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METHODS FOR CALCULATING FAST-NEUTRON LEAKAGE FROM THE SNAP-TSF REACTOR AND PRELIMINARY RESULTS

R. S. Hubner

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METHODS FOR CALCULATING FAST-NEUTRON LEAKAGE FROM THE SNAP-TSF REACTOR AND PRELIMINARY RESULTS*

R. S. Hubner**

OCTOBER 1967

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**On assignment from Atomics International.

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METHODS FOR CALCULATING FAST-NEUTRON LEAKAGE FROM THE SNAP-TSF REACTOR AND PRELIMINARY RESULTS

R. S. Hubner

ABSTRACT

The O5R Monte Carlo code and associated analysis codes were modified for use in the analyses of the ORNL SNAP-TSF experiments on the leakage of fast neutrons from a SNAP reactor. The reactor geometry is given in great detail. Anisotropic elastic scattering, beryllium (n,2n) reactions, and inelastic scattering processes are treated thoroughly. Importance information obtained from adjoint S_n calculations was used to construct biased distributions in O5R for the selection of source neutron parameters and of neutron track lengths between reactions. Input instructions and listings for programs and subroutines that were developed are given in the appendices; flow diagrams for certain routines are also given. Power distributions, angular leakage flux, and fluxes viewed by collimated detectors were calculated for some preliminary analyses; O5R source neutron tapes for subsequent O5R calculations on the penetration of neutrons through a SNAP-2 shield were prepared. Requirements for the final analyses are given.

INTRODUCTION

A SNAP-TSF program is being conducted at Oak Ridge National Laboratory which will determine, experimentally and analytically, leakage of fast neutrons from a SNAP-10A reactor and their transmission through a SNAP-2 shield. The proposed experimental program includes measuring the neutron angular leakage spectra from the bottom face of the reactor with a tightly collimated detector, determining the fast-neutron doses transmitted through a SNAP-2 shield with the SNAP-10A reactor used as the source, and, possibly, studying the transmitted doses from scatter sources outside the shield shadow.

The analyses of these experiments require not only an adequate transport model which adequately handles anisotropic elastic scattering, inelastic scattering, and n,2n reactions but also some way of describing the geometry in three dimensions and in great detail. Monte Carlo methods are easily adapted to these requirements and offer the best available means of doing the work. Problems arise, however, in minimizing computer time or, in other words, extracting as much information as possible from each neutron history so as to process fewer histories. This can be achieved to some degree by using biased distributions in selecting source neutrons and in governing their paths. The biased distributions can be constructed, in principle, if the importance of the neutrons to the desired answer is known as a function of energy, direction, and position. Results of adjoint S_n calculations can be interpreted as importance functions.[1]

The O5R Monte Carlo neutron transport code[2] was selected for the analysis of the SNAP-TSF experiments. It has the above advantages and has had much successful use at ORNL. Adjoint S_n calculations performed with ANISN[3] were used to provide importance functions from which biased distributions were determined.

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[1] R. R. Coveyou, V. R. Cain, and K. J. Yost, "Adjoint and Importance in Monte Carlo Application," Nucl. Sci. Eng. 27, 219 (1967).

[2] D. C. Irving et al., O5R, A General-Purpose Monte Carlo Neutron Transport Code, ORNL-3662 (1965).

[3] W. W. Engle, Jr., A User's Manual for ANISN, A One-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering, K-1693 (1967).

Since the 05R program must be modified for the user's particular problem and since it provides only a collision tape* as output, several programs and subroutines were written to assist in providing input and source description and in analyzing the output. The analytical work reported here involved the development of these machine programs for the CDC 1604A computer and some preliminary calculations using the programs.

There were two separate problems to be analyzed for the SNAP-TSF reactor. The first (referred to later as the shield source problem) was to determine the total leakage neutron angular flux spectra to be used as a source in subsequent 05R calculations of neutron penetration in the SNAP-2 shield. The second (referred to later as the core mapping problem) was to determine the angular flux spectra to be measured by collimated detectors viewing small fractions of the bottom face of the reactor. Each of these problems required different biasing in order to achieve good statistics for a reasonable running time.

The 05R source selection subroutines[4] required that the axial and radial source distributions be separable. A special 05R calculation was made to determine this source distribution.

For the particular SNAP-10A configuration used (which had the control drums in) the leakage angular distribution, spectra, and spatial distribution were determined. As in the proposed core-mapping experiments, the spectra at several collimated detectors were calculated assuming perfect collimation. The leakage source for subsequent calculations of neutron penetration in a SNAP-2 shield was determined.

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*A collision tape contains a variety of neutron parameters for any or all of such events as source, collision, escape from system, etc.

[4] L. G. Mooney, A Cylindrical Volume Source Routine for the 05R Monte Carlo Code, RRA-T53 (June 30, 1965).

I. SNAP-TSF REACTOR MODEL FOR O5R

Reactor Description

The O5R program that was developed for the CDC-1604A computer differed from the usual program in that the 8-medium and 8-scatter limitation was relaxed to accept 16 media and 16 scatterers. The dimensions, atomic densities, and materials on which the geometric and material model for the SNAP-TSF reactor was based are given elsewhere.[5-8] An axial cross section of the reactor as it was described for the O5R geometry input is shown in Fig. 1. Figure 2 shows a cross section through the core perpendicular to the axial direction (Z direction) with the control drums in; the surface numbers are circled and placed on the positive sides of the surfaces. For the position of the drums out, additional blocks and surfaces were required as shown in Fig. 3. Zones were defined by Z = constant planes; the zone boundaries are given in Table 1. Note that the direction from top to bottom of the reactor is positive.

O5R geometry description allows any boundary within the system to be a plane or a quadratic surface with any orientation. Table 2 lists the surfaces required in the SNAP-TSF reactor with the control drums rotated in. For the drums-out configuration the same surfaces were used that are given in Table 2; however, the location zone number was different and can be found in Table 1. To describe the drums, the region between -35.1150 and -4.0 cm was divided into three zones, numbered 3, 4, and 5. Zone 4 contained the drums and had four different surfaces; for this configuration surface 8 is described by

$$X(\cos\theta + \sin\theta) + Y(\cos\theta - \sin\theta) + 29.038 \cos\theta + 0.122 \sin\theta - 5.5124 = 0,$$

---

[5] A. R. Dayes, II, SNAP 10A/2 Nuclear Calculational Model, NAA-SR-MEMO-9248 (Nov. 22, 1963) (Secret RD).

[6] Fuels Quality Control Group, SNAPTRAN V Core-Fuel Element Data Packages, NAA-SR-MEMO-9946 (May 14, 1964) (Secret RD).

[7] A. R. Fallon, Atomics International, internal letter to E. J. Donovan (Aug. 30, 1965).

[8] Atomics International Drawings 7670-12002 through 7670-12007, 7670-11034, 7670-11039, 10FS-16002, 10FS-11012, 10FSM2-15002 through 10FSM2-15005, 7611-18001, 7611-18002, and 7580-18010 through 7580-18035.

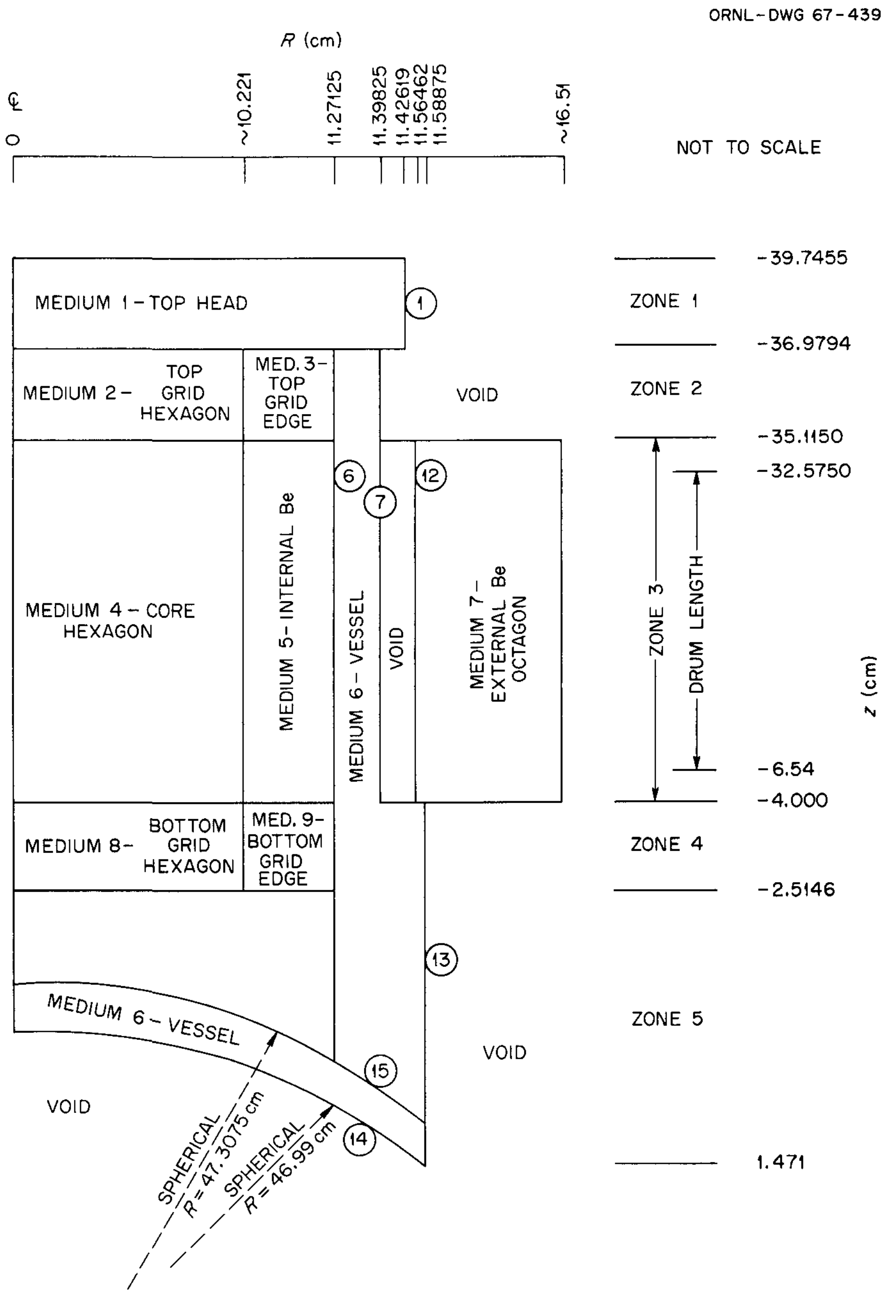

Fig. 1. Axial Geometry of SNAP-TSF Model.

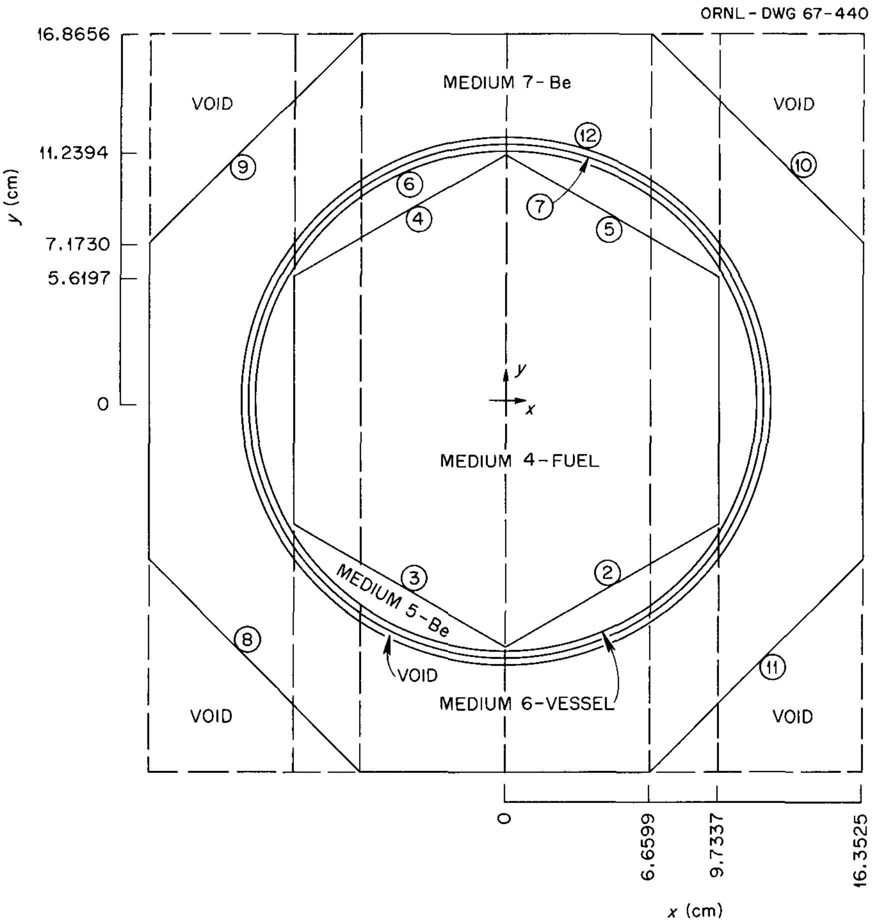

Fig. 2. X,Y Cross Section of Core Zone of SNAP-TSF Reactor Model, Drums In. Dashed lines indicate block boundaries.

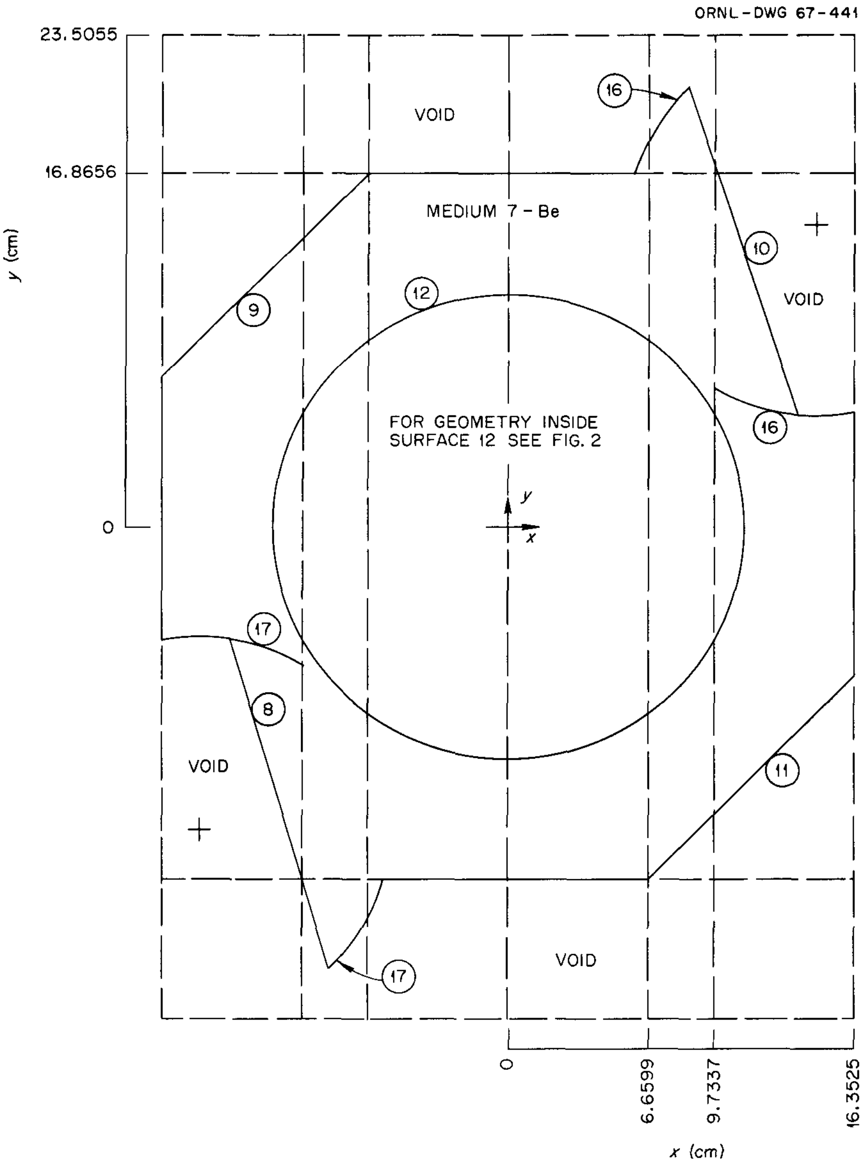

Fig. 3. X,Y Cross Section of Core Zone of SNAP-TSF Reactor Model, Drums at 30 deg.

Table 1. O5R Axial Zone Boundaries

Drums In		Drums Out		
Zone Number	Lower Z Boundary (cm)	Zone Number	Lower Z Boundary (cm)	Description
1	-39.7455	1	-39.7455	Top head
2	-36.9794	2	-36.9794	Top grid and vessel
3	-35.1150	3	-35.1150	Core and stationary reflectors
		4	-32.5750	Core, reflectors, and drums
		5	- 6.54	Core and stationary reflectors
4	- 4.0	6	- 4.0	Bottom grid and vessel
5	- 2.5146	7	- 2.5146	Bottom NaK and bottom vessel
	1.4710		1.4710	(Upper boundary)

Table 2. 05R Surfaces, Drums In

Surface Number	Description	Equation (cm units)	Location, Zone Number
1	Cylindrical top head boundary	$X^2 + Y^2 - 130.55782 = 0$	1
2	Hexagonal core and grid boundaries (planes)	$X - 1.73205Y - 19.4672 = 0$	2,3,4
3		$X + 1.73205Y + 19.4672 = 0$	2,3,4
4		$X - 1.73205Y + 19.4672 = 0$	2,3,4
5		$X + 1.73205Y - 19.4672 = 0$	2,3,4
6	Vessel inner cylinder	$X^2 + Y^2 - 127.04108 = 0$	2,3,4,5
7	Vessel outer cylinder (see also surface 13)	$X^2 + Y^2 - 129.92010 = 0$	2,3
8	Octagonal external reflector boundaries (planes)	$X + Y + 23.52820 = 0$	3
9		$X - Y + 23.52820 = 0$	3
10		$X + Y - 23.52820 = 0$	3
11		$X - Y - 23.52820 = 0$	3
12	External reflector inner cylindrical boundary	$X^2 + Y^2 - 133.74044 = 0$	3
13	Vessel outer cylinder	$X^2 + Y^2 - 134.29913 = 0$	4,5
14	Vessel bottom, exterior (sphere)	$X^2 + Y^2 + Z^2 - 93.98Z = 0$	5
15	Vessel bottom, internal (sphere)	$X^2 + Y^2 + Z^2 - 93.98Z - 29.93946 = 0$	5

and surface 10 by

$$X(\cos\theta + \sin\theta) + Y(\cos\theta - \sin\theta) - 29.038 \cos\theta - 0.122 \sin\theta + 5.5124 = 0 \quad ,$$

where θ was the drum rotation angle. The drum cylinder surfaces were added; the equations were

$$X^2 + Y^2 - 29.16X - 28.916Y + 339.7529 = 0$$

for surface 16 and

$$X^2 + Y^2 + 29.16X + 28.916Y + 339.7529 = 0$$

for surface number 17. Surfaces 18 and 19 were added to describe the original surfaces 8 and 10 in zones 3 and 5.

The media used in the 05R description of the reactor are given in Table 3 along with the atomic densities used in each medium. In the Code 6 input for the system data tape (CODE 6) for each medium, the atomic density for the "other" entry in the element column was added to the atomic density of the element with the asterisk.

The 05R input for subroutine GEOM is given in Appendix A for the drums-in configuration and in Appendix B for the drums rotated out 30° ($\theta = 30°$).

05R System Data Tape - CODE 6

The parameters and probabilities required by 05R for the running of a problem are obtained from a data tape prepared by CODE 6 (ref. 2). The 05R master cross-section library, along with the CODE 6 input - element identification, cross section identification, atomic densities, and number of subgroups per super group for each medium - is processed, and the 05R system data tape is written. Appendix C lists the CODE 6 input for the 05R system data tape used in all 05R runs on the SNAP-TSF reactor. The energy range was from 18 MeV to 0.4 eV. Sixty-four subgroups per supergroup were used for all media.

Table 3. 05R Media and Atomic Densities

05R Medium Number	Description	Element	Atomic Density (atoms/barn·cm)
1	Top head Type 321 stainless steel, NaK	Ni	0.006469
		Fe*	0.04401
		Cr	0.01252
		Na	0.001247
		K	0.002600
		Other	0.00323
2	Top grid hexagon Type 316 stainless steel, Hastelloy N, NaK	Ni*	0.01881
		Fe	0.00747
		Cr	0.00373
		Na	0.003006
		K	0.006267
		Other	0.00335
3	Top grid edge Type 316 stainless steel, René 41, NaK	Ni	0.004786
		Fe*	0.009797
		Cr	0.003964
		Na	0.003750
		K	0.007818
		Other	0.00237
4	Core hexagon Fuel, Be, Hastelloy N, NaK	$^{235}\mathrm{U}$	0.0010964
		$^{238}\mathrm{U}$	0.00008247
		H	0.049956
		Zr	0.02715
		Be	0.008147
		Ni*	0.002646
		Na	0.0005311
		K	0.001107
		Other	0.000989
5	Internal Be reflector Be, NaK	Be	0.11348
		Na	0.0002742
		K	0.0005717
6	Vessel Type 321 stainless steel	Ni	0.008651
		Fe*	0.05885
		Cr	0.01674
		Other	0.004309
7	External Be reflector	Be	0.12014

Table 3 (cont.)

05R Medium Number	Description	Element	Atomic Density (atoms/barn.cm)
8	Bottom grid hexagon Type 316 stainless steel, Hastelloy N, NaK	Ni	0.01093
		Fe*	0.01574
		Cr	0.005163
		Na	0.002967
		K	0.006186
		Other	0.002527
9	Bottom grid edge Type 316 stainless steel, NaK	Ni	0.006740
		Fe*	0.03666
		Cr	0.01027
		Na	0.001712
		K	0.003570
		Other	0.00295
10	Bottom NaK NaK	Na	0.004945
		K	0.010310

*See text.

In 05R each type of reaction is treated as a separate scattering type; thus elastic scatter, inelastic scatter, and n,2n reactions in a given element would be treated as three separate scatterers. As listed in Appendix C, each element generally appears twice in a given medium, once for elastic scatter and once for inelastic scatter; exceptions are hydrogen, which has only elastic scatter; ^{238}U, for which inelastic scatter was ignored; beryllium, in which inelastic scatter was replaced by the n,2n reaction; and zirconium, which has three entries in the core medium. For zirconium the third entry (the n,2n reaction) was a dummy entry and was treated the same as the second entry (inelastic scatter).

In addition, the f_1 coefficients for elastic scatter for all elements except hydrogen were written on the 05R system data tape; the f_1 coefficients for beryllium n,2n reactions were also written on the tape. These are the coefficients for the P_1 term in the Legendre polynomial expansion of the angular scattering distributions.

Phi Tape, Anisotropic Angular Scattering - CODE 8

The master cross-section library contained the coefficients for the expansion of anisotropic angular elastic scattering distributions in Legendre polynomials. For the elements excluding hydrogen used in the SNAP-TSF reactor the order of the expansion was P_8 except for zirconium and the isotopes of uranium, for which it was P_6 and P_{14} respectively; hydrogen elastic scattering was isotropic in the center-of-mass system. 05R used these distributions for the selection of the cosine of the angle of scatter for an elastic reaction. The parameters required for this selection were prepared by CODE 8 (ref. 2) and written on the phi tape. Appendix C lists the CODE 8 input for the phi tape used in all the 05R runs on the SNAP-TSF reactor except the fission distribution run. P_1 scattering was used for the fission distribution calculation; the data, the f_1 coefficients, were obtained from the 05R system data tape.

Thermal Parameters

The thermal neutron option used in the O5R calculation of the SNAP-TSF fission distribution was the one-velocity treatment. Thermal cross sections for the O5R input were obtained from the program QUICKIE;[9] the spectrum was calculated at 700°F.[10] The averaged thermal microscopic cross sections for the elements in the SNAP-10A reactor are given in Table 4. Table 5 lists the macroscopic cross sections for each medium.

O5R Input

For the fission distribution calculation the energy below which neutrons were considered to be in the one-velocity thermal group, EBOT, was 0.4 eV; NTHRML was equal to 1. The LF1 parameters were positive for elastic scattering in order to pick the f_1's from the system data tape and to use the anisotropic distribution function $P(\mu) = (1 + 3f_1\mu)/2$ for the selection of μ, the cosine of the elastic scattering angle. The LF1's were zero for all inelastic scatter and for elastic scatter in hydrogen in order to select μ from an isotropic distribution function in the center-of-mass system. Neutrons with weights below 0.005 were subjected to Russian roulette, with the surviving neutrons given the weight 0.1. The purpose of this procedure was to decrease the time spent in following thermal neutrons. The O5R input for this problem is listed in Appendix D.

The items of interest written on the collision tape were the collision coordinates and the fission weight at each collision point.

For the shield source and core-mapping O5R calculations, the energy below which neutrons were ignored, EBOT, was 0.1 MeV; NTHRML was equal to 0. The LF1 parameters were negative for elastic scattering in order to pick the cosine of the elastic scattering angle from the Legendre polynomial expansion of the anisotropic scattering distribution; the constants were obtained from the phi tape. The LF1's were zero for all inelastic

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[9] M. Boling and W. Rhoades, QUICKIE - A Computer Program for Spatially Independent Multigroup Slowing Down and Thermalization Calculations, NAA-SR-9233 (Apr. 15, 1964).

[10] W. B. Green, Atomics International, private communication.

Table 4. Thermal Microscopic Cross Sections for the SNAP-10A Reactor at 700°F from Program QUICKIE

Element	σ_a (barns)	σ_s (barns)	$\nu\sigma_f$ (barns)
^{235}U	334.28	10.0	690.95
^{238}U	1.583	8.3	0
H	0.17705	59.352	0
Zr	0.09865	6.242	0
Be	0.005337	5.91	0
Ni	2.453	17.5	0
Fe	1.397	10.87	0
Na	0.27998	3.28	0
K	1.104	2.16	0
Mn*	7.305	2.3	0
Cr	1.617	4.23	0
Mo	1.44	5.87	0
B	402.62	3.7	0
Co*	21.03	7.0	0
C	0.002	4.76	0
O	0.0001054	3.86	0

*Maxwell-Boltzmann averaged at 800°F; not from QUICKIE.

Table 5. Thermal Macroscopic Parameters for Each Medium in the SNAP-10A Reactor

Medium Number	Thermal Mean Free Path, $1/\Sigma_T$ (cm)	Thermal Nonabsorption Probability, Σ_s/Σ_T	Average Fission Neutrons per Collision, $\nu\Sigma_f/\Sigma_T$
1	1.3025	0.85613	0
2	1.8396	0.85789	0
3	3.2821	0.80416	0
4	0.27432	0.89166	0.20781
5	1.4834	0.99806	0
6	0.99001	0.85730	0
7	1.40713	0.99909	0
8	2.0463	0.85440	0
9	1.4738	0.85558	0
10	19.5099	0.75092	0

scatter and for elastic scatter in hydrogen in order to select the cosine of the scattering angle from an isotropic distribution function in the center-of-mass system. Russian roulette was not used. The O5R input for these problems is listed in Appendix D.

For the shield source problem the items of interest written on the collision tape were the coordinates, weight, energy, and direction for neutrons escaping from the system. For the core-mapping problem the same parameters were of interest not only for escapes but also for source and collision points; additional parameters required by program ACTIFK (described in a later section) were included.

O5R User Subroutines

In O5R a variety of subroutines must be written for the user's particular problem. These include subroutine SOURCE for the selection of source neutron coordinates, direction, and energy, subroutine NONELAS to control the treatment of inelastic scattering, and subroutine GETETA which governs the selection of track length between reactions in the system.

In the following discussion the programming pertains to the shield source and core-mapping problems. The special case for the fission distribution calculation used the subroutine NONELAS, which allowed only the evaporation model for the treatment of inelastic scattering, and used the regular subroutine GETETA (ref. 2) for track length selection. Subroutine SOURCE for the fission distribution problem was the same as in the following discussion; however, the biasing options were not used.

Source Routines

The neutron source description for O5R allowed the selection of neutron coordinates from a hexagonal volume as in the SNAP-10A core. The power distribution governing this selection was assumed to be separable in the radial and axial directions. Source neutron direction and energy were selected from an isotropic distribution and the ^{235}U fission spectrum respectively. To enhance the desired quantity to be calculated, biasing schemes favoring source neutrons which make important contributions to the answer were available.

The source routine consisted of several subroutines written by Mooney.[4] Subroutine SOURCE was the control routine, with subroutine DATAIN supplying source input data, subroutine SPACE selecting source neutron coordinates, and subroutine VECTOR selecting source neutron directions. Subroutines FISESN and FISSN[11] were written for the selection of source neutron energy. Subroutines SOURCE, DATAIN, SPACE, and VECTOR were modified to suit the requirements of the problems. Listings of all these subroutines may be found in Appendix E. Data input sheets are given in Appendix F.

The selection of source neutron coordinates occurred in subroutine SPACE. Source neutrons were picked from a circular area circumscribing the hexagonal core boundaries. A rejection technique was used to eliminate source neutrons from the area outside the hexagonal core.

If the biasing option was omitted, the coordinates were selected from the normalized cumulative power distributions $I_1(r)$ and $I_2(z)$; thus, if η_i is a random number and R and Z are the random values to be selected, then

$$\eta_1 = I_1(R)$$

$$\eta_2 = I_2(Z) \quad ,$$

where

$$I_1(R) = \int_0^R r\, P_1(r)\, dr \quad ,$$

$$I_2(Z) = \int_{Z_L}^{Z} P_2(z)\, dz \quad ,$$

$$\int_0^{R_n} r\, P_1(r)\, dr = 1 \quad ,$$

$$\int_{Z_L}^{Z_U} P_2(z)\, dz = 1 \quad ,$$

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[11] E. A. Straker, Oak Ridge National Laboratory, private communication.

Z_L = lower z boundary of core,

Z_U = upper z boundary of core,

R_n = radius of core,

P_1 and P_2 = power distributions, radial and axial respectively (normalized).

Values of R and Z were obtained using tabulated values of $I_1(r)$ and $I_2(z)$ with r^2 interpolation for $I_1(r)$ and linear interpolation for $I_2(z)$.

In the biasing option, the biased distributions were controlled by the r and z interval size. Source neutrons were selected from each interval with equal probability. The biased distributions, $P_{B1}(r)$ and $P_{B2}(z)$, were calculated in subroutine DATAIN using the input interval sizes; these distributions were histograms, constant over each interval. The input actual distributions, $P_1(r)$ and $P_2(z)$, were linear in each interval. A source neutron with selected coordinates R and Z had its weight adjusted by the factor

$$\frac{P_1(R)\ P_2(Z)}{P_{B1}(R)\ P_{B2}(Z)} \ .$$

When using biased distributions combined with rejection techniques, the total weight assigned to all source neutrons will be in error by a constant factor. The final answer in units per source neutron will not contain this error; however, in order to make all intermediate calculations correct, the constant was calculated in subroutine DATAIN and applied to the probability distributions.

The selection of source neutron direction occurred in subroutine VECTOR. The actual source neutron direction distribution was assumed to be isotropic, and when biasing was not used, the direction cosines were obtained by calling subroutine GTISO(U,V,W).[2]

For source neutron directions, the cosine of the polar angle measured from the z axis, γ, also can be selected from a biased distribution. Again the biased distribution is controlled by the interval size, values of γ being selected from each interval with equal probability. The resulting biased distribution, $P_B(\gamma)$, is constant over each interval, and its magnitude is a function of the interval size. If N is the number of intervals, then

$$P_B(\gamma) = \frac{1}{N(\gamma_2 - \gamma_1)} \quad \text{for } \gamma_1 < \gamma < \gamma_2 \quad .$$

The real distribution, $P(\gamma)$, was taken to be isotropic; that is, $P(\gamma) = 1/2$. The weight correction factor is given by

$$\frac{P(\gamma)}{P_B(\gamma)} = \frac{N(\gamma_2 - \gamma_1)}{2} \quad \text{for } \gamma_1 < \gamma < \gamma_2 \quad .$$

The selection of source neutron energy occurred in subroutine FISESN.[11] The spectrum used in all calculations was the fission spectrum for ^{235}U. COMMON data for this spectrum were contained in subroutine FISSN.

Biasing in FISESN was achieved by dividing the energy range into several groups and specifying the probability for energy selection in each group. Within a group the selection was from the spectrum as defined in that energy interval. Since the biasing parameters were to be obtained from adjoint S_n calculations, the group structure for FISESN was taken from the structure used in the adjoint S_n problems.

Input parameters for FISESN were read by subroutine SOURCE, Appendix F.

Inelastic Routines

In a more recent version of O5R[12] the treatment used for inelastic scattering is controlled by subroutine NONELAS. When an inelastic event occurs, NONELAS selects the appropriate subroutine to use based on medium and scatterer index. The NONELAS listing is given in Appendix H.

For the SNAP-TSF reactor two inelastic routines were used. The first was subroutine INELAS.[12] This routine gave a discrete level inelastic

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[12] F. B. K. Kam, Oak Ridge National Laboratory, private communication.

scatter treatment. As many levels as are known may be used. For energies above a cutoff energy, EHI, the evaporation model was substituted. Table 6 lists the level energies along with EHI for each of the inelastic scatterers. Absent from the table are ^{238}U whose inelastic scattering was ignored, Be, which was treated in a different subroutine, and H, which has no inelastic scattering. Level energies and excitation probabilities were processed by program NNPCOM[13] (see Appendix G for the program listing and input instructions) to provide COMMON data for use in INELAS.

The second inelastic routine was subroutine BEN2N[14] (see Appendix H for the listing). This routine treated the n,2n reaction in beryllium. Half the reactions used the discrete level model with a level energy of 2.46 MeV; in the remaining reactions the scattered neutron was given the energy 0.79 MeV in the center-of-mass system. The neutron weight was doubled for each reaction.

In all cases inelastic scattering was assumed to be isotropic in the center-of-mass system.

Track Length Selection

Selection of the neutron track length between reactions took place in subroutine GETETA.[2] This routine was rewritten in order to include the exponential transform[15] for the selection of biased track lengths. This method attempts to stretch the track lengths for favorable directions and to contract track lengths for unfavorable directions; thus, neutrons are pushed to regions of high importance. In the leakage from the reactor bottom, the favorable direction was the +Z direction.

Instead of selecting track lengths, ℓ, from the distribution $e^{-\Sigma_T \ell}$, the distribution $\frac{1}{B} e^{-\Sigma_T/\ell B}$ was used, where Σ_T = total macroscopic cross section; $B = 1/[1 - \gamma \cdot (\mathrm{XNU})]$; but if $B < 0.6$, it is set equal to 0.6; γ = Z direction cosine; $(\mathrm{XNU}) = \lambda/\Sigma_T$. The parameter λ can be determined only if the spatial rate of change of the importance of neutrons is known. The slope of the adjoint S_n flux as a function of Z was a measure of this rate of change. For all 05R calculations on the neutron leakage from the bottom of the reactor, this slope was used for λ.

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[13] K. D. Franz, ORNL, private communication.

[14] F. B. K. Kam, ORNL, private communication.

[15] F. H. Clark, The Exponential Transform as an Importance-Sampling Device, A Review, ORNL-RSIC-14 (Jan. 1966).

Table 6. Inelastic Scatter Level Data

Element	Level Energy (Negative Values) (MeV)	EHI (MeV)
Na	0.44 2.08 2.39 2.64 2.71	2.97
K	2.52 2.81 3.05 3.59	3.96
Cr	1.43 2.37	5.50
Fe	0.845 2.09 2.66 2.95 3.01 3.38	4.91
Ni	1.45 2.46	5.0
Zr	0.94	2.0
^{235}U	None	0.0

When selecting track lengths from the above distribution, a weight adjustment must be made. If W_0 was the original neutron weight, then the new weight, W, was

$$W = W_0 \, B \, e^{-\Sigma_r \ell [1-(1/B)]} \quad .$$

Since the weight recorded on the O5R collision tape for an escaping neutron is the old weight, a small change to O5R subroutine BANKR was necessary; the parameter OLDWT was multiplied by the factor $B \, e^{-\Sigma_T \ell [1-(1/B)]}$. This factor, called GLOP, was placed in COMMON.

The listing for subroutine GETETA is found in Appendix I. Input parameters for GETETA are read by subroutine SOURCE, Appendix F.

II. FISSION DISTRIBUTION IN THE SNAP-TSF REACTOR

The more efficient use of O5R for shielding calculations requires that the source distribution be specified and used for all batches of neutrons; thus the neutron thermalization problem can be ignored and neutrons with energies below a cutoff energy can be terminated. The O5R neutron source selection subroutines written for the SNAP-TSF reactor leakage calculation assumed that the source distribution (fission distribution) was separable and that axial and radial distributions would be supplied. A confirmation of separability and a determination of the distributions required that O5R be used in a complete reactor calculation involving neutron thermalization.

O5R Calculation

A special O5R calculation was done to determine the fission distribution for the SNAP-TSF core in the drums-in configuration. Neutrons were allowed to degrade to 0.4 eV; neutrons below 0.4 eV were placed in a one-velocity thermal group. Thermal cross sections were obtained from program QUICKIE.[9] Fissioning was allowed.

Several simplifications were used to conserve machine time: only the evaporation model was used for inelastic scattering, the f_1 treatment of anisotropic elastic scattering was used, there was no neutron source biasing nor track stretching, and Russian roulette was used to kill neutrons whose weights fell below a specified value.

An initial source guess was used for the first batch of neutrons; 05R then calculated the source for each succeeding batch from the information acquired during the previous batch. Fourteen batches of 800 neutrons each were run. The fission weight produced at each collision point was written on the collision tape. Seven collision tapes were required.

The multiplication constant and its standard deviation were calculated using the average values from the last 9 batches. Its value was 1.029 ± 0.011.

Fission Distribution Analysis

An analysis program, ANALYSIS, was written to read the collision tapes and accumulate the fission weights in axial and radial bins and print out the resulting fission distributions with their standard deviations. A listing of the program can be found in Appendix J; input instructions are in Appendix K, along with input listings for the SNAP-TSF drums-in configuration.

The axial and radial bin specifications that were used in the fission distribution analysis for the SNAP-TSF reactor were too fine; that is, the interval sizes were too small. The result was that the standard deviations were large and histogram plots of the fission distributions were irregular. Program POWPOW was written to eliminate this statistical fluctuation without sacrificing the ability to have a well-defined distribution (small interval size). It averaged the axial distributions over larger radial intervals, and averaged the radial distributions over larger axial intervals. Since the radial distributions were averaged over the polar angle, the values near the hexagonal core boundaries required some adjustment so that they could be used in the 05R source routine (SOURCE). POWPOW performed this adjustment by multiplying the fission distribution by the ratio of the radial area increment to the hexagonal core area within the radial increment. POWPOW listings are in Appendix J; input instructions are in Appendix K.

Plots of the fission distribution obtained from POWPOW appear in Figs. 4 through 9. Both axial and radial distributions had a cosine shape. The curvature of the distributions indicated separability in the axial and radial directions.

A cosine fitting program[16] using the function A cos Bx and the method of least squares was used to fit the fission distributions. The results are given in Table 7, with the data plotted in the figure indicated.

After examination of Table 7 the following equations were selected to represent the power distributions in the SNAP-TSF reactor:

$$P(z) = 0.0445 \cos 0.0869 z \quad ,$$

$$P(r) = 0.0104 \cos 0.0896 r \quad ,$$

where P(z) and P(r) were proportional to the axial and radial power distributions respectively. These "smoothed" distributions were used as the actual source distributions in all the remaining O5R runs on the SNAP-TSF reactor (drums-in configuration).

III. NEUTRON LEAKAGE FROM THE SNAP-TSF REACTOR

The O5R calculations of neutron leakage from the SNAP-TSF reactor employed several biasing schemes which increased the number of neutrons making important contributions to the desired quantity. Thus better statistics resulted and fewer neutrons were processed with a saving of calculation time.

For the SNAP-TSF reactor and the SNAP-2 shield system, fair biasing parameters were available from past experience; however, systematic techniques for calculating biasing parameters that are close to optimum have been studied,[1] and it was felt that use of these techniques would be helpful in this investigation. The procedure assumes that an approximate solution to the equation adjoint to the original transport equation is available. This solution would represent the importance of a neutron at each point in phase space, which would then be used to obtain parameters for the biasing techniques. Since the adjoint equation in its complete form is as difficult to solve as the original equation, the adjoint

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[16] M. H. Lietzke, A Generalized Least Squares Program for the IBM-7090 Computer, ORNL-3259 (Mar. 21, 1962).

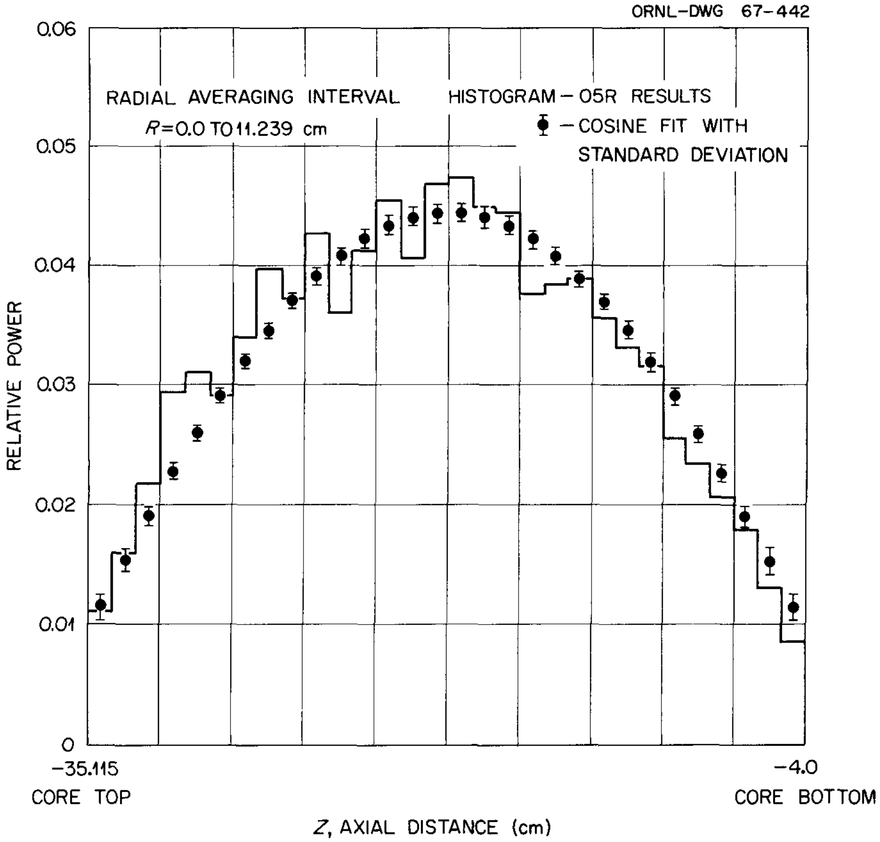

Fig. 4. Axial Relative Power (R = 0.0 to 11.239 cm).

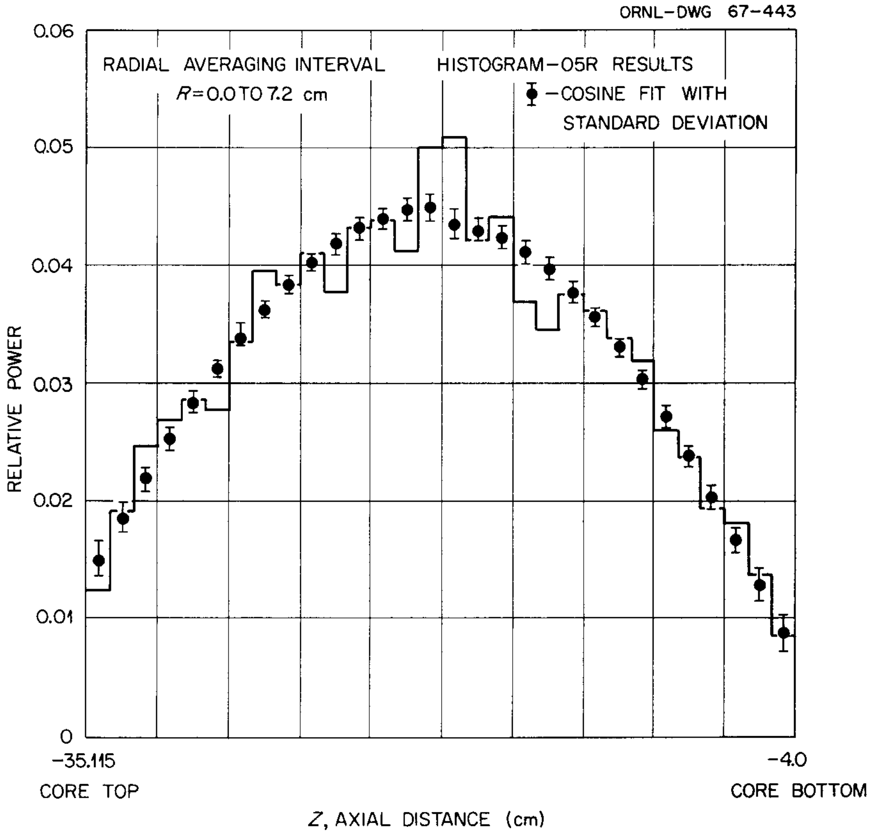

Fig. 5. Axial Relative Power (R = 0.0 to 7.2 cm).

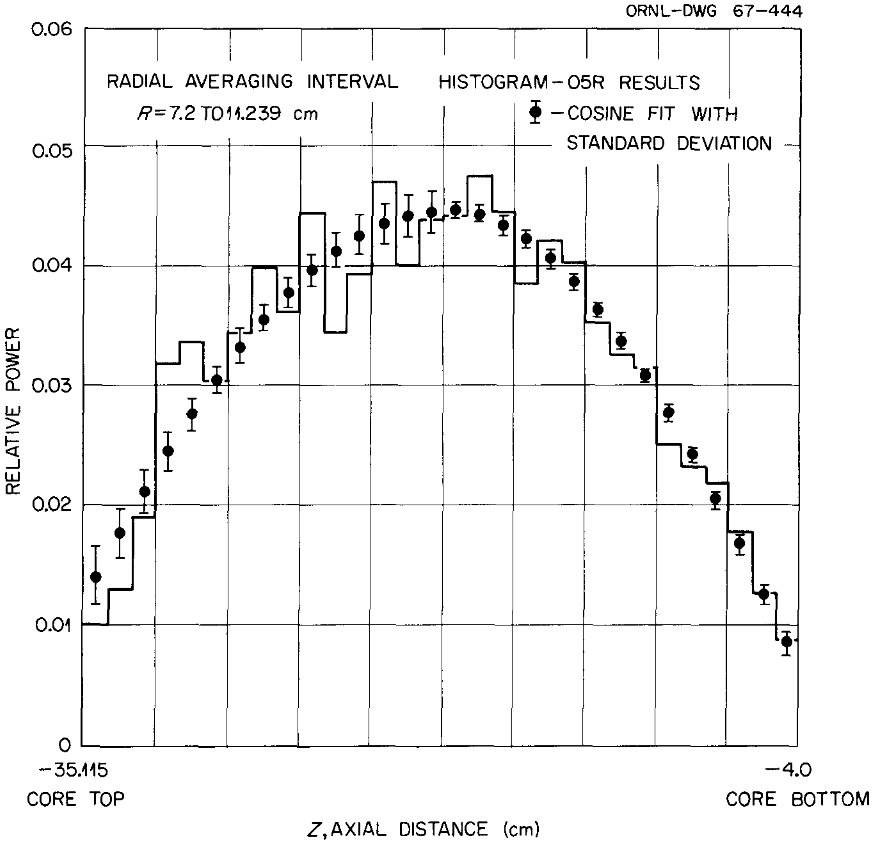

Fig. 6. Axial Relative Power (R = 7.2 to 11.239 cm).

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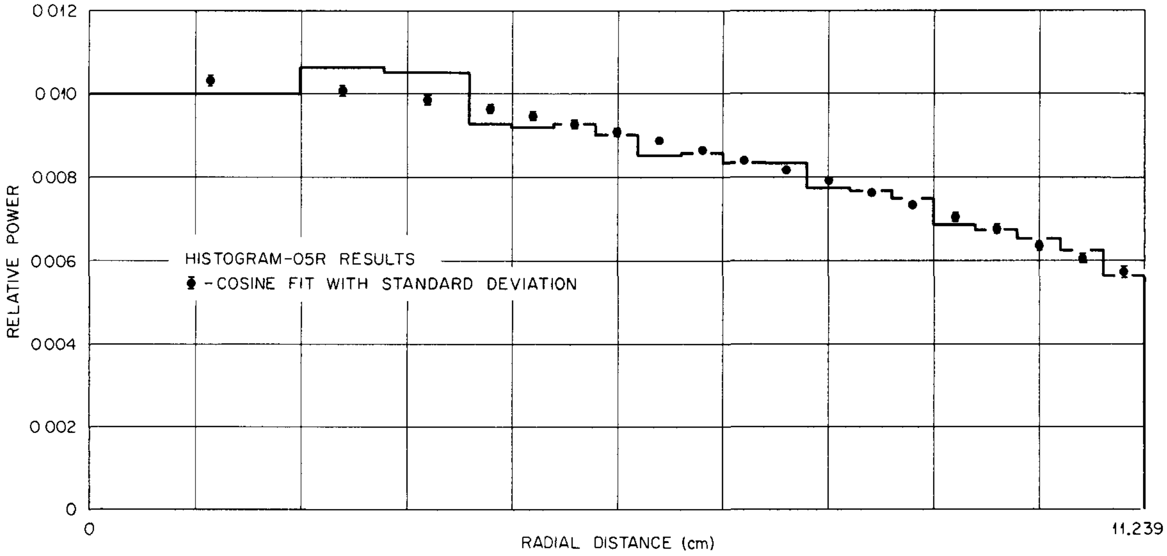

Fig. 7. Radial Relative Power. Axial averaging interval - entire core axial length.

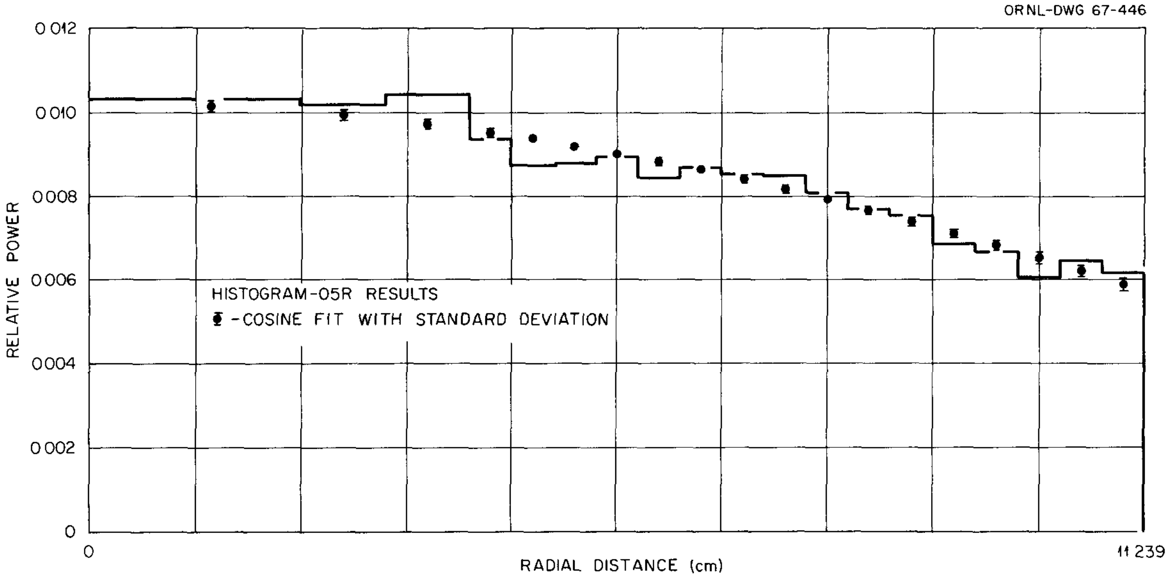

Fig. 8. Radial Relative Power. Axial averaging interval - bottom half of core.

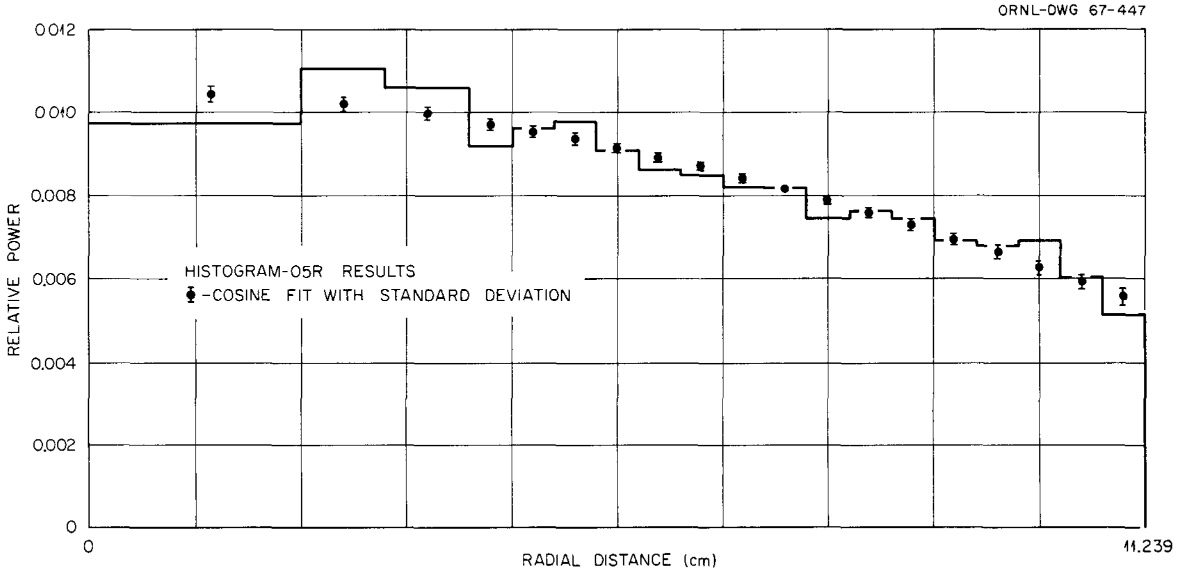

Fig. 9. Radial Relative Power. Axial averaging interval - top half of core.

Table 7. Parameters for $A \cos Bx$ Fitting of Fission Distributions

Direction	Transverse Direction Averaging Interval	Parameter A	Standard Deviation in A	Parameter B	Standard Deviation in B	Figure Number
Axial (center to bottom)	Entire radial dimension	0.0442	0.00071	0.0912	0.0015	
Axial (center to top)	Entire radial dimension	0.0448	0.00126	0.0825	0.0030	
Axial (bottom to top)	Entire radial dimension	0.0445	0.00084	0.0869	0.0019	4
Axial (center to bottom)	R = 0.0 to 7.2 cm	0.0436	0.00117	0.0909	0.0026	5
Axial (center to top)	R = 0.0 to 7.2 cm	0.0451	0.00108	0.0820	0.0026	5
Axial (center to bottom)	R = 7.2 to 11.239 cm	0.0448	0.00074	0.0916	0.0016	6
Axial (center to top)	R = 7.2 to 11.239 cm	0.0446	0.00180	0.0830	0.0043	6
Radial	Entire axial length	0.0104	0.00012	0.0896	0.0018	7
Radial	Bottom half of core	0.0102	0.00014	0.0871	0.0023	8
Radial	Top half of core	0.0105	0.00019	0.0917	0.0027	9
Radial	First quarter of axial length (bottom)	0.0104	0.00023	0.0900	0.0035	
Radial	Second quarter of axial length	0.0100	0.00024	0.0843	0.0040	
Radial	Third quarter of axial length	0.0108	0.00029	0.0960	0.0038	
Radial	Fourth quarter of axial length (top)	0.0102	0.00024	0.0869	0.0038	

calculations were performed with a simpler model to obtain better biasing for efficient Monte Carlo calculations; Program ANISN,[3] a one-dimensional S_n code, was used to provide this information.

ANISN Adjoint S_n Calculations

One-dimensional descriptions for both the SNAP-TSF reactor with the SNAP-2 shield and the SNAP-TSF reactor alone were used in S_{16} adjoint flux calculations with P_2 cross-section representation by program ANISN. The reactor shield model for the slab geometry is given in Table 8. The reactor-alone model did not have zone 7. Atomic densities were the same as those used in O5R (CODE 6).

The energy group structure is given in Table 9. For the reactor plus shield configuration, a shell source was placed in interval number 65, the shield bottom; the S_{16} angle interval index was 1, cosine θ between 0.9494 and 1.0000. Fast-neutron dose factors were divided by the cosine of the midpoint angle of angle interval 1; the result was used as the shell source input. Table 10 lists the source input.

For the reactor alone, a unit isotropic shell source was placed in interval 34 (the reactor vessel bottom).

Source Biasing — Shield Source Problem

The biased distributions required by subroutines SPACE and FISESN (both called by subroutine SOURCE) were obtained from the adjoint S_{16} flux data printed by program ANISN. The reduction of the flux data was accomplished by program BIASOR. Input instructions and program listing for BIASOR are found in Appendix L.

Input for BIASOR consisted of the adjoint S_n total flux as a function of position and energy. The flux was averaged over energy, using the energy-group-dependent fission probabilities as a weighting function. The resulting flux, $\phi_1(z)$, was a function of axial position only and was a measure of the axial importance of the neutron source. If $P(z)$ is the actual power distribution, $P_B(z)$ is the unnormalized biased power distribution, and the adjoint flux is used as the importance function, then

$$P_B(z) = \phi_1(z)\ P(z) \quad .$$

Table 8. One-Dimensional Slab Geometry for ANISN Description of the SNAP-TSF Reactor Plus Shield Configuration

Zone Number	Number of Intervals	Outer Radius (cm)	Zone Description
		0.0	
1	4	2.766	Top head
2	2	4.6304	Top grid
3	20	35.7454	Core
4	2	37.2307	Bottom grid
5	4	39.5307	Bottom NaK
6	2	39.8482	Bottom vessel
7	31	101.8482	Shield

Table 9. ANISN Adjoint S_n Energy Group Structure

Adjoint S_n Group Number	Upper Energy Boundary (eV)	Lower Energy Boundary (eV)
27	1.492×10^7	1.221×10^7
26	1.221×10^7	1.000×10^7
25	1.000×10^7	8.187×10^6
24	8.187×10^6	6.703×10^6
23	6.703×10^6	5.488×10^6
22	5.488×10^6	4.493×10^6
21	4.493×10^6	3.679×10^6
20	3.679×10^6	3.012×10^6
19	3.012×10^6	2.466×10^6
18	2.466×10^6	2.019×10^6
17	2.019×10^6	1.653×10^6
16	1.653×10^6	1.353×10^6
15	1.353×10^6	1.108×10^6
14	1.108×10^6	9.072×10^5
13	9.072×10^5	6.081×10^5
12	6.081×10^5	4.076×10^5
11	4.076×10^5	1.111×10^5
10	1.111×10^5	1.503×10^4
9	1.503×10^4	3.355×10^3
8	3.355×10^3	5.829×10^2
7	5.829×10^2	1.013×10^2
6	1.013×10^2	2.902×10^1
5	2.902×10^1	1.068×10^1
4	1.068×10^1	3.059×10^0
3	3.059×10^0	1.125×10^0
2	1.125×10^0	4.140×10^{-1}
1	4.140×10^{-1}	Thermal

Table 10. ANISN Adjoint S_n Shell Source Input for the SNAP-TSF Reactor Plus Shield Configuration

Adjoint S_n Group Number	Fast-Neutron Dose* (rads hr^{-1} per neutron cm^{-2} sec^{-1})
27	2.0046×10^{-5}
26	1.8878×10^{-5}
25	1.7776×10^{-5}
24	1.7128×10^{-5}
23	1.6511×10^{-5}
22	1.5903×10^{-5}
21	1.5832×10^{-5}
20	1.4452×10^{-5}
19	1.2496×10^{-5}
18	1.1537×10^{-5}
17	1.0840×10^{-5}
16	9.8811×10^{-6}
15	9.2181×10^{-6}
14	8.6247×10^{-6}
13	7.0724×10^{-6}
12	5.9312×10^{-6}
11	4.0400×10^{-6}
10	1.6288×10^{-6}
9	2.1948×10^{-7}

*Divided by 0.9801449.

BIASOR also averaged the adjoint S_n flux over position, using the actual power distribution as a weighting function. The resulting flux, $\phi_2(E)$, is a function of energy only and is a measure of the energy importance of the neutron source. $\phi_2(E)$ was constant over each energy group i; thus, $\phi_{2i} = \phi_2(E)$ for $E_i < E < E_{i+1}$. If F_i were the fission probability for energy group i and QE_i were the biased fission probability, then

$$QE_i = \frac{\phi_{2i}F_i}{\sum_i \phi_{2i}F_i} .$$

Although $\sum_i QE_i = 1$, the printed results from BIASOR may not equal 1 exactly, due to roundoff error; however, QE_i input to FISESN (SOURCE input) must have this property. Appropriate adjustments to the QE_i values must be made.

The adjoint S_n fluxes $\phi_1(z)$ and $\phi_2(E)$ are plotted in Figs. 10 and 11 respectively. The biased axial power distribution results are shown in Table 11. The biased axial power distribution is compared in Fig. 12 with the actual axial power distribution. The biased fission probability results are shown in Table 12.

For the QE_i input to subroutine FISESN, the biased fission source fractions in Table 12 were used except for adjoint S_n group Nos. 19 and 20 and group Nos. 15 through 18, whose values were averaged and placed in two broader energy groups.

An investigation of the adjoint S_n angular fluxes showed that the angular variation was relatively independent of axial position and of energy. For the source angle biased distribution, the adjoint S_n angular flux in the second S_n interval from the core bottom and the S_n energy group number 27 was used. This flux is plotted in Fig. 13 and listed in Table 13.

The biased radial distribution was arbitrarily selected to be flat.

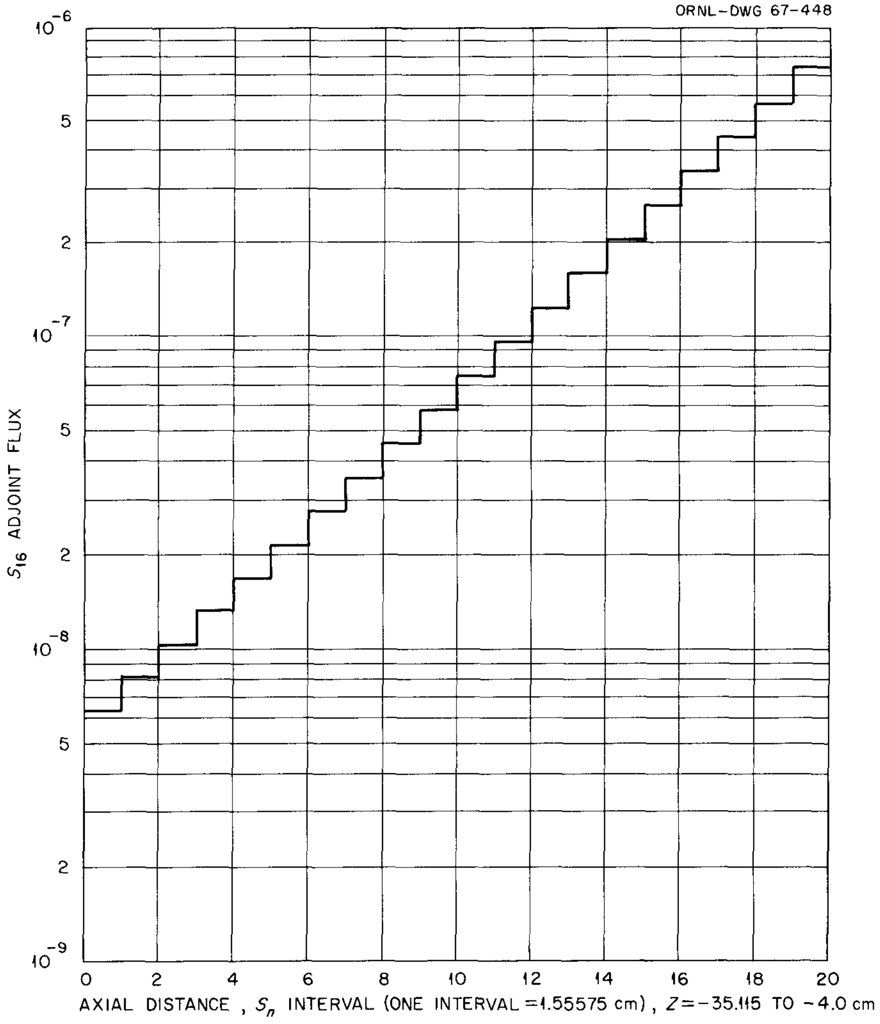

Fig. 10. Axial S_{16} Adjoint Flux for SNAP-TSF Reactor Plus Shield Configuration; Top to Bottom of Core. Averaged over energy with fission spectrum weighting.

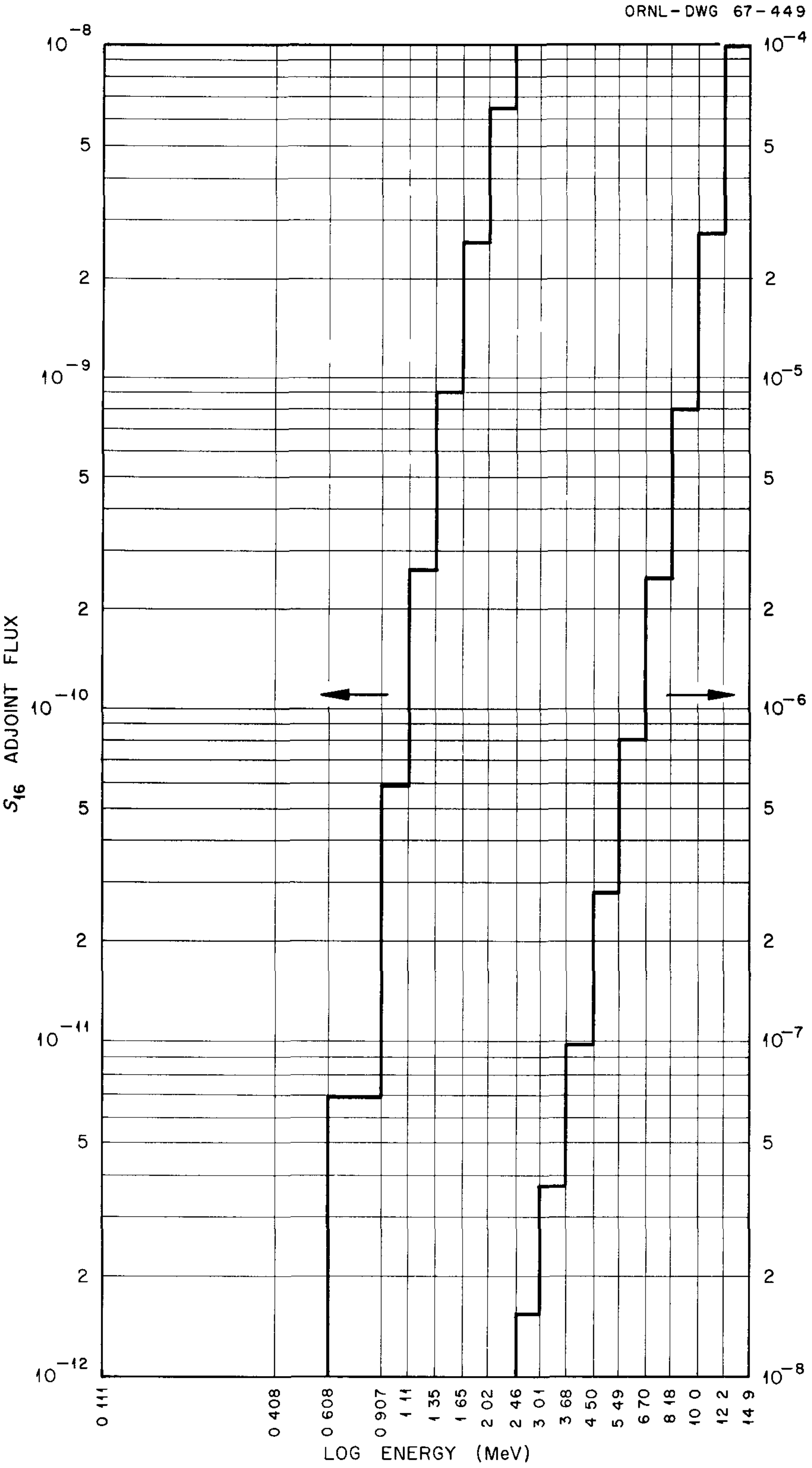

Fig. 11. S_{16} Adjoint Flux Spectrum for SNAP-TSF Reactor Plus Shield Configuration. Averaged over core with axial power distribution weighting.

Table 11. Biased Axial Power Distribution for the SNAP-TSF Reactor Plus Shield Configuration

Adjoint S_n Lower Z, Core Interval Boundary (cm) (Top to Bottom)	A Actual Axial Power Distribution*	B Fission Spectrum Averaged Adjoint S_n Flux	C Biased Axial Power Distribution**
-35.115	0.01955	6.341×10^{-9}	0.00094
-33.559	0.02832	8.091×10^{-9}	0.00173
-32.004	0.03658	1.034×10^{-8}	0.00286
-30.448	0.04415	1.321×10^{-8}	0.00441
-28.892	0.05094	1.690×10^{-8}	0.00650
-27.336	0.05678	2.163×10^{-8}	0.00928
-25.780	0.06159	2.770×10^{-8}	0.01289
-24.225	0.06528	3.552×10^{-8}	0.01752
-22.669	0.06778	4.556×10^{-8}	0.02334
-21.113	0.06904	5.851×10^{-8}	0.03053
-19.558	0.06904	7.518×10^{-8}	0.03922
-18.002	0.06778	9.674×10^{-8}	0.04955
-16.446	0.06528	1.245×10^{-7}	0.06141
-14.890	0.06159	1.605×10^{-7}	0.07470
-13.334	0.05678	2.070×10^{-7}	0.08881
-11.779	0.05094	2.673×10^{-7}	0.10289
-10.223	0.04415	3.452×10^{-7}	0.11517
- 8.667	0.03658	4.467×10^{-7}	0.12348
- 7.112	0.02832	5.777×10^{-7}	0.12363
- 5.556	0.01955	7.523×10^{-7}	0.11114
- 4.000			

*The sum of column A equaled 1.

**Column C equaled column A times column B, normalized such that the sum of column C equaled 1.

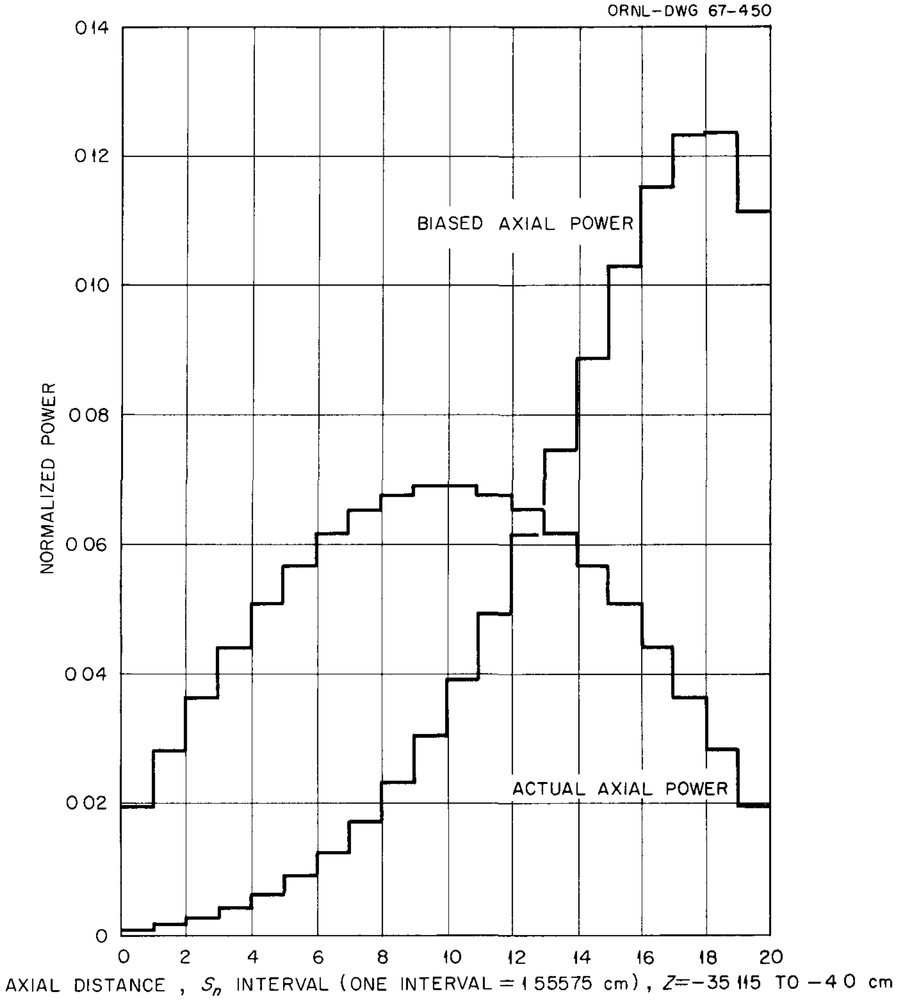

Fig. 12. Normalized Power Distributions for SNAP-TSF Reactor Plus Shield Configuration; Top to Bottom of Core. $\int_0^{20} P(z)\,dz = 1$, where z is in S_n interval units.

Table 12. Source Energy Biasing for the SNAP-TSF Reactor Plus Shield Configuration

Adjoint S_n Group Number	Lower Energy Boundary (MeV)	A Fission Source Fraction from Subroutine FISSN	B Power Distribution Averaged Adjoint S_n Flux in Core	C Normalized Biased Fission Source Fraction*
27	12.2	1.795×10^{-4}	9.837×10^{-5}	0.1334
26	10.0	8.785×10^{-4}	2.704×10^{-5}	0.1795
25	8.18	3.492×10^{-3}	7.967×10^{-6}	0.2102
24	6.70	1.002×10^{-2}	2.469×10^{-6}	0.1870
23	5.49	2.118×10^{-2}	8.038×10^{-7}	0.1287
22	4.5	3.785×10^{-2}	2.788×10^{-7}	0.0797
21	3.68	5.84×10^{-2}	9.750×10^{-8}	0.0430
20	3.01	7.45×10^{-2}	3.711×10^{-8}	0.0209
19	2.46	8.95×10^{-2}	1.534×10^{-8}	0.0104
18	2.02	9.4×10^{-2}	6.46×10^{-9}	0.0046
17	1.65	9.4×10^{-2}	2.574×10^{-9}	0.0018
16	1.35	8.9×10^{-2}	9.024×10^{-10}	0.0006
15	1.11	8.0×10^{-2}	2.613×10^{-10}	0.0002
14	0.907	6.9×10^{-2}	5.826×10^{-11}	0
13	0.608	1.08×10^{-1}	6.816×10^{-12}	0
12	0.4076	7.0×10^{-2}		0
11	0.111	8.3×10^{-2}		0

*Column C was obtained by multiplying column A times column B and normaliz- such that the sum of column C equaled 1.

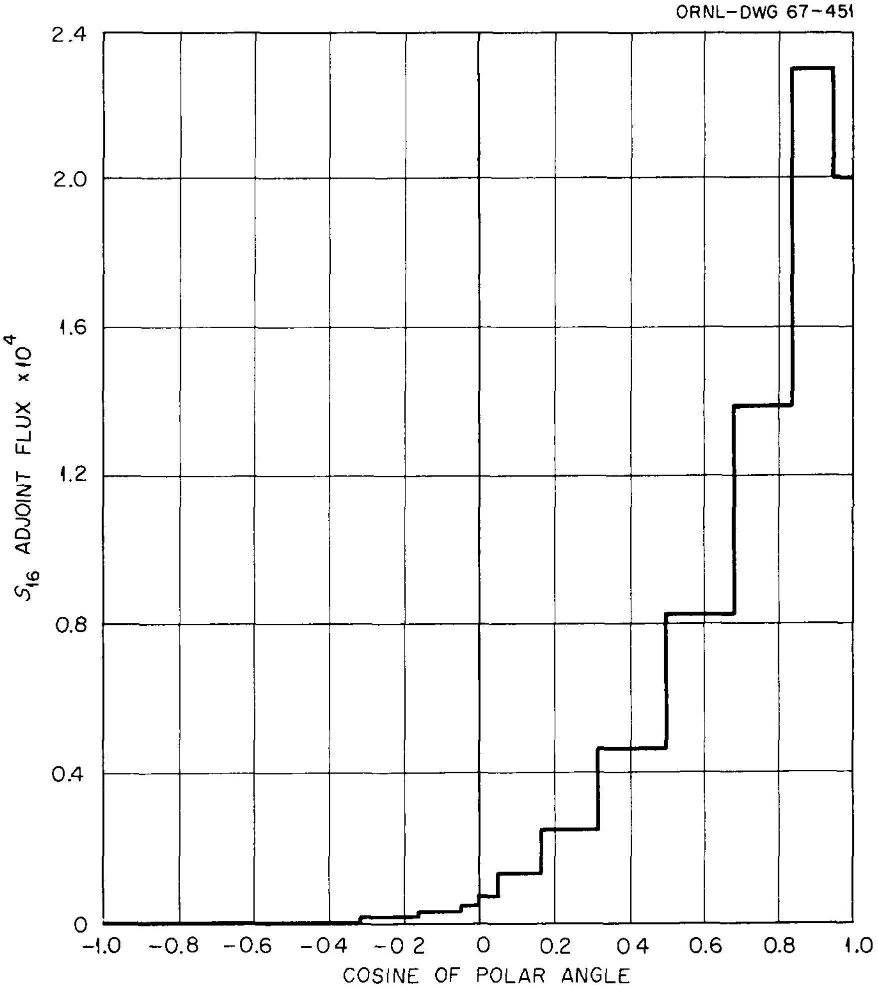

Fig. 13. Source Angle Biased Distribution for SNAP-TSF Reactor Plus Shield Configuration. S_n energy group 8.187 to 10.0 MeV; second S_n interval from core bottom.

Table 13. Source Angle Biased Distribution for SNAP-TSF Reactor Plus Shield Configuration[a]

Angle Index	S_{16} Cosθ Lower Boundary	S_{16} Adjoint Angular Flux (Biased Distribution)
	1.0000000	
1	0.9493858	2.093 x 10^{-4}
2	0.8381952	2.307 x 10^{-4}
3	0.6813418	1.391 x 10^{-4}
4	0.5000000	0.8354 x 10^{-4}
5	0.3186582	0.4679 x 10^{-4}
6	0.1618048	0.2570 x 10^{-4}
7	0.0506142	0.1365 x 10^{-4}
8	0.0000000	0.07426 x 10^{-4}
9	-0.0506142	0.05226 x 10^{-4}
10	-0.1618048	0.03701 x 10^{-4}
11	-0.3186582	0.01987 x 10^{-4}
12	-0.5000000	0.00246 x 10^{-4}
13	-0.6813418	0.00246 x 10^{-4}
14	-0.8381952	0.00246 x 10^{-4}
15	-0.9493858	0.00246 x 10^{-4}
16	-1.0000000	0.00246 x 10^{-4}

[a] S_n energy group 8.187 to 10.0 MeV; second S_n interval from core bottom.

The input for subroutine SOURCE does not include the biased distributions for the axial, radial, and angular selection of source neutron parameters; instead, it requires a specification of interval sizes from which parameters are selected with equal probability. In order to determine the interval sizes appropriate for the biased distributions, program SORSPREP was written. Input instructions and listings for SORSPREP are given in Appendix M.

SORSPREP input consists of the real and biased radial and axial source distributions and the biased angular source distribution. SORSPREP prints and punches the axial, radial, and angular input required by subroutine DATAIN (called by subroutine SOURCE).

Exponential Transform - Shield Source Problem

The selection of track lengths, ℓ, was made from the distribution $\frac{1}{B} e^{-\Sigma_T \ell / B}$, where Σ_T = total macroscopic cross section; $B = \frac{1}{1 - \gamma(\mathrm{XNU})}$, but if $B < 0.6$, it is set equal to 0.6; γ = z direction cosine, $(\mathrm{XNU}) = \lambda/\Sigma_T$, and λ is the slope of the adjoint S_n flux.[1]

Examination of XNU for the adjoint S_n total flux and of XNU for the adjoint S_n angular flux in the first angular interval resulted in the decision to use the angular flux in the first angular interval. XNU's obtained from the total flux seemed too large in view of past experience, and the values did not decrease as the bottom system boundary was approached. The behavior of XNU's obtained from the angular flux seemed more appropriate.

Since the XNU's could be supplied as input by O5R region and by energy group, a large number of calculations of XNU were anticipated. Program IMPORT was written to aid in this work. IMPORT calculates λ and XNU for each S_n energy group. It assumes that over a given broad interval, $z_1 \leq z \leq z_2$, the adjoint S_n flux Φ can be represented by

$$\Phi = A\, e^{\lambda z} \text{ for } z_1 \leq z \leq z_2 \quad ;$$

λ is then calculated using

$$\lambda = \frac{1}{z_2 - z_1} \ell n \frac{\phi_2}{\phi_1} ,$$

and

$$XNU = \frac{\lambda}{\Sigma_T}$$

is obtained. A region of constant cross section may be divided into several broad z intervals containing two or more of the S_n intervals. The flux is then input as a function of energy at each of these broad interval boundaries. Since the adjoint S_n flux is an average value for the S_n interval, the broad interval boundary should be the midpoint of the S_n interval. Either the total flux or the angular flux for any angular group may be input. As many regions of constant cross section as desired may be processed. Input instructions and program listing are given in Appendix L.

For the shield source problem, the values of XNU for each S_n energy group were found to be constant over the entire axial length of the core. Results of these calculations, including values for the NaK at the reactor bottom, are given in Table 14.

Since the values of XNU were found to be relatively constant over energy intervals larger than the S_n energy intervals, the XNU input energy group structure was changed. Table 15 gives the XNU values used in the O5R calculation. Two regions were used: region 1, which was contained in zones 1 through 4 and region 2, which was contained in zone 5.

The source data and the track stretching parameters required as input to O5R for the shield source problem are listed in Appendix F.

Source Biasing - Core-Mapping Problem

The biased distributions required by subroutines SPACE and FISESN were obtained from the adjoint flux data printed by program ANISN for the reactor without the shield. The reduction of the flux data was accomplished by methods described previously.

Table 14. Adjoint S_n Parameters for the Exponential Transform in the SNAP-TSF Reactor Plus Shield Configuration

S_n Energy Index	Lower Energy Boundary (MeV)	A Total Macroscopic Cross Section (cm^{-1})		B Slope of Adjoint S_n Forward Flux* (cm^{-1})		C Exponential Transform Parameter, XNU**	
		Core	Bottom NaK	Core	Bottom NaK	Core	Bottom NaK
27	12.2	0.18421	0.03145	0.1319	0.0242	0.7158	0.7707
26	10.0	0.19930	0.03298	0.1443	0.0249	0.7242	0.7565
25	8.18	0.20991	0.03476	0.1554	0.0256	0.7401	0.7363
24	6.70	0.21877	0.03753	0.1669	0.0266	0.7631	0.7086
23	5.49	0.22281	0.04102	0.1793	0.0290	0.8047	0.7064
22	4.5	0.23420	0.04642	0.1952	0.0332	0.8334	0.7143
21	3.68	0.25072	0.05115	0.2124	0.0372	0.8471	0.7278
20	3.01	0.27134	0.05215	0.2299	0.0388	0.8474	0.7442
19	2.46	0.29687	0.05231	0.2495	0.0400	0.8404	0.7640
18	2.02	0.30808	0.04932	0.2591	0.0388	0.8412	0.7860
17	1.65	0.33424	0.04186	0.2821	0.0341	0.8439	0.8136
16	1.35	0.36937	0.03767	0.3133	0.0315	0.8482	0.8362
15	1.11	0.40723	0.03502	0.3503	0.0297	0.8601	0.8493
14	0.907	0.45383	0.03874	0.3957	0.0334	0.8719	0.8627
13	0.608	0.54014	0.04662	0.4549	0.0397	0.8422	0.8527
12	0.4076	0.63661	0.03861	0.5647	0.0342	0.8870	0.8866
11	0.111	0.76864	0.04311	0.5968	0.0304	0.7765	0.7051

*The adjoint S_{16} angular flux for angle index number 1.

**Column C was obtained by dividing column B by column A.

Table 15. XNU Values Used in 05R for the SNAP-TSF Reactor Plus Shield Configuration

Ith Group Lower Energy Boundary (MeV)	05R Region 1 XNU(1,I)	05R Region 2 XNU(2,I)
8.18	0.727	0.754
5.49	0.784	0.708
3.01	0.843	0.729
1.35	0.843	0.800
0.407	0.865	0.863
0.11	0.776	0.705

The adjoint S_n fluxes $\Phi_1(Z)$ and $\Phi_2(E)$ are plotted in Figs. 14 and 15. The biased axial power distribution was calculated as shown in Table 16. The biased axial power distribution is compared to the actual axial power distribution in Fig. 16. The biased fission probabilities were calculated as shown in Table 17.

For the QE input to subroutine FISESN, the biased fission source fraction in Table 17 was used except for the values for the following adjoint S_n group numbers which were averaged and placed in the corresponding broader energy groups:

> Adjoint S_n group Nos. 25 through 27, 23 and 24, 21 and 22, 19 and 20, 14 and 15, and 12 and 13.

An investigation of the adjoint S_n angular fluxes showed that the angular variation was relatively independent of axial position and of energy. For the source angle biased distribution the adjoint S_n angular flux in the second S_n interval from the core bottom and the S_n energy group No. 27 was used. The flux data are given in Fig. 17 and Table 18.

The biased radial distribution was arbitrarily selected to be flat.

Program SORSPREP was used to prepare the above data for input to the O5R source routines.

Exponential Transform - Core-Mapping Problem

The track stretching parameters XNU were obtained from the slope of the adjoint S_n angular flux in the manner described previously; however, the values for XNU for each S_n energy group were not constant over the entire axial length of the core. The reactor was divided into four axial O5R regions. The bottom NaK and vessel, zone 5, were the fourth region; the rest of the reactor consisted of regions 1 through 3 defined by the planes $Z + 23.4469 = 0$ and $Z + 14.1124 = 0$. Results of the XNU calculations for the four regions are given in Table 19.

Since the values of XNU were found to be relatively constant over larger energy intervals than the S_n energy intervals, the XNU input energy group structure was changed. Table 20 gives the XNU values used in the O5R calculation.

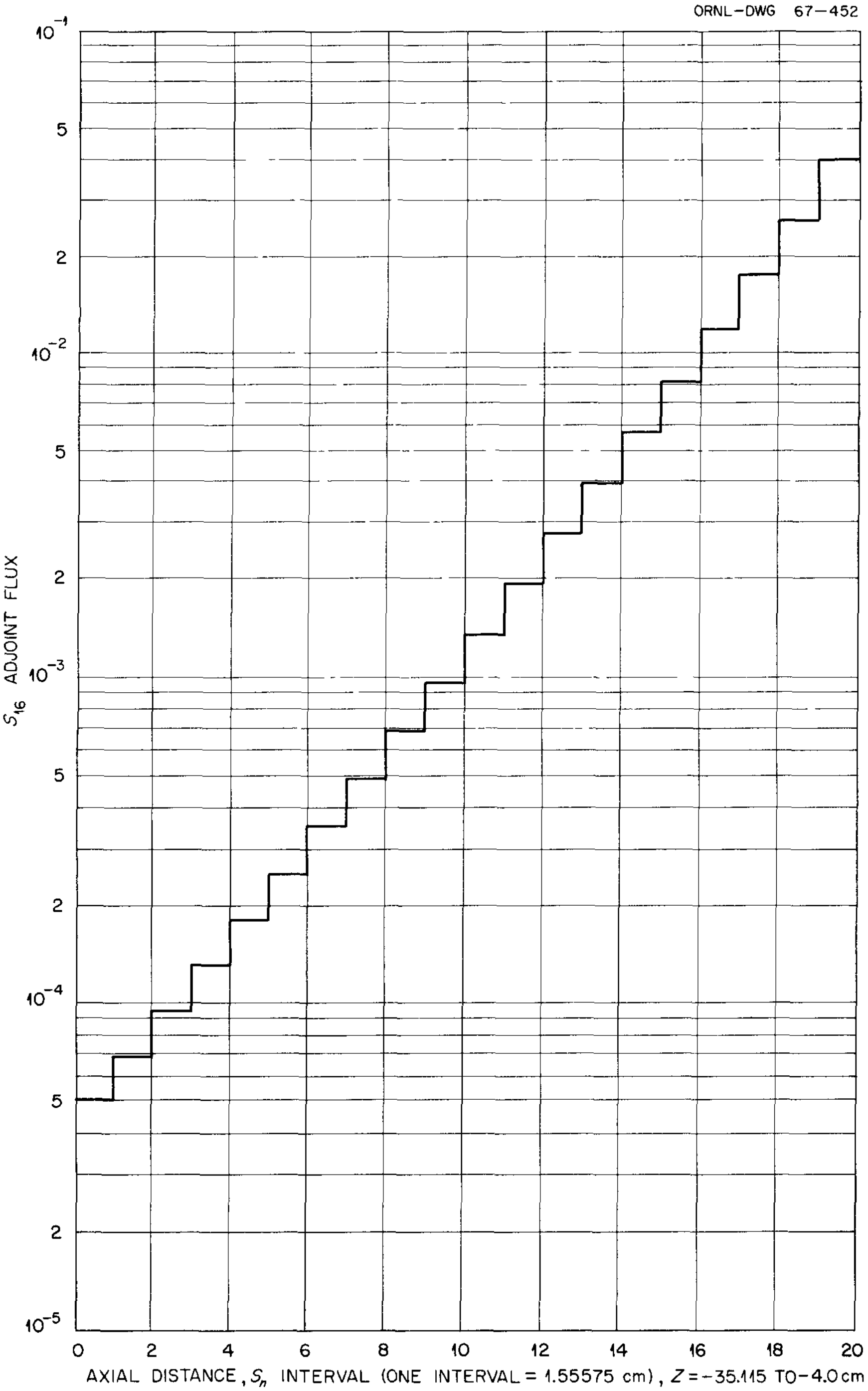

Fig. 14. Axial S_{16} Adjoint Flux for SNAP-TSF Reactor; Top to Bottom of Core. Averaged over energy with fission spectrum weighting.

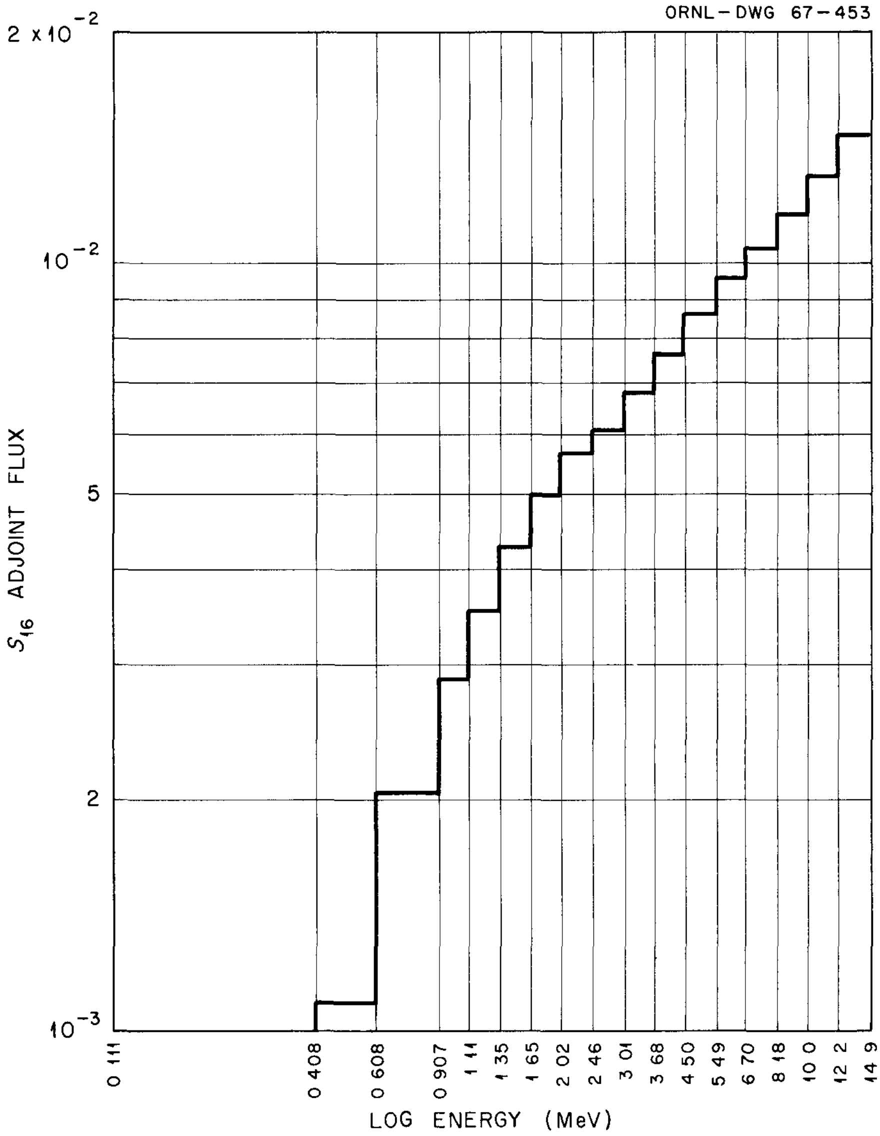

Fig. 15. S_{16} Adjoint Flux Spectrum for SNAP-TSF Reactor. Averaged over core with axial power distribution weighting.

Table 16. Biased Axial Power Distribution for the SNAP-TSF Reactor

Adjoint S_n Lower Z, Core Interval Boundary (cm) (Top to Bottom)	A Actual Axial Power Distribution*	B Fission Spectrum Averaged Adjoint S_n Flux	C Biased Axial Power Distribution**
-35.115	0.01955	5.123×10^{-5}	0.00023
-33.559	0.02832	6.901×10^{-5}	0.00045
-32.004	0.03658	9.469×10^{-5}	0.00080
-30.448	0.04415	1.307×10^{-4}	0.00134
-28.892	0.05094	1.811×10^{-4}	0.00213
-27.336	0.05678	2.519×10^{-4}	0.00331
-25.780	0.06159	3.515×10^{-4}	0.00500
-24.225	0.06528	4.920×10^{-4}	0.00743
-22.669	0.06778	6.909×10^{-4}	0.01083
-21.113	0.06904	9.732×10^{-4}	0.01553
-19.558	0.06904	1.375×10^{-3}	0.02195
-18.002	0.06778	1.952×10^{-3}	0.03059
-16.446	0.06528	2.779×10^{-3}	0.04194
-14.890	0.06159	3.978×10^{-3}	0.05664
-13.334	0.05678	5.716×10^{-3}	0.07504
-11.779	0.05094	8.273×10^{-3}	0.09743
-10.223	0.04415	1.202×10^{-2}	0.12270
- 8.667	0.03658	1.772×10^{-2}	0.14986
- 7.112	0.02832	2.625×10^{-2}	0.17186
- 5.556	0.01955	4.092×10^{-2}	0.18494
- 4.000			

*The sum of columnA equaled 1.

**Column C equaled column A times column B, normalized such that the sum of column C equaled 1.

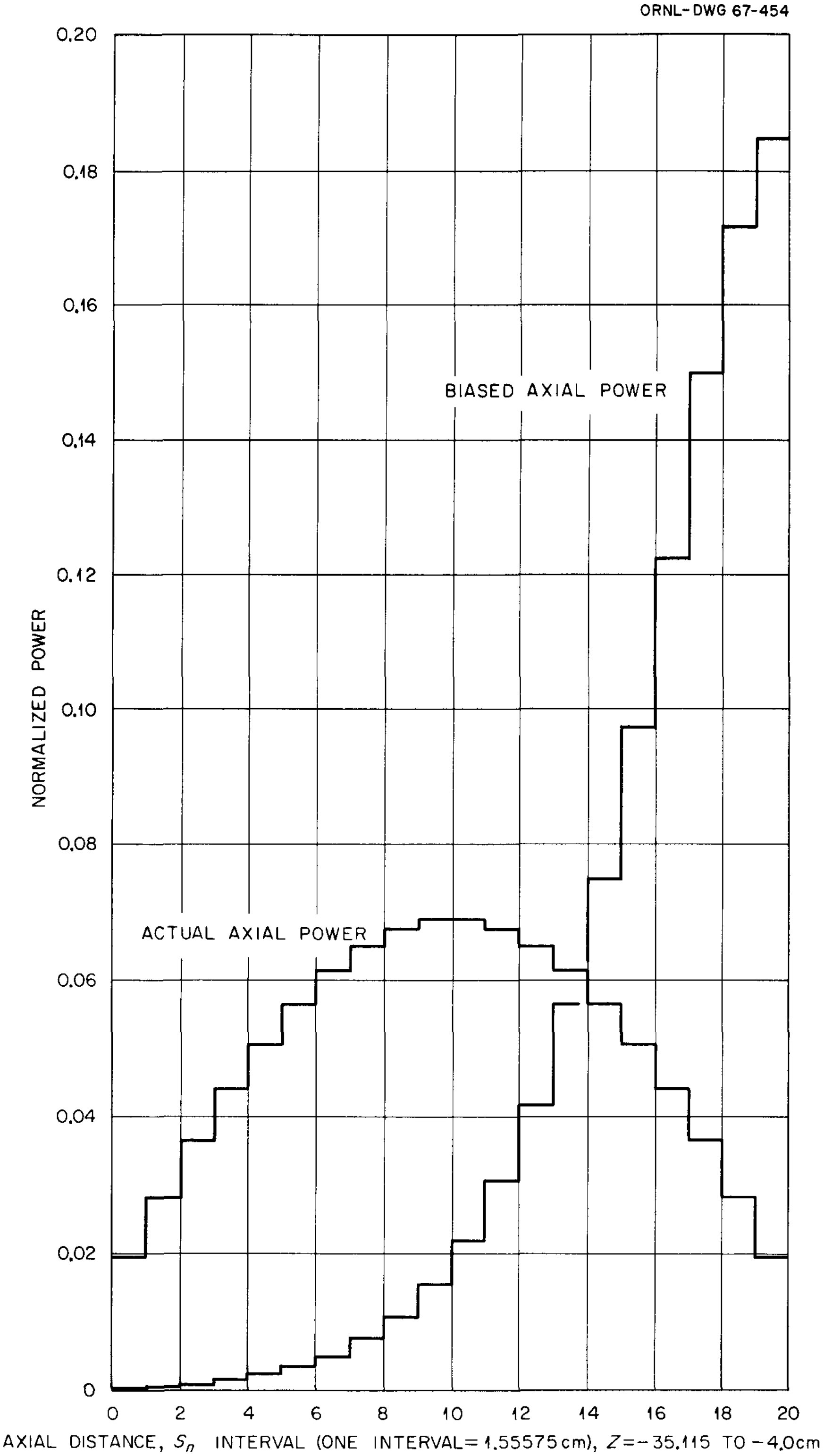

Fig. 16. Normalized Power Distributions for SNAP-TSF Reactor; Top to Bottom of Core. $\int_0^{20} P(z)\,dz = 1$, where z is in S_n interval units.

Table 17. Source Energy Biasing for the SNAP-TSF Reactor

Adjoint Group Number	Lower Energy Boundary (MeV)	A Fission Source Fraction from Subroutine FISSN	B Power Distribution Averaged Adjoint S_n Flux in Core	C Normalized Biased Fission Source Fraction*
27	12.2	1.795×10^{-4}	1.460×10^{-2}	0.0006
26	10.0	8.785×10^{-4}	1.291×10^{-2}	0.0026
25	8.18	3.492×10^{-3}	1.155×10^{-2}	0.0093
24	6.70	1.002×10^{-2}	1.047×10^{-2}	0.0243
23	5.49	2.118×10^{-2}	9.504×10^{-3}	0.0465
22	4.5	3.785×10^{-2}	8.551×10^{-3}	0.0748
21	3.68	5.84×10^{-2}	7.591×10^{-3}	0.1025
20	3.01	7.45×10^{-2}	6.753×10^{-3}	0.1163
19	2.46	8.95×10^{-2}	6.054×10^{-3}	0.1254
18	2.02	9.4×10^{-2}	5.632×10^{-3}	0.1224
17	1.65	9.4×10^{-2}	4.987×10^{-3}	0.1084
16	1.35	8.9×10^{-2}	4.258×10^{-3}	0.0876
15	1.11	8.0×10^{-2}	3.516×10^{-3}	0.0650
14	0.907	6.9×10^{-2}	2.873×10^{-3}	0.0458
13	0.608	1.08×10^{-1}	2.035×10^{-3}	0.0508
12	0.4076	7.0×10^{-2}	1.096×10^{-3}	0.0177

*Column C was obtained by multiplying column A times column B and normalizing such that the sum of column C equaled 1.

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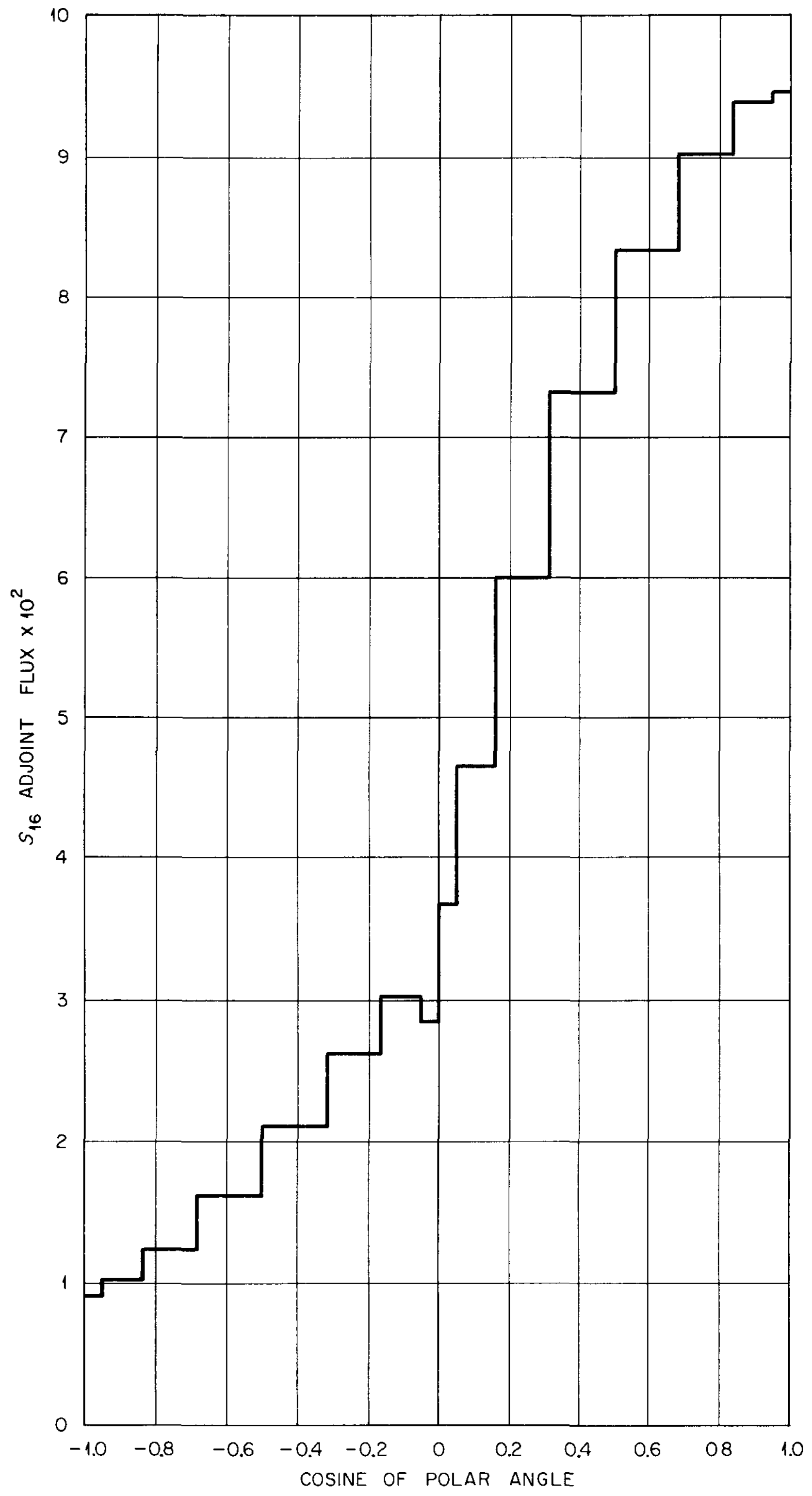

Fig. 17. Source Angle Biased Distribution for SNAP-TSF Reactor. S_n energy group 8.187 to 10.0 MeV; second S_n interval from core bottom.

Table 18. Source Angle Biased Distribution for SNAP-TSF Reactor[a]

Angle Index	S_{16} $\cos\theta$ Lower Boundary	S_{16}, Adjoint Angular Flux (Biased Distribution)
		$\times 10^{-2}$
	1.0000000	
1	0.9493858	9.475
2	0.8381952	9.392
3	0.6813418	9.030
4	0.5000000	8.352
5	0.3186582	7.331
6	0.1618048	6.010
7	0.0506142	4.662
8	0.0000000	3.676
9	-0.0506142	2.849
10	-0.1618048	3.015
11	-0.3186582	2.632
12	-0.5000000	2.110
13	-0.6813418	1.617
14	-0.8381952	1.249
15	-0.9493858	1.022
16	-1.0000000	0.9061

[a] S_n energy group 8.187 to 10.0 MeV; second S_n interval from core bottom.

Table 19. Adjoint S_n Parameters for the Exponential Transform in the SNAP-TSF Reactor

		A Total Macroscopic Cross Section (cm^{-1})		B Slope of Adjoint S_n Forward Flux[a] (cm^{-1})				C Exponential Transform Parameter, XNU[b]			
S_n Energy Index	Lower Energy Boundary (MeV)	Core	Bottom NaK	Top Core[c]	Middle Core[c]	Bottom Core[c]	Bottom NaK	Top Core[c]	Middle Core[c]	Bottom Core[c]	Bottom NaK
27	12.2	0.18421	0.03145	0.1131	0.0995	0.0707	0.0119	0.6138	0.5401	0.3838	0.3788
26	10.0	0.19930	0.03298	0.1238	0.1098	0.0799	0.0115	0.6213	0.5508	0.4008	0.3481
25	8.18	0.20991	0.03476	0.1341	0.1195	0.0886	0.0105	0.6387	0.5692	0.4222	0.3028
24	6.70	0.21877	0.03753	0.1456	0.1302	0.0980	0.0096	0.6653	0.5951	0.4480	0.2545
23	5.49	0.22281	0.04102	0.1582	0.1424	0.1086	0.0091	0.7101	0.6390	0.4872	0.2213
22	4.5	0.23420	0.04642	0.1736	0.1571	0.1215	0.0100	0.7413	0.6710	0.5189	0.2163
21	3.68	0.25072	0.05115	0.1901	0.1730	0.1353	0.0120	0.7581	0.6902	0.5397	0.2353
20	3.01	0.27134	0.05215	0.2067	0.1891	0.1489	0.0131	0.7618	0.6968	0.5486	0.2509
19	2.46	0.29687	0.05231	0.2245	0.2066	0.1647	0.0136	0.7563	0.6959	0.5548	0.2592
18	2.02	0.30808	0.04932	0.2382	0.2197	0.1747	0.0131	0.7733	0.7130	0.5672	0.2648
17	1.65	0.33424	0.04186	0.2620	0.2431	0.1951	0.0116	0.7838	0.7272	0.5836	0.2767
16	1.35	0.36937	0.03767	0.2930	0.2738	0.2231	0.0111	0.7932	0.7413	0.6041	0.2946
15	1.11	0.40723	0.03502	0.3301	0.3108	0.2579	0.0101	0.8106	0.7632	0.6332	0.2898
14	0.907	0.45383	0.03874	0.3764	0.3576	0.3028	0.0111	0.8295	0.7880	0.6672	0.2869
13	0.608	0.54014	0.04662	0.4413	0.4300	0.3843	0.0156	0.8171	0.7962	0.7115	0.3336
12	0.4076	0.63661	0.03861	0.5547	0.5511	0.5254	0.0178	0.8713	0.8657	0.8253	0.4613

a. The adjoint S_{16} angular flux for angle index number 1.

b. Column C was obtained by dividing column B by column A.

c. Top, middle, and bottom cores are described by regions 1, 2, and 3, respectively.

Table 20. XNU Values Used in 05R for the SNAP-TSF Reactor

Ith Group Lower Energy Boundary (MeV)	05R Region 1 XNU (1,I)	05R Region 2 XNU (2,I)	05R Region 3 XNU (3,I)	05R Region 4 XNU (4,I)
8.18	0.6246	0.5534	0.4023	0.3432
4.49	0.7056	0.6350	0.4847	0.2307
2.02	0.7624	0.6990	0.5526	0.2526
1.35	0.7885	0.7342	0.5938	0.2857
0.608	0.8191	0.7825	0.6706	0.3034
0.407	0.8713	0.8657	0.8253	0.4613

The source data and the track stretching parameters required as input to O5R for the core-mapping problem are listed in Appendix F.

O5R Calculations

Preliminary O5R calculations were made on the SNAP-TSF reactor for both the shield source and the core-mapping problems. A summary of the conditions imposed on these calculations follows.

1. The drums-in configuration was used in all cases.
2. The neutron source was obtained from the O5R calculations of the fission distribution.
3. Biasing parameters obtained from adjoint S_n calculations (ANISN) were used.
4. The phi tape was used for elastic scattering.
5. Inelastic scattering was isotropic in the center-of-mass system and a multilevel inelastic scattering model was used where data were known.
6. The lowest energy of interest was 0.1 MeV.

Shield Source Problem

Two O5R calculations were made for the shield source problem. The first consisted of 47 batches of 800 neutrons each, with the value 0000343277244615 used for the starting random number. Since only the neutron parameters for an escape event were recorded, only one collision tape was generated. The second calculation consisted of 50 batches of 800 neutrons each, with the value 1773607236543075 used for the starting random number. Again only one collision tape was generated. The calculation time on the CDC 1604-A computer for this second calculation was 129 min.

Core-Mapping Problem

One O5R calculation was made for the core-mapping problem. It consisted of 60 batches of 800 neutrons each, with the value 0000343277244615 used for the starting random number. Since neutron parameters for source, collision, and escape events were recorded, four collision tapes were generated. The calculation time on the CDC 1604-A computer was 172 min.

IV. ANALYSIS OF O5R LEAKAGE CALCULATIONS

Two programs were involved in the analyses of O5R collision tapes: SNARLS and ACTIFK.[17] SNARLS was written to prepare tapes containing neutrons to be used as the source for subsequent O5R calculations on the penetration of neutrons through a SNAP-2 shield. It obtained its information from tapes prepared by the O5R shield source problem; only neutron escape events were considered. In addition, SNARLS used neutron escape events on the tapes prepared by the O5R core-mapping problem to calculate leakage angular fluxes. ACTIFK, like O5R, required modication by the user for his particular problem. It used neutron source and collision events on the tapes prepared by the O5R core-mapping problem to estimate statistically contributions to collimated detectors.

Program SNARLS

In operating SNARLS, the O5R collision tapes must be prepared with the following values for NBIND: 111000111111110001000110100000000000. The SNARLS input provides for the enclosing of the reactor system by a cylinder and two planes perpendicular to the cylinder axis. The cylinder axis coincides with the z axis. These surfaces become the leakage surfaces. Neutron escapes from the reactor system are traced to these leakage surfaces, and the escape coordinates are changed to values at the intersection of the neutron track and the nearest surface.

SNARLS input instructions, flow diagram, and listings are found in Appendix N.

Source Tape Preparation

Since a great number of leaking neutrons will contribute nothing to a shielded detector, the neutrons which leak must be processed to eliminate unimportant neutrons and to enhance important neutrons. If a neutron weight falls below a specified value, it is killed a specified fraction of the time (Russian roulette); if it survives its weight is increased an appropriate amount. If a neutron weight is above a specified value, it is split into two or more neutrons of equal weight, whose sum is the original weight, such that the individual weight does not exceed the above specified value (splitting).

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[17] F. B. K. Kam and K. D. Franz, ACTIFK, A General Analysis Code for O5R, ORNL-3856 (September 1966).

Russian roulette and splitting are employed according to the following relation, where I is an energy index,

$$W_2 < R(I) < W_1 < S(I) < W_3 \quad .$$

Weights W_1 are accepted, weights W_3 are aplit $(W_3/S(I)) + 1$ times (smallest integer), and weights W_2 have a survival fraction $W_2/R(I)$; surviving neutrons are given the weight R(I). The weight standards S(I) and R(I) can be specified for two angular groups and for either one or two of four possible values of the leakage criteria, JTYPE1 and JTYPE2. The meanings of the possible values of JTYPE1 and JTYPE2 are given below:

1. leakage from the bottom plane (ZBOTNEW), positive Z direction,
2. leakage from the cylinder (RCYLIN), positive Z direction,
3. leakage from the cylinder, negative Z direction,
4. leakage from the top plane (ZTOPNEW), negative Z direction.

The weight standards can be obtained from the adjoint S_n calculation on the reactor-plus-shield configuration by using flux values at the reactor-shield interface. For a particular angular group, the optimum leakage weight W(E) should be proportional to $1/\Phi(E)$, the reciprocal of the adjoint flux spectrum:

$$\widehat{W(E)} \; \Phi(E) = K \quad .$$

Thus as $\Phi(E)$ (the energy-dependent importance) increases, the optimum weight decreases, requiring that a larger number of neutrons leak for a given amount of weight. The constant K may be taken as the average of the neutron weight W(E) times the importance:

$$K = \overline{W(E)\Phi(E)} \quad .$$

If the energy variation is represented by a group structure, then

$$K = \frac{\sum_{I} \phi(I)\ W(I)\ \Delta E(I)}{\sum_{I} \Delta E(I)}$$

where $\Delta E(I)$ is the energy width of group I, and $W(I)$ is the average weight.

A preliminary run with SNARLS will determine the $W(I)$ for two angular groups; hence K can be found and the optimum weight $\widehat{W(I)}$ for each energy group can be calculated. Since an optimum weight range is desired [between $R(I)$ and $S(I)$], SNARLS input weight standards include $\widehat{W(I)}$, $R_1(I)$, and $S_1(I)$, from which $R(I)$ and $S(I)$ are determined:

$$R(I) = R_1(I)\ \widehat{W(I)} \quad ,$$

$$S(I) = S_1(I)\ \widehat{W(I)} \quad .$$

In the input the following variables are used:

For the first angular group

$\text{WBAR(I,JTYPE1)} \rightarrow \widehat{W(I)}$ for leakage JTYPE1

$\text{WBAR(I,JTYPE2)} \rightarrow \widehat{W(I)}$ for leakage JTYPE2

$\text{WK(I)} \rightarrow R_1(I)$

$\text{SWK(I)} \rightarrow S_1(I)$

For the second angular group

$\text{WMAX(I,JTYPE1)} \rightarrow \widehat{W(I)}$ for leakage JTYPE1

$\text{WMAX(I,JTYPE2)} \rightarrow \widehat{W(I)}$ for leakage JTYPE2

$\text{WK1(I)} \rightarrow R_1(I)$

$\text{SWK(I)} \rightarrow S_1(I)$

The source tape preparation option may be omitted.

Neutron Leakage Angular Flux

SNARLS can calculate the neutron leakage angular flux from either the leakage cylinder or the bottom leakage plane or both. The calculation can also be omitted.

In the case of the leakage cylinder, the z axis is divided into one or more intervals. In each interval, escaping neutron coordinates and directions are rotated such that the new x and y coordinates are zero and RCYLIN respectively. Angular bins are obtained by dividing the polar angle θ into equal $\cos\theta$ intervals from 0 to 1; the polar direction is perpendicular to the cylinder surface. An azimuthal angle interval is specified. The neutron weight divided by the cosine of the polar angle is accummated in the appropriate angular bin for that interval. The average over all batches is divided by the area of the cylindrical surface in the z interval and the solid angle for the bin. The result is the average angular flux on the interval.

For the bottom leakage plane, the surface is divided into one or more rings. In each ring, escaping neutron coordinates and directions are rotated such that the new x coordinate is zero. Angular bins are obtained by dividing the polar angle θ into equal $\cos\theta$ intervals from 0 to 1; the polar direction is the positive z direction. An azimuthal angle interval is specified. The neutron weight divided by the cosine of the polar angle is accumulated in the appropriate angular bin for that interval. The average over all batches is divided by the area of the ring and the solid angle for the bin. The result is the average angular flux over the ring.

SNARLS Output

The following items appear in the SNARLS output (certain items may be omitted according to the input specifications):

a. the input data;

b. the angular flux by energy group and space interval for each batch;

c. for each batch, totals of the following items summed over all completed batches and listed by energy group for the bottom leakage plane:
    1. number of escapes
    2. escape weight
       } appear for the three other leakage criteria also,
    3. escape weight by angular group,
    4. number of escapes by angular group;

d. the batch average leakage weight and the total number of escapes by leakage criteria and energy group;

e. the batch average leakage angular flux and its percent standard deviation by energy and angle for each space interval;

f. a statement indicating whether the source tape was written and the number of neutrons and total weight written for each batch.

Provision was made for continuing the source tape on a second reel if necessary. Thus, if NSOR and NSOR1 are specified on the input, NSOR + 1 and NSOR1 + 1 may also be used as tape logical numbers.

Source Tape Checking

A special purpose program, CKSOURPT, was written to print the contents of the source tape prepared by SNARLS. In addition, it prints the total number of escapes and total escape weight for several energy groups and two angular groups. A special version of CKSOURTP just prints the latter. The source tape must be on logical tape unit 5. No provision was made for continuation on another reel. No input is required; changes to energy and angular group structure must be made in the program. Listings for both versions of CKSOURTP are given in Appendix N.

Source Tape Utilization

Subroutine SNEUT(X,Y,Z,A,B,C,W,E,NTAPE,NSKIP) was written to read source tapes prepared by SNARLS and to return the following parameters describing a source neutron for O5R's use:

a. spatial coordinates x, y, and z,

b. direction cosines A, B, and C,

c. weight W,

d. energy E.

This subroutine should be called by 05R's subroutine SOURCE for each source neutron . The data required by SNEUT includes NTAPE, the logical number for the source tape, and NSKIP, the number of records of 50 neutrons to be skipped at the beginning of the source tape. SNEUT returns NTAPE = 0 when there are no more neutrons on the source tape. The calling program (subroutine SOURCE) may reset NTAPE and skip NSKIP records on a new source tape.

The listing for subroutine SNEUT(X,Y,Z,A,B,C,W,E,NTAPE,NSKIP) is given in Appendix N.

Preparation of Source Tape for SNAP-2 Shield Calculation

For the SNARLS leakage surface input, the SNAP-TSF reactor was bounded by the following surfaces:

1. a cylinder of radius 60.96 cm, with its axis coinciding with the z axis,
2. a plane at $z = 1.48$ cm, the bottom of the reactor,
3. a plane at $z = -40.0$, approximately the top of the reactor.

On the SNARLS runs the only leakage criterion of interest was leakage from the bottom of the reactor (JTYPE1=JTYPE2=1). Since the radius of the cylinder was considerably larger than the radius of the reactor system, leakage neutrons from the reactor sides with large z direction cosines were recorded on the bottom surface.

The 05R collision tape prepared by the shield source problem was used.

A preliminary SNARLS run was made to obtain data for the calculation of the energy-dependent optimum weight to be used in splitting and Russian roulette techniques for the final source tape preparation. The two angular groups were $0.7 \leq \mu \leq 1.0$ and $0 \leq \mu < 0.7$, where $\mu = \cos\theta$. The adjoint S_n flux at the reactor-shield interface was found to be separable in energy and angle on the interval $0 \leq \mu \leq 1.0$; the same flux was used for both angular groups. Table 21 summarizes the results of this calculation.

Using the optimum weight K/Φ_i, an optimum weight range, W_{Ri}, was arbitrarily selected:

$$0.333\ K/\Phi_i \leq W_{Ri} \leq 3.0\ K/\Phi_i \quad .$$

Neutron weights below this range were subjected to Russian roulette; neutron weights above this range were subjected to splitting.

Two leakage source tapes were prepared, one using an O5R collision tape containing 47 batches of 800 neutrons each, and one using an O5R collision tape containing 50 batches of 800 neutrons each. (Both O5R problems used biasing obtained from adjoint S_n calculations.) SNARLS input data are listed in Appendix O. The effect of Russian roulette and splitting on the neutron leakage data is given in Tables 22 and 23.

Leakage Angular Flux from Bottom Face of SNAP-TSF Reactor

For the SNARLS leakage surface input the SNAP-TSF reactor was bounded by the following surfaces:

1. a cylinder of radius 18.135 cm, with its axis, with its axis coinciding with the z axis,
2. a plane at $z = 1.48$ cm, the bottom of the reactor,
3. a plane at $z = -40.0$ cm, approximately the top of the reactor.

On the SNARLS runs the leakage angular flux was calculated for the reactor bottom only, $z = 1.48$; a source tape preparation was omitted.

The four O5R collision tapes prepared by the core-mapping problem were used.

Test SNARLS runs showed that the statistics were too poor when a large number of radial, energy, and angular bins were used. The number of bins was reduced in the following ways:

1. The angular flux was averaged over all azimuthal angles (one azimuthal bin).

Table 21. Biasing Parameters for the Source Tape Preparation

Adjoint S_n Energy Group, i	Lower Energy (MeV)	A ΔE_i (MeV)	B Adjoint S_n Normalized Flux, ϕ_i $0 \le \mu \le 1.0$	C Average Neutron Weight, W_i		Optimum Weight, K/ϕ_i*	
				$\mu \ge 0.7$	$\mu < 0.7$	$\mu \ge 0.7$	$\mu < 0.7$
27	12.2	2.8	1.000	1.0×10^{-4}	4.06×10^{-4}	$.789 \times 10^{-4}$	2.77×10^{-4}
26	10.0	2.2	0.302	3.62×10^{-4}	1.35×10^{-3}	2.61×10^{-4}	$.917 \times 10^{-3}$
25	8.18	1.82	0.0968	1.30×10^{-3}	3.13×10^{-3}	8.15×10^{-4}	2.86×10^{-3}
24	6.70	1.48	0.0329	3.40×10^{-3}	9.01×10^{-3}	2.40×10^{-3}	8.42×10^{-3}
23	5.49	1.21	0.0119	7.52×10^{-3}	2.82×10^{-2}	6.63×10^{-3}	2.33×10^{-2}
22	4.5	0.99	0.00462	2.03×10^{-2}	7.36×10^{-2}	1.71×10^{-2}	6.00×10^{-2}
21	3.68	0.82	0.00182	6.10×10^{-2}	1.43×10^{-1}	4.34×10^{-2}	1.52×10^{-1}
20 through 18	2.02	1.66	0.000456	8.49×10^{-2}	1.87×10^{-1}	1.73×10^{-1}	6.07×10^{-1}
17 through 11	0.111	1.909	0.000017	9.92×10^{-2}	2.06×10^{-1}	4.64×10^{0}	16.6×10^{0}

*K was obtained by summing the product of columns A x B x C and dividing the result by the sum of column A.

Table 22. Neutron Leakage Shield Source Data;
47 Batches of 800 Neutrons Each

Lower Energy Boundary (MeV)	05R Leakage				SNARLS Shield Source			
	Number of Neutrons		Total Weight		Number of Neutrons		Total Weight	
	$\mu > 0.7$	$\mu < 0.7$	$\mu > 0.7$	$\mu < 0.7$	$\mu > 0.7$	$\mu < 0.7$	$\mu > 0.7$	$\mu < 0.7$
12.2	2086	677	0.241	0.285	2100	773	0.246	0.290
10.0	2702	977	0.908	1.34	2559	1095	0.913	1.34
8.18	3141	1164	3.53	4.07	3082	1216	3.65	4.13
6.7	2894	1023	10.1	10.4	2825	1048	10.3	10.8
5.49	2113	860	22.7	28.7	2313	921	26.7	29.0
4.5	1414	585	32.4	37.7	1249	520	32.3	37.6
3.68	837	376	56.4	52.6	804	287	57.2	52.7
2.02	1187	804	266.0	270.0	883	345	266.0	269.0
0.100	3048	2313	684.0	859.0	194	91	692.0	891.0

Table 23. Neutron Leakage Shield Source Data; 50 Batches of 800 Neutrons Each

Lower Energy Boundary (MeV)	05R Leakage				SNARLS Shield Source			
	Number of Neutrons		Total Weight		Number of Neutrons		Total Weight	
	$\mu > 0.7$	$\mu < 0.7$	$\mu > 0.7$	$\mu < 0.7$	$\mu > 0.7$	$\mu < 0.7$	$\mu > 0.7$	$\mu < 0.7$
12.2	2253	811	0.242	0.304	2164	903	0.245	0.318
10.0	2968	1009	0.946	1.13	2729	1070	0.951	1.17
8.18	3353	1191	3.93	4.30	3318	1245	3.98	4.37
6.7	3098	1147	9.37	12.6	2839	1194	10.1	12.8
5.49	2229	845	21.4	23.6	2162	840	22.1	24.0
4.5	1427	592	33.5	46.8	1276	576	33.5	47.1
3.68	940	411	50.5	50.5	770	288	50.5	50.4
2.02	1262	849	217.0	280.0	803	355	217.0	281.0
0.100	3155	2373	2740.0	1080.0	352	101	2740.0	1090.0

2. The angular flux as a function of polar angle θ ($\cos\theta = \mu$) was obtained from a SNARLS run in which three energy groups, 2 radial intervals, and 5 polar angle intervals were used; thus the angular flux was calculated as an average over the core bottom for three broad energy groups.

3. The leakage flux as a function of radial position was obtained from a SNARLS run in which three energy groups, one polar angle interval, and ten radial intervals were used.

4. The leakage spectrum was obtained from a SNARLS run in which two radial intervals, one polar angle interval, and ten energy groups were used. Input data for the three SNARLS problems are listed in Appendix O.

The results of the SNARLS leakage angular flux calculations are given in Figs. 18 through 20. The angular flux $\phi(\mu)$ for three energy groups is presented in Fig. 18; the angular fluxes can be approximated by the following equations:

$$0.41 < E < 2.0 \text{ MeV}, \quad \phi(\mu) = 2.11 \times 10^{-5}\ \mu^{1.71}\ \text{neutrons cm}^{-2}\ \text{steradian}^{-1}\ (\text{source neutron})^{-1}$$

$$2.0 < E < 4.0 \text{ MeV}, \quad \phi(\mu) = 9.10 \times 10^{-6}\ \mu^{2.37}\ \text{neutrons cm}^{-2}\ \text{steradian}^{-1}\ (\text{source neutron})^{-1}$$

$$4.0 < E < 18.0 \text{ MeV}, \quad \phi(\mu) = 3.29 \times 10^{-6}\ \mu^{3.14}\ \text{neutrons cm}^{-2}\ \text{steradian}^{-1}\ (\text{source neutron})^{-1} \quad .$$

The leakage flux radial distributions are shown in Fig. 19 for three energy groups. The apparent dip in the distributions at the reactor center is probably due to undersampling in this region; since the biased source distribution was flat radially, fewer source neutrons were picked with small radii. The leakage flux spectrum is given in Fig. 20. The data presented in these figures are tabulated in Tables 24, 25, and 26.

Core Mapping - Program ACTIFK

In order to increase the number of scores at collimated detector locations, each collision point lying in the reactor system and lying in a cone defined by the collimator was allowed to contribute to the dose.

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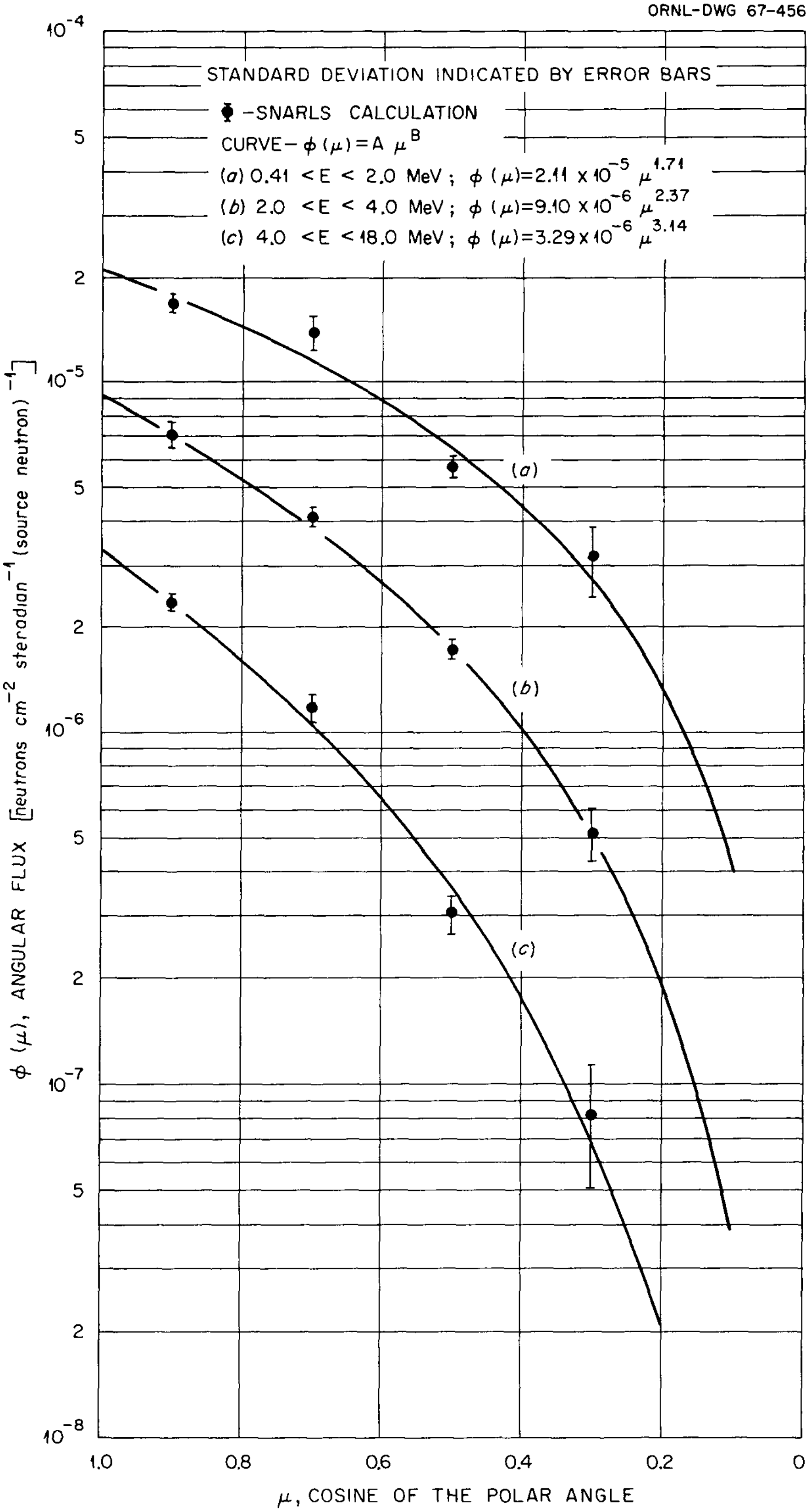

Fig. 18. Angular Leakage Flux from the SNAP-TSF Reactor Bottom. Averaged over radius 0.0 to 11.239 cm and over azimuthal angle.

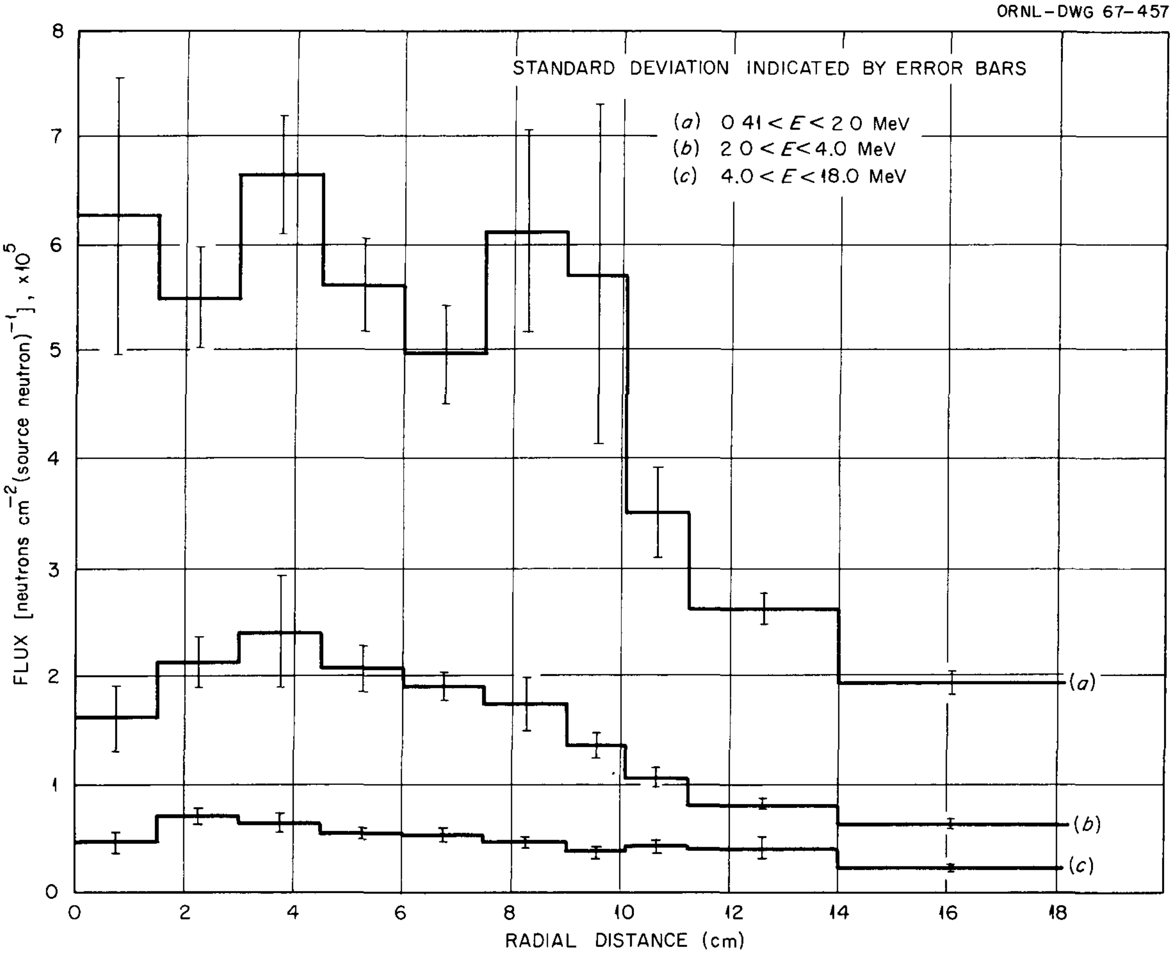

Fig. 19. Leakage Flux Radial Distribution, SNAP-TSF Reactor Bottom.

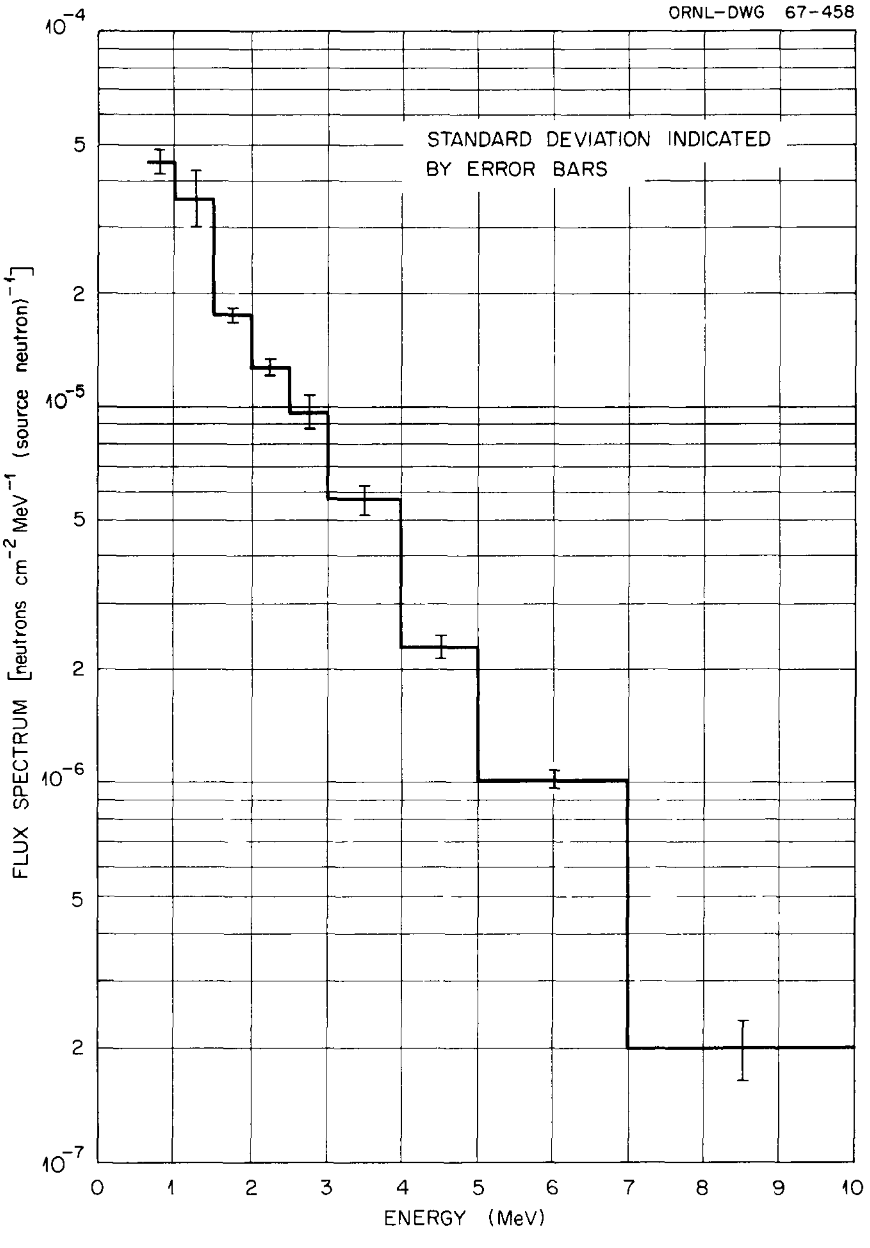

Fig. 20. Leakage Flux Spectrum from the SNAP-TSF Reactor Bottom. Averaged over radius 0.0 to 11.239 cm.

Table 24. Angular Leakage Flux [neutrons cm^{-2} steradian^{-1} (source neutron)$^{-1}$] from SNAP-TSF Reactor Bottom

Cosine of Polar Angle	$0.4076 < E < 2.0$ MeV		$2.0 < E < 4.0$ MeV		$4.0 < E < 18.0$ MeV	
	Angular Flux	Standard Deviation (%)	Angular Flux	Standard Deviation (%)	Angular Flux	Standard Deviation (%)
1-0.8	1.69×10^{-5}	4.8	7.12×10^{-6}	8.1	2.36×10^{-6}	4.9
0.8-0.6	1.40×10^{-5}	11.1	4.14×10^{-6}	6.2	1.19×10^{-6}	8.3
0.6-0.4	5.82×10^{-6}	7.1	1.74×10^{-6}	6.9	3.07×10^{-7}	12.3
0.4-0.2	3.20×10^{-6}	22.7	5.24×10^{-7}	17.8	8.30×10^{-8}	37.6

Table 25. Radial Distribution of Leakage Flux [neutrons cm^{-2} (source neutrons^{-1}] from SNAP-TSF Reactor System

Radial Distance (cm)	$0.4076 < E < 2.0$ MeV		$2.0 < E < 4.0$ MeV		$4.0 < E < 18.0$ MeV	
	Leakage Flux	Standard Deviation (%)	Leakage Flux	Standard Deviation (%)	Leakage Flux	Standard Deviation (%)
0-1.5	6.27×10^{-5}	20.7	1.62×10^{-5}	18.9	4.55×10^{-6}	22.7
1.5-3.0	5.51×10^{-5}	8.6	2.14×10^{-5}	10.8	7.20×10^{-6}	10.8
3.0-4.5	6.66×10^{-5}	8.4	2.42×10^{-5}	22.0	6.48×10^{-6}	15.1
4.5-6.0	5.63×10^{-5}	7.8	2.08×10^{-5}	10.1	5.52×10^{-6}	9.6
6.0-7.5	4.99×10^{-5}	9.0	1.92×10^{-5}	6.9	5.43×10^{-6}	11.4
7.5-9.0	6.14×10^{-5}	15.4	1.76×10^{-5}	14.2	4.73×10^{-6}	12.3
9.0-10.1	5.74×10^{-5}	27.6	1.37×10^{-5}	8.7	3.84×10^{-6}	10.3
10.1-11.239	3.53×10^{-5}	11.9	1.08×10^{-5}	8.2	4.31×10^{-6}	12.5
11.239-14.0	2.64×10^{-5}	5.5	8.27×10^{-6}	5.8	4.18×10^{-6}	23.0
14.0-18.135	1.96×10^{-5}	5.6	6.47×10^{-6}	5.8	2.35×10^{-6}	9.6

Table 26. Leakage Flux Spectrum from the SNAP-TSF Reactor Bottom

Lower Energy (MeV	Energy Width (MeV	Leakage Flux [neutrons cm^{-2} MeV^{-1} (source neutrons)$^{-1}$]	Standard Deviation (%)
10.0	8.0	6.04×10^{-9}	24.7
7.0	3.0	2.00×10^{-7}	18.2
5.0	2.0	1.02×10^{-6}	5.1
4.0	1.0	2.31×10^{-6}	6.3
3.0	1.0	5.75×10^{-6}	8.5
2.5	0.5	9.70×10^{-6}	10.2
2.0	0.5	1.29×10^{-5}	6.1
1.5	0.5	1.76×10^{-5}	4.7
1.0	0.5	3.58×10^{-5}	18.3
0.4076	0.5924	4.51×10^{-5}	8.0

The method, statistical estimation, involved determining the probability that the neutron at each collision point would on its next flight intersect the detector.

At each collision site within the collimator cone (see Fig. 21) the weight W scored at the detector is given by

$$W = \frac{W_o \, P(\mu) \, e^{-\lambda} \, D(\theta)}{r^2} \quad ,$$

where

W_o = the neutron weight at the collision site,

r = the distance from the collision site to the detector,

λ = the number of mean free paths through the system from the collision site to the detector,

μ = the cosine of the angle between the neutron direction before collision and the direction from collision site to the detector,

$P(\mu)$ = the probability per unit solid angle of scattering through an angle defined by μ,

$D(\theta)$ = a collimator response function dependent upon the angle θ between the collimator axis and the line joining the collision site to the collimator vertex (see Fig. 21).

(Realistic values of the last function were not used in this work.)

The accumulated weight W divided by the number of source neutrons is the flux per source neutron at the detector location. The accumulation may be done over energy groups, which gives a flux spectrum at the detector.

Program ACTIFK was modified to calculate flux spectra at the collimated detectors using the SNAP-TSF geometry and the collision tapes prepared by O5R runs on the SNAP-TSF reactor system. ACTIFK uses the same geometry input as O5R and the same approximations for elastic scattering distributions and for inelastic scattering treatment; program modifications

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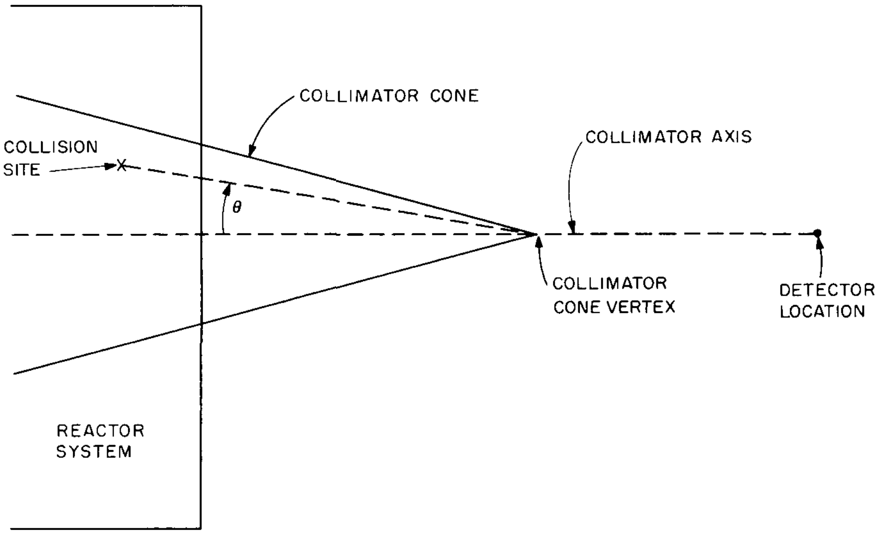


Fig. 21. Collimator Geometry.

are required only in the subroutines which the user must write for each problem.

GEOM Input

With some minor modifications the 05R GEOM input was used for ACTIFK; the internal void medium number 1000 was changed to 500. The ACTIFK version that was used was for a maximum of 8 media and 32 scatterers per medium; however, the 05R collision tapes were prepared with 10-medium description of the reactor. In order to make the collision tapes and ACTIFK compatible, the first three 05R media were changed since collisions in these media were not important to the flux at the reactor bottom. In the GEOM input medium 1, the top head, was changed to medium 8, the bottom grid hexagon. Medium 2, the top grid hexagon, was changed to medium 8 also. Medium 3, the top grid edge, was changed to medium 9, the bottom grid edge. Then all media numbers excepting 1000 and 0 were reduced by 3. Table 27 shows the original 05R GEOM input media numbers and the modified ACTIFK GEOM input media numbers.

Media numbers read by ACTIFK from the 05R collision tapes, excepting 0 and 1000, were reduced by 3 in subroutine RELCOL; collisions with negative media numbers were not processed.

A listing of the ACTIFK GEOM input (drums in) appears in Appendix B

Total Cross Section Tape - CODE 7

Program ACTIFK needs a data tape containing the total cross sections for each medium in order to calculate λ, the number of mean free paths through the system from the collision site to the detector. Program XSECT (CODE 7)[2] generates this tape; however, several CODE 5's, cross-section arithmetic, and Code 4's, delete and recopy cross sections, were required to generate the total cross sections and to put them on the master cross-section library tape. The same compositions used in the 05R systems data tape preparation were used for the seven media in the generation of the total-cross-section tape. Listings of the CODE 4, CODE 5, and CODE 7 inputs are given in Appendix P.

Table 27. ACTIFK GEOM Media Numbers

05R GEOM Media	ACTIFK GEOM Media
1	5
2	5
3	6
4	1
5	2
6	3
7	4
8	5
9	6
10	7
1000	500
0	0

Elastic Scattering Angular Distribution, F Tape - CODE 7

ACTIFK must be able to determine the probability P(μ) of scattering through the angle θ, between the neutron direction before collision and the direction from collision site to the detector. The master cross-section library contains the coefficients for the Legendre polynomial expansion of anisotropic angular elastic scattering probabilities. CODE 7 prepares the tape giving these coefficients for use by ACTIFK. In the SNAP-TSF reactor the order of the expansion for hydrogen was P_0, for zirconium and for the isotopes of uranium was P_6 and P_{14} respectively, and for all other elements was P_8. The CODE 7 input is listed in Appendix P.

ACTIFK Input

For the ACTIFK analysis of the O5R collision tapes generated by the core-mapping problem, the lowest energy of interest, EBOT, was 0.5 MeV. The LF1 parameters were negative for elastic scattering in order to use the F tape data for anisotropic elastic-scattering probabilities. Inelastic scattering was treated as isotropic in the center-of-mass system. Data required by the option for full analysis of the statistics were included; ten space-energy detectors (a space-energy detector is a specified energy group for a specified detector) received this treatment.

Appendixes P and Q contain the ACTIFK input data and input instructions respectively.

ACTIFK User Subroutines

In ACTIFK, as in O5R, a variety of subroutines must be written for the user's particular problem. These include subroutine STBATCH to read in and to print out special data and to initialize certain variables; subroutine SDATA to calculate uncollided flux from source points; subroutine RELCOL to calculate scattered flux from collision sites; subroutine NBATCH to print out results at the end of each batch; subroutine OUTPUT to calculate and to print out batch averaged fluxes and standard deviations at the end of the run; and subroutine NONELAS to control the inelastic scattering treatment. Flow diagrams for these subroutines are given in Appendix R. Subroutine listings are in Appendix S. Input instructions for subroutine STBATCH are found in Appendix Q.

The estimator used in SDATA for the flux contribution from each source point was

$$W = \frac{W_o \, e^{-\lambda} \, D(\theta)}{4\pi r^2} \quad ,$$

and in RELCOL from each collision site was

$$W = \frac{W_o \, e^{-\lambda} \, P(\mu) \, D(\theta)}{r^2} \quad .$$

The collimator response function D(θ) was evaluated in function COLF (C,V,I), where C = cosθ, V is the speed squared, and I is the detector index. Since collimator response functions have not yet been evaluated, this function was set equal to 1.0; this means perfect collimation if the collimator cone description is described properly.

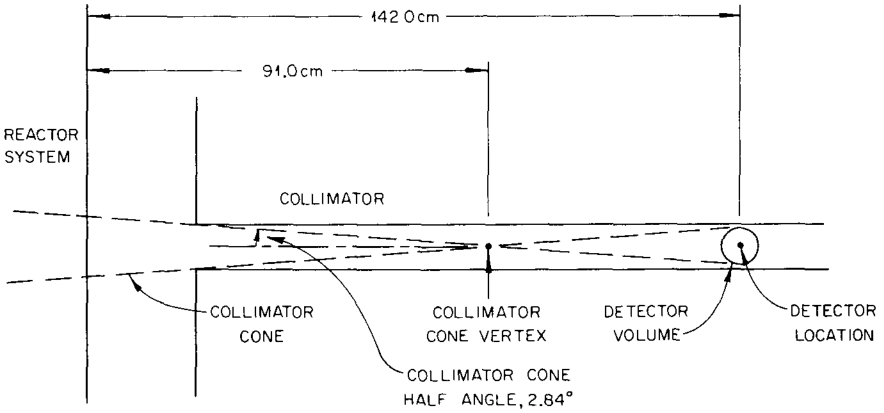
Core Mapping

Collimated Detector Description

For the preliminary ACTIFK analysis of the core-mapping problem, eight collimated detectors were specified. Perfect collimation was assumed. This implies that the collimator cone is defined by the collimator aperture and by the detector size, as shown in Fig. 22. The distance along the collimator axis from the bottom of the core to the detector was 142 cm, and from the bottom of the core to the collimator cone vertex was 91 cm. The collimator cone half-angle was 2.84°.

Table 28 gives the data required for the description of the eight collimated detectors. Detectors 1, 2, and 3 look at the reactor bottom at 0 radius and at angles 0, 30, and 60° respectively. Detector 4 looks at the reactor bottom at a radius of 5.923 cm and at 0°. Detectors 5, 6, 7, and 8 look at the reactor bottom at a radius of 11.864 cm and at angles of 0, 30 (away from reactor center), 30 (toward reactor center), and 60° (toward reactor center) respectively.

ORNL-DWG 67-460



NOT DRAWN TO SCALE

Fig. 22. Perfect Collimator Diagram for Core Mapping Problem.

Table 28. Perfect Collimator Data for Core-Mapping Problem

	Detector Number							
Data Description	1	2	3	4	5	6	7	8
Detector X coordinate, cm	0.0	-71.0	-122.9763	5.923	11.846	-59.154	82.846	143.8223
Detector Y coordinate, cm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector Z coordinate, cm	143.48	124.4563	72.48	143.48	143.48	124.4563	124.4563	72.48
Cone vertex X coordinate	0.0	-45.5	-78.8087	5.923	11.846	-33.654	57.346	90.6547
Cone vertex Y coordinate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cone vertex Z coordinate	92.48	80.2887	46.98	92.48	92.48	80.2887	80.2887	46.98
Cone direction cosine, α	0.0	0.5	0.86603	0.0	0.0	0.5	-0.5	-0.86603
Cone direction cosine, β	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cone direction cosine, γ	-1.0	-0.86603	-0.5	-1.0	-1.0	-0.86603	-0.86603	-0.5
Cosine of cone half angle	0.99876	0.99876	0.99876	0.99876	0.99876	0.99876	0.99876	0.99876

There were eleven energy groups for each collimated detector. The boundaries were 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 6.0, 10.0, and 18.0 MeV. There were ten space-energy detectors at which the full analyses of the statistics were requested. They were the fourth energy group for all detectors except detector number 3, the tenth energy group for detector number 1, and the third and seventh energy groups for detector number 3.

The input data read by subroutine STBATCH for the SNAP-TSF core mapping problem are given in Appendix P.

ACTIFK Calculation

Using the four collision tapes prepared by the O5R run on the core-mapping problem, one ACTIFK run was made. Out of the 60 batches on the tapes the first 40 batches of 800 neutrons each were processed. The running time on the CDC-1604A computer was 175 min.

ACTIFK Results

The flux spectra calculated by ACTIFK at each of the eight detectors are shown in Figs. 23 through 25. The same data are given in Tables 29 and 30. Except for detector No. 6, which was not looking toward the reactor core, and except for the energy group 1.5 to 2.0 MeV, which apparently contained a neutron with an extremely large weight, the standard deviations for 32000 source neutrons generally ranged from 5 to 20%; however, each detector viewed only a portion of the core, and relatively few of the source neutrons contributed anything to a given detector. The ACTIFK frequency table requested for ten of the space-energy detectors showed that the number of source neutrons that counted ranged from 68 to 2218. The frequency table also showed that for these particular ten space-energy detectors no one neutron nor any small group of neutrons contributed a large fraction to the final answer.

For the number of histories processed and for the amount of machine time involved, the results can be considered good.

Although the uncollided flux is treated separately in ACTIFK and averages for each batch are printed out, no provision to calculate the

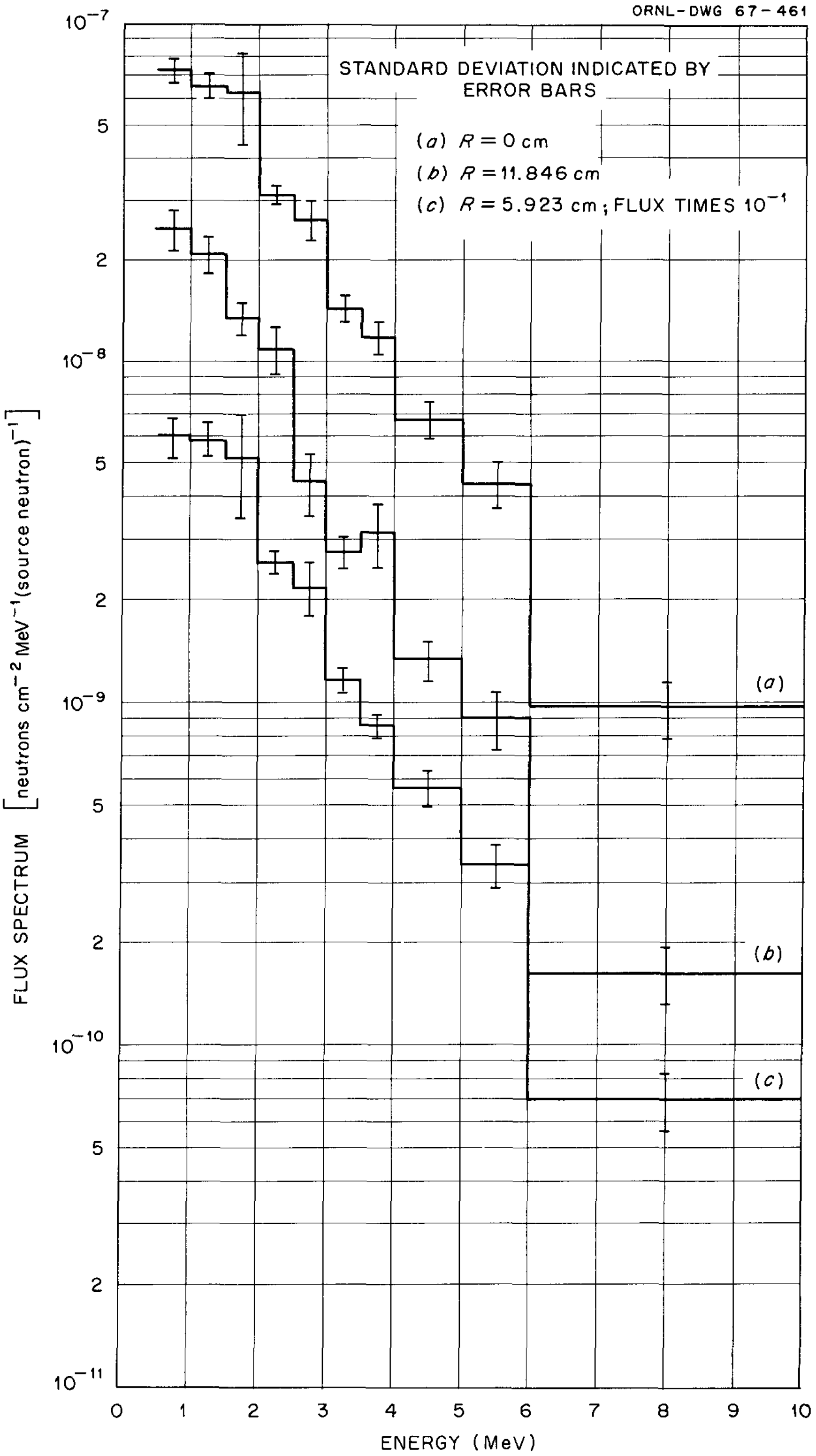


Fig. 23. Collimated Leakage Flux Spectra from the SNAP-TSF Reactor Bottom. Collimator angle 0 deg from normal to reactor bottom; R = radius at which collimator axis intersects reactor bottom (in Y = 0 plane).

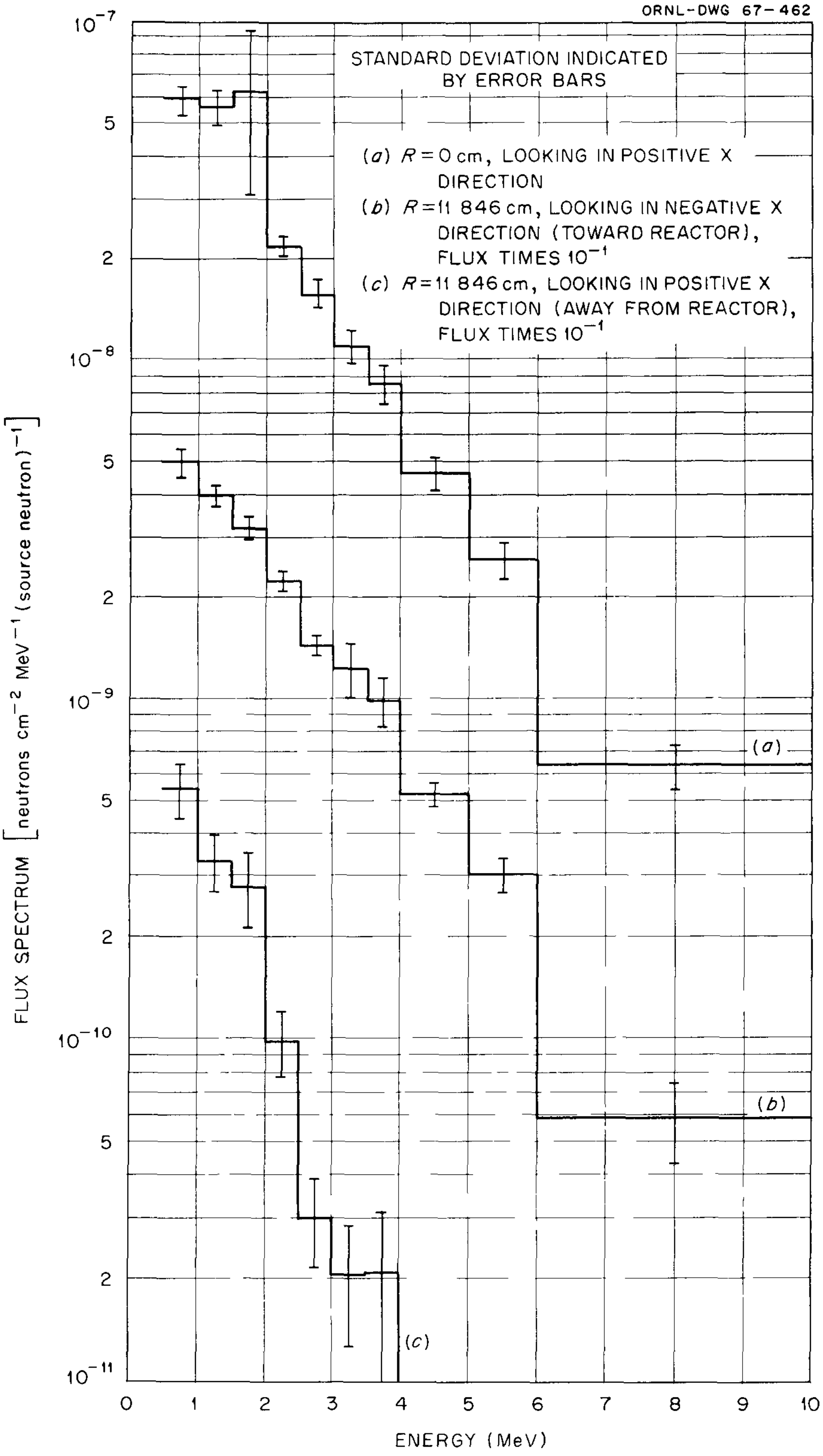


Fig. 24. Collimated Leakage Flux Spectra from the SNAP-TSF Reactor Bottom. Collimator angle 30 deg from normal to reactor bottom in Y = 0 plane; R = radius at which collimator axis intersects reactor bottom.

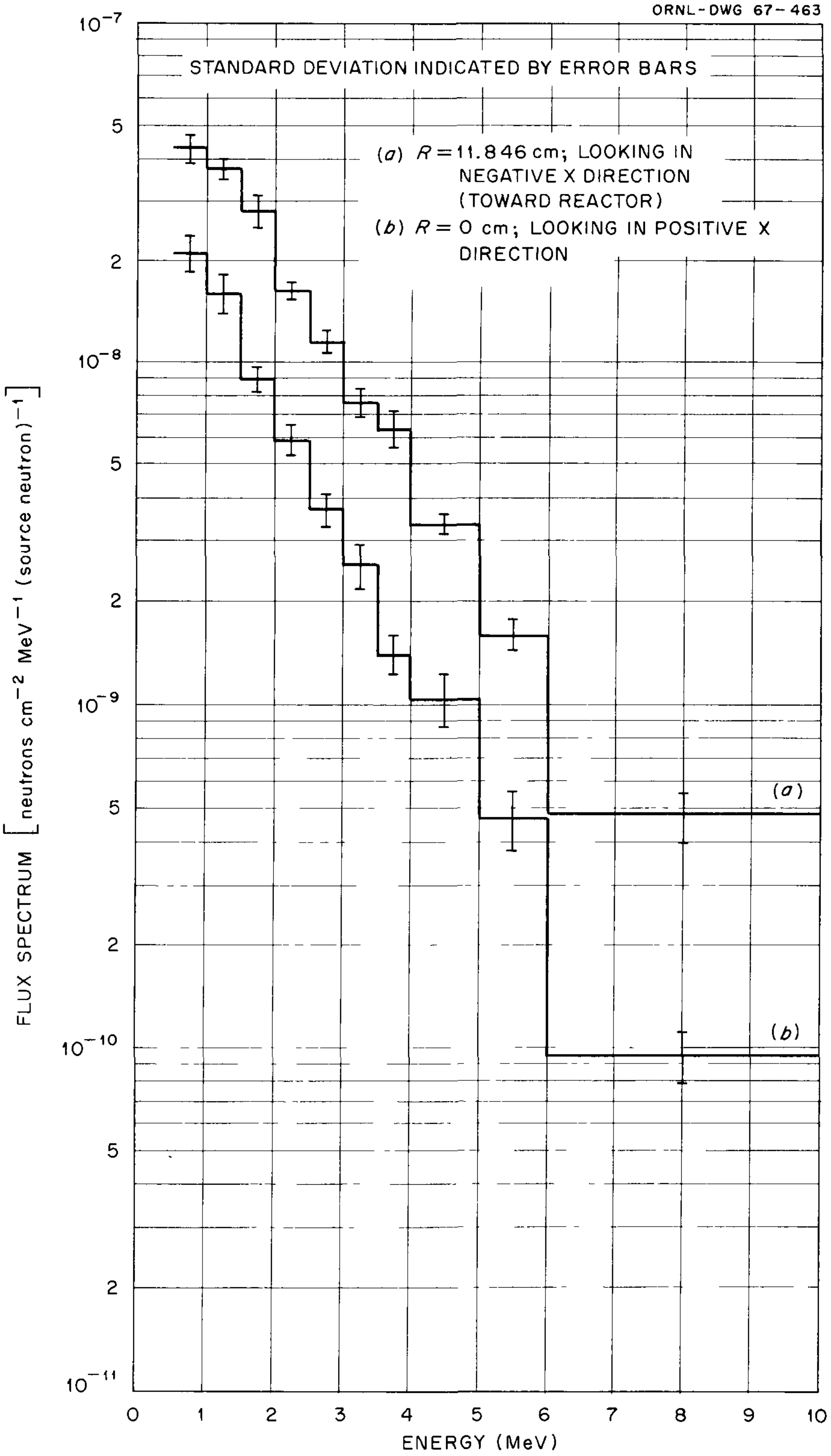


Fig. 25. Collimated Leakage Flux Spectra from the SNAP-TSF Reactor Bottom. Collimator angle 60 deg from normal to reactor bottom in Y = 0 plane; R = radius at which collimator axis intersects reactor bottom.

Table 29. ACTIFK Flux Spectra from the SNAP-TSF Reactor Bottom

Lower Energy (MeV)	Flux Spectra [neutrons cm^{-2} MeV^{-1} (source neutron)$^{-1}$] for Detector							
	No. 1 R = 0.0 cm[a] $\theta = 0°$	No. 2 R = 0.0 cm $\theta = 30°$	No. 3 R = 0.0 cm $\theta = 60°$	No. 4 R = 5.923 cm $\theta = 0°$	No. 5 R = 11.846 cm $\theta = 0°$	No. 6 R = 11.846 cm $\theta = 30°$[b]	No. 7 R = 11.846 cm $\theta = 30°$[c]	No. 8 R = 11.846 cm $\theta = 60°$[c]
0.5	7.30×10^{-8}	5.90×10^{-8}	2.10×10^{-8}	6.00×10^{-8}	2.46×10^{-8}	5.44×10^{-9}	5.00×10^{-8}	4.30×10^{-8}
1.0	6.56×10^{-8}	5.60×10^{-8}	1.61×10^{-8}	5.88×10^{-8}	2.08×10^{-8}	3.32×10^{-9}	4.00×10^{-8}	3.72×10^{-8}
1.5	6.30×10^{-8}	6.22×10^{-8}	8.90×10^{-9}	5.20×10^{-8}	1.34×10^{-9}	2.80×10^{-9}	3.20×10^{-8}	2.80×10^{-8}
2.0	3.12×10^{-8}	2.18×10^{-8}	5.90×10^{-9}	2.56×10^{-8}	1.09×10^{-8}	9.84×10^{-10}	2.24×10^{-8}	1.64×10^{-8}
2.5	2.64×10^{-8}	1.58×10^{-8}	3.72×10^{-9}	2.18×10^{-8}	4.40×10^{-9}	3.04×10^{-10}	1.45×10^{-8}	1.16×10^{-8}
3.0	1.44×10^{-8}	1.10×10^{-8}	2.56×10^{-9}	1.17×10^{-8}	2.76×10^{-9}	2.06×10^{-10}	1.24×10^{-8}	7.64×10^{-9}
3.5	1.18×10^{-8}	8.52×10^{-9}	1.41×10^{-9}	8.56×10^{-9}	3.12×10^{-9}	2.08×10^{-10}	9.92×10^{-9}	6.36×10^{-9}
4.0	6.76×10^{-9}	4.64×10^{-9}	1.04×10^{-9}	5.66×10^{-9}	1.34×10^{-9}	4.81×10^{-11}	5.28×10^{-9}	3.36×10^{-9}
5.0	4.36×10^{-9}	2.60×10^{-9}	4.66×10^{-10}	3.39×10^{-9}	9.04×10^{-10}		3.05×10^{-9}	1.60×10^{-9}
6.0	9.72×10^{-10}	6.44×10^{-10}	9.49×10^{-11}	6.95×10^{-10}	1.63×10^{-10}		5.90×10^{-10}	4.80×10^{-10}
10.0								

a. For each detector R is the radius from the reactor axis and θ is the collimator inclination angle.
b. Directed away from the reactor.
c. Directed toward the reactor.

Table 30. ACTIFK - Standard Deviation for Flux Spectra from the SNAP-TSF Reactor Bottom

Lower Energy (MeV)	Standard Deviation (%) for Detector							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
0.5	8.5	9.4	12.6	12.7	13.5	18.4	9.1	8.9
1.0	8.2	11.6	12.5	10.8	12.9	19.7	7.0	7.0
1.5	30.6	49.9	7.9	33.3	11.0	24.5	7.4	10.8
2.0	6.0	6.2	9.9	7.2	15.8	21.0	6.4	5.1
2.5	13.3	8.9	10.1	18.4	20.8	28.5	6.2	6.7
3.0	8.9	10.8	14.1	7.7	10.5	37.8	18.4	9.6
3.5	11.3	12.7	12.5	7.5	20.7	51.9	16.5	11.9
4.0	11.8	10.7	17.0	11.4	12.8	29.8	8.0	6.2
5.0	15.1	12.3	18.9	13.2	19.5		11.4	10.7
6.0	18.7	14.6	16.5	19.1	18.6		26.2	15.2
10.0								

batch average was made. A hand calculation for the uncollided flux was made for detector No. 1, $R = 0.0$ cm and $\theta = 0^\circ$; these data appear in Table 31.

A comparison between ACTIFK and SNARLS was made. Since the SNARLS results were averaged over the core bottom and azimuthal angle, the comparison was made only with the ACTIFK answers at $R = 0.0$. The flux at the detector, Φ_D, was obtained from

$$\Phi_D = \frac{\phi(\mu)\ \Delta A}{R_2^2\ F} \quad ,$$

where

$\phi(\mu)$ = the SNARLS angular flux for $\mu = 1.0$ (cosine of the polar angle),

ΔA = the area of the reactor bottom within the collimator cone,

R_2 = the distance from the reactor bottom to the detector,

F = the average leakage flux value over the core bottom, assuming that the value at $R = 0.0$ was 1.0 and that the distribution was the same as the radial power distribution.

This equation can be written

$$\Phi_D = \phi(\mu)\ \frac{\Delta A}{R_1^2}\ \frac{R_1^2}{R_2^2\ F} \quad ,$$

where R_1 is the distance from the reactor bottom to the collimator cone vertex. However, since $\Delta A/R_1^2$ is the solid angle $\Delta\Omega$ subtended by the collimator cone,

$$\Phi_D = \phi(\mu)\ \Delta\Omega\ \frac{R_1^2}{R_2^2\ F} \quad .$$

Inserting values for $\Delta\Omega$, R_1, R_2, and F,

$$\Phi_D = 4.22 \times 10^{-3}\ \phi(\mu) \quad .$$

Table 31. ACTIFK Uncollided Flux Spectrum from the SNAP-TSF Reactor Bottom; Detector Number One

Lower Energy (MeV)	Uncollided Flux [neutrons cm^{-2} MeV^{-1} (source neutron)$^{-1}$]	Standard Deviation in Uncollided Flux (%)	Total Flux [neutrons cm^{-2} MeV^{-1} (source neutron)$^{-1}$]	Standard Deviation in Total Flux (%)	Uncollided Flux (% of total flux)
0.5	8.45×10^{-9}	8.6	7.30×10^{-8}	8.5	11.6
1.0	1.14×10^{-8}	5.4	6.56×10^{-8}	8.2	17.4
1.5	1.15×10^{-8}	4.2	6.30×10^{-8}	30.6	18.2
2.0	1.12×10^{-8}	4.2	3.12×10^{-8}	7.5	35.9
2.5	8.55×10^{-9}	5.1	2.64×10^{-8}	13.3	32.4
3.0	6.72×10^{-9}	6.0	1.44×10^{-8}	8.9	46.7
3.5	5.15×10^{-9}	7.2	1.18×10^{-8}	11.3	43.6
4.0	3.48×10^{-9}	5.4	6.76×10^{-9}	11.8	51.5
5.0	1.82×10^{-9}	7.6	4.36×10^{-9}	15.1	41.7
6.0	4.44×10^{-10}	6.4	9.72×10^{-10}	18.9	45.7
10.0					

The comparison is presented in Table 32; the ACTIFK energy groups were combined to form the broader SNARLS energy groups.

V. CONCLUSIONS

The O5R Monte Carlo neutron transport code was modified for the analysis of the ORNL SNAP-TSF experiments. In addition, the development of machine programs for the analyses of O5R collision tapes was completed; included were program SNARLS for the determination of the leakage neutron source to be used in subsequent O5R calculations of neutron penetration in a SNAP-2 shield and program ACTIFK for the calculation of the flux spectra measured by collimated detectors viewing portions of the bottom face of the reactor. A variety of programs were written to assist in the preparation of data for the analyses.

Some preliminary analyses were performed on the SNAP-TSF reactor. The geometry model, material specifications, and neutron reaction processes are given in great detail. For the preliminary analyses the reactor core consisted of a hexagonal volume in which the fuel, cladding, NaK and three beryllium rods were homogenized. The control drums were turned in.

The axial and radial power distributions were determined using O5R. Biased power distributions, neutron source energy distributions, and neutron source angular distributions for the O5R leakage calculations were obtained from importance functions derived from adjoint S_n calculations on the system.

A comparison between the SNARLS and ACTIFK results indicated that the two different flux estimators were in reasonable agreement.

A version of O5R which does not allow leakage from the system is currently under study; although this version is not a subject of this report, it has been tried on the preliminary core-mapping problem. Fewer histories were processed for a given computer running time in this version; however, better statistics are obtained at the lower energies. The final analyses of the experiments may require the use of the regular O5R for high-energy results and use of the "no leakage" version of O5R for the lower energy results.

Table 32. ACTIFK-SNARLS Comparison

Lower Energy (MeV)	SNARLS Angular Flux, $\phi(\mu)$ [neutrons cm^{-2} steradian^{-1} (source neutron)$^{-1}$]	SNARLS Calculated Total Flux, Φ_D [neutrons cm^{-2} (source neutron)$^{-1}$]	ACTIFK Total Flux, Φ_D [neutrons cm^{-2} (source neutron.)$^{-1}$]	SNARLS Deviation from ACTIFK (%)
Detector No. 1; R = 0.0 and θ = 0°				
0.5	2.11×10^{-5}	0.89×10^{-7}	1.01×10^{-7}	-12
2.0	9.10×10^{-6}	3.84×10^{-8}	4.19×10^{-8}	- 8
4.0	3.29×10^{-6}	1.39×10^{-8}	1.51×10^{-8}	- 8
Detector No. 2; R = 0.0 and 2 = 30°				
0.5	1.65×10^{-5}	6.96×10^{-8}	8.86×10^{-8}	-21
2.0	6.47×10^{-6}	2.73×10^{-8}	2.86×10^{-8}	- 5
4.0	2.09×10^{-6}	8.82×10^{-9}	9.82×10^{-9}	-10
Detector No. 3; R = 0.0 and θ = 60°				
0.5	6.45×10^{-6}	2.72×10^{-8}	2.30×10^{-8}	+18
2.0	1.76×10^{-6}	7.43×10^{-9}	6.80×10^{-9}	+ 9
4.0	3.73×10^{-7}	1.57×10^{-9}	1.89×10^{-9}	-17

The final analyses of the SNAP-TSF experiments should be done with certain information on the reactor configuration available. The position of the fine control drums should be specified. If only one beryllium rod is in the core (at the core center), the source specifications should be changed, as well as the atomic densities of the core; one beryllium rod at the center can be handled exactly by the geometry specifications.

In addition, the correct NaK density should be used in the analyses; the preliminary analyses used the density at 20°C for the NaK. In order to improve statistics at small core radii, the radial biased source distribution should be changed. The flat distribution caused too many source neutrons to be picked at large radii. Collimator efficiency data should be obtained for program ACTIFK. These data are required by function COLF to adjust the detector results according to the collimator response for each collision site viewed.

With the improved reactor specifications a new O5R run must be made to determine the fission distribution. With the better fission distribution as the source, the final SNARLS and ACTIFK calculations can be done.

APPENDIX A

GEOM INOUT FOR DRUMS IN

1. Shield Source Problem (2 Regions)

```
    1     MALE
X ZONE       -16,3525,   16.3525                                                 00000020
Y ZONE       -16,8656,   16,8656                                                 00000030
Z ZONE       -39,7455,  -36.9794,  -35.1150,       -4.0,    -2,5146,             00000040
     1,471                                                                       00000050
ZONE       1    1    1                                                           00000060
X BLOCK      -16,3525,   16.3525                                                 00000070
Y BLOCK      -16,8656,   16,8656                                                 00000080
Z BLOCK      -39,7455,  -36.9794                                                 00000090
BLOCK      1    1    1                                                           00000100
MEDIA               1, 1000                                                      00000110
SURFACES            1                                                            00000120
SECTOR -1                                                                        00000130
SECTOR  1                                                                        00000140
REGIONS             1                                                                 141
ZONE       1    1    2                                                           00000150
X BLOCK      -16,3525,  -9,73370,        0,0,     9,7337,    16,3525             00000160
Y BLOCK      -16,8656,   16.8656                                                 00000170
Z BLOCK      -36,9794,  -35,1150                                                 00000180
BLOCK      1    1    1                                                           00000190
MEDIA               3,     6, 1000                                               00000200
SURFACES            6,     7                                                     00000210
SECTOR -1  0                                                                     00000220
SECTOR  1 -1                                                                     00000230
SECTOR  0  1                                                                     00000240
REGIONS             1                                                                 241
BLOCK      2    1    1                                                           00000250
MEDIA               2,     3,     3,     6, 1000                                 00000260
SURFACES            3,     4,     6,     7                                       00000270
SECTOR  1  1  0  0                                                               00000280
SECTOR  0 -1 -1  0                                                               00000290
SECTOR -1  0 -1  0                                                               00000300
SECTOR  0  0  1 -1                                                               00000310
```

```
SECTOR  0  0  0  1                                                      00000320
REGIONS         1                                                            321
BLOCK     3    1    1                                                   00000330
MEDIA           2,    3,    3,    6, 1000                               00000340
SURFACES        2,    5,    6,    7                                     00000350
SECTOR -1 -1  0  0                                                      00000360
SECTOR  0  1 -1  0                                                      00000370
SECTOR  1  0 -1  0                                                      00000380
SECTOR  0  0  1 -1                                                      00000390
SECTOR  0  0  0  1                                                      00000400
REGIONS         1                                                            401
BLOCK     4    1    1                                                   00000410
MEDIA           3,    6, 1000                                           00000420
SURFACES        6,    7                                                 00000430
SECTOR -1  0                                                            00000440
SECTOR  1 -1                                                            00000450
SECTOR  0  1                                                            00000460
REGIONS         1                                                            461
ZONE      1    1    3                                                   00000470
X BLOCK      -16,3525,   -9.7337,   -6,6599,       0,0,    6.6599,      00000480
    9,7337,   16,3525                                                   00000490
Y BLOCK      -16,8656,   16.8656                                        00000500
Z BLOCK      -35,1150,      -4.0                                        00000510
BLOCK     1    1    1                                                   00000520
MEDIA           5,    6, 1000,    7,    0,    0                         00000530
SURFACES        6,    7,    8,    9,   12                               00000540
SECTOR -1  0  0  0  0                                                   00000550
SECTOR  1 -1  0  0  0                                                   00000560
SECTOR  0  1  0  0 -1                                                   00000570
SECTOR  0  0  1  1  1                                                   00000580
SECTOR  0  0 -1  0  0                                                   00000590
SECTOR  0  0  0 -1  0                                                   00000600
REGIONS         1                                                            601
BLOCK     2    1    1                                                   00000610
MEDIA           4,    5,    5,    6, 1000,    7,    0,    0             00000620
SURFACES        3,    4,    6,    7,    8,    9,   12                   00000630
SECTOR  1  1  0  0  0  0  0                                             00000640
```

```
SECTOR  0 -1 -1  0  0  0  0                                             00000650
SECTOR -1  0 -1  0  0  0  0                                             00000660
SECTOR  0  0  1 -1  0  0  0                                             00000670
SECTOR  0  0  0  1  0  0 -1                                             00000680
SECTOR  0  0  0  0  1  1  1                                             00000690
SECTOR  0  0  0  0 -1  0  0                                             00000700
SECTOR  0  0  0  0  0 -1  0                                             00000710
REGIONS         1                                                            711
BLOCK     3    1    1                                                   00000720
MEDIA            4,     5,     5,     6,  1000,     7                   00000730
SURFACES         3,     4,     6,     7,    12                          00000740
SECTOR  1  1  0  0  0                                                   00000750
SECTOR  0 -1 -1  0  0                                                   00000760
SECTOR -1  0 -1  0  0                                                   00000770
SECTOR  0  0  1 -1  0                                                   00000780
SECTOR  0  0  0  1 -1                                                   00000790
SECTOR  0  0  0  0  1                                                   00000800
REGIONS         1                                                            801
BLOCK     4    1    1                                                   00000810
MEDIA            4,     5,     5,     6,  1000,     7                   00000820
SURFACES         2,     5,     6,     7,    12                          00000830
SECTOR -1 -1  0  0  0                                                   00000840
SECTOR  0  1 -1  0  0                                                   00000850
SECTOR  1  0 -1  0  0                                                   00000860
SECTOR  0  0  1 -1  0                                                   00000870
SECTOR  0  0  0  1 -1                                                   00000880
SECTOR  0  0  0  0  1                                                   00000890
REGIONS         1                                                            891
BLOCK     5    1    1                                                   00000900
MEDIA            4,     5,     5,     6,  1000,     7,     0,     0     00000910
SURFACES         2,     5,     6,     7,    10,    11,    12            00000920
SECTOR -1 -1  0  0  0  0  0                                             00000930
SECTOR  0  1 -1  0  0  0  0                                             00000940
SECTOR  1  0 -1  0  0  0  0                                             00000950
SECTOR  0  0  1 -1  0  0  0                                             00000960
SECTOR  0  0  0  1  0  0 -1                                             00000970
SECTOR  0  0  0  0 -1 -1  1                                             00000980
```

```
SECTOR  0  0  0  0  1  0  0                                             00000990
SECTOR  0  0  0  0  0  1  0                                             00001000
REGIONS         1                                                           1001
BLOCK     6    1    1                                                   00001010
MEDIA           5,    6, 1000,    7,    0,    0                         00001020
SURFACES        6,    7,   10,   11,   12                               00001030
SECTOR -1  0  0  0  0                                                   00001040
SECTOR  1 -1  0  0  0                                                   00001050
SECTOR  0  1  0  0 -1                                                   00001060
SECTOR  0  0 -1 -1  1                                                   00001070
SECTOR  0  0  1  0  0                                                   00001080
SECTOR  0  0  0  1  0                                                   00001090
REGIONS         1                                                           1091
ZONE      1    1    4                                                   00001100
XBLOCK       -16.3525,   -9.7337,       0.0,    9.7337,    16.3525      00001110
YBLOCK       -16.8656,    16.8656                                       00001120
ZBLOCK           -4.0,   -2.5146                                        00001130
BLOCK     1    1    1                                                   00001140
MEDIA           9,    6, 1000                                           00001150
SURFACES        6,   13                                                 00001160
SECTOR -1  0                                                            00001170
SECTOR  1 -1                                                            00001180
SECTOR  0  1                                                            00001190
REGIONS         1                                                           1191
BLOCK     2    1    1                                                   00001200
MEDIA           8,    9,    9,    6, 1000                               00001210
SURFACES        3,    4,    6,    13                                    00001220
SECTOR  1  1  0  0                                                      00001230
SECTOR  0 -1 -1  0                                                      00001240
SECTOR -1  0 -1  0                                                      00001250
SECTOR  0  0  1 -1                                                      00001260
SECTOR  0  0  0  1                                                      00001270
REGIONS         1                                                           1271
BLOCK     3    1    1                                                   00001280
MEDIA           8,    9,    9,    6, 1000                               00001290
SURFACES        2,    5,    6,     13                                   00001300
SECTOR -1 -1  0  0                                                      00001310
```

```
SECTOR  0  1 -1  0                                                     00001320
SECTOR  1  0 -1  0                                                     00001330
SECTOR  0  0  1 -1                                                     00001340
SECTOR  0  0  0  1                                                     00001350
REGIONS         1                                                          1351
BLOCK     4    1    1                                                  00001360
MEDIA           9,    6,  1000                                         00001370
SURFACES        6,    13                                               00001380
SECTOR -1  0                                                           00001390
SECTOR  1 -1                                                           00001400
SECTOR  0  1                                                           00001410
REGIONS         1                                                          1411
ZONE      1    1    5                                                  00001420
X BLOCK      -16.3525,    16.3525                                      00001430
Y BLOCK      -16.8656,    16.8656                                      00001440
Z BLOCK       -2.5146,       1.471                                     00001450
BLOCK     1    1    1                                                  00001460
MEDIA           6,    6,     10, 1000, 1000                            00001470
SURFACES        6,    13,    14,    15                                 00001480
SECTOR  1 -1  0  1                                                     00001490
SECTOR  0 -1  1 -1                                                     00001500
SECTOR -1  0  0  1                                                     00001510
SECTOR  0  1  1  0                                                     00001520
SECTOR  0  0 -1  0                                                     00001530
REGIONS         2                                                          1531
   15    QUADRIC SURFACES, DRUMS IN                                    00001540
       1.0XSQ          1.0YSQ   -130.55782      $                      00001550
       1.0X        -1.73205Y      -19.4672      $                      00001560
       1.0X         1.73205Y       19.4672      $                      00001570
       1.0X        -1.73205Y       19.4672      $                      00001580
       1.0X         1.73205Y      -19.4672      $                      00001590
       1.0XSQ          1.0YSQ   -127.04108      $                      00001600
       1.0XSQ          1.0YSQ   -129.92010      $                      00001610
       1.0X            1.0Y       23.52820      $                      00001620
       1.0X           -1.0Y       23.52820      $                      00001630
       1.0X            1.0Y      -23.52820      $                      00001640
       1.0X           -1.0Y      -23.52820      $                      00001650
```

```
      1,0XSQ           1,0YSQ   -133,74044     $                        00001660
      1.0XSQ           1,0YSQ   -134,29913     $                        00001670
      1,0XSQ           1,0YSQ          1,0ZSQ       -93,98Z    $        00001680
      1.0XSQ           1,0YSQ          1,0ZSQ       -93,98Z             00001690
-29,93946      $                                                        00001700
```

2. Core-Mapping Problem (4 Regions)

```
    1     MALE
X ZONE       -16.3525,    16.3525                                           00000020
Y ZONE       -16.8656,    16.8656                                           00000030
Z ZONE       -39.7455,   -36.9794,   -35.1150,      -4.0,    -2.5146,       00000040
     1.471                                                                  00000050
ZONE       1    1    1                                                      00000060
X BLOCK      -16.3525,    16.3525                                           00000070
Y BLOCK      -16.8656,    16.8656                                           00000080
Z BLOCK      -39.7455,   -36.9794                                           00000090
BLOCK      1    1    1                                                      00000100
MEDIA            1, 1000                                                    00000110
SURFACES         1                                                          00000120
SECTOR -1                                                                   00000130
SECTOR  1                                                                   00000140
REGIONS          1                                                               141
ZONE       1    1    2                                                      00000150
X BLOCK      -16.3525,  -9.73370,        0.0,     9.7337,   16.3525        00000160
Y BLOCK      -16.8656,    16.8656                                           00000170
Z BLOCK      -36.9794,   -35.1150                                           00000180
BLOCK      1    1    1                                                      00000190
MEDIA            3,    6, 1000                                              00000200
SURFACES         6,    7                                                    00000210
SECTOR -1   0                                                               00000220
SECTOR  1 -1                                                                00000230
SECTOR  0   1                                                               00000240
REGIONS          1                                                               241
BLOCK      2    1    1                                                      00000250
MEDIA            2,    3,    3,    6, 1000                                  00000260
SURFACES         3,    4,    6,    7                                        00000270
SECTOR  1  1  0  0                                                          00000280
SECTOR  0 -1 -1  0                                                          00000290
SECTOR -1  0 -1  0                                                          00000300
SECTOR  0  0  1 -1                                                          00000310
```

```
SECTOR  0  0  0  1                                                      00000320
REGIONS         1                                                            321
BLOCK     3    1    1                                                   00000330
MEDIA           2,    3,    3,    6, 1000                               00000340
SURFACES        2,    5,    6,    7                                     00000350
SECTOR -1 -1  0  0                                                      00000360
SECTOR  0  1 -1  0                                                      00000370
SECTOR  1  0 -1  0                                                      00000380
SECTOR  0  0  1 -1                                                      00000390
SECTOR  0  0  0  1                                                      00000400
REGIONS         1                                                            401
BLOCK     4    1    1                                                   00000410
MEDIA           3,    6, 1000                                           00000420
SURFACES        6,    7                                                 00000430
SECTOR -1  0                                                            00000440
SECTOR  1 -1                                                            00000450
SECTOR  0  1                                                            00000460
REGIONS         1                                                            461
ZONE      1    1    3                                                   00000470
X BLOCK      -16.3525,   -9.7337,   -6.6599,       0.0,    6.6599,      00000480
    9.7337,   16.3525                                                   00000490
Y BLOCK      -16.8656,   16.8656                                        00000500
Z BLOCK      -35.1150,      -4.0                                        00000510
BLOCK     1    1    1                                                   00000520
MEDIA           5,    6, 1000,    7,    0,    0                         00000530
SURFACES        6,    7,    8,    9,   12                               00000540
SECTOR -1  0  0  0  0                                                   00000550
SECTOR  1 -1  0  0  0                                                   00000560
SECTOR  0  1  0  0 -1                                                   00000570
SECTOR  0  0  1  1  1                                                   00000580
SECTOR  0  0 -1  0  0                                                   00000590
SECTOR  0  0  0 -1  0                                                   00000600
REGIONS         1,    2,    3                                                601
SURFACES       16,   17                                                      602
SECTOR -1  0                                                                 603
SECTOR  1 -1                                                                 604
SECTOR  0  1                                                                 605
```

```
BLOCK     2    1    1                                                   00000610
MEDIA           4,    5,    5,    6, 1000,    7,    0,     0            00000620
SURFACES        3,    4,    6,    7,    8,    9,   12                   00000630
SECTOR  1  1  0  0  0  0  0                                             00000640
SECTOR  0 -1 -1  0  0  0  0                                             00000650
SECTOR -1  0 -1  0  0  0  0                                             00000660
SECTOR  0  0  1 -1  0  0  0                                             00000670
SECTOR  0  0  0  1  0  0 -1                                             00000680
SECTOR  0  0  0  0  1  1  1                                             00000690
SECTOR  0  0  0  0 -1  0  0                                             00000700
SECTOR  0  0  0  0  0 -1  0                                             00000710
REGIONS         1,    2,    3                                                711
SURFACES       16,   17                                                      712
SECTOR -1  0                                                                 713
SECTOR  1 -1                                                                 714
SECTOR  0  1                                                                 715
BLOCK     3    1    1                                                   00000720
MEDIA           4,    5,    5,    6, 1000,    7                         00000730
SURFACES        3,    4,    6,    7,    12                              00000740
SECTOR  1  1  0  0  0                                                   00000750
SECTOR  0 -1 -1  0  0                                                   00000760
SECTOR -1  0 -1  0  0                                                   00000770
SECTOR  0  0  1 -1  0                                                   00000780
SECTOR  0  0  0  1 -1                                                   00000790
SECTOR  0  0  0  0  1                                                   00000800
REGIONS         1,    2,    3                                                801
SURFACES       16,   17                                                      802
SECTOR -1  0                                                                 803
SECTOR  1 -1                                                                 804
SECTOR  0  1                                                                 805
BLOCK     4    1    1                                                   00000810
MEDIA           4,    5,    5,    6, 1000,    7                         00000820
SURFACES        2,    5,    6,    7,    12                              00000830
SECTOR -1 -1  0  0  0                                                   00000840
SECTOR  0  1 -1  0  0                                                   00000850
SECTOR  1  0 -1  0  0                                                   00000860
SECTOR  0  0  1 -1  0                                                   00000870
```

```
SECTOR  0  0  0  1 -1                                                   00000880
SECTOR  0  0  0  0  1                                                   00000890
REGIONS         1,    2,    3                                                891
SURFACES       16,   17                                                      892
SECTOR -1  0                                                                 893
SECTOR  1 -1                                                                 894
SECTOR  0  1                                                                 895
BLOCK     5    1    1                                                   00000900
MEDIA           4,    5,    5,    6, 1000,    7,    0,     0            00000910
SURFACES        2,    5,    6,    7,   10,   11,   12                   00000920
SECTOR -1 -1  0  0  0  0  0                                             00000930
SECTOR  0  1 -1  0  0  0  0                                             00000940
SECTOR  1  0 -1  0  0  0  0                                             00000950
SECTOR  0  0  1 -1  0  0  0                                             00000960
SECTOR  0  0  0  1  0  0 -1                                             00000970
SECTOR  0  0  0  0 -1 -1  1                                             00000980
SECTOR  0  0  0  0  1  0  0                                             00000990
SECTOR  0  0  0  0  0  1  0                                             00001000
REGIONS         1,    2,    3                                               1001
SURFACES       16,   17                                                     1002
SECTOR -1  0                                                                1003
SECTOR  1 -1                                                                1004
SECTOR  0  1                                                                1005
BLOCK     6    1    1                                                   00001010
MEDIA           5,    6, 1000,    7,    0,     0                        00001020
SURFACES        6,    7,   10,   11,   12                               00001030
SECTOR -1  0  0  0  0                                                   00001040
SECTOR  1 -1  0  0  0                                                   00001050
SECTOR  0  1  0  0 -1                                                   00001060
SECTOR  0  0 -1 -1  1                                                   00001070
SECTOR  0  0  1  0  0                                                   00001080
SECTOR  0  0  0  1  0                                                   00001090
REGIONS         1,    2,    3                                               1091
SURFACES       16,   17                                                     1092
SECTOR -1  0                                                                1093
SECTOR  1 -1                                                                1094
SECTOR  0  1                                                                1095
```

```
ZONE      1    1    4                                                   00001100
XBLOCK       -16.3525,   -9.7337,       0.0,    9.7337,   16.3525       00001110
YBLOCK       -16.8656,   16.8656                                        00001120
ZBLOCK           -4.0,   -2.5146                                        00001130
BLOCK     1    1    1                                                   00001140
MEDIA           9,    6, 1000                                           00001150
SURFACES        6,    13                                                00001160
SECTOR -1  0                                                            00001170
SECTOR  1 -1                                                            00001180
SECTOR  0  1                                                            00001190
REGIONS         4                                                           1191
BLOCK     2    1    1                                                   00001200
MEDIA           8,    9,    9,    6, 1000                               00001210
SURFACES        3,    4,    6,   13                                     00001220
SECTOR  1  1  0  0                                                      00001230
SECTOR  0 -1 -1  0                                                      00001240
SECTOR -1  0 -1  0                                                      00001250
SECTOR  0  0  1 -1                                                      00001260
SECTOR  0  0  0  1                                                      00001270
REGIONS         4                                                           1271
BLOCK     3    1    1                                                   00001280
MEDIA           8,    9,    9,    6, 1000                               00001290
SURFACES        2,    5,    6,    13                                    00001300
SECTOR -1 -1  0  0                                                      00001310
SECTOR  0  1 -1  0                                                      00001320
SECTOR  1  0 -1  0                                                      00001330
SECTOR  0  0  1 -1                                                      00001340
SECTOR  0  0  0  1                                                      00001350
REGIONS         4                                                           1351
BLOCK     4    1    1                                                   00001360
MEDIA           9,    6, 1000                                           00001370
SURFACES        6,    13                                                00001380
SECTOR -1  0                                                            00001390
SECTOR  1 -1                                                            00001400
SECTOR  0  1                                                            00001410
REGIONS         4                                                           1411
ZONE      1    1    5                                                   00001420
```

```
X BLOCK      -16,3525,   16,3525                                        00001430
Y BLOCK      -16,8656,   16,8656                                        00001440
Z BLOCK       -2,5146,     1,471                                        00001450
BLOCK     1    1    1                                                   00001460
MEDIA           6,    6,   10, 1000, 1000                               00001470
SURFACES        6,   13,   14,   15                                     00001480
SECTOR  1 -1  0  1                                                      00001490
SECTOR  0 -1  1 -1                                                      00001500
SECTOR -1  0  0  1                                                      00001510
SECTOR  0  1  1  0                                                      00001520
SECTOR  0  0 -1  0                                                      00001530
REGIONS         4                                                           1531
   17   QUADRIC SURFACES, DRUMS IN, 4 REGIONS                               1540
       1.0XSQ          1,0YSQ   -130,55782     $                        00001550
       1,0X       -1,73205Y       -19,4672     $                        00001560
       1.0X        1,73205Y        19.4672     $                        00001570
       1.0X       -1,73205Y        19,4672     $                        00001580
       1,0X        1,73205Y       -19,4672     $                        00001590
       1,0XSQ          1.0YSQ   -127,04108     $                        00001600
       1.0XSQ          1.0YSQ   -129,92010     $                        00001610
       1,0X            1,0Y       23,52820     $                        00001620
       1.0X           -1,0Y       23,52820     $                        00001630
       1.0X            1,0Y      -23,52820     $                        00001640
       1.0X           -1,0Y      -23,52820     $                        00001650
       1,0XSQ          1,0YSQ   -133,74044     $                        00001660
       1.0XSQ          1,0YSQ   -134.29913     $                        00001670
       1,0XSQ          1,0YSQ          1,0ZSQ       -93.987    $        00001680
       1.0XSQ          1,0YSQ          1,0ZSQ       -93.987             00001690
 -29,93946     $                                                        00001700
       1,0Z        23.4469     $                                            1701
       1,0Z        14,1124     $                                            1702
```

APPENDIX B

GEOM INPUT FOR DRUMS OUT 30°

```
    2      MALE                                                                                 00000010
X ZONE       -16.3525,    16.3525                                                               00000020
Y ZONE       -23.5055,    23.5055                                                               00000030
Z ZONE       -39.7455,   -36.9794,   -35.1150,   -32.5750,      -6.54,                          00000040
      -4.0,   -2.5146,     1.4710                                                               00000050
ZONE         1       1       1                                                                  00000060
X BLOCK      -16.3525,    16.3525                                                               00000070
Y BLOCK      -23.5055,    23.5055                                                               00000080
Z BLOCK      -39.7455,   -36.9794                                                               00000090
BLOCK        1       1       1                                                                  00000100
MEDIA                1,  1000                                                                   00000110
SURFACES             1                                                                          00000120
SECTOR -1                                                                                       00000130
SECTOR  1                                                                                       00000140
ZONE         1       1       2                                                                  00000150
X BLOCK      -16.3525,   -9.73370,        0.0,      9.7337,     16.3525                         00000160
Y BLOCK      -23.5055,    23.5055                                                               00000170
Z BLOCK      -36.9794,   -35.1150                                                               00000180
BLOCK        1       1       1                                                                  00000190
MEDIA                3,      6,  1000                                                           00000200
SURFACES             6,      7                                                                  00000210
SECTOR -1  0                                                                                    00000220
SECTOR  1 -1                                                                                    00000230
SECTOR  0  1                                                                                    00000240
BLOCK        2       1       1                                                                  00000250
MEDIA                2,      3,      3,      6,  1000                                           00000260
SURFACES             3,      4,      6,      7                                                  00000270
SECTOR  1  1  0  0                                                                              00000280
SECTOR  0 -1 -1  0                                                                              00000290
SECTOR -1  0 -1  0                                                                              00000300
SECTOR  0  0  1 -1                                                                              00000310
SECTOR  0  0  0  1                                                                              00000320
BLOCK        3       1       1                                                                  00000330
```

```
MEDIA           2,    3,    3,    6, 1000                               00000340
SURFACES        2,    5,    6,    7                                     00000350
SECTØR -1 -1  0  0                                                      00000360
SECTØR  0  1 -1  0                                                      00000370
SECTØR  1  0 -1  0                                                      00000380
SECTØR  0  0  1 -1                                                      00000390
SECTØR  0  0  0  1                                                      00000400
BLØCK     4    1    1                                                   00000410
MEDIA           3,    6, 1000                                           00000420
SURFACES        6,    7                                                 00000430
SECTØR -1  0                                                            00000440
SECTØR  1 -1                                                            00000450
SECTØR  0  1                                                            00000460
ZØNE      1    1    3                                                   00000470
X BLØCK      -16.3525,   -9.7337,   -6.6599,       0.0,    6.6599,      00000480
    9.7337,  16.3525                                                    00000490
Y BLØCK      -23.5055,  -16.8656,   16.8656,   23.5055                  00000500
Z BLØCK      -35.1150,  -32.5750                                        00000510
BLØCK     1    2    1                                                   00000520
MEDIA           5,    6, 1000,    7, 1000, 1000                         00000530
SURFACES        6,    7,   18,    9,   12                               00000540
SECTØR -1  0  0  0  0                                                   00000550
SECTØR  1 -1  0  0  0                                                   00000560
SECTØR  0  1  0  0 -1                                                   00000570
SECTØR  0  0  1  1  1                                                   00000580
SECTØR  0  0 -1  0  0                                                   00000590
SECTØR  0  0  0 -1  0                                                   00000600
BLØCK     2    2    1                                                   00000610
MEDIA           4,    5,    5,    6, 1000,    7, 1000. 1000             00000620
SURFACES        3,    4,    6,    7,   18,    9,   12                   00000630
SECTØR  1  1  0  0  0  0  0                                             00000640
SECTØR  0 -1 -1  0  0  0  0                                             00000650
SECTØR -1  0 -1  0  0  0  0                                             00000660
SECTØR  0  0  1 -1  0  0  0                                             00000670
SECTØR  0  0  0  1  0  0 -1                                             00000680
SECTØR  0  0  0  0  1  1  1                                             00000690
SECTØR  0  0  0  0 -1  0  0                                             00000700
```

```
SECTOR  0  0  0  0  0 -1  0                                             00000710
BLOCK     3    2    1                                                   00000720
MEDIA         4,    5,    5,    6, 1000,     7                          00000730
SURFACES      3,    4,    6,    7,    12                                00000740
SECTOR  1  1  0  0  0                                                   00000750
SECTOR  0 -1 -1  0  0                                                   00000760
SECTOR -1  0 -1  0  0                                                   00000770
SECTOR  0  0  1 -1  0                                                   00000780
SECTOR  0  0  0  1 -1                                                   00000790
SECTOR  0  0  0  0  1                                                   00000800
BLOCK     4    2    1                                                   00000810
MEDIA         4,    5,    5,    6, 1000,     7                          00000820
SURFACES      2,    5,    6,    7,    12                                00000830
SECTOR -1 -1  0  0  0                                                   00000840
SECTOR  0  1 -1  0  0                                                   00000850
SECTOR  1  0 -1  0  0                                                   00000860
SECTOR  0  0  1 -1  0                                                   00000870
SECTOR  0  0  0  1 -1                                                   00000880
SECTOR  0  0  0  0  1                                                   00000890
BLOCK     5    2    1                                                   00000900
MEDIA         4,    5,    5,    6, 1000,    7, 1000, 1000               00000910
SURFACES      2,    5,    6,    7,   19,   11,    12                    00000920
SECTOR -1 -1  0  0  0  0  0                                             00000930
SECTOR  0  1 -1  0  0  0  0                                             00000940
SECTOR  1  0 -1  0  0  0  0                                             00000950
SECTOR  0  0  1 -1  0  0  0                                             00000960
SECTOR  0  0  0  1  0  0 -1                                             00000970
SECTOR  0  0  0  0 -1 -1  1                                             00000980
SECTOR  0  0  0  0  1  0  0                                             00000990
SECTOR  0  0  0  0  0  1  0                                             00001000
BLOCK     6    2    1                                                   00001010
MEDIA         5,    6, 1000,    7, 1000, 1000                           00001020
SURFACES      6,    7,   19,   11,    12                                00001030
SECTOR -1  0  0  0  0                                                   00001040
SECTOR  1 -1  0  0  0                                                   00001050
SECTOR  0  1  0  0 -1                                                   00001060
SECTOR  0  0 -1 -1  1                                                   00001070
```

```
SECTOR  0  0  1  0  0                                                   00001080
SECTOR  0  0  0  1  0                                                   00001090
BLOCK     1    1    1                                                   00001100
MEDIA        1000                                                       00001110
BLOCK     2    1    1                                                   00001120
MEDIA        1000                                                       00001130
BLOCK     3    1    1                                                   00001140
MEDIA        1000                                                       00001150
BLOCK     4    1    1                                                   00001160
MEDIA        1000                                                       00001170
BLOCK     5    1    1                                                   00001180
MEDIA        1000                                                       00001190
BLOCK     6    1    1                                                   00001200
MEDIA        1000                                                       00001210
BLOCK     1    3    1                                                   00001220
MEDIA        1000                                                       00001230
BLOCK     2    3    1                                                   00001240
MEDIA        1000                                                       00001250
BLOCK     3    3    1                                                   00001260
MEDIA        1000                                                       00001270
BLOCK     4    3    1                                                   00001280
MEDIA        1000                                                       00001290
BLOCK     5    3    1                                                   00001300
MEDIA        1000                                                       00001310
BLOCK     6    3    1                                                   00001320
MEDIA        1000                                                       00001330
ZONE      1    1    4                                                   00001340
X BLOCK      -16.3525,   -9.7337,   -6.6599,       0.0,    6.6599,      00001350
    9.7337,   16.3525                                                   00001360
Y BLOCK      -23.5055,  -16.8656,   16.8656,   23.5055                  00001370
Z BLOCK      -32.5750,     -6.54                                        00001380
BLOCK     1    1    1                                                   00001390
MEDIA          7,  1000                                                 00001400
SURFACES        8                                                       00001410
SECTOR  1                                                               00001420
SECTOR -1                                                               00001430
BLOCK     6    3    1                                                   00001440
```

```
MEDIA           7, 1000                                                 00001450
SURFACES       10                                                       00001460
SECTOR -1                                                               00001470
SECTOR  1                                                               00001480
BLOCK     2    1    1                                                   00001490
MEDIA           7, 1000, 1000                                           00001500
SURFACES        8,    17                                                00001510
SECTOR  1 -1                                                            00001520
SECTOR -1  0                                                            00001530
SECTOR  1  1                                                            00001540
BLOCK     5    3    1                                                   00001550
MEDIA           7, 1000, 1000                                           00001560
SURFACES       10,    16                                                00001570
SECTOR -1 -1                                                            00001580
SECTOR  1  0                                                            00001590
SECTOR -1  1                                                            00001600
BLOCK     3    1    1                                                   00001610
MEDIA           7, 1000                                                 00001620
SURFACES       17                                                       00001630
SECTOR -1                                                               00001640
SECTOR  1                                                               00001650
BLOCK     4    3    1                                                   00001660
MEDIA           7, 1000                                                 00001670
SURFACES       16                                                       00001680
SECTOR -1                                                               00001690
SECTOR  1                                                               00001700
BLOCK     4    1    1                                                   00001710
MEDIA        1000                                                       00001720
BLOCK     5    1    1                                                   00001730
MEDIA        1000                                                       00001740
BLOCK     6    1    1                                                   00001750
MEDIA        1000                                                       00001760
BLOCK     1    3    1                                                   00001770
MEDIA        1000                                                       00001780
BLOCK     2    3    1                                                   00001790
MEDIA        1000                                                       00001800
BLOCK     3    3    1                                                   00001810
```

```
MEDIA        1000                                                       00001820
BLOCK     1    2    1                                                   00001830
MEDIA           5,    6, 1000,    7,    7, 1000, 1000                   00001840
SURFACES        6,    7,    8,    9,   12,   17                         00001850
SECTOR -1  0  0  0  0  0                                                00001860
SECTOR  1 -1  0  0  0  0                                                00001870
SECTOR  0  1  0  0 -1  0                                                00001880
SECTOR  0  0  0  1  1  1                                                00001890
SECTOR  0  0  1  0  0 -1                                                00001900
SECTOR  0  0 -1  0  0 -1                                                00001910
SECTOR  0  0  0 -1  0  0                                                00001920
BLOCK     6    2    1                                                   00001930
MEDIA           5,    6, 1000,    7,    7, 1000, 1000                   00001940
SURFACES        6,    7,   10,   11,   12,   16                         00001950
SECTOR -1  0  0  0  0  0                                                00001960
SECTOR  1 -1  0  0  0  0                                                00001970
SECTOR  0  1  0  0 -1  0                                                00001980
SECTOR  0  0  0 -1  1  1                                                00001990
SECTOR  0  0 -1  0  0 -1                                                00002000
SECTOR  0  0  1  0  0 -1                                                00002010
SECTOR  0  0  0  1  0  0                                                00002020
BLOCK     2    2    1                                                   00002030
MEDIA           4,    5,    5,    6, 1000,    7, 1000                   00002040
SURFACES        3,    4,    6,    7,    9,   12                         00002050
SECTOR  1  1  0  0  0  0                                                00002060
SECTOR  0 -1 -1  0  0  0                                                00002070
SECTOR -1  0 -1  0  0  0                                                00002080
SECTOR  0  0  1 -1  0  0                                                00002090
SECTOR  0  0  0  1  0 -1                                                00002100
SECTOR  0  0  0  0  1  1                                                00002110
SECTOR  0  0  0  0 -1  0                                                00002120
BLOCK     5    2    1                                                   00002130
MEDIA           4,    5,    5,    6, 1000,    7, 1000                   00002140
SURFACES        2,    5,    6,    7,   11,   12                         00002150
SECTOR -1 -1  0  0  0  0                                                00002160
SECTOR  0  1 -1  0  0  0                                                00002170
SECTOR  1  0 -1  0  0  0                                                00002180
```

```
SECTOR  0  0  1 -1  0  0                                                00002190
SECTOR  0  0  0  1  0 -1                                                00002200
SECTOR  0  0  0  0 -1  1                                                00002210
SECTOR  0  0  0  0  1  0                                                00002220
BLOCK     3    2    1                                                   00002230
MEDIA           4,    5,    5,    6, 1000,    7                         00002240
SURFACES        3,    4,    6,    7,   12                               00002250
SECTOR  1  1  0  0  0                                                   00002260
SECTOR  0 -1 -1  0  0                                                   00002270
SECTOR -1  0 -1  0  0                                                   00002280
SECTOR  0  0  1 -1  0                                                   00002290
SECTOR  0  0  0  1 -1                                                   00002300
SECTOR  0  0  0  0  1                                                   00002310
BLOCK     4    2    1                                                   00002320
MEDIA           4,    5,    5,    6, 1000,    7                         00002330
SURFACES        2,    5,    6,    7,   12                               00002340
SECTOR -1 -1  0  0  0                                                   00002350
SECTOR  0  1 -1  0  0                                                   00002360
SECTOR  1  0 -1  0  0                                                   00002370
SECTOR  0  0  1 -1  0                                                   00002380
SECTOR  0  0  0  1 -1                                                   00002390
SECTOR  0  0  0  0  1                                                   00002400
ZONE      1    1    5                                                   00002410
X BLOCK      -16,3525,   -9.7337,   -6.6599,       0,0,    6,6599,      00002420
    9,7337,  16,3525                                                    00002430
Y BLOCK      -23,5055,  -16.8656,   16.8656,   23,5055                  00002440
Z BLOCK         -6,54,      -4.0                                        00002450
BLOCK     1    2    1                                                   00002460
MEDIA           5,    6, 1000,    7, 1000, 1000                         00002470
SURFACES        6,    7,   18,    9,   12                               00002480
SECTOR -1  0  0  0  0                                                   00002490
SECTOR  1 -1  0  0  0                                                   00002500
SECTOR  0  1  0  0 -1                                                   00002510
SECTOR  0  0  1  1  1                                                   00002520
SECTOR  0  0 -1  0  0                                                   00002530
SECTOR  0  0  0 -1  0                                                   00002540
BLOCK     2    2    1                                                   00002550
```

```
MEDIA           4,    5,    5,    6, 1000,    7, 1000, 1000             00002560
SURFACES        3,    4,    6,    7,   18,    9,   12                   00002570
SECTOR  1  1  0  0  0  0  0                                             00002580
SECTOR  0 -1 -1  0  0  0  0                                             00002590
SECTOR -1  0 -1  0  0  0  0                                             00002600
SECTOR  0  0  1 -1  0  0  0                                             00002610
SECTOR  0  0  0  1  0  0 -1                                             00002620
SECTOR  0  0  0  0  1  1  1                                             00002630
SECTOR  0  0  0  0 -1  0  0                                             00002640
SECTOR  0  0  0  0  0 -1  0                                             00002650
BLOCK     3    2    1                                                   00002660
MEDIA           4,    5,    5,    6, 1000,    7                         00002670
SURFACES        3,    4,    6,    7,   12                               00002680
SECTOR  1  1  0  0  0                                                   00002690
SECTOR  0 -1 -1  0  0                                                   00002700
SECTOR -1  0 -1  0  0                                                   00002710
SECTOR  0  0  1 -1  0                                                   00002720
SECTOR  0  0  0  1 -1                                                   00002730
SECTOR  0  0  0  0  1                                                   00002740
BLOCK     4    2    1                                                   00002750
MEDIA           4,    5,    5,    6, 1000,    7                         00002760
SURFACES        2,    5,    6,    7,   12                               00002770
SECTOR -1 -1  0  0  0                                                   00002780
SECTOR  0  1 -1  0  0                                                   00002790
SECTOR  1  0 -1  0  0                                                   00002800
SECTOR  0  0  1 -1  0                                                   00002810
SECTOR  0  0  0  1 -1                                                   00002820
SECTOR  0  0  0  0  1                                                   00002830
BLOCK     5    2    1                                                   00002840
MEDIA           4,    5,    5,    6, 1000,    7, 1000, 1000             00002850
SURFACES        2,    5,    6,    7,   19,   11,   12                   00002860
SECTOR -1 -1  0  0  0  0  0                                             00002870
SECTOR  0  1 -1  0  0  0  0                                             00002880
SECTOR  1  0 -1  0  0  0  0                                             00002890
SECTOR  0  0  1 -1  0  0  0                                             00002900
SECTOR  0  0  0  1  0  0 -1                                             00002910
SECTOR  0  0  0  0 -1 -1  1                                             00002920
```

```
SECTOR  0  0  0  0  1  0  0                                             00002930
SECTOR  0  0  0  0  0  1  0                                             00002940
BLOCK     6    2    1                                                   00002950
MEDIA           5,    6, 1000,    7, 1000, 1000                         00002960
SURFACES        6,    7,   19,   11,   12                               00002970
SECTOR -1  0  0  0  0                                                   00002980
SECTOR  1 -1  0  0  0                                                   00002990
SECTOR  0  1  0  0 -1                                                   00003000
SECTOR  0  0 -1 -1  1                                                   00003010
SECTOR  0  0  1  0  0                                                   00003020
SECTOR  0  0  0  1  0                                                   00003030
BLOCK     1    1    1                                                   00003040
MEDIA        1000                                                       00003050
BLOCK     2    1    1                                                   00003060
MEDIA        1000                                                       00003070
BLOCK     3    1    1                                                   00003080
MEDIA        1000                                                       00003090
BLOCK     4    1    1                                                   00003100
MEDIA        1000                                                       00003110
BLOCK     5    1    1                                                   00003120
MEDIA        1000                                                       00003130
BLOCK     6    1    1                                                   00003140
MEDIA        1000                                                       00003150
BLOCK     1    3    1                                                   00003160
MEDIA        1000                                                       00003170
BLOCK     2    3    1                                                   00003180
MEDIA        1000                                                       00003190
BLOCK     3    3    1                                                   00003200
MEDIA        1000                                                       00003210
BLOCK     4    3    1                                                   00003220
MEDIA        1000                                                       00003230
BLOCK     5    3    1                                                   00003240
MEDIA        1000                                                       00003250
BLOCK     6    3    1                                                   00003260
MEDIA        1000                                                       00003270
ZONE      1    1    6                                                   00003280
XBLOCK       -16.3525,   -9.7337,       0.0,    9.7337,   16.3525       00003290
```

```
Y BLOCK       -23.5055,    23.5055                                                        00003300
ZBLOCK            -4.0,    -2.5146                                                        00003310
BLOCK       1       1       1                                                             00003320
MEDIA               9,      6, 1000                                                       00003330
SURFACES            6,     13                                                             00003340
SECTOR -1   0                                                                             00003350
SECTOR  1  -1                                                                             00003360
SECTOR  0   1                                                                             00003370
BLOCK       2       1       1                                                             00003380
MEDIA               8,      9,      9,      6, 1000                                       00003390
SURFACES            3,      4,      6,     13                                             00003400
SECTOR  1   1   0   0                                                                     00003410
SECTOR  0  -1  -1   0                                                                     00003420
SECTOR -1   0  -1   0                                                                     00003430
SECTOR  0   0   1  -1                                                                     00003440
SECTOR  0   0   0   1                                                                     00003450
BLOCK       3       1       1                                                             00003460
MEDIA               8,      9,      9,      6, 1000                                       00003470
SURFACES            2,      5,      6,     13                                             00003480
SECTOR -1  -1   0   0                                                                     00003490
SECTOR  0   1  -1   0                                                                     00003500
SECTOR  1   0  -1   0                                                                     00003510
SECTOR  0   0   1  -1                                                                     00003520
SECTOR  0   0   0   1                                                                     00003530
BLOCK       4       1       1                                                             00003540
MEDIA               9,      6, 1000                                                       00003550
SURFACES            6,     13                                                             00003560
SECTOR -1   0                                                                             00003570
SECTOR  1  -1                                                                             00003580
SECTOR  0   1                                                                             00003590
ZONE        1       1       7                                                             00003600
X BLOCK       -16.3525,    16.3525                                                        00003610
Y BLOCK       -23.5055,    23.5055                                                        00003620
Z BLOCK        -2.5146,      1.471                                                        00003630
BLOCK       1       1       1                                                             00003640
MEDIA               6,      6,     10, 1000, 1000                                         00003650
SURFACES            6,     13,     14,     15                                             00003660
```

```
SECTOR  1 -1  0  1                                                      00003670
SECTOR  0 -1  1 -1                                                      00003680
SECTOR -1  0  0  1                                                      00003690
SECTOR  0  1  1  0                                                      00003700
SECTOR  0  0 -1  0                                                      00003710
   19   QUADRIC SURFACES, DRUMS OUT 30 DEGREES                          00003720
       1.0XSQ          1.0YSQ   -130.55782   $                          00003730
       1.0X       -1.73205Y       -19.4672   $                          00003740
       1.0X        1,73205Y        19,4672   $                          00003750
       1.0X       -1.73205Y        19,4672   $                          00003760
       1.0X        1,73205Y       -19,4672   $                          00003770
       1.0XSQ          1.0YSQ   -127.04108   $                          00003780
       1.0XSQ          1,0YSQ   -129.92010   $                          00003790
       1.0X         .26794Y        14,4186   $                          00003800
       1.0X           -1,0Y       23.52820   $                          00003810
       1.0X         ,26794Y       -14,4186   $                          00003820
       1.0X           -1,0Y      -23.52820   $                          00003830
       1.0XSQ          1,0YSQ   -133,74044   $                          00003840
       1.0XSQ          1,0YSQ   -134,29913   $                          00003850
       1.0XSQ          1.0YSQ           1,0ZSQ      -93.987    $        00003860
       1.0XSQ          1,0YSQ           1,0ZSQ      -93.987             00003870
-29,93946     $                                                         00003880
       1.0XSQ          1.0YSQ       -29.16X       -28.916Y              00003890
 339,7529     $                                                         00003900
       1.0XSQ          1.0YSQ        29.16X        28.916Y              00003910
 339,7529     $                                                         00003920
       1.0X            1,0Y       23,5282    $                          00003930
       1.0X            1.0Y      -23,5282    $                          00003940
```

APPENDIX C

INPUT LISTINGS FOR O5R DATA TAPE PREPARATIONS

1. CODE 6 Input Listing

```
CODE 6   10   12
 SNAP-TSF REACTOR (15 SCATTERERS IN CORE)                                  A
   10       1,8+7      4.0-1                                               B
   10    64                                                               1C
11000     1      2                     ,001247                            1D01
11000    30                            ,001247                            1D02
19000     1      2                     ,002600                            1D03
19000    30                            ,002600                            1D04
24000     1      2                     ,012520                            1D05
24000    30                            ,012520                            1D06
26000     1      2                     ,047240                            1D07
26000    30                            ,047240                            1D08
28000     1      2                     ,006469                            1D09
28000    30                            ,006469                            1D10
   10    64                                                               2C
11000     1      2                     ,003006                            2D01
11000    30                            ,003006                            2D02
19000     1      2                     ,006267                            2D03
19000    30                            ,006267                            2D04
24000     1      2                     ,003730                            2D05
24000    30                            ,003730                            2D06
26000     1      2                     ,007470                            2D07
26000    30                            ,007470                            2D08
28000     1      2                     ,022160                            2D09
28000    30                            ,022160                            2D10
   10    64                                                               3C
11000     1      2                     ,003750                            3D01
11000    30                            ,003750                            3D02
19000     1      2                     ,007818                            3D03
19000    30                            ,007818                            3D04
24000     1      2                     ,003964                            3D05
24000    30                            ,003964                            3D06
26000     1      2                     ,012167                            3D07
```

```
  26000   30                       .012167          3D08
  28000    1     2                 .004786          3D09
  28000   30                       .004786          3D10
     15   64                                        4C
   1001    1     2                 .049956          4D01
   4000    1     2                 .008147          4D02
   4000   46                       .008147          4D03
  11000    1     2                .0005311          4D05
  11000   30                      .0005311          4D06
  19000    1     2                 .001107          4D07
  19000   30                       .001107          4D08
  28000    1     2                 .003635          4D09
  28000   30                       .003635          4D10
  40000    1     2                 .027150          4D11
  40000   30                       .027150          4D12
  40000   46                       .027150          4D13
  92235    1     2     5          .0010964          4D14
  92235    3                      .0010964          4D15
  92238    1     2     3     5   .00008247          4D16
      6   64                                        5C
   4000    1     2                 .113480          5D01
   4000   46                       .113480          5D02
  11000    1     2                .0002742          5D04
  11000   30                      .0002742          5D05
  19000    1     2                .0005717          5D06
  19000   30                      .0005717          5D07
      6   64                                        6C
  24000    1     2                 .016740          6D01
  24000   30                       .016740          6D02
  26000    1     2                 .063159          6D03
  26000   30                       .063159          6D04
  28000    1     2                 .008651          6D05
  28000   30                       .008651          6D06
      2   64                                        7C
   4000    1     2                 .120140          7D01
   4000   46                       .120140          7D02
     10   64                                        8C
```

```
11000    1    2          ,002967          8D01
11000   30               ,002967          8D02
19000    1    2          ,006186          8D03
19000   30               ,006186          8D04
24000    1    2          ,005163          8D05
24000   30               ,005163          8D06
26000    1    2          ,018267          8D07
26000   30               ,018267          8D08
28000    1    2          ,010930          8D09
28000   30               ,010930          8D10
   10   64                                9C
11000    1    2          ,001712          9D01
11000   30               ,001712          9D02
19000    1    2          ,003570          9D03
19000   30               ,003570          9D04
24000    1    2          ,010270          9D05
24000   30               ,010270          9D06
26000    1    2          .039610          9D07
26000   30               ,039610          9D08
28000    1    2          ,006740          9D09
28000   30               ,006740          9D10
    4   64                               10C
11000    1    2          ,004945         10D01
11000   30               ,004945         10D02
19000    1    2          ,010310         10D03
19000   30               .010310         10D04
   10                                      E
 4000   64                                 F01
11000   64                                 F02
19000   64                                 F03
24000   64                                 F04
26000   64                                 F05
28000   64                                 F06
40000   64                                 F07
92235   64                                 F08
92238   64                                 F09
 4001   64                                 F10
```

2. CODE 8 Input Listing

```
CODE 8   10   14
 SNAP-TSF REACTOR PHI TAPE FOR CORE LEAKAGE                                      A
     9     8     8     8     8     8     8     8     6     8     8                 B
      1.8+7     4.0-1    32    32    32    32    32    32    32    32    32        C
 4000    71    72    73    74    75    76    77    78                              D01
11000    71    72    73    74    75    76    77    78                              D02
19000    71    72    73    74    75    76    77    78                              D03
24000    71    72    73    74    75    76    77    78                              D04
26000    71    72    73    74    75    76    77    78                              D05
28000    71    72    73    74    75    76    77    78                              D06
40000    71    72    73    74    75    76                                          D07
92235    71    72    73    74    75    76    77    78    79    80    81    82    83  D08
92238    71    72    73    74    75    76    77    78    79    80    81    82    83  D10
```

APPENDIX D

05R INPUT LISTINGS

1. 05R Input for Fission Distribution Calculation

```
SNAP-TSF REACTØR PØWER DISTRIBUTIØN                                         A
 800 1000    14    1     4.0-1    1                                         B
   10   12   13                                                             C
   2     0   3     0   4     0   5     0   6     0                          1D
     22,99    -22,99      39.1     -39.1      52.0     -52.0     55,85      1E01
    -55,85     58,71    -58,71                                              1E02
    1,3025    ,85613       0.0                                              1F
   2     0   3     0   4     0   5     0   6     0                          2D
     22,99    -22,99      39.1     -39,1      52.0     -52,0     55,85      2E01
    -55,85     58,71    -58,71                                              2E02
    1,8396    ,85789       0.0                                              2F
   2     0   3     0   4     0   5     0   6     0                          3D
     22,99    -22,99      39.1     -39.1      52.0     -52.0     55,85      3E01
    -55,85     58,71    -58,71                                              3E02
    3,2821    ,80416       0.0                                              3F
   0     1   0     2   0     3   0     6   0     7   0     0   8     0    9 4D01
   1.00814     9,012    -9,012     22,99    -22.99      39.1     -39.1      4E01
     58,71    -58,71     91,22    -91,22    -91,22     235,0    -235,0      4E02
     238.0                                                                  4E03
    .27432    ,89166    ,20781                                              4F
   1     0   2     0   3     0                                              5D
     9.012    -9,012     22,99    -22,99      39.1     -39.1                5E
    1,4834   ,998057       0.0                                              5F
   4     0   5     0   6     0                                              6D
      52.0     -52.0     55,85    -55,85     58,71    -58,71                6E
    ,99001    .85730       0,0                                              6F
   1     0                                                                  7D
     9.012    -9,012                                                        7E
   1,40713   ,999098       0.0                                              7F
   2     0   3     0   4     0   5     0   6     0                          8D
     22,99    -22,99      39.1     -39.1      52.0     -52,0     55,85      8E01
    -55,85     58,71    -58,71                                              8E02
    2,0463    ,85440       0.0                                              8F
```

```
    2    0    3    0    4    0    5    0    6    0                          9D
     22,99    -22,99      39.1     -39,1      52.0     -52.0     55,85      9E01
    -55,85     58.71    -58.71                                              9E02
    1,4738    ,85558       0.0                                              9F
    2    0    3    0                                                       10D
     22,99    -22,99      39.1     -39,1                                   10E
   19,5099    ,75092       0,0                                             10F
       0,0       0,0       0,0       0,0       1,0                           G
       0,0       0,0  -19,5575         4         1                           H
    1    3     111000111011110001000110101000000000     010100000            I1
0000343277244615                                                             J
    0    1    1    1                                                         K
    0    0    0    0    0    0       1.0     5,0-3     1.0-1                 M01
   -1                                                                        M02
    1    4                                                                   N
       1,0                                                                   O
    0    0                                                                   P
```

2. 05R Input for the Shield Source Problem

```
SNAP-TSF LEAKAGE (XNU FROM FORWARD ADJOINT)                                  A
  800  800   50    1     1.0+5    0                                          B
   10   12   13                                                              C
   -2    0   -3    0   -4    0   -5    0   -6    0                          1D
     22,99    -22,99      39.1     -39.1      52.0     -52.0     55,85      1E01
    -55,85     58.71    -58.71                                              1E02
   -2    0   -3    0   -4    0   -5    0   -6    0                          2D
     22,99    -22,99      39.1     -39.1      52.0     -52.0     55,85      2E01
    -55,85     58.71    -58.71                                              2E02
   -2    0   -3    0   -4    0   -5    0   -6    0                          3D
     22,99    -22,99      39.1     -39.1      52.0     -52.0     55,85      3E01
    -55,85     58,71    -58.71                                              3E02
    0   -1    0   -2    0   -3    0   -6    0   -7    0    0   -8    0   -9 4D
   1,00814     9,012    -9,012     22,99    -22,99      39.1     -39,1      4E01
     58,71    -58,71     91.22    -91,22    -91.22     235.0    -235.0      4E02
     238.0                                                                  4E03
   -1    0   -2    0   -3    0                                              5D
     9.012    -9,012     22,99    -22,99      39.1     -39,1                5E
   -4    0   -5    0   -6    0                                              6D
      52.0     -52.0     55.85    -55,85     58,71    -58,71                6E
   -1    0                                                                  7D
     9.012    -9.012                                                        7E
   -2    0   -3    0   -4    0   -5    0   -6    0                          8D
     22,99    -22,99      39.1     -39.1      52.0     -52.0     55,85      8E01
    -55,85     58,71    -58.71                                              8E02
   -2    0   -3    0   -4    0   -5    0   -6    0                          9D
     22,99    -22,99      39.1     -39.1      52.0     -52.0     55,85      9E01
    -55,85     58,71    -58.71                                              9E02
   -2    0   -3    0                                                       10D
     22,99    -22,99      39.1     -39,1                                    10E
       0.0       0,0       0.0       0.0       1.0                           G
       0.0       0.0  -19,5575         4         1                           H
    1    3     111000111111110001000110100000000000    000100000            I2
```

```
17736072365430 75                                                              J
    0    0    0    0                                                           K
    0    0                                                                     N
   14    0                                                                     P
```

3. O5R Input for the Core-Mapping Problem

```
SNAP-TSF LEAKAGE   REACTØR ØNLY ADJØINT SN BIAS                             A
 800  800   60     1     1,0+5    0                                         B
  10   12   13                                                              C
  -2     0  -3     0  -4     0  -5     0  -6     0                          1D
     22,99    -22,99      39.1     -39,1      52.0     -52,0     55,85      1E01
    -55,85     58.71    -58.71                                              1E02
  -2     0  -3     0  -4     0  -5     0  -6     0                          2D
     22,99    -22.99      39,1     -39,1      52.0     -52,0     55,85      2E01
    -55,85     58.71    -58,71                                              2E02
  -2     0  -3     0  -4     0  -5     0  -6     0                          3D
     22,99    -22,99      39,1     -39,1      52.0     -52,0     55,85      3E01
    -55,85     58,71    -58,71                                              3E02
   0    -1   0    -2   0    -3   0    -6   0    -7   0     0  -8     0   -9 4D
   1.00814     9.012    -9,012     22,99    -22,99      39,1     -39,1      4E01
     58,71    -58.71     91,22    -91,22    -91,22     235,0    -235,0      4E02
     238,0                                                                  4E03
  -1     0  -2     0  -3     0                                              5D
     9,012    -9,012     22.99    -22,99      39,1     -39,1                5E
  -4     0  -5     0  -6     0                                              6D
      52.0     -52,0     55.85    -55,85     58,71    -58.71                6E
  -1     0                                                                  7D
     9,012    -9,012                                                        7E
  -2     0  -3     0  -4     0  -5     0  -6     0                          8D
     22,99    -22.99      39,1     -39,1      52,0     -52,0     55,85      8E01
    -55,85     58.71    -58.71                                              8E02
  -2     0  -3     0  -4     0  -5     0  -6     0                          9D
     22,99    -22,99      39,1     -39,1      52,0     -52,0     55,85      9E01
    -55,85     58,71    -58.71                                              9E02
  -2     0  -3     0                                                        10D
     22,99    -22,99      39,1     -39,1                                    10E
       0.0       0.0       0,0       0,0       1.0                           G
       0,0       0.0  -19,5575         4         1                           H
   1    3     111000111111110001000110100000000000    110100000            I2
```

```
531717612030555
    0       0       0       0                                                K
    0       0                                                                N
   14       0                                                                P
```

APPENDIX E

05R SOURCE ROUTINE LISTINGS

1. 05R Subroutines SOURCE, DATAIN, SPACE, and VECTOR

```
      SUBROUTINE SOURCE (SPDSQ,U,V,W,X,Y,Z,WATE,N,NMEM,NMED,NREG)
      COMMON / SOURCE / ANG(9,40), BONE, BTHRE, BTWO, CONE, CTHRE,
     A    CTWO, NANG, NOOP, NOPT, NOR, NOZ, NOZE, PROBR(25),
     B    PROBRB(25), PROBZ(30), PROBZB(30), RRR(25), ZE(9), ZEE(30),
     C    RR,WT3,IRASE,RRR2(25)
      COMMON/ESIF/IE(10),QE(9)
      COMMON/XNU/XNU(10,6),EXNU(7),NXNU
      DATA (NO=0)
      IF(NO)   20,  10,  20
   10 CALL DATAIN
      NO = 1
      READ (50,1000)(IE(K),K=1,10),KFIZ
 1000 FORMAT(11I5)
      READ (50,1001)(QE(K),K=1,KFIZ)
 1001 FORMAT(6E12.2)
      READ (50,1000) KREG,KEG
      READ (50,1001) (EXNU(K),K=1,KEG)
      KEG=KEG-1
      READ (50,1001)((XNU(K1,K),K=1,KEG),K1=1,KREG)
   20 CALL FISESN(SO2,WT)
      SPDSQ=SO2
      CALL SPACE (X,Y,Z,WT1,NMEM)
      CALL VECTOR (U,V,W,Z,WT2)
      WATE=WT*WT1*WT2
      IF (WATE) 700,701,701
  700 PRINT 702,WT,WT1,WT2,X,Y,Z,U,V,W
  702 FORMAT (1H1,9E10.2,11H WT,WT1,WT2)
      CALL EXIT
  701 CONTINUE
      RETURN
      END SOURCE
```

```
      SUBROUTINE DATAIN
C
      COMMON / SOURCE / ANG(9,40), BONE, BTHRE, BTWO, CONE, CTHRE,
     A    CTWO, NANG, NOOP, NOPT, NOR, NOZ, NOZE, PROBR(25),
     B    PROBRB(25), PROBZ(30), PROBZB(30), RRR(25), ZE(9), ZEE(30),
     C    RR,WT3,IBASE,RRR2(25)
      DIMENSION CUM ( 30 )
C
      READ INPUT TAPE 50,10, NOOP, NOR, NOZ
   10 FORMAT (3I10)
C
C     NOOP IS POWER DISTRIBUTION OPTION. DISTRIBUTION IS ACTUAL
C     IF NOOP = 1, BIASED IF NOOP = 2,.
C     NOR IS NUMBER OF RADIAL DIVISION BOUNDARIES.
C     NOZ IS NUMBER OF AXIAL  DIVISION BOUNDARIES.
      K = 1
C     TEST NOZ AND NOR FOR DIMENSION STORAGE
      IF (NOZ - 30)    20, 20, 30
   20 IF (NOR - 25)    50, 50, 30
   30 PRINT 40
   40 FORMAT (58H NOZ OR NOR EXCEEDS STORAGE DIMENSION IN SUBROUTINE SOU
     1RCE)
      K = K+1
   50 READ INPUT TAPE 50,60, (RRR(J), J = 1,NOR)
C     RRR(J) IS THE RADIAL BOUNDARY VALUES (CM)
   60 FORMAT (6F10.0)
C     TEST RRR(J) FOR ASCENDING ORDER.
      DO 90  J = 2,NOR
      RRR2(J)=RRR(J)**2
      IF(RRR(J)-RRR(J-1))   70, 70, 90
   70 PRINT 80
   80 FORMAT (52H RRR(J) NOT IN ASCENDING ORDER IN SUBROUTINE SOURCE )
      K = K+1
   90 CONTINUE
      RRR2(1)=RRR(1)**2
```

```
      READ INPUT TAPE 50,60, (PROBR(J), J = 1,NOR)
C     PROBR(J) ARE THE ACTUAL RADIAL POWER DISTRIBUTION PROBABILITIES.
C     TEST NOOP. IF 1, THE DISTRIBUTION IS ASSUMED TO BE OF THE
C     NORMALIZED, CUMULATIVE FORM.  IF 2, NORMALIZE AS FOLLOWS -
C     PROBR(J) = PROBR(J) /(INTEGRAL ( PROBR (R) R DR ) FROM 0.0 TO
C     RRR (NOR) ).
      IF (NOOP - 2)    230, 160, 160
  160 NOR1 = NOR - 1
      TOTAL = 0.0
      DO  161  I = 1, NOR1
      CUM (I) = ( ( RRR (I+1) - RRR (I) ) * ( ( PROBR (I) * ( RRR (I+1)
     A          +  2. * RRR (I) ) ) + ( PROBR (I+1) * ( 2. * RRR (I+1)
     B          +  RRR (I) ) ) ) ) / 6.
      TOTAL = TOTAL + CUM (I)
  161 CONTINUE
      DO  162  I = 1, NOR
  162 PROBR (I) = PROBR (I) / TOTAL
C     CALCULATE THE BIASED RADIAL DISTRIBUTION.
      DO  163  I = 1, NOR1
  163 PROBRB (I) = 2. / ( FLOATF (NOR - 1) * ( ( RRR (I+1) ) **2
     A                - ( RRR (I) ) **2 ) )
  230 BONE = 2. * SINF ( 1.0471976 )
      CONE = RRR (NOR) * BONE
      BTWO = 0.0
      CTWO = RRR (NOR) * SINF ( 1.0471976 )
      BTHRE = - BONE
      CTHRE = CONE
C     BONE, CONE, BTWO, CTWO, BTHRE, CTHRE ARE COEFFICIENTS OF
C     QUADRATICS DEFINING THE CORE HEXAGONAL BOUNDARIES.
      READ INPUT TAPE 50,60, (ZEE(J), J = 1,NOZ)
C     ZEE(J) IS THE AXIAL BOUNDARY VALUES (CM)
C     TEST ZEE(J) FOR ASCENDING ORDER
      DO 260 J = 2, NOZ
      IF (ZEE(J)-ZEE(J-1))    240, 240, 260
  240 PRINT 250
  250 FORMAT (52H ZEE(J) NOT IN ASCENDING ORDER IN SUBROUTINE SOURCE )
      K = K+1
```

```
  260 CONTINUE
      READ INPUT TAPE 50,60, (PROBZ(J), J = 1,NOZ)
C     PROBZ(J) ARE THE ACTUAL AXIAL POWER DISTRIBUTION PROBABILITIES.
C     TEST NOOP.  IF 1, THE DISTRIBUTION IS ASSUMED TO BE OF THE
C     NORMALIZED, CUMULATIVE FORM,  IF 2, NORMALIZE AS FOLLOWS -
C     PROBZ(J) = PROBZ(J) / ( INTEGRAL ( PROBZ(Z) DZ ) FROM Z1 TO ZMAX).
      IF (NOOP - 2)    400, 330, 330
  330 NOZ1 = NOZ - 1
      TOTAL = 0.0
      DO  331  I = 1, NOZ1
      CUM (I) = ( ( ZEE (I+1) - ZEE (I) ) * ( PROBZ (I+1) + PROBZ (I) ))
     A          / 2.
      TOTAL = TOTAL + CUM (I)
  331  CONTINUE
      DO  332  I = 1, NOZ
  332 PROBZ (I) = PROBZ (I) / TOTAL
C     CALCULATE THE BIASED AXIAL DISTRIBUTION.
      DO 333 I=1,NOZ1
  333 PROBZB (I) = 1. / ( FLOATF (NOZ - 1) * ( ZEE (I+1) - ZEE (I) ) )
C   ADD AT END OF DATAIN
      RMIN = SQRTF(3.)/2.*RRR(NOR)
      SIXOPI = 6./3.1415926535
      DO 1013 J=1,NOR
      J0 = J
      IF (RRR(J+1)-RMIN) 1013,1013,1014
 1013 CONTINUE
 1014 JS = J0 + 1
      NOR1 = NOR - 1
      TRIB = 1.0-SIXOPI*PROBRB(J0)*(ACOSF(RMIN/RRR(JS))/2.*RRR(JS)**2
     T - RMIN/2.*RRR(JS)*SQRTF(1.-(RMIN/RRR(JS))**2))
      DO 1015 J=JS,NOR1
 1015 TRIB = TRIB-SIXOPI*PROBRR(J)*(ACOSF(RMIN/RRR(J+1))/2.*RRR(J+1)**2
     T -ACOSF(RMIN/RRR(J))/2.*RRR(J)**2 - RMIN/2.*(RRR(J+1)*SQRTF(1.-
     T (RMIN/RRR(J+1))**2)-RRR(J)*SQRTF(1.-(RMIN/RRR(J))**2)))
      RS=RRR(JS)
      DEI = (PROBR(JS)-PROBR(J0))/(RRR(JS)-RRR(J0))
      EPS = (RRR(JS)*PROBR(J0)-RRR(J0)*PROBR(JS))/(RRR(JS)-RRR(J0))
```

```
      TRI= 1.0-SIXOPI*((DEL/3.*RRR(JS)+EPS/2.)*RRR(JS)**2*ACOSF(RMIN/RS)
     T - (DEL/6.*RRR(JS)+EPS/2.)*RMIN*RRR(JS)*SQRTF(1.-(RMIN/RS)**2)
     T + DEL/6.*RMIN**3*LOGF(RS/RMIN*(1.-SQRTF(1.-(RMIN/RS)**2))))
      DO 1016 J=JS,NOR1
      RD=RRR(J+1)-RRR(J)
      DEL=(PROBR(J+1)-PROBR(J))/RD
      EPS=(RRR(J+1)*PROBR(J)-RRR(J)*PROBR(J+1))/RD
      RJ=RMIN/RRR(J)
      RJ1=RMIN/RRR(J+1)
      RRJ=RRR(J)
      RRJ1=RRR(J+1)
      SQJ=SQRTF(1.-RJ**2)
      SQJ1=SQRTF(1.-RJ1**2)
 1016 TRI = TRI - SIXOPI*((DEL/3.*RRJ1+EPS/2.)*RRJ1**2*ACOSF(RJ1)
     T -(DEL/3.*RRJ+EPS/2.)*RRJ**2*ACOSF(RJ) -(DEL/6.*RRJ1+EPS/2.)*
     T RRJ1*RMIN*SQJ1 + (DEL/6.*RRJ+EPS/2.)*RRJ*RMIN*SQJ + DEL/6.*
     T RMIN**3*LOGF(RRJ1/RRJ*(SQJ1-1.)/(SQJ-1.)))
      DO  390  I = 1, NOR1
      PROBR (I) = PROBR (I) / TRI
  390 PROBRB (I) = PROBRB (I) / TRIB
      PROBR (NOR) = PROBR (NOR) / TRI
  400 READ INPUT TAPE 50,10, NOPT, NOZE, NANG
C     NOPT IS ANGULAR DISTRIBUTION OPTION. FOR NOPT = 1, DISTRIBUTION
C     IS ISOTROPIC ALL SOURCE POINTS. FOR NOPT = 2, DISTRIBUTION IS
C     ANISOTROPIC. *** NOZE IS NUMBER OF Z BOUNDARIES DEFINING CORE
C     DIVISIONS FOR APPLICATION OF ANISOTROPIC ANGULAR DISTRIBUTIONS.
C     NANG IS THE NUMBER OF COSINE THETA VALUES DESCRIBING THE
C     ANISOTROPIC ANGULAR DISTRIBUTION. NANG MUST BE THE SAME IN EACH
C     CORE DIVISION.
      IF (NOPT - 2)                      445, 405,   405
  405 READ INPUT TAPE 50, 60, (ZE(J), J = 1,NOZE)
C     ZE(J) ARE THE BOUNDARIES OF THE CORE DIVISIONS USED FOR THE
C     APPLICATION OF ANISOTROPIC ANGULAR DISTRIBUTIONS.
C     TEST ZE(J) FOR ASCENDING ORDER
      DO 430  J = 2,NOZE
      IF (ZE(J)-ZE(J-1))      410, 410, 430
  410 PRINT 420
```

```
  420 FORMAT(51H ZF(J) NOT IN ASCENDING ORDER IN SUBROUTINE SOURCE )
      K = K+1
  430 CONTINUE
C     READ IN ANG(L,J)
      NOZE1 = NOZE - 1
      DO 440  L = 1,NOZE1
      READ INPUT TAPE 50,60, (ANG(L,J), J = 1,NANG)
  440 CONTINUE
C     TEST K
  445 IF (K-1)      450, 460, 450
  450 CALL EXIT
  460 RETURN
      END DATAIN
```

```
      SUBROUTINE SPACE (X,Y,Z,WT1,NMEM)
C     SUBROUTINE TO CALCULATE SOURCE POINT LOCATION.
      COMMON / SOURCE / ANG(9,40), BONE, BTHRE, BTWO, CONE, CTHRE,
     A    CTWO, NANG, NOOP, NOPT, NOR, NOZ, NOZE, PROBR(25),
     B    PROBRB(25), PROBZ(30), PROBZR(30), RRR(25), ZE(9), ZEE(30),
     C    RR,WT3,IBASE,RRR2(25)
      DATA ( NMEM1 = 0 ), ( NREJECT = 0 ), ( PI = 3.1415927 )
      NMEM1 = NMEM1 + 1
C     TEST OPTION (NOOP), IF NOOP = 1, THEN INPUT POWER DISTRIBUTION
C     IS ACTUAL, IF NOOP = 2, THEN DISTRIBUTION IS BIASED,
      IF (NOOP - 2)   10, 100, 100
    9 NREJECT = NREJECT + 1
   10 RN = FLTRNF(DUMMY)
      DO 20  J = 1, NOR
      IF (RN - PROBR(J))   30, 20, 20
   20 CONTINUE
   30 RR=SQRTF(RFR2(J-1)+((RN-PROBR(J-1))/(PROBR(J)-PROBR(J-1)))*(RRR2(J
     1)-RRR2(J-1)))
C     THE USE OF LINEAR INTERPOLATION ABOVE ASSUMES THAT THE RADIAL
C     PROBABILITY DENSITY FUNCTION VARIES AS 1/R IN EACH INTERVAL.
```

```
   40 RN = FLTRNF(DUMMY)
      THETA = 6.28318 * RN
      XTRY = RR * COSF (THETA)
      YTRY = RR * SINF (THETA)
C     TEST XTRY AND YTRY FOR LOCATION. REJECT IF OUTSIDE
C     HEXAGONAL CORE.
      IF ( ABSF ( XTRY + BONE * YTRY ) - ABSF ( CONE ) ) 50, 50, 9
   50 IF ( ABSF ( XTRY + BTWO * YTRY ) - ABSF ( CTWO ) ) 60, 60, 9
   60 IF ( ABSF ( XTRY + BTHRE * YTRY ) - ABSF ( CTHRE ) ) 70, 70, 9
   70 X = XTRY
      Y = YTRY
C     CALCULATE Z
      RN = FLTRNF(DUMMY)
      DO 80 J = 1, NOZ
      IF (RN - PROBZ(J))    90, 80, 80
   80 CONTINUE
   90 Z = ZEE(J-1) + ((RN - PROBZ(J-1)) / (PROBZ(J) - PROBZ(J-1)))
     1              * (ZEE(J) - ZEE(J-1))
C     THE USE OF LINEAR INTERPOLATION ABOVE ASSUMES THAT THE AXIAL
C     PROBALITY DENSITY FUNCTION IS A HISTOGRAM.
C     CALCULATE WT1
      WT1 = 1.0
      GO TO 190
C     CALCULATE X,Y,Z AND WT1 FOR NOOP = 2.
  100 RN = FLTRNF(DUMMY)
      WNOZ = NOZ - 1
      J = RN * WNOZ
      FJ = J
      J = J + 1
      Z = ZEE(J) + (RN * WNOZ - FJ) * (ZEE(J+1) - ZEE(J))
C     IMPLIES THE ASSUMPTION THAT THE BIASED AXIAL POWER DISTRIBUTION IS
C     CONSTANT IN EACH INTERVAL.
C     FIND A PROBZ AND PROBZB CORRESPONDING TO Z..
  102 GOOP = (Z - ZEE(J)) / (ZEE(J+1) - ZEE(J))
C     PZ = PROBZ
C     PZB= PROBZB
      PZ = PROBZ(J) + GOOP * (PROBZ(J+1) - PROBZ(J))
```

```
      PZB = PROB2B (J)
      PP = PZ/PZB
      GO TO 150
  149 NREJECT = NREJECT + 1
C     CALCULATE X AND Y
  150 RN = FLTRNF(DUMMY)
      WNOR = NOR - 1
      DO 130 J = 2,NOR
      IF (RN - (FLOATF ((J-1)) / WNOR ))    140, 130, 130
  130 CONTINUE
      J = NOR
  140 RN = FLTRNF(DUMMY)
      RR=SQRTF(RRR2(J-1)+RN*(RRR2(J)-RRR2(J-1)))
C     THE USE OF R**2 INTERPOLATION ABOVE ASSUMES THAT THE RADIAL POWER
C     DISTRIBUTION IS CONSTANT IN EACH INTERVAL.
      RN = FLTRNF(DUMMY)
      THETA = 6.28318 * RN
      XTRY = RR * COSF (THETA)
      YTRY = RR * SINF (THETA)
C     TEST XTRY AND YTRY FOR LOCATION. REJECT IF OUTSIDE
C     HEXAGONAL CORE.
      IF ( ABSF ( XTRY + BONE * YTRY ) - ABSF ( CONE ) ) 160, 160, 149
  160 IF ( ABSF ( XTRY + BTWO * YTRY ) - ABSF ( CTWO ) ) 170, 170, 149
  170 IF ( ABSF ( XTRY + BTHRE * YTRY ) - ABSF ( CTHRE ) ) 180, 180, 149
  180 X = XTRY
      Y = YTRY
      EARP = (RR - RRR(J-1)) / (RRR(J) - RRR(J-1))
C     FIND A PROBR AND PROBRB CORRESPONDING TO RR.
C     PR = PROBR, PRB = PROBRB
      PR = PROBR(J-1) + EARP * (PROBR(J) - PROBR(J-1))
C     THE USE OF LINEAR INTERPOLATION ABOVE ASSUMES THAT THE RADIAL
C     POWER DISTRIBUTION IS LINEAR IN EACH INTERVAL.
      PRB = PROBRB (J-1)
      RP = PR / PRB
      WT1 = PP * RP
  190 IF ( NMEM  .NE.  0 ) 193, 191
  191 PRINT 192, NMEM1, NREJECT
```

```
192 FORMAT (1H0,5X, 24HSOURCE HAS BEEN CALLED  ,I8,7H  TIMES/
   A         1H ,5X,5HAND  ,I8,4X,49HREJECTS OCCURRED IN THE RADIAL SAM
   BPLING PROCEDURE)
193 RETURN
    END SPACE





    SUBROUTINE VECTOR (U,V,W,Z,WT2)
C   SUBROUTINE TO CALCULATE DIRECTION COSINES.
    COMMON / SOURCE / ANG(9,40), BONE, BTHRE, BTWO, CONE, CTHRE,
   A    CTWO, NANG, NOOP, NOPT, NOR, NOZ, NOZE, PROBR(25),
   B    PROBRB(25), PROBZ(30), PROBZB(30), RRR(25), ZE(9), ZEE(30),
   C    RR,WT3,IBASE,RRR2(25)
C   TEST OPTION (NOPT)
    IF (NOPT - 2)        10, 20, 20
 10 CALL GTISO (U,V,W)
    WT2 = 1.0
    WT3 = WT2
    GO TO 70
 20 DO 30  J = 2,NOZE
    IF (Z - ZE(J))       40, 30, 30
 30 CONTINUE
 40 J = J - 1
    WNANG = NANG - 1
    RN = FLTRNF(DUMMY)
    I = RN * WNANG
    FI = I
    I = I +1
    ANG1 = ANG(J,I) + (WNANG * RN -FI) * (ANG(J,I+1) - ANG(J,I))
    WT2 = WNANG * (ANG(J,I) - ANG(J,I+1)) / 2.0
    WT3 = WT2
    RN = FLTRNF(DUMMY)
    PHI = 6.28318 * RN
    PINT = SQRTF (1.- (ANG1**2))
    U = COSF (PHI) * PINT
```

```
   V = SINF (PHI) * PINT
   W = ANGI
70 RETURN
   END VECTOR
```

2. 05R Subroutines FISESN and FISSN

```
      SUBROUTINE FISESN(S02,WT)
      COMMON/FISE/ENER(38),FE(38),ALPN(10)
      DIMENSION WONWOR(10)
      COMMON/ESIF/IE(10),QE(9)
      DATA(IST=0)
      IF(IST)2,1,2
    1 CONTINUE
      WTS=1.
      ISPEC=38
      IST=1
      WRITE(51,201)(ALPN(L),L=1,10),(ENER(L),FE(L),L=1,ISPEC)
  201 FORMAT(1H015X24HENERGY DISTRIBUTION FROM10A8//
     13(11X8HE IN MEV15X4HF(E))/(6E19.4))
      QS=0.
      DO 5 L=1,10
      QS=QS+QE(L)
      WONWOR(L)=ENER(IE(L))
      IF(QS-.999999)5,6,6
    5 CONTINUE
      WRITE(51,202)
      CALL EXIT
  202 FORMAT(1H0//29H SUM OF QE(I) IS LESS THAN 1.)
    6 WONWOR(L+1)=ENER(IE(L+1))
      WRITE(51,203)(WONWOR(L1),QE(L1),L1=1,L),WONWOR(L+1)
  203 FORMAT(36H0      ENERGY      BIASED DISTRIBUTION/(E12.4/20X
     1E12.4))
    2 WT=WTS
      R=FLTRNF(R)
      SUM=0.
      J=0
   50 J=J+1
      SUM=SUM+QE(J)
      IF(R-SUM)60,60,50
```

```
 60 KJ=IE(J)
    KL=IE(J+1)
150 PROBJL=FE(KJ)-FE(KL)
    WT=WT*PROBJL/QE(J)
    S=PROBJL*FLTRNF(R1)
    T=S+FE(KL)
    I=KL-1
155 IF(T-FE(I))180,170,160
160 I=I-1
    GO TO 155
170 E=ENER(I)
    GO TO 200
180 TEMP=(T-FE(I))/(FE(I+1)-FE(I))
    E=ENER(I)+TEMP*(ENER(I+1)-ENER(I))
200 SO2=E*1.91322E+18
    RETURN
    END
```

```
         IDENT     FISSN
FISD     BLOCK     86
         COMMON    ENER(38)
         COMMON    FE(38)
         COMMON    ALPN(10)
         ORGR      ENER
 ENER    BSS       0
         DEC       0.
         DEC       0.111
         DEC       0.25
         DEC       0.407
         DEC       0.608
         DEC       0.907
         DEC       1.11
         DEC       1.35
         DEC       1.65
```

```
        DEC     1.8
        DEC     2,02
        DEC     2,46
        DEC     3,01
        DEC     3,68
        DEC     4,00
        DEC     4,50
        DEC     5.00
        DEC     5,49
        DEC     6,00
        DEC     6,30
        DEC     6,7
        DEC     7.00
        DEC     7.50
        DEC     8.18
        DEC     8.50
        DEC     9,00
        DEC     9,50
        DEC     10,00
        DEC     10.5
        DEC     11.0
        DEC     11.5
        DEC     12.2
        DEC     13,0
        DEC     14,0
        DEC     15,0
        DEC     16,0
        DEC     17.0
        DEC     18,0
FE      BSS     0
        DEC     1,000
        DEC     0,9830
        DEC     0,948
        DEC     0,90
        DEC     0,83
        DEC     0.722
        DEC     0.653
```

```
         DEC      0.573
         DEC      0.484
         DEC      0.443
         DEC      0.390
         DEC      0.296
         DEC      0.2065
         DEC      0.132
         DEC      0.1050
         DEC      0.0736
         DEC      0.0512
         DEC      0.03575
         DEC      0.02439
         DEC      0.01967
         DEC      0.01457
         DEC      0.01138
         DEC      7.72E-3
         DEC      4.55E-3
         DEC      3.52E-3
         DEC      2.364E-3
         DEC      1.583E-3
         DEC      1.058E-3
         DEC      7.05E-4
         DEC      4.686E-4
         DEC      3.108E-4
         DEC      1.795E-4
         DEC      8.97E-5
         DEC      3.88E-5
         DEC      1.67E-5
         DEC      7.10E-6
         DEC      3.00E-6
         DEC      0.0
ALPN     BSS      0
         BCD      5  FISSION SPECTRUM
         BCD      5
         END
```

APPENDIX F

INPUT INSTRUCTIONS FOR SOURCE ROUTINES AND INPUT FOR THE FISSION DISTRIBUTION PROBLEM, THE SHIELD SOURCE PROBLEM, AND THE CORE-MAPPING PROBLEM

1. Input Instructions

The source input cards, given below, follow the geometry input for O5R.

Card 1. Format (3I10)

a. NØØP: spatial bias control parameter;
NØØP = 1 for no spatial biasing,
NØØP = 2 to bias both axial and radial selection of source coordinates.

b. NØR: number of radial boundaries including the smallest radius (normally the center) at which the radial source distribution will be specified; NØR $\leq$ 25.

c. NØZ: number of axial boundaries at which the axial source distribution will be specified; NØZ $\leq$ 30.

Card 2. Format (6F10.0)

a. RRR(J), J = 1, NØR: radial boundary values (normally including 0.0), in cm; if NØØP = 2, the biasing is determined by the size of the radial intervals; neutrons are selected with equal probability from each interval: RRR(J-1) < RRR(J). Within each interval the biased power distribution is taken to be constant.

Card 3. Format (6F10.0)

a. PRØBR(J), J = 1, NØR: if NØØP = 1, PROBR(J) is the normalized cumulative radial power distribution and is assumed to be linear in the radial interval, PRØBR(NØR) = 1.0; if NØØP = 2, PRØBR(J) is the unnormalized radial power distribution and is assumed to be linear in the radial interval.

Card 4. Format (6F10.0)

a. ZEE(J), J = 1, NØZ: axial boundary values, in cm; if NØØP = 2, the biasing is determined by the size of the axial intervals; neutrons are selected with equal probability from each interval and uniformly within the interval ZEE(J-1) < ZEE(J). This corresponds to a constant biased power distribution within each interval.

Card 5. Format (6F10.0)

a. PRØBZ(J), J = 1, NØZ: if NØØP = 1, PRØBZ(j) is the normalized cumulative axial power distribution and is assumed to be linear in the axial interval, PRØBZ(NØZ) = 1.0; if NØØP = 2, PRØBZ(J) is the unnormalized axial power distribution and is assumed to be linear in the axial interval.

Card 6. Format (3I10)

a. NØPT: angular bias control parameter;
NØPT = 1 for unbiased isotropic source,
NØPT = 2 for biased isotropic source.

b. NØZE: number of axial boundaries for axial regions in which different angular biasing will be applied. NØZE $\leq$ 9.

c. NANG: number of cosine values for boundary angles describing the biased angular distributions; NANG $\leq$ 40.

Cards 7 and 8 are omitted if NØPT = 1

Card 7. Format (6F10.0)

a. ZE(J), J = 1, NØZE: the axial boundaries, in cm, for regions in which different angular biasing will be applied. ZE(J-1) < ZE(J).

Card 8. Format (6F10.0)

a. ((ANG(L,J), J = 1, NANG), L = 1, NØZE-1)): the cosine of the angles describing the biased angular distributions; (ANG(L,J-1) > ANG(L,J); within an axial region, specified by L, neutron Z-axis direction cosines are picked with equal probability from each angular interval. The azimuthal angle is picked isotropically. The real source angular distribution is assumed to be isotropic.

Card 9. Format (11I5)

a. IE(K), K = 1, 10: Energy group boundary indices from subroutine FISSN; up to 10 values may be given for the specification of source energy biasing. See table below. Within a group, energy is selected from the ^{235}U fission spectrum.

b. KFIZ: number of QE values associated with the energy groups defined by the IE's, also, the number of energy groups. See card 10 for QE definition. KFIZ ≤ 9.

FISSN ENERGY GROUP STRUCTURE

IE	Energy (MeV)
1	0.00
2	0.111
3	0.25
4	0.407
5	0.608
6	0.907
7	1.11
8	1.35
9	1.65
10	1.8
11	2.02
12	2.46
13	3.01
14	3.68
15	4.0
16	4.5
17	5.0
18	5.49
19	6.0
20	6.3
21	6.7
22	7.0
23	7.5
24	8.18
25	8.5
26	9.0
27	9.5
28	10.0
29	10.5
30	11.0

IE	Energy (MeV)
31	11.5
32	12.2
33	13.0
34	14.0
35	15.0
36	16.0
37	17.0
38	18.0

Card 10. Format (6E12.2)

a. QE (K), K = 1, KFIZ: Biased probability that the source neutron energy will be picked from the IE(K) to IE(K+1) energy interval. Within the interval the energy is selected from the ^{235}U fission spectrum. $\Sigma_K QE(K) = 1.0$.

The following cards are for the specification of parameters required for the track length selection using exponential transform (track length stretching). The parameters are region- (O5R regions) and energy-dependent.

Card 11. Format (2I5)

a. KREG: number of O5R regions for the specification of different XNU's (defined on card 13). KREG $\leq$ 10.

b. KEG: number of energy group boundaries, EXNU (card 12), for the specification of XNU's by energy group.

Card 12. Format (6E12.2)

a. EXNU(K), K = 1, KEG: energy group boundaries, in MeV, from high to low energy for the specification of XNU's by energy group.

Card 13. Format (6E12.2)

a. ((XNU(K1,K), K = 1, KEG-1), K1 = 1, KREG): XNU values for track length stretching, used as follows:

$$B = \frac{1}{1 - (\mathrm{XNU})\cdot\gamma} \quad , \quad \text{but } B \geq 0.6 \quad ,$$

and

$$P(\Sigma_T \ell) = \frac{1}{B}\, e^{-\Sigma_T \ell / B} \quad ,$$

where

γ = Z-axis direction cosine,

ℓ = track length,

Σ_T = total macroscopic cross section,

P = biased track length distribution.

2. 05R Subroutine Source Input for the Fission Distribution Problem

```
         1        11        21                                                 1
0.0       1.1239    2.2478    3.3717    4.4956    5.6195                2
6.7434    7.8673    8.9912    10.1151   11.2390                         3
0.0       .014084   .055882   .123659   .215103   .326098               4
.452755   .589835   .869795   1.0                                       5
-35.115   -33.55925 -32.00350 -30.44775 -28.89200 -27.33625             6
-25.78050 -24.22475 -22.66900 -21.11325 -19.55750 -18.00175             7
-16.44600 -14.89025 -13.33450 -11.77875 -10.22300 -8.66725              8
-7.11150  -5.55575  -4.0000                                             9
0.0       .030200   .066231   .107650   .154121   .204865               10
.259216   .316788   .376527   .437930   .50000    .562069               11
.623472   .683211   .740783   .795134   .845879   .892350               12
.933769   .969799   1.0                                                 13
         1                                                              14
```

3. 05R Subroutine Source Input for the Shield Source Problem

```
           2          11          21
           0      3.5541      5.0262      6.1559      7.1082      7.9472
      8.7057      9.4032     10.0525     10.6623     11.2390
    1.000000     .949679     .900245     .851680     .803880     .756963
     .710841     .665529     .620992     .577270     .534380
    -35.1150    -23.2133    -20.0671    -17.9773    -16.4148    -15.1481
    -14.0609    -13.0696    -12.1937    -11.3809    -10.6249     -9.9066
     -9.2312     -8.5633     -7.9333     -7.3034     -6.6740     -6.0448
     -5.3998     -4.6999     -4.0000
     .217090     .949678     .998644     .990243     .962496     .927140
     .887831     .844954     .801775     .757673     .713271     .668210
     .623427     .577031     .531493     .484384     .435881     .386105
     .333877     .275973     .217090
           2           2          11
    -35.1150     -4.0000
    1.000000     .957927     .918913     .880743     .839117     .775810
     .712504     .630228     .524818     .351618   -1.000000
     7    12    14    16    18    21    24    28    32    38     9
         .0072          .0313          .043          .0797         .1287           .187
         .2102          .1795         .1334
     2     7
          18.0           8.18          5.49           3.01          1.35           .407
          .111
          .727           .784          .843           .843          .865           .776
          .754           .708          .729           .800          .863           .705
1
```

4. O5R Subroutine Source Input for the Core-Mapping Problem

```
         2        11        21
         0    3,5541    5,0262    6,1559    7,1082    7,9472
    8,7057    9,4032   10,0525   10,6623   11,2390
  1,000000   ,949679   .900245   ,851680   .803880   .756963
   ,710841   ,665529   ,620992   ,577270   ,534380
  -35,1150  -19,3483  -16,4308  -14,6577  -13,2966  -12,2599
  -11,3509  -10,5525   -9,8507   -9,2167   -8,5981   -8,0790
   -7,5599   -7,0499   -6,5973   -6,1447   -5,6921   -5,2618
   -4,8412   -4,4206   -4.0000
   ,217090   ,999443   ,962873   ,910659   .855469   ,805214
   ,755987   ,708920   ,664638   ,622449   ,579482   ,542195
   ,503929   ,465076   ,429858   ,394170   ,357643   ,322493
   ,287788   .252476   .217090
         2         5        11
  -35,1150  -24,2250  -16,4460   -8,6670   -4,0000
  1,000000   ,949557   ,895898   ,842228   .774077   ,704751
   ,611731   ,506629   ,339123   ,019763 -1,000000
  1,000000   ,943056   ,883712   ,821359   ,749103   ,675011
   ,573246   ,455743   ,285995  -,041101 -1,000000
  1,000000   ,931528   ,861541   ,785151   ,705558   ,610992
   ,509876   ,371070   ,183987  -,175798 -1,000000
  1,000000   ,909689   ,817622   ,721452   ,618734   ,511330
   ,384659   ,236128   ,026786  -,336458 -1,000000
    4    6    8    9   11   12   14   18   24   38    9                      091
       ,0685       ,1108       ,0876       ,1084       ,1224       ,2417     101
       ,1773       ,0708       ,0125                                         102
    4    7                                                                   111
        18,0        8,18         4,5        2,02        1,35        ,608     121
       ,4076                                                                 122
       ,6246       ,7056       ,7624       ,7885       ,8191       ,8713     131
       ,5534       ,6350       ,6990       ,7342       ,7825       ,8657     132
       ,4023       ,4847       ,5526       ,5938       ,6706       ,8253     133
       ,3432       ,2307       ,2526       ,2857       ,3034       ,4613     134
```

APPENDIX G

INPUT INSTRUCTIONS AND LISTING FOR PROGRAM NNPCOM

1. Input Instructions

Card 1. Format (A2, 3X, I2, 3XA2, 2XI3, 2XA3)

a. NAMECØM: two alphanumeric characters to identify the CØMMØN,

b. NSIGS: number of energy levels,

c. NSIGSLFT: number of energy levels, left adjusted,

d. NØEPTS: number of energy points at which cross sections for each level are defined (same energy points for all levels),

e. NEPTSLFT: same as NØEPTS but left adjusted.

Card 2 and Card 3 are repeated for each energy level, J.

Card 2. Format (3I5, 5X, F10.7, 5A8, A2)

a. TITLE(I), I=1, 3: Element identifier
Cross section identifier
Interpolation index

b. QS(J): Energy, in MeV, of Jth level

c. REF1(J), REF2(J), (TITLE(I), I=4, 7): 42 alphanumeric characters.

Card 3 is repeated for each energy point I=1, NØEPTS

Card 3. Format (2E15.9, 2A8)

a. EPT(I): energy, MeV, high to low, at which cross sections are specified,

b. XXSECT(I,J): inelastic cross section for Jth level,

c. REFPT1(I,J), REFPT2(I,J): sixteen alphanumeric characters.

When XXSECT(I,J) = 0 then follow card 3 set with a blank card.

For levels 2 or greater the energy EPT may be omitted from card 3.

2. Program NNPCOM Listing

```
      PROGRAM NNFCOM
      DIMENSION EPT(100),XXSECT(100,16),SUM(100),PROB(100,16),IDENT(15),
     1QS(15),TITLE(10),REFPT1(100,15),REFPT2(100,15),REF1(15),REF2(15)
      EQUIVALENCE(NOEPT1,NOEPTS1)
      DATA(BLANK1=20202020202020208)
    8 READ(50,102) NAMCOM,NSIGS,NSIGSLFT,NOEPTS,NEPTSLFT
  102 FORMAT(A2,3X,I2,3XA2,2XI3,2XA3)
      NOEPT1=NOEPTS-1
      NSIGS1=NSIGS+1
C     INITIALIZE ARRAYS
      DO 9 J=2,NOEPTS
      SUM(J)=0.
      DO 9 I=1,NSIGS1
      REFPT1(J,I)=BLANK1
      REFPT2(J,I)=BLANK1
      PROB(J,I)=0.
    9 XXSECT(J,I)=0.
C     INPUT LOOP FOR ADDITIONS TO MASTER TAPE
      DO 30 J=1,NSIGS
      IO=0
      READ(50,103) (TITLE(I),I=1,3),QS(J),
     1REF1(J),REF2(J),(TITLE(I),I=4,7)
  103 FORMAT(3I5,5X,F10.7,5A8,A2)
      WRITE(51,205)(TITLE(I),I=1,3),QS(J),
     1REF1(J),REF2(J),(TITLE(I),I=4,7)
  205 FORMAT(1H0,3I5,5X,F10.5,5A8,A2)
   11 IO=IO+1
      IHI=NOEPTS-IO+1
      IF(J-1) 1003,1004,1003
 1004 READ(50,104)EPT(IHI),XXSECT(IHI,J),REFPT1(IHI,J),REFPT2(IHI,J)
  104 FORMAT(2E15.9,2A8)
      GO TO 1005
 1003 READ(50,1006)XXSECT(IHI,J),REFPT1(IHI,J),REFPT2(IHI,J)
```

```
 1006 FORMAT(15X,E15.9,2A8)
 1005 SUM(IHI)=SUM(IHI)+XXSECT(IHI,J)
      IF(XXSECT(IHI,J))11,29,11
   29 READ(50,105)BLANK
  105 FORMAT(A8)
   30 CONTINUE
C     CALCULATE PROBABILITIES
      DO 3003 I=2,NOEPTS
      J=0
 3000 J=J+1
      IF(XXSECT(I,J+1)) 3002,3004,3002
 3002 PROB(I,J)=XXSECT(I,J)/SUM(I)
      GO TO 3000
 3004 PROB(I,J)=1.
      J2=J-1
      IF(J2) 3003,3003,3006
 3006 DO 3005 JO=1,J2
 3005 PROB(I,J)=PROB(I,J)-PROB(I,JO)
 3003 CONTINUE
   10 DO 15 J=1,NSIGS
   15 QS(J)=QS(J)*1.91322E+18
      DO 150I=1,NOEPTS
  150 EPT(I)=EPT(I)*1.91322E+12
      NOSTOR1=NOEPTS1*NSIGS
      NOSTOR=NOSTOR1+NOEPTS1+NSIGS+2
      WRITE(52,2000) NAMCOM
 2000 FORMAT(14H         IDENT5X,A2,6HNNPCOM)
      IF(NOSTOR-10) 2003,2004,2004
 2004 IF(NOSTOR-100) 2005,2006,2006
 2006 IF(NOSTOR-1000) 2007,2008,2008
 2003 WRITE(52,2500) NAMCOM,NOSTOR
 2500 FORMAT(A2,3HNNP,4X,5HBLOCK,5X,I1)
      GO TO 2025
 2005 WRITE(52,2501) NAMCOM,NOSTOR
 2501 FORMAT(A2,3HNNP,4X,5HBLOCK,5X,I2)
      GO TO 2025
 2007 WRITE(52,2502) NAMCOM,NOSTOR
```

```
2502 FORMAT(A2,3HNNP,4X,5HBLOCK,5X,I3)
     GO TO 2025
2008 WRITE(52,2503) NAMCOM,NOSTOR
2503 FORMAT(A2,3HNNP,4X,5HBLOCK,5X,I4)
2025 WRITE(52,2504)NAMCOM
2504 FORMAT(15H         COMMON4X1HN,A2,6HEPT(1))
     WRITE(52,2505)NAMCOM
2505 FORMAT(15H         COMMON,4X1HN,A2,4HQ(1))
     WRITE(52,2506)NAMCOM,NOEPT1
2506 FORMAT(15H         COMMON,4X,3HSM2,A2,1H(,I3,1H))
     WRITE(52,2507)NAMCOM,NSIGS
2507 FORMAT(15H         COMMON,4X,1HQ,A2,1H(,I2,1H))
     WRITE(52,2508)NAMCOM,NOSTOR1
2508 FORMAT(15H         COMMON,4X,4HPROB,A2,1H(,I4,1H))
     WRITE(52,2509)NAMCOM
2509 FORMAT(13H         ORGR,6X,1HN,A2,3HEPT)
     WRITE(52,2510)NAMCOM
2510 FORMAT(12H         REM7X1HNA2,3HEPT)
     WRITE(52,2511)NEPTSLFT
2511 FORMAT(12H         DEC7XA2)
     WRITE(52,2512) NAMCOM
2512 FORMAT(12H         REM7X1HNA2,1HQ)
     WRITE(52,2513)NSIGSLFT
2513 FORMAT(12H         DEC7XA4)
     WRITE(52,2514) NAMCOM
2514 FORMAT(12H         REM7X3HSM2,A2)
     WRITE(52,2515) (EPT(I),I=2,NOEPTS)
2515 FORMAT(12H         DEC6XE15.8)
     WRITE(52,2516) NAMCOM
2516 FORMAT(12H         REM7X1HQ,A2)
     WRITE(52,2517) (QS(I),REF1(I),REF2(I),I,I=1,NSIGS)
2517 FORMAT(12H         DEC6XE15.8,7X,2A8,I5)
     WRITE(52,2518) NAMCOM
2518 FORMAT(12H         REM7X,4HPROB,A2)
     DO 2519 K=1,NSIGS
2519 WRITE(52,2520)(PROB(J,K),REFPT1(J,K),REFPT2(J,K),J,K,J=2,NOEPTS)
2520 FORMAT(12H         DEC6XE17.10,7X,2A8,I5,1H,,I2)
```

```
      WRITE(52,2521)
 2521 FORMAT(12H           END)
      WRITE(52,2522)NAMCOM,NAMCOM,NAMCOM,NAMCOM,NOEPTS1,NAMCOM,NSIGS,NAM
     1COM,NOEPTS1,NSIGS
 2522 FORMAT(6X,7HCOMMON/A2,5HNNP/N,A2,5HEPT,N,A2,5HQ,SM2,A2,1H(I3,3H),Q
     1,A2,1H(I2,6H),PROB,A2,1H(I3,1H,,I2,1H))
      GO TO 8
      END
```

APPENDIX H

05R INELASTIC SUBROUTINES

1. 05R Subroutine NONELAS Listing

```
      SUBROUTINE NONELAS
      COMMON/SINGLES/BLZON,EBOT,ECUT,EGROUP,EINC,EMONO,ESOUR,
     1ETAPE,ETA,ETATH,ETAUSD,ETOP,FONE,FTOTL,FWATE,ITERS,ITSTR,
     2LELEM,LF,MARK,MAXGP,MEDIA,MGPREG,MFISTP,MXREG,N,NCOLPR,
     3NWPCOL,NCONT1,NCONT2,NCONTP,NEWNM,NFISH,NFONE,NFPT,NGEOM,
     4NGROUP,NGWT,NHISMX,NHISTR,NINC,NFINC,NPINC,NITS,NKILL,
     5NLAST,NGLAST,NSIGL,NPLAST,NLEFT,NMEM,NMOST,NOEL,NPCOF,
     6NPTAPE,NQUIT,NROOM,NSOUR,NSPLT,NSTAPE,NSTRT,NTHERM,NTHRML,
     7NTYPE,OLDWT,PSIE,SPOLD,THETM,TNUC,UINP,UOLD,VINP,VOLD,
     8WATEF,WINP,WOLD,WTAVR,WTHIR,WTLOR,WTRED,WTSTRT,XOLD,XSTRT,
     9YOLD,YSTRT,ZOLD,ZSTRT,UNUSED(10)
      COMMON/NANNF/NNAEPT,NNAQ,SM2NA(38),QNA(5),PROBNA(38,5)
      COMMON/KNNF/NKEPT,NKQ,SM2K(30),QK(4),PROBK(30,4)
      COMMON/U235NNP/NU235EPT,NU235Q,SM2U235(1),QU235(1),PROBU235(1,1)
      COMMON/FENNP/NFEEPT,NFEQ,SM2FE(35),QFE(6),PROBFE(35,6)
      COMMON/CRNNP/NCREPT,NCRQ,SM2CR(10),QCR(2),PROBCR(10,2)
      COMMON/NINNP/NNIEPT,NNIQ,SM2NI(9),QNI(2),PROBNI(9,2)
      COMMON/ZRNNP/NZREPT,NZRQ,SM2ZR( 4),QZR(1),PROBZR( 4,1)
      COMMON/NEUTRON/NAME,NAMEX,SPDSQ,U,V,W,X,Y,Z,WATE,NMED,NREG,BLZNT
C     ISO=0, LEGENDRE DIST
C     ISO=1, ISOTROPIC DIST
      ISO=1
      GO TO (1,1,1,2,3,4,5,1,1,6) NMED
    1 GO TO (10,20,10,30,10,60,10,50,10,70) LELEM
    2 GO TO (10,10,81,    10,20,10,30,10,70,10,90,91,10,40,10) LELEM
    3 GO TO (10,81,    10,20,10,30) LELEM
    4 GO TO (10,60,10,50,10,70) LELEM
    5 GO TO (10,81    ) LELEM
    6 GO TO (10,20,10,30) LELEM
   10 WRITE(51,1000) NMED,LELEM
 1000 FORMAT(1H1,5HNMED=,I5,3X,6HLELEM=,I5)
      CALL EXIT
   20 CALL INELAS(NNAEPT,NNAQ,SM2NA,QNA,PROBNA,SPDSQ,U,V,W,WATE,NMED,LEL
```

```
     1EM,ISO)
  100 RETURN
   30 CALL INELAS(NKEPT,NKQ,SM2K,QK,PROBK,SPDSQ,U,V,W,WATE,NMED,LELEM,IS
     1O)
      GO TO 100
   40 CALL INELAS(NU235EPT,NU235Q,SM2U235,QU235,PROBU235,SPDSQ,U,V,W,WAT
     1E,NMED,LELEM,ISO)
      GO TO 100
   50 CALL INELAS(NFEEPT,NFEQ,SM2FE,QFE,PROBFE,SPDSQ,U,V,W,WATE,NMED,LEL
     1EM,ISO)
      GO TO 100
   60 CALL INELAS(NCREPT,NCRQ,SM2CR,QCR,PROBCR,SPDSQ,U,V,W,WATE,NMED,LEL
     1EM,ISO)
      GO TO 100
   70 CALL INELAS(NNIEPT,NNIQ,SM2NI,QNI,PROBNI,SPDSQ,U,V,W,WATE,NMED,LEL
     1EM,ISO)
      GO TO 100
   90 CALL INELAS(NZREPT,NZRQ,SM2ZR,QZR,PROBZR,SPDSQ,U,V,W,WATE,NMED,LEL
     1EM,ISO)
      GO TO 100
   81 CALL BEN2N(U,V,W,SPDSQ,WATE)
      GO TO 100
   91 CALL ZRN2N(U,V,W,SPDSQ,WATE)
      GO TO 100
      END
```

2. O5R Subroutine BEN2N (UO,VO,WO,SO2,WTO) Listing

```
      SUBROUTINE BEN2N(UO,VO,WO,SO2,WTO)
      Q1=-2.46*1.91322E+18
      Q2=.79*1.91322E+18
      T=SO2+Q1/.9
      IF(T)10,20,20
   10 WRITE(51,12)SO2,Q1
   12 FORMAT(1H0,4HSO2=E18.8,3X,3HQ1=E18.8,3X,23HINCOMING ENERGY TOO LOW
     1)
      RETURN
   20 ROOT1=SQRTF(T)
      CALL GTISO(EX,EY,EZ)
      IF(FLTRNF(R1)-.5)30,30,40
   30 SP1=.9*ROOT1
      UO=.1*UO+SF1*EX
      VO=.1*VO+SF1*EY
      WO=.1*WO+SF1*EZ
      GO TO 50
   40 SP2=.1*ROOT1
      ROOT2=SQRTF(Q2/.888889)
      SP3=.9*ROOT2
      CALL GTISO(EU,EV,EW)
      UO=.1*UO-SF2*EX+SP3*EU
      VO=.1*VO-SF2*EY+SP3*EV
      WO=.1*WO-SF2*EZ+SP3*EW
   50 SO2=UO*UO+VO*VO+WO*WO
      WTO=WTO*2.
      RETURN
      END
```

APPENDIX I

05R SUBROUTINE GETETA LISTING

```
      SUBROUTINE GETETA
      COMMON/SINGLES/BLZON,EBOT,ECUT,EGROUP,EINC,EMONO,ESOUR,
     1ETAPE,ETA,ETATH,ETAUSD,ETOP,FONE,FTOTL,FWATE,ITERS,ITSTR,
     2LELEM,LF,MARK,MAXGP,MEDIA,MGPREG,MFISTP,MXREG,N,NCOLPR,
     3NWPCOL,NCONT1,NCONT2,NCONTP,NEWNM,NFISH,NFONE,NFPT,NGEOM,
     4NGROUP,NGWT,NHISMX,NHISTR,NINC,NFINC,NPINC,NITS,NKILL,
     5NLAST,NGLAST,NSIGL,NPLAST,NLEFT,NMEM,NMOST,NOEL,NPCOF,
     6NPTAPE,NQUIT,NROOM,NSOUR,NSPLT,NSTAPE,NSTRT,NTHERM,NTHRML,
     7NTYPE,OLDWT,PSIE,SPOLD,THETM,TNUC,UINP,UOLD,VINP,VOLD,
     8WATEF,WINP,WOLD,WTAVR,WTHIR,WTLOR,WTRED,WTSTRT,XOLD,XSTRT,
     9YOLD,YSTRT,ZOLD,ZSTRT,UNUSED(10)
      COMMON/NEUTRON/NAME,NAMEX,SPDSQ,U,V,W,X,Y,Z,WATE,NMED,NREG,BLZNT
      COMMON/XNU/XNU(10,6),EXNU(7),NXNU
      COMMON/GLOF1/GLOP
      DATA(IST=0)
      IF(IST)3,4,3
 4    WRITE(51,100)
100   FORMAT(1H0,26HDIRECT NEUTRONS TOWARD +Z,)
      DO 77 I=1,7
   77 EXNU(I)=1.91322E+18*EXNU(I)
      IST = 1
    3 T=SQRTF(SPDSQ)
      DIR=W/T
      DO 78 NXNU=1,6
      IF (SPDSQ-EXNU(NXNU+1)) 78,79,79
   78 CONTINUE
      NXNU=6
   79 CONTINUE
      BIAS=1./(1.-XNU(NREG,NXNU)*DIR)
      IF(BIAS-.6)1,2,2
 1    BIAS = .6
 2    ETA = BIAS*EXPRNF(X)
      GLOP=BIAS*EXPF(-ETA*(1.-1./BIAS))
```

```
WATE=WATE*GLMP
RETURN
END
```

APPENDIX J

LISTINGS FOR PROGRAMS ANALYSIS (FISSION DISTRIBUTION) AND POWPOW

1. Program ANALYSIS Listing

```
      PROGRAM ANALYSIS
      COMMON/ASINGLES/NSTRT,NITS,NBIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
     1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCOL,NSGP,NCOLPR,N
     2ANISOEL,NDSGP,NLAST,KTH,NGROUP,LBATCH,NVAR,NF,NL,IB,NCPSB2,NCPNGP,
     3NCPELEM,NCPMED,NTYPE,DOSE,NRSUM,NZRO,NBSUM,NYTABLE,NGEOM,NM,MGZ,NO
     4NEUT,NYSUM,NZR,IVAR
      COMMON/CPLIST/NDUMMY(128)
      COMMON/EXTRA9/IRSH
      CALL FIXINFLT
      NCOLPR=8
   60 NPARITY=0
      LBATCH=0
    1 LBATCH=LBATCH+1
  101 CALL STBATCH
    4 CALL O5RREAD
      IF(NTYPE)5,19,15
    5 NPARITY=NPARITY+1
      WRITE(51,7)
    7 FORMAT(34HOPARITY ERROR IN READING COLL TAPE)
      IF(NPARITY-7)4,4,9
    9 LBATCH=LBATCH-1
      IF(LBATCH)10,14,10
   10 CALL ENDRUN
      PRINT 1000,IRSH
 1000 FORMAT (1H0////1H ,I12,50H COLLISIONS HAVE OCCURRED IN THE FISSION
     1ABLE MEDIA)
   14 CALL EXIT
   15 IF(NTYPE-2)17,9,9
   17 CONTINUE
      IF(LBATCH-NITS)1,10,10
   19 DO 41 KTH=1,NCOLPR
      ICOL=NDUMMY(KTH)
      IF (ICOL) 4,4,25
```

```
25 GO TO (31,32,41,33) ICOL
31 CALL SDATA
   GO TO 41
32 CALL RFLCOL
   GO TO 41
33 CALL ESCAPE
41 CONTINUE
   GO TO 4
   END
```

```
   SUBROUTINE STBATCH
   COMMON/ASINGLES/NSTRT,NITS,NEIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
  1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCOL,NSGP,NCOLPR,N
  2ANISOEL,NDSGP,NLAST,KTH,NGROLP,LBATCH,NVAR,NF,NL,IB,NCPSB2,NCPNGP,
  3NCPELEM,NCPMED,NTYPE,DOSE,NRSUM,NZRO,NBSUM,NYTABLE,NGEOM,NM,MGZ,NO
  4NEUT,NYSUM,NZR,IVAR
   COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),XI(8),YI(8),ZI(8),WTI(8),
  1S02(8),U0(8),V0(8),W0(8),NGRP(8),NELEM(8),NMED(8),WATEF(8),
  2DUMMY(8)
   DATA(IJK=0)
   IF(IJK)11,5,11
 5 CALL O5RSET(NHISTR,NHISMX,NREC,NTYPE,NCOLL,NAME,S12,XI,YI,ZI,
  1WTI,S02,U0,V0,W0,NGRP,NELEM,NMED,WATEF)
   IJK=1
11 CONTINUE
   RETURN
   END
```

```
    IDENT      O5RTAPE
    ENTRY      O5RREAD                  READS
    ENTRY      O5RSET                   REWINDS AND SETS ARGUMENTS
```

```
        EXT        Q8QHUNCH          IF(UNIT,I)N1,N2,N3,N4
        EXT        Q8QINGØT          WRITE
        EXT        Q8QGØTTY
        EXT        Q8QENGØT
        EXT        Q8QINBFI
        EXT        Q8QREWND          REWIND
        EXT        Q8QBACKS          BACKSPACE
Ø5RSET  SLJ        Ø5RSET
        SIL    6   SAVE65
        SIU    5   SAVE65
        ENI    5   0
        LIU    6   Ø5RSET
        LDA    6   0                 000 NHISTR 000 NHISMX
        SAU        ANHISMX
        ARS        24
        SAU        ANHISTR
        INI    6   1
        LDA    6   0                 000 NREC 000 NTYPE
        SAL        NTYPE
        ARS        24
        SAL        NREC
        SAL        C(1)
MØRE    INI    6   1
        LDQ    6   0
        ENA        0
        LLS        6
        AJP    N   ENDLEFT
        LLS        18
        SAL    5   ARGS
        INI    5   1
        ENA        0
        LLS        6
        AJP    N   ENDRIGHT
        LLS        18
        SAL    5   ARGS
        INI    5   1
        SLJ        MØRE
```

```
ENDRIGHT INI     6   1
ENDLEFT  SIU     6   EXIT
ANHISTR  LDA         **
         SAL         TAPENUM                TAPE NUMBER ØF HISTØRY TAPE
         STA         =SNHISTR
         SIU     5   A1
         RTJ         G8QREWND               REWIND NHISTR
+        SIL     5   NWPCØL                 WØRDS PER CØLLISIØN
         ENA         125
         ENQ         0
         DVI         NWPCØL
         INA         -1
         SAU         A2
         RTJ         CKUNIT
+        ENA         1
         STA         =SNCHECK
         LDA         A1
         STA     5   ARGS
         LDA         A2
         STA     5   ARGS+1
         LDA         A3
         STA     5   ARGS+2
ANHISMX  LDA         **
         INA         1
         STA         =SNHISMX
         RTJ         BUFFER
SAVE65   ENI     5   **
         ENI     6   **
Ø5RREAD  SLJ         Ø5RREAD                ENTRY FØR READING
         SIU     5   SAVE65
         SIL     6   SAVE65                 SAVE INDEX REGISTERS 5 AND 6
         LDA         NCHECK
         AJP     N   ØN                     TRANSFER IF TAPE NEEDS TØ BE CHECKED
         RTJ         BUFFER
 ØN      RTJ         CKUNIT
+        AJP     F   ØK
         ENA         0
```

```
             STA          NCHECK
             SLJ          SAVE65
      OK     LDA          A+1
             STA     7    NREC
             LDA          A+2
             STA     7    NTYPE
             AJP     N    NSKIP
             SIU     6    I6
             SIL     5    I6
             ENI     6    3                          A INDEX
             ENI     5    0
     ARGS    LDA     6    A
             STA     5    **
             LDA     6    A+1
             STA     5    **
             LDA     6    A+2
             STA     5    **
             LDA     6    A+3
             STA     5    **
             LDA     6    A+4
             STA     5    **
             LDA     6    A+5
             STA     5    **
             LDA     6    A+6
             STA     5    **
             LDA     6    A+7
             STA     5    **
             LDA     6    A+8
             STA     5    **
             LDA     6    A+9
             STA     5    **
             LDA     6    A+10
             STA     5    **
             LDA     6    A+11
             STA     5    **
             LDA     6    A+12
             STA     5    **
```

```
LDA     6   A+13
STA     5   **
LDA     6   A+14
STA     5   **
LDA     6   A+15
STA     5   **
LDA     6   A+16
STA     5   **
LDA     6   A+17
STA     5   **
LDA     6   A+18
STA     5   **
LDA     6   A+19
STA     5   **
LDA     6   A+20
STA     5   **
LDA     6   A+21
STA     5   **
LDA     6   A+22
STA     5   **
LDA     6   A+23
STA     5   **
LDA     6   A+24
STA     5   **
LDA     6   A+25
STA     5   **
LDA     6   A+26
STA     5   **
LDA     6   A+27
STA     5   **
LDA     6   A+28
STA     5   **
LDA     6   A+29
STA     5   **
LDA     6   A+30
STA     5   **
LDA     6   A+31
```

```
         STA   5  **
         LDA   6  A+32
         STA   5  **
         LDA   6  A+33
         STA   5  **
         LDA   6  A+34
         STA   5  **
         LDA   6  A+35
         STA   5  **
A1       INI   6  **                        WORDS PER COLLISION
A2       ISK   5  **                        COLLISIONS PER RECORD
         SLJ      ARGS
A3       SLJ      I6
 I6      ENI   6  **
         ENI   5  **
         RTJ      BUFFER
+        ENA      1
         STA      NCHECK
         SLJ      EXIT
NSKIP    INA      -2
         AJP   N  SKIP
EOFILE   LDA      TAPENUM
         INA      1
+        THS      NHISMX
         LDA      NHISTR
         STA      TAPENUM
         RTJ      QRQREWND                  REWIND TAPENUM
+        RTJ      BUFFER
+        SLJ      ON
 SKIP    ENA      0
         STA      NCHECK
         SLJ      EXIT
 CKUNIT  SLJ      **
         ENA      10
         STA      =SPARERRCT
 WAIT    LDA      TAPENUM
         RTJ      QRQHUNCH                  IF(UNIT,TAPENUM) WAIT, CKUNIT, EOFILE, P
```

```
+        AJP    M  WAIT
         AJP       CKUNIT
         QJP    F  EOFILE
 PARITY  RSO       PARERRCT
         AJP    M  SET
         LDA       TAPENUM
         RTJ       Q8QBACKS                  BACKSPACE TAPENUM
+        RTJ       BUFFER
+        SLJ       WAIT
SET      ENA       51
         ENQ       ..5
+        RTJ       Q8QINGOT
         0         0
+        RTJ       Q8QGOTTY
         0         RET
C(1)     0         0
         01        **                        NREC
         0         0
         01        TAPENUM                   TAPENUM
RET      RTJ       Q8QENGOT
+        ENA       -1
         STA    7  NTYPE
         SLJ       CKUNIT
..5      BCD       4(28H0TAPE ERROR FOLLOWING RECORD
         BCD       4,I5,5X,11HTAPE NUMBER,I5)
BUFFER   SLJ       **
         LDA       TAPENUM
         ENQ       1
         RTJ       Q8QINBFI                  BUFFER IN(TAPENUM,1)(A,
+        0         A
         0         A+127
+        SLJ       BUFFER
 EXIT    EQU       O5RREAD
NWPCOL   OCT       0
TAPENUM  OCT       0
NREC     OCT       0
NTYPE    OCT       0
```

```
A        BSS       128
         END
```

```
      SUBROUTINE ESCAPE
      RETURN
      END
```

```
      SUBROUTINE SDATA
      RETURN
      END
```

```
      SUBROUTINE RELCOL
      COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),X1(8),Y1(8),Z1(8),WT1(8),
     1SO2(8),UO(8),VO(8),WO(8),NGRF(8),NELEM(8),NMED(8),WATEF(8),
     2DUMMY(8)
      COMMON/ASINGLES/NSTRT,NITS,NEIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
     1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCOL,NSGP,NCOLPR,N
     2ANISOEL,NDSGP,NLAST,KTH,NGROLP,LBATCH,NVAR,NF,NL,IB,NCPSB2,NCPNGP,
     3NCPELEM,NCPMED,NTYPE,DOSE,NRSUM,NZRO,NBSUM,NYTABLE,NGEOM,NM,MGZ,NO
     4NEUT,NYSUM,NZR,IVAR
      COMMON/EXTRA1/ZZZ(31),RRR(25),KR,KZ,FWT(25,30,20), KZZ,RRR2(25),KR
     1R,LBAT,LBATO,BCDID(12),VAR(25,30),FWTAVE(25,30),KZ1
      COMMON/EXTRA9/IRSH
      IF (LBATCH-LBAT) 100,100,101
  100 RETURN
  101 LBATO=LBATCH-LBAT
      DO 1 KZZ=2,KZ
      LRSH=1
```

```
      IF (ZZZ(KZZ)-ZI(KTH)) 1,2,2
    1 CONTINUE
      KZZ=KZ
      IRSH=IRSH-1
      LRSH=0
    2 KZZ=KZZ-1
      IRSH=IRSH+1
      RSQ=XI(KTH)**2+YI(KTH)**2
      DO 3 KRR=1,KR
      IF (RRR2(KRR)-RSQ) 3,4,4
    3 CONTINUE
      KRR=KR
      IRSH=IRSH-LRSH
      FWT(KRR,KZZ,LBATO)=FWT(KRR,KZZ,LBATO)+WATEF(KTH)
      GO TO 100
      END
```

```
      SUBROUTINE ENDRUN
      COMMON/EXTRA1/ZZZ(31),RRR(25),KR,KZ,FWT(25,30,20), KZZ,RRR2(25),KR
     1R,LBAT,LBATO,BCDID(12),VAR(25,30),FWTAVE(25,30),KZ1
      DO 20 I=1,KR
      DO 20 K=1,KZ1
      FWTSUM=0.0
      VARK=0.0
      FNITS=LBATO
      DO 8 J=1,LBATO
      FWTSUM=FWTSUM+FWT(I,K,J)
      VARK=VARK+FWT(I,K,J)**2
    8 CONTINUE
      FWTAVE(I,K)=FWTSUM/FNITS
      VARK=VARK/FNITS
      VAR(I,K)=SQRTF((VARK-FWTAVE(I,K)**2)/(FNITS-1.0))
   20 CONTINUE
      DO 30 I=1,KR
```

```
      DO 30 K=1,KZ1
      IF (FWTAVE(I,K)) 31,31,32
   31 VAR(I,K)=0.0
      GO TO 30
   32 VAR(I,K)=100.0*VAR(I,K)/FWTAVE(I,K)
   30 CONTINUE
      DO 700 I=1,KR
      DO 700 K=1,KZ1
      IF (I-1) 702,701,702
  701 RR=0.0
      GO TO 703
  702 RR=RRR2(I-1)
  703 ARR=3.14159*(RRR2(I)-RR)*(ZZZ(K+1)-ZZZ(K))
  700 FWTAVE(I,K)=FWTAVE(I,K)/ARR
      KPRINT=1
      LPRINT=4
   40 IF (KR-KPRINT) 99,41,41
   99 RETURN
   41 PRINT 1000,(RCDID(I),I=1,12)
 1000 FORMAT (1H1,12A6)
      PRINT 1001,LBATO
 1001 FORMAT (1H0,34H FISSION DISTRIBUTION FOR THE LAST,I3,9H BATCHES,)
 1002 FORMAT     (1H0,29X,37HOUTER BOUNDARY OF RADIAL INTERVAL, CM)
      PRINT 1002
      IF (KR-LPRINT) 43,42,42
   42 LPRIN=LPRINT
      GO TO 444
   43 LPRIN=KR
  444 PRINT 1003,(RRR(I),I=KPRINT,LPRIN)
 1003 FORMAT (1H ,7X,  4E22.3)
      PRINT 1004
 1004 FORMAT (1H ,27X,7HPERCENT,15X,7HPERCENT,15X,7HPERCENT,15X,7HPERCEN
     1T)
      PRINT 1005
 1005 FORMAT (1H ,12H LOWER Z, CM,5X,16HFISSION WT   DEV,6X,16HFISSION W
     1T   DEV,6X,16HFISSION WT   DEV,6X,16HFISSION WT   DEV)
      DO 44 K=1,KZ1
```

```
   44 PRINT 1006,ZZZ(K),(FWTAVE(I,K),VAR(I,K),I=KPRINT,LPRIN)
 1006 FORMAT(1H ,    E12.3,4(3X,    E12.3,0P1F7.1))
      PRINT 1007,ZZZ(KZ)
 1007 FORMAT (1H ,    E12.3)
      KPRINT=KPRINT+4
      LPRINT=LPRINT+4
      GO TO 40
      END
```

```
      SUBROUTINE FIXINPUT
      COMMON/ASINGLES/NSTRT,NITS,NBIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
     1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCOL,NSGP,NCOLPR,N
     2ANISOEL,NDSGP,NLAST,KTH,NGROLP,LBATCH,NVAR,NF,NL,IB,NCPSR2,NCPNGP,
     3NCPELEM,NCPMED,NTYPE,DOSE,NRSUM,NZRO,NBSUM,NYTABLE,NGEOM,NM,MGZ,NO
     4NEUT,NYSUM,NZR,IVAR
      COMMON/EXTRA1/ZZZ(31),RRR(25),KR,KZ,FWT(25,30,20), KZZ,RRR2(25),KR
     1R,LBAT,LBATC,BCDID(12),VAR(25,30),FWTAVE(25,30),KZ1
      COMMON/EXTRA9/IRSH
      READ (50,1000) (BCDID(I),I=1,12)
 1000 FORMAT (12A6)
      READ (50,1001) NHISTR,NHISMX,NITS,LBAT,KR,KZ
      KZ1=KZ-1
      DO 10 I=1,25
      DO 10 J=1,30
      DO 10 K=1,20
   10 FWT(I,J,K)=0.0
      READ (50,1002) (RRR(I),I=1,KR)
      READ (50,1002) (ZZZ(I),I=1,KZ)
 1001 FORMAT (6I12)
 1002 FORMAT (6E12.4)
      DO 11 I=1,KR
   11 RRR2(I)=RRR(I)**2
      IRSH=0
      RETURN
```

2. Program POWPOW Listing

```
      PROGRAM POWPOW
      COMMON/MAIN/R(25),       Z(31),AR(25),AS(25),AC(25),P(25,30),F(25),
     1POW(30),IZ1,IZ2,R2(25),DR2(25)
      DATA (X=9,73325),(IX=22)
      READ (50,1000) R
      READ (50,1000) Z
      READ (50,1000)((P(I,J),J=1,30),I=1,25)
      DO 4 I=IX,25
      AR(I)=3,14159*(R(I)+R(I-1))*(R(I)-R(I-1))/6.0
      AS(I)=(3,14159*R(I)**2/2.0)-X*SQRTF(R(I)**2-X**2)-R(I)**2*ASINF(X/
     1R(I))
      IF (I-IX)  2,1,2
    1 AS(I-1)=0,0
    2 AC(I)=AR(I)+AS(I-1)-AS(I)
    4 F(I)=AR(I)/AC(I)
      DO 5 J=1,30
      DO 5 I=IX,25
    5 P(I,J)=P(I,J)*F(I)
      CON2=R(9)**2-R(8)**2
      CON1=R(8)**2-R(7)**2
      CON=CON1+CON2
      DO 6 J=1,30
    6 P(9,J)=(P(9,J)*CON2+P(8,J)*CON1)/CON
      CON2=R(7)**2-R(6)**2
      CON1=R(6)**2-R(5)**2
      CON=CON1+CON2
      DO 7 J=1,30
    7 P(8,J)=(P(7,J)*CON2+P(6,J)*CON1)/CON
      CON5=R(5)**2-R(4)**2
      CON4=R(4)**2-R(3)**2
      CON3=R(3)**2-R(2)**2
      CON2=R(2)**2-R(1)**2
      CON1=R(1)**2
```

```
      CØN=CØN5+CØN4+CØN3+CØN2+CØN1
      DØ 8 J=1,30
    8 P(7,J)=(P(5,J)*CØN5+P(4,J)*CØN4+P(3,J)*CØN3+P(2,J)*CØN2+P(1,J)*CØN
     11)/CØN
      R(8)=R(7)
      R(7)=R(5)
      R(6)=0.0
      IZ1=1
      IZ2=5
      ILØØP=1
    9 F1=IZ2-IZ1+1
      DØ 11 I=7,25
      GLØP=0.0
      DØ 10 J=IZ1,IZ2
   10 GLØP=GLØP+P(I,J)
   11 PØW(I)=GLØP/F1
      CALL PRINTER1
      GØ TØ (21,22,23,24,25,26,27,28,29,30,31,32,33,34,35),ILØØP
   21 IZ1=6
      IZ2=9
      ILØØP=2
      GØ TØ 9
   22 IZ1=10
      IZ2=12
      ILØØP=3
      GØ TØ 9
   23 IZ1=13
      IZ2=15
      ILØØP=4
      GØ TØ 9
   24 IZ1=16
      IZ2=18
      ILØØP=5
      GØ TØ 9
   25 IZ1=19
      IZ2=21
      ILØØP=6
```

```
      GO TO 9
   26 IZ1=22
      IZ2=25
      ILOOP=7
      GO TO 9
   27 IZ1=26
      IZ2=30
      ILOOP=8
      GO TO 9
   28 IZ1=1
      IZ2=9
      ILOOP=9
      GO TO 9
   29 IZ1=10
      IZ2=15
      ILOOP=10
      GO TO 9
   30 IZ1=16
      IZ2=21
      ILOOP=11
      GO TO 9
   31 IZ1=22
      IZ2=30
      ILOOP=12
      GO TO 9
   32 IZ1=1
      IZ2=15
      ILOOP=13
      GO TO 9
   33 IZ1=16
      IZ2=30
      ILOOP=14
      GO TO 9
   34 IZ1=1
      IZ2=30
      ILOOP=15
      GO TO 9
```

```
   35 CØNTINUE
      DØ 36 I=6,25
   36 R2(I)=R(I)**2
      DØ 37 I=7,25
   37 DR2(I)=R2(I)-R2(I-1)
      IZ1=7
      IZ2=9
      ILØØP=1
   39 CØNTINUE
 1000 FØRMAT(6E12.5)
      DØ 42 J=1,30
      F1=0.0
      GLØP=0.0
      DØ 41 I=IZ1,IZ2
      F1=F1+DR2(I)
   41 GLØP=GLØP+F(I,J)*DR2(I)
   42 PØW(J)=GLØP/F1
      CALL PRINTER2
      GØ TØ (51,52,53,54,55,56,57,58,59,60,61),ILØØP
   51 IZ1=10
      IZ2=13
      ILØØP=2
      GØ TØ 39
   52 IZ1=14
      IZ2=17
      ILØØP=3
      GØ TØ 39
   53 IZ1=18
      IZ2=21
      ILØØP=4
      GØ TØ 39
   54 IZ1=22
      IZ2=25
      ILØØP=5
      GØ TØ 39
   55 IZ1=7
      IZ2=13
```

```
      ILOOP=6
      GO TO 39
   56 IZ1=14
      IZ2=19
      ILOOP=7
      GO TO 39
   57 IZ1=20
      IZ2=25
      ILOOP=8
      GO TO 39
   58 IZ1=7
      IZ2=16
      ILOOP=9
      GO TO 39
   59 IZ1=17
      IZ2=25
      ILOOP=10
      GO TO 39
   60 IZ1=7
      IZ2=25
      ILOOP=11
      GO TO 39
   61 CONTINUE
      CALL EXIT
      END


      SUBROUTINE PRINTER1
      COMMON/MAIN/R(25),Z(31),AR(25),AS(25),AC(25),P(25,30),F(25),
     1POW(30),IZ1,IZ2,R2(25),DR2(25)
      PRINT 1000,Z(IZ1),Z(IZ2+1)
 1000 FORMAT (1H1,7SNAP-TSF FISSION DISTRIBUTION PROGRAM POWPOW7//1H ,
     17RADIAL DISTRIBUTION FOR Z INTERVAL7,F8.3,3H TO,F8.3//1H ,
     27OUTER RADIUS OF   FISSION WEIGHT7/1H ,7INTERVAL, CM7,6X,
     37PERVOLUME7)
```

```
      PRINT 1001,(R(I),PØW(I),I=7,25)
 1001 FØRMAT (1H ,F13.3,E16.3)
      GLØP=0.0
      DØ 1 I=7,25
    1 GLØP=GLØP+PØW(I)*(R(I)**2-R(I-1)**2)
      DØ 2 I=7,25
    2 PØW(I)=PØW(I)/GLØP
      PRINT 1000,Z(IZ1),Z(IZ2+1)
      PRINT 2000
 2000 FØRMAT (1H ,7**********NØRMALIZED**********7)
      PRINT 1001,(R(I),PØW(I),I=7,25)
      RETURN
      END PRINTER1



      SUBRØUTINE PRINTER2
      CØMMØN/MAIN/R(25),Z(31),AR(25),AS(25),AC(25),P(25,30),F(25),
     1PØW(30),IZ1,IZ2,R2(25),DR2(25)
      PRINT 1000,R(IZ1-1),R(IZ2)
 1000 FØRMAT(1H1,7SNAP-TSF FISSIØN DISTRIBUTIØN PRØGRAM PØWPØW7//1H ,
     17AXIAL DISTRIBUTIØN FØR R INTERVAL7,F8.3,3H TØ,F8.3//1H ,
     27LØWER Z ØF7,8X,7FISSIØN WEIGHT7/1H ,7INTERVAL, CM7,6X,
     37PERVØLUME7)
      PRINT 1001,(Z(I),PØW(I),I=1,30)
      PRINT 1002,Z(31)
 1001 FØRMAT (1H ,F13.3,E16.3)
 1002 FØRMAT (1H ,F13.3)
      GLØP=0.0
      DØ 1 I=2,31
    1 GLØP=GLØP+PØW(I-1)*(Z(I)-Z(I-1))
      DØ 2 I=1,30
    2 PØW(I)=PØW(I)/GLØP
      PRINT 1000,R(IZ1-1),R(IZ2)
      PRINT 2000
 2000 FØRMAT (1H ,7**********NØRMALIZED**********7)
```

```
PRINT 1001,(Z(I),POW(I),I=1,30)
PRINT 1002,Z(31)
RETURN
END PRINTER2
```

APPENDIX K

INPUT INSTRUCTIONS FOR PROGRAM ANALYSIS (OF FISSION DISTRIBUTION) AND FOR POWPOW; SNAP-TSF DATA FOR PROGRAM ANALYSIS

1. Input Instructions - ANALYSIS

Card 1. Format (12A6)

a. BCDID(I), I = 1, 12: Seventy-two alphanumeric characters.

Card 2. Format (6I12)

a. NHISTR: The logical number assigned to the first collision tape.

b. NHISMX: The highest logical number a collision tape may be assigned.

c. NITS: The number of batches (≤ 20).

d. LBAT: The first LBAT batches will be omitted in the calculations of power distribution and reactivity.

e. KR: Number of radial boundaries, excluding the center, for intervals defining the radial fission distribution ($KR \leq 25$).

f. KZ: Number of axial boundaries for intervals defining the axial fission distribution ($KZ \leq 31$).

Card 3. Format (6E12.4)

a. RRR(I), I=1, KR: Radial boundaries, in cm, excluding the center, for intervals defining the radial fission distribution.

Card 4. Format (6E12.4)

a. ZZZ(I), I=1, KZ: Axial boundaries, in cm, for intervals defining the axial fission distribution ($ZZZ(I-1) < ZZZ(I)$).

This program assumes that the O5R run, which generated the collision tapes, uses specific values of NBIND and NCOLLS that were given in the O5R input for the fission distribution (Appendix D).

Non-standard tapes required: NHISTR through NHISMX.

2. Input Instructions - POWPOW

Program PØWPØW is a special purpose program written to make modifications in the fission distribution output from a particular ANALYSIS run. It assumes that there are 25 radial intervals and 30 axial intervals for a total of 750 intervals defining the fission distribution. It makes the following calculations:

a. multiplies the fission weight in each interval by the ratio of the radial ring area to the area of the core hexagon within that ring;

b. combines radial intervals 8 and 9 into one interval and calls it interval 9;

c. combines radial intervals 6 and 7 into one interval and calls it interval 8;

d. combines radial intervals 1 through 5 into one interval and calls it interval 7.

Items b, c, and d were required because of poor statistics in the core center due to the smaller ring area resulting in fewer neutrons selected there.

PØWPØW then proceeds to average the radial fission distribution over larger axial intervals and to average the axial fission distribution over larger radial intervals. The size of the larger intervals is built into the program. The results are printed.

For all cards: Format (6E12.5); use as many cards as necessary.

Card 1. R(I), I=1, 25: the radial interval boundaries, in cm, excluding the center.

Card 2. Z(I), I=1, 31: the axial interval boundaries, in cm.

Card 3. ((P(I,J), J=1, 30), I=1, 25): the fission distribution as printed from program ANALYSIS; axial values from 1 to 30 are read for each radial interval.

3. ANALYSIS (of Fission Distribution) Input

```
SNAP-TSF FISSION DISTRIBUTION TAPES X-3914,3899,3854,3890,3597,3897-89           10
        1          7          14          5          25          31              20
      ,45        ,90        1.35       1,80        2.25        2.70              31
     3,15       3.60        4,05       4,50        4,95        5,40              32
     5,85       6.30        6,75       7.20        7.65        8,10              33
     8,55       9.00        9,45       9.90       10,35       10.80              34
   11,239                                                                        35
  -35,115    -34,073     -33.036    -31,999     -30.962     -29,925              41
  -28,888    -27,851     -26,814    -25,777     -24.740     -23,703              42
  -22,666    -21,629     -20,592    -19.555     -18,518     -17,481              43
  -16,444    -15.407     -14,370    -13,333     -12,296     -11,259              44
  -10,222     -9,185      -8,148     -7,111      -6.074      -5,037              45
   -4,000                                                                        46
```

APPENDIX L

INPUT INSTRUCTIONS AND PROGRAM LISTINGS FOR PROGRAMS BIASOR AND IMPORT

1. Input Instructions - BIASOR

BIASØR calculates biased source distributions using adjoint S_n (ANISN) flux data. It assumes that the input adjoint fluxes and input power distributions are histograms. It assumes that the S_n intervals are constant throughout the core.

Card 1. Format (9A8)

a. BCDID(I),I=1,9: 72 alphanumeric characters.

Card 2. Format (4I12)

a. INTSTRT: starting S_n interval index in the core (INTSTRT $<$ 40).

b. INTEND: final S_n interval index in core (INTSTRT $<$ INTEND $\leq$ 40).

c. IGPSTRT: starting S_n energy group index (lowest energy of interest) (IGPSTRT $\leq$ 27).

d. IGPEND; final S_n energy group index (highest energy of interest) (IGPEND $\leq$ 27).

Card 3. Format (6E12.5)

Note: One set of cards for each S_n interval, J=INTSTRT,INTEND

a. FLUX(I,J),I=IGPSTRT,IGPEND: The adjoint S_n flux from the lowest energy group to the highest energy group of interest.

Card 4. Format (6E12.4)

a. Z(J),J=INTSTRT,INTEND: the lower axial boundary for each space interval.

Card 5. Format (6E12.5)

a. P(J),J=INTSTRT,INTEND: the power distribution at each space interval.

Card 6. Format (6E12.5)

a. F(I),I=IGPSTRT,IGPEND: the fraction of the fission neutrons produced in energy group I.

Card 7. Format (6E12.5)

a. E(I),I=IGPSTRT,IGPEND: the lower energy boundary, in MeV, for each energy group.

2. Input Instructions - IMPORT

This program calculates the XNU's using adjoint S_n flux data. A region of constant cross section may be divided into several broad Z intervals containing two or more of the S_n intervals. The flux is then input as a function of energy at each of these broad interval boundaries. Since the adjoint flux is an average value for the S_n interval, the broad interval boundary should be a midpoint of a S_n interval. Either the total flux or the angular flux for any angular interval may be input. As many regions of constant cross section as desired may be input. The following card set is for a region of constant cross section.

Card 1. Format (9A8)

a. BCDID(I),I=1,9: 72 alphanumeric characters.

Card 2. Format (3I12)

a. NEGP: number of energy groups to be processed (NEGP $\leq$ 27) energy runs from low to high values.

b. NINTZ: number of broad Z intervals over which XNU is to be averaged (NINTZ $\leq$ 10).

c. NSTRTGP: starting energy group S_n index (NSTRTGP $\leq$ 27).

Card 3. Format (6E12.5)

a. Z(I),I=1,NINTZ+1: Z boundaries, in cm. of broad Z intervals; should be the midpoints of S_n intervals [Z(I) < Z(I+1)].

Card 4. Format (6E12.5)

Note: One set of cards for each boundary of the broad Z intervals (I=1,NINTZ+1).

a. PHI(N,I),N=1,NEGP: adjoint S_n flux for each energy group.

Card 5. Format (6E12.5)

a. CRØSS(N),N=1,NEGP: total macroscopic cross section for each energy group.

3. Program BIASOR Listing

```
      PROGRAM BIASOR
      COMMON/FIRST/FLUX(27,40),BCDID(9),P(40),F(27),INTSTRT,INTEND,IGPST
     1RT,IGPEND,IPOWER,FLUXE(27),QE(27),FLUXZ(40),FLUXZZ(40),Z(41),E(28)
      DIMENSION NE(27)
    1 READ (50,1000) BCDID
 1000 FORMAT (9A8)
      READ (50,1001) INTSTRT,INTEND,IGPSTRT,IGPEND
 1001 FORMAT (6I12)
      DO 2 J=INTSTRT,INTEND
    2 READ (50,1002) (FLUX(I,J),I=IGPSTRT,IGPEND)
 1002 FORMAT (6E12.5)
      READ (50,1002) (Z(J),J=INTSTRT,INTEND)
    3 READ (50,1002) (P(J),J=INTSTRT,INTEND)
    4 READ (50,1002) (F(I),I=IGPSTRT,IGPEND)
      READ (50,1002) (E(I),I=IGPSTRT,IGPEND)
    5 DO 6 I=IGPSTRT,IGPEND
      FLUXE(I)=0.0
      DO 7 J=INTSTRT,INTEND
    7 FLUXE(I)=FLUXE(I)+P(J)*FLUX(I,J)
    6 QE(I)=FLUXE(I)*F(I)
      GLOP=0.0
      DO 8 I=IGPSTRT,IGPEND
    8 GLOP=GLOP+QE(I)
      DO 9 I=IGPSTRT,IGPEND
    9 QE(I)=QE(I)/GLOP
   10 DO 11 J=INTSTRT,INTEND
      FLUXZ(J)=0.0
      DO 12 I=IGPSTRT,IGPEND
   12 FLUXZ(J)=FLUXZ(J)+F(I)*FLUX(I,J)
   11 FLUXZZ(J)=FLUXZ(J)*P(J)
      GLOP=0.0
      DO 13 J=INTSTRT,INTEND
   13 GLOP=GLOP+FLUXZZ(J)
```

```
      DO 14 J=INTSTRT,INTEND
   14 FLUXZZ(J)=FLUXZZ(J)/GLOP
   15 PRINT 2000,BCDID
 2000 FORMAT (1H1,9A8)
      PRINT 2001,(J,Z(J),F(J),FLUXZ(J),FLUXZZ(J),J=INTSTRT,INTEND)
 2001 FORMAT (1H0,7BIASED POWER DISTRIBUTION CALCULATION7//1H ,2HSN,8X,5
     1HLOWER,6X,6HACTUAL,7X,8HSPECTRUM,7X,6HBIASED/9H INTERVAL,3H  Z,10X
     2,5HPOWER,8X,8HAVERAGED,7X,5HPOWER/7H NUMBER,4X,8HBOUNDARY,3X,
     37DISTRIBUTION ADJOINT FLUX   DISTRIBUTION7/(I6,1X,2F12.6,E15.4,F13
     4.6))
   20 PRINT 2000,BCDID
      PRINT 2002,(I,E(I),F(I),FLUXE(I),QE(I),I=IGPSTRT,IGPEND)
 2002 FORMAT (1H0,7SOURCE ENERGY SELECTION PARAMETER QE7//1H ,2HSN,8X,
     15HLOWER,6X,7HFISSION,6X,13HPOWER (SPACE)/7H ENERGY,4X,6HENERGY,5X,
     26HSOURCE,7X,8HAVERAGED,7X,10HNORMALIZED/6H INDEX,5X,3HMEV,8X,
     38H(FISESN),5X,7ADJOINT FLUX   QE7/(I6,1X,2F12.6,E15.4,F9.4))
      DO 21 I=IGFSTRT,IGPEND
      QE(I)=10000.0*QE(I)
   21 NE(I)=QE(I)
      NGLOP=0
      DO 22 I=IGFSTRT,IGPEND
   22 NGLOP=NGLOF+NE(I)
      GLOP=NGLOP
      GLOP=GLOP/10000.0
      PRINT 2003,GLOP
 2003 FORMAT (1H0,39X,5HTOTAL,F10.4)
      GO TO 1
      END BIASOR
```

4. Program IMPORT Listing

```
      PRØGRAM IMPØRT
      DIMENSIØN PHI(27,11),Z(11),DELZ(10),BCDID(9),DLAM(27,10),CRØSS(27)
     1,XNU(27,10)
  100 READ (50,1000) BCDID
 1000 FØRMAT (9A8)
 1001 FØRMAT (1H1,9A8)
      READ (50,1002) NEGP,NINTZ,NSTRTGP
 1002 FØRMAT(6I12)
      NINTZ1=NINTZ+1
      READ (50,1003) (Z(I),I=1,NINTZ1)
 1003 FØRMAT (6E12.5)
      DØ 1 I=1,NINTZ1
    1 READ (50,1003) (PHI(N,I),N=1,NEGP)
      DØ 2 I=2,NINTZ1
      DELZ(I-1)=Z(I)-Z(I-1)
      DØ 2 N=1,NEGP
    2 DLAM(N,I-1)=LØGF(PHI(N,I)/PHI(N,I-1))/DELZ(I-1)
      READ (50,1003) (CRØSS(N),N=1,NEGP)
      DØ 3 I=2,NINTZ1
      DØ 3 N=1,NEGP
    3 XNU(N,I-1)=DLAM(N,I-1)/CRØSS(N)
      DØ 4 I=1,NINTZ
      PRINT 1001,BCDID
      PRINT 1004,Z(I),Z(I+1)
 1004 FØRMAT (1H0,28X,7Z BØUNDARIES7/F8.2,4H TØ ,F8.2/11X,2HGP,3X,5HCRØS
     1S,5X,6HLAMEDA,3X,3HXNU)
      DØ 4 N=1,NEGP
      N1=NSTRTGP+N-1
      PRINT 1005,N1,CRØSS(N  ),DLAM(N,I),XNU(N,I)
 1005 FØRMAT (1H ,10X,I2,F11.6,2F8.4)
    4 CØNTINUE
      GØ TØ 100
      END
```

APPENDIX M

INPUT INSTRUCTIONS AND PROGRAM LISTING FOR PROGRAM SORSPREP

1. Input Instructions

SØRSPREP points and punches input cards required by the 05R source routines when the biasing options are desired. On cards 2, 13, and 17 described below, the values should be the same as those desired in the source routine input. If NØØP = 2, source routine cards 1 through 5 will be punched. If NØPT = 2, source routine cards 6 through 8 will be punched (see Appendix F for source routine card descriptions).

Card 1. Format (9A8)

a. BCDID(I),I=1,9: 72 alphanumeric characters.

Card 2. Format (3I12)

a. NØØP: spatial bias control parameter; NØØP = 1 specifies no spatial biasing, NØØP = 2 specifies bias for both the axial and radial selection of source coordinates.

b. NØR: number of radial boundaries including the center at which the radial source distribution will be specified (NØR $\leq$ 25).

c. NØZ: number of axial boundaries at which the axial source distribution will be specified (NØZ $\leq$ 30).

Omit cards 3 through 12 if NØØP = 1

Card 3. Format (2I12)

a. KR: number of radial boundaries including the center defining the radial biased source distribution histogram (KR $\leq$ 51).

b. KZ: number of axial boundaries defining the axial biased source distribution histogram (KZ $\leq$ 51).

Note: input radial and axial biased distributions may have different interval specifications than the desired output distributions.

Card 4. Format (6E12.5)

a. RRB(K),K=1,KR: radial boundaries, in cm, for the radial biased source distribution histogram (including the smallest value).

Card 5. Format (6E12.5)

a. PRØBRB(K),K=1,KR-1: radial biased source distribution histogram.

Card 6. Format (6E12.5)

a. ZZZ(K),K=1,KZ: axial boundaries, in cm, for the axial biased source distribution histogram.

Card 7. Format (6E12.5)

a. PRØBZB (K),K=1,KZ-1: axial biased source distribution histogram.

Card 8. Format (2I12)

a. NR: number of radial boundaries including the center defining the actual radial source distribution ($NR \leq 51$).

b. NZ: number of axial boundaries defining the actual axial source distribution ($NZ \leq 51$).

Note: input actual radial and axial distributions are specified at the interval boundaries and are assumed to be linear over the interval; they may have different interval specifications than the input biased distributions and the desired output distributions.

Card 9. Format (6E12.5)

a. RACT(K),K=1,NR: radial boundaries, in cm, for the actual radial source distribution (including the smallest value).

Card 10. Format (6E12.5)

a. PRØBRA(K),K=1,NR: actual radial source distribution at each radial boundary; distribution is assumed to be linear between boundaries.

Card 11. Format (6E12.5)

a. ZACT(K),K=1,NZ: axial boundaries, in cm, for the actual axial source distribution.

Card 12. Format (6E12.5)

a. PRØBZA(K),K=1,NZ: actual axial source distribution at each axial boundary; the distribution is assumed to be linear between boundaries.

Card 13. Format (3I12)

a. NØPT: angular bias control parameter;
NØPT=1, unbiased isotropic source;
NØPT=2, biased isotropic source.

b. NØZE: number of axial boundaries for axial regions in which diferent angular biasing will be applied ($NØZE \leq 9$).

c. NANG: number of cosine values for boundary angles describing the biased angular distributions.

Omit cards 14 through 17 if NØPT = 1

Card 14. Format (I12)

a. KANG: number of cosine values to be read in for the angle boundaries defining the biased angular distribution ($KANG \leq 51$).

Card 15. Format (6E12.5)

a. CMU(K),K=1,KANG: cosine value from -1.0 to +1.0 for the angle boundaries defining the biased angular distribution.

Card 16. Format (6E12.5)

Note: One set of cards for each of the NØZE-1 axial regions (see card 13). I=1,NØZE-1.

a. PRØBMU(I,K),K=1,KANG-1: biased source angular distribution histogram.

Card 17. Format (6E12.5)

a. ZE(I),I=1,NØZE: the axial boundaries, in cm, for regions in which different angular biasing will be applied $\{ZE(I-1) < ZE(I)\}$.

2. Program SORSPREP Listing

```
      PROGRAM SORSPREP
      COMMON/MAIN/BCDID(9),NOOP,NOR,NOZ,KR,KZ,KR1,KZ1,PROBRB(50),PROBZB(
     150),NOR1,NOZ1,ZZZ(51),RRB(51),NR1,NZ1,RACT(51),PROBRA(51),NR,NZ,
     2ZACT(51),PROBZA(51),NOPT,NOZE,NANG,NOZE1,KANG,KANG1,CMU(51),PROBMU
     3(8,50)    ,RRR(25),ZEE(30),ZE(9),C(50),PROBR(25),PROBZ(30),NANG1,
     4ANG(8,41)
C     THIS PROGRAM PREPARES INPUT FOR THE BIASING OPTIONS IN SUBROUTINE
C     SOURCE.
      READ (50,1000) BCDID
 1000 FORMAT (9A8)
      READ (50,1001) NOOP,NOR,NOZ
      IF (NOOP-1) 1,2,1
    1 READ (50,1001) KR,KZ
      KR1=KR-1
      KZ1=KZ-1
 1001 FORMAT (6I12)
      READ (50,1002) (RRB(K),K=1,KR)
 1002 FORMAT(6E12.5)
      READ (50,1002) (PROBRB(K),K=1,KR1)
      READ (50,1002) (ZZZ(K),K=1,KZ)
      READ (50,1002) (PROBZB(K),K=1,KZ1)
      READ (50,1001) NR,NZ
      NR1=NR-1
      NZ1=NZ-1
      READ (50,1002)(RACT(K),K=1,NR)
      READ (50,1002)(PROBRA(K),K=1,NR)
      READ (50,1002)(ZACT(K),K=1,NZ)
      READ (50,1002)(PROBZA(K),K=1,NZ)
      NOR1=NOR-1
      NOZ1=NOZ-1
    2 READ (50,1001) NOPT,NOZE,NANG
      NOZE1=NOZE-1
      IF (NOPT-1) 3,5,3
```

```
  3 READ (50,1001) KANG
    KANG1=KANG-1
    READ (50,1002)(CMU(K),K=1,KANG)
    DO 4 I=1,NOZE1
  4 READ (50,1002)(PROBMU(I,K),K=1,KANG1)
    READ (50,1002)(ZE(I),I=1,NOZE)
  5 CONTINUE
    IF (NOOP-1) 91,150,91
 91 GLOP=0.0
    DO 6 K=1,KR1
  6 GLOP=GLOP+FROBRB(K)*(RRB(K+1)**2-RRB(K)**2)/2.0
    DO 7 K=1,KR1
    PROBRB(K)=FROBRB(K)/GLOP
  7 C(K)=PROBRB(K)*(RRB(K+1)**2-RRB(K)**2)/2.0
    FINT=NOR1
    FINT=1.0/FINT
    RRR(1)=RRB(1)
    K=1
    DO 20 I=1,NOR1
    CPRIME=PROBRB(K)*(RRB(K+1)**2-RRR(I)**2)/2.0
    IF (CPRIME-FINT) 10,9,9
  9 RRR(I+1)=SQRTF(RRR(I)**2+2.0*FINT/PROBRB(K))
    GO TO 20
 10 DO 15 L=1,50
    KAL=K+L
    IF (KAL-KR1) 99,99,90
 90 KAL=KAL-1
    GO TO 11
 99 CPRIME=CPRIME+C(KAL)
    L=L
    IF (CPRIME-FINT) 15,11,11
 11 CPRIME=CPRIME-C(KAL)
 12 RRR(I+1)=SQRTF(RRB(KAL)**2+2.0*(FINT-CPRIME)/PROBRB(KAL))
    K=KAL
    GO TO 20
 15 CONTINUE
 20 CONTINUE
```

```
      PROBR(1)=PROBRA(1)
      PROBR(NOR)=PROBRA(NR)
      DO 30 N=2,NOR1
      DO 25 NI=2,NR
      IF (RRR(N)-RACT(NI)) 23,24,25
   23 PROBR(N)=PROBRA(NI-1)+(PROBRA(NI)-PROBRA(NI-1))*(RRR(N)-RACT(NI-1)
     1)/(RACT(NI)-RACT(NI-1))
      GO TO 30
   24 PROBR(N)=PROBRA(NI)
      GO TO 30
   25 CONTINUE
   30 CONTINUE
      PUNCH 2000,NOOP,NOR,NOZ
 2000 FORMAT(3I10)
      PUNCH 2001,(RRR(J),J=1,NOR)
 2001 FORMAT(6F10.4)
      PUNCH 2002,(PROBR(J),J=1,NOR)
 2002 FORMAT(6F10.6)
      PRINT 3000,BCDID
 3000 FORMAT (1H1,9A8)
      PRINT 3001,NOOP,NOR,NOZ
 3001 FORMAT (1H0,3I10)
      PRINT 3002,(RRR(J),J=1,NOR)
 3002 FORMAT (1H0,6F10.4/(6F10.4))
      PRINT 3003,(PROBR(J),J=1,NOR)
 3003 FORMAT (1H0,6F10.6/(6F10.6))
      GLOP=0.0
      DO 106 K=1,KZ1
  106 GLOP=GLOP+PROBZB(K)*(ZZZ(K+1)-ZZZ(K))
      DO 107 K=1,KZ1
      PROBZB(K)=PROBZB(K)/GLOP
  107 C(K)=PROBZB(K)*(ZZZ(K+1)-ZZZ(K))
      FINT=NOZ1
      FINT=1.0/FINT
      ZEE(1)=ZZZ(1)
      K=1
      DO 120 I=1,NOZ1
```

```
      CPRIME=PRØBZB(K)*(ZZZ(K+1)-ZEE(I))
      IF (CPRIME-FINT) 110,109,109
  109 ZEE(I+1)=ZEE(I)+FINT/PRØBZB(K)
      GØ TØ 120
  110 DØ 115 L=1,50
      KAL=K+L
      IF (KAL-KZ1) 199,199,190
  190 KAL=KAL-1
      GØ TØ 111
  199 CPRIME=CPRIME+C(KAL)
      L=L
      IF (CPRIME-FINT) 115,111,111
  111 CPRIME=CPRIME-C(KAL)
  112 ZEE(I+1)=ZZZ(KAL)+(FINT-CPRIME)/PRØBZB(KAL)
      K=KAL
      GØ TØ 120
  115 CØNTINUE
  120 CØNTINUE
      PRØBZ(1)=PRØBZA(1)
      PRØBZ(NØZ)=PRØBZA(NZ)
      DØ 130 N=2,NØZ1
      DØ 125 N1=2,NZ
      IF (ZEE(N)-ZACT(N1)) 123,124,125
  123 PRØBZ(N)=PRØBZA(N1-1)+(PRØBZA(N1)-PRØBZA(N1-1))*(ZEE(N)-ZACT(N1-1)
     1)/(ZACT(N1)-ZACT(N1-1))
      GØ TØ 130
  124 PRØBZ(N)=PRØBZA(N1)
      GØ TØ 130
  125 CØNTINUE
  130 CØNTINUE
      PUNCH 2001,(ZEE(J),J=1,NØZ)
      PUNCH 2002,(PRØBZ(J),J=1,NØZ)
      PRINT 3002,(ZEE(J),J=1,NØZ)
      PRINT 3003,(PRØBZ(J),J=1,NØZ)
  150 IF (NØPT-1) 151,400,151
  151 NANG1=NANG-1
      FINT=NANG1
```

```
      FINT=1.0/FINT
      DO 300 M=1,NOZE1
      GLOP=0.0
      DO 206 K=1,KANG1
  206 GLOP=GLOP+PROBMU(M,K)*(CMU(K+1)-CMU(K))
      DO 207 K=1,KANG1
      PROBMU(M,K)=PROBMU(M,K)/GLOP
  207 C(K)=PROBMU(M,K)*(CMU(K+1)-CMU(K))
      ANG(M,1)=CMU(1)
      K=1
      DO 220 I=1,NANG1
      CPRIME=PROBMU(M,K)*(CMU(K+1)-ANG(M,I))
      IF (CPRIME-FINT) 210,209,209
  209 ANG(M,I+1)=ANG(M,I)+FINT/PROBMU(M,K)
      GO TO 220
  210 DO 215 L=1,50
      KAL=K+L
      IF (KAL-KANG1) 299,299,290
  290 KAL=KAL-1
      GO TO 211
  299 CPRIME=CPRIME+C(KAL)
      L=L
      IF (CPRIME-FINT) 215,211,211
  211 CPRIME=CPRIME-C(KAL)
  212 ANG(M,I+1)=CMU(KAL)+(FINT-CPRIME)/PROBMU(M,KAL)
      K=KAL
      GO TO 220
  215 CONTINUE
  220 CONTINUE
  300 CONTINUE
      PUNCH 2000,NOPT,NOZE,NANG
      PRINT 3001,NOPT,NOZE,NANG
      PUNCH 2001,(ZE(J),J=1,NOZE)
      PRINT 3002,(ZE(J),J=1,NOZE)
      DO 301M=1,NOZE1
      NONG=NANG/2
      DO 302 N=1,NONG
```

```
      STOR=ANG(M,N)
      NUT=NANG-N+1
      ANG(M,N)=ANG(M,NUT)
  302 ANG(M,NUT)=STOR
      PUNCH 2002,(ANG(M,N),N=1,NANG)
  301 PRINT 3003,(ANG(M,N),N=1,NANG)
  400 CONTINUE
      CALL EXIT
      END
```

APPENDIX N

INPUT INSTRUCTIONS, FLOW DIAGRAM, AND LISTINGS FOR PROGRAM SNARLS; LISTINGS FOR PROGRAM CKSOURTP AND SUBROUTINE SNEUT(X,Y,Z,A,B,C,W,E,NTAPE,NSKIP)

1. Input Instructions for Program SNARLS

The following SNARLS input instructions use nomenclature based on the following geometrical configuration. The reactor system is enclosed by a cylinder whose axis is the Z axis and by two planes parallel to the X,Y plane. Since the Z direction runs from the top to the bottom of the reactor system, the "top" plane (located at or above the reactor system) is at a smaller Z location than the "bottom" plane (located at or below the reactor system). The "bottom" plane is at the reactor-shield interface. Neutrons leaking from one or two of these three leakage surfaces may be used to prepare a leakage source tape.

SNARLS was written with the assumption that the Ø5R problem which prepared the collision tape would have data for NCØLL=4 and the following NBIND values (see reference 2 for variable definitions):

1110001111111000100011010000000000.

Card 1. Format (9A8)

a. BCDID(I),I=1,9: 72 columns alphanumeric characters.

Card 2. Format (6I12)

a. NHISTR: logical number, first O5R collision tape

b. NHISMX*: highest logical number for an O5R collision tape

c. NSØR**: logical number intermediate source tape; if NSØR=0, there will be no source tape preparation.

d. NSØR1**: logical number, final source tape.

e. NBAT: omit first NBAT batches on the first O5R collision tape.

f. NITS: number of batches to be processed from the O5R collision tapes including the first NBAT batches.

---

*Collision tape logical numbers will be from NHISTR through NHISMX.

**Logical numbers NSØR+1 and NSØR1+1 may also be used if reels on NSØR or NSØR1 are filled.

Card 3. Format (6I12)

a. NATS: not used; leave blank

b. NSTRT: not used; leave blank

c. IGRP: number of energy groups for both angular flux results and weight standards input; IGRP $\leq$ 10.

d. JTYPE1: first JTYPE to be considered for source tape preparation.

e. JTYPE2: second JTYPE to be considered for source tape preparation (JTYPE1 may equal JTYPE2).

f. NCRS: logical number, scratch tape.

JTYPE	LEAKAGE CRITERIA FOR SOURCE TAPE
1	leakage from bottom plane, positive Z direction cosine
2	leakage from cylinder, positive Z direction cosine
3	leakage from cylinder, negative Z direction cosine
4	leakage from top plane, negative Z direction cosine

Card 4. Format (6I12)

a. NFLUXZ: number of axial intervals for calculation of angular leakage flux from the cylinder; if NFLUXZ=0, the calculation is omitted (NFLUXZ $\leq$ 20).

b. NFLUXR: number of radial intervals for calculation of angular leakage flux from the bottom plane; if NFLUXR=0, the calculation is omitted (NFLUXR $\leq$ 10).

c. NMUZ: number of equal cosine of the polar angle intervals on 0. to 1.0 for calculation of angular leakage flux from the cylinder (polar direction is outward normal to cylinder (NMUZ $\leq$ 5).

d. NMUR: same as NMUZ but for the bottom plane (polar direction is Z direction) (NMUR $\leq$ 5).

e. NPHIZ: number of equal azimuthal angle intervals on 0. to 2π for calculation of the angular leakage flux from the cylinder (NPHIZ $\leq$ 6).

f. NPHIR: same as NPHIZ but for the bottom plane (NPHIR $\leq$ 6).

Card 5. Format (5E12.4)

a. ZTØP: not used, leave blank.

b. ZBØT: not used, leave blank.

c. ZTØPNEW: The top leakage plane, in cm, ZTØPNEW should be smaller than any Z in the reactor system.

d. ZBØTNEW: the bottom leakage plane, in cm, ZBØTNEW should be equal to or greater than the largest Z in the reactor system (ZBØTNEW > ZTØPNEW).

e. RCYLIN: the radius, in cm, of the leakage cylinder with axis coinciding with Z axis. The reactor system should lie within this cylinder.

Card 6. Format (6E12.4)

a. ERUS(I),I=1,IGRP: energy group boundaries, in MeV, from high to low energy with the highest boundary omitted; used to specify weight standards as well as tabulating angular flux results.

Card 7. Format (6E12.4)

a. CØSTHETA(I),I=1,IGRP: cosine of the angle θ for which $\gamma \geq \cos\theta$ (γ = Z direction cosine) neutrons are biased differently than $\gamma < \cos\theta$ neutrons. If $\cos\theta = -1.0$, there will be the same biasing for all γ's; $\cos\theta$ defines two angular groups for each energy group at which different weight standards may be applied.

Card 8. Format (6E12.4)

a. WK(I),I=1,IGRP: Russian roulette weight standard factor by energy group applied to neutrons with $\gamma \geq$ COSTHETA(I); when neutron weight, W, is less than WK(I)*WBAR(I,JTYPE) (see cards 14 and 16), the survival fraction is W/(WK(I)*WBAR(I,JTYPE)); surviving neutrons are given the weight, WK(I)*WBAR(I,JTYPE).

Card 9. Format (6E12.4)

a. WK1(I),I=1,IGRP: Russian roulette weight standard factor by energy group applied to neutrons with $\gamma <$ COSTHETA(I); when neutron weight, W, is less than WK1(I)*WMAX(I, JTYPE) (see cards 15 and 17), the survival fraction is W/(WK1(I)*WMAX(I,JTYPE)); surviving neutrons are given the weight WK1(I)*WMAX(I,JTYPE).

Card 10. Format (6E12.4)

a. SWK(I),I=1,IGRP: Splitting weight standard factor by energy group

  1. for neutrons with $\gamma \geq$ COSTHETA(I) and weight, W, greater than SWK(I)*WBAR(I,JTYPE) (see cards 14 and 16), the neutron is split W/(SWK(I)*WBAR(I,JTYPE))+1 times;
  2. for $\gamma <$ COSTHETA(I) and weight, W, greater than SWK(I)*WMAX(I,JTYPE) (see cards 15 and 17), the neutron is split W/(SWK(I)*WMAX(I,JTYPE))+1 times.

Card 11. Format (6E12.4)

Omit this card if NFLUXZ=0 (on card 4)

a. ZZZ(N),N=1,NFLUXZ+1: the axial boundaries, in cm, for the calculation of angular leakage flux from the cylinder; ZZZ(1)≡ ZTØPNEW;(ZZZ(NFLUXZ+1)≡ZBOTNEW).

Card 12. Format (6E12.4)

Omit this card if NFLUXR=0 (on card 4)

a. RRR(N),N=1,NFLUXR: the radial boundaries, in cm, zero center omitted for the calculation of angular leakage flux from the bottom plane; RRR(NFLUXR)≡RCYLIN.

Omit the remaining cards if NSØR=0 (on card 2)

Card 13. Format (Ø16,I8)

a.	RANDØM:	the starting random number
b.	NREAD:	must be 1

Card 14. Format (6E12.4)

a. WBAR(I,JTYPE1),I=1,IGRP: the optimum weight by energy group for important neutrons with $\gamma \geq$ COSTHETA(I); given for leakage criterion JTYPE1 (on card 3).

Card 15. Format (6E12.4)

a. WMAX(I,JTYPE1),I=1,IGRP: the optimum weight by energy group for important neutrons with $\gamma <$ COSTHETA(I); given for leakage criterion JTYPE1 (on card 3).

Card 16. Format (6E12.4)

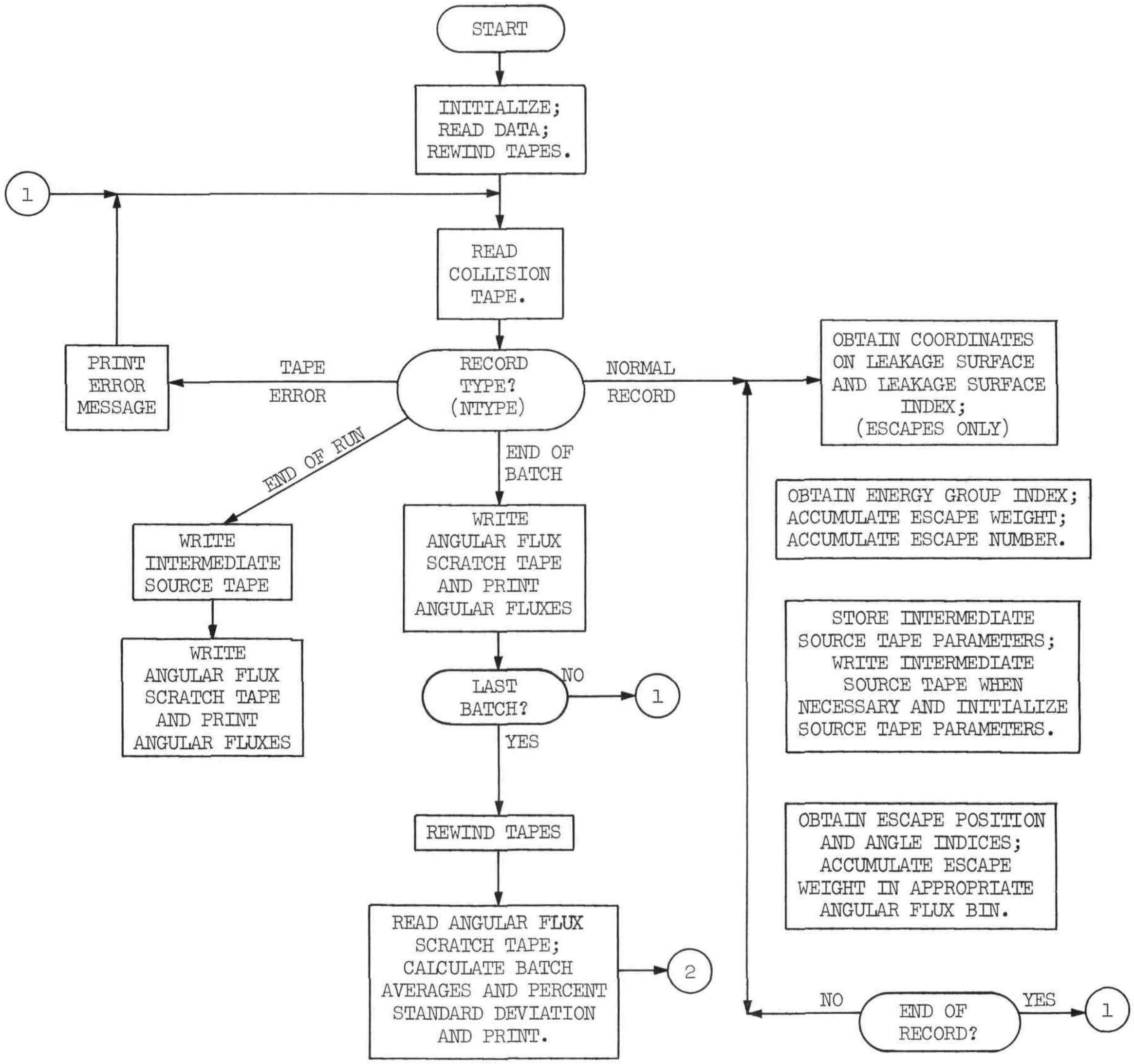
a. WBAR(I,JTYPE2),I=1,IGRP: same as card 14 but for leakage criterion JTYPE2 (on card 3).

Card 17. Format (6E12.4)

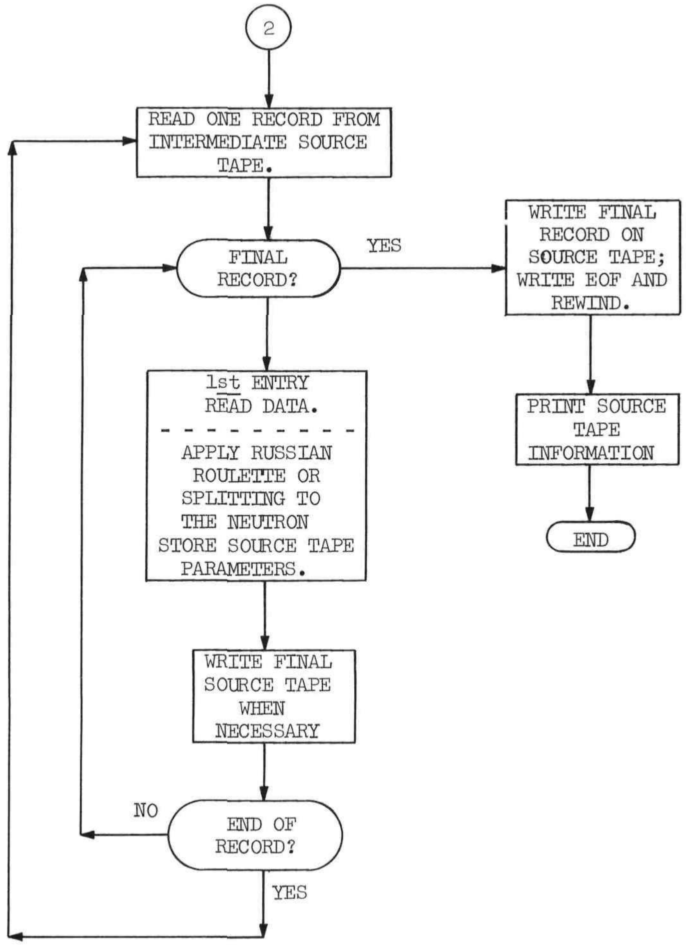
a. WMAX(I,JTYPE2),I=1,IGRP: same as card 15 but for leakage criterion JTYPE2 (on card 3).

2. Flow Diagram for Program SNARLS

Program SNARLS, Page 1



Program SNARLS, Page 2



3. Program SNARLS Listing

```
      PRØGRAM SNARLS                                                    01000101
      CØMMØN/MAIN/KTH,LBATØ,LBATCH,NTYPE,NHISTR,NHISMX,NSØR,            01000201
     1NBAT,NITS,NFLUXZ1,NFLUXR1                                         01000202
      CØMMØN/SIXTH/ALP(50),BET(50),CØSTHETA(10),FRUS(10),               01000213
     1GAM(50),IGFP,JTYPE1,JTYPE2,JTY(50),LBATER(50),                    01000214
     2NSØR1,NAMØ,NAMT,SENGSQ(50),WAITER(50),XØ(50),YØ(50),ZØ(50)        01000215
      CØMMØN/CPLIST/NCØLL(8),NAME(8),S12(8),X1(8),Y1(8),Z1(8),          01000222
     1WT1(8),SØ2(8),UØ(8),VØ(8),WØ(8),ØLDWT(8),NGRP(8),NELEM(8),NMED(8) 01000223
     2,DUMMY(8)
      CALL FIXINFLT                                                     01000301
      NAMT=0                                                            01000301
      NAMSTØR=0                                                         01000301
      NCØLPR=8                                                          01000302
      NPARITY=0                                                         01000303
      LBATCH=0                                                          01000304
    1 LBATCH=LBATCH+1                                                   01000305
      CALL STBATCH                                                      01000306
    4 CALL Ø5RREAD                                                      01000307
      IF (NTYPE) 5,19,15                                                01000308
C  19 NØRMAL RECØRD FRØM CØLLISIØN TAPE.                                01000309
   19 DØ 41 KTH=1,NCØLPR                                                01000310
      ICØL=NCØLL(KTH)                                                   01000311
      IF (ICØL) 4,4,25                                                  01000312
   25 IF (ICØL-4) 41,33,41                                              01000313
   33 CALL ESCAPE                                                       01000314
   41 NAMSTØR=NAME(KTH)                                                 01000315
      GØ TØ 4                                                           01000316
C  15 TEST END ØF RUN ØR END ØF BATCH.                                  01000317
   15 IF (NTYPE-2) 17,9,9                                               01000318
C   9 END ØF RUN.                                                       01000319
    9 IF (NSØR) 91,900,91                                               01000320
   91 CALL SØRSET                                                       01000321
  900 LBATØ=LBATØ+1                                                     01000321
```

```
      NAMT=NAMT+NAMSTOR                                                 01000321
   90 CALL SCRACHIT                                                     01000322
   92 LBATCH=LBATCH-1                                                   01000323
      IF (LBATCH) 10,14,10                                              01000324
   10 CALL ENDRUN                                                       01000325
   14 CALL EXIT                                                         01000401
C  17 END OF BATCH.                                                     01000402
   17 IF (NBAT-LBATCH) 93,944,944                                       01000403
  944 NAMO=NAMO+NAMSTOR                                                 01000403
      NAMT=NAMT+NAMSTOR                                                 01000403
      GO TO 94                                                          01000403
   93 LBATO=LBATO+1                                                     01000404
      NAMT=NAMT+NAMSTOR                                                 01000404
      CALL SCRACHIT                                                     01000405
   94 IF (LBATCH-NITS) 1,95,95                                          01000406
   95 IF (NSOR) 97,10,97                                                01000407
   97 CALL SORSET                                                       01000408
      GO TO 10                                                          01000409
C   5 ERROR IN READING COLLISION TAPE.                                  01000410
    5 NPARITY=NPARITY+1                                                 01000411
      WRITE(51,1000)NPARITY                                             01000412
 1000 FORMAT(1H1,7PARITY ERROR IN READING COLLISION TAPE.7,             01000413
     17  NPARITY=7,I2)                                                  01000414
      IF (NPARITY-20)4,4,92                                             01000415
      END                                                               01000416


      SUBROUTINE FIXINPUT                                               02000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,            02000201
     1NBAT,NITS,NFLUXZ1,NFLUXR1                                         02000202
      COMMON/SECOND/ALPHA1,BETA1,CMU,CMUO,FNPHIR,FNPHIZ,FNMUR,          02000203
     1FNMUZ,GAMMA1,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                     02000204
     2PHICOS,PHISIN,R                                                   02000205
      COMMON/THIRD/NCRS,NFLUXZ,NFLUXR,NESCAPE(10,4),                    02000206
     1RANGFLUX(10,20,30),WRAR(10,4),ZANGFLUX(10,20,30),BCDID(9)         02000207
```

```
      COMMON/FORTH/ALPHA(50),BETA(50),GAMMA(50),IEGP1(50),              02000208
     1JTYPER(50),LBATY(50),NCOLS(50),SENG2(50),WAIT(50),                02000209
     2XS(50),YS(50),ZS(50)                                              02000210
      COMMON/FIFTH/JTYPE,RCYLIN,ZTOP,ZBOT,ZTOPNEW,                      02000211
     1ZBOTNEW                                                           02000212
      COMMON/SIXTH/ALP(50),BET(50),COSTHETA(10),ERUS(10),               02000213
     1GAM(50),IGRP,JTYPE1,JTYPE2,JTY(50),LBATER(50),                    02000214
     2NSOR1,NAMO,NAMT,SENGSQ(50),WAITER(50),XO(50),YO(50),ZO(50)        02000215
      COMMON/SEVENTH/NFLUXZ2,NRITE,RRR(10),WMAX(10,4),                  02000216
     1WTHETA1(10,4),WTHETA2(10,4),ZZZ(21)                               02000217
      COMMON/EIGHTH/NATS,NSTRT,SWK(10),WK(10),WK1(10)                   02000218
      COMMON/GOODY/NESCAPE1(10,4),NESCAPE2(10,4)                        02   229
      READ(50,1000) RCDID                                               02000301
 1000 FORMAT(9A8)                                                       02000302
      PRINT 2000, RCDID                                                 02000303
 2000 FORMAT(1H1,9A8)                                                   02000304
      READ(50,1001) NHISTR,NHISMX,NSOR,NSOR1,NBAT,NITS                  02000305
      READ(50,1001) NATS,NSTRT,IGRP,JTYPE1,JTYPE2,NCRS                  02000306
      NATS=NSOR                                                         02000306
      READ(50,1001) NFLUXZ,NFLUXR,NMUZ,NMUR,NPHIZ,NPHIR                 02000307
 1001 FORMAT(6I12)                                                      02000308
      PRINT 2001, NHISTR,NHISMX,NSOR,NSOR1,NBAT,NITS,                   02000309
     1NATS,NSTRT,IGRP,JTYPE1,JTYPE2,NCRS,                               02000310
     2NFLUXZ,NFLUXR,NMUZ,NMUR,NPHIZ,NPHIR                               02000311
 2001 FORMAT(1H0,7NHISTR=7,I3,3X,7NHISMX=7,I3,5X,                       02000312
     17NSOR=7,I3,4X,7NSOR1=7,I3,4X,7NBAT=7,I4,4X,                       02000313
     27NITS=7,I4,3X,7NATS=7,I4,3X,7NSTRT=7,I4/3H    ,                   02000314
     37IGRP=7,I3,3X,7JTYPE1=7,I2,4X,7JTYPE2=7,I2,6X,                    02000315
     47NCRS=7,I3,2X,7NFLUXZ=7,I3,3X,7NFLUXR=7I3,6X,                     02000316
     57NMUZ=7,I2,4X,7NMUR=7,I2/2H  ,7NPHIZ=7,I2,5X,                     02000317
     67NPHIR=7,I2)                                                      02000318
      READ(50,1002) ZTOP,ZBOT,ZTOPNEW,ZBOTNEW,RCYLIN                    02000319
 1002 FORMAT(6E12.4)                                                    02000320
      READ(50,1002) (ERUS(I),I=1,IGRP)                                  02000321
C     INDEX I=1,IGRP RUNS FROM HIGH TO LOW ENERGY.                      02000322
C     ENERGY, ERUS(I), IS IN MEV.                                       02000323
      READ(50,1002) (COSTHETA(I),I=1,IGRP)                              02000324
```

```
      READ(50,1002) (WK(I),I=1,IGRP)                                    02000325
      READ(50,1002) (WK1(I),I=1,IGRP)                                   02000401
      READ(50,1002) (SWK(I),I=1,IGRP)                                   02000402
      PRINT 2002, ZTOP,ZBOT,ZTOPNEW,ZBOTNEW,RCYLIN                      02000403
 2002 FORMAT(4H0    ,7ZTOP=7,E12.4,6X,7ZBOT=7,E12.4/1H ,                02000404
     17ZTOPNEW=7,E12.4,3X,7ZBOTNEW=7,E12.4,3X,7RCYLIN=7,E12.4)          02000405
      PRINT 2102, (ERUS(I),I=1,IGRP)                                    02000406
      PRINT 2202, (COSTHETA(I),I=1,IGRP)                                02000407
      PRINT 2302, (WK(I),I=1,IGRP)                                      02000408
      PRINT 2402, (WK1(I),I=1,IGRP)                                     02000409
      PRINT 2502, (SWK(I),I=1,IGRP)                                     02000410
 2102 FORMAT(1H0,7ERUS(I),I=1,IGRP7/1H ,(8E12.4))                       02000411
 2202 FORMAT(1H0,7COSTHETA(I),I=1,IGRP7/1H ,(8E12.4))                   02000412
 2302 FORMAT(1H0,7WK(I),I=1,IGRP7/1H ,(8E12.4))                         02000413
 2402 FORMAT(1H0,7WK1(I),I=1,IGRP7/1H ,(8E12.4))                        02000414
 2502 FORMAT(1H0,7SWK(I),I=1,IGRP7/1H ,(8E12.4))                        02000415
      IF (NFLUXZ) 11,11,10                                              02000416
   10 NFLUXZ2=NFLUXZ+1                                                  02000417
      READ(50,1002) (ZZZ(N),N=1,NFLUXZ2)                                02000418
      PRINT 2602, (ZZZ(N),N=1,NFLUXZ2)                                  02000419
 2602 FORMAT(1H0,7ZZZ(N),N=1,NFLUXZ+17/1H ,(8E12.4))                    02000420
   11 IF (NFLUXR) 13,13,12                                              02000421
   12 READ(50,1002) (RRR(N),N=1,NFLUXR)                                 02000422
      PRINT 2702, (RRR(N),N=1,NFLUXR)                                   02000423
 2702 FORMAT(1H0,7RRR(N),N=1,NFLUXR7/1H ,(8E12.4))                      02000424
   13 FNMUZ=NMUZ                                                        02000425
      FNMUR=NMUR                                                        02000501
      FNPHIZ=NPHIZ                                                      02000502
      FNPHIR=NPHIR                                                      02000503
      REWIND NCRS                                                       02000507
      IF (NSOR) 15,15,14                                                02000504
   14 REWIND NSCR1                                                      02000505
      REWIND NSOR                                                       02000506
   15 DO20I=1,10                                                        02000508
      DO16J=1,4                                                         02000509
      WBAR(I,J)=0.0                                                     02000510
      WMAX(I,J)=0.0                                                     02000511
```

```
      WTHETA1(I,J)=0.0                                                  02000512
   16 WTHETA2(I,J)=0.0                                                  02000513
      DO17N=1,20                                                        02000514
      DO17K=1,30                                                        02000515
      ZANGFLUX(I,N,K)=0.0                                               02000516
   17 RANGFLUX(I,N,K)=0.0                                               02000517
   20 CONTINUE                                                          02000518
      DO21I=1,10                                                        02000519
      DO21J=1,4                                                         02000520
      NESCAPE1(I,J)=0                                                   02   520
      NESCAPE2(I,J)=0                                                   02   520
   21 NESCAPE(I,J)=0                                                    02000521
      NRITE=0                                                           02000522
      DO22I=1,50                                                        02000523
      NCOLS(I)=0                                                        02000524
      IEGP1(I)=0                                                        02000525
      JTYPER(I)=0                                                       02000601
      LBATY(I)=0                                                        02000602
      XS(I)=0.0                                                         02000603
      YS(I)=0.0                                                         02000604
      ZS(I)=0.0                                                         02000605
      ALPHA(I)=0.0                                                      02000606
      BETA(I)=0.0                                                       02000607
      GAMMA(I)=0.0                                                      02000608
      SENG2(I)=0.0                                                      02000609
   22 WAIT(I)=0.0                                                       02000610
      DO23I=1,IGRP                                                      02000611
   23 ERUS(I)=1.91322E+18*ERUS(I)                                       02000612
      NAMO=0                                                            02000612
      LBATO=0                                                           02000612
      RETURN                                                            02000613
      END FIXINPUT                                                      02000614


      SUBROUTINE STWATCH                                                03000101
```

```
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,           03000201
     1NBAT,NITS,NFLUXZ1,NFLUXR1                                        03000202
      COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),X1(8),Y1(8),Z1(8),         03000222
     1WT1(8),SO2(8),UO(8),VO(8),WO(8),OLDWT(8),NGRP(8),NELEM(8),NMED(8) 03000223
     2,DUMMY(8)
      DATA(IJK=0)                                                      03000301
      IF (IJK) 11,5,11                                                 03000302
    5 CALL O5RSET(NHISTR,NHISMX,NREC,NTYPE,NCOLL,NAME,                 03000303
     1S12,X1,Y1,Z1,WT1,SO2,UO,VO,WO,OLDWT,NGRP,NELEM,                  03000304
     2NMED)                                                            03000305
      IJK=1                                                            03000306
   11 CONTINUE                                                         03000307
      RETURN                                                           03000308
      END STBATCH                                                      03000309



      SUBROUTINE ESCAPE                                                04000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,           04000201
     1NBAT,NITS,NFLUXZ1,NFLUXR1                                        04000202
      COMMON/SECOND/ALPHA1,BETA1,CMU,CMUD,FNPHIR,FNPHIZ,FNMUR,         04000203
     1FNMUZ,GAMMA1,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                    04000204
     2PHICOS,PHISIN,R                                                  04000205
      COMMON/THIRD/NCRS,NFLUXZ,NFLUXR,NESCAPE(10,4),                   04000206
     1RANGFLUX(10,20,30),WBAR(10,4),ZANGFLUX(10,20,30),BCDID(9)        04000207
      COMMON/FORTH/ALPHA(50),BETA(50),GAMMA(50),IEGP1(50),             04000208
     1JTYPER(50),LBATY(50),NCOLS(50),SENG2(50),WAIT(50),               04000209
     2XS(50),YS(50),ZS(50)                                             04000210
      COMMON/FIFTH/JTYPE,RCYLIN,ZTOP,ZBOT,ZTOPNEW,                     04000211
     1ZBOTNEW                                                          04000212
      COMMON/SIXTH/ALP(50),BET(50),COSTHETA(10),ERUS(10),              04000213
     1GAM(50),IGRP,JTYPE1,JTYPE2,JTY(50),LBATER(50),                   04000214
     2NSOR1,NAMO,NAMT,SENGSQ(50),WAITER(50),XO(50),YO(50),ZO(50)       04000215
      COMMON/SEVENTH/NFLUXZ2,NRITE,RRR(10),WMAX(10,4),                 04000216
     1WTHETA1(10,4),WTHETA2(10,4),ZZZ(21)                              04000217
      COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),X1(8),Y1(8),Z1(8),         04000222
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     1NTI(8),SO2(8),UO(8),V0(8),WO(8),OLDWT(8),NGRP(8),NELEM(8),NMED(8) 04000223
     2,DUMMY(8)
      COMMON/GOODER/NGOOD                                               04000228
      COMMON/GOODY/NESCAPE1(10,4),NESCAPE2(10,4)                        04   229
      IF (NBAT-LBATCH) 2,1,1                                            04000301
    1 CONTINUE                                                          04000302
      RETURN                                                            04000303
    2 SO=SQRTF(SO2(KTH))                                                04000304
      ALPHA1=UO(KTH)/SO                                                 04000305
      BETA1=VO(KTH)/SO                                                  04000306
      GAMMA1=WO(KTH)/SO                                                 04000307
      CALL TRACER                                                       04000308
      IF (NGOOD) 30,333,30                                              04000309
  333 CONTINUE                                                          04000309
      DO 3 I=1,IGRP                                                     04000309
      IF (SI2(KTH)-ERUS(I)) 3,4,4                                       04000310
    3 CONTINUE                                                          04000311
      RETURN                                                            04000312
    4 IEGP=I                                                            04000313
      WBAR(IEGP,JTYPE)=WBAR(IEGP,JTYPE)+OLDWT(KTH)                      04000314
      NESCAPE(IEGP,JTYPE)=NESCAPE(IEGP,JTYPE)+1                         04000315
      WMAX(IEGP,JTYPE)=MAX1F(WMAX(IEGP,JTYPE),OLDWT(KTH))               04000316
      IF (GAMMA1-COSTHETA(IEGP)) 6,5,5                                  04000317
    5 WTHETA1(IEGP,JTYPE)=WTHETA1(IEGP,JTYPE)+OLDWT(KTH)                04000318
      NESCAPE1(IEGP,JTYPE)=NESCAPE1(IEGP,JTYPE)+1                       04   318
      GO TO 7                                                           04000319
    6 WTHETA2(IEGP,JTYPE)=WTHETA2(IEGP,JTYPE)+OLDWT(KTH)                04000320
      NESCAPE2(IEGP,JTYPE)=NESCAPE2(IEGP,JTYPE)+1                       04   320
    7 IF (NSOR) 8,9,8                                                   04000321
    8 NRITE=NRITE+1                                                     04000322
      NCOLS(NRITE)=NCOLL(KTH)                                           04000323
      XS(NRITE)=X1(KTH)                                                 04000324
      YS(NRITE)=Y1(KTH)                                                 04000325
      ZS(NRITE)=Z1(KTH)                                                 04000401
      ALPHA(NRITE)=ALPHA1                                               04000402
      BETA(NRITE)=BETA1                                                 04000403
      GAMMA(NRITE)=GAMMA1                                               04000404
```

```
   SENG2(NRITE)=SO2(KTH)                                              04000405
   WAIT(NRITE)=OLDWT(KTH)                                             04000406
   IEGP1(NRITE)=IEGP                                                  04000407
   JTYPER(NRITE)=JTYPE                                                04000408
   LBATY(NRITE)=LBATO+1                                               04000409
   IF (NRITE-50)9,10,10                                               04000410
10 NRITE=0                                                            04000411
   CALL SORSET                                                        04000412
   DO 11 I=1,50                                                       04000413
   NCOLS(I)=0                                                         04000414
   XS(I)=0.0                                                          04000415
   YS(I)=0.0                                                          04000416
   ZS(I)=0.0                                                          04000417
   ALPHA(I)=0.0                                                       04000418
   BETA(I)=0.0                                                        04000419
   GAMMA(I)=0.0                                                       04000420
   SENG2(I)=0.0                                                       04000421
   WAIT(I)=0.0                                                        04000422
   IEGP1(I)=0                                                         04000423
   JTYPER(I)=0                                                        04000424
11 LBATY(I)=0                                                         04000425
 9 CONTINUE                                                           04000501
   GO TO (12,20,20,30),JTYPE                                          04000502
12 IF (NFLUXR) 30,30,13                                               04000503
13 CALL POSR                                                          04000504
   CALL RANGL                                                         04000505
   IF (CMU-.001) 30,40,40
40 CONTINUE
   RANGFLUX(IEGP,NFLUXR1,IANGL)=RANGFLUX(IEGP,NFLUXR1,IANGL)+OLDWT(KT04000506
  1H)/CMU                                                             04000507
   GO TO 30                                                           04000508
20 IF (NFLUXZ) 30,30,21                                               04000509
21 CALL POSZ                                                          04000510
   CALL ZANGL                                                         04000511
   IF (CMU-.001) 30,41,41
41 CONTINUE
   ZANGFLUX(IEGP,NFLUXZ1,IANGL)=ZANGFLUX(IEGP,NFLUXZ1,IANGL)+OLDWT(KT04000512
```

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     1H)/CMU                                                            04000513
  30 RETURN                                                             04000514
     END ESCAPE                                                         04000515


      SUBROUTINE SORSET                                                 05000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,            05000201
     1NBAT,NITS,NFLUXZ1,NFLUXR1                                         05000202
      COMMON/FORTH/ALPHA(50),BETA(50),GAMMA(50),IEGP1(50),              05000208
     1JTYPER(50),LBATY(50),NCOLS(50),SENG2(50),WAIT(50),                05000209
     2XS(50),YS(50),ZS(50)                                              05000210
 703  WRITE (NSOR) NCOLS,XS,YS,ZS,ALPHA,BETA,GAMMA,                     05000301
     1SENG2,WAIT,IEGP1,JTYPER,LBATY                                     05000302
      IF (EOF,NSOR) 701,702                                             05000302
 701  END FILE NSOR                                                     05000302
      REWIND NSOR                                                       05000302
      NSOR=NSOR+1                                                       05000302
      REWIND NSOR                                                       05000302
      GO TO 703                                                         05000302
 702  END FILE NSOR                                                     05000303
      BACKSPACE NSOR                                                    05000304
      RETURN                                                            05000305
      END SORSET                                                        05000306


      SUBROUTINE SCRACHIT                                               06000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,            06000201
     1NBAT,NITS,NFLUXZ1,NFLUXR1                                         06000202
      COMMON/SECOND/ALPHA1,BETA1,CMU,CMUD,FNPHIR,FNPHIZ,FNMUR,          06000203
     1FNMUZ,GAMMA1,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                     06000204
     2PHICOS,PHISIN,R                                                   06000205
      COMMON/THIRD/NCRS,NFLUXZ,NFLUXR,NESCAPE(10,4),                    06000206
     1RANGFLUX(10,20,30),WBAR(10,4),ZANGFLUX(10,20,30),BCDID(9)         06000207
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      COMMON/FIFTH/JTYPE,RCYLIN,ZTOP,ZBOT,ZTOPNEW,                      06000211
     1ZBOTNEW                                                           06000212
      COMMON/SIXTH/ALP(50),BET(50),COSTHETA(10),FRUS(10),               06000213
     1GAM(50),IGRP,JTYPE1,JTYPE2,JTY(50),LBATER(50),                    06000214
     2NSOR1,NAMO,NAMT,SENGSQ(50),WAITER(50),XO(50),YO(50),ZO(50)        06000215
      COMMON/SEVENTH/NFLUXZ2,NRITE,RRR(10),WMAX(10,4),                  06000216
     1WTHETA1(10,4),WTHETA2(10,4),ZZZ(21)                               06000217
      COMMON/GOODY/NESCAPE1(10,4),NESCAPE2(10,4)                        06   229
      PRINT 1000, RCDID                                                 06000301
 1000 FORMAT(1H1,9A8)                                                   06000302
      PRINT 1001, LBATO                                                 06000303
 1001 FORMAT(1H ,7RESULTS FOR BATCH NUMBER7,I3)                         06000304
      MOOZ=NMUZ*NPHIZ                                                   06000305
      MOOR=NMUR*NPHIR                                                   06000306
      IF (NFLUXZ) 10,10,1                                               06000307
    1 DO 9 N=1,NFLUXZ                                                   06000308
      N1=N+1                                                            06000309
      DELZ=ZZZ(N1)-ZZZ(N)                                               06000310
      AREA=6.28318*DELZ*RCYLIN                                          06000311
      DO 2 I=1,IGRP                                                     06000312
      DO 2 K=1,MOOZ                                                     06000313
    2 ZANGFLUX(I,N,K)=ZANGFLUX(I,N,K)/AREA                              06000314
      PRINT 1002, N,ZZZ(N),ZZZ(N1),(I,I=1,IGRP)                         06000315
 1002 FORMAT(1H0,26X,7ZANGFLUX (WEIGHT/AREA) FOR INTERVAL NO.7          06000316
     1,I3/34X,7Z= 7,E12.4,7 TO 7,E12.4//7 ANGLE7,38X,                   06000317
     27ENERGY INDEX7/7 INDEX7,I5,9I10)                                  06000318
      DO 3 K=1,MOOZ                                                     06000319
    3 PRINT 1003, K,(ZANGFLUX(I,N,K),I=1,IGRP)                          06000320
 1003 FORMAT(1H ,I3,3X,10E10.2)                                         06000321
      DO 4 I=1,IGRP                                                     06000322
      DO 4 K=1,MOOZ                                                     06000323
    4 ZANGFLUX(I,N,K)=ZANGFLUX(I,N,K)*AREA                              06000324
      PRINT 1000, RCDID                                                 06000325
      PRINT 1001, LBATO                                                 06000401
    9 CONTINUE                                                          06000402
   10 IF (NFLUXR) 20,20,11                                              06000403
   11 DO 19 N=1,NFLUXR                                                  06000404
```

```
      IF (N-1) 13,12,13                                                 06000405
   12 RRR2=0.0                                                          06000406
      RRR1=0.0                                                          06000407
      GO TO 14                                                          06000408
   13 RRR2=RRR(N-1)**2                                                  06000409
      RRR1=RRR(N-1)                                                     06000410
   14 AREA=3.14159*(RRR(N)**2-RRR2)                                     06000411
      DO 15 I=1,IGRP                                                    06000412
      DO 15 K=1,MCOR                                                    06000413
   15 RANGFLUX(I,N,K)=RANGFLUX(I,N,K)/AREA                              06000414
      PRINT 1004, N,RRR1,RRR(N),(I,I=1,IGRP)                            06000415
 1004 FORMAT(1H0,26X,7RANGFLUX (WEIGHT/AREA) FOR INTERVAL NO.7          06000416
     1,I3/34X,7R= 7,E12.4,7 TO 7,E12.4//7 ANGLE7,38X,                   06000417
     27ENERGY INDEX7/7 INDEX7,I5,9I10)                                  06000418
      DO 16 K=1,MCOR                                                    06000419
   16 PRINT 1003, K,(RANGFLUX(I,N,K),I=1,IGRP)                          06000420
      DO 17 I=1,IGRP                                                    06000421
      DO 17 K=1,MCOR                                                    06000422
   17 RANGFLUX(I,N,K)=RANGFLUX(I,N,K)*AREA                              06000423
      PRINT 1000, RCDID                                                 06000424
      PRINT 1001,LRATO                                                  06000425
   19 CONTINUE                                                          06000501
   20 PRINT 1005                                                        06000502
 1005 FORMAT(1H0,30X,7NESCAPE, NUMBER OF ESCAPES7/                      06000503
     131X,7WBAR, TOTAL ESCAPE WEIGHT7/31X,                              06000504
     27WTHETA1, WEIGHT WITH GAMMA GREATER THAN COSTHETA7/               06000505
     331X,7WTHETA2, WEIGHT WITH GAMMA LESS THAN COSTHETA7)              06000506
      DO 40 J=1,4                                                       06000507
      GO TO (21,22,23,24),J                                             06000508
   21 PRINT 1006                                                        06000509
 1006 FORMAT(1H0,30X,7BOTTOM OF REACTOR (POSITIVE GAMMA)7)              06000510
      GO TO 25                                                          06000511
   22 PRINT 1007                                                        06000512
 1007 FORMAT(1H0,30X,7SIDE OF REACTOR (POSITIVE GAMMA)7)                06000513
      GO TO 25                                                          06000514
   23 PRINT 1008                                                        06000515
 1008 FORMAT(1H0,30X,7SIDE OF REACTOR (NEGATIVE GAMMA)7)                06000516
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      GØ TØ 25                                                          06000517
   24 PRINT 1009                                                        06000518
 1009 FØRMAT(1H0,30X,7TØP ØF REACTØR (NEGATIVE GAMMA)7)                 06000519
   25 PRINT 1010, (I,I=1,IGRP)                                          06000520
 1010 FØRMAT(1H ,7ENERGY7/7 INDEX7,4X,I3,9I10)                          06000521
      PRINT 1011, (NESCAPE(I,J),I=1,IGRP)                               06000522
 1011 FØRMAT(1H ,7NESCAPE7,3X,I7,9I10)                                  06000523
      PRINT 1012, (WBAR(I,J),I=1,IGRP)                                  06000524
 1012 FØRMAT(1H ,7WBAR7,4X,10E10.2)                                     06000525
      IF (J-1) 40,26,40                                                 06000601
   26 PRINT 1013, (CØSTHETA(I),I=1,IGRP)                                06000602
 1013 FØRMAT(1H ,7CØSTHETA7,10E10.2)                                    06000603
      PRINT 1014, (WTHETA1(I,J),I=1,IGRP)                               06000604
 1014 FØRMAT(1H ,7WTHETA17,1X,10E10.2)                                  06000605
      PRINT 1015, (WTHETA2(I,J),I=1,IGRP)                               06000606
 1015 FØRMAT(1H ,7WTHETA27,1X,10E10.2)                                  06000607
      PRINT 1016,(NESCAPE1(I,J),I=1,IGRP)                               06   607
 1016 FØRMAT(1H ,7NESCAPE17,2X,I7,9I10)                                 06   607
      PRINT 1017,(NESCAPE2(I,J),I=1,IGRP)                               06   607
 1017 FØRMAT(1H ,7NESCAPE27,2X,I7,9I10)                                 06   607
   40 CØNTINUE                                                          06000608
      IF (NFLUXZ+NFLUXR) 32,32,31                                       06000609
   31 WRITE (NCRS) ZANGFLUX                                             06000610
      WRITE (NCRS) RANGFLUX                                             06000611
      END FILE NCRS                                                     06000612
      BACKSPACE NCRS                                                    06000613
      DØ 35 I=1,10                                                      06000614
      DØ 35 N=1,20                                                      06000615
      DØ 35 K=1,30                                                      06000616
      ZANGFLUX(I,N,K)=0.0                                               06000617
   35 RANGFLUX(I,N,K)=0.0                                               06000618
   32 CØNTINUE                                                          06000619
      RETURN                                                            06000620
      END SCRACHIT                                                      06000621
```

```
      SUBROUTINE POSZ                                                   07000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,            07000201
     1NBAT,NITS,NFLUXZI,NFLUXRI                                         07000202
      COMMON/SECOND/ALPHAI,BETAI,CMU,CMUD,FNPHIR,FNPHIZ,FNMUR,          07000203
     1FNMUZ,GAMMAI,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                     07000204
     2PHICOS,PHISIN,R                                                   07000205
      COMMON/THIRD/NCRS,NFLUXZ,NFLUXR,NESCAPE(10,4),                    07000206
     1RANGFLUX(10,20,30),WBAR(10,4),ZANGFLUX(10,20,30),BCDID(9)         07000207
      COMMON/SEVENTH/NFLUXZ2,NRITE,RRR(10),WMAX(10,4),                  07000216
     1WTHETA1(10,4),WTHETA2(10,4),ZZZ(21)                               07000217
      COMMON/CPLIST/NCOLL(8),NAME(8),SI2(8),XI(8),YI(8),ZI(8),          07000222
     1WTI(8),SO2(8),UO(8),VO(8),WO(8),OLDWT(8),NGRP(8),NELEM(8),NMED(8) 07000223
     2,DUMMY(8)
      DO 10 N=2,NFLUXZ2                                                 07000301
      IF (ZI(KTH)-ZZZ(N)) 20,20,10                                      07000302
   10 CONTINUE                                                          07000303
      NFLUXZI=NFLUXZ                                                    07000304
      GO TO 30                                                          07000305
   20 NFLUXZI=N-1                                                       07000306
   30 R=SQRTF(XI(KTH)**2+YI(KTH)**2)                                    07000307
      RETURN                                                            07000308
      END POSZ                                                          07000309
```

```
      SUBROUTINE POSR                                                   08000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,            08000201
     1NBAT,NITS,NFLUXZI,NFLUXRI                                         08000202
      COMMON/SECOND/ALPHAI,BETAI,CMU,CMUD,FNPHIR,FNPHIZ,FNMUR,          08000203
     1FNMUZ,GAMMAI,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                     08000204
     2PHICOS,PHISIN,R                                                   08000205
      COMMON/THIRD/NCRS,NFLUXZ,NFLUXR,NESCAPE(10,4),                    08000206
     1RANGFLUX(10,20,30),WBAR(10,4),ZANGFLUX(10,20,30),BCDID(9)         08000207
      COMMON/SEVENTH/NFLUXZ2,NRITE,RRR(10),WMAX(10,4),                  08000216
     1WTHETA1(10,4),WTHETA2(10,4),ZZZ(21)                               08000217
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      COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),X1(8),Y1(8),Z1(8),          08000222
     1WT1(8),SO2(8),UO(8),VO(8),WO(8),OLDWT(8),NGRP(8),NELEM(8),NMED(8) 08000223
     2,DUMMY(8)
      R=SQRTF(X1(KTH)**2+Y1(KTH)**2)                                    08000301
      DO 10 N=1,NFLUXR                                                  08000302
      IF (R-RRR(N)) 20,20,10                                            08000303
   10 CONTINUE                                                          08000304
      NFLUXR1=NFLUXR                                                    08000305
      GO TO 30                                                          08000306
   20 NFLUXR1=N                                                         08000307
   30 RETURN                                                            08000308
      END POSR                                                          08000309



      SUBROUTINE ZANGL                                                  09000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,            09000201
     1NBAT,NITS,NFLUXZ1,NFLUXR1                                         09000202
      COMMON/SECOND/ALPHA1,BETA1,CMU,CMUD,FNPHIR,FNPHIZ,FNMUR,          09000203
     1FNMUZ,GAMMA1,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                     09000204
     2PHICOS,PHISIN,R                                                   09000205
      COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),X1(8),Y1(8),Z1(8),          09000222
     1WT1(8),SO2(8),UO(8),VO(8),WO(8),OLDWT(8),NGRP(8),NELEM(8),NMED(8) 09000223
     2,DUMMY(8)
      AO=X1(KTH)/R                                                      09000301
      BO=Y1(KTH)/R                                                      09000302
      CMU=ALPHA1*AO+BETA1*BO                                            09000303
      CMUD=SQRTF(1.0-CMU**2)                                            09000304
      IF (CMU-1.0) 20,10,10                                             09000305
   10 PHICOS=1.0                                                        09000306
      PHISIN=0.0                                                        09000307
      GO TO 60                                                          09000308
   20 IF (BO) 40,30,40                                                  09000309
   30 PHISIN=(BETA1-BO*CMU)/(AO*CMUD)                                   09000310
      GO TO 50                                                          09000311
   40 PHISIN=(AO*CMU-ALPHA1)/(BO*CMUD)                                  09000312
```

```
50    PHICOS=GAMMAI/CMUD                                              09000313
60    PHI=ACOSF(PHICOS)                                               09000314
      IF (PHISIN) 70,80,80                                            09000315
70    PHI=6.28318-PHI                                                 09000316
80    CALL ANGLO(NMUZ,FNMUZ,NPHIZ,FNPHIZ,IANGL,CMU,PHI)               09000317
      RETURN                                                          09000318
      END ZANGL                                                       09000319



      SUBROUTINE RANGL                                                10000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,          10000201
     1NBAT,NITS,NFLUXZI,NFLUXRI                                       10000202
      COMMON/SECOND/ALPHAI,BETAI,CMU,CMUD,FNPHIR,FNPHIZ,FNMUR,        10000203
     1FNMUZ,GAMMAI,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                   10000204
     2PHICOS,PHISIN,R                                                 10000205
      COMMON/CPLIST/NCOLL(8),NAME(8),SI2(8),XI(8),YI(8),ZI(8),        10000222
     1WTI(8),SO2(8),U0(8),V0(8),W0(8),OLDWT(8),NGRP(8),NELEM(8),NMED(8) 10000223
     2,DUMMY(8)
      IF (GAMMAI-1.0) 20,10,10                                        10000301
10    PHICOS=1.0                                                      10000302
      PHISIN=0.0                                                      10000303
      GO TO 30                                                        10000304
20    CMU=GAMMAI                                                      10000305
      CMUD=SQRTF(1.0-CMU**2)                                          10000306
      AX=(ALPHAI*XI(KTH)+BETAI*YI(KTH))/R                             10000307
      BX=(BETAI*XI(KTH)-ALPHAI*YI(KTH))/R                             10000308
      ALPHAI=AX                                                       10000309
      BETAI=BX                                                        10000310
      PHICOS=ALPHAI/CMUD                                              10000311
      PHISIN=BETAI/CMUD                                               10000312
30    PHI=ACOSF(PHICOS)                                               10000313
      IF (PHISIN) 40,50,50                                            10000314
40    PHI=6.28318-PHI                                                 10000315
50    CALL ANGLO(NMUR,FNMUR,NPHIR,FNPHIR,IANGL,CMU,PHI)               10000316
      RETURN                                                          10000317
```

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      END RANGL                                                         10000318


      SUBROUTINE ANGLO(NMUA,FNMUA,NPHIA,FNPHIA,IANGLA,CMUA,PHIA)        11000101
      CCMU=1.0                                                          11000301
      DO 10 N=1,NMUA                                                    11000302
      CCMU=CCMU-1.0/FNMUA                                               11000303
      IF (CMUA-CCMU) 10,20,20                                           11000304
   10 CONTINUE                                                          11000305
      IMU=NMUA                                                          11000306
      GO TO 30                                                          11000307
   20 IMU=N                                                             11000308
   30 PPHI=0.0                                                          11000309
      DO 40 N=1,NPHIA                                                   11000310
      PPHI=PPHI+6.28318/FNPHIA                                          11000311
      IF (PHIA-PPHI) 50,50,40                                           11000312
   40 CONTINUE                                                          11000313
      IPHI=NPHIA                                                        11000314
      GO TO 60                                                          11000315
   50 IPHI=N                                                            11000316
   60 IANGLA=(IMU-1)*NPHIA+IPHI                                         11000317
      RETURN                                                            11000318
      END ANGLO                                                         11000319


      SUBROUTINE ENDRUN                                                 12000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,            12000201
     1NBAT,NITS,NFLUXZ1,NFLUXR1                                         12000202
      COMMON/SECOND/ALPHA1,BETA1,CMU,CMUD,FNPHIR,FNPHIZ,FNMUR,          12000203
     1FNMUZ,GAMMA1,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                     12000204
     2PHICOS,PHISIN,R                                                   12000205
      COMMON/THIRD/NCRS,NFLUXZ,NFLUXR,NESCAPE(10,4),                    12000206
     1RANGFLUX(10,20,30),WBAR(10,4),ZANGFLUX(10,20,30),BCDID(9)         12000207
```

```
      COMMON/FORTH/ALPHA(50),BETA(50),GAMMA(50),IEGP1(50),              12000208
     1JTYPER(50),LBATY(50),NCOLS(50),SENG2(50),WAIT(50),                12000209
     2XS(50),YS(50),ZS(50)                                              12000210
      COMMON/FIFTH/JTYPE,RCYLIN,ZTOP,ZBOT,ZTOPNEW,                      12000211
     1ZBOTNEW                                                           12000212
      COMMON/SIXTH/ALP(50),BET(50),COSTHETA(10),ERUS(10),               12000213
     1GAM(50),IGRP,JTYPE1,JTYPE2,JTY(50),LBATER(50),                    12000214
     2NSORI,NAMO,NAMT,SENGSQ(50),WAITER(50),X0(50),Y0(50),Z0(50)        12000215
      COMMON/SEVENTH/NFLUXZ2,NRITE,RRR(10),WMAX(10,4),                  12000216
     1WTHETA1(10,4),WTHETA2(10,4),ZZZ(21)                               12000217
      COMMON/EIGHTH/NATS,NSTRT,SWK(10),WK(10),WK1(10)                   12000218
      DIMENSION RAREA(10),VAR(10,20,30),ZAREA(20)                       12000225
      COMMON/NINTH/NTOT(30),WTOT(30),LBATA                              12000226
      REWIND NCRS                                                       12000302
      DO 1 I=1,IGRP                                                     12000303
    1 ERUS(I)=ERUS(I)/1.91322E+18                                       12000304
      NAMR=NAMT-NAMO                                                    12000305
      DO 2 J=1,4                                                        12000306
      DO 2 I=1,IGRP                                                     12000307
      IF (NESCAPE(I,J)) 3,4,3                                           12000308
    3 WBAR(I,J)=WBAR(I,J)/NESCAPE(I,J)                                  12000309
      GO TO 2                                                           12000310
    4 WBAR(I,J)=0.0                                                     12000311
    2 CONTINUE                                                          12000312
      PRINT 1000, RCDID                                                 12000313
 1000 FORMAT(1H1,9A8)                                                   12000314
      PRINT 1001, LBATO,NITS,NAMR,NAMT                                  12000315
 1001 FORMAT(1H0,41X,7ENDRUN RESULTS7/28X,7LAST7,                       12000316
     1I3,7 BATCHES OF7,I3,7 BATCHES WERE PROCESSED.7/                   12000317
     228X,7LAST7,I7,7 NEUTRONS OF7,I7,7 WERE PROCESSED.7)               12000318
 1002 FORMAT(1H0,41X,7ENDRUN RESULTS7)                                  12000319
      PRINT 1000, RCDID                                                 12000320
      PRINT 1002                                                        12000321
      PRINT 1003,(J,J=1,4)                                              12000322
 1003 FORMAT(1H0,22X,7JTYPE=1, ESCAPE FROM REACTOR 7,                   12000323
     17BOTTOM (POSITIVE GAMMA)7/23X,7JTYPE=2, ESCAPE 7,                 12000324
     27FROM REACTOR SIDES, POSITIVE GAMMA7/23X,                         12000325
```

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     37JTYPE=3, ESCAPE FROM REACTOR SIDES, 7,                            12000401
     47NEGATIVE GAMMA7/23X,7JTYPE=4, ESCAPE FROM 7,                      12000402
     57REACTOR TOP, NEGATIVE GAMMA7//53X,7JTYPE7/                        12000403
     622X,I1,21X,I1,21X,I1,21X,I1/7 LOWER      NUMBER 7,                 12000404
     770F   AVERAGE   NUMBER OF   AVERAGE   NUMBER 7,                    12000405
     870F   AVERAGE   NUMBER OF   AVERAGE7/7 ENERGY 7,                   12000406
     97MEV  ESCAPES    WEIGHT     ESCAPES    WEIGHT     ESCAPES    7     12000407
     17WEIGHT     ESCAPES    WEIGHT7)                                    12000408
      DO 5 I=1,IGRP                                                      12000409
    5 PRINT 1004, ERUS(I),(NESCAPE(I,J),WBAR(I,J),J=1,4)                 12000410
 1004 FORMAT(1H ,E11.3,4(I7,E12.3,3X))                                   12000411
      IF (NFLUXZ+NFLUXR) 6,100,6                                         12000412
    6 DO 7 I=1,10                                                        12000413
      DO 7 N=1,20                                                        12000414
      DO 7 K=1,30                                                        12000415
      ZANGFLUX(I,N,K)=0.0                                                12000416
      RANGFLUX(I,N,K)=0.0                                                12000417
    7 VAR(I,N,K)=0.0                                                     12000418
      FBATO=LBATO                                                        12000419
      IF (NFLUXZ) 8,10,8                                                 12000420
    8 DO 9 N=2,NFLUXZ2                                                   12000421
    9 ZAREA(N-1)=6.28318*RCYLIN*(ZZZ(N)-ZZZ(N-1))                        12000422
      DOMEGAZ=6.28318/(FNPHIZ*FNMUZ)                                     12000423
   10 IF (NFLUXR) 11,15,11                                               12000424
   11 DO 14 N=1,NFLUXR                                                   12000425
      IF (N-1) 13,12,13                                                  12000501
   12 RRR2=0.0                                                           12000502
      GO TO 14                                                           12000503
   13 RRR2=RRR(N-1)**2                                                   12000504
   14 RAREA(N)=3.14159*(RRR(N)**2-RRR2)                                  12000505
      DOMEGAR=6.28318/(FNPHIR*FNMUR)                                     12000506
   15 IF (NFLUXZ) 16,30,16                                               12000507
   16 MOOZ=NMUZ*NPHIZ                                                    12000508
      DO 18 L=1,LBATO                                                    12000509
      READ (NCRS) RANGFLUX                                               12000510
      READ (NCRS)                                                        12000511
      DO 17 I=1,IGRP                                                     12000512
```

```
      DØ 17 N=1,NFLUXZ                                                  12000513
      DØ 17 K=1,MØMZ                                                    12000514
      ZANGFLUX(I,N,K)=ZANGFLUX(I,N,K)+RANGFLUX(I,N,K)                   12000515
   17 VAR(I,N,K)=VAR(I,N,K)+RANGFLUX(I,N,K)**2                          12000516
   18 CØNTINUE                                                          12000517
      REWIND NCRS                                                       12000518
      DØ 19 I=1,IGRP                                                    12000519
      DØ 19 N=1,NFLUXZ                                                  12000520
      DØ 19 K=1,MØMZ                                                    12000521
      ZANGFLUX(I,N,K)=ZANGFLUX(I,N,K)/FBATØ                             12000522
      VAR(I,N,K)=VAR(I,N,K)/FBATØ                                       12000523
      VAR(I,N,K)=SQRTF((VAR(I,N,K)-ZANGFLUX(I,N,K)**2)/                 12000524
     1(FBATØ-1.0))                                                      12000525
      IF (ZANGFLUX(I,N,K)) 20,20,21                                     12000601
   20 VAR(I,N,K)=0.0                                                    12000602
      GØ TØ 19                                                          12000603
   21 VAR(I,N,K)=VAR(I,N,K)*100.0/ZANGFLUX(I,N,K)                       12000604
   19 ZANGFLUX(I,N,K)=ZANGFLUX(I,N,K)/(ZAREA(N)*DØMEGAZ)                12000605
      DØ 28 N=1,NFLUXZ                                                  12000606
      I1=1                                                              12000608
      IF (IGRP-5) 22,22,23                                              12000609
   22 I2=IGRP                                                           12000610
      GØ TØ 24                                                          12000611
   23 I2=5                                                              12000612
   24 PRINT 1000, RCDID                                                 12000613
      PRINT 1002                                                        12000614
      PRINT 1005, ZZZ(N),ZZZ(N+1),(I,I=I1,I2)                           12000615
 1005 FØRMAT(1H0,34X,7NEUTRØN FLUX PER CM**2 PER 7,                     12000616
     17STERADIAN7/32X,7FØR Z INTERVAL FRØM7,                            12000617
     2E10.2,3H TØ,F10.2/1H0,47X,7ENERGY INDEX7/                         12000618
     3I17,4I20)                                                         12000619
      PRINT 1006                                                        12000620
 1006 FØRMAT(1H ,7ANGLE7,12X,7PERCENT7,13X,7PERCENT7                    12000621
     1,13X,7PERCENT7,13X,7PERCENT7,13X,7PERCENT7/                       12000622
     27 INDEX  FLUX7,9X,7DEV     FLUX7,9X,7DEV     FLUX7,               12000623
     39X,7DEV     FLUX7,9X,7DEV     FLUX7,9X,7DEV7)                     12000624
      DØ 25 K=1,MØMZ                                                    12000625
```

```
   25 PRINT 1007, K,(ZANGFLUX(I,N,K),VAR(I,N,K),I=I1,I2)        12000701
 1007 FORMAT(1H ,I4,5(1X,E11.3,F8.2))                            12000702
      IF (I2-IGRP) 26,28,26                                      12000703
   26 I1=I2+1                                                    12000704
      I2=IGRP                                                    12000705
      GO TO 24                                                   12000706
   28 CONTINUE                                                   12000707
      DO 29 I=1,10                                               12000708
      DO 29 N=1,20                                               12000709
      DO 29 K=1,30                                               12000710
      ZANGFLUX(I,N,K)=0.0                                        12000711
      RANGFLUX(I,N,K)=0.0                                        12000712
   29 VAR(I,N,K)=0.0                                             12000713
   30 IF (NFLUXR) 31,100,31                                      12000714
   31 MOOR=NMUR*NPHIR                                            12000715
      DO 33 L=1,LBATO                                            12000716
      READ (NCRS)                                                12000717
      READ (NCRS) ZANGFLUX                                       12000718
      DO 32 I=1,IGRP                                             12000719
      DO 32 N=1,NFLUXR                                           12000720
      DO 32 K=1,MOOR                                             12000721
      RANGFLUX(I,N,K)=RANGFLUX(I,N,K)+ZANGFLUX(I,N,K)            12000722
   32 VAR(I,N,K)=VAR(I,N,K)+ZANGFLUX(I,N,K)**2                   12000723
   33 CONTINUE                                                   12000724
      REWIND NCRS                                                12000725
      DO 34 I=1,IGRP                                             12000801
      DO 34 N=1,NFLUXR                                           12000802
      DO 34 K=1,MOOR                                             12000803
      RANGFLUX(I,N,K)=RANGFLUX(I,N,K)/FBATO                      12000804
      VAR(I,N,K)=VAR(I,N,K)/FBATO                                12000805
      VAR(I,N,K)=SQRTF((VAR(I,N,K)-RANGFLUX(I,N,K)**2)/          12000806
     1(FBATO-1.0))                                               12000807
      IF (RANGFLUX(I,N,K))36,35,36                               12000808
   35 VAR(I,N,K)=0.0                                             12000809
      GO TO 34                                                   12000810
   36 VAR(I,N,K)=VAR(I,N,K)*100.0/RANGFLUX(I,N,K)                12000811
   34 RANGFLUX(I,N,K)=RANGFLUX(I,N,K)/(RAREA(N)*DOMEGAR)         12000812
```

```
      DO 45 N=1,NFLUXR                                                  12000813
      I1=1                                                              12000814
      IF (IGRP-5) 37,37,38                                              12000815
   37 I2=IGRP                                                           12000816
      GO TO 39                                                          12000817
   38 I2=5                                                              12000818
   39 PRINT 1000, RCDID                                                 12000819
      PRINT 1002                                                        12000820
      IF (N-1) 41,40,41                                                 12000821
   40 RRR1=0.0                                                          12000822
      GO TO 42                                                          12000823
   41 RRR1=RRR(N-1)                                                     12000824
   42 PRINT 1105, RRR1,RRR(N),(I,I=I1,I2)                               12000825
 1105 FORMAT(1H0,34X,7NEUTRON FLUX PER CM**2 PER 7,                     12000901
     17STERADIAN7/32X,7FOR R INTERVAL FROM7,                            12000902
     2E10.2,3H TO,E10.2/1H0,47X,7ENERGY INDEX7/                         12000903
     3I17,4I20)                                                         12000904
      PRINT 1006                                                        12000905
      DO 43 K=1,MCOR                                                    12000906
   43 PRINT 1007, K,(RANGFLUX(I,N,K),VAR(I,N,K),I=I1,I2)                12000907
      IF (I2-IGRP) 44,45,44                                             12000908
   44 I1=I2+1                                                           12000909
      I2=IGRP                                                           12000910
      GO TO 39                                                          12000911
   45 CONTINUE                                                          12000912
  100 CONTINUE                                                          12000913
      IF (NSOR) 101,101,102                                             12000914
  101 RETURN                                                            12000915
  102 DO 103 I=1,50                                                     12000916
      JTY(I)=0                                                          12000917
      XO(I)=0.0                                                         12000918
      YO(I)=0.0                                                         12000919
      ZO(I)=0.0                                                         12000920
      ALP(I)=0.0                                                        12000921
      BET(I)=0.0                                                        12000922
      GAM(I)=0.0                                                        12000923
      SENGSQ(I)=0.0                                                     12000924
```

```
      WAITER(I)=0.0                                                     12000925
  103 LBATER(I)=0                                                       12001001
      REWIND NSOR                                                       12000301
      NSOR=NATS                                                         12000301
  104 READ (NSOR) NCOLS,XS,YS,ZS,ALPHA,BETA,GAMMA,                      12001002
     1SENG2,WAIT,IFGP1,JTYPER,LBATY                                     12001003
      IF (EOF,NSOR) 701,702                                             12001003
  701 REWIND NSOR                                                       12001003
      NSOR=NSOR+1                                                       12001003
      REWIND NSOR                                                       12001003
      GO TO 104                                                         12001003
  702 DO 150 I=1,50                                                     12001004
      IF (NCOLS(I)) 200,200,105                                         12001005
  105 IF (JTYPE1-JTYPER(I)) 106,107,106                                 12001006
  106 IF (JTYPE2-JTYPER(I)) 150,107,150                                 12001007
  107 NCRS=I                                                            12001008
      CALL BIASER                                                       12001008
  150 CONTINUE                                                          12001009
      GO TO 104                                                         12001010
  200 WRITE (NSOR1) JTY,XO,YO,ZO,ALP,BET,GAM,                           12001011
     1SENGSQ,WAITER,LBATER                                              12001012
      IF (EOF,NSOR1) 703,704                                            12001012
  703 END FILE NSOR1                                                    12001012
      REWIND NSOR1                                                      12001012
      NSOR1=NSOR1+1                                                     12001012
      REWIND NSOR1                                                      12001012
      GO TO 200                                                         12001012
  704 END FILE NSOR1                                                    12001013
      REWIND NSOR1                                                      12001014
      REWIND NSOR                                                       12001015
      PRINT 1000, RCDID                                                 12001016
      PRINT 2000, NSOR1                                                 12001017
 2000 FORMAT(1H0,7SOURCE TAPE7,I3,7WAS WRITTEN.7)                       12001018
      PRINT 2001,(I,NTOT(I),WTOT(I),I=1,LBATA)                          12001019
 2001 FORMAT(1H0,7BATCH NUMBER   NUMBER OF NEUTRONS7                    12001020
     1,7   TOTAL WEIGHT7/(I11,I17,9X,E12.3))                            12001021
      RETURN                                                            12001022
```

```
      END ENDRUN                                                        12001023



      SUBROUTINE BIASER                                                 13000101
      COMMON/THIRD/NCRS,NFLUXZ,NFLUXR,NESCAPE(10,4),                    13000206
     1RANGFLUX(10,20,30),WBAR(10,4),ZANGFLUX(10,20,30),BCDID(9)         13000207
      COMMON/FORTH/ALPHA(50),BETA(50),GAMMA(50),IEGP1(50),              13000208
     1JTYPER(50),LRATY(50),NCOLS(50),SENG2(50),WAIT(50),                13000209
     2XS(50),YS(50),ZS(50)                                              13000210
      COMMON/SIXTH/ALP(50),BET(50),COSTHETA(10),FRUS(10),               13000213
     1GAM(50),IGRP,JTYPE1,JTYPE2,JTY(50),LRATER(50),                    13000214
     2NSOR1,NAMO,NAMT,SENGSQ(50),WAITER(50),XO(50),YO(50),ZO(50)        13000215
      COMMON/SEVENTH/NFLUXZ2,NRITE,RRR(10),WMAX(10,4),                  13000216
     1WTHETA1(10,4),WTHETA2(10,4),ZZZ(21)                               13000217
      COMMON/EIGHTH/NATS,NSTRT,SWK(10),WK(10),WK1(10)                   13000218
      COMMON/NINTH/NTOT(30),WTOT(30),LBATA                              13000226
      COMMON/RANDOM/RANDOM,GENERA                                       13000227
      DATA(NCNT=0),(NENTER=0)                                           13000299
      IF (NENTER) 3,1,3                                                 13000300
    1 NENTER=1                                                          13000301
      READ (50,1000) RANDOM,NREAD                                       13    302
 1000 FORMAT (O16,I8)                                                   13    303
      IF (NREAD) 701,700,701                                            13    303
  701 READ (50,1001) (WBAR(J,JTYPE1),J=1,IGRP)                          13    303
      READ (50,1001) (WMAX(J,JTYPE1),J=1,IGRP)                          13    303
 1001 FORMAT (6E12.4)                                                   13    303
      IF (JTYPE1-JTYPE2) 702,700,702                                    13    303
  702 READ (50,1001) (WBAR(J,JTYPE2),J=1,IGRP)                          13    303
      READ (50,1001) (WMAX(J,JTYPE2),J=1,IGRP)                          13    303
  700 CONTINUE                                                          13    303
      DO 2 J=1,30                                                       13000304
      NTOT(J)=0                                                         13000305
    2 WTOT(J)=0.0                                                       13000306
    3 I=NCRS                                                            13000307
      IEGP=IEGP1(I)                                                     13000308
```

```
      JTYPE=JTYPER(I)                                                   13000309
      IF (GAMMA(I)-COSTHETA(IEGP)) 300,4,4                              13000310
    4 IF (WAIT(I)-WK(IEGP)*WBAR(IEGP,JTYPE)) 100,5,5                    13000311
    5 IF (WAIT(I)-SWK(IEGP)*WBAR(IEGP,JTYPE)) 6,6,200                   13000312
    6 NSPL=1                                                            13000313
      GO TO 400                                                         13000314
  100 IF (FLTRNF(NARG)*WK(IEGP)*WBAR(IEGP,JTYPE)-WAIT(I))               13000315
     1  102,102,101                                                     13000316
  101 RETURN                                                            13000317
  102 WAIT(I)=WK(IEGP)*WBAR(IEGP,JTYPE)                                 13000318
      NSPL=1                                                            13000319
      GO TO 400                                                         13000320
  200 FOO=WAIT(I)/(SWK(IEGP)*WBAR(IEGP,JTYPE))                          13   321
  201 NSPL=FOO+1.0                                                      13   322
      FOO=NSPL                                                          13   322
      FOO=1.0/FOO                                                       13   322
      WAIT(I)=FOO*WAIT(I)                                               13   322
      GO TO 400                                                         13000323
  300 IF (WAIT(I)-WK1(IEGP)*WMAX(IEGP,JTYPE)) 600,305,305               13   324
  305 IF (WAIT(I)-SWK(IEGP)*WMAX(IEGP,JTYPE)) 6,6,800                   13   325
  600 IF (FLTRNF(NARG)*WK1(IEGP)*WMAX(IEGP,JTYPE)-WAIT(I)) 602,602,101  13   326
  602 WAIT(I)=WK1(IEGP)*WMAX(IEGP,JTYPE)                                13   327
      GO TO 6                                                           13   328
  800 FOO=WAIT(I)/(SWK(IEGP)*WMAX(IEGP,JTYPE))                          13   401
      GO TO 201                                                         13   402
  400 LBATA=LBATY(I)                                                    13000403
      NTOT(LBATA)=NTOT(LBATA)+1                                         13000404
      WTOT(LBATA)=WTOT(LBATA)+WAIT(I)                                   13000405
      NCNT=NCNT+1                                                       13000406
      JTY(NCNT)=JTYPER(I)                                               13000407
      XO(NCNT)=XS(I)                                                    13000408
      YO(NCNT)=YS(I)                                                    13000409
      ZO(NCNT)=ZS(I)                                                    13000410
      ALP(NCNT)=ALPHA(I)                                                13000411
      BET(NCNT)=BETA(I)                                                 13000412
      GAM(NCNT)=GAMMA(I)                                                13000413
      SENGSQ(NCNT)=SENG2(I)                                             13000414
```

```
      WAITER(NCNT)=WAIT(I)                                              13000415
      LBATER(NCNT)=LBATY(I)                                             13000416
      IF (NCNT-50) 402,401,401                                          13000417
  401 WRITE (NSORI) JTY,XO,Y0,ZO,ALP,BET,                               13000418
     1GAM,SENGSQ,WAITER,LBATER                                          13000419
      IF (EOF,NSORI) 903,904                                            13000419
  903 END FILE NSORI                                                    13000419
      REWIND NSORI                                                      13000419
      NSORI=NSORI+1                                                     13000419
      REWIND NSORI                                                      13000419
      GO TO 401                                                         13000419
  904 END FILE NSORI                                                    13000420
      BACKSPACE NSORI                                                   13000421
      NCNT=0                                                            13000422
      DO 500 J=1,50                                                     13000422
  500 JTY(J)=0                                                          13000422
  402 NSPL=NSPL-1                                                       13000423
      IF (NSPL) 403,403,400                                             13000424
  403 RETURN                                                            13000425
      END BIASER                                                        13000501
```

```
      SUBROUTINE TRACER                                                 14000101
      COMMON/MAIN/KTH,LBATO,LBATCH,NTYPE,NHISTR,NHISMX,NSOR,            14000201
     1NBAT,NITS,NFLUXZI,NFLUXRI                                         14000202
      COMMON/SECOND/ALPHAI,BETAI,CMU,CMUD,FNPHIR,FNPHIZ,FNMUR,          14000203
     1FNMUZ,GAMMAI,IANGL,NMUZ,NMUR,NPHIZ,NPHIR,PHI,                     14000204
     2PHICOS,PHISIN,R                                                   14000205
      COMMON/FIFTH/JTYPE,RCYLIN,ZTOP,ZBOT,ZTOPNEW,                      14000211
     1ZBOTNEW                                                           14000212
      COMMON/CPLIST/NCOLL(8),NAME(8),SI2(8),XI(8),YI(8),ZI(8),          14000222
     1WTI(8),SO2(8),UO(8),VO(8),WO(8),OLDWT(8),NGRP(8),NELEM(8),NMED(8) 14000223
     2,DUMMY(8)
      COMMON/GOODER/NGOOD                                               14000228
      DATA (IJK=0),(NOMIT=0)                                            14000301
```

```
C     ZBOTNEW MUST BE GREATER THAN ZTOPNEW.                             14000302
      IF (IJK) 2,1,2                                                    14000303
    1 IJK=1                                                             14000304
      RCYLIN2=RCYLIN**2                                                 14000305
    2 IF (NOMIT-10) 4,3,3                                               14000306
    3 PRINT 1000, NOMIT                                                 14000307
 1000 FORMAT(1H1,I3,7 NEUTRONS COULD NOT BE7,                           14000308
     17 TRACED TO THE SOURCE CYLINDER7)                                 14000309
      CALL EXIT                                                         14000310
    4 IF (Z1(KTH)-ZBOTNEW) 100,5,5                                      14000311
    5 IF (GAMMA1) 6,6,7                                                 14000312
    6 NOMIT=NOMIT+1                                                     14000313
      PRINT 1001, X1(KTH),Y1(KTH),Z1(KTH),ALPHA1,                       14000314
     1BETA1,GAMMA1,NOMIT                                                14000315
 1001 FORMAT(1H1,7UNSUCCESSFUL TRACE TO SOURCE.7,                       14000316
     17  COORDINATES AND DIRECTION COSINES ARE7/                        14000317
     26E12.4/1H ,7ERROR NUMBER7,I3)                                     14000318
      GO TO 900                                                         14000319
    7 T=(Z1(KTH)-ZBOTNEW)/GAMMA1                                        14000320
      X=X1(KTH)-ALPHA1*T                                                14000321
      Y=Y1(KTH)-BETA1*T                                                 14000322
      Z=ZBOTNEW                                                         14000323
      IF (X**2+Y**2-RCYLIN2) 8,8,9                                      14000325
    8 JTYPE=1                                                           14000401
      GO TO 800                                                         14000402
    9 NPLACE=1                                                          14000403
      C1=X1(KTH)**2+Y1(KTH)**2-RCYLIN2                                  14000324
      GO TO 998                                                         14000404
  901 CONTINUE                                                          14000405
      IF (T1) 10,10,6                                                   14000406
   10 IF (T2) 11,11,6                                                   14000407
   11 GO TO 999                                                         14000408
  910 CONTINUE                                                          14000409
      IF (Z-ZTOPNEW) 6,12,12                                            14000410
   12 JTYPE=2                                                           14000411
      IF (Z-ZBOTNEW) 911,911,6                                          14000411
  911 CONTINUE                                                          14000411
```

```
      GO TO 800                                                         14000412
  100 IF (Z1(KTH)-ZTOPNEW) 13,13,200                                    14000413
   13 IF (GAMMA1) 14,6,6                                                14000414
   14 T=(Z1(KTH)-ZTOPNEW)/GAMMA1                                        14000415
      X=X1(KTH)-ALPHA1*T                                                14000416
      Y=Y1(KTH)-BETA1*T                                                 14000417
      Z=ZTOPNEW                                                         14000418
      IF (X**2+Y**2-RCYLIN2) 15,15,16                                   14000420
   15 JTYPE=4                                                           14000421
      GO TO 800                                                         14000422
   16 NPLACE=2                                                          14000423
      C1=X1(KTH)**2+Y1(KTH)**2-RCYLIN2                                  14000419
      GO TO 998                                                         14000424
  902 CONTINUE                                                          14000425
      IF (T1) 17,17,6                                                   14000501
   17 IF (T2) 18,18,6                                                   14000502
   18 GO TO 999                                                         14000503
  920 CONTINUE                                                          14000504
      IF (Z-ZBOTNEW) 19,19,6                                            14000505
   19 JTYPE=3                                                           14000506
      IF (Z-ZTOPNEW) 6,921,921                                          14000506
  921 CONTINUE                                                          14000506
      GO TO 800                                                         14000507
  200 IF (GAMMA1) 300,22,20                                             14000508
   20 T=(ZBOTNEW-Z1(KTH))/GAMMA1                                        14000511
      X=X1(KTH)+ALPHA1*T                                                14000512
      Y=Y1(KTH)+BETA1*T                                                 14000513
      Z=ZBOTNEW                                                         14000514
      IF (X**2+Y**2-RCYLIN2) 21,21,22                                   14000516
   21 JTYPE=1                                                           14000517
      GO TO 800                                                         14000518
   22 NPLACE=3                                                          14000519
      C1=X1(KTH)**2+Y1(KTH)**2-RCYLIN2                                  14000515
      GO TO 998                                                         14000520
  903 CONTINUE                                                          14000521
      GO TO 999                                                         14000522
  930 CONTINUE                                                          14000523
```

```
      IF (Z-ZBOTNEW) 931,931,6                                          14000523
  931 CONTINUE                                                          14000523
      JTYPE=2                                                           14000524
      GO TO 800                                                         14000525
  300 T=(ZTOPNEW-Z1(KTH))/GAMMA1                                        14000601
      X=X1(KTH)+ALPHA1*T                                                14000602
      Y=Y1(KTH)+BETA1*T                                                 14000603
      Z=ZTOPNEW                                                         14000604
      IF (X**2+Y**2-RCYLIN2) 23,23,24                                   14000606
   23 JTYPE=4                                                           14000607
      GO TO 800                                                         14000608
   24 NPLACE=4                                                          14000609
      C1=X1(KTH)**2+Y1(KTH)**2-RCYLIN2                                  14000605
      GO TO 998                                                         14000610
  904 CONTINUE                                                          14000611
      GO TO 999                                                         14000612
  940 CONTINUE                                                          14000613
      IF (Z-ZTOPNEW) 6,941,941                                          14000613
  941 CONTINUE                                                          14000613
      JTYPE=3                                                           14000614
  800 X1(KTH)=X                                                         14000615
      Y1(KTH)=Y                                                         14000616
      Z1(KTH)=Z                                                         14000617
      NGOOD=0                                                           14000618
  801 RETURN                                                            14000619
  900 NGOOD=1                                                           14000620
      GO TO 801                                                         14000621
  998 A=1.0-GAMMA1**2                                                   14000622
      IF (A) 6,6,997                                                    14000622
  997 CONTINUE                                                          14000622
      B=2.0*(ALPHA1*X1(KTH)+BETA1*Y1(KTH))                              14000623
      BZ=B**2                                                           14000624
      D=BZ-4.0*A*C1                                                     14000625
      IF (D) 6,91,91                                                    14000701
   91 D=SQRTF(D)                                                        14000702
      T1=(-B+D)/(2.0*A)                                                 14000703
      T2=(-B-D)/(2.0*A)                                                 14000704
```

```
    GO TO (901,902,903,904),NPLACE                                  14000705
999 T1=MAX1F(T1,T2)                                                 14000706
    X=X1(KTH)+ALPHA1*T1                                             14000707
    Y=Y1(KTH)+BETA1*T1                                              14000708
    Z=Z1(KTH)+GAMMA1*T1                                             14000709
    GO TO (910,920,930,940),NPLACE                                  14000710
    END TRACER                                                      14000711
```

Subroutine O5RTAPE can be found in Appendix J, Part 1.

4. Program CKSOURTP Listing

```
      PROGRAM CKSOURTP
      COMMON/MAINC/JTY(50),XO(50),YO(50),ZO(50),
     1ALP(50),BET(50),GAM(50),SENGSQ(50),WAITER(50),LBATER(50)
      COMMON/MAINP/I,INDEX(50)
      DIMENSION E(9),W1(9),W2(9),N1(9),N2(9)
      DATA(IJK=0),(NCNT=0)
      CMU=.7
      E(1)=.1
      E(2)=2.02
      E(3)=3.68
      E(4)=4.5
      E(5)=5.49
      E(6)=6.70
      E(7)=8.18
      E(8)=10.0
      E(9)=12.2
      DO 700 I=1,9
      W1(I)=0.0
      W2(I)=0.0
      N1(I)=0
  700 N2(I)=0
    1 READ (5) JTY,XO,YO,ZO,ALP,BET,GAM,SENGSQ,
     1WAITER,LBATER
      DO 2 I=1,50
      IF (JTY(I))3,4,3
    3 SENGSQ(I)=SENGSQ(I)/1.91322E+18
      DO 701 N=1,8
      IF (SENGSQ(I)-E(N+1)) 702,702,701
  701 CONTINUE
      N=9
  702 IF (GAM(I)-CMU) 704,703,703
  703 W1(N)=W1(N)+WAITER(I)
      N1(N)=N1(N)+1
```

```
      GO TO 705
  704 W2(N)=W2(N)+WAITER(I)
      N2(N)=N2(N)+1
  705 CONTINUE
    2 INDEX(I)=I+NCNT
      I=51
    4 I=I-1
      IF (IJK) 6,5,6
    5 IJK=1
      PRINT 1000
 1000 FORMAT(1H1,7CHECKOUT OF SOURCE TAPE 7
     1,7PREPARED BY PROGRAM SNARLS.7)
    6 PRINT 1001
 1001 FORMAT(1H0,7LEAKAGE7,18X,7COORDINATES7,10X,
     17DIRECTION COSINES7,6X,7ENERGY7/2X,
     27INDEX  JTYPE BATCH   X7,7X,1HY,7X,1HZ,7X,3HALP,
     35X,3HBET,5X,3HGAM,5X,3HMEV,5X,6HWEIGHT)
 1002 FORMAT(1H ,3I6,3F8.3,3F8.4,F8.3,E12.3)
      IF (I) 7,100,7
    7 PRINT 1002, (INDEX(J),JTY(J),LBATER(J),XO(J),YO(J),
     1ZO(J),ALP(J),BET(J),GAM(J),SENGSQ(J),WAITER(J),
     2J=1,I)
      IF (I-50) 100,8,100
    8 NCNT=INDEX(I)
      GO TO 1
  100 PRINT 1003,(E(N),N=1,9),(W1(N),N=1,9),(N1(N),N=1,9),(W2(N),N=1,9),
     1(N2(N),N=1,9)
 1003 FORMAT (8H1 E, MEV,9E10.2/8H W1     ,9E10.2/8H N1     ,9I10/
     18H W2     ,9E10.2/8H N2     ,9I10)
      CALL EXIT
      END
```

5. Subroutine SNEUT(X,Y,Z,A,B,C,W,E,NTAPE,NSKIP) Listing

```
      SUBROUTINE SNEUT(X,Y,Z,A,B,C,W,E,NTAPE,NSKIP)
      DIMENSION JTY(50),XO(50),YO(50),ZO(50),ALP(50),BET(50),GAM(50),
     1SENGSQ(50),WAITER(50),LBATER(50)
      DATA (NCNT=0),(NGO=1),(JTY(50)=1)
C     NSKIP IS THE NUMBER OF RECORDS OF 50 NEUTRONS TO BE SKIPPED.
C     NTAPE IS THE LOGICAL NUMBER OF THE SOURCE TAPE.
C     IF THIS ROUTINE RETURNS NTAPE=0, THERE ARE NO MORE NEUTRONS ON
C     CURRENT TAPE.  CALLING PROGRAM MAY RESET NTAPE AND SKIP NSKIP REC.
      GO TO (1,3,2,14),NGO
   14 NCNT=0
      JTY(50)=1
    1 REWIND NTAPE
   16 NCNT=NCNT+1
      IF (JTY(50)) 8,8,4
    4 READ (NTAPE) JTY,XO,YO,ZO,ALP,BET,GAM,SENGSQ,WAITER,LBATER
      IF (EOF,NTAPE) 701,702
  701 GO TO (8,8,10,8),NGO
  702 GO TO (12,12,13,12),NGO
   12 IF (NCNT-NSKIP) 16,16,2
    2 NREC=0
      NGO=2
    3 NREC=NREC+1
      X=XO(NREC)
      Y=YO(NREC)
      Z=ZO(NREC)
      A=ALP(NREC)
      B=BET(NREC)
      C=GAM(NREC)
      W=WAITER(NREC)
      E=SENGSQ(NREC)
      IF (NREC-50) 9,5,5
    5 NGO=3
      GO TO 4
```

```
   13 IF (JTY(I)) 11,10,11
    8 PRINT 1000,KCNT
 1000 FORMAT (1H1,7TOO MANY RECORDS,7,I6,7,WERE SKIPPED ON SOURCE TAPE7)
      REWIND NTAPE
      GO TO 15
    9 IF (JTY(NREC+1)) 11,10,11
   10 REWIND NTAPE
      NGO =4
      NTAPE=0
   11 RETURN
   15 CALL EXIT
      END SNFUT
```

APPENDIX O

SNARLS INPUT DATA FOR THE SNAP-TSF REACTOR

1. SNARLS Input Data for the Shield Source Tape Preparation

```
SNARLS FULL ADJØINT SN BIAS 50 BATCHES ØF 800 NEUTS.  SØURCE TAPE BIAS          1
           1           1           3           5            0          50       2
                                   9           1            1           7       3
           0           2           1           4            1           1       4
                               -40.0        1.48        60.96                   5
        12.2        10.0        8.18        6.70         5.49         4.5      61
        3.68        2.02          .1                                           62
          .7          .7          .7          .7           .7          .7      71
          .7          .7          .7                                           72
        .333        .333        .333        .333         .333        .333      81
        .333        .333        .333                                           82
        .333        .333        .333        .333         .333        .333      91
        .333        .333        .333                                           92
         3.0         3.0         3.0         3.0          3.0         3.0     101
         3.0         3.0         3.0                                          102
      11.239       60.96                                                      121
1773607236543075       1                                                       13
      .789-4      2.61-4      8.15-4      2.40-3       6.63-3      1.71-2     141
      4.34-2      1.73-1      4.64+0                                          142
      2.77-4      .917-3      2.86-3      8.42-3       2.33-2      6.00-2     151
      1.52-1      6.07-1      16.3+0                                          152
```

2. SNARLS Input Data for the Calculation of Angular Flux (SNAP-TSF Reactor Bottom)

```
SNARLS FULL ADJOINT SN BIAS 60 BATCHES OF 800 NEUTS. ANG FLUX                  1
           1           3           0           0           0          60       2
                                   3           1           1           7       3
           0           2           1           5           1           1       4
                               -40.0        1.48      18.135                   5
        4.00        2.00       .4076
          .7          .7          .7          .7          .7          .7      71
        .333        .333        .333        .333        .333        .333      81
        .333        .333        .333        .333        .333        .333      91
         3.0         3.0         3.0         3.0         3.0         3.0     101
      11.239      18.135                                                     121
```

3. SNARLS Input Data for the Leakage Flux Radial Distribution (SNAP-TSF Reactor Bottom)

```
SNARLS FULL ADJOINT SN BIAS 60 BATCHES OF 800 NEUTS. RADIAL DISTRIB.
           1           3           0           0           0          60      2
                                   3           1           1           7      3
           0          10           1           1           1           1      4
                               -40.0        1.48      18.135                  5
         4.0         2.0       .4076
          .7          .7          .7          .7          .7          .7     71
        .333        .333        .333        .333        .333        .333     81
        .333        .333        .333        .333        .333        .333     91
         3.0         3.0         3.0         3.0         3.0         3.0    101
         1.5         3.0         4.5         6.0         7.5         9.0
        10.1      11.239        14.0      18.135
```

4. SNARLS Input Data for the Leakage Flux Spectrum (SNAP-TSF Reactor Bottom)

```
SNARLS FULL ADJOINT SN BIAS 60 BATCHES OF 800 NEUTS, SPECTRUM                  1
           1           3           0           0           0          60       2
                                  10           1           1           7       3
           0           2           1           1           1           1       4
                               -40.0        1.48      18.135                   5
        10.0         7.0         5.0         4.0         3.0         2.5
         2.0         1.5         1.0       .4076
          .7          .7          .7          .7          .7          .7      71
          .7          .7          .7          .7
        .333        .333        .333        .333        .333        .333      81
        .333        .333        .333        .333
        .333        .333        .333        .333        .333        .333      91
        .333        .333        .333        .333
         3.0         3.0         3.0         3.0         3.0         3.0     101
         3.0         3.0         3.0         3.0
      11.239      18.135
```

APPENDIX P

INPUT DATA FOR THE CORE-MAPPING PROBLEM

1. Input Data for the Total Cross Section Tape Preparation

```
CODE 4   10   20                                                                   001
76001     1                                                                        002
76002     1                                                                        003
76003     1                                                                        004
76004     1                                                                        005
76005     1                                                                        006
76006     1                                                                        007
77001     1                                                                        008
77002     1                                                                        009
77003     1                                                                        010
77004     1                                                                        011
77005     1                                                                        012
77006     1                                                                        013
77007     1                                                                        014
                                                                                   015
CODE 5   10   20                                                                   016
 SIGMA TOTAL CORE  INTERMEDIATE CALCULATION                                        017
 1001     1   .049956 4000     1    .008147     0     0     3                      018
76001     1    0                                                                   019
CODE 5   10   20                                                                   020
 INTERMEDIATE                                                                      021
11000     1  .00053117600l     1         1.0     0     0     3                     022
76002     1    0                                                                   023
CODE 5   10   20                                                                   024
 INTERMEDIATE                                                                      025
19000     1   .00110776002     1         1.0     0     0     3                     026
76003     1    0                                                                   027
CODE 5   10   20                                                                   028
 INTERMEDIATE                                                                      029
28000     1   .00363576003     1         1.0     0     0     3                     030
76004     1    0                                                                   031
CODE 5   10   20                                                                   032
 INTERMEDIATE                                                                      033
```

```
40000     1    .02715076004     1          1.0    0    0    3                      034
76005     1     0                                                                  035
CODE 5   10   20                                                                   036
 INTERMEDIATE                                                                      037
92235     1   .001096476005     1          1.0    0    0    3                      038
76006     1     0                                                                  039
CODE 5   10   20                                                                   040
 SIGMA TOTAL CORE  FINAL CALCULATION                                               041
92238     1 .00008247 76006     1          1.0    0    0    3                      042
77001     1     0                    CORE SIGMA TOTAL                              043
CODE 4   10   20                                                                   044
76001     1                                                                        045
76002     1                                                                        046
76003     1                                                                        047
76004     1                                                                        048
76005     1                                                                        049
76006     1                                                                        050
                                                                                   051
CODE 5   10   20                                                                   052
 SIGMA TOTAL INTERNAL BE REF.  INTERMEDIATE CALCULATION                            053
 4000     1    .11348011000     1  .0002742   0    0    3                          054
76001     1     0                                                                  055
CODE 5   10   20                                                                   056
 SIGMA TOTAL INTERNAL BE REF.  FINAL CALCULATION                                   057
19000     1   .000571776001     1          1.0    0    0    3                      058
77002     1     0                    INTERNAL BE REF SIG TOT                       059
CODE 5   10   20                                                                   060
 SIGMA TOTAL VESSEL  INTERMEDIATE CALCULATION                                      061
24000     1    .01674026300     1    .063159    0    0    3                        062
76002     1     0                                                                  063
CODE 5   10   20                                                                   064
 SIGMA TOTAL VESSEL  FINAL CALCULATION                                             065
28000     1    .00865176002     1          1.0    0    0    3                      066
77003     1     0                    VESSEL SIG TOT                                067
CODE 5   10   20                                                                   068
 SIGMA TOTAL EXTERNAL BE  FINAL CALCULATION                                        069
 4000     1    .120140 4000     2          0.0    0    0    3                      070
```

```
77004    1    0                 EXTERNAL BE REF SIG TOT                   071
CODE 5  10  20                                                            072
 SIGMA TOTAL BOTTOM GRID HEX  INTERMEDIATE CALCULATION                    073
11000    1   .00296719000    1    .006186    0    0    3                  074
76003    1    0                                                           075
CODE 5  10  20                                                            076
 INTERMEDIATE                                                             077
24000    1   .00516376003    1       1.0     0    0    3                  078
76004    1    0                                                           079
CODE 5  10  20                                                            080
 INTERMEDIATE                                                             081
26000    1   .01826776004    1       1.0     0    0    3                  082
76005    1    0                                                           083
CODE 5  10  20                                                            084
 SIGMA TOTAL BOTTOM GRID HEX  FINAL CALCULATION                           085
28000    1   .01093076005    1       1.0     0    0    3                  086
77005    1    0                 BOT GRID HEX SIG TOT                      087
CODE 4  10  20                                                            088
76001    1                                                                089
76002    1                                                                090
76003    1                                                                091
76004    1                                                                092
76005    1                                                                093
76006    1                                                                094
                                                                          095
CODE 5  10  20                                                            096
 SIGMA TOTAL BOTTOM GRID EDGE  INTERMEDIATE CALCULATION                   097
11000    1   .00171219000    1    .003570    0    0    3                  098
76001    1    0                                                           099
CODE 5  10  20                                                            100
 INTERMEDIATE                                                             101
24000    1   .01027076001    1       1.0     0    0    3                  102
76002    1    0                                                           103
CODE 5  10  20                                                            104
 INTERMEDIATE                                                             105
26000    1   .03961076002    1       1.0     0    0    3                  106
76003    1    0                                                           107
```

```
CODE 5   10   20                                                                                          108
 SIGMA TOTAL BOTTOM GRID EDGE  FINAL CALCULATION                                                          109
28000      |    .00674076003     |          1.0      0      0      3                                      110
77006      |     0                        BOT GRID EDGE SIG TOT                                            111
CODE 5   10   20                                                                                          112
 SIGMA TOTAL NAK  FINAL CALCULATION                                                                       113
11000      |    .00494519000     |     .010310       0      0      3                                      114
77007      |     0                        NAK SIG TOT                                                     115
CODE 4   10   20                                                                                          116
76001      |                                                                                              117
76002      |                                                                                              118
76003      |                                                                                              119
                                                                                                          120
CODE 7   10   15                                                                                          121
 SIG TOTAL TAPE FOR SNAP-TSF, 7 MEDIA                                                                     122
    7    64      1.8+7       .1+6                                                                         123
77001      |    64                                                                                        124
77002      |    64                                                                                        125
77003      |    64                                                                                        126
77004      |    64                                                                                        127
77005      |    64                                                                                        128
77006      |    64                                                                                        129
77007      |    64                                                                                        130
```

2. Input Data for the F Tape Preparation

```
CØDE 7   10   16                                                      131
 F TAPE FØR SNAP-TSF,  9 ANISØ SCATTERERS                             132
   82    32       1.8+7       .1+6                                    133
 4000    71                                                           134
 4000    72                                                           135
 4000    73                                                           136
 4000    74                                                           137
 4000    75                                                           138
 4000    76                                                           139
 4000    77                                                           140
 4000    78                                                           141
11000    71                                                           142
11000    72                                                           143
11000    73                                                           144
11000    74                                                           145
11000    75                                                           146
11000    76                                                           147
11000    77                                                           148
11000    78                                                           149
19000    71                                                           150
19000    72                                                           151
19000    73                                                           152
19000    74                                                           153
19000    75                                                           154
19000    76                                                           155
19000    77                                                           156
19000    78                                                           157
24000    71                                                           158
24000    72                                                           159
24000    73                                                           160
24000    74                                                           161
24000    75                                                           162
24000    76                                                           163
```

```
24000   77                                                              164
24000   78                                                              165
26000   71                                                              166
26000   72                                                              167
26000   73                                                              168
26000   74                                                              169
26000   75                                                              170
26000   76                                                              171
26000   77                                                              172
26000   78                                                              173
28000   71                                                              174
28000   72                                                              175
28000   73                                                              176
28000   74                                                              177
28000   75                                                              178
28000   76                                                              179
28000   77                                                              180
28000   78                                                              181
40000   71                                                              182
40000   72                                                              183
40000   73                                                              184
40000   74                                                              185
40000   75                                                              186
40000   76                                                              187
92235   71                                                              188
92235   72                                                              189
92235   73                                                              190
92235   74                                                              191
92235   75                                                              192
92235   76                                                              193
92235   77                                                              194
92235   78                                                              195
92235   79                                                              196
92235   80                                                              197
92235   81                                                              198
92235   82                                                              199
92235   83                                                              200
```

92235	84	201
92238	71	202
92238	72	203
92238	73	204
92238	74	205
92238	75	206
92238	76	207
92238	77	208
92238	78	209
92238	79	210
92238	80	211
92238	81	212
92238	82	213
92238	83	214
92238	84	215

3. ACTIFK Input Data

```
 SNAP-TSF REACTOR MAPPING  PERFECT COLLIMATION                                                  100
000034327724461 5                                                                               200
  800   27 8000    65       1.8+7        .5+6                                                   300
 15  7 16 16  7 15  6   6  2 10 10  4                                                           400
    0    -1      0    -2     0    -3     0   -6                                                1511
    0    -7      0     0    -8     0    -9                                                     1512
   1.00814      9.012     -9.012      22.99      -22.99        39.1       -39.1                1611
     58.71     -58.71      91.22     -91.22      -91.22       235.0      -235.0                1612
     238.0                                                                                     1613
   -1     0    -2     0    -3     0                                                            2521
     9.012     -9.012      22.99     -22.99        39.1       -39.1                            2621
   -4     0    -5     0    -6     0                                                            3531
      52.0      -52.0      55.85     -55.85       58.71      -58.71                            3631
   -1     0                                                                                    4541
     9.012     -9.012                                                                          4641
   -2     0    -3     0    -4     0    -5     0                                                5551
   -6     0                                                                                    5552
     22.99     -22.99       39.1      -39.1        52.0       -52.0       55.85                5651
    -55.85      58.71     -58.71                                                               5652
   -2     0    -3     0    -4     0    -5     0                                                6561
   -6     0                                                                                    6562
     22.99     -22.99       39.1      -39.1        52.0       -52.0       55.85                6661
    -55.85      58.71     -58.71                                                               6662
   -2     0    -3     0                                                                        7571
     22.99     -22.99       39.1      -39.1                                                    7671
     1    3    15    8                                                                         8700
 10111000111111110001000110100000000000                                                        8800
     9    8    8    8    8    8    8    6   14   14                                            8900
     6                                                                                         9000
     1          1.0-3      1          1.5-3     7         2.5-3                                9101
     4          2.0-2      4          1.0-1     1         5.0-1                                9102
```

4. GEOM Input Data

```
    2     MALE                                                          00000010
X ZONE       -16.3525,   16.3525                                        00000020
Y ZONE       -16,8656,   16,8656                                        00000030
Z ZONE       -39,7455,  -36.9794,  -35.1150,       -4.0,    -2.5146,    00000040
     1.471                                                              00000050
ZONE      1    1    1                                                   00000060
X BLOCK      -16.3525,   16.3525                                        00000070
Y BLOCK      -16,8656,   16.8656                                        00000080
Z BLOCK      -39.7455,  -36.9794                                        00000090
BLOCK     1    1    1                                                   00000100
MEDIA           5,  500                                                 00000110
SURFACES        1                                                       00000120
SECTOR -1                                                               00000130
SECTOR  1                                                               00000140
ZONE      1    1    2                                                   00000150
X BLOCK      -16.3525,  -9,73370,       0.0,     9.7337,    16.3525     00000160
Y BLOCK      -16.8656,   16.8656                                        00000170
Z BLOCK      -36,9794,  -35.1150                                        00000180
BLOCK     1    1    1                                                   00000190
MEDIA           6,    3,  500                                           00000200
SURFACES        6,    7                                                 00000210
SECTOR -1  0                                                            00000220
SECTOR  1 -1                                                            00000230
SECTOR  0  1                                                            00000240
BLOCK     2    1    1                                                   00000250
MEDIA           5,    6,    6,    3,  500                               00000260
SURFACES        3,    4,    6,    7                                     00000270
SECTOR  1  1  0  0                                                      00000280
SECTOR  0 -1 -1  0                                                      00000290
SECTOR -1  0 -1  0                                                      00000300
SECTOR  0  0  1 -1                                                      00000310
SECTOR  0  0  0  1                                                      00000320
BLOCK     3    1    1                                                   00000330
```

```
MEDIA           5,    6,    6,    3,  500                               00000340
SURFACES        2,    5,    6,    7                                     00000350
SECTOR -1 -1  0  0                                                      00000360
SECTOR  0  1 -1  0                                                      00000370
SECTOR  1  0 -1  0                                                      00000380
SECTOR  0  0  1 -1                                                      00000390
SECTOR  0  0  0  1                                                      00000400
BLOCK     4    1    1                                                   00000410
MEDIA           6,    3,  500                                           00000420
SURFACES        6,    7                                                 00000430
SECTOR -1  0                                                            00000440
SECTOR  1 -1                                                            00000450
SECTOR  0  1                                                            00000460
ZONE      1    1    3                                                   00000470
X BLOCK      -16.3525,   -9.7337,   -6.6599,       0.0,    6.6599,      00000480
    9.7337,   16.3525                                                   00000490
Y BLOCK      -16.8656,    16.8656                                       00000500
Z BLOCK      -35.1150,      -4.0                                        00000510
BLOCK     1    1    1                                                   00000520
MEDIA           2,    3,  500,    4,    0,    0                         00000530
SURFACES        6,    7,    8,    9,   12                               00000540
SECTOR -1  0  0  0  0                                                   00000550
SECTOR  1 -1  0  0  0                                                   00000560
SECTOR  0  1  0  0 -1                                                   00000570
SECTOR  0  0  1  1  1                                                   00000580
SECTOR  0  0 -1  0  0                                                   00000590
SECTOR  0  0  0 -1  0                                                   00000600
BLOCK     2    1    1                                                   00000610
MEDIA           1,    2,    2,    3,  500,    4,    0,    0             00000620
SURFACES        3,    4,    6,    7,    8,    9,   12                   00000630
SECTOR  1  1  0  0  0  0  0                                             00000640
SECTOR  0 -1 -1  0  0  0  0                                             00000650
SECTOR -1  0 -1  0  0  0  0                                             00000660
SECTOR  0  0  1 -1  0  0  0                                             00000670
SECTOR  0  0  0  1  0  0 -1                                             00000680
SECTOR  0  0  0  0  1  1  1                                             00000690
SECTOR  0  0  0  0 -1  0  0                                             00000700
```

```
SECTØR  0  0  0  0  0 -1  0                                             00000710
BLØCK     3    1    1                                                   00000720
MEDIA           1,    2,    2,    3,  500,    4                         00000730
SURFACES        3,    4,    6,    7,   12                               00000740
SECTØR  1  1  0  0  0                                                   00000750
SECTØR  0 -1 -1  0  0                                                   00000760
SECTØR -1  0 -1  0  0                                                   00000770
SECTØR  0  0  1 -1  0                                                   00000780
SECTØR  0  0  0  1 -1                                                   00000790
SECTØR  0  0  0  0  1                                                   00000800
BLØCK     4    1    1                                                   00000810
MEDIA           1,    2,    2,    3,  500,    4                         00000820
SURFACES        2,    5,    6,    7,   12                               00000830
SECTØR -1 -1  0  0  0                                                   00000840
SECTØR  0  1 -1  0  0                                                   00000850
SECTØR  1  0 -1  0  0                                                   00000860
SECTØR  0  0  1 -1  0                                                   00000870
SECTØR  0  0  0  1 -1                                                   00000880
SECTØR  0  0  0  0  1                                                   00000890
BLØCK     5    1    1                                                   00000900
MEDIA           1,    2,    2,    3,  500,    4,    0,    0             00000910
SURFACES        2,    5,    6,    7,   10,   11,   12                   00000920
SECTØR -1 -1  0  0  0  0  0                                             00000930
SECTØR  0  1 -1  0  0  0  0                                             00000940
SECTØR  1  0 -1  0  0  0  0                                             00000950
SECTØR  0  0  1 -1  0  0  0                                             00000960
SECTØR  0  0  0  1  0  0 -1                                             00000970
SECTØR  0  0  0  0 -1 -1  1                                             00000980
SECTØR  0  0  0  0  1  0  0                                             00000990
SECTØR  0  0  0  0  0  1  0                                             00001000
BLØCK     6    1    1                                                   00001010
MEDIA           2,    3,  500,    4,    0,    0                         00001020
SURFACES        6,    7,   10,   11,   12                               00001030
SECTØR -1  0  0  0  0                                                   00001040
SECTØR  1 -1  0  0  0                                                   00001050
SECTØR  0  1  0  0 -1                                                   00001060
SECTØR  0  0 -1 -1  1                                                   00001070
```

```
SECTOR  0  0  1  0  0                                                  00001080
SECTOR  0  0  0  1  0                                                  00001090
ZONE      1    1    4                                                  00001100
XBLOCK       -16.3525,   -9.7337,       0.0,    9.7337,   16.3525      00001110
YBLOCK       -16.8656,   16.8656                                       00001120
ZBLOCK           -4.0,   -2.5146                                       00001130
BLOCK     1    1    1                                                  00001140
MEDIA           6,    3,  500                                          00001150
SURFACES        6,   13                                                00001160
SECTOR -1  0                                                           00001170
SECTOR  1 -1                                                           00001180
SECTOR  0  1                                                           00001190
BLOCK     2    1    1                                                  00001200
MEDIA           5,    6,    6,    3,  500                              00001210
SURFACES        3,    4,    6,   13                                    00001220
SECTOR  1  1  0  0                                                     00001230
SECTOR  0 -1 -1  0                                                     00001240
SECTOR -1  0 -1  0                                                     00001250
SECTOR  0  0  1 -1                                                     00001260
SECTOR  0  0  0  1                                                     00001270
BLOCK     3    1    1                                                  00001280
MEDIA           5,    6,    6,    3,  500                              00001290
SURFACES        2,    5,    6,    13                                   00001300
SECTOR -1 -1  0  0                                                     00001310
SECTOR  0  1 -1  0                                                     00001320
SECTOR  1  0 -1  0                                                     00001330
SECTOR  0  0  1 -1                                                     00001340
SECTOR  0  0  0  1                                                     00001350
BLOCK     4    1    1                                                  00001360
MEDIA           6,    3,  500                                          00001370
SURFACES        6,   13                                                00001380
SECTOR -1  0                                                           00001390
SECTOR  1 -1                                                           00001400
SECTOR  0  1                                                           00001410
ZONE      1    1    5                                                  00001420
X BLOCK      -16.3525,   16.3525                                       00001430
Y BLOCK      -16.8656,   16.8656                                       00001440
```

```
Z BLØCK          -2.5146,       1.471                                                           00001450
BLØCK        1      1      1                                                                    00001460
MEDIA               3,      3,      7,    500,    500                                           00001470
SURFACES            6,     13,     14,     15                                                   00001480
SECTØR   1  -1   0   1                                                                          00001490
SECTØR   0  -1   1  -1                                                                          00001500
SECTØR  -1   0   0   1                                                                          00001510
SECTØR   0   1   1   0                                                                          00001520
SECTØR   0   0  -1   0                                                                          00001530
    15    QUADRIC SURFACES, DRUMS IN                                                            00001540
          1.0XSQ             1.0YSQ    -130.55782       $                                       00001550
          1.0X         -1.732055Y        -19.4672       $                                       00001560
          1.0X          1.732055Y         19.4672       $                                       00001570
          1.0X         -1.732055Y         19.4672       $                                       00001580
          1.0X          1.732055Y        -19.4672       $                                       00001590
          1.0XSQ             1.0YSQ    -127.04108       $                                       00001600
          1.0XSQ             1.0YSQ    -129.92010       $                                       00001610
          1.0X               1.0Y        23.52820       $                                       00001620
          1.0X              -1.0Y        23.52820       $                                       00001630
          1.0X               1.0Y       -23.52820       $                                       00001640
          1.0X              -1.0Y       -23.52820       $                                       00001650
          1.0XSQ             1.0YSQ    -133.74044       $                                       00001660
          1.0XSQ             1.0YSQ    -134.29913       $                                       00001670
          1.0XSQ             1.0YSQ            1.0ZSQ          -93.987     $                    00001680
          1.0XSQ             1.0YSQ            1.0ZSQ          -93.987                          00001690
 -29.93946      $                                                                               00001700
```

5. STBATCH Input Data

```
           8                                                               10000
         0.0         0.0      143.48         0.0         0.0       92,48   10101
         0.0         0.0        -1.0      ,99876       -71.0         0.0   10102
    124,4563       -45,5         0.0     80.2887          .5         0.0   10103
     -,86603      .99876   -122,9763         0.0       72.48    -78,8087   10104
         0.0       46,98      ,86603         0.0         -,5      .99876   10105
       5,923         0.0      143,48       5,923         0.0       92,48   10106
         0.0         0.0        -1.0      .99876      11,846         0.0   10107
      143,48      11,846         0,0       92,48         0.0         0.0   10108
        -1.0      .99876     -59.154         0.0    124.4563     -33.654   10109
         0.0     80.2887          .5         0.0     -,86603      .99876   10110
      82,846         0.0    124.4563      57.346         0.0     80.2887   10111
         -.5         0.0     -.86603      .99876    134.8223         0.0   10112
       72.48     90,6547         0,0       46,98     -,86603         0.0   10113
         -,5      .99876                                                   10114
          12                                                               10200
          .5         1.0         1,5         2.0         2,5         3.0   10301
         3,5         4.0         5.0         6.0        10.0        18.0   10302
          10           4          10          15          25          29   10401
```

APPENDIX Q

INPUT INSTRUCTIONS FOR ACTIFK AND ACTIFK USER SUBROUTINE STBATCH

1. Input Instructions - ACTIFK

Card 1. Format (10A8)

- a. 80 alphanumeric characters.

Card 2. Format (Ø16)

- a. RAND: Octal, starting random number ending in 3 or 5.

Card 3. Format (4I5,2E10.5)

- a. NSTRT: number of neutrons per batch
- b. NITS: number of batches
- c. NBIN: NSTRT*NVAR (see card 8 for NVAR)
- d. NETAPE: power of two of highest supergroup energy containing ETØP
- e. ETØP: highest neutron energy, in eV, must be less than or equal to ETØP on the cross-section tape
- f. EBØT: lowest neutron energy, in eV, must be greater than or equal to EBØT on the cross-section tape

Card 4. Format (23I3)

- a. NXTAPE: logical number, cross-section tape; NXTAPE = 0 if none.
- b. NYTAPE: logical number statistical tape (scratch tape); NYTAPE = 0 if full analysis of statistics is not desired.
- c. NFTAPE1: logical number, F tape; NFTAPE1 = 0, if none.
- d. NFTAPE2: logical number, F tape copy; if no copy is to be used, NFTAPE2 = NFTAPE1.
- e. MEDIA: number of media in the system; MEDIA $\leq$ 8.
- f. LMAX(M),M=1,MEDIA: total number of scatterers per medium M; LMAX(M) < 32.

Omit Cards 5 and 6 if MEDIA = 0; Cards 5 and 6 are repeated for each media, M=1,MEDIA.

Card 5. Format (8I5)

a. LF1(LM,M),LM=1,LMAX(M): The type of angular scattering distribution for the LMth scatterer of medium M. The order of scatterers on this card must be the same as the order on the O5R systems data tape.

LF1 = 0, isotropic,

LF1 = -N, anisotropic, use the data for the Nth scatterer on the F tape,

LF1 = +N, treatment written by user in subroutine PMUELAS if elastic or subroutine PMQ if inelastic; use the data for the Nth scatterer on the F tape.

Card 6. Format (7E10.5)

a. MASSES(LM,M),LM=1,LMAX(M): the mass of the LMth scatterer in medium M; MASSES ≥ 0, elastic; MASSES < 0, nonelastic.

Card 7. Format (4I5)

a. NHISTR: logical tape number of the first collision tape.

b. NHISMX: logical tape number of the last collision tape; logical numbers of collision tapes will assume values from NHISTR through NHISMX.

c. NWPCØL: number of collision parameters per neutron collision (NWPCØL $\leq$ 36).

d. NSGP: number of supergroups on the total cross-section tape.

Card 8. Format (I3,36I1)

a. NVAR: number of quantities to be calculated in the problem such as the number of detectors, bins, etc.; includes only those for which the full analysis of statistics is desired.

b. NBIND(I),I=1,36: collision parameter; NBIND(I)=0 means that the Ith collision parameter is not on the collision tape; NBIND(I)=1 means that the Ith collision parameter is on the collision tape.

Omit Card 9 if NFTAPE1 = 0

Card 9. Format (14I5)

a. NANISØEL: number of anisotropic scatterers on the F tape; NANISØEL $\leq$ 20.

b. NFCØF(L),L=1,NANISØEL: number of Legendre coefficients for the Lth scatterer on the F tape.

Omit Cards 10 and 11 when NYTAPE = 0

Card 10. Format (I6)

a. KX: number of distinct interval widths; KX $\geq$ 1; intervals o 0 to 1.0 for the full analysis of statistics.

Card 11. Format (3(I6,E12.6))
(I(N),W(N),N=1,KX)

a. I(N): number of subintervals occurring successively with width W(N).

b. W(N): subinterval width

$$\sum_{N=1}^{KX} I(N)\ W(N) = 1.0$$

$$\sum_{N=1}^{KX} I(N) \leq 100.$$

The geometry input is next; it is identical to that for 05R except that internal voids must be medium number 500 instead of 1000.

2. Input Instructions - ACTIFK User Subroutine STBATCH

This input is for the analysis of 05R collision tapes prepared for the SNAP-TSF core-mapping problem. The space-energy detector index is defined by the Card 5 instructions.

This input follows the ACTIFK geometry input.

Card 1. Format (I12)

a. NØDET: the number of detector spatial locations (NØDET $\leq$ 10).

Card 2. Format (6E12.5) for I=1,NØDET

a. XD(I): detector X coordinate,
b. YD(I): detector Y coordinate,
c. ZD(I): detector Z coordinate,
d. XPT(I): collimator cone vertex X coordinate,
e. YPT(I): collimator cone vertex Y coordinate,
f. ZPT(I): collimator cone vertex Z coordinate,
g. APT(I): collimator cone axis direction cosine α,*
h. BPT(I): collimator cone axis direction cosine β,*
i. CPT(I): collimator cone axis direction cosine γ,*
j. CMU(I): cosine of collimator cone half angle.

Card 3. Format (I12)

a. NESPEC: number of energy group boundaries for all detectors; NESPEC $\leq$ 20.

Card 4. Format (6E12.5)

a. ESPEC(I),I=1,NESPEC: energy group boundaries, in MeV, from low to high energy.

Card 5. Format (6I12)

a. NRSH: number of space-energy detectors for the full analysis of statistics (NRSH $\leq$ 10).

b. NRSH1(I),I=1,NRSH: the space-energy detector index for the full analysis of statistics; the maximum value for NRSH1(I) is NØDET*(NESPEC-1); if II is the space detector index and JJ is the energy index, then NRSH1(I)=(NESPEC-1)*(II-1)+JJ.

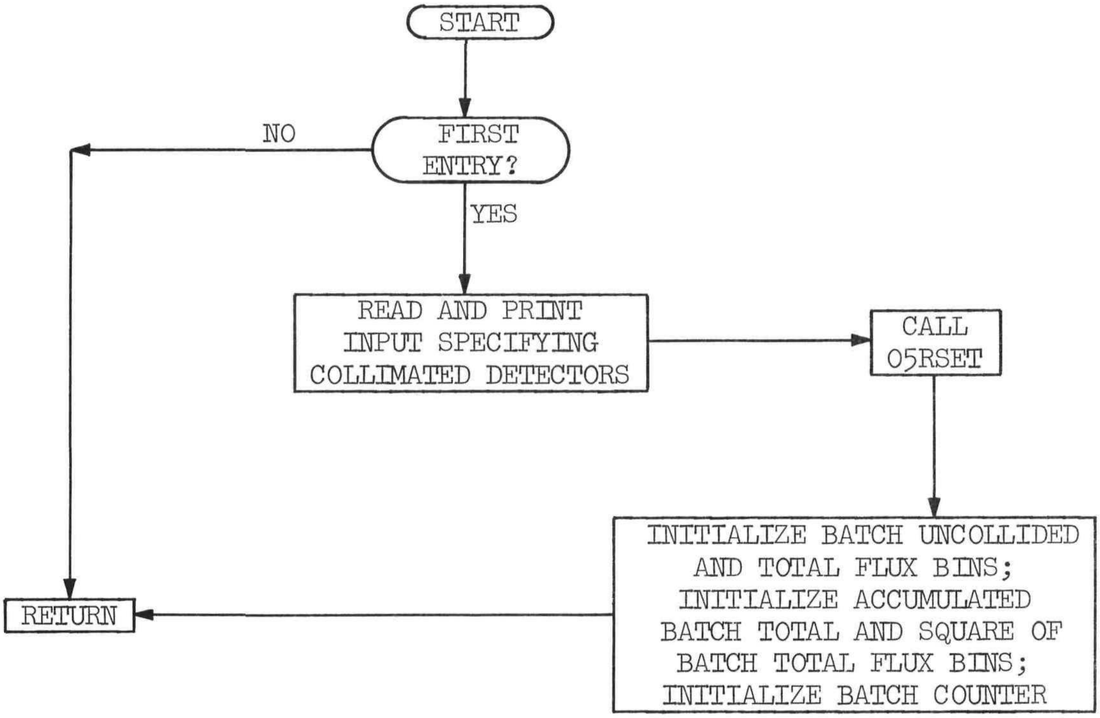
---

*Directions are from collimator cone vertex to the bottom of the reactor.

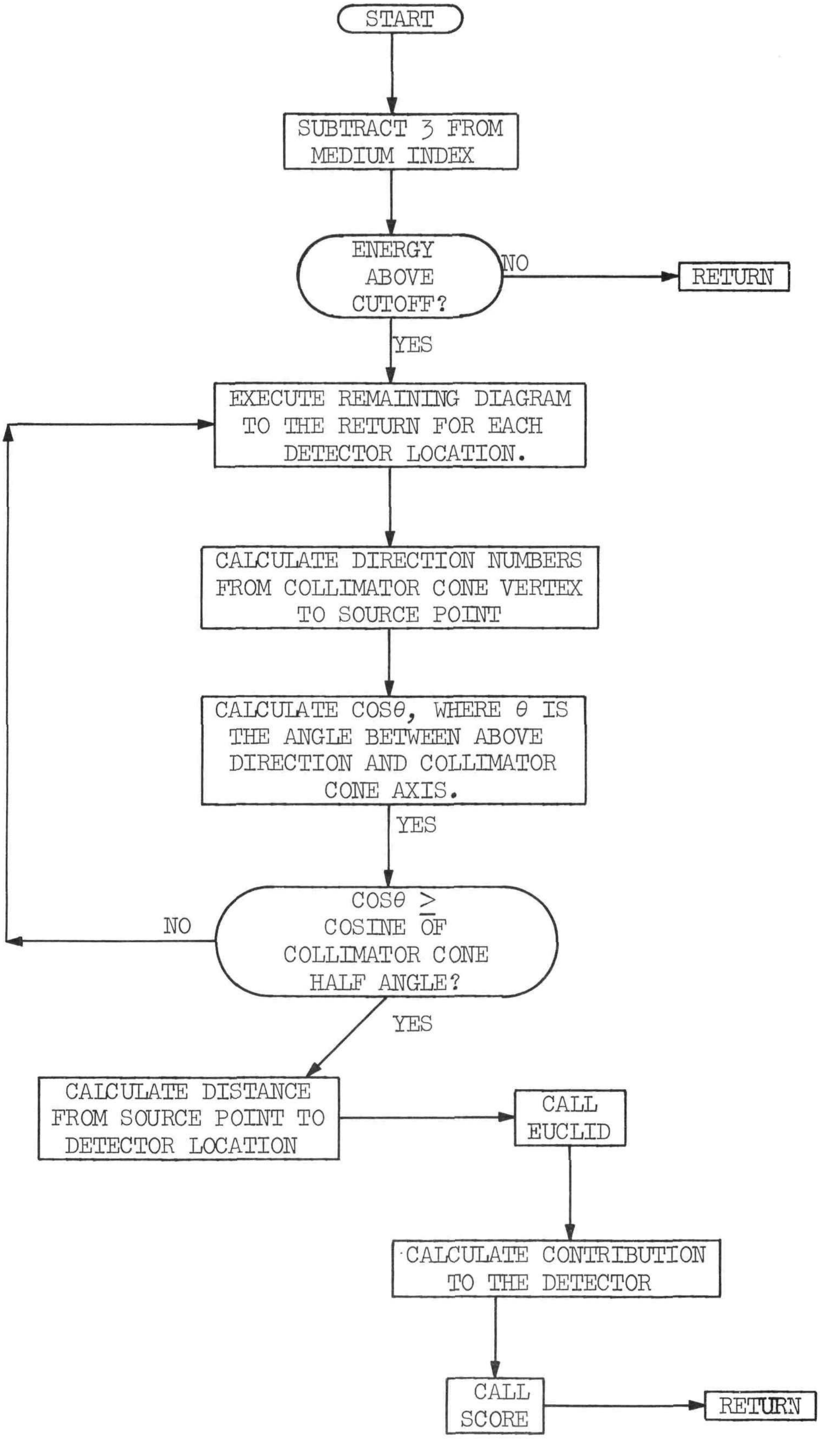
APPENDIX R

FLOW DIAGRAMS FOR ACTIFK USER SUBROUTINES

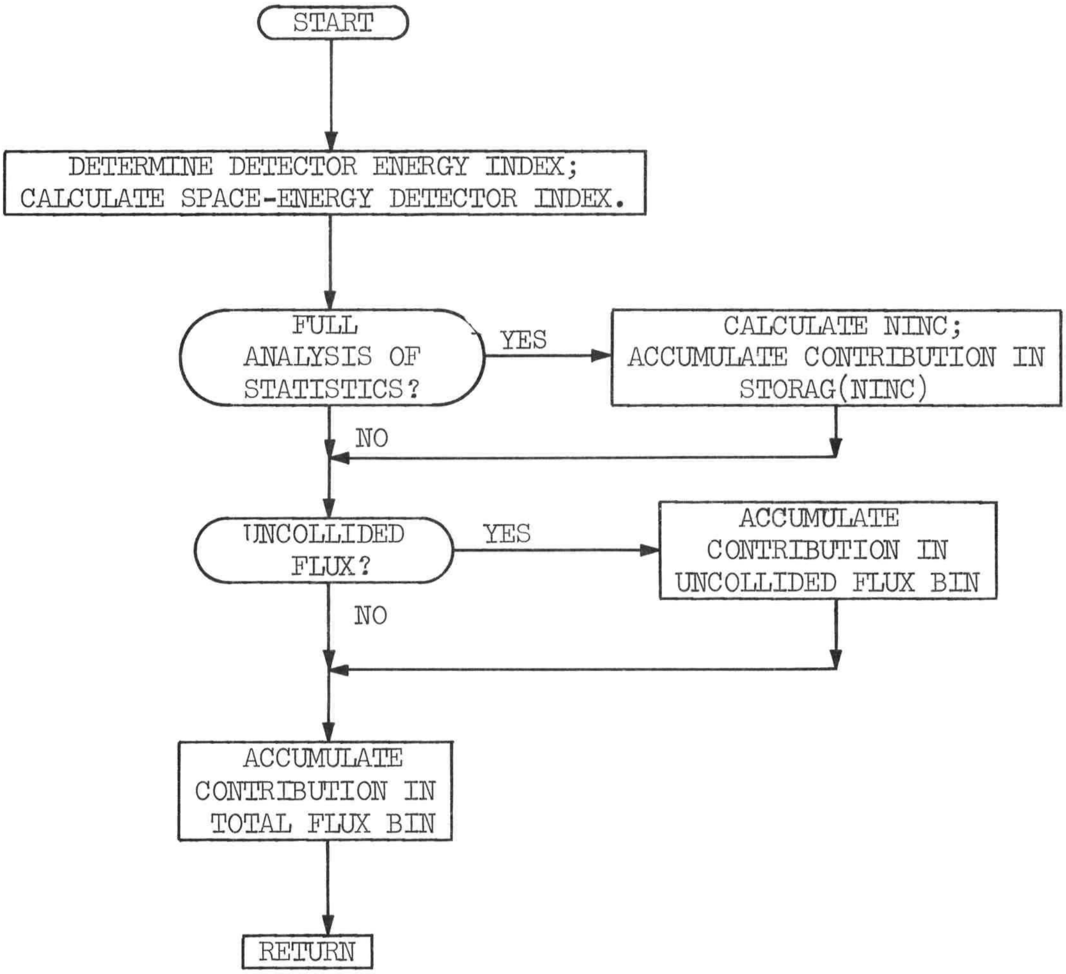
Subroutine STBATCH



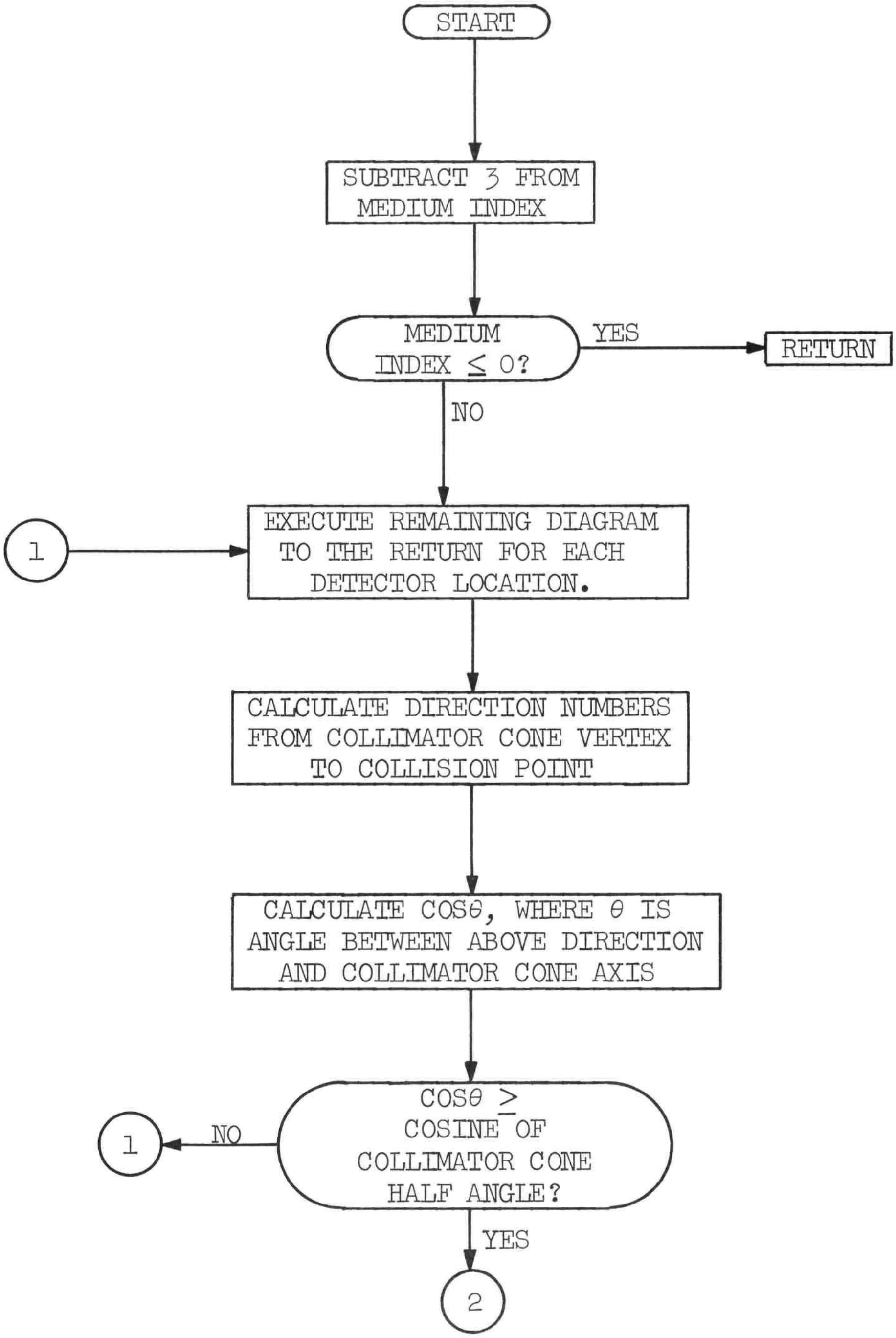
Subroutine SDATA



Subroutine SCORE (IDET,IDOS,CONT,VA2)

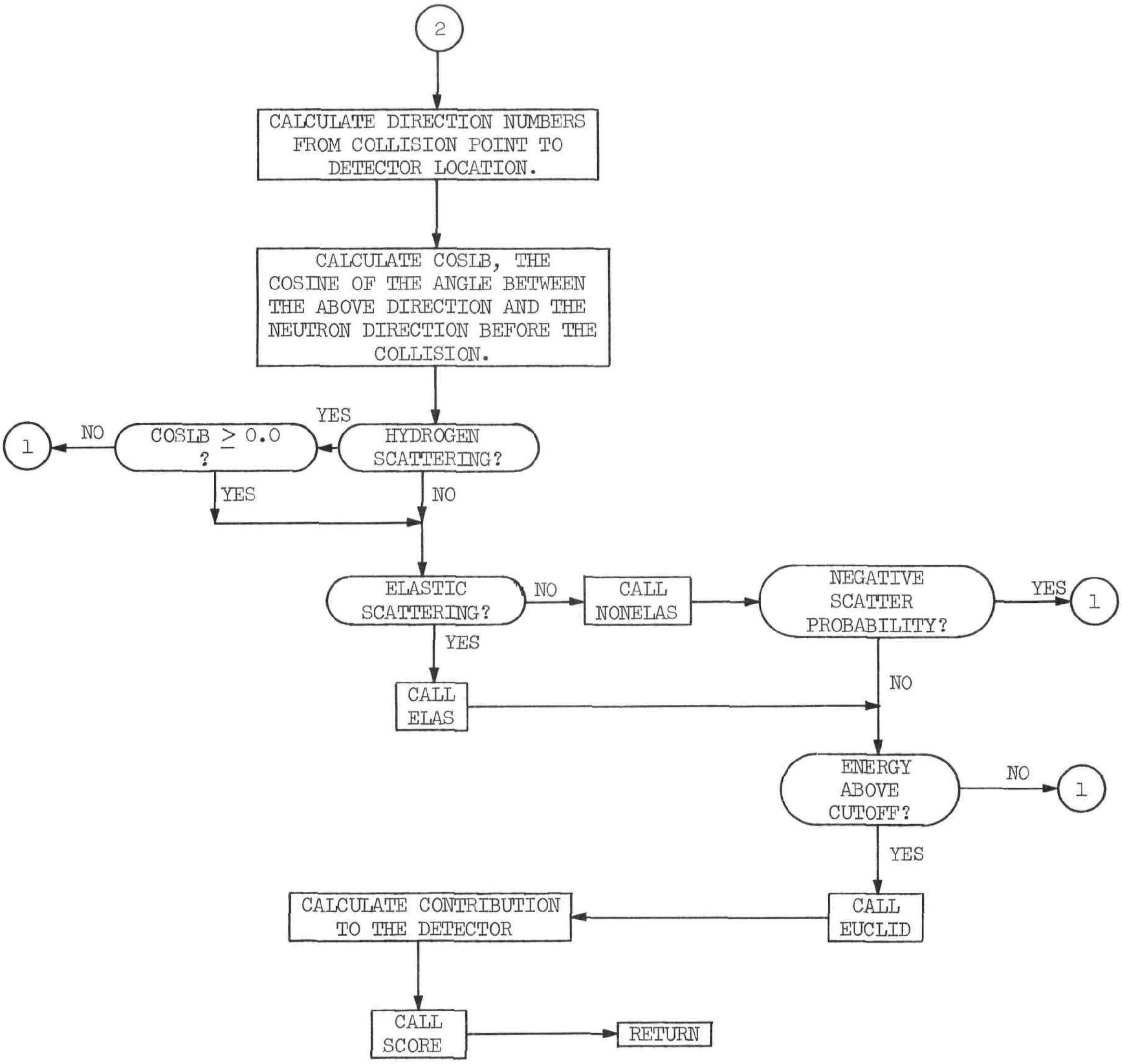


Subroutine RELCOL, Page 1

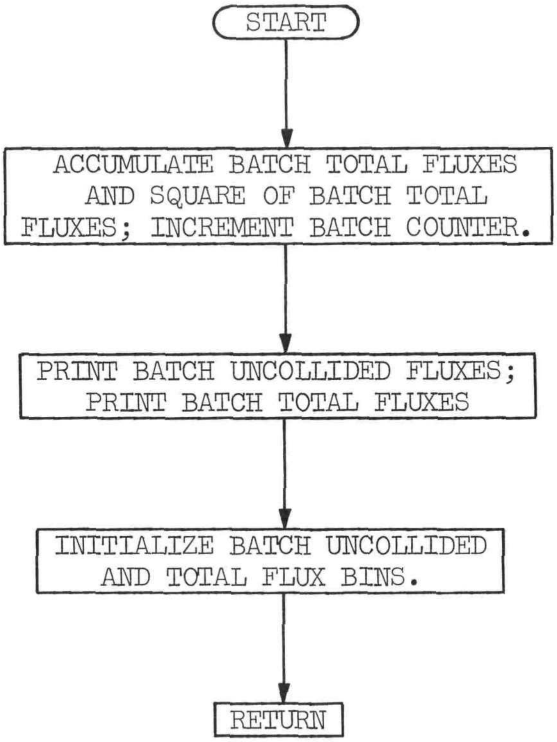


Subroutine RECOL, Page 2

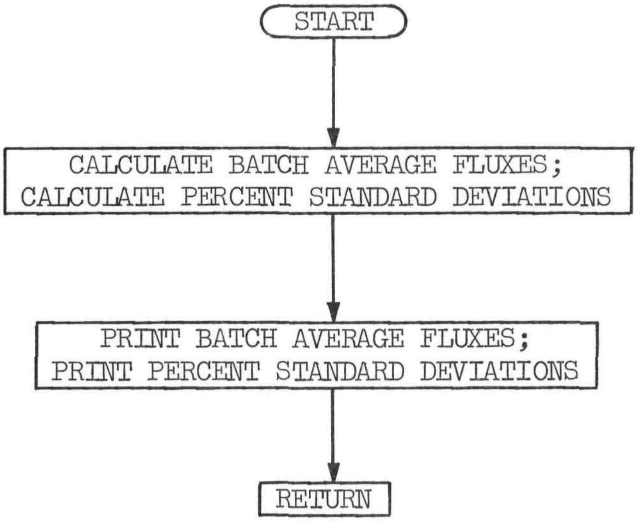
Subroutine RELCOL, Page 2



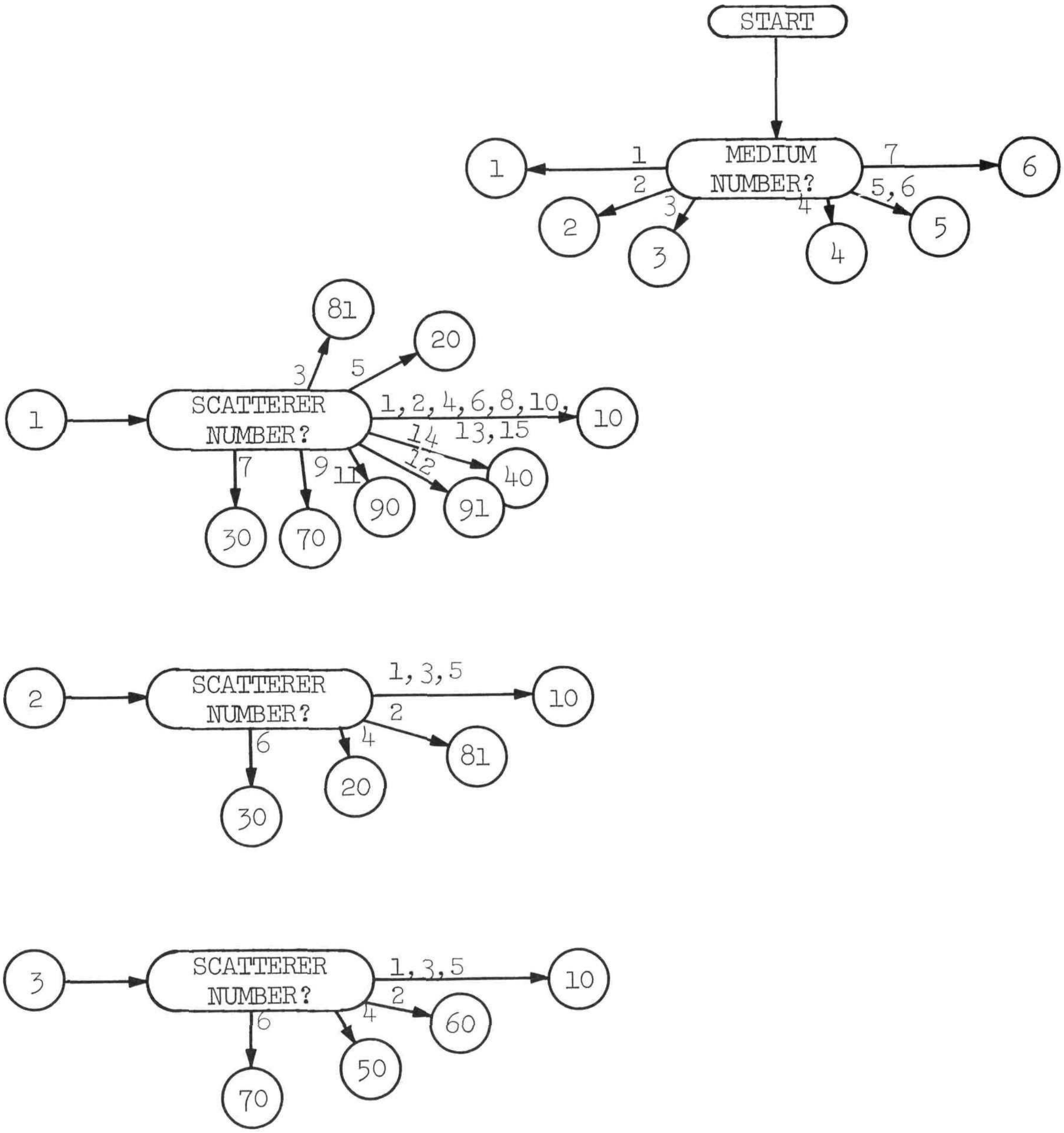
Subroutine NBATCH



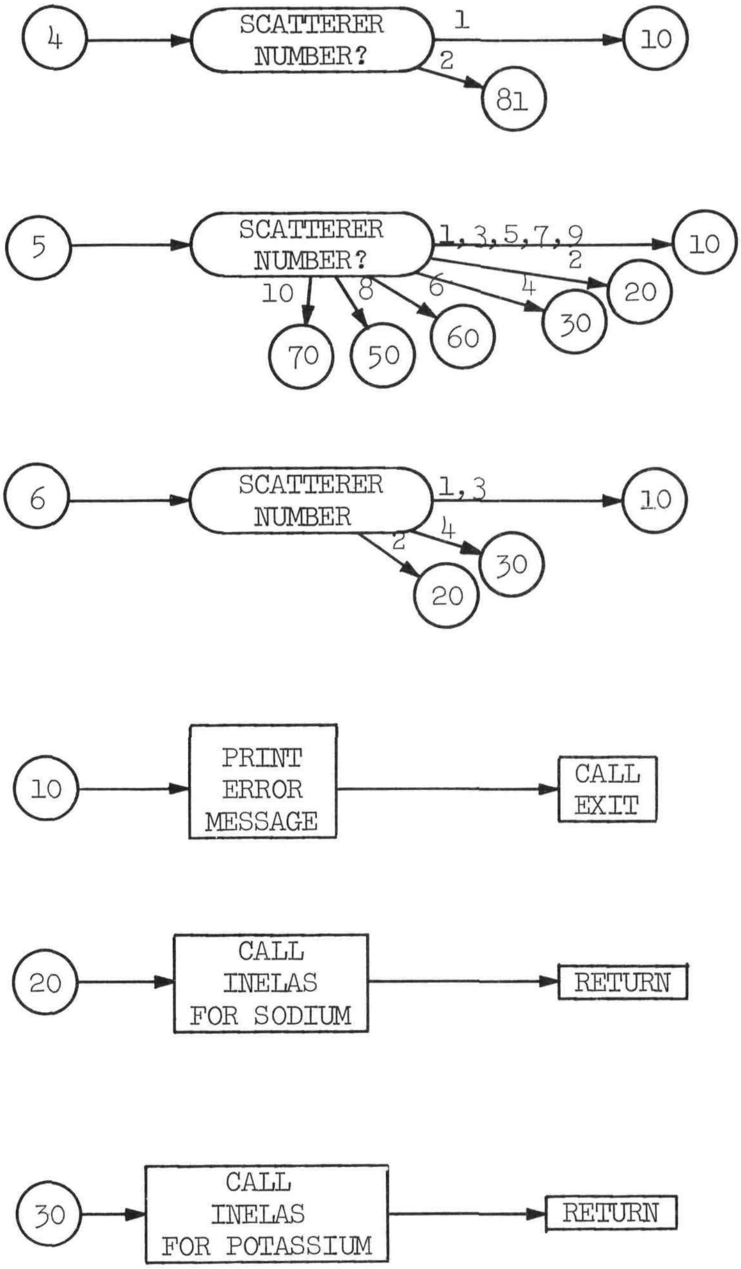
Subroutine OUTPUT



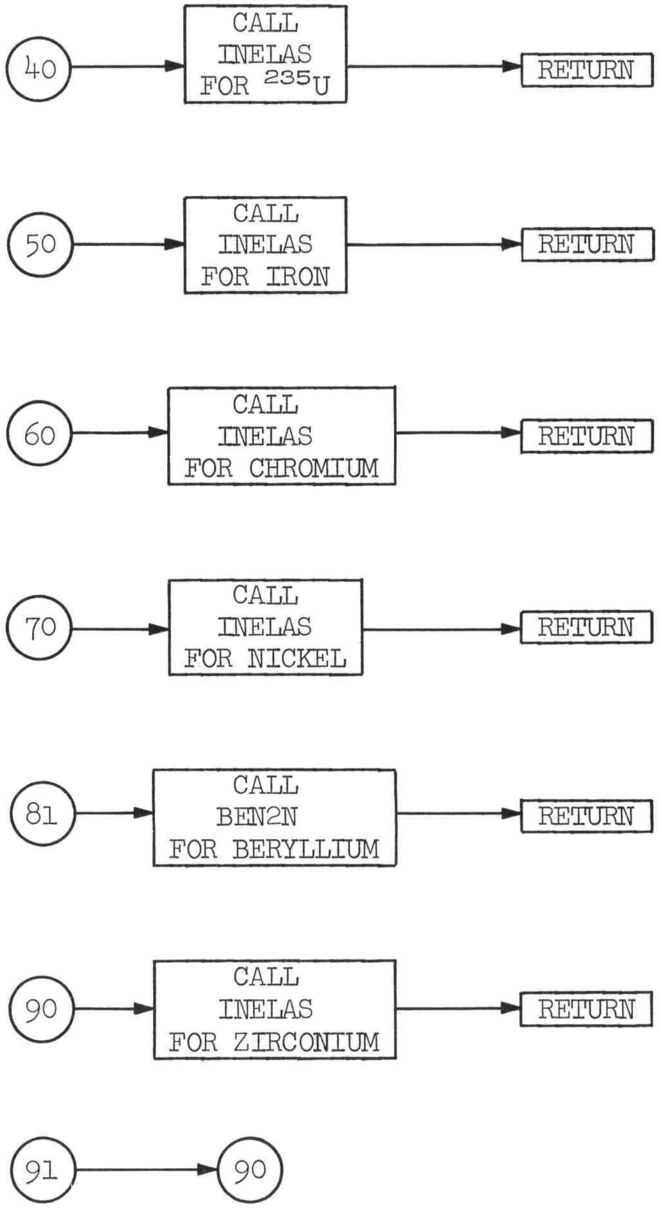
Subroutine NONELAS (COSLB,VA2,FMU), Page 1



Subroutine NONELAS(COSLB,VA2,FMU). Page 2



Subroutine NONELAS(COSLB,VA2,FMU), Page 3



APPENDIX S

ACTIFK USER SUBROUTINE LISTINGS

```
      SUBROUTINE STBATCH
      COMMON/UNCOL/UNCFLUX(190),FLLX(190),FLUX1(190),VAR(190),FBAT,FBAT1
      COMMON/COLL/XPT(10),YPT(10),ZPT(10),APT(10),BPT(10),CPT(10),
     1CMU(10)
      COMMON/SPEC/NESPEC,NESPEC1,ESPEC(20),NRSH,NRSH1(10)
      COMMON/DET/NODET,XD(10),YD(10),ZD(10)
      COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),X(8),Y(8),Z(8),WATE(8),SPOLD
     1(8),UOLD(8),VOLD(8),WOLD(8),OLDWT(8),NGRP(8),LELEM(8),NMED(8),
     2DUM(8)
      COMMON/ASINGLES/NSTRT,NITS,NEIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
     1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCOL,NSGP,NCOLPR,N
     2ANISOEL,NDSGP,NLAST,KTH,NGROLP,LBATCH,NVAR,NF,NL,IR,NCPSR2,NCPNGP,
     3NCPELEM,NCPMED,NTYPE,DOSE,NRSUM,NZRO,NRSUM,NYTABLE,NGEOM,NM,MGZ,NO
     4NEUT,NYSUM,NZR,IVAR
      DATA(IFIRST=0)
      IF(IFIRST) 1,1,2
    1 IFIRST=1
      CALL O5RSET(NHISTR,NHISMX,NREC,NTYPE,NCOLL,NAME,S12,X,Y,Z,WATE,SPO
     1LD,UOLD,VOLD,WOLD,OLDWT,NGRP,LELEM,NMED)
      READ 100,NODET,(XD(I),YD(I),ZD(I),XPT(I),YPT(I),ZPT(I),APT(I),BPT(
     1I),CPT(I),CMU(I),I=1,NODET)
  100 FORMAT(I12/(6E12.5))
      PRINT101,NODET,(XD(I),YD(I),ZD(I),I=1,NODET)
  101 FORMAT(24H0THE NO OF DETECTORS IS ,I5/37H0THE X,Y,Z COORDINATES AR
     1E AS FOLLOWS/1H /(1H ,3(E12.5,3X)))
      PRINT 102,(XPT(I),YPT(I),ZPT(I),APT(I),BPT(I),CPT(I),CMU(I),I=1,NO
     1DET)
  102 FORMAT(1H0,7CONE VERTEX COORD., CONE AXIS DIR. COS., AND COS OF 7,
     17CONE HALF ANGLE7//(1H ,6(E12.5,3X)))
      READ 100,NESPEC,(ESPEC(I),I=1,NESPEC)
C     ESPEC VALUES FROM LOW TO HIGH ENERGY, MEV
      PRINT 104, (ESPEC(I),I=1,NESPEC)
  104 FORMAT (1H0,7DETECTOR ENERGY BOUNDARIES, MEV7//(1H ,8E12.3))
```

```
      NESPEC1=NESPEC-1
      PRINT 105,NESPEC1
  105 FORMAT (1H0,7NUMBER OF DETECTOR ENERGY BINS7//1H ,I12)
      DO 20 I=1,NESPEC
   20 ESPEC(I)=1.91322E+18*ESPEC(I)
      READ 106,NRSH,(NRSH1(I),I=1,NRSH)
  106 FORMAT (6I12)
      PRINT 107,(NRSH1(I),I=1,NRSH)
  107 FORMAT (1H0,7DETECTOR-ENERGY INDEX FOR STATISTICAL ANALYSIS7//1H ,
     110I6)
      DO 19 I=1,190
      FLUX(I)=0.0
      FLUX1(I)=0.0
      VAR(I)=0.0
   19 UNCFLUX(I)=0.0
      FBAT=0.0
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SDATA
      COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),X(8),Y(8),Z(8),WATE(8),SPOLD
     1(8),UOLD(8),VOLD(8),WOLD(8),OLDWT(8),NGRP(8),LELEM(8),NMED(8),
     2DUM(8)
      COMMON/COLL/XPT(10),YPT(10),ZPT(10),APT(10),BPT(10),CPT(10),
     1CMU(10)
      COMMON/DET/NODET,XDET(10),YDET(10),ZDET(10)
      COMMON/ASINGLES/NSTRT,NITS,NEIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
     1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCOL,NSGP,NCOLPR,N
     2ANISOEL,NDSGP,NLAST,KTH,NGROUP,LBATCH,NVAR,NF,NL,IB,NCPSR2,NCPNGP,
     3NCPELEM,NCPMED,NTYPE,DOSE,NRSUM,NZRO,NBSUM,NYTABLE,NGEOM,NM,MGZ,NO
     4NEUT,NYSUM,NZR,IVAR
      NMED(KTH)=NMED(KTH)-3
      SPD2=S12(KTH)
```

```
      IF(SPD2-ECUT) 2,1,1
    1 XA=X(KTH)
      YA=Y(KTH)
      ZA=Z(KTH)
      DO 19 I=1,NODET
      XD=XA-XPT(I)                                                  4   100
      YD=YA-YPT(I)                                                  4   110
      ZD=ZA-ZPT(I)                                                  4   120
      SD=SQRTF(XD*XD+YD*YD+ZD*ZD)                                   4   130
      CCMU=(XD*APT(I)+YD*BPT(I)+ZD*CPT(I))/SD                       4   140
      IF (CCMU-CMU(I)) 19,3,3                                       4   150
    3 CONTINUE                                                      4   160
      XD=XDET(I)
      YD=YDET(I)
      ZD=ZDET(I)
      A=XD-XA
      B=YD-YA
      C=ZD-ZA
      SD2=A*A+B*B+C*C
      SD=SQRTF(SD2)
      CALL EUCLID(XA,YA,ZA,XD,YD,ZD,SD,SPD2,ARG,0)                  4   260
C     .07957753=1.0/(4.0*3.14159)                                   4   270
      IDET=I                                                        4   280
      CONT=WATE(KTH)*EXPF(ARG)*COLF(CCMU,SPD2,IDET)*.07957753/SD2   4   290
      IDOS=0                                                        4   300
      CALL SCORE(IDET,IDOS,CONT,SPD2)                               4   310
   19 CONTINUE                                                      4   320
    2 RETURN
      END


      FUNCTION COLF (C,V,I)
      COLF=1.0
      RETURN
      END COLF
```

```
      SUBROUTINE SCORE(IDET,IDOS,CONT,VA2)
      COMMON/UNCOL/UNCFLUX(190),FLUX(190),FLUXI(190),VAR(190),FBAT,FBATI
      COMMON/SPEC/NESPEC,NESPECI,ESPEC(20),NRSH,NRSHI(10)
      COMMON STORAG(1)
      COMMON/ASINGLES/NSTRT,NITS,NEIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
     1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCOL,NSGP,NCOLPR,N
     2ANISOEL,NDSGP,NLAST,KTH,NGROUP,LBATCH,NVAR,NF,NL,IB,NCPSR2,NCPNGP,
     3NCPELEM,NCPMED,NTYPE,DOSE,NRSUM,NZRO,NBSUM,NYTABLE,NGEOM,NM,MGZ,NO
     4NEUT,NYSUM,NZR,IVAR
      COMMON/CPLIST/NCOLL(8),NAME(8),SI2(8),X(8),Y(8),Z(8),WATE(8),SPOLD
     1(8),UOLD(8),VOLD(8),WOLD(8),OLDWT(8),NGRP(8),LELEM(8),NMED(8),
     2DUM(8)
      NN=NAME(KTH)
      DO 10 J=1,NESPECI
      IF (VA2-ESPEC(J+1)) 11,11,10
   10 CONTINUE
      J=NESPECI
   11 IRSH=NESPECI*(IDET-1)+J
      DO 12 N=1,NRSH
      IF (IRSH-NRSHI(N)) 12,13,12
   12 CONTINUE
      GO TO 15
   13 NINC=NYTABLE+(N-1)*NSTRT+NN-1
      STORAG(NINC)=STORAG(NINC)+CONT
   15 IF (IDOS) 16,16,17
   16 UNCFLUX(IRSH)=UNCFLUX(IRSH)+CONT
   17 FLUX(IRSH)=FLUX(IRSH)+CONT
      RETURN
      END SCORE
```

```
      SUBROUTINE RELCOL
      COMMON/CPLIST/NCOLL(8),NAME(8),SI2(8),X(8),Y(8),Z(8),WATE(8),SPOLD
     1(8),UOLD(8),VOLD(8),WOLD(8),OLDWT(8),NGRP(8),LELEM(8),NMED(8),         5    030
     2DUM(8)                                                                 5    040
      COMMON/COLL/XPT(10),YPT(10),ZPT(10),APT(10),BPT(10),CPT(10),           5    050
     1CMU(10)                                                                5    060
      COMMON STORAG(1)
      COMMON/DET/NODET,XDET(10),YDET(10),ZDET(10)
      COMMON/AMEDELEM/ALFA(32,8),BETA(32,8),ALFABETA(32,8),
     1LFI(32,8),ASSES(32,8)
      COMMON/ASINGLES/NSTRT,NITS,NBIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
     1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCOL,NSGP,NCOLPR,N
     2ANISOEL,NDSGP,NLAST,KTH,NGROUP,LBATCH,NVAR,NF,NL,IB,NCPSB2,NCPNGP,
     3NCPELEM,NCFMED,NTYPE,DOSE,NRSUM,NZRO,NBSUM,NYTABLE,NGEOM,NM,MGZ,NO
     4NEUT,NYSUM,NZR,IVAR
      NMED(KTH)=NMED(KTH)-3                                                  5    151
      IF (NMED(KTH)) 2,2,1                                                   5    152
    1 CONTINUE                                                               5    153
      NN=NAME(KTH)
      XA=X(KTH)
      YA=Y(KTH)
      ZA=Z(KTH)
      SB=SQRTF(SPOLD(KTH))
      JELEM=LELEM(KTH)
      MED=NMED(KTH)
      WT1=WATE(KTH)
      XMASS=ASSES(JELEM,MED)
      DO 180 I=1,NODET
      XD=XA-XPT(I)                                                           5    260
      YD=YA-YPT(I)                                                           5    270
      ZD=ZA-ZPT(I)                                                           5    280
      SD=SQRTF(XD*XD+YD*YD+ZD*ZD)                                            5    290
      CCMU=(XD*APT(I)+YD*BPT(I)+ZD*CPT(I))/SD                                5    300
      IF (CCMU-CMU(I)) 180,3,3                                               5    310
    3 CONTINUE                                                               5    320
      XD=XDET(I)
      YD=YDET(I)
```

```
      ZD=ZDET(I)
      A=XD-XA
      B=YD-YA
      C=ZD-ZA
      SD2=A*A+B*B+C*C
      SD=SQRTF(SD2)
      COSLB=(A*UOLD(KTH)+B*VOLD(KTH)+C*WOLD(KTH))/(SD*SB)
      IF(ABSF(XMASS)-1.008140) 20,20,25
   20 IF(COSLB) 180,25,25
   25 IF(XMASS) 35,35,30
   30 CALL ELAS(COSLB,VA2,FMU)
      GO TO 45
   35 CALL NONELAS(COSLB,VA2,FMU)
   40 IF(FMU) 180,180,45
   45 IF(VA2-ECUT) 180,50,50
   50 CALL EUCLID(XA,YA,ZA,XD,YD,ZD,SD,VA2,ARG,0)                       5   500
      IDET=I                                                             5   510
      CONT=WT1*EXPF(ARG)*FMU*COLF(CCMU,VA2,IDET)/SD2                     5   520
      IDOS=1                                                             5   530
      CALL SCORE(IDET,IDOS,CONT,VA2)                                     5   540
  180 CONTINUE
    2 CONTINUE                                                           5   560
      RETURN
      END



      SUBROUTINE NBATCH                                                  2   010
      COMMON/UNCOL/UNCFLUX(190),FLUX(190),FLUX1(190),VAR(190),FBAT,FBAT1 2   020
      COMMON/DET/NODET,XDET(10),YDET(10),ZDET(10)                        2   030
      COMMON/SPEC/NESPEC,NESPEC1,ESPEC(20),NRSH,NRSH1(10)                2   040
      JRSH=NODET*NESPEC1                                                 2   050
      FBAT=FBAT+1.0                                                      2   060
      FBAT1=FBAT-1.0                                                     2   070
      DO 1 J=1,JRSH                                                      2   080
      FLUX1(J)=FLUX1(J)+FLUX(J)                                          2   090
```

```
    1 VAR(J)=VAR(J)+FLUX(J)**2
      I1=1
      I2=JRSH-NESPEC1+1
      PRINT 1000,FBAT,(J,J=1,NODET)
 1000 FORMAT (1H1,9X,7UNCOLLIDED FLUX FOR BATCH NUMBER7,F5.1//1H ,
     17ENERGY7,34X,7DETECTOR LOCATION INDEX7/1H ,7INDEX7,I5,9I11)
      DO 2 J=1,NESPEC1
      PRINT 1001,J,(UNCFLUX(I),I=I1,I2,NESPEC1)
 1001 FORMAT (1H ,I4,2X,10E11.3)
      I2=I2+1
    2 I1=I1+1
      I1=1
      I2=JRSH-NESPEC1+1
      PRINT 1002,FBAT,(J,J=1,NODET)
 1002 FORMAT (1H1,9X,   7TOTAL FLUX FOR BATCH NUMBER7,F5.1//1H ,7ENERGY7
     1,34X,7DETECTOR LOCATION INDEX7/1H ,7INDEX7,I5,9I11)
      DO 3 J=1,NESPEC1
      PRINT 1001,J,(FLUX(I),I=I1,I2,NESPEC1)
      I2=I2+1
    3 I1=I1+1
      DO 4 J=1,JRSH
      FLUX(J)=0.0
    4 UNCFLUX(J)=0.0
      RETURN
      END NBATCH
```

```
      SUBROUTINE OUTPUT
      COMMON/UNCOL/UNCFLUX(190),FLUX(190),FLUX1(190),VAR(190),FBAT,FBAT1
      COMMON/DET/NODET,XDET(10),YDET(10),ZDET(10)
      COMMON/SPEC/NESPEC,NESPEC1,ESPEC(20),NRSH,NRSH1(10)
      JRSH=NODET*NESPEC1
      DO 4 J=1,JRSH
      FLUX(J)=FLUX1(J)/FBAT
      VAR(J)=SQRTF((VAR(J)-FLUX1(J)**2/FBAT)/(FBAT*FBAT1))
```

```
      IF (FLUX(J)) 2,1,2
    1 VAR(J)=0.0
      GO TO 4
    2 VAR(J)=100.0*VAR(J)/FLUX(J)
    4 CONTINUE
      I1=1
      I2=JRSH-NESPEC1+1
      PRINT 1000,FRAT,(J,J=1,NODET)
 1000 FORMAT (1H1,9X7BATCH AVERAGE TOTAL FLUX FOR7,F5.1,7 BATCHES.7//1H
     1,7ENERGY7,34X,7DETECTOR LOCATION INDEX7/1H ,7INDEX7,I5,9I11)
      DO 5 J=1,NESPEC1
      PRINT 1001,J,(FLUX(I),I=I1,I2,NESPEC1)
 1001 FORMAT (1H ,I4,2X,10F11.3)
      I2=I2+1
    5 I1=I1+1
      I1=1
      I2=JRSH-NESPEC1+1
      PRINT 1002,FRAT,(J,J=1,NODET)
 1002 FORMAT (1H1,9X,7PERCENT STANDARD DEVIATION OF TOTAL FLUX FOR7,F5.1
     1,7BATCHES.7//1H ,7ENERGY7,34X,7DETECTOR LOCATION INDEX7/1H ,
     27INDEX7,I9,9I11)
      DO 6 J=1,NESPEC1
      PRINT 1003,J,(VAR(I),I=I1,I2,NESPEC1)
 1003 FORMAT (1H ,I4,2X,10F11.2)
      I2=I2+1
    6 I1=I1+1
      RETURN
      END OUTPUT
```

```
      SUBROUTINE NONELAS(COSLB,VA2,FMU)
      COMMON/CPLIST/NCOLL(8),NAME(8),S12(8),X(8),Y(8),Z(8),WATE(8),SPOLD
     1(8),UOLD(8),VOLD(8),WOLD(8),OLDWT(8),NGRP(8),NELEM(8),NMED(8),
     2DUM(8)
      COMMON/ASINGLES/NSTRT,NITS,NEIN,NETAPE,ETOP,EBOT,ECUT,NXTAPE,NYTAP
```

```
     1E,NFTAPE1,NFTAPE2,NFTAPEP,MEDIA,NHISTR,NHISMX,NWPCØL,NSGP,NCØLPR,N
     2ANISØEL,NDSGP,NLAST,KTH,NGRØUP,LBATCH,NVAR,NF,NL,IB,NCPSB2,NCPNGP,
     3NCPELEM,NCPMED,NTYPE,DØSE,NRSUM,NZRØ,NRSUM,NYTABLE,NGEØM,NM,MGZ,NØ
     4NEUT,NYSUM,NZR,IVAR
      CØMMØN/NANNF/NNAEPT,NNAQ,SM2NA(38),QNA(5),PRØBNA(38,5)                20
      CØMMØN/KNNF/NKEPT,NKQ,SM2K(30),QK(4),PRØBK(30,4)                      30
      CØMMØN/U235NNF/NU235EPT,NU235Q,SM2U235(1),QU235(1),PRØBU235(1,1)      40
      CØMMØN/FENNF/NFEEPT,NFEQ,SM2FE(35),QFE(6),PRØBFE(35,6)                50
      CØMMØN/CRNNF/NCREPT,NCRQ,SM2CR(10),QCR(2),PRØBCR(10,2)                60
      CØMMØN/NINNF/NNIEPT,NNIQ,SM2NI(9),QNI(2),PRØBNI(9,2)                  70
      CØMMØN/ZRNNF/NZREPT,NZRQ,SM2ZR( 4),QZR(1),PRØBZR( 4,1)                90
      LELEM=NELEM(KTH)                                              7      110
      MED=NMED(KTH)                                                 7      120
      GØ TØ (2,3,4,5,1,1,6),MED                                     7      130
    1 GØ TØ (10,20,10,30,10,60,10,50,10,70) LELEM                          340
    2 GØ TØ (10,10,81,     10,20,10,30,10,70,10,90,91,10,40,10) LELEM      350
    3 GØ TØ (10,81,     10,20,10,30) LELEM                                 360
    4 GØ TØ (10,60,10,50,10,70) LELEM                                      370
    5 GØ TØ (10,81     ) LELEM                                             380
    6 GØ TØ (10,20,10,30) LELEM                                            390
   10 WRITE(51,1000) NMED,LELEM                                            400
 1000 FØRMAT(1H1,5HNMED=,I5,3X,6HLELEM=,I5)                                410
      CALL EXIT                                                            420
   20 CALL INELAS(NNAEPT,NNAQ,SM2NA,QNA,PRØBNA,CØSLB,VA2,FMU)       7      140
  100 RETURN                                                               450
   30 CALL INELAS(NKEPT,NKQ,SM2K,QK,PRØBK,CØSLB,VA2,FMU)            7      160
      GØ TØ 100                                                            480
   40 CALL INELAS(NU235EPT,NU235Q,SM2U235,QU235,PRØBU235,CØSLB,VA2,FMU) 7  180
      GØ TØ 100                                                            510
   50 CALL INELAS(NFEEPT,NFEQ,SM2FE,QFE,PRØBFE,CØSLB,VA2,FMU)       7      200
      GØ TØ 100                                                            540
   60 CALL INELAS(NCREPT,NCRQ,SM2CR,QCR,PRØBCR,CØSLB,VA2,FMU)       7      220
      GØ TØ 100                                                            570
   70 CALL INELAS(NNIEPT,NNIQ,SM2NI,QNI,PRØBNI,CØSLB,VA2,FMU)       7      240
      GØ TØ 100                                                            600
   90 CALL INELAS(NZREPT,NZRQ,SM2ZR,QZR,PRØBZR,CØSLB,VA2,FMU)       7      260
      GØ TØ 100                                                            660
```

```
   81 VA1=SPOLD(KTH)                                                     7
      CALL BEN2N(COSLB,VA2,FMU,VA1)                                      7
      GO TO 100                                                              680
   91 GO TO 90                                                           7   300
      END                                                                    710



      SUBROUTINE BEN2N(COSLB,VA2,FMU,VA1)                                8   010
      DATA (IJK=0)                                                       8   020
      IF (IJK) 2,1,2                                                     8   030
    1 IJK=1                                                              8   040
      Q1=-2.46*1.91322E+18                                               8   050
      Q2=.79*1.91322E+18                                                 8   060
    2 T=VA1+1.125*Q1                                                     8   070
      IF (T) 10,20,20                                                    8   080
   10 WRITE (51,1000) VA1,Q1                                             8   090
 1000 FORMAT(1H0,4HVA1=E18.8,3X,3HQ1=E18.8,3X,23HINCOMING ENERGY TOO LOW 8   100
     1)                                                                  8   110
      FMU=0.0                                                            8   120
      VA2=VA1                                                            8   130
   50 RETURN                                                             8   140
   20 IF (FLTRNF(R1)-.5) 30,30,40                                        8   150
   30 AEFF=SQRTF((90.0*Q1+81.0*VA1)/VA1)                                 8   160
      VA2=VA1*(SQRTF(AEFF**2+COSLB**2-1.0)+COSLB)**2/100.0               8   170
      FMU=SQRTF(COSLB**2+AEFF**2-1.0)                                    8   180
      FMU=(2.0*COSLB    +(FMU+COSLB**2/FMU))/AEFF                        8   190
      FMU=FMU/12.5664                                                    8   200
      GO TO 50                                                           8   210
   40 VA2=Q2                                                             8   220
      FMU=1.0/12.5664                                                    8   230
      GO TO 50                                                           8   240
      END
```

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