u>

$$\Psi(W_R, E_n) = \exp\left[f(W_R, E_n)\right] \tag{2.35}$$

where:

$$f(W_R, E_n) = \sum_{i=0}^{4} \gamma_i(E_n) \cdot W_R^{\,i} \tag{2.36}$$

γ_i = monovariant polynomial coefficients fit to the infinite media neutron spectra data

If, $W_R > 120.0$ gm/cm^2,

$$f(W_R, E_n) = \left[\sum_{i=0}^{4} \gamma_i (E_n) \cdot 120.0^i\right] \cdot \exp\left[-\lambda(E_n) \cdot (W_R - 120.0)\right] \tag{2.37}$$

$\lambda(E_n)$ = parameter for extrapolation of the neutron spectra data for each neutron energy, E_n

Neutron Spectra Bivariant Polynomial

$$\Psi(W_R, E_n) = \exp\left[f(W_R, E_n)\right] \tag{2.38}$$

where:

$$f(W_R, E_n) = \sum_{i=0}^{4} \sum_{j=0}^{6} \Delta_{ij} E_n^{\,i} W_R^{\,i} \tag{2.39}$$

Δ_{ij} = bivariant coefficients fit to the infinite media neutron spectra data

If, $W_R > 120.0$ gm/cm^2,

$$f(W_R, E_n) = \left[\sum_{i=0}^{4} \sum_{j=0}^{6} \Delta_{ij} E_n^{\,i}\, 120.0^i\right] \exp\left[-\lambda(E_n) \cdot (W_R - 120.0)\right] \tag{2.40}$$

2.4.2 Gamma Ray

The KAP-V program calculates and prints as output data both the uncollided and collided (based on buildup factors) gamma ray functions.

The equation coded in the program for computing the response at the detector from each source point for each gamma ray energy group, E_G is:

$$D_\gamma(E_G) = \frac{\Gamma(E_G) \cdot S(\bar{R}_i, \bar{Z}_j, \bar{\theta}_k) \cdot \psi(\rho_m, E_G)}{4\pi \rho^2} \tag{2.41}$$

where: $\Gamma(E_G)$ = the source strength for each group, E_G, and all other terms were defined previously, except $\psi(\rho_m, E_G)$ which is defined below.

Uncollided Gamma Ray Flux

$$\psi(\rho_m, E_G) = \exp\left[-b_T(E_G)\right] \tag{2.42}$$

where:

$$b_T(E_G) = \sum_{m=1}^{M} \mu_m(E_G)\, \rho_m \tag{2.43}$$

$\mu_m(E_G)$ = the gamma ray total absorption coefficient for each material, m, and each gamma ray group, E_G.

Collided Gamma Ray Flux

$$\psi(\rho_m, E_G) = B(\rho_m, E_G) \cdot \exp\left[-b_T(E_G)\right] \tag{2.44}$$

where:

$$B(\rho_m, E_G) = B\left[b_T(E_G)\right] \tag{2.45}$$

or, if $b_T(E_G) > 20.0$,

$$B(\rho_m, E_G) = B(20.0)$$

and,

$$B\left[b_T(E_G)\right] = \sum_{i=0}^{3} \beta_i(E_G) \cdot \left[b_T(E_G)\right]^i \tag{2.46}$$

The quantities, β_i, are the coefficients for the cubic polynomial fit to the infinite media buildup factor data. These values of β_i can be either input to the code or obtained from the built-in library described in Section 2.6. In the above equation, $b_T(E_G)$, is not allowed to exceed 20.0 mean free paths, because the polynomial functions are not valid beyond this range.

The user will note that in equation 2.43, the units of $\mu_m(E_G)$ can be input as either cm^{-1} or cm^2/gm depending upon the units of ρ_m. If the library of the gamma ray absorption coefficients (see Section 2.6) is employed in the program, the units of $\mu_m(E_G)$ are cm^2/gm.

2.5 CONVERSION OF RADIATION LEVELS TO VARIOUS UNITS

A desirable feature of the KAP-V program is the ability to apply conversion factors to the total energy independent fast neutron response, the differential neutron energy response, and the gamma ray response. For example, application of the conversion factors to the gamma ray response could, at the option of the user, provide gamma ray output data in units of: Mev/cm^2-sec, R/hr, R/hr-watt, Rads-carbon/hr, watts/gm-steel, watts/gm-aluminum, etc., all in one run on the computer.

First, the code calculates the total response at a given detector from all source points in a specific source region as follows:

$$DT_n = \sum_{\substack{\text{over all}\\ \text{source points}}} D_n = \text{Total energy-independent fast neutron response} \tag{2.47}$$

$$DT_n(E_n) = \sum_{\substack{\text{over all}\\ \text{source points}}} D_n(E_n) = \text{Total differential fast neutron energy response} \tag{2.48}$$

$$DT_\gamma(E_G) = \sum_{\substack{\text{over all}\\ \text{source points}}} D_\gamma(E_G) = \text{Total gamma ray response} \tag{2.49}$$

where: D_n, $D_n(E_n)$, and $D_\gamma(E_G)$ were previously defined for each source point, in Equations 2.28, 2.34, and 2.41, respectively.

A set of ten energy independent conversion factors may be input to convert the quantity, DT_n, to other units; a second set of ten conversion factors for each group, E_n, may be input to convert the quantity $DT_n(E_n)$, to other units; finally, a third set of ten conversion factors for each group, E_G, may be input to convert the quantity, $DT_\gamma(E_G)$, to other units. Therefore, for each detector point calculation, a total of thirty different responses may be obtained as output data.

The equations solved in applying the conversion factors are as follows:

Albert-Welton Function

$$DT'_{n,1} = DT_n \cdot C_1 \tag{2.50}$$

$$DT'_{n,2} = DT_n \cdot C_2$$

$$\vdots$$

etc.

where: $C_1, C_2, \cdots, C_{10}$ = the input conversion factors, RSPA.

Differential Neutron Spectra Function

$$DT'_{n,1}(E_n) = DT_n(E_n) \cdot C_1(E_n) \tag{2.51}$$

$$DT'_{n,2}(E_n) = DT_n(E_n) \cdot C_2(E_n)$$

$$\vdots$$

etc.

where: $C_1(E_n), C_2(E_n), \cdots, C_{10}(E_n)$ = each set of input conversion factors (RSPN), for each group, E_n.

Gamma Ray Function

$$DT'_{\gamma,1}(E_G) = DT_\gamma(E_G) \cdot C_1(E_G) \tag{2.52}$$

$$DT'_{\gamma,2}(E_G) = DT_\gamma(E_G) \cdot C_2(E_G)$$

•

•

•

etc.

where: $C_1(E_G)$, $C_2(E_G)$, $\cdots$, $C_{10}(E_G)$ = each set of input conversion factors (RSPG), for each group, E_G.

The user will note that at least one set of response functions must be input for each function, DT_n, $DT_n(E_n)$, and $DT_\gamma(E_G)$. Otherwise the program will multiply by zero, and all values of DT'_n, $DT'_n(E_n)$, and $DT'_\gamma(E_G)$ will be printed as zeros.

2.6 LIBRARY DESCRIPTION

Gamma ray library data are included in the program to reduce tedious preparation of input data and to provide the user with latitude in specifying source gamma ray energies (e.g., a single 2.23 Mev gamma ray from hydrogen radiative capture or any of the radioisotope gamma ray source energies). The gamma ray library data consists of: 1) gamma ray mass absorption coefficients as a function of element atomic number (Z)and gamma ray energy(E_G), and 2) gamma ray buildup data as a function of material (H_2O, Al, etc,), type (energy, dose, energy absorption), and gamma ray energy (E_G). The calculated data requested from the library are stored internally by the program in the correct input data array.

2.6.1 Gamma Ray Mass Absorption Coefficient Data

Gamma ray absorption coefficients for each element can either be input to the program, or calculated from library data, or both. The program assumes the library calculated data to be the first set in the coefficient data, and the user (if using both options simultaneously) must input coefficient data at the proper addresses (see Section 4.4).

The gamma ray absorption coefficients in the library are calculated by two methods, depending on the atomic number of the element which is input to the program. These mass absorption coefficients are computed in units of cm^2/gm.

Method 1 ($1 \leq Z \leq 19$)

If the atomic number (Z) of the element is less than $Z = 20$, the program uses parabolic interpolation of tabulated data to obtain the mass absorption coefficient, $\mu/\rho\,(E_G)$, at energy E_G for the specified atomic number. A total of 19 sets of tabulated mass absorption coefficient data are included for $Z = 1$ through 19. Each set contains the 28 energy points presented in Reference 5. The 19 sets of element coefficient data were obtained from References 5 and 8.

Method 2 ($19 < Z \leq 92$)

If the atomic number (Z) of the element is greater than 19, an equation for $\left(\frac{\mu}{\rho}(E_G)\right)$ in the form of a bivariant polynomial is solved to obtain the mass absorption coefficient as a function of element atomic number (Z) and gamma ray energy (E_G). The mass absorption coefficient calculation follows as:

$$\left[\frac{\mu}{\rho}(E_G)\right]_m = \sum_{n=0}^{3}\sum_{g=0}^{3} \tau_{ng}\,(Z_m)^n \left(\frac{1}{E_G}\right)^g \qquad (2.53)$$

The τ_{ng}'s are bivariant polynomial coefficients from Reference 5 fitted over two energy ranges of 0.2 to 2.0 Mev, and 2.0 to 10 Mev. If the input gamma ray energy is below 0.2 Mev, or greater than 10.0 Mev, the program sets the energy equal to the limit (0.2 or 10.0 Mev) and obtains the absorption coefficient at the energy limit.

2.6.2 Gamma Ray Buildup Factor Data

Gamma ray buildup factor data in the KAP V program can either be input to the program as specific energy group data, or the user may calculate the buildup factor using a bivariant polynomial equation. The program contains a library of a single set of bivariant polynomial data (Reference 6) that can be evaluated for each gamma ray energy group. Buildup factor input data to the program is restricted to the cubic polynomial data in the variable, $b_T(E_G)$. The buildup of gamma ray energy is represented by a single material. Hence, the user must select a set of polynomial data which is representative of the system material composition (e.g., in the NERVA-type reactor system, water buildup data is the most applicable data available).

The polynomial form of the buildup factor in the program is:

$$B\left(b_T(E_G)\right) = \sum_{i=0}^{3} \beta_i(E_G)\left[b_T(E_G)\right]^i \tag{2.54}$$

If the user specifies the buildup factor library data, the control word IBILD and the input gamma ray energies, E_G, are used in computing the polynomial coefficients, $\beta_i(E_G)$, to be used in all buildup factor evaluations. The values of $\beta_i(E_G)$ are internally computed by the program from the bivariant polynomial expressions presented in Reference 6. These bivariant polynomials have certain restrictions which the program handles as follows:

1. If the gamma ray energy is less than or greater than the applicable energy range of the bivariant polynomial data, the buildup factor coefficients $\beta_i(E_G)$'s are evaluated at the lower or upper limit of the range (see Table 2).

2. If the polynomial's applicable range (TMFP) of depth penetration, $b_T(E_G)$, in mean free paths, is different than 20.0, the program assigns a value consistent with the buildup data to be used.

3. If the bivariant polynomial data is available for two ranges of energy, the program automatically selects the correct set of data to be evaluated for each energy.

TABLE 2

LIBRARY BIVARIANT POLYNOMIAL DATA

FOR GAMMA RAY BUILDUP COEFFICIENT EVALUATION

IBILD Value	Material	Buildup Type	Applicable Ranges E_G(lower)	E_G(upper)	b_t(upper)*
1	Water	Dose	0.255	10.0	20.0
2	Water	Energy	"	"	"
3	Water	Energy Absorption	"		
4	Aluminum	Dose	0.5		
5	Aluminum	Energy			
6	Aluminum	Energy Absorption			
7	Iron	Dose			
8	Iron	Energy			
9	Iron	Energy Absorption			
10	Uranium	Dose			15.0
11	Uranium	Energy			
12**	Uranium	Energy Absorption			
13	Lead	Dose			
14	Lead	Energy			
15***	Lead	Energy Absorption			
17***	Tin	Dose			
19***	Tin	Energy			
21***	Tin	Energy Absorption			
23***	Tungsten	Dose			
25***	Tungsten	Energy			
27***	Tungsten	Energy Absorption	0.5	10.0	15.0

*b_t(lower) = 0.0 for all data, where b_t is the mean free path

**Data does not exist in Library

***Note: Odd numbered values are applicable between 0.5 and 4 Mev. Even numbered values, which are not given, are applicable between 4.0 and 10.0 Mev. The code automatically handles this problem.

The buildup factor library data presently available in the KAP V program is shown in Table 2 along with the applicable ranges of energy and depth penetration values which are built into the program. The input values of IBILD that will select the desired data are also presented.

The bivariant polynomials solved by the program to obtain the buildup factor coefficients, $\beta_i(E_G)$, are:

$$\beta_i(E_G) = \sum_{j=0}^{J} \xi_{ij}(Z_m)^j \tag{2.55}$$

or

$$\beta_i(E_G) = \sum_{j=0}^{J} \xi_{ij}\left(\frac{1}{Z_m}\right)^j \tag{2.56}$$

The program automatically selects the proper form of the polynomial as indicated by the input values of IBILD, E_G, and Z_m.

2.7 CALCULATIONS FOR A DETECTOR IN A SOURCE REGION

A basic difficulty with the point kernel technique is the calculation of the detector response when the detector is located in, or very close to, the source region. This difficulty arises when the denominator in the kernel approaches zero, i.e., in the equation, $\psi/4\pi\rho 2$, if ρ (the distance from the source point to the detector point) is a very small number, the function, ψ, approaches infinity, and yields misleading, if not erroneous results. To obtain a meaningful (or valid) detector response when the source-detector separation distance is small, the spacing of source points in the near vicinity of the detector must be handled with extreme caution. The preceding discussion applies even when the option (described in this section) is used.

To compute the analytical response at the detector within a source region using this option, the control word ISCP must be input as the composition number of the source region of interest, and SMFP, which is the total mean free path of the source region composition (ISCP), must be input.

This option, which is provided to the program user, should be applied judiciously. Note that the option applies only to a gamma ray calculation. Also, the option is not applicable when the source point and the detector point are at the same identical location.

The program then solves the following equation:

$$\mu_s(E_G) = \sum_{m=1}^{M} \left[\frac{\mu}{\rho}(E_G)\right]_m \cdot \theta_{m,\ ISCP} \qquad (2.57)$$

where:

$\mu_s(E_G)$ = the macroscopic gamma ray absorption coefficient (cm^{-1}) for the source region of interest for each energy group, G.

$\left[\frac{\mu}{\rho}(E_G)\right]_m$ = the microscopic gamma ray absorption coefficient (cm^2/gm) for each energy group, G.

$\theta_{m,\ ISCP}$ = the density (gm/cm^3) of each material, m, in the composition, ISCP.

In the above equation, $\left[\frac{\mu}{\rho}(E_G)\right]_m$, can be input as macroscopic data (cm^{-1}), if θ_m, ISCP are input as dimensionless volume fractions.

Next, the dimensionless quantity, ν, is calculated for each source point as:

$$\nu = \mu_s(E_G) \cdot \rho$$

where ρ is the total distance (cm) from a particular source point to the detector point, and $\mu_s(E_G)$ is defined above.

For each source-detector path calculation, ν is tested against the input quantity, SMFP. If, $\nu \geq$ SMFP, the code calculates the usual attenuation function. But, if $\nu <$ SMFP, the program solves the following equation as the gamma ray attenuation function, $D_\gamma(E_G)$, at the detector for each group, G:

$$D_\gamma(E_G) = \frac{B(E_G, SMFP) \cdot \bar{S}(E_G) \cdot \left(1 - \exp(-SMFP)\right)}{\frac{4}{3}\pi\left(\frac{SMFP}{\mu_s(E_G)}\right)^3 \cdot \left(\mu_s(E_G)\right)} \tag{2.58}$$

where:

$B(E_G, SMFP)$ = the buildup factor for each group, G, computed as: $\beta_o + \beta_1 SMFP$
$= \beta_2(SMFP)^2 + \beta_3(SMFP)^3$

$\bar{S}(E_G)$ = the source (e.g. watts or fissions per second) for the sphere whose radius is defined as ν for each group, G.

$\frac{4}{3}\pi\left(\frac{SMFP}{\mu_s(E_G)}\right)^3$ = the volume, cm^3, of the sphere, calculated for each group, G.

The quantity, $\bar{S}(E_G)$, is calculated as: $\sum_{\text{all source points within radius, } \nu} S'$, where S' is the source for each volume in which a source point is located. Equation 2.58 is simply the solution of the response at a detector point located at the center of a spherical source of ν mean free paths in radius as given in reference 9, page 371.

The quantity, $D_\gamma (E_G)$, is added to the detector response calculated for all the source points external to the sphere. Two examples are given to illustrate some problems associated with the option.:

1. Figure 4 shows an r, z plane cut through an "exclusion" sphere of radius, ν . A typical source point mesh is also shown in Figure 4. The detector point is located at D, the center. For this example, attenuation functions for source points, 1-4, 5, 8, 9, and 12-16 would be calculated by the usual KAP V equations. The source strengths for the volume elements surrounding points 6, 7, 10, and 11 would be used in the "sphere" option.

One can observe that a part of the volume surrounding points 6, 7, 10, and 11 is outside the sphere, but are included in the total source calculations for the sphere; and, that part of the element volume surrounding point no. 8 (for example) which actually lies within the sphere, is not included in the total source for the sphere.

These approximations are part of the option, and introduce some uncertainties in the answer.

2. Figure 5 shows a sphere overlapping two regions having different composition numbers. The zone with composition no. 1 is not a source region. But that portion of the sphere which extends into the region (shown by the shaded area) does, in fact, have a source strength associated with it. Hence, a calculation using this option (as coded) when the detector is near the boundary of a source region, introduces uncertainties in the answer.

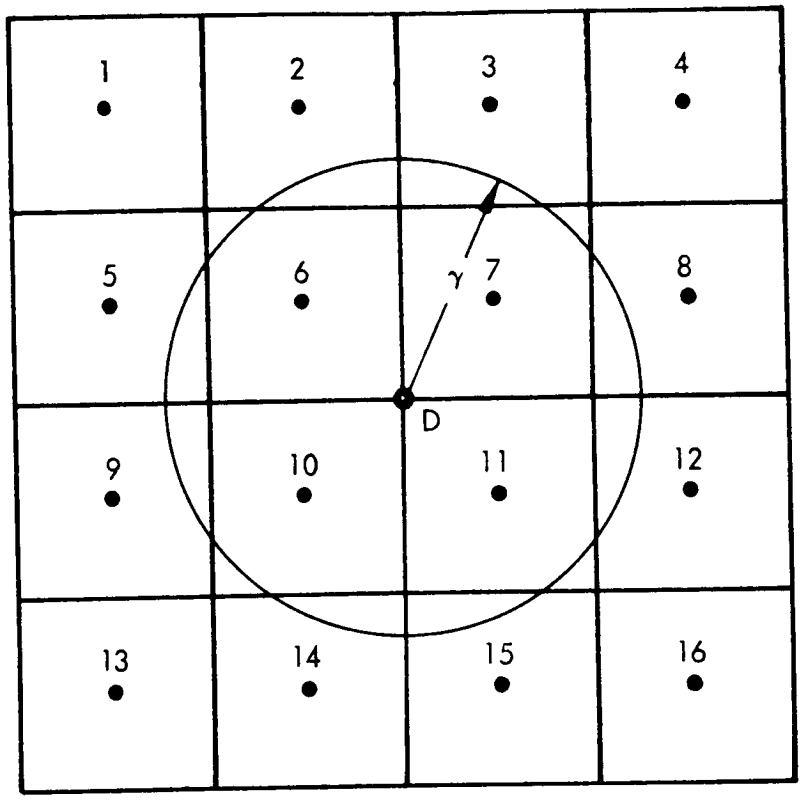

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Figure 4. Example of "Exclusion" Sphere Option

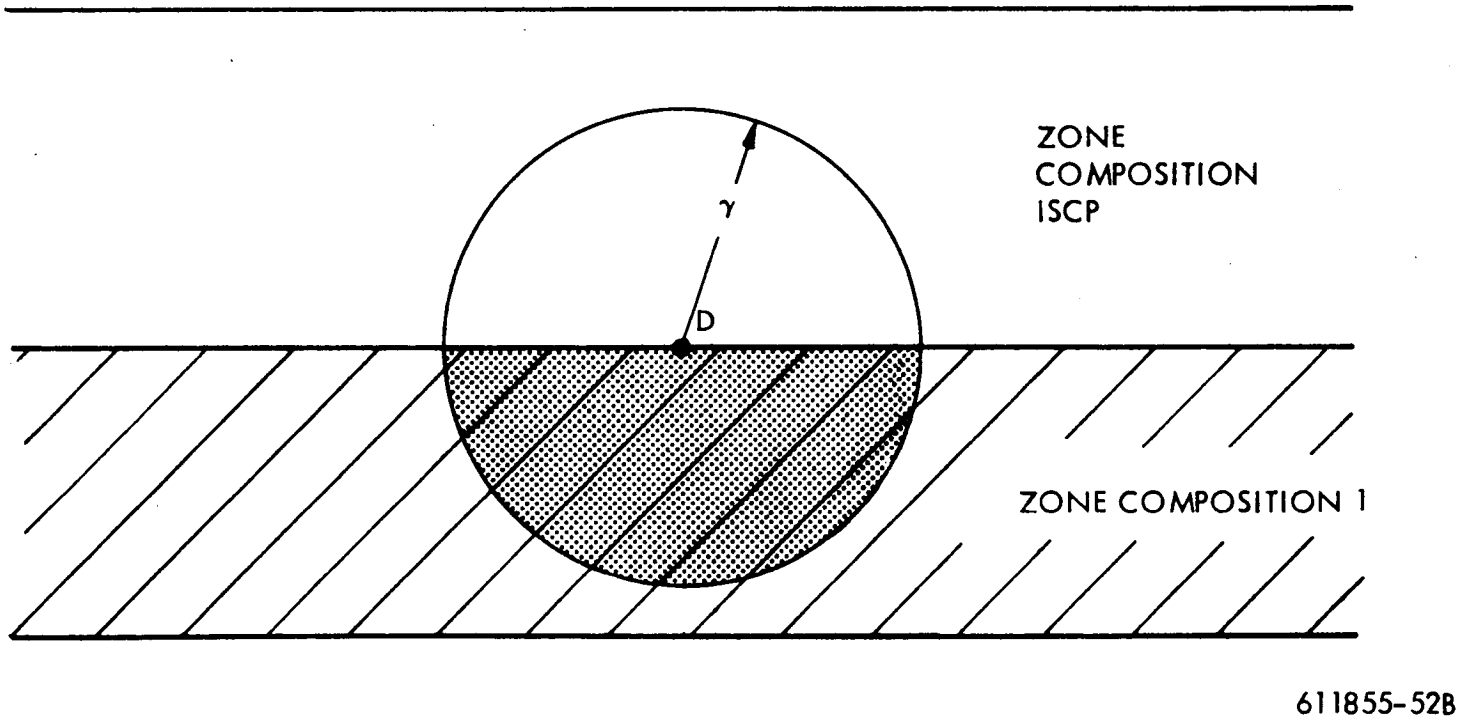

Figure 5. Example of "Exclusion" Sphere Option

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SECTION

3.0 PROGRAM LOGIC

The program logic for the KAP-V program is presented in this section. The flow chart is constructed in a simplified form to illustrate to the user when a certain operation or calculation is performed. The symbolism used in the flow chart is shown in Figure 6 and the actual KAP-V logical flow chart is given in Figure 7. Each of the principal operations performed by KAP-V are described in previous sections. The logic of the program as presented in Figure 7 has the principal FORTRAN DO loops indicated as indexing loops A-D for simplicity.

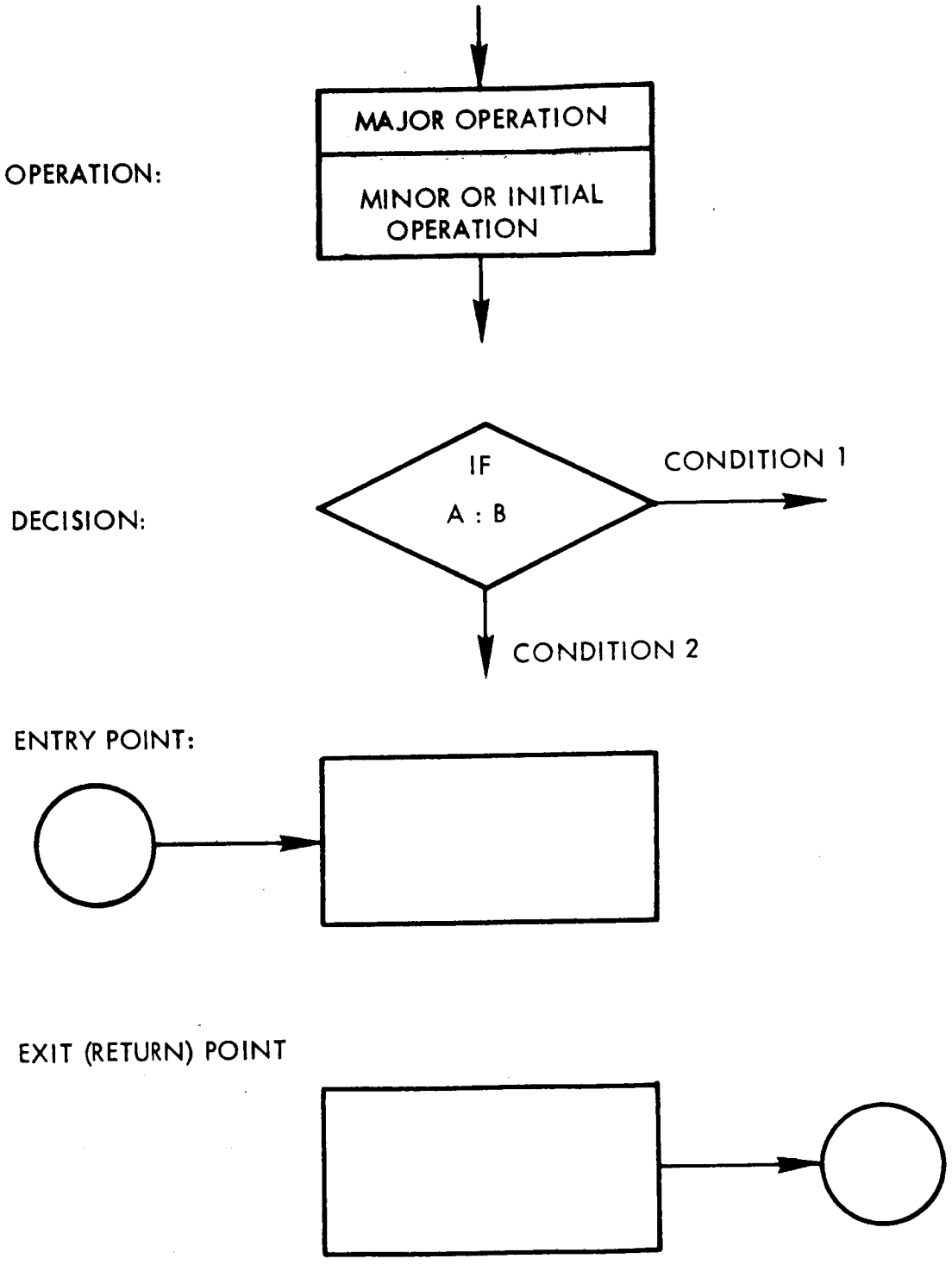

Figure 6. Flow Chart Symbolism

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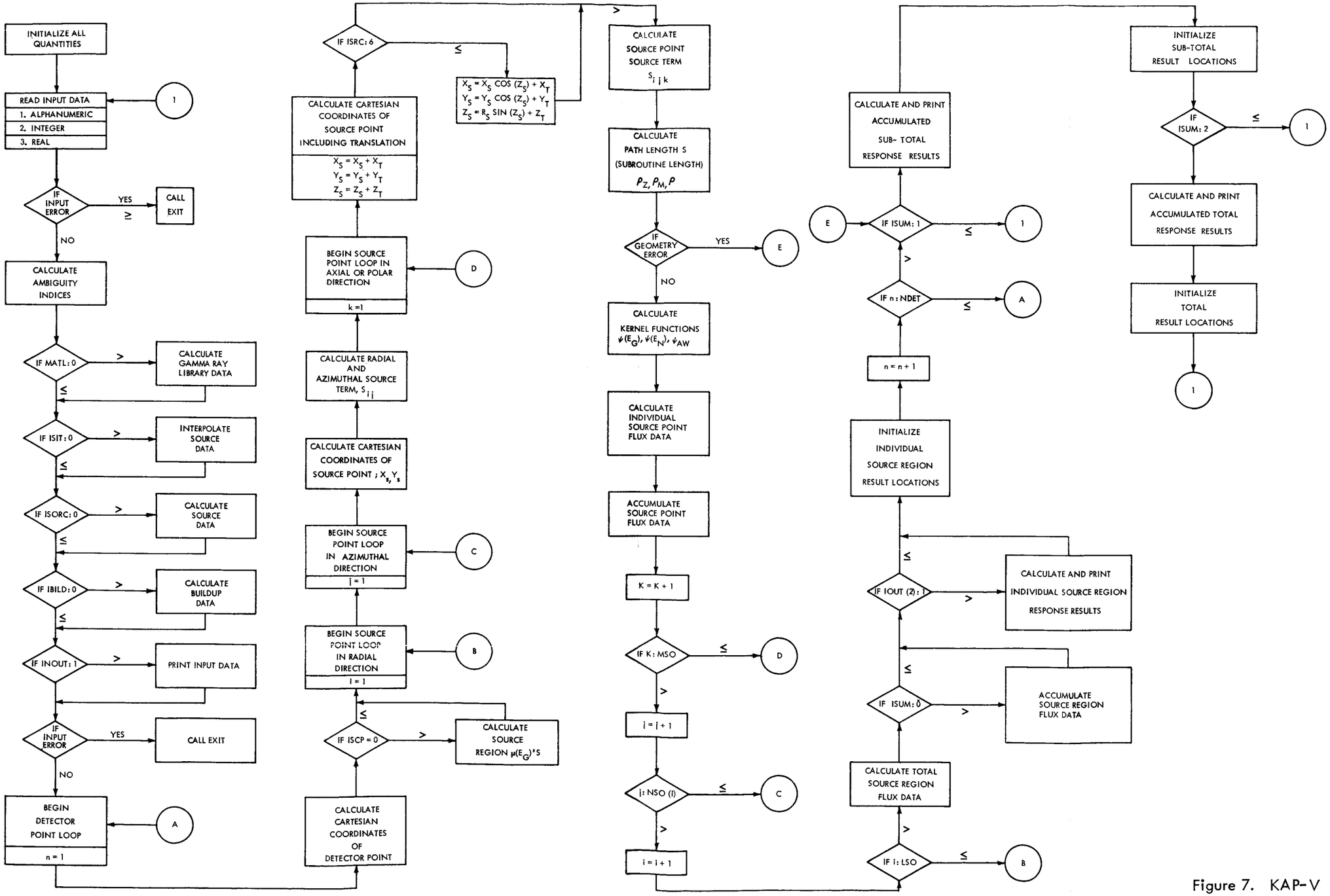

Figure 7. KAP-V Program Logic

SECTION

4.0 INPUT DATA INSTRUCTIONS

4.1 GENERAL DESCRIPTION

The input data to each KAP-V problem or "change case" consists of three types of input data. The types of data are:

1) Alphanumeric data
2) Integer or fixed point data
3) Real or floating point data

The general card format consists of three subfields (card columns 1 - 12) for all types of data, and a subdivided fourth field (card columns 13 - 72) for alphanumeric, integer, or real data. The first three subfields which are read in a (I2, I1, I9) FORTRAN format require the following information which are common to each type of data input:

1) The number of pieces or words of data on the card (right adjusted*).
2) The last card of a particular type of data (i.e., 0 or blank means that more cards of a particular type follow; 1 means this is the last card of a particular type of data).
3) The address or data location of the first piece or word of data on the card. All subsequent data in the fields on the card, up to and including the total pieces of data specified in the first subfield, are stored in sequence from the card address.

The fourth subfield which is divided according to the type of data to be read is described in the following sections. It must be noted that each problem which is input to the program must include at least one data card of each type (alphanumeric, integer, and real). Therefore, the minimum card count for a stacked problem is three cards, one for each type of data with a 1 in column 3 of each card.

The ability to assign the specific address of each data word within any data array allows the user to run stacked problems with minor data changes with a minimum card count.

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*Right adjusted means the least significant digit of the number is at the extreme right of the field.

4.2 ALPHANUMERIC DATA

The card format for the alphanumeric or title data is the FORTRAN format, (I2, I1, I9, 15A4). The last 15 data words (card columns 13 - 72) are subdivided into four character alphanumeric data which are input at the discretion of the user.

The relative location or address of the initial four character word in each title section is tabulated and described below and the breakdown of data sections are described. The option to input specific title data was included because of the output flexibility of the program. It must be noted that the user, in specifying a three word title, has the capability of inputing 12 characters of information. In addition, the breakdown of the 180 and 120 character titles into 3 and 2 lines of 15 alphanumeric data words per line (60 characters per line) must be noted by the user to provide clearly titled output results.

Address	Data	Array Dimension	Description
1	TITLE	(45)	Overall problem title (180 alphanumeric characters) which is output at the beginning of the output printing. (Printed 60 characters to a line.)
46	TITLE	(30)	Title information (120 characters) printed preceding the output of results for each source region and all detector points. (Printed 60 characters to a line.)
76	TITLE	(30)	Title information (120 characters) printed preceding the output of results for the subtotal over a selected set of source regions (i.e., the summation overall reactor subregions). (Printed 60 characters to a line.)
106	TITLE	(30)	Title information (120 characters) printed preceding the output of results for the summation of all source regions, (i.e., summation over subtotals). (Printed 60 characters to a line.)
	TITLE	(3, 10)	Title information (3 words or 12 characters) associated with gamma ray response output data.

Address	Data	Array Dimension	Description
136	TITLE (1)		Gamma ray response No. 1
139	TITLE (2)		Gamma ray response No. 2
142	TITLE (3)		Gamma ray response No. 3
145	TITLE (4)		Gamma ray response No. 4
148	TITLE (5)		Gamma ray response No. 5
151	TITLE (6)		Gamma ray response No. 6
154	TITLE (7)		Gamma ray response No. 7
157	TITLE (8)		Gamma ray response No. 8
160	TITLE (9)		Gamma ray response No. 9
163	TITLE (10)		Gamma ray response No. 10
166	TITLE	(3, 10)	Title information (3 words or 12 characters) associated with each neutron response output data. Data order identical to gamma ray response data.
196	TITLE	(3, 10)	Title information (3 words or 12 characters) associated with each Albert-Welton response output data. Data order identical to gamma ray response title data.
	TITLE	(3, 25)	Title information (3 words or 12 characters) for each detector point in the problem:
226	TITLE (1)		Detector point 1
229	TITLE (2)		Detector point 2
232	TITLE (3)		Detector point 3
235	TITLE (4)		Detector point 4
⋮	⋮		⋮
291-300	TITLE (25)		Detector point 25

4.3 INTEGER OR FIXED POINT DATA

The card format for the integer data is the FORTRAN format (I2, I1, I9, 20I3). The last 20 pieces of data (card columns 13 - 72) are subdivided into three digit fields which are input as "right adjusted" integer data.

The address of each piece of data, or the address of each data array, is tabulated and described below. The addressing of data internal to a data array is also tabulated and described.

Integer or Fixed Point Data

Address	Data	Array Dimension	Description
1	NGG		Total number of gamma ray groups, E_G.($1 \leq NGG \leq 30$)
2	NGN		Total number of neutron groups, E_n.($1 \leq NGN \leq 30$)
3	MAT		Total number of materials or elements (i.e., an element, H, O, or Fe; or a material, H_2O, UO_2) in the material/composition table. Note: The user may input the data, $\mu_m(E_G)$ for MAT elements, or optionally the program will calculate gamma ray coefficients, $\mu_m(E_G)$, for MATL elements, but not materials (such as H_2O). The coefficients, $\mu_m(E_G)$, calculated by the program are in units of cm^2/gm. The internally generated gamma ray data will appear as the first MATL sets of data in the material/composition table. Therefore, the MAT set of data must correspond up to and including the first MATL set of data. ($1 \leq MAT \leq 20$) and ($MAT \leq MATL$)
4	NCOMP		Total number of compositions in the material/composition table. ($1 \leq NCOMP \leq 50$)
5	NDET		Total number of detector points to be evaluated for the source region in the problem. The program will accumulate results for multiple source regions for all detector points under the control of the input quantity, ISUM. ($1 \leq NDET \leq 25$)

Address	Data	Array Dimension	Description
6	NBOUND		Total number of boundary surfaces in the problem geometry. ($1 \leq NBOUND \leq 100$)
7	NREG		Total number of geometric regions or zones in the problem geometry. A region is described by 6 or less boundary surfaces which subdivide the overall problem space. ($1 \leq NREG \leq 100$)
8	NRSPG		Total number of sets of response functions to be applied to the calculated gamma ray flux data at each detector point. ($1 \leq NRSPG \leq 10$)
9	NRSPN		Total number of sets of response functions to be applied to the calculated neutron flux data at each detector point. ($1 \leq NRSPN \leq 10$)
10	NRSPA		Total number of response functions to be applied to the Albert-Welton neutron dose function results at each detector point. ($1 \leq NRSPA \leq 10$)
11	MATL		Total number of elements for which gamma ray coefficient sets are to be internally generated by the program. The MATL sets must be the first MAT sets of the material/composition table. ($0 \leq MATL \leq MAT$)
19	IBILD		Control word for buildup factor input data. IBILD = 0: input buildup factor polynomial coefficients at location BILD IBILD > 0: the program internally computes the buildup factor coefficients from the library (see Section 2.6) If IBILD = 1, H_2O dose buildup If IBILD = 2, H_2O energy buildup If IBILD = 3, H_2O energy absorption buildup

Address	Data	Array Dimension	Description
			If IBILD = 4, A1 dose buildup
			If IBILD = 5, A1 energy buildup
			If IBILD = 6, A1 energy absorption buildup
			If IBILD = 7, Fe dose buildup
			If IBILD = 8, Fe energy buildup
			If IBILD = 9, Fe energy absorption buildup
			If IBILD = 10, U dose buildup
			If IBILD = 11, U energy buildup
			If IBILD = 12, U energy absorption buildup
			If IBILD = 13, Pb dose buildup
			If IBILD = 14, Pb energy absorption buildup
			If IBILD = 15, Pb energy absorption buildup
			If IBILD = 17, Sn dose buildup
			If IBILD = 19, Sn energy buildup
			If IBILD = 21, Sn energy absorption buildup
			If IBILD = 23, W dose buildup
			If IBILD = 25, W energy buildup
20	IGAM		Control word for calculation of gamma ray attenuation functions.
			IGAM = 0: Do not calculate gamma ray attenuation functions.
			IGAM = 1: Calculate gamma ray attenuation functions.
	INEUT	(3)	Control words for calculation of neutron attenuation functions.
			INEUT (i) = 0: Do not calculate neutron attenuation function.
			INEUT (i) = 1: Calculate neutron attenuation function.

Address	Data	Array Dimension	Description
21	INEUT(1)		Control word for Albert-Welton neutron dose calculation.
22	INEUT(2)		Control word for monovariant polynomial, $f(W_R, E_n)$, neutron spectra calculation.
23	INEUT(3)		Control word for bivariant polynomial, $f(W_R, E_n)$, neutron spectra calculation.
24	ISCP		Control word for calculation at a detector in the immediate vicinity of source points. (An analytical result is calculated if the path length between a source point and detector point is less than or equal to SMFP mean free paths in the ISCP composition. (See Section 2.7.) ISCP = 0: Do not calculate analytic result. ISCP > 0: Calculate analytic result with the ISCP composition as the source material.
25	IZSO		The number of the source zone in which all path length calculations are initiated. IZSO = Source zone number.
26	ISORC		Control word for calculation of all source distribution functions. ISORC = 0: Do not calculate source distribution data but use previous problem data. ISORC = 1: Calculate new source distribution data from RS, ZS, PHI, and FSI input data.
27	ISRC		Control word for the calculation of radial source distribution data. ISRC = 0: Do not calculate and renormalize input data, but use RS, ZS, PHI, and FSI as point source data. (This option allows the description of one or more discrete point sources.)

Address	Data	Array Dimension	Description
			Note: The following radial source distribution options are applicable to a cylindrical source geometry. (See Section 2.3.2.)
			ISRC = 1: Uniform or flat source distribution (Does not require FSI input).
			ISRC = 2: Cosine source distribution based on input data, XI's. (Does not require FSI input.)
			ISRC = 3: Source distribution based on a linear variation of input data, FSI, between mesh points, RS.
			ISRC = 4: Source distribution based on input exponential distribution data XI's. (Does not require FSI input.)
			ISRC = 5: Source distribution based on exponential variation of input data, FSI, between mesh points, RS.
			Note: The following radial source distribution options are applicable to a spherical source geometry.
			ISRC = 6: Uniform or flat source distribution. (Does not require FSI input data.)
			ISRC = 7: Source distribution based on a linear variation of input data, FSI, between mesh points, RS.
28	ISZC		Control word for axial or polar source distribution calculations.
			Note: The following source distribution options are applicable to cylindrical source geometry. (See Section 2.3.2.)
			ISZC = 1: Uniform or flat source distribution. (Does not require FSI input.)
			ISZC = 2: Cosine source distribution based on the input data, ETA. (Does not require FSI input data.)
			ISZC = 3: Source distribution based on the linear variation of input data, FSI, between the mesh points, ZS.
			ISZC = 4: Source distribution based on an exponential variation of the source between mesh points, ZS, and the input data, ETA. (Does not require FSI input data.)

Address	Data	Array Dimension	Description
			ISZC = 5: Source distribution based on the exponential variation of the source between mesh points, ZS. (Requires FSI input data.) Note: The following source distribution option is applicable to a spherical source geometry. ISZC = 6: Uniform or flat polar variation. (Does not require FSI input data.)
29	ISTC		Control word for azimuthal source description. (See Section 2.3.2.) Note: All azimuthal source distributions are assumed to be uniform. The user must use the ISRC = 0 option with all input data calculated externally to the program to do otherwise. ISTC = 1: Azimuthal source point spacing from the input data, PHI, with NSO (1) intervals in each radial interval. ISTC = 2: Azimuthal source point spacing from the input data, PHI, with the number of azimuthal intervals for each radial interval set by the input data, NSO. ISTC = 3: Azimuthal source point spacing based on equal azimuthal intervals; the number of intervals is set by the input data, NSO.
30	ISIT		Control word for source distribution interpolation calculation. ISIT = 0: Do not interpolate RSIT, ZSIT, FSIT input data to obtain FSI at RS and ZS. ISIT = 1: Interpolate RSIT, ZSIT, FSIT input data to obtain FSI at RS and ZS.
31	ISUM		Control word for summation of the contribution of individual source regions to the detector response at each detector point.

Address	Data	Array Dimension	Discription
			ISUM = 0: Do not include this region in the summation of individual source region results. ISUM = -1: Start summing individual source region results beginning with this region. When ISUM = -1: The storage allocated for the grand total and subtotal is set to zero. The results for the region are added to the grand total and subtotal. Then ISUM is set equal to +1. ISUM = +1: Add individual source region results to the grand total and the subtotal. ISUM = 2: Add the contribution of the source region to the subtotal and grand total, print the subtotal, then set the subtotal to zero. ISUM = 3: Add the contribution of the source region to the subtotal and the grand total, print the subtotal and the grand total, set the grand total and subtotal to zero.
32	IOUT(1)		Control word for printing input data. IOUT(1) = 0: Do not print input data. IOUT(1) = 1: Print card images of input data. IOUT(1) = 2: Print card images and organized input data. Note: Normalized source distribution data are printed only when IOUT(1) = 2.
33	IOUT(2)		Control word for printing of output data. IOUT(2) = 1: Do not print individual source region results. IOUT(2) = 0: Print all output data for each individual source region.

Address	Data	Array Dimension	Description
	KORD	(3)	Degree or order for each set of the neutron moments method bivariant polynomial data in the independent variable, energy (E_n).
35	KORD(1)		Degree or order of the first set of coefficients for the energy range, BKP(1) to BKP(2).
36	KORD(2)		Degree or order of the second set of coefficients for the energy range, BKP(2) to BKP(3).
37	KORD(3)		Degree or order of the third set of coefficients for the energy range, BKP(3) to BKP(4).
	IORD	(3)	Degree or order for each set of the neutron moments method bivariant polynomial data in the independent variable, depth penetration (W_R).
40	IORD(1)		Degree or order of the first set of coefficients for the energy range, BKP(1) to BKP(2).
41	IORD(2)		Degree or order of the second set of coefficients for the energy range, BKP(2) to BKP(3).
42	IORD(3)		Degree or order of the third set of coefficients for the energy range, BKP(3) to BKP(4).
50	LSO		Total number of radial mesh intervals in the source region description. ($1 \leq LSO \leq 20$)
51	MSO		Total number of axial or polar mesh intervals in the source region description. ($1 \leq MSO \leq 20$)
	NSO	(20)	Total number of azimuthal mesh intervals for each radial interval in the source region description. ($1 \leq NSO(i) \leq 20$)

Address	Data	Array Dimension	Description
52	NSO(1)		Total number of azimuthal mesh intervals in radial interval number 1 or if, ISTC = 1, the total number of intervals in each radial interval.
53	NSO(2)		Total number of azimuthal mesh intervals in radial interval 2.
•	•		•
•	•		•
•	•		•
71	NSO(20)		Total number of azimuthal mesh intervals in radial interval 20.
75	LSIT		Total number of radial source distribution input data values, RSIT and FSIT, to be used in interpolation of source distribution data, FSI, at the mesh points RS. ($1 \leq LSIT \leq 21$)
76	MSIT		Total number of axial source distribution input data values, ZSIT and FSIT, to be used in interpolation of source distribution data, FSI, at the mesh points, ZS. ($1 \leq MSIT \leq 21$)
	NEQBD(j)	(100)	Surface equation type number for each surface or boundary, j, in the problem. (The surface equations and their respective type number are presented preceding the surface equation coefficient input description). ($1 \leq NEQBD(j) \leq 6$)
100	NEQBD(1)		Type number for surface No. 1.
101	NEQBD(2)		Type number for surface No. 2.
•	•		•
•	•		•
•	•		•

Address	Data	Array Dimension	Description
199	NEQBD(100)		Type number for surface No. 100.
	NBNDZN(i)	(100)	The total number of boundaries or surfaces defining each zone, i, in the problem. Each zone must have at least one boundary and no more than six boundaries. ($1 \leq NBNDZN(i) \leq 6$). Note: The sign (±) of NBNDZN(i) denotes whether the zone is an outside or last zone and the user must specify this sign. If NBNDZN is negative, the zone is an outside or last zone.
200	NBNDZN(1)		Total number of boundary surfaces for zone No. 1
201	NBNDZN(2)		Total number of boundary surfaces for zone No. 2.
•	•		•
•	•		•
•	•		•
299	NBNDZN(100)		Total number of boundary surfaces for zone No. 100.
	NCMPZN(i)	(100)	The composition number of the mixture of materials in zone, i, for each zone in the problem.
300	NCMPZN(1)		Composition number in zone 1.
301	NCMPZN(2)		Composition number in zone 2.
•	•		•
•	•		•
•	•		•
399	NCMPZN(100)		Composition number in zone 100.
	LBD(j, i)	(6, 100)	The boundary surface numbers, j, for each zone, i. The user must specify NBNDZN(i) surface numbers for each zone, i, and the surfaces must totally enclose the zone or region in the problem. Outside zones can be described as single boundary zones. Note: The KAP-V program will automatically assign all ambiguity indices (+ or −) of each surface, j, in relation to each zone, i.

Address	Data	Array Dimension	Description
500	LBD(j, 1)		Surface numbers, j = 1, NBNDZN(1), for zone 1.
506	LBD(j, 2)		Surface numbers, j = 1, NBNDZN(1), for zone 2.
•	•		•
•	•		•
•	•		•
1094	LBD(j, 100)		Surface numbers, j = 1, NBNDZN(1), for zone 100.
	NTRYZN(j, i)	(6,100)	The zone identification number for each boundary, j, of each zone, i, which defines the zone encountered upon crossing each boundary of the zone, i. There is a one to one correspondence between LBD and NTRYZN. Note: If more than one zone can be entered upon crossing boundary, j, the user can minimize problem running times by specifying the zone entered the most times, or if this can not be determined, the zone with the lower identification number.
1100	NTRYZN(j, 1)		Zone number, j = 1, NBNDZN(1), for zone 1.
1106	NTRYZN(j, 2)		Zone number, j = 1, NBNDZN(1), for zone 2.
•	•		•
•	•		•
•	•		•
1694	NTRYZN(j, 100)		Zone number, j = 1, NBNDZN(1), for zone 100.

4.4 REAL OR FLOATING POINT DATA

The card format for the real data is the FORTRAN format (I2, I1, I9, 5E12.5). The last 5 pieces of data (card columns 13-72) are subdivided into twelve digit fields which are input as real or floating point data.

The relative location or address of each piece of data, or the initial address of each data array, is tabulated and described below. The addressing of data internal to a data array is also tabulated and described.

Address	Data	Array Dimension	Description
	ASOI	(2)	Gamma ray and neutron source normalization constants. The input constants, ASOI, must be dimensionally consistent with GSOUR, NSOUR, and AWSOUR to provide particles/cm^3-sec.
1	ASOI(1)		Gamma ray source normalization constant.
2	ASOI(2)		Neutron source normalization constant.
			Note: If ASOI(2) is input as 0.0, the program assumes ASOI(2) = ASOI(1) and all gamma ray source distribution data, FSI, are also used for neutron source calculations.
	XI	(2)	Radial source distribution constants used in the truncated cosine or exponential source distribution function.
			For truncated cosine,
3	XI(1)		$= \pi/R^*$, where R^* is the extrapolated region radius.
4	XI(2)		= 0.0
			For exponential
3	XI(1)		$= f(R_o)$, the source value at the left boundary radius, R_o.
4	XI(2)		$= \sigma$, the slope of the source distribution in the region.
	ETA	(2)	Axial source distribution constants used in the truncated cosine or exponential source distribution function.
			For truncated cosine
5	ETA(1)		$= \frac{\pi}{H^*}$, where H^* is the extrapolated height.
6	ETA(2)		$= \frac{H^*}{2}$
			For exponential
5	ETA(1)		$= f(Z_o)$, the source value at the left axial boundary, Z_o.
6	ETA(2)		$= \sigma$, the slope of the source distribution in the region.
7	RS(i)	(21)	Radial dimensions of the source region mesh intervals. (LSO + 1 values)

Address	Data	Array Dimension	Description
28	ZS(m)	(21)	Axial or polar dimensions of source region mesh intervals. (MSO + 1 values)
	PHI(n, i)	(21,20)	Azimuthal dimensions of source region mesh intervals for each radial interval, i.
49	PHI(n, 1)		Dimensions of radial interval No. 1, (NSO(1) + 1 values)
70	PHI(n, 2)		Dimensions of radial interval No. 2, (NSO(2) + 1 values)
•	•		•
•	•		•
•	•		•
448	PHI(n, 20)		Dimensions of radial interval No. 20, (NSO(20) + 1 values)
			Note: PHI(n, i) for K greater than 1 are required only when for ISTC = 2
	FSI	(21, 22, 2)	Source distribution data for radial, axial, or polar, and azimuthal distribution for both gamma ray, K = 1, and neutron, K = 2, source data.
470	FSI(I, 1, 1)		Gamma ray radial source data, (LSO + 1 values)
491	FSI(m, 2, 1)		Gamma ray axial or polar source data, (MSO + 1 values)
512	FSI(n, 3, 1)		Gamma ray azimuthal data for each radial interval, (NSO(1) + 1 values)
			Note: FSI (n, 3, 1) is required input only for the case when the user specifies all source data FSI as input (i.e., a unit point source is input by specifying ISORC = 1, ISRC = 0, FSI(470) = 1.0, FSI(491) = 1.0, FSI(512) = 1.0)
512	FSI(1, 3, 1)		Gamma ray azimuthal data for radial interval No. 1.
533	FSI(2, 3, 1)		Gamma ray azimuthal data for radial interval No. 2.
•	•		•
•	•		•
•	•		•
931	FSI(20, 3, 1)		Gamma ray azimuthal data for radial interval No. 20.

Address	Data	Array Dimension	Description
932	FSI(1, 1, 2)		Neutron source distribution data input which is identical in order to the gamma ray data, but with all addresses increased by 462. Note: If ASOI(2) is input as 0.0, then FSI(1, 1, 2) = FSI(1, 1, 1)
1400	GSOUR	(30)	Gamma ray source by energy group, ENG. Note: GSOUR must be dimensionally consistent with ASOI(1), so that GSOUR(k)·ASOI(1) will provide the units of particles or Mev/cm^3-sec.
1430	NSOUR	(30)	Neutron source by energy group, ENN. Note: NSOUR must be dimensionally consistent with ASOI(2). These quantities provide the user with the capability to input group dependent integration factors (energy band widths) and must not be construed as neutron source spectra.

The following input data (ABD, BBD, CBD, XOBD, YOBD, ZOBD, DBD) are the surface equation coefficients and constants for each boundary (1-100). This input depends on the boundary or surface equation type. The surface equation types which are in the program are the general quadratic equation, and five of the common degenerate forms, as shown below:

Surface Equation Type	Equation
1	$AX^2 + XX_0 + BY^2 + YY_0 + CZ^2 + ZZ_0 = D$
2	$A(X - X_0)^2 + B(Y - Y_0)^2 + C(Z - Z_0)^2 = D$
3	$(X - X_0)^2 + (Y - Y_0)^2 = D$
4	$X = D$
5	$Y = D$
6	$Z = D$

Address	Data	Array Dimension	Description
1460	ABD	(100)	Surface equation coefficient constant, A, for surfaces 1-100.
1560	BBD	(100)	Surface equation coefficient, B, for surfaces 1-100.
1660	CBD	(100)	Surface equation coefficient, C, for surfaces 1-100.
1760	XOBD	(100)	Surface equation constant, X_0, for surfaces 1-100.
1860	YOBD	(100)	Surface equation constant, Y_0, for surfaces 1-100.
1960	ZOBD	(100)	Surface equation constant, Z_0, for surfaces 1-100.
2060	DBD	(100)	Surface equation constant, D, for surfaces 1-100. Note: To eliminate errors in path length calculations, the program automatically squares the input quantity, D, for surface equation types 2 and 3 to provide absolute matching of surface intersections. Therefore, input the quantity, D, as the radius of interest.
	XYZ(j, i)	(3,100)	Cartesian coordinates of the point internal to each zone, i, described by the input data, LBD. There are 3 x NREG required input values. These data are used in computing the ambiguity indices (+ or −) of each surface in relation to the zone and extreme caution must be used in determining input values.
2160	XYZ(j, 1)		(X_p, Y_p, Z_p) for zone 1.
2163	XYZ(j, 2)		(X_p, Y_p, Z_p) for zone 2.
•	•		•
•	•		•
•	•		•
2397	XYZ(j,100)		(X_p, Y_p, Z_p) for zone 100.
	COMP(m, n)	(20,50)	Composition matrix (densities or volume fractions) according to the materials or elements, m, in the problem.

Address	Data	Array Dimension	Description
2460	COMP(m, 1)		COMP(m, 1): data for all materials, m, in composition 1.
2480	COMP(m, 2)		COMP(m, 2): data for all materials, m, in composition 2.
•	•		•
•	•		•
•	•		•
3440	COMP(m, 50)		COMP(m,50): data for all materials, m, in composition 50.
3460	ENN	(30)	Representative energy of each neutron group.
	XSECN(m, i)	(20, 3)	Data for the Albert-Welton and neutron spectra functions.
3490	XSECN(m, 1)		Neutron removal cross sections for each material for use with the Albert-Welton function.
3510	XSECN(m, 2)		Constants (η's) for each material for use with the Albert-Welton function.
3530	XSECN(m, 3)		Neutron removal cross sections for each material for use with the neutron spectra function.
3550	XSNREF		Neutron removal cross section for the material for which the neutron moments data is input (reference material removal cross section).
3551	ALFA	(7)	Constants (α's) for the Albert-Welton function.
3558	AWSOUR		Source strength to be applied to the Albert-Welton kernel. Note: AWSOUR must be dimensionally consistent with ASOI(2).
3560	ENG	(30)	Representative energy of each gamma ray source group.
	XSECG(k, m)	(30, 20)	Gamma ray absorption coefficients for each group, k, and each material, m, in the problem. The program will generate these data from tables and/or polynomial evaluation if requested. (See Section 2.6.)
3590	XSECG(k, 1)		Coefficients for each group k, material 1.

Address	Data	Array Dimension	Description
3620	XSECG(k, 2)		Coefficients for each group k, material 2.
•	•		•
•	•		•
•	•		•
4160	XSECG(k, 30)		Coefficients for each group k, material 30.
	BILD(1, k)	(4, 30)	Gamma ray cubic polynomial build up coefficients for each gamma ray group, k. Note: The program will internally compute these data if so requested. (See Section 2.6.)
4190	BILD(1, 1)		β_0, β_1, β_2, β_3 for group 1.
4194	BILD(1, 2)		β_0, β_1, β_2, β_3 for group 2.
•	•		•
•	•		•
•	•		•
4306	BILD(1, 30)		β_0, β_1, β_2, β_3 for group 30.
4310	SMFP		Total mean free path of source material (source composition ISCP) used in determining the exclusion sphere volume for source points adjacent to detector points. This quantity is used in the empirical solution of the gamma ray flux for detector points internal to source regions. (See Section 2.7)
4311	TMFP		The limit or maximum range of mean free paths of gamma ray depth penetration for cubic polynomial buildup data. The program calculates buildup only on TMFP (or less) mean free paths. If the mean free path exceeds TMFP, the program sets the mean free path equal to TMFP. The program assumes TMFP = 20, if TMFP is not input.
4312	EPSLN		Surface equation-path length calculation error limit used in determining if a surface is crossed. If the test fails, an error statement is given. Note: EPSLN is internally set as 1.0×10^{-6} and is not required as input if the user accepts this value.

Address	Data	Array Dimension	Description
4313	FUDGE		Surface equation-path length calculation step quantity used in providing a means for the calculation to cross a boundary. If two steps are unsuccessful, an error statement is given. Note: FUDGE is internally set as 1.0×10^{-3} and is not required as input if the user accepts this value.
4314	BKP(i)	(4)	For Monovariant Neutron Spectra Data: The neutron depth penetration, gm/cm^2, which is the breakpoint between the two sets of monovariant moments method data. Only BKP(1) is required. For Bivariant Neutron Spectra Data: The neutron energy breakpoints for the applicability of the bivariant polynomial data. BKP(1-4) must be in order of decreasing energy and the last values 2, 3 or 4 must must not be zero (e.g., for only one set of polynomial data, BKP(1) = E (higher) and BKP(2, 3, and 4) = E (lower).
	COM	(5, 30, 2)	Neutron spectra monovariant polynomial coefficients for NGN groups. This data, which is evaluated as a function of depth penetration (W, gm/cm^2 of equivalent neutron attenuation), is assumed to be applicable in the range of $0.0 \geq W \geq 120.0$ gm/cm^2. The two sets of input data divide this range into, $0.0 \geq W \geq BKP(1)$ and $BKP(1) \geq W \geq 120.0$. For any depth penetration in excess of 120.0 gm/cm^2, the group dependent λ's (input quantities, XLAM) are used as simple exponential attenuation as, $\exp[-\lambda(W - 120.0)]$.
4320	COM(i, 1, 1)		COM(1-5): C_5, C_4, C_3, C_2, C_1 for group 1, and $W \leq BKP(1)$.
4325	COM(i, 2, 1)		COM(1-5): C_5, C_4, C_3, C_2, C_1 for group 2, and $W \leq BKP(1)$.
⋮	⋮		⋮
4460	COM(i, 30, 1)		COM(1-5): C_5, C_4, C_3, C_2, C_1 for group 30, and $W \leq BKP(1)$.

Address	Data	Array Dimension	Description
4470	COM(i, 1, 2)		COM(1-5): C_5, C_4, C_3, C_2, C_1 for group 1, and $W \geq BKP(1)$.
4475	COM(i, 2, 2)		COM(1-5): C_5, C_4, C_3, C_2, C_1 for group 2, and $W \geq BKP(1)$.
•	•		•
•	•		•
•	•		•
4615	COM(i, 30, 2)		COM(1-5): C_5, C_4, C_3, C_2, C_1 for group 30, and $W \geq BKP(1)$.
	CON	(5, 5, 4)	Neutron spectra bivariant polynomial coefficients. These data, which are evaluated as a function of depth penetration, W, and neutron energy, E_n, is assumed applicable over the entire range of $W \geq 120.0$ gm/cm^2. The four sets of data divide the energy range into four intervals as determined by BKP(1-4). Calculations for W in excess of 120.0 gm/cm^2 are discussed above in the monovariant polynomial description.
4620	CON(5, 5, 1)		CON(1-25): C_1, C_2, C_3, C_4, C_5 ..... C_{25} for $BKP1 \geq E \geq BKP2$.
4645	CON(5, 5, 2)		CON(1-25): C_1, C_2, C_3 ..... C_{25} for $BKP2 \geq E \geq BKP3$.
4670	CON(5, 5, 3)		CON(1-25): C_1, C_2, C_3 ..... C_{25} for $BKP3 \geq E \geq BKP4$.
•	•		•
•	•		•
•	•		•
4695	CON(5, 5, 4)		CON(1-25): C_1, C_2, C_3 ..... C_{25} for $E \geq BKP4$.
4720	XLAM	(30)	Values of $\lambda(E_n)$ for each neutron energy group for use in extrapolating either the monovariant or bivariant neutron spectra data for values of $W \geq 120.0$ gm/cm^2.

Address	Data	Array Dimension	Description
	RSPG	(30, 10)	Group-dependent gamma ray response functions. The user must input at least one set of data. If collided and uncollided energy flux is desired as output data, one set of RSPG values must be input as 1.0. The program will provide NRSPG sets of data, and the sum or total over NGG groups for each response function.
4750	RSPG(k, 1)		Response function No. 1, for each energy group, k.
4780	RSPG(k, 2)		Response function No. 2, for each energy group, k.
•	•		•
•	•		•
•	•		•
5020	RSPG(k, 10)		Response function No. 10, for each energy group, k.
	RSPN	(30, 10)	Group dependent response functions for the neutron spectra data. The user must input at least one set of data. If the total (sum over groups) response is desired, (i.e., total neutrons/cm^2-sec) the energy width for each group must appear in RSPN or in the neutron group source, NSOUR.
5050	RSPN(i, 1)		RSPN is input in the same order as RSPG starting with address, 5050.
5350	RSPA	(1, 10)	Response functions for the Albert-Welton function. The user must input at least one value of RSPA (i.e., RSPA (1) = 1.0). The program will provide NRSPA values of output.
	RCORD	(3, 25)	Detector point coordinates (R_D, Z_D, θ_D) for NDET detector points. The detector points must not lie on a boundary of a zone. A maximum of 25 detector points per problem are permitted.
5360	RCORD(i, 1)		(R_D, Z_D, θ_D), for detector No. 1.
5363	RCORD(i, 2)		(R_D, Z_D, θ_D), for detector No. 2.

Address	Data	Array Dimension	Description
5369	RCORD(i, 3)		(R_D, Z_D, θ_D), for detector No. 3.
•	•		•
•	•		•
•	•		•
5435	RCORD(i, 25)		(R_D, Z_D, θ_D), for detector No. 25.
5510	SSOT	(3)	Source region translation coordinates (X_T, Y_T, Z_T). The values of SSOT may be used to translate the source region in the problem geometry so that the input source data can be relative to (0, 0, 0).

THE FOLLOWING INPUT DATA ARE REQUIRED ONLY IF MATL IS GREATER THAN ZERO

5513	ZAT	(20)	Atomic number (electrons per atom) of each element for which gamma ray absorption coefficients, are to be calculated by the program. The calculated values, in units of cm^2/gm, will appear as the first MATL sets of gamma ray absorption coefficients. If coefficients are input in conjunction with calculated values, then the input values must be the MATL + 1 to MAT sets of values.

THE FOLLOWING INPUT DATA ARE REQUIRED ONLY IF LSIT IS GREATER THAN 0

5533	RSIT	(21)	Radial coordinates of source distribution data to be used in the source interpolation routine. There are LSIT values required. The range of RSIT should be greater than or equal to the range of the radial values, RS, so that only interpolation of data is used.
5554	ZSIT	(21)	Axial coordinates of the source distribution data to be used in the source interpolation routine. There are MSIT values required. The range of ZSIT should be greater than or equal to the range of the axial values, ZS, so that only interpolation is used.
	FSIT(i, , k)	(21, 2, 2)	Source distribution data to be used in the source interpolation routine. There are LSIT and MSIT values required. Source interpolation is calculated for both gamma ray and neutron source distributions.

Address	Data	Array Dimension	Description
5575	FSIT(i,1,1)		Radial gamma ray source data.
5596	FSIT(i,2,1)		Axial gamma ray source data.
5617	FSIT(i,1,2)		Radial neutron source data.
5638	FSIT(i,2,2)		Axial neutron source data.

SECTION

5.0 OUTPUT DATA FORMAT

The KAP-V output data is dependent upon the input control words IOUT (1) and IOUT (2) entered at address 32 and 33, respectively. The control word, IOUT (1), controls the print out of the input data. The control word, IOUT (2) controls the print out of the output data.

5.1 INPUT DATA PRINT OUT

The print out of the input data will be described first. If IOUT (1) is set at zero, no input data will be printed, except the program title. This is followed by the output data described in Section 5.2.

If IOUT (1) is set equal to one, the program title is printed, and is followed by a print out of the image of each input data card as used by the computer. Therefore, only columns 1 to 72 are printed. One exception must be noted: If the floating point data, input at address 2060, includes the surface equation constant, D, for equation types 1, 2, or 3, the printed value in the card image is D^2 instead of D. The card image output is followed by the output data described in Section 5.2.

If IOUT (1) is set equal to two, the input data is printed out as described for IOUT (1) equal to one plus a set of labeled input data. This labeled print out is self explanatory (See the sample problem print). Included in the labeled print out are the normalized source distribution data. The labeled print out of the input is followed by the output described in Section 5.2.

5.2 OUTPUT DATA PRINT OUT

The output print out is obviously dependent upon the types of material attenuation functions that are requested in a particular problem. The output is also dependent upon the ISUM Control (address 31), and the IOUT (2) Control (address 33).

If IOUT (2) is set equal to zero, output is printed for each individual source region in the problem. If IOUT (2) is equal to one, the output for each source region is not printed out. (A NOTE OF CAUTION: If the problem contains only one source region, IOUT (2) must be set equal to zero in order to obtain any answers).

The control word, (ISUM), controls the subtotal output over various source regions, and the grand total output over all source regions, as described in the input data instructions (Section 4.0).

If a gamma ray calculation is performed, the collided fluxes multiplied by each set of response functions is printed for the first detector point, for each gamma ray group, as well as the total. This is followed by the uncollided gamma ray data.

If an Albert-Welton calculation is performed, the output multiplied by the response functions follows the gamma ray output data.

If neutron spectra are calculated, the neutron spectra data multiplied by the response functions are then printed.

At the end of the output data for each detector point, a comment is printed which tells the program user how many times the value of 20.0 mean free paths, for gamma rays, or 120.0 gm/cm^2, for neutrons, was exceeded for a source region.

A sample printout is included with the sample problem.

SECTION

6.0 SAMPLE PROBLEM

6.1 DESCRIPTION

A sample problem is included here to illustrate more clearly the input and output data of the KAP-V program.

The geometry and material description for the sample problem are shown in Figure 8. The problem consists of three material cylindrical regions (Zones I, II, and III), and three outside regions (Zones IV, V, and VI).

The single cylindrical source region is Zone I. The source distribution which is the same for both neutrons and gamma rays is described as uniform in both the radial and axial directions. Variable azimuthal source spacing is employed. Thirteen gamma ray source energy groups describe the source. Gamma ray total absorption coefficients are requested from the built-in library. Water dose buildup factors are input to the program.

The monovariant neutron spectrum option is employed with carbon as the reference material.

Two sets of response functions for both gamma ray data and neutron data are employed.

The problem consists of five detector points as indicated by D_1, D_2, etc. in Figure 8.

6.2 INPUT DATA

The actual FORTRAN input data sheets for the sample problem are given in Table 3. The letters in columns 73 through 80 for the fixed and floating point data refer to the FORTRAN symbol described previously in Section 4.0.

6.3 OUTPUT DATA

The printed output data from a KAP-V problem (CDC 6600 computer job) for the sample problem is presented in Table 4.

The first three pages of output are the card images. Pages 4 through 14 are the labeled input data. This labeled input data is helpful in locating errors or as a permanent

MATERIAL COMPOSITION TABLE

DESCRIPTION	ELEMENT	H	Li	Be	C	Cr	Fe	Ni	U
	MATERIAL NO.	1	2	3	4	5	6	7	8
	COMPOSITION NO.								
CORE	1	0	0	0	0.5	0	0	0	1.69
SIDE REFLECTOR	2	0.007*	0	1.65	0	0	0	0	0
TOP SHIELD	3	0.0514	0.262	0	0	0.256	2.37	0.576	0
ZONE IV	4	0	0	0	0	.0000001	0	0	0
ZONE V	5	0	0	0	0	0	.0000001	0	0
ZONE VI	6	0	0	0	0	0	0	.0000001	0

*UNITS: GM/CM^3

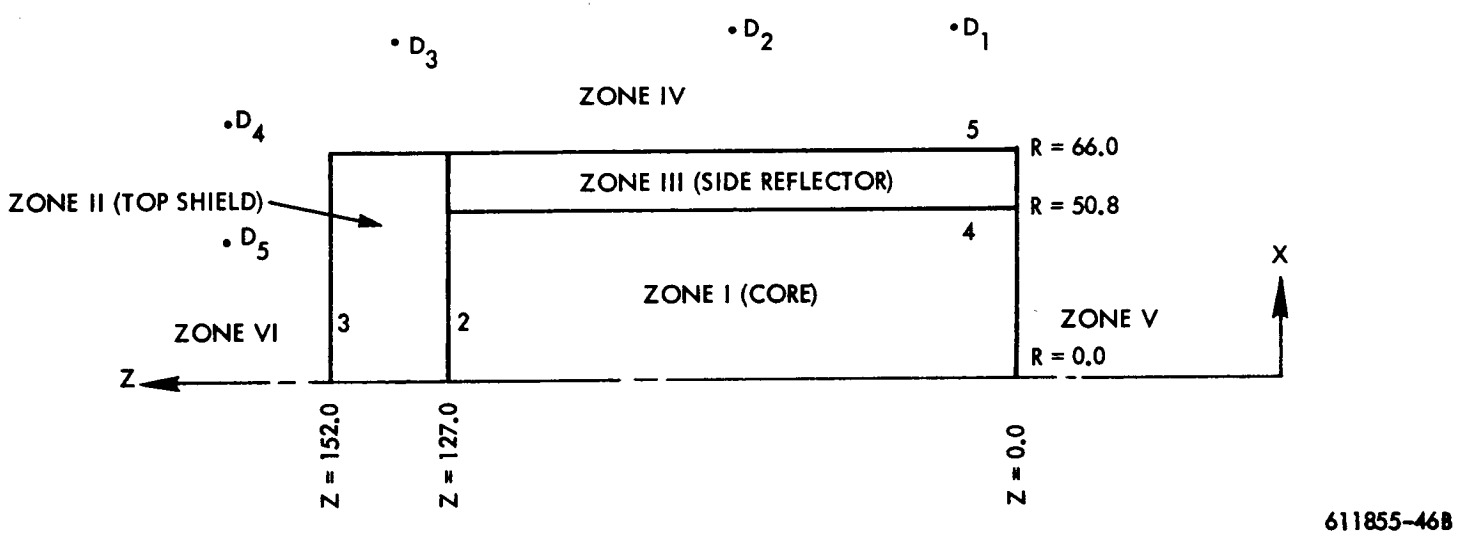

Figure 8. Geometry and Material Compositions for the Sample Problem

record of the input used for a particular problem. The normalized source data are included on pages 5 through 8. The gamma ray absorption coefficients (cm^2/gm) obtained from the program library are listed on pages 10 and 11. Notice that, on page 8, the region ambiguity indices which are computed within the program, are printed out.

The calculated output data printout begins on page 14. The column labeled GAM RESP 1, is the gamma ray flux multiplied by the first set of gamma ray response functions which yield units of R/hr. The column labeled GAM RESP 2, is the gamma ray flux multiplied by the second set of gamma ray response functions which yield units of watts/gm of steel.

The column labeled NEUT. 1 is the neutron spectrum multiplied by the first neutron response function. The units of NEUT. 1 are rads (tissue)/hr. These units were made compatible with the differential neutron spectra data by inputting the NSOUR data as $\Delta E \times 2.46$ neutrons/fission. The column labeled NEUT. 1 is the neutron spectrum multiplied by the second response function, and the units, therefore, are n/cm^2-sec. The remainder of the printout is self-explanatory.

TABLE 3. SAMPLE PROBLEM INPUT SHEETS

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FORTRAN - CODING FORM

TITLE	ANALYST	PHONE	DATE	PROGRAM NO.	DECK NO.	L.S. NO.	SHEET
SAMPLE PROBLEM	TITLE DATA						1 OF 6

REF.	STAT. NO. (1 2 3 4 5)	CONTIN.	FORTRAN STATEMENT (7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72)	DECK NO. (73 74 75)	SEQ. NO. (76 77 78 79 80)
	15		1 MØCKUP FØR GRAPHITE MØDERATED CØRE, FIVE DETECTØR PØINTS,		
	15		16 ØNE CØRE REGIØN, THREE EXTERNAL REGIØNS, SIX INCH SIDE REFL		
	15		31 ECTØR, ØNE FØØT TØP SHIELD		
	15		46 SØURCE REGIØN CALCULATIØNAL RESULTS		
	15		76 SUBTØTAL ØVER SELECTED SØURCE		
	15		106 SUMMATIØN ØVER ALL SØURCE REGIØNS		
	3		136GAM RESP 1		
	3		139GAM RESP 2		
	3		166NEUT. 1		
	3		169NEUT. 2		
	3		226DET. PT. ØNE		
	3		229DET. PT. TWØ		
	3		232DET. PT. THREE		
	3		235DET. PT. FØUR		
	31		238DET. PT. FIVE		

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FORTRAN - CODING FORM

TITLE	ANALYST	PHONE	DATE	PROGRAM NO.	DECK NO.	L.S. NO.	SHEET
SAMPLE PROBLEM	FIXED POINT DATA						2 OF 6

REF.	STAT. NO. (1 2 3 4 5)	CONTIN.	FORTRAN STATEMENT (7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72)	DECK NO. (73 74 75)	SEQ. NO. (76 77 78 79 80)
	11		1 13 10 8 6 5 5 6 2 2 0 8	CØN	TRØLS
	14		20 1 0 1 0 0 1 1 1 1 2 0 3 2 0	ØPT	IØNS
	7		50 5 12 4 6 8 10 10	SØU	RCE
	5		100 6 6 6 3 3	NEQ	BD
	6		200 3 3 4 -1 -1 -1	NBN	DZN
	6		300 1 3 2 4 5 6	NCM	PZN
	3		500 1 2 4	LBD	1
	3		1100 5 2 3	NTR	YZN1
	3		506 2 3 5	LBD	2
	3		1106 1 6 4	NTR	YZN2
	4		512 1 4 2 5	LBD	3
	4		1112 5 1 2 4	NTR	YZN3
	3		518 1 5 3	LBD	4
	3		1118 5 3 6	NTR	YZN4
	1		524 1	LBD	5
	1		1124 1	NTR	YZN5
	1		530 3	LBD	6
	11		1130 2	NTR	YZN6

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FORTRAN - CODING FORM

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TITLE	ANALYST	PHONE	DATE	PROGRAM NO.	DECK NO.	L.S. NO.	SHEET
SAMPLE PROBLEM	FLOATING POINT DATA						3 OF 6

REF.	STAT. NO. (1 2 3 4 5)	CONTIN.	FORTRAN STATEMENT (7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72)	DECK NO. (73 74 75)	SEQ. NO. (76 77 78 79 80)
	2		1 1.0 0.0	ASØI	
	5		7 0.0 10.0 20.0 30.0 40.0	RS	
	1		12 50.8	RS	
	5		28 0.0 15.21 30.5 38.1 50.8	ZS	
	5		33 63.5 76.1 89.0 101.6 114.1	ZS	
	3		38 118.0 120.0 127.0	ZS	
	5		49 0.0 .785 1.57 2.358 3.14	PHI1	
	5		70 0.0 .524 1.048 1.57 2.095	PHI2	
	2		75 2.62 3.14	PHI2	
	5		91 0.0 .3925 .785 1.179 1.57	PHI3	
	4		96 1.96 2.36 2.73 3.14	PHI3	
	5		112 0.0 .314 .628 .942 1.255	PHI4	
	5		117 1.57 1.88 2.20 2.51 2.82	PHI4	
	1		122 3.14	PHI4	
	5		133 0.0 .314 .628 .942 1.255	PHI5	
	5		138 1.57 1.88 2.2 2.51 2.82	PHI5	
	1		143 3.14	PHI5	
	5		1400 1.148 -08 4.347 -08 2.957 -08 4.366 -08 2.354 -08	GSØUR	
	5		1405 3.791 -08 2.213 -08 1.804 -07 4.162 -08 6.997 -08	GSØUR	
	3		1410 4.459 -07 5.677 -08 1.729 -07	GSØUR	
	5		1430 9.78 9.78 7.335 4.89 4.89	NSØUR	
	5		1435 3.668 2.445 2.445 2.017 1.381	NSØUR	
	5		1760 0.0 0.0 0.0 0.0 0.0	XØBD	
	5		1860 0.0 0.0 0.0 0.0 0.0	YØBD	
	5		2060 0.0 127.0 152.0 50.8 66.0	DBD	
	3		2160 1.0 0.0 10.0	XYZ	
	3		2163 1.0 0.0 139.8	XYZ	

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FORTRAN - CODING FORM

TITLE: SAMPLE PROBLEM | ANALYST: FLOATING POINT DATA | PHONE | DATE | PROGRAM NO. | DECK NO. | L.S. NO. | SHEET 4 OF 6

REF.	STAT. NO. (1 2 3 4 5)	FORTRAN STATEMENT (7–72)	DECK NO. (73 74 75)	SEQ. NO. (76 77 78 79 80)
	3	2166 60.0 0.0 10.0	XYZ	
	3	2169 100.0 0.0 10.0	XYZ	
	3	2172 1.0 0.0 -10.0	XYZ	
	3	2175 1.0 0.0 170.0	XYZ	
	5	2460 .5	CØMP	
	1	2467 1.69	CØMP	
	5	2480 7.0 -03 0.0 1.65	CØMP	
	3	2485	CØMP	
	5	2500 5.14 -02 .262 .256	CØMP	
	3	2505 2.37 .576	CØMP	
	5	2520 1.0 -07	CØMP	
	1	2545 1.0 -07	CØMP	
	1	2566 1.0 -07	CØMP	
	5	3530 .6 .1 .072 .0407 .0217	XSECN	
	3	3535 .021 .019 .0091	XSECN	
	1	3550 .0407	XSNREF	
	5	3560 8.5 7.25 6.5 5.5 4.5	ENG	
	5	3565 3.5 2.8 2.5 2.0 1.5	ENG	
	3	3570 1.0 .7 .3	ENG	
	4	4190 1.005 .3616 -6.49 -03 1.354 -04	BILD	
	4	4194 1.004 .3902 -5.852 -03 1.182 -04	BILD	
	4	4198 1.003 .4263 -4.85 -03 9.197 -05	BILD	
	4	4202 1.002 .473 -3.185 -03 4.975 -05	BILD	
	4	4206 1.001 .5357 -1.795 -04 -2.265 -05	BILD	
	4	4210 .999 .6236 5.938 -03 -1.581 -04	BILD	
	4	4214 .9974 .7078 .01478 -3.317 -04	BILD	
	4	4218 .9966 .7516 .02104 -4.414 -04	BILD	

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FORTRAN - CODING FORM

TITLE	ANALYST	PHONE	DATE	PROGRAM NO.	DECK NO.	L.S. NO.	SHEET
SAMPLE PROBLEM	FLOATING POINT DATA						5 OF 6

REF.	STAT. NO. (1 2 3 4 5)	CONT.	FORTRAN STATEMENT (7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72)	DECK NO. (73 74 75)	SEQ. NO. (76 77 78 79 80)
	4		4222 .9954 .8357 .3831 -6.961 -04	BILD	
	4		4226 .9948 .928 .07471 -1.043 -03	BILD	
	4		4230 .9968 .987 .1714 -9.766 -04	BILD	
	4		4234 1.001 .9502 .3278 1.71 -03	BILD	
	4		4238 .9944 1.069 .7272 2.634 -02	BILD	
	1		4314 60.0	BKP	
	5		4320 2.2433 -05 -2.6957 -03 1.0613 -01 -1.6947 -4.5732	CØM	
	5		4325 1.82 -05 -2.1712 -03 8.4253 -02 -1.3253 -3.4433	CØM	
	5		4330 1.17817 -05 -1.416 -03 5.577 -02 -9.0566 -01 -2.3533	CØM	
	5		4335 9.022 -06 -1.08111 -03 4.2464 -02 -6.9692 -01 -1.8333	CØM	
	5		4340 6.743 -06 -8.0525 -04 3.1311 -02 -5.105 -01 -1.3333	CØM	
	5		4345 3.968 -06 -4.5994 -04 1.7025 -02 -2.814 -01 -.80999	CØM	
	5		4350 2.099 -06 -2.4188 -04 8.7182 -03 -1.5642 -01 -.65666	CØM	
	5		4355 1.846 -06 -1.9897 -04 5.9974 -03 -8.1006 -02 -.47666	CØM	
	5		4360 2.64 -08 -3.806 -06 -6.236 -04 2.4483 -02 -.35333	CØM	
	5		4365 -8.848 -07 1.108 -04 -5.27193 -03 9.8162 -02 -.37333	CØM	
	5		4470 +1.219 -10 5.0192 -08 8.487 -05 -8.316 -02 -10.894	CØM	
	5		4475 -3.0577 -10 4.1235 -07 -1.59442 -04 -1.947 -02 -11.065	CØM	
	5		4480 -3.9241 -10 5.0637 -07 -1.94489 -04 -1.367 -02 -7.6239	CØM	
	5		4485 3.2355 -10 -3.1185 -07 9.487 -05 -4.6536 -02 -4.848	CØM	
	5		4490 1.0893 -10 -1.1754 -07 4.661 -05 -4.3353 -02 -3.2356	CØM	
	5		4495 1.933 -11 -1.2622 -08 1.497 -05 -4.587 -02 -1.6727	CØM	
	5		4500 3.182 -11 -2.6598 -08 2.772 -05 -5.1756 -02 -.6649	CØM	
	5		4505 -1.29136 -10 1.4564 -07 -2.848 -05 -4.7853 -02 .169211	CØM	
	5		4510 -5.541 -11 1.161 -07 -3.996 -05 -4.5128 -02 1.1947	CØM	
	5		4515 -1.05155 -10 1.8044 -07 -6.526 -05 -4.296 -02 1.7558	CØM	

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FORTRAN - CODING FORM

TITLE	ANALYST	PHONE	DATE	PROGRAM NO.	DECK NO.	L.S. NO.	SHEET
SAMPLE PROBLEM	FLOATING POINT DATA						6 OF 6

REF.	STAT. NO. (1 2 3 4 5)	CONT.	FORTRAN STATEMENT (7–72)	DECK NO. (73 74 75)	SEQ. NO. (76 77 78 79 80)
	5		4720 .0273 .0245 .027 .0282 .0305	XLAM	
	5		4725 .0322 .0332 .0332 .0332 .0332	XLAM	
	5		4750 8.5 -07 8.8 -07 9.2 -07 9.5 -07 1.05 -06	RSPG	
	5		4755 1.15 -06 1.23 -06 1.27 -06 1.37 -06 1.48 -06	RSPG	
	3		4760 1.61 -06 1.67 -06 1.66 -06	RSPG	
	5		4780 3.91 -15 3.83 -15 3.77 -15 3.69 -15 3.62 -15	RSPG	
	5		4785 3.59 -15 3.62 -15 3.65 -15 3.70 -15 3.88 -15	RSPG	
	3		4790 4.22 -15 4.52 -15 5.45 -15	RSPG	
	5		5050 1.97 -05 1.94 -05 1.78 -05 1.71 -05 1.62 -05	RSPN	
	5		5055 1.49 -05 1.27 -05 1.08 -05 8.72 -06 4.40 -06	RSPN	
	5		5080 1.0 1.0 1.0 1.0 1.0	RSPN	
	5		5085 1.0 1.0 1.0 1.0 1.0	RSPN	
	3		5360 122.0 15.2 0.0	RCØRD	
	3		5363 122.0 91.6 0.0	RCØRD	
	3		5366 122.0 168.0 0.0	RCØRD	
	3		5369 91.6 228.0 0.0	RCØRD	
	3		5372 30.5 228.0 0.0	RCØRD	
	3		5510 0.0 0.0 0.0	SSØT	
	5		5513 1.0 3.0 4.0 6.0 24.0	ZAT	
	31		5518 26.0 28.0 92.0	ZAT	

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TABLE 4. SAMPLE PROBLEM PRINT OUT

```
MOCKUP FOR GRAPHITE MODERATED CORE, FIVE DETECTOR POINTS,
ONE CORE REGION, THREE EXTERNAL REGIONS, SIX INCH SIDE REFL
ECTOR, ONE FOOT TOP SHIELD
11-0        1  13  10   8   6   5   5   6   2   2   0   8
14-0       20   1   0   1   0   0   1   1   1   1   2   0   3   2   0
 7-0       50   5  12   4   6   8  10  10
 2-0       75   0   0
 5-0      100   6   6   6   3   3
 6-0      200   3   3   4  -1  -1  -1
 6-0      300   1   3   2   4   5   6
 3-0      500   1   2   4
 3-0     1100   5   2   3
 3-0      506   2   3   5
 3-0     1106   1   6   4
 4-0      512   1   4   2   5
 4-0     1112   5   1   2   4
 3-0      518   1   5   3
 3-0     1118   5   3   6
 1-0      524   1
 1-0     1124   1
 1-0      530   3
 1 1     1130   2
 2-0        1   1.00000E+00  0.
 5-0        7   0.           1.00000E+01  2.00000E+01  3.00000E+01  4.00000E+01
 1-0       12   5.08000E+01
 3-0       38   1.18000E+02  1.20000E+02  1.27000E+02
 5-0       28   0.           1.52100E+01  3.05000E+01  3.81000E+01  5.08000E+01
 5-0       33   6.35000E+01  7.61000E+01  8.90000E+01  1.01600E+02  1.14100E+02
 5-0       49   0.           7.85000E-01  1.57000E+00  2.35800E+00  3.14000E+00
 5-0       70   0.           5.24000E-01  1.04800E+00  1.57000E+00  2.09500E+00
 2-0       75   2.62000E+00  3.14000E+00
 5-0       91   0.           3.92500E-01  7.85000E-01  1.17900E+00  1.57000E+00
 4-0       96   1.96000E+00  2.36000E+00  2.73000E+00  3.14000E+00
 5-0      112   0.           3.14000E-01  6.28000E-01  9.42000E-01  1.25500E+00
 5-0      117   1.57000E+00  1.88000E+00  2.20000E+00  2.51000E+00  2.82000E+00
 1-0      122   3.14000E+00
 5-0      133   0.           3.14000E-01  6.28000E-01  9.42000E-01  1.25500E+00
 5-0      138   1.57000E+00  1.88000E+00  2.20000E+00  2.51000E+00  2.82000E+00
 1-0      143   3.14000E+00
 5-0     1400   1.14800E-08  4.34700E-08  2.95700E-08  4.36600E-08  2.35400E-08
 5-0     1405   3.79100E-08  2.21300E-08  1.80400E-07  4.16200E-08  6.99700E-08
 3-0     1410   4.45900E-07  5.67700E-08  1.72900E-07
 5-0     1430   9.78000E+00  9.78000E+00  7.33500E+00  4.89000E+00  4.89000E+00
 5-0     1435   3.66800E+00  2.44500E+00  2.44500E+00  2.01700E+00  1.38100E+00
 5-0     1760   0.           0.           0.           0.           0.
 5-0     1860   0.           0.           0.           0.           0.
```

5-0	2060	0.	1.27000E+02	1.52000E+02	2.58064E+03	4.35600E+03
3-0	2160	1.00000E+00	0.	1.00000E+01		
3-0	2163	1.00000E+00	0.	1.39800E+02		
3-0	2166	6.00000E+01	0.	1.00000E+01		
3-0	2169	1.00000E+02	0.	1.00000E+01		
3-0	2172	1.00000E+00	0.	-1.00000E+01		
3-0	2175	1.00000E+00	0.	1.70000E+02		
5-0	2460	-0.	-0.	-0.	5.00000E-01	-0.
1-0	2467	1.69000E+00				
5-0	2480	7.00000E-03	0.	1.65000E+00	-0.	-0.
3-0	2485	-0.	-0.	-0.		
5-0	2500	5.14000E-02	2.62000E-01	-0.	-0.	2.56000E-01
3-0	2505	2.37000E+00	5.76000E-01	-0.		
5-0	2520	-0.	-0.	-0.	-0.	1.00000E-07
1-0	2545	1.00000E-07				
1-0	2566	1.00000E-07				
5-0	3530	6.00000E-01	1.00000E-01	7.20000E-02	4.07000E-02	2.17000E-02
3-0	3535	2.10000E-02	1.90000E-02	9.10000E-03		
1-0	3550	4.07000E-02				
5-0	3560	8.50000E+00	7.25000E+00	6.50000E+00	5.50000E+00	4.50000E+00
5-0	3565	3.50000E+00	2.80000E+00	2.50000E+00	2.00000E+00	1.50000E+00
3-0	3570	1.00000E+00	7.00000E-01	3.00000E-01		
4-0	4190	1.00500E+00	3.61600E-01	-6.49000E-03	1.35400E-04	
4-0	4194	1.00400E+00	3.90200E-01	-5.85200E-03	1.18200E-04	
4-0	4198	1.00300E+00	4.26300E-01	-4.85000E-03	9.19700E-05	
4-0	4202	1.00200E+00	4.73000E-01	-3.18500E-03	4.97500E-05	
4-0	4206	1.00100E+00	5.35700E-01	-1.79500E-04	-2.26500E-05	
4-0	4210	9.99000E-01	6.23600E-01	5.93800E-03	-1.58100E-04	
4-0	4214	9.97400E-01	7.07800E-01	1.47800E-02	-3.31700E-04	
4-0	4218	9.96600E-01	7.51600E-01	2.10400E-02	-4.41400E-04	
4-0	4222	9.95400E-01	8.35700E-01	3.83100E-01	-6.96100E-04	
4-0	4226	9.94800E-01	9.28000E-01	7.47100E-02	-1.04300E-03	
4-0	4230	9.96800E-01	9.87000E-01	1.71400E-01	-9.76600E-04	
4-0	4234	1.00100E+00	9.50200E-01	3.27800E-01	1.71000E-03	
4-0	4238	9.94400E-01	1.06900E+00	7.27200E-01	2.63400E-02	
1-0	4314	6.00000E+01				
5-0	4320	2.24330E-05	-2.69570E-03	1.06130E-01	-1.69470E+00	-4.57320E+00
5-0	4325	1.82000E-05	-2.17120E-03	8.42530E-02	-1.32530E+00	-3.44330E+00
5-0	4330	1.17870E-05	-1.41600E-03	5.57700E-02	-9.05660E-01	-2.35330E+00
5-0	4335	9.02200E-06	-1.08110E-03	4.24640E-02	-6.96920E-01	-1.83330E+00
5-0	4340	6.74300E-06	-8.05250E-04	3.13110E-02	-5.10500E-01	-1.33330E+00
5-0	4345	3.96800E-06	-4.59940E-04	1.70250E-02	-2.81400E-01	-8.09990E-01
5-0	4350	2.09900E-06	-2.41880E-04	8.71820E-03	-1.56420E-01	-6.56660E-01
5-0	4355	1.84600E-06	-1.98970E-04	5.99740E-03	-8.10060E-02	-4.76660E-01
5-0	4360	2.64000E-08	-3.80600E-06	-6.23600E-04	2.44830E-02	-3.53330E-01
5-0	4365	-8.84800E-07	1.10800E-04	-5.27930E-03	9.81620E-02	-3.73330E-01

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5-0	4470	-1.21900E-10	5.01920E-08	8.48700E-05	-8.31600E-02	-1.08940E+01
5-0	4475	-3.05770E-10	4.12350E-07	-1.59420E-04	-1.94700E-02	-1.10050E+01
5-0	4480	-3.92410E-10	5.06370E-07	-1.94890E-04	-1.36700E-02	-7.62390E+00
5-0	4485	3.23550E-10	-3.11850E-07	9.48700E-05	-4.65360E-02	-4.84800E+00
5-0	4490	1.08930E-10	-1.17540E-07	4.66100E-05	-4.43530E-02	-3.23560E+00
5-0	4495	1.93300E-11	-1.26220E-08	1.49700E-05	-4.58700E-02	-1.67270E+00
5-0	4500	3.18200E-11	-2.65980E-08	2.77200E-05	-5.17560E-02	-6.64900E-01
5-0	4505	-1.29360E-10	1.45640E-07	-2.84800E-05	-4.78930E-02	1.69210E-01
5-0	4510	-5.54100E-11	1.16100E-07	-3.99600E-05	-4.51280E-02	1.19470E+00
5-0	4515	-1.05550E-10	1.80440E-07	-6.52600E-05	-4.29600E-02	1.75580E+00
5-0	4720	2.73000E-02	2.45000E-02	2.70000E-02	2.82000E-02	3.05000E-02
5-0	4725	3.22000E-02	3.32000E-02	3.32000E-02	3.32000E-02	3.32000E-02
5-0	4750	8.50000E-07	8.80000E-07	9.20000E-07	9.50000E-07	1.05000E-06
5-0	4755	1.15000E-06	1.23000E-06	1.27000E-06	1.37000E-06	1.48000E-06
3-0	4760	1.61000E-06	1.67000E-06	1.66000E-06		
5-0	4780	3.91000E-15	3.83000E-15	3.77000E-15	3.69000E-15	3.62000E-15
5-0	4785	3.59000E-15	3.62000E-15	3.65000E-15	3.70000E-15	3.88000E-15
3-0	4790	4.22000E-15	4.52000E-15	5.45000E-15		
5-0	5050	1.97000E-05	1.94000E-05	1.78000E-05	1.71000E-05	1.62000E-05
5-0	5055	1.49000E-05	1.27000E-05	1.08000E-05	8.72000E-06	4.40000E-06
5-0	5080	1.00000E+00	1.00000E+00	1.00000E+00	1.00000E+00	1.00000E+00
5-0	5085	1.00000E+00	1.00000E+00	1.00000E+00	1.00000E+00	1.00000E+00
3-0	5360	1.22000E+02	1.52000E+01	0.		
3-0	5363	1.22000E+02	9.16000E+01	0.		
3-0	5366	1.22000E+02	1.68000E+02	0.		
3-0	5369	9.16000E+01	2.28000E+02	0.		
3-0	5372	3.05000E+01	2.28000E+02	0.		
3-0	5510	0.	0.	0.		
5-0	5513	1.00000E+00	3.00000E+00	4.00000E+00	6.00000E+00	2.40000E+01
3 1	5518	2.60000E+01	2.80000E+01	9.20000E+01		

GENERAL PROBLEM INPUT

NO. OF GAMMA GROUPS.....	13
NO. OF NEUTRON GROUPS.....	1[illegible]
NO. OF MATERIALS.....	[illegible]
NO. OF COMPOSITIONS.....	[illegible]
NO. OF DETECTORS.....	5
NO. OF BOUNDARYS.....	5
NO. OF REGIONS.....	6
NO. OF RESPONSES(GAMMA).....	2
NO. OF RESPONSES(NEUTRON).....	2
NO. OF RESPONSES(ALBERT-WELTON)	0
NO. OF MATERIALS FROM LIBRARY..	8

CALCULATION OPTIONS

GAMMA RAY(0/NO,1/YES).....	1
NEUTRON(0/NO,1/YES).....	
ALBERT-WELTON.....	0
MONOVARIANT MOMENTS.....	1
BIVARIANT MOMENTS.....	0

PRINT OPTIONS

SOURCE REGION SUMMATION (0/NO,1/SUM,2/ST,3/GT).....	3
INPUT PRINT(0/NO,1/CI,2/FULL).	2
OUTPUT PRINT (1/ST AND GT ONLY,2/ALL).....	0

SOURCE CALCULATION OPTIONS

SOURCE ZONE COMPOSITION.....	0
MOST PROBABLE ZONE.....	1
SOURCE CALCULATION OPTION.....	1
RADIAL DISTRIBUTION.....	1
AXIAL OR POLAR DISTRIBUTION...	1
AZMUTHIAL DISTRIBUTION.....	2

SOURCE INTERVAL DATA

NO. OF RADIAL.....	5

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NO. OF AXIAL(OR POLAR)..... 12
NO. OF AZMUTHIAL..... 4 6 8 10 10

SOURCE AND DISTRIBUTION PARAMETERS

GAMMA RAY SOURCE(INPUT).....	1.00000E+00
(NORMALIZED).....	1.94343E-06
NEUTRON SOURCE(INPUT).....	0.
(NORMAIZED).....	1.94343E-06
DISTRIBUTION PARAMETERS(XI(1))...	0.
(XI(2))...	0.
(ETA(1))...	0.
(ETA(2))...	0.

SOURCE DISTRIBUTION DATA - RADIAL

PT. NO.	COORDINATE INPUT	COORDINATE MIDPOINT	GAMMA RAY INPUT	GAMMA RAY NORMALIZED	NEUTRON INPUT	NEUTRON NORMALIZED
1	0.	7.071E+00	0.	5.000E+01	0.	5.000E+01
2	1.000E+01	1.581E+01	0.	1.500E+02	0.	1.500E+02
3	2.000E+01	2.550E+01	0.	2.500E+02	0.	2.500E+02
4	3.000E+01	3.536E+01	0.	3.500E+02	0.	3.500E+02
5	4.000E+01	4.572E+01	0.	4.903E+02	0.	4.903E+02
6	5.080E+01		0.		0.	

SOURCE DISTRIBUTION DATA - AXIAL OR POLAR

PT. NO.	COORDINATE INPUT	COORDINATE MIDPOINT	GAMMA RAY INPUT	GAMMA RAY NORMALIZED	NEUTRON INPUT	NEUTRON NORMALIZED
1	0.	7.605E+00	0.	1.521E+01	0.	1.521E+01
2	1.521E+01	2.285E+01	0.	1.529E+01	0.	1.529E+01
3	3.050E+01	3.430E+01	0.	7.600E+00	0.	7.600E+00
4	3.810E+01	4.445E+01	0.	1.270E+01	0.	1.270E+01
5	5.080E+01	5.715E+01	0.	1.270E+01	0.	1.270E+01
6	6.350E+01	6.980E+01	0.	1.260E+01	0.	1.260E+01
7	7.610E+01	8.255E+01	0.	1.290E+01	0.	1.290E+01
8	8.900E+01	9.530E+01	0.	1.260E+01	0.	1.260E+01
9	1.016E+02	1.078E+02	0.	1.250E+01	0.	1.250E+01
10	1.141E+02	1.160E+02	0.	3.900E+00	0.	3.900E+00

11	1.180E+02	1.190E+02	0.	2.000E+00	0.	2.000E+00
12	1.200E+02	1.235E+02	0.	7.000E+00	0.	7.000E+00
13	1.270E+02		0.		0.	

SOURCE DISTRIBUTION DATA - AZMUTHIAL FOR RADIAL INTERVAL 1

PT. NO.	COORDINATE INPUT	COORDINATE MIDPOINT	GAMMA RAY INPUT	GAMMA RAY NORMALIZED	NEUTRON INPUT	NEUTRON NORMALIZED
1	0.	3.925E-01	0.	1.526E-06	0.	1.526E-06
2	7.850E-01	1.177E+00	0.	1.526E-06	0.	1.526E-06
3	1.570E+00	1.964E+00	0.	1.531E-06	0.	1.531E-06
4	2.358E+00	2.749E+00	0.	1.520E-06	0.	1.520E-06
5	3.140E+00		0.		0.	

SOURCE DISTRIBUTION DATA - AZMUTHIAL FOR RADIAL INTERVAL 2

PT. NO.	COORDINATE INPUT	COORDINATE MIDPOINT	GAMMA RAY INPUT	GAMMA RAY NORMALIZED	NEUTRON INPUT	NEUTRON NORMALIZED
1	0.	2.620E-01	0.	1.018E-06	0.	1.018E-06
2	5.240E-01	7.860E-01	0.	1.018E-06	0.	1.018E-06
3	1.048E+00	1.309E+00	0.	1.014E-06	0.	1.014E-06
4	1.570E+00	1.832E+00	0.	1.020E-06	0.	1.020E-06
5	2.095E+00	2.358E+00	0.	1.020E-06	0.	1.020E-06
6	2.620E+00	2.880E+00	0.	1.011E-06	0.	1.011E-06
7	3.140E+00		0.		0.	

SOURCE DISTRIBUTION DATA - AZMUTHIAL FOR RADIAL INTERVAL 3

PT. NO.	COORDINATE INPUT	COORDINATE MIDPOINT	GAMMA RAY INPUT	GAMMA RAY NORMALIZED	NEUTRON INPUT	NEUTRON NORMALIZED
1	0.	1.963E-01	0.	7.628E-07	0.	7.628E-07
2	3.925E-01	5.887E-01	0.	7.628E-07	0.	7.628E-07
3	7.850E-01	9.820E-01	0.	7.657E-07	0.	7.657E-07
4	1.179E+00	1.374E+00	0.	7.599E-07	0.	7.599E-07
5	1.570E+00	1.765E+00	0.	7.579E-07	0.	7.579E-07
6	1.960E+00	2.160E+00	0.	7.774E-07	0.	7.774E-07
7	2.360E+00	2.545E+00	0.	7.191E-07	0.	7.191E-07

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8	2.730E+00	2.935E+00	0.	7.968E-07	0.	7.968E-07
9	3.140E+00		0.		0.	

SOURCE DISTRIBUTION DATA - AZMUTHIAL FOR RADIAL INTERVAL 4

PT. NO.	COORDINATE INPUT	COORDINATE MIDPOINT	GAMMA RAY INPUT	GAMMA RAY NORMALIZED	NEUTRON INPUT	NEUTRON NORMALIZED
1	0.	1.570E-01	0.	6.102E-07	0.	6.102E-07
2	3.140E-01	4.710E-01	0.	6.102E-07	0.	6.102E-07
3	6.280E-01	7.850E-01	0.	6.102E-07	0.	6.102E-07
4	9.420E-01	1.099E+00	0.	6.083E-07	0.	6.083E-07
5	1.255E+00	1.413E+00	0.	6.122E-07	0.	6.122E-07
6	1.570E+00	1.725E+00	0.	6.025E-07	0.	6.025E-07
7	1.880E+00	2.040E+00	0.	6.219E-07	0.	6.219E-07
8	2.200E+00	2.355E+00	0.	6.025E-07	0.	6.025E-07
9	2.510E+00	2.665E+00	0.	6.025E-07	0.	6.025E-07
10	2.820E+00	2.980E+00	0.	6.219E-07	0.	6.219E-07
11	3.140E+00		0.		0.	

SOURCE DISTRIBUTION DATA - AZMUTHIAL FOR RADIAL INTERVAL 5

PT. NO.	COORDINATE INPUT	COORDINATE MIDPOINT	GAMMA RAY INPUT	GAMMA RAY NORMALIZED	NEUTRON INPUT	NEUTRON NORMALIZED
1	0.	1.570E-01	0.	6.102E-07	0.	6.102E-07
2	3.140E-01	4.710E-01	0.	6.102E-07	0.	6.102E-07
3	6.280E-01	7.850E-01	0.	6.102E-07	0.	6.102E-07
4	9.420E-01	1.099E+00	0.	6.083E-07	0.	6.083E-07
5	1.255E+00	1.413E+00	0.	6.122E-07	0.	6.122E-07
6	1.570E+00	1.725E+00	0.	6.025E-07	0.	6.025E-07
7	1.880E+00	2.040E+00	0.	6.219E-07	0.	6.219E-07
8	2.200E+00	2.355E+00	0.	6.025E-07	0.	6.025E-07
9	2.510E+00	2.665E+00	0.	6.025E-07	0.	6.025E-07
10	2.820E+00	2.980E+00	0.	6.219E-07	0.	6.219E-07
11	3.140E+00		0.		0.	

GAMMA RAY SPECTRAL DATA

GROUP NO.	ENERGY	SPECTRAL DATA

1	8.500E+00	1.148E-08
2	7.250E+00	4.347E-08
3	6.500E+00	2.957E-08
4	5.500E+00	4.366E-08
5	4.500E+00	2.354E-08
6	3.500E+00	3.791E-08
7	2.800E+00	2.213E-08
8	2.500E+00	1.804E-07
9	2.000E+00	4.162E-08
10	1.500E+00	6.997E-08
11	1.000E+00	4.459E-07
12	7.000E-01	5.677E-08
13	3.000E-01	1.729E-07

NEUTRON SPECTRAL DATA

GROUP NO.	ENERGY	SPECTRAL DATA
1	0.	9.780E+00
2	0.	9.780E+00
3	0.	7.335E+00
4	0.	4.890E+00
5	0.	4.890E+00
6	0.	3.668E+00
7	0.	2.445E+00
8	0.	2.445E+00
9	0.	2.017E+00
10	0.	1.381E+00

ZONE BOUNDARY SPECIFACTIONS

ZONE	COMP.	BND.	ZONE	BND.	ZONE	BND.	ZONE	BND.	ZONE	BND.	ZONE	BND.	ZONE
1	1	-1	5	2	2	4	3						
2	3	-2	1	3	6	5	4						
3	2	-1	5	-4	1	2	2	5	4				
4	4	-1	5										
5	5	1	1										
6	6	-3	2										

BOUNDARY EQUATION CONSTANTS

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BND. NO.	AND TYPE	A0	X0	B0	Y0	C0	Z0	D0
1	6	0.	0.	0.	0.	0.	0.	0.
2	6	0.	0.	0.	0.	0.	0.	1.270E+02
3	6	0.	0.	0.	0.	0.	0.	1.520E+02
4	3	0.	0.	0.	0.	0.	0.	2.581E+03
5	3	0.	0.	0.	0.	0.	0.	4.356E+03

COMPOSITIONS BY MATERIAL

COMP. NO.	MATERIAL NO. 1	2	3	4	5	6
1	-0.	-0.	-0.	6.000E-01	-0.	0.
2	7.000E-03	0.	1.650E+00	-0.	-0.	-0.
3	5.140E-02	2.620E-01	-0.	-0.	2.560E-01	2.370E+00
4	-0.	-0.	-0.	-0.	1.000E-07	0.
5	0.	0.	0.	0.	0.	1.000E-07
6	0.	0.	0.	0.	0.	0.

COMPOSITIONS BY MATERIAL

COMP. NO.	MATERIAL NO. 7	8
1	0.	1.690E+00
2	-0.	-0.
3	5.760E-01	-0.
4	0.	0.
5	0.	0.
6	1.000E-07	0.

NEUTRON CROSS SECTION DATA

MAT. NO.	ALBERT-WELTON REMOVAL	ETA	MOMENTS REMOVAL
1	0.	0.	6.000E-01
2	0.	0.	1.000E-01
3	0.	0.	7.200E-02
4	0.	0.	4.070E-02
5	0.	0.	2.170E-02
6	0.	0.	2.100E-02

7	0.	0.	1.900E-02
8	0.	0.	9.100E-03

ALBERT-WELTON COEFF.•ALPHA(1)•••• 0.
•ALPHA(2)•••• 0.
•ALPHA(3)•••• 0.
•ALPHA(4)•••• 0.
•ALPHA(5)•••• 0.
•ALPHA(6)•••• 0.
•ALPHA(7)•••• 0.

REFERENCE MATERIAL REMOVAL••••••• 4.070E-02

GAMMA RAY LINEAR ABSORPTION COEFF.

MATERIAL NO.

COMP. NO.	ENERGY	1	2	3	4	5	6
1	8.500E+00	3.550E-02	1.680E-02	1.730E-02	2.050E-02	2.924E-02	2.980E-02
2	7.250E+00	3.969E-02	1.827E-02	1.909E-02	2.227E-02	2.967E-02	3.012E-02
3	6.500E+00	4.260E-02	1.950E-02	2.030E-02	2.360E-02	3.007E-02	3.043E-02
4	5.500E+00	4.720E-02	2.140E-02	2.220E-02	2.560E-02	3.086E-02	3.110E-02
5	4.500E+00	5.350E-02	2.400E-02	2.470E-02	2.840E-02	3.220E-02	3.228E-02
6	3.500E+00	6.290E-02	2.790E-02	2.860E-02	3.270E-02	3.466E-02	3.455E-02
7	2.800E+00	7.250E-02	3.180E-02	3.270E-02	3.720E-02	3.769E-02	3.742E-02
8	2.500E+00	7.750E-02	3.390E-02	3.490E-02	3.950E-02	3.952E-02	3.918E-02
9	2.000E+00	8.760E-02	3.830E-02	3.940E-02	4.440E-02	4.338E-02	4.291E-02
10	1.500E+00	1.030E-01	4.480E-02	4.590E-02	5.180E-02	4.963E-02	4.905E-02
11	1.000E+00	1.260E-01	5.500E-02	5.650E-02	6.360E-02	6.062E-02	5.988E-02
12	7.000E-01	1.480E-01	6.550E-02	6.610E-02	7.450E-02	7.247E-02	7.159E-02
13	3.000E-01	2.120E-01	9.220E-02	9.450E-02	1.060E-01	1.063E-01	1.063E-01

GAMMA RAY LINEAR ABSORPTION COEFF.

MATERIAL NO.

COMP. NO.	ENERGY	7	8
1	8.500E+00	3.038E-02	4.888E-02
2	7.250E+00	3.059E-02	4.730E-02
3	6.500E+00	3.082E-02	4.628E-02
4	5.500E+00	3.136E-02	4.492E-02
5	4.500E+00	3.239E-02	4.383E-02

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6	3.500E+00	3.447E-02	4.373E-02
7	2.800E+00	3.720E-02	4.510E-02
8	2.500E+00	3.889E-02	4.624E-02
9	2.000E+00	4.249E-02	4.824E-02
10	1.500E+00	4.853E-02	5.628E-02
11	1.000E+00	5.920E-02	7.603E-02
12	7.000E-01	7.082E-02	1.103E-01
13	3.000E-01	1.069E-01	4.565E-01

GAMMA RAY BUILDUP COEFF.

GROUP NO.	ENERGY	B0	B1	B2	B3
1	8.500E+00	1.005E+00	3.616E-01	-6.490E-03	1.354E-04
2	7.250E+00	1.004E+00	3.902E-01	-5.852E-03	1.182E-04
3	6.500E+00	1.003E+00	4.263E-01	-4.850E-03	9.197E-05
4	5.500E+00	1.002E+00	4.730E-01	-3.185E-03	4.975E-05
5	4.500E+00	1.001E+00	5.357E-01	-1.795E-04	-2.265E-05
6	3.500E+00	9.990E-01	6.236E-01	5.938E-03	-1.581E-04
7	2.800E+00	9.974E-01	7.078E-01	1.478E-02	-3.317E-04
8	2.500E+00	9.966E-01	7.516E-01	2.104E-02	-4.414E-04
9	2.000E+00	9.954E-01	8.357E-01	3.831E-01	-6.961E-04
10	1.500E+00	9.948E-01	9.280E-01	7.471E-02	-1.043E-03
11	1.000E+00	9.968E-01	9.870E-01	1.714E-01	-9.766E-04
12	7.000E-01	1.001E+00	9.502E-01	3.278E-01	1.710E-03
13	3.000E-01	9.944E-01	1.069E+00	7.272E-01	2.634E-02

MONOVARIANT POLYNOMIAL MOMENTS DATA

GROUP NO.	ENERGY	A0	A1	A2	A3	A4
1	0.	2.243E-05	-2.696E-03	1.061E-01	-1.695E+00	-4.573E+00
2	0.	1.820E-05	-2.171E-03	8.425E-02	-1.325E+00	-3.443E+00
3	0.	1.179E-05	-1.416E-03	5.577E-02	-9.057E-01	-2.353E+00
4	0.	9.022E-06	-1.081E-03	4.246E-02	-6.969E-01	-1.833E+00
5	0.	6.743E-06	-8.053E-04	3.131E-02	-5.105E-01	-1.333E+00
6	0.	3.968E-06	-4.599E-04	1.702E-02	-2.814E-01	-8.100E-01
7	0.	2.099E-06	-2.419E-04	8.718E-03	-1.564E-01	-6.567E-01
8	0.	1.846E-06	-1.990E-04	5.997E-03	-8.101E-02	-4.767E-01
9	0.	2.640E-08	-3.806E-06	-6.236E-04	2.448E-02	-3.533E-01
10	0.	-8.848E-07	1.108E-04	-5.279E-03	9.816E-02	-3.733E-01
1	0.	-1.219E-10	5.019E-08	8.487E-05	-8.316E-02	-1.089E+01
2	0.	-3.058E-10	4.123E-07	-1.594E-04	-1.947E-02	-1.100E+01
3	0.	-3.924E-10	5.064E-07	-1.949E-04	-1.367E-02	-7.624E+00
4	0.	3.236E-10	-3.118E-07	9.487E-05	-4.654E-02	-4.848E+00

5	0.	1.089E-10	-1.175E-07	4.661E-05	-4.435E-02	-3.236E+00
6	0.	1.933E-11	-1.262E-08	1.497E-05	-4.587E-02	-1.673E+00
7	0.	3.182E-11	-2.660E-08	2.772E-05	-5.176E-02	-6.649E-01
8	0.	-1.294E-10	1.456E-07	-2.848E-05	-4.789E-02	1.692E-01
9	0.	-5.541E-11	1.161E-07	-3.996E-05	-4.513E-02	1.195E+00
10	0.	-1.055E-10	1.804E-07	-6.526E-05	-4.296E-02	1.756E+00

BIVARIANT POLYNOMIAL MOMENTS DATA

GROUP NO.	ENERGY RANGE LIMITS UPPER	LOWER	C0	C1	C2	C3	C4
1	6.000E+01	0.	0.				
2	0.	0.	0.				
3	0.	0.	0.				

MOMENTS DATA EXTRAPOLATION PARAMETERS

GROUP NO.	ENERGY	LAMBDA
1	0.	2.730E-02
2	0.	2.450E-02
3	0.	2.700E-02
4	0.	2.820E-02
5	0.	3.050E-02
6	0.	3.220E-02
7	0.	3.320E-02
8	0.	3.320E-02
9	0.	3.320E-02
10	0.	3.320E-02

GAMMA RAY RESPONSE DATA

GROUP NO.	ENERGY 1	2	RESPONSE FUNCTION
1	8.500E+00	8.500E-07	3.910E-15
2	7.250E+00	8.800E-07	3.830E-15
3	6.500E+00	9.200E-07	3.770E-15
4	5.500E+00	9.500E-07	3.690E-15
5	4.500E+00	1.050E-06	3.620E-15
6	3.500E+00	1.150E-06	3.590E-15
7	2.800E+00	1.230E-06	3.620E-15
8	2.500E+00	1.270E-06	3.650E-15
9	2.000E+00	1.370E-06	3.700E-15
10	1.500E+00	1.480E-06	3.880E-15

Astronuclear Laboratory

11	1.000E+00	1.610E-06	4.220E-15
12	7.000E-01	1.670E-06	4.520E-15
13	3.000E-01	1.660E-06	5.450E-15

NEUTRON RESPONSE DATA

GROUP NO.	ENERGY 1	RESPONSE FUNCTION 2	
1	0.	1.970E-05	1.000E+00
2	0.	1.940E-05	1.000E+00
3	0.	1.780E-05	1.000E+00
4	0.	1.710E-05	1.000E+00
5	0.	1.620E-05	1.000E+00
6	0.	1.490E-05	1.000E+00
7	0.	1.270E-05	1.000E+00
8	0.	1.080E-05	1.000E+00
9	0.	8.720E-06	1.000E+00
10	0.	4.400E-06	1.000E+00

ALBERT/WELTON RESPONSE DATA

GROUP NO.	ENERGY 1	RESPONSE FUNCTION
1	1.000E+00	0.

RECEIVER POINT COORDINATES

POINT NO.	COORDINATES R	Z	θ
1	1.220E+02	1.520E+01	0.
2	1.220E+02	9.160E+01	0.
3	1.220E+02	1.680E+02	0.
4	9.160E+01	2.280E+02	0.
5	3.050E+01	2.280E+02	0.

SOURCE POINT TRANSLATION COORDINATES

X..... 0.
Y..... 0.
Z..... 0.

LIBRARY MATERIAL ATOMIC NUMBERS

MAT. ATOMIC

NO.	NUMBER
1	1.000E+00
2	3.000E+00
3	4.000E+00
4	6.000E+00
5	2.400E+01
6	2.600E+01
7	2.800E+01
8	9.200E+01

MISCELLANEOUS DATA

BOUNDARY SEARCH EPSILON..... 1.000E-06
BOUNDARY SEARCH PARAMETER... 1.000E-03
EMPIRICAL SOURCE SOLUTION
MEAN FREE PATHS..... 0.

CALCULATED RESULTS FOR SOURCE REGION 1

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. ONE
COORDINATES R..... 1.22000E+02
Z..... 1.52000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	2.297E-20	1.056E-28
2	7.25	9.569E-20	4.165E-28
3	6.50	7.442E-20	3.050E-28
4	5.50	1.248E-19	4.848E-28
5	4.50	8.248E-20	2.844E-28
6	3.50	1.594E-19	4.975E-28
7	2.80	1.044E-19	3.071E-28
8	2.50	8.978E-19	2.580E-27
9	2.00	1.435E-18	3.877E-27
10	1.50	4.415E-19	1.157E-27

Astronuclear Laboratory

11	1.00	3.068E-18	8.043E-27
12	.70	3.770E-19	1.020E-27
13	.30	4.168E-20	1.368E-28
		---------	---------
		6.926E-18	1.922E-26

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. ONE
COORDINATES R..... 1.22000E+02
Z..... 1.52000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	3.416E-21	1.571E-29
2	7.25	1.291E-20	5.618E-29
3	6.50	8.940E-21	3.663E-29
4	5.50	1.302E-20	5.057E-29
5	4.50	7.196E-21	2.481E-29
6	3.50	1.093E-20	3.412E-29
7	2.80	5.668E-21	1.668E-29
8	2.50	4.293E-20	1.234E-28
9	2.00	8.680E-21	2.344E-29
10	1.50	1.074E-20	2.817E-29
11	1.00	3.766E-20	9.870E-29
12	.70	2.288E-21	6.192E-30
13	.30	7.955E-23	2.612E-31
		---------	---------
		1.645E-19	5.148E-28

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. ONE
COORDINATES R..... 1.22000E+02
Z..... 1.52000E+01

PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	2.756E-17	1.399E-12
2	0.	8.964E-16	4.621E-11
3	0.	2.454E-14	1.378E-09
4	0.	8.225E-14	4.810E-09
5	0.	3.778E-13	2.332E-08
6	0.	9.898E-13	6.643E-08
7	0.	1.095E-12	8.619E-08
8	0.	2.225E-12	2.060E-07
9	0.	5.291E-12	6.068E-07
10	0.	3.386E-12	7.696E-07
		---	---
		1.347E-11	1.765E-06

CALCULATED RESULTS FOR SOURCE REGION 1

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. TWO
COORDINATES R..... 1.22000E+02
Z..... 9.16000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	2.691E-20	1.238E-28
2	7.25	1.123E-19	4.887E-28
3	6.50	8.740E-20	3.582E-28
4	5.50	1.468E-19	5.702E-28
5	4.50	9.721E-20	3.351E-28
6	3.50	1.885E-19	5.885E-28
7	2.80	1.240E-19	3.650E-28
8	2.50	1.069E-18	3.073E-27
9	2.00	1.717E-18	4.638E-27

Astronuclear Laboratory

10	1.50	5.321E-19	1.395E-27
11	1.00	3.740E-18	9.802E-27
12	.70	4.642E-19	1.256E-27
13	.30	5.243E-20	1.721E-28
		---	---
		8.3[illegible]AE-18	2.317E-26

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. TWO
COORDINATES R..... 1.22000E+02
Z..... 9.16000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	4.003E-21	1.841E-29
2	7.25	1.515E-20	6.592E-29
3	6.50	1.050E-20	4.302E-29
4	5.50	1.531E-20	5.948E-29
5	4.50	8.481E-21	2.924E-29
6	3.50	1.293E-20	4.036E-29
7	2.80	6.735E-21	1.982E-29
8	2.50	5.113E-20	1.470E-28
9	2.00	1.039E-20	2.805E-29
10	1.50	1.295E-20	3.395E-29
11	1.00	4.590E-20	1.203E-28
12	.70	2.817E-21	7.623E-30
13	.30	1.001E-22	3.285E-31
		---	---
		1.964E-19	6.135E-28

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. TWO
COORDINATES R..... 1.22000E+02

Z..... 9.16000E+01
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	3.413E-17	1.732E-12
2	0.	1.059E-15	5.457E-11
3	0.	2.878E-14	1.617E-09
4	0.	9.646E-14	5.641E-09
5	0.	4.455E-13	2.750E-08
6	0.	1.176E-12	7.893E-08
7	0.	1.315E-12	1.035E-07
8	0.	2.681E-12	2.483E-07
9	0.	6.408E-12	7.349E-07
10	0.	4.114E-12	9.351E-07
		---	---
		1.627E-11	2.136E-06

CALCULATED RESULTS FOR SOURCE REGION 1

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT.THREE
COORDINATES R..... 1.22000E+02
Z..... 1.68000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	7.343E-21	3.378E-29
2	7.25	3.022E-20	1.315E-28
3	6.50	2.329E-20	9.545E-29
4	5.50	3.845E-20	1.493E-28
5	4.50	2.480E-20	8.548E-29
6	3.50	4.587E-20	1.432E-28
7	2.80	2.854E-20	8.401E-29
8	2.50	2.386E-19	6.856E-28

Astronuclear Laboratory

9	2.00	3.598E-19	9.716E-28
10	1.50	1.004E-19	2.633E-28
11	1.00	5.893E-19	1.544E-27
12	.70	5.959E-20	1.613E-28
13	.30	2.040E-21	6.697E-30
		---------	---------
		1.548E-18	4.356E-27

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT.THREE
COORDINATES R..... 1.22000E+02
Z..... 1.68000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	1.092E-21	5.023E-30
2	7.25	4.077E-21	1.774E-29
3	6.50	2.798E-21	1.147E-29
4	5.50	4.011E-21	1.558E-29
5	4.50	2.163E-21	7.458E-30
6	3.50	3.146E-21	9.820E-30
7	2.80	1.550E-21	4.563E-30
8	2.50	1.141E-20	3.278E-29
9	2.00	2.175E-21	5.875E-30
10	1.50	2.444E-21	6.407E-30
11	1.00	7.232E-21	1.895E-29
12	.70	3.616E-22	9.786E-31
13	.30	3.893E-24	1.278E-32
		---------	---------
		4.246E-20	1.367E-28

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT.THREE

```
COORDINATES R......     1.22000E+02
            Z......     1.68000E+02
            PHI....     0.

        NEUT. 1     NEUT. 2

 1  0.     7.487E-18   3.801E-13
 2  0.     3.197E-16   1.648E-11
 3  0.     8.682E-15   4.877E-10
 4  0.     2.909E-14   1.701E-09
 5  0.     1.275E-13   7.873E-09
 6  0.     3.032E-13   2.035E-08
 7  0.     3.072E-13   2.419E-08
 8  0.     6.062E-13   5.613E-08
 9  0.     1.294E-12   1.484E-07
10  0.     8.097E-13   1.840E-07
           ---------   ---------
           3.486E-12   4.432E-07

           CALCULATED RESULTS FOR SOURCE REGION   1

                        SOURCE REGION CALCULATIONAL RESULTS


RECEIVER POINT DET.PT. FOUR
COORDINATES R......     9.16000E+01
            Z......     2.28000E+02
            PHI....     0.

        GAM RESP 1  GAM RESP 2

 1  8.50   7.586E-22   3.490E-30
 2  7.25   3.139E-21   1.366E-29
 3  6.50   2.407E-21   9.862E-30
 4  5.50   3.886E-21   1.509E-29
 5  4.50   2.372E-21   8.178E-30
 6  3.50   3.906E-21   1.219E-29
 7  2.80   2.072E-21   6.097E-30
```


Astronuclear Laboratory

8	2.50	1.561E-20	4.487E-29
9	2.00	1.883E-20	5.084E-29
10	1.50	3.596E-21	9.428E-30
11	1.00	1.095E-20	2.870E-29
12	.70	5.510E-22	1.491E-30
13	.30	9.759E-24	3.204E-32
		---------	---------
		6.808E-20	2.039E-28

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. FOUR
COORDINATES R..... 9.16000E+01
Z..... 2.28000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	1.128E-22	5.190E-31
2	7.25	4.235E-22	1.843E-30
3	6.50	2.891E-22	1.185E-30
4	5.50	4.053E-22	1.574E-30
5	4.50	2.070E-22	7.135E-31
6	3.50	2.679E-22	8.362E-31
7	2.80	1.125E-22	3.311E-31
8	2.50	7.465E-22	2.145E-30
9	2.00	1.138E-22	3.074E-31
10	1.50	8.751E-23	2.294E-31
11	1.00	1.344E-22	3.522E-31
12	.70	3.343E-24	9.049E-33
13	.30	1.862E-26	6.115E-35
		---------	---------
		2.904E-21	1.005E-29

SOURCE REGION CALCULATIONAL RESULTS

COORDINATES R..... 9.16000E+01
Z..... 2.28000E+02
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	1.398E-18	7.098E-14
2	0.	1.089E-16	5.616E-12
3	0.	2.961E-15	1.663E-10
4	0.	1.019E-14	5.957E-10
5	0.	4.213E-14	2.601E-09
6	0.	8.970E-14	6.020E-09
7	0.	8.360E-14	6.582E-09
8	0.	1.563E-13	1.447E-08
9	0.	3.323E-13	3.811E-08
10	0.	2.036E-13	4.628E-08
		---------	---------
		9.2[illegible]9E-13	1.148E-07

CALCULATED RESULTS FOR SOURCE REGION 1

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. FIVE
COORDINATES R..... 3.05000E+01
Z..... 2.28000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	1.846E-21	8.493E-30
2	7.25	7.787E-21	3.389E-29
3	6.50	6.050E-21	2.479E-29
4	5.50	9.986E-21	3.879E-29
5	4.50	6.299E-21	2.172E-29
6	3.50	1.098E-20	3.428E-29
7	2.80	6.218E-21	1.830E-29

Astronuclear Laboratory

8	2.50	4.862E-20	1.397E-28
9	2.00	6.310E-20	1.704E-28
10	1.50	1.361E-20	3.567E-29
11	1.00	5.064E-20	1.327E-28
12	.70	3.135E-21	8.486E-30
13	.30	1.099E-22	3.610E-31
		---	---
		2.284E-19	6.677E-28

SOURCE REGION CALCULATIONAL RESULTS

RECEIVER POINT DET.PT. FIVE
COORDINATES R..... 3.05000E+01
Z..... 2.28000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	2.746E-22	1.263E-30
2	7.25	1.051E-21	4.572E-30
3	6.50	7.268E-22	2.978E-30
4	5.50	1.042E-21	4.046E-30
5	4.50	5.495E-22	1.895E-30
6	3.50	7.531E-22	2.351E-30
7	2.80	3.377E-22	9.939E-31
8	2.50	2.325E-21	6.681E-30
9	2.00	3.816E-22	1.030E-30
10	1.50	3.311E-22	8.681E-31
11	1.00	6.215E-22	1.629E-30
12	.70	1.903E-23	5.149E-32
13	.30	2.098E-25	6.889E-34
		---	---
		8.4 2E-21	2.836E-29

SOURCE REGION CALCULATIONAL RESULTS

```
COORDINATES R......     3.05000E+01
            Z......     2.28000E+02
            PHI....     0.

        NEUT. 1      NEUT. 2

 1  0.     5.248E-18   2.664E-13
 2  0.     2.941E-16   1.516E-11
 3  0.     8.019E-15   4.505E-10
 4  0.     2.669E-14   1.561E-09
 5  0.     1.152E-13   7.111E-09
 6  0.     2.629E-13   1.764E-08
 7  0.     2.574E-13   2.027E-08
 8  0.     4.981E-13   4.612E-08
 9  0.     1.061E-12   1.217E-07
10  0.     6.594E-13   1.499E-07
           ---------   ---------
           2.889E-12   3.647E-07
```

FOR SOURCE REGION 1 AND DETECTOR POINT 5 THERE HAS BEEN 5928 AND 243 PATH LENGTH CALCULATIONS
IN EXCESS OF 0. MEAN FREE PATHS(GAMMA RAY) AND 120.0 GRAMS/CM**2(NEUTRON),RESPECTIVELY

INTERMEDIATE SUMMARY RESULTS OVER A SUBSET OF SOURCE REGIONS

SUBTOTAL OVER SELECTED SOURCE

```
RECEIVER POINT DET.PT.  ONE
COORDINATES R......     1.22000E+02
            Z......     1.52000E+01
            PHI....     0.

        GAM RESP 1  GAM RESP 2

1  8.50   2.297E-20   1.056E-28
2  7.25   9.569E-20   4.165E-28
3  6.50   7.442E-20   3.050E-28
4  5.50   1.248E-19   4.848E-28
```


Astronuclear Laboratory

5	4.50	8.248E-20	2.844E-28
6	3.50	1.594E-19	4.975E-28
7	2.80	1.044E-19	3.071E-28
8	2.50	8.978E-19	2.580E-27
9	2.00	1.435E-18	3.877E-27
10	1.50	4.415E-19	1.157E-27
11	1.00	3.068E-18	8.043E-27
12	.70	3.770E-19	1.020E-27
13	.30	4.168E-20	1.368E-28
		6.926E-18	1.922E-26

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. ONE
COORDINATES R..... 1.22000E+02
Z..... 1.52000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	3.416E-21	1.571E-29
2	7.25	1.291E-20	5.618E-29
3	6.50	8.940E-21	3.663E-29
4	5.50	1.302E-20	5.057E-29
5	4.50	7.196E-21	2.481E-29
6	3.50	1.093E-20	3.412E-29
7	2.80	5.668E-21	1.668E-29
8	2.50	4.293E-20	1.234E-28
9	2.00	8.680E-21	2.344E-29
10	1.50	1.074E-20	2.817E-29
11	1.00	3.766E-20	9.870E-29
12	.70	2.288E-21	6.192E-30
13	.30	7.955E-23	2.612E-31
		1.645E-19	5.148E-28

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. ONE
COORDINATES R..... 1.22000E+02
Z..... 1.52000E+01
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	2.756E-17	1.399E-12
2	0.	8.964E-16	4.621E-11
3	0.	2.454E-14	1.378E-09
4	0.	8.225E-14	4.810E-09
5	0.	3.778E-13	2.332E-08
6	0.	9.898E-13	6.643E-08
7	0.	1.095E-12	8.619E-08
8	0.	2.225E-12	2.060E-07
9	0.	5.291E-12	6.068E-07
10	0.	3.386E-12	7.696E-07
		---------	---------
		1.347E-11	1.765E-06

INTERMEDIATE SUMMARY RESULTS OVER A SUBSET OF SOURCE REGIONS

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. TWO
COORDINATES R..... 1.22000E+02
Z..... 9.16000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	2.691E-20	1.238E-28
2	7.25	1.123E-19	4.887E-28
3	6.50	8.740E-20	3.582E-28

Astronuclear Laboratory

4	5.50	1.468E-19	5.702E-28
5	4.50	9.721E-20	3.351E-28
6	3.50	1.885E-19	5.885E-28
7	2.80	1.240E-19	3.650E-28
8	2.50	1.069E-18	3.073E-27
9	2.00	1.717E-18	4.638E-27
10	1.50	5.321E-19	1.395E-27
11	1.00	3.740E-18	9.802E-27
12	.70	4.642E-19	1.256E-27
13	.30	5.243E-20	1.721E-28
		---	---
		8.328E-18	2.317E-26

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. TWO
COORDINATES R..... 1.22000E+02
Z..... 9.16000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	4.003E-21	1.841E-29
2	7.25	1.515E-20	6.592E-29
3	6.50	1.050E-20	4.302E-29
4	5.50	1.531E-20	5.948E-29
5	4.50	8.481E-21	2.924E-29
6	3.50	1.293E-20	4.036E-29
7	2.80	6.735E-21	1.982E-29
8	2.50	5.113E-20	1.470E-28
9	2.00	1.039E-20	2.805E-29
10	1.50	1.295E-20	3.395E-29
11	1.00	4.590E-20	1.203E-28
12	.70	2.817E-21	7.623E-30
13	.30	1.001E-22	3.285E-31
		---	---
		1.964E-19	6.135E-28

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. TWO
COORDINATES R..... 1.22000E+02
Z..... 9.16000E+01
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	3.413E-17	1.732E-12
2	0.	1.059E-15	5.457E-11
3	0.	2.878E-14	1.617E-09
4	0.	9.646E-14	5.641E-09
5	0.	4.455E-13	2.750E-08
6	0.	1.176E-12	7.893E-08
7	0.	1.315E-12	1.035E-07
8	0.	2.681E-12	2.483E-07
9	0.	6.408E-12	7.349E-07
10	0.	4.114E-12	9.351E-07
		---	---
		1.627E-11	2.136E-06

INTERMEDIATE SUMMARY RESULTS OVER A SUBSET OF SOURCE REGIONS

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT.THREE
COORDINATES R..... 1.22000E+02
Z..... 1.68000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	7.343E-21	3.378E-29
2	7.25	3.022E-20	1.315E-28

Astronuclear Laboratory

3	6.50	2.329E-20	9.545E-29
4	5.50	3.845E-20	1.493E-28
5	4.50	2.480E-20	8.548E-29
6	3.50	4.587E-20	1.432E-28
7	2.80	2.854E-20	8.401E-29
8	2.50	2.386E-19	6.856E-28
9	2.00	3.598E-19	9.716E-28
10	1.50	1.004E-19	2.633E-28
11	1.00	5.893E-19	1.544E-27
12	.70	5.959E-20	1.613E-28
13	.30	2.040E-21	6.697E-30
		1.548E-18	4.356E-27

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT.THREE
COORDINATES R..... 1.22000E+02
Z..... 1.68000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	1.092E-21	5.023E-30
2	7.25	4.077E-21	1.774E-29
3	6.50	2.798E-21	1.147E-29
4	5.50	4.011E-21	1.558E-29
5	4.50	2.163E-21	7.458E-30
6	3.50	3.146E-21	9.820E-30
7	2.80	1.550E-21	4.563E-30
8	2.50	1.141E-20	3.278E-29
9	2.00	2.175E-21	5.875E-30
10	1.50	2.444E-21	6.407E-30
11	1.00	7.232E-21	1.895E-29
12	.70	3.616E-22	9.786E-31
13	.30	3.893E-24	1.278E-32
		4.246E-20	1.367E-28

SUBTOTAL OVER SELECTED SOURCE

```
RECEIVER POINT DET.PT.THREE
COORDINATES R......     1.22000E+02
            Z......     1.68000E+02
            PHI....     0.

        NEUT. 1      NEUT. 2

1   0.      7.487E-18    3.801E-13
2   0.      3.197E-16    1.648E-11
3   0.      8.682E-15    4.877E-10
4   0.      2.909E-14    1.701E-09
5   0.      1.275E-13    7.873E-09
6   0.      3.032E-13    2.035E-08
7   0.      3.072E-13    2.419E-08
8   0.      6.062E-13    5.613E-08
9   0.      1.294E-12    1.484E-07
10  0.      8.097E-13    1.840E-07
            ---------    ---------
            3.486E-12    4.432E-07

            INTERMEDIATE SUMMARY RESULTS OVER A SUBSET OF SOURCE REGIONS

                         SUBTOTAL OVER SELECTED SOURCE


RECEIVER POINT DET.PT. FOUR
COORDINATES R......     9.16000E+01
            Z......     2.28000E+02
            PHI....     0.

        GAM RESP 1   GAM RESP 2

1   8.50    7.586E-22    3.490E-30
```


Astronuclear Laboratory

2	7.25	3.139E-21	1.366E-29
3	6.50	2.407E-21	9.862E-30
4	5.50	3.886E-21	1.509E-29
5	4.50	2.372E-21	8.178E-30
6	3.50	3.906E-21	1.219E-29
7	2.80	2.072E-21	6.097E-30
8	2.50	1.561E-20	4.487E-29
9	2.00	1.883E-20	5.084E-29
10	1.50	3.596E-21	9.428E-30
11	1.00	1.095E-20	2.870E-29
12	.70	5.510E-22	1.491E-30
13	.30	9.759E-24	3.204E-32
		---------	---------
		6.8[illegible]8E-20	2.039E-28

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. FOUR

COORDINATES R..... 9.16000E+01
Z..... 2.28000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	1.128E-22	5.190E-31
2	7.25	4.235E-22	1.843E-30
3	6.50	2.891E-22	1.185E-30
4	5.50	4.053E-22	1.574E-30
5	4.50	2.070E-22	7.135E-31
6	3.50	2.679E-22	8.362E-31
7	2.80	1.125E-22	3.311E-31
8	2.50	7.465E-22	2.145E-30
9	2.00	1.138E-22	3.074E-31
10	1.50	8.751E-23	2.294E-31
11	1.00	1.344E-22	3.522E-31
12	.70	3.343E-24	9.049E-33
13	.30	1.862E-26	6.115E-35
		---------	---------
		2.9[illegible]4E-21	1.005E-29

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. FOUR
COORDINATES R..... 9.16000E+01
Z..... 2.28000E+02
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	1.398E-18	7.098E-14
2	0.	1.089E-16	5.616E-12
3	0.	2.961E-15	1.663E-10
4	0.	1.019E-14	5.957E-10
5	0.	4.213E-14	2.601E-09
6	0.	8.970E-14	6.020E-09
7	0.	8.360E-14	6.582E-09
8	0.	1.563E-13	1.447E-08
9	0.	3.323E-13	3.811E-08
10	0.	2.036E-13	4.628E-08
		---	---
		9.299E-13	1.148E-07

INTERMEDIATE SUMMARY RESULTS OVER A SUBSET OF SOURCE REGIONS

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. FIVE
COORDINATES R..... 3.05000E+01
Z..... 2.28000E+02
PHI.... 0.

GAM RESP 1 GAM RESP 2

Astronuclear Laboratory

1	8.50	1.846E-21	8.493E-30
2	7.25	7.787E-21	3.389E-29
3	6.50	6.050E-21	2.479E-29
4	5.50	9.986E-21	3.879E-29
5	4.50	6.299E-21	2.172E-29
6	3.50	1.098E-20	3.428E-29
7	2.80	6.218E-21	1.830E-29
8	2.50	4.862E-20	1.397E-28
9	2.00	6.310E-20	1.704E-28
10	1.50	1.361E-20	3.567E-29
11	1.00	5.044E-20	1.327E-28
12	.70	3.135E-21	8.486E-30
13	.30	1.099E-22	3.610E-31
		---	---
		2.284E-19	6.677E-28

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. FIVE

COORDINATES R..... 3.05000E+01
Z..... 2.28000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	2.746E-22	1.263E-30
2	7.25	1.051E-21	4.572E-30
3	6.50	7.268E-22	2.978E-30
4	5.50	1.042E-21	4.046E-30
5	4.50	5.495E-22	1.895E-30
6	3.50	7.531E-22	2.351E-30
7	2.80	3.377E-22	9.939E-31
8	2.50	2.325E-21	6.681E-30
9	2.00	3.816E-22	1.030E-30
10	1.50	3.311E-22	8.681E-31
11	1.00	6.215E-22	1.629E-30
12	.70	1.903E-23	5.149E-32
13	.30	2.098E-25	6.889E-34
		---	---
		8.4 2E-21	2.836E-29

SUBTOTAL OVER SELECTED SOURCE

RECEIVER POINT DET.PT. FIVE
COORDINATES R..... 3.05000E+01
Z..... 2.28000E+02
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	5.248E-18	2.664E-13
2	0.	2.941E-16	1.516E-11
3	0.	8.019E-15	4.505E-10
4	0.	2.669E-14	1.561E-09
5	0.	1.152E-13	7.111E-09
6	0.	2.629E-13	1.764E-08
7	0.	2.574E-13	2.027E-08
8	0.	4.981E-13	4.612E-08
9	0.	1.061E-12	1.217E-07
10	0.	6.594E-13	1.499E-07
		---	---
		2.889E-12	3.647E-07

CUMULATIVE SUMMARY RESULTS OVER ALL SUBSETS OF SOURCE REGIONS

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 1.52000E+01
PHI.... 0.

GAM RESP 1 GAM RESP 2

Astronuclear Laboratory

1	8.50	2.297E-20	1.056E-28
2	7.25	9.569E-20	4.165E-28
3	6.50	7.442E-20	3.050E-28
4	5.50	1.248E-19	4.848E-28
5	4.50	8.248E-20	2.844E-28
6	3.50	1.594E-19	4.975E-28
7	2.80	1.044E-19	3.071E-28
8	2.50	8.978E-19	2.580E-27
9	2.00	1.435E-18	3.877E-27
10	1.50	4.415E-19	1.157E-27
11	1.00	3.068E-18	8.043E-27
12	.70	3.770E-19	1.020E-27
13	.30	4.168E-20	1.368E-28
		---	---
		6.926E-18	1.922E-26

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 1.52000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	3.416E-21	1.571E-29
2	7.25	1.291E-20	5.618E-29
3	6.50	8.940E-21	3.663E-29
4	5.50	1.302E-20	5.057E-29
5	4.50	7.196E-21	2.481E-29
6	3.50	1.093E-20	3.412E-29
7	2.80	5.668E-21	1.668E-29
8	2.50	4.293E-20	1.234E-28
9	2.00	8.680E-21	2.344E-29
10	1.50	1.074E-20	2.817E-29
11	1.00	3.766E-20	9.870E-29
12	.70	2.288E-21	6.192E-30
13	.30	7.955E-23	2.612E-31
		---	---
		1.645E-19	5.148E-28

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 1.52000E+01
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	2.756E-17	1.399E-12
2	0.	8.964E-16	4.621E-11
3	0.	2.454E-14	1.378E-09
4	0.	8.225E-14	4.810E-09
5	0.	3.778E-13	2.332E-08
6	0.	9.898E-13	6.643E-08
7	0.	1.095E-12	8.619E-08
8	0.	2.225E-12	2.060E-07
9	0.	5.291E-12	6.068E-07
10	0.	3.386E-12	7.696E-07
		---------	---------
		1.347E-11	1.765E-06

CUMULATIVE SUMMARY RESULTS OVER ALL SUBSETS OF SOURCE REGIONS

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 9.16000E+01
PHI.... 0.

GAM RESP 1 GAM RESP 2

Astronuclear Laboratory

1	8.50	2.691E-20	1.238E-28
2	7.25	1.123E-19	4.887E-28
3	6.50	8.740E-20	3.582E-28
4	5.50	1.468E-19	5.702E-28
5	4.50	9.721E-20	3.351E-28
6	3.50	1.885E-19	5.885E-28
7	2.80	1.240E-19	3.650E-28
8	2.50	1.069E-18	3.073E-27
9	2.00	1.717E-18	4.638E-27
10	1.50	5.321E-19	1.395E-27
11	1.00	3.740E-18	9.802E-27
12	.70	4.642E-19	1.256E-27
13	.30	5.243E-20	1.721E-28
		---	---
		8.358E-18	2.317E-26

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 9.16000E+01
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	4.003E-21	1.841E-29
2	7.25	1.515E-20	6.592E-29
3	6.50	1.050E-20	4.302E-29
4	5.50	1.531E-20	5.948E-29
5	4.50	8.481E-21	2.924E-29
6	3.50	1.293E-20	4.036E-29
7	2.80	6.735E-21	1.982E-29
8	2.50	5.113E-20	1.470E-28
9	2.00	1.039E-20	2.805E-29
10	1.50	1.295E-20	3.395E-29
11	1.00	4.590E-20	1.203E-28
12	.70	2.817E-21	7.623E-30
13	.30	1.001E-22	3.285E-31
		---	---
		1.964E-19	6.135E-28

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 9.16000E+01
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	3.413E-17	1.732E-12
2	0.	1.059E-15	5.457E-11
3	0.	2.878E-14	1.617E-09
4	0.	9.646E-14	5.641E-09
5	0.	4.455E-13	2.750E-08
6	0.	1.176E-12	7.893E-08
7	0.	1.315E-12	1.035E-07
8	0.	2.681E-12	2.483E-07
9	0.	6.408E-12	7.349E-07
10	0.	4.114E-12	9.351E-07
		1.627E-11	2.136E-06

CUMULATIVE SUMMARY RESULTS OVER ALL SUBSETS OF SOURCE REGIONS

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 1.68000E+02
PHI.... 0.

GAM RESP 1 GAM RESP 2

Astronuclear Laboratory

1	8.50	7.343E-21	3.378E-29
2	7.25	3.022E-20	1.315E-28
3	6.50	2.329E-20	9.545E-29
4	5.50	3.845E-20	1.493E-28
5	4.50	2.480E-20	8.548E-29
6	3.50	4.587E-20	1.432E-28
7	2.80	2.854E-20	8.401E-29
8	2.50	2.386E-19	6.856E-28
9	2.00	3.598E-19	9.716E-28
10	1.50	1.004E-19	2.633E-28
11	1.00	5.893E-19	1.544E-27
12	.70	5.959E-20	1.613E-28
13	.30	2.040E-21	6.697E-30
		---	---
		1.548E-18	4.356E-27

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 1.68000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	1.092E-21	5.023E-30
2	7.25	4.077E-21	1.774E-29
3	6.50	2.798E-21	1.147E-29
4	5.50	4.011E-21	1.558E-29
5	4.50	2.163E-21	7.458E-30
6	3.50	3.146E-21	9.820E-30
7	2.80	1.550E-21	4.563E-30
8	2.50	1.141E-20	3.278E-29
9	2.00	2.175E-21	5.875E-30
10	1.50	2.444E-21	6.407E-30
11	1.00	7.232E-21	1.895E-29
12	.70	3.616E-22	9.786E-31
13	.30	3.893E-24	1.278E-32
		---	---
		4.246E-20	1.367E-28

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 1.22000E+02
Z..... 1.68000E+02
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	7.487E-18	3.801E-13
2	0.	3.197E-16	1.648E-11
3	0.	8.682E-15	4.877E-10
4	0.	2.909E-14	1.701E-09
5	0.	1.275E-13	7.873E-09
6	0.	3.032E-13	2.035E-08
7	0.	3.072E-13	2.419E-08
8	0.	6.062E-13	5.613E-08
9	0.	1.294E-12	1.484E-07
10	0.	8.097E-13	1.840E-07
		---------	---------
		3.486E-12	4.432E-07

CUMULATIVE SUMMARY RESULTS OVER ALL SUBSETS OF SOURCE REGIONS

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 9.16000E+01
Z..... 2.28000E+02
PHI.... 0.

GAM RESP 1 GAM RESP 2

Astronuclear Laboratory

1	8.50	7.586E-22	3.490E-30
2	7.25	3.139E-21	1.366E-29
3	6.50	2.407E-21	9.862E-30
4	5.50	3.886E-21	1.509E-29
5	4.50	2.372E-21	8.178E-30
6	3.50	3.906E-21	1.219E-29
7	2.80	2.072E-21	6.097E-30
8	2.50	1.561E-20	4.487E-29
9	2.00	1.883E-20	5.084E-29
10	1.50	3.596E-21	9.428E-30
11	1.00	1.095E-20	2.870E-29
12	.70	5.510E-22	1.491E-30
13	.30	9.759E-24	3.204E-32
		---------	---------
		6.8 8E-20	2.039E-28

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 9.16000E+01
Z..... 2.28000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	1.128E-22	5.190E-31
2	7.25	4.235E-22	1.843E-30
3	6.50	2.891E-22	1.185E-30
4	5.50	4.053E-22	1.574E-30
5	4.50	2.070E-22	7.135E-31
6	3.50	2.679E-22	8.362E-31
7	2.80	1.125E-22	3.311E-31
8	2.50	7.465E-22	2.145E-30
9	2.00	1.138E-22	3.074E-31
10	1.50	8.751E-23	2.294E-31
11	1.00	1.344E-22	3.522E-31
12	.70	3.343E-24	9.049E-33
13	.30	1.862E-26	6.115E-35
		---------	---------
		2.9J4E-21	1.005E-29

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 9.16000E+01
Z..... 2.28000E+02
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	1.398E-18	7.098E-14
2	0.	1.089E-16	5.616E-12
3	0.	2.961E-15	1.663E-10
4	0.	1.019E-14	5.957E-10
5	0.	4.213E-14	2.601E-09
6	0.	8.970E-14	6.020E-09
7	0.	8.360E-14	6.582E-09
8	0.	1.563E-13	1.447E-08
9	0.	3.323E-13	3.811E-08
10	0.	2.036E-13	4.628E-08
		---	---
		9.209E-13	1.148E-07

CUMULATIVE SUMMARY RESULTS OVER ALL SUBSETS OF SOURCE REGIONS

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 3.05000E+01
Z..... 2.28000E+02
PHI.... 0.

GAM RESP 1 GAM RESP 2

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1	8.50	1.846E-21	8.493E-30
2	7.25	7.787E-21	3.389E-29
3	6.50	6.050E-21	2.479E-29
4	5.50	9.986E-21	3.879E-29
5	4.50	6.299E-21	2.172E-29
6	3.50	1.098E-20	3.428E-29
7	2.80	6.218E-21	1.830E-29
8	2.50	4.862E-20	1.397E-28
9	2.00	6.310E-20	1.704E-28
10	1.50	1.361E-20	3.567E-29
11	1.00	5.064E-20	1.327E-28
12	.70	3.135E-21	8.486E-30
13	.30	1.099E-22	3.610E-31
		---	---
		2.284E-19	6.677E-28

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 3.05000E+01
Z..... 2.28000E+02
PHI.... 0.

		GAM RESP 1	GAM RESP 2
1	8.50	2.746E-22	1.263E-30
2	7.25	1.051E-21	4.572E-30
3	6.50	7.268E-22	2.978E-30
4	5.50	1.042E-21	4.046E-30
5	4.50	5.495E-22	1.895E-30
6	3.50	7.531E-22	2.351E-30
7	2.80	3.377E-22	9.939E-31
8	2.50	2.325E-21	6.681E-30
9	2.00	3.816E-22	1.030E-30
10	1.50	3.311E-22	8.681E-31
11	1.00	6.215E-22	1.629E-30
12	.70	1.903E-23	5.149E-32
13	.30	2.098E-25	6.889E-34
		---	---
		8.412E-21	2.836E-29

SUMMATION OVER ALL SOURCE REGIONS

RECEIVER POINT
COORDINATES R..... 3.05000E+01
Z..... 2.28000E+02
PHI.... 0.

		NEUT. 1	NEUT. 2
1	0.	5.248E-18	2.664E-13
2	0.	2.941E-16	1.516E-11
3	0.	8.019E-15	4.505E-10
4	0.	2.669E-14	1.561E-09
5	0.	1.152E-13	7.111E-09
6	0.	2.629E-13	1.764E-08
7	0.	2.574E-13	2.027E-08
8	0.	4.981E-13	4.612E-08
9	0.	1.061E-12	1.217E-07
10	0.	6.594E-13	1.499E-07
		---	---
		2.889E-12	3.647E-07

ERROR IN INPUT DATA CARD AS FOLLOWS

-0-0 -0

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SECTION

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APPENDIX

Presented here is a listing of the FORTRAN IV Source Program for the KAP-V code for use on the IBM 7094 computer.

```
$IBSYS
$JOB
$EXECUTE        IBJOB
$IBJOB          GO,SOURCE,MAP,FIOCS,FILES
$IBFTC KAPV     NOLIST,  DECK,NODD,M94/2,XR7                                    KAP     1
      COMMON AI(550),NI(1700),FI(5660)                                          KAP     2
      EQUIVALENCE (AI(    1),TITLE )                                            KAP     3
      EQUIVALENCE (NI(    1),NGG   ),(NI(    2),NGN   ),(NI(    3),MAT   ) KAP     4
      EQUIVALENCE (NI(    4),NCOMP ),(NI(    5),NDET  ),(NI(    6),NBOUND) KAP     5
      EQUIVALENCE (NI(    7),NREG  ),(NI(    8),NRSPG ),(NI(   9),NRSPN  ) KAP     6
      EQUIVALENCE (NI(   10),NRSPA ),(NI(   11),MATL  ) ,(NI(   19),IBILD) KAP     7
      EQUIVALENCE (NI(   17),NOVG  ),(NI(   18),NOVN  )                     KAP     8
      EQUIVALENCE (NI(   20),IGAM  ),(NI(   21),INEUT ),(NI(   24),ISCP  ) KAP     9
      EQUIVALENCE (NI(   25),IZSO  ),(NI(   26),ISORC'),(NI(   27),ISRC  ) KAP    10
      EQUIVALENCE (NI(   28),ISZC  ),(NI(   29),ISTC  ),(NI(   30),ISIT  ) KAP    11
      EQUIVALENCE (NI(   31),ISUM  ),(NI(   32),IOUT  )                     KAP    12
      EQUIVALENCE (NI(   35),KORD  ),(NI(   40),IORD  )                     KAP    13
      EQUIVALENCE (NI(   50),LSO   ),(NI(   51),MSO   ),(NI(   52),NSO   ) KAP    14
      EQUIVALENCE (NI(   75),LSIT  ),(NI(   76),MSIT  )                     KAP    15
      EQUIVALENCE (NI(  100),NEQBD ),(NI(  200),NBNDZN),(NI(  300),NCMPZN) KAP    16
      EQUIVALENCE (NI(  400),NBILD ),(NI(  500),LBD   ),(NI(1100),NTRYZN) KAP    17
      EQUIVALENCE (FI(    1),ASOI  ),(FI(    3),XI    ),(FI(    5),ETA   ) KAP    18
      EQUIVALENCE (FI(    7),RS    ),(FI(   28),ZS    ),(FI(   49),PHI   ) KAP    19
      EQUIVALENCE (FI(  470),FSI   ),(FI(1400),GSOUR ),(FI(1430),NSOUR ) KAP    20
      EQUIVALENCE (FI(1460),ABD   ),(FI(1560),BBD   ),(FI(1660),CBD   ) KAP    21
      EQUIVALENCE (FI(1760),XOBD  ),(FI(1860),YOBD  ),(FI(1960),ZOBD  ) KAP    22
      EQUIVALENCE (FI(2060),DBD   ),(FI(2160),XYZ   )                     KAP    23
      EQUIVALENCE (FI(2460),COMP  ),(FI(3460),ENN   )                     KAP    24
      EQUIVALENCE (FI(3490),XSECN ),(FI(3550),XSNREF),(FI(3551),ALFA  ) KAP    25
      EQUIVALENCE (FI(3558),AWSOUR)
      EQUIVALENCE (FI(3560),ENG   ),(FI(3590),XSECG ),(FI(4190),BILD  ) KAP    26
      EQUIVALENCE (FI(4310),SMFP  ),(FI(4311),TMFP  )                     KAP    27
      EQUIVALENCE (FI(4312),EPSLN ),(FI(4313),FUDGE ),(FI(4314),BKP   ) KAP    28
      EQUIVALENCE (FI(4320),COM   ),(FI(4620),CON   ),(FI(4720),XLAM  ) KAP    29
      EQUIVALENCE (FI(4750),RSPG  ),(FI(5050),RSPN  ),(FI(5350),RSPA  ) KAP    30
      EQUIVALENCE (FI(5360),RCORD ),(FI(5510),SSOT  ),(FI(5513),ZAT   ) KAP    31
      EQUIVALENCE (FI(5533),RSIT  ),(FI(5554),ZSIT  ),(FI(5575),FSIT  ) KAP    32
      DIMENSION NSO(20),INEUT(3),IOUT(3),KORD(5),IORD(5)                    KAP    33
      DIMENSION NBNDZN(100),NEQBD(100),NCMPZN(100),NBILD(100),LBD(6,100)KAP    34
      DIMENSION NTRYZN(6,100)                                               KAP    35
      DIMENSION ASOI(2),XI(2),ETA(2),RS(21),ZS(21),PHI(21,20)               KAP    36
      DIMENSION FSI(21,22,2),GSOUR(30),NSOUR(30)                            KAP    37
      DIMENSION RSIT(21),ZSIT(21),FSIT(21,2,2)                              KAP    38
      DIMENSION ASO(2),RSI(20),ZSI(20),PHII(20,20 ),FS(20,22,2)             KAP    39
      DIMENSION ABD(100),BBD(100),CBD(100),DBD(100),XOBD(100),YOBD(100) KAP    40
      DIMENSION ZOBD(100),COMP(20,50),XYZ(3,100)                            KAP    41
      DIMENSION ANEUT(31),AGAM(30),UAGAM(30)                                KAP    42
```

```
      DIMENSION ENN(30),XSECN(20,3),ALFA(9),ENG(30),XSECG(30,20)
      DIMENSION BILD(4,30,1),BKP(4),COM(5,30,2),CON(5,5,4),XLAM(30)
      DIMENSION RSPG(30,10),RSPN(30,10),RCORD(3,50),RSPA(1,10)
      DIMENSION FLUX(151),FLUXS(151,50),XSECS(30),FSP(2),A(2),SVOL(30)
      DIMENSION FSR(2)
      DIMENSION VOLS(30),SVUC(30),CORR(30)
      DIMENSION AX(15),NX(20),FX(5) ,R(6)
      DIMENSION SSOT(3),TITLE(550),SREG(100),ZAT(20)
      REAL NSOUR
      DATA BLANK / 6H       /
C*******************KAP-IVA*********************************************
      INPERR = 0
      TMFP=20.0
      FOURPI = 4.0*3.14159236
      FOUTPI = FOURPI/3.0
      DO 4 K = 1,151
      DO 2 J = 1,50
    2 FLUXS(K,J) = 0.0
    4 FLUX(K) = 0.0
      DO 6 I = 1,550
    6 AI(I) = BLANK
      DO 8 I = 1,1700
    8 NI(I) = 0
      DO 10 I=1,5660
   10 FI(I) = 0.0
      EPSLN = 1.0E-6
      FUDGE = 1.0E-3
      IOUT(1) =1
C
C INSERT INPUT READ ROUTINE
C
C ADDRESSABLE INPUT ROUTINE
   12 READ(5,1000) NN,NL,NA,(AX(I),I=1,15)
 1000 FORMAT(I2,I1,I9,15A4)
      IF(NN.LE.0.OR.NN.GT.15)GO TO 16
      IF(NA.LE.0.OR.NA.GT.550) GO TO 16
C ALPHANUMERIC READ
      DO 14 I = 1,NN
      J = I + NA - 1
   14 AI(J) = AX(I)
      IF(NL.LE.0) GO TO 12
      GO TO 18
   16 WRITE(6,1002) NN,NL,NA,(AX(I),I=1,15)
 1002 FORMAT(36H0ERROR IN INPUT DATA CARD AS FOLLOWS //
     1I3,I2,I10,15A5)
      INPERR=1
      IF(NL.GT.0) GO TO 18
      GO TO 12
```


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   18 WRITE(6,1016) (AI(I),I=1,45)                                  KAP   90
C FIXED                                                             KAP   92
   20 READ(5,1004) NN,NL,NA,(NX(I),I=1,20)                          KAP   93
 1004 FORMAT(I2,I1,I9,20I3)                                         KAP   94
      IF(NN.LE.0.OR.NN.GT.20) GO TO 24                              KAP   95
      IF(NA.LE.0.OR.NN.GT.1700) GO TO 24                            KAP   96
      DO 22 I = 1,NN                                                KAP   97
      J = I + NA - 1                                                KAP   98
   22 NI(J) = NX(I)                                                 KAP   99
      IF(IOUT(1).GT.0) WRITE(6,1006) NN,NL,NA,(NX(I),I=1,NN)        KAP  100
 1006 FORMAT(I3,I2,I10,20I4)                                        KAP  101
      IF(NL.LE.0) GO TO 20                                          KAP  102
      GO TO 26                                                      KAP  103
   24 WRITE(6,1008) NN,NL,NA,(NX(I),I=1,20)                         KAP  104
 1008 FORMAT(36H0ERROR IN INPUT DATA CARD AS FOLLOWS //             KAP  105
     1I3,I2,I10,20I4)                                               KAP  106
      INPERR=1                                                      KAP  107
      IF(NL.GT.0) GO TO 26                                          KAP  108
      GO TO 20                                                      KAP  109
C FLOATING                                                          KAP  110
   26 READ(5,1010) NN,NL,NA,(FX(I),I=1,5)                           KAP  111
 1010 FORMAT(I2,I1,I9,5E12.5)                                       KAP  112
      IF(NN.LE.0.OR.NN.GT.5) GO TO 30                               KAP  113
      IF(NA.LE.0.OR.NA.GT.5660) GO TO 30
      DO 28 I = 1,NN                                                KAP  115
      J = I + NA - 1                                                KAP  116
      IF(J.LT.2060.OR.J.GE.2160) GO TO 28                           KAP  117
      NBND=NEQBD(J-2059)                                            KAP  118
      IF(NBND.LT.2.OR.NBND.GT.3) GO TO 28                           KAP  119
      FX(I)=FX(I)*FX(I)                                             KAP  120
   28 FI(J) = FX(I)                                                 KAP  121
      IF(IOUT(1).GT.0) WRITE(6,1012) NN,NL,NA,(FX(I),I=1,NN)        KAP  122
 1012 FORMAT(I3,I2,I10,1P5E13.5)                                    KAP  123
      IF(NL.LE.0) GO TO 26                                          KAP  124
      GO TO 32                                                      KAP  125
   30 WRITE(6,1014) NN,NL,NA,(FX(I),I=1,5)                          KAP  126
 1014 FORMAT(36H0ERROR IN INPUT DATA CARD AS FOLLOWS //             KAP  127
     1I3,I2,I10,1P5E13.5)                                           KAP  128
 1016 FORMAT(1H1,4X,15A4/(5X,15A4))                                 KAP  129
      INPERR = 1                                                    KAP  130
      IF(NL.GT.0) GO TO 32                                          KAP  131
      GO TO 26                                                      KAP  132
   32 IF(INPERR.GT.0) CALL EXIT                                     KAP  133
C     CALCULATE AMBIGUITY INDICES                                   KAP  134
      DO 48 I=1,NREG                                                KAP  135
      NBND = IABS(NBNDZN(I))                                        KAP  136
      DO 48 J=1,NBND                                                KAP  137
      L= IABS(LBD(J,I))                                             KAP  138
      NEQ = NEQBD(L)                                                KAP  139
```

```
      XO=XYZ(1,I)                                                       KAP  140
      Y = XYZ(2,I)                                                      KAP  141
      Z = XYZ(3,I)                                                      KAP  142
      GO TO (34,36,38,40,42,44),NEQ                                     KAP  143
   34 R(J)=XO*(ABD(L)*XO+XOBD(L))+Y*(BBD(L)*Y+YOBD(L))                  KAP  144
     1+Z*(CBD(L)*Z+ZOBD(L))-DBD(L)                                      KAP  145
      GO TO 46                                                          KAP  146
   36 R(J)=ABD(L)*(XO-XOBD(L))**2+BBD(L)*(Y-YOBD(L))**2                 KAP  147
     1+CBD(L)*(Z-ZOBD(L))**2-DBD(L)                                     KAP  148
      GO TO 46                                                          KAP  149
   38 R(J)=(XO-XOBD(L))**2+(Y-YOBD(L))**2-DBD(L)                        KAP  150
      GO TO 46                                                          KAP  151
   40 R(J)=XO-DBD(L)                                                    KAP  152
      GO TO 46                                                          KAP  153
   42 R(J)=Y-DBD(L)                                                     KAP  154
      GO TO 46                                                          KAP  155
   44 R(J)=Z-DBD(L)                                                     KAP  156
   46 IF(R(J).LT.0.0) LBD(J,I)=+L                                       KAP  157
      IF(R(J).GT.0.0) LBD(J,I)=-L                                       KAP  158
   48 CONTINUE                                                          KAP  159
C INITIALIZE SUMMING QUANITIES                                          KAP  160
      NT2 = 1                                                           KAP  161
      INPERR = 0                                                        KAP  162
      NTOT=NGG*4+NGN+1                                                  KAP  163
      IF(IOUT(1).GT.2) CALL PPLOT                                       KAP  164
      IF(MATL.GT.0) CALL LIBRE(ENG,ZAT,MATL,NGG,XSECG)                  KAP  165
      IF(ISIT.GT.0) CALL SIR(RS,ZS,RSIT,ZSIT,FSI,FSIT,LSO,MSO,LSIT,MSIT)KAP  166
      IF(ISRC.GE.6)ISZC=6                                               KAP  167
      IF(ISORC.GE.0)CALL SOURCE(ASO,RSI,ZSI,PHII,FS,INPERR)             KAP  168
      IF(IBILD.GT.0) CALL BUILD(NGG,ENG,BILD,IBILD,NT2,TMFP )           KAP  169
      IF(IOUT(1).GT.1)CALL INOUT(ASO,RSI,ZSI,PHII,FS,INPERR)            KAP  170
      IF(INPERR.GT.0) CALL EXIT                                         KAP  171
      IF(ISUM.GE.0) GO TO 49
      DO 51 J=1,151
      DO 53 L=1,50
   53 FLUXS(J,L)=0.0
   51 FLUX(J)=0.0
      ISUM = IABS(ISUM)
   49 DO 102 J=1,NDET
      NOVG = 0                                                          KAP  173
      NOVN = 0                                                          KAP  174
      NERR = 0                                                          KAP  175
      RRC = RCORD(1,J)                                                  KAP  176
      ZRC = RCORD(2,J)                                                  KAP  177
      PHIRC = RCORD(3,J)                                                KAP  178
      IF(RRC.GE.0.0) GO TO 50                                           KAP  179
```


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```
      WRITE(6,1018) J,RRC                                               KAP  180
 1018 FORMAT(38H0RECEIVER POINT COORDINATES FOR POINT I5,17H ARE INCORREKAP  181
     1CT R=1PE15.5)                                                     KAP  182
      GO TO 102                                                         KAP  183
C CALCULATE THE CARTESIAN COORDINATES OF THE RECEIVER POINT             KAP  184
   50 XRC = RRC*COS(PHIRC)                                              KAP  185
      YRC = RRC*SIN(PHIRC)                                              KAP  186
   52 IERR3 = 0                                                         KAP  187
      IF(ISCP.LE.0) GO TO 56                                            KAP  188
C CALCULATE THE LINEAR ABSORPTION COEFF. FOR THE SOURCE REGION          KAP  189
      DO 54 L = 1,NRGY                                                  KAP  190
      CORR(L)=0.0                                                       KAP  191
      VOLS(L)=0.0                                                       KAP  192
      SVOL(L)=0.0                                                       KAP  193
      SVUC(L)=0.0                                                       KAP  194
      XSECS(L) = 0.0                                                    KAP  195
      DO 54 I = 1,MAT                                                   KAP  196
   54 XSECS(L) = XSECS(L)+XSECG(L,I)*COMP(I,ISCP)                       KAP  197
C BEGIN THE MAIN SOURCE POINT TO DETECTOR POINT LOOP                    KAP  198
      NTOT=4*NGG+NGN+1                                                  KAP  199
   56 DO 80 L = 1,LSO                                                   KAP  200
      NSOI = NSO(1)                                                     KAP  201
      IF(ISTC.GT.1) NSOI=NSO(L)                                         KAP  202
      DO 80 N = 1,NSOI                                                  KAP  203
      SINS = SIN(PHII(N,L))                                             KAP  204
      COSS = COS(PHII(N,L))                                             KAP  205
C CALCULATE THE CARTESIAN COORDINATES OF THE SOURCE POINT               KAP  206
      XSOM = RSI(L)*COSS                                                KAP  207
      YSOM = RSI(L)*SINS                                                KAP  208
      DO 58 K = 1,2                                                     KAP  209
   58 FSR(K) = FS(L,1,K)*FS(N,L+2,K)                                    KAP  210
      DO 80 M = 1,MSO                                                   KAP  211
      IF(ISRC.LT.6) GO TO 60                                            KAP  212
      COSZ = COS(ZSI(M))                                                KAP  213
      XSO = XSOM*COSZ+SSOT(1)                                           KAP  214
      YSO = YSOM*COSZ+SSOT(2)                                           KAP  215
      ZSOM = SIN(ZSI(M))*RSI(L)+SSOT(3)                                 KAP  216
      GO TO 62                                                          KAP  217
   60 XSO = XSOM+SSOT(1)                                                KAP  218
      YSO = YSOM+SSOT(2)                                                KAP  219
      ZSOM = ZSI(M)+SSOT(3)                                             KAP  220
   62 DO 64 K = 1,2                                                     KAP  221
   64 FSP(K) = FSR(K)*FS(M,2,K)                                         KAP  222
   66 CALL LENGTH(SREG,SSO,XSO,YSO,ZSOM,XRC,YRC,ZRC,IERR1)              KAP  223
      IF(IERR1.LE.0) GO TO 68                                           KAP  224
      NERR = NERR + 1                                                   KAP  225
```

```
      WRITE(6,1020) NERR                                                KAP  226
 1020 FORMAT(46HOTHE LENGTH ROUTINE HAS EXPERIENCED ERROR NO. I2)       KAP  227
      GO TO 104                                                         KAP  228
   68 CALL KERNEL(SREG,SSO, ANEUT,AGAM,UAGAM,TMFP,IERR2)                KAP  229
      IERR3 = MAX0(IERR3,IERR2)                                         KAP  230
      A(2) = FSP(2)/(SSO*SSO)                                           KAP  231
      IF(INEUT(1).GT.0) FLUX(NTOT) = FLUX(NTOT) + A(2)*ANEUT(NGN+1)     KAP  232
      IF(INEUT(2).LE.0.AND.INEUT(3).LE.0) GO TO 72                      KAP  233
      NST = 4*NGG                                                       KAP  234
      DO 70 K = 1,NGN                                                   KAP  235
      KN = NST+K                                                        KAP  236
   70 FLUX(KN) = FLUX(KN) + A(2)*ANEUT(K)                               KAP  237
   72 IF(IGAM.LE.0) GO TO 80                                            KAP  238
   74 A(1) = FSP(1)/(SSO*SSO)                                           KAP  239
      DO 78 K= 1,NGG                                                    KAP  240
      IF(ISCP.LE.0) GO TO 76                                            KAP  241
      EPS = XSECS(K)*SSO                                                KAP  242
      IF(EPS.LT.SMFP)SVOL(K)=SVOL(K)+FSP(1)                             KAP  243
      IF(EPS.LT.SMFP) GO TO 78                                          KAP  244
   76 FLUX(K) = FLUX(K) + A(1)*AGAM(K)                                  KAP  245
      KU = K+NGG                                                        KAP  246
      FLUX(KU) = FLUX(KU) + A(1)*UAGAM(K)                               KAP  247
   78 CONTINUE                                                          KAP  248
   80 CONTINUE                                                          KAP  249
      IF(IGAM.LE.0) GO TO 84                                            KAP  251
      DO 82 K = 1,NGG                                                   KAP  252
      FLUX(K) = GSOUR(K)*FLUX(K)/FOURPI                                 KAP  253
      KG = K + NGG                                                      KAP  254
   82 FLUX(KG) = GSOUR(K)*FLUX(KG)/FOURPI                               KAP  255
   84 IF(INEUT(2).LE.0.AND.INEUT(3).LE.0) GO TO 88                      KAP  256
      KS = 4*NGG                                                        KAP  257
      DO 86 K = 1,NGN                                                   KAP  258
      KN = KS + K                                                       KAP  259
   86 FLUX(KN) = NSOUR(K)*FLUX(KN)/FOURPI                               KAP  260
   88 IF(INEUT(1).GT.0) FLUX(NTOT) = AWSOUR*FLUX(NTOT)/FOURPI
      IF(ISCP.LE.0) GO TO 92                                            KAP  262
      KS = 2*NGG                                                        KAP  263
      DO 90 K = 1,NGG                                                   KAP  264
      IF(SVOL(K).LE.0.0) GO TO 90                                       KAP  265
      VOLS(K) = FOUTPI*((SMFP/XSECS(K))**3)                             KAP  266
      SVUC(K) = SVOL(K)*(1.-EXP(-SMFP))/(VOLS(K)* XSECS(K))             KAP  267
      B1 = 3.0*BILD(3,K,1)+BILD(2,K,1)                                  KAP  268
      B2 = 2.*B1                                                        KAP  269
      CORR(K) = ((BILD(4,K,1)*SMFP+B1)*SMFP+B2+BILD(2,K,1))*SMFP+BILD(2,KAP  270
     1K,1)+BILD(1,K,1)                                                  KAP  271
      KN = KS + K                                                       KAP  272
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      FLUX(KN) = SVUC(K)                                                KAP  273
      KN = KN + NGG                                                     KAP  274
      FLUX(KN) = SVUC(K)*CORR(K)                                        KAP  275
   90 CONTINUE                                                          KAP  276
   92 IF(ISUM.LE.0) GO TO 96                                            KAP  277
      DO 94 K=1,NTOT                                                    KAP  278
      FLUXS(K,J) = FLUXS(K,J) + FLUX(K)                                 KAP  279
      JSUM = J + NDET                                                   KAP  280
   94 FLUXS(K,JSUM) =FLUXS(K,JSUM) + FLUX(K)                            KAP  281
   96 IF(IOUT(2).GT.0) GO TO 98                                         KAP  282
      WRITE(6,1024) IZSO
 1024 FORMAT(1H0,10X,37H CALCULATED RESULTS FOR SOURCE REGION I4    /)
      JOUT=(J-1)*3+226                                                  KAP  283
      CALL FINSET(FLUX,RRC,ZRC,PHIRC,JOUT,46)                           KAP  284
   98 DO 100 K=1,151                                                    KAP  285
  100 FLUX(K)=0.0                                                       KAP  286
  102 WON = 120.0                                                       KAP  287
      WRITE(6,1022)IZSO,J,NOVG,NOVN,TMFP,WON                            KAP  288
 1022 FORMAT(18H0FOR SOURCE REGION I5,20H AND DETECTOR POINT I5,16H THERKAP  289
     1E HAS BEEN I6,4H AND I6,25H PATH LENGTH CALCULATIONS/13H IN EXCESSKAP  290
     2 OFF6.1,32H MEAN FREE PATHS(GAMMA RAY) AND F6.1,34H GRAMS/CM**2(NEKAP  291
     3UTRON),RESPECTIVELY)                                              KAP  292
  104 IF(ISUM.LE.1) GO TO 12                                            KAP  293
      DO 108 J=1,NDET                                                   KAP  294
      JP=J                                                              KAP  295
      RRC  =RCORD(1,JP)                                                 KAP  296
      ZRC  =RCORD(2,JP)                                                 KAP  297
      PHIRC=RCORD(3,JP)                                                 KAP  298
      JOUT=(J-1)*3+226                                                  KAP  299
      WRITE(6,1026)
 1026 FORMAT(1H0,10X,62H INTERMEDIATE SUMMARY RESULTS OVER A SUBSET OF S
     1OURCE REGIONS /)                                                  KAP  300
      CALL FINSET(FLUXS(1,J),RRC,ZRC,PHIRC,JOUT,76)                     KAP  301
      DO 106 K = 1,151                                                  KAP  302
  106 FLUXS(K,J) = 0.0                                                  KAP  303
  108 CONTINUE                                                          KAP  304
  110 IF(ISUM.LE.2) GO TO 12                                            KAP  305
      JS=NDET+1                                                         KAP  306
      JF=2*NDET                                                         KAP  307
      DO 114 J=JS,JF                                                    KAP  308
      JP=J-JS+1                                                         KAP  309
      RRC  =RCORD(1,JP)                                                 KAP  310
      ZRC  =RCORD(2,JP)                                                 KAP  311
      PHIRC=RCORD(3,JP)
      WRITE(6,1028)
 1028 FORMAT(1H0,10X,63H CUMULATIVE SUMMARY RESULTS OVER ALL SUBSETS OF
```

```
     1SOURCE REGIONS /)
      JOUT=(J-1)*3+226                                                  KAP  312
      CALL FINSET(FLUXS(1,J),RRC,ZRC,PHIRC,JOUT,106)                    KAP  313
      DO 112 K = 1,151                                                  KAP  314
  112 FLUXS(K,J) = 0.0                                                  KAP  315
  114 CONTINUE                                                          KAP  316
      GO TO 12                                                          KAP  317
      END                                                               KAP  318
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```
$IBFTC FINSE   NOLIST,  DECK,NODD,M94/2,XR7                          FIN   1
      SUBROUTINE FINSET(FLUX,RRC,ZRC,PHIRC,JOUT,NP)                  FIN   2
      COMMON AI(550),NI(1700),FI(5660)                               FIN   3
      EQUIVALENCE (FI(4750),RSPG),(FI(3560),ENG)                     FIN   4
      EQUIVALENCE (FI(5050),RSPN),(FI(3460),ENN),(FI(5350),RSPA)     FIN   5
      EQUIVALENCE (NI(8),NRSPG),(NI(1),NGG)                          FIN   6
      EQUIVALENCE (NI(9),NRSPN),(NI(2),NGN),(NI(10),NRSPA)           FIN   7
      EQUIVALENCE (AI(1),TITLE),(NI(21),INEUT),(NI(24),ISCP)         FIN   8
      EQUIVALENCE (NI(20),IGAM)                                      FIN   9
      DIMENSION RSPG(30,10),ENG(30)                                  FIN  10
      DIMENSION RSPN(30,10),ENN(30)                                  FIN  11
      DIMENSION RSPA( 1,10)                                          FIN  12
      DIMENSION INEUT(3)                                             FIN  13
      DIMENSION FLUX(151)                                            FIN  14
      DIMENSION TITLE(550)                                           FIN  15
      IF(IGAM.LE.0) GO TO 4                                          FIN  16
      NS = 1                                                         FIN  17
      NF = NGG                                                       FIN  18
      CALL FINOUT(FLUX,RSPG,ENG,TITLE(NP),TITLE(JOUT),TITLE(136),    FIN  19
     1NRSPG,NGG,NS,NF,RRC,ZRC,PHIRC,30)                              FIN  20
      NS = NGG+1                                                     FIN  21
      NF = NGG+NGG                                                   FIN  22
      CALL FINOUT(FLUX,RSPG,ENG,TITLE(NP),TITLE(JOUT),TITLE(136),    FIN  23
     1NRSPG,NGG,NS,NF,RRC,ZRC,PHIRC,30)                              FIN  24
    2 IF(ISCP.LE.0) GO TO 4                                          FIN  25
      NS = 2*NGG+1                                                   FIN  26
      NF = 3*NGG                                                     FIN  27
      CALL FINOUT(FLUX,RSPG,ENG,TITLE(NP),TITLE(JOUT),TITLE(136),    FIN  28
     1NRSPG,NGG,NS,NF,RRC,ZRC,PHIRC,30)                              FIN  29
      NS = 3*NGG+1                                                   FIN  30
      NF = 4*NGG                                                     FIN  31
      CALL FINOUT(FLUX,RSPG,ENG,TITLE(NP),TITLE(JOUT),TITLE(136),    FIN  32
     1NRSPG,NGG,NS,NF,RRC,ZRC,PHIRC,30)                              FIN  33
    4 IF(INEUT(2).LE.0.AND.INEUT(3).LE.0) GO TO 6                    FIN  34
      NS = 4*NGG+1                                                   FIN  35
      NF = 4*NGG+NGN                                                 FIN  36
      CALL FINOUT(FLUX,RSPN,ENN,TITLE(NP),TITLE(JOUT),TITLE(166),    FIN  37
     1NRSPN,NGN,NS,NF,RRC,ZRC,PHIRC,30)                              FIN  38
    6 IF(INEUT(1).LE.0) GO TO 8                                      FIN  39
      NS = 4*NGG+NGN+1                                               FIN  40
      NF = NS                                                        FIN  41
      CALL FINOUT(FLUX,RSPA,1.0,TITLE(NP),TITLE(JOUT),TITLE(196),    FIN  42
     1NRSPA,  1,NS,NF,RRC,ZRC,PHIRC, 1)                              FIN  43
    8 RETURN                                                         FIN  44
      END                                                            FIN  45
```

```
$IBFTC DEBNP   NOLIST,  DECK,NODD,M94/2,XR7                          DEN     1
      SUBROUTINE DEBN(A,NA,NS)                                       DEN     2
      DIMENSION A(NA)                                                DEN     3
      WRITE(6,1000) NS                                               DEN     4
 1000 FORMAT ( 10X,I5)                                               DEN     5
      WRITE(6,1002) (A(N ),N=1,NA)                                   DEN     6
 1002 FORMAT(10X,8E12.5)                                             DEN     7
      RETURN                                                         DEN     8
      END                                                            DEN     9
$IBFTC DEBIP   NOLIST,  DECK,NODD,M94/2,XR7                          DEI     1
      SUBROUTINE DEBI(N,NI,NS)                                       DEI     2
      DIMENSION N(NI)                                                DEI     3
      WRITE(6,1000) NS                                               DEI     4
 1000 FORMAT ( 10X,I5)                                               DEI     5
      WRITE(6,1002) (N(I),I=1,NI)                                    DEI     6
 1002 FORMAT(10X,9I5)                                                DEI     7
      RETURN                                                         DEI     8
      END                                                            DEI     9
```


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```
$ORIGIN        LEVEL1,SYSUT3,REW                                        KER    1
$IBFTC KERN    NOLIST,  DECK,NODD,M94/2,XR7                             KER    2
      SUBROUTINE KERNEL(SMAT,SSO,ANEUT,AGAM,UAGAM,TMFP,IERR2)           KER    3
      COMMON AI(550),NI(1700),FI(5660)                                  KER    4
      EQUIVALENCE (NI(   1),NGG   ),(NI(   2),NGN   ),(NI(   3),MAT   ) KER    5
      EQUIVALENCE (NI(  20),IGAM  ),(NI(  21),INEUT )                   KER    6
      EQUIVALENCE (NI(  35),KORD  ),(NI(  40),IORD  ),(NI( 400),NBILD ) KER    7
      EQUIVALENCE (NI(  17),NOVG  ),(NI(  18),NOVN  )                   KER    8
      EQUIVALENCE (FI(3490),XSECN ),(FI(3550),XSNREF),(FI(3551),ALFA  ) KER    9
      EQUIVALENCE (FI(4314),BKP   ),(FI(4320),COM   ),(FI(4620),CON   ) KER   10
      EQUIVALENCE (FI(4720),XLAM  ),(FI(3460),ENN   ),(FI(3590),XSECG ) KER   11
      EQUIVALENCE (FI(4190),BILD  )                                     KER   12
      DIMENSION INEUT(3),KORD(5),IORD(5),NBILD(100)                     KER   13
      DIMENSION CON(5,5,4),XLAM(30),ENN(30),BILD(4,30,1)                KER   14
      DIMENSION XSECN(20,3),XSECG(30,20),ALFA(9),BKP(4),COM(5,30,2)     KER   15
      DIMENSION SMAT(100),ANEUT(31),AGAM(30),UAGAM(30)                  KER   16
      DIMENSION ANK(5)                                                  KER   17
C******************KERNEL*************************************************KER   18
      IF(INEUT(1).LE.0) GO TO 4                                         KER   19
C ALBERT-WELTON KERNEL                                                  KER   20
      J = NGN + 1                                                       KER   21
      SHYD = 0.0                                                        KER   22
      AN = 0.0                                                          KER   23
      DO 2 I = 1,MAT                                                    KER   24
C TOTAL MEAN FREE PATHS - ALBERT-WELTON                                 KER   25
      AN = AN + SMAT(I)*XSECN(I,1)                                      KER   26
C HYDROGEN MEAN FREE PATHS - ALBERT-WELTON                              KER   27
    2 SHYD = SHYD + SMAT(I)*XSECN(I,2)                                  KER   28
      ANEUT(J) = ALFA(5)*EXP(-AN)                                       KER   29
      IERR=1                                                            KER   30
      IF(SHYD.EQ.0.0) GO TO 4                                           KER   31
      IF(SHYD.LT.ALFA(6)) ANEUT(J) = ANEUT(J)*EXP(-ALFA(7)*SHYD)        KER   32
      IF(SHYD.GE.ALFA(6)) ANEUT(J) =(SHYD**ALFA(2))*(EXP(-ALFA(3)*((SHYDKER   33
     1                              )**ALFA(4))))*ANEUT(J)*(ALFA(1)/   KER   34
     2                              ALFA(5))                            KER   35
      IERR = 0                                                          KER   36
    4 IF(INEUT(2).LE.0.AND.INEUT(3).LE.0) GO TO 26                      KER   37
      AN = 0.0                                                          KER   38
      ANS = 0.0                                                         KER   39
      DO 6 I = 1,MAT                                                    KER   40
    6 AN = AN + SMAT(I)*XSECN(I,3)                                      KER   41
      AN = AN / XSNREF                                                  KER   42
      IF(AN.LE.120.0) GO TO 8                                           KER   43
      ANS = AN - 120.0                                                  KER   44
      AN  = 120.0                                                       KER   45
      NOVN = NOVN + 1
```

```
C MONOVARIANT MOMENTS                                                   KER   46
    8 IF(INEUT(2).LE.0)GO TO 14                                         KER   47
      IF(AN.GT.BKP(1))J = 2                                             KER   48
      IF(AN.LE.BKP(1))J = 1                                             KER   49
      DO 12 II = 1,NGN                                                  KER   50
      ANEUT(II) = 0.0                                                   KER   51
      DO 10 K = 1,5                                                     KER   52
   10 ANEUT(II) = ANEUT(II)*AN + COM(K,II,J)                            KER   53
      IF(ANEUT(II).GT.-88.0) GO TO 13
      ANEUT(II)=0.0
      GO TO 12
   13 ANEUT(II) = EXP(ANEUT(II)-ANS*XLAM(II))                           KER   54
   12 CONTINUE
   14 IF(INEUT(3).LE.0) GO TO 26                                        KER   55
C BIVARIANT MOMENTS                                                     KER   56
      DO 24 K = 1,NGN                                                   KER   57
      IF(ENN(K).LE.BKP(1))GO TO 16                                      KER   58
      WRITE(6,1000) K,ENN(K),BKP(1)                                     KER   59
      ENN(K) = BKP(1)                                                   KER   60
   16 IF(ENN(K).GE.BKP(4)) GO TO 18                                     KER   61
      WRITE (6,1000) K,ENN(K),BKP(4)                                    KER   62
      ENN(K) = BKP(4)                                                   KER   63
   18 ANEUT(K) = 0.0                                                    KER   64
      J=1                                                               KER   65
      IF(ENN(K).LT.BKP(2)) J=2                                          KER   66
      IF(ENN(K).LT.BKP(3)) J=3                                          KER   67
      KK = KORD(J)+1                                                    KER   68
      II = IORD(J)+1                                                    KER   69
      DO 20 L = 1,KK                                                    KER   70
      ANK(L) = 0.0                                                      KER   71
      DO 20 I = 1,II                                                    KER   72
      IJ = II-I + 1                                                     KER   73
   20 ANK(L) = ANK(L)*AN+CON(IJ,L,J)                                    KER   74
      DO 22 L = 1,KK                                                    KER   75
      LJ = KK - L + 1                                                   KER   76
   22 ANEUT(K)  = ANEUT(K)*ENN(K) + ANK(LJ)                             KER   77
      ANEUT(K)  = ANEUT(K)  - ANS*XLAM(K)                               KER   78
      IF(ANEUT(K).GT.-88.0) GO TO 23
      ANEUT(K)=0.0
      GO TO 24
   23 ANEUT(K)  = EXP(ANEUT(K))                                         KER   79
   24 CONTINUE
   26 IF(IGAM.LE.0) GO TO 36                                            KER   80
      DO 34 K = 1,NGG                                                   KER   81
      AGAM(K) = 0.0                                                     KER   82
      AG = 0.0                                                          KER   83
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      DO 28 I = 1,MAT                                                   KER    84
   28 AG = AG + SMAT(I)*XSECG(K,I)                                      KER    85
      IF(AG .LT.88.0) GO TO 29
      UAGAM(K)=0.0
      GO TO 31
   29 UAGAM(K) = EXP(-AG)                                               KER    86
   31 IF(AG.LE.TMFP) GO TO 30                                           KER    87
C MORE THAN TMFP MEAN FREE PATHS                                        KER    88
      NOVG = NOVG + 1                                                   KER    89
      AG = 20.0                                                         KER    90
   30 DO 32 J = 1,4                                                     KER    91
      JJ = 4 - J + 1                                                    KER    92
   32 AGAM(K) = AGAM(K)*AG+BILD(JJ,K,1)                                 KER    93
   34 AGAM(K) = AGAM(K)*UAGAM(K)                                        KER    94
   36 RETURN                                                            KER    95
 1000 FORMAT(88H0ERROR IN BREAKPOINTS FOR RANGE OF BIVARIANT POLYNOMIALSKER    96
     1FOR MOMENTS DATA,ENERGY GROUP...I4//,8H ENERGY=2PE15.5,14H ENERGY KER    97
     2LIMIT=E15.5)                                                      KER    98
      END                                                               KER    99
```

```
$IBFTC LENGTX  NOLIST,  DECK,NODD,M94/2,XR7                                LEN    1
      SUBROUTINE LENGTH(SMAT,SSO,XSO,YSO,ZSOM,XRC,YRC,ZRC,IERR)           LEN    2
      COMMON AI(550),NI(1700),FI(5660)                                    LEN    3
      EQUIVALENCE (NI(   3),MAT   ),(NI(  25),NZSO  ),(NI(   7),NREG  ) LEN    4
      EQUIVALENCE (NI( 200),NBNDZN),(NI( 100),NEQBD ),(NI(1100),NTRYZN) LEN    5
      EQUIVALENCE (NI( 500),LBD   ),(NI( 300),NCMPZN)                     LEN    6
      EQUIVALENCE (FI(4313),FUDGE ),(FI(4312),EPSLN ),(FI(2460),COMP  ) LEN    7
      EQUIVALENCE (FI(1460),ABD   ),(FI(1560),BBD   ),(FI(1660),CBD   ) LEN    8
      EQUIVALENCE (FI(1760),XOBD  ),(FI(1860),YOBD  ),(FI(1960),ZOBD  ) LEN    9
      EQUIVALENCE (FI(2060),DBD   )                                       LEN   10
      DIMENSION NBNDZN(100),NEQBD(100),LBD(6,100),NTRYZN(6,100)           LEN   11
      DIMENSION NCMPZN(100)                                               LEN   12
      DIMENSION COMP(20,50),ABD(100),BBD(100),CBD(100),XOBD(100)          LEN   13
      DIMENSION YOBD(100),ZOBD(100),DBD(100)                              LEN   14
      DIMENSION SMAT(100),R(6)                                            LEN   15
    2 CALL SLITET(4,K000FX)                                               LEN   16
       GO TO(4,4),K000FX                                                  LEN   17
    4 CALL SLITET(1,K000FX)                                               LEN   18
       GO TO(6,8),K000FX                                                  LEN   19
    6 CALL SLITE (1)                                                      LEN   20
      WRITE (6,1000)                                                      LEN   21
 1000 FORMAT(67H0   ZONE      BOUNDARY    DISTANCE        X            Y LEN   22
     1          Z)                                                       LEN   23
    8 DO 10 M=1,MAT                                                       LEN   24
   10 SMAT(M)=0.0                                                         LEN   25
      XO = XSO                                                            LEN   26
      Y=YSO                                                               LEN   27
      Z=ZSOM                                                              LEN   28
      AB = XRC -XO                                                        LEN   29
      BA  =YRC-Y                                                          LEN   30
      GA   =ZRC-Z                                                         LEN   31
      SRC=SQRT(AB*AB+BA*BA+GA*GA)                                         LEN   32
      AB=AB/SRC                                                           LEN   33
      BA=BA/SRC                                                           LEN   34
      GA=GA/SRC                                                           LEN   35
      SSO=SRC                                                             LEN   36
      SMIN=FUDGE                                                          LEN   37
      NP=NZSO                                                             LEN   38
   12 XO=XO+AB*SMIN                                                       LEN   39
      Y=Y+BA*SMIN                                                         LEN   40
      Z=Z+GA*SMIN                                                         LEN   41
      SRC=SRC-SMIN                                                        LEN   42
   14 IL=NP                                                               LEN   43
      IU=NREG                                                             LEN   44
   16 DO 34 I=IL,IU                                                       LEN   45
      JU = IABS(NBNDZN(I))                                                LEN   46
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      DO 32 J=1,JU                                                      LEN   47
      LL = LBD(J,I)                                                     LEN   48
      L = IABS(LL)                                                      LEN   49
      NEQ=NEQBD(L)                                                      LEN   50
      GO TO(18,20,22,24,26,28),NEQ                                      LEN   51
   18 R(J)=XO*(ABD(L)*XO+XOBD(L))+Y*(BBD(L)*Y+YOBD(L))                  LEN   52
     1+Z*(CBD(L)*Z+ZOBD(L))-DBD(L)                                      LEN   53
      GO TO 30                                                          LEN   54
   20 R(J)=ABD(L)*(XO-XOBD(L))**2+BBD(L)*(Y-YOBD(L))**2                 LEN   55
     1+CBD(L)*(Z-ZOBD(L))**2-DBD(L)                                     LEN   56
      GO TO 30                                                          LEN   57
   22 R(J)=(XO-XOBD(L))**2+(Y-YOBD(L))**2-DBD(L)                        LEN   58
      GO TO 30                                                          LEN   59
   24 R(J)=XO-DBD(L)                                                    LEN   60
      GO TO 30                                                          LEN   61
   26 R(J)=Y-DBD(L)                                                     LEN   62
      GO TO 30                                                          LEN   63
   28 R(J)=Z-DBD(L)                                                     LEN   64
   30 BDJI=FLOAT(LL)                                                    LEN   65
      IF(SIGN(1.0,BDJI)*R(J)) 32,32,34                                  LEN   66
   32 CONTINUE                                                          LEN   67
      GO TO 42                                                          LEN   68
   34 CONTINUE                                                          LEN   69
      IF(IU-NP)38,36,36                                                 LEN   70
   36 IL=1                                                              LEN   71
      IU=NP-1                                                           LEN   72
      GO TO 16                                                          LEN   73
   38 IERR=1                                                            LEN   74
      CALL SLITET(1,KOOOFX)                                             LEN   75
       GO TO(106,40),KOOOFX                                             LEN   76
   40 CALL SLITE (1)                                                    LEN   77
      GO TO 2                                                           LEN   78
C                                                                       LEN   79
   42 SMIN=SRC                                                          LEN   80
      KKK=0                                                             LEN   81
      IF(NBNDZN(I))96,96,44                                             LEN   82
   44 DO 94 J=1,JU                                                      LEN   83
      LL = LBD(J,I)                                                     LEN   84
      L = IABS(LL)                                                      LEN   85
      NEQ=NEQBD(L)                                                      LEN   86
      GO TO(46,48,52,54,56,58),NEQ                                      LEN   87
   46 E=(ABD(L)*XO+XOBD(L)/2.0)*AB+(BBD(L)*Y+YOBD(L)/2.0)*BA            LEN   88
     1  +(CBD(L)*Z+ZOBD(L)/2.0)*GA                                      LEN   89
      GO TO 50                                                          LEN   90
   48 E=ABD(L)*AB*(XO-XOBD(L))+BBD(L)*BA*(Y-YOBD(L))                    LEN   91
     1+CBD(L)*GA    *(Z-ZOBD(L))                                       LEN   92
```

```
   50 H=ABD(L)*AB    **2+BBD(L)*BA   **2+CBD(L)*GA    **2                LEN   93
      GO TO 62                                                           LEN   94
   52 E=AB*(XO - XOBD(L))+BA   *(Y-YOBD(L))                              LEN   95
      H=1.0-GA    **2                                                    LEN   96
      GO TO 62                                                           LEN   97
   54 E=AB    /2.0                                                       LEN   98
      GO TO 60                                                           LEN   99
   56 E=BA   /2.0                                                        LEN  100
      GO TO 60                                                           LEN  101
   58 E=GA    /2.0                                                       LEN  102
   60 H=0.0                                                              LEN  103
   62 IF(H)64,66,66                                                      LEN  104
   64 H=-H                                                               LEN  105
      E=-E                                                               LEN  106
      R(J)=-R(J)                                                         LEN  107
      LL = - LL                                                          LEN  108
   66 IF(H-EPSLN)68,68,78                                                LEN  109
   68 IF(R(J))74,70,74                                                   LEN  110
   70 IERR=2                                                             LEN  111
      CALL SLITET(1,KOOOFX)                                              LEN  112
       GO TO(106,72),KOOOFX                                              LEN  113
   72 CALL SLITE (1)                                                     LEN  114
      GO TO 2                                                            LEN  115
   74 IF(ABS(E)-EPSLN)94,94,76                                           LEN  116
   76 SBD=-R(J)/2.0/E                                                    LEN  117
      IF(SBD)94,94,90                                                    LEN  118
   78 IF(R(J))80,70,84                                                   LEN  119
   80 IF(H*SMIN**2+2.0*E*SMIN+R(J))94,94,82                              LEN  120
   82 QUAD=E**2-H*R(J)                                                   LEN  121
      GO TO 88                                                           LEN  122
   84 IF(E)86,94,94                                                      LEN  123
   86 QUAD=E**2-H*R(J)                                                   LEN  124
      IF(QUAD-EPSLN)94,94,88                                             LEN  125
   88 BDJI = FLOAT(LL)                                                   LEN  126
      SBD=(-E+SIGN(SQRT(QUAD),BDJI))/H                                   LEN  127
   90 IF(SBD-SMIN)92,94,94                                               LEN  128
   92 CALL SLITE (4)                                                     LEN  129
      SMIN=SBD                                                           LEN  130
      KKK = LL                                                           LEN  131
      NP=NTRYZN(J,I)                                                     LEN  132
   94 CONTINUE                                                           LEN  133
C                                                                        LEN  134
   96 SMIN=SMIN+FUDGE                                                    LEN  135
      CALL SLITET(1,KOOOFX)                                              LEN  136
       GO TO(98,100),KOOOFX                                              LEN  137
   98 CALL SLITE (1)                                                     LEN  138
```


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```
      WRITE (6,1002)I,KKK,SMIN,XO,Y,Z
 1002 FORMAT(I7,4X,I7,4X,1P4E12.5)
  100 N=NCMPZN(I)
      DO 102 M=1,MAT
  102 SMAT(M)=SMAT(M)+SMIN*COMP(M,N)
      CALL SLITET(4,KOOOFX)
       GO TO(12,104),KOOOFX
  104 IERR=0
  106 CALL SLITE (0)
      RETURN
       END
```

LEN 139
LEN 140
LEN 141
LEN 142
LEN 143
LEN 144
LEN 145
LEN 146
LEN 147
LEN 148
LEN 149

```
$IBFTC FINT    NOLIST,  DECK,NODD,M94/2,XR7                                FIN    1
      SUBROUTINE FINOUT(FLUX,RS,EN,ATITLE,BTITLE,CTITLE,NRS,NG,NS,NF,R,ZFIN    2
     1,P,NL)                                                             FIN    3
      COMMON AI(5500),NI(1700),FI(5560)                                  FIN    4
      DIMENSION FLUX(151),RS(NL,100),EN(300),AOUT(300,6),ATOT(6),ASUM(3) FIN    5
      DIMENSION ATITLE(30),BTITLE(3),CTITLE(30)                          FIN    6
      DATA(ASUM(I),I=1,3)/3H---,3H---,3H---/                             FIN    7
      WRITE(6,1000) (ATITLE(I),I=1,30)                                   FIN   10
 1000 FORMAT(/25X,15A4/)                                                 FIN   11
      WRITE(6,1002) (BTITLE(I)  ,I=1,3),R,Z,P                            FIN   12
 1002 FORMAT(17H0 RECEIVER POINT 3A4/                                    FIN   13
     1        21H  COORDINATES R......1PE15.5/                           FIN   14
     2        21H              Z......  E15.5/                           FIN   15
     3        21H              PHI....  E15.5/)                          FIN   16
      DO 8 N = 1,NRS,6                                                   FIN   17
      NT = N + 6-1                                                       FIN   18
      NT = MIN0(NT,NRS)                                                  FIN   19
      NTS= (N-1)*3+1
      NTE=NT*3                                                           FIN   21
      WRITE(6,1004)(CTITLE(I),I=NTS,NTE)                                 FIN   22
 1004 FORMAT(1H0,9X,18A4)                                                FIN   23
      WRITE(6,1012)
 1012 FORMAT(1H0)
      DO 2 I = 1,6                                                       FIN    8
    2 ATOT(I) = 0.0                                                      FIN    9
      DO 6 K = NS,NF                                                     FIN   24
      DO 4 L = N,NT                                                      FIN   25
      KN=K-NS+1                                                          FIN   26
      M=L-N+1                                                            FIN   27
      AOUT(KN,M)=FLUX(K)*RS(KN,L)                                        FIN   28
    4 ATOT(M ) = ATOT(M )+AOUT(KN,M)                                     FIN   29
    6 WRITE(6,1006) KN,EN(KN),(AOUT(KN,L),L=1,M)                         FIN   30
      WRITE (6,1010) ((ASUM(I),I=1,3),L=1,M)                             FIN   31
    8 WRITE(6,1008)(ATOT(L),L=1,M)                                       FIN   32
 1006 FORMAT(1X,I2,F6.2,1P6E12.3)                                        FIN   33
 1008 FORMAT(9X,1P6E12.3)                                                FIN   34
 1010 FORMAT(9X,6(3X,3A3))                                               FIN   35
      RETURN                                                             FIN   36
      END                                                                FIN   37
```


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```
$ORIGIN        LEVEL1,SYSUT3,REW                                        SOU    1
$IBFTC SOUR    NOLIST,  DECK,NODD,M94/2,XR7                             SOU    2
      SUBROUTINE SOURCE(ASO,RSI,ZSI,PHII,FS ,INPERR )                   SOU    3
      COMMON AI(550),NI(1700),FI(5660)                                  SOU    4
      EQUIVALENCE (NI(  27),ISRC  ),(NI(  28),ISZC  ),(NI(  29),ISTC  ) SOU    5
      EQUIVALENCE (NI(  50),LSO   ),(NI(  51),MSO   ),(NI(  52),NSO   ) SOU    6
      EQUIVALENCE (FI(   7),RS    ),(FI(  28),ZS    ),(FI(  49),PHI   ) SOU    7
      EQUIVALENCE (FI( 470),FSI   ),(FI(   1),ASOI  )                   SOU    8
      EQUIVALENCE (FI(   3),XI    ),(FI(   5),ETA   )                   SOU    9
      DIMENSION FST(3,2),ASOI(2),ASO(2)                                 SOU   10
      DIMENSION RSI(20),ZSI(20),PHII(20,20),FSI(21,22,2)                SOU   11
      DIMENSION FS(20,22,2),XI(2),ETA(2) ,NSO(20)                       SOU   12
      DIMENSION RS(21),ZS(21),PHI(21,20)                                SOU   13
      IF(ASOI(2).GT.0.0) GO TO 4                                        SOU   14
      DO 2 K=1,21                                                       SOU   15
      DO 2 J=1,22                                                       SOU   16
    2 FSI(K,J,2) = FSI(K,J,1)                                           SOU   17
    4 IF(ISRC.EQ.0) GO TO 78                                            SOU   18
      DO 6 J = 1,3                                                      SOU   19
      DO 6 K = 1,2                                                      SOU   20
    6 FST(J,K) = 0.0                                                    SOU   21
      DO 34 L = 1,LSO                                                   SOU   22
      IF(ISRC.GT.1) GO TO 8                                             SOU   23
C CYLINDRIC ,ISRC=1                                                     SOU   24
C UNIFORM RADIAL SOURCE DISTRIBUTION                                    SOU   25
      FS(L,1,1) = (RS(L+1)*RS(L+1)-RS(L)*RS(L))/2.0                     SOU   26
      FS(L,1,2) = FS(L,1,1)                                             SOU   27
      GO TO 30                                                          SOU   28
C COSINE ,ISRC=2                                                        SOU   29
    8 IF(ISRC.GT.2) GO TO 10                                            SOU   30
      AS1=XI(1)*(RS(L+1)-XI(2))                                         SOU   31
      AS2=XI(1)*(RS(L)-XI(2))                                           SOU   32
      FS(L,1,1) = ((RS(L+1)*SIN(AS1)-RS(L)*SIN(AS2))/XI(1)              SOU   33
     1            +(COS(AS1)-COS(AS2))/XI(1))/XI(1)                     SOU   34
      FS(L,1,2) = FS(L,1,1)                                             SOU   35
      GO TO 30                                                          SOU   36
   10 IF(ISRC.GT.3) GO TO 14                                            SOU   37
C LINEAR ,ISRC=3                                                        SOU   38
      DO 12 K = 1,2                                                     SOU   39
      RS1=RS(L+1)                                                       SOU   40
      RS3=RS(L)                                                         SOU   41
      RS2=RS1*RS1                                                       SOU   42
      RS4=RS3*RS3                                                       SOU   43
   12 FS(L,1,K)=(FSI(L+1,1,K)-FSI(L,1,K))*(RS2+RS1*RS3+RS4)/3.0         SOU   44
     1          -(FSI(L+1,1,K)*RS3-FSI(L,1,K)*RS1)*(RS1+RS3)/2.0        SOU   45
      GO TO 30                                                          SOU   46
```

```
   14 IF(ISRC.GT.4) GO TO 18                                            SOU   47
C EXPONENTIAL WITH XI(I)'S AS INPUT ,ISRC=4                             SOU   48
      DO 16 K = 1,2                                                     SOU   49
      AS1=EXP(XI(2)*(RS(L+1)-RS(L)))                                    SOU   50
      AS2 = 1.0                                                         SOU   51
   16 FS(L,1,K) = ((AS1* (XI(2)*RS(L+1)-1.0)-XI(2)*RS(L)+1.0)*XI(1))/   SOU   52
     1(XI(2)*XI(2))                                                     SOU   53
      GO TO 30                                                          SOU   54
   18 IF(ISRC.GT.5) GO TO 24                                            SOU   55
C EXPONENTIAL WITH XI(I)'S CALCULATED FROM INPUT DISTRIBUTIONS,ISRC=5   SOU   56
      DO 22 K=1,2                                                       SOU   57
      IF(FSI(L+1,1,K).EQ.FSI(L,1,K)) FS(L,1,K)= FSI(L,1,K)*(RS(L+1)*RS(LSOU   58
     1+1)-RS(L)*RS(L))/2.0                                              SOU   59
      IF(FSI(L+1,1,K).EQ.FSI(L,1,K)) GO TO 22                           SOU   60
      IF(FSI(L+1,1,K).GT.0.0.AND.FSI(L,1,K).GT.0.0) GO TO 20            SOU   61
      WRITE(6,1002) K,L                                                 SOU   62
      INPERR=1                                                          SOU   63
      GO TO 22                                                          SOU   64
   20 XI(2)=(ALOG(FSI(L+1,1,K)/FSI(L,1,K)))/(RS(L+1)-RS(L))             SOU   65
      XI(1)=FSI(L,1,K)                                                  SOU   66
      AS1=EXP(XI(2)*(RS(L+1)-RS(L)))                                    SOU   67
      AS2 = 1.0                                                         SOU   68
      FS(L,1,K) = ((AS1* (XI(2)*RS(L+1)-1.0)-XI(2)*RS(L)+1.0)*XI(1))/   SOU   69
     1(XI(2)*XI(2))                                                     SOU   70
      XI(1)=0.0                                                         SOU   71
      XI(2)=0.0                                                         SOU   72
   22 CONTINUE                                                          SOU   73
      GO TO 30                                                          SOU   74
C SPHERICAL                                                             SOU   75
   24 IF(ISRC.GT.6) GO TO 26                                            SOU   76
C UNIFORM RADIAL DISTRIBUTION,ISRC=6                                    SOU   77
      FS(L,1,1) =  (RS(L+1)**3-RS(L)**3)/3.0                            SOU   78
      FS(L,1,2) = FS(L,1,1)                                             SOU   79
      GO TO 30                                                          SOU   80
C LINEAR,ISRC=7 OR GREATER                                              SOU   81
   26 RS1 = RS(L+1)                                                     SOU   82
      RS2 = RS(L)                                                       SOU   83
      RS3 = RS1*RS1                                                     SOU   84
      RS4 = RS2*RS2                                                     SOU   85
      RS5 =(RS1+RS2)*(RS3+RS4)/4.0                                      SOU   86
      RS6 =(RS3+RS1*RS2+RS4)/3.0                                        SOU   87
      DO 28 K = 1,2                                                     SOU   88
   28 FS(L,1,K) =  (FSI(L+1,1,K)-FSI(L,1,K))*RS5-                       SOU   89
     1             (FSI(L+1,1,K)*RS2-FSI(L,1,K)*RS1)*RS6                SOU   90
   30 DO 32 K = 1,2                                                     SOU   91
   32 FST(1,K) = FST(1,K) + FS(L,1,K)                                   SOU   92
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   34 RSI(L) = SQRT((RS(L+1)*RS(L+1)+RS(L)*RS(L))/2.0)                  SOU   93
      DO 58 M = 1,MSO                                                   SOU   94
      IF(ISZC.GT.1) GO TO 36                                            SOU   95
C UNIFORM AXIAL DISTRIBUTION                                            SOU   96
      FS(M,2,1) = ZS(M+1)-ZS(M)                                         SOU   97
      FS(M,2,2) = FS(M,2,1)                                             SOU   98
      GO TO 54                                                          SOU   99
   36 IF(ISZC.GT.2) GO TO 38                                            SOU  100
      FS(M,2,1) = (SIN(ETA(1)*(ZS(M+1)-ETA(2)))-SIN(ETA(1)*(ZS(M)-ETA(2)SOU  101
     1)))/ETA(1)                                                        SOU  102
      FS(M,2,2) = FS(M,2,1)                                             SOU  103
      GO TO 54                                                          SOU  104
   38 IF(ISZC.GT.3) GO TO 42                                            SOU  105
      DO 40 K=1,2                                                       SOU  106
   40 FS(M,2,K)=((ZS(M+1)-ZS(M))*(FSI(M+1,2,K)+FSI(M,2,K)))/2.0         SOU  107
      GO TO 54                                                          SOU  108
   42 IF(ISZC.GT.4) GO TO 46                                            SOU  109
C EXPONENTIAL WITH ETA(I)'S AS INPUT                                    SOU  110
      DO 44 K = 1,2                                                     SOU  111
      AS1 = EXP(ETA(2)*(ZS(M+1)-ZS(M)))                                 SOU  112
      AS2 = 1.0                                                         SOU  113
      FS(M,2,K) = (ETA(1)*(AS1-AS2))/ETA(2)                             SOU  114
   44 CONTINUE                                                          SOU  115
      GO TO 54                                                          SOU  116
   46 IF(ISZC.GT.5) GO TO 52                                            SOU  117
C EXPONENTIAL WITH ETA(I)'S CALCULATED FROM INPUT DISTRIBUTIONS         SOU  118
      DO 50 K=1,2                                                       SOU  119
      IF(FSI(M+1,2,K).EQ.FSI(M,2,K))FS(M,2,K)=(ZS(M+1)-ZS(M))*FSI(M,2,KSOU  120
      IF(FSI(M+1,2,K).EQ.FSI(M,2,K)) GO TO 54                           SOU  121
      IF(FSI(M+1,2,K).GT.0.0.AND.FSI(M,2,K).GT.0.0) GO TO 48            SOU  122
      WRITE(6,1004) K,M                                                 SOU  123
      INPERR=1                                                          SOU  124
      GO TO 50                                                          SOU  125
   48 ETA(2) = (ALOG(FSI(M+1,2,K)/FSI(M,2,K)))/(ZS(M+1)-ZS(M))          SOU  126
      ETA(1) = FSI(M,2,K)                                               SOU  127
      AS1 = EXP(ETA(2)*(ZS(M+1)-ZS(M)))                                 SOU  128
      AS2 = 1.0                                                         SOU  129
      FS(M,2,K) = (ETA(1)*(AS1-AS2))/ETA(2)                             SOU  130
      ETA(1)=0.0                                                        SOU  131
      ETA(2)=0.0                                                        SOU  132
   50 CONTINUE                                                          SOU  133
      GO TO 54                                                          SOU  134
C SPHERICAL , POLAR DISTRIBUTION                                        SOU  135
   52 AS1 = SIN(ZS(M+1))                                                SOU  136
      AS2 = SIN(ZS(M))                                                  SOU  137
      FS(M,2,1) = AS1-AS2                                               SOU  138
```

```
      FS(M,2,2) = FS(M,2,1)                                             SOU  139
   54 DO 56 K = 1,2                                                     SOU  140
   56 FST(2,K) = FST(2,K) + FS(M,2,K)                                   SOU  141
   58 ZSI(M) =(ZS(M+1)+ZS(M))/2.0                                       SOU  142
      IF(ISTC.GT.1) GO TO 60                                            SOU  143
      NSTOP = NSO(1)+1                                                  SOU  144
      FST(3,1) = PHI(NSTOP,1) - PHI(1,1)                                SOU  145
      FST(3,2) = FST(3,1)                                               SOU  146
      GO TO 62                                                          SOU  147
   60 NSTOP = NSO(L)+1                                                  SOU  148
      FST(3,1) = PHI(NSTOP,L) - PHI(1,L)                                SOU  149
      FST(3,2) = FST(3,1)                                               SOU  150
   62 DO 64 K = 1,2                                                     SOU  151
      ASO(K) = ASOI(K)/(FST(1,K)*FST(2,K)*FST(3,K))                     SOU  152
      IF(ASOI(2).LE.0.0) ASO(2)=ASO(1)                                  SOU  153
      IF(ASOI(2).LE.0.0) GO TO 66                                       SOU  154
   64 CONTINUE                                                          SOU  155
   66 DO 76 L=1,LSO                                                     SOU  156
      IF(ISTC.LE.1) NSTOP = NSO(1)                                      SOU  157
      IF(ISTC.GT.1) NSTOP = NSO(L)                                      SOU  158
      NSTOP1= NSO(1)+1                                                  SOU  159
      NSTOP2=NSTOP+1                                                    SOU  160
      DO 74 N = 1,NSTOP                                                 SOU  161
      IF(ISTC.GT.1) GO TO 68                                            SOU  162
      PHII(N,L) = (PHI(N+1,1)+PHI(N,1))*0.5                             SOU  163
      DPHI = PHI(N+1,1)-PHI(N,1)                                        SOU  164
      GO TO 72                                                          SOU  165
   68 IF(ISTC.GT.2) GO TO 70                                            SOU  166
      PHII(N,L) =(PHI(N+1,L)+PHI(N,L))*0.5                              SOU  167
      DPHI = PHI(N+1,L)-PHI(N,L)                                        SOU  168
      GO TO 72                                                          SOU  169
   70 DT = NSTOP                                                        SOU  170
      DPHI=(PHI(NSTOP2,L)-PHI(1,L))/DT                                  SOU  171
      DS = N                                                            SOU  172
      PHII(N,L) = PHI(1,L)+(DS-0.5)*DPHI                                SOU  173
      IF (PHI(NSTOP2,L).NE.PHI(NSTOP1,1)) WRITE(6,1000) L               SOU  174
   72 FS(N,L+2,1) = ASO(1)*DPHI                                         SOU  175
   74 FS(N,L+2,2) = ASO(2)*DPHI                                         SOU  176
   76 CONTINUE                                                          SOU  177
 1000 FORMAT(53H0ERROR IN SOURCE DESCRIPTION FOR RADIAL INTERVAL.....I5)SOU  178
      GO TO 86                                                          SOU  179
   78 DO 80 L = 1,LSO                                                   SOU  180
      RSI(L) = RS(L)                                                    SOU  181
      DO 80 K = 1,2                                                     SOU  182
   80 FS(L,1,K) = FSI(L,1,K)                                            SOU  183
      DO 82 M = 1,MSO                                                   SOU  184
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      ZSI(M) = ZS(M)                                                    SOU  185
      DO 82 K = 1,2                                                     SOU  186
   82 FS(M,2,K) = FSI(M,2,K)                                            SOU  187
      NSOI=NSO(1)                                                       SOU  188
      DO 84 N=1,NSOI                                                    SOU  189
      PHII(N,1) = PHI(N,1)                                              SOU  190
      DO 84 K=1,2                                                       SOU  191
   84 FS(N,3,K) = FSI(N,3,K)                                            SOU  192
 1002 FORMAT(59H0ERROR IN RADIAL SOURCE DISTRIBUTION(1/GAMMA,2/NEUTRON).SOU  193
     1...I4,9HPOINT....I4)                                              SOU  194
 1004 FORMAT(59H0ERROR IN AXIAL SOURCE DISTRIBUTION(1/GAMMA,2/NEUTRON)..SOU  195
     1...I4,9HPOINT....I4)                                              SOU  196
   86 RETURN                                                            SOU  197
      END                                                               SOU  198
```

```
$IBFTC SIRR    NOLIST,  DECK,NODD,M94/2,XR7                                SIR    1
      SUBROUTINE SIR(RS,ZS,RSIT,ZSIT,FSI,FSIT,LSO,MSO,LSIT,MSIT)          SIR    2
      DIMENSION RS(21),ZS(21)                                             SIR    3
      DIMENSION RSIT(21),ZSIT(21),FSIT(21,2,2),RTEMP(21),FSI(21,22,2)     SIR    4
      DO 8 K = 1,2                                                        SIR    5
      LSOI = LSO + 1                                                      SIR    8
      DO 4 L = 1,LSOI                                                     SIR    9
    4 FSI(L,1,K) = SI(RSIT,FSIT(1,1,K),RS(L),LSIT,IND,1,1)
      MSOI = MSO + 1                                                      SIR   11
      DO 6 M = 1,MSOI                                                     SIR   12
    6 FSI(M,2,K) = SI(ZSIT,FSIT(1,2,K),ZS(M),MSIT,IND,1,1)                SIR   13
    8 CONTINUE                                                            SIR   14
      RETURN                                                              SIR   15
      END                                                                 SIR   16
$IBFTC PPLOTT  NOLIST,  DECK,NODD,M94/2,XR7                               PPLO
      SUBROUTINE PPLOT                                                    PPLO
      RETURN                                                              PPLO
      END                                                                 PPLO
$IBFTC LIBE    NOLIST,  DECK,NODD,M94/2,XR7                               LIB    1
      SUBROUTINE LIBRE(ENG,ZAT,MAT,NGG,XSECG)                             LIB    2
      COMMON AI(550),NI(1700),FI(5660)                                    LIB    3
      DIMENSION GCO(32) ,GCT(532)  ,ENG(30),ZAT(20),XSECG(30,20),AG(4)    LIB    4
      DIMENSION ETABLE(28),GCI(28)                                        LIB    5
      DATA(ETABLE(I),I=1,28)/ 0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0,1.5,    LIB    6
     12.0,2.5,2.8,3.0,3.5,4.0,4.5,5.0,5.5,6.0,6.5,7.0,7.5,8.0,8.5,9.0,    LIB    7
     29.5,10.0 /                                                          LIB    8
      DATA(GCO(I),I=1,32) / 2.79370E-02,5.53742E-02,-8.83593E-03,9.79086LIB    9
     1E-04,-4.48631E-04,-2.16137E-04,-1.69858E-04,-1.23547E-05,9.66869E-LIB   10
     206,-5.75634E-06,5.1917E-06,5.27906E-07,-5.08811E-08,5.95621E-08,-1LIB   11
     3.50369E-08,2.46673E-09,1.15458E-02,1.14923E-01,-4.93023E-02,-2.740LIB   12
     486E-02,7.03833E-04,-5.98965E-03,9.06059E-03,-4.49765E-03,8.61480E-LIB   13
     507,3.32807E-05,-2.97511E-05,-1.72444E-05,-2.30467E-08,-6.59005E-08LIB   14
     6,8.41048E-08,9.63859E-08/                                           LIB   15
      DATA(GCT(I),  I=1,28)/.0321,.0329,.0341,.0355,.0371,.0388,.0406,    LIB   16
     2.0426,.0446,.0472,.0502,.0535,.0579,.0629,.0691,.0725,.0775,.0876,LIB   17
     3.103 ,.126 ,.132 ,.14  ,.148 ,.160 ,.173 ,.189 ,.212 ,.243/         LIB   18
      DATA(GCT(I),I=29,56  )/ .0169,.0175,.0181,.0187,.0194,.0203,.0212,LIB   19
     1.0221,.0231,.0244,.0257,.0276,.0295,.0322,.0349,.0367,.0395,.0442,LIB   20
     2.0516,.0635,.0671,.0707,.0756,.0805,.0870,.0953,.106 ,.122 /        LIB   21
      DATA(GCT(I),I=57,84 )/  .0154,.0159,.0162,.0168,.0173,.0180,.0185,LIB   22
     2.0195,.0205,.0214,.0226,.0240,.0258,.0279,.0304,.0318,.0339,.0383,LIB   23
     3.0448,.0550,.0579,.0614,.0655,.0697,.0752,.0827,.0922,.1063/        LIB   24
      DATA(GCT(I),I=85,112)/  .0161,.0163,.0167,.0173,.0180,.0187,.0195,LIB   25
     2.0203,.0211,.0222,.0234,.0247,.0266,.0286,.0313,.0327,.0349,.0394,LIB   26
     3.0459,.0565,.0596,.0628,.0661,.0715,.0773,.0847,.0945,.109 /        LIB   27
      DATA(GCT(I),I=113,140)/ .0182,.0183,.0187,.0193,.02  ,.0208,.0216,LIB   28
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2.0234,.0245,.0258,.0273,.0292,.0315,.0315,.0346,.036 ,.0383,.043 ,LIB
3.0503,.0623,.0650,.0683,.0723,.0775,.0842,.0929,.104,. 118 /      LIB
 DATA(GCT(I),I=141,168)/ .0194,.0195,.0199,.0205,.0213,.0219,.0227,LIB
2.0236,.0245,.0256,.0270,.0284,.0304,.0327,.0356,.0372,.0395,.0444,LIB
3.0518,.0636,.0668,.0707,.0745,.0805,.0870,.0953,.106 ,.122 /      LIB
 DATA(GCT(I),I=169,196)/ .02  ,.0203,.0206,.0212,.0218,.0226,.0233,LIB
2.0242,.0249,.0261,.0273,.0289,.0306,.0331,.0357,.0374,.0398,.0445,LIB
3.0517,.0636,.0670,.0707,.0748,.0805,.0869,.0955,.106 ,.123 /      LIB
 DATA(GCT(I),I=197,224)/ .0206,.0208,.0212,.0216,.0224,.0229,.0237,LIB
2.0245,.0254,.0264,.0276,.0289,.0309,.033 ,.0359,.0373,.0396,.0445,LIB
3.0518,.0636,.0666,.0708,.0743,.0806,.087 ,.0953,.107 ,.123 /      LIB
 DATA(GCT(I),I=225,252)/ .0203,.0206,.0210,.0214,.0218,.0224,.0231,LIB
1.0238,.0245,.0255,.0266,.0281,.0296,.0319,.0342,.0358,.0382,.0422,LIB
2.0491,.0602,.0636,.0670,.0716,.0763,.0826,.0907,.102 ,.179 /      LIB
 DATA(GCT(I),I=253,280)/ .0218,.0221,.0225,.0229,.0233,.0339,.0446,LIB
1.0353,.0260,.0270,.0281,.0296,.0312,.0335,.0359,.0375,.0401,.0442,LIB
2.0514,.0630,.0665,.0701,.0749,.0798,.0865,.0950,.106 ,.124 /      LIB
 DATA(GCT(I),I=281,308)/ .0215,.0216,.0220,.0225,.0229,.0236,.0242,LIB
2.0248,.0254,.0263,.0274,.0285,.0303,.0322,.0348,.0361,.0383,.0427,LIB
3.0496,.0608,.0641,.0676,.0716,.0770,.0833,.0912,.102 ,.118 /      LIB
 DATA(GCT(I),I=309,336)/ .0228,.0234,.0238,.0240,.0242,.0250,.0255,LIB
2.0258,.0266,.0273,.0286,.0295,.0315,.0330,.0360,.0361,.0385,.0442,LIB
3.0512,.0627,.0640,.0699,.0725,.0795,.086 ,.0944,.106 ,.122 /      LIB
 DATA(GCT(I),I=337,364)/ .0229,.0230,.0231,.0235,.0241,.0242,.0245,LIB
2.0255,.0264,.0271,.0282,.0300,.0310,.0335,.0353,.0375,.0390,.0432,LIB
3.0500,.0614,.0650,.0683,.0720,.0777,.0840,.0922,.103 ,.120 /      LIB
 DATA(GCT(I),I=365,392)/ .0243,.0245,.0250,.0252,.0254,.0260,.0263,LIB
2.0272,.0277,.0285,.0296,.0308,.0323,.0342,.0367,.0375,.0396,.0447,LIB
3.0517,.0635,.0650,.0706,.0740,.0802,.0869,.0954,.107 ,.125 /      LIB
 DATA(GCT(I),I=393,420)/ .0242,.0245,.0247,.0248,.0252,.0255,.0260,LIB
2.0264,.0273,.0279,.0290,.0299,.0316,.0330,.0358,.0368,.0390,.0436,LIB
3.0502,.0617,.0620,.0685,.0710,.0780,.0846,.0928,.104 ,.122 /      LIB
 DATA(GCT(I),I=421,448)/ .0255,.0256,.0258,.0260,.0266,.0270,.0275,LIB
2.0278,.0284,.0292,.0302,.0314,.0328,.0348,.0371,.0383,.0403,.0448,LIB
3.0519,.0635,.066 ,.0707,.0742,.0806,.0874,.0958,.108 ,.127 /      LIB
 DATA(GCT(I),I=449,476)/ .0252,.0254,.0257,.0259,.0262,.0266,.0271,LIB
1.0275,.0280,.0287,.0295,.0306,.0318,.0338,.0358,.0373,.0395,.0432,LIB
2.0498,.0610,.0646,.0682,.0730,.0779,.0845,.0931,.105 ,.126 /      LIB
 DATA(GCT(I),I=477,504)/ .0243,.0245,.0247,.0249,.0251,.0254,.0258,LIB
1.0262,.0266,.0273,.0280,.0290,.0301,.0319,.0338,.0352,.0372,.0406,LIB
2.0468,.0573,.0606,.0639,.0685,.0731,.0790,.0868,.0978,.117 /      LIB
 DATA(GCT(I),I=505,532)/ .0267,.0269,.0271,.0273,.0275,.0279,.0283,LIB
1.0287,.0291,.0298,.0305,.0316,.0327,.0346,.0366,.0380,.0402,.0439,LIB
2.0505,.0620,.0654,.0689,.0737,.0786,.0854,.0938,.106 ,.126 /      LIB
 DO 12 N = 1,MAT                                                   LIB
 NZ=(ZAT(N)-1.0)*28.0+1.0                                          LIB
```

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      DO 12 K = 1,NGG                                                   LIB    75
      ENGI=ENG(K)
      IF(ENG(K).GT.10.0)ENGI=10.0
      IF(ENG(K).LT.0.2)ENGI=0.2
    2 IF(ZAT(N).GT.19.0) GO TO 6                                        LIB    80
      DO 4 L=1,28                                                       LIB    81
      LI = 28-L+1                                                       LIB    82
      NL=N7+L-1                                                         LIB    83
    4 GCI(LI)=GCT(NL)                                                   LIB    84
      XSECG(K,N)=SI(ETABLE,GCI,ENGI,28,IND,1,1)
      GO TO 12                                                          LIB    86
    6 ENGI = 1.0/ENGI
      DO 8 I = 1,4                                                      LIB    88
      AG(I) = 0.0                                                       LIB    89
      DO 8 J = 1,4                                                      LIB    90
      JB=4-J+1+(I-1)*4                                                  LIB    91
      IF(ENG(K).GE.2.0) JB=JB+16                                        LIB    92
    8 AG(I) = AG(I)*ENGI+GCO(JB)                                        LIB    93
      ATOT = 0.0                                                        LIB    94
      DO 10 I = 1,4                                                     LIB    95
      IB = 4-I+1                                                        LIB    96
   10 ATOT = ATOT*ZAT(N)+AG(IB)                                         LIB    97
      XSECG(K,N) = ATOT                                                 LIB    98
   12 CONTINUE                                                          LIB    99
   14 RETURN                                                            LIB   100
      END                                                               LIB   101
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$IBFTC BUILDP  LIST,  DECK,M94/2,XR7                                    BUI    1
      SUBROUTINE BUILD(NGG,ENG,BILD,NT1,NT2,TMFP)                       BUI    2
      COMMON AI(550),NI(1700),FI(5600)                                  BUI    3
      DIMENSION ENG(NGG),BILD(4,30,1)                                   BUI    4
      DIMENSION CIJ(720),ENGL(30),ENGH(30),NENG(30)                     BUI    5
      DATA (ENGL(I),I=1,30) / 3*0.255,27*0.5 /                          BUI    6
      DATA (ENGH(I),I=1,30) / 30*10.0 /                                 BUI    7
      DATA (NENG(I),I=1,30) / 9*1,5*2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2 / BUI    8
C SET NO.  01 WATER            DOSE                20MFP,.255 .LE.E.LE.20.0
      DATA (CIJ(I),I=  1, 24)                                           BUI    9
     1/1.01094E 00,1.16772E-01,-7.65869E-03,1.67068E-04,                BUI   10
     2 -6.00394E-02,2.32125E 00,-1.79023E-02,5.69295E-04,               BUI   11
     3 7.20778E-02,-2.12801E 00,2.41735E-01,-7.96332E-03,               BUI   12
     4 -3.01498E-02,7.67783E-01,-4.34443E-02,7.23758E-03,               BUI   13
     5 3.94733E-03,-9.08139E-02,-1.34203E-03,-9.87237E-04,4*0.0/        BUI   14
C SET NO.  02 WATER            ENERGY              20MFP,.255 .LE.E.LE.10.0
      DATA (CIJ(I),I= 25, 48)                                           BUI   15
     1/1.01257E 00,7.40320E-02,8.38751E-04,-8.65720E-05,                BUI   16
     2 -6.02566E-02,1.87800E 00,-5.95322E-02,1.86960E-03,               BUI   17
     3 6.68495E-02,-1.34203E 00,2.87149E-01,-9.32518E-03,               BUI   18
     4 -2.66927E-02,4.09055E-01,-7.77038E-02,7.32451E-03,               BUI   19
     5 3.40102E-03,-4.19963E-02,4.60445E-03,-1.03618E-03,4*0.0/         BUI   20
C SET NO.  03 WATER            ENERGY ABSORPTION 20MFP,.255 .LE.E.LE.10.0
      DATA (CIJ(I),I= 49, 72)                                           BUI   21
     1/1.00935E 00,6.75909E-02,-2.88512E-03,3.54158E-05,                BUI   22
     2 -5.05187E-02,2.73952E 00,-7.11806E-02,1.98272E-03,               BUI   23
     3 5.93863E-02,-2.82306E 00,3.98796E-01,-1.19564E-02,               BUI   24
     4 -2.43717E-02,1.11668E 00,-1.50948E-01,9.52922E-03,               BUI   25
     5 3.14779E-03,-1.41350E-01,1.65266E-02,-1.36541E-03,4*0.0/         BUI   26
C SET NO.  04 ALUMINUM         DOSE                20MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I= 73, 96)                                           BUI   27
     1/1.00768E 00,-1.03807E-02,1.30705E-02,-3.29348E-04,               BUI   28
     2 -4.98085E-02,3.32216E 00,-1.58167E-01,4.60315E-03,               BUI   29
     3 7.23425E-02,-5.52427E 00,6.89496E-01,-2.04255E-02,               BUI   30
     4 -3.93841E-02,4.16706E 00,-5.59836E-01,2.00554E-02,               BUI   31
     5 7.35778E-03,-1.04638E 00,1.41308E-01,-5.29934E-03,4*0.0/         BUI   32
C SET NO.  05 ALUMINUM         ENERGY              20MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I= 97,120)                                           BUI   33
     1/9.98999E-01,2.05580E-02,9.19873E-03,-2.20889E-04,                BUI   34
     2 3.30215E-02,2.24760E 00,-1.06481E-01,3.12263E-03,                BUI   35
     3 -1.57934E-01,-2.78878E 00,4.70427E-01,-1.44741E-02,              BUI   36
     4 1.77751E-01,1.86286E 00,-3.20438E-01,1.36015E-02,                BUI   37
     5 -5.34320E-02,-4.42225E-01,7.13308E-02,-3.36259E-03,4*0.0/        BUI   38
C SET NO.  06 ALUMINUM         ENERGY ABSORPTION 20MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=121,144)                                           BUI   39
     1/9.97130E-01,-3.85219E-02,1.27816E-02,-3.39093E-04,               BUI   40
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     2 6.54640E-02,3.27946E 00,-1.64393E-01,5.04304E-03,                BUI   41
     3 -2.68716E-01,-4.74349E 00,7.45795E-01,-2.38346E-02,              BUI   42
     4 2.84908E-01,3.39495E 00,-6.26720E-01,2.53658E-02,                BUI   43
     5 -8.33177E-02,-8.37392E-01,1.66032E-01,-7.07268E-03,4*0.0/        BUI   44
C SET NO.  07 IRON            DOSE              20MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=145,168)                                           BUI   45
     1/1.01460E 00,-4.12104E-02,1.88074E-03,1.20198E-03,                BUI   46
     2 -1.88657E-01,2.72752E 00,1.00217E-01,-9.83313E-03,               BUI   47
     3 6.38649E-01,-3.76728E 00,-1.31988E-01,2.06002E-02,               BUI   48
     4 -6.55159E-01,2.42384E 00,1.68976E-01,-1.75251E-02,               BUI   49
     5 1.90742E-01,-5.54657E-01,-5.80710E-02,4.75673E-03,4*0.0/         BUI   50
C SET NO.  08 IRON            ENERGY            20MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=169,192)                                           BUI   51
     1/1.00790E 00,-6.14584E-02,1.67258E-02,-2.78863E-05,               BUI   52
     2 -5.67036E-02,2.43299E 00,-6.93560E-02,1.48430E-03,               BUI   53
     3 1.13800E-01,-3.33783E 00,3.27144E-01,-9.70973E-03,               BUI   54
     4 -8.67732E-02,2.27697E 00,-2.53954E-01,1.03942E-02,               BUI   55
     5 2.16742E-02,-5.47806E-01,5.89867E-02,-2.95818E-03,4*0.0/         BUI   56
C SET NO.  09 IRON            ENERGY ABSORPTION 20MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=193,216)                                           BUI   57
     1/1.00029E 00,-9.76981E-02,3.07480E-03,5.43036E-04,                BUI   58
     2 -2.69391E-02,2.81567E 00,5.47069E-02,-3.05850E-03,               BUI   59
     3 1.06797E-01,-3.14590E 00,-1.33763E-04,2.43681E-03,               BUI   60
     4 -1.11725E-01,1.91566E 00,1.03003E-01,-1.57016E-03,               BUI   61
     5 3.27028E-02,-4.17820E-01,-4.79248E-02,5.35111E-04,4*0.0/         BUI   62
C SET NO.  10 URANIUM         DOSE              15MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=217,240)                                           BUI   63
     1/1.01765E 00,4.24238E-02,-1.42252E-02,5.93162E-04,                BUI   64
     2 -1.65482E-02,3.31303E-01,-2.90268E-03,-1.84501E-04,              BUI   65
     3 5.84308E-03,-1.24381E-01,6.06091E-03,-7.15165E-05,               BUI   66
     4 -8.56681E-04,1.62433E-02,-1.24102E-03,3.86282E-05,               BUI   67
     5 4.03127E-05,-7.01931E-04,6.59820E-05,-2.68878E-06,4*0.0/         BUI   68
C SET NO.  11 URANIUM         ENERGY            15MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=241,264)                                           BUI   69
     1/1.01118E 00,7.08631E-02,-1.69975E-02,6.66422E-04,                BUI   70
     2 -5.09776E-03,2.68038E-01,4.02443E-03,-4.01263E-04,               BUI   71
     3 8.49397E-04,-1.03017E-01,2.68537E-03,4.66308E-05,                BUI   72
     4 -9.01452E-05,1.34460E-02,-7.07914E-04,1.49376E-05,               BUI   73
     5 3.14201E-06,-5.77921E-04,4.02867E-05,-1.38432E-06,4*0.0/         BUI   74
C SET NO.  12 URANIUM         ENERGY ABSORPTION 15MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=265,288)                                           BUI   75
     1/24*0.0/                                                          BUI   76
C SET NO.  13 LEAD            DOSE              15MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=289,312)                                           BUI   77
     1/9.59342E-01,6.78254E-02,-2.26626E-02,6.39872E-04,                BUI   78
     2 1.13722E-01,4.50412E-01,7.55191E-03,1.52094E-04,                 BUI   79
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     3 -7.39816E-02,-2.15037E-01,5.10254E-03,-6.04837E-04,                BUI   80
     4 1.87767E-02,4.05189E-02,-1.89332E-03,2.42263E-04,                  BUI   81
     5 -2.04254E-03,-3.40802E-03,1.93415E-04,-2.93865E-05,                BUI   82
     6 7.93621E-05,1.06510E-04,-6.24306E-06,1.13914E-06/                  BUI   83
C SET NO.  14 LEAD            ENERGY            15MFP,.5   .LE.E.LE.10.0
      DATA (CIJ(I),I=313,336)                                             BUI   84
     1/1.02149E 00,5.09979E-02,-2.32211E-02,7.46627E-04,                  BUI   85
     2 -1.82412E-02,4.38781E-01,2.69198E-02,-1.39819E-03,                 BUI   86
     3 5.63188E-03,-2.16009E-01,-1.06625E-02,6.78031E-04,                 BUI   87
     4 -7.34572E-04,4.19148E-02,2.32140E-03,-1.18583E-04,                 BUI   88
     5 2.87951E-05,-3.63958E-03,-2.61850E-04,1.08867E-05,                 BUI   89
     6 3.16311E-07,1.17723E-04,1.10200E-05,-4.19951E-07/                  BUI   90
C SET NO.  15 LEAD            ENERGY ABSORPTION 15MFP,.5   .LE.E.LE.4.0
      DATA (CIJ(I),I=337,360)                                             BUI   91
     1/9.99305E-01,-3.49764E-01,2.89886E-02,1.28555E-03,                  BUI   92
     2 1.13017E-02,2.79914E 00,-7.10002E-02,-4.75607E-03,                 BUI   93
     3 -3.44367E-03,-2.20399E 00,-1.11108E-02,7.04843E-03,                BUI   94
     4 2.04092E-03,5.02301E-01,1.45444E-02,-2.31052E-03,8*0.0/            BUI   95
C             LEAD            ENERGY ABSORPTION 15MFP,4.   .LE.E.LE.10.0
      DATA (CIJ(I),I=361,384)                                             BUI   96
     1/1.02626E 00,4.15814E-01,5.64179E-02,-4.83073E-03,                  BUI   97
     2 -7.44724E-03,-6.14701E-02,-1.42153E-02,1.76866E-03,                BUI   98
     3 3.81090E-04,3.09491E-03,7.33689E-04,-1.07370E-04,12*0.0/           BUI   99
C SET NO.  17 TIN             DOSE              15MFP,.5   .LE.E.LE.4.0
      DATA (CIJ(I),I=385,408)                                             BUI  100
     1/1.00210E 00,9.67305E-03,2.60452E-02,1.69043E-03,                   BUI  101
     2 -5.90106E-03,1.72069E 00,-2.98161E-03,-6.86263E-03,                BUI  102
     3 7.46265E-03,-1.51375E 00,1.37709E-03,6.65061E-03,                  BUI  103
     4 -2.26120E-03,3.95385E-01,-4.49948E-03,-1.76174E-03,8*0.0/          BUI  104
C             TIN             DOSE              15MFP,4.0  .LE.E.LE.10.0
      DATA (CIJ(I),I=409,432)                                             BUI  105
     1/1.01739E 00,5.94570E-01,6.71332E-02,-6.41932E-03,                  BUI  106
     2 -5.18996E-03,-7.32374E-02,-1.27457E-02,2.20348E-03,                BUI  107
     3 2.96454E-04,2.88294E-03,6.04488E-04,-1.28823E-04,12*0.0/           BUI  108
C SET NO.  19 TIN             ENERGY            15MFP,.5   .LE.E.LE.1.0
      DATA (CIJ(I),I=433,456)                                             BUI  109
     1/1.00128E 00,-2.22495E-02,1.57823E-02,1.52341E-03,                  BUI  110
     2 -4.33121E-05,1.53249E 00,2.22903E-02,-6.24165E-03,                 BUI  111
     3 -1.87778E-03,-1.22288E 00,-2.01839E-02,6.03325E-03,                BUI  112
     4 1.26439E-03,3.00313E-01,1.21119E-03,-1.58488E-03,8*0.0/            BUI  113
C             TIN             ENERGY            15MFP,4.0  .LE.E.LE.10.0
      DATA (CIJ(I),I=457,480)                                             BUI  114
     1/1.00283E 00,5.45757E-01,4.10166E-02,-3.39265E-03,                  BUI  115
     2 -2.88528E-04,-7.96688E-02,-5.63538E-03,1.15437E-03,                BUI  116
     3 -1.03720E-04,3.93131E-03,8.91808E-05,-5.68006E-05,12*0.0/          BUI  117
C SET NO.  21 TIN             ENERGY ABSORPTION 15MFP,.5   .LE.E.LE.4.0
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      DATA (CIJ(I),I=481,504)                                           BUI  118
     1/9.89251E-01,-1.63257E-01,-4.60405E-02,5.33386E-03,               BUI  119
     2 2.75399E-02,2.37559E 00,3.09663E-01,-2.13112E-02,                BUI  120
     3 -1.51933E-02,-1.45840E 00,-3.44253E-01,2.27751E-02,              BUI  121
     4 2.37931E-03,3.13123E-01,9.59164E-02,-6.52903E-03,8*0.0/          BUI  122
C             TIN              ENERGY ABSORPTION 15MFP,4.0  .LE.E.LE.10.0
      DATA (CIJ(I),I=505,528)                                           BUI  123
     1/9.81435E-01,7.86492E-01,1.21135E-02,1.08376E-03,                 BUI  124
     2 5.18941E-03,-1.42993E-01,1.83417E-03,-3.60388E-05,               BUI  125
     3 -4.14965E-04,7.77610E-03,-3.65658E-04,1.39440E-05,12*0.0/        BUI  126
C SET NO.  23 TUNGSTEN         DOSE                15MFP,.5   .LE.E.LE.4.0
      DATA (CIJ(I),I=529,552)                                           BUI  127
     1/1.00431E 00,-3.36453E-02,4.80434E-02,2.14764E-03,                BUI  128
     2 -2.85210E-02,1.61132E 00,-1.60382E-01,-6.82751E-03,              BUI  129
     3 3.94170E-02,-1.55660E 00,1.38446E-01,7.09074E-03,                BUI  130
     4 -1.20482E-02,4.13688E-01,-3.72797E-02,-2.03649E-03,8*0.0/        BUI  131
C             TUNSTEN          DOSE                15MFP,4.0  .LE.E.LE.10.0
      DATA (CIJ(I),I=553,576)                                           BUI  132
     1/1.02025E 00,4.36394E-01,7.25198E-02,-7.31585E-03,                BUI  133
     2 -5.62425E-03,-5.13127E-02,-1.69606E-02,2.67259E-03,              BUI  134
     3 1.46397E-04,2.58908E-03,7.10875E-04,-1.47831E-04,12*0.0/         BUI  135
C SET NO.  25 TUNGSTEN         ENERGY              15MFP,.5   .LE.E.LE.4.0
      DATA (CIJ(I),I=577,600)                                           BUI  136
     1/9.84430E-01,-1.85010E-02,2.39337E-02,2.49665E-03,                BUI  137
     2 7.05675E-02,1.26928E 00,-4.10157E-02,-9.93778E-03,               BUI  138
     3 -7.45804E-02,-1.10232E 00,1.85800E-03,1.11526E-02,               BUI  139
     4 2.24076E-02,2.69689E-01,4.22866E-03,-3.33528E-03,8*0.0/          BUI  140
C             TUNGSTEN         ENERGY              15MFP,4.0  .LE.E.LE.10.0
      DATA (CIJ(I),I=601,624)                                           BUI  141
     1/1.02106E 00,3.76582E-01,6.05907E-02,-5.26242E-03,                BUI  142
     2 -6.54573E-03,-4.62584E-02,-1.42730E-02,1.96063E-03,              BUI  143
     3 2.65408E-04,2.30558E-03,6.39547E-04,-1.11335E-04,12*0.0/         BUI  144
      DATA (CIJ(I),I=625,648)                                           BUI  145
     1/24*0.0/                                                          BUI  146
      DATA (CIJ(I),I=649,672)                                           BUI  147
     1/24*0.0/                                                          BUI  148
      DATA (CIJ(I),I=673,696)                                           BUI  149
     1/24*0.0/                                                          BUI  150
      DATA (CIJ(I),I=697,720)                                           BUI  151
     1/24*0.0/                                                          BUI  152
      DO 6 K=1,120
    6 BILD(K,1,1) = 0.0
      NS=(NT1-1)*24+1                                                   BUI  153
      NT = NT1
      DO 4 K = 1,NGG                                                    BUI  155
      ENGI = ENG(K)                                                     BUI  156
      NSI = NS
      IF(ENGI.LT.ENGL(NT1))ENGI = ENGL(NT1)                             BUI  157
```


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```
      IF(ENGI.GT.ENGH(NT1))ENGI = ENGH(NT1)                          BUI  158
      IF(NT1.GE.15.AND.ENGI.GT.4.0) NSI = NS + 24
      IF(NT1.GE.15.AND.ENGI.GT.4.0) NT = NT1+1                       BUI  16
      NN = NENG(NT)                                                  BUI  161
      IF(NN.EQ.1) ENGI = 1.0/ENGI                                    BUI  162
      DO 2 M = 1,4                                                   BUI  163
      DO 2 N = 1,6                                                   BUI  164
      NR=(6-N)*4+M+NSI-1                                             BUI  165
      BILD(M,K,1) = BILD(M,K,1)*ENGI + CIJ(NR)                       BUI  167
    2 CONTINUE                                                       BUI  168
    4 CONTINUE                                                       BUI  169
      TMEP = 20.0                                                    BUI  17
      IF(NT1.GT.9) TMEP = 15.0                                       BUI  171
      RETURN                                                         BUI  172
      END                                                            BUI  173
```


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```
$IBFTC SIIR    NOLIST,  DECK,NODD,M94/2,XR7                              SII    1
      FUNCTION SI(XTBL,YTBL,XX,NN,IND,INDLE,INDUE)                       SII    2
C                                                                        SII    3
      X=XX                                                               SII    4
      N=NN                                                               SII    5
C                                                                        SII    6
C     IND   = INDICATES TYPE-OF-EXTRAPOLATION THAT WAS USED   (IF ANY)   SII    7
C             (IND=0 INDICATES NO EXTRAPOLATION WAS NEEDED ON X)         SII    8
C             (IND=1 INDICATES LOWER EXTRAPOLATION WAS NEEDED ON X)      SII    9
C             (IND=2 INDICATES UPPER EXTRAPOLATION WAS NEEDED ON X)      SII   10
C     INDLE = INDICATES TYPE-OF-LOWER-EXTRAPOLATION TO BE USED ON X      SII   11
C             (INDLE=1 INDICATES LOWER EXTRAP. ON X IS TO BE LINEAR)     SII   12
C             (INDLE=2 INDICATES LOWER EXTRAP. ON X IS TO BE PARABOLIC)  SII   13
C             (INDLE=3 INDICATES LOWER-LINEAR EXTRAP. ON X AND ERROR PRISII   14
C             (INDLE=4 INDICATES LOWER-PARABOLIC EXTR. ON X AND ERROR PRSII   15
C     INDUE = INDICATES TYPE-OF-UPPER-EXTRAPOLATION TO BE USED ON X      SII   16
C             (INDUE=1 INDICATES UPPER EXTRAP. ON X IS TO BE LINEAR)     SII   17
C             (INDUE=2 INDICATES UPPER EXTRAP. ON X IS TO BE PARABOLIC)  SII   18
C             (INDUE=3 INDICATES UPPER-LINEAR EXTRAP. ON X AND ERROR PRISII   19
C             (INDUE=4 INDICATES UPPER-PARABOLIC EXTR. ON X AND ERROR PRSII   20
C     N     = NUMBER-OF-POINTS IN EACH TABLE                             SII   21
C     X     = PARTICULAR VALUE OF INDEPENDENT VARIABLE                   SII   22
C     XTBL  = NAME OF INDEPENDENT VARIABLE TABLES                        SII   23
C     YTBL  = NAME OF DEPENDENT VARIABLE TABLES                          SII   24
      DIMENSION XTBL(2),YTBL(2)                                          SII   25
C                                                                        SII   26
    2 IND=0                                                              SII   27
C                                                                        SII   28
C     CHECK TO SEE IF LOWER OUT-OF-RANGE EXTRAPOLATION WILL BE NEEDED    SII   29
      IF(X-XTBL)4,6,8                                                    SII   30
C                                                                        SII   31
C     LOWER OUT-OF-RANGE EXTRAPOLATION WAS FOUND NECESSARY  (SET IND=1)  SII   32
    4 IND=1                                                              SII   33
    6 II=2                                                               SII   34
      GO TO 18                                                           SII   35
C                                                                        SII   36
C     CHECK TO SEE IF UPPER OUT-OF-RANGE EXTRAPOLATION WILL BE NEEDED    SII   37
    8 IF(XTBL(N)-X)10,12,14                                              SII   38
C                                                                        SII   39
C     UPPER OUT-OF-RANGE EXTRAPOLATION WAS FOUND NECESSARY  (SET IND=2)  SII   40
   10 IND=2                                                              SII   41
      II=N                                                               SII   42
      GO TO (18,12,18,12),INDUE                                          SII   43
   12 II=N-1                                                             SII   44
      GO TO 18                                                           SII   45
C                                                                        SII   46
```


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```
C     (X IS IN-RANGE      MAKE A POINT SEARCH ON X TO OBTAIN II)
   14 NM1=N-1
      DO 16 IK=2,NM1
      II=IK
      IF(XTBL(IK)-X)16,18,18
   16 CONTINUE
C
   18 X1=XTBL(II-1)
      X2=XTBL(II)
      Y1=YTBL(II-1)
      Y2=YTBL(II)
C
C     CHECK IF (UPPER OR LOWER) EXTRAPOLATION WAS FOUND TO BE NECESSARY
      IF(IND-1)26,20,22
C
C     LOWER EXTRAPOLATION IS NEEDED - CHECK INDLE FOR TYPE TO BE USED
   20 GO TO (32,26,30,24),INDLE
C
C     UPPER EXTRAPOLATION IS NEEDED - CHECK INDUE FOR TYPE TO BE USED
   22 GO TO (32,26,30,24),INDUE
C
C     ERROR PRINTOUT
   24 CALL ERROR(33H TABLE EXTRAPOLATED PARABOLICALLY)
C
   26 X3=XTBL(II+1)
      Y3=YTBL(II+1)
C
C     PARABOLIC INTERPOLATION OR EXTRAPOLATION
   28 SI=Y1+(1.+(X2-X)/(X3-X1))*(Y2-Y1)*(X-X1)/(X2-X1)-(X2-X)/(X3-X1)*(
     1X-X1)/(X3-X2)*(Y3-Y2)
      GO TO 34
C
C     ERROR PRINTOUT
   30 CALL ERROR(28H TABLE EXTRAPOLATED LINEARLY)
C
C     LINEAR EXTRAPOLATION
   32 SI=Y1+(Y2-Y1)*(X-X1)/(X2-X1)
   34 RETURN
      END
```

```
$ORIGIN        LEVEL1,SYSUT3,REW                                        INO    1
$IBFTC INOT    NOLIST,  DECK,NODD,M94/2,XR7                             INO    2
      SUBROUTINE INOUT(ASO,RSI,ZSI,PHII,FS,INPERR)                      INO    3
C INSERT COMMON,DIMENSION,AND EQUIVALENCE WHICH ARE IDENTICAL TO THE    INO    4
C MAIN PROGRAM KAPV                                                     INO    5
      COMMON AI(550),NI(1700),FI(5660)                                  INO    6
      EQUIVALENCE (AI(    1),TITLE )                                    INO    7
      EQUIVALENCE (NI(    1),NGG   ),(NI(    2),NGN '  ),(NI(    3),MAT   ) INO    8
      EQUIVALENCE (NI(    4),NCOMP ),(NI(    5),NDET   ),(NI(    6),NBOUND) INO    9
      EQUIVALENCE (NI(    7),NREG  ),(NI(    8),NRSPG  ),(NI(    9),NRSPN  ) INO   10
      EQUIVALENCE (NI(   10),NRSPA ),(NI(   11),MATL   )                INO   11
      EQUIVALENCE (NI(   20),IGAM  ),(NI(   21),INEUT  ),(NI(   24),ISCP  ) INO   12
      EQUIVALENCE (NI(   25),IZSO  ),(NI(   26),ISORC  ),(NI(   27),ISRC  ) INO   13
      EQUIVALENCE (NI(   28),ISZC  ),(NI(   29),ISTC   ),(NI(   30),ISIT  ) INO   14
      EQUIVALENCE (NI(   31),ISUM  ),(NI(   32),IOUT   )                INO   15
      EQUIVALENCE (NI(   35),KORD  ),(NI(   40),IORD   )                INO   16
      EQUIVALENCE (NI(   50),LSO   ),(NI(   51),MSO    ),(NI(   52),NSO   ) INO   17
      EQUIVALENCE (NI(   75),LSIT  ),(NI(   76),MSIT   )                INO   18
      EQUIVALENCE (NI(  100),NEQBD ),(NI(  200),NBNDZN),(NI(  300),NCMPZN) INO   19
      EQUIVALENCE (NI(  400),NBILD ),(NI(  500),LBD    ),(NI(1100),NTRYZN) INO   20
      EQUIVALENCE (FI(    1),ASOI  ),(FI(    3),XI     ),(FI(    5),ETA   ) INO   21
      EQUIVALENCE (FI(    7),RS    ),(FI(   28),ZS     ),(FI(   49),PHI   ) INO   22
      EQUIVALENCE (FI(  470),FSI   ),(FI(1400),GSOUR  ),(FI(1430),NSOUR  ) INO   23
      EQUIVALENCE (FI(1460),ABD    ),(FI(1560),BBD    ),(FI(1660),CBD    ) INO   24
      EQUIVALENCE (FI(1760),XOBD   ),(FI(1860),YOBD   ),(FI(1960),ZOBD   ) INO   25
      EQUIVALENCE (FI(2060),DBD    ),(FI(2160),XYZ    )                 INO   26
      EQUIVALENCE (FI(2460),COMP   ),(FI(3460),ENN    )                 INO   27
      EQUIVALENCE (FI(3490),XSECN  ),(FI(3550),XSNREF),(FI(3551),ALFA   ) INO   28
      EQUIVALENCE (FI(3560),ENG    ),(FI(3590),XSECG  ),(FI(4190),BILD   ) INO   29
      EQUIVALENCE (FI(4310),SMFP   ),(FI(4311),TMFP   )                 INO   30
      EQUIVALENCE (FI(4312),EPSLN  ),(FI(4313),FUDGE  ),(FI(4314),BKP    ) INO   31
      EQUIVALENCE (FI(4320),COM    ),(FI(4620),CON    ),(FI(4720),XLAM   ) INO   32
      EQUIVALENCE (FI(4750),RSPG   ),(FI(5050),RSPN   ),(FI(5350),RSPA   ) INO   33
      EQUIVALENCE (FI(5360),RCORD  ),(FI(5510),SSOT   ),(FI(5513),ZAT    ) INO   34
      EQUIVALENCE (FI(5533),RSIT   ),(FI(5554),ZSIT   ),(FI(5575),FSIT   ) INO   35
      DIMENSION NSO(20),INEUT(3),IOUT(3),KORD(5),IORD(5)                INO   36
      DIMENSION NBNDZN(100),NEQBD(100),NCMPZN(100),NBILD(100),LBD(6,100)INO   37
      DIMENSION NTRYZN(6,100)                                           INO   38
      DIMENSION ASOI(2),XI(2),ETA(2),RS(21),ZS(21),PHI(21,20)           INO   39
      DIMENSION FSI(21,22,2),GSOUR(30),NSOUR(30)                        INO   40
      DIMENSION RSIT(21),ZSIT(21),FSIT(21,2,2)                          INO   41
      DIMENSION ASO(2),RSI(20),ZSI(20),PHII(20,20 ),FS(20,22,2)         INO   42
      DIMENSION ABD(100),BBD(100),CBD(100),DBD(100),XOBD(100),YOBD(100) INO   43
      DIMENSION ZOBD(100),COMP(20,50),XYZ(3,100)                        INO   44
      DIMENSION ANEUT(31),AGAM(30),UAGAM(30)                            INO   45
      DIMENSION ENN(30),XSECN(20,3),ALFA(9),ENG(30),XSECG(30,20)        INO   46
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      DIMENSION BILD(4,30,1),BKP(4),COM(5,30,2),CON(5,5,4),XLAM(30)      INO   47
      DIMENSION RSPG(30,10),RSPN(30,10),RCORD(3,50),RSPA(1,10)           INO   48
      DIMENSION SSOT(3),TITLE(550  ) ,ZAT(20)                            INO   49
C INPUT DATA CONSISTENCY CHECK                                           INO   50
      IF(IGAM.LE.1) GO TO 32                                             INO   51
      IF(NGG.GT.0.OR.NGG.LE.30) GO TO 2                                  INO   52
      INPERR = 1                                                         INO   53
      CALL POUT(56HNO. OF GAMMA RAY GROUPS IN ERROR                      INO   54
     1     )                                                             INO   55
    2 IF(NRSPG.GT.0.OR.NRSPG.LE.10) GO TO 4                              INO   56
      INPERR = 1                                                         INO   57
      CALL POUT(56HNO. OF GAMMA RAY RESPONSES IN ERROR                   INO   58
     1     )                                                             INO   59
    4 DO 6 J = 1,NRSPG                                                   INO   60
      DO 6 K = 1,NGG                                                     INO   61
      IF(RSPG(K,J).GT.0.0) GO TO 8                                       INO   62
    6 CONTINUE                                                           INO   63
      INPERR = 1                                                         INO   64
      CALL POUT(56HGAMMA RAY RESPONSES ARE ALL ZERO                      INO   65
     1     )                                                             INO   66
    8 IF(ASOI(1).GT.0.0) GO TO 10                                        INO   67
      INPERR = 1                                                         INO   68
      CALL POUT(56HGAMMA RAY SOURCE MUST BE NON-ZERO AND POSITIVE        INO   69
     1     )                                                             INO   70
   10 DO 12 K = 1,NGG                                                    INO   71
      IF(GSOUR(K).GT.0.0) GO TO 14                                       INO   72
   12 CONTINUE                                                           INO   73
      INPERR = 1                                                         INO   74
      CALL POUT(56HGAMMA RAY SOURCE SPECTRA MUST BE NON-ZERO AND POS.    INO   75
     1     )                                                             INO   76
   14 DO 16 K = 1,NGG                                                    INO   77
      IF(ENG(K).GT.0.0) GO TO 16                                         INO   78
      INPERR = 1                                                         INO   79
      CALL POUT(56HALL GAMMA RAY ENERGIES MUST BE NON-ZERO AND POSITIVE  INO   80
     1     )                                                             INO   81
   16 CONTINUE                                                           INO   82
      DO 18 K = 1,NGG                                                    INO   83
      DO  18 M = 1,MAT                                                   INO   84
      IF(XSECG.GT.0.0) GO TO 20                                          INO   85
   18 CONTINUE                                                           INO   86
      INPERR = 1                                                         INO   87
      CALL POUT(56HGAMMA RAY COEFF. MUST NOT ALL BE ZERO AND NON-POS.    INO   88
     1     )                                                             INO   89
   20 DO 22 K = 1,NGG                                                    INO   90
      DO 22 L=1,3                                                        INO   91
      DO 22 J = 1,4                                                      INO   92
```

```
      IF(BILD(J,K,L).NE.0.0) GO TO 24                                   INO   93
   22 CONTINUE                                                          INO   94
      INPERR = 1                                                        INO   95
      CALL POUT(56HNO GAMMA RAY BUILDUP COEFFICIENTS ARE SPECIFIED      INO   96
     1    )                                                             INO   97
   24 DO 26 J = 1,NRSPG                                                 INO   98
      DO 26 K = 1,NGG                                                   INO   99
      IF(RSPG(K,J).GT.0.0) GO TO 28                                     INO  100
   26 CONTINUE                                                          INO  101
      INPERR = 1                                                        INO  102
      CALL POUT(56HNO GAMMA RAY RESPONSE FUNCTION DATA IS SPECIFIED     INO  103
     1    )                                                             INO  104
   28 DO 30 J = 1,2                                                     INO  105
      DO 30 K = 1,LSO                                                   INO  106
      IF(FSI(K,J,1).GT.0.0) GO TO 30                                    INO  107
      INPERR = 1                                                        INO  108
      CALL POUT(56HALL SOURCE DISTRIBUTION DATA MUST BE NON-ZERO AND POSINO  109
     1.   )                                                             INO  110
   30 CONTINUE                                                          INO  111
   32 CONTINUE                                                          INO  112
      DO 100 J=1,NREG
      JU=IABS(NBNDZN(J))
      DO 100 K=1,JU
      IF(LBD(K,J).EQ.0) GO TO 102
      IF(NTRYZN(K,J).EQ.0) GO TO 102
      GO TO 100
  102 INPERR = 1
      CALL POUT(57H ALL GEOMETRY PARAMETERS(LBD AND NTRYZN) MUST BE NON-
     1ZERO)
  100 CONTINUE
      WRITE(6,1000) NGG,NGN,MAT,NCOMP,NDET,NBOUND,NREG,NRSPG,NRSPN,NRSPAINO  113
     1,MATL                                                             INO  114
 1000 FORMAT(22H1GENERAL PROBLEM INPUT            //                    INO  115
     1        32H NO. OF GAMMA GROUPS............ I4 /                  INO  116
     2        32H NO. OF NEUTRON GROUPS........... I4 /                INO  117
     3        32H NO. OF MATERIALS................ I4 /                 INO  118
     4        32H NO. OF COMPOSITIONS............ I4 /                  INO  119
     5        32H NO. OF DETECTORS................ I4 /                 INO  120
     6        32H NO. OF BOUNDARYS................ I4 /                 INO  121
     7        32H NO. OF REGIONS.................. I4 /                 INO  122
     8        32H NO. OF RESPONSES(GAMMA)........ I4 /                  INO  123
     9        32H NO. OF RESPONSES(NEUTRON)...... I4 /                  INO  124
     1        32H NO. OF RESPONSES(ALBERT-WELTON) I4 /                  INO  125
     1        32H NO. OF MATERIALS FROM LIBRARY.. I4 /)                 INO  126
      WRITE(6,1002) IGAM,(INPUT(I),I=1,3)                               INO  127
 1002 FORMAT(20H0CALCULATION OPTIONS              //                    INO  128
     1        32H  GAMMA RAY(0/NO,1/YES)......... I4 /                  INO  129
     2        32H  NEUTRON(0/NO,1/YES)........... /                    INO  130
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     3        32H    ALBERT-WELTON................ I4 /                    INO  131
     4        32H    MONOVARIANT MOMENTS.......... I4 /                    INO  132
     5        32H    BIVARIANT MOMENTS............ I4 /)                   INO  133
      WRITE(6,1003) ISUM,IOUT(1),IOUT(2)
 1003 FORMAT(14H0PRINT OPTIONS  //
     1        32H  SOURCE REGION SUMMATION            /
     2        32H   (0/NO,1/SUM,2/ST,3/GT)....... I4 /
     3        32H  INPUT PRINT(0/NO,1/CI,2/FULL). I4 /
     4        32H  OUTPUT PRINT                       /
     5        32H   (1/ST AND GT ONLY,2/ALL)..... I4 /)
      WRITE(6,1004) ISCP,IZSO,ISORC,ISRC,ISZC,ISTC                         INO  134
      WRITE(6,1006)LSO,MSO,(NSO(I),I=1,LSO)                                INO  135
 1004 FORMAT(27H0SOURCE CALCULATION OPTIONS      //                        INO  136
     1        32H  SOURCE ZONE COMPOSITION....... I4 /                     INO  137
     2        32H  MOST PROBABLE ZONE............ I4 /                     INO  138
     3        32H  SOURCE CALCULATION OPTION..... I4 /                     INO  139
     4        32H  RADIAL DISTRIBUTION........... I4 /                     INO  140
     5        32H  AXIAL OR POLAR DISTRIBUTION... I4 /                     INO  141
     6        32H  AZMUTHIAL DISTRIBUTION........ I4 /)                    INO  142
 1006 FORMAT(21H0SOURCE INTERVAL DATA            //                        INO  143
     7        32H  NO. OF RADIAL................. I4 /                     INO  144
     8        32H  NO. OF AXIAL(OR POLAR)........ I4 /                     INO  145
     9        32H  NO. OF AZMUTHIAL.............. 10I4/(32X,10I4))         INO  146
      WRITE(6,1008) ASOI(1),ASO(1),ASOI(2),ASO(2),XI(1),XI(2),ETA(1),ETAINO  147
     1(2)                                                                  INO  148
      IF(ISIT.GT.0) WRITE(6,1007) LSIT,MSIT
 1007 FORMAT(26H0SOURCE INTERPOLATION DATA  //
     1        32H  NO. OF RADIAL VALUES.......... I4 /
     2        32H  NO. OF AXIAL VALUES........... I4 /)
 1008 FORMAT(35H0SOURCE AND DISTRIBUTION PARAMETERS //                     INO  149
     1        35H  GAMMA RAY SOURCE(INPUT)..........1PE15.5/               INO  150
     2        18X                17H(NORMALIZED).....  E15.5/               INO  151
     3        35H  NEUTRON SOURCE(INPUT)............  E15.5/               INO  152
     4        16X              19H(NORMAIZED)........  E15.5/               INO  153
     5        35H  DISTRIBUTION PARAMETERS(XI(1))...  E15.5/               INO  154
     6        25X                        10H(XI(2))...  E15.5/               INO  155
     7        25X                        10H(ETA(1))..  E15.5/               INO  156
     8        25X                        10H(ETA(2))..  E15.5/)              INO  157
      WRITE(6,1010)                                                        INO  158
      WRITE(6,1012)                                                        INO  159
 1010 FORMAT(34H0SOURCE DISTRIBUTION DATA - RADIAL //)                     INO  160
 1012 FORMAT(3X3HPT.,7X10HCOORDINATE,14X9HGAMMA RAY,16X7HNEUTRON /         INO  161
     1        3X3HNO.,5X5HINPUT,7X8HMIDPOINT,2X,2(2X5HINPUT,7X10HNORMALIZINO  162
     2FD)//)                                                               INO  163
      DO 34 I=1,LSO                                                        INO  164
   34 WRITE(6,1014) I,RS(I),RSI(I),FSI(I,1,1),FS(I,1,1),FSI(I,1,2),FS(I,INO  165
     11,2)                                                                 INO  166
 1014 FORMAT(I6,3X,1P7E12.3)                                               INO  167
      LSOI = LSO+1                                                         INO  168
```

```
      WRITE(6,1016)(I,RS(I),FSI(I,1,1),FSI(I,1,2),I=LSOI,LSOI)          INO  169
 1016 FORMAT (I6,3X,1PE12.3,12X,E12.3,12X,E12.3)                        INO  170
      WRITE(6,1018)                                                     INO  171
      WRITE(6,1012)                                                     INO  172
 1018 FORMAT(42H0SOURCE DISTRIBUTION DATA - AXIAL OR POLAR //)          INO  173
      DO 36 I=1,MSO                                                     INO  174
   36 WRITE(6,1014) I,ZS(I),ZSI(I),FSI(I,2,1),FS(I,2,1),FSI(I,2,2),FS(I,INO  175
     12,2)                                                              INO  176
      MSOI = MSO + 1                                                    INO  177
      WRITE(6,1016)(I,ZS(I),FSI(I,2,1),FSI(I,2,2),I=MSOI,MSOI)          INO  178
      DO 40 J=1,LSO                                                     INO  179
      WRITE(6,1020) J                                                   INO  180
      WRITE(6,1012)                                                     INO  181
 1020 FORMAT(57H0SOURCE DISTRIBUTION DATA - AZMUTHIAL FOR RADIAL INTERVAINO  182
     1L I4 //)                                                          INO  183
      NSOI=NSO(J)                                                       INO  184
      L=J+2                                                             INO  185
      DO 38 I=1,NSOI                                                    INO  186
   38 WRITE(6,1014) I,PHI(I,J),PHII(I,J),FSI(I,L,1),FS(I,L,1),FSI(I,L,2)INO  187
     1,FS(I,L,2)                                                        INO  188
      NSOI = NSOI+1                                                     INO  189
      WRITE(6,1016)(I,PHI(I,J),FSI(I,L,1),FSI(I,L,2),I=NSOI,NSOI)       INO  190
      IF(ISTC.LE.1) GO TO 42                                            INO  191
   40 CONTINUE                                                          INO  192
   42 WRITE(6,1022)                                                     INO  193
      WRITE(6,1024)                                                     INO  194
 1022 FORMAT(24H0GAMMA RAY SPECTRAL DATA //)                            INO  195
 1024 FORMAT(33H GROUP        ENERGY       SPECTRAL / ,                INO  196
     1        6H   NO.,21X                4HDATA //)                    INO  197
      WRITE(6,1028)(K,ENG(K),GSOUR(K),K=1,NGG)                          INO  198
      WRITE(6,1026)                                                     INO  199
      WRITE(6,1024)                                                     INO  200
 1026 FORMAT(22H0NEUTRON SPECTRAL DATA  //)                             INO  201
      WRITE(6,1028)(K,ENN(K),NSOUR(K),K=1,NGN)                          INO  202
 1028 FORMAT(I6,3X,1P2E12.3)                                            INO  203
      WRITE(6,1030)                                                     INO  204
 1030 FORMAT(28H0ZONE BOUNDARY SPECIFACTIONS //12H ZONE  COMP.          INO  205
     16(12H BND.  ZONE )/)                                              INO  206
      DO 44 K=1,NREG                                                    INO  207
      KS=IABS(NBNDZN(K))                                                INO  208
   44 WRITE(6,1032) K,NCMPZN(K),(LBD(KP,K),NTRYZN(KP,K),KP=1,KS)        INO  209
 1032 FORMAT(14(1X,I4,1X))                                              INO  210
      WRITE(6,1034)                                                     INO  211
 1034 FORMAT(28H0BOUNDARY EQUATION CONSTANTS//18H BND. NO. AND TYPE,2X  INO  212
     12HA0,10X,2HX0,10X,2HB0,10X,2HY0,10X,2HC0,10X,2HZ0,10X,2HD0//)     INO  213
      DO 46 K = 1,NBOUND                                                INO  214
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   46 WRITE(6,1036) K,NEQBD(K), ABD(K),XOBD(K), BBD(K),YOBD(K), CBD(K),
     1 ZOBD(K),DBD(K)
 1036 FORMAT(2(I6,3X),1P8E12.3)
      DO 48 MS= 1,MAT,6
      MF = MS+ 6 - 1
      MF = MINO(MF,MAT)
      WRITE(6,1038)(MP,MP=MS,MF)
 1038 FORMAT(25H0COMPOSITIONS BY MATERIAL //
     2        10H COMP.     ,30X12HMATERIAL NO.  /
     3         9H   NO.     6(3X,I6,3X)//)
      DO 48 K = 1,NCOMP
   48 WRITE(6,1040) K,(COMP(M,K),M=MS,MF)
 1040 FORMAT(I6,3X,1P6E12.3)
      WRITE(6,1042)
 1042 FORMAT(27H0NEUTRON CROSS SECTION DATA //
     1        44H  MAT.          ALBERT-WELTON            MOMENTS  /
     2        44H   NO.        REMOVAL      ETA           REMOVAL  //)
      DO 50 M = 1,MAT
   50 WRITE(6,1014)M,(XSECN(M,K),K=1,3)
      WRITE(6,1044)(ALFA(MP),MP=1,7),XSNREF
 1044 FORMAT(34H0ALBERT-WELTON COEFF.,ALPHA(1)....1PE12.3/
     1                        21X,13H,ALPHA(2)....  E12.3/
     2                        21X,13H,ALPHA(3)....  E12.3/
     3                        21X,13H,ALPHA(4)....  E12.3/
     4                        21X,13H,ALPHA(5)....  E12.3/
     5                        21X,13H,ALPHA(6)....  E12.3/
     6                        21X,13H,ALPHA(7)....  E12.3//
     7        34H REFERENCE MATERIAL REMOVAL.......  E12.3/)
      DO 54 MS=1,MAT,6
      MF=MS+6-1
      MF=MINO(MF,MAT)
      WRITE(6,1046)(MP,MP=MS,MF)
 1046 FORMAT(35H0GAMMA RAY LINEAR ABSORPTION COEFF. //
     1                            40X,12HMATERIAL NO. //
     2        18H COMP.       ENERGY   /
     3        6H   NO.           12X,6(3X,I6,3X)/)
      DO 52 K=1,NGG
   52 WRITE(6,1014)K,ENG(K),(XSECG(K,M),M=MS,MF)
   54 CONTINUE
      WRITE(6,1048)
 1048 FORMAT(25H0GAMMA RAY BUILDUP COEFF. //
     1        18H GROUP       ENERGY  7X,2HB0,10X,2HB1,10X,2HB2,10X,2HB3/,
     2         6H   NO. )
      DO 56 K=1,NGG
   56 WRITE(6,1014)K,ENG(K),(BILD(J,K,1),J=1,4)
      WRITE(6,1050)
```

```
1050 FORMAT(36HOMONOVARIANT POLYNOMIAL MOMENTS DATA //                INO  261
    1        20H GROUP       ENERGY   4X,2HA0,10X,2HA1,10X,2HA2,10X,2HA3,INO  262
    210X,2HA4/6H   NO./)                                              INO  263
     DO 58 J=1,2                                                      INO  264
     DO 58 K=1,NGN                                                    INO  265
  58 WRITE(6,1014)K,ENN(K),(COM(I,K,J),I=1,5)                         INO  266
     WRITE(6,1052)                                                    INO  267
1052 FORMAT(36HOBIVARIANT POLYNOMIAL MOMENTS DATA   //                INO  268
    1        32H GROUP       ENERGY RANGE LIMITS  4X,2HC0,10X,2HC1,10X,2HINO  269
    2C2,10X,2HC3,10X,2HC4/                                            INO  270
    3        30H   NO.       UPPER        LOWER  /)                   INO  271
     DO 60 J=1,3                                                      INO  272
     J1=J+1                                                           INO  273
     KK=KORD(J)+1                                                     INO  274
     II=IORD(J)+1                                                     INO  275
     DO 60 K=1,KK                                                     INO  276
  60 WRITE(6,1014)J,BKP(J),BKP(J1), (CON(I,K,J),I=1,II)               INO  277
     WRITE(6,1054)(K,ENN(K),XLAM(K),K=1,NGN)                          INO  278
1054 FORMAT(38HOMOMENTS DATA EXTRAPOLATION PARAMETERS //              INO  279
    1        30H GROUP       ENERGY       LAMBDA  /                   INO  280
    2         6H   NO./(I6,3X,2E12.3))                                INO  281
     WRITE(6,1056)                                                    INO  282
1056 FORMAT(24HOGAMMA RAY RESPONSE DATA  //)                          INO  283
     DO 62 MS=1,NRSPG,5                                               INO  284
     MF=MS+5-1                                                        INO  285
     MF=MIN0(MF,NRSPG)                                                INO  286
     WRITE(6,1058)(MP,MP=MS,MF)                                       INO  287
     DO 62 K=1,NGG                                                    INO  288
  62 WRITE(6,1040) K,ENG(K),(RSPG(K,MP),MP=MS,MF)                     INO  289
1058 FORMAT(18H GROUP       ENERGY,14X,       17HRESPONSE FUNCTION /  INO  290
    2         6H   NO.,7X,I2,4(10X,I2))                               INO  291
     WRITE(6,1060)                                                    INO  292
1060 FORMAT(22HONEUTRON RESPONSE DATA  //)                            INO  293
     DO 64 MS=1,NRSPN,5                                               INO  294
     MF=MS+5-1                                                        INO  295
     MF=MIN0(MF,NRSPN)                                                INO  296
     WRITE(6,1058)(MP,MP=MS,MF)                                       INO  297
     DO 64 K=1,NGN                                                    INO  298
  64 WRITE(6,1040)K,ENN(K),(RSPN(K,MP),MP=MS,MF)                      INO  299
     WRITE(6,1062)                                                    INO  300
1062 FORMAT(28HOALBERT/WELTON RESPONSE DATA  //)                      INO  301
     DO 66 MS=1,NRSPA,5                                               INO  302
     MF=MS+5-1                                                        INO  303
     MF=MIN0(MF,NRSPA)                                                INO  304
     WRITE(6,1058)(MP,MP=MS,MF)                                       INO  305
     WON=1.0                                                          INO  306
```


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      DO 66 K=1,1                                                       INO  307
   66 WRITE(6,1040) K,WCN,(RSPA(K,MP),MP=MS,MF)                         INO  308
      WRITE(6,1064)                                                     INO  309
 1064 FORMAT(27H0RECEIVER POINT COORDINATES  //                         INO  310
     1         6H POINT          ,16X,11HCOORDINATES      /            INO  311
     2         6H   NO.  8X,1HR,     11X,1HZ,     11X,1HO )             INO  312
      WRITE(6,1066)                                                     INO  313
 1066 FORMAT(1H+,37X,1H-)                                               INO  314
      DO 68 K=1,NDET                                                    INO  315
   68 WRITE(6,1040)K,(RCORD(J,K),J=1,3)                                 INO  316
      WRITE(6,1068)(SSOT(J),J=1,3)                                      INO  317
 1068 FORMAT(37H0SOURCE POINT TRANSLATION COORDINATES //                INO  318
     1         9H  X......1PE12.3 /                                    INO  319
     2         9H  Y......  E12.3 /                                    INO  320
     3         9H  Z......  E12.3  )                                   INO  321
      WRITE(6,1070)                                                     INO  322
 1070 FORMAT(32H0LIBRARY MATERIAL ATOMIC NUMBERS  //                    INO  323
     1        18H  MAT.       ATOMIC  /                                INO  324
     2        18H   NO.       NUMBER   )                               INO  325
      DO 70 K=1,MATL                                                    INO  326
   70 WRITE(6,1040) K,ZAT(K)                                            INO  327
      WRITE(6,1072)  EPSLN,FUDGE,SMFP                                   INO  328
 1072 FORMAT(29H0MISCELLANEOUS DATA  //                                 INO  329
     1        29H BOUNDARY SEARCH EPSILON.....1PE12.3 /                INO  330
     2        29H BOUNDARY SEARCH PARAMETER...  E12.3 /                INO  331
     3        29H EMPIRICAL SOURCE SOLUTION            /               INO  332
     4        29H MEAN FREE PATHS.............  E12.3 / )              INO  333
      RETURN                                                            INO  334
      END                                                               INO  335
```


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```
$IBFTC POTS     NOLIST,  DECK,NODD,M94/2,XR7                    POT     1
      SUBROUTINE POUT(NAME)                                     POT     2
      DIMENSION NAME(14)                                        POT     3
      WRITE(6,1000)(NAME(I),I=1,14)                             POT     4
 1000 FORMAT(10X,14A4)                                          POT     5
      RETURN                                                    POT     6
      END                                                       POT     7
$ENTRY
$DATA
```


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