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RADHEAT-V4: A Code System to Generate Multigroup Constants and Analyze Radiation Transport for Shielding Safety Evaluation

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Abstract

A modular code system RADHEAT-V4 has been developed for performing precisely neutron and photon transport analyses, and shielding safety evaluations. The system consists of the functional modules for producing coupled multi-group neutron and photon cross section sets, for analyzing the neutron and photon transport, and for calculating the atom displacement and the energy deposition due to radiations in a nuclear reactor or shielding material. A precise method named Direct Angular Representation (DAR) has been developed for eliminating an error associated with the method of the finite Legendre expansion in evaluating angular distributions of cross sections and radiation fluxes. The DAR method implemented in the code system has been described in detail. To evaluate the accuracy and applicability of the code system, some test calculations on strong anisotropy problems have been performed. From the results, it has been concluded that RADHEAT-V4 is successfully applicable to evaluating shielding problems accurately for fission and fusion reactors and radiation sources. The method employed in the code system is very effective in eliminating negative values and oscillations of angular fluxes in a medium having an anisotropic source or strong streaming. Definitions of the input data required in various options of the code system and the sample problems are also presented.

Keywords: Modular Code system, RADHEAT-V4, Neutron and Photon Transport, Radiation Shielding, Angular Distribution, Anisotropy Problem, Computer Code Manual, Transport Equation, Secondary Gamma-Ray Yield, Atomic Displacement Cross Section, Energy Deposition Factor.

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RADHEAT-V4：遮蔽安全評価用群定数作成および放射線輸送解析コードシステム

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（1987年5月13日受理）

要　　旨

遮蔽安全評価および中性子と光子の輸送解析を精確に行うモジュラーコードシステムRADHEAT-V4が開発された。本システムは中性子-光子の結合多群定数を作成し，中性子と光子の輸送解析を行い，さらに原子炉または遮蔽材中の放射線による発熱と原子のはじき出しを計算する種々の機能モジュールで構成されている。断面積および放射線束の角度分布を評価する際に，従来の有限項ルジャンドル展開法による誤差を除くため，直接角度表示（DAR）法と呼ばれる精確な手法が開発された。本コードシステムに組み込まれたDAR法の詳細が述べられている。本コードシステムの精度および適用性を評価するために，非等方性の強い問題に対していくつかのテスト計算が行われた。この結果より，核分裂炉，核融合炉および放射線源における遮蔽問題を正確に評価する目的に対して，RADHEAT-V4は十分に適用可能であることが結論された。本コードシステムに採用された手法は，非等方線源あるいは強いストリーミングが存在する体系内の角度線束の振動と負値を除くために十分有効である。本コードシステムの種々のオプションを使用するために必要な入力データの定義と例題についても述べられている。

* 住友原子力工業株式会社

** 富士通株式会社

Program Abstract in NEA DATA BANK Format

1. Name: RADHEAT-V4
2. Computer for which the program is designed and others upon which it is possible: FACOM-M380
3. Nature of physical problem solved: Multi-group cross sections for neutron and photon are generated by using the evaluated nuclear data, ENDF/B, JENDL and DLC-15 for transport, heat generation and radiation damage calculations in nuclear reactors and shields. The secondary gamma-ray production cross section by the neutron induced reaction and the Bremsstrahlung effect is also generated. The radiation transport problems for shielding designs and safety analyses of fusion and fission reactors are solved.
4. Method of solution: A point-wise processing technique and the Bondarenko-type resonance self-shielding factors are adopted to generate multi-group cross sections. One- and two-dimensional S_N -transport methods and three-dimensional Monte Carlo method are used for shielding calculation.
5. Restrictions on the complexity of the problem: The maximum number of neutron and photon fine-group are 200 and 50, respectively. The maximum number of angular meshes in the macroscopic cross section are 64. The energy ranges from 2.61×10^{-5} eV to 16.74 MeV for neutron and those from 1 keV to 20 MeV for photon are available.
6. Typical running time: (a) FAIR-CROSS: At step 1, an iron run with 100 neutron groups takes about 3 minutes. At step 2, a preparation of the macroscopic cross section of water takes about 2 minutes. At step 3, the generation of P_5 cross section takes about 5 seconds for a material. (b) TWOWAY: For a uranium run with 20 photon groups it takes about 1 minute. (c) FDEM: For the production of few -group cross section of a material it takes about 10 seconds. (d) BREM: For the production of Bremsstrahlung data of a material it takes about 20 seconds. (e) DIAC: For a problem of coupled neutron and photon ($100n+20\gamma$) with 32 angular meshes and 50 spatial intervals it takes 30 seconds for a material. (f) ESPRIT: For a problem of coupled neutron and photon ($15n+5\gamma$) with 48 angular meshes and 50×50 spatial intervals it takes 2 minutes for a material. (g) MCACE: The time estimation strongly depends on the particular problem. (h) VISUAL: For the production of a graph it takes less than 1 second. (i) POOL: For the operation with a command it takes mainly about less than 1 second.
7. Unusual features of the program: The angular distribution of the group cross section is expressed by the form of Direct Angular Representation instead of finite Legendre expansion.
8. Related and auxiliary programs: RADHAT-V4 can produce also the cross sections compatible with the ANISN, DOT, MORSE codes by using the FAIR-CROSS step 3.
9. Status:
10. References: "RADHEAT-V4: A Code System to Generate Multigroup Constants and Analyze Radiation Transport for Shielding Safety Evaluation", to be published as the JAERI report (1989). "JSD1000: Multi-Group Cross Section Sets for Shielding Materials", JAERI-M84-038 (1984).
11. Machine requirement: Requires about 1 Mbytes of core storage in addition to the usual complement of tapes and the large-size direct access devices.
12. Programming language used: FACOM M-380 FORTRAN-77. Some ASSEMBLER routine are included.
13. Operating System or monitor under which the program is executed: FACOM MST
14. Any other programming or operating information or restrictions: The program is approximately 76000 source cards. Overlay structures are employed.
15. Name and establishment of author: N. Yamano et al., JAERI Tokai Research Establishment, Tokai -mura, Ibaraki-ken, 319-11, Japan.
16. Material available:

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1. INTRODUCTION

A new version of shielding analysis code system RADHEAT has been developed. In the first version of the RADHEAT system[1], computer codes SUPERTOG[2], GAMLEG[3], POPOP4[4] and some other codes were joined with each other to generate, in the ANISN-format[5], the neutron and photon coupled multigroup cross sections and the energy deposition factor, from ENDF/B-Ⅲ and POPOP4 libraries.

In 1977, the modified version, RADHEAT-V3[6], was developed. The RADHEAT-V3 code system introduced the Bondarenko-type resonance self-shielding factor to generate effective macroscopic cross sections. The anisotropy of the scattering cross section was expressed by the method of finite Legendre expansion.

RADHEAT-V3 was utilized for the mock-up analysis of the primary shield of the Nuclear Ship MUTSU[7]. Varied experience of using the code system has shown that more rigorous treatments for producing the group cross sections from nuclear data and for performing the transport calculations should be essentially needed to improve the accuracy of shielding design and safety calculations. Particularly, the angular flux distribution is a basic quantity for evaluating the radiation current in shield regions. In order to enhance the accuracy in determining the angular flux distibutions, various attempts have been made for describing more precisely the anisotropic scattering of radiations. One of the effective methods is the use of the discrete ordinates S_N-transport calculation by expressing the anisotropic scattering cross section with the Legendre expansion of the cosine of the scattering angle adopted in the RADHEAT-V3 code system.

However, it is known[8),9)] that the S_N-transport calculation gives the negative angular fluxes frequently when a strong anisotropic source is present in the shielding material. One of the causes for the fact that negative angular fluxes appear in the S_N-transport calculation is a fitting error of the differential cross section by using the finite Legendre expansion. The other is the fitting error of the scattering source obtained in the S_N-transport calculation. In removing the former cause, a difficulty exists in generating group to group transfer cross sections as far as the finite Legendre expansion is used. The data of angular dependence in the evaluated nuclear data file such as ENDF/B-Ⅳ are given generally in the form of the Legendre coefficients. The order of these coefficients required in the calculation increases accordingly as the energy of incident neutron goes up. Therefore, in order to enhance the accuracy in describing the angular dependence of the scattering cross section, it is necessary to consider up to the maximum order of the coefficients given in the library[10]. However, the fitting error of scattering cross section is remarkable in the case of treating the neutron scattering of hydrogen by using the finite Legendre expansion. In addition, even a higher order of expansion is needed when the nucleus has the anisotropy like a delta-function of the scattering angles. It is practically difficult because of the actual restrictions in the computation time and computer memories.

In eliminating the latter cause, the first collision method is generally effective. However, it is not effective as a remedy for the former cause. Therefore, an improvement for obtaining the accurate angular flux has to be done by using the method without adopting the Legendre expansion in generating the group to group transfer cross sections and in performing the S_N-transport calculation.

Takeuchi[11] and Nakai[12] et al. have developed a method in which scattering sources are calculated without using the Legendre expansion for the elastic scattering component in the integral-type transport equation. This method is effective to eliminate the latter cause mentioned above. Takahashi et al.[9] introduced a new function $I_l(\mu', \mu)$ to express an anisotropic part of scattering kernel in the differential -type transport equation. The scattering kernel $I_l(\mu', \mu)$ adds to the isotropic scattering component. It is

therefore not easy to generalize and systematize the algorithm using the conventional form of group cross sections for dealing with $I_i(\mu', \mu)$. Nakaya et al.[13] calculated the group to group transfer cross sections with respect to the representative angles of each solid angle bin in the one-dimentional differential-type transport equation. Therefore, this method assumes that the scattering integral is approximately constant inside each solid angle bin and hence it is apt to introduce an error in the angular dependency. Recently, a BERMUDA[14] code system which can eliminate the difficulties mentioned above has been developed at JAERI for fusion neutronics application. The BERMUDA code system can solve one- and two-dimensional integral-type transport equations.

As the code system for generating coupled multi-group neutron and photon cross sections, modular codes AMPX[15] and MINX[16] developed at ORNL, NJOY[17] at LANL and THEMIS-4[18] at CEA have been used in nuclear criticality and shielding calculations. These codes generally have a feature that the precise treatments such as a point-wise processing technique are adopted to generate multi-group cross sections from resonance parameters given in nuclear data files. However, the angular distributions of the cross sections are expressed by the conventional method of finite Legendre expansion.

Recently, in Monte Carlo applications, a method which directly uses the point-wise cross section for energy and angle has been developed and adopted in such codes as MCNP[19], TRIPOLI-2[20]. On the other hand, MORSE-DD[21] which uses the multi-group DDX (Double Differential X-sec.) has been developed. These codes can eliminate the difficulties mentioned above, while deep penetration problems are not easily solved by the Monte Carlo codes without using some adequate biasing techniques.

The RADHEAT-V4 code system which is the latest version of RADHEAT has been developed to perform more precise evaluation of the angular fluxes in shield regions and has completed to eliminate the difficulty mentioned above. The system consists of the functional modules for producing the neutron and photon coupled multi-group cross section sets from a nuclear data library of ENDF/B format, and for analyzing the neutron and photon transport and the atomic displacement in shield regions with one-, two-, and three-dimensional configurations. Most of the functional modules contained in RADHEAT-V4 have been newly developed. The features of the system are as follows: 1) a method for generating point-wise cross sections is adopted to produce an "ultra-fine" group cross section, (The "ultra-fine" group structure consists of 3829 groups), 2) the secondary gamma-ray production cross sections can be calculated from the ENDF/B-IV and the POPOP4 library, 3) the Bondarenko-type self-shielding factors[22] and the infinite dilution cross sections are generated by using the ultra-fine group cross sections, 4) the method for generating atomic displacement cross sections has been changed to a modified Dorant method, 5) the angular distribution of the group cross section is expressed by using the "Direct Angular Representation (DAR)" method[23] instead of the method of the finite Legendre expansion, 6) the transport calculations of one-, two- and three-dimensions can be carried out by using the group cross sections with the discrete-type DAR form directly, so that the errors associated with the use of the finite Legendre expansion can be eliminated, 7) the secondary gamma-ray production by the Bremsstrahlung effect can be estimated for the one-dimensional configuration, 8) many types of data produced by the system are stored in a direct-access data base and can be handled easily with an interactive management utility, and 9) a quick evaluation of data generated by the system can be performed by using an interactive plotting utility.

The hierarchy of RADHEAT-V4 developed with the above considerations is shown in **Fig. 1.1**. The neutron multi-group cross sections based on the infinite dilution approximation and the Bondarenko-type resonance self-shielding factors of each reaction are produced in FAIR-CROSS step. 1. Atomic displacement cross section and energy deposition factor can also be obtained by using the FAIR-CROSS step 1. The secondary gamma-ray production cross sections are produced in TWOWAY by using the ENDF/B-IV and the POPOP4 library. The coupled neutron and photon group cross sections for the transport calculation are generated in FAIR-CROSS step 2. The radiation transport is calculated by DIAC (one-dimensional S_N-transport method), ESPRIT (two-dimensional S_N-transport method) and

MCACE (three-dimensional Monte Carlo method). The effective cross sections for heterogeneous zones and collapsed cross sections are generated in FDEM. VISUAL[24] is prepared for a graphic plotting of the various data produced in RADHEAT-V4. POOL is an interactive management utility of the RADHEAT -V4 data base. DATA-POOL means the RADHEAT-V4 data base which consists of a control package and a direct-access memory device. FAIR-CROSS step 3 converts the format of cross section from the discrete-type DAR form to the finite Legendre expansion one named as the ANISN-type group cross section, so that the cross section generated by the RADHEAT-V4 can be utilized for the conventional transport code like ANISN[25], DOT[26] and MORSE[27].

The multi-group cross section library used for ordinary shielding calculations has been produced by FAIR-CROSS and TWOWAY modules. The library contains the following data: 1) The ultra-fine group cross sections at 300, 560 and 900K, 2) the fine-group cross sections at 300, 560 and 900K, 3) the self-shielding factors at 300, 560 and 900K, 4) the secondary gamma-ray data at 300, 560 and 900K, and 5) the coupled neutron and photon group cross sections.

Cross sections for 43 nuclides are generated from ENDF/B-IV and the JAERI standard 100 energy group structure[28] is adopted as the fine-group ones. The neutron and photon cross sections for 32 materials are generated in S_{32} approximation of the discrete-type DAR form. The photon energy group structure is the same as that of the EURLIB 20 groups[36]. The weighting function used in the calculation consists of three part: a Maxwellian shape from 10^{-5} eV to 0.125 eV, a $1/E$ spectrum from 0.125 eV to 820.8 keV, and a fission spectrum (neutron temperature $\theta_T = 1.4$ MeV) from 820.8 keV to 16.5 MeV. The multi-group cross section library named "JSD1000" will be used in shielding safety analyses after detailed evaluation is performed. The description of the JSD1000 library[29] is given in the reference and the method of cross section generation is shown in Chap. 2.

The transport calculation is performed by the three modules described above. The DIAC module adopts a one-dimensional S_N-transport method[23]. The method makes use of the transfer probability function P to eliminate the fitting error due to the finite Legendre expansion. The DIAC module is an improved version of ANISN-JR[25], so that the functions available in DIAC are the same as in ANISN-JR. The description of DIAC is shown in Chap. 3.1. To assess the new method, some test calculations have been carried out and compared with exact solutions. It has been shown that the method applied to DIAC is effective for eliminating negative values and oscillations of the angular flux in anisotropic S_N-transport calculations. The detailed descriptions for the results of the test calculations and for the usage of DIAC are also given in the chapter.

The ESPRIT module uses the same method as adopted in DIAC except for introducing a geometrical form function G. The method adopted in the ESPRIT module is described in Chap. 3.2. For two-dimensional geometries containing a strong streaming pass, the error associated with the use of the finite Legendre expansion appears remarkable in the evaluation of leakage current. The accuracy for leakage current estimation is demonstrated in the results obtained by using ESPRIT module, as shown in Chap 3.2. The ESPRIT module is an improved version of DOT-3.5[26], so that the functions available in ESPRIT are the same as in DOT-3.5. The input instruction and notes to operation for ESPRIT are also given in the chapter.

Three-dimensional Monte Carlo code, MCACE, is an improved version of MORSE-CG[27]. The procedures to calculate cumulative probabilities and to determine a scattering angle by a random number are changed for adopting directly the group cross sections of the discrete-type DAR form. Many kind of surface crossing estimators have been added as detectors. A bootstrap calculation can also be performed by utilizing the surface crossing estimator. Three biasing techniques have been newly developed for MCACE. One of them is named "Region penetration Biasing", which is a method joining the splitting and the path length stretching techniques. The second of them is "Collision Times Biasing" technique for duct -streaming problems. The third of the new biasing techniques is called "Automatic Russian Roulette Biasing". The detailed description and the verification for these biasing techniques are given in Chap. 3.3.

The input instruction and notes to operation for MCACE are also described in the chapter.

The estimation of the secondary gamma-ray production by the Bremsstrahlung effect is performed by the BREM module, as shown in Chap. 3.4. The processes of the calculations are also shown in Chap. 5.

The data generated in RADHEAT-V4 are stored in a direct-access data base named "DATA-POOL". The data base consists of a control, a directory and a data section. The directory section has information for node names and direct addresses of records. The node name which consists of 4-characters is arbitrarily defined by the user, and is used for searching the records of the data. The data generated in RADHEAT-V4 are classified according to several tree structures of the node names and stored in the data section. The detailed structure of the DATA-POOL is described in Chap. 4.1 and also shown in the reference.

The management utility POOL has been prepared to maintain the DATA-POOL. POOL has 14 operation commands such as INIT (initialize the DATA-POOL), DELETE (delete node name and data), TREE (display tree structure), RENAME (rename node name) and so on. It can be used from TSS terminals or by batch jobs. The usage for POOL is described in Chap. 4.2.

The utility VISUAL has been prepared to plot various data generated by the RADHEAT-V4 code system. The graphic patterns plotted with VISUAL are of three types that are two-dimensional graph $(f(x);x)$, contour-line map $(f(x,y);x,y)$ and three-dimensional graph as the bird's eye view $(f(x,y);x,y)$. The input instruction for VISUAL is described in Chap. 4.3.

Some test calculations and sample problems have been also discussed in order to grasp the characteristics of the DAR method applied to the RADHEAT-V4 code system.

From the above test calculations, it has been shown that the method is effective for eliminating negative values and oscillations of the angular flux in anisotropic transport calculations. In order to evaluate the accurate angular flux in a medium having an anisotropic source or a strong streaming, it will be necessary to use the method which can calculate the radiation transport without using the Legendre expansion for expressing the anisotropic components. Using this code system, it is possible to perform systematic calculations starting from the generation of the group cross sections to the transport calculations for strong anisotropic problem.

The input FIDO format adopted in the RADHEAT-V4 code system is described in Appendix A and the input instruction of Combinatorial Geometry used in the MCACE module is shown in Appendix B. The record format of the DATA-POOL is shown in Appendix C. The sample input/output lists for the problems described in Chap. 5 are shown in Appendix D.

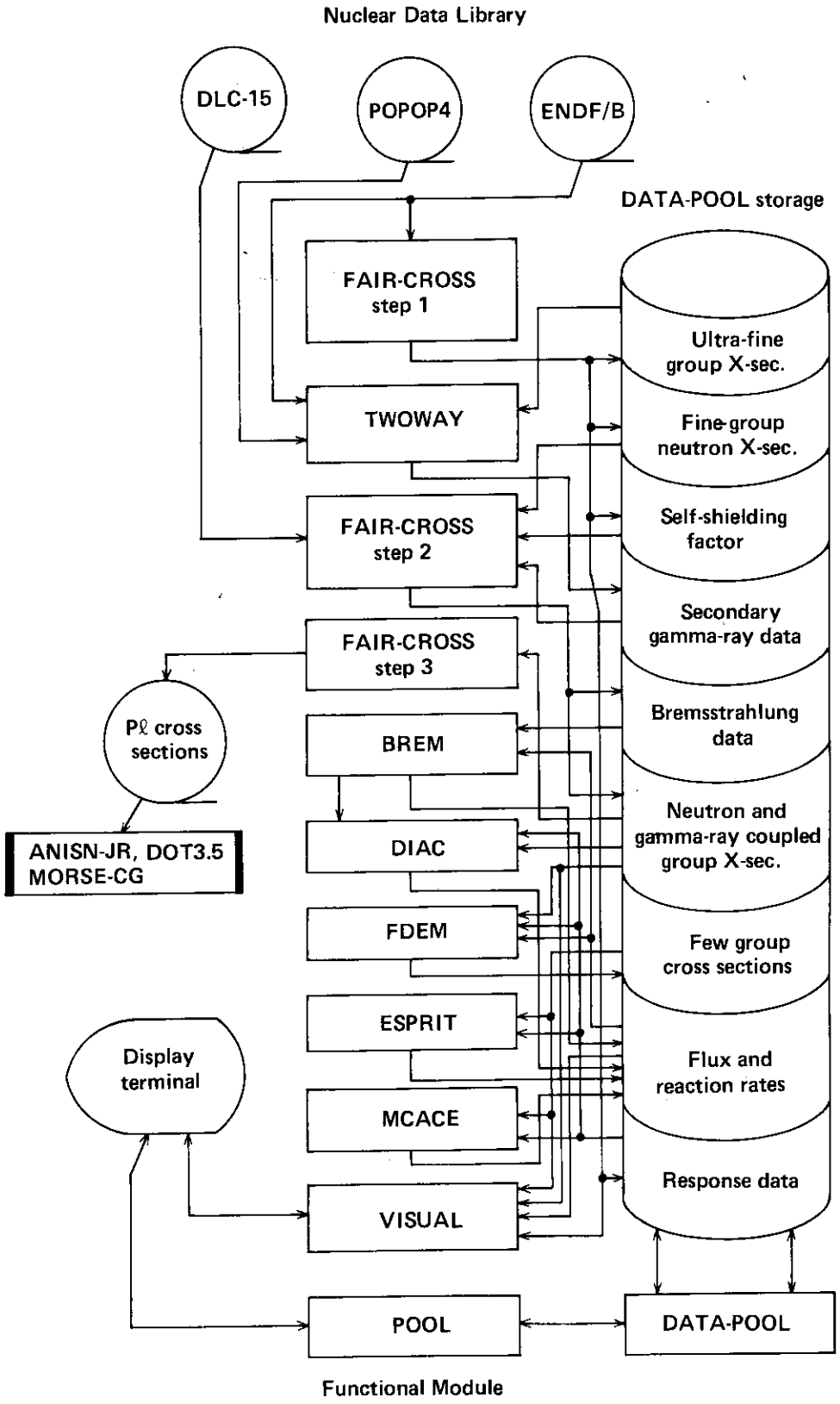


Fig. 1.1 Hierarchy of the RADHEAT–V4 code system

2. Module for Generating Multigroup Cross Sections

The FAIR-CROSS and the TWOWAY modules are used to generate multigroup cross sections in the RADHEAT-V4 code system. Nuclear data of ENDF/B[10], JENDL[30], POPOP4[4] and DLC-15[31] libraries can be used to generate the cross sections. The system flow of the FAIR-CROSS and TWOWAY modules is shown in **Fig. 2.1**. The FAIR-CROSS is a major part in the RADHEAT-V4 code system and has many processing subroutines, so that the module is divided into three steps. The ultra-fine group cross sections are produced in the beginning stage of the FAIR-CROSS step 1. The fine-group cross sections and Bondarenko-type self-shielding factors of each reaction are generated in the later stage of the FAIR-CROSS step 1. Scattering matrices including up-scattering and atomic displacement cross sections are also produced in this step. Secondary gamma-ray production cross sections are produced by the TWOWAY module using the ultra-fine group cross sections and nuclear data libraries, ENDF/B or POPOP4. Effective neutron and gamma-ray coupled macroscopic cross sections for a homogenized mixture are produced in the FAIR-CROSS step 2. Gamma-ray cross sections are generated by using an empirical formula or DLC-15 library. Bremsstrahlung data can also be calculated at the step 2. Step 3 converts the cross sections of the discrete-type DAR form to the Legendre expansion one. Each stage for generating the cross sections is described in the following sections.

2.1 FAIR-CROSS

FAIR-CROSS is a program which generates coupled neutron and gamma-ray cross sections for multigroup transport calculations using evaluated nuclear data file such as ENDF/B or JENDL. Various considerations have been taken into account to compute cross sections are exactly as possible. The features of each step are as follows:

step 1:
1) resolved resonance cross sections are reconstructed from resonance parameters given in the ENDF/B or JENDL library to pointwise cross sections by using the same scheme as adopted in the RESEND[33] code and unresolved resonance cross sections are reconstructed to average cross sections by using the same scheme as in the MC^2 code[34],
2) temperature dependent cross sections associated with the Doppler broadening are computed by using a kernel broadening technique adopted in the SIGMA1 code[47],
3) the ultra-fine group cross sections which consist of 3829 groups are computed as the basic data to generate scattering matrices, atomic displacement cross sections, energy deposition factors, secondary gamma-ray production cross sections and the fine-group cross sections,
4) the Bondarenko-type self-shielding factors for each background cross section and temperature are computed for total, elastic scattering, fission and (n, γ) reactions with the fine-group structure,
5) group-to-group scattering matrices for elastic, inelastic and $(n, 2n)$ scattering reactions are generated by using a new DAR method so that the angular distribution of the scattering matrices is directly represented by a function of the scattering angle,
6) atomic displacement cross sections and energy deposition factors by the primary knock-on atom are computed,

step 2:
1) the effective coupled neutron and gamma-ray cross sections are generated by using the method of spline fitting to interpolate the self-shielding factors,
2) the secondary gamma-ray production cross sections are produced by using the effective neutron cross sections and the data computed by the TWOWAY module,

3) the gamma-ray cross sections and the energy-absorption coefficients are computed by using an empirical formula or DLC-15 library,

4) the group to group transfer cross sections are represented as the functions of fixed scattering angles defined by the user (the discrete-type DAR form),

5) Bremsstrahlung data are generated to estimate photon-electron-photon interactions,

step 3: 1) the cross section tables represented in each scattering angle are converted to the conventional forms of Legendre expansion adopted in ANISN, DOT and MORSE codes.

The various models and the methods for numerical processing are adopted in the FAIR-CROSS module. The descriptions of generating methods are shown in the following sections. The data generated in the FAIR-CROSS module are stored in the DATA-POOL in association with appropriate node names. The record formats of the data are described in Appendix C.

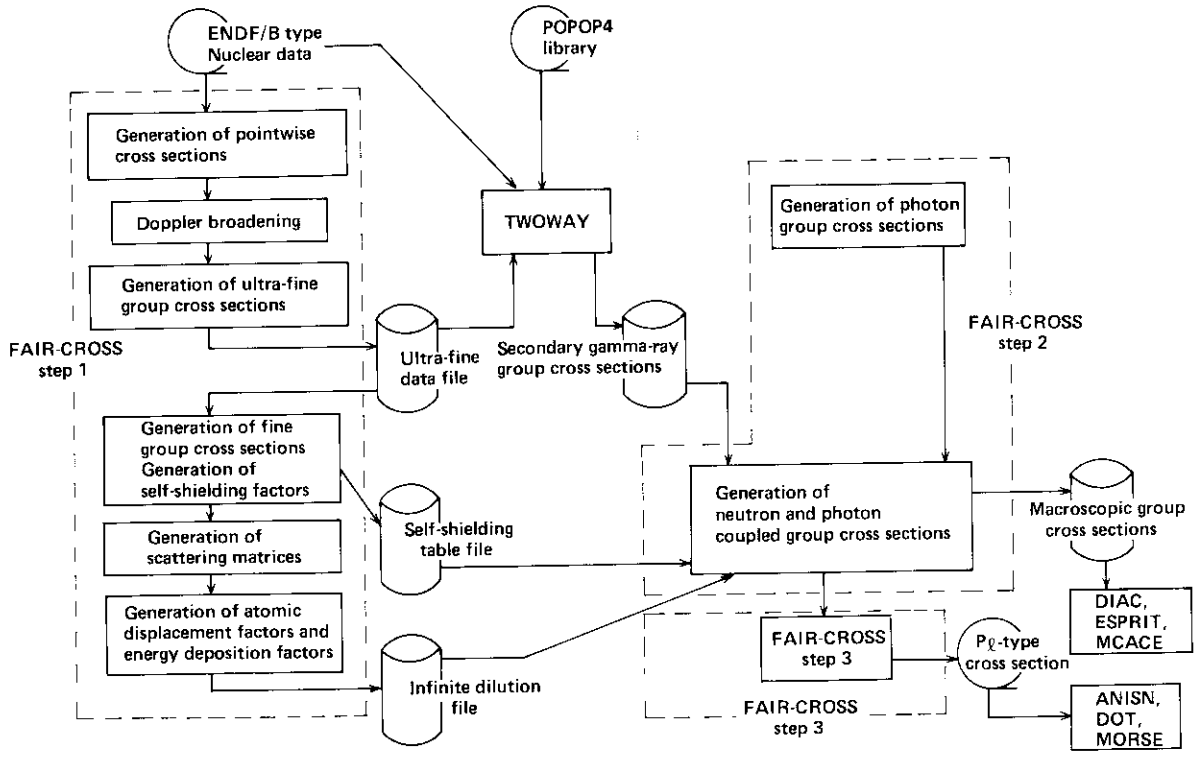


Fig. 2.1 Flow chart of group cross section generation in the RADHEAT-V4 code system

2.1.1 Ultra-Fine Group Cross Section

The ultra-fine group cross sections are generated by processing the nuclear data of ENDF/B format. The calculational process is divided into three parts of resonance treatment, Doppler-broadening and weighting procedures.

In the energy region of resolved resonance, point-wise cross sections are generated from resonance parameters in the nuclear data file by using the method adopted in a modified version[32] of the RESEND[33] program. In the method, the following algorithm is used to reconstruct the resonances exactly within some specified tolerance.

(a) Neighbouring two peak energies of resonances are selected as shown in **Fig. 2.2** (points A and B)

(b) The exact cross section value f_1 at the mid-point E_1 between two peaks is calculated using a specified formula.

(c) The approximate value $\bar{f}_1$ at the E_1 is calculated by the linear interpolation and compared with

the exact value. If the fractional difference at the mid-point is larger than the specified tolerance, a new mid-point E_2 is appointed in the left half interval and the same process described above is repeated.

(d) When the fractional difference is attained smaller than the specified tolerance, the energy interval is fixed and the process is repeated for the right side of energy interval.

To reduce the computing time, a linear interpolation scheme can be used for the tail of resonance in the FAIR-CROSS. The energy region of the tail is defined by the α times of the resonance width Γ:

$$E<E_0-\alpha\Gamma \text{ and } E>E_0+\alpha\Gamma \tag{2. 1}$$

where E_0 is the peak energy of a resonance and α is given by the input data (AVERR in 10* array). The use of this technique should be avoided by setting α to zero even if the exact cross sections are desired.

For the energy region of unresolved resonance, the averaged cross sections are computed by the method adopted in the MC^2 code. In this method, the infinite dilution cross sections and self-shielded cross sections with Doppler-broadening are directly obtained.

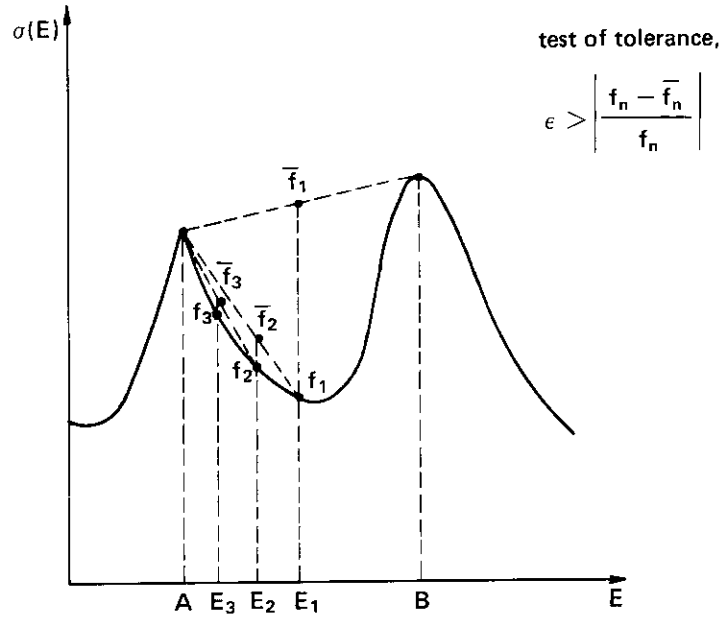


Fig. 2.2 Reconstruction procedure for resolved resonances

FAIR-CROSS adopts the subroutines that are modified ones of the SUPERTOG-JR3[35] code (subroutine RESU et al.).

A special option has been added to the input instruction of LINK1=2 in 4$ array. In this option, the infinite dilution and unbroadened cross sections are computed by the same method adopted in the resolved resonance region. The effects of the self-shielding and the Doppler broadening are considered by multiplying the ratios of the effective cross sections to the infinite diluted and unbroaded ones calculated in the RESU subroutine. In some nuclear data files, the discontinuity may appear in the boundary of the resolved and unresolved resonance regions. For this case, this option is useful to hold the continuity at the boundary.

Temperature dependence of the cross section is taken into account by the method[47] of kernel-broadening described below.

The change of cross sections caused by the thermal motion of a target nucleus at temperature T is given by the following equation:

$$\sigma(v, T)=\frac{1}{\rho v}\int dv'\cdot\rho\cdot|v-v'|\cdot\sigma(|v-v'|, T=0)\,P(v', T), \tag{2. 2}$$

where ρ : density of a target nucleus,

v, v' : velocities of a incident neutron and a target nucleus,

$\sigma(|v-v'|, T=0)$: cross section for a static target nucleus ($T=0$ K)

$P(v', T)$: velocity distribution function of a target nucleus in the laboratory system.

Assuming that the distribution function is a Maxwell–Boltzmann distribution, this function is given by following equation:

$$P(v', T)dv' = (\frac{\beta}{\pi})^{3/2}\exp(-\beta v'^2)dv', \tag{2. 3}$$

where

$$\beta = \frac{M}{2kT},$$

M is the mass of a target nucleus and k is the Boltzmann constant. Let's define a relative velocity $V = |v-v'|$, and Eq. (2.2) becomes

$$\sigma(v, T) = \frac{1}{v^2}(\frac{\beta}{\pi})^{1/2}\int_0^\infty dV\sigma(V, 0)V^2[\exp\{-\beta(V-v)^2\} - \exp\{-\beta(V+v)^2\}] . \tag{2. 4}$$

Converting the velocity v to the energy $E = mv^2/2$, Eq. (2.4) becomes

$$\sigma(E, T) = \frac{1}{2E}(\frac{\alpha}{\pi})^{1/2}\int_0^\infty dE_r\sqrt{E_r}\sigma(E_r, 0)[\exp\{-\alpha(\sqrt{E_r}-\sqrt{E})^2\} - \exp\{-\alpha(\sqrt{E_r}+\sqrt{E})^2\}] , \tag{2. 5}$$

where, $\alpha = A/kT$ (Doppler width constant),

$A = M/m$ (atomic mass ratio),

$E_r = mV^2/2$ (relative energy).

Now let's define new variables x and y for a numerical calculation;

$$x^2 = \alpha E_r ,$$

$$y^2 = \alpha E .$$

Substitution of the variables into Eq. (2.5) yields,

$$\sigma(y, T) = \frac{1}{y^2}(\frac{1}{\pi})^{1/2}\int_0^\infty dx\cdot x^2\sigma(x, 0)[\exp\{-(x-y)^2\} - \exp\{-(x+y)^2\}] , \tag{2. 6}$$

Equation (2.6) is divided into two terms which are called Doppler broadening and Doppler thinning, respectively.

$$\sigma(y, t) = \sigma^*(y, T) + \sigma^*(-y, T) , \tag{2. 7}$$

where

$$\sigma^*(y, T) = \frac{1}{y^2}(\frac{1}{\pi})^{1/2}\int_0^\infty x^2\sigma(x, 0)\exp\{-(x-y)^2\}dx . \tag{2. 8}$$

when $|x-y| \gg 1$, the exponential term in Eq. (2.8) becomes near zero, so that we have the following equation:

$$\sigma^*(y, T) = \frac{1}{y^2}(\frac{1}{\pi})^{1/2}\int_{y-\Delta}^{y-\Delta} x^2\sigma(x, 0)\exp\{-(x-y)^2\}dx + R(y) , \tag{2. 9}$$

where

$$R(y) = \frac{1}{y^2}(\frac{1}{\pi})^{1/2}\{\int_0^{y-\Delta} x^2\sigma(x, 0)\exp\{-(x-y)^2\}dx + \int_{y+\Delta}^0 x^2\sigma(x, 0) \times \exp\{-(x-y)^2\}dx\} . \tag{2. 10}$$

If we determine the value Δ to make the tolerance $\varepsilon > R(y)/\sigma^*(y, T)$, Eq. (2.8) can be approximated by

the following expression:

$$\sigma^*(y,\ T)=\frac{1}{y^2}\left(\frac{1}{\pi}\right)^{1/2}\int_{y-\Delta}^{y+\Delta}x^2\sigma(x,\ 0)\exp\{-(x-y)^2\}\,dx\ . \tag{2.11}$$

In this procedure, 4.0 is set for Δ. This condition is equivalent to set the tolerance $\varepsilon=10^{-3}$. Assuming that $\sigma(x,\ 0)$ is given by a linear interpolation with the point-wise data of $(x_i,\ \sigma_i)$, Eq. (2.11) becomes simple form described below:

$$\sigma(x,\ 0)=\sigma_i+S_i(x^2-x_i^2)\quad for\quad x_i\leq x\leq x_{i+1} \tag{2.12}$$

where

$$S_i=(\sigma_{i-1}-\sigma_i)/(x_{i+1}^2-x_i^2)\ ,$$

$$\sigma^*(y,\ T)=\frac{1}{y^2}\left(\frac{1}{\pi}\right)^{1/2}\sum_i\int_{x_i}^{x_{i+1}}x^2\cdot\sigma_i+S_i(x^2-x_i^2)\exp\{-(x-y)^2\}\,]\,dx\ . \tag{2.13}$$

Defining $z=x-y$, Eq. (2.13) becomes

$$\begin{aligned}\sigma^*(y,\ T)&=\frac{1}{y^2}\left(\frac{1}{\pi}\right)^{1/2}\sum_i\int_{x_i-y}^{x_{i+1}-y}(z+y)^2\{\sigma_i-S_ix_i^2+S_i(z+y)^2\}\exp(-z^2)dz\\&=\sum_i\{A_i(\sigma_i-S_ix_i^2)+B_iS_i\}\ ,\end{aligned} \tag{2.14}$$

where

$$A_i=\frac{1}{y^2}\left(\frac{1}{\pi}\right)^{1/2}\int_{x_i-y}^{x_{i+1}-y}(y+z)^2\exp(-z^2)dz\ , \tag{2.15}$$

$$B_i=\frac{1}{y^2}\left(\frac{1}{\pi}\right)^{1/2}\int_{x_i-y}^{x_{i+1}-y}(y+z)^4\exp(-z^2)dz\ . \tag{2.16}$$

The above A_i and B_i are computed as follows:

For $a,\ b\geq 0\ (a<b)$

$$A_i=H_2(a,\ b)/y^2+2H_1(a,\ b)/y+H_0(a,\ b)\ , \tag{2.17}$$

$$B_i=H_4(a,\ b)/y^2+4H_3(a,\ b)/y-6H_2(a,\ b)-4yH_1(a,\ b)+y^2H_0(a,\ b)\ , \tag{2.18}$$

For $a,\ b<0\ (a>b)$

$$A_i=H_2(a,\ b)/y^2-2H_1(a,\ b)/y+H_0(a,\ b)\ , \tag{2.19}$$

$$B_i=H_4(a,\ b)/y^2-4H_3(a,\ b)/y+6H_2(a,\ b)-4yH_1(a,\ b)+y^2H_0(a,\ b)\ , \tag{2.20}$$

where the function $H_n(a,\ b)$ is defined below:

$$\begin{aligned}H_n(a,\ b)&\equiv\left(\frac{1}{\pi}\right)^{1/2}\int_a^b z^n\exp(-z^2)dz\ ,\\&=F_n(a)-F_n(b)\ ,\end{aligned} \tag{2.21}$$

and

$$F_0(a)=\mathrm{erfc}(a)/2\ , \tag{2.22}$$

$$F_1(a)=\left(\frac{1}{\pi}\right)^{1/2}\exp(-a^2)/2\ , \tag{2.23}$$

$$F_n(a)=\frac{1}{2}\ \{(n-1)F_{n-2}(a)+a^{n-1}\left(\frac{1}{\pi}\right)^{1/2}\exp(-a^2)\}\ ,\ (n\geq 2)\ . \tag{2.24}$$

In Eq. (2.22) erfc(a) is the error function. The Doppler-broadening described above is calculated for the energy range from 50 meV to 3 MeV. Reactions for which the Doppler-broadening is taken into

consideration are total, elastic scattering, fission, (n, γ), (n, p) and (n, α).

The ultra-fine group cross sections are produced by averaging the point cross sections generated as above. A weighting function for average process is given by the following equation:

$$\phi(E, \sigma_0, T)=\frac{\phi_s(E, T)}{\sigma_t(E, T)+\sigma_0}$$

$$\phi_s(E, T)=\begin{cases}\sqrt{E}\exp(-E/T_c) & 0.8205\text{MeV}^{\dagger}\leq E \\ 1/E & 0.125\text{eV}^{\dagger}<E<0.8205\text{MeV}^{\dagger} \\ E\exp(-E/kT), & E\leq 0.125\text{eV}^{\dagger}\end{cases} \tag{2. 26}$$

where σ_t is the total cross section, k is the Boltzman constant and T_c the neutron temperature of fission spectrum selected as $T_c=1.4$ MeV†.

Group cross sections with the ultra-fine group structure are calculated by two equations as follows:

For outside of the unresolved resonance region,

$$\sigma_x^i(\sigma_0, T)=\frac{\int_{E_i}^{E_{i+1}}\sigma_x(E, T)\cdot\phi(E, \sigma_0, T)dE}{\int_{E_i}^{E_{i+1}}\phi(E, \sigma_0, T)dE}, \tag{2. 27}$$

and for the unresolved resonance region,

$$\sigma_x^i(\sigma_0, T)=\sigma_{ux}^i(\sigma_0, T), \tag{2. 28}$$

where,

σ_x^i : group cross section for the ultra-fine group i and the reaction type x,

$\sigma_x(E, T)$: Doppler broaded point-wise cross section,

$\sigma_{ux}^i(\sigma_0, T)$: averaged unresolved resonance cross section for the ultra-fine group i and the reaction type x,

$\phi(E, \sigma_0, T)$: weighting function described above,

σ_0, T : background cross section and temperature, respectively.

The number of group average neutrons per fission $\bar{\nu}^i$ is calculated by the following way.

For outside of the resonance region,

$$\bar{\nu}^i=\frac{\int_{E_i}^{E_{i+1}}\nu(E)\phi_f(E, T_0)\phi_s(E, T_0)dE}{\int_{E_i}^{E_{i-1}}\sigma_f(E, T_0)\phi_s(E, T_0)dE} \tag{2. 29}$$

and for the resonance region,

$$\bar{\nu}^i=\frac{\int_{E_i}^{E_{i+1}}\nu(E)\phi_s(E, T_0)dE}{\int_{E}^{E_{i+1}}\phi_s(E, T_0)dE}, \tag{2. 30}$$

where σ_f is the fission cross section and T_0 a standard temperature selected as 300 K.

The ultra-fine group structure consists of 3829 groups as shown in **Table 2.1**††. The reaction type contained in the ultra-fine group cross sections are shown in **Table 2.2**.

The basic flow of generating the ultra-fine group cross sections is shown in **Fig. 2.3**.

† These values can be changed by the user (7*array).

†† The energy group structure can be changed by replacing a subroutine GETFG.

Table 2.1 Energy group structure for the ultra-fine group cross sections

Group No.	Lower energy (ev)	Lower velocity (cm/sec)	Lower lethargy
1	2.6082E−5+	7.0640E+3	26.67236
		an equi-velocity width of 2700.0	
326	4.0898E−1	8.8455E+5	17.01218
327	4.1399E−1	8.8995E+5	17.00000
			an equi-lethargy width of 0.005
3727	1.0000E+7	4.3740E+9	0.0
			an equi-lethargy width of 0.005
3829	1.6736E+7*	5.6585E+9*	−0.515*

+) Read as 2.6082×10^{-5}

*) These values indicate the upper ones of the energy group.

Table 2.2 Reaction types and the identification numbers for the ultra-fine group cross sections

Reaction type	Reaction I. D. No.
Total	1
Elastic scattering	2
Total inelastic scattering	4
Total (n, 2n) scattering	16
Excited (n, 2n) scattering	6-9, 46-49
Fission	18
Neutrons per fission	452
(n, n'α) scattering	22
(n, n'3α) scattering	23
(n, 2nα) scattering	24
(n, n'p) scattering	28
Absorption	27
Inelastic discrete level	51-90
Inelastic continuum level	91
(n, γ)	102
(n, p)	103
(n, d)	104
(n, t)	105
(n, ^{3}He)	106
(n, α)	107
(n, 2α)	108

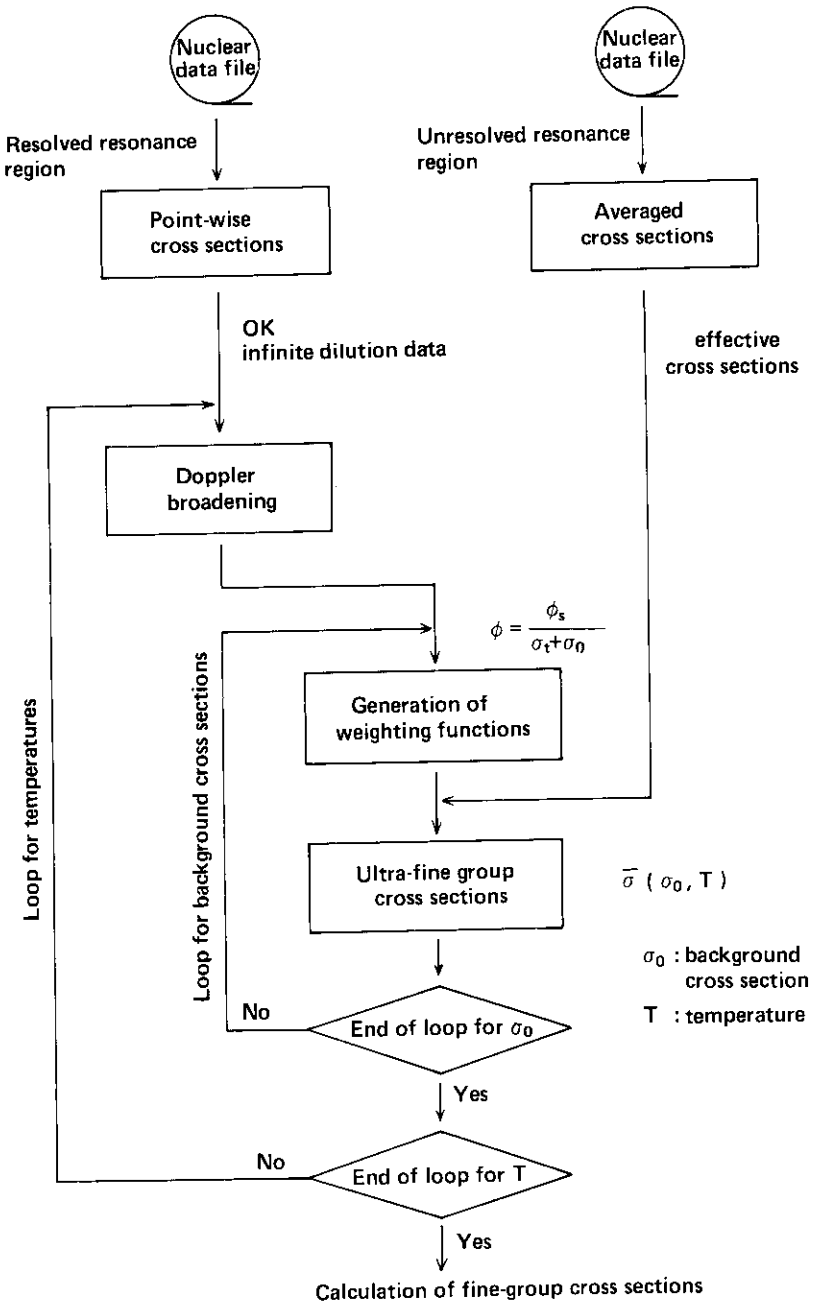


Fig. 2.3 Calculational process of ultra-fine group cross sections

2.1.2 Infinite Dilution Cross Section

Infinite dilution cross sections of each reaction ($\sigma_0=\infty$) are generated by using the following equations:

$$\sigma_k^j(\sigma_0, T)=\frac{\sum_{i\in j}\sigma_x^i(\sigma_0, T)W^i(\sigma_0, T)(E_{i+1}-E_i)}{\sum_{i\in j}W^i(\sigma_0, T)(E_{i+1}-E_i)}, \tag{2. 31}$$

$$\bar{\nu}^j=\frac{\sum_{i\in j}\nu^i\sigma_f^i(\sigma_0, T_0)W^i(\sigma_0, T_0)(E_{i+1}-E_i)}{\sum_{i\in j}\sigma_f^i(\sigma_0, T_0)W^i(\sigma_0, T_0)(E_{i+1}-E_i)}, \tag{2. 32}$$

where a suffix i shows a ultra-fine group number, j shows a fine-group number, $i \in j$ means the ultra-fine group numbers included in a fine-group number j, and W^i is given by the following equation:

$$W^i(\sigma_0, T) = \frac{\int_{E_i}^{E_{i+1}} \phi(E, \sigma_0, T) dE}{E_{i+1} - E_i} . \quad (2.33)$$

When the boundary energy of the fine-group structure is not equal to that of the ultra-fine group structure, the ultra-fine group cross section is assumed to be constant in the fine-group in calculating Eqs. (2.31) and (2.32). If the both boundary energies are equal, the fine-group cross sections calculated by Eq. (2.31) is exactly the same as the fine-group cross sections calculated directly from Eq. (2.27).

The fine-group cross section for total reaction is calculated from the total cross section given by the nuclear data file, so that the elastic scattering cross section is modified to conserve the neutron balance. The modification is performed by the following manner:

$$\delta^j = \sigma_t^j(\sigma_0 = \infty, T_0) - \sigma_e^j(\sigma_0 = \infty, T_0) - \sigma_f^j(\sigma_0 = \infty, T_0) - \sigma_{n\gamma}^j(\sigma_0 = \infty, T_0) - \sigma_{others}^j , \quad (2.34)$$

$$\sigma_e'^j(\sigma_0, T) = \sigma_e^j(\sigma_0, T) + \delta^j . \quad (2.35)$$

The δ^j means the sum of residual cross sections which are not processed by the FAIR-CROSS module, and is the error of calculation. Reactions contained in the fine-group cross sections are shown in **Table 2.3**.

Table 2.3 Reaction types and the identification numbers for the fine-group cross sections

No.	Reaction Type
1	Total cross section
2	Elastic scattering cross section
4	Total inelastic cross section
16	(n, 2n) cross section
18	Total fission cross section
27	Absorption cross section
102	(n, γ) radiative capture cross section
103	(n, p) cross section
107	(n, α) cross section
452	$\bar{\nu}$, average total (prompt plus delayed) number of neutrons released per fission event

2.1.3 Self-Shielding Factor

Temperature dependent self-shielded cross section $\sigma_x^j(\sigma_0, T)$ is calculated only for total, elastic scattering, capture and fission reactions. For the other reactions, the infinite dilution cross sections for 0 K are calculated except for (n, p) and (n, α) reactions. The (n, p) and (n, α) reaction cross sections are calculated for a standard temperature, normally 300 K. Self-shielding factors are calculated from the fine-group cross sections by using the following equations:

$$f_t^j(\sigma_0, T) = \frac{\sigma_e^j(\sigma_0, T) + \sigma_f^j(\sigma_0, T) + \sigma_{n\gamma}^j(\sigma_0, T) + \sigma_{others}^j}{\sigma_t^j(\sigma_0 = \infty, T_0)} , \quad (2.36)$$

$$f_x^j(\sigma_0, T) = \frac{\sigma_x^j(\sigma_0, T)}{\sigma_x^j(\sigma_0 = \infty, T_0)} \quad (2.37)$$

where the reaction type x means elastic scattering, fission and capture.

The data library of the RADHEAT-V4 code system contains these self-shielding factors at σ_0=0, 1, 10, 100, 1000, 10000 and T=300, 560, 900 K. The data are utilized for generating the effective cross section. The basic flow of generating the self-shielding factor and the fine-group cross section is shown in **Fig. 2.4**.

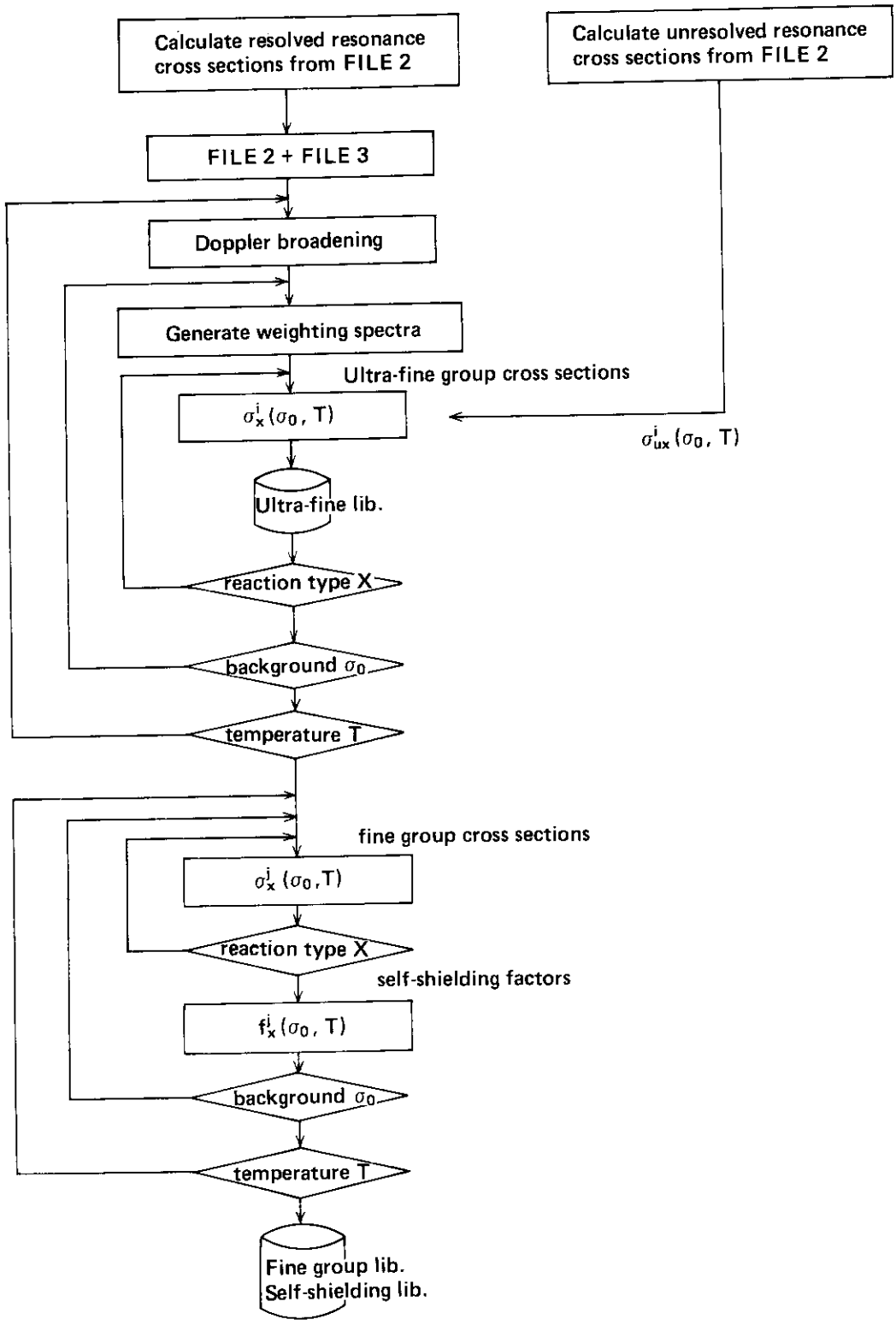


Fig. 2.4 Calculational flow of self-shielding factors and fine-group cross sections

2.1.4 Scattering Matrix

The angular distribution of neutron scattering cross section becomes anisotropic in the high energy region. In the fine energy group structure, the anisotropy becomes much noticeable. Most of the codes for generating multigroup cross sections such as SUPERTOG, AMPX and NJOY adopt the P_ℓ-approximation to represent the angular distribution. However, it is impossible to describe the anisotropy of angular cross section accurately by the P_ℓ-approximation of the limited order in the fine energy group structure.

For this reason, FAIR-CROSS adopts a method to represent the angular distributions of the scattering matrix named DAR (Direct Angular Representation). The processing method to generate the scattering matrix has been developed and is described in this section.

The double differential scattering cross section is given by the following form:

$$\sigma_s(E', E, \mu)\frac{\sigma_s(E')}{\pi} f(E', \eta)g(E', E, \eta) \mid \frac{d\eta}{d\mu} \mid , \tag{2.38}$$

where
- E' : energy of the incident neutron,
- E : energy of the scattered neutron,
- μ : cosine of a scattering angle in the laboratory system,
- η : cosine of scattering angle in the center of mass system,
- $\sigma_s(E')$: scattering total cross section,
- $f(E', \eta)$: angular distribution of the scattered neutron,
- $g(E', E, \eta)$: energy distribution of the scattered neutron.

The angular distribution $f(E', \eta)$ is taken from the nuclear data file. This form is defined by Legendre expansion shown in Eq. (2.39) or a tabular representation:

$$f(E', \eta)=\frac{1}{2}\ \{1+\sum_{\ell=1}^{N}(2\ell+1)f_\ell(E')P_\ell(\eta)\}\ , \tag{2.39}$$

where
- N : maximum order of the Legendre expansion,
- $f_\ell(E')$: Legendre coefficients,
- $P_\ell(\eta)$: Legendre polynomials.

The energy distribution $g(E', E, \eta)$ for the elastic scattering and the discrete part of the inelastic scattering are given by the conservation laws of energy and momentum:

$$g(E', E, \eta)=\delta(E-\frac{A^2+1}{(A+1)^2}E'+\frac{A}{A+1}Q_i-\frac{2}{A+1}\eta\sqrt{E'}$$

$$\sqrt{(\frac{A}{A+1})^2E'-\frac{A}{A+1}Q_i})\ , \tag{2.40}$$

where
- δ : Dirac delta function,
- Q_i : Q-value of the i-th exited level (for elastic scattering, $Q_i=0$),
- A : atomic mass ratio.

The relation between the scattering angles in the center of mass system and the laboratory system is derived from the conservation law as,

$$\mu=\frac{\gamma+\eta}{\sqrt{\gamma^2+2\gamma\eta+1}}\ , \tag{2.41}$$

where

$$\gamma=\frac{1}{A}\sqrt{\frac{E'}{E'-(1+1/A)Q_i}} \tag{2.42}$$

The conversion factor $\mid d\eta/d\mu \mid$ is obtained from Eq. (2.41) as,

$$\left|\frac{d\eta}{d\mu}\right| = \left|2\gamma\mu \pm \gamma\sqrt{\frac{1}{\gamma^2}+\mu^2-1} \mp \frac{\gamma\mu^2}{\sqrt{\frac{1}{\gamma^2}+\mu^2-1}}\right| . \tag{2.43}$$

The group to group transfer matrix used in the multi-group transport calculation is defined as follows:

$$\sigma_{g'g}(\mu) = \frac{\int_{E_{g'+1}}^{E_{g'}} dE' \int_{E_{g-1}}^{E_g} n\sigma_s(E', E, \mu)\phi(E')dE}{\int_{E_{g'+1}}^{E_{g'}} \phi(E')dE'} , \tag{2.44}$$

where g': energy group of the incident neutron ($E_{g'+1} \leqq E \leqq E_{g'}$)

g: energy group of the scattered neutron ($E_{g-1} \leqq E \leqq E_g$),

$\sigma_{g'g}(\mu)$: group to group transfer cross section for the scattering from g' to g by a direction cosine μ of a scattering angle, which is named as the cross section of the DAR form,

n: number of scattered neutrons (n = 1 for the elastic and inelastic scattering, n = 2 for the $(n, 2n)$ scattering),

$\phi(E')$: weighting function.

Because the energy distribution $g(E', E, \eta)$ is given by the Dirac delta function, Eq. (2.44) becomes

$$\sigma_{g'g}(\mu) = \frac{n\int_a^b \frac{\sigma_s(E')}{2\pi} f(E',\eta) \left|\frac{d\eta}{d\mu}\right| \phi(E')dE'}{\int_{E_{g'+1}}^{E_{g'}} \phi(E')dE'} . \tag{2.45}$$

The integral boundaries a and b indicate the limits of the incident energy E' in which it is possible to scatter into group g with a direction cosine μ. These limits are obtained from Eqs. (2.40) and (2.41) as

$$a = Max\{E_{g'-1}, h(E_{g+1}, \mu)\} , \tag{2.46}$$

$$b = Min\{E_{g'}, h(E_g, \mu)\}$$

where

$$h(E, \mu) = E' = \frac{(A^2-1)E + A(A-1)Q + 2E\mu^2 - 2E\mu\sqrt{\mu^2 + A^2 - 1 + A(A-1)Q/E}}{(A-1)^2} . \tag{2.47}$$

A special treatment is required to calculate Eq. (2.45) in the cases of inelastic and $(n, 2n)$ reactions at the vicinity of threshold energy, $\frac{A+1}{A}Q \leq E' \leq \frac{A}{A-1}Q$. The relation between E' and E given by Eq. (2.47) is shown in **Fig. 2.5**. In the energy range, γ defined by Eq. (2.42) becomes greater than unity, so that the integration of Eq. (2.45) should be divided into two regions at the minimum value of E' shown in **Fig. 2.5**. The scattered neutron energy EBND at the minimum value of E' is given as follows:

$$\frac{dE'}{dE} = \frac{dh(E,\mu)}{dE} = 0 , \tag{2.48}$$

where

$$\text{EBND} = \frac{AQ\mu^2}{(\mu^2+A^2-1)(A+1)} \tag{2.49}$$

The integration of Eq. (2.45) is computed in the following manner:

(i) $E_{g+1} \geq$ EBND (Region 1 shown in **Fig. 2.5**),

$$\left.\begin{aligned} a &= Max\ \{E_{g'+1},\ h(E_{g+1}, \mu)\}\ , \\ b &= Min\ \{E_{g'}, h(E_g, \mu)\}\ , \\ \eta &= \gamma(\mu^2-1)+\mu\sqrt{1+\gamma^2(\mu^2-1)}. \end{aligned}\right\} \tag{2.50}$$

(ii) $E_g \leq$ EBND (Region 2 shown in **Fig. 2.5**)

$$\left.\begin{aligned} a &= Max\ \{E_{g'-1},\ h(E_g, \mu)\}\ , \\ b &= Min\ \{E_{g'}, h(E_{g+1}, \mu)\}\ , \\ \eta &= \gamma(\mu^2-1)-\mu\sqrt{1+\gamma^2(\mu^2-1)}\ . \end{aligned}\right\} \tag{2.51}$$

(iii) $E_{g+1} <$ EBND $< E_g$,
The integral boundary is divided into two regions of 1 and 2,

$$\left.\begin{aligned} a &= Max\ \{E_{g'+1},\ h(\text{EBND}, \mu)\}\ , \\ b &= Min\ \{E_{g'}, h(E_g, \mu)\}\ , \\ \eta &= \gamma(\mu^2-1)+\mu\sqrt{1+\gamma^2(\mu^2-1)}\ , \end{aligned}\right\} \text{(Region 1)} \tag{2.52}$$

$$\left.\begin{aligned} a &= Max\ \{E_{g'+1},\ h(\text{EBND}, \mu)\}\ , \\ b &= Min\ \{E_{g'}, h(E_{g+1}, \mu)\}\ , \\ \eta &= \gamma(\mu^2-1)-\mu\sqrt{1+\gamma^2(\mu^2-1)}\ . \end{aligned}\right\} \text{(Region 2)} \tag{2.53}$$

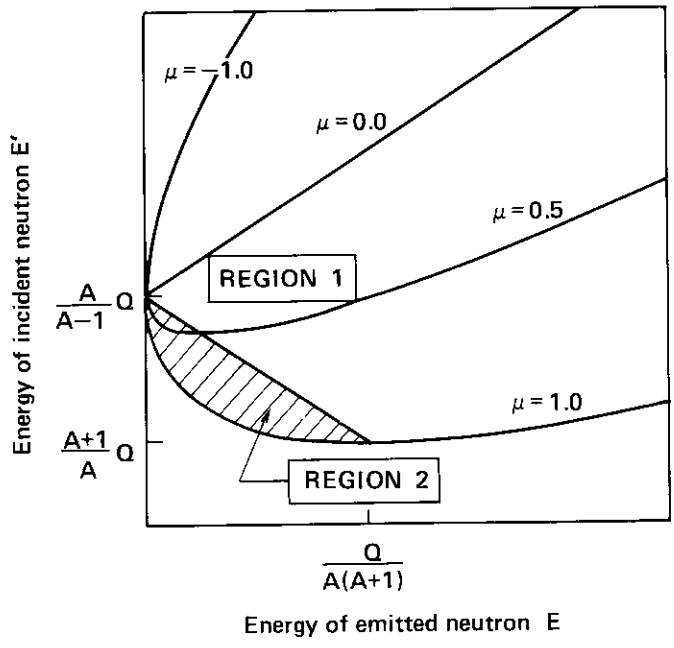


Fig. 2.5 Function $E'=h(E, \mu)$

For the continuum parts of the inelstic and $(n, 2n)$ reactions, the energy distribution $g(E', E, \eta)$ is given in the nuclear data file. The form is given in an evapolation model, a tabular representation, Maxwellian or Watt spectrum. This energy distribution is independent of the scattering angle. Therefore, Eq. (2.44) can be approximated by the following equation:

$$\sigma_{g'g}(\mu)=\frac{\int_{E_{g'+1}}^{E_{g'}} f(E',\mu)\sigma_s(E')\phi(E')dE'}{\int_{E_{g'+1}}^{E_{g'}} \sigma_s(E')\phi(E')dE'} \times \frac{\int_{E_{g'+1}}^{E_{g'}} dE' \int_{E_{g-1}}^{E_g} dE\, n\frac{\sigma_s(E')}{2} g(E',E)\phi(E')}{\int_{E_{g'-1}}^{E_{g'}} \phi(E')dE'} \quad (2.54)$$

With Eqs. (2.45) through (2.54), we can compute the scattering matrix directly by the function of the scattering angle. However, it is difficult to determine the fixed angular mesh to fit the function $\sigma_{g'g}(\mu)$ accurately because the shape of this function differs for the kind of nuclides and the incident energy. For this reason, the scattering matrices of each reaction are calculated by using the following algorithm, and a point-wise angular distribution is generated, which is named a "Direct Angular Representation" form in the fine-group structure. The computation is performed as follows:

1) Selection of a scattered energy group g. $(E_{g-1}\leq E\leq E_g)$
2) Determination of the bounds of the source energy E' in which it is possible to scatter to the energy group g.

i) For $E_{g+1}\geq \frac{Q}{A(A+1)}$,

$$\left.\begin{aligned} E'_{max}&=h(E_g,\mu=-1),\\ E'_{min}&=h(E_{g-1},\mu=1)\ . \end{aligned}\right\} \quad (2.55)$$

ii) For $E_{g+1}< \frac{Q}{A(A+1)} < E_g$,

$$\left.\begin{aligned} E'_{max}&=h(E_g,\mu=-1),\\ E'_{min}&=(A+1)Q/A\ . \end{aligned}\right\} \quad (2.56)$$

iii) For $E_g\leq \frac{Q}{A(A+1)}$,

$$\left.\begin{aligned} E'_{max}&=h(E_g,\mu=-1),\\ E'_{min}&=h(E_g,\mu=1)\ . \end{aligned}\right\} \quad (2.57)$$

3) Selection of a source energy group $g'(E_{g'+1}\leq E\leq E_{g'})$ in the above energy range.
4) Determination of the bounds of the scattering angle for the scattering from the energy group g' to g. The cosine of scattering angle μ is obtained by Eq. (2.47):

$$\mu(E',E)=\frac{1}{2}\left\{(A+1)\sqrt{\frac{E}{E'}}-(A-1)\sqrt{\frac{E'}{E}}+\frac{AQ}{\sqrt{E'\cdot E}}\right\}\ . \quad (2.58)$$

The boundary energy EBND in the integration range is given by Eqs. (2.49) and (2.58).

$$\mathrm{EBND}(E')=\frac{A}{A+1}Q-\frac{A-1}{A+1}E'\ . \quad (2.59)$$

i) For $E\geq \mathrm{EBND}(E_{g'+1})$, (Region 1)

$$\left.\begin{aligned} \mu_{max}&=\mu(E_{g'-1},E_g),\\ \mu_{min}&=\mu(E_{g'},E_{g'+1})\ , \end{aligned}\right\} \quad (2.60)$$

ii) For $E \leq \mathrm{EBND}(E_{g'})$, (Region 2)

$$\left.\begin{aligned} \mu_{max} &= \mu(E_{g'-1}, E_{g-1}), \\ \mu_{min} &= \mu(E_{g'}, E_g) , \end{aligned}\right\} \tag{2. 61}$$

iii) For $\mathrm{EBND}(E_{g'}) \leq E \leq \mathrm{EBND}(E_{g'-1})$, (Region 1 and 2)

$$\left.\begin{aligned} \mu_{max} &= Max\ \{\mu(E_{g'+1}, E_g), \mu(E_{g'+1}, E_{g+1})\} , \\ \mu_{min} &= Min\ \{\mu(E_{g'}, E_{g+1}, (\sqrt{\gamma^2-1}/\gamma)\} . \end{aligned}\right\} \tag{2. 62}$$

5) Calculation of the cross section from Eq. (2.45) or (2.54) at 5 angular points which divide the range of the scattering angle into four. (In **Fig. 2.6**, cross sections denoted from σ_0 to σ_4 are calculated at the cosine of scattering angles from μ_0 to μ_4, respectively.)

6) Calculation of approximate integral of σ^t over the scattering angle by using the 4-th order Newton-Cotes formula:

$$\sigma^t = \int_{-1}^{1} \sigma_{g'g}(\mu)\, d\mu,$$

$$= \frac{m}{45}\ \{14(\sigma_0+\sigma_4)+64(\sigma_1+\sigma_2)+24\sigma_3\} , \tag{2. 63}$$

where m is the interval of the angular mesh.

7) Test of whether a linear interpolation can be applied between μ_0 and μ_1

$$\mu_m = (\mu_0+\mu_1)/2 , \tag{2. 64a}$$

$$\sigma' = (\sigma_0+\sigma_1)/2 , \tag{2. 64b}$$

i.e.,

i) test of relative error, (condition 1)

$$\left| \frac{\sigma(\mu_m)-\sigma'}{\sigma(\mu_m)} \right| < \varepsilon \tag{2. 65a}$$

ii) test of integral error, (condition 2)

$$\sigma(\mu_m)-\sigma' \left| \frac{\mu_0-\mu_1}{2} < \frac{\varepsilon}{20}\sigma^t, \right. \tag{2. 65b}$$

where ε is a permissible tolerance specified by the user. The condition 2 becomes severe for a peak of the cross section and loose for the part of small value. Therefore, this condition is useful to decrease the number of the angular mesh in the part of small value.

8) When either condition is satisfied, no additional points are required between μ_0 and μ_1. Otherwise the angular point μ_m is added and the step (7) is repeated for the two intervals of (μ_0, μ_m) and (μ_m, μ_1). This iteration is executed until the either condition is satisfied.

9) For other intervals (μ_1, μ_2), (μ_2, μ_3) and (μ_3, μ_4), the same process is executed.

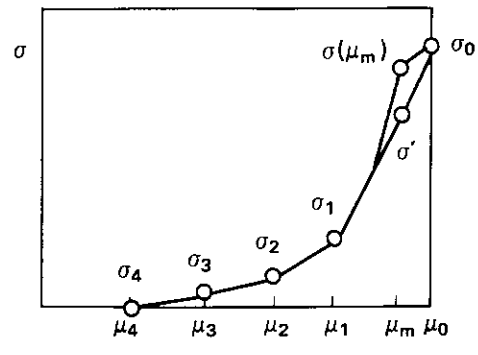


Fig. 2.6 Algorithm to determine the optimum angular mesh

The reaction types to be processed are shown in **Table 2.4**. The scattering matrices are summed up with respect to three reaction types, elastic, inelastic and $(n, 2n)$ scattering reactions, and are normalized to the total scattering cross sections, respectively. The cross section to the scattering to the energy below the lowest energy group is added to the cross section of the lowest energy group. Owing to the DAR method, the angular distributions of cross sections do not take any negative value for all directions.

The FAIR-CROSS step 1 can take into account of the up-scattering component of the thermal scattering cross section by using the $S(\alpha, \beta, T)$ function as follows:

$$\frac{d^2\sigma(E_i \rightarrow E_j, \mu)}{d\Omega dE} = \sum_{n=0}^{NS} \frac{M_n \sigma_{bn}}{4\pi kT} \sqrt{\frac{E_j}{E_i}}\, e^{-\beta/2} S_n(\alpha, \beta, T), \tag{2.66}$$

where

M_n : number of the n-th type atoms in the molecule,

T : moderator temperature (K),

k : Boltzmann constant (eV/K),

β : energy transfer $(E_j - E_i)/kT$,

α : momentum transfer $(E_i + E_j - 2\mu\sqrt{E_i E_j}/A_0 kT)$,

A_n : mass of the n-th type atom, A_0 is the mass of the principal scattering atom in the molecule,

σ_{bn} : bound atom scattering cross section of the n-th type atom,

$$\sigma_{bn} = \sigma_{fn}\left(\frac{A_n + 1}{A_n}\right)^2,$$

σ_{fn} : free atom scattering cross section of the n-th type atom,

μ : cosine of the scattering angle in the laboratory system.

The $S(\alpha, \beta, T)$ function is given by the following forms in the file 7 in the ENDF/B format,

(i) tabulated form:
the data for only the principal scattering atom are defined,

(ii) free-gas scattering law:

$$S(\alpha, \beta, T) = \frac{1}{\sqrt{4\pi\alpha}}\, e^{-\frac{\alpha^2+\beta^2}{4\alpha}}, \tag{2.67}$$

(iii) diffusion-motion scattering law:

$$S(\alpha, \beta, T) = \frac{2\alpha d}{\pi}\left(c^2 + \frac{1}{4}\right) e^{2\alpha cd} K_1(X)/X, \tag{2.68}$$

where K_1 is the modified Bessel function, coefficients c and d are given in the file 7 and X is denoted as

$$X = \left[\left(c^2 + \frac{1}{4}\right)(\beta^2 + 4\alpha^2 d^2)\right]^{1/2}. \tag{2.69}$$

Table 2.4 Reaction types in the scattering matix to be calculated

Reaction type	MT number
Elastic Scattering	2
(n, 2n) Scattering	6~9, 16, 46~49
(n, n′ α) Scattering	22
(n, n′ 3α) Scattering	23
(n, 2nα) Scattering	24
(n, n′ p) Scattering	28
Inelastic Scattering	51~91

When the $S(\alpha, \beta, T)$ is given by the tabulated form, the value exceeding the β_{max} is treated by the short collision time approximation:

$$S(\alpha, \beta, T) = \frac{e^{\beta/2} e^{-\frac{T}{4\alpha T_{eff}}(\alpha-\beta)^2}}{\sqrt{4\pi\alpha T_{eff}/T}}, \tag{2. 70}$$

where T_{eff} is effective temperature given as the input data. (TEFF in the 10* array). If the TEFF is set to zero, the short collision time approximation is not adopted and $S(\alpha, \beta, T)$ is also set to zero. The calculation of the up-scattering is performed up to the limit of $\beta_{max}=36.8$ which means that the ratio between the up-scattering component and the elastic one corresponds to 10.

The group to group scattering cross section corresponding to Eq. (2.66) is produced in the following manner:

$$\sigma_{g'g}(\mu_k) = \frac{\sum_{i=1}^{NOGTH} W(E_{g'}^i) \Delta E_{g'}^i \sum_{j=1}^{NOGTH} \frac{d^2\sigma(E_g^i \to E_{g'}^j, \mu_k)}{d\Omega dE} \Delta E_g^j}{\sum_{i=1}^{NOGTH} W(E_{g'}^i) \Delta E_{g'}^i}, \tag{2. 71}$$

where $E_{g'}^i$ and E_g^j show the average energies of the sub-group i and j, and NOGTH is the number of the sub-groups per each energy group which is given as the input data in the 13$ array.

Angular distribution is computed for angular meshes which are equally spaced from 0 to π and is recomputed in order to reduce the number of angular meshes by using the linear interpolation. The reduction process is terminated when the relative error in the interpolation becomes less than or equal to the limit value given as the input data. (ERR2 in the 10* array) The normalization of the scattering matrix is performed by using the integral value $\sigma_{g'}^{exact}$,

$$\sigma_{g'g}(\mu_k) = \frac{\sigma_{g'}^{exact}}{\sigma_{g'}^{approx.}} \sigma_{g'g}(\mu_k), \tag{2. 72a}$$

where

$$\sigma_{g'}^{exact} = \frac{\int_{E_{g'+1}}^{E_{g'}} dE' \int_0^\infty dE \int_{-1}^{1} d\mu 2\pi \frac{d^2\sigma(E' \to E, \mu)}{d\Omega dE} \phi(E')}{\int_{E_{g'+1}}^{E_{g'}} dE' \phi(E')}, \tag{2. 72b}$$

$$\sigma_{g'}^{approx.} = \sum_g \sum_k \sigma_{g'g}(\mu_k) 2\pi \Delta\mu_k. \tag{2. 72c}$$

The highest energy group in the up-scattering is given as the input data (NGTH in the 13$ array). The maximum source energy for the up-scattering is set to the average one of the highest sub-group in the group NGTH. If NGTH is set to zero, the boundary energy ε for the static model in file 7 of ENDF /B format is adopted.

Once the computation of the up-scattering is performed, the total and elastic scattering cross sections for the thermal groups are revised by using the values calculated from the thermal scattering law:

$$\sigma_{total}^{thermal} = \sigma_{\substack{MF=3,\\MT=1}} + \sigma_{\substack{MF=7,\\MT=4}} - \sigma_{\substack{MF=3,\\MT=2}}, \tag{2. 73a}$$

$$\sigma_{elastic}^{thermal} = \sigma_{\substack{MF=7,\\MT=4}} + \delta, \tag{2. 73b}$$

where values of MF and MT show the file number and the reaction number of ENDF/B format, respectively, and δ is the same as in Eq. (2.35).

2.1.5 Atomic Displacement Cross Section and Energy Deposition Factor

The atomic displacement cross section F and the energy deposition factor H at the neutron energy E are defined as follows:

$$F(E)=\sigma(E)\int_{-1}^{1}P(E,\eta)\cdot\nu\left[T(E,\eta)\right]\,d\eta, \tag{2.74}$$

$$H(E)=C\cdot\sigma(E)\int_{-1}^{1}P(E,\eta)\,T(E,\eta)\,d\eta, \tag{2.75}$$

where T is the kinetic energy in the laboratory system of the primary knock-on atom (PKA) which is scattered by a center of mass angle $\beta(\beta=\cos^{-1}\eta)$, with the probability $P(E,\eta)$. The $\nu(T)$ means the number of secondary displacements produced by the PKA in coming to rest, which is calculated by using the Lindhard model[37] of slowing down for energetic atoms in solids. A constant C in Eq. (2.75) is the conversion factor. The units of $F(E)$ and $H(E)$ are (barn) and (barn • watt • sec), respectively.

The number of displacement $\nu(T)$ is defined as follows:

$$\nu(T)=0.8T_D/2E_d, \qquad (T>2E_d) \tag{2.76}$$

$$T_D=T/(1+K_L\cdot g(\varepsilon)), \tag{2.77}$$

$$K_L=0.1334Z^{2/3}/A^{1/2}, \tag{2.78a}$$

$$g(\varepsilon)=\varepsilon+0.40244\varepsilon^{3/4}+3.4008\varepsilon^{1/6}, \tag{2.78b}$$

$$\varepsilon=0.01151T/Z^{7/3}, \tag{2.78c}$$

where E_d is an effective displacement energy and A and Z are the atomic weight and atomic number, respectively.

A general relation between T, E, η and E_p (the energy of scattered neutron) in the center of mass system is found from the conservation of momentum:

$$T=\alpha_1\alpha_2E+(\alpha_1/\alpha_2)E_P-2\alpha_1\eta\sqrt{E\cdot E_P}\,, \tag{2.79}$$

where $\alpha_1=1/(1+A)$ and $\alpha_2=A/(1+A)$. The values of $F(E)$ and $H(E)$ are calculated for each ultra-fine group and then converted to the fine-group structure in the following manner:

$$F_g=\int_{E_g}^{E_{g+1}}F(E)\phi(E)dE/\int_{E_g}^{E_{g+1}}\phi(E)dE, \tag{2.80}$$

$$H_g=\int_{E_g}^{E_{g+1}}H(E)\phi(E)dE/\int_{E_g}^{E_{g+1}}\phi(E)dE, \tag{2.81}$$

where ϕ is weighting function retrieved from the ultra-fine group cross section library.

For elastic scattering reaction, the energy conservation law gives the following relation:

$$E_P=\alpha_2^2E. \tag{2.82}$$

Therefore Eq. (2.79) becomes

$$T=2\alpha_1\alpha_2E(1-\eta), \tag{2.83}$$

The probability $P(E,\eta)$ in Eq. (2.74) is written as

$$P(E,\eta)=\frac{2\pi}{\sigma(E)}\cdot\frac{d\sigma(E,\eta)}{d\Omega}. \tag{2.84}$$

The differential scattering cross section $d\sigma/d\Omega$ is calculated with the ultra-fine group structure, so that Eqs. (2.74) and (2.75) are rewritten as follows:

$$\begin{aligned}F(E)&=2\pi\int_{-1}^{\eta_{max}}\frac{d\sigma(E,\eta)}{d\Omega}\cdot\frac{0.8}{2E_d}\cdot\frac{2\alpha_1\alpha_2E(1-\eta)}{1+K_L\cdot g(\varepsilon)}\,d\eta\\&=-\frac{1.6\pi\alpha_1\alpha_2E}{E_d}\int_{-1}^{\eta_{max}}\frac{d\sigma(E,\eta)}{d\Omega}\cdot\frac{1-\eta}{1+K_L\cdot g(\varepsilon)}\,d\eta,\end{aligned} \tag{2.85}$$

$$H(E)=C\cdot 2\pi\int_{-1}^{+1}\frac{d\sigma(E,\eta)}{d\Omega}\cdot 2\alpha_1\alpha_2E(1-\eta)d\eta$$

$$=C\cdot 4\pi\alpha_1\alpha_2E\int_{-1}^{-1}\frac{d\sigma(E,\eta)}{d\Omega}(1-\eta)d\eta, \tag{2.86}$$

where η_{max} is defined as

$$\eta_{max}=1-\frac{E_d}{\alpha_1\alpha_2E}. \tag{2.87}$$

The inelastic scattering component is computed for the discrete and continuum parts separately. The contribution from discrete levels to the atomic displacement cross section is computed as follows:

$$F(E)=\sum_i F_i(E), \tag{2.88}$$

where $F_i(E)$ is the atomic displacement cross section due to the i-th discrete level. The energy conservation law for inelastic scattering gives the following relation:

$$E_P=\alpha_2(\alpha_2E-Q_i), \tag{2.89}$$

where Q_i is the nuclear excitation energy for the i-th discrete level. Substituting Eq. (2.89) into Eq. (2.79) yields

$$T_i=2\alpha_1\alpha_2\{E-\eta\sqrt{E(E-Q_i/\alpha_2)}\}-\alpha_1Q_i. \tag{2.90}$$

Assuming that the angular distribution is isotropic, Eqs. (2.74) and (2.75) are rewritten as follows:

$$F_i(E)=\frac{\sigma_i(E)}{2}\int_{-1}^{+1}\nu[T_i(E,\eta)]d\eta$$

$$=\frac{\sigma_i(E)}{5T_d}\int_{-1}^{+1}\frac{2\alpha_1\alpha_2\{E-\eta\sqrt{E(E-Q_i/\alpha_2)}\}-\alpha_1Q_i}{1+K_L\cdot g(\varepsilon)}d\eta, \tag{2.91}$$

$$H_i(E)=C\cdot\frac{\sigma_i(E)}{2}\int_{-1}^{+1}T_i(E,\eta)d\eta$$

$$=C\cdot\sigma_i(E)(2\alpha_1\alpha_2E-\alpha_1Q_i). \tag{2.92}$$

For the continuum part, the energy E_p of the scattered neutron is given by the energy distribution function $f(E, E_p)$. The function f is calculated for each ultra-fine energy group in the computation of inelastic scattering matrix. Using this function, Eqs. (2.74) and (2.75) are rewritten as follows:

$$F(E)=\frac{\sigma(E)}{2}\int_0^{E_P^{max}}f(E,E_P)\int_{-1}^{+1}\nu[T(E,E_P,\eta)]d\eta dE_P$$

$$=\frac{\sigma(E)}{5T_d}\int_0^{E_P^{max}}f(E,E_P)\int_{-1}^{+1}\frac{\alpha_1\alpha_2E+(\alpha_1/\alpha_2)E_P-2\alpha_1\eta\sqrt{E\cdot E_P}}{1+K_L\cdot g(\varepsilon)}d\eta dE_P, \tag{2.93}$$

$$H(E)=C\frac{\sigma(E)}{2}\int_0^{E_P^{max}}f(E,E_P)\int_{-1}^{+1}T(E,E_P,\eta)d\eta dE_P$$

$$=C\cdot\sigma(E)\int_0^{E^{max}}f(E,E_P)\{\alpha_1\alpha_2E+(\alpha_1/\alpha_2)E_P\}dE_P. \tag{2.94}$$

For the $(n, 2n)$ scattering reaction, a model called "one-neutron model"[48] is adopted. In this model, Eq. (2.79) is expressed as follows:

$$T=\frac{A}{A-1}\frac{\alpha_1}{\alpha_2}E_P+\frac{A-1}{A}\overline{T}_1-2\eta\sqrt{\frac{\alpha_1}{\alpha_2}\overline{T}_1E_P'}, \tag{2.95}$$

where E_p' is the energy of the second neutron and $\overline{T}_1$ is the mean recoil energy after the emission of the first neutron defined as follows:

$$\overline{T}_1=\alpha_1\alpha_2E+(\alpha_1/\alpha_2)E_P, \tag{2.96}$$

Assuming $E_p^{'}=E_p$, Eq. (2.95) becomes

$$T=\frac{A-1}{(A+1)^2}E+(\frac{1}{A-1}+\frac{A-1}{A^2})E_P-\frac{2\eta}{A}\left[E_P\left\{\frac{A^2}{(A+1)^2}E+E_P\right\}\right]^{1/2}. \tag{2.97}$$

The $F(E)$ and $H(E)$ are now obtained in the same manner as for the case of the inelastic continuum part.

For (n, γ) reaction, it is assumed that the kinetic energy of PKA is equal to the recoil energy in the (n, γ) reaction, i.e.,

$$T=\frac{1}{2}\frac{\overline{E}_\gamma^2}{(A+1)C^2}$$

$$=\frac{1}{1.862\times10^9}\cdot\frac{Q}{A+1}, \tag{2.98}$$

where E_γ means the gamma-ray energy and Q means Q-value for the (n, γ) reaction.

For charged particle emission, Eq. (2.79) becomes

$$T=\frac{A_{rn}}{(A+1)^2}E+\frac{A_P}{A_{rn}}E_P-\frac{(4A_PE_PE)^{1/2}}{(A+1)}\eta, \tag{2.99}$$

where A_{rn} and A_p mean atomic weights for a residual nucleus and an emitted particle, respectively. The energy distribution function $f(E, E_p)$ is expressed by using the statistical model of nuclear reaction:

$$f(E, E_P)=\frac{1}{I}E_P\rho(\frac{A}{A+1}E+Q-E_P)\sigma_C(E_P), \tag{2.100}$$

$$I=\int_0^{E_p^{max}}E_P\rho(\frac{A}{A+1}E+Q-E_P)\sigma_C(E_P)dE_P, \tag{2.101}$$

where ρ is the level density for all J states and σ_c is the compound nucleus formation cross section of an inversed process which is calculated by ELIESE-3[38] based on the optical model.

The $\rho(u)$ at the excitation energy is given by the Gilbert-Cameron's formula[49]:

(i) For $E^*\geq E_x$

$$\rho(u)=\rho_2(u)=\frac{\sqrt{\pi}}{12}\frac{1}{a^{1/4}u^{5/4}}\exp(2\sqrt{au})\frac{1}{\sqrt{2\pi}\,\sigma}, \tag{2.102a}$$

where $u = E^*-\Delta$,

$$E^* = \frac{A}{A+1}E+Q-E_p,$$

$$E_x = 2.5+150/A+\Delta,$$

$$\sigma^2 = 0.0888(au)^{1/2}A^{2/3},$$

and Δ means pairing energy.

(ii) For $E^*< E_x$

$$\rho(u)=\rho_1(E^*)=\frac{1}{T}\exp\left[(E^*-E_0)/T\right], \tag{2.102b}$$

where $1/T = \sqrt{\frac{a}{u_x}}-\frac{3}{2u_x}$,

$$E_0 = E_x-T\log\left[T\cdot\rho_2(u_x)\right],$$

$$u_x = E_x-\Delta,$$

and a is obtained from the appropriate correlation of a/A with the total shell correction S. The

relation is defined as follows:

$$a/A=0.00917S+0.142(\mathrm{MeV}^{-1}),\ \text{(for underformed nuclei)} \tag{2. 103a}$$

or

$$a/A=0.00917S+0.120(\mathrm{MeV}^{-1}).\ \text{(for deformed nuclei; } 86\leq A-Z\leq 122,\ 130\leq A-Z\leq 182,\ 54\leq Z\leq 78,\ 86\leq Z\leq 122) \tag{2. 103b}$$

The calculations of $F(E)$ and $H(E)$ are now performed in the same manner as used for the inelastic continuum part.

For fission reaction, the following energy deposition factor is calculated:

$$H(E)=C\cdot H_f\cdot \sigma_f(E), \tag{2. 104}$$

where H_f means the kinetic energy of fission fragments given as the input data of HFB in the 11* array.

The atomic displacement cross sections and energy depositon factors of each reaction are stored in DATA-POOL with the reaction identification numbers shown in **Table 2.5**. The effective displacement energy E_d must be given by the user. **Table 2.6** shows a list of some evaluations. The adopted value shown in the table means that the value is used to generate the multigroup cross section library named JSD1000.

Table 2.5 Reaction types and identification numbers for the energy deposition factor and the atomic displacement cross section

No.	Reaction Type
1002	Energy deposition by elastic scattering
1004	Energy deposition by inelastic reaction
1016	Energy deposition by (n, 2n) reaction
1018	Energy deposition by fission reaction
1102	Energy deposition by (n, γ) reaction
1103	Energy deposition by (n, p) reaction
1107	Energy deposition by (n, α) reaction
2002	Atomic displacement by elastic scattering
2004	Atomic displacement by inelastic reaction
2016	Atomic displacement by (n, 2n) reaction
2102	Atomic displacement by (n, γ) reaction
2103	Atomic displacement by (n, p) reaction
2107	Atomic displacement by (n, α) reaction

Table 2.6 Threshold displacement energies adopted in the calculations of atomic displacement cross sections

Nuclide	ENDF/B-IV material No.	Adopted value	References**							
			76Ide + (adopt)	76Dran (adopt)	76Gabriel (adopt)	73Nelson (adopt)	72Doran (adopt)	65Chadderton (Exp. compile)	Sone (Exp. compile)	Brooks (Exp. review)
C	1274	47	47*					25(300° K)	28	
Si	1194	46	46*							
Al	1193	27	27*	25*	27*				32, 16.5±3, 17	
Ti	1286	48	48*		30*				29	
V	1196	43	43*	40*	40*					
Cr	1191	40	40*	40*	40*		33*			
Fe	1192	40	40*	40*	40*	37*or40*	33*	24*(4.2° K)	24	
Ni	1190	40	40*	40*	40*		33*	34.5(4.2° K)	24	
Cu	1295	32	33*	30*	30*			25(78° K)–19(4.2° K)	22*, 19, 16–19	20–22
Zn		40							17.5±1.5	
Ge	–	40						31(78° K)		
Zr	1284	60		40*						
Nb	1189	62	60*	60*	60*				36	
Mo	1287	45	62*	60*					37	
Ag	1138	90						28*(4.2° K)	28, 24	
Ta	1127	90	90*				68*		32	
Au	1283	25						40*(4.2° K)	740, 33–36	
Pb	1288	40		25*						
W	–	–	60*	90*					735	
316SUS	–	–	40*		40*		35*			

*) Adopted value is the effective value.

**) Threshold displacement energies are compiled in Ref. 56

2.1.6 Effective Macroscopic Cross Section

The effective macroscopic cross section of neutron and gamma-ray coupled multi-group structure is produced at the FAIR-CROSS step 2. At this step, the following 4 processes are executed:

Process-1: Calculate the effective neutron cross sections by using the infinite dilution cross sections and the self-shielding factors and convert the group to group transfer matrices form into the discrete-type DAR form.

Process-2: Calculate the effective secondary gamma-ray production cross sections.

Process-3: Calculate the gamma-ray cross sections.

Process-4: Couple the neutron cross sections with the gamma-ray ones and generate the cross section tables for coupled multi-group transport calculations.

In the process-1, the following quantities are calculated:

$$\sigma^i_{eff,\,x,\,n}=f^i_{x,\,n}(T,\,\sigma_0)\cdot\sigma^i_{x,\,n}\,, \tag{2.105}$$

$$\sigma_0=\frac{1}{\rho_n}\sum_{m\neq n}\rho_m\sigma_{eff,\,total,\,m}\,, \tag{2.106}$$

where
- i : neutron energy group,
- x : reaction type,
- n : nuclide
- ρ : atomic number density,
- σ_x : infinite dilution cross section for the reaction type x,
- σ_{eff} : effective cross section,
- $f(T,\,\sigma_0)$: self-shielding factor.

It is necessary to compute Eqs. (2.105) and (2.106) iteratively for total cross section in order to get accurate σ_0. The FAIR-CROSS module performes the computation of the effective total cross section until the relative error between two successive iterations becomes less than 1.0 percent. The cubic spline functions are used to interpolate given data points. In the case of $\sigma_0=0$, the self-shielding factor can not be calculated, so that $\sigma_0=0.01$ is adopted approximately.

In the process-1, the angular distributions of the group to group transfer cross sections of the DAR form are also converted into the form of the discrete-type DAR which is slightly different from that adopted at the FAIR-CROSS step 1. The discrete-type Direct Angular Representation means that the data are given for each of the fixed discrete angular points which correspond to those of the symmetrical S_N-quadrature set. This form is suitable for applying the group cross sections directly to the S_N-transport calculation. The number of the angular points can be chosen from 12 to 64 by the user.

In the process-2, the secondary gamma-ray production cross sections are generated by following equation:

$$\sigma_{n\to g}=\sigma_n\cdot Y_n\cdot P_{n\to g}\,, \tag{2.107}$$

where the notations are the same as those in Eqs. (2.144) and (2.145) in Section 2.2.1.

In the process-3, the gamma-ray cross sections for photo-electric effect, compton scattering, coherent scattering and pair-production are calculated. The calculational scheme is described in Section 2.1.7.

In the process-4, the neutron and gamma-ray cross sections are coupled. In this coupling, the gamma-ray groups are positioned below the neutron ones and the secondary gamma-ray production cross sections are treated as the down-scattering components from each of the neutron groups. The energy deposition factor and the atomic displacement cross section are positioned at the top of the cross section table as shown in **Table 2.7**. The detailed format of the cross section table is described in Appendix C.

When the up-scattering components are included in the effective macroscopic cross section, the length of cross section table is changed. The parameters IHT, IHS, NUP and IHM shown in **Table 2.7** are defined as follows:

for NUP=0 (down-scattering only),

$$\left.\begin{aligned} &\text{IHM}=\text{NOACT}+3+\text{ING}+\text{IGG},\\ &\text{IHT}=\text{NOACT}+3,\\ &\text{IHS}=\text{NOACT}-4,\\ &\text{NOACT}=0\sim2\ (\text{NHEAT}+\text{NDISP in the 29\$ array}),\end{aligned}\right\} \quad (2.\ 108a)$$

for NUP>0 (up-scattering included)

$$\left.\begin{aligned} &\text{IHM}=\text{NOACT}+4+\text{ING}+\text{IGG}+\text{NUPIN},\\ &\text{IHT}=\text{NOACT}+3,\\ &\text{IHS}=\text{NOACT}+5+\text{NUPIN},\\ &\text{NUPIN}=\text{NUP},\\ &\text{NOACT}=0\sim2(\text{NHEAT}+\text{NDISP in the 29\$ array}).\end{aligned}\right\} \quad (2.\ 108b)$$

The maximum numbers of up-scattering groups for each nucleus are different from each other at the FAIR-CROSS step 1. The length of the effective macroscopic cross section is however fixed to NUPIN which is defined by the input data in the 4$ array, so that the group to group transfer cross sections which consist of NUP groups of up-scattering are transformed as follows:

for NUP<NUPIN,

$$\sigma(\text{I}\rightarrow\text{I}-\text{J})=0.0,\quad(\text{NUP}+1\leq\text{J}\leq\text{NUPIN}) \quad (2.\ 109a)$$

for NUP>NUPIN,

$$\sigma(\text{I}\rightarrow\text{I}-\text{NUPIN})=\sigma(\text{I}\rightarrow\text{I}-\text{NUPIN})+\sum_{\text{J}=\text{NUPIN}+1}^{\text{NUP}}\sigma(\text{I}\rightarrow\text{I}-\text{J}). \quad (2.\ 109b)$$

The effective macroscopic cross sections for the conventional Legendre expansion form are produced by using the FAIR-CROSS step 3. The conversion of cross section from the discrete-type DAR form to Legendre expansion one is performed by the following process:

$$\Sigma^{l}_{g'g}=(2l+1)\sum_{k=1}^{\text{IPO}}2\pi\Sigma_S(g'\rightarrow g,\ \mu_k)\int_{\mu_k}^{\mu_{k+1}}P_l(\mu)d\mu, \quad (2.\ 110)$$

where ℓ shows the order of Legendre coefficient, IPO is the number of discrete angular meshes and the integration of Legendre function is perfomed by,

$$\int P_l(\mu)d\mu=\{\mu P_l(\mu)-P_{l-1}(\mu)\}/(l+1). \quad (2.\ 111)$$

When the up-scattering componnt exists in the P_ℓ-type cross section, the table length and the position of the total up scattering cross section denoted Σ^{up}_T in **Table 2.7** for ANISN-JR are different from those for DOT3.5. The difference is shown in **Table 2.8**. If the cross section consists of down-scattering only, the total up-scattering cross section is omitted in the table.

Table 2.7 Arrangement of the group cross section table for neutrons and gamma-rays*

Position	Neutron groups ($1 \leq I \leq ING$)	Gamma-ray groups ($ING+1 \leq J \leq ING+IGG$)
1	$H_n(I)$	$H_\gamma(J)$
2	$D_n(I)$	0.0
•	$\Sigma_a(I)$	$\Sigma_a(J)$
IHT−1	$\nu\Sigma_f(I)$	0.0
IHT	$\Sigma_T(I)$	$\Sigma_T(J)$
IHT+1†	$\Sigma_T^{up}(I)$**	0.0
IHS−NUP	$\Sigma_{nn}(I+NUP \rightarrow I)$	0.0
⋮	⋮	⋮
IHS	$\Sigma_{nn}(I \rightarrow I)$	$\Sigma_{\gamma\gamma}(J \rightarrow J)$
IHS+1	$\Sigma_{nn}(I-1 \rightarrow I)$	$\Sigma_{\gamma\gamma}(J-1 \rightarrow J)$
⋮	⋮	⋮
	$\Sigma_{nn}(1 \rightarrow I)$	$\Sigma_{\gamma\gamma}(ING+1 \rightarrow J)$
	0.0	$\Sigma_{n\gamma}(ING \rightarrow J)$
	⋮	$\Sigma_{n\gamma}(ING-1 \rightarrow J)$
		⋮
		$\Sigma_{n\gamma}(1 \rightarrow J)$
		0.0
⋮	⋮	⋮
IHM	⋮	0.0

† Omit this record when NUP=0.

* ING and IGG are respectively the numbers of neutron groups and gamma-ray groups, and IHM is (IHT+ING+IGG+NUP+1) (NUP>0) or (IHT+ING+IGG) (NUP=0).

** Σ_T^{up} means the total cross section summed up the up-scattering cross sections emitted from the energy group.

Table 2.8 Table length and the position of total up-scattering cross section

	ANISN-JR			DOT3.5
	group independent form		material-wise	
	Forward	Adjoint	Forward	Forward
Position of the total up-scattering cross section	IHM+1	IHM+1	none	IHT+1
Table length of cross section	IHM	IHM	IHM	IHM+1

2.1.7 Gamma-Ray Cross Section and Bremsstrahlung Data

Gamma-ray cross sections and Bremsstrahlung data are calculated at the FAIR-CROSS step 2. The gamma-ray cross sections for photo-electric effect, pair-production, incoherent scattering and coherent scattering are generated by using the DLC-15 library or an empirical formula adopted in GAMLEG-JR[39]. The KERMA factor is also computed.

The way to generate the gamma-ray cross section by using the DLC-15 library is recommended when the low energy gamma-ray flux is relatively important (e.g., as in the phantom calculation) because the gamma-ray cross sections below 50 keV calculated by GAMLEG-JR have some errors due to the empirical formula. The comparison between cross sections generated by using DLC-15 and the Klein-Nishina formula[40] for Compton scattering is shown in **Fig. 2.7**. The comparisons between cross sections generated by using DLC-15 and the empirical formula for each component are also shown in **Figs. 2.8 ~2.11**.

The DLC-15 contains various cross section in the energy range from 1 keV to 100 MeV. The data used at the FAIR-CROSS step 2 are reactions of MT=502 (coherent scattering), MT=504 (incoherent scattrering), MT=516 (pair-production), MT=551 (energy absorption) and MT=602 (photo-electric effect).

The angular distribution of the incoherent scattering (Compton scattering) is calculated by the Klein-Nishina formula and represented in the DAR form. The angular distributions for the other reactions are the same as in GAMLEG-JR.

The differential scattering cross section of Compton scattering is denoted as follows:

$$\sigma(E', \mu) = \frac{3}{16\pi}\left(\frac{E}{E'}\right)^2 \left[\mu^2 + E'(1-\mu) + \frac{1}{1+E'(1-\mu)}\right], \tag{2. 112}$$

$$E = \frac{E'}{1+E'(1-\mu)}, \tag{2. 113}$$

where E' and E are the energies of the photon before and after the scattering, μ is the direction cosine of scattering angle. The units of energy and cross sections are the rest mass energy of an electron ($m_e c^2$) and the Thomson unit ($8\pi/3(e^2/m_e c^2)^2 = 0.6656$), respectively. The group to group transfer cross section from group g' to group g by the direction cosine μ of scattering angle is given as follows:

$$\sigma_{g'g}(\mu) = \frac{\int_{\gamma'}^{\beta'} \sigma(E', \mu)\phi(E')dE'}{\int_{E_{g-1}}^{E_g} \phi(E')dE'} \quad \text{for } 1 + \frac{1}{E_{g'}} - \frac{1}{E_{g+1}} \leq \mu \leq 1 + \frac{1}{E_{g'+1}} - \frac{1}{E_g},$$

$$= 0 \quad \text{otherwise,} \tag{2. 114}$$

where $\gamma' = Min(E_{g'}, \gamma)$, (2. 115a)

$\beta' = Max(E_{g'+1}, \beta)$, (2. 115b)

$\gamma = \frac{E_{g-1}}{1 - E_{g+1}(1-\mu)}$ (2. 115c)

$$\left.\begin{aligned} \beta &= \frac{E_g}{1 - E_g(1-\mu)} \quad (\beta < E_1), \\ &= E_1 \qquad\qquad\quad (\beta \geq E_1), \end{aligned}\right\} \tag{2. 115d}$$

and $\phi(E)$ is the weighting function. To compute Eq. (2.114), the direction cosine μ is divided into 96 points used in the Gauss-Legendre integration.

The weighting procedure is performed by assuming the weighting function to be constant or linear. In the case of the constant weight (KON=0 in the 17$ array), the numerator of Eq. (2.114) becomes

$$\int_{\gamma'}^{\beta'}\sigma(E',\mu)\phi(E')dE'$$

$$=\frac{3}{16\pi}\left[\frac{1}{1-\mu}\ln\{1+E'(1-\mu)\}+\frac{1+\mu}{1+E'(1-\mu)}-\frac{1}{2(1-\mu)\{1+E'(1-\mu)\}^2}\right]_{\gamma'}^{\beta'} \quad (2.116)$$

The other cross sections are averaged as follows:

$$\sigma_g=\frac{\int_{E_{g+1}}^{E_g}y(E)dE}{E_g-E_{g+1}}, \quad (2.117)$$

where the integration is performed analytically based on the interpolation scheme for $y(E)$ defined in the DLC-15 library. In the case of the linear weight (KON=1 in the 17$ array), the numerator of Eq. (2.114) becomes

$$\int_{\gamma'}^{\beta'}\sigma(E',\mu)\phi(E')dE$$

$$=\frac{3}{16}\pi\sum_i^N\frac{a_i}{1-\mu}\left[(1-\mu)E'+(\mu^2-2)\ln\{1+E'(1-\mu)\}+\frac{\mu^2-2}{1+E'(1-\mu)}+\frac{1}{2\{1+E'(1-\mu)\}^2}\right]_{E_{i-1}}^{E_i}+b_i\left[\frac{1}{1-\mu}\ln\{1+E'(1-\mu)\}+\frac{1+\mu}{1-E'(1-\mu)}-\frac{1}{2(1-\mu)\{1+E'(1-\mu)\}^2}\right]_{E_{i+1}}^{E_i}, \quad (2.118)$$

where

$$\phi(E')=a_iE'+b_i \quad \text{for} \quad E_{i+1}<E'<E_i. \quad (2.119)$$

The other cross sections are averaged as follows:

$$\sigma_g=\frac{\int_{E_{g+1}}^{E_g}f(E)y(E)dE}{\int_{E_{g+1}}^{E_g}f(E)dE},$$

$$=\frac{\sum_i^N\{f(E_i)y(E_i)+f(E_{i+1})y(E_{i+1})\}\frac{E_i-E_{i+1}}{2}}{\sum_i^N\{f(E_i)+f(E_{i+1})\}\frac{E_i-E_{i+1}}{2}}, \quad (2.120)$$

where $E_i=E_{g+1}+(i-1)\cdot\frac{E_g-E_{g+1}}{N}$, (2.121)

N : number of meshes in an energy group (N in the 17$ array),

$f(E_i)$: interpolated value of the weighting function at E_i,

$y(E_i)$: interpolated value of the DLC-15 library at E_i.

The energy deposition factor is also calculated in the form of KERMA factor as follows:

$$h_g=1.6\times10^{-19}\ (\mu_{en}/\rho)E_g, \quad (2.122)$$

where h_g is the KERMA factor for energy group g, (μ_{en}/ρ) indicates the energy-absorption coefficient and E_g shows the mean energy of energy group g. The unit of the KERMA factor is (barn • watt • sec).

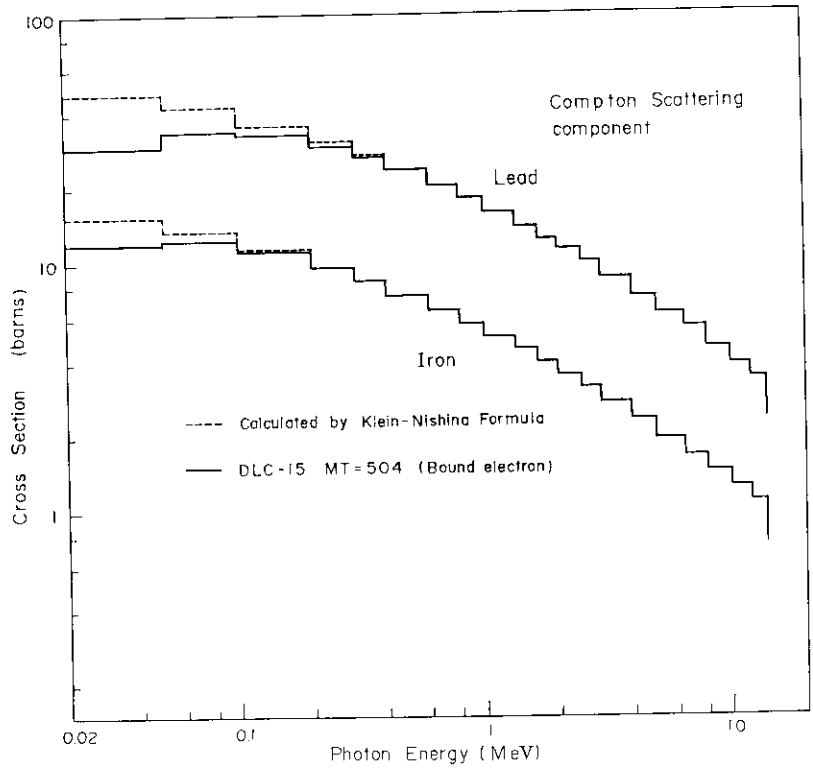
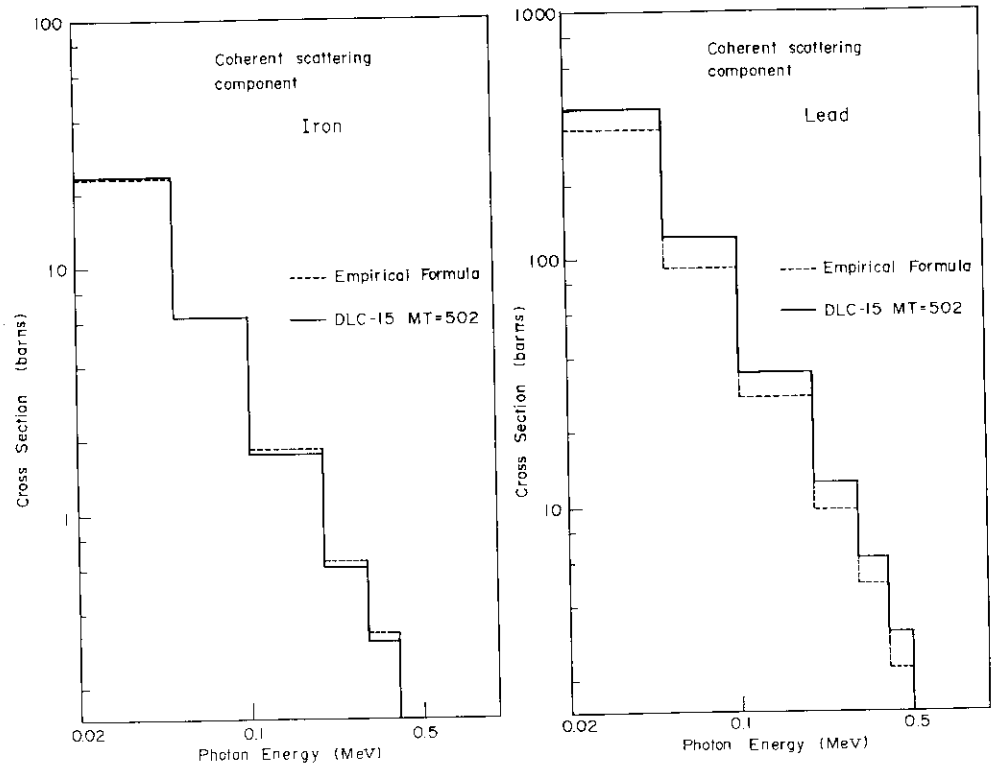


Fig. 2.7 Comparison of Compton scattering cross sections produced by the Klein–Nishina formula and DLC–15 library



(a) For iron (b) For lead

Fig. 2.8 Comparison of Coherent scattering cross sections produced by the empirical formula and DLC–15 library

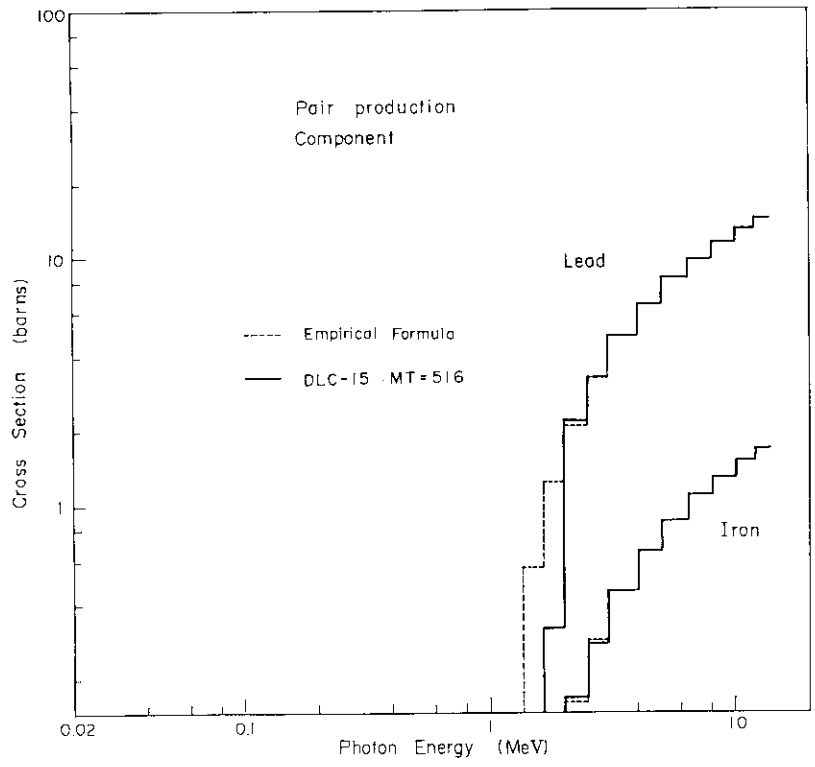
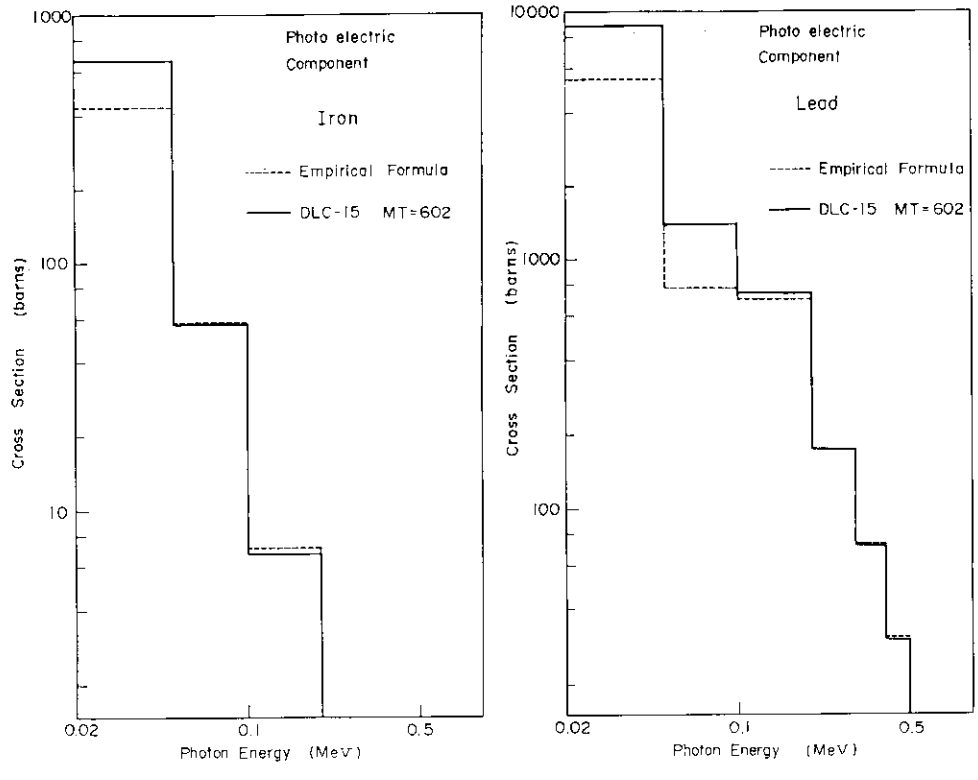


Fig. 2.9 Comparison of Pair-production cross sections produced by the empirical formula and DLC-15 library



(a) For iron (b) For lead

Fig. 2.10 Comparison of Photo-electric cross sections produced by the empirical formula and DLC-15 library

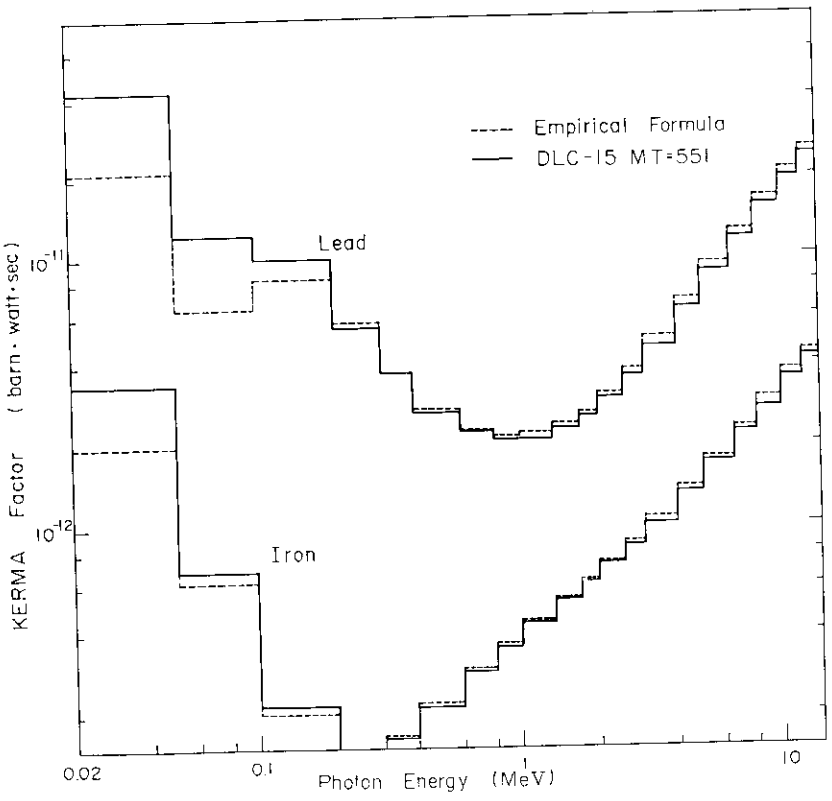


Fig. 2.11 Comparison of KERMA factors produced by the empirical formula and DLC-15 library

Bremsstrahlung effect for the gamma-ray penetration in heavy nuclei becomes important when the high energy photon source enters the material. FAIR-CROSS step 2 generates the cross sections of photon-electron and electron-photon interactions. The secondary electron production cross sections for Compton scattering, pair-production and photo-electric processes are considered. The photon spectrum data for thick targets are adopted to estimate the electron-photon interaction. The data for C, Al, Fe, Cu, Mo and W at the electron energies of 1, 3, 10 and 30 MeV are contained in the program as the block data statement. The description of the materials is shown in **Table 2.9**.

The secondary electron production cross section for Compton scattering is calculated as follows:

$$\sigma_C(E^\gamma \to E^e) = \frac{\pi r_0^2}{\alpha_\gamma^2 m_0 c^2}\{2 + (\frac{E^e}{E^\gamma - E^e})[\frac{1}{\alpha_\gamma^2} + \frac{E^\gamma - E^e}{E^\gamma} - \frac{2}{\alpha_\gamma}(\frac{E^\gamma - E^e}{E^e})]\}, \quad (2.123)$$

where
$$\left.\begin{aligned} &\alpha_\gamma = E^\gamma / m_0 c^2, \\ &r_0 = e^2 / m_0 c^2, \\ &0 \le E^e \le E^\gamma \frac{2E^\gamma / m_0 c^2}{1 + 2E^\gamma / m_0 c^2}. \end{aligned}\right\} \quad (2.124)$$

The group cross section is generated as follows:

$$\sigma_c(E_i^\gamma \to E_j^e) = \frac{\int_{E_{i-1}^\gamma}^{E_i^\gamma} f(E_i^\gamma) \int_{E_{j-1}^e}^{E_j^e} \sigma_c(E^\gamma \to E^e) dE^e dE^\gamma}{\int_{E_{i+1}^\gamma}^{E_i^\gamma} f(E^\gamma) dE^\gamma}, \quad (2.125)$$

$$= \frac{\sum_{n=1}^{N} \{f(E_n^\gamma) \int_{E_{j+1}^e}^{E_j^e} \sigma_c(E_n^\gamma \to E^e) dE^e + f(E_{n+1}^\gamma) \int_{E_{j+1}^e}^{E_j^e} \sigma_c(E_{n-1}^\gamma \to E^e) dE^e\}}{\sum_{n=1}^{N} \{f(E_n^\gamma) + f(E_{n-1}^\gamma)\}} \quad (2.126)$$

where $f(E_n^\gamma)$ means the weighting function and

$$E_n^\gamma = E_{i+1}^\gamma + (n-1)\frac{E_i^\gamma - E_{i+1}^\gamma}{N}. \tag{2.127}$$

The integral of σ_c in Eq. (2.126) can be expressed as

$$\int_{E_{j-1}^e}^{E_j^e} \sigma_c(E^\gamma \to E^e)\,dE^e$$

$$= \frac{8}{3}\pi r_0^2 \cdot \frac{3}{8}\frac{1}{\alpha_\gamma^2}\left[\frac{\alpha^2}{2\alpha_\gamma} + \left(\frac{1}{\alpha_\gamma^2} - \frac{2}{\alpha_\gamma}\right)\alpha - \frac{1}{\alpha} + \left(\alpha_\gamma - \frac{2}{\alpha_\gamma} - 2\right)\ln\alpha\right]_a^b, \tag{2.128}$$

where $\alpha = E^e/m_0c^2$; m_0: electron rest mass,
$a = \alpha_\gamma - \alpha(E_j^e)$,
$b = \alpha_\gamma - \alpha(E_{j+1}^e)$. (2.129)

The total cross section calculated by the process is normalized to the value of MT=504 in the DLC-15 library.

The secondary electron production cross section for pair-production process is calculated as follows:

$$\sigma_P(E^\gamma \to E^e) = 2\sigma_P(E^\gamma)\,g(E^\gamma \to E^e), \tag{2.130}$$

where σ_p is retrieved from the value of MT=516 in the DLC-15 library and $g(E^\gamma \to E^e)$ is the emitted electron spectrum for which the formulation[50] of Bethe and Heitler is adopted. The group cross section is generated as follows:

$$\sigma_P(E_i^\gamma \to E_j^e) = 2\sigma_P(E_i^\gamma)\,g(E_i^\gamma \to E_j^e), \tag{2.131}$$

$$g(E_i^\gamma \to E_j^e) = \frac{\phi(E_i^\gamma,\ E_j^e)\,\Delta E_j^e}{\int_0^{E_i^\gamma - 2mc^2}\phi(E_i^\gamma,\ E^e)\,dE^e}, \tag{2.132}$$

where

$$\phi(K,\ E_O)\,dE_O = \frac{Z^2}{137}\left(\frac{e^2}{\mu}\right)^2\frac{P_O P_+}{K^3}\,dE_O\left\{-\frac{4}{3} - 2E_O E + \frac{P_O^2 + P_+^2}{P_O^2 P_+^2}\right.$$
$$+\mu^2\left(\frac{\varepsilon_O E_+}{P_O^3} + \frac{\varepsilon_+ E_O}{P_+^3} - \frac{\varepsilon_+ E_O}{P_O P_-}\right) + \left[\frac{K^2}{P_O^3 P_+^3}(E_O^2 E_-^2 - P_O^2 P_+^2) - \frac{8}{3}\frac{E_O E_+}{P_O P_+}\right] log$$
$$\left. + \frac{\mu^2 K}{2P_O P_+}\left[\frac{E_O E_+ - P_O^2}{P_O^3}\varepsilon_O + \frac{E_O E_- - P_+^2}{P_-^3}\varepsilon_- + \frac{2KE_O E_+}{P_O^2 P_-^2}\right] log\right\}, \tag{2.133}$$

$$E_O = E_j^e + \mu,$$
$$P_O = \sqrt{E_O^2 - \mu^2},$$
$$K = E_O + E_-,$$
$$\varepsilon_O = ln\frac{E_O + P_O}{E_O - P_O} = 2\ln\frac{E_O + P_O}{\mu},$$
$$\varepsilon_+ = 2\ln\frac{E_+ + P_+}{\mu},$$
$$\log = \ln\frac{E_O K - P_O^2 + P_O P_+}{E_O K - P_O^2 - P_O P_+} = 2\ln\frac{E_O E_+ + P_O P_- + \mu^2}{\mu K} \tag{2.134}$$

and

K : incident photon energy,
E_o, E_+ : emitted total energies of electron and positron, respectively,
P_o, P_+ : momenta of electron and positron, respectively.
μ : m_0c^2 (0.511 MeV).

The secondary electron production cross section for photo-electric process is calculated as follows:

$$\sigma_{ph}(E_i^\gamma \rightarrow E_j^e) = \sigma_{ph}(E^\gamma)\delta(E^\gamma - E_{BK} - E^e), \tag{2. 135}$$

where E_{BK} is the energy level of K-shell. The value of MT=602 in the DLC-15 library is adopted as σ_{ph}. The group cross section is generated as follows:

$$\sigma_{ph}(E_i^\gamma \rightarrow E_j^e) = \frac{\int_a^b f(E) \cdot \sigma_{ph}(E^\gamma)dE}{\int_{E_{i+1}^\gamma}^{E_i^\gamma} f(E)dE}, \tag{2. 136}$$

where f is the weighting function and

$$\left.\begin{aligned} a &= Max\ [E_{i+1}^\gamma,\ E_{j+1}^e + E_{BK}] \ , \\ b &= Min\ [E_i^\gamma,\ E_j^e + E_{BK}] \ . \end{aligned}\right\} \tag{2. 137}$$

The integration of Eq. (2.136) is performed by using the trapezoidal rule for N meshes in a gamma-ray group. (N is given by the input in the 17$ array), If the constant approximation is assigned for the weighting function, the integration is performed analytically corresponding to the assigned interpolation scheme.

The photon spectrum data are obtained by the Monte Carlo code ETRAN[41)42)] which computes electron-photon interations in the slab configuration as shown in **Fig. 2.12**. The data are given in the tabular form for electron energy, photon energy and angle and normalized by an incident electron. Therefore, the data are transformed in the following manner and stored as the block data statements:

$$P(E^e,\ E^\gamma) = \frac{1}{N_A}\int_{-1}^{1}\left(\frac{d^2n}{dE^\gamma \cdot d\Omega}\right)2\pi d\mu, \tag{2. 138}$$

where N_A is the atomic number density of target material (n/cm^3), E^e is the incident electron energy, E^γ is the emitted photon energy and n means the photon intensity per incident electron. The transformed data $P(E^e,\ E^\gamma)$ are shown in **Table 2.10**. The data are interpolated in the incident electron energy as follows:

$$P(E^e,\ E^\gamma) = I \cdot P(E_i^e,\ E_i^\gamma), \tag{2. 139}$$

where
E^e : incident electron energy,
E^γ : emitted photon energy $E^\gamma = E^e E_i^\gamma / E_i^e$,
E_i^e : incident electron energy in the block data, that is the nearest one to E^e,
E_i^γ : photon energy group boundary for the incident electron energy E_i^e,
I : normalization factor.

The normalization factor is defined in such a way as the integrated value of $P(E^e,\ E^\gamma)$ over E^γ agrees with the interpolated one between the integrated value of $P_n(E_n^e,\ E_n^\gamma)$ and $P_{n-1}(E_{n-1}^e,\ E_{n-1}^\gamma)$ or $P_{n+1}(E_{n+1}^e,\ E_{n+1}^\gamma)$. The interpolation scheme in log-log is adopted in the calculation. The electron energy group structure adopted in the computation is shown in **Table 2.11**. The data for 6 elements only are stored. When the different material is assigned, the nearest high-Z element in the data is adopted. Therefore, the Bremsstrahlung contribution is roughly estimated in this case.

The Bremsstrahlung data for each material are finally generated and stored in DATA-POOL with a node name of BREM, as follows:

$$\Sigma(E_i^\gamma \rightarrow E_j^e) = \sum_n N_A^n \left\{\sigma_c(E_i^\gamma \rightarrow E_j^e) + \sigma_p(E_i^\gamma \rightarrow E_j^e) + \sigma_{ph}(E_i^\gamma \rightarrow E_j^e)\right\}, \tag{2. 141}$$

$$P(E_j^e \to E_k^\gamma) = \sum_n N_A^n P^n(E_j^e,\ E_k^\gamma) \cdot \Delta E_k^\gamma, \tag{2. 142}$$

$$\Sigma_B(E_i^\gamma \to E_k^\gamma) = \sum_j \Sigma(E_i^\gamma \to E_j^e) \cdot P(E_j^e \to E_k^\gamma). \tag{2. 143}$$

The method of Bremsstrahlung calculation is described in Section 3.4, where a benchmark result is also discussed.

Table 2.9 Description of targets

Element	Z	A	Density (g/cm^3)	I_{adj}* (eV)	Thickness T_0(MeV)	Thickness g/cm^2
C	6	12.01115	2.25	78	1	4.895×10^{-1}
					3	1.704×10^{0}
					10	5.615×10^{0}
					30	1.501×10^{1}
Al	13	26. 9815	2.70	163.0	1	5.508×10^{-1}
					3	1.873×10^{0}
					10	5.899×10^{0}
					30	1.459×10^{1}
Fe	26	55.847	7.86	285.4	1	6.066×10^{-1}
					3	2.016×10^{0}
					10	6.036×10^{0}
					30	1.364×10^{1}
Cu	29	63.54	8.98	314.1	1	6.250×10^{-1}
					3	2.066×10^{0}
					10	6.118×10^{0}
					30	1.360×10^{1}
Mo	42	95.94	10.22	438.8	1	6.726×10^{-1}
					3	2.168×10^{0}
					10	6.149×10^{0}
					30	1.291×10^{1}
W	74	183.85	19.3	748.2	1	7.658×10^{-1}
					3	2.363×10^{0}
					10	6.219×10^{0}
					30	1.199×10^{1}

* I_{adj}: Adjusted mean excitation energy

Table 2.10 Results of the calculation for secondary photons generated by the electron Bremsstrahlung effect

Photon Energy Range (MeV)	Incident Electron Energy (1 MeV)					
	C	AL	FE	CU	MO	W
0.03−0.05	3.40E+00	9.81E+00	3.56E+00	2.90E+00	2.24E+00	6.21E+00
0.05−0.10	1.50E+00	5.53E+00	5.03E+00	4.79E+00	4.68E+00	1.23E+01
0.10−0.15	6.49E−01	2.57E+00	3.32E+00	3.51E+00	5.05E+00	3.67E+00
0.15−0.20	3.59E−01	1.43E+00	1.99E+00	2.16E+00	3.69E+00	3.64E+00
0.20−0.25	2.21E−01	8.81E−01	1.27E+00	1.40E+00	2.51E+00	3.07E+00
0.25−0.30	1.46E−01	5.89E−01	8.59E−01	9.43E−01	1.76E+00	2.42E+00
0.30−0.35	1.00E−01	4.03E−01	5.97E−01	6.59E−01	1.27E+00	1.87E+00
0.35−0.40	7.10E−02	2.87E−01	4.32E−01	4.79E−01	9.24E−01	1.45E+00
0.40−0.45	5.09E−02	2.11E−01	3.14E−01	3.56E−01	6.86E−01	1.11E+00
0.45−0.50	3.69E−02	1.53E−01	2.34E−01	2.62E−01	5.14E−01	8.62E−01
0.50−0.55	2.76E−02	1.12E−01	1.76E−01	1.95E−01	3.94E−01	6.69E−01
0.55−0.60	1.99E−02	8.31E−02	1.29E−01	1.46E−01	2.98E−01	5.03E−01
0.60−0.65	1.40E−02	6.04E−02	9.69E−02	1.08E−01	2.28E−01	3.92E−01
0.65−0.70	9.93E−03	4.33E−02	6.94E−02	7.94E−02	1.65E−01	2.91E−01
0.70−0.75	6.93E−03	2.94E−02	4.90E−02	5.85E−02	1.20E−01	2.21E−01
0.75−0.80	4.80E−03	2.04E−02	3.62E−02	3.97E−02	8.32E−02	1.61E−01
0.80−0.85	2.74E−03	1.20E−02	2.30E−02	2.61E−02	5.67E−02	1.17E−01
0.85−0.90	1.48E−03	7.77E−03	1.40E−02	1.63E−02	3.52E−02	7.75E−02
0.90−0.95	8.61E−04	3.88E−03	7.78E−03	9.12E−03	2.00E−02	4.56E−02
0.95−1.00	2.30E−04	1.09E−03	2.64E−03	2.62E−03	6.48E−03	1.71E−02
TOTAL	2.29E−01	8.18E−01	8.04E−01	8.20E−01	1.17E+00	1.77E+00

Photon Energy Range (MeV)	Incident Electron Energy (3 MeV)					
	C	AL	FE	CU	MO	W
0.05−0.10	6.07E+00	2.01E+01	1.02E−01	8.44E+00	5.21E+00	1.82E+01
0.10−0.20	2.48E+00	9.39E+00	1.07E+01	1.08E−01	1.24E+01	6.07E+00
0.20−0.30	1.13E+00	4.30E+00	5.72E+00	6.17E+00	9.95E+00	8.45E+00
0.30−0.45	5.95E−01	2.27E+00	3.07E+00	3.35E+00	5.91E+00	7.01E+00
0.45−0.60	3.37E−01	1.27E+00	1.75E+00	1.90E+00	3.46E+00	4.82E+00
0.60−0.75	2.13E−01	8.10E−01	1.11E+00	1.21E+00	2.24E+00	3.27E+00
0.75−0.90	1.44E−01	5.48E−01	7.56E−01	8.39E−01	1.53E+00	2.34E+00
0.90−1.05	1.03E−01	3.88E−01	5.33E−01	5.92E−01	1.08E+00	1.69E+00
1.05−1.20	7.35E−02	2.82E−01	3.88E−01	4.34E−01	7.93E−01	1.27E+00
1.20−1.35	5.43E−02	2.07E−01	2.90E−01	3.17E−01	5.95E−01	9.25E−01
1.35−1.50	4.00E−02	1.55E−01	2.17E−01	2.36E−01	4.51E−01	7.29E−01
1.50−1.65	3.05E−02	1.16E−01	1.62E−01	1.80E−01	3.40E−01	5.58E−01
1.65−1.80	2.17E−02	8.91E−02	1.27E−01	1.32E−01	2.63E−01	4.30E−01
1.80−1.95	1.61E−02	6.46E−02	8.88E−02	9.90E−02	1.90E−01	3.23E−01
1.95−2.10	1.13E−02	4.73E−02	6.94E−02	7.48E−02	1.38E−01	2.50E−01
2.10−2.25	8.38E−03	3.29E−02	4.81E−02	5.18E−02	1.03E−01	1.87E−01
2.25−2.40	5.49E−03	2.31E−02	3.37E−02	3.65E−02	6.98E−02	1.33E−01
2.40−2.55	3.03E−03	1.40E−02	2.09E−02	2.43E−02	4.47E−02	9.16E−02
2.55−2.70	1.77E−03	7.88E−03	1.29E−02	1.55E−02	3.10E−02	6.45E−02
2.70−2.85	9.57E−04	3.52E−03	5.76E−03	6.63E−03	1.68E−02	3.73E−02
2.85−3.00	2.17E−04	1.25E−03	2.04E−03	2.53E−03	4.40E−03	1.35E−02
TOTAL	9.13E−01	3.32E+00	3.45E+00	3.54E+00	5.08E+00	5.98E+00

Table 2.10 (continued)

Photon Energy Range (MeV)	Incident Electron Energy (10 MeV)					
	C	AL	FE	CU	MO	W
0.30— 0.50	2.73E+00	9.66E+00	1.22E+01	1.32E+01	2.10E+01	1.90E+01
0.50— 1.00	1.24E+00	4.33E+00	5.52E+00	5.98E+00	1.04E+01	1.37E+01
1.00— 1.50	5.80E−01	2.04E+00	2.54E+00	2.74E+00	4.68E+00	6.53E+00
1.50— 2.00	3.49E−01	1.22E+00	1.51E+00	1.63E+00	2.81E+00	3.95E+00
2.00— 2.50	2.30E−01	8.10E−01	1.01E+00	1.10E+00	1.87E+00	2.64E+00
2.50— 3.00	1.61E−01	5.71E−01	7.12E−01	7.71E−01	1.31E+00	1.83E+00
3.00— 3.50	1.17E−01	4.17E−01	5.20E−01	5.60E−01	9.49E−01	1.33E+00
3.50— 4.00	8.76E−02	3.15E−01	3.92E−01	4.25E−01	7.11E−01	9.90E−01
4.00— 4.50	6.61E−02	2.36E−01	2.94E−01	3.22E−01	5.39E−01	7.53E−01
4.50— 5.00	5.08E−02	1.84E−01	2.30E−01	2.50E−01	4.22E−01	5.76E−01
5.00— 5.50	3.82E−02	1.43E−01	1.78E−01	1.88E−01	3.24E−01	4.37E−01
5.50— 6.00	2.96E−02	1.09E−01	1.37E−01	1.46E−01	2.46E−01	3.46E−01
6.00— 6.50	2.23E−02	8.40E−02	1.07E−01	1.14E−01	1.89E−01	2.67E−01
6.50— 7.00	1.62E−02	6.47E−02	8.00E−02	8.45E−02	1.46E−01	2.02E−01
7.00— 7.50	1.26E−02	4.40E−02	5.70E−02	6.34E−02	1.08E−01	1.52E−01
7.50— 8.00	8.55E−03	3.15E−02	4.06E−02	4.43E−02	7.54E−02	1.10E−01
8.00— 8.50	4.80E−03	1.73E−02	2.42E−02	2.68E−02	4.61E−02	7.47E−02
8.50— 9.00	2.90E−03	1.09E−02	1.38E−02	1.56E−02	2.65E−02	4.76E−02
9.00— 9.50	1.57E−03	5.63E−03	7.95E−03	8.40E−03	1.54E−02	2.53E−02
9.50—10.00	4.74E−04	1.88E−03	2.19E−03	2.70E−03	5.38E−03	9.82E−03
TOTAL	2.06E+00	7.25E+00	9.12E+00	9.87E+00	1.66E+01	2.08E+01

Photon Energy Range (MeV)	Incident Electron Energy (30 MeV)					
	C	AL	FE	CU	MO	W
0.50— 1.00	3.95E+00	1.30E+01	1.58E+01	1.69E+01	2.85E+01	3.40E+01
1.00— 2.00	1.72E+00	5.49E+00	6.15E+00	6.53E+00	1.05E+01	1.34E+01
2.00— 3.00	8.95E−01	2.85E+00	3.14E+00	3.31E+00	5.27E+00	6.58E+00
3.00— 4.50	5.29E−01	1.68E+00	1.83E+00	1.92E+00	2.99E+00	3.61E+00
4.50— 6.00	3.27E−01	1.03E+00	1.10E+00	1.16E+00	1.78E+00	2.09E+00
6.00— 7.50	2.23E−01	6.97E−01	7.37E−01	7.73E−01	1.17E+00	1.34E+00
7.50— 9.00	1.59E−01	5.00E−01	5.26E−01	5.44E−01	8.14E−01	9.25E−01
9.00—10.50	1.18E−01	3.68E−01	3.87E−01	3.98E−01	6.02E−01	6.60E−01
10.50—12.00	8.95E−02	2.79E−01	2.89E−01	3.05E−01	4.47E−01	4.94E−01
12.00—13.50	7.07E−02	2.16E−01	2.24E−01	2.30E−01	3.43E−01	3.80E−01
13.50—15.00	5.43E−02	1.68E−01	1.77E−01	1.82E−01	2.68E−01	2.97E−01
15.00—16.50	4.29E−02	1.35E−01	1.36E−01	1.43E−01	2.07E−01	2.25E−01
16.50—18.00	3.38E−02	1.03E−01	1.09E−01	1.10E−01	1.64E−01	1.79E−01
18.00—19.50	2.61E−02	8.45E−02	8.38E−02	8.91E−02	1.31E−01	1.39E−01
19.50—21.00	1.99E−02	6.37E−02	6.53E−02	6.72E−02	9.95E−02	1.09E−01
21.00—22.50	1.50E−02	4.68E−02	4.94E−02	5.04E−02	7.42E−02	7.75E−02
22.50—24.00	1.05E−02	3.34E−02	3.48E−02	3.67E−02	5.75E−02	5.82E−02
24.00—25.50	6.43E−03	2.14E−02	2.23E−02	2.40E−02	3.49E−02	3.61E−02
25.50—27.00	4.16E−03	1.38E−02	1.37E−02	1.46E−02	1.86E−02	2.04E−02
27.00—28.50	2.05E−03	7.15E−03	7.39E−03	7.46E−03	1.20E−02	1.25E−02
28.50—30.00	6.20E−04	2.31E−03	2.68E−03	2.75E−03	3.83E−03	4.95E−03
TOTAL	7.19E+00	2.30E+01	2.59E−01	2.74E+01	4.39E+01	5.29E+01

Table 2.11 Energy group structure for electrons in the Bremsstrahlung calculation

Group	Electron Energy (eV)	Mean Energy
1	25.0 – 35.0	30.0
2	20.0 – 25.0	22.5
3	15.0 – 20.0	17.5
4	12.0 – 15.0	13.5
5	10.0 – 12.0	11.0
6	8.0 – 10.0	9.0
7	6.5 – 8.0	7.25
8	5.0 – 6.5	5.75
9	4.0 – 5.0	4.5
10	3.0 – 4.0	3.5
11	2.5 – 3.0	2.75
12	2.0 – 2.5	2.25
13	1.66 – 2.0	1.83
14	1.33 – 1.66	1.495
15	1.1 – 1.33	1.215
16	0.9 – 1.1	1.0
17	0.0 – 0.9	0.45

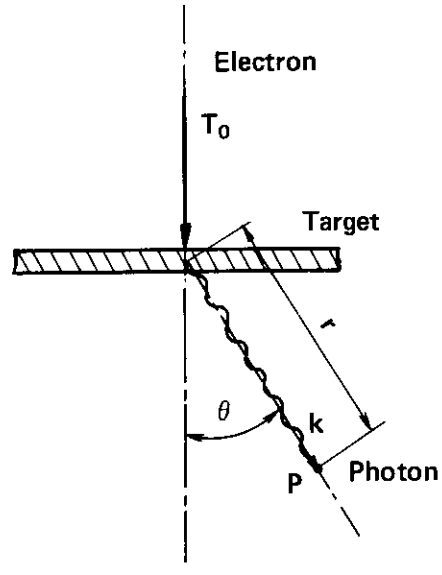


Fig. 2.12 Configuration for computation of Bremsstrahlung

2.1.8 Input Instruction

Input data to FAIR-CROSS are written in the FIDO format except for title cards and a unit assignment card for DATA-POOL.

In the following, a size of data arrays is given in square brackets, and the condition under which the data array is to be specified is given in parentheses. The data array without the condition must always be specified.

1. Main title card Format (20A4)
   Arbitrary comments are given.

2. DATA-POOL assignment card
   Logical unit numbers for each cross section library are written in this card whose format is a Name list input described below:

   &UNIT ULTX=n1, INFX=n2, FTBL=n3, SGXL=n4, FXSN=n5, SELF=n6 &END

   '&UNIT' should be written from 2nd column. Unit names, ULTX, etc., indicate following libraries.

   ULTX : Ultra-fine group cross section library
   INFX : Infinite dilution cross section library
   FTBL : Self-shielding factor library
   SGXL : Secondary gamma-ray cross section library
   FXSN : Effective macroscopic cross section library
   SELF : Self-shielding factors for each composition

   The logical unit numbers (n1~n6) are desired to be chosen from 91 to 99.

3. Control parameters for Main routine

   1$ Main parameters [8]

   1. ISTEP : Selection of the calculational step.
      1=step 1 (generate micro cross sections)
      2=step 2 (generate macro cross sections)
      3=step 3 (convert to P_ℓ cross sections)
   2. NMAT : Number of nuclide or material.
      For step 1, NMAT means number of nuclides to be processed.
      For step 2, it means number of nuclides included in a mixture and means number of materials to be convert to P_ℓ cross sections for step 3.
   3. ING : Number of neutron energy groups.
   4. IGG : Number of gamma-ray energy groups.
   5. IPO : Number of angular meshes.
      This has no effect for step 1.
      This should be selected from the values of 16, 24, 32, 48, 64 and 96 for step 2 and step 3.
   6. NODEEG : Node name for the energy group structure (4-characters). This data is specified by a form of 4HXXXX, where XXXX shows a node name.
   7. ITYPE : Selection of the neutron energy group boundary.
      0=use the data with the node name of NODEEG
      1=input by cards (2* array)
      2=use the default values (same as the JSD1000 library)
   8. JTYPE : Selection of gamma-ray energy group boundary.
      0=use the data with the node name of NODEEG
      1=input by cards (3* array)

2=use the default values (same as the JSD1000 library)

T Termination of this data block.

2* Neutron energy group boundary [ING+1] (ITYPE=1)
3* Gamma-ray energy group boundary [IGG+1] (JTYPE=1)

T Termination of this data block.

If both of ITYPE and JTYPE are not equal to 1, skip the above data block.

4. Input data for step 1 (ISTEP=1)
Repeat this input data by the number of nuclides to be processed (NMAT).
a. Title card Format (20A4)
This title is used for the comment of a nuclide in the cross section library.
4$ Integer parameters [16]
1. MATNO : Material number in a nuclear data file.
2. NDFB : Logical unit number for a nuclear data file.
Negative number indicates that the processed nuclear data file is ENDF/B-V.
3. ISTART : Restart option.
0=not restart
1=generate the ultra-fine group cross section only
2=restart from the ultra-fine group library
3=restart from the fine-group library
4. NTMP : Number of temperature.
5. NSIG : Number of background cross sections, including the infinite dilution cross section.
6. IW : Option for the weighting function.
1=$1/E$
2=constant
3=arbitrary weighting function (read in the 8$ and 9* arrays)
4=Maxwell+$1/E$+fission spectrum
(joint energies are given in the 7* array)
7. N1 : Parameter for the arbitrary weighting function.
0=no effect
N=number of interpolation regions used to specify this function defined as in ENDF/B-IV (IW=3)
8. N2 : Parameter for the arbitrary weighting function.
0=no effect
N=number of energy point in this function (IW=3)
9. LINK1 : Calculation of resonance parameters.
0=no
1=yes, infinite dilution cross sections for the unresolved resonance region are calculated by the method used in the MC^2 code
2=yes, infinite dilution cross sections for the unresolved resonance region are calculated by the same method adopted in the resolved resonance region
10. LINK2 : Calculation of scattering matrices.
0=no
1=yes

11. LINK3 : Calculation of atomic displacement cross sections and energy deposition factors.
    0=no
    1=yes
12. LINK4 : Calculation of thermal scattering cross sections from the scattering law data given in the nuclear data file.
    0=no
    1=yes
13. NGOUT : Output of the ultra-fine group library.
    0=no
    1=output of the infinite dilution cross section for a standard temperature (first temperature in the 5* array)
    2=output of cross sections for all background cross sections and temperatures
14. NPRT1 : Print of point-wise cross sections in the resolved resonance region.
    0=no
    1=yes
15. NPRT2 : Print of the ultra-fine group cross sections.
    0=no
    1=yes, number of reaction type to be printed. Reaction types are specified in the 12$ array.
16. NPRT3 : Print of scattering matrices.
    0=no
    1=yes, print of group-to-group matrix
    2=yes, print of the double differential cross sections

T Termination of this data block.

5* Temperature in Kelvin [NTMP]
At first a standard temperature should be inputted.

6* Background cross sections in barns [NSIG]
At the first, 10^8 for the infinite dilution cross section should be inputted.

7* Parameters for the weighting function [3] (IW=4)

1. EB : Boundary energy in eV between Maxwellian and $1/E$.
2. TC : Temperature in eV for a fission spectrum.
3. EC : Boundary energy in eV between $1/E$ and a fission spectrum.

8$ Interpolation schemes for the arbitrary weighting function [2*N1] (IW=3)
Last point numbers and interpolation schemes in the interpolation region are inputted alternately. This form is the same as that in the ENDF/B file.

9* Energies and weights for the arbitrary weighting function [2*N2] (IW=3)
Energies should be given in the increasing order in eV. Energies and weights are given alternately.

10* Reconstruction tolerance [4]

1. ERR : Permissible relative error in resolved resonance cross sections.
2. AVERR : Specification of a resonance tail for the approximation method in the resolved resonance calculation. If zero is set, this option is neglected.
3. ERR2 : Permissible relative error in double differential cross sections.
4. TEFF : Effective temperature (Kelvin) in the short collision time approximation for thermal scattering calculation. If zero is set, this approximation is not adopted.

11* Constants for the calculation of atomic displacement cross sections and energy deposition factors [5] (LINK3=1)

1. ED : Effective displacement energy in eV.
2. QNG : Q-value for the (n, γ) reaction in eV.
3. QNP : Q-value for the (n, p) reaction in eV.
4. ANA : Q-value for the (n, α) reaction in eV.
5. HFB : Kinetic energy of the fission fragment in eV.

If a Q-value is set to zero, the value in ENDF/B File 3 is used for each reaction type.

12$ Reaction types to be printed in the ultra-fine group cross sections [NPRT2] (NPRT2≠0)

Reaction types are specified by the MT numbers in the ENDF/B library.

13$ Data for thermal scattering calculation [4] (LINK4=1)

1. MATNO2 : Material identification number of the nuclear data file, including thermal scattering law.
2. NDSL : Logical unit number for the nuclear data file.
3. NGTH : The energy group number of the upper limit for source energy of thermal up-scattering.
   If the value is set to zero, the appropriate value given in the File 7 of ENDF/B format is set.
4. NOGTH : Number of meshes per each energy group to be calculated.

T Termination of this data block.

5. Input data for step 2 (ISTEP=2)

a. Title card Format (20A4)

This title is used for the comment of a material in the cross section library.

4$ Selection of modules [6]

1. MATID : Node name for the macroscopic cross section in the library (4-characters).
   This data is specified as 4HXXXX, where XXXX is a node name.
2. IOPT1 : Execution of FACTOR that calculates effective microscopic neutron cross sections.
   0=no
   1=yes
3. IOPT2 : Execution of SGRX that calculates secondary gamma-ray production cross sections.
   0=no
   1=yes
4. IOPT3 : Execution of GAMMA that calculates gamma-ray cross sections.
   0=no
   1=yes, an empirical formula is adopted.
   2=yes, DLC-15 library is adopted.
   3=yes, DLC-15 library is adopted and Bremsstrahlung data are also generated.
5. IOPT4 : Execution of TCUP that couples neutron and gamma-ray cross sections and output to a library.
   0=no
   1=yes
6. NUPIN : Number of energy groups for up-scattering.

5$ Data identification numbers in the fine-group library for each composition. [NMAT]

MATNO specified in the 4$ array of step 1 must be assigned here.

7$ Data identification numbers in the self-shielding library for each composition. [NMAT] (IOPT1=1)
MATNO specified in the 4$ array of step 1 must be used for this number. For a composition which is not given in the self-shielding library, put zero to the number.
The order of the numbers should be the same as that in the 5$ array. Also in the following data arrays (8*~10*), the same order in required.

8* Atomic numbers for each composition [NMAT] (IOPT2=1 or IOPT3=1)

9* Atomic number densities for each composition [NMAT]
The unit is [atom/barn • cm]

10* Temperatures in Kelvin for each composition [NMAT]

T Termination of this data block.

b. Input data for the FACTOR module (IOPT1=1)

12$ Output options [2]

1. NPUN : Output of the self-shielding factor for each composition to the DATA-POOL.
   0=no
   1=yes
2. IPR1 : Print of the effective neutron cross sections for each composition.
   0=no
   1=yes

T Termination of this data block.

c. Input data for SGRX module (IOPT2=1)

Repeat the 13$ and 14$ arrays for each composition.

The order of input compositions is arbitrary.

13$ Control parameters [4]

1. MATNO : Data identification number specified in the 5$ array.
2. NMATLS : Number of the reaction type to be processed.
   If there is no reaction, put zero.
3. NXSEC : Selection of the interaction cross sections for the nonresonance reaction.
   0=Secondary gamma-ray cross section library
   1=Infinite dilution cross section library
1. LOOK : Print of the secondary gamma-ray production cross sections.
   0=no
   1=print for total reaction
   2=print for each reaction type

T Termination of this data block.

14$ Data identification numbers in the secondary gamma-ray library for each reaction type [NMATLS] (NMATLS≠0)

T Termination of this data block.

d. Input data for the GAMMA module (IOPT3≥1)

17$ Control parameters [6]

1. N : Number of fine energy meshes per group.
2. KON : Option for the weighting function.
   0=constant
   1=input the weighting function in the 21*, 22* arrays
3. IF : Number of energy points for the weighting function.
   For KON=0, put zero.
4. LOOK : Print of the gamma-ray cross section.
   0=no
   1=yes
5. IPRTO : Print of absorption and coherent scattering cross sections.
   0=no
   1=print for each group
   2=print for each fine energy mesh
6. IPRJ1 : Print of the energy deposition factor
   0=no
   1=print for each group
   2=print for each fine energy mesh

T Termination of this data block.

21* Energy points for the weighting function. [IF] (KON=1)
Energies should in given in the descending order by MeV.

22* Weights for the weighting function. [IF] (KON=1)
These data should correspond to the 21* array, and a linear interpolation is used between the energy ponts.

T Termination of thie data block.

e. Input data for the TCUP module (IOPT4=1)

29$ Control parameters [4]

1. NPUN : Output of macroscopic cross sections to a library.
   0=yes
   1=no
2. IPRT : Print of macroscopic cross sections.
   0=no
   1=print
   2=print with the DAR form
3. NHEAT : Incorporation of the energy deposition factors into the cross sections table.
   0=no
   1=yes
4. NDISP : Incorporation of the atomic displacement cross sections into the cross section table.
   0=no
   1=yes

T Termination of this data block.

6. Input data for step 3

30$ Control parameters [3]

1. LOR : Maximum order of the Legendre expansion to be generated.
2. LIB : Output form of the cross section library.
   1=ANISN-JR material-wise
   2=DOT material-wise
   3=ANISN-JR forward-group-wise (group independent)
   4=ANISN-JR adjoint-group-wise (group independent)
3. IPG : Print of cross sections
   −1=print cross sections by each energy group
   0=no print
   N=print cross sections for the energy groups defined in the 33$ array

T Termination of this data block.

31$ Node names of materials contained in the cross section library [NMAT]

32$ Material identification numbers for each material defined in the 31$ array [NMAT]

33$ Energy groups to be printed [IPG]

T Termination of this data block.

2.1.9 Input/Output File Assignment

FAIR-CROSS requires various direct-access devices during the execution. **Table 2.12** shows the names of the data sets. The logical unit number marked with a circle in the table is required to execute the job. The logical unit number which is marked with a condition in parentheses is required when the condition is satisfied. The value for the first space estimation changes with the various conditions of computation, so that it is roughly estimated.

2.1.10 Job Control Language

The job control languages for FAIR-CROSS step 1, step 2 and step 3 are shown in **Figs. 2.13(a)**, **(b)** and **(c)**, respectively.

Table 2.12 Requirements for external data sets in FAIR–CROSS

Logical Unit	Files required in FAIR–CROSS			Contents	1st. Space Estimation (Tracks)	DCB Information		
	step 1	step 2	step 3			LRECL	BLKSIZE	RECFM
ULTX	○*			DATA-POOL	—	3600	3600	F
INFX	○*	○*						
FTBL	○*	○*						
SGXL		○*						
FXSN		○*	○*					
SELF		○*						
NDFB	○			Nuclear Data (ENDF/B format)				FB
NDSL	(LINK4=1)			Thermal Scattering Law Data (ENDF/B format)				
FT08F001		(IOPT3≥2)		DLC–15 Library				
FT01F001	○		○	Scratch	30			
FT02F001	○		○	Scratch	30			
FT03F001	○		○	Scratch	30			
FT04F001	○			Scratch	30	19064	19068	VBS
FT10F001	○			Scratch	30	(13030)	(13034)	
FT11F001	○	○		Scratch	30			
FT12F001	○			Scratch	30			
FT13F001	○	○		Scratch	300 for step 1 30 for step 2	16804	16804	F
FT14F001	○	○		Scratch	30			
FT15F001	○			Scratch	30			
FT16F001		○		Scratch	30			
FT17F001		○		Scratch	30	19064	19068	VBS
FT18F001		○		Scratch	30	(13030)	(13034)	
FT21F001 ~ FT29F001		○†		Scratch for each nucleus	30			
FT40F001			○	P_l X.-sec. (material wise)	100			
FT50F001			(LIB≥3)	P_l X.-sec. (group independent)				

* Logical unit numbers are defined by the unit assignment card.

† Number of scratch files is equal to the number of nuclei to be processed.

```
//JCLG  JOB                                                          00000100
// EXEC JCLG                                                         00000200
//SYSIN DD DATA,DLM='++'                                             00000300
// JUSER 82903679,NA.YAMANO,0954.100                                 00000400
   T.41.5P.OW.3C.5 SRP                                              00000500
 OPTP PASSWORD=XX                                                   00000600
// EXEC FORT77,SO='J9646.FCSTEP1X',A='ELM(*),NOS'                    00000700
// EXEC LKED77,PRVLIB='J9646.DPOOL2',                                00000800
//       A=OVLY,CNTL=NO                                             00000900
//SYSLMOD DD DSN=J9646.FCSTEP1X.LOAD,UNIT=MSS,DISP=SHR               00000910
 OVERLAY SEG000                                                     00001000
 INSERT  SPTOG                                                      00001100
 OVERLAY SEG100                                                     00001200
 INSERT  CONT,LIST,TAB1,TAB2,TRID,IMAT,TPOS,HOLL,XTND,SAVE,GAUS16   00001300
 INSERT  GRATE,ECSI,TERPD,TERP,TERP1,GETG1,ERR,ERROR,RDGCS,SET      00001400
 INSERT  RECS                                                       00001500
 OVERLAY SEG200                                                     00001600
 INSERT  ZERO,ININ,GETFG,TMF1,SKPFIL,SETIN,EED                     00001700
 OVERLAY SEG200                                                     00001800
 INSERT  TAB1M,PRSECT,FINDXS,FCOPY,FINDB                            00001900
 OVERLAY SEG310                                                     00002000
 INSERT  PROF2,TMF2,SIGMA,DUMPCS,RDBW,CSMLBW,CSSLBW,FACTS,FACPHI    00002100
 INSERT  MESH,ORDER,CSTTL,CSNORP,JTEST,NODEX,CCBW                   00002200
 INSERT  CSAA,CSRM,CSUNR1,CSUNR2,CSV,FLCTFC,GNRL,INTERF,INTER1      00002300
 INSERT  INVERS,RDAA,RDBW1,RDFIL2,RONORP,RDUNR1,RDUNR2,RDV,UNFAC    00002400
 OVERLAY SEG310                                                     00002500
 INSERT  PROF3,COMBR,FINDR,STORS,LOADR                              00002600
 OVERLAY SEG310                                                     00002700
 INSERT  DOPPLR,DOPCAL,CHKRNG,ERF,ERFC,FUNKY,HUNKY,INP,LOPAGE      00002800
 INSERT  LINRIZ,SIGBAR,SGBRDN,SGTHIN,FINDX,STORS1,CZERO             00002900
 OVERLAY SEG200                                                     00003000
 INSERT  SMOOTH,GETW,MAXWEL,GENT1,GPAVE1,FETCH,STORE,DELETE         00003100
 INSERT  COMB,COMBP,IPDS,FPDS,LRIDS,ADD,SUB,MULT,DIV,LIBOUT         00003200
 INSERT  RESU,FJ,DLAG,INTER                                         00003300
 INSERT  DENS                                                       00003400
 OVERLAY SEG200                                                     00003500
 INSERT  RDFGX,CROS,STORX,PRFTL,OUT3,RDSMT,VDIMEN                   00003600
 OVERLAY SEG200                                                     00003700
 INSERT  FCNTRO,GALT,EXTPO                                          00003800
 INSERT  TRANCE,CALNW,ERRLST,ETASIG,GFLMAX,GDASMA,INLST1,GZERO,DCHAG 00003900
 INSERT  INTEG,OFLOW,PICARD,PREP,WELPOT,HOSEI,GNUE5                 00004000
 OVERLAY SEG200                                                     00004100
 INSERT  SMAT,INSCAT,NORMAT,INTGLN,SPOSIT,REDUC,INTGST              00004200
 INSERT  FILE5                                                      00004300
 OVERLAY SEG350                                                     00004400
 INSERT  TRANS,ARNG,CLELS,CONVME,DCSIG,ERR1,EXPNS,GETEN,INTRP       00004500
 INSERT  MURAG,RELX,SENGY,SETEM,TMF4,XTABL,LEGDDN                   00004600
 INSERT  FCNTR1,GNUE,FCNTR3,GNUE1                                   00004700
 OVERLAY SEG350                                                     00004800
 INSERT  INELAS,IMAT,TMF5,INF5,LFONE,INPROB,SUMLEV                  00004900
 INSERT  FCNTR2,GNUE2,GNUE4                                         00005100
 OVERLAY SEG350                                                     00005200
 INSERT  PROF7,PRE7,CKER1,CKER2,FEINT,FEINA,FKC,GNC,GNCR            00005300
 INSERT  KERA,KERC,K1F,REATS,REKON,TERP2,TERP3                      00005400
 OVERLAY SEG100                                                     00005500
 INSERT  SNOUT,FCNOUT                                               00005600
//FCROSS EXEC LMGO,LM='J9646.FCSTEP1X',OBSIZE=137,ORECFM=FA          00006000
// EXPAND DISK,DDN=FT01F001,SPC='100,20'                             00006100
// EXPAND DISK,DDN=FT02F001,SPC='100,20'                             00006200
// EXPAND DISK,DDN=FT03F001,SPC='100,20'                             00006300
// EXPAND DISK,DDN=FT04F001,SPC='100,20'                             00006400
// EXPAND DISKTO,DDN=FT08F001,DSN='J1615.ENDFB4O8',DISP=SHR          00006500
// EXPAND DISK,DDN=FT10F001,SPC='100,20'                             00006600
// EXPAND DISK,DDN=FT11F001,SPC='100,20'                             00006700
// EXPAND DISK,DDN=FT12F001,SPC='100,20'                             00006800
// EXPAND DISK,DDN=FT13F001,SPC='800'                                00006900
// EXPAND DISK,DDN=FT14F001,SPC='100,20'                             00007000
// EXPAND DISK,DDN=FT15F001,SPC='100,20'                             00007100
// EXPAND DISKTO,DDN=FT91F001,DSN='J9646.POOL77',MODE=OUT            00007700
//SYSIN DD *                                                         00007800
   FAIR-CROSS STEP1                                                 00007900
 &UNIT   INFX=91,FTBL=91 &END                                       00008000
 1**   1  1  100  20  0 4HEGRP  2  2  T                            00008100
 1276 0-16 FROM ENDF/B-IV                                           00008200
 4**   1276 8 0 1 7 4 0 0 1 1 0 0 0 0 0 1   T                      00008300
 5**   300.0                                                        00008400
 6**   1.0+8  0.0 1.0 10.0 100.0 1000.0  10000.0                    00008500
 7**   1.25-1   1.4+6   8.208+5                                     00008600
10**   0.01  0.0  0.03  0.0                                        00008700
   T                                                                00008900
++                                                                  00009000
//                                                                  00009100
```

(a) For step 1

Fig. 2.13 Job control cards and input data for FAIR-CROSS for use on the FACOM M-380 computer at JAERI

```
//JCLG  JOB                                                          00000070
// EXEC JCLG                                                         00000080
//SYSIN DD DATA,DLM='++'                                             00000090
// JUSER 81929646,KA.MINAMI,0954.100                                 00000100
 T.2 C.1 W.2 1.3 P.0 SRP                                            00000110
 OPTP PASSWORD=K,NOTIFY=J9646                                       00000120
// EXEC FOR177,SO='J3679.FCSTEP2X',A='ELM(*),NOS',Q='.FORT'          00000140
// EXEC LKED77,PRVLIB='J9646.DPOOL2'                                 00000160
// EXEC GO                                                           00000170
// EXPAND DISK,DDN=FT11F001,SPC='50,20'                              00000190
// EXPAND DISK,DDN=FT13F001,SPC='50,20'                              00000200
// EXPAND DISK,DDN=FT14F001,SPC='50,20'                              00000210
// EXPAND DISK,DDN=FT16F001,SPC='50,20'                              00000220
// EXPAND DISK,DDN=FT17F001,SPC='50,20'                              00000230
// EXPAND DISK,DDN=FT18F001,SPC='50,20'                              00000240
// EXPAND DISK,DDN=FT21F001,SPC='50,20'                              00000250
// EXPAND DISK,DDN=FT22F001,SPC='50,20'                              00000260
// EXPAND DISK,DDN=FT23F001,SPC='50,20'                              00000270
// EXPAND DISKTO,DDN=FT91F001,DSN='J3679.RADHDP02'                   00000280
// EXPAND DISKTO,DDN=FT92F001,DSN='J9646.POOL78',MODE=OUT            00000290
// EXPAND DISKTO,DDN=FT93F001,DSN='J3679.CROSS1'                     00000291
//SYSIN DD *                                                         00000300
   EXECUTION OF FAIR-CROSS STEP2                                    00000310
 &UNIT INFX=92,FIBL=92,SGXL=91,FXSN=92 &END                         00000320
 1**     2    1  100   20   16     4HEGRP  0  0 T                   00000330
  0-16  (ENDF/B)                                                    00000340
 4**     4HO16     1    1    1    1    0                            00000350
 5**            1276                                               00000360
 7**            1276                                               00000370
 8**             8.0                                               00000380
 9**             1.0                                               00000390
10**           300.0                                               00000400
  T                                                                 00000410
12**     0    0    T                                               00000420
13**  1276    4    0    0    T                                     00000430
14**   108  608  208  308    T                                      00000440
17**    10   5RO             T                                     00000450
29**     1    1    0    0                                          00000460
  T                                                                 00000470
++                                                                  00000480
//                                                                  00000490
```

(b) For step 2

```
//JCLG  JOB                                                          00000010
// EXEC JCLG                                                         00000020
//SYSIN DD DATA,DLM='++'                                             00000030
// JUSER 81929646,KA.MINAMI,0954.100                                 00000040
 T.5 C.4 W.3 1.4 P.0 SRP                                            00000050
 OPTP PASSWORD=K,NOTIFY=J9646                                       00000060
// EXEC LHGO,LM='J3679.FCSTEP2X'                                     00000070
// EXPAND DISK,DDN=FT01F001,SPC='100,20'                             00000080
// EXPAND DISK,DDN=FT02F001,SPC='100,20'                             00000090
// EXPAND DISK,DDN=FT03F001,SPC='100,20'                             00000100
// EXPAND DISK,DDN=FT40F001,SPC='100,20'                             00000110
// EXPAND DISKPSN,DDN=FT50F001,DSN=GRP1N,SPC='100,20'                00000120
// EXPAND DISKTO,DSN='J9646.POOL79',DDN=FT91F001                     00000130
//SYSIN DD *                                                         00000140
  CONVERSION TO PL XSEC                                             00000150
 &UNIT INFX=91,FXSN=91 &END                                         00000160
 1**  3  2  100  20  16  4HEGRP  0  0   T                           00000170
30**  3  3  0                    T                                  00000180
31**  4HAIR   4HCONC                                                00000190
32**     100      200                                              00000200
  T                                                                 00000210
++                                                                  00000220
//                                                                  00000230
```

(c) For step 3

2.1.11 Data Notes for FAIR-CROSS

Limitations and Notes for using FAIR-CROSS are described in this section.

Note 1) The maximum number for the ultra-fine groups is 4000, and the value for the fine-groups of neutron is 200. The maximum number of gamma-ray groups is 50.

Note 2) The energy range between 16.736 MeV and 2.6082×10^{-5} eV can be processed for neutrons. The gamma-ray energy less than 1 keV can not be treated when the DLC-15 library is adopted.

Note 3) The maximum number of nuclei in a homogenized mixture is limited up to 20.

Note 4) The maximum number of the background cross sections in a computation is limited to 10.

Note 5) The number of the fixed angular meshes is restricted to among the 16, 24, 32, 48, 64 and 96.

Note 6) The macroscopic cross sections for neutron are generated by using the infinite dilution cross sections and the self-shielding factors of each nucleus, so that the table of self-shielding factors should be produced before the calculation of homogenized mixture. When the self-shielding factors are calculated, NSIG in the 4$ array must be given a number more than one in the computation of FAIR-CROSS step 1. If NTMP in the 4$ array is set a number greater than one, the shielf-shielding factor becomes temperature dependent. The first data in the 5* array must be 10^8 which indicates the infinite dilution approximation because that the denominator in the calculation of the self-shielding factor is set to the first cross section in the 5* array (background cross section) and the 6* array (temperature). If NSIG and NTMP are set to one, only the self-shielded cross section is generated and the self-shielding factor is not produced.

Note 7) FAIR-CROSS step 1 may require too long computation time for the nucleus which has many resonance, e.g., ^{238}U or ^{239}Pu. In this case the step 1 can be divided into three parts. The processes are i) the production of the ultra-fine group cross sections, ii) the production of the fine-group cross sections and the self-shielding factors, and iii) the production of the scattering matrices, the atomic displacement cross sections and the energy deposition factors. These parts can be executed separately by using the restart option, as shown in **Table 2.13**.

Note 8) When the secondary gamma-ray production cross section is computed, the interaction cross section can be selected from that in the fine-group library (NXSEC=1) or the secondary gamma-ray production library (NXSEC=0) for the nonresonance reaction. The interaction cross sections for all excited levels of inelastic reactions are given in the fine-group library. The secondary gamma-ray production cross sections may be overestimated when the yield data corresponding to the interaction cross sections are given only for some excited levels and NXSEC is set to 1. For this case, the interaction cross sections in the secondary gamma-ray production library should be used by setting NXSEC to zero.

Note 9) The numbers of up-scattering groups for each nucleus are different from each other in the process of FAIR-CROSS step 1. The numbers are normalized to NUPIN in the process of FAIR-CROSS step 2. In the FAIR-CROSS step 3, the length of cross section table for ANISN-JR or DOT3.5 is changed according to whether the up-scattering exists or not, so that the user should be attentive in using the data set.

Note 10) The parameters for the calculation of up-scattering are limited by the following conditions:

$$\mathrm{NUPIN} \leq 100,$$
$$\mathrm{NOGTH} \times \mathrm{NUPIN} \leq 200,$$
$$\mathrm{NOGTH} \times \mathrm{NUPOUT} \leq 180,$$
$$\mathrm{NUPIN} \times \mathrm{NUPOUT} \leq 2500,$$

where NUPIN is the number of thermal groups (ING−NGTH+1) and NUPOUT is the number of up-scattered groups.

Table 2.13 Usage of the restart option in FAIR-CROSS

ISTART	NGOUT	LINK1	LINK2	LINK3	Calculated part
0	0/1/2*	1/2	1	0/1	All parts
1	2	1/2	0	0	Ultra-fine group cross section
2	0	0	0	0	Fine-group cross section and Self-shielding factor
3	0	0	1	0/1	Scattering matrix
0	1/2	1/2	0	0	Ultra-fine and fine-group cross sections and self-shielding factor
3	0	0	1	0/1	Scattering matrix

*This indicates that the variable is set to 0, 1 or 2.

2.2 TWOWAY

TWOWAY module converts secondary gamma-ray production data given by a nuclear data file to the arbitrary neutron and gamma-ray energy group structure for the coupled neutron and gamma-ray transport calculation. This module can process two type of nuclear data file, the ENDF/B and POPOP4 library. In this module, neutron interaction cross sections are retrieved from the ultra-fine group cross section library produced at the FAIR-CROSS step 1, and the secondary gamma-ray production data calculated by this module are processed at the FAIR-CROSS step 2 to produce coupled neutron and gamma-ray cross sections.

In the secondary gamma-ray production data, yields and gamma-ray spectra are stored separately for each reaction type. This form is useful to compare and estimate the secondary gamma-ray production data of the ENDF/B and POPOP4 library. This module has two techniques which convert the given energy spectra to the required gamma-ray group structure. These techniques are (1) a constant weighting and (2) an energy weighting. The latter technique conserves the total release energy, so that, this is preferable for the computation with the broad energy group structure.

2.2.1 Secondary Gamma-Ray Production Cross Section

Data generated in the TWOWAY module are the neutron interaction cross section σ_n, the gamma-ray yields Y, and the probabilities $P_{n\to g}$ for each reaction. The relations with the three quantities are as follows:

$$Y_n = \sum_n \sigma_{n\to g}/\sigma_n, \tag{2.144}$$

$$P_{n\to g} = \sigma_{n\to g}/Y_n\sigma_n. \tag{2.145}$$

Secondary gamma-ray (Photon) production data are stored in the ENDF/B File by the following forms:

File 12 Multiplicities for
continuous photon energy and discrete photon energy.
Transition probability arays.

File 13 Photon production cross section for
continuous photon energy and discrete photon energy.

File 14 Photon angular distributions.

File 15 Continuous photon energy spectra.

File 16 Photon energy-angle distributions.

TWOWAY cannot calculate the angular distribution of the secondary gamma-ray production cross

sections in this version. This module calculates secondary gamma-ray production cross sections for a required neutron and gamma-ray energy group structure by the following three schemes.

(1) Multiplicities

Yields, $Y(E)$, at the midpoint energy of the ultra-fine energy group are calculated by interpolating the tabulated multiplicities (File 12).

The yields for the ultra-fine energy groups are multiplied by the neutron interaction cross section, $\sigma_n(E)$, and weighting function, $\phi(E)$, retrieved from the ultra-fine group cross section library:

$$\sigma(n\rightarrow E_\gamma)=\frac{\int_{E_n}^{E_{n+1}} Y(E)\sigma_n(E)\phi(E)dE}{\int_{E_n}^{E_{n+1}}\phi(E)dE}, \tag{2.146}$$

where $E_\gamma(E_{g+1}\leq E_\gamma\leq E_g)$ is a discrete phjoton energy.

When yields are given for a discrete photon energy, the secondary gamma-ray production cross sections for the gamma-ray group g from a neutron interaction in the neutron group n, $\sigma_{n\rightarrow g}$, are calculated according to the specified weighting option.

(A) Constant weighting

$$\sigma_{n\rightarrow g}=\sigma(n\rightarrow E_\gamma), \tag{2.147a}$$

(B) Energy weighting

$$\sigma_{n\rightarrow g}=\frac{2E_\gamma}{E_g+E_{g-1}}\cdot\sigma(n\rightarrow E_\gamma), \tag{2.147b}$$

When the yield is given by a continuous photon emission probabilty $P(E\rightarrow E_\gamma)$ at the neutron energy E, the probability is integrated in the energy interval for each gamma-ray group g according to the specified weighting option:

(A) Constant weighting

$$P_g(E)=\int_{E_g}^{E_{g+1}} P(E\rightarrow E_\gamma)dE_\gamma, \tag{2.148a}$$

(B) Energy weighting

$$P_g(E)=\frac{2\int_{E_g}^{E_{g+1}} P(E\rightarrow E_\gamma)\cdot E_\gamma dE_\gamma}{E_g+E_{g-1}}. \tag{2.148b}$$

Then the secondary gamma-ray production cross sections are calculated as follows:

$$\sigma_{n\rightarrow g}=\frac{\int_{E_n}^{E_{n+1}} Y(E)\sigma_n(E)\phi(E)P_g(E)dE}{\int_{E_n}^{E_{n+1}}\phi(E)dE} \tag{2.149}$$

(2) Transition probability arrays

The secondary gamma-ray production cross section is given according to transitions between specific levels. The photon energy in a transition from the level j to the level i is given by,

$$E_\gamma=ES_j-ES_i, \tag{2.150}$$

where ES_i is the energy of level i. The secondary gamma-ray production cross section at the photon energy E corresponding to a transition from the level j to the level i is given as

$$\sigma(n\rightarrow E_\gamma) = TP(j,\ i)\ \cdot\ GP(j,\ i)\ \frac{\int_{E_n}^{E_{n+1}} \sigma_n(E)\phi(E)dE}{\int_{E_n}^{E_{n+1}} \phi(E)dE}, \qquad (2.\ 151)$$

where $TP(j, i)$ is the probability of a direct transition from the level j to the level i in the File 12 of the ENDF/B library, $GP(j, i)$ is the probability of a photon transition from the level j to the level i (i.e., the conditional probability of photon emission), and $\sigma_n(E)$ is the neutron cross section for inelastic scattering to the level j. The secondary gamma-ray production cross section $\sigma(n\rightarrow E_\gamma)$ is converted to the group cross section in the same manner as used in the preceding section.

(3) Photon production cross section

The photon production cross sections are given by the same form as the multiplicities. A conversion technique for this form is the same as that for the multiplicities except that the photon production cross sections are not multiplied by neutron interaction cross sections.

In the POPOP4 Library, the photon production matrices are given not for point energies but by group cross sections. To convert this matrices with the same technique used for processing the ENDF/B file, the photon production matrices are separated into yields and probabilities, and these probabilities are converted to energy spectra by using the energy weighting of the gamma-ray energy group. The latter process is the same as used for processing the ENDF/B fiile.

The output cross sections in the DATA-POOL are named by new reaction type numbers. The data of each reaction are identified by the three digits. The first digit indicates the reaction channel defined in **Table 2.14**. In this table, the code number 3 includes the inelastic scattering (MT=4 or 51–91), $(n, n'\alpha)$ reaction (MT=22), $(n, n'3\alpha)$ reaction (MT=23), and $(n, n'p)$ reaction (MT=28). The code number 4 includes the $(n, 2n)$ reaction (MT=16) and $(n, 2n\alpha)$ reaction(MT=24). The second and third digits indicate the atomic number of the nuclide. For processing the ENDF/B library the second and third digits are given by the input data (NSEQ in card 4), and for the case of the POPOP4 library, three digits are given by the input data (card 7).

Table 2.14 Identification number of the reaction channel in the secondary gamma-ray production cross section

Code No.	Reaction channel	ENDF/B MT number
1	(n, γ) non-fission	102
2	(n, $\alpha\gamma$)	107
3	(n, n$'\gamma$)	4, 22, 23, 28, 51–91
4	(n, 2n$'\gamma$)	16, 24
5	(n, 3n$'\gamma$)	17
6	(n, pγ)	104
7	not used	—
8	(n, γ) fission	18
9	non-elastic	3

2.2.2 Input Instruction

Input data for TWOWAY are described below.

1. Title card FORMAT (18A4)
   This title is used for the comment of a nuclide in the cross section library.

2. DATA-POOL assignment card
   Logical unit numbers for each cross section libraries are written in this card whose format is a Name list input described below:
   &UNIT ULTX=n1, SGXL=n2, INFX=n3 &END
   '&UNIT' should be written from the 2nd column. Unit names, ULTX, INFX and SGXL indicate following libraries:
   ULTX : Ultra-fine group cross section library
   SGXL : Secondary gamma-ray production cross section library
   INFX : Infinite dilution cross section library
   The logical unit numbers (n1, n2, n3) are desireble to be shosen from 91 to 99.

3. Main control parameters Format (A4, 1X, 5I5)
   1. NODE : Node name of the energy group structure for neutron and gamma-ray. (4-characters)
   2. ING : Number of the neutron energy group.
   3. IGG : Number of the gamma-ray energy group.
   4. ITWO : Selecton of the secondary gamma-ray data.
      1=ENDF/B-IV or ENDF/B-V (File 12~15)
      2=POPOP4 library
   5. ICON : Weighting option for energy spectrum.
      0=constant weighting
      1=energy weighting
   6. IPRT : Print option.
      0=print brief information
      1=print detailed information

4. Control data for the path to ENDF/B library (ITWO=1) Format (3I5, A8)
   1. MATNO : Material number in ENDF/B library.
   2. NDFB : Logical unit number for the ENDF/B tape.
      Negative number indicates that the processed nuclear data file is ENDF/B-V.
   3. NSEQ : Data identification code number. ($0 \leq NSEQ \leq 99$)
   4. NAME : Material name.

5. Control data for the path to the POPOP4 library (ITWO=2) Format (2I5)
   1. MATNO : Material number of ENDF/B-IV.
   2. NMATLS : Number of the reaction type to be processed.

6. Control data for the path to the POPOP4 library (ITWO=2) Format (7I10)
   Data numbers for reactions in the POPOP4 library to be processed.

7. Control data for the path to the POPOP4 library (ITWO=2) Format (7I10)
New identification code numbers for reactions should be written on the DATA-POOL. The order of these code numbers should be the same as the above data array.

2.2.3 Input/Output File Assignment

TWOWAY requires various data sets during execution. **Table 2.15** shows the specification of the data sets.

Table 2.15 Requirements for external data sets in TWOWAY

Logical Unit	Contents	1st. Space Estimation (Tracks)	DCB Information		
			LRECL	BLKSIZE	RECFM
ULTX INFX SGXL	DATA-POOL	—	3600	3600	F
NDFB	Nuclear Data in ENDF/B form	—	—	—	—
FT10F001	POPOP4 library	—	—	—	—
FT01F001	Scratch (ITP1) for broad-group cross section	30			
FT02F001	Scratch (ITP2) for broad-group yield data	30			
FT03F001	Scratch (ITP3) for fine-group yield data or broad-group probability	30	19064	19068	VBS
FT04F001	Scratch (ITP4) for fine-group yield data	30			
FT08F001	Scratch (ITP8) for broad-group photon production cross section	30			

2.2.4 Job Control Language

Figure 2.14 shows a typical job control language for TWOWAY execution.

```
//JCLG JOB                                                        00000100
// EXEC JCLG                                                      00001100
//SYSIN DD DATA,DLM='++'                                          00002100
// JUSER 75173679,NA.YAMANO,0951.200                              00003100
 T.5 C.4 W.2 I.4 P.0 OPN NLP                                     00004100
 OPTP PASSWORD=ACCORD,NOTIFY=J3679                               00005100
// EXEC LHGO,LM='J3679.TWOWAY',Q='.LOAD.K'                        00007100
// EXPAND DISK,DDN=FT01F001                                       00008100
// EXPAND DISK,DDN=FT02F001                                       00009100
// EXPAND DISK,DDN=FT03F001                                       00010100
// EXPAND DISK,DDN=FT04F001                                       00011100
// EXPAND DISK,DDN=FT08F001                                       00012100
// EXPAND DISKTO,DDN=FT10F001,DSN='J1615.ENDFB4O9'                00013100
// EXPAND DISKTO,DDN=FT91F001,DSN='J3679.CROSS2'                  00014100
// EXPAND DISKTO,DDN=FT92F001,DSN='J3679.CROSS1'                  00015100
// EXPAND DISKTO,DDN=FT93F001,DSN='J3679.RADHDP02'                00016100
//SYSIN DD *                                                      00054100
 TWOWAY ENDF/B-IV  TI ( 300 K )                                  00055100
 &UNIT  ULTX=91,INFX=92,SGXL=93 &END                             00056100
EGRP   100   20    1    0    0                                   00056110
 1193   10   22  22-TI ENDF/B-IV ( 300 K )                       00056120
++                                                               00057100
//                                                               00058100
```

Fig. 2.14 Job control cards and input data for TWOWAY for use on the FACOM M-380 computer at JAERI

2.2.5 Data Notes for TWOWAY

Notes for using TWOWAY are described in this section. The user should pay attention to these notes before execution.

Note 1) TWOWAY uses the neutron and gamma-ray group structures stored in the infinite dilution cross section library, so that these group structures should be generated previously in that library.

Note 2) Ultra-fine group cross sections used by TWOWAY are those at the temperature of 300 K and the first background cross section computed in FAIR-CROSS step 1 (normally the infinite dilution cross section). The node name is ULTX-matno-TMP1-SIG1.

Note 3) Processed reaction code numbers for POPOP4 library are 1, 2, 3, 4, 5, 6 and 8 in **Table 2.14**.

2.3 FDEM

FDEM generates cell-averaged few-group cross sections and collapsed response functions for ESPRIT and MCACE calculations. The module is also prepared to store arbitrary response data in the DATA-POOL. The processing method can be chosen from 5 options. The effective microscopic and macroscopic cross sections are collapsed by using one of the three options. The response function is produced by using one of the two other options. The cell-averaged effective cross sections are computed by using spatial dependent fluxes calculated by DIAC. The response data to be collapsed are chosen from sequential data sets prepared by the user and the microscopic cross sections contained in the DATA-POOL. The flow diagram of FDEM is shown in **Fig. 2.15.**

2.3.1 Collapsed Few-group Cross Section

Collapsing energy groups to few groups can be performed by choosing one of the two procedures described below:

(i) Macroscopic cross section is used. (ICAL=2)

(ii) Infinite dilution microscopic cross section and self-shielding factor are used. (ICAL=1 or 3)

When the former process is selected, the collapsed macroscopic cross sections with the same angular meshes as those in the fine-group cross sections are generated. On the other hand, the number of angular meshes can be arbitrary defined if the latter process is selected. The weighting procedure is performed in the following manner:

$$\bar{\sigma}_x^i = \frac{\int_{E_{i+1}}^{E_i} dE' \sigma_x(E') f(E')}{\int_{E_{i+1}}^{E_i} dE' f(E')}, \tag{2.152}$$

$$\bar{\sigma}_s^{i\to j} = \frac{\int_{E_{i+1}}^{E_i} dE' \int_{E_{j+1}}^{E_j} dE \sigma_s(E' \to E) f(E')}{\int_{E_{i+1}}^{E_i} dE' f(E')}, \tag{2.153}$$

$$\bar{\sigma}_s^{i\to j}(\mu_k) = \frac{\int_{E_{i+1}}^{E_i} dE' \int_{E_{j+1}}^{E_j} dE \sigma_s(E' \to E, \mu_k) f(E')}{\int_{E_{i+1}}^{E_i} dE' f(E')}, \tag{2.154}$$

$$f(E) = \int_{r \in R} \phi(r, E) dr' \tag{2.155}$$

where $\bar{\sigma}_x$ indicates the collapsec cross section of the reaction X, $r \in R$ means that the spatial interval r is included in a zone R and the other notations are conventional.

The effective microscopic cross section is also generated by using the latter procedure described

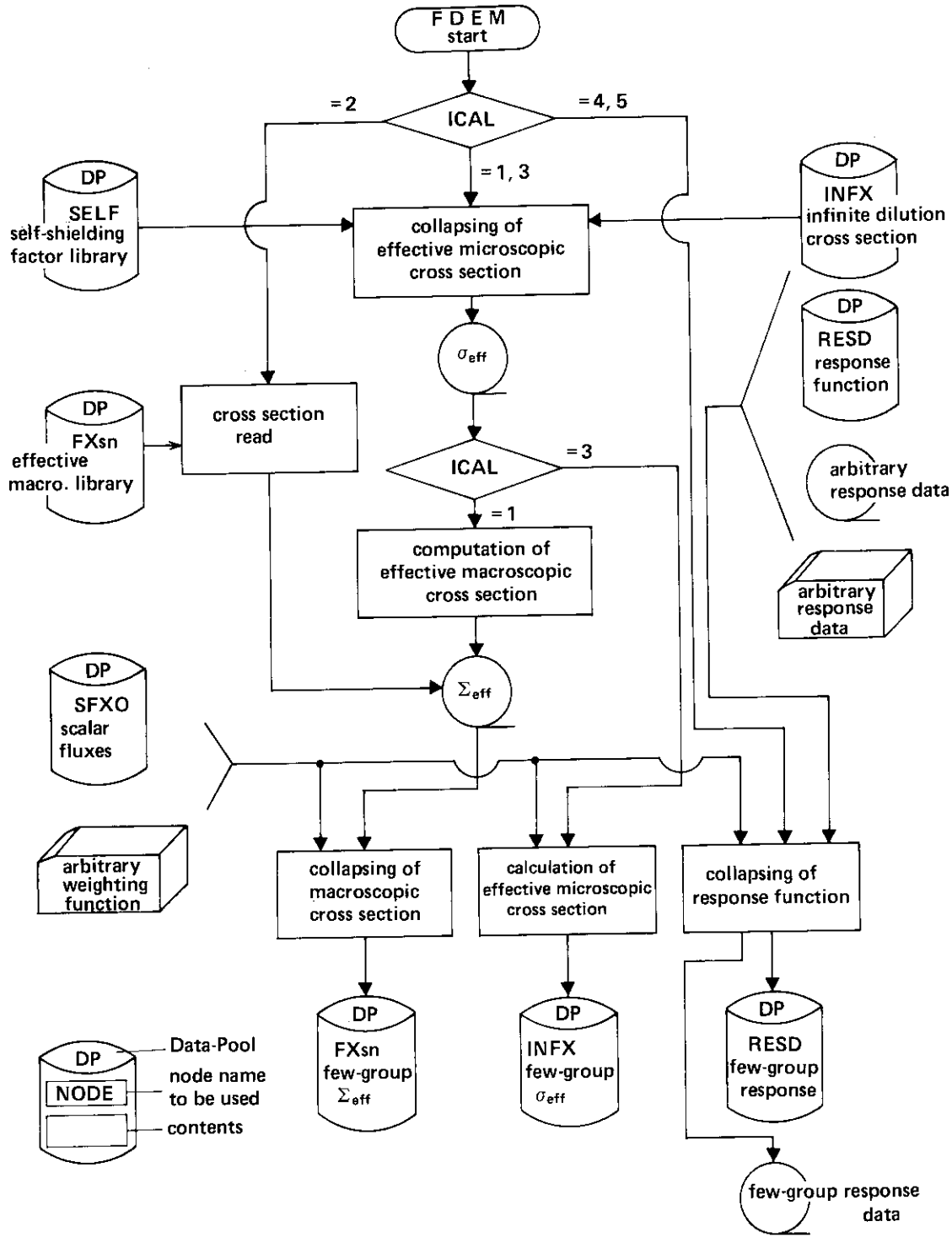


Fig. 2.15 Flow chart of the FDEM module

above. The format of the effective microscopic cross section is the same as that of the infinite dilution cross section except that the fixed angular meshes are adopted. The cell-averaged response data can be also computed.

2.3.2 Input Instruction

Input data for FDEM are written in the FIDO format except for a title, a unit assignment for DATA-POOL, node name assignment and response data. In the following, a size of the array is given in square brackets, and the condition under which the data array is to be specified is given in parentheses. The data array without the condition should always be specified.

1. Title card Format (20A4)
   Arbitrary comments are given.

2. DATA-POOL assignment card
   Logical unit number for each cross section and the flux data are written in this card whose format is a Name List input described below:
   &UNIT INFX=n1, SELF=n2, FXSN=n3, SFLX=n4, NFEW=n5, EFFX=n6,
   RESD=n7 &END

where
- INFX : infinite dilution cross section
- SELF : self-shielding factor library
- FXSN : macroscopic cross section
- SFLX : scalar fluxes generated by DIAC
- NFEW : collapsed few-group macroscopic cross section library
- EFFX : collapsed effective microscopic cross section library
- RESD : response data library.

When the number is set to zero, the access to the DATA-POOL is prohibited.

1$ Control parameters [19]

1. ICAL : few-group collapsing scheme.
   1=few-group macroscopic cross sections are generated by using infinite dilution cross sections and self-shielding factors
   2=few-group macroscopic cross sections are generated by using fine-group macroscopic cross sections
   3=few-group effective microscopic cross sections are generated by using infinite dilution cross sections and self-shielding factors
   4=few-group response data are generated by using infinite dilution cross sections
   5=few-group response data are generated by using data given by the user
2. ING : number of neutron energy groups before collapsing.
3. IGG : number of gamma-ray energy groups before collapsing.
4. NODE1 : node name for the energy group structure before collapsing.
5. INGF : number of neutron energy groups after collapsing.
6. IGGF : number of gamma-ray energy groups after collapsing.
7. NODE2 : node name for the energy group structure after collapsing.
8. IFLX : option of weighting function.
   1=neutron and gamma-ray fluxes calculated by DIAC
   2=$1/E$ for neutron
   3=Maxwell distribution+$1/E$+fission spectrum for neutron (6* array)
   4=arbitrary weighting function (7$, 8*, 9$, 10* arrays)

when IFLX=2 or 3 is adopted, the weighting function for gamma-ray is given by the 9$ and the 10* arrays.

9. MTP : number of materials or responses to be inputted.
10. MTPO : number of materials or responses to be outputted.
11. IZM : number of zones in the DIAC calculation.
When IFLX≠1, IZM should be set to zero.
12. ICELL : option for cell averaging.
0=no effect
1=cell weighting
When ICAL=3, ICEL should be set to zero.
13. IRESPI : input format of response data. (ICAL=5)
1=data are given in the DATA-POOL
5=data are given by cards
n=data are given by a sequential data set on the logical unit FTnF001 (n≥30)
When ICAL≠5, IRESPI should be set to zero.
14. IRESPO : output format of response data. (ICAL=4 or 5)
0=only print
1=data are stored in the DATA-POOL
7=punch cards
n=data are stored in a sequential data set on the logical unit FTnF001 (n≥30)
When ICAL≤3, IRESPO should be set to zero.
15. IPRT : print option for collapsed cross section.
0=no effect
1=print group cross sections
2=print group cross sections and angular distributions
16. NN1 : parameter of the arbitrary weighting function for neutron.
0=no effect
N=number of interpolation regions used to specify this function
17. NN2 : parameter for the arbitrary weighting function for neutron.
0=no effect
N=number of energy points in this function
18. NG1 : parameter of the arbitrary weighting function for gamma-ray.
0=no effect
N=number of interpolation regions used to specify this function
19. NG2 : parameter of the arbitrary weighting function for gamma-ray.
0=no effect
N=number of energy points in this function

T Termination of this data block.

2$ Parameter for generating effective cross section [4] (ICAL=1 or 3)

1. IPN : number of fixed angular meshes to be outputted.
(16, 24, 32, 48 to 64 is allowed)
2. NUP : table length for up-scattering component in the collapsed cross section table.
3. NHEAT : incorporation of energy deposition factor.
0=no
1=yes
This option is valid for ICAL=1.

4. NDISP : incorporation of atomic displacement cross section.
   0=no
   1=yes

3$ Few-group structure for neutron [ING] (ING≠0)
The few-group number corresponded to the fine-group one is assigned.

4$ Few-group structure for gammaray [IGG] (IGG≠0)
The few-group number corresponded to the fine-group one is assigned.

5$ Node names for fluxes calculated by DIAC [3] (IFLX=1)
The first node means the energy group structure, the second node name means the identification of the problem. The third node name is the fixed name of SFX0. These names must be given by the form of 4HXXXX.

6* Parameters for weighting function [4] (IFLX=3)

1. TB : temperature of Maxwell distribution. (eV)
2. EB : boundary energy in eV between Maxwellian and $1/E$.
3. TC : temperature of fission spectrum. (eV)
4. EC : boundary energy in eV between $1/E$ and fission spectrum.

7$ Interpolation schemes for the arbitrary weighting function of neutron [2*NN1] (IFLX=4)
Last point numbers and interpolation schemes in the interpolation region are inputted alternately.
Five interpolation schemes can be selected as follows:

1=Y is constant
2=Y is linear in X
3=Y is linear in $\ln X$
4=$\ln Y$ is linear in X
5=$\ln Y$ is linear in $\ln X$

8* Energies and weights for the arbitrary weighting function of neutron [2*NN2] (IFLX=4)
Energies should be given in the increasing order in eV.
Energies and weights are given alternately.

9$ Interpolation schemes for the arbitrary weighting function of gamma-ray
[2*NG1] (IGG≠0 and IFLX≠1)
Data are given in the same manner for neutron.

10* Energies and weights for the arbitrary weighting function of gamma-ray
[2*NG2] (IGG≠0 and IFLX≠1)
Data are given in the same manner for neutron.

11$ Node names of materials or response functions to be collapsed in the DATA-POOL
[2+MTP] (omit if ICAL=5 and IRESPI≠1)
Node names are assigned as follows:

In the case of ICAL=1 or 3;
The first node name is the energy group structure, the second node name is SELF and the following is the node names of each material.

In the case of ICAL=2;
The first node name is the energy group structure, the second node name is FXsn and the following is the node names of each material.

In the case of ICAL=4;
The first node name is the energy group structure, the second node name is INFX and the following is the node names of each material.

In the case of ICAL=5 and IRESPI=1;
The first node name is the energy group structure, the second node name is RESD and the following is the node names of each response function.

12$ Identification number of the reaction type to be collapsed [MTP] (ICAL=4)
The identification number is given by the form of MT number in ENDF/B and used to retrieve the cross section from the infinite dilution cross section library. The order should correspond to the data given in the 11$ array.

13$ Identification number of material to be collapsed by each zone
[IZM] (IFLX=1 and ICAL=1, 2 or 3)
The zones correspond to those in the DIAC calculation.
The identification number is assigned by the order of materials given in the 11$ array. When zero is assigned, the flux for the zone is not used.

14$ Identification number for cell-weighting [IZM] (IFLX=1 and ICELL=1)
The cell numbers are assigned in each zone. When zero is assigned, cell-averaged collapsing is not performed.

15$ Number of cell regions or zones to generate response data
[MTP] (IFLX=1 and ICAL=4 or 5)
The number is given for each response function.

16$ Identification numbers for cell regions or zones to generate response data
[MTPO] (IFLX=1 and ICAL=4 or 5)
The cell numbers or zone numbers are assigned for each response function.

T Termination of this data block.

3. Node name assignment cards [MTPO] Format (A4, 19A4)
A node name and an arbitrary comment to be outputted are given for each material or response function.

When IFLX=1, the order is as follows:
In the case of ICAL=1, 2 or 3;
The order is the same as that for data given in the 13$ array. (If ICELL=1, the order is the same as that for data given in the 14$ array.)
In the case of ICAL=4 or 5;
The order is the same as that for data given in the 16$ array.
When IFLX≠1, the order is the same as that for data given in the 11$ or 12$ array.

4. Response data cards (ICAL=5 and IRESPI=5)
4a NELM: number of response functions. Format (I5)
4b TITLE: title for the response function. Format (20A4)
4c (DR(I), I=1, IGM): values for response function. Format (6E12.4)
Cards 4b and 4c are repeated by NELM times.
When IGG≠0, cards from 4a to 4c are repeated for gamma-ray response data.

2.3.3 Input/Output File Assignment

FDEM requires various direct-access devices during execution. **Table 2.16** shows the names of the data sets. The logical unit number marked with circle in the table is required to execute the job. The logical unit number which is marked with by a condition in parentheses is required when the condition is satisfied. The value for the first memory space estimations is changed according to the various conditions of computation, so that it is roughly estimated.

Table 2.16 Requirements for external data sets in FDEM

Logical Unit	Option of Computation				1st. Space Estimation (Tracks)	DCB Information		
	ICAL=1	ICAL=2	ICAL=3	ICAL=4, 5		LRECL	BLKSIZE	RECFM
INFX†	○		○	(ICAL=4)	—			
SELF†	○		○		—			
FXSN†		○			—			
SFLX†	(IFLX=1)	(IFLX=1)	(IFLX=1)	(IFLX=1)	—	3600	3600	F
NFEW†	○	○			—			
EFFX†			○		—			
RESD†				(IRESPI=1 / IRESPO=1)	—			
IRESPI††				(IRESPI≠5)	5	80	800	FB
IRESPO††				(IRESPO≠0)	5	80	800	FB
FT01F001	○				50			
FT02F001	○				50			
FT03F001	○	○			50			
FT04F001	○	○	○		50	19064	19068	VBS
FT08F001	○		○		50			
FT10F001 ~ FT29F001	○*				50			

† Logical unit numbers are defined by the unit assignment card.

†† Logical unit number is defined by data in the 1$ array.

* Number of scratch files is equal to the maximum number of nuclei contained in each material.

2.3.4 Job Control Language

FDEM includes five kind of processing scheme. The typical job control languages with each input data are shown in **Figs. 2.16(a)**, **(b)**, **(c)**, **(d)** and **(e)**.

```
//JCLG  JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER ????????,XX.XXXXXX,YYYY.ZZZ
 T.X C.X W.X I.X
 OPTP PASSWORD=??
//  EXEC   LMGO,LM='J1446.FDEMX'
//  EXPAND DISK,DDN=FT01F001,SPC='50,10'
//  EXPAND DISK,DDN=FT02F001,SPC='50,10'
//  EXPAND DISK,DDN=FT03F001,SPC='50,10'
//  EXPAND DISK,DDN=FT04F001,SPC='50,10'
//  EXPAND DISK,DDN=FT08F001,SPC='50,10'
//  EXPAND DISK,DDN=FT10F001,SPC='50,10'
//  EXPAND DISK,DDN=FT11F001,SPC='50,10'
//  EXPAND DISK,DDN=FT12F001,SPC='50,10'
//  EXPAND DISKTO,DDN=FT91F001,DSN='J3679.CROSS1'
//  EXPAND DISKTO,DDN=FT92F001,DSN='J2925.SBP00L0'
//  EXPAND DISKTO,DDN=FT93F001,DSN='J9765.P00L'
//SYSIN DD *
    TEST DATA  1  (ICAL=1,IFLX=1,ICELL=0)
 &UNIT  INFX=91,SELF=92,SFLX=92,NFEW=0  &END
 1¥¥ 1  100  0  4HEGRP  28  0  4HSB28  1  2  4  9  0  0  0  2  4R0  T
 2¥¥ 16   0  0  0
 3¥¥ 6R1  4R2  3R3  3R4  2R5  3R6  3R7  2R8  9 3R10  3R11  3R12  3R13
     3R14  3R15  3R16  3R17  2R18  3R19  5R20  6R21  6R22  6R23  5R24
     3R25  2R26  9R27  2R28
 5¥¥  4HEGRP  4H   1  4HSFX0
11¥¥  4HEGRP  4HSELF  4HOFEE  4HOAIR
13¥¥  0  1  1  1  0  0  0  0  2
  T
FEE2  IRON (ENDF/B) COLLAPSED BY ZONE 2
FEE3  IRON (ENDF/B) COLLAPSED BY ZONE 3
FEE4  IRON (ENDF/B) COLLAPSED BY ZONE 4
AIR   AIR  (ENDF/B) COLLAPSED BY ZONE 9
++
//
```

Fig. 2.16(a) Job control cards and input data for collapsing infinite dilution cross sections with FDEM on the FACOM M-380 computer at JAERI

```
//JCLG  JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER ????????,XX.XXXXXX,YYYY.ZZZ
 T.X C.X W.X I.X
 OPTP PASSWORD=??
//  EXEC   LMGO,LM='J1446.FDEMX'
//  EXPAND DISK,DDN=FT01F001,SPC='100,10'
//  EXPAND DISK,DDN=FT02F001,SPC='100,10'
//  EXPAND DISK,DDN=FT03F001,SPC='100,10'
//  EXPAND DISK,DDN=FT04F001,SPC='100,10'
//  EXPAND DISKTO,DDN=FT91F001,DSN='J2925.SBP00L0'
//SYSIN DD *
  SHIELDING BENCHMARK TEST OF ORNL
 &UNIT  FXSN=91,SFLX=91,NFEW=91 &END
 1¥¥ 2  100  0  4HEGRP  28  0  4HSB28  1  2  8  9  0  0  0  1  4R0  T
 3¥¥ 6R1  4R2  3R3  3R4  2R5  3R6  3R7  2R8  9 3R10  3R11  3R12  3R13
     3R14  3R15  3R16  3R17  2R18  3R19  5R20  6R21  6R22  6R23  5R24
     3R25  2R26  9R27  2R28
 5¥¥  4HEGRP  4H   1  4HSFX0
11¥¥  4HEGRP  4HFX16  4HOFEE  4HOAIR
13¥¥  0  1  1  1  1  1  1  1  2
  T
FEE2  IRON (ENDF/B) COLLAPSED BY ZONE 2
FEE3  IRON (ENDF/B) COLLAPSED BY ZONE 3
FEE4  IRON (ENDF/B) COLLAPSED BY ZONE 4
FEE5  IRON (ENDF/B) COLLAPSED BY ZONE 5
FEE6  IRON (ENDF/B) COLLAPSED BY ZONE 6
FEE7  IRON (ENDF/B) COLLAPSED BY ZONE 7
FEE8  IRON (ENDF/B) COLLAPSED BY ZONE 8
AIR9  AIR  (ENDF/B) COLLAPSED BY ZONE 9
++
//
```

Fig. 2.16(b) Job control cards and input data for collapsing macroscopic cross sections with FDEM on the FACOM M-380 computer at JAERI

```
//JCLG  JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER ????????,XX.XXXXXX,YYYY.ZZZ
 T.X C.X W.X I.X
 OPTP PASSWORD=??
//  EXEC   LMGO,LM='J1446.FDEMX'
//  EXPAND DISK,DDN=FT01F001,SPC='50,10'
//  EXPAND DISK,DDN=FT02F001,SPC='50,10'
//  EXPAND DISK,DDN=FT03F001,SPC='50,10'
//  EXPAND DISK,DDN=FT04F001,SPC='100,10'
//  EXPAND DISK,DDN=FT08F001,SPC='200,20'
//  EXPAND DISK,DDN=FT10F001,SPC='50,10'
//  EXPAND DISK,DDN=FT11F001,SPC='50,10'
//  EXPAND DISK,DDN=FT12F001,SPC='50,10'
//  EXPAND DISKTO,DDN=FT91F001,DSN='J3679.CROSS1'
//  EXPAND DISKTO,DDN=FT92F001,DSN='J2925.SBP00L0'
//  EXPAND DISKTO,DDN=FT93F001,DSN='J9765.POOL'
//SYSIN DD *
    TEST DATA  3  (ICAL=3,IFLX=1,ICELL=0)
 &UNIT  INFX=91,SELF=92,SFLX=92,EFFX=0  &END
 1¥¥ 3  100  0  4HEGRP  28  0  4HSB28  1  2  2  9  0  0  0  2  4R0  T
 2¥¥ 16   0  0  0
 3¥¥ 6R1  4R2  3R3  3R4  2R5  3R6  3R7  2R8  9 3R10  3R11  3R12  3R13
     3R14  3R15  3R16  3R17  2R18  3R19  5R20  6R21  6R22  6R23  5R24
     3R25  2R26  9R27  2R28
 5¥¥  4HEGRP  4H   1  4HSFXO
11¥¥  4HEGRP  4HSELF  4HOFEE  4HOAIR
13¥¥  0  1  0  0  0  0  0  0  2
  T
FEE   IRON (ENDF/B) COLLAPSED BY ZONE 2
AIR   AIR  (ENDF/B) COLLAPSED BY ZONE 9
++
//
```

Fig. 2.16(c) Job control cards and input data for collapsing effective microscopic cross sections with FDEM on the FACOM M-380 computer at JAERI

```
//JCLG  JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER ????????,XX.XXXXXX,YYYY.ZZZ
 T.X C.X W.X I.X
 OPTP PASSWORD=??
//  EXEC   LMGO,LM='J1446.FDEMX'
//  EXPAND DISK,DDN=FT01F001,SPC='100,20'
//  EXPAND DISK,DDN=FT02F001,SPC='100,20'
//  EXPAND DISK,DDN=FT03F001,SPC='100,20'
//  EXPAND DISK,DDN=FT04F001,SPC='100,10'
//  EXPAND DISKTO,DDN=FT91F001,DSN='J3679.CROSS1'
//  EXPAND DISKTO,DDN=FT92F001,DSN='J2925.SBP00L0'
//SYSIN DD *
  SHIELDING BENCHMARK TEST OF ORNL
 &UNIT  INFX=91,SFLX=92  &END
 1¥¥ 4  100  0  4HEGRP  28  0  4HSB28  1  2  2  9  0  0  0  0  4R0  T
 3¥¥ 6R1  4R2  3R3  3R4  2R5  3R6  3R7  2R8  9 3R10  3R11  3R12  3R13
     3R14  3R15  3R16  3R17  2R18  3R19  5R20  6R21  6R22  6R23  5R24
     3R25  2R26  9R27  2R28
 5¥¥  4HEGRP  4H   1  4HSFXO
11¥¥  4HEGRP  4HINFX  4H1192  4H1192
12¥¥  1  2
15¥¥  1  1
16¥¥  2  3
  T
2601  IRON TOTAL C.S.
2602  IRON ELASTIC C.S.
++
//
```

Fig. 2.16(d) Job control cards and input data for generating response functions by collapsing infinite dilution cross sections with FDEM on the FACOM M-380 computer at JAERI

```
//JCLG  JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER ????????,XX.XXXXXX,YYYY.ZZZ
 T.X C.X W.X I.X
 OPTP PASSWORD=??
//  EXEC   LMGO,LM='J1446.FDEMX'
//  EXPAND DISK,DDN=FT01F001,SPC='100,20'
//  EXPAND DISK,DDN=FT02F001,SPC='100,20'
//  EXPAND DISK,DDN=FT03F001,SPC='100,20'
//  EXPAND DISK,DDN=FT04F001,SPC='100,10'
//  EXPAND DISKTO,DDN=FT91F001,DSN='J2925.SBPOOLO'
//SYSIN DD *
  SHIELDING BENCHMARK TEST OF ORNL
 &UNIT  INFX=91,SFLX=91  &END
 1¥¥ 5  100  0  4HEGRP  28  0  4HSB28  1  1  2  9  0  5  0  0  4R0  T
 3¥¥ 6R1  4R2  3R3  3R4  2R5  3R6  3R7  2R8  9 3R10  3R11  3R12  3R13
     3R14  3R15  3R16  3R17  2R18  3R19  5R20  6R21  6R22  6R23  5R24
     3R25  2R26  9R27  2R28
 5¥¥  4HEGRP  4H   1  4HSFXO
15¥¥  2
16¥¥  2  3
  T
B032  BONNER BALL 3.09INCH AT ZONE 2
B033  BONNER BALL 3.09INCH AT ZONE 3
    1
    RESPONSE FUNCTION FOR 3.09INCH BONNER BALL
   4.03560-3   4.70537-3   5.41792-3   6.31045-3   7.29520-3   8.44028-3
   9.62593-3   1.16664-2   1.36336-2   1.49930-2   1.66156-2   1.92740-2
   2.21567-2   2.54025-2   2.90567-2   3.31404-2   3.76543-2   4.24742-2
   4.78692-2   5.37193-2   6.01985-2   6.71505-2   7.47266-2   8.26308-2
   9.10475-2   9.97097-2   1.09037-1   1.19038-1   1.29032-1   1.39039-1
   1.49038-1   1.59864-1   1.70357-1   1.80945-1   1.91594-1   2.02105-1
   2.12186-1   2.23141-1   2.33038-1   2.43041-1   2.52731-1   2.62205-1
   2.71700-1   2.80918-1   2.89939-1   2.98954-1   3.08008-1   3.16975-1
   3.25920-1   3.34902-1   3.43952-1   3.52924-1   3.61870-1   3.70911-1
   3.80064-1   3.89122-1   4.02888-1   4.22348-1   4.41655-1   4.61589-1
   4.81705-1   5.02825-1   5.25528-1   5.48789-1   5.73968-1   6.00536-1
   6.26431-1   6.54713-1   6.81556-1   7.04638-1   7.42348-1   7.72834-1
   8.04130-1   8.40747-1   8.60950-1   8.14149-1   7.06517-1   7.68286-1
   8.23388-1   8.57677-1   8.81667-1   8.85713-1   9.50461-1   9.89825-1
   1.02084+0   1.05092+0   1.08092+0   1.11090+0   1.13954+0   1.16054+0
   1.17918+0   1.18890+0   1.18712+0   1.16315+0   1.09986+0   9.78544-1
   7.69513-1   4.22222-1   2.92407-2   5.08269-6
++
//
```

Fig. 2.16(e) Job control cards and input data for collapsing response functions given by cards with FDEM on the FACOM M-380 computer at JAERI

2.3.5 Data Notes for FDEM

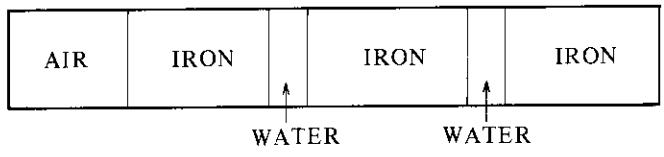
FDEM has some limitations to computing collapsed cross sections and response functions. The limitations are noted below in this section. The notes for using the FDEM module are also presented. The user should pay due attention to the information.

Note 1) Number of the output materials or response functions (MTPO in the 1$ array) is determined according to the following:

ICAL	IFLX	ICELL	Value of MTPO
1/2/3	1	0	no. of region assigned non-zero material number in the 13$ array.
1/2	1	1	no. of cell region in the 14$ array
4/5	1	0/1	total value in the 15$ array
any	2/3/4	–	same number as MTP in the 1$ array

Note 2) Material number and cell number in the 13$ and 14$ arrays are assigned in the following manner.

For example, input data to collapse the cross sections of the following configuration are as follows:




```
11$   4HEGRP   4HFX16   4HIRON   4HH2O
13$   0   1   2   1   2   1
```

To compute the cell averaged cross section for the iron and water regions, the following data array should be added.

```
14$   0   1   1   2   2   3
```

Note 3) In the cell averaging calculation, the maximum number of compositions in a cell region is 50.

Note 4) When arbitrary reaction cross sections including infinite dilution cross sections are stored in the DATA-POOL without collapsing, the user can omit some input data such as follows:

In the case of ICAL=4 or 5 in the 1$ array;

INGF=ING, IGGF=IGG,

NODE1=node name for input energy group structure,

NODE2=node name for output energy group structure,

MTP=number of response functions,

MTPO=MTP,

IRESPI=form of input response function and IRESPO=1 are assigned.

2$～10* arrays can be omitted.

11$, 12$ array node names and reaction identification numbers in the infinite dilution cross sections are assigned when ICAL=5.

13$～16$ arrays can be omitted.

card 3 node names and comments to be outputted

card 4 response data are given when ICAL=5 IRESPI=5.

The node name for input energy group structure must be the same as that contained in the INFX DATA-POOL, that the unit assignment for INFX is always needed.

3. Module for Analyzing Neutron and Gamma-Ray Transport

To perform precise evaluation of radiation shield, a method named DAR has been developed to describe the angular distribution of cross sections exactly. A new transport method has also been developed to be consistent with the cross section of the DAR form. The method uses a probability function P to eliminate fitting errors due to the finite Legendre expansion. The fitting error ordinarily appears in angular fluxes are negative values or oscillations when the strong anisotropic source exists.

Three calculation modules names DIAC, ESPRIT and MCACE have been developed to calculate neutron and gamma-ray transport by using the new method mentioned above and these modules have been introduced into the code system RADHEAT-V4.

The DIAC module adopts the new one-dimensional S_N-transport method. The fundamental test calculations and the verification for the new method have been carried out by using the module. The DIAC module is an improved version of ANISN-JR, so that the functions available in DIAC are the same as in ANISN-JR.

The ESPRIT module introduces the new two-dimensional S_N-transport method. The method adopted in ESPRIT is the extended method used in DIAC. For two-dimensional configuration containing a strong streaming pass, the remarkable error associated with use of the finite Legendre expansion appears in the evaluation of leakage current. The accuracy of leakage angular flux estimation has been improved extensively by using the ESPRIT module. The ESPRIT module is an improved version of DOT3.5, so that the functions available in ESPRIT are the same as in DOT3.5.

The MCACE module is three-dimensional Monte Carlo code and a modified version of MORSE-CG. The procedures to calculate cumulative probabilities and to determine a scattering angle by a random number are changed for adopting directly the group cross section of the discrete-type DAR form. Many kind of surface crossing estimators have been added. A bootstrap calculation can be performed by utilizing the surface crossing estimator.

The BREM module has been prepared to compute secondary gamma-ray productions by the Bremsstrahlung effect. The BREM module generates the secondary gamma-ray source by using the gamma-ray fluxes computed by DIAC and the Bremsstrahlung data calculated by the FAIR-CROSS step 2. The secondary gamma-ray transport is calculated by DIAC and then the contribution of the Bremsstrahlung effect to the gamma-ray flux is also computed by the BREM module.

The functions and the input instructions for each module are described in this chapter. The validity of the new methods adopted in these modules is also discussed.

3.1 DIAC

The DIAC module introduces a method using the probability function $P_{i,\,m'\to m,\,j'\to j}$ described below to represent the angular distribution of the scattering integral precisely. The scattering integral Q using the Legendre expansion in the S_N-method is generally given as follows:

$$Q(\vec{r},\,\mu_m,\,E_j)=\sum_{j'}\sum_{\ell}P_\ell(\mu_m)\Sigma_s^\ell(\vec{r},\,E_{j'}\to E_j)\phi^\ell(\vec{r},\,E_{j'}). \tag{3.1}$$

In the DIAC module, however, the scattering integral is defined as follows:

$$Q(\vec{r},\,\mu_m,\,E_j)=\sum_{j'}\sum_{m'}W_{m'}\phi(\vec{r},\,\mu_{m'},\,E_{j'})\times P(\vec{r},\,\mu_{m'}\to\mu_m,\,E_{j'}\to E_j), \tag{3.2}$$

where W_m is the weight for angular mesh and

$$P(\vec{r}, \mu_{m'} \to \mu_m, E_{j'} \to E_j) = \frac{1}{W_m W_{m'}} \int_{\Delta\mu_m} \int_{\Delta\mu_{m'}} \int_0^{\pi} \Sigma_s(\vec{r}, E_{j'} \to E_j, \eta) d\phi' d\mu' d\mu,$$

= probability which a particle having energy $E_{j'}$ and direction cosine $\mu_{m'}$ is scattered to energy E_j and direction cosine μ_m at position $\vec{r}$.

The integration in the function P is performed with respect to the cosine of the scattering angle by rotating the coodinates from (ϕ', μ') to (ϕ, μ) related to the direction of the scattering source:

$$P(\vec{r}, \mu_{m'} \to \mu_m, E_{j'} \to E_j) = \frac{1}{W_m W_{m'}} \int_{\Delta\mu_m} \sum_k \Sigma_s(\vec{r}, E_{j'} \to E_j, \eta_k) \int_{\Delta\eta_k} \int_{\Delta\phi} d\phi d\eta d\mu, \quad (3.3)$$

where

$$\int_{\Delta\phi} d\phi = \cos^{-1}\left[\frac{\mu\cdot\eta - \mu^*_{m'+1}}{\{(1-\mu^2)(1-\eta)\}^{1/2}}\right] - \cos^{-1}\left[\frac{\mu\cdot\eta - \mu^*_{m'}}{\{(1-\mu^2)(1-\eta)\}^{1/2}}\right], \quad (3.4a)$$

$$\eta = \{(1-\mu^2)(1-\mu_m^2)\}^{1/2} \cos\phi + \mu\mu_m, \quad (3.4b)$$

$$\cos\phi = (\mu_m\eta - \mu)/\{(1-\mu_m^2)(1-\eta)\}^{1/2}, \quad (3.4c)$$

where, μ^* is the boundary value of the angular mesh and the other notations are conventional.

In order to grasp the characteristics of the method, some test calculations were carried out and compared with exact solutions.

The uncollided scalar flux from a plane source with a cosine angular distribution was calculated in an infinite medium. As shown in **Fig. 3.1**, a good agreement is obtained beteeen the DIAC results and the exact solution. The difference between these results is only 0.5% relatively.

As another problem which can be solved exactly, the one-group scalar flux in an infinite medium with an isotropic point source was calculated as a function of a parameter C which is the ratio of the scattering to the total cross section. The result obtained from DIAC agrees very well with the exact solution at distances farther than about 0.3 mfp from the center, as shown in **Figs. 3.2(a)** and **(b)**. The difference between these results is not more than 10% at the distance of 10 mfp. However, the difference is rather large in the range up to 0.3 mfp, because the source geometry is approximated by the volume source with a redius of 0.1 cm in the DIAC calculations.

The next problem deals with an iron-paraffin-iron configuration with uniformly distributed sources in the iron slabs of both sides. In this configuration, the currents in right and left directions are balanced at the center of the paraffin. Therefore, as shown in **Fig. 3.3(a)**, the angular fluxes calculated by DIAC and ANISN-JR (in P_5S_{16} approximation) are exactly the same. For a paraffin slab with a plane unidirectional source incident normally to the left surface of the slab as shown in **Fig. 3.3(b)**, the angular flux is not symmetric due to a strong anisotropy of the source. The angular flux calculated by ANISN-JR in the P_5S_{16} approximation takes negative values in some angles due to the fitting error of the scattering source by the finite Legendre expansion. The angular flux calculated by DIAC, however, does not take any negative value for all directions.

From the test calculations noted above, it is shown that the method applied to DIAC is effective for eliminating negative values and oscillations of the angular flux in anisotropic S_N-transport calculations. The input instruction for DIAC is described in the next section. Input/output file assignments and the Job Control Language for executing DIAC are noted in the Sections 3.1.2 and 3.1.3, respectively. The limitations and the notes to operation are shown in the Section 3.1.4.

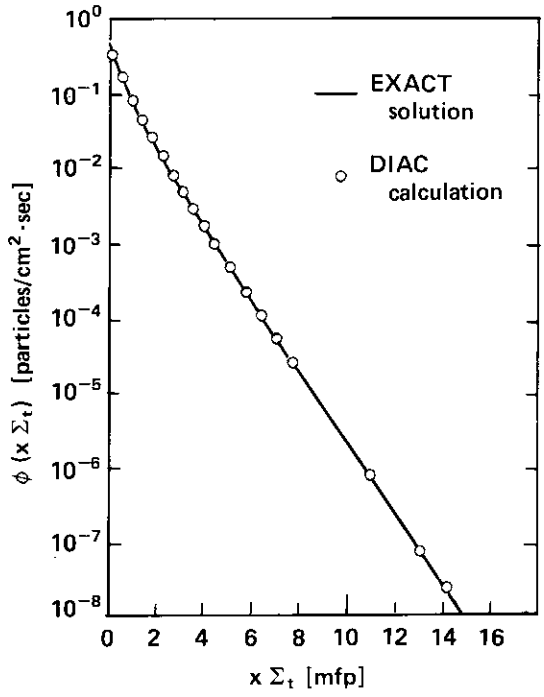
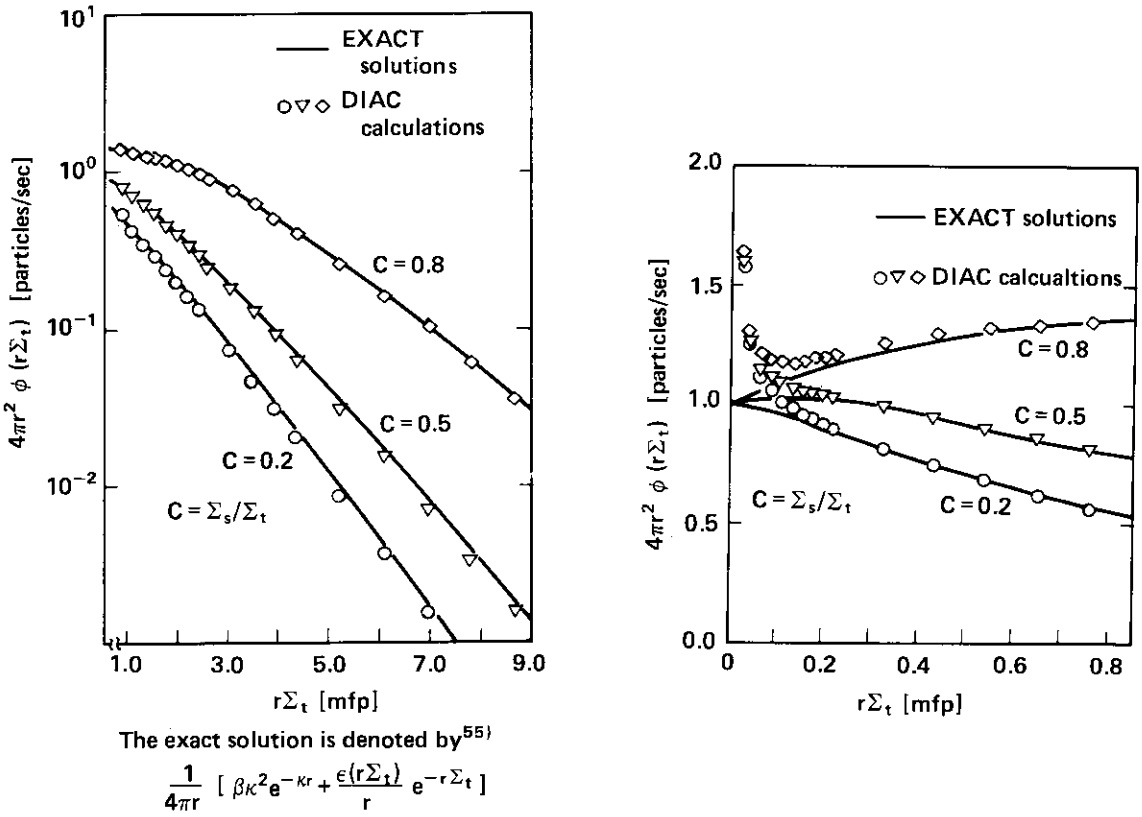
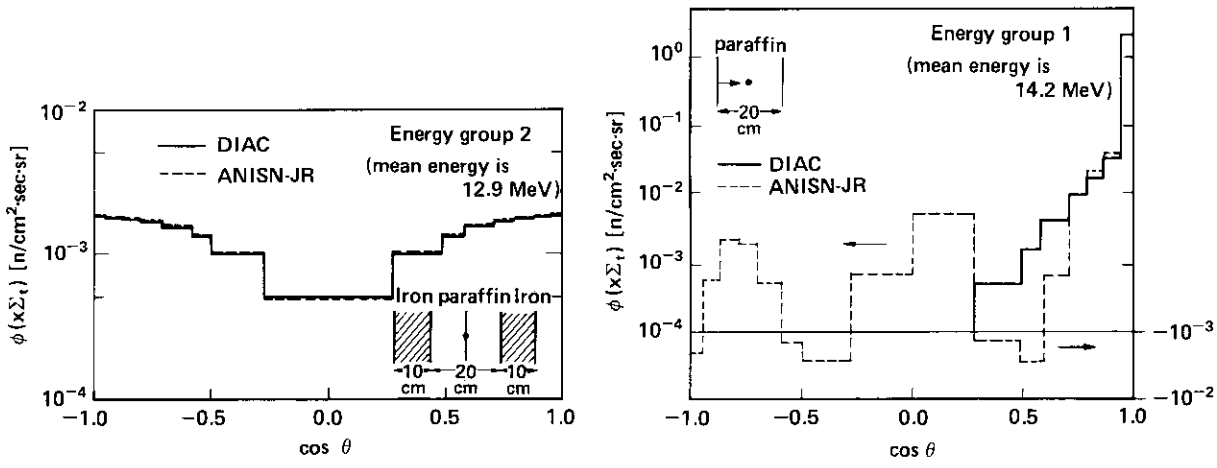


Fig. 3.1 Comparison of exact solution and DIAC calculation of the uncollided scalar flux in infinite medium with cosine-distributed plane source



(a) For $0.8 < r\Sigma t \leqq 9.0$ (b) For $0.0 \leqq r\Sigma t \leqq 0.8$

Fig. 3.2 Comparison between exact solution and DIAC calculation for isotropic point source in infinite medium



(a) For iron–paraffin–iron configuration

(b) For paraffin slab with plane uni-directional source incident normally to the left surface of slab

Fig. 3.3 Comparison of angular fluxes at the center of paraffin calculated by DIAC and ANISN-JR

3.1.1 Input Instruction

Input data to DIAC are written in the FIDO format except for title cards, a unit assignment card for DATA-POOL and detector response cards.

In the following, a size of data arrays is given in square brackets, and the condition under which the data array is to be specified is given in parentheses. The data array without the condition should always be specified.

1. Title card Format (12A4)

2. DATA-POOL assignment card

Logical unit numbers for a cross section library and flux DATA-POOL are written on this card whose format is a Name list input described below:

&UNIT FXSN=n1, FLX1=n2, FLX2=n3, RESD=n4 &END

'&UNIT' should be written from the 2nd column. Unit names, FXSN etc., indicate following libraries:

FXSN : Region-wise macroscopic cross section library

FLX1 : Scalar flux file

FLX2 : Angular flux file

RESD : Response or detector file

The logical unit numbers (n1~n4) are desirable to be chosen from 91 to 99. For an unused library, the assignment to this library should be omitted or the unit number n should be set to zero.

14$ Integer parameters (Additional option) [11]

1. ING : Number of neutron energy groups.
2. IGG : Number of gamma-ray energy groups.
3. NREACT : Calculation of reaction rates.

0=no

1=calculate and print reaction rates for neutron and gamma-ray with the response functions given by cards (card 3)

2=calculate with the response function given in a sequential data set on FT51F001

3=calculate with the response functions given in a DATA-POOL (logical unit is given by RESD)

4. NNELM : Number of neutron response functions.
5. NGELM : Number of gamma-ray response functions.
6. IIANLL : Output option of angular flux.
   0=print and output angular fluxes at all interval meshes controlled by ID1 in the 15$ array.
   N=print and output angular fluxes at only required meshes. N indicates number of interval meshes to be outputted and the interval numbers are given by the 29$ array.
7. IIBOUD : Fluxes print option by every interval.
   0=print fluxes at the midpoint of each mesh interval
   1=print fluxes at the boundary of each mesh interval
8. IISPTM : Fluxes print option.
   0=print fluxes ϕ_g at each mesh interval
   1=print fluxes $\phi_g/\Delta E_g$ at each mesh interval
   2=print fluxes $\phi_g/\Delta u_g$ at each mesh interval
9. NACTPR : Activities print option.
   0=print activities summed over energy group
   1=print activities by each energy group

If the printing of activities is required, ID3=N and/or ID4=1 in the 15$ array must be entered.

10. NRESAT : Restart option.
    0=no
    1=write/read fluxes on a tape for use as an initial flux guess for the next run

Fluxes are written on the logical unit FT15 and read from FT14. For the first run, NRESAT=1 and IFN=0 or 1 (in the 15$ array) should be specified, and for the following run, NRESAT=1 and IFN=3 (in the 15$ array) must be given.

11. NPLOT : Generation of plotting data file.
    0=no
    1=output plotting data of scalar fluxes on FT30F001
    −1=same as above but the plotting data are boundary fluxes
    −2=same as above but the plotting data are j_+ (right boundary leakage currents)
    −3=same as above but the plotting data are J (right boundary total currents)
    −4=same as above but the plotting data are right leakage
    −5=same as above but the plotting data are $4\pi r^2 J$/MeV
    −6=same as above but the plotting data are $4\pi r^2 J/\Delta u$

If the above additional options in the 14$ array are not used, the 14$ array can be omitted.

15$ Control parameters [36]

1. ID : Problem ID number. (ID≤9999)
   This number is also used as a node name of the flux DATA-POOL.
2. ITH : 0=forward solution
   1=adjoint solution
3. ISCT : Number of angular meshes in the cross section library.
4. ISN : Order of the angular quadrature.
5. IGE : 1=slab
   2=cylinder
   3=sphere

6. IBL : Left boundary condition.
   0=vacuum (no reflection)
   1=reflection
   2=periodic
   3=white/albedo
7. IBR : Right boundary condition, the same options as IBL.
8. IZM : Number of zones or regions.
9. IM : Number of mesh intervals.
10. LEVT : Eigenvalue type.
    0=fixed source
    1=k calculation
    2=the Rossi α calculation
    3=concentration search
    4=zone width search
    5=outer radius search
    6=buckling search
11. IGM : Number of energy groups.
12. IHT : Position of σ_{total} in the cross section table.
13. IHS : Position of σ_{gg} (self-scatter) in the cross section table.
14. IHM : Length of cross section table.
15. MS : Not used.
16. MCR : Not used.
17. MTP : Number of cross section sets to be read from DATA-POOL. (13$ array)
18. MT : Total number of cross section sets. (MT=MTP)
19. IDFM : 0=density factors (21* array) not used
    1=density factors used
20. IPVT : 0=no effect
    1=enter k_0 as PV (16* array)
    2=enter α_0 as PV
21. IQM : 0=no effect
    1=enter distributed source (17* array)
    2=enter distributed source from an external file (FT20F001)
22. IPM : 0=no effect
    1=enter shell source by group and angle (18* array)
    IM=enter shell source by interval, group and angle
23. IPP : Interval mesh number which contains shell source is IPM=1; 0 otherwise.
24. IIM : Inner iteration maximum.
25. ID1 : 0=no effect
    1=print angular flux
    2=punch scalar flux
    3=both 1 and 2
26. ID2 : 1=use specially prepared cross section library. ID2=1 should always be specified
27. ID3 : 0=no effect
    N=compute N activities by zone where N is any positive integer
28. ID4 : 0=no effect
    1=compute N activities by interval where N refers to ID3
29. ICM : Outer iteration maximum.
30. IDAT1 : IDAT1=2 should always be specified.

31. IDAT2 : 0=no effect
    1=execute diffusion solution for specified groups (24$ array)
32. IFG : IFG=0 should always be specified.
33. IFLU : 0=step model used when linear extrapolation yields negative flux (mixed mode)
    1=use linear model only
    2=use step model only
34. IFN : 0=enter fission guess (2* array)
    1=enter flux guess (3* array)
    2=use fluxes from previous case
    3=use restart fluxes on FT14F001
35. IPRT : 0=print cross sections
    1=do not print cross sections
36. IXTR : Spare

16* Floating point parameters [14]

1. EV : First guess for eigenvalue.
2. EVM : Eigenvalue modifier.
3. EPS : Epsilon-accuracy desired.
4. BF : Buckling factor, normally 1.420892.
5. DY : Cylinder or plane height for buckling correction.
6. DZ : Plane depth for buckling correction.
7. DFM1 : Transverse dimension for void streaming correction.
8. XNF : Normalization factor.
9. PV : 0.0, k_0 or α_0 according to IPVT=0, 1 or 2.
   k_0 or α_0 means desired eigenvalue for search problems.
10. RYF : λ_2 relaxation factor, normally 0.5. (see Note 9)
11. XLAL : Point flux convergence criterion if entered greater than zero.
12. XLAH : Upper limit for $|1.0-\lambda_1|$ used in linear search. (see Note 12)
13. EQL : Eigenvalue change epsilon for search calculations, zero otherwise. (see Note 12)
14. XNPM : New parameter modifier for search calculations, zero otherwise. (see Note 12)

T Termination of this data block.

6* Angular quadrature weights [MM][a)]
7* Angular quadrature cosines [MM]

T Termination of this data block.

13$ Cross section library [MTP+2]
Node names for the macroscopic cross section in the library. (4-characters)
This data is specified using 4HXXXX, where XXXX is a node name. The first name should be the same as the first node name of the cross section library. The second name should be the same as the second node name of the cross section library. The following MTP entries indicate the third node names of each material.

T Termination of this data block.

---

a) MM=ISN+1 for plane or sphere, MM=(ISN×(ISN−4))/4 for cylinder.

17* Distributed source [IGM×IM] (IEVT=0 and IQM=1)
18* Shell source [IGM×IPM×MM] (IEVT=0 and IPM>0)

T Termination of this data block.

2* Fission density [IM] (IFN=0)
3* Flux guess [IM] (IFN=1)

T Termination of this data block.

1* Fission spectrum [IGM]
4* Radii by interval boundary [IM+1]
5* Velocities [IGM]
8$ Zone numbers by interval [IM]
9$ Material numbers by zone [IZM]
20* Radius modifiers by zone [IZM] (IEVT=4)
21* Density factors by interval [IM] (IDFM=1)
22$ Material numbers for activities [ID3] (ID3>0)
23$ Cross section table position for activities [ID3] (ID3>0)
24$ Diffusion calculation markers [IGM] (IDAT2=1)
25* Albedo by group - right boundary [IGM] (IBR=3)
26* Albedo by group - left boundary [IGM] (IBL=3)
27$ Node names for neutron response functions [NNELM+2] (NREACT=3)
First name is that of the energy group structure, second name is RESD and remainders are node names of each response function.
28$ Node names for gamma-ray response functions [NGELM=2] (NREACT=3)
Input form is the same as neutrons.
29$ Interval numbers to print/output angular fluxes [IIANLL] (IIANLL≠0)

T Termination of this data block.

3. Response function (NREACT=1)
This data set should be given respectively for neutrons and gamma-rays.
Card a Format (20A4)
DXCM: Title of a response function
Card b Format (6E12.5)
Response function in descending order of energy
Note: Cards a and b are repeated NNELM and NGELM times.

3.1.2 Input/Output File Assignment

DIAC requires various direct-access devices during execution. **Table 3.1** shows the names of the data sets. The logical unit number marked with circle in the table is required to execute the job. The logical unit number which is marked with a condition in paretheses is required when the condition is satisfied. The value for the memory space estimation is varied according to the various conditions of computation, so that it is roughly estimated.

Table 3.1 Requirements for external data sets in DIAC

Logical Unit	Condition	Contents	1st. Space Estimation (Tracks)	DCB Information		
				LRECL	BLKSIZE	RECFM
FXSN*	○	Cross section library	—			
FLX1*	(FLX1≠0)	Scalar flux output	—	3600	3600	F
FLX2*	(FLX2≠0)	Angular flux output	—			
RESD*	(RESD≠0)	Response data input	—			
FT01F001	○	Scratch	300			
FT02F001	○	Scratch	300	19064	19068	VBS
FT03F001	○	Scratch	300			
FT08F001	○	Scratch	300			
FT12F001	○	Scratch	300			
FT14F001	(NRESAT=1 and IFN=3)	Restart file input	—			
FT15F001	(NRESAT=1 and IFN=0or1)	Restart file output	50			
FT20F001	(IQM=2)	Distributed source input	—			
FT30F001	(NPLOT≠0)	Plotting data output	5			
FT51F001	(NREACT=2)	Response data input	—	80	3120	FB

* Logical unit numbers are defined by the unit assignment card.

3.1.3 Job Control Language

Figure 3.4 shows a typical job control language for executing DIAC.

```
//JCLG  JOB                                                          00001000
// EXEC JCLG                                                         00002000
//SYSIN DD DATA,DLM='++'                                             00003000
// JUSER 75173679,NA.YAMANO,0951.200                                 00004000
  C.5 T.6 W.2 I.5  OPN                                              00005000
 OPTP PASSWORD=ACCORD,MSGLEVEL=(1,1),NOTIFY=J3679                   00006000
//DIAC EXEC LMGO,LM='J3679.DIAC',ORECFM=FA,OBSIZE=137,SYSOUT=*       00007000
// EXPAND DISK,DDN=FT01F001,SPC='300,200',                           00008000
//        DCB='BLKSIZE=19068,LRECL=19064,RECFM=VBS,DSORG=PS'         00009000
// EXPAND DISK,DDN=FT02F001,SPC='300,200',                           00010000
//        DCB='BLKSIZE=19068,LRECL=19064,RECFM=VBS,DSORG=PS'         00011000
// EXPAND DISK,DDN=FT03F001,SPC='300,200',                           00012000
//        DCB='BLKSIZE=19068,LRECL=19064,RECFM=VBS,DSORG=PS'         00013000
// EXPAND DISK,DDN=FT08F001,SPC='300,200',                           00014000
//        DCB='BLKSIZE=19068,LRECL=19064,RECFM=VBS,DSORG=PS'         00015000
// EXPAND DISK,DDN=FT12F001,SPC='300,200',                           00016000
//        DCB='BLKSIZE=19068,LRECL=19064,RECFM=VBS,DSORG=PS'         00017000
//*EXPAND DISK,DDN=FT20F001,SPC='300,200'                           00018000
//*  FT30 IS LOGICAL UNIT FOR PLOTTING DATA FILE                     00019000
// EXPAND DISKTO,DDN=FT30F001,DSN='J3679.KFK1'                       00020000
// EXPAND DISKTO,DDN=FT91F001,DSN='J3679.FNSPOOL',DISP=SHR           00021000
//*EXPAND DISKTO,DDN=FT92F001,DSN='J????.?????????',DISP=SHR        00022000
//*EXPAND DISKTO,DDN=FT93F001,DSN='J????.?????????',DISP=SHR        00023000
//SYSIN    DD   DSN=J2925.LLLDATA.DATA(FE101),DISP=SHR              00002800
++                                                                  00002900
//                                                                  00003000
```

Fig. 3.4 Job control cards for DIAC for use on the FACOM M-380 computer at JAERI

3.1.4 Data Notes for DIAC

DIAC adopts a variable dimension technique to allocate core memories. The maximum size of memories is set to a default value of 100000. The value is set when the load module is generated, so that it may be insufficient for the large-size problems. In the case, the user must compile a next program to extend the maximum size and generate a new load module.

```
COMMON/BULKBU/D(1), LIM1, D(XXXX)
LIM1=XXXX
CALL DTLIST
CALL CONTRL
STOP
END
```

where XXXX means the maximum size of memory.

Notes for using DIAC are described below. The user should pay attention to these information before execution.

Note 1) Number of neutron and gamma-ray group — ING, IGG, IGM
IGM must be equal to the sum of neutron group, ING, and gamma-ray group, IGG, and the maximum numbers for ING and IGG are 200 and 100 respectively. A computation for only neutron or gamma-ray group is possible even if the coupled neutron and gamma-ray cross sections are used. In that case, the length of cross section table IHM in the 15$ array must be equal to that of the cross section library.

Note 2) Material node names and material numbers — 13$, 9$, 22$
An example of material node names in the 13$ array is shown as follows:

```
13$   4HEGRP   4HFX16   4HIRON   4HCONC  ···
```

where the first node name shows the energy group structure which is given in FAIR-CROSS step 1, the second node name shows the macroscopic cross sections whose angular mesh is 16 and after that, material node names which are given in the cross section library follows as the third node names. Material numbers used in the 9$ and 22$ array are chosen from 1 to MTP according to the material order specified in the 13$ array.

Note 3) Density factors — IDFM, 21*
All cross sections appropriate to an interval are multiplied by the density factor for that interval. Thus one may easily and efficiently describe a void or a density variation by interval.

Note 4) Distributed source — IQM, 17*
The distributed source is entered by group and interval as follows: group 1, interval 1 through IM; group 2, etc.

Note 5) Shell source — IPM, IPP, 18*
If IPM=1, the shell source is entered by group and angle for interval IPP as follows: group 1, angle 1 thgouth angle MM; group 2 etc.
If IPM=IM, the shell source is entered by group, interval and angle as follows: group1, interval 1, angle 1 through angle MM; interval 2, etc.

Note 6) Angular fluxes — IIANLL, ID1, 29$
If ID1 is specified as 1 or 3, angular fluxes are printed. When FLX2≠0 in the DATA-POOL assignment card is specified, angular fluxes are outputted to the DATA-POOL. In this process if IIANLL is specified as zero, angular fluxes for all intervals are processed, but if IIANLL is not zero, angular fluxes for the intervals specified in the 29$ array are processed.

Note 7) Activities — NACTPR, ID3, ID4, 22$, 23$
Activities may be computed by zone and interval as specified in ID3 and ID4 and also computed by each energy group as specified in NACTPR. The zone activity is a total reaction

rate and the interval activity is that per unit volume. The following table illustrates the use of activity specifications.

	22$	23$
1.	1	3
2.	−5	1
3.	7	−1
4.	−3	−1

1. Compute activity for material 1, cross section position 3 in the intervals and/or zones in which material 1 appears.
2. Compute activity for material 5, cross section position 1 in all intervals and/or zones.
3. Compute activity for material 7, position 1 in appropriate intervals and/or zones and multiply interval activities by a geometry factor 1.0, $2\pi r$, or $4\pi r^2$ for slab, cylinder, or sphere, respectively.
4. Compute activity for material 3, position 1 in all intervals and/or zones and multiply interval activities by a geometry factor.

Note: The position σ_t must be non-zero for all groups if activity in position 1 is desired.

Note 8) Starting guess — IFN, 2*, 3*

If IFN is specified as zero, DIAC will execute a diffusion calculation for the first outer iteration. Since this is undesirable in fixed source calculations where one normally desires a zero flux guess, one may set IFN = 1 and enter no guess. Simply enter a card with a T in the column three for that section of data.

Note 9) Convergence — EPS, XLAL, RYF

The inner or flux iteration is considered converged when both the integral self-scatter error and the integral removal error are less than EPG or when the maximum flux deviation is less then EPS. EPG is related to EPS by a normalization factor, the total source divided by IGM. Since the integral tests are sometimes easily satisfied, a point flux convergence may be specified. If XLAL is greater than zero, the inner iterations are not considered converged until the maximum flux diviation is less than XLAL.

The outer or power iteration is considered converged when the total source ratio between successive iterations differs from 1.0 by less than EPS, the total scatter ratio differs from 1.0 by less than EPS/RYF and the upscatter ratio differs from 1.0 by less than EPS/RYF.

Note 10) Buckling correction — BF, DY, DZ

DIAC computes a correction factor of the DB^2 form for finite transverse dimensions. The correction is applicable only with "transport corrected" P_0 cross section set where the position IHT is occupied by the transport cross section.

Note 11) Void streaming correction — DFM1

Since the DB^2 term is not applicable to a void region, DIAC computes a simple correction[51] which effectively removes the transverse component of each angular flux in the void region. This correction term is not included in the calculation of the absorption reaction rate as the DB^2 loss. This omission causes the neutron balance to differ from 1.0. The quantity DFM1 is the height or extent of the void region in centimeters. If DFM1 is zero, or if the total cross section is non-zero for the void regions, no correction is computed for the void regions.

Note 12) Searches —XLAH, EQL, XNPM

When the absolute value of the difference between two successive lambdas (λ_I) is less than EQL, the eigenvalue, EV, is changed. The first EV change is the result of adding or subtracting the eigenvalue modifier, EVM. The second EV change is the result of a linear extrapolation. To prevent large changes early in the calculation, the absolute value of the difference between 1.0 and λ_I is not allowed to exceed XLAH. To prevent oscillations when

using the linear search, the extrapolation is limited by XNPM. The third EV change is the result of the quadratic search. The quadratic search is used until the absolute value of $1.0-\lambda_I$ is less than EQL. At this point, the linear search is used to complete the problem. XLAH is normally 0.05 and XNPM is normally 0.75. EQL should be larger than 0.001 and three times EPS.

3.2 ESPRIT

The ESPRIT module adopts the method using the probability function $P(\vec{r}, E' \to E, \vec{\Omega}_j \to \vec{\Omega}_i)$ to express the angular distribution of the scattering integral. The scattering source Q for two-dimensional calculation is generally given by the following form:

$$Q(\vec{r}, E, \eta, \phi) = \int dE' \int d\eta' \int d\phi' \Sigma_s(\vec{r}, E' \to E, \xi) \phi(\vec{r}, E', \eta', \phi'), \tag{3.5}$$

where η' and η are cosines of polar angles before and after scattering, and ϕ' and ϕ show azimuthal angles before and after scattering, respectively, and ξ indicates direction cosine between (η', ϕ') and (η, ϕ) as given by

$$\xi = \eta\eta' + \sqrt{1-\eta^2}\sqrt{1-(\eta')^2}\cos(\phi-\phi'). \tag{3.6}$$

We obtain the scattering source for energy E and solid angle $\vec{\Omega}_i$ from Eq. (3.5) by using the probability function P:

$$\begin{aligned} Q(\vec{r}, E, \vec{\Omega}_i) &= \frac{1}{W_i} \int_{\Delta\eta_i} d\eta \int_{\Delta\phi_i} d\phi Q(\vec{r}, E, \eta, \phi), \\ &= \int dE' \sum_j W_j \phi(\vec{r}, E', \vec{\Omega}_j) \frac{1}{W_i W_j} \int_{\Delta\eta_i} d\eta \int_{\Delta\phi_i} d\phi \int_{\Delta\eta_j} d\eta' \int_{\Delta\phi_j} d\phi' \Sigma(\vec{r}, E' \to E, \xi), \\ &\equiv \int dE' \sum_j W_j \phi(\vec{r}, E', \vec{\Omega}_j) P(\vec{r}, E' \to E, \vec{\Omega}_j \to \vec{\Omega}_i), \end{aligned} \tag{3.7}$$

where W_i is the weight for solid angle $\vec{\Omega}_i$:

$$W_i = \int_{\Delta\eta_i} d\eta \int_{\Delta\phi_i} d\phi. \tag{3.8}$$

The integration in the definition of the function P in Eq. (3.7) can not be performed in an analytical form, so that we define the following function $G(\vec{\Omega}_j \to \vec{\Omega}_i, \theta)$:

$$G(\vec{\Omega}_j \to \vec{\Omega}_i, \theta) = \begin{cases} a \cdot \cos^2\left\{\dfrac{(\pi/2)}{\theta_i + \theta_j}(\theta - \theta_0)\right\} & \theta_{min} \le \theta \le \theta_{max} \\ 0 & \text{otherwise} \end{cases}, \tag{3.9}$$

The function $G(\vec{\Omega}_j \to \vec{\Omega}_i, \theta)$ is a distribution function for the scattering angle θ from a solid angle $\vec{\Omega}_j$ to a solid angle $\vec{\Omega}_i$ and named Geometrical Form Function. The Geometrical Form Function holds the following relation:

$$\int_0^\pi G(\vec{\Omega}_j \to \vec{\Omega}_i, \theta) d\theta = 1. \tag{3.10}$$

In Eq. (3.9), angles θ_0, θ_i, θ_j, θ_{min} and θ_{max} corresponding to those in **Fig. 3.5** are obtained by the S_N-quadrature weights and cosines:

$$\cos\theta_0 = \mu\mu_j - \eta\eta_j \pm \sqrt{(1-\mu_i^2-\eta_i^2)(1-\mu_j^2-\eta_j^2)}, \tag{3.11a}$$

$$\cos\theta_i = 1 - W_i, \tag{3.11b}$$

$$\cos\theta_j = 1 - W_j, \tag{3.11c}$$

$$\theta_{\min}=\text{Max}\ [0,\ \theta_0-\theta_i-\theta_j]\ , \tag{3.11d}$$

$$\theta_{\max}=\text{Min}\ [\pi,\ \theta_0+\theta_i+\theta_j]\ , \tag{3.11e}$$

From Eq. (3.10), we obtain the coefficient a in Eq. (3.9) as follows:

$$a=\frac{2\pi}{(\theta_i+\theta_j)(\alpha_{max}-\alpha_{min}+\sin\alpha_{max}-\sin\alpha_{min})}\ , \tag{3.12}$$

where

$$\left.\begin{aligned}\alpha_{\max}&=\frac{\pi}{\theta_i+\theta_j}(\theta_{max}-\theta_0),\\ \alpha_{min}&=\frac{\pi}{\theta_i+\theta_j}(\theta_{min}-\theta_0).\end{aligned}\right\} \tag{3.13}$$

Using Eq. (3.9), we define the probability function P as follows:

$$\begin{aligned}&P(\vec{r},\ E'\to E,\ \vec{\Omega}_j\to\vec{\Omega}_i)\\ &\quad\equiv 2\pi\int_0^{\pi}\ \{G(\vec{\Omega}_j\to\vec{\Omega}_i,\ \theta)+G(\vec{\Omega}_{j'}\to\vec{\Omega}_i,\ \theta)\}\ \Sigma_s(\vec{r},\ E',\ \to E,\ \theta)d\theta,\\ &\quad=2\pi\sum_k\Sigma_s(\vec{r},\ E'\to E,\ \theta_k)\int_{\theta_k}^{\theta_{k+1}}\ \{G(\vec{\Omega}_j\to\vec{\Omega}_i,\ \theta)+G(\vec{\Omega}_{j'}\to\vec{\Omega}_i,\ \theta)\}\ d\theta.\end{aligned} \tag{3.14}$$

where $\vec{\Omega}_{j'}$ is the solid angle symmetric to $\vec{\Omega}_j$ with respect to the R–Z plane.

The integration of the probability function P by using the geometrical form function G is able to perform in an analytical form, and the results of integration shows a good approximation compared with that of the numerical integration of the probability function P, which spends much time on the computation.

The scattering source given by Eq. (3.7) is normalized by using the following relation:

$$\sum_i W_i Q(\vec{r},\ E,\ \vec{\Omega}_i)=\int\Sigma_s(\vec{r},\ E'\to E)\phi(\vec{r},\ E')dE', \tag{3.15}$$

where

$$\left.\begin{aligned}\Sigma_s(\vec{r},\ E')&=2\pi\int\Sigma_s(\vec{r},\ E'\to E,\ \xi)d\xi,\\ \phi(\vec{r},\ E')&=\sum_i W_i\phi(\vec{r},\ E',\ \vec{\Omega}_i).\end{aligned}\right\} \tag{3.16}$$

For applying this method to the conventional S_N–transport code using the Legendre expansion, any change in the algorithm is not needed. We have introduced the present approach to the S_N–transport code, DOT3.5 and the improved version is named ESPRIT.

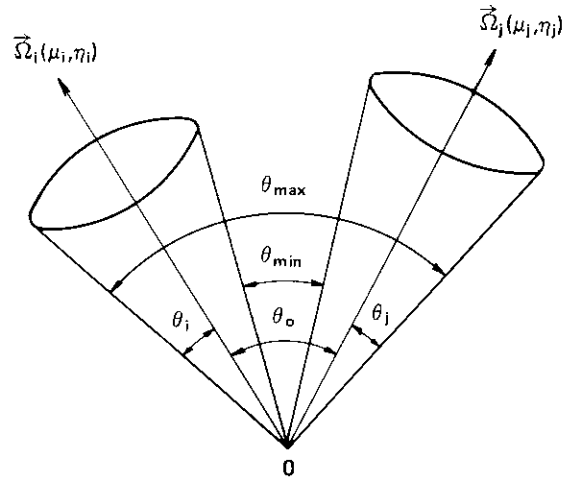


Fig. 3.5 Relation between incident and emitted solid angles in ESPRIT

In order to grasp the characteristics of the method, a test calculation was done for a strong anisotropy problem. The problem deals with a water slab with a plane unidirectional source incident normally to the left surface of the slab, as shown in **Fig. 3.6**. The angular flux at the center of the slab calculated by DOT 3.5 in the P5–S96 approximation takes negative values in some angles due to the error of fitting the scattering source by using the finite Legendre expansion. The negative values are marked with ⊠ in this figure. The angular flux calculated by ESPRIT (in S96 approximation), however, does not have any negative value or oscillation for all directions. The same problem is also computed by DIAC (in S12 approximation). The angular flux calculated by DIAC is shown in **Fig. 3.6**, where the results are marked with +. A good agreement is obtained between angular fluxes calculated by DIAC and ESPRIT. From this test calculation, it is shown that the method applied to ESPRIT is effective for eliminating negative values and oscillations of the angular flux in anisotropic S_N–transport calculations and the reliability of the method is the same as the method applied to DIAC. In the following section, the input instruction for ESPRIT is described. The data set requirement and the job control language to execute ESPRIT are shown in Sections 3.2.2 and 3.2.3, respectively. The limitations and the notes to operation are described in Section 3.2.4.

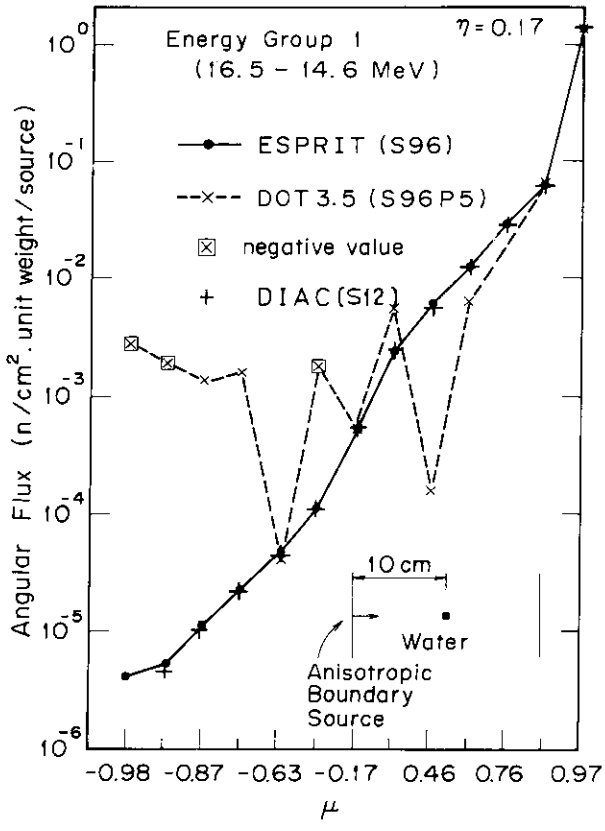


Fig. 3.6 Comparison of angular fluxes calculated by ESPRIT and DOT3.5

3.2.1 Input Instruction

Input data to ESPRIT are written in the FIDO format except for information of a title, a unit assignment for DATA–POOL and additional data for detector responses. In the following, a size of data arrays is given in square brackets, and the condition under which the data array is to be specified is given in parentheses. The data array without the condition should always be specified.

1. Title card Format (12A4)

The title is used for the comment of the calculation and the first 4 characters are used for the 2nd

node name of scalar and angular fluxes in DATA-POOL.

2. DATA-POOL assignment card

Logical unit numbers for the cross section library, the calculated scalar and angular fluxes, and the detector response data are written on the card whose format is a Name List input described below:

&UNIT FXSN=n1, RESD=n2, FLX1=n3, FLX2=n4 &END

'&UNIT' should be written from the 2nd column. Unit names are the same as the input of DIAC. The logical unit numbers n1~n4 are desirable to be chosen from 91 to 99.

The following data arrays are specified in the FIDO format.

60$ ESPRIT additional option [6]

1. ING : Number of neutron energy groups.
2. IGG : Number of gamma-ray energy groups.
3. NR1 : Calculation of reaction rates.
   0=no
   1=yes, response functions are given by cards (Cards 3 and 4)
   2=yes, response functions are given by a tape on the logical unit of FT51F001
   3=yes, response functions are given by the DATA-POOL
4. NR2 : Number of axial intervals to print reaction rates. The axial interval numbers are given by the 35$ array.
5. NR3 : Number of neutron responses used in the calculation of reaction rate.
6. NR4 : Number of gamma-ray responses used in the calculation of reaction rate.

If these additional options in the 60$ array are not used, this 60$ array can be omitted.

61$ Control parameters [61]

1. A02 : 0=forward solution
   1=adjoint solution
2. A03 : Number of angles in macroscopic cross section.
3. IZM : Number of material zones.
4. IM : Number of radial intervals.
5. JM : Number of axial intervals.
6. IGM : Number of energy groups.
7. IHT : Position of the total cross section.
8. IHS : Position of the self-scatter cross section.
9. ITL : Cross section table length per group.
10. MO1 : Not used.
11. MCR : Not used.
12. MTP : Number of materials from DATA-POOL.
13. MT : Total number of materials.
14. IP5 : 0=fluxes and moments are stored in core
    1=fluxes and moments are stored externally
15. A04 : Maximum number of angles in angular quadrature.
16. IGE : Two-dimensional geometry type.
    0=X-Y geometry (rectangular)
    1=R-Z geometry (cylindrical)
    2=R-θ geometry (circular)

17. B01 : Left boundary conditions. (see Note 3)
    0=vacuum (no reflection)
    1=reflection (mirror symmetry)
    2=periodic (repeating)
    4=input boundary source from cards (18*)
    6=input boundary source from tape on the logical unit NBSO
18. B02 : Right boundary condition. (see Note 3)
    0=vacuum
    1=reflection
    2=periodic
    3=white (isotropic incoming flux, total incoming flux equals to the total outgoing flux)
    4=input boundary source from cards (18*)
    5=albedo boundary condition (the same as the white except for the total incoming flux is a fixed fraction of the total outgoing flux)
    6=input boundary source from tape on the logical unit NBSO
19. B04 : Bottom boundary condition, the same as for B02.
20. B03 : Top boundary condition, the same as for B02.
21. D05 : Outer iteration maximum.
22. S04 : Initial inner iteration maximum, used until ABS (LAMBDA-1.0). LT.10*EPS.
23. G07 : Inner iteration maximum per group. (if negative, limit is in the 28$ array)
24. FXT : Flux calculational model. (see Note 4)
    0=mixed linear-step (use linear equations and recompute negative flux with step equations)
    1=linear mode
    2=step mode
    3=weighted difference mode
    4=mixed linear-weighted (use linear equations and recompute negative flux with weighted difference equations)
25. I04 : Problem type.
    0=fixed, volume distributed source
    1=k (multiplication factor) calculation
    2=the Rossi-α (time absorption) calculation
    3=concentration search
    4=zone thickness search
    5=fixed, exterior or interior boundary source
    6=use the first collision source on the logical unit NPSO
    7=calculate the analytic first collision source, and write on the logical unit NPSO
26. IP1 : Acceleration technique.
    0=space-independent scaling
    1=over-relaxation
    2=space-dependent scaling (the WWESOL subroutine is used)
27. S02 : Type of parametric eigenvalue search.
    0=no effect
    1=search for specified k
    2=search for specified α

28. IZ : Number of radial zones for zone thickness search.
29. JZ : Number of axial zones for zone thickness search.
30. IZC : Zone convergence. (see Note 2)
    0=no effect
    N=number of zones specified in the 32$ array
31. IB4 : Not used.
32. ISC : Theory selector.
    0=no effect
    1=enter number of quadrature angles by group in the 29$ array, zero for diffusion theory
33. IZ3 : The first collision source input.
    0=no effect
    N=length of source angular distribution table in the 33* and 34* arrays (Used if I04=−6)
34. M07 : Flux input.
    0=A(G); enter a single 3* array containing IGM values. Input flux is uniform in space, and is energy dependent.
    1=[N(I, J)]G; enter IGM 3* arrays, each containing IM*JM values. Flux is space and energy dependent.
    2=A(G)*N(I, J); enter two 3* arrays: IGM values in the first and IM*JM values in the second. Flux is separable in space and energy.
    3=A(G)*B(I)*C(J); enter three 3* arrays: IGM values in the first, IM values in the second, and JM values in the third. Flux is separable in all variables.
    4=[B(I)*C(J)]G; enter two 3* arrays for each group: IM values in the first and JM values in the second. Flux is only separable in spatial variables.
    5=ESPRIT expects restart fluxes from the logical unit of FT50F001. In this case, the data block of 3* must be omitted.
35. M06 : Distributed source input.
    0, 1, 2, 3, and 4, the same as for N07 except for the array is designated by the 17*
    5=source on the logical unit NBSO
36. IZ1 : Radial interior boundary source input.
    0=no effect
    N=source for radial boundary $1<N\leq IM$ entered on cards (15*)
    −N=source for radial boundary $1<N\leq IM$ entered on the logical unit NBSO
37. IZ2 : Axial interior boundary source input.
    0, N, −N, the same as for IZ1 except for axial boundary $1<N\leq JM$.
38. IB5 : Radial interior boundary angular flux output.
    0=no effect
    N=write angular fluxes for angles with positive mu's at the radial boundary N on the logical unit NBFT
    −N=write angular fluxes for angles with negtative mu's at the radial boundary N on the logical unit NBFT
39. IB6 : Axial interior boundary angular flux output.
    0=no effect
    N=write angular fluxes for angles with positive eta's at the axial boundary N on the logical unit NBFT
    −N=write angular fluxes for angles with negative eta's at the axial boundary N on the logical unit NBFT

40. IZ4 : Final total scattering source output.
    0=no effect
    N=final total scattering source is written on the logical unit N
41. IB2 : Cross section and scalar flux print.
    0=no effect
    1=no cross section print
    2=no scalar flux print
    3=both 1 and 2
42. M05 : Activity calculation. (see Note 6)
    N=calculate N zone and point activities
    −N=calculate N zonewize activities
43. IB1 : Zone balance tables.
    0=no effect
    N=number of zones specified in the 30$ array for which zone balance tables are desired
44. IP3 : Fission density output.
    0=no effect
    1=fission distribution is outputted on the logical unit FT07F001
45. IAFT : Angular flux output.
    0=no angular flux output
    1=angular fluxes are outputted on the logical unit NAFT
    2=angular fluxes are printed
    3=both 1 and 2
    (if DATA-POOL output is assigned, IAFT≥1 is required)
46. IP4 : Angular flux output.
    0=no effect
    1=output angular flux without doing extra outer iteration (used with 1-iteration problems)
47. IS2 : Not used.
48. IS3 : Not used.
49. IZ5 : Lower iteration limit for the WWESOL subroutine which solves for the space-point scaling factors.
    (if 0, default=8)
50. IZ6 : Upper iteration limit for the WWESOL subroutine.
    (if 0, default=100)
51. IMG : Number of inner iterations before a space-point rescaling which is performed in the WWESOL subroutine.
    (IMG=2 is recommended)
52. IP2 : Number of inner iterations between successive the space-point rescalings.
    (IP2=1 is recommended)
53. IB3 : Damping constant for the space-point rescalings.
    (IB3=4 is recommended)
54. IT1 : Not used.
55. IFLUX : Flux guess preparation control.
    0=no effect
    INN=prepare a flux guess from the logical unit NN as specified by I, write on NFLUX1

56. IGMI : Number of groups for the flux guess input.
57. IA03I : Order of scatter for the flux guess input.
58. IA04I : Number of angles for the flux guess input.
59. ISRCE : Source copy.
    0=no effect
    N=copy source from the logical unit N to NBSO for I04=5, to NPSO for I04=6
60. IGIXS : Cross section copy.
    0=no effect
    N=copy group-organized cross-sections from the logical unit N to the logical unit NCR1
61. IPRT : Print option.
    0=no effect
    1=print uncollided flux, mus and etas
    2=print uncollided flux, mus, etas, and the first collision source

62$ Logical unit parameters [14]

1. NCR1 : Data set ref no., scratch. (if 0, default=2)
2. NFLUX1 : Data set ref no., scratch. (if 0, default=3)
3. NSCRAT : Data set ref no., scratch. (if 0, default=4)
4. NBSO : Data set ref no., boundary or volume-distributed source input. (if 0, default=14)
5. NPSO : Data set ref no., first collision source input. (if 0, default=15)
6. NFLSV : Data set ref no., scalar flux and moments output. (if 0, default=9)
7. NAFT : Data set ref no., angular flux output. (if 0, default=10)
8. NBFT : Data set ref no., interior boundary angular flux output. (if 0, default=11)
9. NGAM : Data set ref no., activity output. (if 0, default=12)
10. NZBT : Data set ref no., search for zone balance tables. (if 0, default=13)
11. NLIB : Not used.
12. NBUF : Not used.
13. JBRL : Angular flux output.
    0=no effect
    N=lower axial interval for the angular flux output
14. JBRU : Angular flux output.
    0=no effect
    N=upper axial interval for the angular flux output

63* Floating parameters [18]

1. S01 : Source normalization factor. (see Note 8)
2. EPS : General convergence criterion. (integral inner iteration, LAMBDA and fission density)
3. G06 : Pointwise flux error criterion. (integral inner iteration test is used if G06=0.0)
4. G05 : Maximum CPU time for this problem.
5. S03 : Parametric eigenvalue for search. (k or α)

6. EV : First eigenvalue guess.
7. EVM : Eigenvalue increment to be added to EV.
8. LAL : Linear extrapolation used when converged closer than LAL.
9. EPSA : Convergence criterion for changing EV in search.
10. LAH : Upper limit on ABS(LAMBDA−1.0) in linear search. (0.05 is recommended)
11. POD : Parameter oscillation damper. (0.75 is recommended)
12. SH : Height of point source. (see Note 7)
13. HSA : Cosine of angle with Z axis into which source is emitted. (see Note 7)
14. SF : Source magnitude. (see Note 7)
15. ZEXC : Exclusion radius. (see Note 7)
16. ORF : Not used.
17. SFE : Not used.
18. SPE : Space-point rescaling convergence criterion. (if 0, default = 1.E−4)

T Termination of this data block.

Data Block 1:

Array Name	Data
7*	Direction cosines: mu and eta. The mu's precede the eta's. [2*A04 entries]
T	Terminator

Data Block 2:

Array Name	Data
6*	Quadrature weights [A04 entries]
T	Terminator

Data Block 3: (omit this block if IFLUX1* ≠ 2 or 3)

Array Name	Data (If IFLUX1 = 2)	Data (If IFLUX1 = 3)
64$	Old group number for each new group [IGM entries] (Default: old group = new group)	Old group number for each new group [IGM entries] (Default: old broup = new group)
65*	New total flux by group, arbitrary unit [IGM entries] (enter only if 66* is also entered)	Radial flux by interval, then by group, followed by the axial flux [IGM*(IM + JM) entries] (Default: flux = 0)
66*	Old total flux by group, arbitrary unit [IGMI entries] (Default: old flux = new flux)	Old total flux by group, arbitrary unit [IGMI entries] (Default: old flux taken from the first spatial interval or radial flux)
T	Terminator	Terminator

*Note: IFLUX in the 61$ array is prepared by the equation: IFLUX = IFLUX1*100 + NN, where NN indicates the logical unit number of flux guess input.

Data Block 4:

Array Name	Data
13$	Material identification node name for cross sections from DATA-POOL on the logical unit FXSN in the unit assignment card. (MTP≠0) [MTP+2 entries] (see Note 5)
T	Terminator

Data Block 5:

Array Name	Data
17*	Fixed, volume-distributed source. When more than one 17* array is required, each must be followed by a "T". (I04=0 and M06=0, 1, 2, 3, 4)
T	Terminator

Data Block 6:

Array Name	Data
18*	Fixed exterior boundary source. (I04=5 and B01=4 or B02=4 or B03=4 or B04=4) (see Note 3)
T	Terminator

Data Block 7:

Array Name	Data
15*	Fixed interior boundary source. (IZ1≠0 or IZ2≠0) (see Note 3)
T	Terminatolr

Data Block 8:

Array Name	Data
3*	Initial flux. When more than one 3* array is required, each must be followed by a "T". (M07=0, 1, 2, 3, 4)
T	Terminator

Data Block 9:

Array Name	Data
1*	Fission spectrum [IGM entries] (see Note 10)
2*	Axial (Y, Z, θ) interval boundaries [JM+1 entries] (see Note 9)
4*	Radial (X, R, R) interval boundaries [IM+1 entries]
5*	Velocities (if I04≠−6) of source (if I04=−6) by group [IGM entries]
8$	Zone number by interval, starting at the lower left corner of mesh, sweeping from left to right, then from bottom to top [IM*JM entries]
9$	Material number by zone [IZM entries] (see Note 5)
19$	Material numbers for activity print (see Note 6) (M05≠0) [M05 entries]
20$	Cross-section table position for activity print (M05≠0) [M05 entries]
21$	Radial search zone numbers (I04=4) [IM entries]
22*	Radial zone modifiers (I04=4) [IZ entries]
23$	Axial search zone numbers (I04=4) [JM entries]
24*	Axial zone modifiers (I04=4) [JZ entries]
25*	Right boundary albedo (B02=5) [JM*IGM entries]
26*	Top boundary albedo (B03=5) [IM*IGM entries]
27*	Bottom boundary albedo (B04=5) [IM*IGM entries]

28$ Inner iteration maximum by group, overrides S04 and G07 (IMG=1) [IGM entries]

29$ Number of quadrature angles by group. Zero entry for diffusion theory; otherwise A04 (ISC=1) [IGM entries]

30$ Zone numbers for zone balance tables (IB1≠0) [IB1 entries]

32$ Zone numbers for zones of convergence (IZC≠0) [IZC entries] (see Note 3)

33* Direction cosines, eta's, for source input for uncollided flux calculation. (I04=−6) [IZ3 entries] (see Note 7)

34* Source magnitude: $f(\eta)$, for uncollided flux calculation (I04=−6) [IZ3 entries]

36$ Axial interval numbers to print reaction rates (NR1≠0) [NR2 entries]

37$ Node names for neutron response functions (NR1=3, NR3≠0) [NR3+2 entries] (see Note 5)

38$ Node names for gamma-ray response functions (NR1=3, NR4≠0) [NR4+2 entries] (see Note 5)

T Terminator

3. Neutron response data (NR1=1, NR3≠0)

TITLE : Identification name of the response function (20A4)

RESP : Data of response function (6E12.5)

The set of response data are repeated by NR3 times.

4. Gamma-ray response data (NR1=1, NR4≠0)

TITLE : Identification name of the response function (20A4)

RESP : Data of response function (6E12.5)

The set of response data are repeated by NR4 times.

3.2.2 Input/Output File Assignment

ESPRIT requires various direct-access devices during execution. **Table 3.2** shows the names of the data sets. The logical unit number marked with circle in the table is required to execute the job. The logical unit number marked with a condition in parentheses is required when the condition is satisfied. The value for the memory space estimation is varied by the various conditions of computation, so that it is roughly estimated.

Table 3.2 Requirements for external data sets in ESPRIT.

Logical Unit	Condition	Contents	1st. Space Estimation (Tracks)	DCB Information		
				LRECL	BLKSIZE	RECFM
FXSN*	○	Cross section library	—	3600	3600	F
RESD*	(RESD≒0)	Response data input	—			
FLX1*	(FLX1≒0)	Scalar flux output	—			
FLX2*	(FLX2≒0)	Angular flux output	—			
NCR1†	○	Scratch	100	18632	18636	VBS
NFLUX1†	○	Scratch	300			
NSCRAT†	○	Scratch	300			
NBSO†	○	Boundary source	100			
NPSO†	○	First collision source	100			
NFLSV†	○	Scalar flux output	100			
NAFT†	○	Angular flux output	100			
NBFT†	○	Boundary angular flux	100			
NGAM†	○	Pointwise activity	100			
NZBT†	○	Scratch	100			
FT30F001	○	Scratch	500			
FT50F001	(M07=5)	Flux guess input	—			
FT51F001	(NR1=2)	Response data input	—	80	3120	FB

* Logical unit numbers are defined by unit assignment card.

† Logical unit numbers are defined by the data in the 62$ array.

3.2.3 Job Control Language

Figure 3.7 shows a typical job control language for executing ESPRIT.

```
//JCLG  JOB                                                          00000010
// EXEC JCLG                                                         00000020
//SYSIN DD DATA,DLM='++'                                             00000030
// JUSER CARD                                                        00000040
  C.5 T.6 W.3 I.5 OPN                                               00000050
 OPTP PASSWORD=????????,MSGLEVEL=(1,1)                              00000060
//FORT  EXEC FORTHE                                                 00000070
       SUBROUTINE ALOCAT(LOC,SUB)                                   00000080
       COMMON/DCOMMN/D(200000)                                      00000090
       IF(LOC.GT.0) GO TO 10                                        00000100
       LOC=200000                                                   00000110
       CALL DTLIST                                                  00000120
       GO TO 999                                                    00000130
   10  CONTINUE                                                     00000140
       CALL SUB(D,LOC)                                              00000150
  999  RETURN                                                       00000160
       E          N          D                                     00000170
//LINK  EXEC LKEDIT,LM='J3679.ESPRIT',CNTL=NO                       00000180
 REPLACE DCOMMN                                                     00000190
 ENTRY   MAIN                                                       00000200
 INCLUDE OLDLM(TEMPNAME)                                            00000210
 NAME    TEMPNAME(R)                                                00000220
//ESPRIT EXEC GO,ORECFM=FA,OBSIZE=137,SYSOUT=*                      00000230
//FT01F001 DD DSN=&&FT01,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000240
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000250
//FT02F001 DD DSN=&&FT02,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000260
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000270
//FT03F001 DD DSN=&&FT03,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000280
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000290
//FT04F001 DD DSN=&&FT04,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000300
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000310
//FT08F001 DD DSN=&&FT08,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000320
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000330
//FT09F001 DD DSN=&&FT09,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000340
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000350
//FT10F001 DD DSN=&&FT10,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000360
//         SPACE=(TRK,(200,50)),UNIT=WK10,DISP=(NEW,DELETE)         00000370
//FT11F001 DD DSN=&&FT11,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000380
//         SPACE=(TRK,(200,50)),UNIT=WK10,DISP=(NEW,DELETE)         00000390
//FT12F001 DD DSN=&&FT12,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000400
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000410
//FT20F001 DD DSN=&&FT20,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000420
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000430
//FT21F001 DD DSN=&&FT21,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000440
//         SPACE=(TRK,(30,10)),UNIT=WK10,DISP=(NEW,DELETE)          00000450
//FT30F001 DD DSN=&&FT30,DCB=(RECFM=VBS,LRECL=6208,BLKSIZE=6212),   00000460
//         SPACE=(TRK,(200,50)),UNIT=WK10,DISP=(NEW,DELETE)         00000470
//*   FT91 IS LOGICAL UNIT FOR CROSS SECTION LIBRARY                00000480
// EXPAND DISKTO,DDN=FT91F001,DSN='J????.????????',DISP=SHR         00000490
//SYSIN    DD    *                                                  00000500
//*************************************************               00000510
//*                                                 *               00000520
//*    INPUT DATA  FOR  E S P R I T                 *               00000530
//*                                                 *               00000540
//*************************************************               00000550
++                                                                  00000560
//                                                                  00000570
```

Fig. 3.7 Job control cards for ESPRIT for use on the FACOM M-380 computer at JAERI

3.2.4 Data Notes for ESPRIT

ESPRIT adopts a variable dimension technique to allocate core memories. The maximum size of memories is set to a default value of 200000. The value is set when the load module is generated, so that it may be insufficient for the large-size problems. In the case, the user must compile a following program to extend the maximum size and replace the old load module.

```
      SUBROUTINE ALOCAT (LOC, SUB)
      COMMON/DCOMMN/D (XXXX)
      IF (LOC.GT.0) GO TO 10
      LOC=XXXX
      CALL DTLIST
      GO TO 999
   10 CONTINUE
      CALL SUB (D, LOC)
  999 RETURN
      END
```

where XXXX means the maximum size of memory.

Notes for using ESPRIT are described below. The user should pay attention to these information before execution.

Note 1) Number of neutron and gamma-ray group

IGM must be equal to the sum of neutron group, ING, and gamma-ray group, IGG. A computation for only neutron or gamma-ray group is possible even if the coupled neutron and gamma-ray cross sections are used. In such case the length of cross section table ITL in the 61$ array must be equal to that of the cross section library.

Note 2) Convergence

There are three levels of iteration in ESPRIT. The first is the inner iteration for within-group scattering. The second is the fission-source iteration, and the third is the iteration for searches.

Inner Iteration Convergence – Inner iterations are necessary for within-group scattering, because neutrons may scatter from any angle to any other angle, and the flux at all angles is unknown at the beginning of an iteration. The iterations are continued until the scalar flux converges according to one of the following criteria:

a. If G06=0.0 and IZC=0, an integral iteration test on all zones is used with EPS as the criterion. Convergence is achieved when

$$\frac{1}{V}\int \left| \frac{\phi^n(\vec{r})-\phi^{n-1}(\vec{r})}{\phi^n(\vec{r})} \right| d\vec{r} \leq EPS,$$

where the integration is over the entire system volume V.

b. If G06≠0.0 and IZC=0, a pointwise scalar flux criterion is used on all zones with G06 as the criterion. Convergence is achieved when

$$\mathrm{MAX}\left\{ \left| \frac{\phi^n(\vec{r})-\phi^{n-1}(\vec{r})}{\phi^n(\vec{r})} \right| \right\} \leq G06$$

c. If IZC>0 in the case of a or b above, the criterion is applied only to material zones listed in the 32$ array.

d. If IMG=0 and $|LA-1.0| \geq 10.0*EPS$, then the iteration is stopped after S04 cycles. This criterion is also used for a 1 iteration problem. (LA is the ratio between successive estimates.)

e. If IMG=0 and $|LA-1.0| < 10.0*EPS$, then the iteration is stopped after G07 cycles.

f. If IMG≠0, then the iteration is stopped after cycles of the number indicated for the group in the 28$ array.

g. Iteration is stopped when the time limit, TMAX, has been exceeded.

Fission Source and Search Convergence – In a given power iteration, the fission source is determined by the flux in the previous iteration. The iterations are continued until

$$| 1.0 - S^n / S^{n-1} | < EPS.$$

In a k_{eff} calculation, S^n is given by

$$S^n = \frac{1}{k^n} \int\int \nu\Sigma_f \phi^n dE d\vec{r}.$$

In a search, S^n is given by the above integral with k^n of unity. In a fixed source calculation with fissions, S^n is given by

$$S^n = \int\int (SO - \nu\Sigma_f \phi^n) dE d\vec{r},$$

where SO is the fixed source. In the k_{eff} calculation and search, the S^{n-1} is always normalized to the normalization factor S01. In fixed source calculations, the fixed source, SO, is *so* normalized.

It has been observed that, for some systems, the fission source iteration is either nonconvergent or slowly convergent. Many of these problems have been solved by applying a pointwise flux criterion, G06 $\neq 0$. Recommended values are from 0.001 to 0.005. For most other problems, the integral inner iteration criterion is adequate. For fission source iteration, an EPS of 0.001 is usually used. (Convergence beyond 0.00001 is probably not useful on FACOM M380 machines.)

Note 3) Boundary Conditions and Boundary Sources

The boundary conditions may deserve comment. In the white boundary condition, the incoming flux is isotropic, and is adjusted in magnitude to effectively zero net current. in the albedo (or gray) boundary condition, the incoming isotropic flux is set to a fixed fraction (the albedo) of the outgoing flux. In the periodic condition, the incoming flux is set to the value of the outgoing flux in the same direction at the opposite boundary. This can be used for certain cell problems and in the $R\theta$ geometry.

The periodic boundary condition is generally used at the top and bottom sides of a 360° $R\theta$ problem, insuring that flux match at the two boundaries is obtained.

In general, vacuum and reflective condition problems more easily converge than white or periodic ones. The reflective condition is often used at the left side of RZ and $R\theta$ problems, as well as at the right side of cylindrical "cell" problems. The white condition is sometimes used for both these applications, although it can sometimes cause serious errors.

A boundary source on either the left, right, top, and/or bottom boundary is inputted to ESPRIT by specifying the angle, space, and energy dependent inward boundary flux which emerges from the source. The source may be entered by cards or an external data set located on the logical unit NBSO. The following rules are applied to either method of input:

a. The data for each group comprise a separate data block for input from cards, or a logical record for input from external data set.
b. If more than one boundary source is specified, they are entered in the order of the parameters B01, B02, B03, and B04, i.e., for a right and bottom boundary source, the right is entered first followed by the bottom. The choice between cards or external data set must be made only once and used for all boundary sources present. In the case of cards, the data for all boundaries within a group fall within one 18* block. In the case of an external data set, data for each boundary within a group comprise a single record.
c. The angular fluxes are entered in order of angle, interval, and then group.
d. For the left and right boundaries, the interval sweep is from bottom to top.
e. For the top and bottom boundaries, the interval sweep is from left to right.
f. For the left boundary, a total of MMRT*JM*IGM entries are required where MMRT is the

number of directions having $\mu > 0.0$. The entries by angle are ordered as specified by the quadrature direction set (7*).

g. For the right boundary, a total of MMLT*JM*IGM entries are required where MMLT is the number of directions having $\mu < 0.0$. The entries by angle are ordered as specified in the 7* array. Initializing directions (weight = 0) are included.

h. For the top boundary, a total of MMDN*IM*IGM entries are required when MMDN is the number of directions having $\eta < 0.0$. The entries by angle are ordered as specified in the 7* array. Initializing directions are included.

i. For the bottom boundary, a total of MMUP*IM*IGM entries are required where MMUP is the number of directions having $\eta > 0.0$.

Interior boundary sources are entered in a similar fashion, except that the data for each group are identified as 15* block. If IZ1 $\neq$ 0 and IZ2 = 0, MM*JM entries are read for each group where MM is the total number of directions. If IZ2 $\neq$ 0, MM* IM enteries are read.

Note 4) Flux Calculation Model

Given a non-negative source, a sufficient angular quadrature set, and enough spatial intervals, one would achieve positive fluxes in most problems of practical interest. The economics of storage and computing time, however, often requires treating problems with more coaresly defined form. The linear difference equation, which is most accurate in adequately meshed problems, overextends to negative fluxes, especially in zones of large σ_t. These negative values, of course, are physically meaningless, and may cause error which propagate to adjacent regions.

Note 5) Material Assignment

ESPRIT assigns storage space for MT sets of cross sections, called "materials". The cross section data are stored in the order indicated by the 13$ array. The materials can be specified by the 9$ array for use in a zone. The assignments for the node names stored in DATA-POOL are as follows:

```
13$$   4HEGRP  4HFX32   4HCORE  4HAIR    4H1389 ——
37$$   4HEGRP  4HRESP   4HSNNP  4HDOSE   4HALNA ——
38$$   4HEGRP  4HRESP   4HALKM  4HCUKM   ——
```

The first entry of each array is the first node name in DATA-POOL that means the energy group structure. The second entry shows the second node name in DATA-POOL. From the third entry, material identification names are defined. The first number specified in the 9$ array corresponds to the third entry in the 13$ array.

Note 6) Activities

Activities can be computed by spatial interval and zone (if M05 > 0) or by zone only (if M05 < 0). The zone activity is a total reaction rate, and the pointwise activity is that per unit volume:

$$A^n_{i-1/2,\, j-1/2} = \sum_g \phi_{i-1/2,\, j-1/2,\, g} \sigma^n_g ,$$

$$A^n_k = \sum_{i,\, j} A^n_{i-1/2,\, j-1/2} V_{i-1/2,\, j-1/2}$$

where

$A^n_{i-1/2,\, j-1/2} = n^{th}$ pointwise activity for the interval $(i-1/2,\ j-1/2)$

$A^n_k = n^{th}$ zonewise activity for the zone k,

$V_{i-1/2,\, j-1/2}$ = volume of the interval $(i-1/2,\ j-1/2)$

$\phi_{i-1/2,\, j-1/2,\, g}$ = flux at the point (i, j), the group g,

σ_g^n=cross section for the group g for the material and the table position specified by the n^{th} elements of the 19$ and 20$ arrays, respectively.

If the 19$ entry is negative, the activity is calculated for all intervals; but if it is positive, it is calculated only if the material is assigned to that interval by the 9$ array. The following table illustrates the used of activity specifications:

	19$	20$
1.	1	3
2.	−5	1

1. Compute activity for material 1, cross-section position 3 in the intervals and zones in which material 1 appears;
2. Compute activity for material 5, cross-section position 1 in all intervals.

Note 7) Analytic First-Collision Source

If I04=−6, the uncollided flux due to a point source located anywhere on the Z axis of an RZ problem will be calculated. The uncollided flux at any point is

$$\phi_{i-1/2,\, j-1/2,\, g}=\frac{S\, f(\eta)\; e^{-\lambda} y_g}{4\pi\left[R_{i+1/2}^2+(Z_{j+1/2}-h)^2\right]},$$

where

$\phi_{i-1/2,\, j+1/2,\, g}$ = uncollided flux for the group g in the interval $R_i<R<R_{i+1}$, $Z_j<Z<Z_{j+1}$,
$R_{i-1/2}$ = midpoint of the i^{th} radial interval,
$Z_{j-1/2}$ = midpoint of the j^{th} axial interval,
h = source height (SH),
S = source magnitude (SF),
y_g = source yield in g^{th} group (5* array),
λ = $\int \Sigma_g^T\, dr$ along the ray from the source location to $(R_{i-1/2}, Z_{i-1/2})$,
η = cosine of the angle between the ray and the Z axis,
$f(\eta)$ = angular distribution function from the table formed by the 34* array vs. the 33* array.

The tabulated $f(\eta)$ is normalized by the integration using the trapezoidal rule, and the table is interpolated using linear interpolation, so that the total source is obtained effectively as

$$\text{total source}=S\sum_g y_g,$$

If HSA≠0, the uncollided flux will be nonzero only at the points where $\eta^2>\text{HSA}^2$ and η*HSA>0. Thus, a source-filled cone can be directed either upward or downward.

Note 8) Normalization

Multiplication factor k calculations are normalized such that

$$\text{NF}=\frac{1}{k}\int\int \nu\Sigma_f(\vec{r}, E)\phi(\vec{r}, E)d\vec{r}\, dE,$$

where NF is normalization factor, and the integration is over all energy and space. For searches, the normalization is given by the above equation with k=1.0. For problems with fixed volume distributed source, the normalization is

$$\text{NF}=\int\int \text{S}(\vec{r}, E)\; d\vec{r}\, dE.$$

For problems with a fixed surface flux condition, the normalization is

$$NF=\int\int\phi(\vec{r_s},\vec{\Omega},E)\vec{\Omega}\cdot\vec{n}\,ds\,dE\ ,$$

where ϕ is the angle and energy dependent flux specified at the surface r_s, and n is normal to the differential surface element ds.

Note 9) Units

The units of X, Y, Z, and R in ESPRIT are consistent with the units of the cross sections, usually centimeters. The output fluxes and other data in XY or $R\theta$ problems are normalized as if the missing Z dimension were unity. In $R\theta$ problems, the θ variable is entered in rotations, 360° to the rotation. Velocities are normally in units of centimeters/second. Scalar fluxes are in particles/second/centimeter^2. Boundary sources and angular fluxes are in units of particles/second/centimeter^2, per unit sphere. (to convert to the angular flux per steradian, one must divide by 4π) Volume-distributed sources are in particles/second/centimeter^3.

Note 10) Fixed-Source solutions with Multiplication

Fixed-source problems are normally run with putting the fission spectrum data 1* as 0. If 1* is non -zero, a system with both fixed and fission sources is implied. If the system is subcritical, a special acceleration technique will be used to provide rapid convergence. If the system is supercritical, even slightly, such a problem will probably fail.

3.3 MCACE

MCACE adopts a method which computes directly the cumulative distribution function by using cross sections of the discrete-type DAR form and determines the scattering angle by a random number.

The cumulative distribution function is generated by using the cross section of the discrete-type DAR form as follows:

$$P^E_{ij}=\frac{\sum_{m=i}^{j}\Sigma_{i\to m}}{\sum_{n=1}^{MAXG}\Sigma_{i\to n}}\ , \tag{3.17a}$$

$$P^A_{ijk}=\frac{\sum_{m=i}^{k}\Sigma_{i\to j}(\mu_m)\Delta\mu_m}{\sum_{n=1}^{NSCT}\Sigma_{i\to j}(\mu_n)\Delta\mu_n}\ , \tag{3.17b}$$

where MAXG means the lowest energy group scattered from the group i, NSCT is the number of angular meshes and $\Delta\mu_m$ shows the interval from μ_m to μ_{m+1}. Then a random number R with uniform distribution from 0 to 1 is generated to determine the scattering angle and the scattered energy as follows:

a) determine the scattered energy group j by using the following condition,

$$P^E_{i,j-1}<R<P^E_{i,j}\ , \tag{3.18a}$$

b) determine the cosine of scattering angle μ by using the following interpolation,

$$\mu=\mu_{k-1}+\frac{R-P^A_{i,j,k-1}}{P^A_{i,j,k}-P^A_{i,j,k-1}}(\mu_k-\mu_{K-1})\ , \tag{3.18b}$$

where k is determined by the following condition:

$$P^A_{i,j,k-1}<R<P^A_{i,j,k}\ . \tag{3.19}$$

We have introduced the method into MORSE-CG in order to use the cumulative distribution

function without using the finite Legendre expansion, so that the scattering angle can be determined more correctly in the bounds of angular mesh intervals.

MCACE has the point and the surface crossing estimators to compute scalar and angular fluxes. The surface crossing estimators for real crossing and expected crossing have also been introduced. The surfaces for sphere, cylinder, (R, θ) plane and (X, Y) plane are allowable. The scoring is available for scalar flux, leakage current (J^+ and J^-) and angular flux. These estimators are illustrated in **Fig. 3.8**. The surface crossing estimator is also utilized to the bootstrap option by computing arbitrary boundary fluxes.

The point detector estimation is performed by computing uncollided flux densities from each collision site to the detector as follows:

$$\phi_j^D = \frac{1}{r^2} \cdot \mathrm{WATE} \cdot \frac{\sum_{m=i}^{\mathrm{MAXG}} \Sigma_{i\to m}(\mu_k)}{\Sigma_i^T} e^{-\Sigma_j^t r}, \tag{3. 20}$$

where WATE means the particle weight, r is the flight length from each collision site to the detector, Σ_j^t is the total macroscopic cross section of the scattered particle. The scattered energy group j is determined in the following manner. The cumulative distribution function for the incident energy group i, the cosine of scattering angle μ_k and the scattered energy group j, as shown in **Fig. 3.9** is produced as follows:

$$P_j^D = \frac{\sum_{m=i}^{j} \Sigma_{i\to m}(\mu_k)}{\sum_{m=i}^{\mathrm{MAXG}} \Sigma_{i\to m}(\mu_k)}. \tag{3. 21}$$

Then the random number R which is uniformly distributed from 0 to 1 is generated to determine the

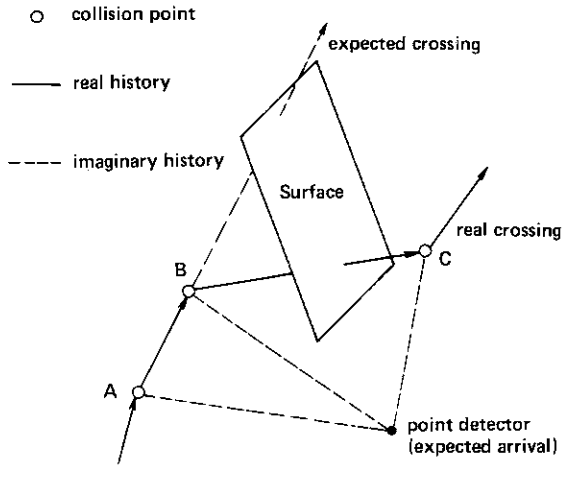


Fig. 3.8 Schematic representation for various estimators in MCACE

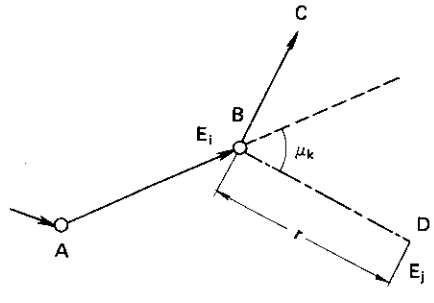


Fig. 3.9 Point detector estimation scheme in MCACE

scattered energy group j by using the following condition:

$$P^D_{j-1} < R < P^D_j. \tag{3. 22}$$

The surface crossing estimation for spherical geometry is performed by the following procedure. We assume that the latest collision point and the crossing point are A and B in **Fig. 3.10**, respectively. The coordinates (x_t, y_t, z_t) at the point B satisfy the following equations:

$$\left.\begin{aligned} x_t &= x_1 + ut, \\ y_t &= y_1 + vt, \\ z_t &= z_1 + wt, \\ (x_t - x_0)^2 + (y_t - y_0)^2 + (z_t - z_0)^2 &= r^2, \end{aligned}\right\} \tag{3. 23}$$

where u, v and w are the direction cosines of the incident particle, t means the pass length to the surface and r is the radius of the sphere. From the above equations, we obtain

$$t = -\{(x_1 - x_0)u + (y_1 - y_0)v + (z_1 - z_0)w\} \pm \sqrt{D}, \tag{3. 24}$$

whrere

$$D = \{(x_1 - x_0)u + (y_1 - y_0)v + (z_1 - z_0)w\}^2 - d^2 + r^2, \tag{3. 25}$$

$$d^2 = (x_1 - x_0)^2 + (y_1 - y_0)^2 + (z_1 - z_0)^2. \tag{3. 26}$$

The solution for t exists under the following conditions,

$$D > 0 \quad \text{and} \quad t \geq 0, \tag{3. 27}$$

and

$$\cos\theta_2 \leq \cos\theta \leq \cos\theta_1, \tag{3. 28}$$

where $\cos\theta_1$ and $\cos\theta_2$ mean the boundaries of the spatial division, as shown in **Fig. 3.10**, and $\cos\theta$ is given by the following equation:

$$\cos\theta = \frac{(x_t - x_0)u_1 + (y_t - y_0)v_1 + (z_t - z_0)w_1}{r}. \tag{3. 29}$$

Then we obtain the flux density by using the following equation:

$$\phi^s = \text{WATE} \cdot \exp\left(-\int_A^B \Sigma^T dt\right) / \{2\pi r^2 \mid \cos\eta \mid (\cos\theta_1 - \cos\theta_2)\}, \tag{3. 30}$$

where $\cos\eta$ is the direction cosine to the normal vector given as

$$\cos\eta = \frac{(x_t - x_0)u + (y_t - y_0)v + (z_t - z_0)w}{r}, \tag{3. 31}$$

and the other notations are the same as those for the point detector estimation.

In the case of cylindrical geometry, the coordinates (x_t, y_t, z_t) in **Fig. 3.11** satisfy the following equations:

$$\left.\begin{aligned} x_t &= x_0 + ut, \\ y_t &= y_0 + vt, \\ z_t &= z_0 + wt, \\ (x_t - x_m)^2 + (y_t - y_m)^2 &= r^2, \end{aligned}\right\} \tag{3. 32}$$

where r is the radius of the cylinder. Note that the axial direction of the cylinder is parallel to the z-axis of the system coordinates. From the above equations, we obtain

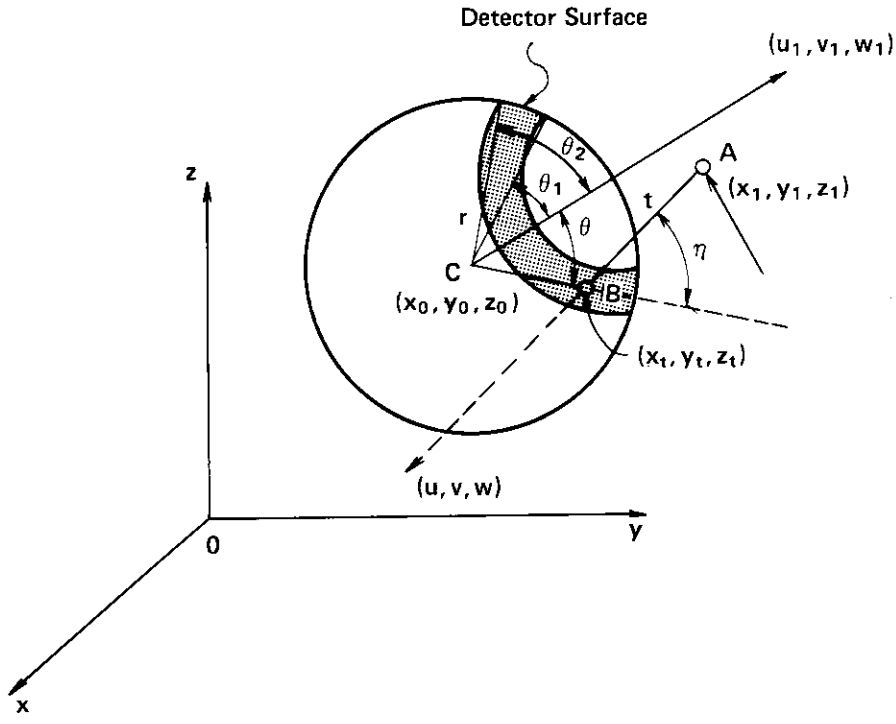


Fig. 3.10 Surface crossing estimation scheme for spherical geometry in MCACE

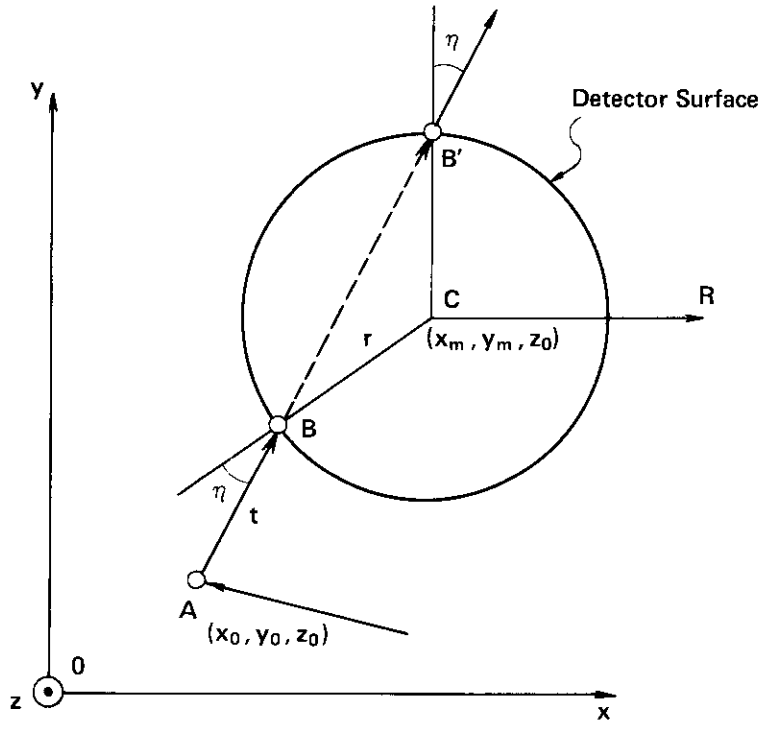


Fig. 3.11 Surface crossing estimation scheme for cylindrical geometry in MCACE

$$t=\frac{-\{u(x_0-x_m)+v(y_0-y_m)\}\pm\sqrt{D}}{u^2+v^2}. \tag{3.33}$$

where

$$D=(u^2+v^2)r^2-\{v(x_0-x_m)-u(y_0-y_m)\}^2 . \tag{3.34}$$

The solution for t exists under the following conditions:

$$t\geq 0, \tag{3.35a}$$

and

$$Z_{min}\leq Z_t\leq Z_{max} , \tag{3.35b}$$

where Z_{min} and Z_{max} are the lower and the upper limits of the cylinder. Then we obtain the flux density by using the following equation:

$$\phi^s=\text{WATE}\cdot\exp\{-\int_A^B\Sigma^T dt\}\ /\ \{2\pi r(Z_{max}-Z_{min})\cdot|\cos\eta|\} , \tag{3.36}$$

where $\cos\eta$ is the direction cosine to the normal vector given as

$$\cos\eta=\frac{u(x_t-x_m)+v(y_t-y_m)}{r}. \tag{3.37}$$

When the axial direction of the cylinder is parallel to the x or y axis of the system coordinates, the following transformation of coordinate system is performed.

a) In the case of parallel to the x-axis:

$$\left.\begin{array}{l} x\rightarrow z \\ y\rightarrow x \\ z\rightarrow y \end{array}\right\}, \tag{3.38}$$

b) In the case of parallel to the y-axis:

$$\left.\begin{array}{l} x\rightarrow y \\ y\rightarrow z \\ z\rightarrow x \end{array}\right\}. \tag{3.39}$$

In the case of plane geometry, the coordinates (x_t, y_t, z_t) in **Fig. 3.12** satisfy the following equations:

$$\left.\begin{array}{l} x_t=x_1+ut, \\ y_t=y_1+vt, \\ z_t=z_1+w_t, \\ u_1(x_t-x_0)-v_1(y_t-y_0)+w_1(z_t-z_0)=0. \end{array}\right\} \tag{3.40}$$

From the above equations, we obtain

$$t=\frac{u_1(x_0-x_1)+v_1(y_0-y_1)+w_1(z_0-z_1)}{uu_1+vv_1+ww_1}. \tag{3.41}$$

The solution for t exists under the following conditions:

$$t\geq 0 , \tag{3.42a}$$

and

$$r_1\leq\sqrt{(x_t-x_0)^2+(y_t-y_0)^2+(z_t-z_0)^2}\leq r_2 , \tag{3.42b}$$

where r_1 and r_2 means the inner and the outer radii of the detector surface, as shown in **Fig. 3.12**. Then

we obtain the flux density by using the following equations:

$$\phi^s = \text{WATE} \cdot \exp\ \{-\int_A^B \Sigma^T dt\}\ /\ \{\pi \mid \cos\theta \mid (r_2^2 - r_1^2)\}\ , \tag{3.43}$$

where $\cos\theta$ is the direction cosine to the normal vector given as

$$\cos\theta = uu_1 + vv_1 + ww_1, \tag{3.44}$$

and the other notations are the same as those for the point detector.

The estimators mentioned above are defined as the expected estimators called the next event surface crossing estimators. We can also use the real crossing estimation. The judgment whether the event is the real crossing or not, is made by te following conditions:

$t < 0$: no real crossing,

$t = 0$: real crossing,

$t > 0$: real crossing if $T \geq t$. (see **Fig. 3.13**)

The computation of the real crossing is performed by using the value of the expected crossing at the point A in**Fig. 3.13**. Note that the number of the crossing counts is twice when the estimation geometry is sphere or cylinder. (see **Fig. 3.14**)

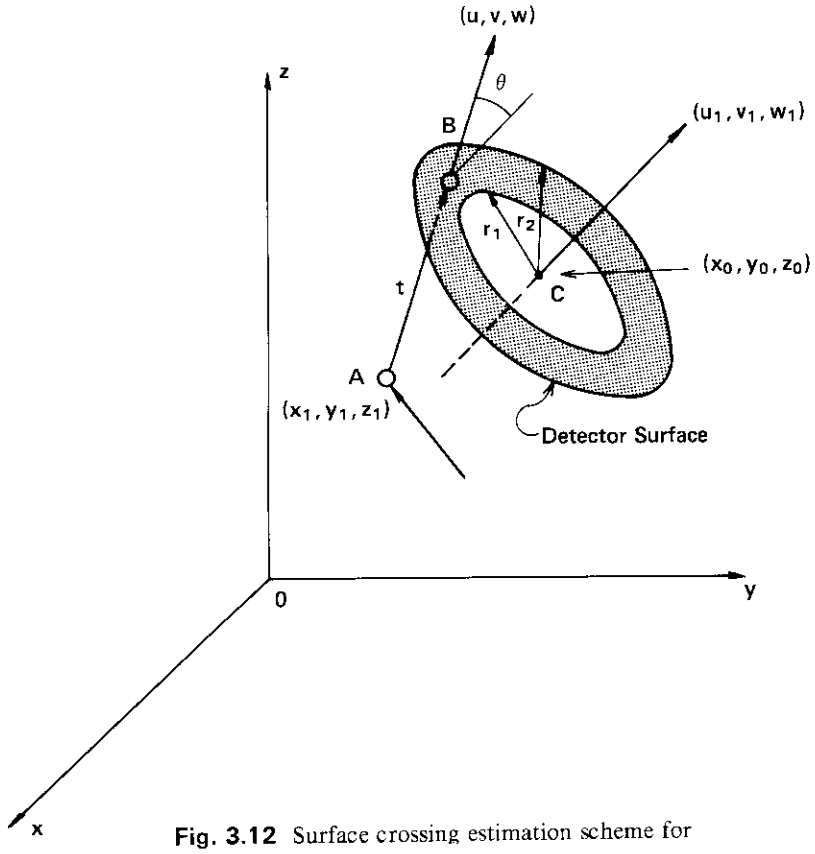


Fig. 3.12 Surface crossing estimation scheme for plane geometry in MCACE

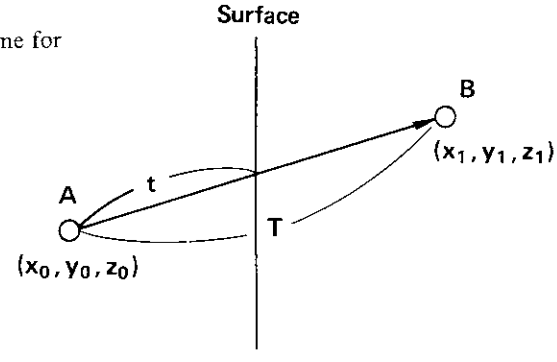


Fig. 3.13 Condition of real crossing estimation in MCACE

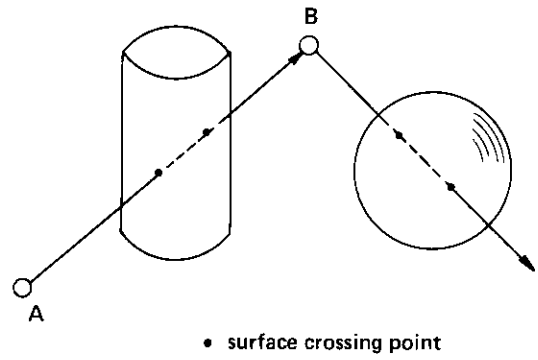


Fig. 3.14 Schematic representation of surface crossing in MCACE

The values for flux density, leakage current and angular flux are computed by using the following equations:

a) expected crossing

(i) flux density

$$F = \frac{1}{n} \Sigma \frac{1}{S} \frac{WATE}{|\eta|} \exp\left\{-\int_A^B \Sigma^T dt\right\}, \tag{3.45}$$

(ii) leakage current

$$F = \frac{1}{n} \Sigma \frac{\eta}{S} \frac{WATE}{|\eta|} \exp\left\{-\int_A^B \Sigma^T dt\right\}, \tag{3.46}$$

(iii) angular flux

$$F = \frac{1}{n} \Sigma \frac{1}{S} \frac{4\pi}{Q} \frac{WATE}{|\eta|} \exp\left\{-\int_A^B \Sigma^T dt\right\}, \tag{3.47}$$

b) real crossing

(i) flux density

$$F = \frac{1}{n} \Sigma \frac{1}{S} \frac{WATE}{|\eta|}, \tag{3.48}$$

(ii) leakage current

$$F = \frac{1}{n} \Sigma \frac{\eta}{S} \frac{WATE}{|\eta|}, \tag{3.49}$$

(iii) angular flux

$$F = \frac{1}{n} \Sigma \frac{1}{S} \frac{4\pi}{Q} \frac{WATE}{|\eta|}, \tag{3.50}$$

where n: number of particles,

S: area of scoring,

Q: solid angle of scoring,

and the other notations are the same as those for the point detector. The summation is done for particles which cross the surface.

MCACE has various biasing methods to prevent wasteful computations. The particle splitting, the Russian roulette, the exponential transform and the energy biasing techniques are the same as those in MORSE-CG.

Three biasing techniques are newly developed for the MCACE module. The one of these is named "Region Penetration Biasing", which is a method coupling the splitting and the path length stretching techniques. The biasing is only set when the particles are collided in the arbitrary region defined by the user. When the scattering event occurs within the region, the particle is splitted. The path length for the

one of the splitted particles is stretched when the next collision site is outisde of the region. The other splitted particle is not applied the biasing. The weight of the stretched particle is modified as folows:

$$\left.\begin{aligned} &\mathrm{ETA}=\sum_i S_i\Sigma_i^T, \\ &\mathrm{BIASX}=\mathrm{ETA}/\mathrm{EXPRNF}(0), \\ &\mathrm{WATE'}=\mathrm{WATE}*\mathrm{BIASX}*\exp\left(-\mathrm{ETA}\cdot\frac{\mathrm{BIASX}-1}{\mathrm{BIASX}}\right), \end{aligned}\right\} \tag{3.51}$$

where S_i is the pass length of the particle in the region i, Σ_i^T means the total macroscopic cross section of the region i, EXPRNF indicates a random number with exponential distribution and WATE is the previous weight for the particle. The Region Penetration Biasing is useful to apply deep penetrating problems.

The "Collision Times Biasing" technique has been prepared for duct-streaming problems. The random walk process is cut off forcedly when the following condition is satisfied:

$$\varepsilon \geq \left| \frac{\sum_{n=1}^{N} R^n - \sum_{n=1}^{N-1} R^n}{\sum_{n=1}^{N} R^n} \right|, \tag{3.52}$$

where R^n means the fluence by the scattering of n-times and ε is the relative difference defined by the user.

The third of the new biasing techniques is called "Automatic Russian Roulette Biasing". The Russian roulette is frequently used in the ordinary Monte Calro calculations. However it is not easy to set adequate values to the weights for playing and surviving by each energy group and zone. The Automatic Russian Roulette Biasing is prepared to avoid the difficulty mentioned above. The automatic procedure is achieved as follows:

i) compute random walk processes with or without ordinary Russian roulette until the number of batches assigned by the user.

ii) compute the average contributions $\bar{f}_g$ of each collision to the fluence of the point detector using the results obtained in the preceding process. If the number of detectors is more than one, the minimum contributor is selected.

iii) the Russian roulette is played when the collision has the smaller value than $\bar{f}_g$*FVR. The particle survives on the condition that the weight is more than WAV. (see Sections 3.3.1 and 3.3.4 in detail)

To verify the biasing techniques described above, two problems shown in **Figs. 3.15** and **3.16** have been computed and the results are summarized in **Table 3.3** and **3.4**. For the straight cylindrical duct problem, the Collision Times Biasing with $\varepsilon=0.01$ can reduce the collision times about 30%, as shown in **Table 3.3**. The next problem deals with a gamma-ray skyshine problem for a concrete silo. The experiment was performed at Kansas State University. In this configuration, the concrete silo is assigned to the penetrating region. **Table 3.4** shows the MCACE results by using the Region Penetration Biasing and the Collision Times Biasing. A good agreement has been obtained between the MCACE result and the experimental value. However, the MCACE result in the same histories without using these biasing techniques shows the poor agreement with the experiment. **Table 3.4** also shows the MCACE result by using the Automatic Russian Roulette Biasing. The computation time was reduced about 70% by using the new biasing techniques implemented in the MCACE.

The computational flows of these biasing methods, the program notes and limitations are shown in Section 3.3.4. The input instruction of MCACE is described in the following section. Input/output file requirements during execution and the job control language for MCACE are shown in Sections 3.3.2 and 3.3.3, respectively.

Table 3.3 Calculated results of the cylindrical duct problem by MCACE

Detector	Estimation**	Collision Times Biasing*	
		Without	With
D_1	Total Flux (F. S. D.)†	2.1064×10^{-6} (0.010)	2.0962×10^{-6} (0.011)
	Uncollided Flux (F. S. D.)†	1.9281×10^{-6} (0.0)	1.9281×10^{-6} (0.0)
	Ratio of Total Collisions	1.0	0.66
D_2	Total Flux	9.6792×10^{-8} (0.151)	1.2299×10^{-7} (0.162)
	Uncollided Flux	2.0085×10^{-9} (0.0)	2.0085×10^{-9} (0.0)
	Ratio of Total Collisions	1. 0	0.74

* Relative difference $\varepsilon=0.01$ is adopted.

† F. S. D. means Fluence Standard Deviation.

** The unit of the flux is arbitrary unit.

Table 3.4 Comparisons between experimental and calculated results for the gamma-ray skyshine problem.

Detector	Experiment (mR/hr/Ci)	MCACE results		
		no biasing technique	Region Penetration and Collision Times Biasing	Automatic Russian Roulette Biasing
D_0 (F. S. D.)*	——	——	——	1.83×10^{1} (0.13)
D_1 (F. S. D.)*	7.67×10^{-1}	4.20×10^{-1} (0.22)	5.62×10^{-1} (0.11)	5.02×10^{-1} (0.15)
D_2 (F. S. D.)*	1.45×10^{-1}	8.60×10^{2} (0.31)	1.55×10^{-1} (0.16)	——
D_3 (F. S. D.)*	3.71×10^{-2}	5.01×10^{-2} (0.64)	3.73×10^{-2} (0.22)	——
CPU time (min.)	——	4.0 (3000 histories)	2.9 (3000 histories)	1.8 (6000 histories)

Note a) In the Collision Times Biasing, $\varepsilon=0.01$ is adopted.

Note b) In the Automatic Russian Roulette Biasing, FVR=0.1, WAV=3.0 for Region 1 and 2, WAV=0.0 for the other regions are adopted.

* F. S. D. means Fluence Standard Deviation.

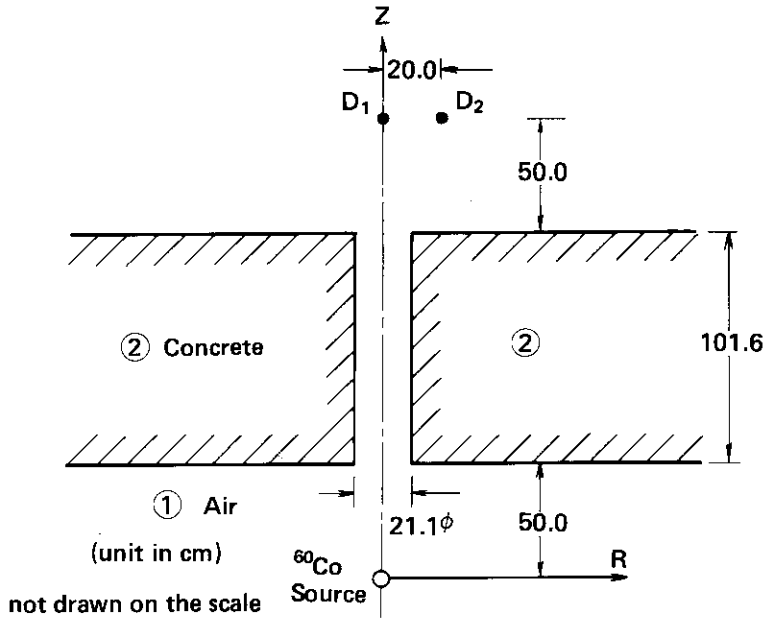


Fig. 3.15 Streaming problem for a streight cylindrical duct

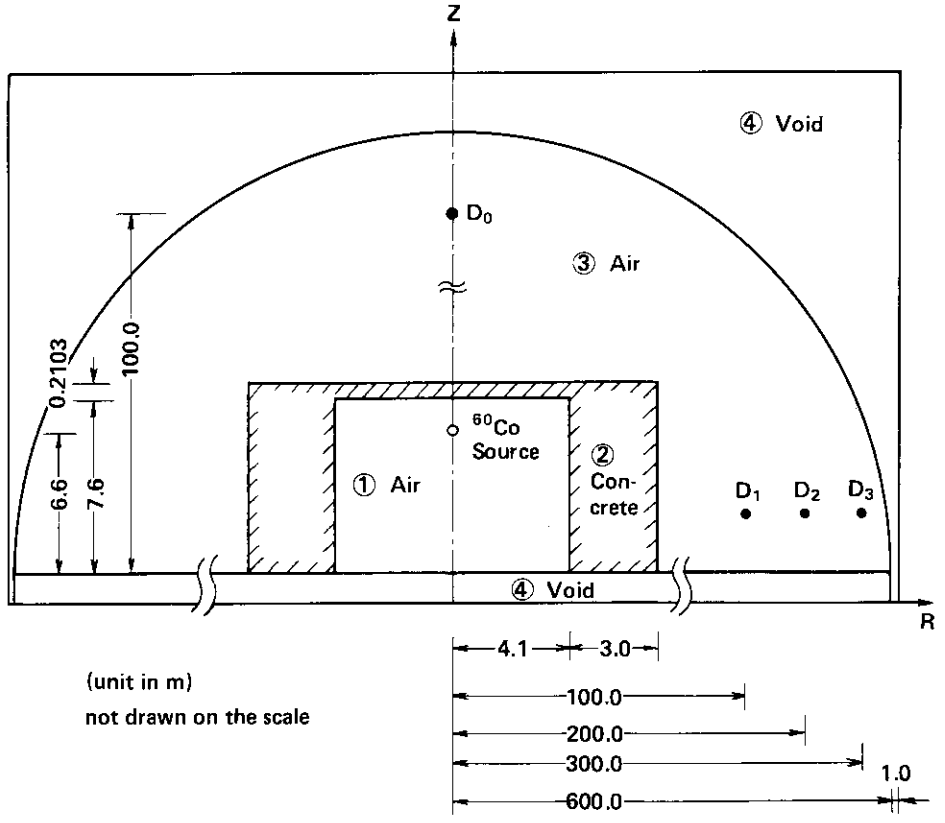


Fig. 3.16 Gamma-ray skyshine problem for concrete silo

3.3.1 Input Instruction

Input data to MCACE are similar to those of MORSE-CG. The FIDO input format is not adopted, so that data must be specified in the fixed formats given in parentheses. The condition under which the data are to be specified is given in square brackets.

Random Walk Input Instructions

The input read by subroutine INPUT is as follows:

CARD A Format (20A4)

Title card.

(Any character other than a blank or alphameric in column one will terminate the job.)

CARD B Format (14I5)

1. NSTRT : number of particles per batch.
2. NMOST : maximum number of particles allowed for in the bank(s); equal to NSTRT if no splitting, fission, and secondary generation.
3. NITS : number of batches.
4. NQUIT : number of sets of NITS batches to be run without calling the subroutine INPUT.
5. NGPQTN* : number of neutron groups to be analyzed.
6. NGPQTG* : number of gamma-ray groups to be analyzed.
7. NMGP* : number of primary particle groups for which cross sections are stored; should be the same as NGP (or the same as NGG when NGP=0) on Card XB read by the subroutine XSEC.
8. NMTG* : total number of groups for which cross sections are stored; should be the same as NGP+NGG on Card XB read by the subroutine XSEC.
9. NCOLTP : set greater than zero if a collision tape is desired; the collision tape is written by the user subroutine BANKR.
10. IADJM : set greater than zero for an adjoint problem.
11. MAXTIM : maximum clock time in minutes allowed for the problem to be on the computer (FACOM M380 c.p.u. time); e.g., 4.5 entered here allows 4 and 1/2 minutes.
12. MEDIA : number of cross-section media; should agree with NMED on Card XB read by the subroutine XSEC.
    if NSCT on Card XB in negative, number of materials to be read from DATA-POOL.
13. MEDALB : albedo scattering medium is absolute value of MEDALB.
    if MEDALB=0, no albedo information to be read in,
    MEDALB<0, albedo only problem - no cross sections are to be read,
    MEDALB>0, coupled albedo and transport problem.
14. IREST : restart option.
    if IREST=0, no effect
    IREST=1, restart calculation is done.

CARD C Format (4I5, 5E10.5)

1. ISOUR : source energy group if>0,
    if ISOUR<0 or if ISOUR=0 and NGPFS≠0, SORIN is called for input of Cards E1 and E2.

* See **Table 3.5** for sample input.

2. NGPFS : number of groups for which te source spectrum is to be defined; if ISOUR<0, NGPFS≥ 2.
3. ISBIAS : no source energy biasing if set equal to zero; otherwise the source energy is to be biased, and Cards E2 are required.
4. NOTUSD : an unused variable.
5. WTSTRT : weight assigned to each source particle.
6. EBOTN : lower energy limit of the lowest neutron group (eV) (group NMGP).
7. EBOTG : lower energy limit of the lowest gamma-ray group (eV) (group NMTG).
8. TCUT : age in sec at which particles are retired; if TCUT$=0$, no time kill is performed.
9. VELTH : velocity of the group NMGP when NGPQTN>0; i.e., thermal-neutron velocity (cm/sec).

CARD C1 Format (I5)

1. IBOOT : bootstrap option.
   if IBOOT$=0$, no effect,
   IBOOT$=1$, bootstrap calculation is performed.

CARD D Format (7E10.4) [Omit if IBOOT$=1$]

1. XSTRT
2. YSTRT
3. ZSTRT

coordinates for source particles.

4. AGSTRT: starting age for source particles.

5. UINP
6. VINP
7. WINP

source particle direction cosines; if all are zero, isotropic directions are chosen.

Source data on Cards C and D will be overridden by any changes in the subroutine SOURCE.

CARD E1 Format (7E10.4) [Omit if ISOUR on Card C>0 or if IBOOT$=1$ or if ISOUR$=$NGPFS$=0$]

NGPFS values of FS, where FS is equal to the unnormalized fraction of source particles in each group.

CARD E2 Format (7E10.4) [Omit if ISOUR>0 or if IBOOT$=1$ or if ISOUR≤ 0 and ISBIAS$=0$]

If ISBIAS>0, NGPFS values of BFS, the relative importance of a source in group I, are required.

CARD E3 Format (3I5, E10.3, I5) [Omit if IBOOT$=0$]

1. JTYPE : selection of boundary source.
   if JTYPE$=\pm 1$, plane (R, θ) source from MCACE,
   ($-/+$ = real/expected surface crossing)
   JTYPE$=\pm 2$, plane (X, Y) source from MCACE,
   ($-/+$ = real/expected surface crossing)
   JTYPE$=3$, axial boundary source from DOT/ESPRIT,
   JTYPE$=4$, radial boundary source from DOT/ESPRIT.
2. IDIST : spatial distribution function of total flux for JTYPE$=\pm 1$ or 2.
   if IDIST$=0$, read from tape,
   IDIST$=1$, assume constant,
   IDIST$=2$, assume cosine disribution,

IDIST=3, assume (cosine)^2 distribution.

3. JDIST : angular distribution function for JTYPE=±1 or 2.
   if JDIST=0, read from tape,
   JDIST=1, assume constant,
   JDIST=2, assume cosine distribution,
   JDIST=3, assume (cosine)^2 distribution.
4. FNORM : normalization factor (n/sec); if zero is set, the value is normalized to the total leakage current.
5. NSURF : plane identification number (stored in the bootstrap tape) to be connected. (JTYPE=±1, 2)

CARD E4 Format (6E10.3) [IBOOT=1 and JTYPE=±1, 2]

1. X00
2. Y00
3. Z00

center coordinates of a bootstrap surface,

4. U00
5. V00
6. Z00

direction cosines of a normal vector to the bootstrap surface.

CARD E5 Format (3E10.3) [IBOOT=1 and JTYPE=±1, 2]

1. U11
2. V11
3. Z11

direction cosines of the R or X axis at the bootstrap surface to X, Y and Z-axes.

CARD E6 Format (3E10.3) [IBOOT=1 and JTYPE=4]

1. R00 radius of the surface+,
2. THMIN
3. THMAX

range of angle. ($-\pi \leq \theta \leq \pi$)

$\theta=0$ means on the line of X axis.

CARD F Format (7E10.4)

NMTG values of ENER, the energies (in eV) at the upper edge of the energy group boundaries.
NOTE: The lower energies of groups NMGP and NMTG were read on Card C.

CARD G Format (2I5, 5X, 36I1, 5X, 13I1) [Omit if NCOLTP on Card B≤0]

NHISTR : logical tape number for the first collision tape.
NHISMX : the highest logical unit number that a collision tape is assigned.
NBIND(J) : J=1, 36 – an index to indicate the collision parameters to be written on tape.
NCOLLS(J) : J=1, 13 – an index to indicate the types of collisions to be put on tape.
(See **Tables 3.6(a)** and **3.6(b)** for information concerning NBIND and NCOLLS.)

CARD H Format (Z12), on FACOM M380

RANDOM : starting random number.

CARD I Format (9I5)

+ This value means the radius of surface in DOT/ESPRIT calculation.

1. NSPLT : index indicating that splitting is allowed if >0.
2. NKILL : index indicating that Russian roulette is allowed if >0.
3. NPAST : index indicating that exponential transform is invoked if >0 (subroutine DIREC required).
4. NOLEAK : index indicating that non-leakage is invoked if >0.
5. IEBIAS : index indicating that energy biasing is allowed if >0.
6. MXREG : number of regions described by geometry input (will be set to one if ≤ 0).
7. MAXGP : group number of the last group to which Russian roulette or splitting or exponential transform is to be applied. For adjoint, set=NMTG or overstoring results.
8. IREGX : number of regions used for the region penetration biasing. (IREGX ≤ 100)
9. NITSO : number of batches to calculate mean fluence $\bar{f}_g$ for automatic Russian roulette biasing technique.

CARD IA Format (12I5) [IREGX >0]

1. INREG : region numbers used for the region penetration biasing. (IREGX entries)

CARD J Format (6I5, 4E10.5) [Omit if NSPLT+NKILL+NPAST=0]

1. NGP1
2. NDG
3. NGP2
4. NRG1
5. NDRG
6. NRG2

from energy group NGP1 to energy group NGP2 inclusive in steps of NDG and from region NRG1 to NRG2 inclusive in steps of NDRG; if NGP=0, groups 1 to MAXGP will be used; if NRG1=0, regions 1 to MXREG will be used (both in steps of one). Usually NDG=1 and NDRG=1.

7. WTHIH1 : weight above which splitting will occur.
8. WTLOW1 : weight below which Russian roulette is played.
9. WTAVE1 : weight given to those particles surviving Russian roulette.
10. PATH : path-length stretching parameters for use in the exponential transform (usually $0 \leq$ PATH < 1).

CARD JA Format (30X, 2E10.5) [Omit if NITSO=0]

1. FVR : fluence below which Russian roulette is played for automatic biasing technique. (F_{LOR}=FVR$\times \bar{f}_g$)
2. WAV : weight given to particles surviving Russian roulette for automatic biasing technique. If the value is set to zero, Russian roulette kill or survival is not played.

The above information is repeated until data for all groups and regions are inputted.

End Cards J with negative value of NGP1 (e.g., -1 in columns 4 and 5).

CARD K Format (7E10.4) [Omit if IEBIAS on Card I ≤ 0]

((EPROB(IG, NREG), IG=1, NMTG), NREG=1, MXREG)

Values of the relative energy importance of particles leaving a collision in the region NREG.

NOTE: Input for each region must start on a new card.

CARD L Format (4I5)

1. NSOUR : set ≤ 0 for a fixed source problem; otherwise the source is from fissions generated in a previous batch.
2. MFISTP : index for fission problem; if ≤ 0, no fissions are allowed.

3. NKCALC : the number of the first batch to be included in the estimate of k; if ≤ 0, no estimate of k is made.
4. NORMF : the weight standards and fission weights are unchanged if ≤ 0; otherwise fission weights will be multiplied, at the end of each batch, by the latest estimate of k and the weight standards are multiplied by the ratio of the fission weight produced in the previous batch to the average starting weight for the previous batch. For time-dependent decaying systems, NORMF should be >0.

CARD M Format (7E10.4) [Omit if MFISTP on Card L ≤ 0]
(FWLO(I), I=1, MXREG)
Values of the weight to be assigned to fission neutrons.

CARD N Format (7E10.4) [Omit if MFISTP on Card L ≤ 0]
(FSE(IG, IMED), IG=1, NMTG), IMED=1, MEDIA)
The fraction of fission-induced source particles in the group IG and the medium IMED.
NOTE: Input for each medium must start on a new card.

CARD O Format (7E10.5) [Omit if NGPQTN=0 or NGPQTG=0, i.e., include if coupled neutron-gamma-ray problem]
((GWLO(IG, NREG), IG=1, NMGP or NMTG - NMGP), NREG=1, MXREG)
Values of the probability of generating a gamma-ray. NMGP groups are read for each region in a forward problem and NMTG-NMGP for an adjoint.
NOTE: Input for each region must start on a new card.

Combinatorial Geometry Input Instuctions

The combinatorial geometry (CG) describes general three dimensional material configurations by considering unions, differences intersections of simple bodies such as spheres, boxes, cylinders, etc. In effect, the geometric description subdivides the problem space into unique zones. Each zone is the result of combining one or more of the following geometric bodies:

1. Rectangular Parallelepiped (RPP),
2. Box (An RPP randomly oriented in space) (BOX),
3. Sphere (SPH),
4. Right Circular Cylinder (RCC),
5. Right Elliptical Cylinder (REC),
6. Truncated Right Angle Cone (TRC),
7. Ellipsoid (ELL),
8. Right Angle Wedge (WED),
9. Arbitrary Convex Polyhedron of 4, 5, or 6 sides (ARB).

The body types 2~9 are arbitrarily oriented with respect to the x, y, and z-axes used to determine the space. The basic technique for the description of the geometry consists of defining the location and shape of the various zones in terms of the intersections and unions of the geometric bodies. A special operator notation involving the symbols (+), (−), and (OR) is used to describe the intersections and unions. These symbols are used by the program to construct information relating material descriptions to the body definitions. The details for the CG input are the same as those in the MORSE-CG, and are quoted in Appendix C.

CARD CGA Format (2I5, 10X, 10A6)
1. IVOPT : option which defines the method by which region volumes are determined;

if IVOPT=0, volumes set equal to 1,
IVOPT=1, concentric sphere volumes are calculated,
IVOPT=2, slab volumes (1-dim.) are calculated,*
IVOPT=3, volumes are inputted by card.

2. IDBG : if IDBG>0, the subroutine PR is called to print results of combinatorial geometry calculations during execution. Use only for debugging.
3. JTY : alphanumeric title for geometry input (columns 21-80).

CARD CGB Format (2X, A3, 1X, I4, 6D10.3)

One set of CGB cards is required for each body and for the NED card (see **Table 3.6(d)**). Leave columns 1-6 blank on all continuation cards.

1. ITYPE : specifies body type or END to terminate reading of body data (for example BOX, RPP, ARB, etc.). Leave blank for continuation cards.
2. IALP : body number assigned by the user (all input body numbers must form a sequence set beginning at 1). If left blank, numbers are assigned sequentially. Assign either all or none of the numbers. Leave blank for continuation cards.
3. FPD(I) : real data required for the given body as shown in **Table 3.6(d)**. This data must be in cm.

CARD CGC Format (2X, A3, I5, 9(A2, I5))

Input zone specification cards. One set of cards required for each input zone, with input zone numbers being assigned sequentially.

1. IALP : IALP must be a nonblank for the first card of each set of cards defining an input zone. If IALP is blank, this card is treated as a continuation of the previous zone card.
   IALP - END denotes the end of zone description.
2. NAZ : total number of zones that can be entered upon leaving any of the bodies defined for this input region (some zones may be counted more than once). Leave blank for continuation cards for a given zone. (If NAZ≤0 on the first card of the zone card set, then it is set to 5). This is used to allocate blank common. Alternate IIBIAS(I) and JTY(I) for all bodies defining this input zone.
3. IIBIAS(I) : specify the "OR" operator if required for the JTY(I) body.
4. JTY(I) : body number with the (+) or (-) sign as required for the zone description.

CARD CGD Format (14I5)

MRIZ(I) : MRIZ(I) is the region number in which the "I-th" input zone is contained (I=1, to the number of input zones). Region numbers must be sequentially defined from 1.

CARD CGE Format (14I5)

MMIZ(I) : MMIZ(I) is the medium number in which the "I-th" input zone is contained (I=1, to the number of input zones). Medium numbers must be sequentially defined from 1.

CARD CGF Format (7D10.5) [Omit if IVOPT≠3]

* Not operational.

VNOR(I) : volume of the "I-th" region (I=1 to MXREG, the number of regions).

MORSEC – Cross-Section Module Input Instructions

CARD XA Format (20A4)

Title card for cross sections. This title is also written on tape if a processed tape is written; therefore, it is suggested that the title be definitive.

CARD XB Format (13I5)

1. NGP* : number of primary groups for which there are cross sections to be stored; should be the same as NMGP input in MCACE.
2. NDS : number of primary downscatters for NGP (usually NGP).
3. NGG* : number of secondary groups for which there are cross sections to be stored.
4. NDSG : number of secondary downscatters for NGG (usually NGG).
5. INGP* : total number of groups for which cross sections are to be inputted.
6. ITBL : table length, i.e., the number of cross sections for each group (usually equal to number of downscatters + number of upscatters + 3).
7. ISGG : location of within-group scattering cross sections (usually equal to number of upscatters + 4).
8. NMED : number of media for which cross sections are to be stored; should be the same as MEDIA input in MCACE. If NSCT<0, number of materials to be read from DATA-POOL.
9. NELEM : number of elements for which cross sections are to be read.
10. NMIX : number of mixing operations (elements times density operations) to be performed (must be≥1).
    If NSCT<0, not used.
11. NCOEF : number of coefficients for each element, including P_0.
    If NSCT<0, not used.
12. NSCT : number of discrete angle (usually NCOEF/$2_{integral}$).
    If NSCT<0, | NSCT means number of discrete angles stored in DATA-POOL.
13. ISTAT : flag to store Legendre coefficients if greater than zero. If NSCT<0, not used.

CARD XC Format (11I5)

IRDSC† : switch to print the cross sections as they are read if>0.
ISTR† : switch to print cross sections as they are stored if>0.
IFMU† : switch to print intermediate results of μ's calculation if>0.
IMOM† : switch to print moments of angular distribution if>0.
IRRIN† : switch to print angles and probabilities if>0.
IPUN† : switch to print results of bad Legendre coefficients if>0.
IDTF† : switch to signal that input format is of DTF-IV if>0; otherwise, the ANISN format is assumed.
IXTAPE : logical tape unit for a binary cross section tape; set equal to 0 if cross sections are from cards. If negative, then the processed cross sections and other necessary data from a previous run will be read; in this case (IXTAPE<0) no cross sections from

* See **Table 3.5** for sample input.

† Switches are ignored if IXTAPE<0.

cards and no mixing cards are inputted. The absolute value of IXTAPE is the logical tape unit.
If NSCT$<$0, set equal to 0.

JXTAPE : logical tape unit of a processed cross-section tape to be written. This processed tape will contain the title card, the variables from COMMON LOCSIG and the pertinent cross sections from blank COMMON.

14. IO6RT : logical tape unit of a point cross-section tape in the O6R[52] format. (not operable)
15. IGQPT : last group (MORSE multigroup structure) for which the O6R point cross sections are to be used ($\leq$NMGP).

CARD XCA DATA-POOL assignment card [Omit if NSCT$\geq$0]
&DPUNIT NLIB=nl &END
where nl is the logical unit number for DATA-POOL that stores cross section data.

CARD XD Format (14I5) [NSCT$\geq$0] or Format (12(1X, A4)) [NSCT$<$0]
[Omit if IXTAPE$\leq$0 and NSCT$\geq$0]
Element identifiers for the cross-section tape. If element identifiers are in the same order as elements on tape, the efficiency of the code is increased due to fewer tape rewinds. If NSCT$<$0, node names of the materials to be read from DATA-POOL are assigned as follows:

EGRP FX32 IRON H2O AIR ……

CARD XE [Omit if IXTAPE$\neq$0]
If cross sections are in free-form, a card with ** in columns 2 and 3 must precede the actual data. ANISN format if IDTF$\leq$0; otherwise, DTF-IV format. Cross sections for INGP groups with a table length ITBL for NELEM elements each with NCOEF coefficients.

CARD XF Format (2I5, E10.5) [Omit if IXTAPE$<$0, or if NSCT$<$0]
NHIX (see Card XB) cards are required.

KM : medium number.
KE : element number occurring in the medium KM (negative value indicates last mixing operation for that medium). Failure to have a negative value causes the code not to generate angular probabilities for that media (LEGEND and ANGLE are not called).
RHO : density of the element KE in medium KM.

CARD XG Format (I5) [Omit if IO6RT$\leq$0]
NXPM : number of point cross-section sets per medium found on an O6R[52] tape;
if NXPM=1, total cross section only,
NXPM=2, total + scattering cross section,
NXPM=3, total scattering, and ν*fission cross section.

SAMBO Analysis Input Instructions

The following data are read from cards by SCORIN:

CARD AA Format (20A4)
Title information is immediately outputted.

CARD BB Format (9I5, E12.4)

ND : number of detectors (set=1 if ≤0).

NS : number of surface detectors.

NNE : number of primary particle (neutron) energy bins to be used (must be≤NE).

NE : total number of energy bins (set=0 if ≤1).

NT : number of time bins for each detector (may be negative, in which case | NT | values are to be read and used for every detector) (set=0 if | NT ≤1).

NA : number of angle bins (set=0 if ≤1).

NRESP : number of energy-dependent response functions to be used. If NRESP>0, the response functions are read by cards EE and EF. If NRESP<0, these are read from DATA-POOL.

NEX : number of extra arrays of size NMTG to be set aside (useful, for example, as a place to store an array of group-to-group transfer probabilities for estimator routines).

NEXND : number of extra arrays of size ND to be set aside (useful, for example, as a place to store detector-dependent counters)

EPS : relative difference for collision times biasing technique.

CARD SS Format (3E10.4) (ND cards will be read)

X, Y, Z : detector location. (If other than point detectors are desired, the point locations must still be inputted and can be combined with additional data built into the user routines to define fully each detector.)

Note that the distance between the points (X, Y, Z) and (XSTRT, YSTRT, ZSTRT) and the initial age, AGSTRT, will be used to define the lower limit of the first time bin.

CARD DD Format (20A4)

Title or units for total responses for all detectors; will be used in columns 54 through 133 of the title for the print of these arrays.

CARD EE Format (20A4) [NRESP>0]

Title or units for each total response for all detectors.

CARD FF Format (7E10.4) [NRESP>0]

Response function values. NMTG values will be read in each set of FF cards. Input order is from energy group 1 to NMTG (order of decreasing energy).

NOTE: Cards EE and FF are read in the following order: EE, FF1, ··· FFN, EE, FF1, ··· FFN, etc. NRESP sets of EE, FF cards will be read.

CARD EEA DATA-POOL assignment card [NRESP<0]

&DPUNIT RESD=n &END

This card defines the logical unit number for DATA-POOL which stores the response data.

CARD FFA Format (12(1X, A4)) [NRESP<0]

Node names of the response functions. The first entry is the first node name which defines the energy group structure. The second entry is the second node name 'RESD'. Remainders are the third node names of each response function. (| NRESP | entries)

CARD GG Format (20A4) [Omit if NE≤1]

Units for energy-dependent fluence for all detectors.

CARD HH Format (14I5) [Omit if NE≤1]

Energy group numbers defining lower limit of energy bins (in order of increasing group number). The NNE (if>0) energy must equal NGPQTN; the NE entry must be set to NMGP + NGPQTG for a combined problem, or else NGPQTG or NGPQTN.

CARD II Format (20A4) [Omit if | NT | ≤1]

Units for time-dependent total responses for all detectors.

CARD JJ Format (20A4) [Omit if | NT | ≤1 or NE≤1]

Units for time and energy-dependent fluence for all detectors.

CARD KK Format (7E10.4) [Omit if | NT | ≤1]

NT values of upper limits of time bins for each detector (in order of increasing time and detector number). The values for each detector must start on a new card. NT | values only are read if NT is negative. They are then used for every detector.

CARD LL Format (20A4) [Omit if NA≤1]

Units for angle- and energy-dependent fluence for all detectors.

CARD MM Format (7E10.4) [Omit if NA≤1]

NA values of upper limits of angle bins (actually cosine bins; the NA-th value must equal one). Following the input for the SAMBO analysis module, input cards for user-written routines INSCOR, SOURCE, and ENDRUN.

The following data from the card NN to the card VV are used for surface crossing estimator. If NS>0 on the card BB, the records from the card NN to the card SS are repeated by NS times and the records from the card TT to the card VV are used only if the scoring of angular flux is performed. If NS=0, the records are omitted.

CARD NN Format (A3, 2X, 11I5)

1. ITYPE : selection of surface.
   SPH=sphere,
   RCC=cylinder,
   RRT=plane(R, θ),
   PXY=plane (X, Y).
2. IREAL : real crossing estimator.
   0=no,
   1=yes.
3. IEXP : expected crossing estimator.
   0=no,
   1=yes.
4. IFLUX : scoring of flux.
   0=no,
   1=yes.

5. ILEAK : scoring of leakage current.
   0=no,
   1=yes.
6. IANG : scoring of angular flux.
   0=no,
   1=yes.
7. IOUT : output data for bootstrap calculation.
   0=no,
   1=yes. (data are written on the logical unit FT42F001)
8. MESH1 : number of meshes for the first axis.
   if ITYPE=SPH, the first axis is θ,
   ITYPE=RCC, the first axis is Z,
   ITYPE=PRT, the first axis is R,
   ITYPE=PXY, the fixst axis is X.
9. MESH2 : number of meshes for the second axis.
   if ITYPE=PRT, the second axis is θ,
   ITYPE=PXY, the second axis is Y.
   MESH2 means the total section number.
10. IETA : number of meshes for the polar angle η. (IANG=1)
11. IPHI : number of meshes for the azimuthal angle ϕ. IPHI means the total number for angular meshes (IANG=1).
12. IPRT : print option.
   if IPRT=0, print all informations,
   IPRT=1, meshwise values are not printed,
   IPRT=2, angular fluxes are not printed.

CARD OO Format (6E10.3)

1. X0
2. Y0
3. Z0

   center positions of the surface,

4. U0
5. V0
6. W0

   direction cosines of the normal vector on the surface.

If ITYPE=SPH, X0=Y0=Z0=U0=V0=W0=0.0. If ITYPE=RCC, X0, Y0, Z0 are defined as the center points of bottom surface, U0, V0, W0 are defined as the directions of center axis and either U0, V0 or W0 should be parallel to the one of X, Y or Z-axis.

CARD PP Format (4E10.3)

1. U1
2. V1
3. W1

   direction cosines of R(PRT) or X(PXY)-axis of the surface,

4. RADIUS radius of the sphere or cylinder.

If ITYPE=SPH, the direction of the R-axis should be set to 1.0; ITYPE=RCC, U1, V1, W1 should be set to 0.0.

CARD QQ Format (7E10.3) [MESH1+1 entries]

Mesh boundaries of the first axis (θ for SPH, Z for RCC, R for PRT and X for PXY). Unit is radian for θ and the others are cm.

CARD RR Format (12I5) [MESHI entries and omit if ITYPE=SPH or RCC]

Number of meshes for the second axis (θ for PRT and Y for PXY) in a mesh of the first axis.

CARD SS Format (7E10.3) [MESH1 + MESH2 entries and omit if ITYPE=SPH or RCC]

Mesh boundaries of the second axis. Unit is radian for θ and cm for Y.

CARD TT Format (7E10.3) [IETA + 1 entries and omit if IANG=0]

Mesh boundaries of the polar angle. The values are given by the descending order. ($1.0 \geq \eta \geq 0.0$)

CARD UU Format (12I5) [IETA entries and omit if IANG=0]

Number of meshes for the azimuthal mesh in a polar mesh.

CARD VV Format (7E10.3) [IETA+IPHI entries and omit if IANG=0]

Mersh boundaries of the azimuthal angle. The values are given by the descending order. ($2\pi \geq \phi \geq 0$)

SOURCE - Source Condition Input Instructions

[Omit if the bootstrap option is used.]

CARD S1 Format (10X, 3I5, 2E10.3, I5)

1. NSORCE : source condition and spatial distribution.
   if NSORCE=1, point source,
   NSORCE=2, rectangular source and uniform distribution,
   NSORCE=3, rectangular source and cosine distribution,
   NSORCE=4, cylindrical source and uniform distribution,
   NSORCE=5, cylindrical source and cosine distribution,
   NSORCE=6, spherical source and uniform distribution,
   NSORCE=7, circular plane source and uniform distribution,
   NSORCE=8, annular plane source and uniform distribution.
2. NEMIS : source angular distribution.
   if NEMIS=1, uni-directional distribution,
   NEMIS=2, isotropic distribution,
   NEMIS=3, cosine distribution,
   NEMIS=4, arbitrary distribution defined by the user,
   NEMIS=5, biased isotropic distribution.
3. NSPEC : source energy distribution.
   if NSPEC=0, arbitary spectrum defined by the SORIN subroutine,
   NSPEC=1, fission spectrum,
   NSPEC=2, arbitrary spectrum defined by the user,
   NSPEC=3, mono-energy distribution.
4. ETOP : the highest source energy (eV).
5. EBOT : the lowest source energy (eV).
6. JDIREC : rotation of the direction cosines for angular distribution.
   if JDIREC=1, no effect,
   JDIREC=2, rotate X to Y, Y to Z, Z to X,
   JDIREC=3, rotate Z to Y, Y to X, X to Z.

CARD S2 Format (10X, 3F10.3)

1. X0
2. Y0
3. Z0

center coordinates of the source.

CARD S3 Format (10X, 6F10.3)

1. XL
2. XR
3. YL
4. YR
5. ZL
6. ZR

left and right coordinates that X, Y and Z-axis cross the source region. Needless data are set to zero. (see **Fig. 3.25**)

CARD S4 Format (10X, 3F10.3) [NEMIS=1]

1. UINP
2. VINP
3. WINP

direction cosines of uni-directional source, $UINP^2+VINP^2+WINP^2=1$.

CARD S5 Format (10X, 2F10.3) [NEMIS=5]

1. U0 : direction cosines with X axis where source is biased.
2. V0 : importance of particles.

When the biasing axis is not X-axis, use JDIREC option on the card S1.

CARD S6 Format (I5) [NSPEC=2, 3]

1. IMAX1 : number of energy points.

CARD S7 Format (2E10.3) [NSPEC=2, 3]

1. E(I) : upper energy of the energy group (eV),
2. FE(I) : source energy spectrum (n/cm^2/sec/eV).

Card S7 is repeated by IMAX1 times.

CARD S8 Format (2I5) [NEMIS=4]

1. IMAX : number of energy points,
2. JMAX : number of angular points.

CARD S9 Format (8E10.3) [NEMIS=4] (IMAX entries)

1. E(I) : upper energy of the energy group (eV).

CARD S10 Format (8F10.4) [NEMIS=4] (JMAX entries)

1. DEG(I) : cosines of angular meshes.

CARD S11 Format (8E10.3) [NEMIS=4]

1. ANGDIS(I) : energy and angular distributions of source (n/cm^2/sec).

The data are given by angle and then group.

[(IMAX−1) × (JMAX−1)] entries are required.

Table 3.5 Sample group input numbers for some representative problems*

Case A: Neutron Cross Sections (22 groups)
Case B: Gamma-Ray Cross Sections (18 groups)
Case C: Neutron-Gamma-Ray-Coupled Cross Sections (22-18 groups)

Input Variable	Problem Type: Case A Top 14 groups	Case B Top 17 groups	Case C Neutrons Only Top 14 groups	Case C Gamma-Rays Only Top 17 groups	Case C Neutron-Gamma Top 14 Neutron, Top 17 Gamma Groups	
MCACE Input:						
NGPQTN	14	0	14	17	14	
NGPQTG	0	17	0	0	17	CARD B,
NMGP	22	18	22	17	22	Variables
NMTG	22	18	22	17	40	
NGP	22	18	22	0	22†	
NGG	0	0	0	17	18	CARD XB
INGP	22	18	40	40	40	Variables

* For cross sections with full downscatter, NDS=NGP, NDSG=NGG, INDS=INGP, and ITBL=number of downscatters + number of upscatters + 3. Usually, ISGG=number of upscatters + 4; i. e., NUS + 4.

† Must be equal to the total number of neutron groups in the data-otherwise it picks up gammas from wrong location.

Table 3.6 Input required on CGB cards for each body type

Card Columns / Body Type	ITYPE 3–5	IALP 7–10	Real Data Defining Particular Body 11–20	21–30	31–40	41–50	51–60	61–70	Number of Cards Needed
Box	BOX	IALP is assigned by the user or by the code if left blank.	Vx	Vy	Vz	H1x	H1y	H1z	
			H2x	H2y	H2z	H3x	H3y	H3z	
Right Parallelepiped	RPP		Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	1
Sphere	SPH		Vx	Vy	Vz	R	--	--	1
Right Circular Cylinder	RCC		Vx	Vy	Vz	Hx	Hy	Hz	1 of 2
			R	--			—	—	2 of 2
Right Elliptic Cylinder	REC		Vx	Vy	Vz	Hx	Hy	Hz	1 of 2
			R1x	R1y	R1z	R2x	R2y	R2z	2 of 2
Ellipsoid	ELL		V1x	V1y	V1z	V2x	V2y	V2z	1 of 2
			L	—	—	—	—	—	2 of 2
Truncated Right Cone	TRC		Vx	Vy	Vz	Hx	Hy	Hz	1 of 2
			L1	L2	—	—	—	—	2 of 2
Right Angle Wedge	WED or RAW		Vx	Vy	Vz	H1x	H1y	H1z	1 of 2
			H2x	H2y	H2z	H3x	H3y	H3z	2 of 2
Arbitrary Polyhedron	ARB		V1x	V1y	V1z	V2x	V2y	V2z	1 of 5
			V3x	V3y	V3z	V4x	V4y	V4z	2 of 5
			V5x	V5y	V5z	V6x	V6y	V6z	3 of 5
			V7x	V7y	V7z	V8x	V8y	V8z	4 of 5
			Face Descriptions (see note below)						5 of 5
Termination of Body Input Data	END								

NOTE: Card 5 of the arbitrary polyhedron input contains a four-digit number for each of the six faces of an ARB body. The format is 6D10.3, beginning in column 11. See the ARB write-up in Section 4.7 of Reference 27 for an example.

Table 3.6(a) Variables to be written on tape (NBIND)

J	Variable*	J	Variable*
1	NCOLL	19	WTBC
2	NAME	20	ETAUSD
3	IG	21	ETA
4	U	22	AGE
5	V	23	OLDAGE
6	W	24	NREG
7	X	25	NMED
8	Y	26	NAMEX
9	Z	27	WATEF
10	WATE	28	BLZNT
11	IGO	29	BLZON
12	UOLD	30	VEL (IG)
13	VOLD	31	VEL (IGO)
14	WOLD	32	TSIG
15	XOLD	33	PNAB
16	YOLD	34	NXTRA
17	ZOLD	35	EXTRA1
18	OLDWT	36	EXTRA2

* These variables are defined in Table 3.6(C).

Table 3.6(b) BANKR arguments (NCOLLS)

BANKR argument	Called from	Location of call in Walk
−1	MORSE	After call to INPUT–to set parameters for new problem
−2	MORSE	At the beginning of each batch of NSTRT particles
−3	MORSE	At the end of each batch of NSTRT particles
−4	MORSE	At the end of each set of NITS batches–a new problem is about to begin
1	MSOUR	After a source event
2	TESTW	After a splitting has occurred–commented in column 1
3	FPROB	After a fission has occurred
4	GSTORE	After a secondary particle has been generated
5	MORSE	After a real collision has occurred–post–collision parameters are available
6	MORSE	After an albedo collision has occurred–post–collision parameters are available
7	NXTCOL	After a boundary crossing occurs (the track has encountered a new geometry medium other than the albedo or void media)
8	NXTCOL	After an escape occurs (the gemetry has encountered medium zero)
9	MORSE	After the post–collision energy group exceeds the maximum desired–commented in column 1
10	MORSE	After the maximum chronological age has been exceeded–commented in column 1
11	TESTW	After a Russian roulette kill occurs–commented in column 1
12	TESTW	After a Russian roulette survival occurs–commented in column 1
13	GSTORE	After a secondary particle has been generated but no room in the bank is available–commented in column 1

Table 3.6(c) Definition of variables described in Table 3.6(a)

Variable name	Definition
NCOLL	A type of event: (1) sources generated (2) splittings occurring (3) fissions occurring (4) gamma-rays generated (5) real collisions (6) albedo scatterings (7) boundary crossings (8) escapes (9) energy cutoffs (10) time cutoffs (11) Russian roulette kills (12) Russian roulette survivals (13) gamma-rays not generated because bank was full
NAME	Particle's first name
IG	Current energy group index
U, V, W	Current direction cosines
X, W, Z	Current locations
WATE	Current weight
IGO	Previous energy group index
UOLD, VOLD, WOLD	Previous direction cosines
XOLD, YOLD, ZOLD	Previous locations
OLDWT	Previous weight
WTBC	Weight just before current collision
ETAUSD	Flight path in m. f. p. (mean free path), which has been used since the last event
ETA	Mean free path between collisions
AGE	Current age
OLDAGE	Previous age
NREG	Region number at the current location
NMED	Medium number at the current location
NAMEX	Particle's family name (Note: particles do not marry)
WATEF	Weight of fission neutron to be banked
BLZNT	Current block and zone number (packed)
BLZON	Previous block and zone number (packed)
VEL	Velocity corresponding to the mean energy for neutron groups and the speed of light for gamma-ray groups (in cm/sec)
TSIG	Macroscopic total cross section provided by the NSIGTA subroutine
PNAB	Non-absorption probability
NXTRA	Not used
EXTRA1	Not used
EXTRA2	Not used

3.3.2 Input/Output File Assignment

MCACE requires various direct-access devices during execution. **Table 3.7** shows the name of the data sets. The logical unit number marked with a circle in the table is required to execute the job. The logical unit number which is marked with a condition in parentheses is required when the condition is satisfied. The value for the memory space estimation changes with the various conditions of computation, so that it is roughly estimated.

Table 3.7 Requirements for external data sets in MCACE

Logical Unit	Condition	Contents	1st. Space Estimation (Tracks)	DCB Information		
				LRECL	BLKSIZE	RECFM
NLIB*	(NSCT<0)	Cross Section library	—	3600	3600	F
RESD*	(NRESP<0)	Response data input	—			
IXTAPE†	(NSCT>0)	Cross Section library (with Legendre expansion)	—	19064	19068	VBS
FT16F001	○	Scratch	100			
FT40F001	(IBOOT=1)	Bootstrap data input	—			
FT41F001	○	Restart data output	100			
FT42F001	(IOUT=1)	Bootstrap data output	50			
FT51F001	(IREST=1)	Restart data input	—			
NHISTR†† ~ NHISMX††	(NCOLTP>0)	Collision data output	50			

* Logical unit numbers are defined by the unit assignment card.

† Logical unit number is defined by IXTAPE in the card XC.

†† Logical unit numbers are defined in the card G.

3.3.3 Job Control Language

Figure 3.17 shows a typical job control language and data for executing MCACE.

```
//JCLG  JOB                                                              00000020
// EXEC JCLG                                                             00000030
//SYSIN DD DATA,DLM='++'                                                 00000040
// JUSER 82469686,KA.MINAMI,0341.200                                     00000050
 1.5 C.4 W.1 1.1 P.0 SRP                                                00000060
 OPTP PASSWORD=K                                                        00000070
//*EXEC FORT77,SO='J3679.MCACE',A='ELM(*)'                              00000080
//*EXEC LKED77,PRVLIB='J3679.DPODL2'                                    00000090
//*EXEC GO                                                              00000100
// EXEC LMGO,LM='J3679.MCACEX'                                          00000101
// EXPAND DISK,DDN=FT16F001,SPC='100,20'                                00000110
// EXPAND DISK,DDN=FT41F001,SPC='100,20'                                00000120
// EXPAND DISKIO,DDN=FT92F001,DSN='J3679.POOL77',Q='.DATA.M'            00000150
//SYSIN DD *                                                            00000160
  GAMMA-RAY SKY-SHONE                                                   00000170
  200  240   60    1    9    0    9    9    0    0   10    2    0    0  00000180
    0    1    0    0 1.0       0.02   +6 0.0       0.0       2.2   +5  00000190
    0                                                                   00000200
  0.0                                                                   00000210
  1.0                                                                   00000220
  1.33  +6  1.0   +6  0.8   +6  0.6   +6  0.4   +6  0.3   +6  0.2   +6  00000230
  0.1   +6  0.05  +6                                                    00000240
0123456789                                                              00000250
    0    1    0    0    0    4    9    0                               00000260
    1    1    9    1    1    4 100.0      1.0    -3 1.0    -2  0.0      00000270
   -1                                                                   00000280
    0                                                                   00000290
    0    0   SKY-SHINE PROBLEM                                         00000300
  RCC    1  0.0       0.0       0.0       0.0       0.0       7.6   +2  00000310
            4.1   +2                                                    00000320
  RCC    2  0.0       0.0       0.0       0.0       0.0       7.8103+2  00000330
            7.1   +2                                                    00000340
  RPP    3 -6.0   +4 6.0    +4 -6.0   +4 6.0    +4 0.0       6.0   +4  00000350
  RPP    4 -6.01  +4 6.01   +4 -6.01  +4 6.01   +4 -10.0     6.01  +4  00000360
  END                                                                   00000370
  AIR          +1                                                       00000380
  WAL          +2      -1                                               00000390
  AIR          +3      -2                                               00000400
  VID          +4      -3                                               00000410
  END                                                                   00000420
    1    2    3    4                                                   00000430
    1    2    1    0                                                   00000440
  CROSS SECTION FROM DATA POOL                                          00000450
    0    0    9    9    9   12    4    2    2    0    0  -16    0       00000460
    0    0    0    0    0    0   -1    0                               00000470
 &DPUNIT  NLIB=92  &END                                                 00000480
 GO9  FX16 AIR  CONC                                                    00000490
  SANBO INPUT TOTAL FLUX AND DODE RATE                                  00000500
    3    1    9    9    0    0   -1    1    1                          00000510
  1.0   +4  0.0      1.5    +2                                          00000520
  2.0   +4  0.0      1.5    +2                                          00000530
  3.0   +4  0.0      1.5    +2                                          00000540
  RESPONSE FUNCTION (MR/HR)                                             00000550
 &DPUNIT  RESD=92  &END                                                 00000560
 GO9  RESD DOSE                                                        00000570
  PHOTON/SEC/CM**2/EV                                                   00000580
    1    2    3    4    5    6    7    8    9                          00000590
PRT     1    1    1    0    0    0    9    9    0    0    0             00000591
 0.0       0.0       1.5    +2 0.0       0.0       1.0                 00000592
 1.0       0.0       0.0                                               00000593
 70.0   +2 90.0   +2 110.0  +2 140.0  +2 180.0  +2 220.0  +2 250.0  +2  00000594
 280.0  +2 320.0  +2 380.0  +2                                         00000595
    1    1    1    1    1    1    1    1                              00000596
 0.0       6.283     0.0       6.283     0.0       6.283     0.0       00000597
 6.283     0.0       6.283     0.0       6.283     0.0       6.283     00000598
 0.0       6.283     0.0       6.283                                   00000599
 SOURCE       1    5    3  1.33  +6 0.02   +6    3                     00000600
           0.0       0.0       660.0                                 00000610
           0.0       0.0       0.0                                   00000620
           0.273     0.0                                             00000630
   1                                                                    00000640
 1.25   +6  1.0                                                        00000650
++                                                                      00000660
//                                                                      00000670
```

Fig. 3.17 Job control cards and input data for MCACE for use on the FACOM M-380 computer at JAERI

3.3.4 Data Notes for MCACE

The notes and the limitations to execute MCACE are described in this section. The descriptions consist of the estimators, the biasing techniques, the source option, the restart option and the bootstrap option. The information is useful to execute MCACE effectively.

Note 1) Estimators

The surface crossing estimator for spherical geometry is allowable when the center of sphere is set to the origin of the system coordinates. The scoring is available by each angular mesh of the direction cosine to the x–, y– or z–axis defined by the card PP. The number of the angular meshes is defined by MESH1 on the card NN. The angular flux is scored by each the direction cosine to the normal vector. (see **Fig. 3.18**)

The surface crossing estimator for cylindrical geometry is allowable when the axial direction of the cylinder is set to parallel to x–, y– or z–axis defined by the card OO. The scoring is performed by each axial mesh of the cylinder. The number of the axial meshes is defined by MESH1 on the card NN. The scoring is only available for the side of the cylinder. The angular flux is scored by each direction cosine to the normal vector. (see **Fig. 3.19**)

The surface crossing estimator for the (R, θ) plane geometry can be divided by the radius and the angle from the R–axis defined by the user. The direction cosine of the R–axis to the system coordinates is defined by the card PP. The number of the radial meshes and the number of the angle meshes are defined by MESH1 and MESH2 on the card NN, respectively. Note that the MESH2 should be the total number of the sectors and the assignment of the angular mesh should be started from zero by each radial level on the card SS. The scoring for the angular flux is performed by each direction cosine η and ϕ to the normal vector of the plane. (see **Fig. 3.20**) The angular mesh boundaries of ϕ are given by each η mesh on the card VV.

The surface crossing estimator for the (X, Y) plane geometry is assigned by the x'–axis and the normal vector. The x'–axis is defined by the card PP and y'–axis is automatically set to the vertical direction to the x'–axis. The number of meshes for x'–axis and y'–axis are defined by MESH1 and MESH2 on the card NN, respectively. The MESH2 should be the total number of the sectors. The mesh boundaries for y'–axis should be given by each level for x'–axis on the card SS. The scoring for the angular flux is performed by each direction cosine of η and ϕ to the normal vector of the plane. (see **Fig. 3.21**) The angular mesh boundaries of ϕ are given by each η mesh on the card VV.

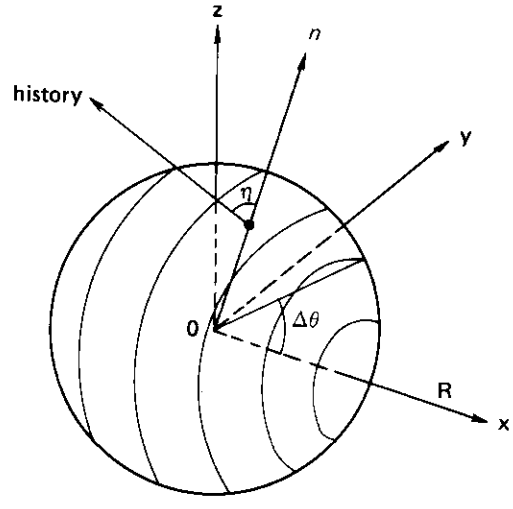


Fig. 3.18 Surface crossing estimation scheme for spherical geometry in MCACE

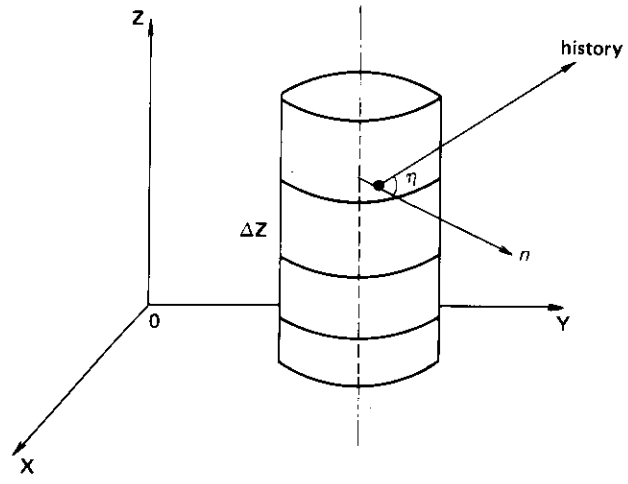


Fig. 3.19 Surface crossing estimation scheme for cylindrical geometry in MCACE

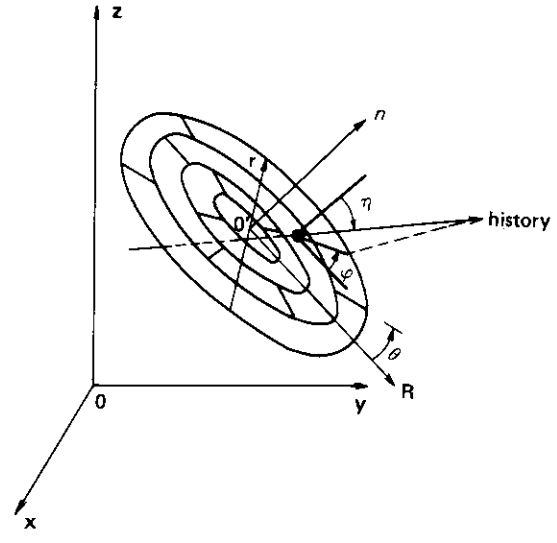


Fig. 3.20 Surface crossing estimation scheme for circular plane geometry in MCACE

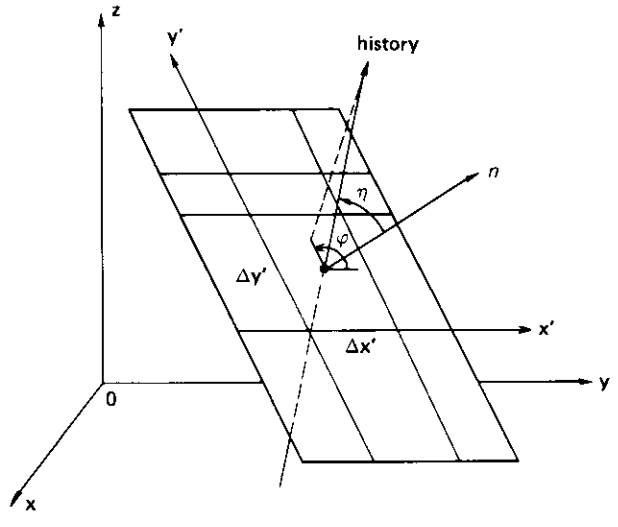


Fig. 3.21 Surface crossing estimation scheme for plane geometry in MCACE

The maximum number of the surface crossing estimators is 5. The surface crossing estimator for the (R, θ) or (X, Y) plane is also utilized for the bootstrap option. The particle scoring is performed by each surface, spatial mesh and energy group. The leakage current scoring is also available to compute J^+ and J^-. The angular flux scoring is performed by each angular mesh for η and ϕ.

The following surface crossing estimations are performed and printed out by each surface.

a) reaction rate and scalar flux

$$\frac{1}{S}\sum_g f_g \sum_i S_i \phi_{i,g}\,, \qquad \text{(mean value)}$$

$$\sum_g f_g \phi_{i,g}\,. \qquad \text{(meshwise value)}$$

b) energy spectrum

$$\frac{1}{S}\sum_i S \phi_{i,g}/\triangle E_g\,, \qquad \text{(mean value)}$$

$$\phi_{i,g}/\triangle E_g\,. \qquad \text{(meshwise value)}$$

c) leakage current

$$\sum_g \sum_i S_i J^-_{i,g}\,,\ \sum_g \sum_i S_i J^-_{i,g}\,, \qquad \text{(total leakage)}$$

$$\sum_i S_i J^-_{i,g}\,,\ \sum_i S_i J^-_{i,g}\,, \qquad \text{(mean value)}$$

$$\sum_g J^+_{i,g}\,,\ \sum_g J^-_{i,g}\,, \qquad \text{(meshwise value)}$$

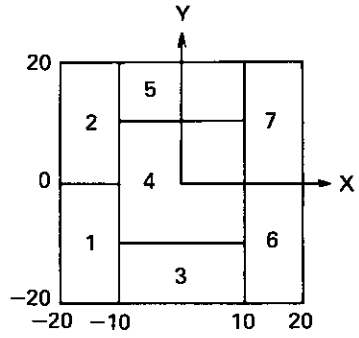
$$J^+_{i,g}\,,\ J^-_{i,g}\,. \qquad \text{(meshwise and groupwise value)}$$

d) angular flux

$$\phi_{i,g,k}\,. \qquad \text{(meshwise, groupwise and anglewise value)}$$

The number of response function to compute the reaction rate on the surface is only one which is the first response function on the cards FF. In scoring of angular fluxes the angular mesh structure given by the cards TT, UU and VV should be the same for all surfaces.

The way to partition the space and angle is very flexible. For example, any number of Y meshes is possible for each X mesh, as shown below.



Input data for this surface:
ITYPE = PXY
MESH1 = 3
MESH2 = 7
Card QQ = -20, -10, 10, 20
Card RR = 2, 3, 2
Card SS = -20, 0, 20, -20, -10, 10, 20, -20, 0, 20

Fig. 3.22 A sample input for the PXY surface crossing estimator

Note 2) Biasing techniques

The Collision Times Biasing technique is effective in the case that a few collision components from source mainly contribute to the fluxes at the detector position. The biasing effect in computing the fluxes may be influenced by detector locations and the other biasing techniques (splitting or russian roulette kill), so that the user should confirm the merit of the biasing technique by using the other biasing techniques jointly. The process of the Collision Times Biasing technique is shown in **Fig. 3.23**.

The Region Penetration Biasing technique is effective in the case that a deep penetrating region exists between sources and detectors. The biasing technique gives good estimations when the Collision Times Biasing technique is also used, as shown in Section 3.3.1. The process flow of the Region Penetration Biasing technique is shown in **Fig. 3.24**.

The Automatic Russian Roulette Biasing technique can be ordinarily used as a standard biasing technique, however, the biasing effect in computing the fluxes is sensitive to the values of FVR and WAV defined by the user. When WAV is set to the relatively small value (for example WAV=0.1), any improvements from the biasing technique used may not be expected because many particles are survived and much computation times are needed. To improve the estimation effectively, some extra detectors may be also located in the configuration, such as D_0 shown in **Fig. 3.16**.

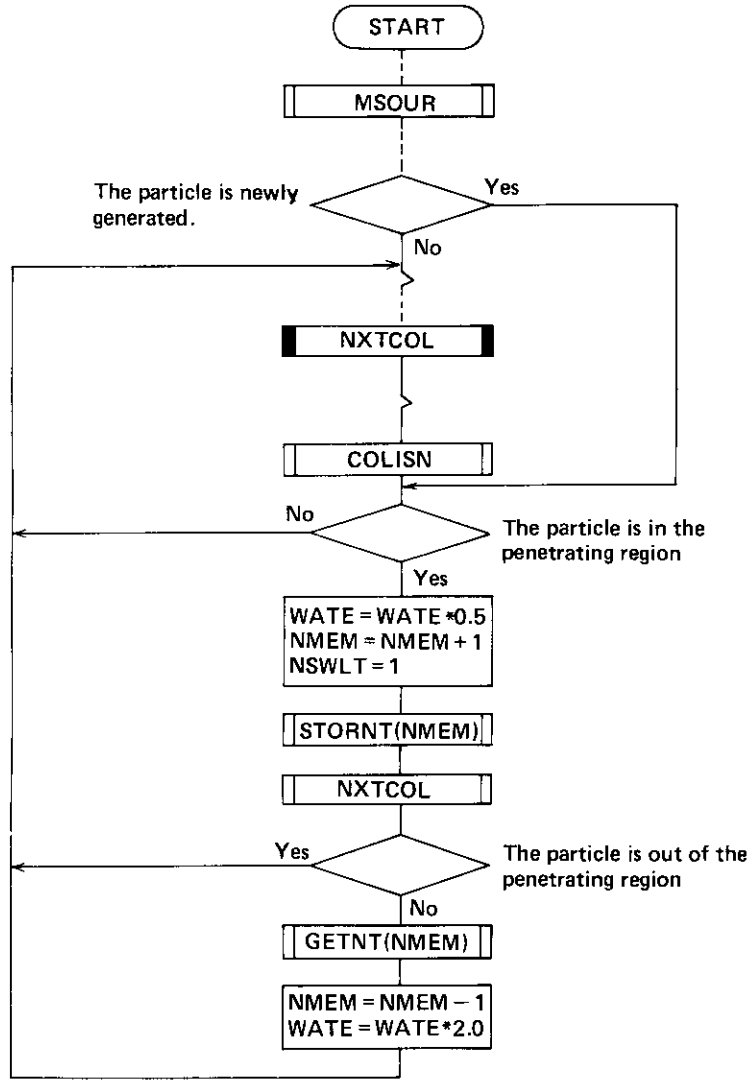


Fig. 3.23 Calculational flow of the Collision Times Biasing in MCACE

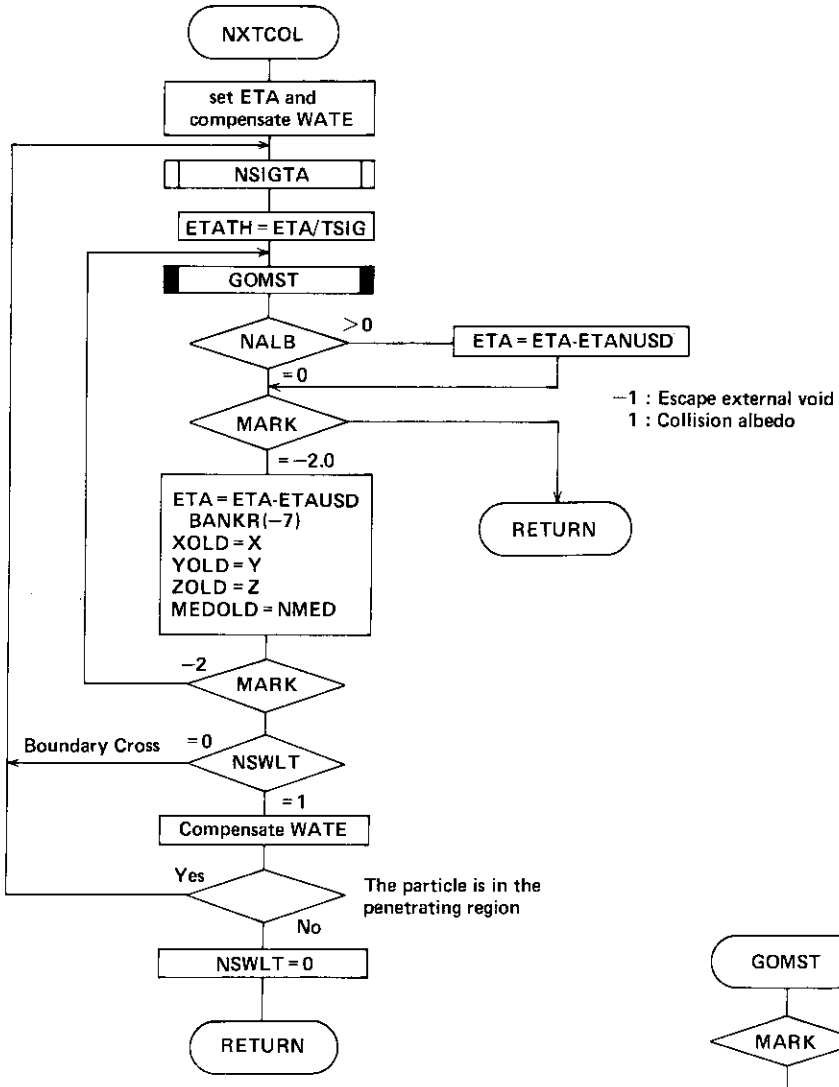


Fig. 3.23 (continued)

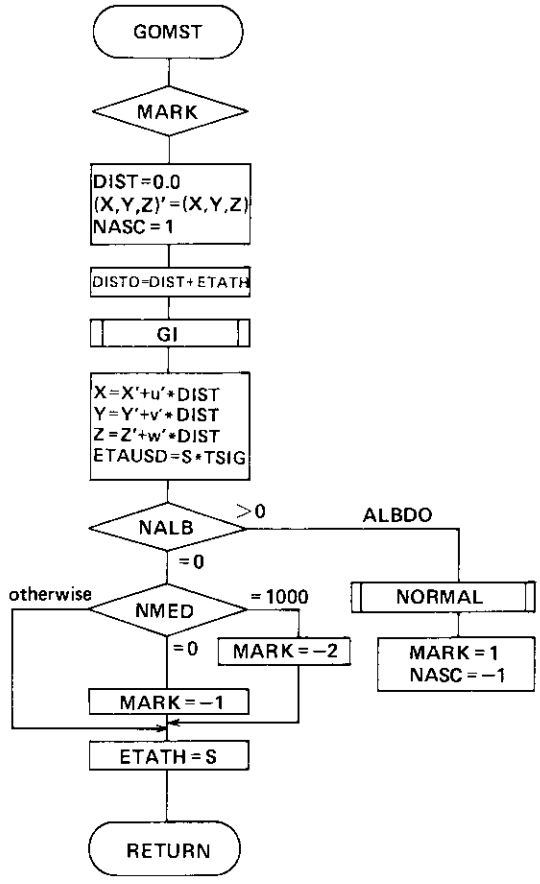


Fig. 3.23 (continued)

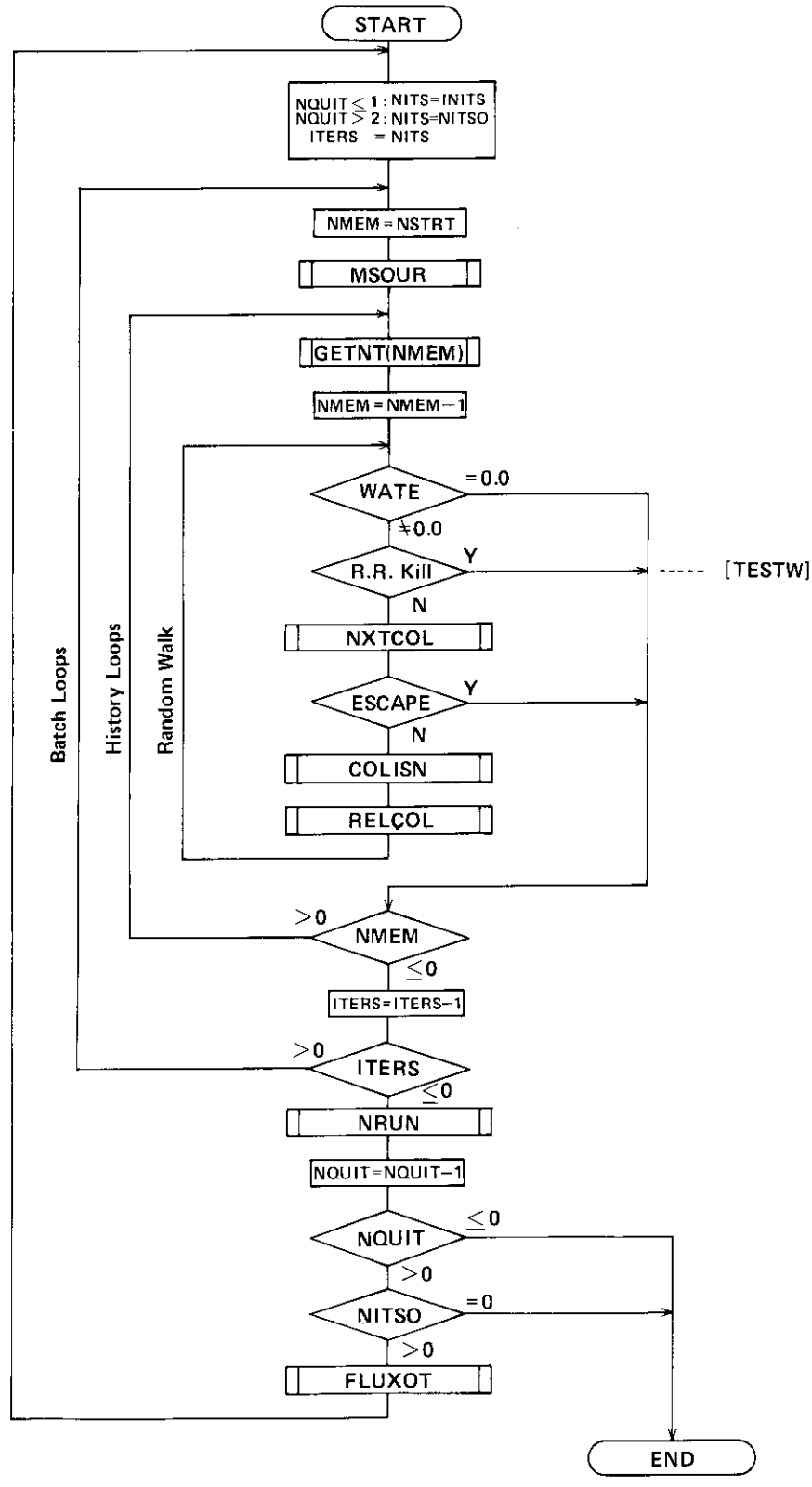


Fig. 3.24 Calculational flow of the Region Penetration Biasing in MCACE

Note 3) Source option

MCACE has many options corresponding to various source conditions. The subroutines SOURCE and SDATA have been newly added to treat the options. The following geometry and spatial distributions of the source are available in the MCACE module:

a) Source geometry and spatial distribution. (see **Fig. 3.25**)

(i) point: (NSORCE=1)

(ii) rectangular with the uniform distribution: (NSORCE=2)

(iii) rectangular with the cosine distribution: (NSORCE=3)

$$p(x)dx=\cos(\frac{\pi}{2\ell}x)dx.$$

(iv) cylinder with the uniform distribution: (NSORCE=4)

$$p(r)rdr=\frac{2}{R_0^2}rdr,$$

$$x=r\cos\theta,$$

$$y=r\sin\theta,$$

$$p(z)dz=dz/L\ .$$

(v) cylinder with the cosine distribution in z only: (NSORCE=5)

$$p(r)rdr=\frac{2}{R_0^2}rdr,$$

$$x=r\cos\theta,$$

$$y=r\sin\theta,$$

$$p(z)dz=\cos(\frac{\pi}{2\ell}z)dz.$$

(vi) sphere with the uniform distribution: (NSORCE=6)

$$p(r)r^2dr=\frac{3}{R_0^3}r^2dr,$$

$$x=r(2\rho_1-1),$$

$$y=r(2\rho_1-4\rho_1^2)^{1/2}\cos\{\pi(2\rho_2-1)\},$$

$$z=r(2\rho_1-4\rho_1^2)^{1/2}\sin\{\pi(2\rho_2-1)\}.$$

(vii) circular plane with the uniform distribution: (NSORCE=7)

$$p(r)dr=\frac{2}{R_0^2}rdr,$$

$$x=r\cos\theta,$$

$$y=r\sin\theta.$$

(viii) annular plane with the uniform distribution: (NSORCE=8)

$$p(r)rdr=\frac{2r}{R_1^2-R_2^2}dr,\ R_2\leq r\leq R_1$$

$$x=r\cos\theta,$$

$$y=r\sin\theta.$$

In these distributions ρ_1 and ρ_2 are random numbers with the uniform distribution from 0 to 1. The $\sin\theta$ and $\cos\theta$ mean the distributions with uniform the distribution in θ from 0 to 2π, respectively, and these values are given by calling the subroutine AZIRN(SIN, COS).

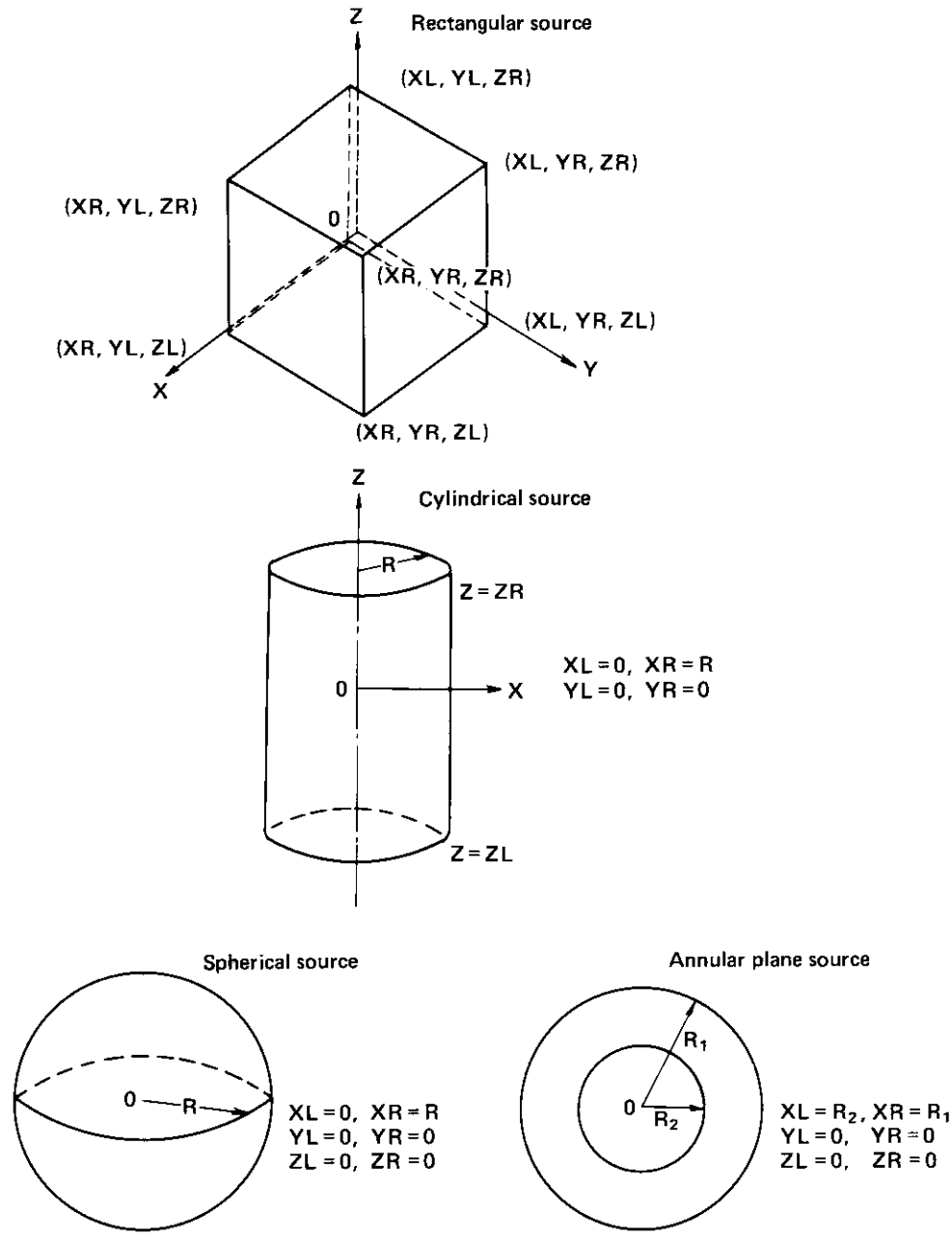


Fig. 3.25 Source geometry in the subroutine SOURCE

b) Angular distribution of source.

(i) pencil beam. (NEMIS=1)

(ii) isotropic emission, (NEMIS=2)

$$u=2R_1-1,$$

$$v=\sqrt{1-u^2}\cos\{\pi(2R_2-1)\},$$

$$w=\sqrt{1-u^2}\sin\{\pi(2R_2-1)\}.$$

(iii) cosine emission, (NEMIS=3)

$$u=\sqrt{R_1},$$

$$v=\sqrt{1-u^2}\cos\{\pi(2R_2-1)\},$$

$$w=\sqrt{1-u^2}\sin\{\pi(2R_2-1)\}.$$

(iv) $P(\mu)$ emission. (NEMIS=4)

In the above expression, R_1 and R_2 mean random numbers with the uniform distribution from 0 to 1.

c) The uncollided fluences for these angular distributions of sources are computed as follows:

(i) pencil beam,

$$\phi_{un}=\mathrm{WATE}*\exp\{-\int_A^B\Sigma^T dt\}\ .$$

(ii) isotropic and cosine emissions,

$$\phi_{un}=\frac{\mathrm{WATE}}{4\pi r^2}*\exp\{-\int_A^B\Sigma^T dt\}\ .$$

(iii) $P(\mu)$ emission,

$$\phi_{un}=\frac{\mathrm{WATE}}{r^2}*P(\mu)*\exp\{-\int_A^B\Sigma^T dt\}\ .$$

In the above expression WATE is the particle weight, r means the pass length from the source at A to the detector B. Σ^T is the total macroscopic cross section and $P(\mu)$ is the angular distribution function of the source.

Note 4) Restart option

To use the restart option the restart tape which was generated as FT41F001 should be assigned to FT51F001 and the input data should be the same as that of the previous job excepting that the number of batches; NITS on the card B should be changed to the number of total batches including the previous one (The starting random number on the card H is changed automatically to the next random number of the previous batch).

Note 5) Bootstrap option

MCACE can perform the bootstrap calculation using the leakage current on a surface detector of the plane geometry in the previous job. To use this option the bootstrap tape which was generated as FT42F 001 by specifying ILEAK=1 and IOUT=1 on the card NN should be assigned to FT40F001. The plane identification number, NSURF on the card E3, is the same as the sequence number of surfaces in the previous job. There are following limitations for a bootstrap surface.

Number of energy groups	≤ 25
Number of total sections (MESH2 on card NN)	≤ 100
Number of meshes for polar angle (IETA on card NN)	≤ 5
Number of total angular meshes (IPHI on card NN)	≤ 24

The bootstrap tape is written in the unformatted form and contains following information:

1st rec. (TITLE(I), I=1, 20)
2nd rec. N, ITYPE, IREAL, IEXP, MESH1, MESH2, IETA, IPHI, IANG, NE
3rd rec. X0, Y0, Z0, U0, V0, W0, U1, V1, W1,
(R(I), I=1, MESH1+1), (T(I), I=1, MESH1+MESH2),
(NR(I), I=1, MESH1+1)
4th rec. (ETA(I), I=1, IETA+1), (PHI(I), I=1, IETA+IPHI),
(NETA(I), I=1, IETA)
This 4th record is omitted if IANG=0.
5th rec. (RLEAK(I), I=1, MESH2) for the group 1
6th rec. ((RFLUX(I, J), I=1, IPHI), J=1, MESH2) for the group 1
This 6th record is omitted if IANG=0
Repeat 5th and 6th records until the group NE.
7th rec. (ELEAK(I), I=1, MESH2) for the group 1
8th rec. ((EFLUX(I, J), I=1, IPHI), J=1, MESH2) for the group 1
This 8th record is omitted if IANG=0.
Repeat 7th and 8th records until the group NE.

where,
- N : sequence number of the surface
- R(I), T(I) : mesh boundaries for R and θ axes or X and Y axes
- NR(I) : number of meshes of the second axis on a mesh of the first axis
- ETA(I), PHI(I) : mesh boundaries for polar and azimuthal angles
- NETA(I) : number of meshes for the azimuthal angle on a polar mesh
- RLEAK, RFLUX : leakage and flux for the real crossing estimator
- ELEAK, EFLUX : leakage and flux for the expected crossing estimator

Other notations are the same as those in the input instruction.

The above data records are for a surface detector, therefore, these data records are repeated by NS times.

In order to use the boundary sources generated by DOT/ESPRIT, the following information on a tape are required:

1st rec. IGM, IGE, MM, IM, JM, IB5, IB6, MMUP, MMRT,
(TITLE(I), I=1, 18)
2nd rec. (XNU(I), I=1, MM), (XETA(I), I=1, MM), (WT(I), I=1, MM),
(R(I), I=1, IM+1), (Z(I), I=1, JM+1)
3rd rec. ((FLUX(M, J), M=1, N1), J=1, N2) for the group 1
Repeat this record until the group IGM.

where,
- IGM : number of groups
- IGE : type
- MM : number of angles
- IM, JM : number of radial and axial intervals
- IB5, IB6 : interval number for radial and axial boundary
- MMUP, MMRT : number of up-ward and right-ward angles
- XNU, XETA, WT : Sn constants (μ, η and weights)
- R, Z : radial and axial interval boundaries
- FLUX : boundary flux at the position IB5 or IB6

N1=MMUP, N2=IM for IB5≠0
N1=MMRT, N2=JM for IB6≠0

The information after the 3rd record is the same as the interior boundary angular flux data set written on the logical unit NBFT by DOT/ESPRIT.

The boundary fluxes obtained by DOT/ESPRIT for the radial or axial interior boundary of the (R, Z) geometry are allowable in using the bootstrap option. In the case of the radial interior boundary, the

system coordinates for the bootstrap calculation should be the same as those for the DOT/ESPRIT calculation. The source angular biasing which means angular fluxes oriented between θ_{min} and θ_{max}

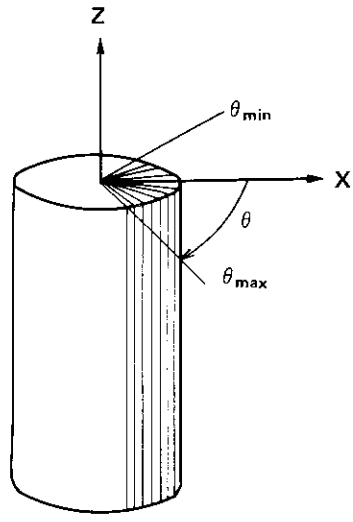


Fig. 3.26 Source biasing option used in the bootstrap calculation

indicated as shadow in **Fig. 3.26** are only treated as the source for MCACE, is also available by using THMIN as θ_{min} and THMAX as θ_{max} on the Card E6.

3.4 BREM

BREM computes secondary gamma-ray contributions due to the Bremsstrahlung effect. The gamma-ray transport calculation is performed by DIAC. The BREM has two processing options named "source option" and "edit option". The source option generates secondary gamma-ray sources by using gamma-ray fluxes calculated by DIAC and the Bremsstrahlung data. The edit option adds the primary gamma-ray fluxes and the secondary gamma-ray ones generated by the Bremsstrahlung effect, and computes total gamma-ray fluxes and arbitrary reaction rates. The flow of calculations is shown in **Fig. 3.27**.

In the source option, secondary gamma-ray sources by each energy group and spatial interval are generated in the form of volume distributed sources used in the DIAC calculation. The calculation of the secondary gamma-ray transport is also performed by DIAC with the source data generated in the source option of BREM (IQM=2 in the 15$ array should be specified in this calculation).

In the edit option, the primary gamma-ray fluxes and the secondary gamma-ray ones are edited. The total gamma-ray fluxes, spectra and reaction rates for arbitrary response functions are computed in this edit option. The total gamma-ray fluxes can be also stored in the DATA—POOL.

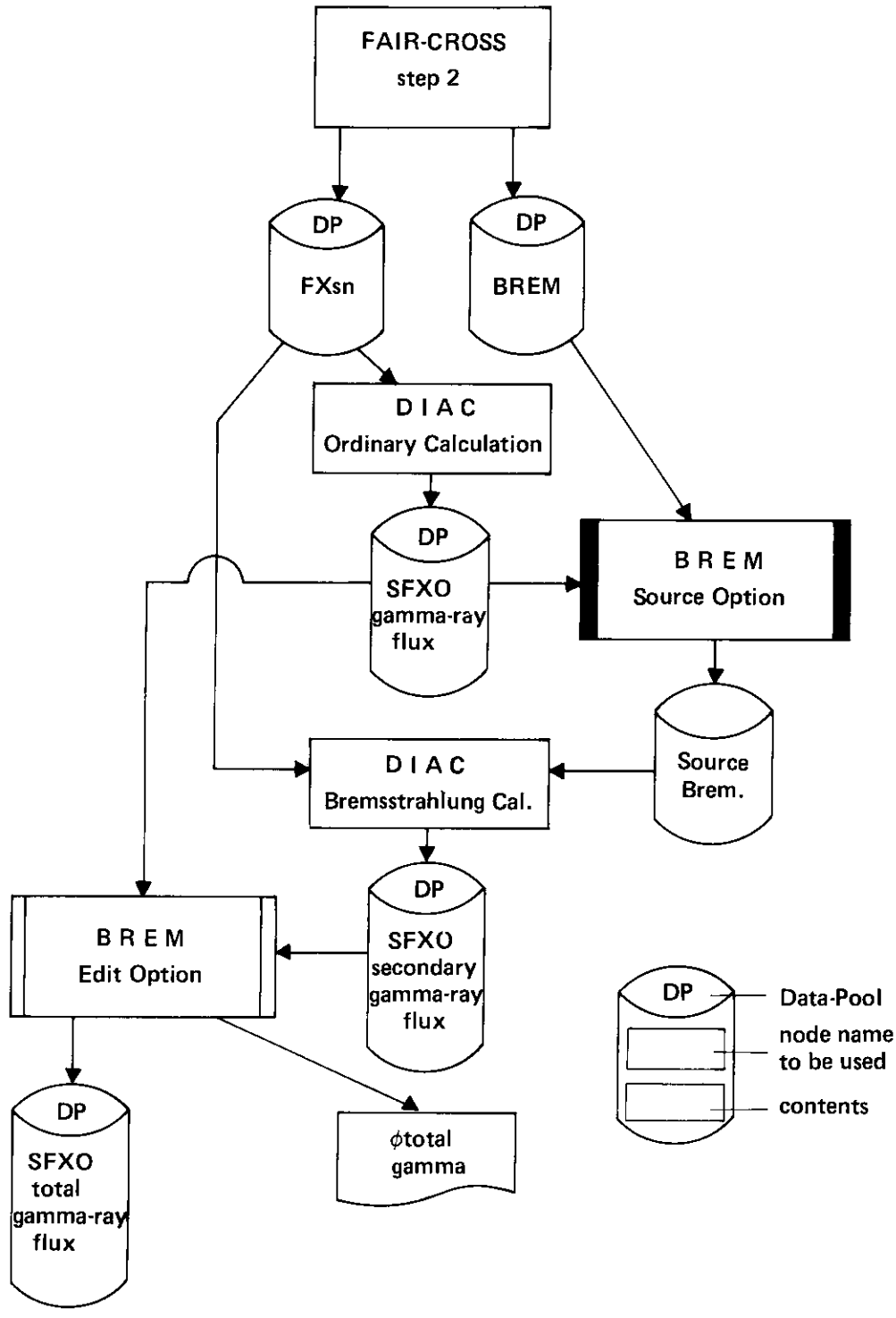


Fig. 3.27 Schematic flow of Bremsstrahlung calculation

3.4.1 Input Instruction

Input data to BREM are written in the FIDO format except for a title, a DATA-POOL unit assignment and response functions data. In the following, a size of data arrays is given in square brackets, and the condition under which the data array is to be specified is given in parentheses. The data array without the condition should always be specified.

1. Title card Format (18A4)
   Arbitrary comments are given.

2. DATA-POOL assignment card
   Logical unit numbers for DATA-POOL used in computation are assigned.
   The input format is a Namelist statement described below:
   &UNIT FLX1=n1, FLX2=n2, FLX3=n3, BREM=n4, RESD=n5 &END
   '&UNIT' should be written from the 2nd column. Unit names, FLX1 etc., indicate following libraries:
   - FLX1 : scalar fluxes generated in the primary calculation with DIAC (include no Bremsstrahlung effect)
   - FLX2 : scalar fluxes generated in the second calculation with DIAC (contributions of the secondary gamma-ray sources due to the Bremsstrahlung effect)
   - FLX3 : total scalar fluxes including the Bremsstrahlung effect to be outputted
   - BREM : Bremsstrahlung data
   - RESD : response functions for gamma-ray

The numbers from n1 to n5 correspond to those of the logical unit for DATA-POOL. When the number is set to zero, the access to the DATA-POOL is prohibited.

1$ Control parameters [8]

1. ID : problem identification number. The number is used as a node name for total scalar fluxes to be outputted.
2. MODE : computational option.
   1=source option
   2=edit option
3. IM : number of spatial mesh intervals in the primary DIAC calculation.
4. MT : number of materials in the primary DIAC calculation.
5. IDFM : density factor flag.
   0=density factor is not used in the primary DIAC calculation
   1=density factor is used in the primary DIAC calculation
6. IISPTM : print option for the gamma-ray flux.
   0=no print
   1=$\phi/\Delta E$
   2=$\phi/\Delta u$
7. NREACT : reaction rate calculation.
   0=no effect
   1=response data are given by cards
   2=response data are given by a sequential data set on FT50F001
   3=response data are given by DATA-POOL
8. NGELM : number of response functions. (MODE=2 and NREACT≠0)

T Termination of this data block.

2$ Node names for scalar fluxes to be inputted [2] (MODE=1)
The node names of the first and the second levels are assigned.

3$ Node names for scalar fluxes to be inputted [3] (MODE=2)
The node names of the first level (energy group structure) and the second level. (problem identification numbers for the primary and the secondary DIAC calculations)

13$ Node names for materials of Bremsstrahlung data [2+MT] (MODE=1)
Node names and the sequence are the same as the data in the 13$ array in the primary DIAC calculation.

21* Density factors [IM] (IDFM=1)
The values are the same as the data in the 21* array in the primary DIAC calculation.

28$ Node names for gamma-ray response functions [2+NGELM] (NREACT=3)
The first node name shows the energy group structure. (e.g., 4HEGRP) The second node name is 4HRESD and the following are response names to be used.

T Termination of this data block.

3. Gamma-ray response data (NREACT=1 and NGELM≠0)
   a) title of response data Format (20A4)
   b) response data Format (6E12.4)
   The above data are repeated by NGELM times.

3.4.2 Input/Output File Assignment

BREM requires various direct-access devices during computation. **Table 3.8** shows the names of the data sets. The logical unit number marked with a circle in the table is required to execute the job. The logical unit number which is marked with a condition in parentheses is required when the condition is satisfied.

Table 3.8 Requirements for external data sets in BREM

Logical Unit	MODE in the 1$ array		Contents
	1	2	
FT01F001	○		Secondary gamma-ray source output
FT50F001		(NREACT=2)	Response data input
FLX1*	○	○	Gamma-ray fluxes generated by the Primary DIAC calculation
FLX2*		○	Gamma-ray fluxes generated by the Secondary DIAC calculation
FLX3*		(FLX3≠0)	Total gamma-ray fluxes output
BREM*	○		Bremsstrahlung data input
RESD*		(NREACT=3)	Response data input

*Logical unit numbers are defined by the unit assignment card.

4. Module for Data Base Management

The RADHEAT-V4 system has to treat and manage various data sets of cross sections, secondary gamma-ray yield data, neutron and gamma-ray fluxes, response data and reaction rates. Each of data set is large in data size, and there are various data forms which are used to store data sets on files. In order to retrieve and manage these data set easily, a direct access data base "DATA-POOL" has been developed. In this chapter, the structure of DATA-POOL and the functions of DATA-POOL utilities, POOL and VISUAL, are described. The DATA-POOL is a kind of structured data base with a tree structure characterized by a chain of nodes. Data belonging to the same category are assigned to a level of node structure. An information retrieval is performed by assigning a specific combination of node names directly from a data input or output routine. The DATA-POOL adopts a fixed and an unblocked record length of 3600 bytes and consists of three sections. The structure of the DATA-POOL and descriptions of the access package are described in Section 4.1.

A maintenance utility POOL is prepared for the management of the DATA-POOL. The utility has 14 functions such as copy, delete, condense, backup and rename. The utility POOL can be utilized by conversational operations with TSS terminals or batch jobs. The maintenance operations including repairs of DATA-POOL can be mainly performed by using the utility POOL. The usage of POOL is described in Section 4.2.

It is not an easy task for users to analyze and evaluate the huge data in the DATA-POOL, so that a plotting utility VISUAL has been developed to plot the data on a display system using TSS terminal of TEKTRONIX T4014. The VISUAL can plot a graph of the two-dimensions, contour-line map and three -dimensions by conversational operation. Various commands are defined in the program and the default values are mainly set to the input data so that the user's operations can be confined to the minimum. The data contained in the DATA-POOL can be plotted as an arbitrary graph. The usage of VISUAL is described in Section 4.3.

4.1 DATA-POOL

Data sets used in RADHEAT-V4 are stored in a form of DATA-POOL. The basic concept of this DATA-POOL was based on the concept of the "DATA-POOL" which[43] was designed by the JAERI Nuclear Code Committee. The DATA-POOL code[44] was developed at the JAERI Computing Center in 1980. In the DATA-POOL code, arbitrary relations of node names can be defined by the user and large information retrievals can be performed. However, the DATA-POOL code must pass a pre-compilation process to compile specific command statements to the ordinary FORTRAN statements.

The data used in shielding calculations are large in size, but the classified node names are not so many. The data base which is designed to allow the large directory retrieval, is not required to treat the cross sections or radiation fluxes in shielding calculations. Therefore, a new DATA-POOL has been developed to treat effectively the cross sections and the other related data.

The DATA-POOL access package is a simplified version of the DATA-POOL code and has a feature that the number of I/O accesses can be reduced to a half in comparison with the DATA-POOL code to retrieve the same data. The difference is due to the use of a simple and appropreate form of directories. The minimum retrieval procedure is achieved to find the specified node name and data. The access package consists of several subroutines written in the FORTRAN 77 language. An ASSEMBLER subroutine of GETDCB is only used in the access packages to get the DCB information in the DD statement of the job control language. The structure of the DATA-POOL is described in Section 4.1.1.

The node names and the structures adopted in the RADHEAT-V4 code system are shown in Section 4.1.2. The description of the DATA-POOL access package is given in Section 4.1.3.

4.1.1 Structure of DATA-POOL

The DATA-POOL consists of three sections named a "Control Section", a "Directory Section" and a "Data Section", as shown in **Fig. 4.1**. Arbitrary data are stored/retrieved in the DATA-POOL by using a standardized format, so that the management of the data can be easily achieved.

In the DATA-POOL, the data are labelled by a combination of arbitrary node names which consists of 4-characters defined by the user, and stored in the Data Section. A node name is related to the others and a tree structure is generated as shown in **Fig. 4.2**. In this figure, EGRP means an energy group structure commonly used in the data. SGRX means an attribution of secondary gamma-ray production cross sections. INFX means an attribution of infinite dilution cross sections. ELA means an attribution of elastic scattering matrices. The node name frequently referred in the system is located at the upper level of the tree structure, and the order of assigned node names to identify a data set is essential to improve the efficiency of data retrieval.

The tree structure and the node names are stored in the Directory Section together with the direct-access record addresses. The data retrieval is carried out from the node of the first level to that of the lower levels, so that the most suitable tree structure is essentially needed according to the property of the data.

The data retrieval for the DATA-POOL is carried out by setting a series of the node names in PFIND/PSET subroutines, and then the data access is carried out by PREAD/PRITE subroutines.

An exclusive control is adopted for writing access in order to prevent the destruction of DATA-POOL from multiple job access. In the period between PWSTAT subroutine and PWEND subroutine, the writing access by the other jobs is prohibited. These functional subroutines are described in Section 4.1.3.

a) Control Section

The Control Section is located at the first record of DATA-POOL and has a size of 40 words. The veriables in the section are used for the control of DATA-POOL. The record structure of the Control Section is shown in **Fig. 4.3**. The initialization of the Control Section is carried out by calling the PINIT subroutine.

b) Directory Section

The Directory Section takes an important role which determines the relation between the node name and the record address of the data, and keeps the information of the lower nodes in the tree structure. The Directory Section consists of the several sub-directories. The sub-directory has the information of the node name, the head address of the data section associated with the node name, the data of creation and control variables defined by the user. The structure of the Directory Section is shown in **Fig. 4.4**. A sub-directory takes 12 words in the Directory Section and directory holds a physical record length, so that the maximum number of nodes associated with the same level is limited to the next value:

$$N_{max} = \left[\frac{(1\ physical\ record\ length\ (words) - 4)}{12}\right]$$

The DATA-POOL of RADHEAT-V4 has a fixed physical record length of 3600 bytes (900 words), so that the value of N_{max} is 74. The DATA-POOL has a feature that the information for the nodes of the lower levels can be obtained at once by referring a directory. The DATA-POOL will not be suitable, however, for systems with a tree structure consisting of many lower nodes and levels. In the sub-directory, up to 5 information can be recorded by the user. The record area is prepared to specify the property or the condition for the many kinds of data associated with the node condition, for the many kinds of names,

and will be used as control flags whether data are existent or nonexistent in the Data Section. The needless access to the Data Section is prevented by utilizing the information in the sub-directory.

c) Data Section

The Data Section consists of several sub-data sets. A sub-data set is created by executing a writing. The writing is carried out by calling a subroutine of PRITE-PRITE4. The subroutine PRITE only creates the comments of the node. The data of one-dimensional array are written in the regions from DATA1 to DATA4 by calling subroutines of PRITE1 to PRITE4, respectively, as shown in **Fig. 4.5**.

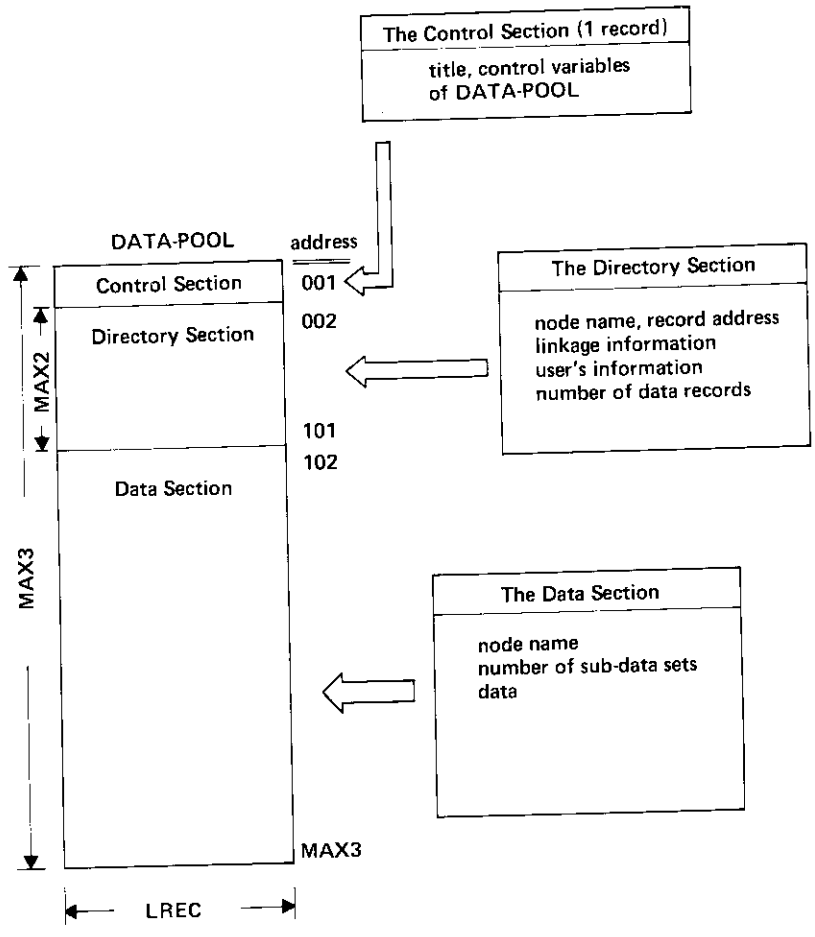


Fig. 4.1 Structure of DATA-POOL

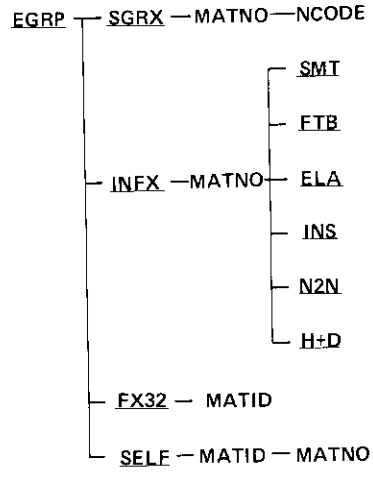


Fig. 4.2 Fundamental node tree structure

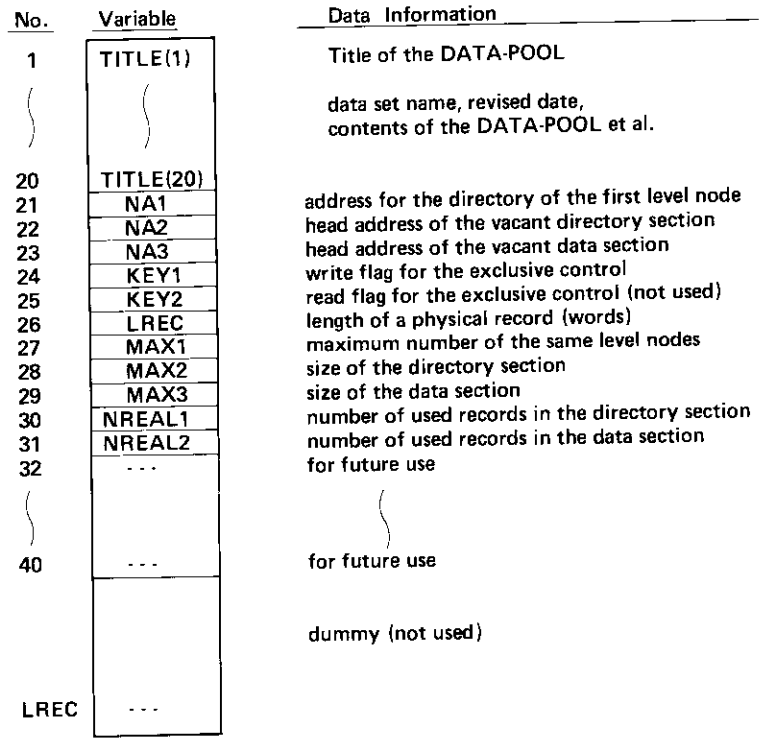


Fig. 4.3 Record information of the Control Section in DATA–POOL

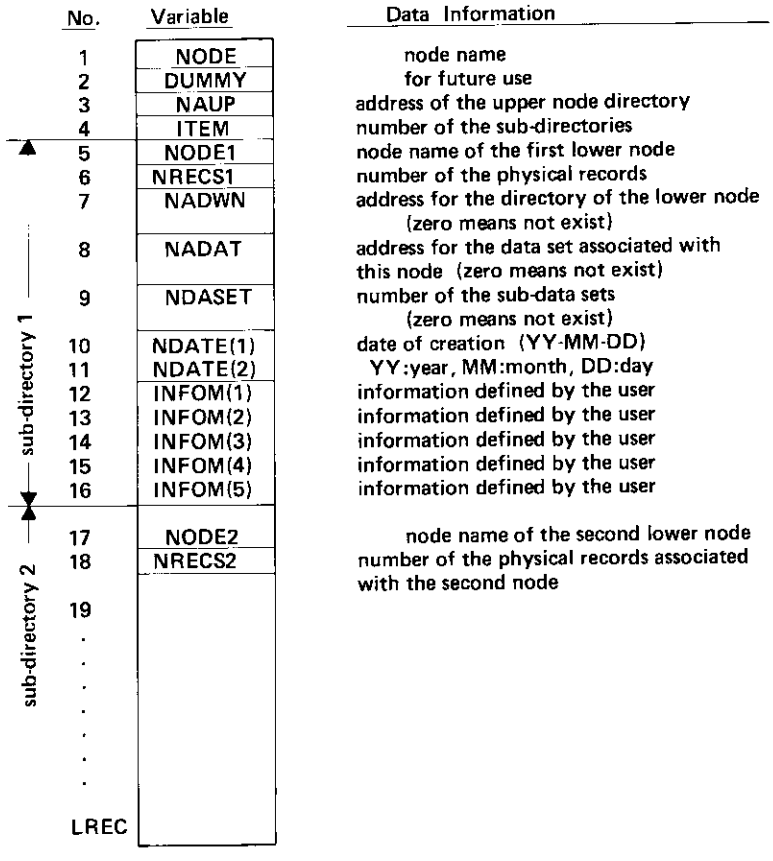


Fig. 4.4 Record information of the Directory Section in DATA–POOL

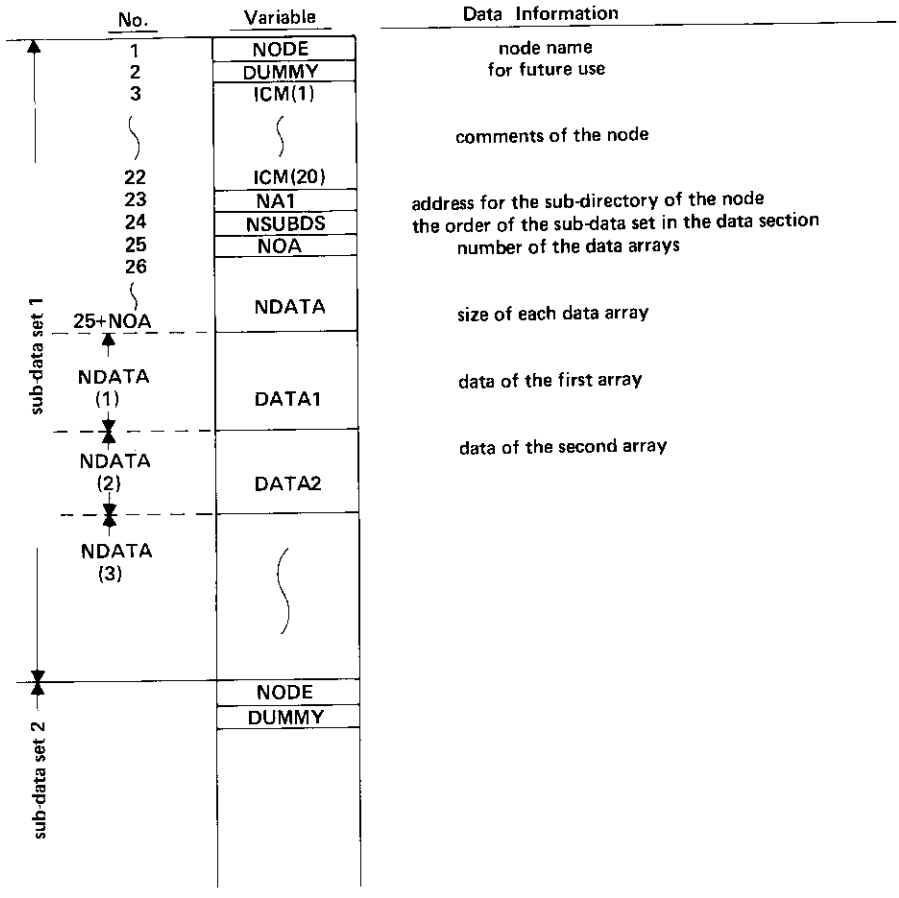


Fig. 4.5 Record information of the Data Section in DATA-POOL

4.1.2 Node Structure

Data sets processed in the RADHEAT-V4 code system are classified according to a specific chain of nodes, as shown in **Fig. 4.6**. The node names and the node structure in the tree structure are described in this section. The data are mainly associated with the nodes of the last level, so that the data are classified and stored in the forms described below. In the following description, the node name with capital letters in the classification is used as the fixed name, and lower case letters mean that the name may change for each of data.

a) ULTX Data Form

ULTX-matno-TMPi-SIGj

This form contains the ultra-fine group cross section. The identifications for the node names are as follows:

level 1: ULTX indicates the ultra-fine group data. The energy group structure is stored in the node.

level 2: "matno" indicates the nuclide number. The numbers in RADHEAT-V4 correspond to those of ENDF/B-IV.

level 3: TMPi indicates the temperature. The index i indicates the temperature of i. In RADHEAT -V4, i=1, 2, 3, 4 and 5 means 300, 560, 900, 1200 and 2100 K, respectively.

level 4: SIGj indicates the background cross section. The index j indicates the σ_0 value. j=1 means 10^8 in RADHEAT-V4.

b) SMT Data Form

EGRP-INFX-matno-SMT

This form contains the smooth cross sections, SMT, with the fine-group structure. The identifica-

tions for the node names are as follows:

level 1: EGRP indicates the fine-group data. The energy group structure is stored in the node.

level 2: INFX indicates the infinite dilution cross section.

level 3: "matno" indicates the nuclide number. The numbers in RADHEAT-V4 correspond to those of ENDF/B-IV.

level 4: SMT indicates the smooth cross section.

c) FTB Data Form

EGRP-INFX-matno-FTB

This form contains the self-shielding factors for each σ_0 value. The identifications for the node names from level 1 to 3 are the same as in the SMT data form. The node name FTB indicates that the self-shielding factors are stored in the node.

d) ELA Data Form

EGRP-INFX-matno-ELA

This form contains the scattering matrix of elastic reaction. The identifications for the node names from level 1 to 3 are the same as in the SMT data form. The node name ELA indicates that the scattering matrix of elastic reaction is stored in the node.

e) INS Data Form

EGRP-INFX-matno-INS

This form contains the scattering matrix of inelastic reaction. The identifications for the node names from level 1 to 3 are the same as in the SMT data form. The node name INS indicates that the scattering matrix of inelastic reaction is stored in the node.

f) N2N Data Form

EGRP-INFX-matno-N2N

This form contains the scattering matrix of $(n, 2n)$ reaction. The identifications for the node names from level 1 to 3 are the same as in the SMT data form. The node name N2N indicates that the scattering matrix of $(n, 2n)$ reaction is stored in the node.

g) H+D Data Form

EGRP-INFX-matno-H+D

This form contains the energy deposition factor and atomic displacement cross section. The identifications for the node names from level 1 to 3 are the same as in the SMT data form. The node name H+D indicates that the energy deposition factor and the atomic displacement cross section are stored in the node.

h) SGRX Data Form

EGRP-SGRX-matno-ncode

This form contains the secondary gamma-ray production cross sections of each reaction. The identifications for the node names are as follows:

level 1: EGRP indicates the fine-group data of the SMT data form.

level 2: SGRX indicates the secondary gamma-ray production cross section.

level 3: "matno" indicates the nuclide number. The numbers in RADHEAT-V4 correspond to those of ENDF/B-IV.

level 4: ncode indicates the reaction channel.

i) FXsn Data Form

EGRP-FXsn-matid

This form contains the effective macroscopic cross section. The identifications for the node names are as follows:

level 1: EGRP indicates the fine-group data of the SMT data form.

level 2: FXsn indicates the effective macroscopic cross section and the number of angular points.

level 3: "matid" indicates the material name.

j) SELF Data Form

EGRP-SELF-matid-matno

This form contains the self-shielding factors of each nuclide in the material defined by the "matid" in the FXsn data form. The data are utilized for generating the effective macroscopic cross section. The identifications for the node names are as follows:

level 1: EGRP indicates the fine-group data of the SMT data form.

level 2: SELF indicates that the self-shielding factors of each nuclide are defined in the FXsn data form.

level 3: "matid" indicates the material name defined in the FXsn data form.

level 4: "matno" indicates the nuclide number contained in the material.

These record formats are described in Appendix C.

k) SFX0/SFX1 Data Form

EGRP——problem no.——SFX0
                    └ SFX1

This form contains forward scalar fluxes (SFX0) and adjoint scalar fluxes (SFX1) calculated by the one-dimensional S_N-transport code DIAC. The data are used for generating few-group cross sections and for calculations of reaction rates. The identifications for the node names are as follows:

level 1: EGRP indicates the fine-group data of the SMT data form.

level 2: problem no. indicates the problem identification number specified by the first value of the 15$ array in the input data of DIAC.

level 3: SFX0 means forward scalar fluxes from DIAC.
SFX1 indicates adjoint scalar fluxes from DIAC.

l) SFX2/SFX3 Data Form

EGFG——problem no.——SFX2
                    └ SFX3

This form contains forward scalar fluxes (SFX2) and adjoint scalar fluxes (SFX3) calculated by the two-dimensional S_N-transport code ESPRIT. The data are used for calculations of reaction rates. The identifications for the node names are as follows:

level 1: EGFG indicates the energy group structure used in the ESPRIT calculations.

level 2: problem no. indicates the problem identification number of the name (4-characters) specified by the first data in the title card of ESPRIT.

level 3: SFX2 indicates forward scalar fluxes from ESPRIT.
SFX3 means adjoint scalar fluxes from ESPRIT.

m) AFX0/AFX1 Data Form

EGRP——problem no.——AFX0
                    └ AFX1

This form contains forward angular fluxes (AFX0) and adjoint angular fluxes (AFX1) calculated by

the one-dimensional S_N-transport code DIAC. The identifications for the node names are as follows:

level 1: EGRP means the energy group structure of the SMT data form.

level 2: problem no. is the same as in the SFX0/SFX1 data form.

level 3: AFX0 indicates forward angular fluxes from DIAC

AFX1 means adjoint angular fluxes from DIAC.

n) AFX2/AFX3 Data Form

EGFG——problem no.—┬—AFX2
└—AFX3

This form contains forward angular fluxes (AFX2) and adjoint angular fluxes (AFX3) calculated by the two-dimensional S_N-transport code ESPRIT. The identifications for the node names are as follows:

level 1: EGFG is the same as in the SFX2/SFX3 data form.

level 2: problem no. is the same as in the SFX2/SFX3 data form.

level 3: AFX2 indicates forward angular fluxes from ESPRIT.

AFX3 means adjoint angular fluxes from ESPRIT.

o) RESD Data Form

EGRP——RESD——detector name

This form contains response functions to calculate reaction rates. The identifications for the node names are as follows:

level 1: EGRP indicates the energy group structure.

level 2: RESD means the response data.

level 3: detector name indicates identification names of the detector response functions.

p) EFsn Data Form

EGRP——EFsn——matid——matno—┬—SMT
├— H+D
├— ELA
├— INS
— N2N

This form contains the effective microscopic group cross section generated by FDEM. The identifications for the node names are as follows:

level 1: EGRP means the energy group structure. The energy group structure is stored in the node.

level 2: EFsn indicates the effective microscopic cross section. The sn means the number of angular meshes.

level 3: matid indicates the material identification name.

level 4: matno indicates the nuclide identification numbers contained in the material. The names are ordinarily the same as the material numbers in the ENDF/B file.

level 5: SMT, H+D, ELA, INS, and N2N indicate reaction types of smooth cross section, energy deposition and atomic displacement, elastic scattering matrix, inelastic scattering matrix and $(n, 2n)$ scattering matrix, respectively.

q) BREM Data Form

EGRP–FXsn–matid–BREM

This form contains the Bremsstrahlung data. The secondary gamma-ray production data generated by the FAIR-CROSS step 2 are stored in the node. The identifications for the node names are as follows:

level 1: EGRP indicates the energy group structure. The energy group structure is contained in the node.

level 2: FXsn indicates the macroscopic cross section.

level 3: matid indicates the material identification name.

level 4: BREM indicates the Bremsstrahlung data. The secondary gamma-ray production data by the Bremsstrahlung effect are stored in the node.

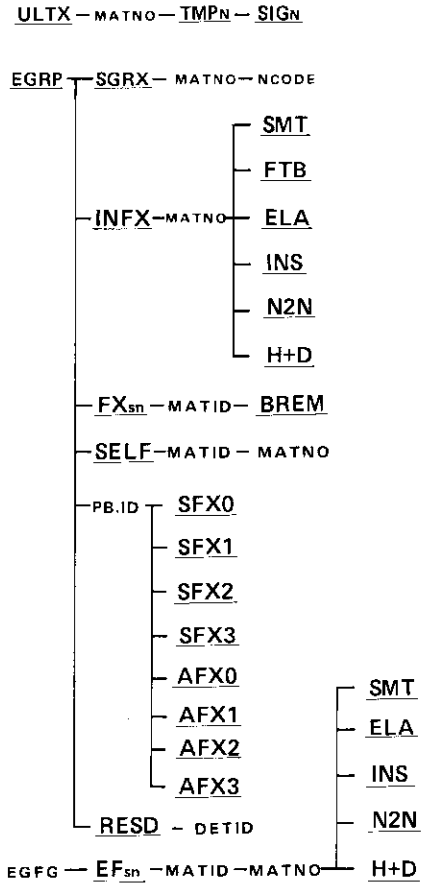


Fig. 4.6 Hierarchy of node names in DATA-POOL adopted in the RADHEAT-V4 code system

4.1.3 Access Package

The access for DATA-POOL is carried out by using access subroutines and common tables described in this section. The user can easily treat data in the DATA-POOL by calling the access subroutines in the user's program written in the FORTRAN language. Only a subroutine GETDCB is written in the ASSEMBLER language. The 29 access subroutines are as follows:

(1) PINIT : initialize DATA-POOL and clear the Control Section,

(2) POPEN : declare the access of DATA-POOL and open the data set,

(3) PWSTAT : declare the start of writing into DATA-POOL and set the write flag on in order to prohibit the writing access by the other jobs,

(4) PWEND : declare the end of writing into DATA-POOL and reset the write flag,

(5) PSET : set the node name and the record address to the Directory Section in order to write the data,

(6) PFIND : retrieve the node name and the record address from the Directory Section in order to read the data,

(7) PRITE~PRITE4 : write data into the Data Section,

(8) PREAD~PREAD4 : read data from the Data Section,

(9) PDELT : delete node name and data,
(10) PAGET : retrieve the next record address to be read or write,
(11) PDGET : retrieve the directory information,
(12) PASTO : set the record address to be read or write,
(13) PSKIP : skip arbitrary logical records,
(14) NODEER : error check,
(15) CATLST : display the Directory Section.

The other subroutines are supplementary ones to the subroutines described above, so that the descriptions are omitted. The functions and usage these subroutines are described in a report of DATA-POOL[53]. The detailed information may be referred to in the report.

4.2 POOL

DATA-POOL is a special direct-access data base, so that the management utility POOL has been prepared to maintain the data set. POOL has 14 operation commands and can be used from TSS terminals or by batch jobs. The commands and these operands are listed in **Table 4.1**. Input instructions for conversational operations and batch jobs are described in Section 4.2.1. Input/Output file assignments during execution are noted in Secton 4.2.2. The job control language and the cataloged procedures for executing POOL are shown in Section 4.2.3 The detailed information for the utility POOL may be also referred to in the report of DATA-POOL.

Table 4.1 Commands and the functions in POOL.

Command	Abbre-viation	Operand	Function of the Command
HELP	——	———	Command names and the functions are displayed.
INIT	——	DSN†	DATA-POOL initialization
		UNIT PARAMETER	
		SPACE, UNIT	
		Directory size	
		Comments	
FLAG	F	DSN	Reset exclusive control
DELETE	DEL	DSN	Delete node name and data
		Node names	
TREE	T	DSN	Display tree structure
CATL	C	DSN	Display Directory information
LIST	L	DSN	Display record information
		Node names	
RENAME	RE	DSN	Rename node names
		Old node names	
		New node nomes	
COPY	——	1st. DSN	Copy data from DATA-POOL
		2nd. DSN	
CONDENSE	COND	DSN	Condense a DATA-POOL
		TSS/Batch	
MEND	——	DSN	Mend a DATA-POOL
		CONT/DIREC/COM	
MTSAVE	——	———	Backup a DATA-POOL to a Magnetic Tape
MTCOPY	——	———	Restore a DATA-POOL form a Magnetic Tape
END	——	———	Terminate the utility POOL

† DSN means Data Set Name.

4.2.1 Input Instruction

On the TSS terminals, the following operations is necessary to utilize the utility POOL. The statement with underline indicates the user's input on the TSS terminal. CR means a carriage return.

READY
EX 'J3679.TSSMAC.CLIST(POOLX)' CR

The "TSSMAC.CLIST" is a default data set name consisting of user's cataloged procedures in the JAERI computing center. The user who has a data set named TSSMAC.CLIST(POOLX) can execute POOL by a simple operation:

READY
POOLX CR

When the cataloged procedure has been executed, the following display appears:

```
READY
POOLX
 FILE B NOT FREED, IS NOT ALLOCATED
 FILE DCB NOT FREED, IS NOT ALLOCATED
 FILE FT01F001 NOT FREED, IS NOT ALLOCATED
 FILE FT02F001 NOT FREED, IS NOT ALLOCATED
 FILE FT91F001 NOT FREED, IS NOT ALLOCATED
    ***** STARTS RADHEAT-V4 DATA POOL UTILITY *****
 ENTER COMMAND NAME ===>
```

The 14 functions in the utility POOL can be selected by the user with entering a command name. HELP command is prepared when the user forgets command names. END command is used for terminating the execution. When HELP command has been entered, the following display appears:

```
ENTER COMMAND NAME ===> HELP

COMMAND                CONTENTS
CATL       PRINT OF CONTROL AND DIRECTORY SECTION
CONDENSE   CONDENSE OF A DATA POOL
COPY       COPY OF A NODE DATA
DELETE     DELETE OF A NODE DATA
FLAG       CHANGE OF A WRITE FLAG
INIT       INITIALIZATION OF A DATA POOL
LIST       LISTING OF A NODE DATA (SUB-DIRECTORY AND FORM OF DATA ARRAYS)
MEND       MENDING OF A CONTROL, DIRECTORY AND DATA COMMENT
MTCOPY     LOAD OF A BACK-UP TAPE TO A DATA POOL
MTSAVE     MAKING OF A BACK-UP TAPE
RENAME     RENAME OF A NODE
TREE       PRINT OF ALL NODE NAMES IN A DATA POOL BY A TREE STRUCTURE
ENTER COMMAND NAME ===>
```

Some commands have the abbreviated forms such as follows:

FRAG	F
DELETE	DEL
TREE	T
CATL	C
LIST	L
RENAME	RE
CONDENSE	COND

The functions and usages of these commands are described below.

a) INIT Command

DATA-POOL is initialized by using the INIT command.

The initialization is executed by the conversational operation with on TSS terminals. The initialization for the cataloged data set means erasing all of data in the DATA-POOL. The sample procedure is given as follows:

```
ENTER COMMAND NAME ===> INIT

ENTER DSN OF DATA POOL ===> J3679.DATAPOOL.DATA
ALLOCATION OF DATA SET (NEW/OLD) ====> NEW
UNIT PARAMETER         ==============> TSSWK
SPACE PARAMETER (1-ST SPACE)   ======> 50
SPACE PARAMETER (INCREMENT)    ======> 10
SPACE PARAMETER (SPACE UNIT T/CY) ===> T
ENTER DIRECTORY SIZE
01100 ?
        20
ENTER TITLE (64 CHARACTERS)
01500 ?
       RADHEAT-V4 DATA-POOL FOR CROSS SECTIONS STORAGE
*** MESSAGE FROM PINIT ***
    NO. OF INITIALIZED RECORD IS 1000
*********   C O N T R O L  S E C T I O N   *********
     COL.
    1-18  TITLE   :
                RADHEAT-V4 DATA-POOL FOR CROSS SECTIONS STORAGE
      21  ADDRESS FOR THE DIRECTORY OF FIRST LEVEL NODE  :    2
      22  HEAD ADDRESS FOR THE VACANT DIRECTORY AREA     :    3
      23  HEAD ADDRESS FOR THE VACANT DATA AREA          :   22
      24  WRITE FLAG                                     :    0
      25  READ FLAG (NOT USED)                           :    0
      26  LENGTH OF THE ONE PHYSICAL RECORD              :  900
      27  MAXIMUM NUMBER OF THE SAME LEVEL NODE          :   74
      28  SIZE OF THE DIRECTORY SECTION                  :   20
      29  SIZE OF THE DATA SECTION                       :  979
      30  REAL NUMBER OF THE DIRECTORY RECORDS           :    1
      31  REAL NUMBER OF THE DATA SET RECORDS            :    0
ERROR SUMMARY (FORTRAN77)
ERROR NUMBER ERROR COUNT
    232      001
```

In the sample, the UNIT PARAMETER means the unit name defined in a DD statement such as D0950B, TDS, TSSWK, MSS. The SPACE means the allocation space and the UNIT of T (track=19 k bytes) or CY (cylinder=250 k bytes) can be specified. After the specifications for the data set, two input data for a directory size and a comment (64-characters) are required. When the initialization is completed, the Control Section is displayed and the initialized records can be known. An error of the error number 232 is prearranged, so that it is not necessary to pay attention. The data set name must be specified as a full name because the abbreviated form may cause an error. Note that the volume number and the group number are required when the allocation for MSS is specified. The allocation space for MSS is a multiple of cylinders, e.g.,

```
ENTER COMMAND NAME ===> INIT

ENTER DSN OF DATA POOL ===> J3679.MSSDPOOL.DATA
ALLOCATION OF DATA SET (NEW/OLD) ====> NEW
UNIT PARAMETER         ==============> MSS
SPACE PARAMETER (1-ST SPACE)   ======> 10
SPACE PARAMETER (INCREMENT)    ======> 2
SPACE PARAMETER (SPACE UNIT T/CY) ===> CY
MSS GROUP          ===================> MSS04
MSS VOLUME NUMBER      ===============> MA0072
```

b) FLAG Command

The control flag for the exclusive access of DATA-POOL in the Control Section is set to zero by using the FLAG command such as follows:

```
ENTER COMMAND NAME ===> FLAG

ENTER DSN OF DATA POOL ===> J3679.DATAPOOL.DATA
 CURRENT STATUS OF WRITE FLAG = 0
 NOW CHANGE WRITE FLAG TO 0
```

c) DELETE Command

The node name and data are deleted by using the DELETE command. A sample follws as

```
 ENTER COMMAND NAME ===> DELETE

 ENTER DSN OF DATA POOL ===> J3679.TEST00.DATA
 ENTER NODE NAME
 00900 ?
HA92.SELF.FEE4
 NORMAL RETURN  ***  NODE NAME = HA92.SELF.FEE4.
 ENTER NODE NAME
 00900 ?
BAD .NODE.NAME
 ABNORMAL RETURN  ***  NODE NAME = BAD .NODE.NAME.
 ENTER NODE NAME
 00900 ?
/*
```

The node name to be deleted must be specified by the form such as "NOD1. NOD2. NOD3. NOD 4" from the first column. A period between two node names must be specified. The all lower nodes and data including the last node name, NOD4 specified by the user are erased. When the process is successfully ended, "NORMAL RETURN" is displayed. However, the process is not ended completely, "ABNORMAL RETURN" is displayed. To terminate the process, /* CR or CR should be entered.

d) TREE Command

The TREE command displays tree structures of node names as follows:

```
ENTER COMMAND NAME ===> TREE

ENTER DSN OF DATA POOL ===> J3679.TEST00.DATA

                  N O D E   T R E E
TITLE OF A DATA POOL          ***
              RADHEAT-V4 DATA-POOL FOR SKYSHINE CALCULATION
LENGTH OF A RECORD                    ***     900
MAXIMUM NUMBER OF THE SAME LEVEL NODE ***      74
SIZE OF THE DIRECTORY SECTION         ***      40 (USED RECORDS  10)
SIZE OF THE DATA SECTION              ***     928 (USED RECORDS 391)
REMAINS OF THE DIRECTORY SECTION      ***      29
REMAINS OF THE DATA SECTION           ***     534

LEVEL     1       2       3       4       5       6       7       8

    NAGE :  ENERGY GROUP STRUCTURE
     I
     I------INFX :INFINITE DILUTION CROSS SECTION LIBRARY
            I
            I-----1276 :1276 G FROM ENDF/B-IV (300K)
                  I
                  I----- SMT : SMOOTH CROSS SECTIONS
                  I----- FTB : F-TABLE LIBRARY
                  I----- ELA : ELASTIC SCATTERING MATRIX
                  I----- INS : INELASTIC SCATTERING MATRIX
```

```
G09  :  ENERGY GROUP STRUCTURE
 |
 |------TEST :TEST GAMMA-RAY SKYSHINE
         |
         |-----SFX2 :TEST GAMMA-RAY SKYSHINE
         |-----AFX2 :TEST GAMMA-RAY SKYSHINE

HA92 :  ENERGY GROUP STRUCTURE
 |
 |------SELF : SELF-SHIELDING FACTOR
 |------FX16 : ANGULAR MESH
         |
         |-----FEE4 :IRON ENDF/B-IV MACRO X-SEC. 92G
 |
 |------1010 :NO.101 IRON (0.9MFP) SPHERE (30DEG)
         |
         |-----SFX0 :NO.101 IRON (0.9MFP) SPHERE (30DEG)
```

e) CATL Command

The CATL command displays the information of the Directory Section. The sample shown below corresponds to the node structure displayed by the TREE command shown above. In the sample, "INDEX" means the address of physical record. The node name shown as "////" means that the directory is erased. The other variables are referred to Section 4.1.

```
ENTER COMMAND NAME ===> CATL

ENTER DSN OF DATA POOL ===> J3679.TEST00.DATA

                                    D I R E C T O R Y  L I S T
*********  C O N T R O L  S E C T I O N  *********
    COL.
   1-18  TITLE   :
              RADHEAT-V4 DATA-POOL FOR SKYSHINE CALCULATION
     21  ADDRESS FOR THE DIRECTORY OF FIRST LEVEL NODE  :    2
     22  HEAD ADDRESS FOR THE VACANT DIRECTORY AREA     :   13
     23  HEAD ADDRESS FOR THE VACANT DATA AREA          :  436
     24  WRITE FLAG                                     :    0
     25  READ FLAG (NOT USED)                           :    0
     26  LENGTH OF THE ONE PHYSICAL RECORD              :  900
     27  MAXIMUM NUMBER OF THE SAME LEVEL NODE          :   74
     28  SIZE OF THE DIRECTORY SECTION                  :   40
     29  SIZE OF THE DATA SECTION                       :  928
     30  REAL NUMBER OF THE DIRECTORY RECORDS           :   10
     31  REAL NUMBER OF THE DATA SET RECORDS            :  391
*********  D I R E C T O R Y  S E C T I O N  *********
*** INDEX =    2 ***
       NODE NAME =
       ADDRESS FOR THE UPPER NODE DIRECTORY =  0
       NUMBER OF THE LOWER NODE             =  3
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    1    NAGE       1         3        42          1  84-01-20
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                102             0             0             0             0
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    2    G09        1         6       134          1  84-01-24
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  0             9             0             0             0
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    3    HA92       1         8       291          1  84-01-26
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                 92             0             0             0             0
*** INDEX =    3 ***
       NODE NAME = NAGE
       ADDRESS FOR THE UPPER NODE DIRECTORY =  2
       NUMBER OF THE LOWER NODE             =  1
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    1    INFX       1         4        43          1  84-01-20
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  0             0             0             0             0
```

```
*** INDEX =    4 ***
      NODE NAME = INFX
      ADDRESS FOR THE UPPER NODE DIRECTORY =  3
      NUMBER OF THE LOWER NODE             =  1
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    1    1276       1         5        44          1   84-01-20
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
             1276             0             0             0             0

*** INDEX =    5 ***
      NODE NAME = 1276
      ADDRESS FOR THE UPPER NODE DIRECTORY =  4
      NUMBER OF THE LOWER NODE             =  4
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    1     SMT       3         0        45          2   84-01-20
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  0             0             0             0             0
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    2     FTB       4         0        48          2   84-01-20
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  0             0             0             0             0
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    3     ELA      57         0        52         12   84-01-20
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                 18             0             0             0             0
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    4     INS      25         0       109         12   84-01-20
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  0             0             0             0             0
*** INDEX =    6 ***
      NODE NAME = G09
      ADDRESS FOR THE UPPER NODE DIRECTORY =  2
      NUMBER OF THE LOWER NODE             =  1
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    1    TEST       2         7       135          1   84-01-24
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  5            41            29             2            48
*** INDEX =    7 ***
      NODE NAME = TEST
      ADDRESS FOR THE UPPER NODE DIRECTORY =  6
      NUMBER OF THE LOWER NODE             =  2
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    1    SFX2      18         0       137          9   84-01-24
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  0             9             0             0             0
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    2    AFX2     136         0       155         46   84-01-24
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  0             9             0            48             5

*** INDEX =    8 ***
      NODE NAME = HA92
      ADDRESS FOR THE UPPER NODE DIRECTORY =  2
      NUMBER OF THE LOWER NODE             =  3
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    1    SELF       1         9       292          1   84-01-26
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  0             0             0             0             0
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    2    FX16       1        11       296          1   84-01-26
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                 16             0             0             0             0
  NO.    NODE   NRECS     NADWN     NADAT     NDASET      DATE
    3    1010       1        12       434          1   84-01-26
           INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
                  3             9             1             2            16
*** INDEX =    9 ***
      NODE NAME = SELF
      ADDRESS FOR THE UPPER NODE DIRECTORY =  8
      NUMBER OF THE LOWER NODE             =  0
*** INDEX =   10 ***
      NODE NAME = ////
      ADDRESS FOR THE UPPER NODE DIRECTORY =  9
      NUMBER OF THE LOWER NODE             =  2
```

```
 NO.    NODE   NRECS     NADWN     NADAT     NDASET     DATE
   1    1192       1         0       294          1   84-01-26
          INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
             FEE4             2             4             0             0
 NO.    NODE   NRECS     NADWN     NADAT     NDASET     DATE
   2    1274       1         0       295          1   84-01-26
          INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
             FEE4             2             4             0             0
*** INDEX =   11 ***
      NODE NAME = FX16
      ADDRESS FOR THE UPPER NODE DIRECTORY =  8
      NUMBER OF THE LOWER NODE             =  1
 NO.    NODE   NRECS     NADWN     NADAT     NDASET     DATE
   1    FEE4     137         0       297         93   84-01-26
          INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
             FEE4             4             3            95             0
*** INDEX =   12 ***
      NODE NAME = 1010
      ADDRESS FOR THE UPPER NODE DIRECTORY =  8
      NUMBER OF THE LOWER NODE             =  1
 NO.    NODE   NRECS     NADWN     NADAT     NDASET     DATE
   1    SFX0       1         0       435          1   84-01-26
          INFOM(1)      INFOM(2)      INFOM(3)      INFOM(4)      INFOM(5)
               92             0             0             0             0
```

f) LIST Command

The LIST command displays the record information for the node name specified by the user. A sample follows as

```
 ENTER COMMAND NAME ===> LIST

 ENTER DSN OF DATA POOL ===> J3679.TEST00.DATA
 ENTER NODE NAME
 00900 ?
NAGE.INFX.1276
 RECORD INFORMATION FOR NODE NAME NAGE.INFX.1276.
  ITEM         CONTENTS
     1  NODE NAME                =    1276
     2  TOTAL LENG. OF DATA SET =       1
     3  ADDRESS OF A LOWER NODE =       5
     4  ADDRESS OF A DATA SET   =      44
     5  NO. OF SUB-DATA SETS    =       1
     6  DATE OF CREATION        =84-01-20
     8  DATA 1 =           1276
     9  DATA 2 =              0
    10  DATA 3 =              0
    11  DATA 4 =              0
    12  DATA 5 =              0
  ** INFORMATION FOR SUB-DATA SET   1 **
    1276 0 FROM ENDF/B-IV (300K)
    NO. OF DATA ARRAYS =  1
    LENGTH OF DATA 1=    10  LENGTH OF DATA
```

g) RENAME Command

The node names can be renamed by using the RENAME command. The renaming is performed to the last node name specified by the user. To terminate the process, /* CR or CR should be entered. A sample follows as

```
 ENTER COMMAND NAME ===> RENAME

 ENTER DSN OF DATA POOL ===> J3679.TEST00.DATA
 ENTER A OLD NODE NAME
 00900 ?
HA92.SELF
 ENTER A NEW NODE NAME
 00900 ?
HA92.COOP
 RENAME IS FINISHED SUCCESSFULLY
 ENTER A OLD NODE NAME
 00900 ?
/*
```

h) COPY Command

The copy from DATA-POOL to the other data-sets can be performed by using the COPY command. When "*ALL" is entered as a node name, all of data contained in DATA-POOL are copied. If the node names are entered, data with the last node and the lower levels of the node are copied. When the node name already exists in the second data-sets, the copy will not be executed. The second data-sets should be initialized when the data-sets is newly created. To terminate the process, /* CR or CR should be entered. A sample follows as

```
 ENTER COMMAND NAME ===> COPY

 ENTER DSN OF DATA POOL ===> J3679.TEST00.DATA
 ENTER DSN OF 2-ND DATA POOL ===> J3679.DATAPOOL.DATA
 ENTER NODE NAME. IF *ALL IS ENTERD, ALL DATA IS COPIED
 00900 ?
NAGE.INFX.1276
 *** INFORMATION OF DATA POOL USAGE ***
     LOGICAL UNIT NO.        =     92
     DATA SET NAME           = J3679.DATAPOOL.DATA
     NO. OF WRITTEN RECORDS =     92
     REMAINS RECORDS         =    887
 DATA COPY WAS FINISHED SUCCESSFULLY
 ENTER NEXT NODE NAME
 00900 ?
G09 .TEST
 *** INFORMATION OF DATA POOL USAGE ***
     LOGICAL UNIT NO.        =     92
     DATA SET NAME           = J3679.DATAPOOL.DATA
     NO. OF WRITTEN RECORDS =    157
     REMAINS RECORDS         =    730
 DATA COPY WAS FINISHED SUCCESSFULLY
 ENTER NEXT NODE NAME
 00900 ?
/*
```

i) CONDENSE Command

The area for directories and data erased by the DELETE command remains as the unusable area, so that the release of the area can be performed by using the CONDENSE command. The condense procedure with TSS or a batch job can be chosen. In the case of TSS procedure, a sample is shown as follows:

```
 ENTER COMMAND NAME ===> CONDENSE

 EXECUTION OF CONDENSE COMMAND (TSS/BATCH) ===> TSS
 ENTER DSN OF DATA POOL ===> J3679.TEST00.DATA
 BACK-UP DATA SET J3679.CONDENSE          WAS CREATED
 *** INFORMATION OF DATA POOL USAGE ***
     LOGICAL UNIT NO.        =     91
     DATA SET NAME           = J3679.TEST00.DATA
     NO. OF WRITTEN RECORDS =    390
     REMAINS RECORDS         =    538
 ENTRY (A) J3679.CONDENSE DELETED
```

In the case of batch job, the next Job Control Language is displayed. A TSS terminal with FSO (Full Screen Option) or a full screen editor such as IBM-SPF is needed to use the option for the batch job. The sample JCL is shown as follows:

```
ENTER COMMAND NAME ===> COND

EXECUTION OF CONDENSE COMMAND (TSS/BATCH) ===> BATCH

 EDIT-FSO (V01/L06) --- J3679.@POOLJCL.CNTL
==>
ROW SCROLL ==>     PAGE       COLUMN SCROLL ==> 40          NONULLS 50
     ----*----1----*----2----*----3----*----4----*----5----*----6----*----7
0010 //JCLG  JOB
0020 //*****************************************************************
0030 //*        JOB CONTROL LANGUAGE FOR CONDENSE COMMAND               *
0040 //*                                                                *
0050 //*    PLEASE CHANGE JUSER CARD, PASSWORD, DATA POOL NAME AND      *
0060 //*        BACK-UP FILE NAME                                       *
0061 //*    AT END OF CHANGE PLEASE ENTER SUBMIT COMMAND                *
0070 //*                                                                *
0080 //*****************************************************************
0090 // EXEC JCLG
0100 //SYSIN DD DATA,DLM='++'
0110 // JUSER ????????,XX.XXXXXX,YYYY.ZZZ
0120  T.4 C.1 W.0 I.5 P.0 OPN
0130  OPTP PASSWORD=??
0140 // EXEC LMGO,LM='J3679.POOLX',PNM=COND
0150 //*   DATA POOL
0160 //*    CHANGE DSN:DATA SET NAME
0170 // EXPAND DISKTO,DDN=FT91F001,DSN='JXXXX.????????',MODE=OUT
0180 //*   BACK-UP FILE
0190 //*    CHANGE DSN:DATA SET NAME
0220 // EXPAND DISKTN,DDN=FT01F001,DSN='JXXXX.@@BACKUP',UNIT=TSSWK,
0230 //        SPC='500,300'
0240 // EXPAND DISK,DDN=FT02F001
0250 ++
0260 //
*** END OF DATA SET ***
```

The condensation starts after the backup data-set is created. When the condensation is abnormally terminated and the data-set is destroyed, the recovery of the data can be performed by using a MTCOPY command. The description of the MTCOPY command is shown later.

j) MEND Command

The MEND command has been prepared for reconstruction of DATA-POOL when the data set is destroyed. The user can directly change data in the Control, the Directory and the comment of the Data Sections, so that the revision of tree structures, information in the sub-directory and control variables are also possible. The user should search the structure of data-linkage by using the CATL command before the MEND command is executed.

At the first stage of MEND execution, 3 options can be selected by the user. The option names are CONT, DIREC and COM that must be entered from the first column. The CONT option is used for the revision for the Control Section of DATA-POOL. A sample is shown as follows:

```
ENTER COMMAND NAME ===> MEND

ENTER DSN OF DATA POOL ===> J3679.DATAPOOL.DATA
 ++ DATA POOL INFORMATION ++
 TITLE :
         RADHEAT-V4 DATA-POOL FOR CROSS SECTIONS STORAGE
 1ST. RECORD NO. OF DIRECTORY :    2
LAST  RECORD NO. OF DIRECTORY :    7
REAL  RECORD NO. OF DIRECTORY :    6
WRITE PERMIT OF THE DATA POOL :    0
ENTER OPTION NAME  CONT/DIREC/COM/END
00320 ?
```

```
CONT
 *********  C O N T R O L  S E C T I O N  *********
      ITEM
        1  TITLE   :
                RADHEAT-V4 DATA-POOL FOR CROSS SECTIONS STORAGE
       21  ADDRESS FOR THE DIRECTORY OF FIRST LEVEL NODE  :    2
       22  HEAD ADDRESS FOR THE VACANT DIRECTORY AREA     :    8
       23  HEAD ADDRESS FOR THE VACANT DATA AREA          :  271
       24  WRITE FLAG                                     :    1
       25  READ FLAG (NOT USED)                           :    0
       26  LENGTH OF THE ONE PHYSICAL RECORD              :  900
       27  MAXIMUM NUMBER OF THE SAME LEVEL NODE          :   74
       28  SIZE OF THE DIRECTORY SECTION                  :   20
       29  SIZE OF THE DATA SECTION                       :  979
       30  REAL NUMBER OF THE DIRECTORY RECORDS           :    6
       31  REAL NUMBER OF THE DATA SET RECORDS            :  249
 ENTER ITEM NO. TO MEND. IF ENTER 0, END TO PROCESS
 00550 ?
1
 ENTER NEW TITLE
 00630 ?
DATA-POOL COPIED FROM J3679.TEST00.DATA
 ENTER ITEM NO. TO MEND. IF ENTER 0, END TO PROCESS
 00550 ?
0
 END OF MENDING A CONTROL SECTION SUCCESSFULLY
 *********  C O N T R O L  S E C T I O N  *********
      ITEM
        1  TITLE   :
       DATA-POOL COPIED FROM J3679.TEST00.DATA
       21  ADDRESS FOR THE DIRECTORY OF FIRST LEVEL NODE  :    2
       22  HEAD ADDRESS FOR THE VACANT DIRECTORY AREA     :    8
       23  HEAD ADDRESS FOR THE VACANT DATA AREA          :  271
       24  WRITE FLAG                                     :    1
       25  READ FLAG (NOT USED)                           :    0
       26  LENGTH OF THE ONE PHYSICAL RECORD              :  900
       27  MAXIMUM NUMBER OF THE SAME LEVEL NODE          :   74
       28  SIZE OF THE DIRECTORY SECTION                  :   20
       29  SIZE OF THE DATA SECTION                       :  979
       30  REAL NUMBER OF THE DIRECTORY RECORDS           :    6
       31  REAL NUMBER OF THE DATA SET RECORDS            :  249
```

The user selects items to be changed from the item No. (1～3). The new value or title is entered next. These entries are given by a free format. The sequence is repeated untill a CR or a 0 CR entry. The revised Control Section is displayed at the end of processing, and a next option is required. To terminate the MEND command, enter an END command.

The DIREC option is used to change the Directory Section. The user can change the sub-directory (SUB) and the head information defined in the directory (HEAD). A sample is shown below for the case of revision of the sub-directory.

```
 ENTER OPTION NAME  CONT/DIREC/COM/END
 00320 ?
DIREC
 ENTER NODE NAME. IF ENTER NOTHING, END TO PROCESS
 00900 ?
NAGE.INFX.1276. SMT
 ENTER OPTION NAME  SUB/LOW
 01040 ?
SUB
  ITEM         CONTENTS
     1  NODE NAME                =      SMT
     2  TOTAL LENG. OF DATA SET  =        3
     3  ADDRESS OF A LOWER NODE  =        0
     4  ADDRESS OF A DATA SET    =       25
     5  NO. OF SUB-DATA SETS     =        2
     6  DATE OF CREATION         =84-01-20
     8  DATA 1 =              0
     9  DATA 2 =              0
```

```
   10  DATA 3 =              0
   11  DATA 4 =              0
   12  DATA 5 =              0
 ENTER ITEM NO. TO MEND OR DEL TO DELETE THIS SUB-DIRECTORY
  IF ENTER 0, END TO MEND THE SUB-DIRECTORY
 01210 ?
11
 ENTER NEW VALUE
 01430 ?
777
 INPUT VALUE WAS INTEGER TYPE   777
 ENTER ITEM NO. TO MEND OR DEL TO DELETE THIS SUB-DIRECTORY
  IF ENTER 0, END TO MEND THE SUB-DIRECTORY
 01210 ?
0
 END OF MENDING A SUB-DIRECTORY SECTION SUCCESSFULLY
  ITEM         CONTENTS
     1  NODE NAME                =     SMT
     2  TOTAL LENG. OF DATA SET =       3
     3  ADDRESS OF A LOWER NODE =       0
     4  ADDRESS OF A DATA SET   =      25
     5  NO. OF SUB-DATA SETS    =       2
     6  DATE OF CREATION        =84-01-20
     8  DATA 1 =              0
     9  DATA 2 =              0
    10  DATA 3 =              0
    11  DATA 4 =            777
    12  DATA 5 =              0
```

In the option, the node names to be revise must be entered such as "NOD1. NOD2. NOD3. NOD4" from the first column. The user selects items to be changed from the item No. (1～12) or enters a DEL command from the first column to erase the sub-directory. When the item No. is entered, the new value must be entered next. The format is free but a real quantity should be less than 13 digits including a decimal point. The process is repeated unitil CR or 0 CR is entered.

A sample is shown below when the option of "HEAD" is entered.

```
 ENTER OPTION NAME  CONT/DIREC/COM/END
 00320 ?
DIREC
 ENTER NODE NAME. IF ENTER NOTHING, END TO PROCESS
 00900 ?
NAGE.INFX.1276
 ENTER OPTION NAME  SUB/HEAD
 01040 ?
HEAD
 DIRECTORY HEAD
 ITEM     CONTENTS
   1   NODE NAME 1              1276
   2   NODE NAME 2
   3   UPPER DIRECTORY ADDRESS     4
   4   NO. OF SUB-DIRECTORY        4
 NODE NAMES FOR EACH SUB-DIRECTORY
   SMT    FTB    ELA    INS
 ENTER ITEM NO. TO MEND OR DEL TO DELETE THIS DIRECTORY HEAD
  IF ENTER 0, END TO MEND THE DIRECTORY
 01890 ?
DEL
 DIRECTORY HEAD1276 WAS DELETED
 ENTER OPTION NAME  CONT/DIREC/COM/END
 00320 ?
END
 END OF MEND COMMAND
```

The directory has the node names and the linkage information consisting of 4 variables at the first part of each record. The user can change the tree structures of node names by using the "HEAD" option and setting 3 or 4 to the item No. If the user enters "DEL" from the first column, the directory and the linkage of the lower sub-directories are erased.

When the option of "COM" is selected, the commands of the sub-data sets are displayed. The user selects the sub-data set No. and enters a new comment (80 characters). The sequence is repeated until 0 CR or CR is entered. A sample is given as follows:

```
 ENTER OPTION NAME  CONT/DIREC/COM/END
 00320 ?
COM
 ENTER NODE NAME. IF ENTER NOTHING, END TO PROCESS
 00900 ?
NAGE.INFX
 NO. OF SUB-DATA-SET IS   1
 DAT NO.        COMMENT
      1   INFINITE DILUTION CROSS SECTION LIBRARY
 ENTER DAT NO. TO MEND. IF ENTER 0, END TO PROCESS
 02470 ?
1
 ENTER NEW COMMENT
 02540 ?
    INFINITE DILUTION CROSS SECTIONS
 ENTER DAT NO. TO MEND. IF ENTER 0, END TO PROCESS
 02470 ?
0
 END OF MENDING DATA COMMENTS SUCCESSFULLY
 DAT NO.        COMMENT
      1      INFINITE DILUTION CROSS SECTIONS
```

The MEND command requires the complicated data entries, so that the user should take care to enter exact values. The operations flow of the MEND command is shown in **Fig. 4.7**.

k) MTSAVE Command

The MTSAVE command generates a Job Control Language for deposit the data in DATA-POOL with a backup tape or a sequential data-set. The user specifies the data-set names of DATA-POOL and of MT, the volume serial No. and the position, then enters an EDIT-mode command of "SUBMIT". A TSS terminal with FSO is needed to use the command. A sample JCL is shown as follows:

```
 ENTER COMMAND NAME ===> MTSAVE

  EDIT-FSO (VOI/LO6) --- J3679.@POOLJCL.CNTL
==>
 ROW SCROLL ==>     PAGE       COLUMN SCROLL ==> 40          NONULLS 50
      ----*----1----*----2----*----3----*----4----*----5----*----6----*----7
 0010 //JCLG  JOB
 0020 //*****************************************************************
 0030 //*        JOB CONTROL LANGUAGE FOR MTSAVE COMMAND                *
 0040 //*                                                               *
 0050 //*    PLEASE CHANGE JUSER CARD, PASSWORD, DATA POOL NAME AND     *
 0060 //*        BACK-UP TAPE NAME                                      *
 0061 //*    AT END OF CHANGE PLEASE ENTER SUBMIT COMMAND               *
 0070 //*                                                               *
 0080 //*****************************************************************
 0090 // EXEC JCLG
 0100 //SYSIN DD DATA,DLM='++'
 0110 // JUSER ????????,XX.XXXXXX,YYYY.ZZZ
 0120  T.4 C.1 W.0 I.5 P.0 OPN MTU
 0130  OPTP PASSWORD=??
 0140 // EXEC LMGO,LM='J3679.POOLX',PNM=MTSAVE
 0150 //*   DATA POOL
 0160 //*    CHANGE DSN:DATA SET NAME
 0170 // EXPAND DISKTO,DDN=FT91F001,DSN='JXXXX.????????'
```

```
0180 //*   BACK-UP TAPE
0190 //*    CHANGE DSN:DATA SET NAME
0200 //*           MTV:VOLUME NUMBER OF A TAPE
0210 //*           POS:DATA SET POSITION ON A TAPE
0220 // EXPAND TAPE,DDN=FT01F001,DSN='JXXXX.????????',MTV=??????,MTU=TAPE,
0230 //        POS=?,DISP='NEW,PASS'
0240 // EXPAND DISK,DDN=FT02F001
0250 ++
0260 //
*** END OF DATA SET ***
```

1) MTCOPY Command

The MTCOPY command is prepared to recover data from a MT or a sequential data-set deposited by using the MTSAVE command. The user specifies the data-set names of DATA-POOL and of MT, the volume serial No. and the position, then enters an EDIT-mode command of "SUBMIT". A sample JCL is shown as follows:

```
ENTER COMMAND NAME ===> MTCOPY

 EDIT-FS0 (V01/L06) --- J3679.@POOLJCL.CNTL
==>
ROW SCROLL ==>     PAGE       COLUMN SCROLL ==> 40          NONULLS 50
     ----*----1----*----2----*----3----*----4----*----5----*----6----*----7
0010 //JCLG  JOB
0020 //*****************************************************************
0030 //*        JOB CONTROL LANGUAGE FOR MTCOPY COMMAND                 *
0040 //*                                                                *
0050 //*    PLEASE CHANGE JUSER CARD, PASSWORD, DATA POOL NAME AND      *
0060 //*        BACK-UP TAPE NAME                                       *
0061 //*    AT END OF CHANGE PLEASE ENTER SUBMIT COMMAND                *
0070 //*                                                                *
0080 //*****************************************************************
0090 // EXEC JCLG
0100 //SYSIN DD DATA,DLM='++'
0110 // JUSER ????????,XX.XXXXXX,YYYY.ZZZ
0120  T.4 C.1 W.0 I.5 P.0 OPN MTU
0130  OPTP PASSWORD=??
0140 // EXEC LMGO,LM='J3679.POOLX',PNM=MTCOPY
0150 //*   DATA POOL
0160 //*    CHANGE DSN:DATA SET NAME
0170 // EXPAND DISKTO,DDN=FT91F001,DSN='JXXXX.????????',MODE=OUT
0180 //*   BACK-UP TAPE
0190 //*    CHANGE DSN:DATA SET NAME
0200 //*           MTV:VOLUME NUMBER OF A TAPE
0210 //*           POS:DATA SET POSITION ON A TAPE
0220 // EXPAND TAPE,DDN=FT01F001,DSN='JXXXX.????????',MTV=??????,MTU=TAPE,
0230 //        POS=?
0240 ++
0250 //
*** END OF DATA SET ***
```

Note that excess data more than 50000 words in the sub-data set can not be treated by using the MTCOPY and the MTSAVE commands. When the recovery of DATA-POOL is performed by using the MTCOPY command, the DATA-POOL should be initialized before the batch job is submitted. The title in the Control Section will be replaced to the title in the backup tape.

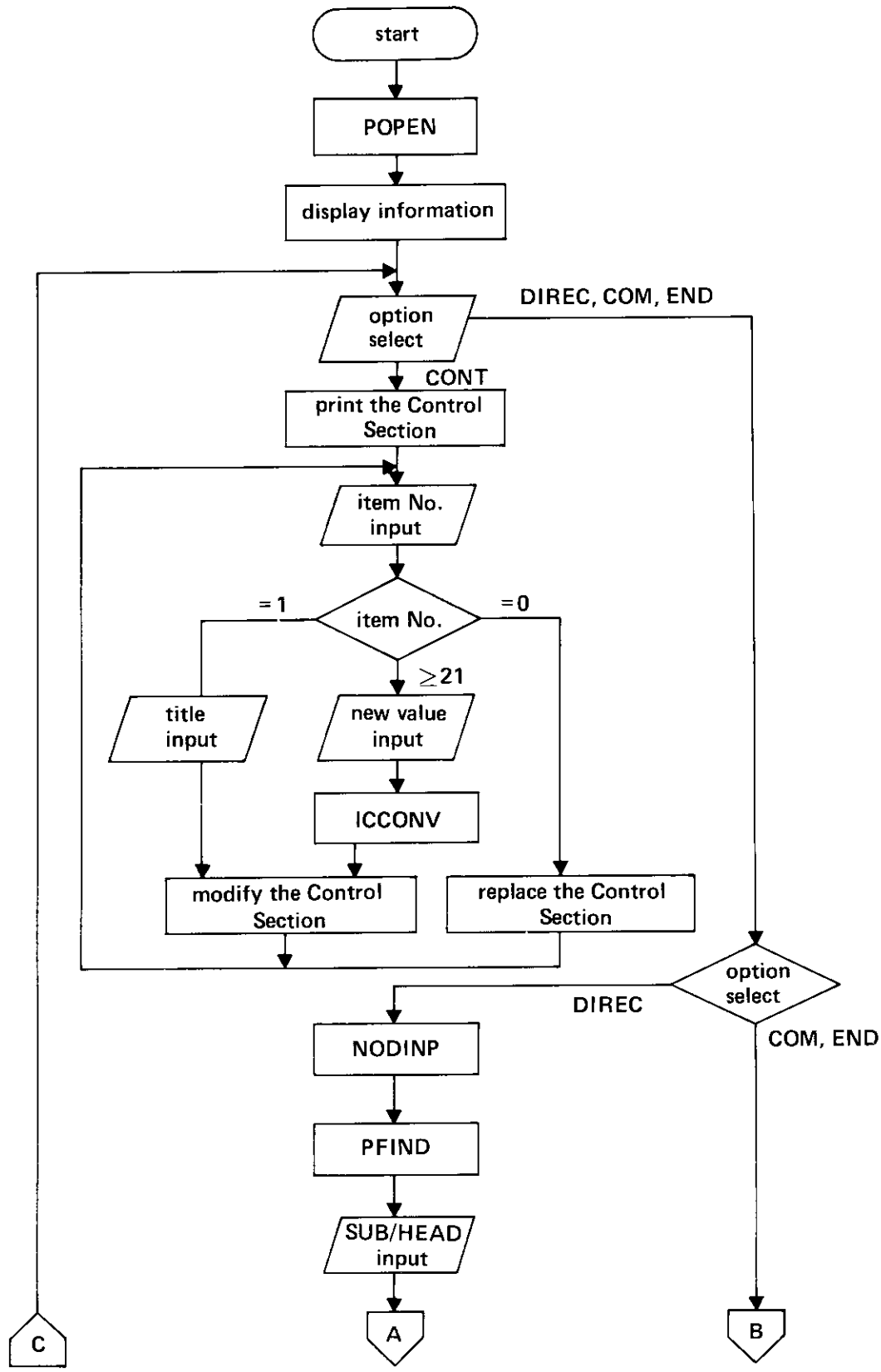


Fig. 4.7 Schematic flow in the utility POOL

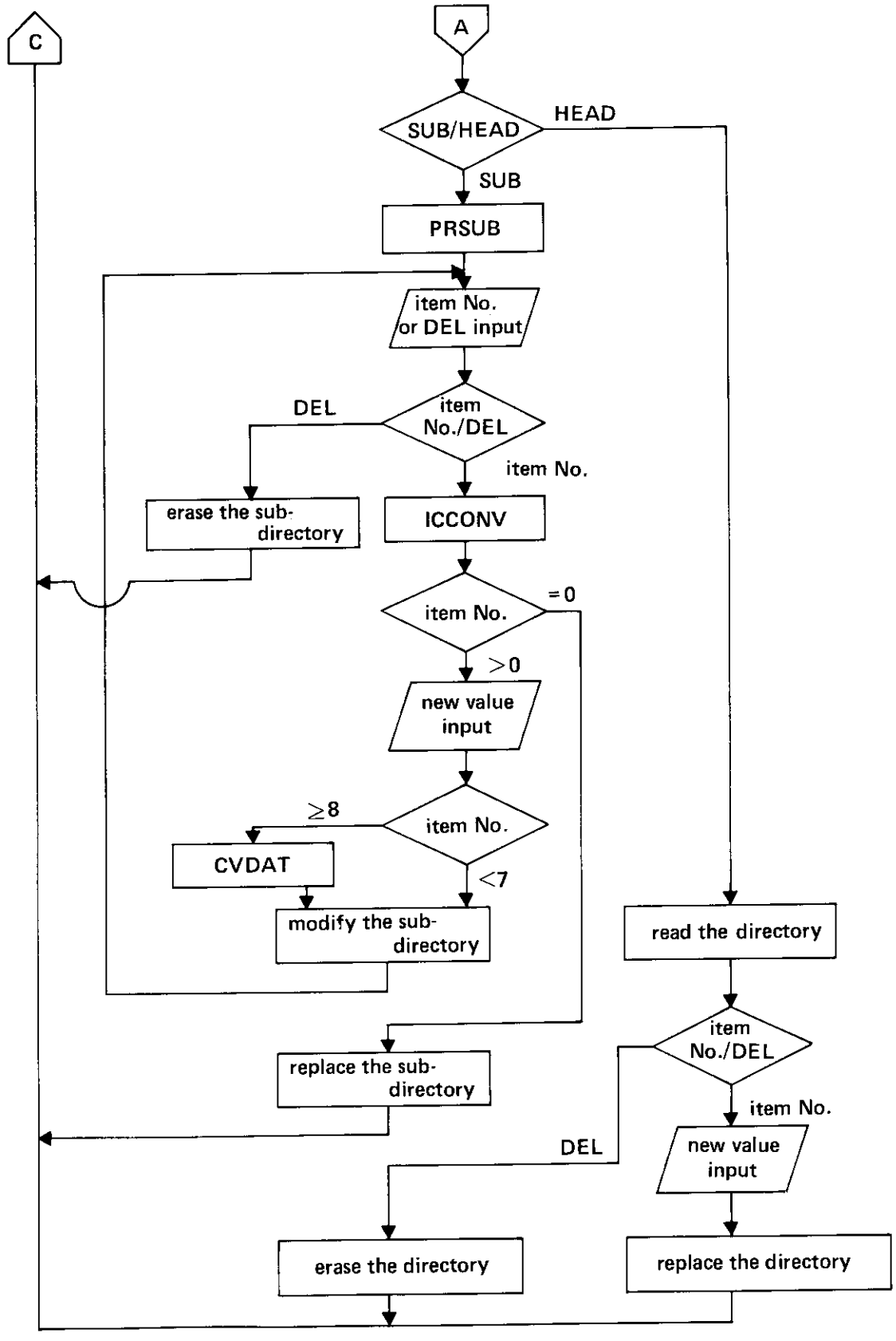


Fig. 4.7 (continued)

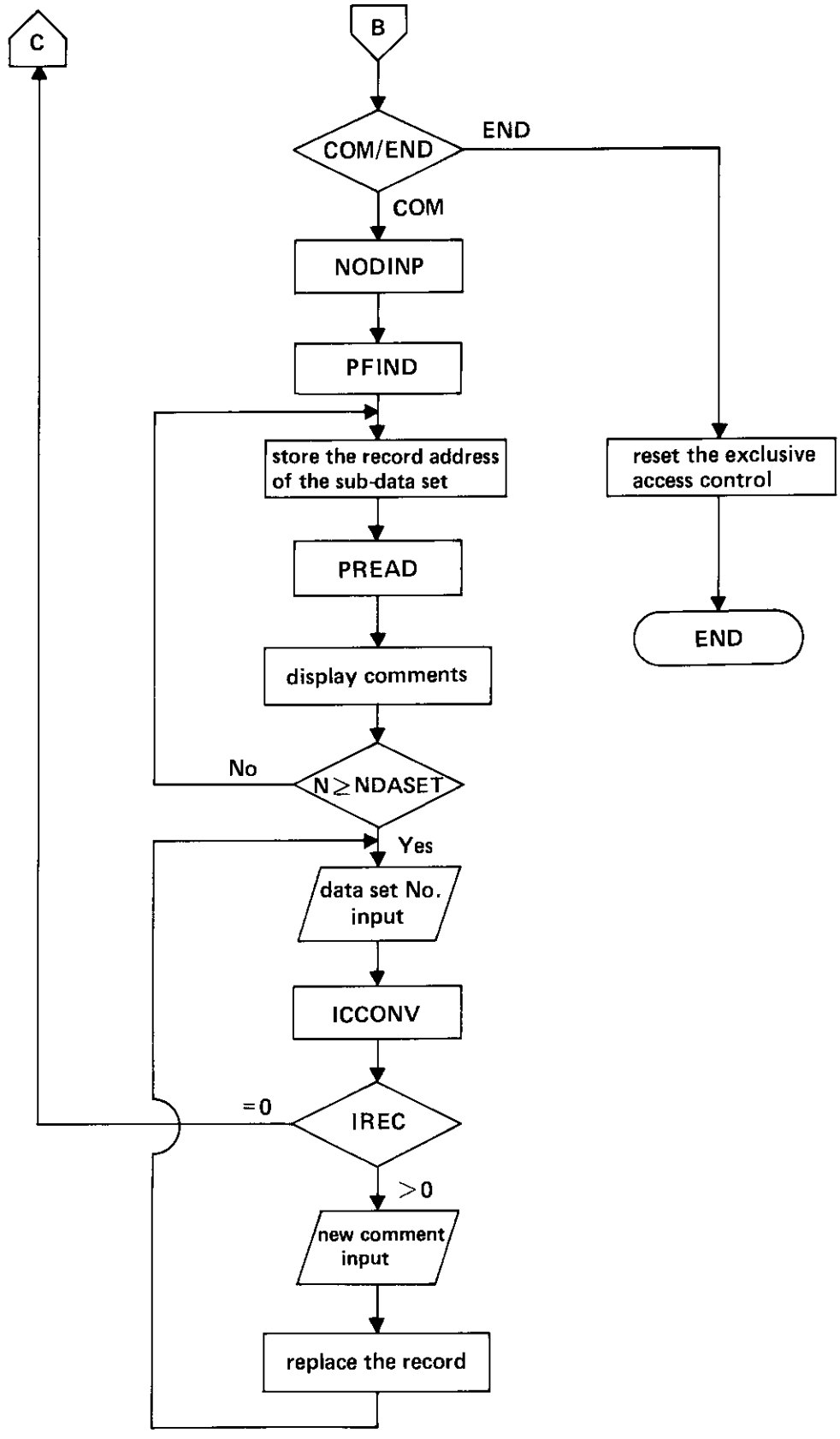


Fig. 4.7 (continued)

4.2.2 Input/Output File Assignment

The utility POOL requires various direct-access devices during execution. **Table 4.2** shows the names of the data sets. The logical unit number marked with a circle in the table is required to execute the job. The value for the first memory space estimation is changed by the various conditions of computation, so that it is roughly estimated. On the conversational operation with a TSS terminal, scratch data sets are automatically allocated, so that the user is required only to set the data set name of DATA-POOL according to prompt messages displayed on the TSS terminals.

4.2.3 Job Control Language

When the utility POOL is to be executed by a batch job, the following operation is required.

The load module of POOL is generated by each command name, so that the executions are performed by specifying the program name (PNM name).

// EXEC LMGO, LM='J3679.POOLX', PNM=program name

Table 4.2 shows the program names. The input data for each program are the same as the data entries described in Section 4.2.1. The entry of carriage return can be replaced by a blank card.

The cataloged procedure using the conversational operation described in Section 4.2.1 is shown in **Fig. 4.8**.

Table 4.2 Requirements for external data sets in POOL

Commands	Scratch		DATA-POOL		J3679. POOLX. LOAD	J3679. TSSMAC. CNTL
	FT01F001	FT02F001	FT91F001	FT92F001		
HELP					○	
INIT			○		○	
FLAG			○		○	
DELETE			○		○	
TREE			○		○	
CATL			○		○	
LIST			○		○	
RENAME			○		○	
COPY	○	○	○	○	○	
CONDENSE	○	○	○		○	○
MEND			○		○	
MTSAVE	○		○		○	○
MTCOPY	○		○		○	○
END					○	
contents	data for backup	data for directory	used as 1st. DSN	used as 2nd. DSN	load module	JCL file
1st. space estimation (tracks)	500	10	—	—	168	1
DCB information LRECL	19064	6400	3600	3600	0	80
DCB information BLKSIZE	19068	6404	3600	3600	13030	3120
DCB information RECFM	VBS	VBS	F	F	U	FB

```
PROC 0
CONTROL PROMPT
FREE ATTRLIST(B)
FREE ATTRLIST(DCB)
ATTR B LRECL(133) RECFM(U A)
ATTR DCB LR(3600) BL(3600) REC(F)
FREE F(FT01F001)
FREE F(FT02F001)
FREE F(FT06F001)
FREE F(FT91F001)
ALLOC DA(*) F(FT06F001) USING(B)
WRITE    ***** STARTS RADHEAT-V4 DATA POOL UTILITY *****
STAT:WRITENR ENTER COMMAND NAME ===>
READ &ELM
IF &ELM=INIT THEN GOTO JUMP1
IF &ELM=F    THEN SET &ELM=FLAG
IF &ELM=FLAG THEN GOTO JUMP2
IF &ELM=DEL  THEN SET &ELM=DELETE
IF &ELM=DELETE THEN GOTO JUMP2
IF &ELM=T    THEN SET &ELM=TREE
IF &ELM=TREE THEN GOTO JUMP2
IF &ELM=C    THEN SET &ELM=CATL
IF &ELM=CATL THEN GOTO JUMP2
IF &ELM=MEND THEN GOTO JUMP2
IF &ELM=L    THEN SET &ELM=LIST
IF &ELM=LIST THEN GOTO JUMP2
IF &ELM=RE   THEN SET &ELM=RENAME
IF &ELM=RENAME THEN GOTO JUMP2
IF &ELM=COPY THEN GOTO JUMP4
IF &ELM=CONDENSE THEN SET &ELM=COND
IF &ELM=COND THEN GOTO JUMP3
IF &ELM=MTSAVE THEN GOTO JUMP5
IF &ELM=MTCOPY THEN GOTO JUMP5
IF &ELM=HELP THEN GOTO RUN
IF &ELM=END  THEN GOTO FINIS
WRITE ERROR COMMAND NAME. PLEASE RECONFIRM BY HELP COMMAND
GOTO STAT
JUMP1:WRITENR ENTER DSN OF DATA POOL ===>
READ &DSN
WRITENR ALLOCATION OF DATA SET (NEW/OLD) =====>
READ &ANS
IF &ANS=OLD THEN +
   DO
   ALLOC F(FT91F001) DSN('&DSN') SHR
   GOTO RUN
   END
WRITENR UNIT PARAMETER          ===============>
READ &UNIT
WRITENR SPACE PARAMETER (1-ST SPACE )   ======>
READ &SPC
WRITENR SPACE PARAMETER (INCREMENT)     ======>
READ &INC
WRITENR SPACE PARAMETER (SPACE UNIT T/CY ) ===>
READ &T
IF &UNIT=MSS THEN GOTO JUMP11
ALLOC DA('&DSN') F(FT91F001) UNIT(&UNIT) SP(&SPC &INC) &T US(DCB) +
 NEW CAT
GOTO RUN
JUMP11:WRITENR MSS GROUP        ================>
READ &MSVGP
WRITENR MSS VOLUME NUMBER       ================>
READ &VOL
ALLOC DA('&DSN') F(FT91F001) UNIT(&UNIT) MSVGP(&MSVGP) VO(&VOL)  +
 SP(&SPC &INC) &T US(DCB) NEW CAT
GOTO RUN
JUMP2:WRITENR ENTER DSN OF DATA POOL ===>
READ &DSN
ALLOC F(FT91F001) DSN('&DSN') SHR
GOTO RUN
JUMP3:WRITENR EXECUTION OF CONDENSE COMMAND (TSS/BATCH) ===>
READ &TSS
IF &TSS=TSS THEN GOTO JUMP4
GOTO JUMP5
JUMP4:WRITENR ENTER DSN OF DATA POOL ===>
READ &DSN
ALLOC F(FT91F001) DSN('&DSN') SHR
IF &ELM=COPY THEN +
   DO
   WRITENR ENTER DSN OF 2-ND DATA POOL ===>
   READ &DSN2
   ALLOC DA('&DSN2') F(FT92F001) SHR
   END
ALLOC DSN(CONDENSE) F(FT01F001) NEW SP(500 200) T UNIT(TSSWK) CAT
ALLOC F(FT02F001) NEW SP(10 10) T UNIT(TSSWK)
GOTO RUN
JUMP5:COPY 'J3679.TSSMAC.CNTL(&ELM)' @POOLJCL.CNTL
E @POOLJCL.CNTL CN;FS
DEL @POOLJCL.CNTL
GOTO STAT
RUN:CALL 'J3679.POOLX.LOAD(&ELM)'
IF &ELM NE HELP THEN FREE F(FT91F001)
IF &ELM=COPY OR &ELM=COND THEN +
   DO
   DEL CONDENSE
   FREE F(FT02F001)
   END
GOTO STAT
FINIS:FREE ATTRLIST(B)
FREE ATTRLIST(DCB)
FREE F(FT06F001)
EXIT
```

Fig. 4.8 Cataloged procedure of POOL

4.3 VISUAL

The utility VISUAL has been prepared to plot various data generated by the RADHEAT–V4 code system. The VISUAL is executed by conversational operations with a TSS terminal of TEKTRONIX T4014. It can be also executed by batch job stream to plot graphs on digital graphic equipments, COM (Computer Output Microfilm) and NLP (Nihongo Laser Printer). The hierarchy of VISUAL in the RADHEAT–V4 code system and the general flow are shown in **Figs. 4.9** and **4.10**, respectively.

To achieve simplified conversational operations, a concept of Conversational Management Mode (CMM) is adopted in VISUAL. The CMM consists of 28 commands and controls the plotting procedure.

The graphic patterns plotted with VISUAL are of three types that are two–dimensional graph ($f(x)$; x), contour–line map ($f(x,y);x,y$) and three–dimensional graph as the bird's eye view ($f(x,y);x,y$). These patterns are defined as MODE–1, MODE–2 and MODE–3 in the CMM operation. Parameters and variables to determine the plotting forms for each mode can be fixed to default values defined in the program. The values can be easily altered by the user.

This flow diagram of CMM is shown in **Fig. 4.11** and the functions of the commands are described below:

(a) Command to enter into the MODE–x

MOD1	Entry command for MODE–1.
MOD2	Entry command for MODE–2.
MOD3	Entry command for MODE–3.
END	Terminate the execution of the MODE.

(see **Table 4.3～4.5** for the variables)

(b) Command to set the default values

DEFAULTC	Set the default values for the common variables.
DEFAULT1	Set the default values for MODE–1.
DEFAULT2	Set the default values for MODE–2.
DEFAULT3	Set the default values for MODE–3.

(see **Table 4.3～4.5** for the default values)

(c) Comand to display the executing variables

LISTC	Display the executing common variables.
LIST1	Display the executing variables for MODE–1.
LIST2	Display the executing variables for MODE–2.
LIST3	Display the executing variables for MODE–3.

(d) Command to describe the functions of the executing variables

TABLEC	Describe the functions of the common variables.
TABLE1	Describe the functions of the MODE–1 variables.
TABLE2	Describe the functions of the MODE–2 variables.
TABLE3	Describe the functions of the MODE–3 variables.

(e) Command to update the executing variables

UPDATEC	Update the executing common variables.
UPDATE1	Update the executing variables for MODE–1.
UPDATE2	Update the executing variables for MODE–2.
UPDATE3	Update the executing variables for MODE–3.
ENDU	Terminate the updating of the executing variables. This command must be used after UPDATEC, UPDATE1, UPDATE2 and UPDATE3 commands.

(f) Command to execute plotting

RUN1 Execute MODE-1 plot.

RUN2 Execute MODE-2 plot.

RUN3 Execute MODE-3 plot.

(g)

HELP Display the functions of all commands.

(h)

TIME Show the used CPU time.

(i)

NLPW Write the executing data in the sequential file on logical unit FT50F001 for plotting with NLP.

(j)

BYE Terminate the execution of VISUAL.

Captions and comments inserted in the graph are processed by the Text Management Mode (TMM) which enables the user to display capital, lower case and special letters including super- or sub-script form by using simple indicators.

The input instruction for the utility VISUAL is described in the following section. The requirement for data sets during execution is described in Section 4.3.2. The Job Control Language for VISUAL is shown in Section 4.3.3. The detailed information is also referred to in the report of VISUAL[24].

4.3.1 Input Instruction

The input data for VISUAL are given in the free form. In the CMM and TMM operations, variable names are defined for each mode. The value for each variable is given by the following notation:

variable name=value;.

The variable names and the definitions for each mode are shown in **Tables 4.3**, **4.4** and **4.5**, respectively. In these tables, "Size" means the number of array and "Default" indicates that variable has been given the default value. If the variable size is more than one, the variable names are written as follows:

variable name (1)=value 1; variable name (2)=value 2;

In the case that the variable size is of two-dimensions, data are given as

variable name (1)=value 1 value 2 value 3 ----,

variable name (2)=value 4 value 5 value 6 ----.

The arbitrary form is allowable to set the value as follows:

1.236+3, 1.236E+3, 1.236E3, 1236.0 or 1236.

In the TMM operation, captions and comments are given as follows:

variable name=document;.

The input fields from the column 1 to 80 are usable and the semicolon (;) must be given as the partition of the data. The notation can be set in succession and in arbitrary order.

In the TMM operation, the VISUAL can be to plot the main title, the captions of the X-, Y- and Z -axes, the legend using Greek characters and the other special symbols according as the following procedure. The text consists of the character control command and the character lines. The plotting symbols written with capital and lower case letters treated by TMM are shown in **Tables 4.6(a)** and **4.6 (b)**, respectively.

The character control commands control the form of the character lines. Usually, the text are written with lower case letters of English and numerals used in the FORTRAN language. The character control command changes the character form of the following character lines. The character control commands are used as follows:

(i) $
The character lines after this command are written with capital letters until "?" command appears.

(ii) ?
After this command, the functions of all commands are reset and the character lines are written with lower case letters of English and numerals.
Moreover, this is used to reset the function of super–/sub–script.

(iii) @
After this command, all of the character lines are plotted as the super–script until "?" command appears.

(iv) "
After this command, all of the character lines are plotted as the sub–script until "?" command apears.

(v) !
This command is used to plot Greek letters or the other special characters that are defined by the code number written in three digits. After this command, the code number of the three digits is given as a character line. The code numbers of the special characters are described in **Tables 4.6(a)** and **4.6(b)**.

Examples:
"$N?EUTRON YIELDS OF @239?$P?U$–B?E$(?!042107?N$) ?SOURCES" is displayed as "Neutron yields of ^{239}Pu–Be(α, n) sources", and
"$B?OUCHER@26)? DETERMINED THIS TO BE $1.23!023?$0.05?FOR $C?M"2?$0?"3?" is displayed as
"Boucher[26] determined this to be 1.23 ± 0.05 for Cm_2O_3".

As shown in these examples, the character control command can be written in succession. It is noted that the user should not write a blank after the command "!", because it causes an error.

Examples:

(i) $@
After these commands, the character lines are plotted as super–script with capital letters.

(ii) ?"!035
After these commnds, π is plotted as sub–script with a lower case letter.

(iii) $@!034061043
After these commands, $\mu\times\delta$ is plotted as super–script with capital letters.

Once a character control command is given, the function continues until the reset command "?" appears.

The user can execute the utility VISUAL effectively by using various operation commands in the CMM and TMM. A sample input operation is shown below to demonstrate the usage of these commands. In the description, the sentence with underline shows the user's input, <re> means carriage return and "b" indicates a blank space. When the execution of VISUAL is started, the message for functions of each mode is displayed. One of these commands should be entered subsequently and then the message is displayed that the default values are set to the executing variables. Operations are shown as follows:

```
      *** PLEASE KEY IN COMMAND ***
(1)   ? LISTC <re>
      *** PLEASE KEY IN COMMAND ***
```

(2) ? UPDATEC <re>
*** PLEASE KEY IN UPDATE STRING (UPDATEC) ***

(3) ? XTITL=$N?EUTRON $E?NERGY $(?E$V); <re>
? YTITL=$C?ROSS $S?ECTION $(?BARN/SR/$M?E$V); <re>

(4) ? UNIT(1)=91;UNIT(2)=91;UNIT(3)=91; <re>

(5) ? NODE(1)=EXPbbbbb0000bbbbbb92; <re>
? NODE(2)=102G; <re>
? NODE(3)=102GbbbbDDXbbbbb1001bbbbbb33; <re>

(6) ? CODE(1)=0b7b7b7b7; <re>
? CODE(2)=0b1b2b3b4; <re>
? XW=150.0;YW=130.0; <re>

(7) ? ENDU <re>
<The screen is cleared automatically>
*** PLEASE KEY IN COMMAND ***

These operations correspond to the following executions:

(1) : The table for the common variables is displayed. (see **Table 4.3**)
(2) : The command to update the executing data for the common variables is entered.
(3) : This indicates to update XTITL.
(4) : This indicates a update string.
(5) : The variable name NODE is declared double-precision, so that 8 characters are entered in a word.
(6) : A blank space is inserted in the type of two-dimensional array.
(7) : This indicates the end of updating.

After these operations, the user can enter "RUN1" command to plot a graph. After plotting a graph, when XN=0.0 and YN=0.0 (see **Table 4.3**) has been given, hair-line cursors are displayed. The user can set them to the arbitrary initial X-Y coordinates and key in the carriage return after a space entry. Then the comment and the sub-title are plotted on the graph.

If the hair-line cursors are set on the X and Y axes within 5 millimeters and key in the carriage return after a space entry, the plotting graph is cleared. Then, the comment and the sub-title are plotted. If the user enters "NLPW" command, XN and YN are given negative values, then the plotting data is stored in a work file on logical unit FT50F001. If XN and YN are less than 0.0, the comment and the sub-title are plotted on the next page of the graph.

Command "END" is used to execute the other mode. After plotting a graph, if the user inputs the command "END", the system urges him to enter the modal option.

Example:

<Plot a graph of MODE-1>

*** PLEASE KEY IN COMMAND ***
? END <re>
*** PLEASE KEY IN MODAL OPTION ***

? MOD2 <re>
*** DEFAULT VALUE SET FOR COMMON DATA ***
*** DEFAULT VALUE SET FOR MODE-2 DATA ***
*** PLEASE KEY IN COMMAND ***

It is posible that the user sets the default values for the common variables, MODE–1, MODE–2 or MODE–3 variables anytime by using the command DEFAULTC, DEFAULT1, DEFAULT2 and DEFAULT3, respectively.

4.3.2 Input/Output File Assignment

VISUAL requires various direct–access data sets during execution. The logical unit numbers for the data sets depend on the conditions of input data. They must be allocated before the execution. **Table 4.7** shows the minimum requirements for the data sets.

4.3.3 Job Control Language

The Job Control Language of VISUAL for TSS operation and for batch job at JAERI are described below. In the description, sentences with underline indicates the user's input and <re> means a carriage return.

1) TSS Operation

PLEASE LOGON
(a) LOGON TSS J$$$$/???? S(1024) <re>

Session open messages are displayed.

READY
(b) .PTSIO <re>
(c) .DISKTO DD(FT91F001) DSN('J$$$$.AAAA.DATA') <re>

(d) <Key in the procedures to allocate DATA–POOL in the same way as above.>

(e) ALLOC F(FT50F001) DA('J$$$$.BBBB.DATA') <re>

(f) <Key in the procedures to allocate the work files according to MODE option. (Logical units are described in **Table 4.7**)>

READY
(g) CALL 'J9338.VISUAL.LOAD' <re>

VISUAL START
(h) A screen for PTS is displayed.

<VISUAL opening messages are displayed.>

(i) *** PLEASE KEY IN MODEL OPTION ***

<A message for functions of each MODE is displayed.>

? MOD1 (or MOD2 or MOD3) <re>

```
 *** DEFAULT VALUE SET FOR COMMON DATA ***
 *** DEFAULT VALUE SET FOR MODE-1 DATA ***

(j) *** PLEASE KEY IN COMMAND ***

(k) ? UPDATEC <re>
(l) *** PLEASE KEY IN UPDATE STRING (UPDATEC) ***
    |
    |
(m) |
    |
    |
(n) ? ENDU <re>
    *** PLEASE KEY IN COMMAND ***
(o) ? UPDATE1 <re>
    *** PLEASE KEY IN UPDATE STRING (UPDATE1) ***
    |
    |
(p) |
    |
    ? ENDU <re>
    *** PLEASE KEY IN COMMAND ***
(q) ? LISTC <re>
    |
    |
    |
(r) ? LIST1 <re>
    |
    |
    *** PLEASE KEY IN COMMAND ***
(s) ? RUN1 <re>
    |
    |
(t) |
    |
    *** PLEASE KEY IN COMMAND ***
(u) ? NLPW <re>
    *** PLOTTING COMMON DATA ARE WRITTEN IN THE FILE ***
    *** PLOTTING MODE-1 DATA ARE WRITTEN IN THE FILE ***
    *** PLEASE KEY IN COMMAND ***
(v) ? HELP <re>
    |
    |
    *** PLEASE KEY IN COMMAND ***
(w) ? TIME <re>
    |
    *** PLEASE KEY IN COMMAND ***
```

(x) ? END <re>
(y) *** PLEASE KEY IN MODAL OPTION ***

(z) ? MOD2 (or MOD1 or MOD3) <re>
*** DEFAULT VALUE SET FOR COMMON DATA ***
*** DEFAULT VALUE SET FOR MODE-2 DATA ***

*** PLEASE KEY IN COMMAND ***
(α) ? BYE <re>

(β)

READY
(γ) LOGOFF <re>

The input procedures shown above are described in the following:

(a) : Open the user's ssession.

(b) : Assign logical units for PTSLIB[46] on TSS.

(c) : DATA-POOL is allocated on the logical unit FT91F001.

(d) : Allocate another DATA-POOL in which plotting data are stored.

(e) : The logical unit FT50F001 must be assigned as a work file to store the executing data for NLP or COM.

(f) : The logical units (shown in **Table 4.7**) must be assigned as temporary files.

(g) : Enter VISUAL execution.

(h) : Display the open message of PTS screen.

(i) : Select plotting MODE.

(j) : Message urges a user to key in a Command.

(k) : Command to update the common executing variables.

(l) : Urging to key in the updating terms.

(m) : Key in the updating terms for common variables in succession. (see Section 4.3.1 for detail)

(n) : Terminate the updating mode for common variables.

(o) : Command to update the executing variables for MODE-1.

(p) : Key in the updating terms for MODE-1 in succession.

(q) : Command to diaplay the executing values for common variables.

(r) : Command to display the executing values for MODE-1 variables.

(s) : Command to execute the plotting for MODE-1.

(t) : Plot graph.

(u) : Command to store the executing values in a work file for NLP.

(v) : Command to diaplay the functions of all Commands.

(w) : Command to display used CPU time.

(x) : Command to select the other MODE.

(y) : Same as (i).

(z) : Command to execute the plotting for MODE-2.

(α) : Command to terminate VISUAL.

(β) : Display a farewell massage.

(γ) : Close the user' section.

2) Batch Job

Job control language of VISUAL for FACOM M-380 with NLP or COM equipment at JAERI is described as follows:

```
      //JCLG JOB
      // EXEC JCLG
(a)   //JUSER ****************************
(b)      C.4 T.n1 I.n2 W.n3 OPN GRP
(c)   OPTP PASSWORD=????, NOTIFY=J$$$$
(d)   // EXEC LMGO, LM= 'J9338.VISUALNL'
(e)   // EXPAND GRNLP
      // EXPAND DISKTO, DDN=FT91F001, DSN= 'J$$$$.AAAA' , Q= '.DATA'
      |
(f)   |
      |
(g)   // EXPAND DISKTO, DDN=FT50F001, DSN= 'J$$$$.DATA' , Q= '.DATA'
      |
(h)   |
      |
      //SYSIN DD *
(i)   RUN1
      |
(j)   |
      |
(k)   BYE
(l)   /*
      ++
      //
```

Descriptions of the JCL cards of VISUAL are given in the following:

(a) : User's job card.

(b) : System's resources of the job. Usually, C.4(1536 KBytes) and GRP must be set for NLP and C35 for COM.

(c) : Description of optional parameters. Usually, PASSWORD must be written.

(d) : Specify the load module name to execute VISUAL.

(e) : Assign the graphic library for NLP.
In the case of COM, GCOM35 is assigned.

(f) : Allocate the data set of DATA-POOL in which plotting data are stored.

(g) : Allocate the data set of work file in which executing data are stored.

(h) : Allocate the logical unit according to the MODE.

(i) : Input data to execute MODE-1.

(j) : Specify the RUN (RUN1, RUN2 and RUN3) command in order to plot a graph.

(k) : Terminate VISUAL execution.

(l) : Indicate the end of input data.

A sample is shown in **Fig. 4.25**. When the user will execute the commands shown in Section 4.3.1 on the batch job, the user inputs the procedures from (i)–modal option to (α)–terminate command shown in Section 4.3.3. A example is shown in **Fig. 4.26**. In this case, if XN and YN are greater than 0.0, the comment and the sub-title are plotted from these coordinates, and if less than 0.0, they are plotted from the absolute values of XN and YN coordinates on the next page.

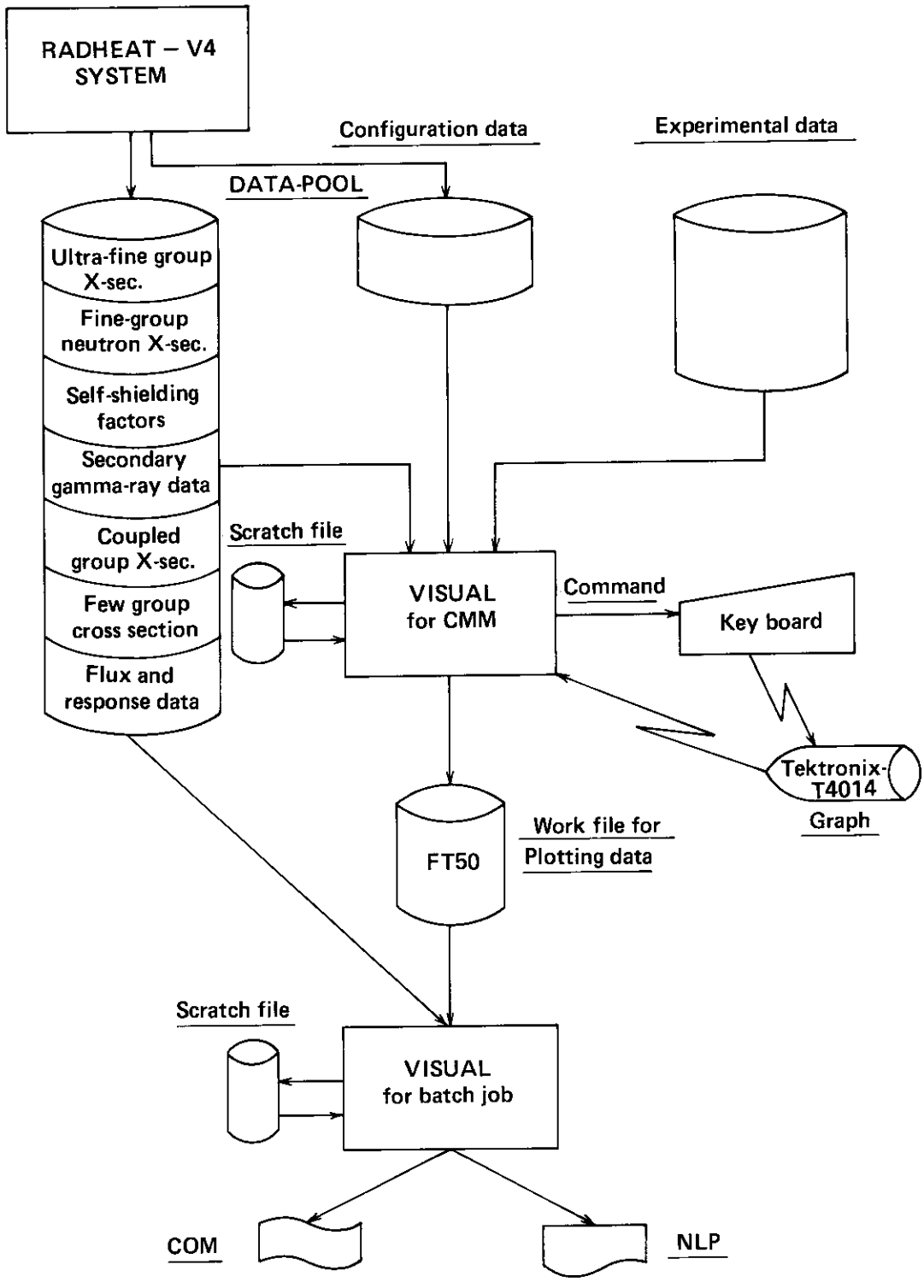


Fig. 4.9 Hierarchy of VISUAL

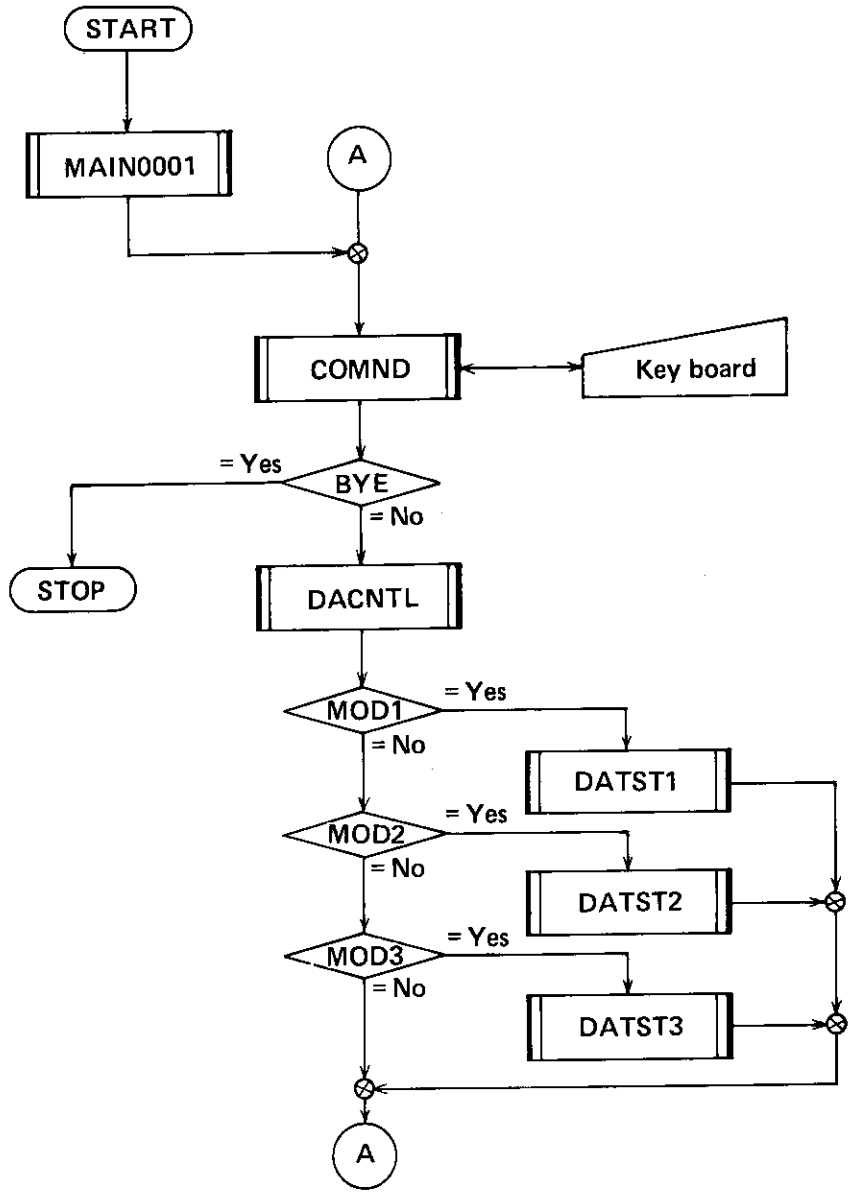


Fig. 4.10 General flow diagram of VISUAL

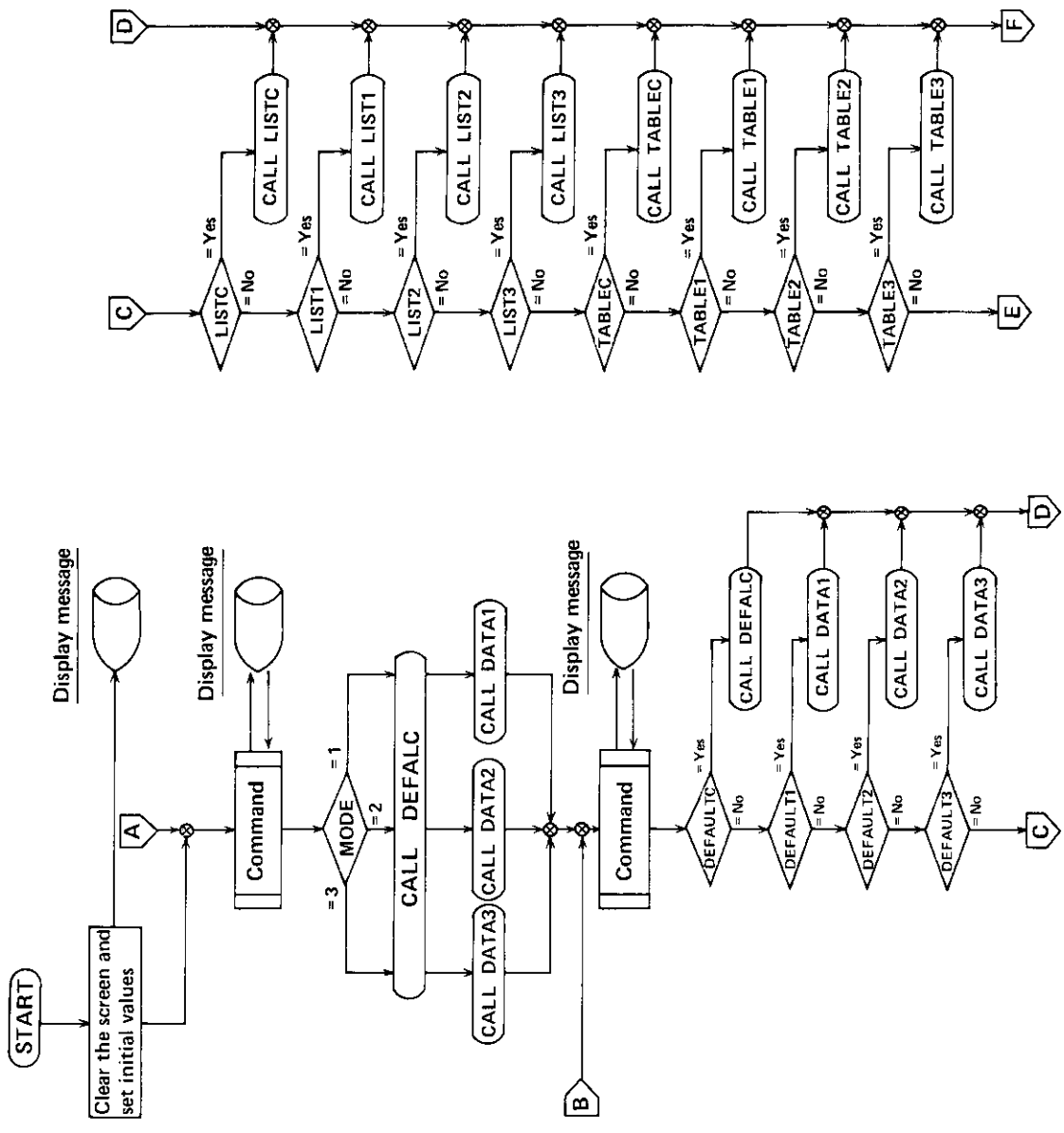


Fig. 4.11 Schematic flow in VISUAL

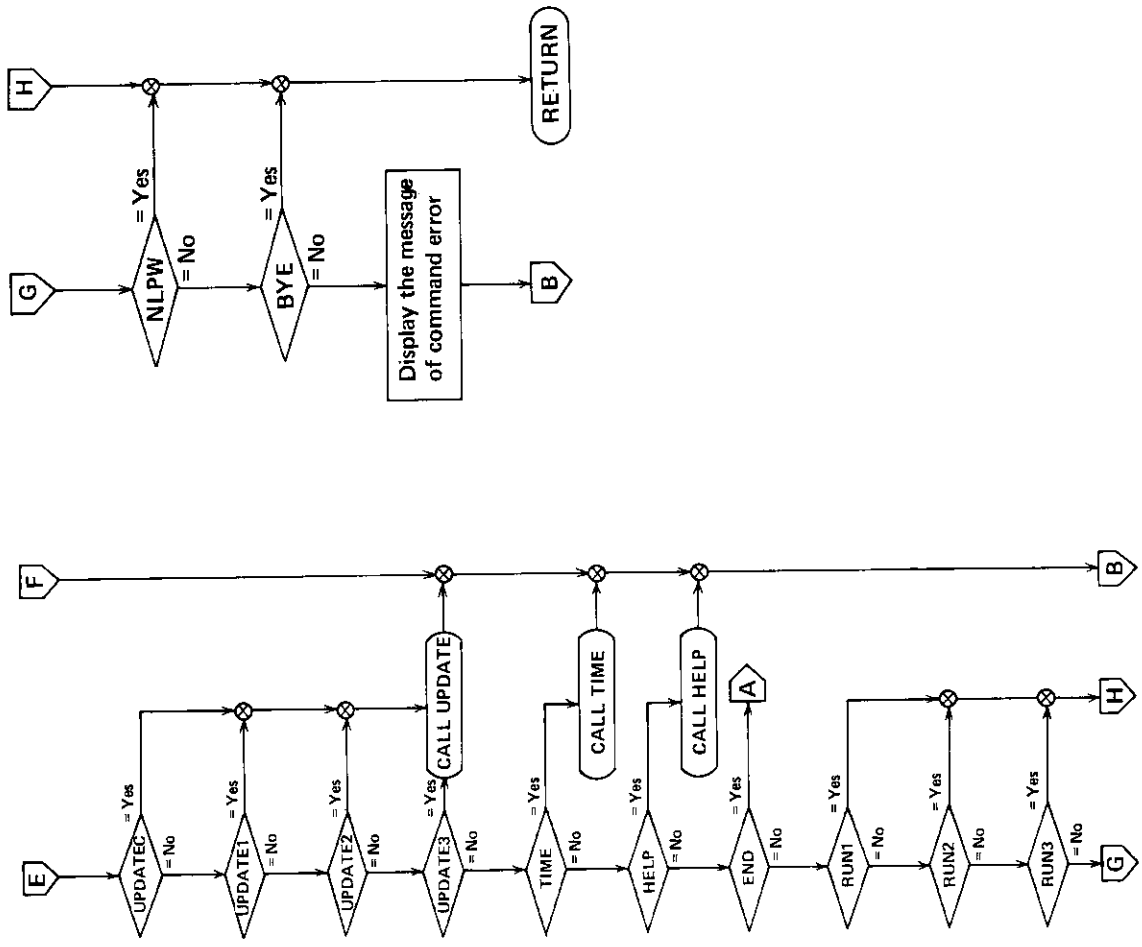


Fig. 4.11 (continued)

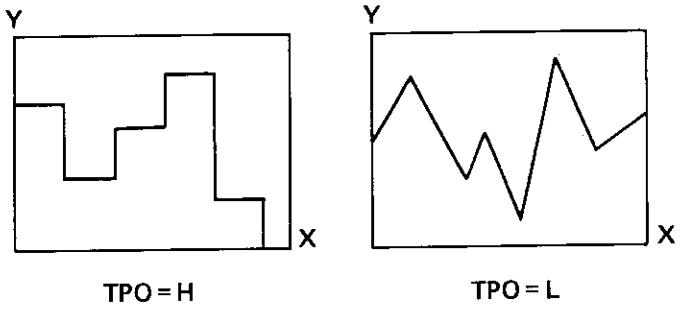


Fig. 4.12 Step–line and linear–line patterns assigned by TPO

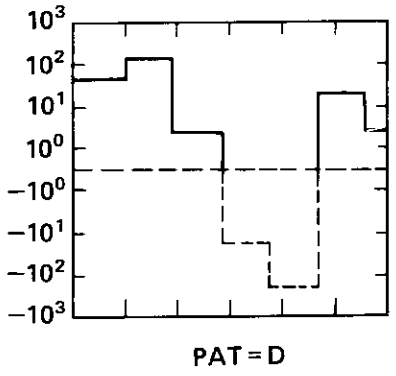


Fig. 4.13 Double graphic pattern assigned by PAT

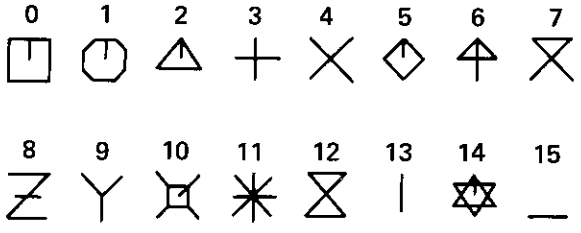


Fig. 4.14 Symbol code for calculated quantities

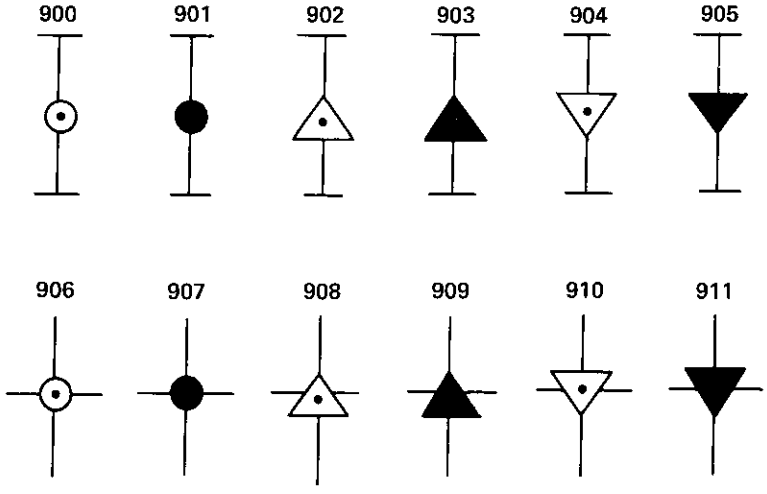


Fig. 4.15 Symbol code for experimental data

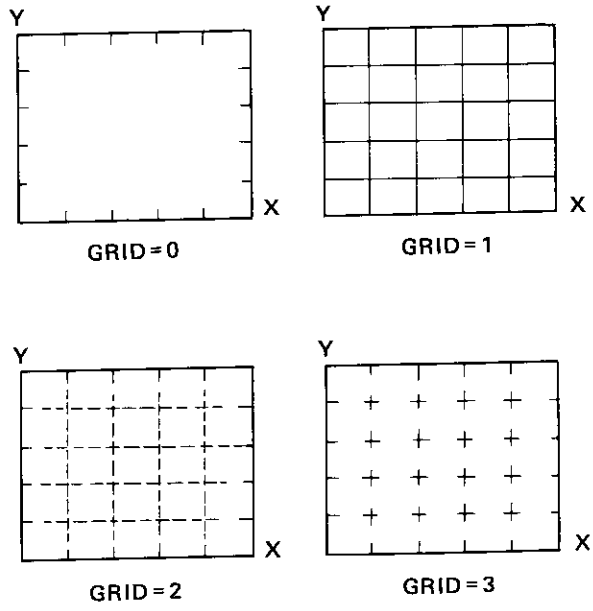


Fig. 4.16 Grid patterns assigned by GRID

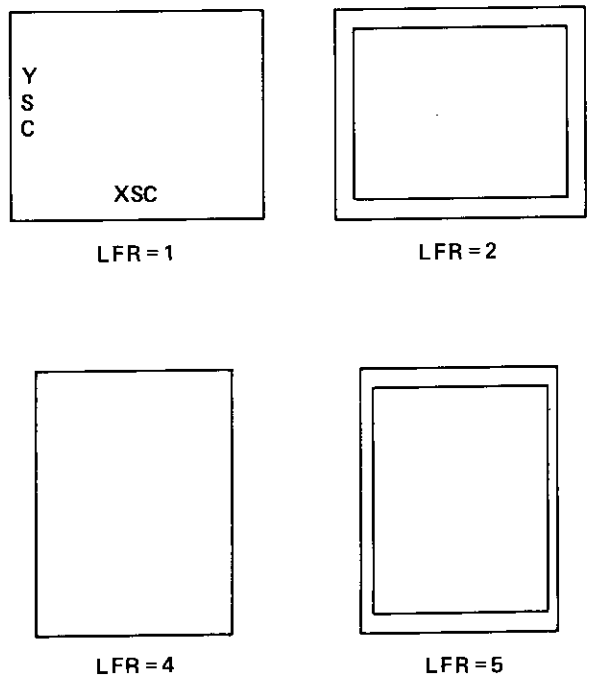


Fig. 4.17 Frame patterns assigned by LFR

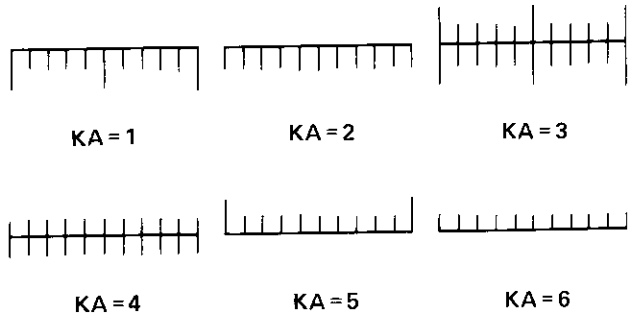


Fig. 4.18 Graduation types assigned by KA

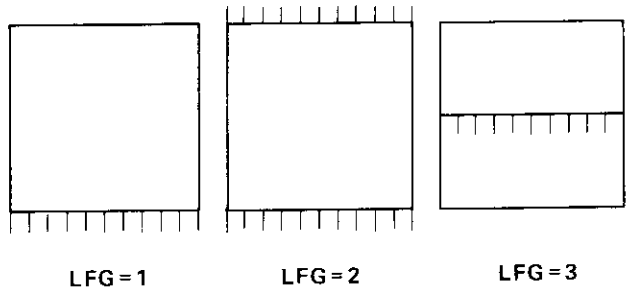


Fig. 4.19 Positions of graduation assigned by LFG

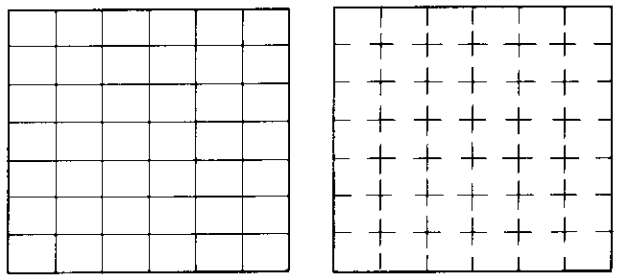


Fig. 4.20 Grid patterns assigned by IGRID

No blanking	Blanking of inner area of contour line	Blanking of outer area of contour line	Kind of contour line
1	- 1	- 101	(solid line)
2	- 2	- 102	(thick solid line)
3	- 3	- 103	(dot line)
4	- 4	- 104	(dash line)
5	- 5	- 105	(chain dot line)

Fig. 4.21 Kind of contour lines and options of blanking area

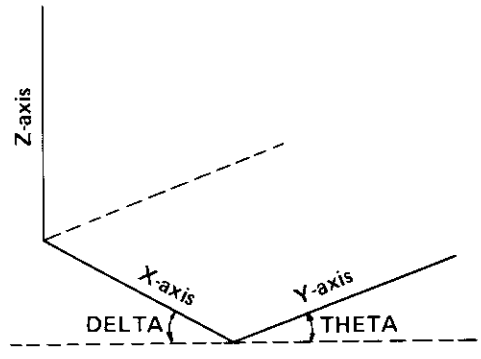


Fig. 4.22 Definition of THETA and DELTA

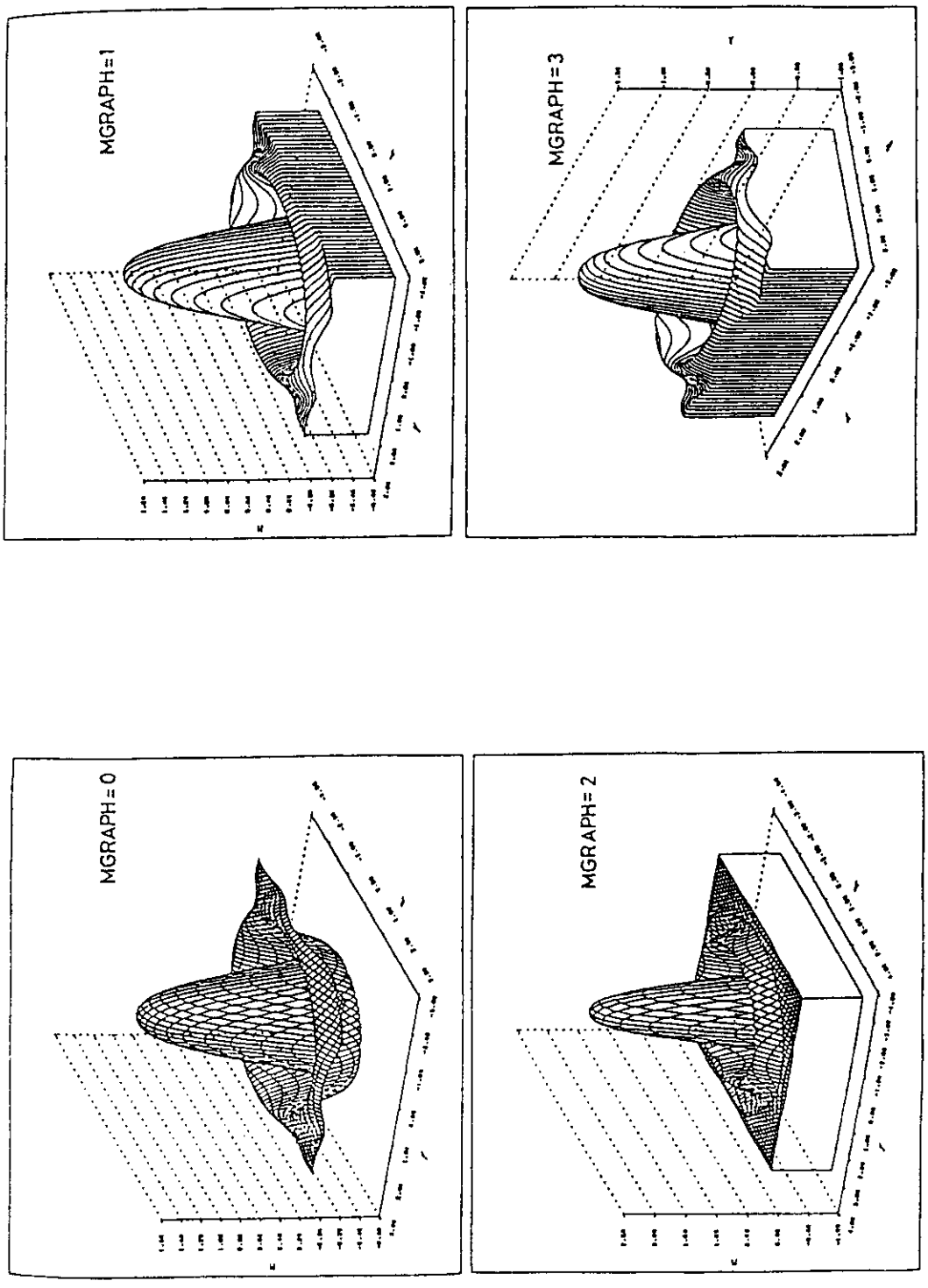


Fig. 4.23 Types of graphs assigned by MGRAPH

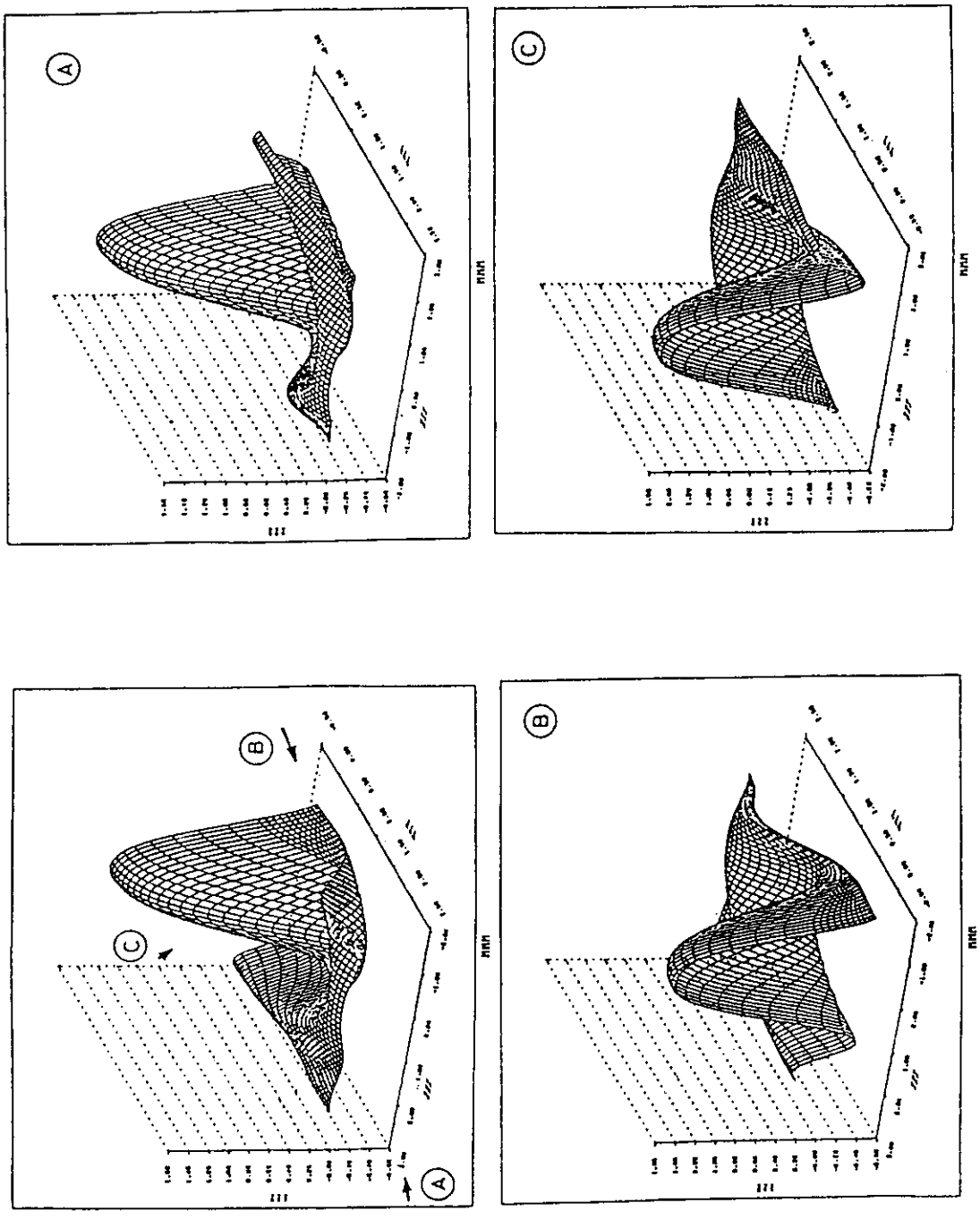


Fig. 4.24 Graphic patterns viewed from four directions

```
----*----1----*----2----*----3----*----4----*----5----*----6----*
//JCLG JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER
       T.2 C.4 W.4 I.3 OPN GRP
 OPTP PASSWORD=  ,NOTIFY=
// EXEC LMGO,LM='J9338.VISUALNL'
// EXPAND GRNLP
// EXPAND DISKTO,DDN=FT91F001,DSN='J3679.RADHDP06',Q='.DATA'
// EXPAND DISKTO,DDN=FT50F001,DSN='J9338.VWORK1',Q='.DATA'
//SYSIN DD *
RUN1
LISTC
LIST1
TIME
RUN1
TIME
LISTC
LIST1
BYE
/*
++
//
```

Fig. 4.25 Job control cards and input commands for VISUAL for use of the FACOM M-380 computer at JAERI

```
----*----1----*----2----*----3----*----4----*----5----*----6----*
//JCLG JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER
       T.1 C.4 W.4 I.3 OPN GRP NLP
 OPTP PASSWORD=????,NOTIFY=JXXXX
// EXEC LMGO,LM='J9338.VISUALNL'
// EXPAND GRNLP
// EXPAND DISKTO,DDN=FT91F001,DSN='JXXXX.$$$$',Q='.DATA'
//SYSIN DD *
MOD1
UPDATEC
XTITL=$N?EUTRON $E?NERGY $(?E$V);
YTITL=$C?ROSS $S?ECTION $(?BARN/$R/$M?E$V);
UNIT(1)=91;UNIT(2)=91;UNIT(3)=91;
NODE(1)=EXP      0000       92;
NODE(2)=102G;
NODE(3)=102G     DDX      9204       33;
CODE(1)=0 7 7 7 7;
CODE(2)=0 1 2 3 4;
ENDU
UPDATE1
NPL=5;
COMT=$DDX ?AT $139 ?DEGREE;
SUBT(1)= CALCULATED TOTAL VALUE;
SUBT(2)= CALCULATED INELA. VALUE;
SUBT(3)= CALCULATED INS. CONT. VALUE;
SUBT(4)= CALCULATED (N.$2?N) VALUE;
SUBT(5)= EXPERIMENTAL DATA $N?O.$499;
TPO=H;ECODE(1)=906;SSIZE=3.0;YSCALE=1;
XN=-100.0;
YN=-180.0;
ENDU
RUN1
LISTC
LIST1
TIME
BYE
/*
++
//
```

Fig. 4.26 Job control cards and input data for VISUAL for use of the FACOM M-380 computer at JAERI

Table 4.3 Variables used in MODE−1 of VISUAL

Variable	Size	Default	Description of the Data
TITLE			Main title of the graph.
XTITL			Caption of X-axis.
YTITL			Caption of Y-axis.
ZTITL			Caption of Z-axis.
UNIT	(10)	0	Logical unit number of DATA-POOL.
NODE	(10, 10)		Node structure of data in DATA-POOL.
CODE	(10, 10)	0	Code number of the plotting data.
XW		220.0	X-axis length (mm).
YW		190.0	Y-axis length (mm).
NPL		1	Number of the plotting lines in a graph. ($\leqq 15$) Number of lines for calculation data is limited to 10 and number of lines for experimental data is less than 5.
TRANS		A	Tansformation type of the plotting data. =A: absolute representation =C: alpha-transformation =O: +, − or / transformation
ALPHA		1.0	Transform constant. If TRANS is set to C, the plotting data are multiplied by ALPHA.
OPERA		/	Transformation operator of the plotting data. If TRANS=O, enter next Operands. =+: add; =−: subtract; =/: divide.
COMP		1	Data number for the denominator. If TRANS=O, then enter.
EUNIT	(5)	0	Logical unit number (from 41 to 45) of sequential data sets for experimental data.
COMT			Common comment for all data.
SUBT	(10)		Comment for each data.
TPO		L	Option for line form. =H: step-line form =L: linear-line form (see Fig. 4.12 for detail)
PAT		S	Graphic pattern. =S: single graph; =D: double graph. (see Fig 4.13 for detail)
SYMBOL		0	Plotting option of symbol for calculation data. =0: not plot =N: plot symbols to every N+1 data points
SCODE	(10)	0	Symbol code of the calculation data. (see Fig. 4.14 for detail.)

Table 4.3 (continued)

Variable	Size	Default	Description of the Data
ECODE	(5)	0	Symbol code of the experimental data. (see Fig. 4.15 for detail.)
EID	(5)	0	Plotting identification number of the experimental data in the sequential data set.
ESIZE		2.0	Height of symbol for the experimental data (mm). Enter as ESIZE =3. 5.
SSIZE		4.0	Height of character for the legend (mm). Enter as SSIZE=4. 5.
XN		0.0	Starting position on X-axis to plot the legend (mm).
YN			Starting position on Y-axis to plot the legend (mm).
GRID		0	Option for grid patten. =0, 1, 2 or 3 (see Fig. 4.16 for detail.)
XSCALE		0	Scaling option for X-axis. =0: linear scaling; =1: log scaling
YSCALE		0	Scaling option for Y-axis. (Same as XSCALE.)
SCALE		0	Method of scaling type. =0: automatic scaling =1: manual scaling
XMIN		0.0	Minimum value for the X-axis. If SCALE=1, enter it as XMIN=1. 0E-6.
XMAX		0.0	Maximum value for the X-axis. (Same as XMIN.)
YMIN		0.0	Minimum value for the Y-axis. (Same as XMIN.)
YMAX		0.0	Maximum value for the Y-axis. (Same as XMIN.)
YDMIN		0.0	Minimum value for the Y-axis in the double graph. When SCALE=1 and PAT=D are given, enter this value.
YDMAX			Maximum value for the Y-axis in the double graph. (Same as YDMIN.)

Table 4.4 Variables used in MODE−2 of VISUAL

Variable	Size	Default	Description of the Data
IOP		1	Option of the screen size. =1: A4; =2: B5; =3: A3 =4: B4 (Except for these, the size is defined by XSC and YSC.)
XSC		297.0	Horizontal length of the screen (mm).
YSC		210.0	Vertical length of the screen (mm). If IOP=1, 2, 3 or 4, these are dummy.
LFR		1	Option of the screen type. =1, 2, 3, 4, 5, 6 (Samples are shown in Fig. 4.17)
IFRAM		1	Option to plot a frame. =1: plot; =0: no effect
XO		30.0	Initial position for X-axis (mm).
YO		10.0	Initial position for Y-axis (mm).
ZMIN		0.0	Minimum value for Z-axis. Enter it as ZMIN=3.0E-6.
ZMAX		0.0	Maximum value for Z-axis. Enter it as ZMAX=6.0E+8.
KA		5	Option for graduation type. =1, 2, 3, 4, 5, 6 (Samples are show in Fig. 4.18)
SIZE		3.0	Height of graduation number (mm). If SIZE>0.0, plot with this size. If SIZE=0.0, plot with default value.
NCONV		1	Option to transform the data.
LFG		2	Option of graduation position. =1, 2, 3 (Samples are show in Fig. 4.19)
IGRID		0	Option of grid type. =0 : no effect =1, 2: (Samples are show in Fig. 4.20)
MX		0	Number of grids for X-axis. <0: no effect; =0: auto >0: manual
MY		0	Number of grids for Y-axis. (Same as MX.)
INTER		0	Approximation type for contour value. =0: linear-interpolation =1: spline-fitting
NCONTR		−1	Number of contour lines. <0: AUTO; +N: N lines; =0; Inital value (CONTV(1)), increasing value (CONTV(2)) and final value (CONTV(3)) must be given. Then number of contour lines and contour values are calculated in the program.
CONTV	NCONTR	−1.0	Contour values for lines. NCONTR<0: no effect NCONTR=0: set initial, increasing and final values NCONTR=N: set contour values up to N

Table 4.4 (continued)

Variable	Size	Default	Description of the Data
KIND	NCONTR	1	Kind of contour line. NCONTR≦0: no effect NCONTR>0: set next value =0: no effect; =1: solid =2: thick solid; =3: dot =4: dash; =5: chain dot (see Fig. 4.21 for detail)
LCVOP		1	Option to plot contour value. =0: plot contour value on the line =1: plot sequential number on the line
ISTL		1	First line number for plotting contour value. LCVOP=1: no effect
ML		1	Interval for plotting contour value. Plot contour value to every ML−1 line from ISTL.
ICMT			Comment for the contour map.
XST		0.0	Starting position on X-axis to plot the legend (mm).
YST		0.0	Starting position on Y-axis to plot the legend (mm).
THETA		0.0	Angle of the character (degree).
CHIGH		4.0	Height of the character (mm).
IREAL		0	Option for figure size.
ID	(2)		Identification for the figure. Fixed 'CONTOUR1' .
COMT			Common comment for all data.
SUBT	(10)		Comment for each data.

Table 4.5 Variables used in MODE−3 of VISUAL

Variable	Size	Default	Description of the Data
XSCALE		0	Scaling option for X-axis. =0: linear scaling ; =1: log scaling
YSCALE		0	Scaling option for Y-axis. (Same as XSCALE)
ZSCALE		0	Scaling option for Z-axis. (Same as XSCALE)
NSTEP		0	Reading or writing option for original data. =0: write to work file =1: read from work file
THETA		30.0	Angle of Y-axis for holizontal direction. (degree) (see Fig. 4.22 for detail)
DELTA		10.0	Angle of X-axis for holizontal direction. (degree) (see Fig. 4.22 for detail)
BETA		1.0	Ratio of Y-axis length to X-axis length.
MGRAPH		1	Graphic type option. =0, 1, 2, 3 (Examples are shown in Fig. 4.23)
NXCH		0	Option to change the order of going up and down for X-axis data array. =0: no effect; =1: change
NYCH		0	Option to change the order of going up and down for Y-axis data array. (Same as NXCH.) (Examples for NXCH and NYCH are shown in Fig. 4.24)
NVALUE		0	Input option for the threshold value. =0: no effect; =1: input
ALPHA		0.0	Threshold value for Z-axis. If NVALUE=1, then input.
LIMIT		0	Interpolated point number. =0: interpolate all points =N: interpolate every N+1 data points
PRINT		0	Print option of input data. =0: no effect; =1: print
DDXY		0.1	Minimum mesh width for interpolation (mm).

Table 4.6(a) Character code numbers used in the TMM mode in VISUAL

For capital letters

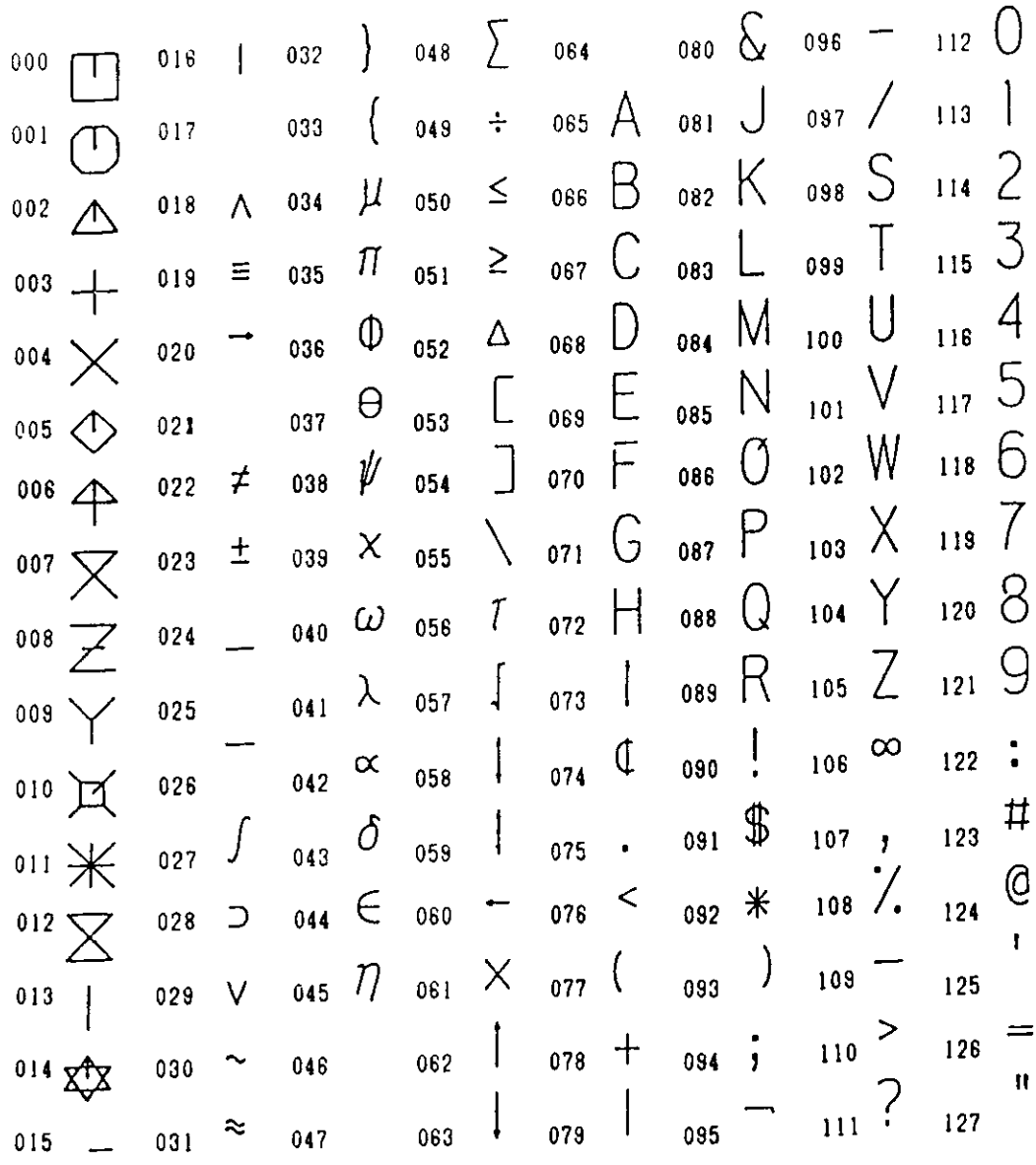


Table 4.6(b) For lower case letters

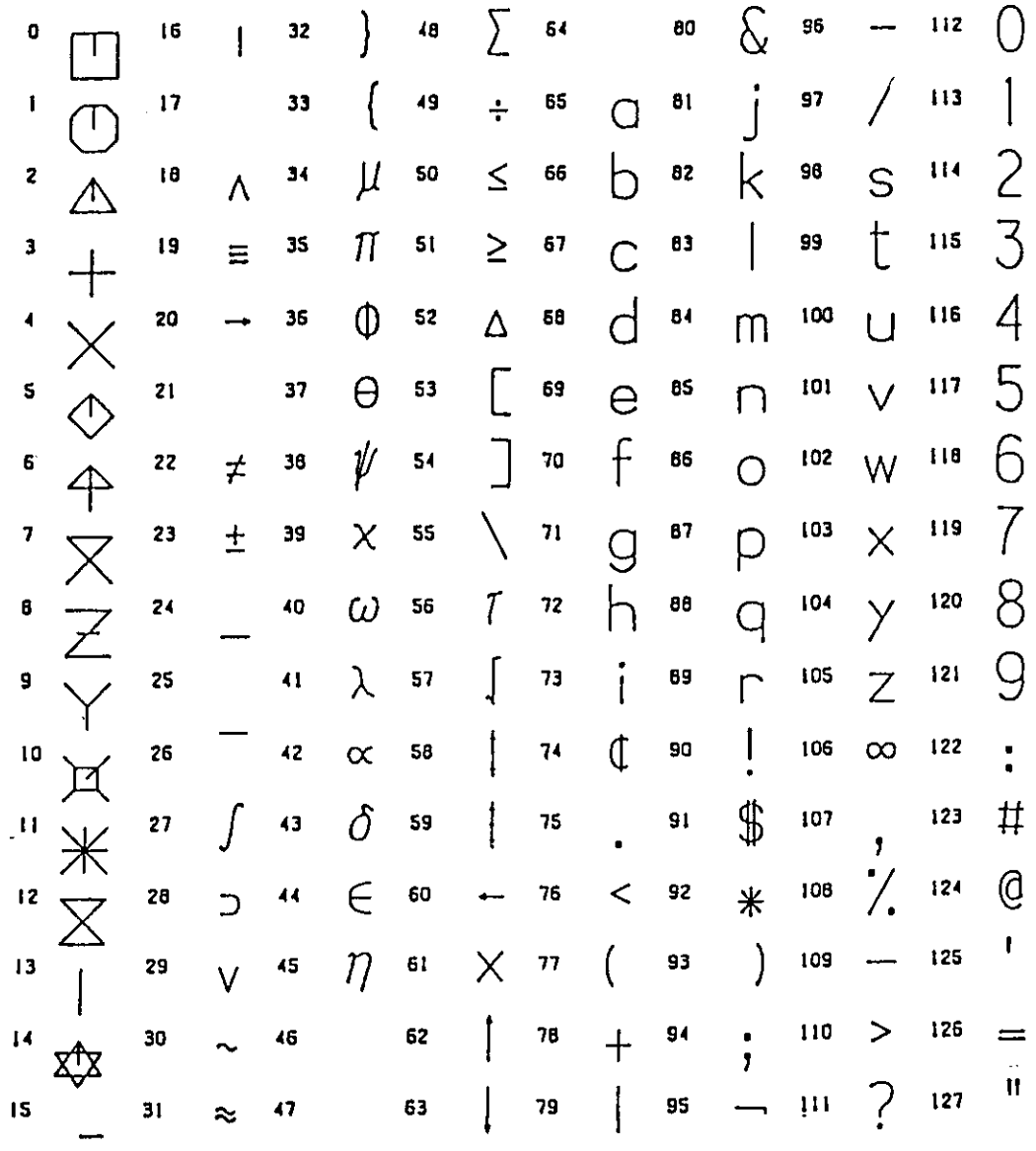


Table 4.7 Input/output file assignments for VISUAL

	Logical unit No.	Comment
COMMON	FT91	
	|	Input of the DATA-POOL file
	FT93	
	FT50	Output of the executing data
		Input of the executing data for batch job
	FT05	Input
	FT06	Print output
MODE-1	FT41	
	|	Input of the experimental data file
	FT45	
	from FT10	Scratch file to plot matrix data (EGRP-INFX-Mat. No.-INS (N2N or ELA))
MODE-2	FT01	Scratch file
	FT96	Scratch file
	FT97	Scratch file
	FT98	Scratch file
	FT99	Scratch file
MODE-3	FT01	Output of the plotting data
	FT02	Input of the plotting data
	FT10	Scratch file to plot matrix data (EGRP-INFX-Mat. No.-INS (N2N or ELA))

5. Sample Problems for RADHEAT-V4

The RADHEAT-V4 code system consists of many functional modules for producing coupled multi-group neutron and gamma-ray cross sections, and for analyzing the neutron and gamma-ray transports of one-, two-, and three-dimensional configurations.

Sample problems for all the functions of the system can not be described in this report, so that typical problems are only given in this chapter.

The productions of neutron and gamma-ray group cross sections for air and iron are described in Section 5.1. The FAIR-CROSS module is used in this procedure. The generations of secondary gamma-ray production data for oxigen, nitrogen and iron by using TWOWAY are given in Section 5.2.

In Section 5.3, a sample problem of the one-dimensional transport calculation with a simple iron-air configuration is described. The DIAC module is used in this procedure. The collapsing of the group cross sections generated in Section 5.1 is given in Section 5.4. The weighting fluxes in the collapsing procedure of FDEM are used those produced in Section 5.3.

A gamma-ray skyshine problem with the two-dimensional configuration is described in Section 5.5 as the sample problem for ESPRIT. The gamma-ray cross sections and the flux-to-dose conversion factor used in the calculation are also produced in the section.

In Section 5.6, a sample problem of gamma-ray skyshine with the three-dimensional configuration is described for MCACE. The cross sections and the flux-to-dose conversion factor used in the calculation are the same as those produced in Section 5.5

The Bremsstrahlung calculation in a one-dimensional infinite lead slab with ^{16}N source is described in Section 5.7 as the sample problem for BREM.

The job control cards and the input data for each problem are shown in these sections indicated above. The output lists of these computations take a large space, so that these are shown collectively in Appendix D.

5.1 Sample Problem for FAIR-CROSS

5.1.1 Step 1

A sample problem for FAIR-CROSS step 1 is a problem for generating ultra-fine group cross sections and infinite dilution cross sections of oxigen, nitrogen and iron. The energy group structures of the cross sections are the same as in the JSD1000 library.

The job control cards and the input data for each nuclides are described below. The result of computation for oxigen is shown in Appendix D as a sample output. The results for nitrogen and iron are omitted because the output forms of these nuclides are the same as that of oxigen.

```
MEMBER NAME > B:RRSTEP1.TXT   ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.4 I.5 P.0 W.3 C.5 SRP
    6 :   OPTP PASSWORD=########
    7 :  //FCROSS EXEC LMGO,LM='J1446.FCSTEP1X',OBSIZE=137,ORECFM=FA
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(100,20)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
```

```
MEMBER NAME > B:RRSTEP1.TXT  ---------------------------------------------- PAGE :  2
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(100,20)),
   11 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(100,20)),
   13 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(100,20)),
   15 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT10F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(100,20)),
   17 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT11F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(100,20)),
   19 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   20 :  //FT12F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(100,20)),
   21 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   22 :  //FT13F001 DD DSN=&&FD,UNIT=WK10,SPACE=(TRK,(600,50)),
   23 :  //  DCB=(LRECL=16804,BLKSIZE=16804,RECFM=F)
   24 :  //FT14F001 DD DSN=&&FE,UNIT=WK10,SPACE=(TRK,(100,20)),
   25 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   26 :  //FT15F001 DD DSN=&&FF,UNIT=WK10,SPACE=(TRK,(100,20)),
   27 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   28 :  //* THE FOLLOWING DSN WILL BE CHANGED BY NUCLIDE (406 OR 408)
   29 :  //FT08F001 DD DSN=J1615.ENDFB406.DATA,DISP=SHR,LABEL=(,,,IN)
   30 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   31 :  //SYSIN DD *
   32 :    FAIR-CROSS STEP-1 SAMPLE PROBLEM NO.1
   33 :   &UNIT ULTX=91,INFX=91,FTBL=91 &END
   34 :  1¥¥ 1  1  100  20  0  4HEGRP  2  2  T
   35 :  MAT=1276 O-16 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)
   36 :  4¥¥ 1276  8  0  1  7  4  0  0  1  1  0  0  2  0  0  1  T
   37 :  5** 300.0
   38 :  6** 1.0+8  0.0  1.0  10.0  100.0  1000.0  10000.0
   39 :  7** 1.25E-1  1.4E+6  8.208E+5
   40 :  10** 0.01  0.0  0.03  0.0
   41 :   T
   42 :  ++
   43 :  //
   44 :    FAIR-CROSS STEP-1 SAMPLE PROBLEM NO.2
   45 :   &UNIT ULTX=91,INFX=91,FTBL=91 &END
   46 :  1¥¥ 1  1  100  20  0  4HEGRP  2  2  T
   47 :  MAT=1275 N-14 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)
   48 :  4¥¥ 1275  8  0  1  7  4  0  0  1  1  0  0  2  0  0  1  T
   49 :  5** 300.0
   50 :  6** 1.0+8  0.0  1.0  10.0  100.0  1000.0  10000.0
   51 :  7** 1.25E-1  1.4E+6  8.208E+5
   52 :  10** 0.01  0.0  0.03  0.0
   53 :   T
   54 :  ++
   55 :  //
   56 :    FAIR-CROSS STEP-1 SAMPLE PROBLEM NO.3
   57 :   &UNIT ULTX=91,INFX=91,FTBL=91 &END
   58 :  1¥¥ 1  1  100  20  0  4HEGRP  2  2  T
   59 :  MAT=1192 FE-26 PROCESS FROM ENDF/B-IV AT 300K (TAPE 406)
   60 :  4¥¥ 1192  8  0  1  7  4  0  0  1  1  0  0  2  0  0  1  T
   61 :  5** 300.0
   62 :  6** 1.0+8  0.0  1.0  10.0  100.0  1000.0  10000.0
   63 :  7** 1.25E-1  1.4E+6  8.208E+5
   64 :  10** 0.01  0.0  0.03  0.0
   65 :   T
   66 :  ++
   67 :  //
------------------------------------ END OF FILE ------------------------------------
```

5.1.2 Step 2

A sample problem for FAIR-CROSS step 2 is a problem for generating effective macroscopic cross sections of air and iron. The secondary gamma-ray production data for oxigen, nitrogen and iron used in this step have been produced already by using the TWOWAY module shown in Section 5.2.

The job control cards and the input data for each materials are described below. The result of computation for air is shown in Appendix D as a sample output. The result for iron is omitted because the output form of the iron is the same as that of air.

```
MEMBER NAME > B:RSTEP2.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.2 I.3 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC LMGO,LM='J1446.FCSTEP2X'
    8 :  //FT11F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,20)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT13F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,20)),
   11 :  //   DCB=(LRECL=16804,BLKSIZE=16804,RECFM=F)
   12 :  //FT14F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,20)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT16F001 DD DSN=&&F6,UNIT=WK10,SPACE=(TRK,(50,20)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT17F001 DD DSN=&&F7,UNIT=WK10,SPACE=(TRK,(50,20)),
   17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT18F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,20)),
   19 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   20 :  //FT21F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,20)),
   21 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   22 :  //FT22F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(50,20)),
   23 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   24 :  //FT23F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(50,20)),
   25 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   26 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   27 :  //SYSIN DD *
   28 :   FAIR-CROSS STEP-2 SAMPLE PROBLEM NO.1
   29 :   &UNIT ULTX=91,INFX=91,FTBL=91,SGXL=91,SELF=91,FXSN=91 &END
   30 :   1¥¥ 2  2  100  20  16  4HEGRP  0  0  T
   31 :  AIR BY ENDF/B-IV AT 300K
   32 :   4¥¥  4HAIR0  1  1  1  1  0
   33 :   5¥¥    1276  1275
   34 :   7¥¥    1276  1275
   35 :   8**     8.0   7.0
   36 :   9**   1.130E-5 4.250E-5
   37 :  10**    300.0  300.0
   38 :    T
   39 :  12¥¥  1  0  T
   40 :  13¥¥  1276   4   0   0   T
   41 :  14¥¥   108 608 208 308   T
   42 :  13¥¥  1275   4   0   0   T
   43 :  14¥¥   107 607 207 307   T
   44 :  17¥¥    10  5R0          T
   45 :  29¥¥     0   0   0   0   T
   46 :  ++
   47 :  //
   48 :   FAIR-CROSS STEP-2 SAMPLE PROBLEM NO.2
   49 :   &UNIT ULTX=91,INFX=91,FTBL=91,SGXL=91,SELF=91,FXSN=91 &END
   50 :   1¥¥ 2  1  100  20  16  4HEGRP  0  0  T
   51 :  IRON BY ENDF/B-IV AT 300K
   52 :   4¥¥  4HIRON  1  1  1  1  0
   53 :   5¥¥    1192
   54 :   7¥¥    1192
   55 :   8**    26.0
   56 :   9**   8.464E-2
   57 :  10**    300.0
   58 :    T
   59 :  12¥¥  1  0  T
   60 :  13¥¥  1192   3   0   0   T
   61 :  14¥¥   926 126 326       T
   62 :  17¥¥    10  5R0          T
   63 :  29¥¥     0   0   0   0   T
   64 :  ++
   65 :  //
------------------------------------ END OF FILE ------------------------------------
```

5.1.3 Step 3

A sample problem for FAIR-CROSS step 3 is a problem to convert the air cross section generated by FAIR-CROSS step 2 to the *Pl*-type cross section which can be read by ANISN, DOT and MORSE.

The job control cards and the input data are described below. The result of computation is shown in Appendix D.

```
MEMBER NAME > B:RSTEP3.TXT  ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.4 I.4 P.0 W.3 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC LMGO,LM='J1446.FCSTEP2X'
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,20)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(50,20)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,20)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT40F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,20)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT50F001 DD DSN=J1446.GRPXSEC.DATA,SPACE=(TRK,(50,10)),UNIT=TSSWK,
   17 :  //   DISP=(NEW,CATLG,DELETE),DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS),
   18 :  //   LABEL=(,,,OUT)
   19 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   20 :  //SYSIN DD *
   21 :   FAIR-CROSS STEP-3 SAMPLE PROBLEM NO.1
   22 :   &UNIT INFX=91,FXSN=91 &END
   23 :   1¥¥  3  1  100  20  16  4HEGRP  0  0  T
   24 :  30¥¥  3  3  0   T
   25 :  31¥¥  4HAIR0
   26 :  32¥¥    1000
   27 :    T
   28 :  ++
   29 :  //
------------------------------------ END OF FILE ------------------------------------
```

5.2 Sample Problem for TWOWAY

A sample problem for TWOWAY is a problem to generate the secondary gamma-ray cross sections of oxigen, nitrogen and iron. The ultra-fine group cross sections used in TWOWAY have been produced already by FAIR-CROSS step 1 described in Section 5.1.1.

The job control cards and the input data for each nuclides are described below. The result of computation for oxigen is shown in Appendix D as a sample output. The results for nitrogen and iron are omitted because the output forms of these nuclides are the same as that of oxigen.

```
MEMBER NAME > B:TWOWAY.TXT  ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.5 I.4 P.0 W.2 C.5 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC FORT77,SO='J1446.RADHEAT',A='ELM(TWOWAY),NOS'
    8 :  // EXEC LKED77,PRVLIB='J1446.DPOOL2'
    9 :  // EXEC GO
   10 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,10)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(50,10)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,10)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
```

```
16 : //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,10)),
17 : //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
18 : //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,10)),
19 : //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
20 : //FT10F001 DD DSN=J1615.ENDFB408.DATA,DISP=SHR,LABEL=(,,,IN)
21 : //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
22 : //SYSIN DD *
23 :  TWOWAY SAMPLE PROBLEM NO.1
24 :  &UNIT ULTX=91,INFX=91,SGXL=91 &END
25 : EGRP   100   20    1    0    0
26 :  1276   10    8  8-O-16 ENDF/B-IV 300K
27 : ++
28 : //
29 :  TWOWAY SAMPLE PROBLEM NO.2
30 :  &UNIT ULTX=91,INFX=91,SGXL=91 &END
31 : EGRP   100   20    1    0    0
32 :  1275   10    7  7-N-14 ENDF/B-IV 300K
33 : ++
34 : //
35 :  TWOWAY SAMPLE PROBLEM NO.3
36 :  &UNIT ULTX=91,INFX=91,SGXL=91 &END
37 : EGRP   100   20    1    0    0
38 :  1192   10   26  26-FE  ENDF/B-IV 300K
39 : ++
40 : //
------------------------------------ END OF FILE ------------------------------------
```

5.3 Sample Problem for DIAC

A sample problem for DIAC is a shielding problem of a simple iron–air configuration which is one of the KfK shielding benchmark problems[54]. This problem is to compute the leakage neutron flux from iron sphere of 15 cm diameter with a ^{252}Cf source in the center. The fission source is simulated as a shell source at the 0.88 cm radius from the center of the sphere.

The job control cards and the input data are described below. The result of computation is shown in Appendix D.

```
MEMBER NAME > B:DIACT.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
   1 : //JCLG JOB
   2 : // EXEC JCLG
   3 : //SYSIN DD DATA,DLM='++'
   4 : // JUSER ########,##.######,####.##
   5 :  T.6 I.5 P.0 W.2 C.5 SRP
   6 :  OPTP PASSWORD=########
   7 : //DIAC EXEC LMGO,LM='J1446.DIACX',OBSIZE=137,ORECFM=FA
   8 : //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(300,100)),
   9 : //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
  10 : //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(300,100)),
  11 : //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
  12 : //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(300,100)),
  13 : //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
  14 : //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(300,100)),
  15 : //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
  16 : //FT12F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(300,100)),
  17 : //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
  18 : //FT20F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(300,100)),
  19 : //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
  20 : //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
  21 : //SYSIN DD *
  22 : DIAC SAMPLE PROBLEM NO.1   (IRON-AIR) CONFIGULATION
  23 :  &UNIT  FXSN=91,FLX1=91,FLX2=0 &END
  24 : 14** 100 20  0  0  0  0  1  0  0  0  0
  25 : 15** 777  0  16  16  3  1  0  2  19  0  120  3  4  123  0  0  2  2  0
  26 :        0  0   1   2  80  0  1  0  0  1  2  0  0  0  1  1  0
  27 : 16**  1.0  0.1  1.0-4  1.420892  3R0.0  1.0  0.0  0.5  2.0-4  3R0.0 T
  28 :  6**  0.0 0.0244936 0.0413296 0.0392569 0.0400796 0.0643754
  29 :           0.0442079 0.109085  0.1371702  1N8
```

```
 30 :   7**  -0.9902984 -0.9805009 -0.9092855 -0.8319956 -0.7467506
 31 :        -0.6504264 -0.5370966 -0.3922893 -0.1389568 1M8  T
 32 :  13**  4HEGRP  4HFX16  4HIRON  4HAIR0  T
 33 :  18**  9R0.0  8R1.8345E-4  9R0.0  8R1.0055E-3 9R0.0  8R1.7562E-3
 34 :        9R0.0  8R3.3073E-3  9R0.0  8R6.3987E-3 9R0.0  8R7.7603E-3
 35 :        9R0.0  8R1.0485E-2  9R0.0  8R2.7372E-2 9R0.0  8R2.4542E-2
 36 :        9R0.0  8R2.3317E-2  9R0.0  8R5.6820E-2 9R0.0  8R4.6661E-2
 37 :        9R0.0  8R5.2674E-2  9R0.0  8R5.5554E-2 9R0.0  8R3.8945E-2
 38 :        9R0.0  8R7.5470E-2  9R0.0  8R5.7153E-2 9R0.0  8R5.4869E-2
 39 :        9R0.0  8R5.1871E-2  9R0.0  8R4.8635E-2 9R0.0  8R4.4425E-2
 40 :        9R0.0  8R4.0553E-2  9R0.0  8R3.6464E-2 9R0.0  8R3.2480E-2
 41 :        9R0.0  8R2.8699E-2  9R0.0  8R2.5156E-2 9R0.0  8R2.1921E-2
 42 :        9R0.0  8R1.9004E-2  9R0.0  8R1.6328E-2 9R0.0  8R1.4017E-2
 43 :        9R0.0  8R1.1989E-2  9R0.0  8R1.0221E-2 9R0.0  8R8.6337E-3
 44 :        9R0.0  8R7.3178E-3  9R0.0  8R6.1910E-3 9R0.0  8R5.2226E-3
 45 :        9R0.0  8R4.3684E-3  9R0.0  8R3.6735E-3 9R0.0  8R3.0848E-3
 46 :        9R0.0  8R5.1313E-3  9R0.0  8R1.6934E-3 9R0.0  8R1.4946E-3
 47 :        9R0.0  8R1.1771E-3  9R0.0  8R1.0389E-3 F0.0         T
 48 :   3**  F0.0  T
 49 :   1**  F0.0
 50 :   4**  0.0 0.4 610.88 218.38 11.38 13.38 18.38 28.38 48.38 78.38 108.3
 51 :      158.75
 52 :   5** F1.0
 53 :   8**  2R1  7R1  10R2
 54 :   9**  1     2     T
 55 :  ++
 56 :  //
---------------------------------- END OF FILE ----------------------------------
```

5.4 Sample Problem for FDEM

A sample problem for FDEM is a problem for generating the few group cross sections using neutron and gamma-ray fluxes calculated by DIAC shown in the previous section. The fine-group cross sections have been produced already in Section 5.1.2.

The job control cards and the input data are described below. The result of computation is shown in Appendix D.

```
MEMBER NAME > B:FDEM.TXT      ------------------------------------------------ PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.5 I.4 P.0 W.2 C.2 SRP
    6 :   OPTP PASSWORD=########
    7 :  //FDEM EXEC LMGO,LM='J1446.FDEMX',OBSIZE=137,ORECFM=FA
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,10)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(50,10)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,10)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,10)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,10)),
   17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT10F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,10)),
   19 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   20 :  //FT11F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(50,10)),
   21 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   22 :  //FT12F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(50,10)),
   23 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   24 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   25 :  //SYSIN DD *
   26 :  FDEM SAMPLE PROBLEM NO.1 (ICAL=2,IFLX=1,ICELL=0)
   27 :   &UNIT  FXSN=91,SFLX=91,NFEW=91 &END
```

```
 28 :   1¥¥  2 100  20  4HEGRP  28  5  4HSB32  1  2  2  2  0  0  0  1  4R0 T
 29 :   2¥¥  16  0  0  0
 30 :   3¥¥  6R1  4R2  3R3  3R4  2R5  3R6  3R7  2R8    9  3R10 3R11 3R12 3R13
 31 :        3R14 3R15 3R16 3R17 2R18 3R19 5R20 6R21 6R22 6R23 5R24 3R25 2R26
 32 :        9R27 2R28
 33 :   4¥¥  5R1  5R2  5R3  4R4    5
 34 :   5¥¥  4HEGRP  4H 777 4HSFX0
 35 :  11¥¥  4HEGRP  4HFX16 4HIRON  4HAIR0
 36 :  13¥¥  1    2
 37 :    T
 38 :  CLFE IRON (ENDF/B-IV) COLLAPSED BY ZONE 1 FLUX OF DIAC
 39 :  CAIR AIR  (ENDF/B-IV) COLLAPSED BY ZONE 2 FLUX OF DIAC
 40 :  ++
 41 :  //
---------------------------------- END OF FILE ----------------------------------
```

5.5 Sample Problem for ESPRIT

A sample problem for ESPRIT is a gamma-ray skyshine problem. The gamma-ray cross sections for air and concrete used in the calculation are generated by FAIR-CROSS step 2. The flux-to-dose conversion factor is also produced by FDEM.

The job control cards and the input data are shown below. At the first, the generations of the gamma -ray cross sections for air and concrete are described. The second is the production of the flux-to-dose conversion factor. The last is the skyshine calculation by ESPRIT. The results of computations for each procedure are shown in Appendix D. The result of the cross section production for concrete is omitted because the output form of the concrete is the same as that of air.

```
MEMBER NAME > B:EMCROS.TXT    ------------------------------------------------ PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.2 I.3 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC LMGO,LM='J1446.FCSTEP2X'
    8 :  //FT08F001 DD DUMMY
    9 :  //FT11F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,20)),
   10 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   11 :  //FT13F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,20)),
   12 :  //   DCB=(LRECL=16804,BLKSIZE=16804,RECFM=F)
   13 :  //FT14F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,20)),
   14 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   15 :  //FT16F001 DD DSN=&&F6,UNIT=WK10,SPACE=(TRK,(50,20)),
   16 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   17 :  //FT17F001 DD DSN=&&F7,UNIT=WK10,SPACE=(TRK,(50,20)),
   18 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   19 :  //FT18F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,20)),
   20 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   21 :  //FT21F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,20)),
   22 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   23 :  //FT22F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(50,20)),
   24 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   25 :  //FT23F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(50,20)),
   26 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   27 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   28 :  //SYSIN DD *
   29 :   FAIR-CROSS STEP-2 FOR GAMMA-RAY SKYSHINE PROBLEM
   30 :   &UNIT FXSN=91 &END
   31 :   1¥¥ 2   4   0   9  16  4HG09   1  1  T
   32 :   3**  1.660E+6  1.330E+6  1.000E+6  0.800E+6  0.600E+6  0.400E+6
   33 :        0.300E+6  0.200E+6  0.100E+6  0.050E+6  T
   34 :  AIR  CROSS SECTION BY EMPIRICAL FORMULA
   35 :   4¥¥  4HAIR   0  0  1  1  0
```

```
 36 :   5¥¥     6      7      8      1
 37 :   8**     6.0    7.0    8.0    1.0
 38 :   9**    7.5847-9  3.9099-5  1.0537-5  7.1991-9
 39 :  10**     300.0      300.0      300.0      300.0
 40 :    T
 41 :  17¥¥     10  0  0  0  2  2  T
 42 :  29¥¥      0   1   0   0   T
 43 :  ++
 44 :  //
 45 :   FAIR-CROSS STEP-2 FOR GAMMA-RAY SKYSHINE PROBLEM
 46 :   &UNIT FXSN=91 &END
 47 :   1¥¥ 2    3    0    9   16   4HG09    1   1   T
 48 :   3**  1.660E+6  1.330E+6  1.000E+6  0.800E+6  0.600E+6  0.400E+6
 49 :        0.300E+6  0.200E+6  0.100E+6  0.050E+6  T
 50 :  CONC CROSS SECTION BY EMPIRICAL FORMULA
 51 :   4¥¥  4HCONC  0  0  1  1  0
 52 :   5¥¥     1      8     14
 53 :   8**     1.0    8.0   14.0
 54 :   9**    5.5183-3  4.2401-2  2.3250-2
 55 :  10**     300.0      300.0      300.0
 56 :    T
 57 :  17¥¥     10  0  0  0  2  2  T
 58 :  29¥¥      0   1   0   0   T
 59 :  ++
 60 :  //
---------------------------------- END OF FILE ----------------------------------
```

```
MEMBER NAME > B:FDEMDOSE.TXT  ------------------------------------------------ PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
  1 :  //JCLG JOB
  2 :  // EXEC JCLG
  3 :  //SYSIN DD DATA,DLM='++'
  4 :  // JUSER ########,##.######,####.##
  5 :   T.2 I.2 P.0 W.0 C.3 SRP
  6 :   OPTP PASSWORD=########
  7 :  // EXEC FORT77,SO='J1446.FDEM',A='ELM(*),NOS'
  8 :  // EXEC LKED77,PRVLIB='J1446.DPOOL2'
  9 :  // EXEC GO,ORECFM=FA,OBSIZE=137
 10 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,10)),
 11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
 12 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(50,10)),
 13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
 14 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,10)),
 15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
 16 :  //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,10)),
 17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
 18 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
 19 :  //SYSIN DD *
 20 :  FDEM REGISTRATION OF DOSE CONVERSION FACTOR
 21 :   &UNIT  INFX=91,RESD=91 &END
 22 :   1¥¥  5    0    9  4HG09    0  9  4HG09    0  1  1  0  0  5  1  5R0  T
 23 :   T
 24 :  DOSE  PHOTON DOSE CONVERSION FACTOR
 25 :      0
 26 :      1
 27 :    PHOTON DOSE CONVERSION FACTOR
 28 :   2.30000E-03 2.10000E-03 1.80000E-03 1.40000E-03 1.00000E-03 7.10000E-04
 29 :   4.90000E-04 2.70000E-04 1.50000E-04
 30 :  ++
 31 :  //
---------------------------------- END OF FILE ----------------------------------
```

```
MEMBER NAME > B:ESPRIT.TXT    ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 : //JCLG JOB
    2 : // EXEC JCLG
    3 : //SYSIN DD DATA,DLM='++'
    4 : // JUSER ########,##.######,####.##
    5 :  T.7 I.5 P.0 W.3 C.5 SRP
    6 :  OPTP PASSWORD=########
    7 : //FORT EXEC FORT77
    8 :       SUBROUTINE ALOCAT(LOC,SUB)
    9 :       DIMENSION D(300000)
   10 :       IF(LOC.GT.0) GO TO 10
   11 :       LOC=300000
   12 :       CALL DTLIST
   13 :       GO TO 999
   14 :    10 CONTINUE
   15 :       CALL SUB(D,LOC)
   16 :   999 RETURN
   17 :       E   N   D
   18 : //F2     EXEC FORT77,SO='J1446.ESPRIT',A='ELM(*),NOS',DISP=MOD
   19 : //LINK   EXEC LKED77,PRVLIB='J1446.DPOOL2'
   20 : //ESPRIT EXEC GO,ORECFM=FA,OBSIZE=137,SYSOUT=*
   21 : //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(100,100)),
   22 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   23 : //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(100,100)),
   24 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   25 : //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(300,100)),
   26 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   27 : //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(300,100)),
   28 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   29 : //FT09F001 DD DSN=&&F9,UNIT=WK10,SPACE=(TRK,(100,100)),
   30 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   31 : //FT10F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(100,100)),
   32 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   33 : //FT12F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(100,100)),
   34 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   35 : //FT13F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(100,100)),
   36 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   37 : //FT14F001 DD DSN=&&FD,UNIT=WK10,SPACE=(TRK,(100,100)),
   38 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   39 : //FT15F001 DD DSN=&&FE,UNIT=WK10,SPACE=(TRK,(100,100)),
   40 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   41 : //FT30F001 DD DSN=&&FF,UNIT=WK10,SPACE=(TRK,(100,100)),
   42 : //   DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
   43 : //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   44 : //SYSIN DD *
   45 : ESPRIT SAMPLE PROBLEM NO.1
   46 :  &UNIT FXSN=91,RESD=91,FLX1=0,FLX2=0 &END
   47 : 60¥¥    0    9    3    1    0       1
   48 : 61¥¥    0   16    2   41   29       9    3    4   12    0
   49 :         0    2    2    1   48       1    1    0    0    0
   50 :         1   60   60    0   -6       2    0    0    0    0
   51 :         0    0    2    0    0       0    0    0    0    0
   52 :         0    0    0    0    1       1    0    0    0    0
   53 :         2    2    4    0    0       0    0    0    0    0
   54 :         0
   55 : 62¥¥    2    3    4   14   15       9   10    0   12   13
   56 :         1   65    1    5
   57 : 63**  0.0    0.005   0.005   0.0    0.0
   58 :       0.0    0.0     0.0     0.0    0.0
   59 :       0.0  660.0     0.237   1.0  100.0
   60 :       0.0    0.0     0.0
   61 :  T
   62 :  7**   -.3086067 -.2182179  .2182179 -.6172134 -.5773503
```

```
MEMBER NAME > B:ESPRIT.TXT     ---------------------------------------------- PAGE :  2
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
   63 :          -.2182179  1M2
   64 :          -.8164966 -.7867958 -.5773503 -.2182179  1M3
   65 :          -.9759001 -.9511897 -.7867958 -.5773503 -.2182179  1M4
   66 :          1Q24
   67 :        3R-.9511897  5R-.7867958  7R-.5773503  9R-.2182179
   68 :        3R.9511897   5R.7867958   7R.5773503   9R.2182179
   69 :          T
   70 :   6**   0.0         2R.02665019  0.0  4R.02529318  0.0
   71 :           .02529318   .01829035   .02529318  1N3
   72 :          0.0           .02665019    .02529318   .02529318   .02665019
   73 :          1N4   1Q24    T
   74 :  13**  4HG09  4HFX16  4HCONC  4HAIR
   75 :     T
   76 :   3**  F0.0
   77 :     T
   78 :   1**  F0.0
   79 :   2**   0.0     300.0      600.0     760.0   81763.03    781.03
   80 :      1000.0  312000.0  911000.0   60000.0
   81 :   4**   0.0    7110.0   141410.0     710.0  111000.0  313000.0
   82 :     11000.0 1114000.0  1122000.0   28000.0 3132000.0   56000.0
   83 :   5**   1.0  F0.0
   84 :   8**   9R2  15R1  17R2   2Q41
   85 :              24R1  17R2   9Q41
   86 :         F2
   87 :   9**   1    2
   88 :  33**   1.0   -1.0
   89 :  34**   1.0    1.0
   90 :  36**   1
   91 :  38**   4HG09   4HRESD  4HDOSE
   92 :    T
   93 :  ++
   94 :  //
------------------------------------ END OF FILE ------------------------------------
```

5.6 Sample Problem for MCACE

A sample problem for MCACE is a gamma-ray skyshine problem. The cross sections and the flux-to-dose conversion factor used in the calculation are the same as those produced in the previous section.

The job control cards and the input data are described below. The result of computation is shown in Appendix D.

```
MEMBER NAME > B:MCACE.TXT      ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.5 I.1 P.0 W.1 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  //MCACE  EXEC LMGO,LM='J1446.MCACEX'
    8 :  //FT16F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(100,20)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT41F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(100,20)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT92F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   13 :  //SYSIN DD *
   14 :  MCACE SAMPLE PROBLEM NO.1
   15 :    200  240   60    1    9    0    9    9    0    0   10    2    0    0
   16 :      0    1    0    0 1.0       0.02   +6 0.0       0.0       2.2    +5
   17 :      0
   18 :    0.0
   19 :    1.0
   20 :    1.33  +6  1.0   +6  0.8   +6  0.6   +6  0.4   +6  0.3   +6  0.2   +6
   21 :    0.1   +6  0.05  +6
   22 :  0123456789
```

```
23 :      0    1    0    0    0    4    9    0
24 :      1    1    9    1    1    4 100.0      1.0     -3 1.0     -2  0.0
25 :     -1
26 :      0
27 :      0    0   SKY-SHINE PROBLEM
28 :    RCC    1  0.0        0.0         0.0         0.0         0.0          7.6    +2
29 :               4.1    +2
30 :    RCC    2  0.0        0.0         0.0         0.0         0.0          7.8103+2
31 :               7.1    +2
32 :    RPP    3 -6.0    +4 6.0     +4 -6.0    +4 6.0     +4 0.0           6.0    +4
33 :    RPP    4 -6.01   +4 6.01    +4 -6.01   +4 6.01    +4 -10.0         6.01   +4
34 :    END
35 :    AIR           +1
36 :    WAL           +2      -1
37 :    AIR           +3      -2
38 :    VID           +4      -3
39 :    END
40 :      1    2    3    4
41 :      1    2    1    0
42 :    CROSS SECTION FROM DATA-POOL
43 :      0    0    9    9    9   12    4    2    2    0    0  -16    0
44 :      0    0    0    0    0    0   -1    0
45 :   &DPUNIT  NLIB=92  &END
46 :   G09  FX16 AIR  CONC
47 :    SAMBO INPUT TOTAL FLUX AND DOSE RATE
48 :      3    1    9    9    0    0   -1    1    1
49 :    1.0   +4  0.0       1.5    +2
50 :    2.0   +4  0.0       1.5    +2
51 :    3.0   +4  0.0       1.5    +2
52 :    RESPONSE FUNCTION (MR/HR)
53 :   &DPUNIT  RESD=92  &END
54 :   G09  RESD DOSE
55 :    PHOTON/SEC/CM**2/EV
56 :      1    2    3    4    5    6    7    8    9
57 :  PRT     1    1    1    0    0    0    9    9    0    0    0
58 :   0.0       0.0       1.5    +2 0.0       0.0       1.0
59 :   1.0       0.0       0.0
60 :   70.0   +2 90.0   +2 110.0  +2 140.0  +2 180.0  +2 220.0  +2 250.0  +2
61 :   280.0  +2 320.0  +2 380.0  +2
62 :      1    1    1    1    1    1    1    1    1
63 :   0.0       6.283     0.0       6.283     0.0       6.283     0.0
64 :   6.283     0.0       6.283     0.0       6.283     0.0       6.283
65 :   0.0       6.283     0.0       6.283
66 :   SOURCE        1    5    3  1.33  +6 0.02   +6    3
67 :              0.0       0.0       660.0
68 :              0.0       0.0       0.0
69 :              0.273     0.0
70 :      1
71 :   1.25   +6  1.0
72 :   END OF SAMPLE PROBLEM : PROGRAM MCACE TERMINATED
73 :  ++
74 :  //
------------------------------------ END OF FILE ------------------------------------
```

5.7 Sample Problem for BREM

A gamma-ray penetration problem for the ^{16}N source is shown as a sample application of BREM. The configuration of the problem is a one-dimensional infinite lead slab of 5 cm thickness.

The $^{16}O(n, p)^{16}N$ reaction gamma-rays with the energies of 6.13 and 7.12 MeV are considered as a plane isotropic source at the left surface of the slab.

The calculational procedure is divided into 4 steps. At the first step, cross sections including the Bremsstrahlung data are generated. In the second step, an ordinary gamma-ray transport calculation is performed by DIAC. The third step consists of the estimation of the secondary gamma-ray source due to the Bremsstrahlung effect and the gamma-ray transport calculation. The SOURCE option in the BREM module and the one-dimensional transport code DIAC are used.The total gamma-ray flux is calculated

in the last step, where the EDIT option in the BREM module is provided.

The job control cards and the input data are described below. The results of these computations are shown in Appendix D.

```
MEMBER NAME > B:BSTEP2.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.2 I.3 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC LMGO,LM='J1446.FCSTEP2X'
    8 :  //FT08F001 DD DSN=J3631.DLC15.DATA,DISP=SHR,LABEL=(,,,IN)
    9 :  //FT11F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,20)),
   10 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   11 :  //FT13F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,20)),
   12 :  //   DCB=(LRECL=16804,BLKSIZE=16804,RECFM=F)
   13 :  //FT14F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,20)),
   14 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   15 :  //FT16F001 DD DSN=&&F6,UNIT=WK10,SPACE=(TRK,(50,20)),
   16 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   17 :  //FT17F001 DD DSN=&&F7,UNIT=WK10,SPACE=(TRK,(50,20)),
   18 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   19 :  //FT18F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,20)),
   20 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   21 :  //FT21F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,20)),
   22 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   23 :  //FT22F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(50,20)),
   24 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   25 :  //FT23F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(50,20)),
   26 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   27 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   28 :  //SYSIN DD *
   29 :   FAIR-CROSS STEP-2 FOR BREMSSTRAHLUNG SAMPLE PROBLEM
   30 :   &UNIT FXSN=91 &END
   31 :   1¥¥ 2  1     0   19   16   4HEG19   1   1   T
   32 :   3**  7.235E+6  7.065E+6  6.215E+6  6.045E+6  5.535E+6  5.025E+6
   33 :        4.515E+6  4.005E+6  3.495E+6  2.985E+6  2.475E+6  2.135E+6
   34 :        1.795E+6  1.455E+6  1.115E+6  0.775E+6  0.605E+6  0.435E+6
   35 :        0.265E+6  0.095E+6   T
   36 :  LEAD CROSS SECTION BY DLC-15
   37 :   4¥¥  4HPB00  0  0  3  1  0
   38 :   5¥¥      82
   39 :   8**     82.0
   40 :   9**   3.295E-2
   41 :  10**    300.0
   42 :    T
   43 :  17¥¥    10  0  0  0  2  2  T
   44 :  29¥¥     0   1   0   0   T
   45 :  ++
   46 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
MEMBER NAME > B:BDIAC1.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.3 I.4 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  //DIAC EXEC LMGO,LM='J1446.DIACX',OBSIZE=137,ORECFM=FA
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(300,100)),
    9 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(300,100)),
   11 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(300,100)),
   13 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(300,100)),
   15 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT12F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(300,100)),
   17 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   19 :  //SYSIN DD *
   20 :  DIAC SAMPLE PROBLEM NO.1 FOR BREMSSTRAHLUNG OF 5CM LEAD
   21 :   &UNIT  FXSN=91,FLX1=91,FLX2=0 &END
   22 :  14**    0 19  0  0  0  0  0  1    0  0  0
   23 :  15** 500  0  16  16  1  0  0  1  12  0    19  3  4   22  0  0  1  1  1
   24 :         0  0   1   1  50  0  0  0  0  1  2  0  0  0  1  0  0
   25 :  16**  1.0  0.1  1.0-4  1.420892  3R0.0  0.0  0.0  0.5  1.0-4  3R0.0 T
   26 :   6**  0.0 0.0244936 0.0413296 0.0392569 0.0400796 0.0643754
   27 :            0.0442079 0.109085  0.1371702  1N8
   28 :   7**  -0.9902984 -0.9805009 -0.9092855 -0.8319966 -0.7467506
   29 :        -0.6504264 -0.5370966 -0.3922893 -0.1389568 1M8  T
   30 :  13**  4HEG19  4HFX16  4HPB00 T
   31 :  18**  17R0.07  17R0.0  17R0.93  F0.0  T
   32 :   3**  F0.0  T
   33 :   1**  F0.0
   34 :   4**  1110.0  6.0
   35 :   5** F1.0
   36 :   8**  F1
   37 :   9**  1
   38 :  21**  0.0  10R1.0  0.0
   39 :    T
   40 :  ++
   41 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
MEMBER NAME > B:BDIAC2.TXT    ---------------------------------------------- PAGE :  1
LINE NO:  ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.3 I.4 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  //BREM EXEC LMGO,LM='J1446.BREM',
    8 :  //   ORECFM=FA,OBSIZE=137,SYSOUT=*
    9 :  //FT01F001 DD DSN=J1446.BSOURCE.DATA,UNIT=TSSWK,SPACE=(TRK,(10,5)),
   10 :  // DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS),DISP=(NEW,CATLG,DELETE)
   11 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   12 :  //SYSIN DD *
   13 :  BREMSSTRAHLUNG SOURCE CALCULATION FOR LEAD
   14 :   &UNIT FLX1=91,BREM=91 &END
   15 :   1¥¥  10  1  12  1  1  0  0  0  T
   16 :   2¥¥  4HEG19  4H 500
   17 :  13¥¥  4HEG19  4HFX16  4HPB00
   18 :  21**  0.0  10R1.0  0.0  T
   19 :  /*
   20 :  //DIAC EXEC LMGO,LM='J1446.DIACX',OBSIZE=137,ORECFM=FA
   21 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(300,100)),
   22 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   23 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(300,100)),
   24 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   25 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(300,100)),
   26 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   27 :  //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(300,100)),
   28 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   29 :  //FT12F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(300,100)),
   30 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   31 :  //FT20F001 DD DSN=J1446.BSOURCE.DATA,DISP=SHR
   32 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   33 :  //SYSIN DD *
   34 :  SAMPLE PROBLEM NO.2 FOR BREMSSTRAHLUNG 5CM LEAD
   35 :   &UNIT  FXSN=91,FLX1=91,FLX2=0 &END
   36 :  14¥¥   0 19  0  0  0  0  0  1   0  0  0
   37 :  15¥¥ 600  0  16  16  1  0  0  1  12  0   19  3  4   22  0  0  1  1  1
   38 :         0  2   0   0  50  0  0  0  0  1  2  0  0  0  1  0  0
   39 :  16**  1.0  0.1  1.0-4  1.420892  3R0.0  0.0  0.0  0.5  1.0-4  3R0.0  T
   40 :   6**  0.0 0.0244936 0.0413296 0.0392569 0.0400796 0.0643754
   41 :            0.0442079 0.109085  0.1371702  1N8
   42 :   7**  -0.9902984 -0.9805009 -0.9092855 -0.8319966 -0.7467506
   43 :        -0.6504264 -0.5370966 -0.3922893 -0.1389568 1M8  T
   44 :  13¥¥  4HEG19  4HFX16  4HPB00 T
   45 :   3**  F0.0  T
   46 :   1**  F0.0
   47 :   4**  1110.0  6.0
   48 :   5** F1.0
   49 :   8¥¥  F1
   50 :   9¥¥  1
   51 :  21**  0.0  10R1.0  0.0
   52 :    T
   53 :  ++
   54 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
MEMBER NAME > B:BREM.TXT      ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.1  I.2 P.0 W.0 C.1 SRP
    6 :   OPTP PASSWORD=########
    7 :  //BREM EXEC LMGO,LM='J1446.BREM',
    8 :  //    ORECFM=FA,OBSIZE=137,SYSOUT=*
    9 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   10 :  //SYSIN DD *
   11 :  BREMSSTRAHLUNG EDIT CALCULATION FOR LEAD
   12 :   &UNIT FLX1=91,FLX2=91,FLX3=91 &END
   13 :   1¥¥ 700   2   12   1   1   1   0   0   T
   14 :   3¥¥  4HEG19   4H 500   4H 600
   15 :  13¥¥  4HEG19   4HFX16   4HPB00
   16 :  21**  0.0   10R1.0   0.0   T
   17 :  ++
   18 :  //
------------------------------------ END OF FILE ------------------------------------
```

6. Conclusion

The RADHEAT-V4 code system consists of various functional modules for performing coupled neutron and gamma-ray transport analyses. The detailed descriptions for the modules have been presented in this report. Some test calculations and sample problems have been discussed to verify the effectiveness for the new methods applied in the code system.

Extensive tests and evaluations of the RADHEAT-V4 code system as benchmark analyses have been performed by two different working groups of the Japan Nuclear Code Committee and the Japan Nuclear Data Committee.

The result obtained by these benchmark analyses indicates that the RADHEAT-V4 code system can accurately solve neutron and gamma-ray transport problems, even if there have strong anisotropies of radiation source and of angular fluxes in a medium.

The evaluation work of the RADHEAT-V4 code system has completed and the report of the benchmark analyses has now being compiled in the Japan Nuclear Code Committee. It will be published in the near future.

Acknolwedgements

The authors wish to express their thanks to T. Asaoka, M. Hirata, M. Ishikawa and M. Hirano of Japan Atomic Energy Research Institute for their useful advices and encouragements to develop this code system. Their thanks are also expressed for the guidance and counsel of S. Miyasaka during the planning stages and of Y. Kikuchi and M. Kawai during the evaluation stages.

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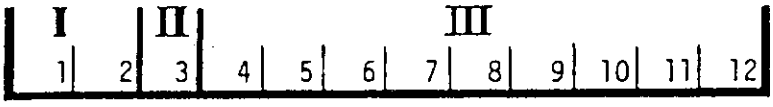
Appendix A FIDO Input Format(*)

Type 1 Format

Each card is divided up into six 12-digit data fields which are in turn divided up into 3 subfields, as illustrated in the following figure where only one data field is shown.



The first subfield is a two-digit integer; and the second subfield contains either a $, *, R, I, T, S, F, A, C, E, Q, L, N, M, O, U, V, Z, +, −, or a blank. The third subfield contains either a fixed or floating point number. The contents of the first two subfields will define the operation to be performed on the third field.

Blank fields are ignored. One can use any or all fields on a card. For example, a box of blank cards sandwiched anywhere in a data array would be completely ignored.

Each data array is identified by a two-digit integer in a first subfield. There are both fixed and floating point arrays; a fixed point array is designated by a $ in the second subfield, and a floating point array by an *.

The second subfield contains an operator which specifies the type of operation to be performed on the data. The possible operators are listed below.

Array Operators

$ indicates the beginning of an integer array. The first subfield contains a one- or two-digit number identifying the array.

* indicates the beginning of a floating point array. The first subfield identifies the array.

R indicates that the entry in the third subfield is to be repeated the number of times specified in the first subfield.

I indicates linear interpolation between the entry in the third subfield and the entry in the third subfield of the next data field. The number in the first subfield gives the number of points to be placed equally spaced in the specified range.

T indicates termination of data reading for a block. RADHEAT-V4 can require several data blocks and each block must be ended with a T. A block can contain any number of arrays. Data on a card after a T will be ignored.

S indicates skip. The first subfield defines the number of entries to be skipped. The third field can contain the first entry following the skips. A blank third subfield would be ignored.

F is used to fill the remainder of an array with item given in the third subfield.

A is used to address a particular location in an array. This location is specified in the third subfield, while the first subfield is blank.

C is used to obtain a count of the number of items read into an array up to the point where the C is placed. An integer ZZ in front of the C will be used as identification in producing a message as follows:

XX ENTRIES READ IN THE YY ARRAY at ZZC.

E may be used to end specifying data for an array. This option is particularly useful when it is desired to replace only some items in a particular array. The items in question are replaced, and the used of an E

* All of the descriptions are reproduced from Ref. 5.

prevents having to count and skip to the end of the array.

Q is used to repeat sequences of numbers. The length of the sequence is defined in the third subfield. The number of times to repeat the sequence is given in the first subfield.

L is similar to I except that a logarithmic interpolation is performed between the entry points. This option is particularly useful for defining energy structures equally spaced in lethargy.

N is used to repeat a sequence of numbers in reverse order. The length of the sequence is defined in the third subfield. The number of times to repeat a sequence is given in the first subfield.

M is used to negate and repeat an inverted sequence. The length of the sequence is given in the third subfield. The number of times to repeat a sequence is given in the first subfield.

O is used to turn on (or off) the card image edit of ANISN input data. As with the C option, an integer in front of the O identifies the particular entry. The default (starting) condition is not to edit the data.

U is used to replace the ANISN input format for an array. The array number is given in the first subfield. The format, written in normal FORTRAN, is specified on the card immediately following the card containing a U. The parentheses normally capsulating a format should be included.

V specifies that the array identified in the first subfield will be read according to the last variable format read in.

Z is used to specify a string of zeroes; e.g., 49Z would place forty-nine zeros into an array.

+ or − indicates exponentiation. The data in the third field is multiplied by $10^{\pm N}$, where N is an integer in the first subfield. This option allows one to specify a number in up to nine significant digits.

Integer data in the third subfield must be right adjusted. Floating point data may be written with or without an exponent. If the decimal is omitted, it is assuemd to be immediately to the left of the exponent field. If there is no exponent, the decimal point is assumed to be to the extreme right of the nine-column subfield.

Input Restrictions

The following restrictions must be observed when using the ANISN input format:

(1) Blank data fields are ignored.

(2) If the interpolation option (I) is used, the next data field may not be either blank or an A entry.

(3) The third subfield of a data field containing a $ or a * may contain an integer N. The next data entry is assumed to be the (N+1)-th member of the array. Normally the third subfield is blank and is ignored.

(4) All data arrays must be filled with the correct number of entries. A data array is ended by either starting a new data array or by ending a data block.

Type 2 Format (Free Form)

The transferral of input data to input forms or punched cards for a code requiring significant amounts of input is always a time consuming, distasteful and error-prone process. The original ANISN formats were designed to help reduce these difficulties. The options are convenience features. The usefulness of the "F" option which fills an array is obvious, but it is somewhat harder to see the practical uses for some of the more obscure ones like N, M, and Q. However, frequent use will turn up situations where these options are invaluable. For example, the S_n cosines are negated and reflected about 90°, a fact of which suggests the use of the M option.

There are justifiable complaints with the input formats; for example, where convenience options are not applicable, data can be hard to write because of the manner in which the data fields are spread on the card. This is especially true of integer arrays, where the data are right adjusted in 12-column fields. The ANISN input forms help to some extent, but the actual key-punching is still troublesome.

This input format has been greatly improved by Ward Engle of ORNL who has designed and

implemented an all-FORTRAN free-form ANISN input scheme which has data items separated by blanks (as others do), but still allows all of the important convenience features of the earlier formats. The restrictions on the use of this input are essentially that the user writes the data in a form that he can interpret within the context of the ANISN options. Data is easily written and key-punched, since there is now worry about which type character falls in which column or how many blanks are left between entries.

The free-form input can be interspersed with the fixed form input. To select free-form, an array is identified as either a $$ or a ** array for integer and floating point arrays, respectively.

The restrictions are:

(1) Any third subfield (data entry) must be followed by one or more blanks. This is an obvious restriction, otherwise data interpretation would be impossible.

(2) Only columns 1-72 are used.

(3) Number with exponents must not have imbedded blanks; e.g., use 1.0E+4, but not 1.0 E+4 or 1.0E+ 4.

(4) The old + or − options (2nd subfield) are not operational.

(5) No more than 9 digits in a number can be entered. The exponent in not counted; e.g., 9234+09 or 923400000+1 will work, but 9234000000 will not work. Nine-digit accuracy is clearly beyond the significance available for single precision IBM 360 floating point operations.

(6) A blank must not appear between items which fall in the first and second subfields with the old format, e.g., 24R, but not 24 R. Note that the 99 restriction on the number of repeats, interpolations, etc., has been eliminated.

(7) The Z-entry must be entered as 738Z, but not as Z738. The old format allowed either.

(8) The Q, M and N entries must be specified as Q4, but not as 4Q. The old format allows either. An entry like 3Q4 accomplishes the same as Q4 Q4 Q4. This is now true for either format.

The character (') in column 1 of a card will cause the contents of the card to be listed as comments, while the data is read in. Column 2 should contain the proper carriage control character; e.g., blank, 0,1,2, etc. This card is ignored as a data card. This option is also available with the old formats.

Some examples of the new format are given below:

1$$25R1_0_4_3Q3_2$$_3R42_E_T

The first 25 entries of the 1$ array are 1's followed by 0 and 4, and then the sequence 1 0 4 is repeated three times. The 2$ array has three 42's and then data input to the array ends. The T terminates a data block.

42**_0.0_0.1666667_0.3333333_N2

43**_−1.0_−0.8819171_0.3333333 M2

This example puts 0.0, 0.1666667, 0.3333333, 0.3333333, 0.1666667 in the 42* array and −1.0, −0.8819171, −0.3333333, 0.3333333, 0.8819171 in the 43* array.

Appendix B Combinatorial Geometry Input(*)

Combinatorial geometry (CG) describes general three dimensional material configurations by considering unions, differences intersections of simple bodies such as spheres, boxes, cylinders, etc. In effect, the geometric description subdivides the problem space into unique zones. Each zone is the result of combining one or more of the following geometric bodies.

1. Rectangular Parallelepiped (RPP)
2. Box (An RPP randomly oriented in space)
3. Sphere (SPH)
4. Right Circular Cylinder (RCC)
5. Right Elliptic Cylinder (REC)
6. Truncated Right Angle Cone (TRC)
7. Ellipsoid (ELL)
8. Right Angle Wedge (WED)
9. Arbitrary Convex Polyhedron of 4, 5, or 6 sides. (ARB)

Body types 2–9 may be arbitrarily oriented with respect to the x, y, z coordinate axes used to determine the space. Body 1, a special body described below, must have sides which are parallel to the coordinate axes.

The basic technique for the description of the geometry consists of difining the location and shape of the various zones in terms of the intersections and unions of the geometric bodies. A special operator notation involving the symbols (+), (−), and (OR) is used to describe the intersections and unions. These symbols are used by the program to construct information relating material descriptions to the body definitions.

If a body appears in a zone description with a (+) operator, it means that the zone being described is wholly contained in the body. If a body appears in a zone description with a (−) operator, it means that the zone being described is wholly outside the body. If the body appears with an (OR) operator, it means that the zone being described includes all points in the body. In some instances, a zone may be described in terms of subzones lumped together by (OR) statements. When (OR) operators are used there are always two or more of them, and they refer to all body numbers following them, either (+) or (−).

Techniques for describing a particular geometry are best illustrated by examples. Consider an object composed of a sphere and a cylinder as shown in **Fig. B.1**. To describe the object, one takes a spherical body (2) penetrated by a cylindrical body (3) (see **Fig. B.1**). If the materials in the sphere and cylinder are the same, then they can be considered as one zone, say zone I (**Fig. B.1c**). The description of zone I would be

$$I = OR + 2OR + 3$$

This means that a point is in zone I it is either inside body 2 or inside body 3.

If different materials are used in the sphere and cylinder, then the sphere with a cylindrical hole in it would be given a different zone number (say J) from that of the cylinder (K).

The description of zone J would be (**Fig. B.1d**):

$$J = +2-3$$

* All of the description are reproduced from Ref. 27.

This means that points in zone J are all those points inside body 2 which are not inside body 3.

The description of zone K is simply (**Fig. B.1e**):

$$K=+3$$

That is, all points in zone K lie inside body 3.

Combinations of more than two bodies and similar zone descriptions could contain a long string of (+), (−), and (OR) operators. It is important however to remember that every spatial point in the geometry must be located in one and only one zone.

As a more complicated example of the use of the (OR) operator, consider the system shown in **Fig. B.2** consisting of the shaded zone A and the unshaded zone B. These zones can be described by the two BOX's, bodies 1 and 3, and the RCC, body 2. The zone description would be

$$A=+1+2$$

and

$$B=OR+3-1OR+3-2$$

Notice that the OR operator refers to all following body numbers until the next OR operator is reached.

The geometry must be specified by establishing two tables. The first table describes the type and location of the set of bodies used in the geometrical description. The second table identifies the physical zones in terms of these bodies. The input routine processes these tables to put the data in the form required for ray tracing. Because the ray tracing routines cannot track across the outermost body, all of the zones must be within a surrounding external void so that all escaping particles are absorbed. Also no point may be in more than one zone.

The information required to specify each type of body is as follows:

a) Rectangular Parallelepiped (RPP)
Specify the minimum and maximum values of the x, y, and z coordinates which bound the parallelepiped.

b) Sphere (SPH)
Specify the vertex V at the center and the scalar, R, denoting the radius.

c) Right Circular Cylinder (RCC)
Specify the vertex V at the center of one base, a height vector, H, expressed in terms of its x, y, and z components, and a scalar, R, denoting the radius.

d) Right Elliptical Cylinder (REC)
Specify coordinates of the center of the base ellipse, a height vector, and two vectors in the plane of the base defining the major and minor axes. Presently this body is not implemented.

e) Truncated Right Angle Cone (TRC)
Specify a vertex V at the center of the lower base, the height vector, H, expressed in terms of its z, y, z components, and two scalars, R_1 and R_2, denoting the radii of the lower and upper bases.

f) Ellipsoid (ELL)
Specify two vertices, V_1 and V_2, denoting the coordinates of the foci and a scalar, R, denoting the length of the major axis.

g) Wedge (WED)
Specify the vertex V at one of the corners by giving its (x, y, z) coordinates. Specify a set of three mutually perpendicular vectors, a_i, with a_1 and a_2 describing the two legs of the right triangle of the wedge. That is, the x, y, and z components of the height, width, and length vectors are given.

h) Box (BOX)

Specify the vertex V at one of the corners by giving its (x, y, z) coordinates. Specify a set of three mutually perpendicular vectors, a_i representing the height, width, and length of the box, respectively. That is, the x, y, and z components of the height, width, and length vetors are given.

i) Arbitrary Polyhedron (ARB)

Assign an index (1 to 8) to each vertex. For each vertex, give the x, y, z coordinates. Each of the six faces are then described by a four-digit number giving the indices of the four vertex points in that face. For each face these indices must be entered in either clockwise or counterclockwise order.

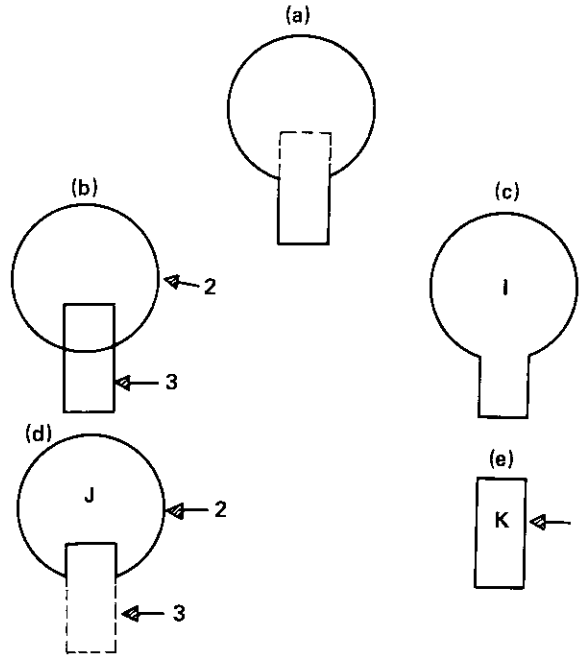


Fig. B.1 Examples of combinatorial geometry method

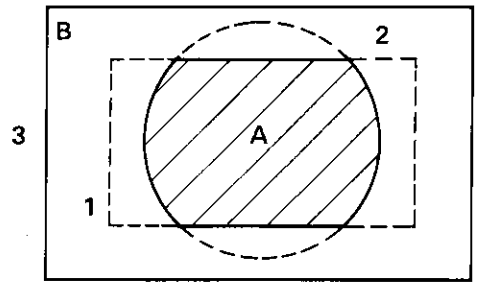


Fig. B.2 Use of OR operators

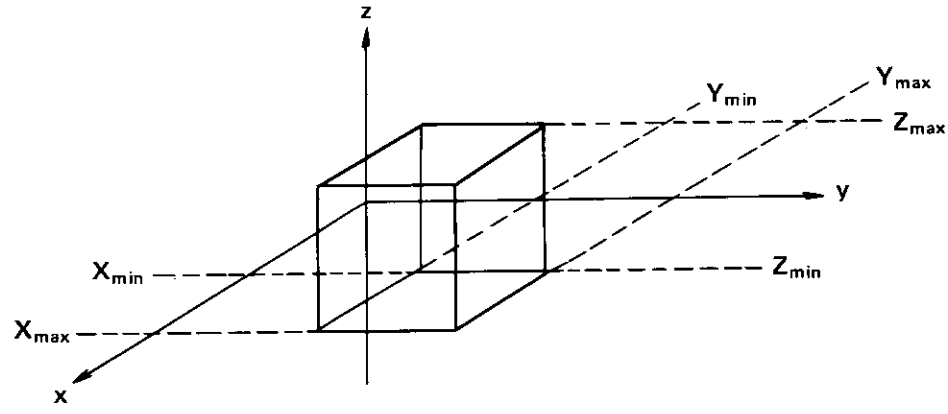


Fig. B.3 Rectangular Parallelepiped (RPP)

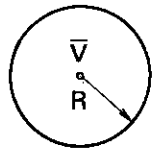


Fig. B.4 Sphere (SPH)

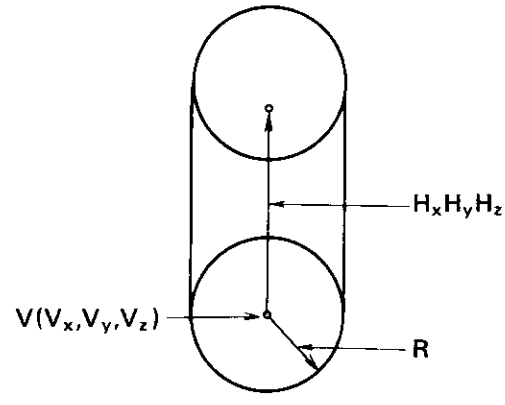


Fig. B.5 Right Circular Cylinder (RCC)

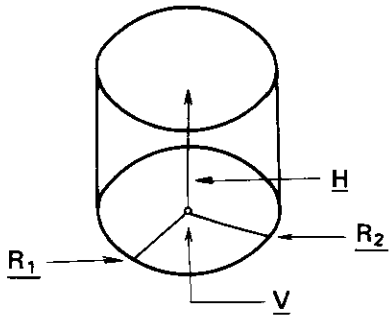


Fig. B.6 Right Elliptical Cylinder (REC)

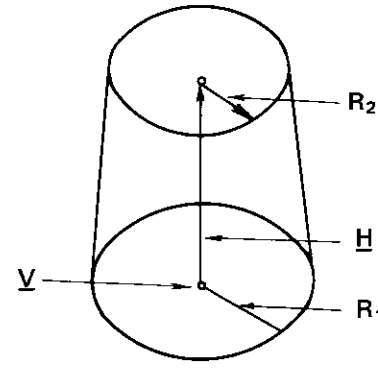


Fig. B.7 Truncated Right Angle Cone (TRC)

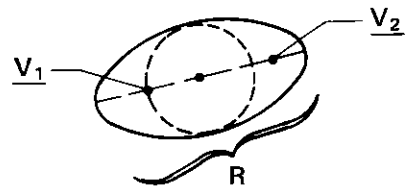


Fig. B.8 Ellipsoid (ELL)

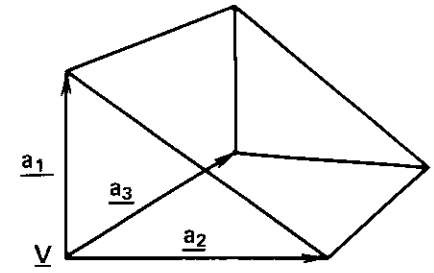


Fig. B.9 Right Angle Wedge (WED)

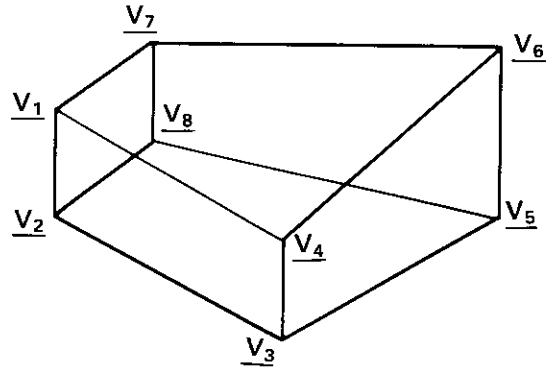


Fig. B.10 Box (BOX)

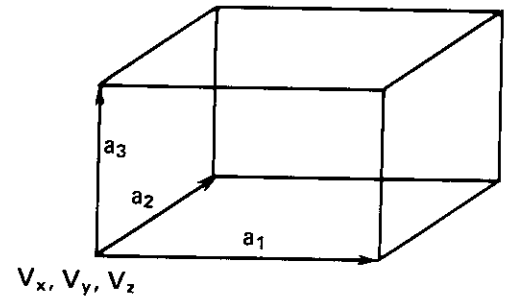


Fig. B.11 Arbitrary Polyhedron (ARB)

Appendix C Record Format of Data Stored in DATA-POOL

The record formats of data generated by the RADHEAT-V4 code system are classified according to the data forms described in Section 4.1.2. DATA-POOL has the user information in the Directory Section and the data in the Data Section. Each data is utilized for the functional modules in the RADHEAT-V4 code system. The user information consisting of 5 words are stored by using the PSET subroutine and read by using the PFIND subroutine in the DATA-POOL access package, respectively. The data in the Data Section are stored by using the PRITE - PRITE4 subroutines and read by using the PREAD - PREAD 4 subroutines described in Section 4.1.3.

The data forms of DATA-POOL used in the RADHEAT-V4 code system are described below. In the following description, an "information" means the user information in the Directory Section and a "data" indicates tha data in the Data Section. The node name with a capital letter shows the fixed name, and a lower case letter means that the name changes for each data.

a) ULTX Data Form

level 1 node : ULTX

information NGRP, 0, 0, 0, 0

data PREAD1 (N, NCOM, NGRP+1, FEGRP)

level 2 node : matno

information NATNO, MTMAX, NTMP, NSIG, LFI

data PREAD3 (N, NCOM, MTMAX, MTYPE, NTMP, TMP, NSIG, SIG0)

level 3 node : TMPi

information TMP, 0, 0, 0, 0

data PREAD (N, NCOM)

level 4 node : SIGj

information SIG, MTMAX2, 0, 0, 0

data PREAD2 (N, NCOM, MTMAX2, MTYPE2, NGRP, W)

DO 1 I=1, MTMAX2

1 PREAD2 (N, NCOM, 5, NDATA, M, GCS)

where NGRP : number of the ultra-fine energy groups

N : logical unit number of DATA-POOL

NCOM : comment of the node (20 words)

MATNO : material identification number

MTMAX : number of reactions

NTMP : number of temperatures

NSIG : length of σ_0 table

LFI : fission flag (0: non fission, 1: fission)

MTMAX2 : number of reactions for each σ_0 value

FEGRP : energy group boundaries (eV)

MTYPE : reaction identification numbers

TMP : temperatures

SIG0 : σ_0 values

MTYPE2 : reaction identification numbers

W : weighting spectrum

NDATA : MTYPE(I), C1, C2, NLOW, NUP

M : NUP−NLOW+1
GCS : ultra-fine group cross sections from the group NLOW to NUP

b) SMT Data Form

level 1 node : EGRP
information ING, IGG, 0, 0, 0
data PREAD1 (N, NCOM, ING+1, GNG) (IGG=0)
PREAD2 (N, NCOM, ING+1, GNG, IGG+1, GGG) (IGG≠0)
level 2 node : INFX
information 0, 0, 0, 0, 0
data PREAD (N, NCOM)
level 3 node : matno
information MATNO, 0, 0, 0, 0
data PREAD (N, NCOM)
level 4 node : SMT
information 0, 0, 0, 0, 0
data PREAD3 (N, NCOM, M, MT, 1, TMP, 1, SIG0)
PREAD1 (N, NCOM, MM, SMT)
where ING : number of neutron energy groups
IGG : number of gamma-ray energy groups
N : logical unit number of DATA-POOL
NCOM : comment of the node (20 words)
MT : reaction identification numbers
TMP : temperature
SIG0 : σ_0 value
M : number of reactions (10)
MM : ING×M
SMT : smooth cross section

c) FTB Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto
level 2 node : INFX
information same as the SMT data form
data ditto
level 3 node : matno
information same as the SMT data form
data ditto
level 4 node : FTB
information 0, 0, 0, 0, 0
data PREAD3 (N, NCOM, M, MT, NTMP, TMP, NSIG, SIG0)
DO 1 I=1, NTMP
1 PREAD4 (N, NCOM, LEN, SFT, LEN, SFE, LEN, SFF, LEN, SFC)
where M : number of reactions (4)
MT : reaction identification numbers
NTMP : number of temperatures
NSIG : number of σ_0 values

N : logical unit number of DATA-POOL
NCOM : comment of the node (20 words)
LEN : NSIG×ING
TMP : temperatures
SIG0 : σ_0 values
SFT : self-shielding factor for the total reaction
SFE : self-shielding factor for the elastic reaction
SFF : self-shielding factor for the fission reaction
SFC : self-shielding factor for the capture reaction

d) ELA Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto
level 2 node : INFX
information same as the SMT data form
data ditto
level 3 node : matno
information same as the SMT data form
data ditto
level 4 node : ELA
information 0, 0, 0, 0, 0
data PREAD3 (N, NCOM, 1, MT, 1, TMP, 1, SIG0)
DO 1 I=1, ING, 10
1 PREAD3 (N, NCOM, ING×10, NOA, NTP, ANG, NTP, SIG)

where
N : logical unit number of DATA-POOL
NCOM : comment of the node (20 words)
MT : reaction identification number (MT=2)
TMP : temperature
SIG0 : σ_0 value
NOA : number of angular points for each energy group
NTP : summation of NOA(M) values from M=1 to M=ING×10
ANG : cosine of scattering angles
SIG : elastic scattering cross section in the DAR form

e) INS Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto
level 2 node : INFX
information same as the SMT data form
data ditto
level 3 node : matno
information same as the SMT data form
data ditto
level 4 node : INS

information 0, 0, 0, 0, 0
data PREAD3 (N, NCOM, 1, MT, 1, TMP, 1, SIG0)
DO 1 I=1, ING, 10
1 PREAD3 (N, NCOM, ING×10, NOA, NTP, ANG, NTP, SIG)
where MT : reaction identification number (MT=4)
SIG : inelastic scattering cross section in the DAR form
The other notations are the same as the ELA data form.

f) N2N Data Form
level 1 node : EGRP
information same as the SMT data form
data ditto
level 2 node : INFX
information same as the SMT data form
data ditto
level 3 node : matno
information same as the SMT data form
data ditto
level 4 node : N2N
information 0, 0, 0, 0, 0
data PREAD3 (N, NCOM, 1, MT, 1, TMP, 1, SIG0)
DO 1 I=1, ING, 10
1 PREAD3 (N, NCOM, ING×10, NOA, NTP, ANG, NTP, SIG)
where MT : reaction identification number (MT=16)
SIG : (n, 2n) scattering cross section in the DAR form
The other notations are the same as the ELA data form.

g) H+D Data Form
level 1 node : EGRP
information same as the SMT data form
data ditto
level 2 node : INFX
information same as the SMT data form
data ditto
level 3 node : matno
information same as the SMT data form
data ditto
level 4 node : H+D
information 0, 0, 0, 0, 0
data PREAD3 (N, NCOM, M, MT, 1, TMP, 1, SIG0)
PREAD1 (N, NCOM, MM, HD)
where N : logical unit number of DATA-POOL
NCOM : comment of the node (20 words)
M : number of reaction channels (M=13)
MT : reaction identification numbers
TMP : temperature
SIG0 : σ_0 value
MM : ING×M

HD : energy deposition factors and atomic displacement cross sections

h) SGRX Data Form

level 1 node : EGRP

information same as the SMT data form

data ditto

level 2 node : SGRX

information 0, 0, 0, 0, 0

data PREAD (N, NCOM)

level 3 node : matno

information MATNO, 0, 0, 0, 0

data PREAD (N, NCOM)

level 4 node : ncode

information ITWO, ICON, KEY, NHI, NLOW

data PREAD3 (N, NCOM, LEN, X, LEN, Y, LEN1, P)

where MATNO : material identification number

N : logical unit number of DATA-POOL

NCOM : comment of the node (20 words)

ITWO : flag of the nuclear data
(1: ENDF/B-IV, 2: POPOP4)

ICON : flag of the weighting procedure
(0: constant weighting, 1: energy weighting)

KEY : flag of the reaction
(0: no effect, 1: inelastic excitation)

NHI : the highest energy group for non-zero values

NLOW : the lowest energy group for non-zero values

LEN : NHI−NLOW+1

LEN1 : IGG×LEN

X : neutron interaction cross sections

Y : yields

P : probabilities ((P(i, j), i=1, IGG), j=1, LEN)

i) FXsn Data Form

level 1 node : EGRP

information same as the SMT data form

data ditto

level 2 node : FXsn

information IPO, 0, 0, 0, 0

data PREAD1 (N, NCOM, IPO+1, ANG)

level 3 node ; matid

information MATID, IHS, IHT, IHM, NUP

data PREAD4 (N, NCOM, NMAT, MAT1, NMAT, MAT2, NMAT, ATOM, NMAT, TMP)
DO 1 I=1, ING÷IGG

1 PREAD2 (N, NCOM, IGT1, CRX, IGT2, CRY)

where IPO : number of fixed angular points (IPO=sn)

N : logical unit number of DATA-POOL

NCOM : comment of the node (20 words)

MATID : material identification name
IHS : position of the self-scattering cross section
IHT : position of the total cross section
IHM : cross section table length
NUP : table length for up-scattering
NMAT : number of nuclides in the material
MAT1 : nuclide identification numbers for the SMT data
MAT2 : nuclide identification numbers for the FTB data
ATOM : atomic number densities (n/barn • cm)
TMP : temperatures
IGT1 : IHM
IGT2 : IPO×(i+NUP)
CRX : effective macroscopic cross section Σ_g
CRY : effective macroscopic cross section $\Sigma_{g\to g',m}$

In the data, CRX and CRY are defined by the following sequences:

position	1 ---- NOACT+1 -- IHT IHT+1* IHT-NUP -- IHS ---------- IHM
CRX	$\Sigma_{activation}--\Sigma_a\ \bar{\nu}\Sigma_f\ \Sigma_t\ \Sigma_t^{up}\ \Sigma_{g+NUP\to g}$ -- $\Sigma_{gg}\ \Sigma_{g-1\to g}$ -- $\Sigma_{1\to g}$ -- 0.0

*) Omit this record when NUP=0.

where NOACT is the number of the activation cross sections consisting of the energy deposition factor and the atomic displacement cross section. The above sequence repeats ING+IGG times.

No. \ angle	1	2	3	-----	IPO
1	$\Sigma_{g+NUP\to g}(\mu_1)$	$\Sigma_{g+NUP\to g}(\mu_2)$	$\Sigma_{g+NUP\to g}(\mu_3)$	-----	$\Sigma_{g+NUP\to g}(\mu_{ipo})$
2	:	:	:	:	:
	:	:	:		:
:	:	:	:		:
:	:	:	:		:
NUP+1	$\Sigma_{g\to g}(\mu_1)$	$\Sigma_{g\to g}(\mu_2)$	$\Sigma_{g\to g}(\mu_3)$	-----	$\Sigma_{g\to g}(\mu_{ipo})$
NUP+2	$\Sigma_{g-1\to g}(\mu_1)$	$\Sigma_{g-1\to g}(\mu_2)$	$\Sigma_{g-1\to g}(\mu_3)$	-----	$\Sigma_{g-1\to g}(\mu_{ipo})$
:	:	:	:		:
:	:	:	:		:
:	:	:	:		:
NUP+g	$\Sigma_{1\to g}(\mu_1)$	$\Sigma_{1\to g}(\mu_2)$	$\Sigma_{1\to g}(\mu_3)$	-----	$\Sigma_{1\to g}(\mu_{ipo})$

where CRY data are stored by starting at top left corner, sweeping from left to right, then from top to bottom. The sequence repeats ING+IGG times.

j) SELF Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto
level 2 node : SELF
information 0, 0, 0, 0, 0
data PREAD (N, NCOM)
level 3 node : matid

information MATID, NMAT, MTMAX, 0, 0
data PREAD4 (N, NCOM, NMAT, MAT1, NMAT, MAT2, NMAT, ATOM, NMAT, TMP)

level 4 node : matno
information MATNO, 0, 0, 0, 0
data PREAD4 (N, NCOM, ING, FTM, ING, FEM, ING, FFM, ING, FCM)
where N : logical unit number of DATA-POOL
NCOM : comment of the node (20 words)
MATID : material identification number
NMAT : number of nuclides in the material
MTMAX : number of reactions (4)
MAT1 : nuclide identification number of the SMT data
MAT2 : nuclide identification number of the FTB data
ATOM : atomic number densities (n/barn • cm)
TMP : temperatures
FTM : self-shielding factor for the total cross section
FEM : self-shielding factor for the elastic cross section
FFM : self-shielding factor for the fission cross section
FCM : self-shielding factor for the capture cross section

k) SFX0/SFX1 Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto

level 2 node : id. name
information IGE, IM, JM, IZM, MM
data PREAD4 (N, NCOM, IM+1, R, JM+1, Z, IM, MA, IZM, MZ)
where IGE : identification for the geometrical configuration
1-slab, 2-cylinder, 3-sphere } one-dimensional configuration
4-(X-Y), 5-(R-Z), 6-(R-θ) } two-dimensional configuration
IM : number of interval meshes for X or R axis
JM : number of interval meshes for Y, Z or θ axis
(for the case of one-dimension, JM=1)
IZM : number of zones
MM : number of angular quadratures
N : logical unit number of DATA-POOL
NCOM : comment of the node (20 words)
R : spatial interval meshes for X or R axis (cm)
Z : spatial interval meshes for Y, Z or θ axis (cm)
MA : zone numbers by interval
MZ : material numbers by interval

level 3 node : SFX0/SFX1

SFX0 shows forward scalar flux and SFX1 means adjoint scalar flux for the one-dimensional configuration.

information ING, IGG, ITH, 0, 0
data PREAD1 (N, NCOM, IM×IGM, FLX)
where ITH : solution indicator (0: forward, 1: adjoint)
FLX : scalar fluxes

l) SFX2/SFX3 Data Form

level 1 node : EGRP
information same as the SFX0/SFX1 data form
data ditto

level 2 node : id. name
information same as the SFX0/SFX1 data form
data PREAD4 (N, NCOM, IM+1, R, JM+1, Z, IM×JM, MA, IZM, MZ)

where notations are the same as those of the SFX0/SFX1 data form.

level 3 node : SFX2/SFX3

SFX2 shows forward scalar flux and SFX3 means adjoint scalar flux for the two-dimensional configuration.

information same as the SFX0/SFX1 data form
data DO 10 I=1, IGM
10 PREAD1 (N, NCOM, IM×JM, FLX)

where notations are the same as those of the SFX0/SFX1 data form.

m) AFX0/AFX1 Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto

level 2 node : id. name
information same as the SFX0/SFX1 data form
data ditto

level 3 node : AFX0/AFX1

AFX0 shows forward angular flux and AFX1 means adjoint angular flux for the one-dimensional configuration.

information ING, IGG, ITH, MM, IPMESH
data PREAD3 (N, NCOM, MM, W, MM, DSN, IPMESH, NOANLL)
DO 1 I=1, IGM
1 PREAD1 (N, NCOM, MM×IPMESH, AFX)
where ITH : solution indicator (0: forward, 1: adjoint)
MM : number of angular quadratures
IPMESH : number of spatial intervals
W : angular quadrature weights
DSN : angular quadrature cosines
NOANLL : spatial interval numbers
AFX : angular fluxes

n) AFX2/AFX3 Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto

level 2 node : id. name

information same as the SFX2/SFX3 data form
data ditto

level 3 node : AFX2/AFX3

AFX2 shows forward angular flux and AFX3 means adjoint angular flux for the two-dimensional configuration.

information same as the AFX0/AFX1 data form
data PREAD4 (N, NCOM, MM, W, MM, AMU, MM, ETA, IPMESH, NOANLL)
DO 1 I=1, IGM
DO 1 J=1, IPMESH
1 PREAD1 (N, NCOM, MM×IM, AFX)
where W : angular quadrature weights
AMU : angular quadrature cosines for μ
ETA : angular quadrature cosines for η
IPMESH : number fo spatial interval meshes for Y, Z or θ axis
AFX : angular fluxes

o) RESD Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto
level 2 node : RESD
information 0, 0, 0, 0, 0
data PREAD (N, NCOM)
level 3 node : matid
information IGM, IFLAG, 0, 0, 0
data PREAD1 (N, NCOM, IGM, RD)
where IGM : number of energy groups
IFLAG : detector identification (1: neutron, 2: gamma-ray)
RD : detector response function

p) EFsn Data Form

level 1 node : EGRP
information same as the SMT data form
data ditto
level 2 node : EFsn
information IPN, 0, 0, 0, 0
data PREAD1 (N, NCOM, IPN+1, ANG)
where IPN : number of angular meshes (IPN=sn)
ANG : angular meshes
level 3 node : matid
information MATID, NMAT, 0, 0, 0
data PREAD4 (N, NCOM, NMAT, MAT1, NMAT, MAT2, NMAT, ATOM, NMAT, TMP)

where notations are the same as those of the SELF data form.

level 4 node : matno
information MATNO, 0, 0, 0, 0
data PREAD (N, NCOM)
level 5 node : SMT

information 0, 0, 0, 0, 0
data PREAD3 (N, NCOM, 10, MT, 1, TMP, 1, SIG0)
PREAD1 (N, NCOM, 10×INGF, CRXF)
level 5 node : H+D
information 0, 0, 0, 0, 0
data PREAD3 (N, NCOM, 13, MT, 1, TMP, 1, SIG0)
PREAD1 (N, NCOM, 13×INGF, CRXF)
level 5 node : ELA
information NUPF, 0, 0, 0, 0
data PREAD3 (N, NCOM, 1, MT, 1, TMP, 1, SIG0)
PREAD1 (N, NCOM, IPN×(INGF+NUPF)×INGF, CRYF)
level 5 node : INS
information NUPF, 0, 0, 0, 0
data PREAD3 (N, NCOM, 1, MT, 1, TMP, 1, SIG0)
PREAD1 (N, NCOM, IPN×(INGF+NUPF)×INGF, CRYF)
level 5 node : N2N
information NUPF, 0, 0, 0, 0
data PREAD3 (N, NCOM, 1, MT, 1, TMP, 1, SIG0)
PREAD1 (N, NCOM, IPN×(INGF+NUPF)×INGF, CRYF)
where MT : reaction type identification numbers
TMP : temperature (Kelvin)
SIG0 : background cross section
INGF : number of energy groups
IPN : number of angular meshes
NUPF : number of up-scattering groups
CRXF : effective microscopic cross sections
(The form is the same as that of CRX in the FXsn data form)
CRYF : effective microscopic scattering matrix
(The form is the same as that of CRY in the FXsn data form)

q) BREM Data Form
level 1 node : EGRP
information same as the FXsn data form
data ditto
level 2 node : FXsn
information same as the FXsn data form
data ditto
level 3 node : matid
information same as the FXsn data form
data ditto
level 4 node : BREM
information 0, 0, 0, 0, 0
data PREAD1 (N, NCOM, IGG×IGG, BR)
where IGG : number of gamma-ray energy groups
BR(k, i) : Bremsstrahlung data from the group i to k

Appendix D Sample Output Lists of RADHEAT-V4

Sample output lists for each sample problem described in Chap. 5 are presented. The job control cards and the input data are also shown for the user's convenience. Detailed information for the sample problems is referred to Chap. 5.

D.1 Sample Problem for FAIR-CROSS step 1

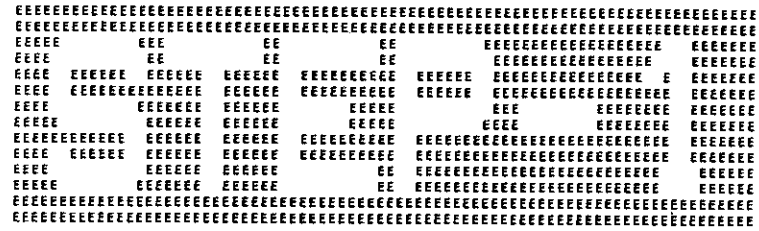
```
MEMBER NAME > B:RRSTEP1.TXT   ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.4 I.5 P.0 W.3 C.5 SRP
    6 :   OPTP PASSWORD=########
    7 :  //FCROSS EXEC LMGO,LM='J1446.FCSTEP1X',OBSIZE=137,ORECFM=FA
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(100,20)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(100,20)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(100,20)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(100,20)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT10F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(100,20)),
   17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT11F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(100,20)),
   19 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   20 :  //FT12F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(100,20)),
   21 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   22 :  //FT13F001 DD DSN=&&FD,UNIT=WK10,SPACE=(TRK,(600,50)),
   23 :  //   DCB=(LRECL=16804,BLKSIZE=16804,RECFM=F)
   24 :  //FT14F001 DD DSN=&&FE,UNIT=WK10,SPACE=(TRK,(100,20)),
   25 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   26 :  //FT15F001 DD DSN=&&FF,UNIT=WK10,SPACE=(TRK,(100,20)),
   27 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   28 :  //* THE FOLLOWING DSN WILL BE CHANGED BY NUCLIDE (406 OR 408)
   29 :  //FT08F001 DD DSN=J1615.ENDFB406.DATA,DISP=SHR,LABEL=(,,,IN)
   30 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   31 :  //SYSIN DD *
   32 :    FAIR-CROSS STEP-1 SAMPLE PROBLEM NO.1
   33 :   &UNIT ULTX=91,INFX=91,FTBL=91 &END
   34 :  1¥¥ 1   1   100   20   0   4HEGRP   2   2   T
   35 :  MAT=1276 O-16 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)
   36 :  4¥¥ 1276   8   0   1   7   4   0   0   1   1   0   0   2   0   0   1   T
   37 :  5** 300.0
   38 :  6** 1.0+8   0.0   1.0   10.0   100.0   1000.0   10000.0
   39 :  7** 1.25E-1   1.4E+6   8.208E+5
   40 :  10** 0.01   0.0   0.03   0.0
   41 :   T
   42 :  ++
   43 :  //
   44 :    FAIR-CROSS STEP-1 SAMPLE PROBLEM NO.2
   45 :   &UNIT ULTX=91,INFX=91,FTBL=91 &END
   46 :  1¥¥ 1   1   100   20   0   4HEGRP   2   2   T
   47 :  MAT=1275 N-14 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)
   48 :  4¥¥ 1275   8   0   1   7   4   0   0   1   1   0   0   2   0   0   1   T
   49 :  5** 300.0
   50 :  6** 1.0+8   0.0   1.0   10.0   100.0   1000.0   10000.0
   51 :  7** 1.25E-1   1.4E+6   8.208E+5
   52 :  10** 0.01   0.0   0.03   0.0
   53 :   T
```

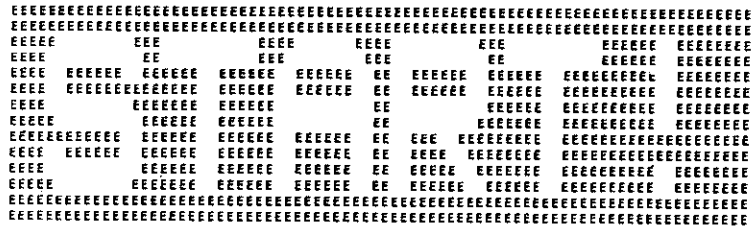
```
MEMBER NAME > B:RRSTEP1.TXT  ------------------------------------------------ PAGE :  2
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
   54 :  ++
   55 :  //
   56 :    FAIR-CROSS STEP-1 SAMPLE PROBLEM NO.3
   57 :   &UNIT ULTX=91,INFX=91,FTBL=91 &END
   58 :  1¥¥ 1  1  100  20  0  4HEGRP  2  2  T
   59 :  MAT=1192 FE-26 PROCESS FROM ENDF/B-IV AT 300K (TAPE 406)
   60 :  4¥¥ 1192  8  0  1  7  4  0  0  1  1  0  0  2  0  0  1  T
   61 :  5** 300.0
   62 :  6** 1.0+8  0.0  1.0  10.0  100.0  1000.0  10000.0
   63 :  7** 1.25E-1  1.4E+6  8.208E+5
   64 :  10** 0.01  0.0  0.03  0.0
   65 :   T
   66 :  ++
   67 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
1¥ ARRAY       8 ENTRIES READ

 T

                              ****          MAIN TITLE          ****

      FAIR-CROSS STEP-1 SAMPLE PROBLEM NO.1


                              **** MAIN CONTROL PARAMETERS ****

                  SELECTION OF THE CALCULATIONAL STEP          ---      1

                  NO. OF NUCLIDE OR MIXTURE TO BE PROCESSED    ---      1

                  NO. OF NEUTRON ENERGY GROUPS                 ---    100

                  NO. OF GAMMA-RAY ENERGY GROUPS               ---     20

                  NO. OF ANGULAR MESH IN CROSS SECTION TABLE   ---      0

                  NODE NAME OF ENERGY GROUP STRUCTURE          --- EGRP

                  TYPE OF INPUT NEUTRON GROUP STRUCTURE        ---      2

                  TYPE OF INPUT GAMMA-RAY GROUP STRUCTURE      ---      2
```

ENERGY GROUP STRUCTURE

--- NEUTRON GROUP ---						--- GAMMA GROUP ---		
GROUP	ENERGY	RANGE	GROUP	ENERGY	RANGE	GROUP	ENERGY	RANGE
1	1.6487E+07	1.4550E+07	51	3.1828E+04	2.8088E+04	1	1.4000E+07	1.2000E+07
2	1.4550E+07	1.2840E+07	52	2.8088E+04	2.4788E+04	2	1.2000E+07	1.0000E+07
3	1.2840E+07	1.1331E+07	53	2.4788E+04	2.1875E+04	3	1.0000E+07	8.0000E+06
4	1.1331E+07	1.0000E+07	54	2.1875E+04	1.9305E+04	4	8.0000E+06	6.5000E+06
5	1.0000E+07	8.8250E+06	55	1.9305E+04	1.7036E+04	5	6.5000E+06	5.0000E+06
6	8.8250E+06	7.7880E+06	56	1.7036E+04	1.5034E+04	6	5.0000E+06	4.0000E+06
7	7.7880E+06	6.8729E+06	57	1.5034E+04	1.1709E+04	7	4.0000E+06	3.0000E+06
8	6.8729E+06	6.0653E+06	58	1.1709E+04	9.1188E+03	8	3.0000E+06	2.5000E+06
9	6.0653E+06	5.3526E+06	59	9.1188E+03	7.1017E+03	9	2.5000E+06	2.0000E+06
10	5.3526E+06	4.7237E+06	60	7.1017E+03	5.5308E+03	10	2.0000E+06	1.6600E+06
11	4.7237E+06	4.1686E+06	61	5.5308E+03	4.3074E+03	11	1.6600E+06	1.3300E+06
12	4.1686E+06	3.6788E+06	62	4.3074E+03	3.3546E+03	12	1.3300E+06	1.0000E+06
13	3.6788E+06	3.2465E+06	63	3.3546E+03	2.6126E+03	13	1.0000E+06	8.0000E+05
14	3.2465E+06	2.8650E+06	64	2.6126E+03	2.0347E+03	14	8.0000E+05	6.0000E+05
15	2.8650E+06	2.5284E+06	65	2.0347E+03	1.5846E+03	15	6.0000E+05	4.0000E+05
16	2.5284E+06	2.2313E+06	66	1.5846E+03	1.2341E+03	16	4.0000E+05	3.0000E+05
17	2.2313E+06	1.9691E+06	67	1.2341E+03	9.6112E+02	17	3.0000E+05	2.0000E+05
18	1.9691E+06	1.7377E+06	68	9.6112E+02	7.4852E+02	18	2.0000E+05	1.0000E+05
19	1.7377E+06	1.5336E+06	69	7.4852E+02	5.8295E+02	19	1.0000E+05	5.0000E+04
20	1.5336E+06	1.3534E+06	70	5.8295E+02	4.5400E+02	20	5.0000E+04	2.0000E+04
21	1.3534E+06	1.1943E+06	71	4.5400E+02	3.5357E+02			
22	1.1943E+06	1.0540E+06	72	3.5357E+02	2.7536E+02			
23	1.0540E+06	9.3014E+05	73	2.7536E+02	2.1445E+02			
24	9.3014E+05	8.2085E+05	74	2.1445E+02	1.6702E+02			
25	8.2085E+05	7.2440E+05	75	1.6702E+02	1.3007E+02			
26	7.2440E+05	6.3928E+05	76	1.3007E+02	1.0130E+02			
27	6.3928E+05	5.6416E+05	77	1.0130E+02	7.8893E+01			
28	5.6416E+05	4.9787E+05	78	7.8893E+01	6.1442E+01			
29	4.9787E+05	4.3937E+05	79	6.1442E+01	4.7851E+01			
30	4.3937E+05	3.8774E+05	80	4.7851E+01	3.7267E+01			
31	3.8774E+05	3.4218E+05	81	3.7267E+01	2.9023E+01			
32	3.4218E+05	3.0197E+05	82	2.9023E+01	2.2603E+01			
33	3.0197E+05	2.6649E+05	83	2.2603E+01	1.7603E+01			
34	2.6649E+05	2.3518E+05	84	1.7603E+01	1.3710E+01			
35	2.3518E+05	2.0754E+05	85	1.3710E+01	1.0677E+01			
36	2.0754E+05	1.8316E+05	86	1.0677E+01	8.3153E+00			
37	1.8316E+05	1.6163E+05	87	8.3153E+00	6.4760E+00			
38	1.6163E+05	1.4264E+05	88	6.4760E+00	5.0435E+00			
39	1.4264E+05	1.2588E+05	89	5.0435E+00	3.9279E+00			
40	1.2588E+05	1.1109E+05	90	3.9279E+00	3.0590E+00			
41	1.1109E+05	9.8037E+04	91	3.0590E+00	2.3824E+00			
42	9.8037E+04	8.6517E+04	92	2.3824E+00	1.8554E+00			
43	8.6517E+04	7.6351E+04	93	1.8554E+00	1.4450E+00			
44	7.6351E+04	6.7379E+04	94	1.4450E+00	1.1254E+00			
45	6.7379E+04	5.9462E+04	95	1.1254E+00	8.7642E-01			
46	5.9462E+04	5.2475E+04	96	8.7642E-01	6.8256E-01			
47	5.2475E+04	4.6309E+04	97	6.8256E-01	5.3158E-01			
48	4.6309E+04	4.0868E+04	98	5.3158E-01	4.1399E-01			
49	4.0868E+04	3.6066E+04	99	4.1399E-01	1.5183E-01			
50	3.6066E+04	3.1828E+04	100	1.5183E-01	3.5238E-04			





```
 5* ARRAY      1 ENTRIES READ

 6* ARRAY      7 ENTRIES READ

 7* ARRAY      3 ENTRIES READ

10* ARRAY      4 ENTRIES READ

 T


     **** INPUT DATA LIST OF STEP1 MODULE  ***

               MATNO ( MATERIAL NO.                      ) =  1276
               NDFB  ( FILE NO. OF NUCLEAR DATA FILE     ) =     8
               ISTRT ( RESTART OPTION 0/1/2/3            ) =     0
               NTMP  ( NO. OF TEMPERATURE                ) =     1
               NSIG  ( NO. OF BACKGROUND C.S.            ) =     7
               IW    ( WEIGHTING OPTION                  ) =     4
               N1    ( NO. OF DATA POINT FOR IW=3        ) =     0
               N2    ( NO. OF DATA POINT FOR IW=3        ) =     0
               LINK1 ( RESONANCE CAL.                    ) =     1
               LINK2 ( SCATTERING MATRIX CAL.            ) =     1
               LINK3 ( HEAT GENE. AND ATOMIC DISP.       ) =     0
               LINK4 ( THERMAL SCATTERING CAL.           ) =     0
               NGOUT ( OUTPUT OF ULTRA-FINE              ) =     2
               NPRT1 ( PRINT OF RESONANCE C.S.           ) =     0
               NPRT2 ( PRINT OF ULTRA-FINE C.S.          ) =     0
               NPRT3 ( PRINT OF ANGULAR C.S.             ) =     1

               TEMPERATURE  =   3.000E+02

               BACKGROUND   =   1.000E+08   0.0          1.000E+00   1.000E+01   1.000E+02   1.000E+03

               BACKGROUND   =   1.000E+04

               WEIGHTING FUNCTION
               EB =   1.2499982E-01
               TC =   1.4000000E+06
               EC =   8.2080000E+05

               PARAMETERS FOR THE RESONANCE CALCULATION
                ERR  =   9.9999942E-03
               AVERR =   0.0

               ACCURACY FOR DIFFERENTIAL SCATTERING MATRICES
                ERR  =   2.9999983E-02



     ENDF/B TAPE ID NO. =        408
  THE (TAPE) DESCRIPTION OF MATERIAL  1276 IS -
       8- 0- 16 LASL        EVAL-AUG73 P.YOUNG,D.FOSTER,JR,G.HALE
                            DIST-JUN74 REV-JUN75
     ***************  DNA 4134 MOD 2   8/31/73  ***********************

      THE DATA SET WAS EXTENSIVELY CHANGED TO INCLUDE NEW EXPERIMENT-
      AL AND THEORETICAL RESULTS.  FILE 1 WAS REVISED TO INCLUDE THE
      NEW RESULTS, AND A SUMMARY OF THE CHANGES IS AS FOLLOWS,

          1. THE RESULTS OF AN R-MATRIX ANALYSIS OF THE O16(N,N),
             O16(N,ALPHA)C13, AND C13(ALPHA,ALPHA) REACTIONS BELOW
             6 MEV WAS INCORPORATED IN MF=3,MT=1,2,107,780.
          2. ADJUSTMENTS WERE MADE IN MF=3,MT=4,51-55,103,107,780-782
             SO THAT MT=2 BETTER AGREES WITH ELASTIC MEASUREMENTS
             FROM 7 TO 11 MEV.  ADJUSTMENTS WERE MADE PARTICULARLY TO
             MT=51 TO IMPROVE AGREEMENT WITH (N,NPRIME) MEASUREMENTS,
             AND MT=51-89 WERE MODIFIED TO IMPROVE (SOMEWHAT) AGREE-
             MENT WITH SPHERE TRANSMISSION INTEGRAL MEASUREMENTS.
          3. LEGENDRE COEFFICIENTS IN MF=4,MT=2 WERE MODIFIED TO IN-
             CLUDE RESULTS FROM THE R-MATRIX ANALYSIS BELOW 6 MEV AND
             NEW EXPERIMENTAL DATA ABOVE 6 MEV.
          4. ANISOTROPIC INELASTIC NEUTRON ANGULAR DISTRIBUTIONS WERE
             ADDED FOR MT=51-55.
          5. ANISOTROPIC SECONDARY GAMMA RAY ANGULAR DISTRIBUTIONS
             WERE ADDED FOR THE 6.131- AND 6.917-MEV GAMMAS.
          6. GAMMA-RAY PRODUCTION CROSS SECTIONS IN MF=13 WERE AJUST-
             ED TO INCLUDE THE REVISIONS IN ITEM 2 AND 5 USING GAMMA-
             RAY DECAY SCHEMES FOR THE APPROPRIATE RESIDUAL NUCLEI.
          7. CROSS SECTIONS FOR MT=  4,51-89,103,104,107,780-783 IN
             MF=3 AND 13 WERE THINNED ABOVE EN=6 MEV USING THE RE-
             QUIREMENT THAT INTERPOLATED VALUES BETWEEN ANY TWO POINTS
             LIE WITHIN 2 PER CENT OF THE FINE-GRID VALUE, PROVIDING
             THAT A CERTAIN BASIC GRID (200 KEV INTERVALS BELOW EN=
             10 MEV AND 500 KEV ABOVE EN=10 MEV) BE MAINTAINED. BELOW
             EN=6 MEV, A MORE STRINGENT REQUIREMENT OF 1.00 PER CENT
             WAS IMPOSED ON MT=780 AND 107.
          8. THE MT=2 LEGENDRE COEFFICIENTS IN MF=4 WERE THINNED WITH
             THE REQUIREMENT THAT THE INTERPOLATED ANGULAR DISTRI-
             BUTION HAVE AN RMS DEVIATION FROM THE FINE-GRID SET OF
             LESS THAN 2.5 PER CENT AND THAT THE MAXIMUM EXCURSION AT
             ANY ANGLE BE LESS THAN 5.0 PER CENT.
          9. THE NONELASTIC CROSS SECTION (MT=3) WAS REMOVED FROM
             FILE 3.
     ************************************************************

     *         *          *          *          *          *          *

     O-16 FREE ATOM EVAL. - AUG.1971 - P.G.YOUNG,D.G.FOSTER,JR. (LASL)
                           REFERENCE  -- LA-4780 (ENDF-174), 1972

     MF=2 -------- RESONANCE PARAMETERS ----------

       MT=151      EFFECTIVE SCATTERING RADIUS =0.54614E-12 CM.

     MF=3 -------- SMOOTH CROSS SECTIONS --------
         THE 2200 M/S CROSS SECTIONS ARE AS FOLLOWS,
             MT=1     SIGMA = 3.7483 BARNS
             MT=2     SIGMA = 3.7481 BARNS
```

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 CHANGE Q-VALUE   Q = -6.05200E+06   EMIN =  6.43400E+06   CQ = -6.05235E+06   MT =   4
 CHANGE Q-VALUE   Q = -6.05200E+06   EMIN =  6.43400E+06   CQ = -6.05235E+06   MT =  51
 CHANGE Q-VALUE   Q = -6.13100E+06   EMIN =  6.51800E+06   CQ = -6.13136E+06   MT =  52
 CHANGE Q-VALUE   Q = -6.91700E+06   EMIN =  7.35300E+06   CQ = -6.91683E+06   MT =  53
 CHANGE Q-VALUE   Q = -7.11900E+06   EMIN =  7.56800E+06   CQ = -7.11908E+06   MT =  54
 CHANGE Q-VALUE   Q = -8.87200E+06   EMIN =  9.43100E+06   CQ = -8.87157E+06   MT =  55
 CHANGE Q-VALUE   Q = -9.59700E+06   EMIN =  1.02020E+07   CQ = -9.59683E+06   MT =  56
 CHANGE Q-VALUE   Q = -9.84700E+06   EMIN =  1.04680E+07   CQ = -9.84706E+06   MT =  57
 CHANGE Q-VALUE   Q = -1.03540E+07   EMIN =  1.10070E+07   CQ = -1.03541E+07   MT =  58
 CHANGE Q-VALUE   Q = -1.09520E+07   EMIN =  1.16430E+07   CQ = -1.09524E+07   MT =  59
 CHANGE Q-VALUE   Q = -1.10800E+07   EMIN =  1.17790E+07   CQ = -1.10803E+07   MT =  60
 CHANGE Q-VALUE   Q = -1.10960E+07   EMIN =  1.17960E+07   CQ = -1.10963E+07   MT =  61
 CHANGE Q-VALUE   Q = -1.12600E+07   EMIN =  1.19700E+07   CQ = -1.12600E+07   MT =  62
 CHANGE Q-VALUE   Q = -1.14400E+07   EMIN =  1.21610E+07   CQ = -1.14396E+07   MT =  63
 CHANGE Q-VALUE   Q = -1.15210E+07   EMIN =  1.22480E+07   CQ = -1.15215E+07   MT =  64
 CHANGE Q-VALUE   Q = -1.16300E+07   EMIN =  1.23630E+07   CQ = -1.16296E+07   MT =  65
 CHANGE Q-VALUE   Q = -1.20530E+07   EMIN =  1.28130E+07   CQ = -1.20530E+07   MT =  66
 CHANGE Q-VALUE   Q = -1.24420E+07   EMIN =  1.32270E+07   CQ = -1.24424E+07   MT =  67
 CHANGE Q-VALUE   Q = -1.25280E+07   EMIN =  1.33180E+07   CQ = -1.25280E+07   MT =  68
 CHANGE Q-VALUE   Q = -1.27950E+07   EMIN =  1.36020E+07   CQ = -1.27952E+07   MT =  69
 CHANGE Q-VALUE   Q = -1.29670E+07   EMIN =  1.37850E+07   CQ = -1.29673E+07   MT =  70
 CHANGE Q-VALUE   Q = -1.31500E+07   EMIN =  1.39790E+07   CQ = -1.31498E+07   MT =  71
 CHANGE Q-VALUE   Q = -1.34500E+07   EMIN =  1.42980E+07   CQ = -1.34499E+07   MT =  72
 CHANGE Q-VALUE   Q = -1.37500E+07   EMIN =  1.46170E+07   CQ = -1.37499E+07   MT =  73
 CHANGE Q-VALUE   Q = -1.40500E+07   EMIN =  1.49360E+07   CQ = -1.40500E+07   MT =  74
 CHANGE Q-VALUE   Q = -1.43500E+07   EMIN =  1.52550E+07   CQ = -1.43501E+07   MT =  75
 CHANGE Q-VALUE   Q = -1.46500E+07   EMIN =  1.55740E+07   CQ = -1.46502E+07   MT =  76
 CHANGE Q-VALUE   Q = -1.49500E+07   EMIN =  1.58930E+07   CQ = -1.49503E+07   MT =  77
 CHANGE Q-VALUE   Q = -1.52500E+07   EMIN =  1.62120E+07   CQ = -1.52503E+07   MT =  78
```

```
          ***  PROCESSED REACTION TYPE  ***
     1     2     4    51    52    53    54    55    56    57
    58    59    60    61    62    63    64    65    66    67
    68    69    70    71    72    73    74    75    76    77
    78    79   102   103   104   107

*** ULTRA-FINE GROUP CROSS SECTIONS WERE WRITTEN TO A DATA POOL
    NODE NAME = ULTX 1276 TMP1 SIG1

*** ULTRA-FINE GROUP CROSS SECTIONS WERE WRITTEN TO A DATA POOL
    NODE NAME = ULTX 1276 TMP1 SIG2

*** ULTRA-FINE GROUP CROSS SECTIONS WERE WRITTEN TO A DATA POOL
    NODE NAME = ULTX 1276 TMP1 SIG3

*** ULTRA-FINE GROUP CROSS SECTIONS WERE WRITTEN TO A DATA POOL
    NODE NAME = ULTX 1276 TMP1 SIG4

*** ULTRA-FINE GROUP CROSS SECTIONS WERE WRITTEN TO A DATA POOL
    NODE NAME = ULTX 1276 TMP1 SIG5

*** ULTRA-FINE GROUP CROSS SECTIONS WERE WRITTEN TO A DATA POOL
    NODE NAME = ULTX 1276 TMP1 SIG6

*** ULTRA-FINE GROUP CROSS SECTIONS WERE WRITTEN TO A DATA POOL
    NODE NAME = ULTX 1276 TMP1 SIG7

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.        =     91
    DATA SET NAME           = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS  =    150
    REMAINS RECORDS         =  11349
```

GROUP	TOTAL	ABSORPTION	FISSION	NEUTRONS PER FISSION	(N,GAMMA)	ELASTIC SCATTERING	(ELASTIC) SCATTERING	INELASTIC
1	1.6620E+00	1.3993E-01	0.0	0.0	7.2627E-09	9.7654E-01	9.7647E-01	5.4555E-01
2	1.6109E+00	1.8520E-01	0.0	0.0	7.7560E-09	9.8480E-01	9.8476E-01	4.4086E-01
3	1.6454E+00	2.0953E-01	0.0	0.0	8.256BE-09	1.0987E+00	1.0986E+00	3.3726E-01
4	1.4032E+00	1.9037E-01	0.0	0.0	8.7344E-09	9.6296E-01	9.6294E-01	2.4982E-01
5	1.2244E+00	1.4688E-01	0.0	0.0	9.3065E-09	8.3199E-01	8.3189E-01	2.4753E-01
6	1.2174E+00	8.2010E-02	0.0	0.0	9.9006E-09	8.9192E-01	8.9192E-01	2.4352E-01
7	1.2036E+00	8.6040E-02	0.0	0.0	1.0585E-08	9.5896E-01	9.5873E-01	1.5860E-01
8	1.0028E+00	8.1570E-02	0.0	0.0	1.1203E-08	9.0311E-01	9.0308E-01	1.8109E-02
9	1.3057E+00	2.7418E-02	0.0	0.0	1.1914E-08	1.2783E+00	1.2781E+00	0.0
10	1.3952E+00	9.0000E-02	0.0	0.0	1.2673E-08	1.3052E+00	1.3051E+00	0.0
11	1.7994E+00	8.3352E-02	0.0	0.0	1.3501E-08	1.7161E+00	1.7161E+00	0.0
12	2.4109E+00	3.5402E-02	0.0	0.0	1.4377E-08	2.3755E+00	2.3754E+00	0.0
13	3.1519E+00	1.7130E-03	0.0	0.0	1.5315E-08	3.1502E+00	3.1503E+00	0.0
14	1.6030E+00	1.1137E-04	0.0	0.0	1.6292E-08	1.6028E+00	1.6029E+00	0.0
15	1.1097E+00	3.0794E-08	0.0	0.0	1.7413E-08	1.1097E+00	1.1097E+00	0.0
16	6.9310E-01	1.8446E-08	0.0	0.0	1.8428E-08	6.9310E-01	6.9310E-01	0.0
17	1.4205E+00	1.9600E-08	0.0	0.0	1.9600E-08	1.4205E+00	1.4205E+00	0.0
18	2.1139E+00	2.0864E-08	0.0	0.0	2.0864E-08	2.1139E+00	2.1139E+00	0.0
19	2.1013E+00	2.2196E-08	0.0	0.0	2.2196E-08	2.1013E+00	2.1013E+00	0.0
20	2.3652E+00	2.3668E-08	0.0	0.0	2.366BE-08	2.3652E+00	2.3652E+00	0.0
21	3.8428E+00	2.5163E-08	0.0	0.0	2.5163E-08	3.8428E+00	3.8428E+00	0.0
22	3.4620E+00	2.6827E-08	0.0	0.0	2.6827E-08	3.4620E+00	3.4620E+00	0.0
23	6.4310E+00	2.8535E-08	0.0	0.0	2.8535E-08	6.4310E+00	6.4310E+00	0.0
24	3.0973E+00	3.0425E-08	0.0	0.0	3.0425E-08	3.0973E+00	3.0973E+00	0.0
25	2.6791E+00	3.2361E-08	0.0	0.0	3.2361E-08	2.6791E+00	2.6791E+00	0.0
26	2.7434E+00	3.4561E-08	0.0	0.0	3.4561E-08	2.7434E+00	2.7434E+00	0.0
27	2.9691E+00	3.6650E-08	0.0	0.0	3.6650E-08	2.9691E+00	2.9691E+00	0.0
28	3.7805E+00	3.9233E-08	0.0	0.0	3.9233E-08	3.7805E+00	3.7805E+00	0.0
29	1.0308E+01	4.1631E-08	0.0	0.0	4.1631E-08	1.0308E+01	1.0308E+01	0.0
30	9.0187E+00	4.4159E-08	0.0	0.0	4.4159E-08	9.0187E+00	9.0187E+00	0.0
31	4.3620E+00	4.6990E-08	0.0	0.0	4.6990E-08	4.3620E+00	4.3620E+00	0.0
32	3.6910E+00	5.0035E-08	0.0	0.0	5.0035E-08	3.6910E+00	3.6910E+00	0.0
33	3.5169E+00	5.3313E-08	0.0	0.0	5.3313E-08	3.5169E+00	3.5169E+00	0.0
34	3.4654E+00	5.6698E-08	0.0	0.0	5.6698E-08	3.4654E+00	3.4654E+00	0.0
35	3.4570E+00	6.0405E-08	0.0	0.0	6.0405E-08	3.4570E+00	3.4570E+00	0.0
36	3.4679E+00	6.4326E-08	0.0	0.0	6.4326E-08	3.4679E+00	3.4679E+00	0.0
37	3.4871E+00	6.8412E-08	0.0	0.0	6.8412E-08	3.4871E+00	3.4871E+00	0.0
38	3.5052E+00	7.2979E-08	0.0	0.0	7.2979E-08	3.5052E+00	3.5052E+00	0.0
39	3.5274E+00	7.7524E-08	0.0	0.0	7.7524E-08	3.5274E+00	3.5274E+00	0.0
40	3.5483E+00	8.2758E-08	0.0	0.0	8.2758E-08	3.5483E+00	3.5483E+00	0.0
41	3.5669E+00	8.7864E-08	0.0	0.0	8.7864E-08	3.5669E+00	3.5669E+00	0.0
42	3.5856E+00	9.3850E-08	0.0	0.0	9.3850E-08	3.5856E+00	3.5856E+00	0.0
43	3.6033E+00	9.9583E-08	0.0	0.0	9.9583E-08	3.6033E+00	3.6033E+00	0.0
44	3.6189E+00	1.0642E-07	0.0	0.0	1.0642E-07	3.6189E+00	3.6189E+00	0.0
45	3.6328E+00	1.1293E-07	0.0	0.0	1.1293E-07	3.6328E+00	3.6328E+00	0.0
46	3.6449E+00	1.2057E-07	0.0	0.0	1.2057E-07	3.6449E+00	3.6449E+00	0.0
47	3.6560E+00	1.2834E-07	0.0	0.0	1.2834E-07	3.6560E+00	3.6560E+00	0.0
48	3.6666E+00	1.3632E-07	0.0	0.0	1.3632E-07	3.6666E+00	3.6666E+00	0.0
49	3.6760E+00	1.4583E-07	0.0	0.0	1.4583E-07	3.6760E+00	3.6760E+00	0.0
50	3.6844E+00	1.5439E-07	0.0	0.0	1.5439E-07	3.6844E+00	3.6844E+00	0.0

GROUP	TOTAL	ABSORPTION	FISSION	NEUTRONS PER FISSION	(N,GAMMA)	ELASTIC SCATTERING	(ELASTIC) SCATTERING	INELASTIC
51	3.6918E+00	1.6410E-07	0.0	0.0	1.6410E-07	3.6918E+00	3.6918E+00	0.0
52	3.6983E+00	1.7464E-07	0.0	0.0	1.7464E-07	3.6983E+00	3.6983E+00	0.0
53	3.7040E+00	1.8585E-07	0.0	0.0	1.8585E-07	3.7040E+00	3.7040E+00	0.0
54	3.7091E+00	1.9796E-07	0.0	0.0	1.9796E-07	3.7091E+00	3.7091E+00	0.0
55	3.7135E+00	2.1079E-07	0.0	0.0	2.1079E-07	3.7135E+00	3.7135E+00	0.0
56	3.7175E+00	2.2422E-07	0.0	0.0	2.2422E-07	3.7175E+00	3.7175E+00	0.0
57	3.7225E+00	2.4661E-07	0.0	0.0	2.4661E-07	3.7225E+00	3.7225E+00	0.0
58	3.7280E+00	2.7949E-07	0.0	0.0	2.7949E-07	3.7279E+00	3.7280E+00	0.0
59	3.7323E+00	3.1672E-07	0.0	0.0	3.1672E-07	3.7323E+00	3.7323E+00	0.0
60	3.7358E+00	3.5894E-07	0.0	0.0	3.5894E-07	3.7358E+00	3.7358E+00	0.0
61	3.7385E+00	4.0689E-07	0.0	0.0	4.0689E-07	3.7385E+00	3.7385E+00	0.0
62	3.7406E+00	4.6126E-07	0.0	0.0	4.6126E-07	3.7406E+00	3.7406E+00	0.0
63	3.7423E+00	5.2294E-07	0.0	0.0	5.2294E-07	3.7423E+00	3.7423E+00	0.0
64	3.7436E+00	5.9295E-07	0.0	0.0	5.9295E-07	3.7436E+00	3.7436E+00	0.0
65	3.7446E+00	6.7220E-07	0.0	0.0	6.7220E-07	3.7445E+00	3.7446E+00	0.0
66	3.7453E+00	7.6184E-07	0.0	0.0	7.6184E-07	3.7453E+00	3.7453E+00	0.0
67	3.7459E+00	8.6321E-07	0.0	0.0	8.6321E-07	3.7459E+00	3.7459E+00	0.0
68	3.7464E+00	9.7819E-07	0.0	0.0	9.7819E-07	3.7464E+00	3.7464E+00	0.0
69	3.7468E+00	1.1098E-06	0.0	0.0	1.1098E-06	3.7468E+00	3.7468E+00	0.0
70	3.7471E+00	1.2516E-06	0.0	0.0	1.2516E-06	3.7471E+00	3.7471E+00	0.0
71	3.7473E+00	1.4181E-06	0.0	0.0	1.4181E-06	3.7473E+00	3.7473E+00	0.0
72	3.7475E+00	1.6072E-06	0.0	0.0	1.6072E-06	3.7475E+00	3.7475E+00	0.0
73	3.7476E+00	1.8221E-06	0.0	0.0	1.8221E-06	3.7476E+00	3.7476E+00	0.0
74	3.7478E+00	2.0644E-06	0.0	0.0	2.0644E-06	3.7478E+00	3.7478E+00	0.0
75	3.7478E+00	2.3394E-06	0.0	0.0	2.3394E-06	3.7478E+00	3.7478E+00	0.0
76	3.7479E+00	2.6525E-06	0.0	0.0	2.6525E-06	3.7479E+00	3.7479E+00	0.0
77	3.7480E+00	3.0066E-06	0.0	0.0	3.0066E-06	3.7480E+00	3.7480E+00	0.0
78	3.7481E+00	3.4076E-06	0.0	0.0	3.4076E-06	3.7481E+00	3.7481E+00	0.0
79	3.7482E+00	3.8620E-06	0.0	0.0	3.8620E-06	3.7482E+00	3.7482E+00	0.0
80	3.7482E+00	4.3771E-06	0.0	0.0	4.3771E-06	3.7482E+00	3.7482E+00	0.0
81	3.7483E+00	4.9614E-06	0.0	0.0	4.9614E-06	3.7483E+00	3.7483E+00	0.0
82	3.7483E+00	5.6240E-06	0.0	0.0	5.6240E-06	3.7483E+00	3.7483E+00	0.0
83	3.7484E+00	6.3755E-06	0.0	0.0	6.3755E-06	3.7484E+00	3.7484E+00	0.0
84	3.7484E+00	7.2276E-06	0.0	0.0	7.2276E-06	3.7484E+00	3.7484E+00	0.0
85	3.7484E+00	8.1932E-06	0.0	0.0	8.1932E-06	3.7484E+00	3.7484E+00	0.0
86	3.7486E+00	9.2871E-06	0.0	0.0	9.2871E-06	3.7486E+00	3.7484E+00	0.0
87	3.7492E+00	1.0526E-05	0.0	0.0	1.0526E-05	3.7492E+00	3.7483E+00	0.0
88	3.7497E+00	1.1931E-05	0.0	0.0	1.1931E-05	3.7497E+00	3.7483E+00	0.0
89	3.7501E+00	1.3527E-05	0.0	0.0	1.3527E-05	3.7501E+00	3.7482E+00	0.0
90	3.7504E+00	1.5347E-05	0.0	0.0	1.5347E-05	3.7504E+00	3.7482E+00	0.0
91	3.7506E+00	1.7419E-05	0.0	0.0	1.7419E-05	3.7506E+00	3.7482E+00	0.0
92	3.7508E+00	1.9723E-05	0.0	0.0	1.9723E-05	3.7508E+00	3.7482E+00	0.0
93	3.7510E+00	2.2269E-05	0.0	0.0	2.2269E-05	3.7509E+00	3.7482E+00	0.0
94	3.7511E+00	2.5168E-05	0.0	0.0	2.5168E-05	3.7511E+00	3.7482E+00	0.0
95	3.7522E+00	2.8539E-05	0.0	0.0	2.8539E-05	3.7521E+00	3.7481E+00	0.0
96	3.7580E+00	3.2332E-05	0.0	0.0	3.2332E-05	3.7580E+00	3.7481E+00	0.0
97	3.7633E+00	3.6655E-05	0.0	0.0	3.6655E-05	3.7633E+00	3.7481E+00	0.0
98	3.7674E+00	4.1550E-05	0.0	0.0	4.1550E-05	3.7674E+00	3.7481E+00	0.0
99	3.7738E+00	5.7418E-05	0.0	0.0	5.7418E-05	3.7737E+00	3.7481E+00	0.0
100	3.7586E+00	1.5766E-04	0.0	0.0	1.5766E-04	3.7584E+00	3.7480E+00	0.0

GROUP	(N,2N)	(N,P)	(N,ALPHA)	(N,D)	(N,T)	(N,HE)	(N,2ALP)	(N,N'ALP)
1	0.0	3.5409E-02	9.3407E-02	1.1116E-02	0.0	0.0	0.0	0.0
2	0.0	4.1278E-02	1.2911E-01	1.4812E-02	0.0	0.0	0.0	0.0
3	0.0	4.2855E-02	1.6020E-01	6.4726E-03	0.0	0.0	0.0	0.0
4	0.0	3.0575E-03	1.8721E-01	9.9298E-05	0.0	0.0	0.0	0.0
5	0.0	0.0	1.4488E-01	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	8.2010E-02	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	8.6040E-02	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	8.1570E-02	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	2.7418E-02	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	9.0000E-02	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	8.3352E-02	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	3.5402E-02	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	1.7130E-03	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	1.1135E-04	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	1.3381E-08	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	1.7504E-11	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

AFTER GROUP 17 SAME AS ABOVE

*** INFINITE DILUSION CROSS SECTIONS (SMOOTH CROSS SECTION) WERE OUTPUT TO A DATA POOL ****
NODE NAME =EGRP-INFX-1276- SMT

*** INFORMATION OF DATA POOL USAGE ***
LOGICAL UNIT NO. = 91
DATA SET NAME = J1446.POOL87.DATA
NO. OF WRITTEN RECORDS = 6
REMAINS RECORDS = 11343

*** F-TABLES WERE OUTPUT TO A DATA POOL ***
NODE NAME =EGRP-INFX-1276- FTB

*** INFORMATION OF DATA POOL USAGE ***
LOGICAL UNIT NO. = 91
DATA SET NAME = J1446.POOL87.DATA
NO. OF WRITTEN RECORDS = 4
REMAINS RECORDS = 11339

*** TABLE OF THE SELF-SHIELDING FACTORS ***
REACTION TYPE = TOTAL TEMP.= 300.0

GROUP	--- SIG-0 ---					
	0.0	1.0	10.0	100.0	1000.0	10000.0
1	0.9987	0.9992	0.9998	1.0000	1.0000	1.0000
2	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000
3	0.9985	0.9990	0.9998	1.0000	1.0000	1.0000
4	0.9941	0.9965	0.9992	0.9999	1.0000	1.0000
5	0.9978	0.9987	0.9998	1.0000	1.0000	1.0000
6	0.9728	0.9858	0.9974	0.9997	1.0000	1.0000
7	0.9650	0.9806	0.9962	0.9996	0.9995	0.9996
8	0.9556	0.9779	0.9959	0.9998	0.9998	0.9998
9	0.9482	0.9690	0.9933	0.9999	0.9996	0.9996
10	0.9200	0.9461	0.9856	0.9988	0.9998	0.9998
11	0.9204	0.9487	0.9875	0.9989	1.0014	1.0014
12	0.8809	0.9172	0.9757	0.9971	1.0003	1.0003
13	0.9983	0.9986	0.9994	0.9999	1.0000	0.9999
14	0.9088	0.9385	0.9835	0.9977	1.0001	1.0001
15	0.9998	0.9999	0.9999	1.0000	1.0000	1.0000
16	0.6397	0.8985	0.9863	1.0001	1.0001	1.0001
17	0.9921	0.9954	0.9986	0.9996	0.9996	0.9996
18	0.9478	0.9615	0.9884	0.9990	1.0004	1.0004
19	0.9446	0.9534	0.9796	0.9971	0.9999	0.9999
20	0.9851	0.9894	0.9973	0.9998	0.9998	0.9998
21	0.9074	0.9241	0.9706	0.9966	1.0001	1.0001
22	0.9684	0.9751	0.9913	0.9986	1.0002	1.0002
23	0.9579	0.9641	0.9846	0.9983	0.9997	0.9997
24	0.9882	0.9909	0.9971	0.9994	0.9996	0.9996
25	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
26	0.9998	0.9999	0.9999	1.0000	0.9999	0.9999
27	0.9990	0.9990	0.9996	0.9998	1.0002	1.0003
28	0.9850	0.9881	0.9963	0.9986	0.9995	0.9997
29	0.8515	0.8656	0.9261	0.9872	0.9965	0.9975
30	0.8916	0.9018	0.9463	0.9912	0.9974	0.9981
31	0.9929	0.9943	0.9974	0.9995	1.0002	1.0003
32	0.9994	0.9995	0.9997	0.9998	0.9999	0.9999
33	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000
34	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
35	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
36	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
37	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
38	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
39	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
40	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
41	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
42	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
43	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
44	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
46	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
47	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
48	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
49	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
50	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

*** TABLE OF THE SELF-SHIELDING FACTORS ***
REACTION TYPE = ELASTIC TEMP.= 300.0

GROUP	--- SIG-0 ---					
	0.0	1.0	10.0	100.0	1000.0	10000.0
1	0.9978	0.9987	0.9997	1.0000	1.0000	1.0000
2	0.9998	0.9998	1.0000	1.0000	1.0000	1.0000
3	0.9977	0.9985	0.9997	1.0000	1.0001	1.0001
4	0.9915	0.9949	0.9988	0.9998	1.0000	1.0000
5	0.9967	0.9981	0.9997	1.0000	1.0000	1.0000
6	0.9629	0.9806	0.9964	0.9996	1.0001	1.0001
7	0.9560	0.9757	0.9952	0.9994	0.9994	0.9994
8	0.9507	0.9755	0.9954	0.9997	0.9997	0.9997
9	0.9471	0.9683	0.9932	0.9999	0.9996	0.9996
10	0.9145	0.9424	0.9846	0.9987	0.9998	0.9998
11	0.9165	0.9462	0.9869	0.9988	1.0014	1.0015
12	0.8792	0.9160	0.9753	0.9971	1.0003	1.0003
13	0.9983	0.9986	0.9994	0.9999	1.0000	0.9999
14	0.9088	0.9385	0.9835	0.9977	1.0001	1.0001
15	0.9998	0.9999	0.9999	1.0000	1.0000	1.0000
16	0.6397	0.8985	0.9863	1.0001	1.0001	1.0001
17	0.9921	0.9954	0.9986	0.9996	0.9996	0.9996
18	0.9478	0.9615	0.9884	0.9990	1.0004	1.0004
19	0.9446	0.9534	0.9796	0.9971	0.9999	0.9999
20	0.9851	0.9894	0.9973	0.9998	0.9998	0.9998
21	0.9074	0.9241	0.9706	0.9966	1.0001	1.0001
22	0.9684	0.9751	0.9913	0.9986	1.0002	1.0002
23	0.9579	0.9641	0.9846	0.9983	0.9997	0.9997
24	0.9882	0.9909	0.9971	0.9994	0.9996	0.9996
25	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
26	0.9998	0.9999	0.9999	1.0000	0.9999	0.9999
27	0.9990	0.9990	0.9996	0.9998	1.0002	1.0003
28	0.9850	0.9881	0.9963	0.9986	0.9995	0.9997
29	0.8515	0.8656	0.9261	0.9872	0.9965	0.9975
30	0.8916	0.9018	0.9463	0.9912	0.9974	0.9981
31	0.9929	0.9943	0.9974	0.9995	1.0002	1.0003
32	0.9994	0.9995	0.9997	0.9998	0.9999	0.9999
33	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000
34	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
35	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
36	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
37	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
38	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
39	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
40	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
41	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
42	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
43	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
44	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
45	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
46	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
47	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
48	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
49	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
50	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

*** TABLE OF THE SELF-SHIELDING FACTORS ***
REACTION TYPE = CAPTURE TEMP.= 300.0

GROUP	--- SIG-0 ---					
	0.0	1.0	10.0	100.0	1000.0	10000.0
1	0.9995	0.9998	1.0000	1.0000	1.0000	1.0000
2	1.0002	1.0001	1.0001	1.0000	1.0000	1.0000
3	0.9993	0.9996	1.0000	1.0001	1.0001	1.0001
4	1.0005	1.0004	1.0001	1.0000	1.0000	1.0000
5	1.0004	1.0002	1.0000	1.0001	1.0001	1.0001
6	1.0009	1.0003	1.0002	1.0000	1.0000	1.0000
7	1.0022	1.0010	1.0002	1.0000	1.0001	1.0001
8	1.0002	1.0002	0.9999	1.0000	1.0000	1.0000
9	1.0004	1.0003	1.0000	1.0001	1.0000	1.0000
10	1.0004	1.0003	1.0001	1.0000	1.0000	1.0000
11	0.9963	0.9978	0.9995	1.0000	1.0001	1.0001
12	0.9938	0.9957	0.9989	0.9999	1.0000	1.0000
13	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.0053	1.0034	1.0009	1.0001	1.0000	1.0000
15	1.0003	1.0001	1.0001	1.0000	1.0000	1.0000
16	1.0017	1.0005	1.0000	1.0000	1.0000	1.0000
17	0.9984	0.9991	0.9997	0.9999	0.9999	0.9999
18	1.0015	1.0010	1.0002	1.0000	0.9999	0.9999
19	0.9994	0.9996	0.9999	0.9999	0.9999	0.9999
20	0.9981	0.9987	0.9997	1.0000	1.0000	1.0000
21	1.0045	1.0035	1.0012	1.0001	1.0000	1.0000
22	0.9971	0.9977	0.9992	0.9999	1.0000	1.0000
23	1.0022	1.0019	1.0007	1.0002	1.0000	1.0001
24	1.0016	1.0012	1.0004	1.0001	1.0001	1.0001
25	0.9999	1.0000	1.0000	1.0001	1.0001	1.0001
26	0.9997	0.9999	0.9999	1.0001	0.9999	0.9999
27	0.9995	0.9994	0.9998	0.9999	1.0001	1.0002
28	0.9978	0.9983	0.9995	0.9998	0.9999	1.0000
29	0.9939	0.9945	0.9970	0.9995	0.9999	0.9999
30	1.0060	1.0054	1.0028	1.0005	1.0001	1.0001
31	1.0015	1.0012	1.0005	1.0001	1.0000	0.9999
32	1.0004	1.0003	1.0002	1.0002	1.0001	1.0001
33	1.0002	1.0001	1.0000	1.0000	1.0000	1.0000
34	1.0002	1.0002	0.9999	0.9999	0.9999	0.9999
35	1.0000	1.0000	1.0001	1.0001	1.0001	1.0001
36	0.9998	0.9999	0.9999	1.0000	1.0000	1.0000
37	1.0001	1.0001	0.9999	0.9999	0.9999	0.9999
38	1.0000	1.0000	1.0001	1.0001	1.0001	1.0001
39	0.9998	0.9999	0.9999	0.9999	0.9999	0.9999
40	1.0001	1.0001	1.0000	1.0000	1.0000	1.0000
41	1.0000	1.0000	1.0000	1.0001	1.0001	1.0000
42	0.9998	0.9998	0.9999	0.9999	0.9999	0.9999
43	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001
44	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000
45	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
46	1.0001	1.0001	1.0002	1.0002	1.0002	1.0002
47	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000
48	1.0000	1.0000	0.9999	0.9999	0.9999	0.9999
49	1.0000	1.0000	1.0001	1.0001	1.0001	1.0001
50	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999

*** ELASTIC SCATTERING MATRIX ***

SINK	SOC. 1	SOC. 2	SOC. 3	SOC. 4	SOC. 5	SOC. 6	SOC. 7	SOC. 8
1	6.75644E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.65042E-01	6.23525E-01	0.0	0.0	0.0	0.0	0.0	0.0
3	3.57528E-02	3.00538E-01	6.22274E-01	0.0	0.0	0.0	0.0	0.0
4	3.50144E-05	6.06523E-02	3.27526E-01	4.61136E-01	0.0	0.0	0.0	0.0
5	0.0	4.41503E-05	1.48626E-01	3.36530E-01	3.59609E-01	0.0	0.0	0.0
6	0.0	0.0	1.85746E-04	1.65098E-01	3.38195E-01	3.09265E-01	0.0	0.0
7	0.0	0.0	0.0	1.71028E-04	1.33992E-01	3.93775E-01	3.40038E-01	0.0
8	0.0	0.0	0.0	0.0	8.88743E-05	1.88720E-01	4.37396E-01	3.11746E-01
9	0.0	0.0	0.0	0.0	0.0	1.55463E-04	1.81181E-01	3.91317E-01
10	0.0	0.0	0.0	0.0	0.0	0.0	1.11412E-04	1.99946E-01
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.17051E-05
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SINK 13 THRU SINK 100 SAME AS ABOVE							

SINK	SOC. 9	SOC. 10	SOC. 11	SOC. 12	SOC. 13	SOC. 14	SOC. 15	SOC. 16
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SINK 2 THRU SINK 8 SAME AS ABOVE							
9	5.41562E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	5.57025E-01	5.83638E-01	0.0	0.0	0.0	0.0	0.0	0.0
11	1.79436E-01	4.92149E-01	7.96786E-01	0.0	0.0	0.0	0.0	0.0
12	6.25703E-05	2.29304E-01	6.37886E-01	1.09262E+00	0.0	0.0	0.0	0.0
13	0.0	4.67136E-05	2.83068E-01	7.96752E-01	1.50790E+00	0.0	0.0	0.0
14	0.0	0.0	3.57537E-04	4.85969E-01	9.49878E-01	7.25780E-01	0.0	0.0
15	0.0	0.0	0.0	1.00655E-04	6.92082E-01	6.09488E-01	3.71780E-01	0.0
16	0.0	0.0	0.0	0.0	4.02645E-04	2.67524E-01	5.53504E-01	2.39869E-01
17	0.0	0.0	0.0	0.0	0.0	5.96928E-05	1.84378E-01	2.81877E-01
18	0.0	0.0	0.0	0.0	0.0	0.0	6.28065E-05	1.71159E-01
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.95313E-04
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SINK 21 THRU SINK 100 SAME AS ABOVE							

SINK	SOC. 17	SOC. 18	SOC. 19	SOC. 20	SOC. 21	SOC. 22	SOC. 23	SOC. 24
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SINK 2 THRU SINK 16 SAME AS ABOVE							
17	3.78573E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	6.68044E-01	7.97022E-01	0.0	0.0	0.0	0.0	0.0	0.0
19	3.73713E-01	7.90832E-01	5.68926E-01	0.0	0.0	0.0	0.0	0.0
20	1.60444E-04	5.25795E-01	9.39883E-01	7.11521E-01	0.0	0.0	0.0	0.0
21	0.0	2.23989E-04	5.92210E-01	1.08544E+00	1.85190E+00	0.0	0.0	0.0
22	0.0	0.0	3.07859E-04	5.68127E-01	1.12010E+00	1.01077E+00	0.0	0.0
23	0.0	0.0	0.0	8.77037E-05	8.70116E-01	1.07041E+00	2.38377E+00	0.0
24	0.0	0.0	0.0	0.0	6.64314E-04	1.37939E+00	1.80461E+00	8.68219E-01
25	0.0	0.0	0.0	0.0	0.0	1.44247E-03	2.24213E+00	1.54854E+00
26	0.0	0.0	0.0	0.0	0.0	0.0	4.80083E-04	6.80386E-01
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.94452E-04
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SINK 29 THRU SINK 100 SAME AS ABOVE							

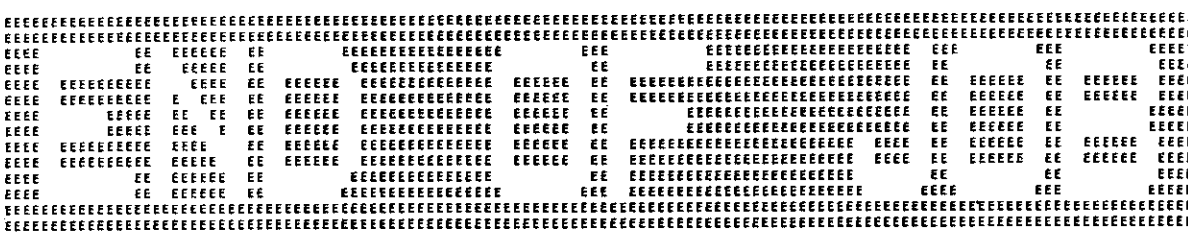
SINK	SOC. 25	SOC. 26	SOC. 27	SOC. 28	SOC. 29	SOC. 30	SOC. 31	SOC. 32
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SINK 2 THRU SINK 24 SAME AS ABOVE							
25	6.83501E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	1.41629E+00	7.73601E-01	0.0	0.0	0.0	0.0	0.0	0.0
27	5.79076E-01	1.44110E+00	9.87942E-01	0.0	0.0	0.0	0.0	0.0
28	1.91051E-04	5.28493E-01	1.53439E+00	1.54144E+00	0.0	0.0	0.0	0.0
29	0.0	1.64179E-04	4.46670E-01	1.93395E+00	4.45683E+00	0.0	0.0	0.0

*** INELASTIC SCATTERING MATRIX ***

SINK	SOC. 1	SOC. 2	SOC. 3	SOC. 4	SOC. 5	SOC. 6	SOC. 7	SOC. 8
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SINK 2 THRU SINK 3 SAME AS ABOVE							
4	8.33254E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	2.21954E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5.55527E-02	5.19357E-03	0.0	0.0	0.0	0.0	0.0	0.0
7	4.84318E-02	3.55394E-02	0.0	0.0	0.0	0.0	0.0	0.0
8	2.92639E-02	6.28084E-02	7.43498E-03	0.0	0.0	0.0	0.0	0.0
9	2.49817E-02	5.45223E-02	3.73642E-02	0.0	0.0	0.0	0.0	0.0
10	2.88030E-02	3.32492E-02	6.88841E-02	7.28029E-03	0.0	0.0	0.0	0.0
11	3.57558E-02	2.17592E-02	6.20009E-02	2.45844E-02	0.0	0.0	0.0	0.0
12	3.85475E-02	2.43995E-02	4.28119E-02	4.19766E-02	7.06578E-04	0.0	0.0	0.0
13	3.98425E-02	2.91367E-02	1.81242E-02	4.74392E-02	1.23814E-02	0.0	0.0	0.0
14	4.07328E-02	3.36330E-02	1.21986E-02	3.87200E-02	2.71679E-02	0.0	0.0	0.0
15	3.63389E-02	3.20937E-02	1.08566E-02	2.94857E-02	4.85889E-02	4.14691E-04	0.0	0.0
16	2.90010E-02	2.68324E-02	1.39648E-02	1.40459E-02	5.03615E-02	1.02298E-02	0.0	0.0
17	2.24416E-02	2.20593E-02	1.43503E-02	9.23965E-03	3.93273E-02	2.58000E-02	0.0	0.0
18	1.60967E-02	1.63719E-02	1.28084E-02	5.51034E-03	2.94399E-02	3.40129E-02	0.0	0.0
19	1.18951E-02	1.17301E-02	1.05881E-02	3.32280E-03	1.57108E-02	4.03548E-02	5.88410E-05	0.0
20	9.21112E-03	8.69685E-03	7.71540E-03	3.76017E-03	9.35142E-03	3.86189E-02	2.70756E-03	0.0
21	8.17773E-03	6.41053E-03	4.99775E-03	4.16891E-03	6.41001E-03	2.69822E-02	1.10084E-02	0.0
22	7.46564E-03	4.46863E-03	3.45381E-03	4.07565E-03	4.03916E-03	1.85203E-02	1.82836E-02	0.0
23	6.58793E-03	3.25727E-03	2.54797E-03	3.65280E-03	1.78456E-03	1.34458E-02	2.07950E-02	0.0
24	5.83829E-03	2.38756E-03	1.84254E-03	3.11324E-03	5.07405E-04	7.87310E-03	2.13141E-02	0.0
25	4.86970E-03	1.71194E-03	1.33681E-03	2.54198E-03	8.95428E-05	4.77683E-03	2.14310E-02	0.0
26	4.17414E-03	1.19822E-03	9.54987E-04	1.94373E-03	1.08080E-04	4.54028E-03	1.82708E-02	0.0
27	3.46992E-03	8.13568E-04	7.14034E-04	1.43398E-03	1.49237E-04	4.09406E-03	1.33080E-02	1.26618E-04
28	2.88582E-03	5.70116E-04	5.42051E-04	1.04279E-03	1.68471E-04	3.42130E-03	9.56587E-03	8.04578E-04
29	2.39784E-03	4.29158E-04	3.88374E-04	7.55667E-04	1.72058E-04	2.77766E-03	7.10107E-03	1.57547E-03
30	1.94924E-03	3.20650E-04	3.00770E-04	5.20248E-04	1.68821E-04	2.23506E-03	5.30701E-03	2.04937E-03
31	1.56316E-03	2.42878E-04	2.40143E-04	3.49187E-04	1.60140E-04	1.74223E-03	3.71616E-03	2.10893E-03
32	1.24144E-03	1.84067E-04	1.92006E-04	2.22500E-04	1.47478E-04	1.26388E-03	2.23025E-03	2.02420E-03
33	9.96943E-04	1.44861E-04	1.53366E-04	1.31496E-04	1.35068E-04	8.68774E-04	1.26205E-03	1.88948E-03
34	7.93607E-04	1.20263E-04	1.18089E-04	9.61121E-05	1.07706E-04	5.59983E-04	7.37448E-04	1.70974E-03
35	6.27632E-04	9.75351E-05	9.04568E-05	7.50931E-05	8.56372E-05	3.32004E-04	4.31906E-04	1.50942E-03
36	5.06933E-04	7.85743E-05	6.92013E-05	6.31336E-05	5.95911E-05	2.09156E-04	2.89547E-04	1.24674E-03
37	4.04220E-04	6.55557E-05	5.15597E-05	5.07969E-05	4.75384E-05	1.54179E-04	1.67535E-04	9.31662E-04
38	3.29027E-04	5.52221E-05	3.86663E-05	4.24104E-05	3.58812E-05	1.10825E-04	1.07998E-04	6.83175E-04
39	2.61776E-04	4.64594E-05	2.84414E-05	3.43838E-05	2.73143E-05	7.67683E-05	8.71603E-05	4.42690E-04
40	2.14438E-04	3.92035E-05	2.06140E-05	2.80306E-05	2.05435E-05	5.02622E-05	7.37562E-05	2.95018E-04
41	1.72537E-04	3.31083E-05	1.58393E-05	2.27493E-05	1.57050E-05	3.02772E-05	6.31195E-05	1.99902E-04
42	1.38959E-04	2.85737E-05	1.26587E-05	1.81779E-05	1.21083E-05	1.54229E-05	5.34919E-05	1.37667E-04
43	1.13842E-04	2.39035E-05	1.01618E-05	1.46558E-05	9.24013E-06	4.67129E-06	4.59492E-05	9.80446E-05
44	9.08753E-05	2.04649E-05	8.23040E-06	1.19152E-05	7.03295E-06	0.0	3.74606E-05	7.09666E-05
45	7.07679E-05	1.67536E-05	6.61899E-06	9.58239E-06	5.36502E-06	0.0	2.95097E-05	5.16443E-05
46	5.58019E-05	1.33057E-05	5.26362E-06	7.80272E-06	4.19377E-06	0.0	2.32244E-05	3.80118E-05
47	4.35900E-05	1.05117E-05	4.11269E-06	6.28338E-06	3.21026E-06	0.0	1.86364E-05	2.79538E-05
48	3.46307E-05	8.03428E-06	3.20516E-06	4.86922E-06	2.43404E-06	0.0	1.49019E-05	2.08265E-05
49	2.82354E-05	6.57662E-06	2.51201E-06	3.86055E-06	1.89857E-06	0.0	1.18267E-05	1.57323E-05
50	2.31912E-05	5.43050E-06	1.98848E-06	2.98306E-06	1.46005E-06	0.0	9.00663E-06	1.18731E-05
51	1.63565E-05	4.48321E-06	1.62287E-06	2.35415E-06	1.18281E-06	0.0	7.36690E-06	8.76485E-06
52	1.69155E-05	3.13569E-06	1.31930E-06	1.91854E-06	8.85474E-07	0.0	6.02813E-06	6.71488E-06
53	1.31185E-05	3.52413E-06	9.43187E-07	1.57016E-06	6.48452E-07	0.0	4.91988E-06	5.07353E-06
54	1.05908E-05	2.72444E-06	9.59437E-07	1.17386E-06	5.19742E-07	0.0	3.58981E-06	3.91939E-06
55	7.95930E-06	2.18567E-06	7.50009E-07	1.19048E-06	3.98059E-07	0.0	2.93457E-06	3.08265E-06
56	6.40115E-06	1.68570E-06	5.91252E-07	9.44380E-07	3.63605E-07	0.0	2.41685E-06	3.06447E-06
57	1.06637E-05	2.69363E-06	8.90420E-07	1.33927E-06	5.15762E-07	0.0	4.33112E-06	2.35126E-06
								3.64319E-06

```
***   ELASTIC SCATTERING MATRIX    WERE OUTPUT TO A DATA POOL
    NODE NAME = EGRP-INFX-1276- ELA
***   INELASTIC SCATTERING MATRIX  WERE OUTPUT TO A DATA POOL
    NODE NAME = EGRP-INFX-1276- INS

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.          =     91
    DATA SET NAME             = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS    =     50
    REMAINS RECORDS           =  11289
```



```
TOTAL CPU TIME ---    1.32 MIN
```

D.2 Sample Problem for FAIR-CROSS step 2

```
MEMBER NAME > B:RSTEP2.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.2 I.3 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC LMGO,LM='J1446.FCSTEP2X'
    8 :  //FT11F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,20)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT13F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,20)),
   11 :  //   DCB=(LRECL=16804,BLKSIZE=16804,RECFM=F)
   12 :  //FT14F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,20)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT16F001 DD DSN=&&F6,UNIT=WK10,SPACE=(TRK,(50,20)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT17F001 DD DSN=&&F7,UNIT=WK10,SPACE=(TRK,(50,20)),
   17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT18F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,20)),
   19 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   20 :  //FT21F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,20)),
   21 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   22 :  //FT22F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(50,20)),
   23 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   24 :  //FT23F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(50,20)),
   25 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   26 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   27 :  //SYSIN DD *
   28 :   FAIR-CROSS STEP-2 SAMPLE PROBLEM NO.1
   29 :   &UNIT ULTX=91,INFX=91,FTBL=91,SGXL=91,SELF=91,FXSN=91 &END
   30 :   1¥¥ 2  2  100  20  16  4HEGRP  0  0  T
   31 :  AIR BY ENDF/B-IV AT 300K
   32 :   4¥¥  4HAIR0  1  1  1  1  0
   33 :   5¥¥    1276  1275
   34 :   7¥¥    1276  1275
   35 :   8**     8.0   7.0
   36 :   9**   1.130E-5 4.250E-5
   37 :  10**    300.0  300.0
   38 :    T
   39 :  12¥¥  1  0  T
   40 :  13¥¥  1276   4   0   0   T
   41 :  14¥¥   108 608 208 308   T
   42 :  13¥¥  1275   4   0   0   T
   43 :  14¥¥   107 607 207 307   T
   44 :  17¥¥    10  5R0          T
   45 :  29¥¥     0   0   0   0   T
   46 :  ++
   47 :  //
   48 :   FAIR-CROSS STEP-2 SAMPLE PROBLEM NO.2
   49 :   &UNIT ULTX=91,INFX=91,FTBL=91,SGXL=91,SELF=91,FXSN=91 &END
   50 :   1¥¥ 2  1  100  20  16  4HEGRP  0  0  T
   51 :  IRON BY ENDF/B-IV AT 300K
   52 :   4¥¥  4HIRON  1  1  1  1  0
   53 :   5¥¥    1192
   54 :   7¥¥    1192
   55 :   8**    26.0
   56 :   9**   8.464E-2
   57 :  10**    300.0
   58 :    T
   59 :  12¥¥  1  0  T
   60 :  13¥¥  1192   3   0   0   T
   61 :  14¥¥   926 126 326       T
   62 :  17¥¥    10  5R0          T
```

```
MEMBER NAME > B:RSTEP2.TXT    ------------------------------------------------ PAGE :  2
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
   63 :  29¥¥      0   0   0   0   T
   64 :  ++
   65 :  //
------------------------------------ END OF FILE -------------------------------------
```

```
1¥ ARRAY      8 ENTRIES READ

 T

                          ****       MAIN TITLE        ****

          FAIR-CROSS STEP-2 SAMPLE PROBLEM NO.1


                          **** MAIN CONTROL PARAMETERS ****

                SELECTION OF THE CALCULATIONAL STEP        ---     2

                NO. OF NUCLIDE OR MIXTURE TO BE PROCESSED ---     2

                NO. OF NEUTRON ENERGY GROUPS               ---   100

                NO. OF GAMMA-RAY ENERGY GROUPS             ---    20

                NO. OF ANGULAR MESH IN CROSS SECTION TABLE---    16

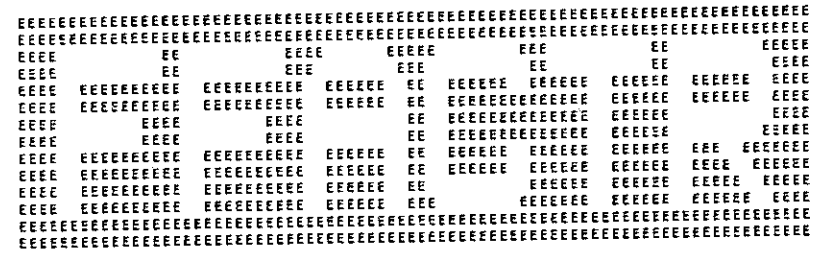
                NODE NAME OF ENERGY GROUP STRUCTURE        --- EGRP

                TYPE OF INPUT NEUTRON GROUP STRUCTURE      ---     0

                TYPE OF INPUT GAMMA-RAY GROUP STRUCTURE    ---     0
```

```
*** MATERIAL COMPOSITION IN THIS REGION ***

        ---- MATERIAL NO. ----     ATOMIC        ATOM          TEMP.
          ENDF/B      F-TABLE      NUMBER       DENSITY
  1         1276         1276          8.     1.1300E-05        300.0
  2         1275         1275          7.     4.2500E-05        300.0
```



```
12% ARRAY      2 ENTRIES READ

  T


*** READ INFINITE DILUSION CROSS SECTION ***
      MATNO=  1276      MAT=1276 O-16 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)
      MATNO=  1275      MAT=1275 N-14 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)

FFACTR REQUIRES       8221 LOCATIONS VS. AVAILABLE    300000

*** READ F-TABLE LIBRARY ***
      MATNO=  1276      MAT=1276 O-16 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)
      MATNO=  1275      MAT=1275 N-14 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)
```

*** SIGMA-0 ***

MCODE	1276	1275
GRP 1	5.957E+00	4.419E-01
GRP 2	5.903E+00	4.283E-01
GRP 3	5.598E+00	4.375E-01
GRP 4	5.285E+00	3.731E-01
GRP 5	4.866E+00	3.255E-01
GRP 6	5.073E+00	3.237E-01
GRP 7	5.254E+00	3.200E-01
GRP 8	5.075E+00	2.666E-01
GRP 9	5.311E+00	3.429E-01
GRP 10	4.617E+00	3.612E-01
GRP 11	6.380E+00	4.693E-01
GRP 12	7.048E+00	6.206E-01
GRP 13	6.224E+00	8.380E-01
GRP 14	6.206E+00	4.158E-01
GRP 15	5.217E+00	2.951E-01
GRP 16	5.610E+00	1.790E-01
GRP 17	5.849E+00	3.777E-01
GRP 18	7.170E+00	5.538E-01
GRP 19	7.609E+00	5.457E-01
GRP 20	8.200E+00	6.268E-01
GRP 21	6.524E+00	9.839E-01
GRP 22	7.054E+00	9.108E-01
GRP 23	6.135E+00	1.677E+00
GRP 24	5.711E+00	8.235E-01
GRP 25	7.249E+00	7.123E-01
GRP 26	8.676E+00	7.294E-01
GRP 27	6.579E+00	7.894E-01
GRP 28	8.273E+00	1.005E+00
GRP 29	9.804E+00	2.537E+00
GRP 30	1.190E+01	2.281E+00
GRP 31	1.094E+01	1.160E+00
GRP 32	1.146E+01	9.814E-01
GRP 33	1.206E+01	9.351E-01
GRP 34	1.262E+01	9.214E-01
GRP 35	1.319E+01	9.191E-01
GRP 36	1.371E+01	9.220E-01
GRP 37	1.418E+01	9.272E-01
GRP 38	1.472E+01	9.328E-01
GRP 39	1.524E+01	9.379E-01
GRP 40	1.582E+01	9.434E-01
GRP 41	1.639E+01	9.484E-01
GRP 42	1.712E+01	9.533E-01
GRP 43	1.789E+01	9.581E-01
GRP 44	1.858E+01	9.622E-01
GRP 45	1.941E+01	9.659E-01
GRP 46	2.021E+01	9.691E-01
GRP 47	2.096E+01	9.720E-01
GRP 48	2.177E+01	9.749E-01
GRP 49	2.253E+01	9.774E-01
GRP 50	2.327E+01	9.796E-01
GRP 51	2.393E+01	9.816E-01
GRP 52	2.457E+01	9.833E-01
GRP 53	2.513E+01	9.848E-01
GRP 54	2.564E+01	9.862E-01
GRP 55	2.620E+01	9.874E-01
GRP 56	2.673E+01	9.884E-01
GRP 57	2.736E+01	9.897E-01

*** SELF SHIELDING FACTOR ***

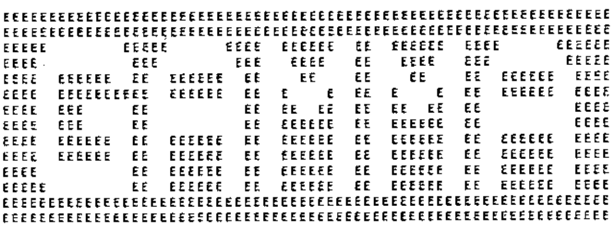
MATNO= 1276 MCODE= 1276

GROUP	TOTAL	ELASTIC	FISSION	CAPTURE
1	9.99738E-01	9.99554E-01	1.00000E+00	9.99967E-01
2	9.99956E-01	9.99929E-01	1.00000E+00	1.00007E+00
3	9.99618E-01	9.99429E-01	1.00000E+00	9.99892E-01
4	9.98555E-01	9.97895E-01	1.00000E+00	1.00016E+00
5	9.99491E-01	9.99252E-01	1.00000E+00	1.00005E+00
6	9.94568E-01	9.92582E-01	1.00000E+00	1.00021E+00
7	9.92536E-01	9.90623E-01	1.00000E+00	1.00036E+00
8	9.91490E-01	9.90548E-01	1.00000E+00	9.99982E-01
9	9.87557E-01	9.87290E-01	1.00000E+00	1.00002E+00
10	9.73416E-01	9.71575E-01	1.00000E+00	1.00018E+00
11	9.81614E-01	9.80718E-01	1.00000E+00	9.99279E-01
12	9.68023E-01	9.67543E-01	1.00000E+00	9.98497E-01
13	9.99249E-01	9.99249E-01	1.00000E+00	9.99996E-01
14	9.75443E-01	9.75442E-01	1.00000E+00	1.00130E+00
15	9.99899E-01	9.99899E-01	1.00000E+00	1.00012E+00
16	9.71336E-01	9.71336E-01	1.00000E+00	1.00011E+00
17	9.97998E-01	9.97998E-01	1.00000E+00	9.99602E-01
18	9.85003E-01	9.85003E-01	1.00000E+00	1.00030E+00
19	9.76467E-01	9.76467E-01	1.00000E+00	9.99832E-01
20	9.96753E-01	9.96753E-01	1.00000E+00	9.99605E-01
21	9.62189E-01	9.62189E-01	1.00000E+00	1.00160E+00
22	9.89111E-01	9.89111E-01	1.00000E+00	9.99016E-01
23	9.80153E-01	9.80153E-01	1.00000E+00	1.00096E+00
24	9.95718E-01	9.95718E-01	1.00000E+00	1.00059E+00
25	9.99987E-01	9.99987E-01	1.00000E+00	1.00003E+00
26	9.99906E-01	9.99906E-01	1.00000E+00	9.99887E-01
27	9.99506E-01	9.99506E-01	1.00000E+00	9.99729E-01
28	9.95809E-01	9.95809E-01	1.00000E+00	9.99435E-01
29	9.25463E-01	9.25463E-01	1.00000E+00	9.96996E-01
30	9.50311E-01	9.50311E-01	1.00000E+00	1.00263E+00
31	9.97537E-01	9.97537E-01	1.00000E+00	1.00052E+00
32	9.99731E-01	9.99731E-01	1.00000E+00	1.00019E+00
33	9.99996E-01	9.99996E-01	1.00000E+00	1.00000E+00
34	1.00001E+00	1.00001E+00	1.00000E+00	9.99855E-01
35	1.00000E+00	1.00000E+00	1.00000E+00	1.00013E+00
36	9.99998E-01	9.99998E-01	1.00000E+00	9.99958E-01
37	9.99991E-01	9.99992E-01	1.00000E+00	9.99904E-01
38	1.00001E+00	1.00001E+00	1.00000E+00	1.00009E+00
39	9.99991E-01	9.99992E-01	1.00000E+00	9.99923E-01
40	1.00000E+00	1.00000E+00	1.00000E+00	1.00001E+00
41	1.00000E+00	1.00000E+00	1.00000E+00	1.00004E+00
42	9.99991E-01	9.99991E-01	1.00000E+00	9.99894E-01
43	1.00001E+00	1.00001E+00	1.00000E+00	1.00012E+00
44	9.99999E-01	1.00000E+00	1.00000E+00	1.00000E+00
45	9.99991E-01	9.99991E-01	1.00000E+00	9.99876E-01
46	1.00001E+00	1.00001E+00	1.00000E+00	1.00016E+00
47	9.99997E-01	9.99997E-01	1.00000E+00	9.99966E-01
48	9.99996E-01	9.99997E-01	1.00000E+00	9.99899E-01
49	1.00000E+00	1.00000E+00	1.00000E+00	1.00008E+00
50	9.99996E-01	9.99996E-01	1.00000E+00	9.99932E-01
51	1.00000E+00	1.00000E+00	1.00000E+00	1.00004E+00
52	1.00000E+00	1.00000E+00	1.00000E+00	1.00004E+00
53	9.99995E-01	9.99995E-01	1.00000E+00	9.99887E-01

*** SELF SHIELDING FACTOR ***

MATNO= 1275 MCODE= 1275

GROUP	TOTAL	ELASTIC	FISSION	CAPTURE
1	1.00002E+00	1.00003E+00	1.00000E+00	1.00013E+00
2	1.00000E+00	1.00000E+00	1.00000E+00	1.00006E+00
3	9.99029E-01	9.98315E-01	1.00000E+00	9.99399E-01
4	9.99309E-01	9.98892E-01	1.00000E+00	9.99212E-01
5	9.99826E-01	9.99751E-01	1.00000E+00	9.98700E-01
6	9.93865E-01	9.91322E-01	1.00000E+00	9.94587E-01
7	9.94410E-01	9.92404E-01	1.00000E+00	9.90377E-01
8	9.96931E-01	9.96046E-01	1.00000E+00	9.89244E-01
9	9.98297E-01	9.97980E-01	1.00000E+00	1.00036E+00
10	9.81667E-01	9.76029E-01	1.00000E+00	9.75616E-01
11	9.82555E-01	9.77551E-01	1.00000E+00	9.81790E-01
12	9.96479E-01	9.95490E-01	1.00000E+00	1.00345E+00
13	9.95808E-01	9.94571E-01	1.00000E+00	1.00020E+00
14	9.95297E-01	9.94275E-01	1.00000E+00	9.93254E-01
15	9.97302E-01	9.96858E-01	1.00000E+00	9.98952E-01
16	9.97378E-01	9.97145E-01	1.00000E+00	9.96882E-01
17	9.98759E-01	9.98681E-01	1.00000E+00	1.00072E+00
18	9.75000E-01	9.73647E-01	1.00000E+00	9.95319E-01
19	9.79289E-01	9.78745E-01	1.00000E+00	9.98514E-01
20	9.89662E-01	9.88930E-01	1.00000E+00	9.99664E-01
21	9.62413E-01	9.61458E-01	1.00000E+00	9.98204E-01
22	9.42830E-01	9.42616E-01	1.00000E+00	1.00513E+00
23	9.28765E-01	9.28296E-01	1.00000E+00	9.97907E-01
24	9.94473E-01	9.94439E-01	1.00000E+00	1.00030E+00
25	9.98006E-01	9.97984E-01	1.00000E+00	1.00016E+00
26	9.98855E-01	9.98800E-01	1.00000E+00	1.00014E+00
27	9.91901E-01	9.91618E-01	1.00000E+00	1.00014E+00
28	9.98538E-01	9.98527E-01	1.00000E+00	1.00012E+00
29	9.97683E-01	9.97639E-01	1.00000E+00	1.00001E+00
30	9.618148E-01	9.61793E-01	1.00000E+00	9.99759E-01
31	9.99958E-01	9.99959E-01	1.00000E+00	1.00000E+00
32	9.99958E-01	9.99959E-01	1.00000E+00	1.00000E+00
33	9.99955E-01	9.99955E-01	1.00000E+00	1.00000E+00
34	9.99958E-01	9.99958E-01	1.00000E+00	9.99972E-01
35	9.99960E-01	9.99960E-01	1.00000E+00	9.99948E-01
36	9.99966E-01	9.99966E-01	1.00000E+00	9.99958E-01
37	9.99966E-01	9.99967E-01	1.00000E+00	9.99944E-01
38	9.99964E-01	9.99965E-01	1.00000E+00	9.99952E-01
39	9.99967E-01	9.99967E-01	1.00000E+00	9.99952E-01
40	9.99964E-01	9.99964E-01	1.00000E+00	9.99950E-01
41	9.99967E-01	9.99968E-01	1.00000E+00	9.99944E-01
42	9.99957E-01	9.99958E-01	1.00000E+00	9.99948E-01
43	9.99960E-01	9.99960E-01	1.00000E+00	9.99954E-01
44	9.99965E-01	9.99965E-01	1.00000E+00	9.99946E-01
45	9.99961E-01	9.99961E-01	1.00000E+00	9.99945E-01
46	9.99965E-01	9.99965E-01	1.00000E+00	9.99948E-01
47	9.99965E-01	9.99966E-01	1.00000E+00	9.99941E-01
48	9.99967E-01	9.99967E-01	1.00000E+00	9.99951E-01
49	9.99967E-01	9.99968E-01	1.00000E+00	9.99940E-01
50	9.99969E-01	9.99969E-01	1.00000E+00	9.99948E-01
51	9.99973E-01	9.99973E-01	1.00000E+00	9.99953E-01
52	9.99976E-01	9.99976E-01	1.00000E+00	9.99949E-01
53	9.99978E-01	9.99978E-01	1.00000E+00	9.99945E-01



17* ARRAY 6 ENTRIES READ

T

```
 INPUT DATA

 IZ    NO. OF INPUT ATOMIC NUMBERS              2   IG    NO. OF GROUPS                          20
 N     NO. OF INTEGRATION POINTS/GROUP         10   KON   -1/0/1=FLUX/NONE/SOURCE                 0
 IF    NO. OF INPUT FLUXES                      0   LOOK  0/1/2=PRINT X-SEC TABLE NO/PO/ALL       0
 PRTO  0/1/2=PRINT ABSORB X-SEC NO/FEW/FINE     0   PRT1  0/1/2=PRINT HEAT   X-SEC NO/FEW/FINE    0

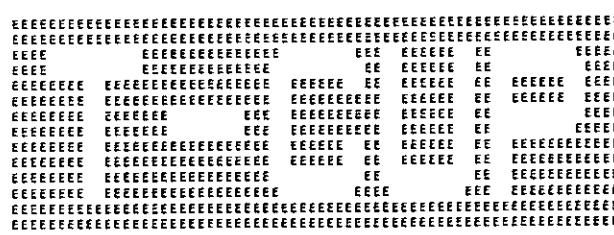
       GROUP ENERGY BOUNDS
    1  0.14000E+02
    2  0.12000E+02
    3  0.10000E+02
    4  0.80000E+01
    5  0.65000E+01
    6  0.50000E+01
    7  0.40000E+01
    8  0.30000E+01
    9  0.25000E+01
   10  0.20000E+01
   11  0.16600E+01
   12  0.13300E+01
   13  0.10000E+01
   14  0.80000E+00
   15  0.60000E+00
   16  0.40000E+00
   17  0.30000E+00
   18  0.20000E+00
   19  0.10000E+00
   20  0.50000E-01
   21  0.20000E-01

GROUP   AVG FLUX     AVG SIGMA S

  1   1.00000E+01   6.32161E-02
  2   1.00000E+01   7.15951E-02
  3   1.00000E+01   8.29348E-02
  4   1.00000E+01   9.67064E-02
  5   1.00000E+01   1.13681E-01
  6   1.00000E+01   1.33869E-01
  7   1.00000E+01   1.57641E-01
  8   1.00000E+01   1.82669E-01
  9   1.00000E+01   2.05919E-01
 10   1.00000E+01   2.31569E-01
 11   1.00000E+01   2.58752E-01
 12   1.00000E+01   2.94883E-01
 13   1.00000E+01   3.34515E-01
 14   1.00000E+01   3.76226E-01
 15   1.00000E+01   4.36155E-01
 16   1.00000E+01   5.02207E-01
 17   1.00000E+01   5.63456E-01
 18   1.00000E+01   6.69888E-01
 19   1.00000E+01   7.89390E-01
 20   1.00000E+01   8.86323E-01

 WARNING FOR NORMALIZATION AT GROUP= 1     7.5 PERCENT

 WARNING FOR NORMALIZATION AT GROUP= 2     7.1 PERCENT
```



```
   29W ARRAY      4 ENTRIES READ

    T

     ING  NUMBER OF NEUTRON GROUPS                    100

    IGG  NUMBER OF GAMMA   GROUPS                     20

    IHM  LENGTH OF COUPLED CROSS SECTION TABLE        123

    IHT  POS. OF TOTAL CROSS SECTION                    3

    IHS  POS. OF SELF SCATTERING CROSS SECTION          4

    IFO  NO. OF ANGULAR MESH                           16

    NHEAT  INCORP. OF HEAT GENERATION COEFF.            0

    NDISP  INCORP. OF ATOMIC DISPLACEMENT C.S.          0

    IPRT CROSS SECTION PRINT (0/1/2=NO/FEW/ALL)         0

CROSS SECTIONS REQUIRED     31998 COMMON POSITIONS OF THE    300000 POSITIONS ALLOCATED

 **** MACRO CROSS SECTION TABLE WAS OUTPUT TO A DATA POOL
      NODE NAME = EGRP-FX16-AIRD-

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.        =     91
    DATA SET NAME           = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS  =    213
    REMAINS RECORDS         =   9970
```

D.3 Sample Problem for FAIR-CROSS step 3

```
MEMBER NAME > B:RSTEP3.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.4 I.4 P.0 W.3 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC LMGO,LM='J1446.FCSTEP2X'
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,20)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(50,20)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,20)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT40F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,20)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT50F001 DD DSN=J1446.GRPXSEC.DATA,SPACE=(TRK,(50,10)),UNIT=TSSWK,
   17 :  //   DISP=(NEW,CATLG,DELETE),DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS),
   18 :  //   LABEL=(,,,OUT)
   19 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   20 :  //SYSIN DD *
   21 :   FAIR-CROSS STEP-3 SAMPLE PROBLEM NO.1
   22 :   &UNIT INFX=91,FXSN=91 &END
   23 :    1¥¥  3  1  100  20  16  4HEGRP  0  0  T
   24 :   30¥¥  3  3  0   T
   25 :   31¥¥  4HAIR0
   26 :   32¥¥    1000
   27 :     T
   28 :  ++
   29 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
1¥ ARRAY      8 ENTRIES READ

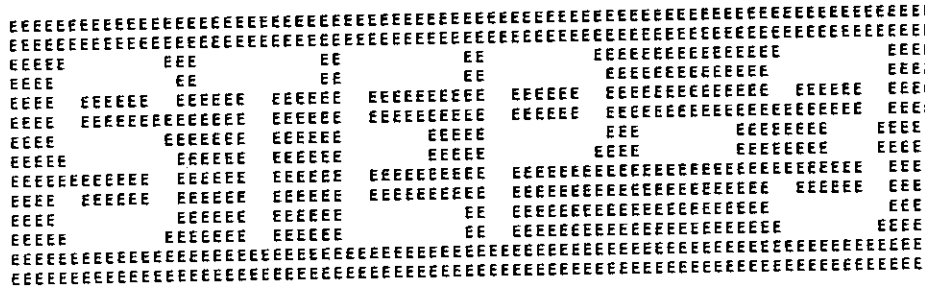
 T

                              ****        MAIN TITLE        ****

     FAIR-CROSS STEP-3 SAMPLE PROBLEM NO.1


                              **** MAIN CONTROL PARAMETERS ****

                    SELECTION OF THE CALCULATIONAL STEP        ---     3
                    NO. OF NUCLIDE OR MIXTURE TO BE PROCESSED ---     1
                    NO. OF NEUTRON ENERGY GROUPS               ---   100
                    NO. OF GAMMA-RAY ENERGY GROUPS             ---    20
                    NO. OF ANGULAR MESH IN CROSS SECTION TABLE---    16
                    NODE NAME OF ENERGY GROUP STRUCTURE        --- EGRP
                    TYPE OF INPUT NEUTRON GROUP STRUCTURE      ---     0
                    TYPE OF INPUT GAMMA-RAY GROUP STRUCTURE    ---     0
```



```
          INPUT  DATA  LIST  FOR  STEP3
LOR   LEGENDRE EXPANSION ORDER                                          =  3
LIB   OUTPUT LIBRARY TYPE (1/2/3/4 = ANISN/DOT/GRP.(NORMAL)/GRP.(ADJOINT)  =  3
IPG   CROSS SECTION PRINT (-1/0/N = ALL GROUP/NONE/33*ARRAY)            =  0
MATERIAL NODE NAME
    AIRO
OUTPUT MATERIAL NUMBER
    1000
```

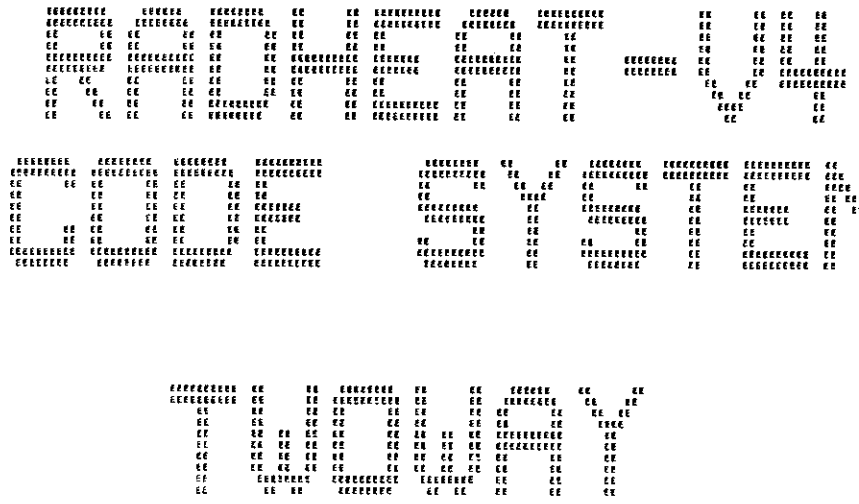
```
A MATERIAL-WISE TAPE WAS PRODUCED ON FT40F001

     IGM =    120
     IHM =    123
     IHT =      3
     IHS =      4
     NUP =      0
     LOR =      3
     MTP =      4

     MATNO        COMMENT
      1000  AIRO AIR BY ENDF/B-IV AT 300K
```

D.4 Sample Problem for TWOWAY

```
MEMBER NAME > B:TWOWAY.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.5 I.4 P.0 W.2 C.5 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC FORT77,SO='J1446.RADHEAT',A='ELM(TWOWAY),NOS'
    8 :  // EXEC LKED77,PRVLIB='J1446.DPOOL2'
    9 :  // EXEC GO
   10 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,10)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(50,10)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,10)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,10)),
   17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,10)),
   19 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   20 :  //FT10F001 DD DSN=J1615.ENDFB408.DATA,DISP=SHR,LABEL=(,,,IN)
   21 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   22 :  //SYSIN DD *
   23 :   TWOWAY SAMPLE PROBLEM NO.1
   24 :   &UNIT ULTX=91,INFX=91,SGXL=91 &END
   25 :  EGRP   100   20    1    0    0
   26 :   1276   10    8  8-O-16 ENDF/B-IV 300K
   27 :  ++
   28 :  //
   29 :   TWOWAY SAMPLE PROBLEM NO.2
   30 :   &UNIT ULTX=91,INFX=91,SGXL=91 &END
   31 :  EGRP   100   20    1    0    0
   32 :   1275   10    7  7-N-14 ENDF/B-IV 300K
   33 :  ++
   34 :  //
   35 :   TWOWAY SAMPLE PROBLEM NO.3
   36 :   &UNIT ULTX=91,INFX=91,SGXL=91 &END
   37 :  EGRP   100   20    1    0    0
   38 :   1192   10   26  26-FE  ENDF/B-IV 300K
   39 :  ++
   40 :  //
------------------------------------ END OF FILE ------------------------------------
```



```
                  *** START FOR PROCESSING OF ENDF/B FILE ***

     MATNO OF A PROCESSING MATERIAL IS    1276

     TITLE OF A FINE GROUP NEUTRON CROSS SECTION LIBRARY
                   ULTRA FINE GROUP CROSS SECTION LIBRARY
ENDF/B-IV TAPE 408 (REV. 3)                          1-SEPT-76    4


MF      THE FILE NUMBER                                  12
MT      THE REACTION TYPE NUMBER                        102
LO      THE OPTION FLAG TO DETERMINE WHETHER
        MULTIPLICITIES OR TRANSITION PROBABILITY          1
LG      THE TRANSION PROBABILITY ARRAY FLAG               0
NK      THE TOTAL NUMBER OF SUBSECTIONS                   4
GROUP AVERAGED X-SEC FOR MT = 102
        7.2627E-09   7.7560E-09   8.2568E-09   8.7344E-09   9.3065E-09   9.9006E-09   1.0585E-08   1.1203E-08
        1.1914E-08   1.2673E-08   1.3501E-08   1.4377E-08   1.5315E-08   1.6292E-08   1.7413E-08   1.8428E-08
        1.9600E-08   2.0864E-08   2.2196E-08   2.3668E-08   2.5163E-08   2.6827E-08   2.8535E-08   3.0425E-08
        3.2361E-08   3.4561E-08   3.6650E-08   3.9233E-08   4.1631E-08   4.4159E-08   4.6990E-08   5.0035E-08
        5.3313E-08   5.6698E-08   6.0405E-08   6.4326E-08   6.8412E-08   7.2979E-08   7.7524E-08   8.2758E-08
        8.7864E-08   9.3850E-08   9.9583E-08   1.0642E-07   1.1293E-07   1.2057E-07   1.2834E-07   1.3632E-07
        1.4583E-07   1.5439E-07   1.6410E-07   1.7464E-07   1.8585E-07   1.9796E-07   2.1079E-07   2.2422E-07
        2.4661E-07   2.7949E-07   3.1672E-07   3.5894E-07   4.0689E-07   4.6126E-07   5.2294E-07   5.9295E-07
        6.7220E-07   7.6184E-07   8.6321E-07   9.7819E-07   1.1098E-06   1.2516E-06   1.4181E-06   1.6072E-06
        1.8221E-06   2.0644E-06   2.3394E-06   2.6525E-06   3.0066E-06   3.4076E-06   3.8620E-06   4.3771E-06
        4.9614E-06   5.6240E-06   6.3755E-06   7.2276E-06   8.1932E-06   9.2871E-06   1.0526E-05   1.1931E-05
        1.3527E-05   1.5347E-05   1.7419E-05   1.9723E-05   2.2269E-05   2.5168E-05   2.8539E-05   3.2332E-05
        3.6655E-05   4.1550E-05   5.7418E-05   1.5766E-04


LIST OF PROCESSING DATA INFORMATION
MF      THE FILE NUMBER                                  13
MT      THE REACTION TYPE NUMBER                          4
NK      THE TOTAL NUMBER OF SUBSECTIONS                  13
GROUP AVERAGED X-SEC FOR MT =   4
        5.4555E-01   4.4086E-01   3.3726E-01   2.4982E-01   2.4753E-01   2.4352E-01   1.5860E-01   1.8109E-02
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0          0.0          0.0          0.0


LIST OF PROCESSING DATA INFORMATION
MF      THE FILE NUMBER                                  13
MT      THE REACTION TYPE NUMBER                         22
NK      THE TOTAL NUMBER OF SUBSECTIONS                   1
**** CAUTION !! NOT FOUND REACTION TYPE MT = 22
```

```
      1    2    4   51   52   53   54   55   56   57   58   59   60   61   62   63   64   65   66   67
     68   69   70   71   72   73   74   75   76   77   78   79  102  103  104  107


LIST OF PROCESSING DATA INFORMATION
MF      THE FILE NUMBER                              13
MT      THE REACTION TYPE NUMBER                    103
NK      THE TOTAL NUMBER OF SUBSECTIONS               3
GROUP AVERAGED X-SEC FOR MT = 103
        3.5409E-02    4.1278E-02    4.2855E-02    3.0575E-03    0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0


LIST OF PROCESSING DATA INFORMATION
MF      THE FILE NUMBER                              13
MT      THE REACTION TYPE NUMBER                    107
NK      THE TOTAL NUMBER OF SUBSECTIONS               6
GROUP AVERAGED X-SEC FOR MT = 107
        9.3407E-02    1.2911E-01    1.6020E-01    1.8721E-01    1.4488E-01    8.2010E-02    8.6040E-02    8.1570E-02
        2.7418E-02    9.0000E-02    8.3352E-02    3.5402E-02    1.7130E-03    1.1135E-04    1.3381E-08    1.7504E-11
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
        0.0           0.0           0.0           0.0

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.        =     91
    DATA SET NAME           = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS  =      1
    REMAINS RECORDS         =  10895

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.        =     91
    DATA SET NAME           = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS  =      1
    REMAINS RECORDS         =  10894

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.        =     91
    DATA SET NAME           = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS  =      3
    REMAINS RECORDS         =  10891




*** THIS SECONDARY GAMMA-RAY DATA IS WRITTEN ON A DATA POOL.

TITLE    MAT=1276 O-16 PROCESS FROM ENDF/B-IV AT 300K (TAPE 408)

MATNO   IDENTIFICATION CODE OF ELEMENT                1276
MT      REACTION TYPE CODE                             102
ITWO    SECTION OF THE SECONDARY GAMMA-RAY               1
ICON    WEIGHTING OPTION FOR ENERGY SPECTRA              0
KEY                                                      0

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.        =     91
    DATA SET NAME           = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS  =      1
    REMAINS RECORDS         =  10890
```

*** YEILDS FOR REACTION ***

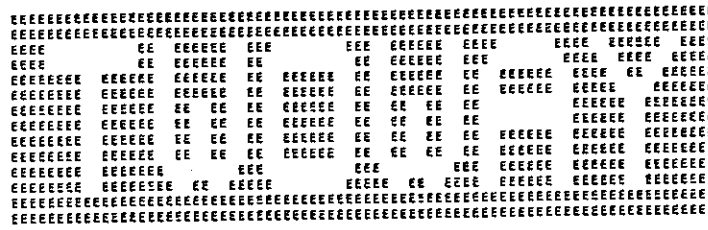
MF=	12	13	13	13
ING	MT 102	MT 4	MT 103	MT 107
1	2.85400E+00	6.62378E-01	7.57014E-01	9.47093E-01
2	2.85400E+00	8.92740E-01	7.94193E-01	9.20116E-01
3	2.85400E+00	1.24234E+00	8.25519E-01	9.36409E-01
4	2.85400E+00	1.29752E+00	8.91597E-01	9.44909E-01
5	2.85400E+00	1.20412E+00	0.0	7.70337E-01
6	2.85400E+00	1.25003E+00	0.0	5.62152E-01
7	2.85400E+00	1.51618E+00	0.0	1.02239E-01
8	2.85400E+00	1.58566E+00	0.0	1.26018E-02
9	2.85400E+00	0.0	0.0	1.15153E-03
10	2.85400E+00	0.0	0.0	0.0
11	2.85400E+00	0.0	0.0	0.0
12	2.85400E+00	0.0	0.0	0.0
13	2.85400E+00	0.0	0.0	0.0
14	2.85400E+00	0.0	0.0	0.0
15	2.85400E+00	0.0	0.0	0.0
16	2.85400E+00	0.0	0.0	0.0
17	2.85400E+00	0.0	0.0	0.0
18	2.85400E+00	0.0	0.0	0.0
19	2.85400E+00	0.0	0.0	0.0
20	2.85400E+00	0.0	0.0	0.0
21	2.85400E+00	0.0	0.0	0.0
22	2.85400E+00	0.0	0.0	0.0
23	2.85400E+00	0.0	0.0	0.0
24	2.85400E+00	0.0	0.0	0.0
25	2.85400E+00	0.0	0.0	0.0
26	2.85400E+00	0.0	0.0	0.0
27	2.85400E+00	0.0	0.0	0.0
28	2.85400E+00	0.0	0.0	0.0
29	2.85400E+00	0.0	0.0	0.0
30	2.85400E+00	0.0	0.0	0.0
31	2.85400E+00	0.0	0.0	0.0
32	2.85400E+00	0.0	0.0	0.0
33	2.85400E+00	0.0	0.0	0.0
34	2.85400E+00	0.0	0.0	0.0
35	2.85400E+00	0.0	0.0	0.0
36	2.85400E+00	0.0	0.0	0.0
37	2.85400E+00	0.0	0.0	0.0
38	2.85400E+00	0.0	0.0	0.0
39	2.85400E+00	0.0	0.0	0.0
40	2.85400E+00	0.0	0.0	0.0
41	2.85400E+00	0.0	0.0	0.0
42	2.85400E+00	0.0	0.0	0.0
43	2.85400E+00	0.0	0.0	0.0
44	2.85400E+00	0.0	0.0	0.0
45	2.85400E+00	0.0	0.0	0.0
46	2.85400E+00	0.0	0.0	0.0
47	2.85400E+00	0.0	0.0	0.0
48	2.85400E+00	0.0	0.0	0.0
49	2.85400E+00	0.0	0.0	0.0
50	2.85400E+00	0.0	0.0	0.0
51	2.85400E+00	0.0	0.0	0.0
52	2.85400E+00	0.0	0.0	0.0
53	2.85400E+00	0.0	0.0	0.0
54	2.85400E+00	0.0	0.0	0.0
55	2.85400E+00	0.0	0.0	0.0

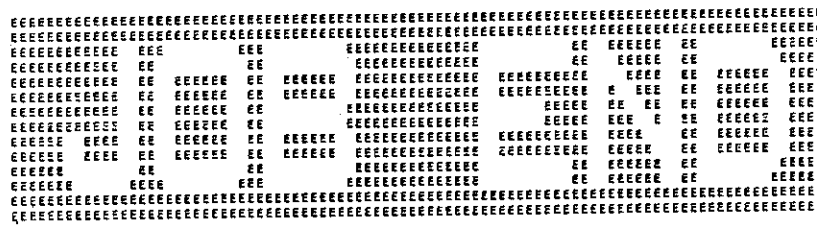
*** PROBABILITY FOR MF= 13 MT= 4 ***

N GP	G GP 1	G GP 2	G GP 3	G GP 4	G GP 5	G GP 6	G GP 7	G GP 8
1	0.0	0.0	1.01591E-02	2.21996E-01	3.26173E-01	7.28024E-02	1.68877E-02	1.07236E-01
2	0.0	0.0	1.06792E-02	2.49143E-01	3.23925E-01	3.28546E-02	9.97456E-03	1.12725E-01
3	0.0	0.0	8.52403E-03	2.00711E-01	2.98234E-01	2.00087E-03	8.27006E-04	8.99758E-02
4	0.0	0.0	6.78101E-03	2.64746E-01	3.34876E-01	0.0	0.0	7.15774E-02
5	0.0	0.0	4.08922E-04	2.14402E-01	4.50410E-01	0.0	0.0	4.31640E-03
6	0.0	0.0	0.0	1.46104E-01	4.55044E-01	0.0	0.0	0.0
7	0.0	0.0	0.0	1.15427E-02	3.07167E-01	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	2.66024E-01	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	N GP 10 THRU N GP 100 SAME AS ABOVE							

N GP	G GP 9	G GP 10	G GP 11	G GP 12	G GP 13	G GP 14	G GP 15	G GP 16
1	1.38673E-02	2.37048E-02	0.0	0.0	8.32053E-05	0.0	2.07090E-01	0.0
2	6.25801E-03	2.49180E-02	0.0	0.0	9.07493E-05	0.0	2.29432E-01	0.0
3	3.81116E-04	1.98894E-02	0.0	0.0	7.59059E-05	0.0	3.79381E-01	0.0
4	0.0	1.58223E-02	0.0	0.0	1.10259E-04	0.0	3.06087E-01	0.0
5	0.0	9.54154E-04	0.0	0.0	7.56008E-05	0.0	3.29433E-01	0.0
6	0.0	0.0	0.0	0.0	4.23036E-05	0.0	3.98810E-01	0.0
7	0.0	0.0	0.0	0.0	2.45067E-06	0.0	6.81288E-01	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	7.33977E-01	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	N GP 10 THRU N GP 100 SAME AS ABOVE							

N GP	G GP 17	G GP 18	G GP 19	G GP 20
1	0.0	0.0	0.0	0.0
	N GP 2 THRU N GP 100 SAME AS ABOVE			





D.5 Sample Problem for DIAC

```
MEMBER NAME > B:DIACT.TXT      ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.6 I.5 P.0 W.2 C.5 SRP
    6 :   OPTP PASSWORD=########
    7 :  //DIAC EXEC LMGO,LM='J1446.DIACX',OBSIZE=137,ORECFM=FA
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(300,100)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(300,100)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(300,100)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(300,100)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT12F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(300,100)),
   17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT20F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(300,100)),
   19 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   20 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   21 :  //SYSIN DD *
   22 :  DIAC SAMPLE PROBLEM NO.1    (IRON-AIR) CONFIGULATION
   23 :   &UNIT  FXSN=91,FLX1=91,FLX2=0 &END
   24 :  14** 100 20  0  0  0  0  1  0  0  0  0
   25 :  15** 777  0  16  16  3  1  0  2  19  0  120  3  4  123  0  0  2  2  0
   26 :        0  0   1   2  80  0  1  0  0  1  2  0  0  0  1  1  0
   27 :  16**  1.0  0.1  1.0-4  1.420892  3R0.0  1.0  0.0  0.5  2.0-4  3R0.0 T
   28 :   6**  0.0 0.0244936 0.0413296 0.0392569 0.0400796 0.0643754
   29 :            0.0442079 0.109085  0.1371702  1N8
   30 :   7**  -0.9902984 -0.9805009 -0.9092855 -0.8319966 -0.7467506
   31 :        -0.6504264 -0.5370966 -0.3922893 -0.1389568 1M8  T
   32 :  13**  4HEGRP  4HFX16  4HIRON  4HAIR0  T
   33 :  18**  9R0.0  8R1.8345E-4  9R0.0  8R1.0055E-3 9R0.0  8R1.7562E-3
   34 :        9R0.0  8R3.3073E-3  9R0.0  8R6.3987E-3 9R0.0  8R7.7603E-3
   35 :        9R0.0  8R1.0485E-2  9R0.0  8R2.7372E-2 9R0.0  8R2.4542E-2
   36 :        9R0.0  8R2.3317E-2  9R0.0  8R5.6820E-2 9R0.0  8R4.6661E-2
   37 :        9R0.0  8R5.2674E-2  9R0.0  8R5.5554E-2 9R0.0  8R3.8945E-2
   38 :        9R0.0  8R7.5470E-2  9R0.0  8R5.7153E-2 9R0.0  8R5.4869E-2
   39 :        9R0.0  8R5.1871E-2  9R0.0  8R4.8635E-2 9R0.0  8R4.4425E-2
   40 :        9R0.0  8R4.0553E-2  9R0.0  8R3.6464E-2 9R0.0  8R3.2480E-2
   41 :        9R0.0  8R2.8699E-2  9R0.0  8R2.5156E-2 9R0.0  8R2.1921E-2
   42 :        9R0.0  8R1.9004E-2  9R0.0  8R1.6328E-2 9R0.0  8R1.4017E-2
   43 :        9R0.0  8R1.1989E-2  9R0.0  8R1.0221E-2 9R0.0  8R8.6337E-3
   44 :        9R0.0  8R7.3178E-3  9R0.0  8R6.1910E-3 9R0.0  8R5.2226E-3
   45 :        9R0.0  8R4.3684E-3  9R0.0  8R3.6735E-3 9R0.0  8R3.0848E-3
   46 :        9R0.0  8R5.1313E-3  9R0.0  8R1.6934E-3 9R0.0  8R1.4946E-3
   47 :        9R0.0  8R1.1771E-3  9R0.0  8R1.0389E-3 F0.0         T
   48 :   3**  F0.0  T
   49 :   1**  F0.0
   50 :   4**  0.0 0.4 610.88 218.38 11.38 13.38 18.38 28.38 48.38 78.38 108.3
   51 :      158.75
   52 :   5** F1.0
   53 :   8**  2R1  7R1  10R2
   54 :   9**  1     2     T
   55 :  ++
   56 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
DIAC SAMPLE PROBLEM NO.1   (IRON-AIR) CONFIGULAT

  14¥ ARRAY     11 ENTRIES READ

  15¥ ARRAY     36 ENTRIES READ

  16¥ ARRAY     14 ENTRIES READ

    T

13590 LOCATIONS WILL BE USED FOR THIS PROBLEM

   6¥ ARRAY     17 ENTRIES READ

   7¥ ARRAY     17 ENTRIES READ

    T

  13¥ ARRAY      4 ENTRIES READ

    T

 9429 LOCATIONS WILL BE USED TO READ X-SEC.

ANGULAR CROSS SECTION LIBRARY IS USED ---  ANGULAR MESH
IGMN=100 IGMG= 20 IHM=123 ISCT= 16 MTP=  2
ANGULAR MESH BOUNDARY
-1.0000E+00 -9.7285E-01 -9.1059E-01 -8.1544E-01 -6.9081E-01 -5.4121E-01 -3.7205E-01 -1.8945E-01  0.0          1.8945E-01
3.7205E-01  5.4121E-01  6.9081E-01  8.1544E-01  9.1059E-01  9.7285E-01  1.0000E+00
MATERIAL ID. NUMBER
      IRON         AIRO

  18¥ ARRAY   2040 ENTRIES READ

    T

   3¥ ARRAY     19 ENTRIES READ

    T

   1¥ ARRAY    120 ENTRIES READ

   4¥ ARRAY     20 ENTRIES READ

   5¥ ARRAY    120 ENTRIES READ

   8¥ ARRAY     19 ENTRIES READ

   9¥ ARRAY      2 ENTRIES READ

    T
```

```
    D I A C  CONTROL  OPTION
  ING     NO. OF NEUTRON   ENERGY GROUP                    100
  IGG     NO. OF GAMMA-RAY ENERGY GROUP                    20
  NREACT  0/1/2/3= REACTION RATE NO/CARD/TAPE/DATA POOL     0
  NNELM   NO. OF NEUTRON RESPONSE                           0
  NGELM   NO. OF GAMMA-RAY RESPONSE                         0
  IIANLL  0/1=PRINT ANGULAR FLUX ALL/INPUT                  0
  IIBOUD  0/1=PRINT TOTAL FLUX AT MID./BOUND.               1
  IISPTM  0/1/2=PRINT SPECTRUM NO/DELTA E/DELTA U           0
  NACTPR  0/1=PRINT ACTIVITY NORMAL/DETAIL                  0
  NRESAT  0/1=USE RESTART OPTION NO/YES                     0
  NPLOT   0/1=OUTPUT PLOT DATA NO/YES                       0

  ID    PROBLEM ID NO.                  777      ITH   0/1 = REG./ADJ.                    0
  ISCT  NO. OF ANGULAR MESH              16      ISN   QUADRATURE ORDER                  16
  IGE   1/2/3 = PLA/CYL/SPH               3      IBL   0/1/2/3 = NO REFL/REFL/PER/WHITE   1
  IBR   RT. B.C. SAME AS LEFT B.C./IBL    0      IIM   NO. OF ZONES                       2
  IM    NO. OF INTERVALS                 19      IEVT  0/1/2/3/4/5/6=Q/K/ALPHA/C/I/R/H    0
  IGM   NO. OF GROUPS                   120      IHT   POS. OF SIGMA T                    3
  IHS   POS. OF SIGMA GG                  4      IHM   TABLE LENGTH                     123
  MS    NOT USED                          0      MCR   NOT USED                           0
  MTP   NO. MATLS. FROM L1B TAPE          2      MT    NO. OF MATLS.                      2
  IDFM  0/1=NONE/DENSITY FACTORS(21*)     0      IPVT  0/1/2=NONE/K/ALPHA                 0
  IQM   0/1=NONE/DIST. SOURCE             0      IPM   0/1/IM=NONE/S(MM,IPP)/S(MM,1M)    1
  IPP   INTERVAL OF SHELL SOURCE          2      IIM   INNER ITER. MAX.                  80
  ID1   0/1/2/3=NO/PRNT NO/PNCH N/BOTH    0      ID2   NOT USED                           1
  ID3   0/N=NO/N ACT. BY ZONE             0      ID4   0/1=NO/N ACT. BY INT.              0
  ICM   OUTER ITER. MAX.                  1      IDAT1 0/1/2=NO/MIN/MAX TAPE              2
  IDAT2 0/1=NO/DIFFUSION(24*)             0      IFG   0/1=NO/FEW GRP.                    0
  IFLU  0/1/2=BOTH/LINEAR/STEP            0      IFN   0/1/2=INPUT 2*/3*/PREV. CASE       1
  IPRT  0/1 = PRINT X-SEC/DO NOT          1      IXTR  0/1=CALC/READ P-L CONSTANTS        0

  EV    EIGENVALUE GUESS          1.00000E+00    EVM   EIGENVALUE MODIFIER       1.00000E-01
  EPS   PRECISION DESIRED         9.99998E-05    BF    BUCKLING FACTOR           1.42089E+00
  DY    CYL OR PLA HEIGHT         0.0            DZ    PLANE DEPTH               0.0
  DFM1  MT. FOR VOID CONR.        0.0            XNF   NORM. FACTOR              1.00000E+00
  PV    IPVT*1/2 - K/ALPHA  *     0.0            RYF   LAMBDA2 RELAXATION        5.00000E-01
  XLAL  PT CNVRG EPS. IF .NE.0    2.00000E-04    XLAH  1-LAMBDA MAX.-SEARCH      0.0
  EQL   EV CHANGE EPS.-SEARCH     0.0            XNPM  NEW PARAM. MOD.-SEARCH    0.0
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 OUTER INNER      NEUT BAL     UPSCATTER RATIO     EIGENVALUE          LAMBDA1          LAMBDA2
     0     0   0.0                 0.0                9.9999964E-01   0.0                   0.0
 GRP.   1 REQUIRED    7 ITERATIONS. MFD OF  7.59057E-05 OCCURRED IN INT.    3
 GRP.   2 REQUIRED    7 ITERATIONS. MFD OF  5.87252E-05 OCCURRED IN INT.    3
 GRP.   3 REQUIRED    7 ITERATIONS. MFD OF  4.74877E-05 OCCURRED IN INT.    4
 GRP.   4 REQUIRED    7 ITERATIONS. MFD OF  7.66395E-05 OCCURRED IN INT.    4
 GRP.   5 REQUIRED    7 ITERATIONS. MFD OF  1.02104E-04 OCCURRED IN INT.    4
 GRP.   6 REQUIRED    7 ITERATIONS. MFD OF  9.09285E-05 OCCURRED IN INT.    4
 GRP.   7 REQUIRED    7 ITERATIONS. MFD OF  1.22738E-04 OCCURRED IN INT.    4
 GRP.   8 REQUIRED    8 ITERATIONS. MFD OF  6.55437E-05 OCCURRED IN INT.    3
 GRP.   9 REQUIRED    8 ITERATIONS. MFD OF  5.40818E-05 OCCURRED IN INT.    3
 GRP.  10 REQUIRED    7 ITERATIONS. MFD OF  9.19305E-05 OCCURRED IN INT.    4
 GRP.  11 REQUIRED    8 ITERATIONS. MFD OF  7.18021E-05 OCCURRED IN INT.    3
 GRP.  12 REQUIRED    7 ITERATIONS. MFD OF  9.54342E-05 OCCURRED IN INT.    4
 GRP.  13 REQUIRED    8 ITERATIONS. MFD OF  3.84516E-05 OCCURRED IN INT.    3
 GRP.  14 REQUIRED    9 ITERATIONS. MFD OF  4.02918E-05 OCCURRED IN INT.    1
 GRP.  15 REQUIRED    8 ITERATIONS. MFD OF  4.48233E-05 OCCURRED IN INT.    3
 GRP.  16 REQUIRED    7 ITERATIONS. MFD OF  9.88859E-05 OCCURRED IN INT.    5
 GRP.  17 REQUIRED    7 ITERATIONS. MFD OF  8.70494E-05 OCCURRED IN INT.   15
 GRP.  18 REQUIRED    7 ITERATIONS. MFD OF  6.50802E-05 OCCURRED IN INT.    5
 GRP.  19 REQUIRED    7 ITERATIONS. MFD OF  8.36779E-05 OCCURRED IN INT.   15
 GRP.  20 REQUIRED    7 ITERATIONS. MFD OF  4.25552E-05 OCCURRED IN INT.   15
 GRP.  21 REQUIRED    7 ITERATIONS. MFD OF  5.69783E-05 OCCURRED IN INT.   16
 GRP.  22 REQUIRED    6 ITERATIONS. MFD OF  6.97114E-05 OCCURRED IN INT.    2
 GRP.  23 REQUIRED    7 ITERATIONS. MFD OF  4.27661E-05 OCCURRED IN INT.    5
 GRP.  24 REQUIRED    8 ITERATIONS. MFD OF  3.46996E-05 OCCURRED IN INT.    3
 GRP.  25 REQUIRED    8 ITERATIONS. MFD OF  8.03316E-05 OCCURRED IN INT.    5
 GRP.  26 REQUIRED    7 ITERATIONS. MFD OF  4.39191E-05 OCCURRED IN INT.    5
 GRP.  27 REQUIRED    7 ITERATIONS. MFD OF  4.32357E-05 OCCURRED IN INT.    5
 GRP.  28 REQUIRED    8 ITERATIONS. MFD OF  3.78338E-05 OCCURRED IN INT.    6
 GRP.  29 REQUIRED    8 ITERATIONS. MFD OF  3.10877E-05 OCCURRED IN INT.    5
 GRP.  30 REQUIRED    9 ITERATIONS. MFD OF  5.10631E-05 OCCURRED IN INT.    1
 GRP.  31 REQUIRED    7 ITERATIONS. MFD OF  3.22598E-05 OCCURRED IN INT.    4
 GRP.  32 REQUIRED    7 ITERATIONS. MFD OF  5.16973E-05 OCCURRED IN INT.    5
 GRP.  33 REQUIRED    7 ITERATIONS. MFD OF  4.43167E-05 OCCURRED IN INT.    5
 GRP.  34 REQUIRED    7 ITERATIONS. MFD OF  9.71353E-05 OCCURRED IN INT.    5
 GRP.  35 REQUIRED    8 ITERATIONS. MFD OF  2.39673E-05 OCCURRED IN INT.    5
 GRP.  36 REQUIRED    8 ITERATIONS. MFD OF  8.87314E-05 OCCURRED IN INT.    1
 GRP.  37 REQUIRED    7 ITERATIONS. MFD OF  2.57984E-05 OCCURRED IN INT.    4
 GRP.  38 REQUIRED    7 ITERATIONS. MFD OF  9.60394E-05 OCCURRED IN INT.    1
 GRP.  39 REQUIRED    6 ITERATIONS. MFD OF  8.62452E-05 OCCURRED IN INT.    2
 GRP.  40 REQUIRED    7 ITERATIONS. MFD OF  8.36939E-05 OCCURRED IN INT.    5
 GRP.  41 REQUIRED    7 ITERATIONS. MFD OF  1.09886E-04 OCCURRED IN INT.    1
 GRP.  42 REQUIRED    8 ITERATIONS. MFD OF  9.41345E-05 OCCURRED IN INT.    1
 GRP.  43 REQUIRED    7 ITERATIONS. MFD OF  8.10265E-05 OCCURRED IN INT.    4
 GRP.  44 REQUIRED    8 ITERATIONS. MFD OF  8.46746E-05 OCCURRED IN INT.    5
 GRP.  45 REQUIRED    7 ITERATIONS. MFD OF  9.73599E-05 OCCURRED IN INT.   15
 GRP.  46 REQUIRED    7 ITERATIONS. MFD OF  1.45621E-04 OCCURRED IN INT.   15
 GRP.  47 REQUIRED    8 ITERATIONS. MFD OF  6.92747E-05 OCCURRED IN INT.   10
 GRP.  48 REQUIRED    7 ITERATIONS. MFD OF  1.63661E-04 OCCURRED IN INT.   16
 GRP.  49 REQUIRED    7 ITERATIONS. MFD OF  1.92955E-04 OCCURRED IN INT.    1
 GRP.  50 REQUIRED    7 ITERATIONS. MFD OF  1.19630E-04 OCCURRED IN INT.    1
 GRP.  51 REQUIRED    7 ITERATIONS. MFD OF  5.97024E-05 OCCURRED IN INT.   14
 GRP.  52 REQUIRED    7 ITERATIONS. MFD OF  7.42927E-05 OCCURRED IN INT.   16
 GRP.  53 REQUIRED    4 ITERATIONS. MFD OF  1.96791E-04 OCCURRED IN INT.    1
 GRP.  54 REQUIRED    5 ITERATIONS. MFD OF  9.72672E-05 OCCURRED IN INT.    6
 GRP.  55 REQUIRED    6 ITERATIONS. MFD OF  2.29465E-05 OCCURRED IN INT.    6
 GRP.  56 REQUIRED    6 ITERATIONS. MFD OF  5.81853E-05 OCCURRED IN INT.    6
 GRP.  57 REQUIRED    7 ITERATIONS. MFD OF  8.51958E-05 OCCURRED IN INT.    1
 GRP.  58 REQUIRED    8 ITERATIONS. MFD OF  1.37030E-04 OCCURRED IN INT.   10
 GRP.  59 REQUIRED    8 ITERATIONS. MFD OF  1.84536E-04 OCCURRED IN INT.   12
 GRP.  60 REQUIRED   10 ITERATIONS. MFD OF  7.28429E-05 OCCURRED IN INT.    1

 GRP.  61 REQUIRED    9 ITERATIONS. MFD OF  1.18028E-04 OCCURRED IN INT.    1
 GRP.  62 REQUIRED    9 ITERATIONS. MFD OF  1.73745E-04 OCCURRED IN INT.    1
 GRP.  63 REQUIRED    9 ITERATIONS. MFD OF  1.22183E-04 OCCURRED IN INT.    1
 GRP.  64 REQUIRED    9 ITERATIONS. MFD OF  1.48127E-04 OCCURRED IN INT.    1
 GRP.  65 REQUIRED    9 ITERATIONS. MFD OF  1.56842E-04 OCCURRED IN INT.    1
 GRP.  66 REQUIRED    9 ITERATIONS. MFD OF  1.50994E-04 OCCURRED IN INT.    1
 GRP.  67 REQUIRED    9 ITERATIONS. MFD OF  1.12931E-04 OCCURRED IN INT.    1
 GRP.  68 REQUIRED    9 ITERATIONS. MFD OF  1.25521E-04 OCCURRED IN INT.    1
 GRP.  69 REQUIRED    8 ITERATIONS. MFD OF  1.91275E-04 OCCURRED IN INT.    1
 GRP.  70 REQUIRED    8 ITERATIONS. MFD OF  1.67176E-04 OCCURRED IN INT.    1
 GRP.  71 REQUIRED    8 ITERATIONS. MFD OF  1.50999E-04 OCCURRED IN INT.    1
 GRP.  72 REQUIRED    8 ITERATIONS. MFD OF  1.40162E-04 OCCURRED IN INT.    1
 GRP.  73 REQUIRED    8 ITERATIONS. MFD OF  1.25476E-04 OCCURRED IN INT.    1
 GRP.  74 REQUIRED    8 ITERATIONS. MFD OF  1.19150E-04 OCCURRED IN INT.    1
 GRP.  75 REQUIRED    8 ITERATIONS. MFD OF  1.09176E-04 OCCURRED IN INT.    1
 GRP.  76 REQUIRED    7 ITERATIONS. MFD OF  1.89011E-04 OCCURRED IN INT.    1
 GRP.  77 REQUIRED    7 ITERATIONS. MFD OF  1.77922E-04 OCCURRED IN INT.    1
 GRP.  78 REQUIRED    7 ITERATIONS. MFD OF  1.71303E-04 OCCURRED IN INT.    1
 GRP.  79 REQUIRED    7 ITERATIONS. MFD OF  1.68246E-04 OCCURRED IN INT.    1
 GRP.  80 REQUIRED    7 ITERATIONS. MFD OF  1.65427E-04 OCCURRED IN INT.    1
 GRP.  81 REQUIRED    7 ITERATIONS. MFD OF  1.61658E-04 OCCURRED IN INT.    1
 GRP.  82 REQUIRED    7 ITERATIONS. MFD OF  1.57006E-04 OCCURRED IN INT.    1
 GRP.  83 REQUIRED    7 ITERATIONS. MFD OF  1.52382E-04 OCCURRED IN INT.    1
 GRP.  84 REQUIRED    7 ITERATIONS. MFD OF  1.49700E-04 OCCURRED IN INT.    1
 GRP.  85 REQUIRED    7 ITERATIONS. MFD OF  1.49110E-04 OCCURRED IN INT.    1
 GRP.  86 REQUIRED    7 ITERATIONS. MFD OF  1.47889E-04 OCCURRED IN INT.    1
 GRP.  87 REQUIRED    7 ITERATIONS. MFD OF  1.44970E-04 OCCURRED IN INT.    1
 GRP.  88 REQUIRED    7 ITERATIONS. MFD OF  1.46018E-04 OCCURRED IN INT.    1
 GRP.  89 REQUIRED    7 ITERATIONS. MFD OF  1.43966E-04 OCCURRED IN INT.    1
 GRP.  90 REQUIRED    7 ITERATIONS. MFD OF  1.44800E-04 OCCURRED IN INT.    1
 GRP.  91 REQUIRED    7 ITERATIONS. MFD OF  1.44177E-04 OCCURRED IN INT.    1
 GRP.  92 REQUIRED    7 ITERATIONS. MFD OF  1.45103E-04 OCCURRED IN INT.    1
 GRP.  93 REQUIRED    7 ITERATIONS. MFD OF  1.43016E-04 OCCURRED IN INT.    1
 GRP.  94 REQUIRED    7 ITERATIONS. MFD OF  1.40838E-04 OCCURRED IN INT.    1
 GRP.  95 REQUIRED    7 ITERATIONS. MFD OF  1.41547E-04 OCCURRED IN INT.    1
 GRP.  96 REQUIRED    7 ITERATIONS. MFD OF  1.31964E-04 OCCURRED IN INT.    1
 GRP.  97 REQUIRED    7 ITERATIONS. MFD OF  1.31063E-04 OCCURRED IN INT.    1
 GRP.  98 REQUIRED    7 ITERATIONS. MFD OF  1.31570E-04 OCCURRED IN INT.    1
 GRP.  99 REQUIRED    8 ITERATIONS. MFD OF  1.99658E-04 OCCURRED IN INT.    1
 GRP. 100 REQUIRED    7 ITERATIONS. MFD OF  1.44479E-04 OCCURRED IN INT.    5
 GRP. 101 REQUIRED    1 ITERATIONS. MFD OF  0.0          OCCURRED IN INT.   19
 GRP. 102 REQUIRED    3 ITERATIONS. MFD OF  7.20829E-05 OCCURRED IN INT.   16
 GRP. 103 REQUIRED    3 ITERATIONS. MFD OF  1.19683E-04 OCCURRED IN INT.   15
 GRP. 104 REQUIRED    3 ITERATIONS. MFD OF  1.66759E-04 OCCURRED IN INT.   15
 GRP. 105 REQUIRED    4 ITERATIONS. MFD OF  1.04433E-05 OCCURRED IN INT.   19
 GRP. 106 REQUIRED    4 ITERATIONS. MFD OF  4.51579E-06 OCCURRED IN INT.    1
 GRP. 107 REQUIRED    4 ITERATIONS. MFD OF  2.06806E-05 OCCURRED IN INT.    1
 GRP. 108 REQUIRED    4 ITERATIONS. MFD OF  8.12493E-06 OCCURRED IN INT.    9
 GRP. 109 REQUIRED    4 ITERATIONS. MFD OF  2.85895E-05 OCCURRED IN INT.    1
 GRP. 110 REQUIRED    4 ITERATIONS. MFD OF  2.82809E-05 OCCURRED IN INT.    1
 GRP. 111 REQUIRED    4 ITERATIONS. MFD OF  4.93519E-05 OCCURRED IN INT.    1
 GRP. 112 REQUIRED    5 ITERATIONS. MFD OF  2.01744E-05 OCCURRED IN INT.    1
 GRP. 113 REQUIRED    5 ITERATIONS. MFD OF  1.72778E-05 OCCURRED IN INT.   16
 GRP. 114 REQUIRED    5 ITERATIONS. MFD OF  3.43893E-05 OCCURRED IN INT.    1
 GRP. 115 REQUIRED    6 ITERATIONS. MFD OF  2.96208E-05 OCCURRED IN INT.    1
 GRP. 116 REQUIRED    6 ITERATIONS. MFD OF  2.38015E-05 OCCURRED IN INT.    2
 GRP. 117 REQUIRED    7 ITERATIONS. MFD OF  5.93455E-05 OCCURRED IN INT.   10
 GRP. 118 REQUIRED    7 ITERATIONS. MFD OF  5.67205E-05 OCCURRED IN INT.   10
 GRP. 119 REQUIRED    5 ITERATIONS. MFD OF  2.38883E-05 OCCURRED IN INT.   10
 GRP. 120 REQUIRED    4 ITERATIONS. MFD OF  1.62141E-05 OCCURRED IN INT.   12                    ANG. FLX ON  1
    1   826   9.9988806E-01   0.0              9.9999964E-01   1.0000000E+00   0.0
    1   826   9.9988806E-01   0.0              9.9999964E-01   1.0000000E+00   0.0              FINAL MONITOR
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****** OUTER ITERATION LIMIT REACHED

ELAPSED TIME    1.87 MIN.

*** SCALAR FLUX WAS OUTPUT TO A DATA POOL
    NODE NAME = EGRP- 777-SFXO

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.        =     91
    DATA SET NAME           = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS  =      4
    REMAINS RECORDS         =   9582
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DIAC SAMPLE PROBLEM NO.1 (IRON-AIR) CONFIGULAT

INT.	ZONE NUMBER	RADIUS	INT. MIDPOINT	AREA	VOLUME	FISSION DENS
1	1	0.0	2.00000E-01	0.0	2.68082E-01	0.0
2	1	4.00000E-01	6.39999E-01	2.01062E+00	2.58645E+00	0.0
3	1	8.79999E-01	1.41571E+00	9.73139E+00	2.82730E+01	0.0
4	1	1.95143E+00	2.48714E+00	4.78536E+01	8.45742E+01	0.0
5	1	3.02285E+00	3.55857E+00	1.14827E+02	1.71787E+02	0.0
6	1	4.09428E+00	4.62999E+00	2.10652E+02	2.89912E+02	0.0
7	1	5.16571E+00	5.70142E+00	3.35328E+02	4.38950E+02	0.0
8	1	6.23714E+00	6.77285E+00	4.88855E+02	6.18899E+02	0.0
9	1	7.30856E+00	7.84428E+00	6.71234E+02	8.29764E+02	0.0
10	2	8.37999E+00	8.87999E+00	8.82465E+02	9.91958E+02	0.0
11	2	9.37999E+00	9.87999E+00	1.10564E+03	1.22770E+03	0.0
12	2	1.03800E+01	1.08800E+01	1.35395E+03	1.48858E+03	0.0
13	2	1.13800E+01	1.23800E+01	1.62740E+03	3.86033E+03	0.0
14	2	1.33800E+01	1.58800E+01	2.24968E+03	1.59754E+04	0.0
15	2	1.83800E+01	2.33800E+01	4.24521E+03	6.97378E+04	0.0
16	2	2.83800E+01	3.83800E+01	1.01212E+04	3.78588E+05	0.0
17	2	4.83800E+01	6.33799E+01	2.94131E+04	1.54265E+06	0.0
18	2	7.83799E+01	9.33400E+01	7.72004E+04	3.30377E+06	0.0
19	2	1.08300E+02	1.33525E+02	1.47389E+05	1.14375E+07	0.0
20		1.58750E+02		3.16692E+05		

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DIAC SAMPLE PROBLEM NO.1   (IRON-AIR) CONFIGULAT

TOTAL FLUX(BY MESH POINTS,NOT MIDPOINTS)

INT.   GRP.  1      GRP.  2      GRP.  3      GRP.  4      GRP.  5      GRP.  6      GRP.  7      GRP.  8
   1  1.45868E-08  1.96491E-07  4.97353E-07  1.38893E-06  4.10309E-06  6.61103E-06  1.01299E-05  1.77366E-05
   2  1.89718E-08  2.03026E-07  6.19386E-07  1.53947E-06  2.86097E-06  4.68070E-06  7.13384E-06  1.94664E-05
   3  3.76801E-05  2.06693E-04  3.61270E-04  6.80651E-04  1.31780E-03  1.59991E-03  2.16333E-03  5.64234E-03
   4  4.69684E-06  2.58670E-05  4.53575E-05  8.53416E-05  1.65324E-04  2.01818E-04  2.73432E-04  7.08085E-04
   5  1.51836E-06  8.39315E-06  1.47538E-05  2.76712E-05  5.35833E-05  6.57524E-05  8.91892E-05  2.28937E-04
   6  6.89552E-07  3.82202E-06  6.72837E-06  1.25726E-05  2.43203E-05  2.99592E-05  4.06418E-05  1.03434E-04
   7  3.68493E-07  2.04648E-06  3.60527E-06  6.70883E-06  1.29572E-05  1.60103E-05  2.17056E-05  5.47761E-05
   8  2.14348E-07  1.19166E-06  2.09907E-06  3.88818E-06  7.49395E-06  9.28133E-06  1.25630E-05  3.14209E-05
   9  1.31199E-07  7.27825E-07  1.27841E-06  2.35500E-06  4.51983E-06  5.58602E-06  7.51438E-06  1.86008E-05
  10  8.52117E-08  4.70967E-07  8.23582E-07  1.51154E-06  2.89196E-06  3.56460E-06  4.76427E-06  1.16873E-05
  11  6.69847E-08  3.69340E-07  6.44713E-07  1.18275E-06  2.25934E-06  2.77448E-06  3.69543E-06  9.05781E-06
  12  5.42110E-08  2.98511E-07  5.20535E-07  9.54563E-07  1.82164E-06  2.23230E-06  2.96755E-06  7.27036E-06
  13  4.48390E-08  2.46700E-07  4.29906E-07  7.88133E-07  1.50305E-06  1.83948E-06  2.44240E-06  5.98204E-06
  14  3.72039E-08  1.77010E-07  3.08220E-07  5.64820E-07  1.07631E-06  1.31523E-06  1.74389E-06  4.26977E-06
  15  1.70068E-08  9.30402E-08  1.61896E-07  2.96547E-07  5.64690E-07  6.89229E-07  9.12873E-07  2.23443E-06
  16  7.11050E-09  3.89304E-08  6.77363E-08  1.24073E-07  2.36237E-07  2.88249E-07  3.81646E-07  9.33951E-07
  17  2.43932E-09  1.33645E-08  2.32563E-08  4.26017E-08  8.11170E-08  9.89767E-08  1.31025E-07  3.20556E-07
  18  9.26548E-10  5.07885E-09  8.84043E-09  1.61959E-08  3.08426E-08  3.76399E-08  4.98244E-08  1.21869E-07
  19  4.84147E-10  2.65470E-09  4.62169E-09  8.46731E-09  1.61268E-08  1.96834E-08  2.60518E-08  6.37172E-08
  20  2.24546E-10  1.23160E-09  2.14507E-09  3.93088E-09  7.48667E-09  9.13832E-09  1.20926E-08  2.95780E-08

INT.   GRP.  9      GRP. 10      GRP. 11      GRP. 12      GRP. 13      GRP. 14      GRP. 15      GRP. 16
   1  3.60812E-05  4.62386E-05  9.02622E-05  1.40565E-04  2.04500E-04  3.06683E-04  3.66286E-04  5.51693E-04
   2  2.67593E-05  3.61448E-05  6.81377E-05  1.16328E-04  1.74760E-04  2.71185E-04  3.32054E-04  5.00699E-04
   3  5.08026E-03  4.84255E-03  1.17753E-02  9.74636E-03  1.10581E-02  1.17617E-02  8.41420E-03  1.61245E-02
   4  6.51416E-04  6.29233E-04  1.50953E-03  1.30171E-03  1.52390E-03  1.67960E-03  1.31703E-03  2.41458E-03
   5  2.15138E-04  2.10173E-04  4.97511E-04  4.45225E-04  5.38280E-04  6.11082E-04  5.16562E-04  9.21913E-04
   6  9.87497E-05  9.71661E-05  2.27543E-04  2.09395E-04  2.60058E-04  3.02737E-04  2.70508E-04  4.76494E-04
   7  5.30335E-05  5.24742E-05  1.21747E-04  1.12812E-04  1.43627E-04  1.56179E-04  1.44655E-04  2.54999E-04
   8  2.92342E-05  2.88333E-05  6.64433E-05  6.20678E-05  8.03509E-05  9.66594E-05  9.21432E-05  1.61593E-04
   9  1.81284E-05  1.78609E-05  4.08084E-05  3.87535E-05  5.10306E-05  6.04223E-05  5.62320E-05  9.94476E-05
  10  1.12603E-05  1.09287E-05  2.49407E-05  2.33449E-05  3.09284E-05  3.60065E-05  3.39379E-05  6.06720E-05
  11  8.64735E-06  8.34207E-06  1.90913E-05  1.76801E-05  2.33074E-05  2.69349E-05  2.48806E-05  4.53585E-05
  12  6.91204E-06  6.64841E-06  1.52362E-05  1.40368E-05  1.84588E-05  2.12548E-05  1.95135E-05  3.57411E-05
  13  5.67381E-06  5.44813E-06  1.24953E-05  1.14769E-05  1.50708E-05  1.73198E-05  1.58674E-05  2.90858E-05
  14  4.03998E-06  3.87232E-06  8.88830E-06  8.13771E-06  1.06697E-05  1.22383E-05  1.12496E-05  2.05135E-05
  15  2.11113E-06  2.02116E-06  4.64115E-06  4.23980E-06  5.55361E-06  6.36366E-06  5.84275E-06  1.06520E-05
  16  8.81779E-07  8.43943E-07  1.93739E-06  1.76800E-06  2.31529E-06  2.65220E-06  2.43612E-06  4.43562E-06
  17  3.02627E-07  2.89726E-07  6.64390E-07  6.06036E-07  7.93821E-07  9.09612E-07  8.36044E-07  1.51982E-06
  18  1.15092E-07  1.10255E-07  2.52410E-07  2.30232E-07  3.01690E-07  3.45867E-07  3.18166E-07  5.77476E-07
  19  6.01036E-08  5.75880E-08  1.31903E-07  1.20128E-07  1.57401E-07  1.80470E-07  1.65993E-07  3.01168E-07
  20  2.79145E-08  2.67504E-08  6.11347E-08  5.57219E-08  7.29466E-08  8.36432E-08  7.69438E-08  1.39640E-07

INT.   GRP. 17      GRP. 18      GRP. 19      GRP. 20      GRP. 21      GRP. 22      GRP. 23      GRP. 24
   1  6.20683E-04  6.54157E-04  6.35623E-04  9.18964E-04  8.30590E-04  7.18101E-04  6.39220E-04  4.79854E-04
   2  5.71094E-04  6.10700E-04  5.90958E-04  8.67426E-04  7.85014E-04  6.78953E-04  6.02627E-04  4.47238E-04
   3  1.24331E-02  1.19893E-02  1.13531E-02  1.09737E-02  1.00153E-02  9.11119E-03  8.19772E-03  7.20832E-03
   4  1.99203E-03  1.97190E-03  1.87952E-03  2.02588E-03  1.86605E-03  1.70278E-03  1.56530E-03  1.32966E-03
   5  7.97109E-04  8.12885E-04  7.78917E-04  9.05128E-04  8.55816E-04  7.89160E-04  7.46978E-04  6.24021E-04
   6  4.24656E-04  4.44600E-04  4.27620E-04  5.16003E-04  4.44737E-04  4.15291E-04  4.07235E-04  3.39047E-04
   7  2.30043E-04  2.48232E-04  2.38814E-04  2.98280E-04  2.62720E-04  2.84153E-04  2.84743E-04  2.37643E-04
   8  1.47077E-04  1.61738E-04  1.55727E-04  1.99380E-04  1.98397E-04  1.88942E-04  1.84633E-04  1.55324E-04
   9  8.99965E-05  1.01070E-04  9.70088E-05  1.25485E-04  1.25300E-04  1.21242E-04  1.32981E-04  1.12997E-04
  10  5.35880E-05  6.12595E-05  5.81606E-05  7.55993E-05  7.71254E-05  7.61004E-05  8.39719E-05  7.25103E-05
  11  3.97103E-05  4.55360E-05  4.30612E-05  5.58009E-05  5.67762E-05  5.62240E-05  6.07625E-05  5.24654E-05
  12  3.11420E-05  3.57574E-05  3.37409E-05  4.36413E-05  4.43531E-05  4.40023E-05  4.71441E-05  4.07089E-05
  13  2.52689E-05  2.90330E-05  2.73590E-05  3.53428E-05  3.58949E-05  3.56502E-05  3.80321E-05  3.28376E-05


DIAC SAMPLE PROBLEM NO.1   (IRON-AIR) CONFIGULAT

SHELL SOURCE IN INTERVAL   2 - G=GROUP NO.   N=  0

ANGL   G=N+  1      G=N+  2      G=N+  3      G=N+  4      G=N+  5      G=N+  6      G=N+  7      G=N+  8
   1  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      ANGL    2 THRU ANGL    9 SAME AS ABOVE
  10  7.52817E-05  4.12623E-04  7.20686E-04  1.35721E-03  2.62581E-03  3.18457E-03  4.30269E-03  1.12326E-02
      ANGL   11 THRU ANGL   17 SAME AS ABOVE

SHELL SOURCE IN INTERVAL   2 - G=GROUP NO.   N=  8

ANGL   G=N+  1      G=N+  2      G=N+  3      G=N+  4      G=N+  5      G=N+  6      G=N+  7      G=N+  8
   1  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      ANGL    2 THRU ANGL    9 SAME AS ABOVE
  10  1.00712E-02  9.56852E-03  2.33170E-02  1.91481E-02  2.16156E-02  2.27975E-02  1.59817E-02  3.09704E-02
      ANGL   11 THRU ANGL   17 SAME AS ABOVE

SHELL SOURCE IN INTERVAL   2 - G=GROUP NO.   N= 16

ANGL   G=N+  1      G=N+  2      G=N+  3      G=N+  4      G=N+  5      G=N+  6      G=N+  7      G=N+  8
   1  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      ANGL    2 THRU ANGL    9 SAME AS ABOVE
  10  2.34537E-02  2.25164E-02  2.12861E-02  1.99582E-02  1.82305E-02  1.66416E-02  1.49636E-02  1.33287E-02
      ANGL   11 THRU ANGL   17 SAME AS ABOVE

SHELL SOURCE IN INTERVAL   2 - G=GROUP NO.   N= 24

ANGL   G=N+  1      G=N+  2      G=N+  3      G=N+  4      G=N+  5      G=N+  6      G=N+  7      G=N+  8
   1  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      ANGL    2 THRU ANGL    9 SAME AS ABOVE
  10  1.17771E-02  1.03232E-02  8.99564E-03  7.79860E-03  6.70046E-03  5.75211E-03  4.91988E-03  4.19435E-03
      ANGL   11 THRU ANGL   17 SAME AS ABOVE

SHELL SOURCE IN INTERVAL   2 - G=GROUP NO.   N= 32

ANGL   G=N+  1      G=N+  2      G=N+  3      G=N+  4      G=N+  5      G=N+  6      G=N+  7      G=N+  8
   1  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      ANGL    2 THRU ANGL    9 SAME AS ABOVE
  10  3.54298E-03  3.00298E-03  2.54058E-03  2.14318E-03  1.79264E-03  1.50748E-03  1.26590E-03  2.10571E-03
      ANGL   11 THRU ANGL   17 SAME AS ABOVE

SHELL SOURCE IN INTERVAL   2 - G=GROUP NO.   N= 40

ANGL   G=N+  1      G=N+  2      G=N+  3      G=N+  4      G=N+  5      G=N+  6      G=N+  7      G=N+  8
   1  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      ANGL    2 THRU ANGL    9 SAME AS ABOVE
  10  6.94915E-04  6.13334E-04  4.83042E-04  4.26330E-04  0.0          0.0          0.0          0.0
      ANGL   11 THRU ANGL   17 SAME AS ABOVE

SHELL SOURCE IN INTERVAL   2 - G=GROUP NO.   N= 48

ANGL   G=N+  1      G=N+  2      G=N+  3      G=N+  4      G=N+  5      G=N+  6      G=N+  7      G=N+  8
   1  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      ANGL    2 THRU ANGL   17 SAME AS ABOVE

SHELL SOURCE IN INTERVAL   2 - G=GROUP NO.   N= 56

ANGL   G=N+  1      G=N+  2      G=N+  3      G=N+  4      G=N+  5      G=N+  6      G=N+  7      G=N+  8
   1  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      ANGL    2 THRU ANGL   17 SAME AS ABOVE
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SUMMARY FOR ZONE 1 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 121

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	1.84361E-04	0.0	0.0	7.60808E-05	1.01100E-04	1.30876E-05	7.01893E-05	9.99957E-01
2	1.01049E-03	0.0	1.16465E-05	4.88200E-04	5.58786E-04	7.82846E-05	3.85155E-04	9.99958E-01
3	1.76492E-03	0.0	6.14755E-05	9.63459E-04	1.03154E-03	1.25324E-04	6.69685E-04	9.99959E-01
4	3.32372E-03	0.0	1.18003E-04	2.03373E-03	2.01857E-03	1.97156E-04	1.22627E-03	9.99961E-01
5	6.43047E-03	0.0	2.46075E-04	4.42804E-03	4.03162E-03	3.12090E-04	2.33336E-03	9.99961E-01
6	7.79884E-03	0.0	5.18507E-04	5.88245E-03	5.16441E-03	3.09958E-04	2.84357E-03	9.99964E-01
7	1.05371E-02	0.0	7.74970E-04	8.52266E-03	7.22603E-03	3.25661E-04	3.76112E-03	9.99965E-01
8	2.75079E-02	0.0	1.22395E-03	2.22849E-02	1.89142E-02	6.14588E-04	9.20516E-03	9.99964E-01
9	2.46639E-02	0.0	3.09965E-03	2.11549E-02	1.86704E-02	4.22026E-04	8.67299E-03	9.99967E-01
10	2.34328E-02	0.0	3.94582E-03	2.05560E-02	1.87986E-02	2.97304E-04	8.28440E-03	9.99970E-01
11	5.71022E-02	0.0	4.80539E-03	4.90735E-02	4.23302E-02	5.29316E-04	1.90519E-02	9.99969E-01
12	4.68927E-02	0.0	9.90136E-03	4.38054E-02	3.90738E-02	3.76710E-04	1.73466E-02	9.99973E-01
13	5.29356E-02	0.0	1.40891E-02	5.25518E-02	4.40059E-02	3.49360E-04	2.26733E-02	9.99972E-01
14	5.58299E-02	0.0	1.90198E-02	6.25954E-02	4.86548E-02	2.89666E-04	2.59098E-02	9.99970E-01
15	3.91384E-02	0.0	2.52927E-02	6.01689E-02	4.05148E-02	1.75978E-04	2.37431E-02	9.99979E-01
16	7.58447E-02	0.0	3.25323E-02	9.57204E-02	6.48483E-02	2.11466E-04	4.33231E-02	9.99973E-01
17	5.74368E-02	0.0	4.23963E-02	8.21828E-02	6.24124E-02	1.28232E-04	3.72968E-02	9.99979E-01
18	5.51415E-02	0.0	4.29737E-02	7.69317E-02	5.50998E-02	1.05014E-04	4.29147E-02	9.99978E-01
19	5.21286E-02	0.0	4.83315E-02	7.15387E-02	6.01031E-02	9.41432E-05	4.02670E-02	9.99980E-01
20	4.88765E-02	0.0	6.21757E-02	8.71148E-02	5.91327E-02	1.17540E-04	5.18058E-02	9.99983E-01
21	4.46456E-02	0.0	5.52127E-02	8.99091E-02	4.72465E-02	1.21328E-04	5.24941E-02	9.99982E-01
22	4.07544E-02	0.0	5.82665E-02	6.40216E-02	4.65825E-02	1.23339E-04	5.23168E-02	9.99981E-01
23	3.66451E-02	0.0	5.05963E-02	7.45834E-02	3.16745E-02	1.64498E-04	5.54057E-02	9.99981E-01
24	3.26413E-02	0.0	3.90524E-02	7.25127E-02	2.37406E-02	1.87358E-04	4.77688E-02	9.99979E-01
25	2.88415E-02	0.0	4.43791E-02	1.10755E-01	3.40421E-02	2.14684E-04	3.89657E-02	9.99987E-01
26	2.52809E-02	0.0	5.85006E-02	7.73100E-02	1.84231E-02	2.89073E-04	6.50718E-02	9.99986E-01
27	2.20299E-02	0.0	4.24677E-02	5.30503E-02	1.76852E-02	2.06033E-04	4.66085E-02	9.99983E-01
28	1.90984E-02	0.0	3.76429E-02	6.71418E-02	2.22178E-02	1.68211E-04	3.43568E-02	9.99987E-01
29	1.64091E-02	0.0	3.78955E-02	6.37206E-02	2.42388E-02	1.53827E-04	2.99133E-02	9.99988E-01
30	1.40866E-02	0.0	3.63327E-02	7.35124E-02	3.04679E-02	1.27366E-04	1.98247E-02	9.99992E-01
31	1.20485E-02	0.0	4.23274E-02	5.16360E-02	1.02299E-02	1.90227E-04	4.39573E-02	9.99986E-01
32	1.02717E-02	0.0	2.11642E-02	3.11403E-02	4.80393E-03	1.16071E-04	2.65170E-02	9.99983E-01
33	8.67657E-03	0.0	1.47493E-02	2.05365E-02	6.30344E-03	8.29166E-05	1.70403E-02	9.99983E-01
34	7.35414E-03	0.0	1.53068E-02	2.50837E-02	8.62228E-03	9.36111E-05	1.39456E-02	9.99987E-01
35	6.22174E-03	0.0	1.56666E-02	2.79185E-02	8.25643E-03	9.24012E-05	1.35400E-02	9.99989E-01
36	5.24853E-03	0.0	1.43105E-02	2.76845E-02	1.01125E-02	6.33994E-05	9.38344E-03	9.99992E-01
37	4.39009E-03	0.0	1.43699E-02	1.62461E-02	5.13656E-03	6.77073E-05	1.35561E-02	9.99988E-01
38	3.69174E-03	0.0	8.83348E-03	1.26237E-02	8.78582E-03	2.80690E-05	3.71153E-03	9.99992E-01
39	3.10012E-03	0.0	1.34914E-02	1.19019E-02	2.87171E-03	6.02476E-05	1.36601E-02	9.99986E-01
40	5.15678E-03	0.0	6.02699E-03	1.13394E-02	5.14007E-03	3.89876E-05	6.00510E-03	9.99983E-01
41	1.70181E-03	0.0	7.18006E-03	1.13318E-02	5.25701E-03	3.72618E-05	3.58771E-03	9.99995E-01
42	1.50202E-03	0.0	6.69109E-03	1.14050E-02	6.07222E-03	3.06049E-05	2.09035E-03	9.99996E-01
43	1.18295E-03	0.0	7.56711E-03	1.32399E-02	2.04373E-03	5.93592E-05	6.64705E-03	9.99995E-01
44	1.04406E-03	0.0	3.76766E-03	9.91775E-03	1.26863E-03	3.42531E-05	3.50891E-03	9.99992E-01
45	0.0	0.0	2.46391E-03	2.74404E-03	1.34988E-03	9.18915E-06	1.10483E-03	1.00000E+00
46	0.0	0.0	1.98267E-03	2.73956E-03	1.36099E-03	7.48416E-06	6.14179E-04	1.00000E+00
47	0.0	0.0	1.88473E-03	3.34846E-03	1.18465E-03	3.37994E-06	6.96681E-04	1.00000E+00
48	0.0	0.0	1.66490E-03	2.61505E-03	1.12871E-03	2.77493E-06	5.33403E-04	1.00000E+00
49	0.0	0.0	1.51062E-03	2.53661E-03	1.15020E-03	6.64597E-06	3.53768E-04	1.00000E+00
50	0.0	0.0	1.48442E-03	2.49374E-03	1.29332E-03	4.63099E-06	1.86463E-04	1.00000E+00
51	0.0	0.0	1.60155E-03	1.73283E-03	1.56463E-03	1.49827E-06	3.54225E-05	1.00000E+00
52	0.0	0.0	1.86607E-03	3.60001E-03	7.59151E-05	1.50953E-05	1.77505E-03	1.00000E+00
53	0.0	0.0	3.16938E-04	7.41096E-05	4.34521E-05	1.18272E-06	2.72303E-04	1.00000E+00
54	0.0	0.0	2.24562E-04	1.10520E-04	5.23675E-05	3.88255E-07	1.71785E-04	1.00000E+00
55	0.0	0.0	2.18719E-04	1.44525E-04	6.67513E-05	2.49145E-07	1.51719E-04	1.00000E+00
56	0.0	0.0	3.07069E-04	2.54178E-04	1.11575E-04	1.38414E-07	1.95356E-04	1.00000E+00
57	0.0	0.0	7.03405E-04	1.17048E-03	2.31127E-04	2.36589E-06	4.69911E-04	1.00000E+00
58	0.0	0.0	7.63594E-04	1.78286E-03	4.20398E-04	5.17867E-06	3.38020E-04	1.00000E+00
59	0.0	0.0	7.45015E-04	4.26687E-03	6.00494E-04	1.07330E-05	1.33774E-04	1.00001E+00
60	0.0	0.0	7.74988E-04	4.23779E-03	4.64469E-04	9.18741E-06	3.01320E-04	1.00001E+00
61	0.0	0.0	5.67661E-04	1.76861E-03	3.07257E-04	2.21195E-06	2.58188E-04	1.00000E+00
62	0.0	0.0	3.64542E-04	1.39178E-03	2.08819E-04	2.14342E-06	1.53577E-04	1.00000E+00
63	0.0	0.0	2.47051E-04	8.48357E-04	1.48067E-04	6.75448E-07	9.83050E-05	1.00001E+00
64	0.0	0.0	1.74189E-04	6.38564E-04	1.11065E-04	6.44100E-07	6.24776E-05	1.00001E+00
65	0.0	0.0	1.28866E-04	4.98608E-04	8.62156E-05	9.35294E-07	4.17135E-05	1.00001E+00
66	0.0	0.0	9.82865E-05	3.99602E-04	6.86664E-05	4.62848E-07	2.91563E-05	1.00000E+00
67	0.0	0.0	7.68946E-05	3.05150E-04	4.90474E-05	7.96780E-06	1.98786E-05	1.00000E+00
68	0.0	0.0	5.46644E-05	2.31514E-04	3.95652E-05	3.98732E-07	1.46999E-05	1.00001E+00
69	0.0	0.0	4.32670E-05	1.89305E-04	3.19809E-05	3.45458E-07	1.09405E-05	1.00000E+00
70	0.0	0.0	3.45676E-05	1.54111E-04	2.59825E-05	3.08812E-07	8.27603E-06	1.00000E+00
71	0.0	0.0	2.77709E-05	1.25827E-04	2.10908E-05	2.79542E-07	6.40036E-06	1.00000E+00
72	0.0	0.0	2.24236E-05	1.02680E-04	1.71552E-05	2.52696E-07	5.01547E-06	1.00000E+00
73	0.0	0.0	1.81498E-05	8.36222E-05	1.39496E-05	2.29709E-07	3.97028E-06	1.00001E+00
74	0.0	0.0	1.46571E-05	6.78735E-05	1.12799E-05	2.09294E-07	3.16768E-06	1.00001E+00
75	0.0	0.0	1.18438E-05	5.48266E-05	9.12488E-06	1.89487E-07	2.52931E-06	1.00001E+00
76	0.0	0.0	9.51899E-06	4.40402E-05	7.32376E-06	1.72622E-07	2.02246E-06	1.00001E+00
77	0.0	0.0	7.62768E-06	3.52237E-05	5.85508E-06	1.56369E-07	1.61613E-06	1.00001E+00
78	0.0	0.0	6.09166E-06	2.80544E-05	4.66288E-06	1.41013E-07	1.28768E-06	1.00001E+00
79	0.0	0.0	4.84718E-06	2.22539E-05	3.69870E-06	1.26548E-07	1.02185E-06	1.00001E+00
80	0.0	0.0	3.84232E-06	1.75782E-05	2.92163E-06	1.13357E-07	8.07295E-07	1.00000E+00
81	0.0	0.0	3.03344E-06	1.38245E-05	2.29751E-06	1.01009E-07	6.34874E-07	1.00001E+00
82	0.0	0.0	2.38482E-06	1.08220E-05	1.79859E-06	8.93684E-08	4.96827E-07	1.00000E+00
83	0.0	0.0	1.86650E-06	8.42868E-06	1.40075E-06	7.90216E-08	3.86711E-07	1.00000E+00
84	0.0	0.0	1.45371E-06	6.52192E-06	1.08542E-06	6.93846E-08	2.98888E-07	1.00000E+00
85	0.0	0.0	1.12512E-06	5.01640E-06	8.35140E-07	6.03878E-08	2.29581E-07	1.00001E+00
86	0.0	0.0	8.65794E-07	3.83468E-06	6.38193E-07	5.23832E-08	1.75205E-07	1.00001E+00
87	0.0	0.0	6.62298E-07	2.90606E-06	4.84838E-07	4.50022E-08	1.32448E-07	1.00001E+00
88	0.0	0.0	5.02427E-07	2.18845E-06	3.64518E-07	3.84035E-08	9.94982E-08	1.00001E+00
89	0.0	0.0	3.78857E-07	1.63502E-06	2.72287E-07	3.24614E-08	7.41042E-08	1.00000E+00
90	0.0	0.0	2.83524E-07	1.21033E-06	2.01586E-07	2.72881E-08	5.46457E-08	1.00001E+00
91	0.0	0.0	2.10331E-07	8.87554E-07	1.47838E-07	2.25969E-08	3.98941E-08	1.00001E+00
92	0.0	0.0	1.54654E-07	6.43890E-07	1.07263E-07	1.86036E-08	2.87860E-08	1.00000E+00
93	0.0	0.0	1.12575E-07	4.59787E-07	7.70932E-08	1.50742E-08	2.04066E-08	1.00001E+00
94	0.0	0.0	8.07462E-08	3.24161E-07	5.44224E-08	1.20485E-08	1.42742E-08	1.00001E+00
95	0.0	0.0	5.72457E-08	2.25774E-07	3.78930E-08	9.49975E-09	9.85224E-09	1.00001E+00
96	0.0	0.0	4.01479E-08	1.52643E-07	2.62892E-08	7.29266E-09	6.56571E-09	1.00000E+00
97	0.0	0.0	2.74120E-08	1.01120E-07	1.76463E-08	5.48251E-09	4.28288E-09	1.00000E+00
98	0.0	0.0	1.83962E-08	6.63658E-08	1.15676E-08	4.06267E-09	2.76573E-09	1.00000E+00
99	0.0	0.0	1.45691E-08	9.64000E-08	3.93658E-09	7.25192E-09	3.38037E-09	1.00001E+00
100	0.0	0.0	5.59828E-09	2.50494E-08	6.70930E-11	4.81335E-09	7.17788E-10	1.00000E+00
101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00000E+00
102	0.0	0.0	7.70030E-06	1.22124E-07	2.57983E-06	3.31633E-06	1.80415E-06	9.99999E-01
103	0.0	0.0	1.22454E-03	2.74247E-05	4.62211E-04	4.48146E-04	3.14272E-04	9.99965E-01
104	0.0	0.0	2.03104E-03	5.26671E-05	8.96038E-04	6.22771E-04	5.12285E-04	9.99987E-01
105	0.0	0.0	3.86682E-03	1.55274E-04	1.97043E-03	9.49051E-04	9.47358E-04	9.99997E-01
106	0.0	0.0	5.39150E-03	2.31403E-04	3.16220E-03	9.71441E-04	1.25903E-03	9.99892E-01
107	0.0	0.0	3.02212E-02	2.04870E-03	1.99813E-02	3.74533E-03	6.49520E-03	9.99991E-01
108	0.0	0.0	2.53658E-02	1.32899E-03	1.84772E-02	1.85701E-03	5.03261E-03	9.99980E-01
109	0.0	0.0	4.31482E-02	3.18594E-03	3.32614E-02	1.78895E-03	8.09820E-03	9.99996E-01
110	0.0	0.0	4.49851E-02	3.20705E-03	3.62972E-02	1.00214E-03	7.68610E-03	9.99996E-01
111	0.0	0.0	4.02955E-02	3.81312E-03	3.28919E-02	4.09530E-04	6.99480E-03	9.99991E-01
112	0.0	0.0	7.99310E-02	1.15828E-02	6.78357E-02	4.63973E-04	1.16319E-02	9.99996E-01
113	0.0	0.0	4.91856E-01	6.76939E-02	4.34475E-01	3.74608E-03	5.36430E-02	9.99992E-01
114	0.0	0.0	1.91301E-01	3.84105E-02	1.62896E-01	2.36455E-03	2.60436E-02	1.00000E+00
115	0.0	0.0	2.29305E-01	8.21695E-02	1.93090E-01	6.59120E-03	2.96238E-02	1.00000E+00
116	0.0	0.0	2.07521E-01	6.94455E-02	1.76799E-01	1.28488E-02	1.78736E-02	1.00000E+00
117	0.0	0.0	3.78071E-01	2.19581E-01	2.93234E-01	6.37283E-02	2.11083E-02	1.00000E+00
118	0.0	0.0	4.22756E-01	4.32990E-01	1.15826E-01	2.95331E-01	1.15982E-02	1.00000E+00
119	0.0	0.0	1.16388E-01	3.57482E-02	2.93560E-03	1.13138E-01	3.14222E-04	1.00000E+00
120	0.0	0.0	4.80264E-03	4.24678E-04	-2.32831E-09	4.79851E-03	4.16985E-06	9.99996E-01
121	1.00000E+00	0.0	3.30222E+00	2.80957E+00	2.58068E+00	5.22730E-01	1.19889E+00	9.99990E-01

GRP.	RT BDY FLUX	RT BDY J+	RT BDY J	RT LEAKAGE	LFT LEAKAGE	FISS RATE	TOTAL FLUX	DENSITY
1	8.52117E-08	7.95378E-08	7.95378E-08	7.01893E-05	0.0	0.0	9.18624E-04	9.18625E-04
2	4.70967E-07	4.36454E-07	4.36454E-07	3.85155E-04	0.0	0.0	5.08320E-03	5.08320E-03
3	8.23582E-07	7.58883E-07	7.58881E-07	6.69685E-04	0.0	0.0	8.93305E-03	8.93305E-03
4	1.51154E-06	1.38960E-06	1.38959E-06	1.22627E-03	0.0	0.0	1.66639E-02	1.66639E-02
5	2.89196E-06	2.64417E-06	2.64414E-06	2.33336E-03	0.0	0.0	3.21800E-02	3.21800E-02
6	3.56460E-06	3.22239E-06	3.22231E-06	2.84357E-03	0.0	0.0	3.95680E-02	3.95681E-02
7	4.76427E-06	4.26224E-06	4.26207E-06	3.76112E-03	0.0	0.0	5.35314E-02	5.35314E-02
8	1.16873E-05	1.04315E-05	1.04312E-05	9.20516E-03	0.0	0.0	1.35905E-01	1.35905E-01
9	1.12603E-05	9.82848E-06	9.82814E-06	8.67299E-03	0.0	0.0	1.29492E-01	1.29492E-01
10	1.09287E-05	9.38843E-06	9.38781E-06	8.28440E-03	0.0	0.0	1.26834E-01	1.26834E-01
11	2.49407E-05	2.15907E-05	2.15895E-05	1.90519E-02	0.0	0.0	2.97154E-01	2.97154E-01
12	2.33449E-05	1.96582E-05	1.96570E-05	1.73466E-02	0.0	0.0	2.72436E-01	2.72436E-01
13	3.09284E-05	2.56962E-05	2.56932E-05	2.26733E-02	0.0	0.0	3.38539E-01	3.38540E-01
14	3.60065E-05	2.93663E-05	2.93607E-05	2.59098E-02	0.0	0.0	3.92557E-01	3.92557E-01
15	3.39379E-05	2.69119E-05	2.69054E-05	2.37431E-02	0.0	0.0	3.48494E-01	3.48495E-01
16	6.06720E-05	4.90996E-05	4.90933E-05	4.33231E-02	0.0	0.0	6.19242E-01	6.19242E-01
17	5.35880E-05	4.22699E-05	4.22644E-05	3.72968E-02	0.0	0.0	5.46291E-01	5.46291E-01
18	6.12595E-05	4.86383E-05	4.86306E-05	4.29147E-02	0.0	0.0	5.78344E-01	5.78344E-01
19	5.81606E-05	4.56377E-05	4.56301E-05	4.02670E-02	0.0	0.0	5.54835E-01	5.54835E-01
20	7.55993E-05	5.87167E-05	5.87059E-05	5.18058E-02	0.0	0.0	6.78310E-01	6.78311E-01
21	7.71254E-05	5.94979E-05	5.94858E-05	5.24941E-02	0.0	0.0	6.59379E-01	6.59379E-01
22	7.61004E-05	5.92962E-05	5.92849E-05	5.23168E-02	0.0	0.0	6.19294E-01	6.19294E-01
23	8.39719E-05	6.28020E-05	6.27852E-05	5.54057E-02	0.0	0.0	6.13911E-01	6.13911E-01
24	7.25103E-05	5.41510E-05	5.41311E-05	4.77688E-02	0.0	0.0	5.16143E-01	5.16143E-01
25	6.38217E-05	4.41824E-05	4.41556E-05	3.89657E-02	0.0	0.0	5.19873E-01	5.19873E-01
26	1.00732E-04	7.37497E-05	7.37388E-05	6.50718E-02	0.0	0.0	6.62034E-01	6.62035E-01
27	7.15478E-05	5.28276E-05	5.28162E-05	4.66085E-02	0.0	0.0	4.72919E-01	4.72919E-01
28	5.57365E-05	3.89499E-05	3.89328E-05	3.43568E-02	0.0	0.0	3.95432E-01	3.95432E-01
29	4.92673E-05	3.39087E-05	3.38975E-05	2.99133E-02	0.0	0.0	3.68379E-01	3.68379E-01
30	3.46449E-05	2.24741E-05	2.24652E-05	1.98247E-02	0.0	0.0	3.07074E-01	3.07074E-01
31	7.00396E-05	4.98240E-05	4.98120E-05	4.39573E-02	0.0	0.0	4.51270E-01	4.51270E-01
32	4.17357E-05	3.00642E-05	3.00488E-05	2.65170E-02	0.0	0.0	2.67085E-01	2.67085E-01
33	2.66014E-05	1.93311E-05	1.93099E-05	1.70403E-02	0.0	0.0	1.79503E-01	1.79503E-01
34	2.26674E-05	1.58168E-05	1.58030E-05	1.39456E-02	0.0	0.0	1.66758E-01	1.66758E-01
35	2.24224E-05	1.53524E-05	1.53434E-05	1.35400E-02	0.0	0.0	1.66285E-01	1.66285E-01
36	1.61429E-05	1.06406E-05	1.06332E-05	9.38344E-03	0.0	0.0	1.30466E-01	1.30466E-01
37	2.18836E-05	1.53686E-05	1.53617E-05	1.35561E-02	0.0	0.0	1.46243E-01	1.46243E-01
38	6.49122E-06	4.21137E-06	4.20587E-06	3.71153E-03	0.0	0.0	6.22049E-02	6.22049E-02
39	2.15582E-05	1.54859E-05	1.54794E-05	1.36601E-02	0.0	0.0	1.33689E-01	1.33689E-01
40	9.63368E-06	6.80826E-06	6.80492E-06	6.00510E-03	0.0	0.0	7.92065E-02	7.92065E-02
41	6.30780E-06	4.07206E-06	4.06555E-06	3.58771E-03	0.0	0.0	5.50441E-02	5.50441E-02
42	3.87706E-06	2.37261E-06	2.36877E-06	2.09035E-03	0.0	0.0	4.02059E-02	4.02060E-02
43	1.08129E-05	7.53459E-06	7.53237E-06	6.64705E-03	0.0	0.0	7.80557E-02	7.80557E-02
44	5.90082E-06	3.97801E-06	3.97626E-06	3.50891E-03	0.0	0.0	4.50818E-02	4.50818E-02
45	1.86805E-06	1.25556E-06	1.25199E-06	1.10483E-03	0.0	0.0	1.49584E-02	1.49584E-02
46	1.08547E-06	6.98283E-07	6.95981E-07	6.14179E-04	0.0	0.0	9.75406E-03	9.75406E-03
47	1.21855E-06	7.90371E-07	7.89472E-07	6.96681E-04	0.0	0.0	1.08211E-02	1.08211E-02
48	9.38088E-07	6.04933E-07	6.04447E-07	5.33403E-04	0.0	0.0	8.46017E-03	8.46017E-03
49	6.41304E-07	4.01367E-07	4.00886E-07	3.53768E-04	0.0	0.0	6.59305E-03	6.59305E-03
50	3.50631E-07	2.11690E-07	2.11298E-07	1.86463E-04	0.0	0.0	4.47332E-03	4.47332E-03
51	7.91574E-08	4.04094E-08	4.01405E-08	3.54225E-05	0.0	0.0	1.39413E-03	1.39413E-03
52	2.87704E-06	2.01162E-06	2.01146E-06	1.77505E-03	0.0	0.0	1.89813E-02	1.89813E-02
53	4.12645E-07	3.08795E-07	3.08571E-07	2.72303E-04	0.0	0.0	2.32290E-03	2.32290E-03
54	2.70466E-07	1.95762E-07	1.94665E-07	1.71785E-04	0.0	0.0	1.61497E-03	1.61497E-03
55	2.40743E-07	1.72294E-07	1.71926E-07	1.51719E-04	0.0	0.0	1.44019E-03	1.44019E-03
56	3.14817E-07	2.23533E-07	2.21375E-07	1.95356E-04	0.0	0.0	1.86593E-03	1.86593E-03
57	7.94948E-07	5.32812E-07	5.32499E-07	4.69911E-04	0.0	0.0	5.29900E-03	5.29900E-03
58	5.99007E-07	3.83451E-07	3.83041E-07	3.38020E-04	0.0	0.0	5.25917E-03	5.25917E-03
59	2.59768E-07	1.51898E-07	1.51591E-07	1.33774E-04	0.0	0.0	4.07176E-03	4.07176E-03
60	5.44574E-07	3.41605E-07	3.41453E-07	3.01320E-04	0.0	0.0	6.62855E-03	6.62855E-03
61	4.52259E-07	2.92850E-07	2.92576E-07	2.58188E-04	0.0	0.0	4.34210E-03	4.34210E-03
62	2.75407E-07	1.74278E-07	1.74032E-07	1.53577E-04	0.0	0.0	2.79880E-03	2.79880E-03
63	1.76093E-07	1.11553E-07	1.11398E-07	9.83050E-05	0.0	0.0	1.76523E-03	1.76523E-03
64	1.13009E-07	7.08993E-08	7.07990E-08	6.24776E-05	0.0	0.0	1.19968E-03	1.19968E-03
65	7.58544E-08	4.73341E-08	4.72693E-08	4.17135E-05	0.0	0.0	8.54597E-04	8.54597E-04
66	5.31976E-08	3.30836E-08	3.30397E-08	2.91563E-05	0.0	0.0	6.32351E-04	6.32351E-04
67	3.64044E-08	2.25573E-08	2.25263E-08	1.98786E-05	0.0	0.0	4.55729E-04	4.55729E-04
68	2.68769E-08	1.66794E-08	1.66577E-08	1.46999E-05	0.0	0.0	3.38607E-04	3.38607E-04
69	2.00846E-08	1.24137E-08	1.23977E-08	1.09405E-05	0.0	0.0	2.61630E-04	2.61630E-04
70	1.52247E-08	9.39042E-09	9.37832E-09	8.27603E-06	0.0	0.0	2.04282E-04	2.04282E-04
71	1.17850E-08	7.26206E-09	7.25282E-09	6.40036E-06	0.0	0.0	1.61664E-04	1.61664E-04
72	9.23971E-09	5.69070E-09	5.68348E-09	5.01547E-06	0.0	0.0	1.28897E-04	1.28897E-04
73	7.31734E-09	4.50481E-09	4.49909E-09	3.97028E-06	0.0	0.0	1.03270E-04	1.03270E-04
74	5.83864E-09	3.59414E-09	3.58958E-09	3.16768E-06	0.0	0.0	8.29508E-05	8.29509E-05
75	4.66313E-09	2.86986E-09	2.86619E-09	2.52931E-06	0.0	0.0	6.65439E-05	6.65439E-05
76	3.72874E-09	2.29480E-09	2.29184E-09	2.02246E-06	0.0	0.0	5.32840E-05	5.32840E-05
77	2.97958E-09	1.83378E-09	1.83139E-09	1.61613E-06	0.0	0.0	4.25784E-05	4.25784E-05
78	2.37401E-09	1.46111E-09	1.45918E-09	1.28768E-06	0.0	0.0	3.39085E-05	3.39085E-05
79	1.88395E-09	1.15948E-09	1.15795E-09	1.02185E-06	0.0	0.0	2.68973E-05	2.68973E-05
80	1.48845E-09	9.16040E-10	9.14819E-10	8.07295E-07	0.0	0.0	2.12459E-05	2.12459E-05
81	1.17061E-09	7.20400E-10	7.19433E-10	6.34874E-07	0.0	0.0	1.67089E-05	1.67089E-05
82	9.16139E-10	5.63761E-10	5.63000E-10	4.96827E-07	0.0	0.0	1.30798E-05	1.30798E-05
83	7.13150E-10	4.38813E-10	4.38217E-10	3.86711E-07	0.0	0.0	1.01871E-05	1.01871E-05
84	5.51265E-10	3.39161E-10	3.38697E-10	2.98888E-07	0.0	0.0	7.88258E-06	7.88258E-06
85	4.23495E-10	2.60518E-10	2.60159E-10	2.29581E-07	0.0	0.0	6.06293E-06	6.06293E-06
86	3.23242E-10	1.98817E-10	1.98541E-10	1.75205E-07	0.0	0.0	4.63468E-06	4.63468E-06
87	2.44415E-10	1.50300E-10	1.50089E-10	1.32448E-07	0.0	0.0	3.51233E-06	3.51233E-06
88	1.83648E-10	1.12910E-10	1.12750E-10	9.94982E-08	0.0	0.0	2.64501E-06	2.64501E-06
89	1.36814E-10	8.40939E-11	8.39741E-11	7.41042E-08	0.0	0.0	1.97612E-06	1.97612E-06
90	1.00923E-10	6.20132E-11	6.19240E-11	5.46457E-08	0.0	0.0	1.46285E-06	1.46285E-06
91	7.37074E-11	4.52735E-11	4.52076E-11	3.98941E-08	0.0	0.0	1.07274E-06	1.07274E-06
92	5.32097E-11	3.26681E-11	3.26200E-11	2.87860E-08	0.0	0.0	7.78238E-07	7.78238E-07
93	3.77470E-11	2.31592E-11	2.31245E-11	2.04066E-08	0.0	0.0	5.55725E-07	5.55725E-07
94	2.64231E-11	1.62001E-11	1.61754E-11	1.42742E-08	0.0	0.0	3.91801E-07	3.91801E-07
95	1.85536E-11	1.11617E-11	1.11645E-11	9.85224E-09	0.0	0.0	2.72886E-07	2.72886E-07
96	1.21845E-11	7.45210E-12	7.44020E-12	6.56571E-09	0.0	0.0	1.84495E-07	1.84495E-07
97	7.96205E-12	4.86128E-12	4.85332E-12	4.28288E-09	0.0	0.0	1.22220E-07	1.22220E-07
98	5.15165E-12	3.13931E-12	3.13410E-12	2.76573E-09	0.0	0.0	8.02145E-08	8.02145E-08
99	6.35630E-12	3.83711E-12	3.83060E-12	3.38037E-09	0.0	0.0	1.03586E-07	1.03586E-07
100	1.41026E-12	8.15271E-13	8.13391E-13	7.17788E-10	0.0	0.0	2.59609E-08	2.59610E-08
101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
102	2.95432E-09	2.04743E-09	2.04445E-09	1.80415E-06	0.0	0.0	2.57864E-05	2.57864E-05
103	5.14633E-07	3.56130E-07	3.56129E-07	3.14272E-04	0.0	0.0	4.03382E-03	4.03382E-03
104	8.52346E-07	5.80572E-07	5.80516E-07	5.12285E-04	0.0	0.0	6.70237E-03	6.70237E-03
105	1.53995E-06	1.07373E-06	1.07354E-06	9.47358E-04	0.0	0.0	1.27739E-02	1.27739E-02
106	2.06141E-06	1.42682E-06	1.42672E-06	1.25903E-03	0.0	0.0	1.73149E-02	1.73149E-02
107	1.06432E-05	7.36036E-06	7.36029E-06	6.49520E-03	0.0	0.0	9.54266E-02	9.54266E-02
108	8.25212E-06	5.70294E-06	5.70290E-06	5.03261E-03	0.0	0.0	7.40114E-02	7.40114E-02
109	1.33688E-05	9.17745E-06	9.17680E-06	8.09820E-03	0.0	0.0	1.20761E-01	1.20761E-01
110	1.27858E-05	8.70981E-06	8.70981E-06	7.68610E-03	0.0	0.0	1.16312E-01	1.16312E-01
111	1.14292E-05	7.92668E-06	7.92644E-06	6.99480E-03	0.0	0.0	9.66228E-02	9.66228E-02
112	1.94397E-05	1.31812E-05	1.31811E-05	1.16319E-02	0.0	0.0	1.83119E-01	1.83119E-01
113	9.93997E-05	6.07878E-05	6.07878E-05	5.36430E-02	0.0	0.0	1.01791E+00	1.01791E+00
114	4.25584E-05	2.95102E-05	2.95101E-05	2.60416E-02	0.0	0.0	3.61287E-01	3.61287E-01
115	5.03794E-05	3.35699E-05	3.35694E-05	2.96238E-02	0.0	0.0	4.22152E-01	4.22152E-01
116	3.27945E-05	2.02551E-05	2.02541E-05	1.78736E-02	0.0	0.0	3.22778E-01	3.22779E-01
117	4.05591E-05	2.39315E-05	2.39197E-05	2.11083E-02	0.0	0.0	5.77916E-01	5.77916E-01
118	2.29588E-05	1.31649E-05	1.31430E-05	1.15982E-02	0.0	0.0	4.82953E-01	4.82953E-01
119	8.93701E-07	3.59181E-07	3.56074E-07	3.14222E-04	0.0	0.0	2.29326E-02	2.29326E-02
120	9.72640E-09	4.77513E-09	4.72524E-09	4.16985E-06	0.0	0.0	1.31026E-04	1.31026E-04
121	1.86219E-03	1.35894E-03	1.35857E-03	1.19889E+00	0.0	0.0	1.63635E+01	1.63635E+01

SUMMARY FOR SYSTEM

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	1.84361E-04	0.0	0.0	7.64783E-05	1.01605E-04	1.32246E-05	6.95804E-05	9.99868E-01
2	1.01049E-03	0.0	1.18126E-05	4.90221E-04	5.61594E-04	7.91387E-05	3.81846E-04	9.99866E-01
3	1.76492E-03	0.0	6.24809E-05	9.66727E-04	1.03632E-03	1.26789E-04	6.64755E-04	9.99874E-01
4	3.32372E-03	0.0	1.19972E-04	2.03885E-03	2.02711E-03	1.99576E-04	1.21784E-03	9.99878E-01
5	6.43047E-03	0.0	2.50140E-04	4.43687E-03	4.04673E-03	3.15927E-04	2.31959E-03	9.99878E-01
6	7.79884E-03	0.0	5.27034E-04	5.89313E-03	5.18410E-03	3.14413E-04	2.82928E-03	9.99885E-01
7	1.05371E-02	0.0	7.87485E-04	8.53727E-03	7.25282E-03	3.31485E-04	3.74276E-03	9.99889E-01
8	2.75079E-02	0.0	1.24228E-03	2.23245E-02	1.89701E-02	6.28025E-04	9.15824E-03	9.99893E-01
9	2.46639E-02	0.0	3.13694E-03	2.11953E-02	1.87317E-02	4.32677E-04	8.64214E-03	9.99898E-01
10	2.34328E-02	0.0	3.99452E-03	2.05920E-02	1.88429E-02	3.14102E-04	8.27555E-03	9.99904E-01
11	5.71022E-02	0.0	4.85836E-03	4.91790E-02	4.24786E-02	5.84606E-04	1.89095E-02	9.99901E-01
12	4.68927E-02	0.0	9.99579E-03	4.39058E-02	3.92384E-02	4.29359E-04	1.72314E-02	9.99906E-01
13	5.29356E-02	0.0	1.42288E-02	5.26861E-02	4.42231E-02	4.11327E-04	2.25433E-02	9.99901E-01
14	5.58299E-02	0.0	1.92180E-02	6.27049E-02	4.88823E-02	3.45555E-04	2.58355E-02	9.99896E-01
15	3.91384E-02	0.0	2.55124E-02	6.02403E-02	4.07014E-02	2.10059E-04	2.37519E-02	9.99903E-01
16	7.58447E-02	0.0	3.27521E-02	9.58549E-02	6.52044E-02	2.50128E-04	4.31663E-02	9.99889E-01
17	5.74368E-02	0.0	4.26895E-02	8.23233E-02	6.27720E-02	1.53497E-04	3.72205E-02	9.99901E-01
18	5.51415E-02	0.0	4.33472E-02	7.71720E-02	5.55990E-02	1.36532E-04	4.27753E-02	9.99888E-01
19	5.21286E-02	0.0	4.87587E-02	7.17706E-02	6.06107E-02	1.09727E-04	4.01874E-02	9.99898E-01
20	4.88765E-02	0.0	6.27050E-02	8.74344E-02	5.98173E-02	1.72512E-04	5.16166E-02	9.99889E-01
21	4.46456E-02	0.0	5.58536E-02	9.02676E-02	4.78911E-02	1.38434E-04	5.24942E-02	9.99878E-01
22	4.07544E-02	0.0	5.88983E-02	6.43464E-02	4.73184E-02	1.26178E-04	5.22331E-02	9.99875E-01
23	3.66451E-02	0.0	5.12729E-02	7.50321E-02	3.25543E-02	1.69120E-04	5.32201E-02	9.99855E-01
24	3.26413E-02	0.0	3.98471E-02	7.27236E-02	2.43414E-02	1.90652E-04	4.79784E-02	9.99848E-01
25	2.88415E-02	0.0	4.51663E-02	1.10937E-01	3.46004E-02	2.20778E-04	3.92029E-02	9.99890E-01
26	2.52809E-02	0.0	5.90687E-02	7.76575E-02	1.94522E-02	3.39899E-04	6.45850E-02	9.99837E-01
27	2.20299E-02	0.0	4.33165E-02	5.32765E-02	1.82981E-02	2.26181E-04	4.68425E-02	9.99844E-01
28	1.90984E-02	0.0	3.84233E-02	6.73854E-02	2.27704E-02	1.72535E-04	3.45929E-02	9.99878E-01
29	1.64091E-02	0.0	3.84965E-02	6.41035E-02	2.49569E-02	1.64232E-04	2.97966E-02	9.99889E-01
30	1.40866E-02	0.0	3.70037E-02	7.37585E-02	3.10077E-02	1.27631E-04	1.99624E-02	9.99927E-01
31	1.20485E-02	0.0	4.28579E-02	5.19059E-02	1.12473E-02	1.90718E-04	4.34863E-02	9.99837E-01
32	1.02717E-02	0.0	2.19810E-02	3.13073E-02	5.42477E-03	1.16373E-04	2.67227E-02	9.99828E-01
33	8.67657E-03	0.0	1.55361E-02	2.06506E-02	6.71599E-03	8.31123E-05	1.74209E-02	9.99849E-01
34	7.35414E-03	0.0	1.58167E-02	2.51811E-02	8.96654E-03	9.37696E-05	1.41162E-02	9.99877E-01
35	6.22174E-03	0.0	1.60446E-02	2.80170E-02	8.59701E-03	9.25533E-05	1.35821E-02	9.99880E-01
36	5.24853E-03	0.0	1.46547E-02	2.77559E-02	1.03558E-02	6.35049E-05	9.48747E-03	9.99911E-01
37	4.39009E-03	0.0	1.44546E-02	1.63519E-02	5.69180E-03	6.78575E-05	1.36904E-02	9.99860E-01
38	3.69174E-03	0.0	9.14484E-03	1.26556E-02	8.89144E-03	2.81124E-05	3.91852E-03	9.99942E-01
39	3.10012E-03	0.0	1.36984E-02	1.20167E-02	3.24918E-03	6.03989E-05	1.36945E-02	9.99835E-01
40	5.15678E-03	0.0	6.29779E-03	1.13932E-02	5.31567E-03	3.90560E-05	6.10255E-03	9.99882E-01
41	1.70181E-03	0.0	7.43348E-03	1.13656E-02	5.36617E-03	3.72832E-05	3.73315E-03	9.99928E-01
42	1.50202E-03	0.0	6.83163E-03	1.14254E-02	6.13805E-03	3.06291E-05	2.16573E-03	9.99955E-01
43	1.18295E-03	0.0	7.65204E-03	1.33043E-02	2.25002E-03	5.94330E-05	6.52799E-03	9.99861E-01
44	1.04406E-03	0.0	3.91745E-03	9.95386E-03	1.38389E-03	3.42934E-05	3.54462E-03	9.99870E-01
45	0.0	0.0	2.61357E-03	2.75690E-03	1.39082E-03	9.20304E-06	1.21389E-03	9.99933E-01
46	0.0	0.0	2.05582E-03	2.74691E-03	1.38430E-03	7.49185E-06	6.64203E-04	9.99957E-01
47	0.0	0.0	1.91678E-03	3.35648E-03	1.21004E-03	3.38617E-06	7.03552E-04	9.99947E-01
48	0.0	0.0	1.68981E-03	2.62138E-03	1.14871E-03	2.78144E-06	5.38483E-04	9.99953E-01
49	0.0	0.0	1.53278E-03	2.54099E-03	1.16402E-03	6.65049E-06	3.62217E-04	9.99966E-01
50	0.0	0.0	1.50088E-03	2.49617E-03	1.30096E-03	4.63350E-06	1.95340E-04	9.99982E-01
51	0.0	0.0	1.61185E-03	1.73338E-03	1.56638E-03	1.49884E-06	4.39780E-05	9.99999E-01
52	0.0	0.0	1.87037E-03	3.62259E-03	1.46747E-04	1.53194E-05	1.70908E-03	9.99846E-01
53	0.0	0.0	3.59689E-04	7.81184E-05	5.60089E-05	1.18711E-06	3.02594E-04	9.99860E-01
54	0.0	0.0	2.59468E-04	1.13292E-04	6.10603E-05	3.91388E-07	1.98079E-04	9.99879E-01
55	0.0	0.0	2.30206E-04	1.48742E-04	7.36948E-05	2.51758E-07	1.56313E-04	9.99885E-01
56	0.0	0.0	3.14798E-04	2.56977E-04	1.20318E-04	1.41834E-07	1.94406E-04	9.99894E-01
57	0.0	0.0	7.14991E-04	1.18360E-03	2.46107E-04	2.37482E-06	4.66662E-04	9.99893E-01
58	0.0	0.0	7.78535E-04	1.79265E-03	4.31560E-04	5.18606E-06	3.41893E-04	9.99933E-01
59	0.0	0.0	7.56239E-04	4.27096E-03	6.05156E-04	1.07364E-05	1.40373E-04	9.99983E-01
60	0.0	0.0	7.79769E-04	4.26649E-03	4.74384E-04	9.19558E-06	2.96250E-04	9.99948E-01
61	0.0	0.0	5.77496E-04	1.77643E-03	3.16183E-04	2.22010E-06	2.59170E-04	9.99933E-01
62	0.0	0.0	3.73482E-04	1.39661E-03	2.14327E-04	2.14903E-06	1.57052E-04	9.99940E-01
63	0.0	0.0	2.52610E-04	8.51497E-04	1.51645E-04	6.79492E-07	1.00312E-04	9.99947E-01
64	0.0	0.0	1.77797E-04	6.40587E-04	1.13369E-04	6.47013E-07	6.37979E-05	9.99953E-01
65	0.0	0.0	1.31188E-04	4.99978E-04	8.77789E-05	9.37496E-07	4.24826E-05	9.99960E-01
66	0.0	0.0	9.98609E-05	4.00575E-04	6.97763E-05	4.64592E-07	2.96281E-05	9.99960E-01
67	0.0	0.0	7.80113E-05	3.05824E-04	4.98155E-05	7.96914E-06	2.02319E-05	9.99966E-01
68	0.0	0.0	5.54378E-05	2.32017E-04	4.01385E-05	3.99855E-07	1.49032E-05	9.99966E-01
69	0.0	0.0	4.38433E-05	1.89683E-04	3.24118E-05	3.44605E-07	1.10882E-05	9.99965E-01
70	0.0	0.0	3.50006E-05	1.54400E-04	2.63112E-05	3.09623E-07	8.38197E-06	9.99969E-01
71	0.0	0.0	2.81011E-05	1.26052E-04	2.13481E-05	2.80253E-07	6.47447E-06	9.99970E-01
72	0.0	0.0	2.26818E-05	1.02858E-04	1.73589E-05	2.53327E-07	5.07094E-06	9.99971E-01
73	0.0	0.0	1.83542E-05	8.37647E-05	1.41121E-05	2.30275E-07	4.01279E-06	9.99974E-01
74	0.0	0.0	1.48201E-05	6.79882E-05	1.14109E-05	2.09804E-07	3.20015E-06	9.99976E-01
75	0.0	0.0	1.19752E-05	5.49193E-05	9.23065E-06	1.89949E-07	2.55520E-06	9.99976E-01
76	0.0	0.0	9.62511E-06	4.41150E-05	7.40908E-06	1.73041E-07	2.04346E-06	9.99976E-01
77	0.0	0.0	7.71330E-06	3.52839E-05	5.92367E-06	1.56749E-07	1.63328E-06	9.99975E-01
78	0.0	0.0	6.16044E-06	2.81025E-05	4.71779E-06	1.41356E-07	1.30160E-06	9.99975E-01
79	0.0	0.0	4.90214E-06	2.22921E-05	3.74242E-06	1.26856E-07	1.03309E-06	9.99977E-01
80	0.0	0.0	3.88603E-06	1.76085E-05	2.95625E-06	1.13634E-07	8.16359E-07	9.99973E-01
81	0.0	0.0	3.06804E-06	1.38484E-05	2.32477E-06	1.01256E-07	6.42154E-07	9.99976E-01
82	0.0	0.0	2.41207E-06	1.08407E-05	1.81994E-06	8.96075E-08	5.02655E-07	9.99972E-01
83	0.0	0.0	1.88784E-06	8.44323E-06	1.41738E-06	7.92152E-08	3.91359E-07	9.99974E-01
84	0.0	0.0	1.47034E-06	6.53318E-06	1.09827E-06	6.95533E-08	3.02597E-07	9.99974E-01
85	0.0	0.0	1.13800E-06	5.02505E-06	8.45006E-07	6.05347E-08	2.32511E-07	9.99976E-01
86	0.0	0.0	8.75692E-07	3.84129E-06	6.45734E-07	5.25103E-08	1.77487E-07	9.99977E-01
87	0.0	0.0	6.69857E-07	2.91106E-06	4.90576E-07	4.51112E-08	1.34201E-07	9.99977E-01
88	0.0	0.0	5.08145E-07	2.19221E-06	3.68848E-07	3.84963E-08	1.00825E-07	9.99977E-01
89	0.0	0.0	3.83155E-07	1.63782E-06	2.75520E-07	3.25398E-08	7.51134E-08	9.99976E-01
90	0.0	0.0	2.86727E-07	1.21239E-06	2.03973E-07	2.73537E-08	5.54129E-08	9.99978E-01
91	0.0	0.0	2.12696E-07	8.89063E-07	1.49581E-07	2.26512E-08	4.04732E-08	9.99978E-01
92	0.0	0.0	1.56382E-07	6.44980E-07	1.08519E-07	1.86481E-08	2.92213E-08	9.99977E-01
93	0.0	0.0	1.13823E-07	4.60560E-07	7.79821E-08	1.51100E-08	2.07357E-08	9.99979E-01
94	0.0	0.0	8.16318E-08	3.24702E-07	5.50423E-08	1.20769E-08	1.45159E-08	9.99981E-01
95	0.0	0.0	5.78659E-08	2.26148E-07	3.83200E-08	9.52200E-09	1.00260E-08	9.99981E-01
96	0.0	0.0	4.05766E-08	1.52893E-07	2.65763E-08	7.30951E-09	6.69246E-09	9.99980E-01
97	0.0	0.0	2.76989E-08	1.01283E-07	1.78346E-08	5.49499E-09	4.37026E-09	9.99982E-01
98	0.0	0.0	1.85840E-08	6.64716E-08	1.16895E-08	4.07181E-09	2.82335E-09	9.99983E-01
99	0.0	0.0	1.46925E-08	9.66397E-08	3.97726E-09	7.26727E-09	3.44876E-09	9.99972E-01
100	0.0	0.0	5.63562E-09	2.51095E-08	6.76537E-11	4.82252E-09	7.45608E-10	9.99987E-01
101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00000E+00
102	0.0	0.0	7.88086E-06	1.22401E-07	2.58569E-06	3.31846E-06	1.97743E-06	9.99955E-01
103	0.0	0.0	1.22461E-03	2.74879E-05	4.63277E-04	4.48437E-04	3.13088E-04	9.99920E-01
104	0.0	0.0	2.03463E-03	5.27869E-05	8.95082E-04	6.23169E-04	5.13620E-04	9.99942E-01
105	0.0	0.0	3.87937E-03	1.55619E-04	1.97482E-03	9.49641E-04	9.55275E-04	9.99953E-01
106	0.0	0.0	5.39815E-03	2.31901E-04	3.16904E-03	9.72023E-04	1.25872E-03	9.99850E-01
107	0.0	0.0	3.02270E-02	2.05281E-03	2.00216E-02	3.74739E-03	6.46099E-03	9.99951E-01
108	0.0	0.0	2.53734E-02	1.33164E-03	1.85145E-02	1.85801E-03	5.00379E-03	9.99943E-01
109	0.0	0.0	4.31994E-02	3.19220E-03	3.33277E-02	1.78987E-03	8.08508E-03	9.99962E-01
110	0.0	0.0	4.50020E-02	3.21317E-03	3.63682E-02	1.00260E-03	7.63443E-03	9.99965E-01
111	0.0	0.0	4.03396E-02	3.82113E-03	3.29628E-02	4.09683E-04	6.97044E-03	9.99959E-01
112	0.0	0.0	7.99788E-02	1.16040E-02	6.79634E-02	6.64004E-04	1.15561E-02	9.99971E-01
113	0.0	0.0	4.91914E-01	6.77931E-02	4.35143E-01	3.74613E-03	5.30503E-02	9.99974E-01
114	0.0	0.0	1.91560E-01	3.84882E-02	1.63243E-01	2.36459E-03	2.59620E-02	9.99976E-01
115	0.0	0.0	2.29716E-01	8.23291E-02	1.93488E-01	6.59131E-03	2.96468E-02	9.99979E-01
116	0.0	0.0	2.07910E-01	6.95461E-02	1.77086E-01	1.28489E-02	1.79802E-02	9.99987E-01
117	0.0	0.0	3.78744E-01	2.19790E-01	2.93551E-01	6.37288E-02	2.14700E-02	9.99992E-01
118	0.0	0.0	4.23304E-01	4.33263E-01	1.15912E-01	2.95333E-01	1.20619E-02	9.99997E-01
119	0.0	0.0	1.16473E-01	3.57615E-02	2.93712E-03	1.13138E-01	3.97463E-04	1.00000E+00
120	0.0	0.0	4.80415E-03	4.24952E-04	-2.32831E-09	4.79861E-03	5.58725E-06	9.99996E-01
121	1.00000E+00	0.0	3.32010E+00	2.81670E+00	2.59846E+00	5.23348E-01	1.19882E+00	9.99939E-01

GRP.	RT BDY FLUX	RT BDY J+	RT BDY J	RT LEAKAGE	LFT LEAKAGE	FISS RATE	TOTAL FLUX	DENSITY
1	2.24546E-10	2.19710E-10	2.19710E-10	6.95806E-05	0.0	0.0	1.29923E-02	1.29923E-02
2	1.23160E-09	1.20574E-09	1.20574E-09	3.81846E-04	0.0	0.0	7.20268E-02	7.20268E-02
3	2.14507E-09	2.09906E-09	2.09906E-09	6.64755E-04	0.0	0.0	1.25290E-01	1.25290E-01
4	3.93008E-09	3.84552E-09	3.84552E-09	1.21784E-03	0.0	0.0	2.29659E-01	2.29659E-01
5	7.48667E-09	7.32443E-09	7.32443E-09	2.31959E-03	0.0	0.0	4.37213E-01	4.37213E-01
6	9.13832E-09	8.93386E-09	8.93386E-09	2.82928E-03	0.0	0.0	5.32534E-01	5.32534E-01
7	1.20926E-08	1.18183E-08	1.18183E-08	3.74276E-03	0.0	0.0	7.04515E-01	7.04515E-01
8	2.95780E-08	2.89185E-08	2.89185E-08	9.15824E-03	0.0	0.0	1.72775E+00	1.72775E+00
9	2.79145E-08	2.72888E-08	2.72888E-08	8.64214E-03	0.0	0.0	1.63528E+00	1.63528E+00
10	2.67504E-08	2.61313E-08	2.61313E-08	8.27555E-03	0.0	0.0	1.56539E+00	1.56539E+00
11	6.11347E-08	5.97096E-08	5.97096E-08	1.89095E-02	0.0	0.0	3.57635E+00	3.57635E+00
12	5.57219E-08	5.44107E-08	5.44107E-08	1.72314E-02	0.0	0.0	3.26841E+00	3.26841E+00
13	7.29466E-08	7.11838E-08	7.11838E-08	2.25433E-02	0.0	0.0	4.25384E+00	4.25384E+00
14	8.36432E-08	8.15793E-08	8.15793E-08	2.58355E-02	0.0	0.0	4.86753E+00	4.86753E+00
15	7.69438E-08	7.50002E-08	7.50002E-08	2.37519E-02	0.0	0.0	4.44381E+00	4.44382E+00
16	1.39640E-07	1.36304E-07	1.36304E-07	4.31663E-02	0.0	0.0	8.07422E+00	8.07422E+00
17	1.20544E-07	1.17529E-07	1.17529E-07	3.72205E-02	0.0	0.0	6.95130E+00	6.95130E+00
18	1.38591E-07	1.35069E-07	1.35069E-07	4.27753E-02	0.0	0.0	7.95395E+00	7.95395E+00
19	1.30314E-07	1.26898E-07	1.26898E-07	4.01874E-02	0.0	0.0	7.47118E+00	7.47118E+00
20	1.67375E-07	1.62987E-07	1.62987E-07	5.16166E-02	0.0	0.0	9.55635E+00	9.55635E+00
21	1.70367E-07	1.65758E-07	1.65758E-07	5.24942E-02	0.0	0.0	9.66774E+00	9.66774E+00
22	1.69519E-07	1.64934E-07	1.64934E-07	5.22331E-02	0.0	0.0	9.60314E+00	9.60314E+00
23	1.79440E-07	1.74365E-07	1.74365E-07	5.52201E-02	0.0	0.0	1.01010E+01	1.01010E+01
24	1.55973E-07	1.51499E-07	1.51499E-07	4.79784E-02	0.0	0.0	8.74641E+00	8.74642E+00
25	1.27857E-07	1.23789E-07	1.23789E-07	3.92029E-02	0.0	0.0	7.18780E+00	7.18781E+00
26	2.09553E-07	2.03937E-07	2.03937E-07	6.45850E-02	0.0	0.0	1.17348E+01	1.17348E+01
27	1.52454E-07	1.47912E-07	1.47912E-07	4.68425E-02	0.0	0.0	8.48364E+00	8.48364E+00
28	1.12837E-07	1.09232E-07	1.09232E-07	3.45929E-02	0.0	0.0	6.28669E+00	6.28669E+00
29	9.71555E-08	9.40872E-08	9.40872E-08	2.97966E-02	0.0	0.0	5.45374E+00	5.45374E+00
30	6.53095E-08	6.30342E-08	6.30342E-08	1.99624E-02	0.0	0.0	3.70768E+00	3.70768E+00
31	1.41342E-07	1.37314E-07	1.37314E-07	4.34863E-02	0.0	0.0	7.90575E+00	7.90576E+00
32	8.73044E-08	8.43808E-08	8.43808E-08	2.67227E-02	0.0	0.0	4.86961E+00	4.86961E+00
33	5.72885E-08	5.50091E-08	5.50091E-08	1.74209E-02	0.0	0.0	3.17280E+00	3.17281E+00
34	4.61899E-08	4.45741E-08	4.45741E-08	1.41162E-02	0.0	0.0	2.59738E+00	2.59738E+00
35	4.43290E-08	4.28874E-08	4.28874E-08	1.35821E-02	0.0	0.0	2.50017E+00	2.50017E+00
36	3.10803E-08	2.99581E-08	2.99581E-08	9.48747E-03	0.0	0.0	1.75266E+00	1.75266E+00
37	4.39877E-08	4.25979E-08	4.25979E-08	1.34904E-02	0.0	0.0	2.45645E+00	2.45645E+00
38	1.30328E-08	1.23733E-08	1.23733E-08	3.91852E-03	0.0	0.0	7.29886E-01	7.29886E-01
39	4.39520E-08	4.26108E-08	4.26108E-08	1.34945E-02	0.0	0.0	2.45613E+00	2.45613E+00
40	2.00539E-08	1.92697E-08	1.92697E-08	6.10255E-03	0.0	0.0	1.12765E+00	1.12765E+00
41	1.23999E-08	1.17880E-08	1.17880E-08	3.73315E-03	0.0	0.0	6.89005E-01	6.89006E-01
42	7.16635E-09	6.83860E-09	6.83860E-09	2.16573E-03	0.0	0.0	4.09018E-01	4.09018E-01
43	2.12401E-08	2.06131E-08	2.06131E-08	6.52799E-03	0.0	0.0	1.19300E+00	1.19300E+00
44	1.16455E-08	1.11927E-08	1.11927E-08	3.54462E-03	0.0	0.0	6.48717E-01	6.48717E-01
45	4.11058E-09	3.83304E-09	3.83304E-09	1.21389E-03	0.0	0.0	2.21666E-01	2.21666E-01
46	2.23416E-09	2.09732E-09	2.09732E-09	6.64203E-04	0.0	0.0	1.23507E-01	1.23507E-01
47	2.31321E-09	2.22157E-09	2.22157E-09	7.03552E-04	0.0	0.0	1.30938E-01	1.30938E-01
48	1.77289E-09	1.70034E-09	1.70034E-09	5.38483E-04	0.0	0.0	1.00083E-01	1.00083E-01
49	1.19918E-09	1.14375E-09	1.14375E-09	3.62217E-04	0.0	0.0	6.80744E-02	6.80744E-02
50	6.52147E-10	6.16814E-10	6.16814E-10	1.95340E-04	0.0	0.0	3.75316E-02	3.75316E-02
51	1.53544E-10	1.38867E-10	1.38867E-10	4.39780E-05	0.0	0.0	8.79974E-03	8.79974E-03
52	5.54533E-09	5.39666E-09	5.39666E-09	1.70908E-03	0.0	0.0	3.11536E-01	3.11536E-01
53	1.03621E-09	9.55486E-10	9.55486E-10	3.02594E-04	0.0	0.0	5.31732E-02	5.31732E-02
54	6.81989E-10	6.25464E-10	6.25464E-10	1.98079E-04	0.0	0.0	3.61324E-02	3.61324E-02
55	5.18771E-10	4.93581E-10	4.93581E-10	1.56313E-04	0.0	0.0	2.85505E-02	2.85505E-02
56	6.38043E-10	6.13864E-10	6.13864E-10	1.94406E-04	0.0	0.0	3.54234E-02	3.54234E-02
57	1.53104E-09	1.47355E-09	1.47355E-09	4.66662E-04	0.0	0.0	8.53254E-02	8.53254E-02
58	1.13048E-09	1.07958E-09	1.07958E-09	3.41893E-04	0.0	0.0	6.36913E-02	6.36913E-02
59	4.69406E-10	4.43248E-10	4.43248E-10	1.40373E-04	0.0	0.0	2.79842E-02	2.79842E-02
60	9.72810E-10	9.35452E-10	9.35452E-10	2.96250E-04	0.0	0.0	5.66870E-02	5.66870E-02
61	8.55413E-10	8.18366E-10	8.18366E-10	2.59170E-04	0.0	0.0	4.86925E-02	4.86925E-02
62	5.22114E-10	4.95914E-10	4.95914E-10	1.57052E-04	0.0	0.0	2.95982E-02	2.95982E-02
63	3.33351E-10	3.16751E-10	3.16751E-10	1.00312E-04	0.0	0.0	1.88936E-02	1.88936E-02
64	2.12128E-10	2.01451E-10	2.01451E-10	6.37979E-05	0.0	0.0	1.20864E-02	1.20864E-02
65	1.41185E-10	1.34145E-10	1.34145E-10	4.24828E-05	0.0	0.0	8.10431E-03	8.10431E-03
66	9.84301E-11	9.35549E-11	9.35549E-11	2.96281E-05	0.0	0.0	5.68915E-03	5.68915E-03
67	6.72732E-11	6.38853E-11	6.38853E-11	2.02319E-05	0.0	0.0	3.90857E-03	3.90857E-03
68	4.95015E-11	4.70591E-11	4.70591E-11	1.49032E-05	0.0	0.0	2.88360E-03	2.88360E-03
69	3.68353E-11	3.50125E-11	3.50125E-11	1.10882E-05	0.0	0.0	2.15483E-03	2.15483E-03
70	2.78447E-11	2.64673E-11	2.64673E-11	8.38197E-06	0.0	0.0	1.63547E-03	1.63547E-03
71	2.15053E-11	2.04441E-11	2.04441E-11	6.47447E-06	0.0	0.0	1.26744E-03	1.26744E-03
72	1.68448E-11	1.60122E-11	1.60122E-11	5.07094E-06	0.0	0.0	9.95149E-04	9.95149E-04
73	1.33309E-11	1.26710E-11	1.26710E-11	4.01279E-06	0.0	0.0	7.88879E-04	7.88879E-04
74	1.06321E-11	1.01049E-11	1.01049E-11	3.20015E-06	0.0	0.0	6.29852E-04	6.29852E-04
75	8.49169E-12	8.06842E-12	8.06842E-12	2.55520E-06	0.0	0.0	5.03333E-04	5.03333E-04
76	6.79282E-12	6.45253E-12	6.45253E-12	2.04366E-06	0.0	0.0	4.02667E-04	4.02667E-04
77	5.43055E-12	5.15731E-12	5.15731E-12	1.63328E-06	0.0	0.0	3.21870E-04	3.21870E-04
78	4.32848E-12	4.11000E-12	4.11000E-12	1.30160E-06	0.0	0.0	2.56507E-04	2.56507E-04
79	3.43605E-12	3.26214E-12	3.26214E-12	1.03309E-06	0.0	0.0	2.03589E-04	2.03589E-04
80	2.71556E-12	2.57777E-12	2.57777E-12	8.16359E-07	0.0	0.0	1.60877E-04	1.60877E-04
81	2.13636E-12	2.02769E-12	2.02769E-12	6.42154E-07	0.0	0.0	1.26548E-04	1.26548E-04
82	1.67248E-12	1.58721E-12	1.58721E-12	5.02655E-07	0.0	0.0	9.90599E-05	9.90599E-05
83	1.30233E-12	1.23577E-12	1.23577E-12	3.91359E-07	0.0	0.0	7.71308E-05	7.71309E-05
84	1.00711E-12	9.55495E-13	9.55495E-13	3.02597E-07	0.0	0.0	5.96432E-05	5.96433E-05
85	7.73957E-13	7.34187E-13	7.34187E-13	2.32511E-07	0.0	0.0	4.58350E-05	4.58350E-05
86	5.90884E-13	5.60442E-13	5.60442E-13	1.77487E-07	0.0	0.0	3.49962E-05	3.49962E-05
87	4.46863E-13	4.23758E-13	4.23758E-13	1.34201E-07	0.0	0.0	2.64726E-05	2.64726E-05
88	3.35774E-13	3.18370E-13	3.18370E-13	1.00825E-07	0.0	0.0	1.98973E-05	1.98973E-05
89	2.50191E-13	2.37182E-13	2.37182E-13	7.51134E-08	0.0	0.0	1.48301E-05	1.48301E-05
90	1.84610E-13	1.74974E-13	1.74974E-13	5.54129E-08	0.0	0.0	1.09461E-05	1.09461E-05
91	1.34866E-13	1.27800E-13	1.27800E-13	4.04732E-08	0.0	0.0	7.99951E-06	7.99951E-06
92	9.73957E-14	9.22704E-14	9.22704E-14	2.92213E-08	0.0	0.0	5.77941E-06	5.77941E-06
93	6.91383E-14	6.54758E-14	6.54758E-14	2.07357E-08	0.0	0.0	4.10456E-06	4.10456E-06
94	4.84144E-14	4.58361E-14	4.58361E-14	1.45159E-08	0.0	0.0	2.87612E-06	2.87612E-06
95	3.34494E-14	3.16587E-14	3.16587E-14	1.00260E-08	0.0	0.0	1.98886E-06	1.98886E-06
96	2.23451E-14	2.11324E-14	2.11324E-14	6.69246E-09	0.0	0.0	1.33012E-06	1.33012E-06
97	1.45999E-14	1.37997E-14	1.37997E-14	4.37026E-09	0.0	0.0	8.70481E-07	8.70481E-07
98	9.43485E-15	8.91514E-15	8.91514E-15	2.82335E-09	0.0	0.0	5.63711E-07	5.63712E-07
99	1.15295E-14	1.08900E-14	1.08900E-14	3.44876E-09	0.0	0.0	6.94712E-07	6.94712E-07
100	2.50898E-15	2.35437E-15	2.35437E-15	7.45608E-10	0.0	0.0	1.54750E-07	1.54750E-07
101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
102	6.56444E-12	6.24401E-12	6.24401E-12	1.97743E-06	0.0	0.0	3.57839E-04	3.57839E-04
103	1.01212E-09	9.88622E-10	9.88622E-10	3.13088E-04	0.0	0.0	5.68138E-02	5.68138E-02
104	1.66399E-09	1.62183E-09	1.62183E-09	5.13620E-04	0.0	0.0	9.34409E-02	9.34409E-02
105	3.10255E-09	3.01642E-09	3.01642E-09	9.55275E-04	0.0	0.0	1.74328E-01	1.74328E-01
106	4.07596E-09	3.97458E-09	3.97458E-09	1.25872E-03	0.0	0.0	2.29971E-01	2.29971E-01
107	2.08889E-08	2.04015E-08	2.04015E-08	6.46099E-03	0.0	0.0	1.18858E+00	1.18858E+00
108	1.61769E-08	1.58002E-08	1.58002E-08	5.00379E-03	0.0	0.0	9.20651E-01	9.20651E-01
109	2.61874E-08	2.55298E-08	2.55298E-08	8.08508E-03	0.0	0.0	1.48641E+00	1.48641E+00
110	2.46839E-08	2.41068E-08	2.41068E-08	7.63443E-03	0.0	0.0	1.40594E+00	1.40594E+00
111	2.25534E-08	2.20102E-08	2.20102E-08	6.97044E-03	0.0	0.0	1.27794E+00	1.27794E+00
112	3.73648E-08	3.64900E-08	3.64900E-08	1.15561E-02	0.0	0.0	2.13802E+00	2.13802E+00
113	1.71769E-07	1.67514E-07	1.67514E-07	5.30503E-02	0.0	0.0	9.89531E+00	9.89531E+00
114	8.40444E-08	8.19787E-08	8.19787E-08	2.59620E-02	0.0	0.0	4.72950E+00	4.72950E+00
115	9.63354E-08	9.36140E-08	9.36140E-08	2.96468E-02	0.0	0.0	5.36147E+00	5.36147E+00
116	5.87699E-08	5.67750E-08	5.67750E-08	1.79802E-02	0.0	0.0	3.29527E+00	3.29527E+00
117	7.05066E-08	6.77945E-08	6.77945E-08	2.14700E-02	0.0	0.0	4.12152E+00	4.12152E+00
118	3.98064E-08	3.80873E-08	3.80873E-08	1.20619E-02	0.0	0.0	2.49934E+00	2.49934E+00
119	1.40188E-09	1.25505E-09	1.25505E-09	3.97463E-04	0.0	0.0	9.00261E-02	9.00261E-02
120	1.98194E-11	1.76426E-11	1.76426E-11	5.58725E-06	0.0	0.0	1.08114E-03	1.08114E-03
121	3.99656E-06	3.78545E-06	3.78545E-06	1.19882E+00	0.0	0.0	2.21435E+02	2.21435E+02

ELAPSED TIME 1.92 MIN.

D.6 Sample Problem for FDEM

```
MEMBER NAME > B:FDEM.TXT        ------------------------------------------------ PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.5 I.4 P.0 W.2 C.2 SRP
    6 :   OPTP PASSWORD=########
    7 :  //FDEM EXEC LMGO,LM='J1446.FDEMX',OBSIZE=137,ORECFM=FA
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,10)),
    9 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(50,10)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,10)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,10)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,10)),
   17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT10F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,10)),
   19 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   20 :  //FT11F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(50,10)),
   21 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   22 :  //FT12F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(50,10)),
   23 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   24 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   25 :  //SYSIN DD *
   26 :  FDEM SAMPLE PROBLEM NO.1 (ICAL=2,IFLX=1,ICELL=0)
   27 :   &UNIT  FXSN=91,SFLX=91,NFEW=91 &END
   28 :   1¥¥  2 100  20  4HEGRP  28  5  4HSB32  1  2  2  2  0  0  0  1  4R0 T
   29 :   2¥¥  16  0  0  0
   30 :   3¥¥  6R1  4R2  3R3  3R4  2R5  3R6  3R7  2R8    9  3R10 3R11 3R12 3R13
   31 :        3R14 3R15 3R16 3R17 2R18 3R19 5R20 6R21 6R22 6R23 5R24 3R25 2R26
   32 :        9R27 2R28
   33 :   4¥¥  5R1  5R2  5R3  4R4    5
   34 :   5¥¥  4HEGRP  4H 777 4HSFX0
   35 :  11¥¥  4HEGRP  4HFX16 4HIRON  4HAIR0
   36 :  13¥¥  1    2
   37 :    T
   38 :  CLFE IRON (ENDF/B-IV) COLLAPSED BY ZONE 1 FLUX OF DIAC
   39 :  CAIR AIR  (ENDF/B-IV) COLLAPSED BY ZONE 2 FLUX OF DIAC
   40 :  ++
   41 :  //
------------------------------------ END OF FILE ------------------------------------
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 1# ARRAY      19 ENTRIES READ

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                        ***  LIST OF INPUT PARAMETERS  ***

                TITLE = FDEM SAMPLE PROBLEM NO.1 (ICAL=2,IFLX=1,ICELL=0)

ICAL     KIND OF COLLAPSING                                  2     ING      NO. OF FINE NEUTRON GROUP                         100
IGG      NO. OF FINE GAMMA GROUP                            20     NODE1    NODE NAME OF FINE GROUP STRUCTURE                 EGRP
INGF     NO. OF FEW NEUTRON GROUP                           28     IGGF     NO. OF FEW GAMMA GROUP                              5
NODE2    NODE NAME OF FEW GROUP STRUCTURE                 SB32     IFLX     KIND OF WEIGHTING FLUX                              1
MTP      NO. OF INPUT MATERIAL OR RESPONSE FUNC.            2      MTPO     NO. OF OUTPUT MATERIAL OR RESPONSE FUNC.            2
IZM      NO. OF REGION IN DIAC  (IFLX=1)                    2      ICELL    CELL AVERAGE ( 0/1 = NO/YES)                        0
IRESPI   INPUT FORM OF RESPONSE FUNCTION                    0      IRESPO   OUTPUT FORM OF RESPONSE FUNCTION                    0
IPRT     PRINT OPTION                                       1
NN1   LENGTH OF INTERP. TABLE FOR NEUTRONS (IFLX=4)         0      NN2   LENGTH OF FLUX TABLE FOR NEUTRONS (IFLX=4)            0
NG1   LENGTH OF INTERP. TABLE FOR GAMMAS(IFLX.NE.1)         0      NG2   LENGTH OF FLUX TABLE FOR GAMMAS (IFLX.NE.1)           0

 2# ARRAY       4 ENTRIES READ

 3# ARRAY     100 ENTRIES READ

 4# ARRAY      20 ENTRIES READ

 5# ARRAY       3 ENTRIES READ

11# ARRAY       4 ENTRIES READ

13# ARRAY       2 ENTRIES READ

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ENERGY GROUP STRUCTURE

--- NEUTRON GROUP ---						--- GAMMA GROUP ---		
GROUP	ENERGY RANGE		GROUP	ENERGY RANGE		GROUP	ENERGY RANGE	
1	1.6487E+07	1.4550E+07	51	3.1828E+04	2.8088E+04	1	1.4000E+07	1.2000E+07
2	1.4550E+07	1.2840E+07	52	2.8088E+04	2.4788E+04	2	1.2000E+07	1.0000E+07
3	1.2840E+07	1.1331E+07	53	2.4788E+04	2.1875E+04	3	1.0000E+07	8.0000E+06
4	1.1331E+07	1.0000E+07	54	2.1875E+04	1.9305E+04	4	8.0000E+06	6.5000E+06
5	1.0000E+07	8.8250E+06	55	1.9305E+04	1.7036E+04	5	6.5000E+06	5.0000E+06
6	8.8250E+06	7.7880E+06	56	1.7036E+04	1.5034E+04	6	5.0000E+06	4.0000E+06
7	7.7880E+06	6.8729E+06	57	1.5034E+04	1.1709E+04	7	4.0000E+06	3.0000E+06
8	6.8729E+06	6.0653E+06	58	1.1709E+04	9.1188E+03	8	3.0000E+06	2.5000E+06
9	6.0653E+06	5.3526E+06	59	9.1188E+03	7.1017E+03	9	2.5000E+06	2.0000E+06
10	5.3526E+06	4.7237E+06	60	7.1017E+03	5.5308E+03	10	2.0000E+06	1.6600E+06
11	4.7237E+06	4.1686E+06	61	5.5308E+03	4.3074E+03	11	1.6600E+06	1.3300E+06
12	4.1686E+06	3.6788E+06	62	4.3074E+03	3.3546E+03	12	1.3300E+06	1.0000E+06
13	3.6788E+06	3.2465E+06	63	3.3546E+03	2.6126E+03	13	1.0000E+06	8.0000E+05
14	3.2465E+06	2.8650E+06	64	2.6126E+03	2.0347E+03	14	8.0000E+05	6.0000E+05
15	2.8650E+06	2.5284E+06	65	2.0347E+03	1.5846E+03	15	6.0000E+05	4.0000E+05
16	2.5284E+06	2.2313E+06	66	1.5846E+03	1.2341E+03	16	4.0000E+05	3.0000E+05
17	2.2313E+06	1.9691E+06	67	1.2341E+03	9.6112E+02	17	3.0000E+05	2.0000E+05
18	1.9691E+06	1.7377E+06	68	9.6112E+02	7.4852E+02	18	2.0000E+05	1.0000E+05
19	1.7377E+06	1.5336E+06	69	7.4852E+02	5.8295E+02	19	1.0000E+05	5.0000E+04
20	1.5336E+06	1.3534E+06	70	5.8295E+02	4.5400E+02	20	5.0000E+04	2.0000E+04
21	1.3534E+06	1.1943E+06	71	4.5400E+02	3.5357E+02			
22	1.1943E+06	1.0540E+06	72	3.5357E+02	2.7536E+02			
23	1.0540E+06	9.3014E+05	73	2.7536E+02	2.1445E+02			
24	9.3014E+05	8.2085E+05	74	2.1445E+02	1.6702E+02			
25	8.2085E+05	7.2440E+05	75	1.6702E+02	1.3007E+02			
26	7.2440E+05	6.3928E+05	76	1.3007E+02	1.0130E+02			
27	6.3928E+05	5.6416E+05	77	1.0130E+02	7.8893E+01			
28	5.6416E+05	4.9787E+05	78	7.8893E+01	6.1442E+01			
29	4.9787E+05	4.3937E+05	79	6.1442E+01	4.7851E+01			
30	4.3937E+05	3.8774E+05	80	4.7851E+01	3.7267E+01			
31	3.8774E+05	3.4218E+05	81	3.7267E+01	2.9023E+01			
32	3.4218E+05	3.0197E+05	82	2.9023E+01	2.2603E+01			
33	3.0197E+05	2.6649E+05	83	2.2603E+01	1.7603E+01			
34	2.6649E+05	2.3518E+05	84	1.7603E+01	1.3710E+01			
35	2.3518E+05	2.0754E+05	85	1.3710E+01	1.0677E+01			
36	2.0754E+05	1.8316E+05	86	1.0677E+01	8.3153E+00			
37	1.8316E+05	1.6163E+05	87	8.3153E+00	6.4760E+00			
38	1.6163E+05	1.4264E+05	88	6.4760E+00	5.0435E+00			
39	1.4264E+05	1.2588E+05	89	5.0435E+00	3.9279E+00			
40	1.2588E+05	1.1109E+05	90	3.9279E+00	3.0590E+00			
41	1.1109E+05	9.8037E+04	91	3.0590E+00	2.3824E+00			
42	9.8037E+04	8.6517E+04	92	2.3824E+00	1.8554E+00			
43	8.6517E+04	7.6351E+04	93	1.8554E+00	1.4450E+00			
44	7.6351E+04	6.7379E+04	94	1.4450E+00	1.1254E+00			
45	6.7379E+04	5.9462E+04	95	1.1254E+00	8.7642E-01			
46	5.9462E+04	5.2475E+04	96	8.7642E-01	6.8256E-01			
47	5.2475E+04	4.6309E+04	97	6.8256E-01	5.3158E-01			
48	4.6309E+04	4.0868E+04	98	5.3158E-01	4.1399E-01			
49	4.0868E+04	3.6066E+04	99	4.1399E-01	1.5183E-01			
50	3.6066E+04	3.1828E+04	100	1.5183E-01	3.5238E-04			

ENERGY GROUP STRUCTURE

--- NEUTRON GROUP ---

GROUP	ENERGY RANGE	
1	1.6487E+07	7.7880E+06
2	7.7880E+06	4.7237E+06
3	4.7237E+06	3.2465E+06
4	3.2465E+06	2.2313E+06
5	2.2313E+06	1.7377E+06
6	1.7377E+06	1.1943E+06
7	1.1943E+06	8.2085E+05
8	8.2085E+05	6.3928E+05
9	6.3928E+05	5.6416E+05
10	5.6416E+05	3.8774E+05
11	3.8774E+05	2.6649E+05
12	2.6649E+05	1.8316E+05
13	1.8316E+05	1.2588E+05
14	1.2588E+05	8.6517E+04
15	8.6517E+04	5.9462E+04
16	5.9462E+04	4.0868E+04
17	4.0868E+04	2.8088E+04
18	2.8088E+04	2.1875E+04
19	2.1875E+04	1.5034E+04
20	1.5034E+04	4.3074E+03
21	4.3074E+03	9.6112E+02
22	9.6112E+02	2.1445E+02
23	2.1445E+02	4.7851E+01
24	4.7851E+01	1.3710E+01
25	1.3710E+01	6.4760E+00
26	6.4760E+00	3.9279E+00
27	3.9279E+00	4.1399E-01
28	4.1399E-01	3.5238E-04

--- GAMMA GROUP ---

GROUP	ENERGY RANGE	
1	1.4000E+07	5.0000E+06
2	5.0000E+06	1.6600E+06
3	1.6600E+06	4.0000E+05
4	4.0000E+05	5.0000E+04
5	5.0000E+04	2.0000E+04

**** WEIGHT FLUX ****

FLUX FROM DIAC NODE NAME=EGRP 777 (DIAC SAMPLE PROBLEM NO.1 (IRON-AIR) CONFIGULAT)

**** MATERIAL ASSIGNMENT ****

ZONE	INPUT NODE	OUTPUT NODE	
1	IRON	CLFE	(IRON (ENDF/B-IV) COLLAPSED BY ZONE 1 FLUX OF DIAC)
2	AIRO	CAIR	(AIR (ENDF/B-IV) COLLAPSED BY ZONE 2 FLUX OF DIAC)

USED DATA AREA = 8107 (ALLOCATED AREA =100000)

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    *** FEW GROUP CROSS SECTIONS ***

   INPUT NODE NAME = EGRP FX16 IRON      IRON BY ENDF/B-IV AT 300K
   OUTPUT NODE NAME= SB32 FX16 CLFE   (CLFE IRON (ENDF/B-IV) COLLAPSED BY ZONE 1 FLUX OF DIAC
   WEIGHTING FLUX  = ZONE   1
   IGM=  33  IHM=  36  IHT=   3  IHS=   4  NUP=   0

*** MACRO CROSS SECTION WAS OUPUT TO A DATA POOL
    NODE NAME = SB32-FX16-CLFE
```

**** ISOTROPIC CROSS SECTION TABLE ****

POS.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	1.00235E-02	3.72301E-03	1.38239E-03	4.97768E-04	2.07397E-04	1.75961E-04	2.71641E-04	4.26224E-04
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2.69132E-01	3.09104E-01	2.99623E-01	2.74338E-01	2.46178E-01	2.19484E-01	1.79262E-01	2.03936E-01
4	1.43475E-01	1.78651E-01	1.80026E-01	1.81838E-01	1.59063E-01	1.55941E-01	1.40163E-01	1.87929E-01
5	0.0	1.86422E-02	1.98208E-02	3.98076E-02	3.72351E-02	3.38651E-02	1.45797E-02	1.07356E-02
6	0.0	0.0	1.84284E-02	2.14313E-02	5.37302E-03	4.07548E-02	4.85228E-02	1.69487E-02
7	0.0	0.0	0.0	2.19999E-02	1.94726E-02	1.59956E-02	4.63552E-03	1.22251E-03
8	0.0	0.0	0.0	0.0	1.34167E-02	2.11696E-02	1.81752E-02	2.20418E-03
9	0.0	0.0	0.0	0.0	0.0	1.61903E-02	1.73220E-02	1.11656E-02
10	0.0	0.0	0.0	0.0	0.0	0.0	1.10569E-02	6.61203E-03
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.97123E-03
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	POS. 13 THRU POS. 36 SAME AS ABOVE							

POS.	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	4.35663E-04	4.19657E-04	4.33492E-04	5.38094E-04	4.56028E-04	6.12383E-04	7.44421E-04	4.69739E-04
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.50008E-01	2.63099E-01	1.39264E-01	2.32848E-01	1.68710E-01	2.90344E-01	2.22068E-01	4.26758E-01
4	1.12176E-01	2.34233E-01	1.31812E-01	2.10518E-01	1.59878E-01	2.55086E-01	2.11548E-01	3.87410E-01
5	1.35905E-02	3.74300E-02	2.84324E-02	7.02383E-03	2.18231E-02	8.39570E-03	3.48062E-02	9.76786E-03
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	8.81096E-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	5.97582E-04	1.60219E-02	6.05410E-03	0.0	0.0	0.0	0.0	0.0
9	6.22262E-04	1.54541E-03	5.66284E-03	8.85798E-03	0.0	0.0	0.0	0.0
10	4.98083E-03	2.63331E-03	8.38345E-04	4.10529E-04	5.24725E-03	0.0	0.0	0.0
11	2.51745E-03	1.01793E-02	1.65830E-03	0.0	2.28261E-04	2.69556E-03	0.0	0.0
12	1.95859E-03	5.32626E-03	6.24992E-03	1.03172E-03	0.0	1.04812E-04	1.92503E-03	0.0
13	0.0	4.33113E-03	5.16803E-03	3.14989E-03	6.42355E-04	1.53937E-05	5.97384E-05	6.05387E-04
14	0.0	0.0	2.42042E-03	3.11159E-03	1.53187E-03	2.93145E-04	1.71630E-05	2.85807E-05
15	0.0	0.0	0.0	1.58243E-03	1.53786E-03	8.30283E-04	1.40981E-04	8.24688E-06
16	0.0	0.0	0.0	0.0	8.67565E-04	1.02063E-03	4.06158E-04	7.67912E-05
17	0.0	0.0	0.0	0.0	0.0	5.96268E-04	6.98592E-04	1.84861E-04
18	0.0	0.0	0.0	0.0	0.0	0.0	4.09808E-04	4.80137E-04
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.81658E-04
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	POS. 21 THRU POS. 36 SAME AS ABOVE							

POS.	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	1.02526E-03	7.64077E-04	1.57651E-04	1.15923E-03	1.66471E-03	1.51454E-03	3.25099E-03	6.54316E-03
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	8.65463E-01	1.78827E-01	1.30925E-01	5.96862E-01	6.18548E-01	8.66689E-01	9.64236E-01	9.71451E-01
4	7.38837E-01	1.76023E-01	1.28090E-01	5.83675E-01	6.10507E-01	8.53885E-01	9.49089E-01	9.49231E-01
5	3.88741E-02	1.25566E-01	2.03929E-03	2.26728E-02	1.20006E-02	6.36333E-03	1.16649E-02	1.20834E-02
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	POS. 7 THRU POS. 13 SAME AS ABOVE							
14	3.97947E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	1.35696E-05	2.30341E-04	0.0	0.0	0.0	0.0	0.0	0.0
16	3.92837E-06	4.82222E-06	2.56961E-04	0.0	0.0	0.0	0.0	0.0
17	3.70192E-05	1.38460E-06	3.93873E-06	8.80596E-04	0.0	0.0	0.0	0.0
18	8.92688E-05	1.32159E-05	1.16257E-06	3.33128E-06	6.23580E-05	0.0	0.0	0.0
19	3.29992E-04	3.26430E-05	1.07908E-05	9.31445E-07	4.55068E-07	3.07937E-06	0.0	0.0
20	1.93580E-04	1.60430E-04	2.79563E-05	9.87810E-06	1.55642E-07	2.75647E-08	3.20654E-08	0.0
21	0.0	9.41113E-05	1.76632E-04	2.83370E-05	1.38983E-06	7.46296E-09	0.0	0.0
22	0.0	0.0	1.03616E-04	2.76986E-04	4.51152E-06	3.78242E-08	0.0	0.0
23	0.0	0.0	0.0	1.62485E-04	8.64061E-05	3.82672E-07	0.0	0.0
24	0.0	0.0	0.0	0.0	5.06877E-05	1.92799E-05	7.67180E-08	0.0
25	0.0	0.0	0.0	0.0	0.0	1.13100E-05	4.30191E-06	1.57217E-08
26	0.0	0.0	0.0	0.0	0.0	0.0	2.52359E-06	8.81584E-07

```
  27  0.0           0.0           0.0           0.0           0.0           0.0           0.0           5.17155E-07
  28  0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
      POS.   29 THRU POS.   36 SAME AS ABOVE

POS.   GRP. 25       GRP. 26       GRP. 27       GRP. 28       GRP. 29       GRP. 30       GRP. 31       GRP. 32
   1  1.11030E-02   1.53350E-02   2.47805E-02   9.31345E-02   8.59659E-02   2.20960E-02   6.52320E-03   3.44841E-01
   2  0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0
   3  9.76294E-01   9.80527E-01   9.90654E-01   1.06153E+00   2.37511E-01   3.08019E-01   5.32623E-01   1.30217E+00
   4  9.30935E-01   9.06116E-01   9.62668E-01   9.64900E-01   1.86385E-02   6.24672E-02   2.81690E-01   9.55242E-01
   5  1.56894E-02   3.39976E-02   5.88175E-02   2.24187E-03   8.24177E-02   5.57772E-02   1.63835E-01   2.44409E-01
   6  0.0           0.0           0.0           0.0           2.19694E-02   5.38546E-02   5.64261E-02   5.96206E-02
   7  0.0           0.0           0.0           0.0           1.35954E-02   1.42608E-02   2.55727E-02   2.07029E-02
   8  0.0           0.0           0.0           0.0           9.84350E-03   8.82506E-03   6.80700E-03   1.69958E-02
   9  0.0           0.0           0.0           0.0           5.80093E-03   6.38963E-03   4.21239E-03   4.47009E-03
  10  0.0           0.0           0.0           0.0           2.88222E-03   3.76551E-03   3.04991E-03   2.76623E-03
  11  0.0           0.0           0.0           0.0           1.34273E-03   1.87091E-03   1.79735E-03   2.00285E-03
  12  0.0           0.0           0.0           0.0           1.44793E-03   8.71595E-04   8.93021E-04   1.18031E-03
  13  0.0           0.0           0.0           0.0           1.01223E-03   9.92553E-04   4.16031E-04   5.86438E-04
  14  0.0           0.0           0.0           0.0           1.31763E-04   6.00137E-04   4.86553E-04   2.73203E-04
  15  0.0           0.0           0.0           0.0           6.77957E-04   1.08077E-04   3.43694E-04   4.14806E-04
  16  0.0           0.0           0.0           0.0           7.97563E-04   4.43207E-04   4.90746E-05   5.28529E-05
  17  0.0           0.0           0.0           0.0           3.49639E-04   8.24097E-04   2.12718E-04   2.87466E-05
  18  0.0           0.0           0.0           0.0           5.68805E-04   4.14542E-04   3.39535E-04   1.56034E-04
  19  0.0           0.0           0.0           0.0           4.67917E-04   6.45440E-04   1.65245E-04   3.19364E-04
  20  0.0           0.0           0.0           0.0           3.48448E-04   5.30952E-04   2.79041E-04   1.53370E-04
  21  0.0           0.0           0.0           0.0           4.11304E-04   3.95388E-04   2.29549E-04   2.17846E-04
  22  0.0           0.0           0.0           0.0           3.31493E-04   4.82621E-04   1.70940E-04   1.79201E-04
  23  0.0           0.0           0.0           0.0           3.3311BE-04   3.91604E-04   2.11479E-04   1.33447E-04
  24  0.0           0.0           0.0           0.0           3.46630E-04   3.95524E-04   1.72049E-04   1.62765E-04
  25  0.0           0.0           0.0           0.0           3.38955E-04   4.11714E-04   1.73788E-04   1.32050E-04
  26  3.33098E-09   0.0           0.0           0.0           2.17347E-04   4.02598E-04   1.80902E-04   1.32525E-04
  27  1.86783E-07   1.16122E-09   0.0           0.0           1.34399E-04   2.58157E-04   1.76897E-04   1.37887E-04
  28  1.09571E-07   6.57953E-08   1.60135E-09   0.0           9.47469E-05   1.59634E-04   2.73088E-02   1.34834E-04
  29  0.0           3.85970E-08   9.07331E-08   1.88666E-10   7.14817E-05   1.36855E-04   5.03069E-02   8.66594E-05
  30  0.0           0.0           5.32255E-08   1.06899E-08   4.84435E-05   7.53369E-03   7.02043E-02   5.34632E-05
  31  0.0           0.0           0.0           6.27092E-09   3.05888E-03   6.13512E-02   8.77199E-02   3.76897E-05
  32  0.0           0.0           0.0           0.0           2.82243E-02   1.09618E-01   1.47542E-01   2.84349E-05
  33  0.0           0.0           0.0           0.0           0.0           1.31152E-01   1.86041E-01   1.92706E-05
  34  0.0           0.0           0.0           0.0           0.0           0.0           1.96611E-01   4.50519E-03
  35  0.0           0.0           0.0           0.0           0.0           0.0           0.0           1.39502E-02
  36  0.0           0.0           0.0           0.0           0.0           0.0           0.0           0.0

POS.   GRP. 33
   1  3.66227E+01
   2  0.0
   3  3.98639E+01
   4  3.24119E+00
   5  2.08699E-03
   6  0.0
      POS.    7 THRU POS.    8 SAME AS ABOVE
   9  3.76388E-02
  10  9.85438E-03
  11  6.09817E-03
  12  4.41528E-03
  13  2.60199E-03
  14  1.29281E-03
  15  6.02281E-04
  16  7.05990E-04
  17  9.48150E-05
  18  5.41482E-05
  19  3.34895E-04
  20  4.95524E-04
```

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 *** FEW GROUP CROSS SECTIONS ***

 INPUT NODE NAME = EGRP FX16 AIRO
 OUTPUT NODE NAME= SB32 FX16 CAIR   (CAIR AIR  (ENDF/B-IV) COLLAPSED BY ZONE 2 FLUX OF DIAC
 WEIGHTING FLUX  = ZONE   2
 IGM=  33  IHM=  36  IHT=   3  IHS=   4  NUP=   0

*** MACRO CROSS SECTION WAS OUPUT TO A DATA POOL
    NODE NAME = SB32-FX16-CAIR
```

**** ISOTROPIC CROSS SECTION TABLE ****

POS.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	1.00808E-05	9.00501E-06	1.66731E-05	8.02689E-06	4.12046E-06	3.53436E-06	4.02822E-07	3.20843E-06
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	7.26641E-05	7.04678E-05	1.02098E-04	7.57759E-05	9.40779E-05	1.15080E-04	1.20281E-04	1.22573E-04
4	3.52551E-05	4.38030E-05	5.41816E-05	3.93860E-05	4.31825E-05	7.52488E-05	8.17786E-05	4.93259E-05
5	0.0	1.53971E-05	1.36979E-05	3.07351E-05	2.78101E-05	4.67710E-05	3.62968E-05	3.77395E-05
6	0.0	0.0	3.07310E-06	8.02295E-07	7.61996E-08	5.12300E-07	0.0	0.0
7	0.0	0.0	0.0	3.46898E-06	6.77214E-07	1.57574E-07	4.19155E-10	0.0
8	0.0	0.0	0.0	0.0	1.91536E-06	8.22956E-07	9.11699E-08	6.71193E-09
9	0.0	0.0	0.0	0.0	0.0	1.70114E-06	6.97252E-07	2.66305E-08
10	0.0	0.0	0.0	0.0	0.0	0.0	8.05701E-07	3.55739E-07
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.95547E-07
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	POS. 13 THRU POS. 36 SAME AS ABOVE							

POS.	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	2.51508E-06	1.04284E-06	6.57087E-08	6.51561E-08	6.50826E-08	6.53617E-08	6.65094E-08	6.89011E-08
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.07277E-04	1.87672E-04	1.72929E-04	1.87251E-04	2.05863E-04	2.23640E-04	2.47207E-04	2.77779E-04
4	2.82473E-05	1.32546E-04	1.26650E-04	1.25758E-04	1.25050E-04	1.67994E-04	1.99241E-04	1.82951E-04
5	4.72487E-05	7.65154E-05	5.40763E-05	4.62117E-05	6.14280E-05	8.07482E-05	5.55809E-05	4.78978E-05
6	3.60323E-07	2.27885E-05	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	5.08151E-09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	7.85335E-09	1.41465E-08	0.0	0.0	0.0	0.0	0.0	0.0
11	1.32151E-07	3.51975E-08	6.75504E-09	0.0	0.0	0.0	0.0	0.0
12	1.17025E-07	2.49497E-07	4.33533E-08	3.02481E-09	0.0	0.0	0.0	0.0
13	0.0	2.51241E-07	1.11023E-07	3.28596E-08	1.50309E-09	0.0	0.0	0.0
14	0.0	0.0	1.43789E-07	4.96357E-08	1.71331E-08	7.97146E-10	0.0	0.0
15	0.0	0.0	0.0	7.75632E-08	2.54911E-08	8.72330E-09	4.84968E-10	0.0
16	0.0	0.0	0.0	0.0	4.17575E-08	1.27099E-08	4.33613E-09	3.11458E-10
17	0.0	0.0	0.0	0.0	0.0	2.32138E-08	6.73271E-09	2.13059E-09
18	0.0	0.0	0.0	0.0	0.0	0.0	1.43540E-08	3.66862E-09
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.14556E-09
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	POS. 21 THRU POS. 36 SAME AS ABOVE							

POS.	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	7.46265E-08	8.26885E-08	9.62974E-08	1.40487E-07	2.52972E-07	5.61862E-07	1.20459E-06	2.43258E-06
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.00026E-04	3.20344E-04	3.37825E-04	3.62985E-04	3.94717E-04	4.31274E-04	4.57531E-04	4.67721E-04
4	2.49329E-04	1.99465E-04	2.14116E-04	3.27491E-04	3.83306E-04	4.11220E-04	4.34008E-04	4.35465E-04
5	9.47590E-05	5.02617E-05	1.20796E-04	1.23611E-04	3.53436E-05	1.11251E-05	1.94131E-05	2.20636E-05
6	0.0	0.0	3.60878E-07	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	POS. 8 THRU POS. 16 SAME AS ABOVE							
17	1.93742E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	1.10306E-09	8.54255E-11	0.0	0.0	0.0	0.0	0.0	0.0
19	1.99237E-09	4.19893E-10	8.69077E-11	0.0	0.0	0.0	0.0	0.0
20	4.84239E-09	7.64250E-10	3.57113E-10	1.10400E-10	0.0	0.0	0.0	0.0
21	0.0	2.87323E-09	7.75768E-10	3.87242E-10	1.61225E-11	0.0	0.0	0.0
22	0.0	0.0	1.94219E-09	8.08120E-10	4.57371E-11	1.20775E-12	0.0	0.0
23	0.0	0.0	0.0	1.69425E-09	1.04284E-10	3.34207E-12	7.01261E-14	0.0
24	0.0	0.0	0.0	0.0	2.15301E-10	7.42751E-12	1.11261E-13	0.0
25	0.0	0.0	0.0	0.0	0.0	1.21677E-11	1.11489E-13	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	3.73123E-15	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.79453E-16
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

POS. 29 THRU POS. 36 SAME AS ABOVE

POS.	GRP. 25	GRP. 26	GRP. 27	GRP. 28	GRP. 29	GRP. 30	GRP. 31	GRP. 32
1	4.11387E-06	5.68865E-06	9.17206E-06	3.40692E-05	4.25433E-06	1.04265E-06	1.76363E-08	3.75923E-07
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	4.70413E-04	4.74689E-04	4.78202E-04	5.07955E-04	3.09187E-05	5.12382E-05	9.27631E-05	1.49960E-04
4	4.03076E-04	3.57663E-04	4.62042E-04	4.68461E-04	3.29805E-06	1.10136E-05	4.80351E-05	1.49408E-04
5	2.87831E-05	6.23748E-05	1.08043E-04	3.91281E-06	1.72114E-06	9.80119E-06	2.87235E-05	4.47103E-05
6	0.0	0.0	0.0	0.0	4.67773E-07	1.16163E-06	9.92428E-06	1.04585E-05
7	0.0	0.0	0.0	0.0	2.90336E-07	3.15702E-07	9.58327E-09	3.64089E-06
8	0.0	0.0	0.0	0.0	2.09872E-07	1.95949E-07	2.60075E-09	0.0
9	0.0	0.0	0.0	0.0	1.23974E-07	1.41642E-07	1.61465E-09	0.0
10	0.0	0.0	0.0	0.0	6.15077E-08	8.36660E-08	1.16729E-09	0.0
11	0.0	0.0	0.0	0.0	2.87018E-08	4.15024E-08	6.89182E-10	0.0
12	0.0	0.0	0.0	0.0	1.28845E-08	1.93506E-08	3.41815E-10	0.0
13	0.0	0.0	0.0	0.0	7.15234E-09	8.65063E-09	1.59378E-10	0.0
14	0.0	0.0	0.0	0.0	4.83720E-09	4.74551E-09	7.13358E-11	0.0
15	0.0	0.0	0.0	0.0	4.02825E-09	3.14870E-09	3.92027E-11	0.0
16	0.0	0.0	0.0	0.0	3.40142E-09	2.58032E-09	2.61165E-11	0.0
17	0.0	0.0	0.0	0.0	2.87826E-09	2.13141E-09	2.14752E-11	0.0
18	0.0	0.0	0.0	0.0	2.29001E-09	1.75020E-09	1.78288E-11	0.0
19	0.0	0.0	0.0	0.0	1.88241E-09	1.50768E-09	1.47393E-11	0.0
20	0.0	0.0	0.0	0.0	1.55404E-09	9.85513E-10	1.11718E-11	0.0
21	0.0	0.0	0.0	0.0	1.22461E-09	7.11748E-10	8.59854E-12	0.0
22	0.0	0.0	0.0	0.0	1.08288E-09	4.15293E-10	6.43175E-12	0.0
23	0.0	0.0	0.0	0.0	1.05948E-09	1.45588E-10	4.11619E-12	0.0
24	0.0	0.0	0.0	0.0	1.07983E-09	1.28842E-12	2.03084E-12	0.0
25	0.0	0.0	0.0	0.0	1.09924E-09	4.14028E-13	8.69243E-13	0.0
26	0.0	0.0	0.0	0.0	1.19363E-09	3.81171E-13	7.67608E-13	0.0
27	0.0	0.0	0.0	0.0	1.51463E-09	3.22603E-13	7.06690E-13	0.0
28	1.24670E-17	0.0	0.0	0.0	1.22908E-09	2.69061E-13	5.98107E-13	0.0
29	0.0	2.26345E-18	0.0	0.0	8.05150E-10	2.29122E-13	4.98839E-13	0.0
30	0.0	0.0	1.30264E-18	0.0	9.12017E-10	4.31200E-08	4.24792E-13	0.0
31	0.0	0.0	0.0	1.46336E-20	8.87360E-07	8.60179E-07	3.68296E-13	0.0
32	0.0	0.0	0.0	0.0	8.51637E-06	5.69761E-06	1.41333E-07	0.0
33	0.0	0.0	0.0	0.0	0.0	9.81193E-06	2.47581E-06	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0	4.40946E-06	9.36354E-10
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.56645E-07
36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

POS.	GRP. 33
1	1.02700E-04
2	0.0
3	3.91755E-04
4	2.89056E-04
5	1.76038E-07
6	0.0
	POS. 7 THRU POS. 36 SAME AS ABOVE

*** INFORMATION OF DATA POOL USAGE ***
LOGICAL UNIT NO. = 91
DATA SET NAME = J1446.POOL87.DATA
NO. OF WRITTEN RECORDS = 70
REMAINS RECORDS = 9510

D.7 Sample Problem for ESPRIT

```
MEMBER NAME > B:EMCROS.TXT    ------------------------------------------------ PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.2 I.3 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC LMGO,LM='J1446.FCSTEP2X'
    8 :  //FT08F001 DD DUMMY
    9 :  //FT11F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,20)),
   10 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   11 :  //FT13F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,20)),
   12 :  //   DCB=(LRECL=16804,BLKSIZE=16804,RECFM=F)
   13 :  //FT14F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,20)),
   14 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   15 :  //FT16F001 DD DSN=&&F6,UNIT=WK10,SPACE=(TRK,(50,20)),
   16 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   17 :  //FT17F001 DD DSN=&&F7,UNIT=WK10,SPACE=(TRK,(50,20)),
   18 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   19 :  //FT18F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,20)),
   20 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   21 :  //FT21F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,20)),
   22 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   23 :  //FT22F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(50,20)),
   24 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   25 :  //FT23F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(50,20)),
   26 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   27 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   28 :  //SYSIN DD *
   29 :   FAIR-CROSS STEP-2 FOR GAMMA-RAY SKYSHINE PROBLEM
   30 :   &UNIT FXSN=91 &END
   31 :   1¥¥ 2   4   0   9  16  4HG09    1   1   T
   32 :   3**  1.660E+6  1.330E+6  1.000E+6  0.800E+6  0.600E+6  0.400E+6
   33 :        0.300E+6  0.200E+6  0.100E+6  0.050E+6  T
   34 :  AIR  CROSS SECTION BY EMPIRICAL FORMULA
   35 :   4¥¥  4HAIR   0  0  1  1  0
   36 :   5¥¥    6     7     8     1
   37 :   8**    6.0   7.0   8.0   1.0
   38 :   9**   7.5847-9  3.9099-5  1.0537-5  7.1991-9
   39 :  10**    300.0     300.0     300.0     300.0
   40 :    T
   41 :  17¥¥    10  0  0  0  2  2  T
   42 :  29¥¥     0   1   0   0   T
   43 :  ++
   44 :  //
   45 :   FAIR-CROSS STEP-2 FOR GAMMA-RAY SKYSHINE PROBLEM
   46 :   &UNIT FXSN=91 &END
   47 :   1¥¥ 2   3   0   9  16  4HG09    1   1   T
   48 :   3**  1.660E+6  1.330E+6  1.000E+6  0.800E+6  0.600E+6  0.400E+6
   49 :        0.300E+6  0.200E+6  0.100E+6  0.050E+6  T
   50 :  CONC CROSS SECTION BY EMPIRICAL FORMULA
   51 :   4¥¥  4HCONC  0  0  1  1  0
   52 :   5¥¥    1     8    14
   53 :   8**    1.0   8.0  14.0
   54 :   9**   5.5183-3  4.2401-2  2.3250-2
   55 :  10**    300.0     300.0     300.0
   56 :    T
   57 :  17¥¥    10  0  0  0  2  2  T
   58 :  29¥¥     0   1   0   0   T
   59 :  ++
   60 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
MEMBER NAME > B:FDEMDOSE.TXT  ------------------------------------------------  PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.2 I.2 P.0 W.0 C.3 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC FORT77,SO='J1446.FDEM',A='ELM(*),NOS'
    8 :  // EXEC LKED77,PRVLIB='J1446.DPOOL2'
    9 :  // EXEC GO,ORECFM=FA,OBSIZE=137
   10 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,10)),
   11 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(50,10)),
   13 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,10)),
   15 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,10)),
   17 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   19 :  //SYSIN DD *
   20 :  FDEM REGISTRATION OF DOSE CONVERSION FACTOR
   21 :   &UNIT   INFX=91,RESD=91 &END
   22 :   1¥¥  5    0   9  4HG09    0  9  4HG09   0  1  1  0  0  5  1  5R0  T
   23 :   T
   24 :  DOSE  PHOTON DOSE CONVERSION FACTOR
   25 :      0
   26 :      1
   27 :    PHOTON DOSE CONVERSION FACTOR
   28 :   2.30000E-03 2.10000E-03 1.80000E-03 1.40000E-03 1.00000E-03 7.10000E-04
   29 :   4.90000E-04 2.70000E-04 1.50000E-04
   30 :  ++
   31 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
MEMBER NAME > B:ESPRIT.TXT    ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
   1 :  //JCLG JOB
   2 :  // EXEC JCLG
   3 :  //SYSIN DD DATA,DLM='++'
   4 :  // JUSER ########,##.######,####.##
   5 :   T.7 I.5 P.0 W.3 C.5 SRP
   6 :   OPTP PASSWORD=########
   7 :  //FORT EXEC FORT77
   8 :        SUBROUTINE ALOCAT(LOC,SUB)
   9 :        DIMENSION D(300000)
  10 :        IF(LOC.GT.0) GO TO 10
  11 :        LOC=300000
  12 :        CALL DTLIST
  13 :        GO TO 999
  14 :     10 CONTINUE
  15 :        CALL SUB(D,LOC)
  16 :    999 RETURN
  17 :        E   N   D
  18 :  //F2     EXEC FORT77,SO='J1446.ESPRIT',A='ELM(*),NOS',DISP=MOD
  19 :  //LINK   EXEC LKED77,PRVLIB='J1446.DPOOL2'
  20 :  //ESPRIT EXEC GO,ORECFM=FA,OBSIZE=137,SYSOUT=*
  21 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(100,100)),
  22 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  23 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(100,100)),
  24 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  25 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(300,100)),
  26 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  27 :  //FT04F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(300,100)),
  28 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  29 :  //FT09F001 DD DSN=&&F9,UNIT=WK10,SPACE=(TRK,(100,100)),
  30 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  31 :  //FT10F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(100,100)),
  32 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  33 :  //FT12F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(100,100)),
  34 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  35 :  //FT13F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(100,100)),
  36 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  37 :  //FT14F001 DD DSN=&&FD,UNIT=WK10,SPACE=(TRK,(100,100)),
  38 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  39 :  //FT15F001 DD DSN=&&FE,UNIT=WK10,SPACE=(TRK,(100,100)),
  40 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  41 :  //FT30F001 DD DSN=&&FF,UNIT=WK10,SPACE=(TRK,(100,100)),
  42 :  //  DCB=(LRECL=18632,BLKSIZE=18636,RECFM=VBS)
  43 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
  44 :  //SYSIN DD *
  45 :  ESPRIT SAMPLE PROBLEM NO.1
  46 :   &UNIT FXSN=91,RESD=91,FLX1=0,FLX2=0 &END
  47 :  60¥¥    0    9    3    1    0       1
  48 :  61¥¥    0   16    2   41   29       9    3    4   12    0
  49 :          0    2    2    1   48       1    1    0    0    0
  50 :          1   60   60    0   -6       2    0    0    0    0
  51 :          0    0    2    0    0       0    0    0    0    0
  52 :          0    0    0    0    1       1    0    0    0    0
  53 :          2    2    4    0    0       0    0    0    0    0
  54 :          0
  55 :  62¥¥    2    3    4   14   15       9   10    0   12   13
  56 :          1   65    1    5
  57 :  63**  0.0    0.005   0.005   0.0    0.0
  58 :        0.0    0.0     0.0     0.0    0.0
  59 :        0.0  660.0     0.237   1.0  100.0
  60 :        0.0    0.0     0.0
  61 :   T
  62 :   7**   -.3086067 -.2182179  .2182179 -.6172134 -.5773503
```

```
MEMBER NAME > B:ESPRIT.TXT    ---------------------------------------------  PAGE :  2
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
   63 :          -.2182179  1M2
   64 :          -.8164966 -.7867958 -.5773503 -.2182179  1M3
   65 :          -.9759001 -.9511897 -.7867958 -.5773503 -.2182179  1M4
   66 :          1Q24
   67 :        3R-.9511897  5R-.7867958  7R-.5773503  9R-.2182179
   68 :        3R.9511897   5R.7867958   7R.5773503   9R.2182179
   69 :          T
   70 :   6**   0.0         2R.02665019  0.0  4R.02529318  0.0
   71 :           .02529318   .01829035   .02529318  1N3
   72 :          0.0          .02665019    .02529318   .02529318   .02665019
   73 :          1N4   1Q24    T
   74 :  13**  4HG09  4HFX16  4HCONC  4HAIR
   75 :    T
   76 :   3**  F0.0
   77 :    T
   78 :   1**  F0.0
   79 :   2**   0.0     300.0      600.0     760.0   81763.03    781.03
   80 :      1000.0  312000.0  9110000.0   60000.0
   81 :   4**   0.0    7110.0   141410.0     710.0  111000.0  313000.0
   82 :     11000.0 1114000.0  1122000.0   28000.0 3132000.0   56000.0
   83 :   5**   1.0  F0.0
   84 :   8**   9R2  15R1  17R2   2Q41
   85 :              24R1  17R2   9Q41
   86 :         F2
   87 :   9**   1    2
   88 :  33**   1.0   -1.0
   89 :  34**   1.0    1.0
   90 :  36**   1
   91 :  38**   4HG09   4HRESD  4HDOSE
   92 :    T
   93 :  ++
   94 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
1* ARRAY      8 ENTRIES READ
 T
3* ARRAY     10 ENTRIES READ
 T
```

**** MAIN TITLE ****

FAIR-CROSS STEP-2 FOR GAMMA-RAY SKYSHINE PROBLEM

**** MAIN CONTROL PARAMETERS ****

SELECTION OF THE CALCULATIONAL STEP	---	2
NO. OF NUCLIDE OR MIXTURE TO BE PROCESSED	---	4
NO. OF NEUTRON ENERGY GROUPS	---	0
NO. OF GAMMA-RAY ENERGY GROUPS	---	9
NO. OF ANGULAR MESH IN CROSS SECTION TABLE	---	16
MODE NAME OF ENERGY GROUP STRUCTURE	---	G09
TYPE OF INPUT NEUTRON GROUP STRUCTURE	---	1
TYPE OF INPUT GAMMA-RAY GROUP STRUCTURE	---	1

*** MATERIAL COMPOSITION IN THIS REGION ***

	MATERIAL NO. ENDF/B	MATERIAL NO. F-TABLE	ATOMIC NUMBER	ATOM DENSITY	TEMP.
1	6	0	6.	7.5846E-09	300.0
2	7	0	7.	3.9099E-05	300.0
3	8	0	8.	1.0537E-05	300.0
4	1	0	1.	7.1990E-09	300.0

```
    CROSS SECTION TABLE

 POS     GRP  1        GRP  2        GRP  3        GRP  4        GRP  5        GRP  6        GRP  7        GRP  8
   1  1.19862E-07  1.46151E-08  4.69976E-09  8.33504E-09  2.00596E-08  5.21031E-08  1.48542E-07  8.78511E-07
   2  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
   3  6.17627E-05  7.02873E-05  7.97605E-05  8.97761E-05  1.04262E-04  1.20428E-04  1.37088E-04  1.64855E-04
   4  6.25775E-06  1.00014E-05  1.03109E-05  1.64109E-05  2.98244E-05  3.12591E-05  5.43860E-05  1.24957E-04
   5  0.0          1.29063E-05  1.26276E-05  2.03111E-05  3.13750E-05  2.87443E-05  5.23911E-05  8.25531E-05
   6  0.0          0.0          7.69331E-06  1.22023E-05  1.91319E-05  1.50930E-05  2.97932E-05  3.67255E-05
   7  0.0          0.0          0.0          8.16256E-06  1.33870E-05  1.13308E-05  2.21960E-05  1.58797E-05
   8  0.0          0.0          0.0          0.0          1.01264E-05  9.01179E-06  1.81403E-05  4.69273E-06
   9  0.0          0.0          0.0          0.0          0.0          7.32483E-06  1.30425E-05  5.30812E-07
  10  0.0          0.0          0.0          0.0          0.0          0.0          9.17171E-06  0.0
  11  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
  12  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0

 POS     GRP  9
   1  7.97723E-06
   2  0.0
   3  2.11187E-04
   4  2.03209E-04
   5  3.90201E-05
   6  0.0
      POS     7 THRU  POS    12 SAME AS ABOVE

 **** MACRO CROSS SECTION TABLE WAS OUTPUT TO A DATA POOL
      NODE NAME = G09 -FX16-AIR -

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.        =     91
    DATA SET NAME           = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS  =     12
    REMAINS RECORDS         =  10203
```

```
    *** MATERIAL COMPOSITION IN THIS REGION ***

          ---- MATERIAL NO. ----      ATOMIC        ATOM          TEMP.
            ENDF/B      F-TABLE       NUMBER       DENSITY

        1         1            0          1.    5.5183E-03       300.0

        2         8            0          8.    4.2401E-02       300.0

        3        14            0         14.    2.3250E-02       300.0
```

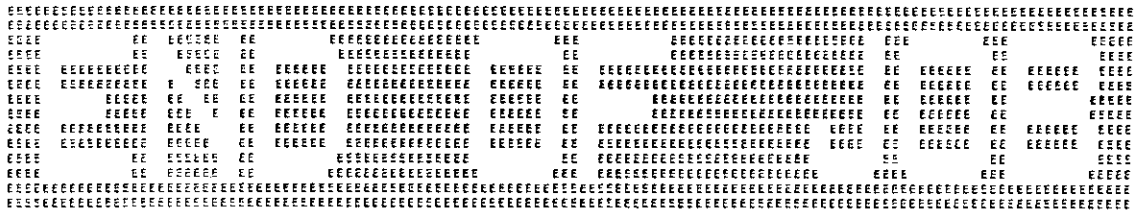
```
    CROSS SECTION TABLE

 POS     GRP  1        GRP  2        GRP  3        GRP  4        GRP  5        GRP  6        GRP  7        GRP  8
   1  3.59326E-04  7.05293E-05  5.98427E-05  1.06378E-04  2.55673E-04  6.60759E-04  1.86790E-03  1.08391E-02
   2  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
   3  1.15800E-01  1.31705E-01  1.49514E-01  1.68418E-01  1.95957E-01  2.27150E-01  2.60498E-01  3.24235E-01
   4  1.17643E-02  1.88113E-02  1.94582E-02  3.09933E-02  5.63973E-02  5.96690E-02  1.04097E-01  2.40353E-01
   5  0.0          2.41597E-02  2.36379E-02  3.80209E-02  5.87318E-02  5.38073E-02  9.80724E-02  1.54533E-01
   6  0.0          0.0          1.44013E-02  2.28418E-02  3.58135E-02  2.82529E-02  5.57707E-02  6.87474E-02
   7  0.0          0.0          0.0          1.52797E-02  2.50595E-02  2.12104E-02  4.15493E-02  2.97257E-02
   8  0.0          0.0          0.0          0.0          1.89559E-02  1.68694E-02  3.39574E-02  8.78445E-03
   9  0.0          0.0          0.0          0.0          0.0          1.37115E-02  2.44147E-02  9.93639E-04
  10  0.0          0.0          0.0          0.0          0.0          0.0          1.71683E-02  0.0
  11  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
  12  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0

 POS     GRP  9
   1  9.52321E-02
   2  0.0
   3  4.97579E-01
   4  4.02547E-01
   5  7.30427E-02
   6  0.0
      POS     7 THRU  POS    12 SAME AS ABOVE

 **** MACRO CROSS SECTION TABLE WAS OUTPUT TO A DATA POOL
      MODE NAME = G09 -FX16-CONC-

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.          =     91
    DATA SET NAME             = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS    =     10
    REMAINS RECORDS           =  10189
```



```
                TOTAL CPU TIME ---    0.0  MIN
```

```
 1V ARRAY     19 ENTRIES READ

 T

                          ***  LIST OF INPUT PARAMETERS  ***

                   TITLE = FDEM REGISTRATION OF DOSE CONVERSION FACTOR

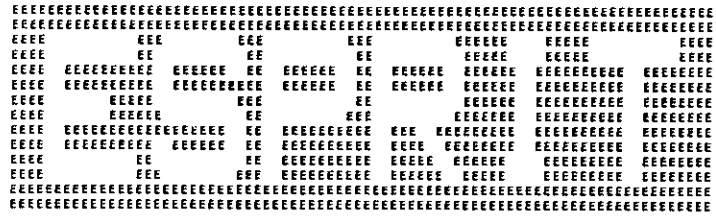
 ICAL    KIND OF COLLAPSING                          5    ING     NO. OF FINE NEUTRON GROUP                   0
 IGG     NO. OF FINE GAMMA GROUP                     9    NODE1   NODE NAME OF FINE GROUP STRUCTURE         G09
 INGF    NO. OF FEW NEUTRON GROUP                    0    IGGF    NO. OF FEW GAMMA GROUP                      9
 NODE2   NODE NAME OF FEW GROUP STRUCTURE          G09    IFLX    KIND OF WEIGHTING FLUX                      0
 NTP     NO. OF INPUT MATERIAL OR RESPONSE FUNC.     1    NTPO    NO. OF OUTPUT MATERIAL OR RESPONSE FUNC.    1
 IZM     NO. OF REGION IN DIAC  (IFLX=1)             0    ICELL   CELL AVERAGE ( 0/1 = NO/YES)              0
 IRESPI  INPUT FORM OF RESPONSE FUNCTION             5    IRESPO  OUTPUT FORM OF RESPONSE FUNCTION           1
 IPRT    PRINT OPTION                                0
 NN1  LENGTH OF INTERP. TABLE FOR NEUTRONS (IFLX=4)  0    NN2  LENGTH OF FLUX TABLE FOR NEUTRONS (IFLX=4)   0
 NG1  LENGTH OF INTERP. TABLE FOR GAMMAS(IFLX.NE.1)  0    NG2  LENGTH OF FLUX TABLE FOR GAMMAS (IFLX.NE.1)  0

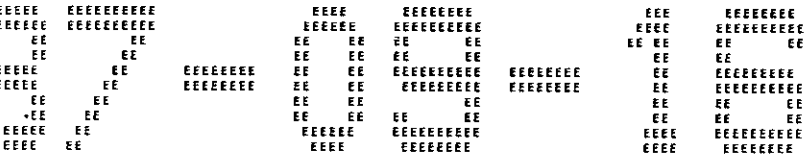
 T

   ***  FEW GROUP RESPONSE FUNCTIONS  ***
 1    PHOTON DOSE CONVERSION FACTOR
      INPUT FUNCTION
         1  2.3000E-03     2  2.1000E-03     3  1.8000E-03     4  1.4000E-03     5  1.0000E-03     6  7.1000E-04
         7  4.9000E-04     8  2.7000E-04     9  1.5000E-04
      OUTPUT NAME = DOSE  PHOTON DOSE CONVERSION FACTOR
      COLLAPSED FUNCTION
         1  2.3000E-03     2  2.1000E-03     3  1.8000E-03     4  1.4000E-03     5  1.0000E-03     6  7.1000E-04
         7  4.9000E-04     8  2.7000E-04     9  1.5000E-04

*** RESPONSE FUNCTION WAS OUTPUT TO A DATA POOL
    NODE NAME = G09 -RESP-DOSE

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.          =     91
    DATA SET NAME             = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS    =      2
    REMAINS RECORDS           =  10187
```





```
ESPRIT SAMPLE PROBLEM NO.1

 ING =     0          NUMBER OF NEUTRON GROUP
 IGG =     9          NUMBER OF GAMMA-RAY GROUP
 NR1 =     3          0/1/2/3=NO EFFECT/REACTION RATE CAL. USING RESPONSE FUNCTION FROM CARDS/TAPE(FT51)/DATA POOL(RESD)
 NR2 =     1          NUMBER OF AXIAL INTERVALS TO BE PRINTED THE REACTION RATE
 NR3 =     0          NUMBER OF NEUTRON RESPONSE FUNCTIONS
 NR4 =     1          NUMBER OF GAMMA-RAY RESPONSE FUNCTIONS

 AQ2 =     0          0/1 = FORWARD/ADJOINT CALCULATION
 AQ3 =    16          NUMBER OF ANGLES IN ANGULAR CROSS SECTION
 IZM =     2          NUMBER OF MATERIAL ZONES
  IM =    41          NUMBER OF RADIAL INTERVALS
  JM =    29          NUMBER OF AXIAL  INTERVALS

 IGM =     9          NUMBER OF ENERGY GROUPS
 IHT =     3          POSITION OF TOTAL CROSS SECTION
 IHS =     4          POSITION OF SELF-SCATTER CROSS SECTION
 ITL =    12          CROSS SECTION TABLE LENGTH PER GROUP
 MQ1 =     0          NOT USED

 MCR =     0          NOT USED
 MTP =     2          NUMBER OF MATERIALS FROM NLIB
  MT =     2          TOTAL NUMBER OF MATERIALS
 IPS =     1          0/1 = FLUXES AND MOMENTS IN CORE/STORED EXTERNALLY
 AQ4 =    48          MAXIMUM NUMBER OF ANGLES IN ANGULAR QUADRATURE

 IGE =     1          0/1/2 = X-Y/R-Z/R-THETA GEOMETRY
 BQ1 =     1          LEFT BOUNDARY CONDITION, 0/1/2/4/6 = VACUUM/REFLECTED/PERIODIC/BOUNDARY SOURCE(CARDS)/BOUNDARY SOURCE(TAPE)
 BQ2 =     0          RIGHT BOUNDARY CONDITION, 0/1/2/3/4/5/6 = 0,1,2,4,6 SAME AS FOR BQ1, 3/WHITE, 5/ALBEDO
 BQ4 =     0          BOTTOM BOUNDARY CONDITION, SAME AS FOR BQ2
 BQ3 =     0          TOP BOUNDARY CONDITION, SAME AS FOR BQ2

 DQS =     1          OUTER ITERATION MAXIMUM
 SQ4 =    20          INITIAL INNER ITERATION MAXIMUM, USED UNTIL ABS(LAMBDA-1.0).LT.10**EPS
 GQ7 =    20          INNER ITERATION MAXIMUM PER GROUP (IF NEGATIVE, LIMIT IS IN 28W ARRAY)
 FXT =     0          0/1/2/3/4 = MIXED/LINEAR/STEP/WEIGHTED/MIXED LINEAR WEIGHTED
 IQ4 =    -6          0/1/2/3/4/5/6/-6 = Q/K/ALPHA/C/Z/BNDRY SRC/USE 1ST COLL SRC ON NPSQ/CALC ANALYTIC 1ST COLL SRC, WRITE ON NPSQ

 IP1 =     2          0/1/2   = REGULAR SCALING/OVER-RELAXATION/SPACE DEPENDENT
 SQ2 =     0          0/1/2 = NO PARAMETRIC EIGENVALUE SEARCH/K/ALPHA
  I2 =     0          NUMBER OF RADIAL ZONES FOR ZONE THICKNESS SEARCH
  J2 =     0          NUMBER OF AXIAL  ZONES FOR ZONE THICKNESS SEARCH
 IZC =     0          0/N = NO EFFECT/ENTER N ZONE NUMBERS IN 32W ARRAY FOR ZONES OF CONVERGENCE

 IQ4 =     0          NOT USED
 ISC =     0          0/1 = NO EFFECT/ENTER NUMBER OF QUADRATURE ANGLES PER GROUP BY GROUP IN 29W ARRAY, ZERO FOR DIFFUSION THEORY
 IZ3 =     2          0/N = NO EFFECT/ENTER N NUMBERS IN 33* AND 34* ARRAYS, ANGULAR DISTRIBUTION OF POINT SOURCE FOR IQ4=-6
 MQ7 =     0          FLUX INPUT, 0/1/2/3/4/5 = A(G)/N(I,J)*G/A(G)*N(I,J)/A(G)*B(I)*C(J)/(B(I)*C(J))*G/FLUX GUESS ON UNIT FSQ
 MQ6 =     0          DISTRIBUTED SOURCE INPUT, SAME AS MQ7, EXCEPT              S=SOURCE ON LOGICAL UNIT NBSQ

 IZ1 =     0          -N/N = INTERIOR BOUNDARY SOURCE AT RADIAL BOUNDARY N INPUT FROM TAPE/CARDS
 IZ2 =     0          -N/N = INTERIOR BOUNDARY SOURCE AT AXIAL BOUNDARY N INPUT FROM TAPE/CARDS
 IB5 =     0          -N/N = ANGULAR FLUX LEFT/RIGHT AT RADIAL BOUNDARY N WRITTEN ON NBFT BY GROUP
 IB6 =     0          -N/N = ANGULAR FLUX DOWN/UP AT AXIAL BOUNDARY N WRITTEN ON NBFT BY GROUP
 IZ4 =     0          0/N = NO EFFECT/FINAL TOTAL SCATTERING SOURCE WRITTEN ON N BY GROUP

 IB2 =     0          0/1/2/3 = NO EFFECT/NO X-S PRINT/NO FLUX PRINT/BOTH
 MQS =     0          -N/N = CALCULATE N ZONEWISE ACTIVITIES/N ZONE AND POINT ACTIVITIES
 IB1 =     0          0/N = NO EFFECT/ENTER N ZONE NUMBERS IN 30W ARRAY FOR ZONE BALANCE TABLES
 IP3 =     0          0/1 = NO EFFECT/PUNCH FISSION DISTRIBUTION


IAFT =     1          0/1/2/3 = NO ANGULAR FLUX OUTPUT/WRITE ON LOG NAFT/PRINT/BOTH


 IP4 =     1          0/1 = NO EFFECT/ANGULAR FLUX WITHOUT EXTRA OUTER ITERATION
 IS2 =     0          SPARE
 IS3 =     0          SPARE
 IZ5 =     0          MINIMUM SPS ITERATIONS (0 DEFAULT = 8)
 IZ6 =     0          MAXIMUM SPS ITERATIONS (0 DEFAULT = 100)

 IMG =     2          NUMBER OF INNER ITERATIONS BEFORE SPACE-POINT RESCALING
 IP2 =     2          NUMBER OF INNER ITERATIONS BETWEEN SUCCESSIVE SPACE-POINT RESCALINGS
 IB3 =     4          DAMPING CONSTANT FOR SPACE-POINT RESCALINGS
 IT1 =     0          SPARE
IFLUX=     0          0/1NN = NO EFFECT/PREPARE A FLUX GUESS FROM LOGICAL UNIT NN AS SPECIFIED BY I, WRITE ON NFLUX1

 IGM1=     0          NUMBER OF GROUPS FOR FLUX GUESS INPUT
IAQ31=     0          ORDER OF SCATTER FOR FLUX GUESS INPUT
IAQ41=     0          NUMBER OF ANGLES FOR FLUX GUESS INPUT
ISRCE=     0          0/N = NO EFFECT/COPY FIXED SOURCE FROM LOGICAL UNIT N TO NBSQ FOR IQ4 = 5, TO NPSQ FOR IQ4 = 6
IG1XS=     0          0/N = NO EFFECT/COPY GROUP - ORGANIZED CROSS-SECTION TAPE FROM LOGICAL UNIT N TO NCR1

 IPRT=     0          0/1/2 = NO PRINT/PRINT UNCOLLIDED FLUX, MUS AND EYAS/AS 1 + PRINT FIRST COLLISION SOURCE

  NCR1         2      DATA SET REF NO., SCRATCH (0 DEFAULT = 2)
NFLUX1         3      DATA SET REF NO., SCRATCH (0 DEFAULT = 3)
NSCRAT         4      DATA SET REF NO., SCRATCH (0 DEFAULT = 4)
  NBSQ        14      DATA SET REF NO., BOUNDARY OR VOLUME-DIST. SOURCE INPUT (0 DEFAULT = 14)
  NPSQ        15      DATA SET REF NO., FIRST COLLISION SOURCE INPUT (0 DEFAULT = 15)

 NFLSV         9      DATA SET REF NO., SCALAR FLUX AND MOMENTS OUTPUT (0 DEFAULT = 9)
  NAFT        10      DATA SET REF NO., ANGULAR FLUX OUTPUT (0 DEFAULT = 10)
  NBFT         0      DATA SET REF NO., INTERIOR BOUNDARY ANGULAR FLUX OUTPUT (0 DEFAULT = 11)
  NGAM        12      DATA SET REF NO., ACTIVITY OUTPUT (0 DEFAULT = 12)
  NZBT        13      DATA SET REF NO., SCRATCH FOR ZONE BALANCE TABLES (0 DEFAULT = 13)

  NLIB        91      NOT USED
  NBUF        65      NOT USED
  JBRL         1      0/N = NO EFFECT/LOWER AXIAL INTERVAL FOR ANGULAR FLUX OUTPUT
  JBRU         5      0/N = NO EFFECT/UPPER AXIAL INTERVAL FOR ANGULAR FLUX OUTPUT


 SQ1 = 0.0              SOURCE NORMALIZATION FACTOR
 EPS = 0.10000E-01      GENERAL CONVERGENCE CRITERION(INTEGRAL INNER ITERATION, LAMBDA AND FISSION DENSITY)
 GQ6 = 0.10000E-01      POINTWISE FLUX ERROR CRITERION (INTEGRAL INNER ITERATION TEST USED IF GQ6=0.0)
 GQS = 0.0              MAXIMUM CPU TIME FOR THIS PROBLEM
 SQ3 = 0.0              PARAMETRIC EIGENVALUE FOR SEARCH (K OR ALPHA)

  EV = 0.0              FIRST EIGENVALUE GUESS
 EVM = 0.0              EIGENVALUE INCREMENT TO BE ADDED TO EV
 LAL = 0.0              LINEAR EXTRAPOLATION USED WHEN CONVERGED CLOSER THAN LAL
EPSA = 0.0              CONVERGENCE CRITERION FOR CHANGING EV IN SEARCH
 LAH = 0.0              UPPER LIMIT ON ABS(LAMBDA-1.0) IN LINEAR SEARCH, R.V. = 0.05

 POD = 0.0              PARAMETER OSCILLATION DAMPER, R.V. = 0.75
  SH = 0.66000E+03      HEIGHT OF POINT SOURCE
 HSA = 0.23700E+00      COSINE OF ANGLE WITH Z AXIS  INTO WHICH SOURCE IS EMITTED
  SF = 0.10000E+01      SOURCE MAGNITUDE
IEXC = 0.10000E+03      EXCLUDED RADIUS

 ORF = 0.0              SPARE
 SFE = 0.0              SPARE
 SPE = 0.0              SPACE-POINT RESCALING CONVERGENCE CRITERION (0 DEFAULT = 1.E-4)
```

```
 PROBLEM STORES FLUXES AND MOMENTS EXTERNALLY
     7= ARRAY      96 ENTRIES READ
     OT
     6= ARRAY      48 ENTRIES READ
     OT
 PROBLEM REQUIRES  232054 LOCATIONS FOR COMPUTATION, VS. AVAILABLE  300000
    13¥ ARRAY       4 ENTRIES READ
     OT
 PROBLEM REQUIRES   30789 LOCATIONS FOR CROSS SECTION INPUT, VS. AVAILABLE  300000
     3= ARRAY       9 ENTRIES READ
     OT
     1= ARRAY       9 ENTRIES READ
     2= ARRAY      30 ENTRIES READ
     4= ARRAY      42 ENTRIES READ
     5= ARRAY       9 ENTRIES READ
     8¥ ARRAY    1189 ENTRIES READ
     9¥ ARRAY       2 ENTRIES READ
    33= ARRAY       2 ENTRIES READ
    34= ARRAY       2 ENTRIES READ
    36¥ ARRAY       1 ENTRIES READ
    38¥ ARRAY       3 ENTRIES-READ
     OT
 ID, INPUT PARAMETERS, M2, M0, K7. W0, M7, M5, R0, Z0 HAVE BEEN WRITTEN ON NAFT=    10.
```

```
 ZONE NUMBER BY INTERVAL
  29... 22222222222222222222222222222222222222222
  28... 22222222222222222222222222222222222222222
  27... 22222222222222222222222222222222222222222
  26... 22222222222222222222222222222222222222222
  25... 22222222222222222222222222222222222222222
  24... 22222222222222222222222222222222222222222
  23... 22222222222222222222222222222222222222222
  22... 22222222222222222222222222222222222222222
  21... 22222222222222222222222222222222222222222
  20... 22222222222222222222222222222222222222222
  19... 22222222222222222222222222222222222222222
  18... 22222222222222222222222222222222222222222
  17... 22222222222222222222222222222222222222222
  16... 22222222222222222222222222222222222222222
  15... 22222222222222222222222222222222222222222
  14... 22222222222222222222222222222222222222222
  13... 11111111111111111111111112222222222222222
  12... 11111111111111111111111112222222222222222
  11... 11111111111111111111111112222222222222222
  10... 11111111111111111111111112222222222222222
   9... 11111111111111111111111112222222222222222
   8... 11111111111111111111111112222222222222222
   7... 11111111111111111111111112222222222222222
   6... 11111111111111111111111112222222222222222
   5... 11111111111111111111111112222222222222222
   4... 11111111111111111111111112222222222222222
   3... 22222222211111111111111112222222222222222
   2... 22222222211111111111111112222222222222222
   1... 22222222211111111111111112222222222222222
 YZT
    XRR 12345678901234567890123456789012345678901
        00000000011111111112222222222333333333344

 SYMBOL =    1  2

 NUMBER =    1  2
```

ESPRIT SAMPLE PROBLEM NO.1

	MIXTURE SUM	COMPONENT	DENSITY	RADIUS	R MIDPOINT	HEIGHT	H MIDPOINT	MAT BY ZONE	CH1	VELOCITY
1				0	5.0000E+00	0	1.5000E+02	1	0	1.0000E+00
2				1.0000E+01	3.5000E+01	3.0000E+02	4.5000E+02	2	0	0
3				6.0000E+01	8.5000E+01	6.0000E+02	6.8000E+02		0	0
4				1.1000E+02	1.3500E+02	7.6000E+02	7.6151E+02		0	0
5				1.6000E+02	1.8500E+02	7.6303E+02	7.6403E+02		0	0
6				2.1000E+02	2.3500E+02	7.6503E+02	7.6603E+02		0	0
7				2.6000E+02	2.8500E+02	7.6703E+02	7.6803E+02		0	0
8				3.1000E+02	3.3500E+02	7.6903E+02	7.7003E+02		0	0
9				3.6000E+02	3.8500E+02	7.7103E+02	7.7203E+02		0	0
10				4.1000E+02	4.2000E+02	7.7303E+02	7.7403E+02			
11				4.3000E+02	4.4000E+02	7.7503E+02	7.7603E+02			
12				4.5000E+02	4.6000E+02	7.7703E+02	7.7803E+02			
13				4.7000E+02	4.8000E+02	7.7903E+02	7.8003E+02			
14				4.9000E+02	5.0000E+02	7.8103E+02	8.9051E+02			
15				5.1000E+02	5.2000E+02	1.0000E+03	1.5000E+03			
16				5.3000E+02	5.4000E+02	2.0000E+03	3.0000E+03			
17				5.5000E+02	5.6000E+02	4.0000E+03	5.0000E+03			
18				5.7000E+02	5.8000E+02	6.0000E+03	7.0000E+03			
19				5.9000E+02	6.0000E+02	8.0000E+03	9.0000E+03			
20				6.1000E+02	6.2000E+02	1.0000E+04	1.2500E+04			
21				6.3000E+02	6.4000E+02	1.5000E+04	1.7500E+04			
22				6.5000E+02	6.6000E+02	2.0000E+04	2.2500E+04			
23				6.7000E+02	6.8000E+02	2.5000E+04	2.7500E+04			
24				6.9000E+02	7.0000E+02	3.0000E+04	3.2500E+04			
25				7.1000E+02	8.5500E+02	3.5000E+04	3.7500E+04			
26				1.0000E+03	1.5000E+03	4.0000E+04	4.2500E+04			
27				2.0000E+03	2.5000E+03	4.5000E+04	4.7500E+04			
28				3.0000E+03	4.0000E+03	5.0000E+04	5.2500E+04			
29				5.0000E+03	6.0000E+03	5.5000E+04	5.7500E+04			
30				7.0000E+03	8.0000E+03	6.0000E+04				
31				9.0000E+03	1.0000E+04					
32				1.1000E+04	1.2500E+04					
33				1.4000E+04	1.6000E+04					
34				1.8000E+04	2.0000E+04					
35				2.2000E+04	2.3500E+04					
36				2.5000E+04	2.6500E+04					
37				2.8000E+04	3.0000E+04					
38				3.2000E+04	3.5000E+04					
39				3.8000E+04	4.1000E+04					
40				4.4000E+04	4.7000E+04					
41				5.0000E+04	5.3000E+04					
42				5.6000E+04						

CROSS-SECTION EDIT

***** GROUP 1 CROSS-SECTIONS *****

POS	MAT 1	MAT 2
1	3.59326E-04	1.19862E-07
2	0.0	0.0
3	1.15800E-01	6.17627E-05
4	1.17643E-02	6.25775E-06
5	0.0	0.0

POS 6 THRU POS 12 SAME AS ABOVE

NUFISSION CROSS-SECTIONS HAVE BEEN WRITTEN ON ANGULAR FLUX TAPE

***** GROUP 2 CROSS-SECTIONS *****

POS	MAT 1	MAT 2
1	7.05293E-05	1.46151E-08
2	0.0	0.0
3	1.31705E-01	7.02873E-05
4	1.88113E-02	1.00014E-05
5	2.41597E-02	1.29063E-05
6	0.0	0.0

POS 7 THRU POS 12 SAME AS ABOVE

NUFISSION CROSS-SECTIONS HAVE BEEN WRITTEN ON ANGULAR FLUX TAPE

***** GROUP 3 CROSS-SECTIONS *****

POS	MAT 1	MAT 2
1	5.98427E-05	4.69976E-09
2	0.0	0.0
3	1.49514E-01	7.97605E-05
4	1.94582E-02	1.03109E-05
5	2.36379E-02	1.26276E-05
6	1.44013E-02	7.69331E-06
7	0.0	0.0

POS 8 THRU POS 12 SAME AS ABOVE

NUFISSION CROSS-SECTIONS HAVE BEEN WRITTEN ON ANGULAR FLUX TAPE

***** GROUP 4 CROSS-SECTIONS *****

POS	MAT 1	MAT 2
1	1.06378E-04	8.33504E-09
2	0.0	0.0
3	1.68418E-01	8.97761E-05
4	3.09933E-02	1.64109E-05
5	3.80209E-02	2.03111E-05
6	2.28418E-02	1.22023E-05
7	1.52797E-02	8.16256E-06
8	0.0	0.0

POS 9 THRU POS 12 SAME AS ABOVE

NUFISSION CROSS-SECTIONS HAVE BEEN WRITTEN ON ANGULAR FLUX TAPE

***** GROUP 5 CROSS-SECTIONS *****

POS	MAT 1	MAT 2
1	2.55673E-04	2.00596E-08
2	0.0	0.0
3	1.95957E-01	1.04262E-04

```
 UNCOLLIDED FLUX ZONE MAP - - -

 ZONE NUMBER BY INTERVAL

  29... 22222222222222222222222222222222222222222
  28... 22222222222222222222222222222222222222222
  27... 22222222222222222222222222222222222222222
  26... 22222222222222222222222222222222222222222
  25... 22222222222222222222222222222222222222222
  24... 22222222222222222222222222222222222222222
  23... 22222222222222222222222222222222222222222
  22... 22222222222222222222222222222222222222222
  21... 22222222222222222222222222222222222222222
  20... 2222222222222222222222222222222222222222
  19... 222222222222222222222222222222222222
  18... 22222222222222222222222222222222222
  17... 2222222222222222222222222222222222
  16... 222222222222222222222222222222222
  15... 22222222222222222222222222
  14... 2222222222222222222222222
  13... 1111111111111
  12... 1111111111111
  11... 111111111111
  10... 111111111111
   9... 11111111111
   8... 11111111111
   7... 11111111111
   6... 1111111111
   5... 1111111111
   4... 111111111
   3...
   2...
   1...
 YZT
    XRR 12345678901234567890123456789012345678901
        00000000011111111112222222222333333333344

 SYMBOL =    1  2

 NUMBER =    1  2

  FIRST COLLISION SOURCE FOR GROUP  1 ON LOGICAL UNIT 15

  FIRST COLLISION SOURCE FOR GROUP  2 ON LOGICAL UNIT 15

  FIRST COLLISION SOURCE FOR GROUP  3 ON LOGICAL UNIT 15

  FIRST COLLISION SOURCE FOR GROUP  4 ON LOGICAL UNIT 15

  FIRST COLLISION SOURCE FOR GROUP  5 ON LOGICAL UNIT 15

  FIRST COLLISION SOURCE FOR GROUP  6 ON LOGICAL UNIT 15

  FIRST COLLISION SOURCE FOR GROUP  7 ON LOGICAL UNIT 15

  FIRST COLLISION SOURCE FOR GROUP  8 ON LOGICAL UNIT 15

  FIRST COLLISION SOURCE FOR GROUP  9 ON LOGICAL UNIT 15

  UNCOLLIDED FLUX FOR GROUP  1 ON LOGICAL UNIT 15


 FLUX  2   LC    0   11    0   MB  0.0            TI   0.04  EQS  0.0          EV  0.0           LA  0.0

 IGV,S2,S4=     1  0.0          0.0
  GROUP   1  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
  GROUP   1  INNER ITERATION =  2 FLUX ERROR = 0.64416E+00 MAX AT ( 40, 15)  WWESOL REQUIRED 22 ITERATIONS, ERROR = 0.68561E-04
  GROUP   1  INNER ITERATION =  3 FLUX ERROR = 0.97624E+00 MAX AT ( 38, 26)
  GROUP   1  INNER ITERATION =  4 FLUX ERROR = 0.18214E+00 MAX AT (  1, 29)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.39721E-05
  GROUP   1  INNER ITERATION =  5 FLUX ERROR = 0.39520E-01 MAX AT ( 19, 10)
  GROUP   1  INNER ITERATION =  6 FLUX ERROR = 0.92290E-02 MAX AT ( 12, 13)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.17694E-05
 ANGULAR FLUXES FOR GROUP     1 WRITTEN ON NAFT=     10
  GROUP   1  INNER ITERATION =  7 FLUX ERROR = 0.96035E-02 MAX AT ( 12, 13)
  GROUP   1  INNER ITERATION =  7 FLUX ERROR = 0.96035E-02 MAX AT ( 12, 13)
  GROUP   1 FLUXES WRITTEN ON LOGICAL UNIT  9

 IGV,UP1,XS,FLX=     1  0.0          1.1764E-02  4.0382E-11
 SCAT,ASCAT=    5.212E-16   8.159E-21
 IGV,S2,S4=     2  5.2119E-16  8.1590E-21
  GROUP   2  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
  GROUP   2  INNER ITERATION =  2 FLUX ERROR = 0.74212E+00 MAX AT ( 25,  1)  WWESOL REQUIRED 23 ITERATIONS, ERROR = 0.38668E-04
  GROUP   2  INNER ITERATION =  3 FLUX ERROR = 0.18762E+00 MAX AT ( 24,  3)
  GROUP   2  INNER ITERATION =  4 FLUX ERROR = 0.64474E+00 MAX AT ( 31,  1)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.80048E-05
  GROUP   2  INNER ITERATION =  5 FLUX ERROR = 0.25026E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION =  6 FLUX ERROR = 0.25073E-01 MAX AT ( 12,  5)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.10506E-05
  GROUP   2  INNER ITERATION =  7 FLUX ERROR = 0.24873E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION =  8 FLUX ERROR = 0.25093E-01 MAX AT ( 12,  5)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.80215E-06
  GROUP   2  INNER ITERATION =  9 FLUX ERROR = 0.24832E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION = 10 FLUX ERROR = 0.25093E-01 MAX AT ( 12,  5)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.89539E-06
  GROUP   2  INNER ITERATION = 11 FLUX ERROR = 0.24803E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION = 12 FLUX ERROR = 0.25096E-01 MAX AT ( 12,  5)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.83549E-06
  GROUP   2  INNER ITERATION = 13 FLUX ERROR = 0.24775E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION = 14 FLUX ERROR = 0.25095E-01 MAX AT ( 12,  5)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.96733E-06
  GROUP   2  INNER ITERATION = 15 FLUX ERROR = 0.24752E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION = 16 FLUX ERROR = 0.25095E-01 MAX AT ( 12,  5)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.92512E-06
  GROUP   2  INNER ITERATION = 17 FLUX ERROR = 0.24733E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION = 18 FLUX ERROR = 0.25096E-01 MAX AT ( 12,  5)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.88282E-06
  GROUP   2  INNER ITERATION = 19 FLUX ERROR = 0.24717E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION = 20 FLUX ERROR = 0.25096E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION = 20 FLUX ERROR = 0.25096E-01 MAX AT ( 12,  5)  WWESDL REQUIRED  8 ITERATIONS, ERROR = 0.84508E-06
 ANGULAR FLUXES FOR GROUP     2 WRITTEN ON NAFT=     10
  GROUP   2  INNER ITERATION = 21 FLUX ERROR = 0.24700E-01 MAX AT ( 12,  5)
  GROUP   2  INNER ITERATION = 21 FLUX ERROR = 0.24700E-01 MAX AT ( 12,  5)
  GROUP   2 FLUXES WRITTEN ON LOGICAL UNIT  9

 IGV,UP1,XS,FLX=     2  0.0          1.8811E-02  1.5945E-11
 SCAT,ASCAT=    3.107E-16   9.098E-21
 SCAT,ASCAT=    5.120E-16   3.549E-20
 IGV,S2,S4=     3  5.1202E-16  3.5494E-20
  GROUP   3  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
  GROUP   3  INNER ITERATION =  2 FLUX ERROR = 0.72351E+00 MAX AT (  1,  1)  WWESOL REQUIRED 22 ITERATIONS, ERROR = 0.51201E-04
  GROUP   3  INNER ITERATION =  3 FLUX ERROR = 0.33896E+00 MAX AT ( 41,  2)
  GROUP   3  INNER ITERATION =  4 FLUX ERROR = 0.26062E+00 MAX AT ( 19, 10)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.45297E-05
  GROUP   3  INNER ITERATION =  5 FLUX ERROR = 0.19201E+00 MAX AT ( 20,  9)
  GROUP   3  INNER ITERATION =  6 FLUX ERROR = 0.62759E-01 MAX AT ( 20, 11)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.47717E-05
  GROUP   3  INNER ITERATION =  7 FLUX ERROR = 0.68421E-01 MAX AT ( 20, 11)
  GROUP   3  INNER ITERATION =  8 FLUX ERROR = 0.62597E-01 MAX AT ( 20, 11)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.46499E-05
  GROUP   3  INNER ITERATION =  9 FLUX ERROR = 0.68239E-01 MAX AT ( 20, 11)
  GROUP   3  INNER ITERATION = 10 FLUX ERROR = 0.62605E-01 MAX AT ( 20, 11)  WWESDL REQUIRED  8 ITERATIONS, ERROR = 0.42684E-05
  GROUP   3  INNER ITERATION = 11 FLUX ERROR = 0.68119E-01 MAX AT ( 20, 11)
  GROUP   3  INNER ITERATION = 12 FLUX ERROR = 0.62613E-01 MAX AT ( 20, 11)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.39523E-05
  GROUP   3  INNER ITERATION = 13 FLUX ERROR = 0.68016E-01 MAX AT ( 20, 11)
  GROUP   3  INNER ITERATION = 14 FLUX ERROR = 0.62621E-01 MAX AT ( 20, 11)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.40447E-05
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```
 GROUP   3  INNER ITERATION = 15 FLUX ERROR = 0.67934E-01 MAX AT ( 20, 11)
 GROUP   3  INNER ITERATION = 16 FLUX ERROR = 0.62626E-01 MAX AT ( 20, 11)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.33082E-05
 GROUP   3  INNER ITERATION = 17 FLUX ERROR = 0.67857E-01 MAX AT ( 20, 11)
 GROUP   3  INNER ITERATION = 18 FLUX ERROR = 0.62629E-01 MAX AT ( 20, 11)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.29724E-05
 GROUP   3  INNER ITERATION = 19 FLUX ERROR = 0.67791E-01 MAX AT ( 20, 11)
 GROUP   3  INNER ITERATION = 20 FLUX ERROR = 0.62636E-01 MAX AT ( 20, 11)
 GROUP   3  INNER ITERATION = 20 FLUX ERROR = 0.62636E-01 MAX AT ( 20, 11)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.28390E-05
ANGULAR FLUXES FOR GROUP     3 WRITTEN ON NAFT=    10
 GROUP   3  INNER ITERATION = 21 FLUX ERROR = 0.67733E-01 MAX AT ( 20, 11)
 GROUP   3  INNER ITERATION = 21 FLUX ERROR = 0.67733E-01 MAX AT ( 20, 11)
 GROUP   3 FLUXES WRITTEN ON LOGICAL UNIT  9

IGV,UP1,XS,FLX=    3  0.0          1.9458E-02  1.7578E-11
SCAT,ASCAT=   3.296E-16   1.146E-19
SCAT,ASCAT=   5.242E-16   1.857E-19
SCAT,ASCAT=   8.812E-16   3.663E-19
IGV,S2,S4=     4  8.8121E-16  3.6625E-19
 GROUP   4  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
 GROUP   4  INNER ITERATION =  2 FLUX ERROR = 0.70026E+00 MAX AT (  1,  1)  WWESOL REQUIRED 22 ITERATIONS, ERROR = 0.71002E-04
 GROUP   4  INNER ITERATION =  3 FLUX ERROR = 0.21575E+00 MAX AT (  2,  2)
 GROUP   4  INNER ITERATION =  4 FLUX ERROR = 0.48588E-01 MAX AT ( 23,  1)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.11798E-04
 GROUP   4  INNER ITERATION =  5 FLUX ERROR = 0.20939E-01 MAX AT ( 39, 29)
 GROUP   4  INNER ITERATION =  6 FLUX ERROR = 0.15883E-01 MAX AT ( 22,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.13572E-05
 GROUP   4  INNER ITERATION =  7 FLUX ERROR = 0.16076E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION =  8 FLUX ERROR = 0.15812E-01 MAX AT ( 22,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.10994E-05
 GROUP   4  INNER ITERATION =  9 FLUX ERROR = 0.16065E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION = 10 FLUX ERROR = 0.15800E-01 MAX AT ( 22,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.96433E-06
 GROUP   4  INNER ITERATION = 11 FLUX ERROR = 0.16023E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION = 12 FLUX ERROR = 0.15801E-01 MAX AT ( 22,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.10226E-05
 GROUP   4  INNER ITERATION = 13 FLUX ERROR = 0.15985E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION = 14 FLUX ERROR = 0.15804E-01 MAX AT ( 22,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.97215E-06
 GROUP   4  INNER ITERATION = 15 FLUX ERROR = 0.15952E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION = 16 FLUX ERROR = 0.15806E-01 MAX AT ( 22,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.98825E-06
 GROUP   4  INNER ITERATION = 17 FLUX ERROR = 0.15925E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION = 18 FLUX ERROR = 0.15808E-01 MAX AT ( 22,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.70821E-06
 GROUP   4  INNER ITERATION = 19 FLUX ERROR = 0.15901E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION = 20 FLUX ERROR = 0.15810E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION = 20 FLUX ERROR = 0.15810E-01 MAX AT ( 22,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.10488E-05
ANGULAR FLUXES FOR GROUP     4 WRITTEN ON NAFT=    10
 GROUP   4  INNER ITERATION = 21 FLUX ERROR = 0.15879E-01 MAX AT ( 22,  4)
 GROUP   4  INNER ITERATION = 21 FLUX ERROR = 0.15879E-01 MAX AT ( 22,  4)
 GROUP   4 FLUXES WRITTEN ON LOGICAL UNIT  9

IGV,UP1,XS,FLX=    4  0.0          3.0993E-02  4.2707E-11
SCAT,ASCAT=   4.089E-16   6.829E-18
SCAT,ASCAT=   6.224E-16   8.293E-18
SCAT,ASCAT=   9.587E-16   9.608E-18
SCAT,ASCAT=   2.299E-15   1.316E-17
IGV,S2,S4=     5  2.2986E-15  1.3160E-17
 GROUP   5  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
 GROUP   5  INNER ITERATION =  2 FLUX ERROR = 0.68060E+00 MAX AT ( 24,  1)  WWESOL REQUIRED 23 ITERATIONS, ERROR = 0.50579E-04
 GROUP   5  INNER ITERATION =  3 FLUX ERROR = 0.30778E+00 MAX AT (  1,  2)
 GROUP   5  INNER ITERATION =  4 FLUX ERROR = 0.98521E-01 MAX AT (  1,  3)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.35315E-04
 GROUP   5  INNER ITERATION =  5 FLUX ERROR = 0.10435E+00 MAX AT ( 41, 29)
 GROUP   5  INNER ITERATION =  6 FLUX ERROR = 0.62330E-01 MAX AT ( 34, 28)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.18071E-05
 GROUP   5  INNER ITERATION =  7 FLUX ERROR = 0.47743E-02 MAX AT ( 21, 11)
ANGULAR FLUXES FOR GROUP     5 WRITTEN ON NAFT=    10
 GROUP   5  INNER ITERATION =  8 FLUX ERROR = 0.55329E-02 MAX AT ( 22,  6)
 GROUP   5  INNER ITERATION =  8 FLUX ERROR = 0.55329E-02 MAX AT ( 22,  6)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.97843E-06
 GROUP   5 FLUXES WRITTEN ON LOGICAL UNIT  9

IGV,UP1,XS,FLX=    5  0.0          5.6397E-02  7.5957E-10


SCAT,ASCAT=   2.958E-16   7.206E-17
SCAT,ASCAT=   4.395E-16   9.011E-17
SCAT,ASCAT=   6.387E-16   1.015E-16
SCAT,ASCAT=   1.283E-15   1.177E-16
SCAT,ASCAT=   2.312E-14   2.022E-16
IGV,S2,S4=     6  2.3117E-14  2.0217E-16
 GROUP   6  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
 GROUP   6  INNER ITERATION =  2 FLUX ERROR = 0.48166E+00 MAX AT ( 23,  1)  WWESOL REQUIRED 22 ITERATIONS, ERROR = 0.29292E-04
 GROUP   6  INNER ITERATION =  3 FLUX ERROR = 0.19936E+00 MAX AT ( 41,  1)
 GROUP   6  INNER ITERATION =  4 FLUX ERROR = 0.57873E-01 MAX AT ( 22,  1)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.28703E-04
 GROUP   6  INNER ITERATION =  5 FLUX ERROR = 0.59374E-01 MAX AT ( 20,  8)
 GROUP   6  INNER ITERATION =  6 FLUX ERROR = 0.13457E-01 MAX AT ( 22,  8)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.75058E-05
 GROUP   6  INNER ITERATION =  7 FLUX ERROR = 0.16375E-01 MAX AT ( 17,  7)
 GROUP   6  INNER ITERATION =  8 FLUX ERROR = 0.14185E-01 MAX AT ( 22,  8)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.60408E-05
 GROUP   6  INNER ITERATION =  9 FLUX ERROR = 0.15633E-01 MAX AT ( 17,  7)
 GROUP   6  INNER ITERATION = 10 FLUX ERROR = 0.14246E-01 MAX AT ( 22,  8)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.54924E-05
 GROUP   6  INNER ITERATION = 11 FLUX ERROR = 0.15521E-01 MAX AT ( 17,  7)
 GROUP   6  INNER ITERATION = 12 FLUX ERROR = 0.14246E-01 MAX AT ( 22,  8)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.52202E-05
 GROUP   6  INNER ITERATION = 13 FLUX ERROR = 0.15439E-01 MAX AT ( 17,  7)
 GROUP   6  INNER ITERATION = 14 FLUX ERROR = 0.14249E-01 MAX AT ( 22,  8)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.46033E-05
 GROUP   6  INNER ITERATION = 15 FLUX ERROR = 0.15369E-01 MAX AT ( 17,  7)
 GROUP   6  INNER ITERATION = 16 FLUX ERROR = 0.14255E-01 MAX AT ( 22,  8)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.42137E-05
 GROUP   6  INNER ITERATION = 17 FLUX ERROR = 0.15314E-01 MAX AT ( 17,  7)
 GROUP   6  INNER ITERATION = 18 FLUX ERROR = 0.14259E-01 MAX AT ( 22,  8)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.37945E-05
 GROUP   6  INNER ITERATION = 19 FLUX ERROR = 0.15263E-01 MAX AT ( 17,  7)
 GROUP   6  INNER ITERATION = 20 FLUX ERROR = 0.14263E-01 MAX AT ( 22,  8)
 GROUP   6  INNER ITERATION = 20 FLUX ERROR = 0.14263E-01 MAX AT ( 22,  8)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.38152E-05
ANGULAR FLUXES FOR GROUP     6 WRITTEN ON NAFT=    10
 GROUP   6  INNER ITERATION = 21 FLUX ERROR = 0.15220E-01 MAX AT ( 17,  7)
 GROUP   6  INNER ITERATION = 21 FLUX ERROR = 0.15220E-01 MAX AT ( 17,  7)
 GROUP   6 FLUXES WRITTEN ON LOGICAL UNIT  9

IGV,UP1,XS,FLX=    6  0.0          5.9669E-02  4.2944E-09
SCAT,ASCAT=   3.704E-16   1.049E-15
SCAT,ASCAT=   5.783E-16   1.575E-15
SCAT,ASCAT=   8.972E-16   2.224E-15
SCAT,ASCAT=   1.845E-15   3.116E-15
SCAT,ASCAT=   2.448E-14   6.984E-15
SCAT,ASCAT=   2.495E-13   1.055E-14
IGV,S2,S4=     7  2.4946E-13  1.0545E-14
 GROUP   7  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
 GROUP   7  INNER ITERATION =  2 FLUX ERROR = 0.59827E+00 MAX AT ( 21,  1)  WWESOL REQUIRED 22 ITERATIONS, ERROR = 0.37277E-04
 GROUP   7  INNER ITERATION =  3 FLUX ERROR = 0.17470E+00 MAX AT ( 37,  1)
 GROUP   7  INNER ITERATION =  4 FLUX ERROR = 0.84195E-01 MAX AT ( 21,  1)  WWESOL REQUIRED 10 ITERATIONS, ERROR = 0.87139E-04
 GROUP   7  INNER ITERATION =  5 FLUX ERROR = 0.39863E-01 MAX AT ( 29, 25)
 GROUP   7  INNER ITERATION =  6 FLUX ERROR = 0.42787E-01 MAX AT ( 41, 29)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.16357E-04
 GROUP   7  INNER ITERATION =  7 FLUX ERROR = 0.16799E-01 MAX AT ( 19,  4)
 GROUP   7  INNER ITERATION =  8 FLUX ERROR = 0.25632E-01 MAX AT ( 39, 29)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.25973E-05
 GROUP   7  INNER ITERATION =  9 FLUX ERROR = 0.31300E-02 MAX AT ( 11, 10)
ANGULAR FLUXES FOR GROUP     7 WRITTEN ON NAFT=    10
 GROUP   7  INNER ITERATION = 10 FLUX ERROR = 0.26617E-02 MAX AT ( 11, 10)
 GROUP   7  INNER ITERATION = 10 FLUX ERROR = 0.26617E-02 MAX AT ( 11, 10)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.10602E-05
 GROUP   7 FLUXES WRITTEN ON LOGICAL UNIT  9

IGV,UP1,XS,FLX=    7  0.0          1.0410E-01  3.2619E-08
SCAT,ASCAT=   9.330E-18   7.053E-17
SCAT,ASCAT=   2.092E-16   1.291E-15
SCAT,ASCAT=   1.227E-14   4.669E-14
SCAT,ASCAT=   1.700E-13   4.056E-13
SCAT,ASCAT=   2.863E-12   3.835E-12
IGV,S2,S4=     8  2.8628E-12  3.8351E-12
 GROUP   8  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
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 GROUP   8  INNER ITERATION =  2 FLUX ERROR = 0.58018E+00 MAX AT ( 22,  2)  WWESOL REQUIRED 27 ITERATIONS, ERROR = 0.54061E-04
 GROUP   8  INNER ITERATION =  3 FLUX ERROR = 0.31810E+00 MAX AT ( 25,  3)
 GROUP   8  INNER ITERATION =  4 FLUX ERROR = 0.14186E+00 MAX AT ( 30,  1)  WWESOL REQUIRED 18 ITERATIONS, ERROR = 0.80481E-04
 GROUP   8  INNER ITERATION =  5 FLUX ERROR = 0.72573E-01 MAX AT ( 41, 29)
 GROUP   8  INNER ITERATION =  6 FLUX ERROR = 0.19882E-01 MAX AT ( 34,  1)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.46539E-04
 GROUP   8  INNER ITERATION =  7 FLUX ERROR = 0.21884E-01 MAX AT ( 16,  8)
 GROUP   8  INNER ITERATION =  8 FLUX ERROR = 0.13657E-01 MAX AT ( 19,  7)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.13954E-04
 GROUP   8  INNER ITERATION =  9 FLUX ERROR = 0.20486E-01 MAX AT ( 41, 28)
 GROUP   8  INNER ITERATION = 10 FLUX ERROR = 0.12484E-01 MAX AT ( 40, 29)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.29040E-05
 GROUP   8  INNER ITERATION = 11 FLUX ERROR = 0.17768E-01 MAX AT ( 41,  1)
 GROUP   8  INNER ITERATION = 12 FLUX ERROR = 0.13057E-01 MAX AT ( 41,  1)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.14808E-05
 GROUP   8  INNER ITERATION = 13 FLUX ERROR = 0.16827E-01 MAX AT ( 40,  2)
 GROUP   8  INNER ITERATION = 14 FLUX ERROR = 0.47638E-02 MAX AT ( 39,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.10163E-05
ANGULAR FLUXES FOR GROUP     8 WRITTEN ON NAFT=    10
 GROUP   8  INNER ITERATION = 15 FLUX ERROR = 0.49229E-02 MAX AT ( 23,  8)
 GROUP   8  INNER ITERATION = 15 FLUX ERROR = 0.49229E-02 MAX AT ( 23,  8)
 GROUP   8 FLUXES WRITTEN ON LOGICAL UNIT  9

IGV,UP1,XS,FLX=    8  0.0          2.4035E-01  3.5801E-08
SCAT,ASCAT=   1.397E-12   2.635E-12
IGV,S2,S4=    9  1.3970E-12  2.6348E-12
 GROUP   9  INNER ITERATION =  1 FLUX ERROR = 0.10000E+01 MAX AT (  1,  1)
 GROUP   9  INNER ITERATION =  2 FLUX ERROR = 0.56732E+00 MAX AT ( 30,  1)  WWESOL REQUIRED 42 ITERATIONS, ERROR = 0.77533E-04
 GROUP   9  INNER ITERATION =  3 FLUX ERROR = 0.22929E+00 MAX AT ( 25,  3)
 GROUP   9  INNER ITERATION =  4 FLUX ERROR = 0.13833E+00 MAX AT ( 41,  1)  WWESOL REQUIRED 33 ITERATIONS, ERROR = 0.44688E-04
 GROUP   9  INNER ITERATION =  5 FLUX ERROR = 0.11358E+00 MAX AT (  3, 19)
 GROUP   9  INNER ITERATION =  6 FLUX ERROR = 0.43466E-01 MAX AT ( 27,  1)  WWESOL REQUIRED 11 ITERATIONS, ERROR = 0.76006E-04
 GROUP   9  INNER ITERATION =  7 FLUX ERROR = 0.22458E-01 MAX AT ( 16,  9)
 GROUP   9  INNER ITERATION =  8 FLUX ERROR = 0.11612E-01 MAX AT ( 16,  4)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.50413E-04
 GROUP   9  INNER ITERATION =  9 FLUX ERROR = 0.99621E-02 MAX AT ( 17,  7)
ANGULAR FLUXES FOR GROUP     9 WRITTEN ON NAFT=    10
 GROUP   9  INNER ITERATION = 10 FLUX ERROR = 0.62426E-02 MAX AT ( 17,  5)
 GROUP   9  INNER ITERATION = 10 FLUX ERROR = 0.62426E-02 MAX AT ( 17,  5)  WWESOL REQUIRED  8 ITERATIONS, ERROR = 0.18201E-04
 GROUP   9 FLUXES WRITTEN ON LOGICAL UNIT  9

IGV,UP1,XS,FLX=    9  0.0          4.0235E-01  2.2246E-08
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 ESPRIT SAMPLE PROBLEM NO.1

 * * * NOTE - SUMMARY FOR SYSTEM CONTAINS COLLIDED INFORMATION ONLY * * *

     SUMMARY FOR SYSTEM, INCLUDING SUM OVER ALL GROUPS IN GROUP  10

       GROUP      FIXED SO     FISSION SO     IN-SCATTER   SELF-SCATTER   OUT-SCATTER   ABSORPTIONS       BALANCE
          1   3.80075E-02   0.0            0.0           4.27450E-03   3.76950E-02   1.24216E-04   9.99997E-01
          2   7.80504E-02   0.0            8.78251E-03   1.43993E-02   8.64045E-02   4.98816E-05   9.99995E-01
          3   4.65328E-02   0.0            2.33282E-02   1.03913E-02   6.94878E-02   2.83920E-05   9.99975E-01
          4   4.93712E-02   0.0            4.33634E-02   2.07452E-02   9.20109E-02   6.30722E-05   9.99981E-01
          5   6.12499E-02   0.0            8.45779E-02   5.79145E-02   1.43225E-01   2.32695E-04   9.99963E-01
          6   4.43041E-02   0.0            1.03493E-01   5.09708E-02   1.42843E-01   5.02996E-04   9.99979E-01
          7   5.54751E-02   0.0            2.12260E-01   1.67121E-01   2.48840E-01   2.67398E-03   9.99917E-01
          8   0.0           0.0            3.44678E-01   9.33270E-01   2.84538E-01   3.66168E-02   9.99220E-01
          9   0.0           0.0            2.84801E-01   1.63729E+00  -8.77380E-05   2.54255E-01   9.99746E-01
         10   3.72991E-01   0.0            1.10528E+00   2.89637E+00   1.10496E+00   2.94547E-01   9.99777E-01

       GROUP     HZ-LEAKAGE    LFT-LEAKAGE     RT-LEAKAGE     VT-LEAKAGE    TOP-LEAKAGE    BOT-LEAKAGE    NET-LEAKAGE
          1   4.21088E-05   0.0            4.21088E-05   1.46038E-04   1.25340E-04  -2.06975E-05   1.88147E-04
          2   1.02652E-04   0.0            1.02652E-04   2.75433E-04   2.50478E-04  -2.49553E-05   3.78085E-04
          3   9.63845E-05   0.0            9.63845E-05   2.46746E-04   1.80722E-04  -6.60245E-05   3.43131E-04
          4   1.54305E-04   0.0            1.54305E-04   5.06643E-04   2.16790E-04  -2.87853E-04   6.58948E-04
          5   2.49036E-04   0.0            2.49036E-04   2.11588E-03   2.79147E-04  -1.83673E-03   2.36491E-03
          6   1.73444E-04   0.0            1.73444E-04   4.27477E-03   1.73333E-04  -4.10144E-03   4.44821E-03
          7   2.55181E-04   0.0            2.55181E-04   1.59881E-02   2.31799E-04  -1.57563E-02   1.62433E-02
          8   7.58863E-04   0.0            7.58863E-04   2.24956E-02   6.49206E-04  -2.18464E-02   2.32545E-02
          9   3.82549E-03   0.0            3.82549E-03   2.67365E-02   2.69215E-03  -2.40444E-02   3.05620E-02
         10   5.65747E-03   0.0            5.65747E-03   7.27837E-02   4.79896E-03  -6.79847E-02   7.84411E-02

 FLUX  4   LC    1   II  134   NB  0.999777E+00   TI   4.02   EQS  0.0          EV  0.0            LA  0.100000E+01

  FINAL VALUES OF DATA IN VO,R1,Z1, HAVE BEEN WRITTEN ON ANGULAR FLUX TAPE

 ***** UNCOLLIDED FLUXES ADDED TO COLLIDED FLUXES

 ***** SCALAR FLUXES, MOMENTS AND BOUNDARY ANGULAR FLUXES HAVE BEEN WRITTEN ON LOGICAL UNIT  9
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ESPRIT SAMPLE PROBLEM NO.1

GAMMA-RAY FLUX FOR GROUP 1

XRR	YZT 1	YZT 2	YZT 3	YZT 4	YZT 5	YZT 6	YZT 7	YZT 8
1	4.03822E-11	1.53753E-10	7.49920E-10	6.53408E-06	4.81730E-06	3.77103E-06	2.94945E-06	2.30501E-06
2	5.14969E-11	1.83687E-10	7.86123E-10	5.79428E-06	4.23018E-06	3.28999E-06	2.56098E-06	1.99524E-06
3	6.63909E-11	1.81512E-10	6.04202E-10	3.66594E-06	2.55007E-06	1.91370E-06	1.44031E-06	1.08713E-06
4	7.51467E-11	1.55299E-10	4.29579E-10	2.12064E-06	1.37458E-06	9.70138E-07	6.91267E-07	4.96874E-07
5	6.63103E-11	1.32476E-10	5.71240E-10	1.26710E-06	7.46945E-07	4.87452E-07	3.20798E-07	2.13610E-07
6	5.25750E-11	1.29656E-10	8.39789E-10	8.02060E-07	4.18088E-07	2.50074E-07	1.52550E-07	9.52389E-08
7	4.66275E-11	1.36082E-10	9.96564E-10	5.30417E-07	2.49122E-07	1.37137E-07	7.71358E-08	4.46727E-08
8	4.54728E-11	1.46129E-10	1.10233E-09	3.63417E-07	1.50876E-07	7.58787E-08	3.91223E-08	2.03998E-08
9	4.26829E-11	1.60029E-10	1.12777E-09	2.58504E-07	9.67736E-08	4.41891E-08	2.10764E-08	1.08013E-08
10	8.84955E-12	4.66286E-11	3.35971E-10	1.78457E-09	6.45030E-08	2.88776E-08	1.33468E-08	5.60676E-09
11	2.20969E-12	1.32460E-11	9.80061E-11	3.64434E-10	8.52486E-10	7.35688E-10	8.96447E-09	4.13861E-09
12	5.76915E-13	3.88338E-12	2.89345E-11	8.02629E-11	1.64788E-10	2.00776E-10	2.90822E-10	2.75667E-10
13	1.57533E-13	1.15770E-12	8.49380E-12	1.86826E-11	3.34471E-11	4.58697E-11	6.49081E-11	6.99310E-11
14	4.41905E-14	3.45796E-13	2.49754E-12	4.51136E-12	7.05259E-12	1.02968E-11	1.46988E-11	1.73634E-11
15	1.26895E-14	1.03917E-13	7.33328E-13	1.11254E-12	1.53916E-12	2.29932E-12	3.34887E-12	4.24528E-12
16	3.70322E-15	3.12470E-14	2.15613E-13	2.83922E-13	3.49399E-13	5.18442E-13	7.69272E-13	1.03080E-12
17	1.09496E-15	9.42180E-15	6.35906E-14	7.48024E-14	8.66663E-14	1.21883E-13	1.82286E-13	2.55258E-13
18	3.26855E-16	2.84422E-15	1.87849E-14	2.17110E-14	2.36398E-14	3.27562E-14	4.84216E-14	6.87823E-14
19	9.84309E-17	8.62004E-16	5.60134E-15	6.34511E-15	9.71536E-15	1.27044E-14	1.77395E-14	2.52648E-14
20	3.03233E-17	2.63963E-16	1.75310E-15	4.63963E-15	5.84187E-15	7.74775E-15	1.06815E-14	1.43301E-14
21	1.15285E-17	8.58733E-17	6.13076E-16	3.75877E-15	5.17125E-15	6.65802E-15	8.61902E-15	1.19042E-14
22	1.45249E-17	4.51507E-17	2.91567E-16	3.34468E-15	4.49683E-15	5.98375E-15	8.29558E-15	1.10134E-14
23	6.66562E-17	1.07344E-16	3.02828E-16	3.29693E-15	4.62550E-15	5.98987E-15	7.54393E-15	1.02618E-14
24	4.56268E-16	6.39315E-16	1.03637E-15	4.18635E-15	5.25719E-15	6.51812E-15	8.61791E-15	1.10755E-14
25	6.94541E-15	1.37619E-14	3.74745E-14	8.26214E-14	8.73453E-14	9.14011E-14	9.56909E-14	1.00271E-13
26	1.33414E-14	2.11666E-14	4.08274E-14	5.16866E-14	5.14189E-14	5.11911E-14	5.09204E-14	5.06051E-14
27	1.41455E-14	2.03781E-14	3.30779E-14	3.37115E-14	3.37002E-14	3.36977E-14	3.37001E-14	3.37078E-14
28	1.22289E-14	1.96493E-14	2.63855E-14	3.21800E-14	3.23568E-14	3.24970E-14	3.26366E-14	3.27754E-14
29	1.27068E-14	1.42780E-14	1.25538E-14	9.39840E-15	9.26872E-15	9.18273E-15	9.09618E-15	9.00919E-15
30	9.34931E-15	6.21285E-15	5.55742E-15	4.28135E-15	4.26346E-15	4.25180E-15	4.23998E-15	4.22857E-15
31	3.35893E-15	3.81421E-15	3.82175E-15	3.54988E-15	3.55221E-15	3.55462E-15	3.55749E-15	3.56017E-15
32	2.57698E-15	2.40001E-15	2.22911E-15	2.31803E-15	2.31634E-15	2.31479E-15	2.31304E-15	2.31104E-15
33	1.34664E-15	1.29835E-15	1.32489E-15	1.24286E-15	1.24275E-15	1.24272E-15	1.24278E-15	1.24297E-15
34	8.70585E-16	1.06669E-15	1.26037E-15	1.44592E-15	1.45079E-15	1.45463E-15	1.45841E-15	1.46206E-15
35	8.81867E-16	8.55520E-16	9.15864E-16	7.39216E-16	7.34955E-16	7.32129E-16	7.29327E-16	7.26531E-16
36	6.33638E-16	7.02252E-16	6.39197E-16	5.98802E-16	5.98604E-16	5.98468E-16	5.98351E-16	5.98256E-16
37	4.85554E-16	4.05500E-16	4.05100E-16	4.22761E-16	4.22904E-16	4.23011E-16	4.23102E-16	4.23187E-16
38	2.15929E-16	2.42090E-16	2.35266E-16	2.19847E-16	2.19522E-16	2.19273E-16	2.19029E-16	2.18790E-16
39	1.70033E-16	1.62027E-16	1.80662E-16	2.02529E-16	2.03189E-16	2.03709E-16	2.04226E-16	2.04740E-16
40	9.47639E-17	1.04612E-16	1.10245E-16	9.38133E-17	9.34260E-17	9.31721E-17	9.29189E-17	9.26657E-17
41	6.78416E-17	5.95858E-17	5.26290E-17	4.92410E-17	4.91274E-17	4.90382E-17	4.89487E-17	4.88607E-17

XRR	YZT 9	YZT 10	YZT 11	YZT 12	YZT 13	YZT 14	YZT 15	YZT 16
1	1.80025E-06	1.40551E-06	1.09718E-06	8.56520E-07	6.68730E-07	1.54592E-07	1.17285E-08	1.25490E-09
2	1.55574E-06	1.21392E-06	9.47799E-07	7.40419E-07	5.78670E-07	1.63690E-07	1.42492E-08	1.44812E-09
3	8.22612E-07	6.20444E-07	4.74657E-07	3.61989E-07	2.76777E-07	1.26390E-07	1.46538E-08	1.63755E-09
4	3.59926E-07	2.62973E-07	1.93019E-07	1.42407E-07	1.06704E-07	8.21326E-08	1.44393E-08	1.53033E-09
5	1.44881E-07	9.98411E-08	6.95194E-08	4.90280E-08	3.51927E-08	4.92925E-08	1.32731E-08	1.90938E-09
6	6.03100E-08	3.90016E-08	2.56524E-08	1.71220E-08	1.17220E-08	2.86810E-08	1.11840E-08	2.04862E-09
7	2.63642E-08	1.59605E-08	9.78694E-09	6.29474E-09	4.17726E-09	1.60486E-08	9.69280E-09	2.03326E-09
8	1.12669E-08	6.49458E-09	3.86049E-09	2.41058E-09	1.56798E-09	8.85204E-09	8.55837E-09	1.98706E-09
9	5.58001E-09	2.84932E-09	1.65715E-09	9.63731E-10	5.83174E-10	4.86085E-09	7.58482E-09	1.89250E-09
10	2.90758E-09	1.70445E-09	9.54173E-10	6.17523E-10	4.22234E-10	3.17306E-09	6.93269E-09	1.80245E-09
11	1.89343E-09	9.26372E-10	5.10584E-10	3.00208E-10	1.70276E-10	2.50940E-09	6.58024E-09	1.75174E-09
12	2.32045E-10	5.69013E-10	2.77693E-10	1.45308E-10	8.72584E-11	1.97811E-09	6.24053E-09	1.70235E-09
13	6.02064E-11	4.05393E-11	3.58844E-11	8.13005E-11	4.56828E-11	1.56093E-09	5.91218E-09	1.65473E-09
14	1.51855E-11	1.16189E-11	1.04091E-11	9.11880E-12	7.41023E-12	1.23473E-09	5.59568E-09	1.60913E-09

GAMMA-RAY FLUX FOR GROUP 2

XRR	YZT 1	YZT 2	YZT 3	YZT 4	YZT 5	YZT 6	YZT 7	YZT 8
1	1.59447E-11	5.31542E-11	2.07777E-10	2.42524E-07	5.40192E-07	6.05669E-07	6.00707E-07	5.60011E-07
2	1.85612E-11	5.80143E-11	2.26790E-10	2.17048E-07	4.83877E-07	5.47156E-07	5.50758E-07	5.20532E-07
3	2.22155E-11	6.13905E-11	2.47439E-10	1.90026E-07	3.47564E-07	3.59834E-07	3.43344E-07	3.14433E-07
4	2.44601E-11	7.59647E-11	7.67172E-10	1.47468E-07	2.43888E-07	2.28272E-07	1.99755E-07	1.68323E-07
5	2.81749E-11	1.44017E-10	2.18596E-09	1.00520E-07	1.50082E-07	1.25390E-07	9.90412E-08	7.73534E-08
6	3.41268E-11	2.58307E-10	3.48306E-09	7.24780E-08	8.88506E-08	6.93903E-08	5.34900E-08	4.11273E-08
7	4.76231E-11	3.89256E-10	4.21014E-09	5.16988E-08	5.91110E-08	4.38664E-08	3.30207E-08	2.15280E-08
8	5.91572E-11	4.86442E-10	4.61124E-09	3.52354E-08	3.62937E-08	2.51256E-08	1.69525E-08	1.11682E-08
9	7.70358E-11	6.04932E-10	4.72289E-09	2.55883E-08	2.62149E-08	1.69191E-08	1.07172E-08	7.21643E-09
10	2.13168E-11	1.74904E-10	1.34243E-09	4.55564E-09	9.37301E-09	8.15229E-09	6.09498E-09	3.22908E-09
11	6.20855E-12	5.22395E-11	3.90277E-10	9.32587E-10	1.42053E-09	1.29249E-09	1.97047E-09	1.60553E-09
12	1.71094E-12	1.44238E-11	1.05227E-10	2.07345E-10	2.85387E-10	3.43442E-10	3.97545E-10	3.81480E-10
13	4.88863E-13	4.15396E-12	2.93574E-11	4.90466E-11	6.12017E-11	7.58305E-11	8.89377E-11	7.43806E-11
14	1.37783E-13	1.17453E-12	8.14109E-12	1.19007E-11	1.37078E-11	1.70780E-11	2.05274E-11	2.11241E-11
15	3.94866E-14	3.37567E-13	2.26630E-12	2.96096E-12	3.19496E-12	3.93501E-12	4.82438E-12	5.32337E-12
16	1.12645E-14	9.61905E-14	6.33674E-13	7.49371E-13	7.74183E-13	9.34848E-13	1.15879E-12	1.34531E-12
17	3.25131E-15	2.77506E-14	1.78946E-13	1.95681E-13	1.97363E-13	2.33161E-13	2.89857E-13	3.49276E-13
18	9.36213E-16	7.95822E-15	5.00442E-14	5.41845E-14	5.50802E-14	6.44832E-14	8.03159E-14	1.00960E-13
19	2.72267E-16	2.30569E-15	1.42714E-14	1.80924E-14	1.98563E-14	2.38775E-14	3.04115E-14	3.88148E-14
20	7.98531E-17	6.68518E-16	4.12458E-15	8.13410E-15	1.01944E-14	1.29089E-14	1.64212E-14	2.15146E-14
21	2.66851E-17	2.02098E-16	1.30550E-15	5.79112E-15	7.54915E-15	9.64035E-15	1.27065E-14	1.73528E-14
22	2.35527E-17	8.23571E-17	5.15595E-16	4.84226E-15	6.73902E-15	9.32448E-15	1.22669E-14	1.83039E-14
23	8.48612E-17	1.33544E-16	4.07057E-16	4.84673E-15	6.53730E-15	8.13747E-15	1.14581E-14	1.60546E-14
24	4.86854E-16	6.41224E-16	1.04244E-15	4.88665E-15	6.43426E-15	8.85937E-15	1.16637E-14	1.54183E-14
25	8.03179E-15	2.22849E-14	9.85278E-14	3.30582E-13	3.57760E-13	3.81233E-13	4.06368E-13	4.33254E-13
26	2.15055E-14	4.36182E-14	1.57502E-13	2.34035E-13	2.32752E-13	2.31620E-13	2.30220E-13	2.28512E-13
27	4.40296E-14	8.55280E-14	1.85182E-13	1.96442E-13	1.96683E-13	1.96893E-13	1.97127E-13	1.97392E-13
28	5.02822E-14	9.87166E-14	1.42098E-13	1.53204E-13	1.53780E-13	1.54240E-13	1.54696E-13	1.55144E-13
29	7.26719E-14	8.79377E-14	6.76374E-14	5.16752E-14	5.12126E-14	5.09027E-14	5.05903E-14	5.02766E-14
30	5.77407E-14	3.30586E-14	2.76807E-14	3.71147E-14	3.70535E-14	3.70079E-14	3.69645E-14	3.69233E-14
31	1.46574E-14	2.15056E-14	3.03793E-14	2.54662E-14	2.55240E-14	2.55678E-14	2.56102E-14	2.56512E-14
32	2.15506E-14	2.06495E-14	1.68490E-14	1.90754E-14	1.90532E-14	1.90365E-14	1.90205E-14	1.90051E-14
33	1.04366E-14	1.05425E-14	1.30772E-14	1.19910E-14	1.20092E-14	1.20231E-14	1.20366E-14	1.20498E-14
34	8.76614E-15	9.09322E-15	8.84519E-15	1.01723E-14	1.01760E-14	1.01795E-14	1.01833E-14	1.01875E-14
35	7.59155E-15	8.51016E-15	7.51969E-15	6.19989E-15	6.19011E-15	6.18162E-15	6.17261E-15	6.16305E-15
36	4.76000E-15	3.90911E-15	3.66555E-15	4.51452E-15	4.52371E-15	4.53199E-15	4.54086E-15	4.55041E-15
37	3.17400E-15	4.00064E-15	3.93658E-15	3.59037E-15	3.58624E-15	3.58219E-15	3.57775E-15	3.57266E-15
38	2.24794E-15	1.97528E-15	1.95100E-15	2.10980E-15	2.11209E-15	2.11441E-15	2.11709E-15	2.12022E-15
39	1.28241E-15	1.59804E-15	1.53398E-15	1.44303E-15	1.44206E-15	1.44080E-15	1.43914E-15	1.43704E-15
40	9.78968E-16	7.56980E-16	7.62090E-16	8.35363E-16	8.36307E-16	8.37581E-16	8.39261E-16	8.41368E-16
41	4.34748E-16	4.42170E-16	5.09361E-16	4.63303E-16	4.62898E-16	4.62531E-16	4.61990E-16	4.61256E-16

XRR	YZT 9	YZT 10	YZT 11	YZT 12	YZT 13	YZT 14	YZT 15	YZT 16
1	5.03677E-07	4.42858E-07	3.83383E-07	3.28130E-07	2.78354E-07	6.41606E-08	6.53571E-09	4.18279E-10
2	4.72992E-07	4.18368E-07	3.62956E-07	3.10353E-07	2.62364E-07	8.40738E-08	7.56480E-09	5.84979E-10
3	2.76636E-07	2.39037E-07	2.02787E-07	1.70055E-07	1.41282E-07	6.27965E-08	9.29526E-09	8.59157E-10
4	1.39558E-07	1.14157E-07	9.22113E-08	7.38884E-08	5.87504E-08	3.52524E-08	9.39994E-09	1.20774E-09
5	6.11337E-08	4.81874E-08	3.88357E-08	3.07406E-08	2.42105E-08	1.92216E-08	8.40275E-09	1.56746E-09
6	3.09467E-08	2.31986E-08	1.75291E-08	1.28751E-08	9.48130E-09	1.22425E-08	6.46409E-09	1.73977E-09
7	1.50580E-08	1.08579E-08	7.99802E-09	5.94914E-09	4.42676E-09	7.29705E-09	4.91561E-09	1.77408E-09
8	7.94708E-09	5.58729E-09	3.86675E-09	2.71710E-09	1.95901E-09	4.55133E-09	3.84953E-09	1.75761E-09
9	4.77030E-09	3.07190E-09	2.05911E-09	1.53860E-09	1.08596E-09	2.83859E-09	3.08853E-09	1.68766E-09
10	2.20954E-09	1.69506E-09	1.15664E-09	8.27525E-10	6.22439E-10	2.02461E-09	2.65151E-09	1.57232E-09
11	1.05946E-09	6.88200E-10	5.49118E-10	4.01887E-10	2.96983E-10	1.68706E-09	2.43838E-09	1.49607E-09
12	3.61007E-10	2.93473E-10	1.94100E-10	1.41832E-10	1.20472E-10	1.38887E-09	2.24904E-09	1.41991E-09
13	7.65780E-11	7.74420E-11	6.91096E-11	5.31462E-11	3.90756E-11	1.14499E-09	2.07478E-09	1.34503E-09
14	2.03596E-11	2.00301E-11	1.56785E-11	1.24004E-11	1.11293E-11	9.47985E-10	1.91617E-09	1.27216E-09
15	5.37245E-12	5.34974E-12	4.68838E-12	4.09886E-12	3.97063E-12	7.90124E-10	1.77864E-09	1.19889E-09
16	1.42360E-12	1.45715E-12	1.41016E-12	1.30529E-12	1.46646E-12	6.63092E-10	1.65052E-09	1.12995E-09

```
***  REACTION RATE  ***      DOSE -PHOTON DOSE CONVERSION FACTOR

RESPONSE  FUNCTION IS,

          2.3000E-03    2.1000E-03    1.8000E-03    1.4000E-03    1.0000E-03    7.1000E-04    4.9000E-04    2.7000E-04
          1.5000E-04

 GROUP TOTAL
 YZT=  1
  1  3.3013E-11    2  4.0168E-11    3  4.7161E-11    4  5.0352E-11    5  4.8712E-11    6  4.3473E-11    7  3.9197E-11
  8  3.6338E-11    9  3.3887E-11   10  8.1843E-12   11  1.8276E-12   12  3.8995E-13   13  8.4843E-14   14  1.8536E-14
 15  4.1459E-15   16  9.4893E-16   17  2.1991E-16   18  5.1315E-17   19  1.3733E-17   20  8.8007E-18   21  2.7721E-17
 22  1.4495E-16   23  7.8675E-16   24  4.2879E-15   25  3.4742E-14   26  5.6201E-14   27  6.1644E-14   28  3.8687E-14
 29  2.7350E-14   30  1.7315E-14   31  1.1699E-14   32  7.8807E-15   33  4.9060E-15   34  2.8038E-15   35  1.8755E-15
 36  1.3041E-15   37  9.1009E-16   38  5.3124E-16   39  2.9028E-16   40  1.5011E-16   41  7.5505E-17


   THIS PROBLEM TERMINATED AT                  4.03 SEC.

     NINP          5
     NOUT          6
     NCR1          3
   NSCRAT          4
     NBSQ         14
     NPSQ         15
   NFLUX1          2
     NAFT         10
    NFLSV          9
     NZBT         13
     NBFT         11
     NGAM         12

   ESPRIT SAMPLE PROBLEM NO.1

   TIME SUMMARY (MINUTES) OF TIME IN ITERATION PHASE - -

                  OUTER      INNER      WANDR      GRIND      WWESOL
   REAL TIME=      0.52       2.40       0.02       0.98       0.07
   CPU TIME =      0.52       2.40       0.02       0.98       0.07

   TOTAL REAL TIME =       3.98

   TOTAL CPU TIME  =       3.98

   TIME SUMMARY (PERCENTAGES) OF TIME IN ITERATION PHASE - -

                  OUTER      INNER      WANDR      GRIND      WWESOL
   REAL TIME=     13.06      60.22       0.41      24.50       1.81
   CPU TIME =     13.06      60.21       0.41      24.50       1.82
```

D.8 Sample Problem for MCACE

```
MEMBER NAME > B:MCACE.TXT      ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.5 I.1 P.0 W.1 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  //MCACE  EXEC LMGO,LM='J1446.MCACEX'
    8 :  //FT16F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(100,20)),
    9 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT41F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(100,20)),
   11 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT92F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   13 :  //SYSIN DD *
   14 :  MCACE SAMPLE PROBLEM NO.1
   15 :    200  240   60    1    9    0    9    9    0    0   10    2    0    0
   16 :      0    1    0    0 1.0       0.02   +6 0.0       0.0       2.2    +5
   17 :      0
   18 :    0.0
   19 :    1.0
   20 :    1.33  +6  1.0   +6  0.8   +6  0.6   +6  0.4   +6  0.3   +6  0.2   +6
   21 :    0.1   +6  0.05  +6
   22 :  0123456789
   23 :      0    1    0    0    0    4    9    0
   24 :      1    1    9    1    1    4 100.0      1.0    -3 1.0    -2  0.0
   25 :     -1
   26 :      0
   27 :      0    0   SKY-SHINE PROBLEM
   28 :    RCC    1  0.0       0.0       0.0       0.0       0.0       7.6   +2
   29 :                4.1   +2
   30 :    RCC    2  0.0       0.0       0.0       0.0       0.0       7.8103+2
   31 :                7.1   +2
   32 :    RPP    3 -6.0   +4 6.0    +4 -6.0   +4 6.0    +4 0.0       6.0   +4
   33 :    RPP    4 -6.01  +4 6.01   +4 -6.01  +4 6.01   +4 -10.0     6.01  +4
   34 :    END
   35 :    AIR          +1
   36 :    WAL          +2      -1
   37 :    AIR          +3      -2
   38 :    VID          +4      -3
   39 :    END
   40 :      1    2    3    4
   41 :      1    2    1    0
   42 :    CROSS SECTION FROM DATA-POOL
   43 :      0    0    9    9    9   12    4    2    2    0    0 -16    0
   44 :      0    0    0    0    0    0   -1    0
   45 :   &DPUNIT  NLIB=92  &END
   46 :   G09  FX16 AIR  CONC
   47 :    SAMBO INPUT TOTAL FLUX AND DOSE RATE
   48 :      3    1    9    9    0    0   -1    1    1
   49 :    1.0   +4  0.0       1.5    +2
   50 :    2.0   +4  0.0       1.5    +2
   51 :    3.0   +4  0.0       1.5    +2
   52 :    RESPONSE FUNCTION (MR/HR)
   53 :   &DPUNIT  RESD=92  &END
   54 :   G09  RESD DOSE
   55 :    PHOTON/SEC/CM**2/EV
   56 :      1    2    3    4    5    6    7    8    9
   57 :  PRT      1    1    1    0    0    0    9    9    0    0    0
   58 :   0.0        0.0       1.5    +2 0.0       0.0       1.0
   59 :   1.0        0.0       0.0
   60 :   70.0   +2 90.0   +2 110.0  +2 140.0  +2 180.0  +2 220.0  +2 250.0  +2
   61 :   280.0  +2 320.0  +2 380.0  +2
   62 :      1    1    1    1    1    1    1    1    1
```

```
MEMBER NAME > B:MCACE.TXT      ------------------------------------------------ PAGE :  2
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
   63 :   0.0       6.283     0.0       6.283     0.0       6.283     0.0
   64 :   6.283     0.0       6.283     0.0       6.283     0.0       6.283
   65 :   0.0       6.283     0.0       6.283
   66 :   SOURCE       1    5    3  1.33  +6 0.02   +6    3
   67 :               0.0       0.0       660.0
   68 :               0.0       0.0       0.0
   69 :               0.273     0.0
   70 :       1
   71 :   1.25   +6  1.0
   72 :   END OF SAMPLE PROBLEM : PROGRAM MCACE TERMINATED
   73 :  ++
   74 :  //
------------------------------------ END OF FILE -------------------------------------
```

```
            *** MCACE CARD INPUT DATA IMAGE LIST ****

 1-> MCACE SAMPLE PROBLEM NO.1
 2->   200  240   60     1     9     0     9     9     0     0    10     2     0     0
 3->     0    1     0     0 1.0         0.02   +6 0.0          0.0         2.2    +5
 4->     0
 5->   0.0
 6->   1.0
 7->   1.33  +6  1.0   +6  0.8   +6  0.6   +6  0.4   +6  0.3   +6  0.2   +6
 8->   0.1   +6  0.05  +6
 9-> 0123456789
10->     0     1     0     0     0     4     9     0
11->     1     1     9     1     1     4 100.0       1.0     -3 1.0     -2  0.0
12->    -1
13->     0
14->     0     0   SKY-SHINE PROBLEM
15->   RCC     1  0.0         0.0         0.0         0.0         7.6    +2
16->               4.1    +2
17->   RCC     2  0.0         0.0         0.0         0.0         0.0         7.8103+2
18->               7.1    +2
19->   RPP     3 -6.0   +4 6.0     +4 -6.0   +4 6.0     +4 0.0          6.0    +4
20->   RPP     4 -6.01  +4 6.01    +4 -6.01  +4 6.01    +4 -10.0        6.01   +4
21->   END
22->   AIR            +1
23->   WAL            +2       -1
24->   AIR            +3       -2
25->   VID            +4       -3
26->   END
27->     1     2     3     4
28->     1     2     1     0
29->   CROSS SECTION FROM DATA-POOL
30->     0     0     9     9     9    12     4     2     2     0     0  -16     0
31->     0     0     0     0     0     0    -1     0
32->  &DPUNIT  NL1B=92  &END
33->  GD9  FX16 AIR  CONC
34->   SAMBO INPUT TOTAL FLUX AND DOSE RATE
35->     3     1     9     9     0     0    -1     1     1
36->   1.0   +4  0.0         1.5     +2
37->   2.0   +4  0.0         1.5     +2
38->   3.0   +4  0.0         1.5     +2
39->   RESPONSE FUNCTION (MR/HR)
40->  &DPUNIT  RESD=92  &END
41->  GD9  RESD DOSE
42->   PHOTON/SEC/CM**2/EV
43->      1     2     3     4     5     6     7     8     9
44-> PRT       1     1     1     0     0     0     9     9     0     0     0
45->  0.0          0.0         1.5     +2 0.0          0.0         1.0
46->  1.0          0.0         0.0
47->  70.0   +2 90.0    +2 110.0  +2 140.0  +2 180.0  +2 220.0  +2 250.0  +2
48->  280.0  +2 320.0   +2 380.0  +2
49->     1     1     1     1     1     1     1     1     1
50->  0.0          6.283       0.0         6.283       0.0         6.283       0.0
51->  6.283        0.0         6.283       0.0         6.283       0.0         6.283
52->  0.0          6.283       0.0         6.283
53->  SOURCE          1     5     3  1.33  +6 0.02    +6     3
54->                0.0         0.0         660.0
55->                0.0         0.0         0.0
56->                0.273       0.0
57->     1
58->  1.25   +6  1.0
59->  END OF SAMPLE PROBLEM : PROGRAM MCACE TERMINATED
```

```
MCACE SAMPLE PROBLEM NO.1

NSTRT=  200      NMOST=  240      NITS=  60        NQUIT=   1       NGPQTN=   9
NGPQTG=   0      NMGP=    9       NMTG=    9       NCOLTP=   0      IADJM=    0
      MAXIMUM EXECUTION TIME =   10 MINUTES       MEDIA=    2      MEDALB=     0      IREST=     0

ISOUR=     0    NGPFS=     1    ISBIAS=     0    NRESP=     0
  WTSRT= 1.0000E+00    EBDTM= 2.0000E+04    EBDTG= 0.0           TCUT= 0.0           VELTH= 2.2000E+05    IBOOT= 0

XSRT= 0.0                 YSTRT= 0.0                ZSTRT= 0.0                AGSTRT= 0.0
UINP= 0.0                 VINP= 0.0                 WINP= 0.0

              SOURCE DATA
     GROUP    UNNORMALIZED     NORMALIZED
                FRACTION         FRACTION
        1      1.0000E+00        1.000000
   TOTAL       1.0000E+00

GROUP PARAMETERS, GROUP NUMBERS GREATER THAN     9 CORRESPOND TO SECONDARY PARTICLES

   GROUP      UPPER EDGE          VELOCITY
                (EV)              (CM/SEC)
     1       1.3300E+06        1.4927E+09
     2       1.0000E+06        1.3120E+09
     3       8.0000E+05        1.1571E+09
     4       6.0000E+05        9.7793E+08
     5       4.0000E+05        8.1819E+08
     6       3.0000E+05        6.9150E+08
     7       2.0000E+05        5.3563E+08
     8       1.0000E+05        3.7875E+08
     9       5.0000E+04        2.2000E+05

INITIAL RANDOM NUMBER =      45678900

NSPLT= 0      NKILL= 1      NPAST= 0      NOLEAK= 0      IEBIAS= 0      MXREG=  4      MAXGP=  9      IREGX=  0      NITSO=   0

WEIGHT STANDARDS FOR SPLITTING AND RUSSIAN ROULETTE AND PATHLENGTH STRETCHING PARAMETERS

 NGP1  NDG NGP2  NRG1 NDRG NRG2     WTNIM1       WTLOW1       WTAVE1        XNU        F VAR      WTAVE2
   1    1    9     1    1    4   1.0000E+02  1.0000E-03  1.0000E-02  0.0          3.3741E-79  6.0733E-79

NSOUR= 0      MFISTP=  0      NKCALC= 0      NORMF= 0
```

```
          NE PROBLEM

                    IVOPT = 0          IDBG = 0


                                                    BODY DATA
 RCC    1  0.0              0.0             0.0             0.0             0.0             0.76000000D+03   3
           0.41000000D+03
 RCC    2  0.0              0.0             0.0             0.0             0.0             0.78103000D+03  12
           0.71000000D+03
 RPP    3 -0.60000000D+05  0.60000000D+05 -0.60000000D+05  0.60000000D+05  0.0             0.60000000D+05  21
 RPP    4 -0.60100000D+05  0.60100000D+05 -0.60100000D+05  0.60100000D+05 -0.10000000D+02  0.60100000D+05  29
 END    5  0.0              0.0             0.0             0.0             0.0             0.0             37
NUMBER OF BODIES       4
LENGTH OF FPD-ARRAY   42


                                                    INPUT ZONE DATA
 AIR    0      1      0      0      0      0      0      0      0      0  I  1
 WAL    0      2     -1      0      0      0      0      0      0      0  I  2
 AIR    0      3     -2      0      0      0      0      0      0      0  I  3
 VID    0      4     -3      0      0      0      0      0      0      0  I  4
 END    0      0      0      0      0      0      0      0      0      0  I  5
NUMBER OF INPUT ZONES       4
NUMBER OF  CODE ZONES       4
LENGTH OF INTEGER ARRAY   101

CODE ZONE     INPUT ZONE     ZONE DATA LOC.     NO. OF BODIES     REGION NO.     MEDIA NO.
     1             1              29                 1              1              1
     2             2              34                 2              2              2
     3             3              43                 2              3              1
     4             4              52                 2              4              0

   I    KR1(I)    KR2(I)
   1        1         1
   2        2         2
   3        3         3
   4        4         4

         MORSE REGION IN INPUT ZONE(I) ARRAY   MRIZ(I),I=1, 4)

            1   2   3   4

         MORSE MEDIA IN INPUT ZONE(I) ARRAY  MMIZ(I),I=1, 4)

            1   2   1   0



   CROSS SECTION FROM DATA-POOL

 NUMBER OF PRIMARY GROUPS (NGP)            0
 NUMBER OF PRIMARY DOWNSCATTERS (NDS)      0
 NUMBER OF SECONDARY GROUPS (NGG)          9
 NUMBER OF SECONDARY DOWNSCATTERS (NDSG)   9
 NUMBER OF PRIM+SEC GROUPS (INGP)          9
 TABLE LENGTH (ITDL)                      12
 LOC OF WITHIN GROUP (SIG GG) (ISGG)       4
 NUMBER OF MEDIA (NMED)                    2
 NUMBER OF INPUT ELEMENTS (NELEM)          2
 NUMBER OF MIXING ENTRIES (NMIX)           0
 NUMBER OF COEFFICIENTS (NCOEF)            0
 NUMBER OF ANGLES (NSCT)                 -16
 RESTORE COEFF (ISTAT)                     0
 ADJOINT SWITCH (FROM MORSE)               0


 INPUT/OUTPUT OPTIONS
      IRDSG (AS READ)          0
      ISTR (AS STORE)          0
      IFMU (MUS)               0
      IMOM (MOMENTS)           0
      IPRIN (ANGLES,PROB)      0
      IPUN (IMPOSSIBLE COEF)   0
      CARD FORMAT (IDIF)      -1
      INPUT TAPE (IXTAPE)      0
      MORSEC TAPE (JXTAPE)     0
      O&R TAPE (IO&RT)         0

 D.P. UNIT NUMBER --- LIB =    92


 READ NODE NAME IN XSEC --   G09   FX16  AIR   CONC


 READ THE ANGULER MESH BOUNDARIES
   -1.000E+00  -9.728E-01  -9.106E-01  -8.154E-01  -6.908E-01  -5.412E-01  -3.721E-01  -1.895E-01   0.0          1.895E-01
    3.721E-01   5.412E-01   6.908E-01   8.154E-01   9.106E-01   9.728E-01   1.000E+00


 THE ANGULER MESH INTERVALES
    2.715E-02   6.225E-02   9.516E-02   1.246E-01   1.496E-01   1.692E-01   1.826E-01   1.895E-01   1.895E-01   1.826E-01
    1.692E-01   1.496E-01   1.246E-01   9.516E-02   6.225E-02   2.715E-02

 STORAGE ALLOCATIONS
 CROSS SECTIONS START AT       1199
 LAST LOCATION USED (PERM)     4299
 TEMP LOCATIONS USED           4299 TO    5127
 EXCESS STORAGE (TEMP)        24873

 ***  G09  FX16 AIR   CROSS SECTION READ ***
 *** SUB. STORE1 ENTER IE=   1***

 ***  G09  FX16 CONC  CROSS SECTION READ ***
 *** SUB. STORE1 ENTER IE=   2***
```

```
   SAMBO INPUT TOTAL FLUX AND DOSE RATE

 ND=  3,NS=  1, NNE=  9, NE=  9, MT=  0, MA=  0, MRESP= -1, NEX=  1, NEXND=  1, EPS=  0.0

 DET      X              Y              Z             RAD            TO
  1   1.0000E+04      0.0          1.5000E+02     1.0001E+04     6.6998E-06
  2   2.0000E+04      0.0          1.5000E+02     2.0001E+04     1.3399E-05
  3   3.0000E+04      0.0          1.5000E+02     3.0000E+04     2.0097E-05

 GROUP        RESP( 1)
     1      2.3000E-03
     2      2.1000E-03
     3      1.8000E-03
     4      1.4000E-03
     5      1.0000E-03
     6      7.1000E-04
     7      4.9000E-04
     8      2.7000E-04
     9      1.5000E-04

        NUMBER OF PRIMARY ENERGY BINS      9
        TOTAL NUMBER OF ENERGY BINS        9
           LOWER     LOWER
BIN NO.    LIMIT     ENERGY        DELTA
           GROUP     LIMIT           E

                  1.330E+06
   1          1    1.000E+06    3.300E+05
   2          2    8.000E+05    2.000E+05
   3          3    6.000E+05    2.000E+05
   4          4    4.000E+05    2.000E+05
   5          5    3.000E+05    1.000E+05
   6          6    2.000E+05    1.000E+05
   7          7    1.000E+05    1.000E+05
   8          8    5.000E+04    5.000E+04
   9          9    2.000E+04    3.000E+04

      NUMBER OF TIME BINS   0

      NUMBER OF ANGLE BINS   0
UPPER LIMITS OF COSINE BINS


          **************************
          **** SURFACE DETECTOR *****
          **************************


SURFACE NO. -----   1
ITYPE =PRT  IREAL = 1 IEXP = 1 IFLUX = 1 ILEAK = 0 IANG = 0 IOUT = 0
MESH1 =   9 MESH2 =   9 IETA =   0 IPHI =   0 IPRT = 0
XO = 0.0        YO = 0.0        ZO = 0.150E+03
UO = 0.0        VO = 0.0        WO = 0.100E+01
U1 = 0.100E+01 V1 = 0.0         W1 = 0.0        RADIUS = 0.0

  730 CELLS USED BY ANALYSIS,21371 CELLS REMAIN UNUSED.



YOU ARE USING THE DEFAULT VERSION OF STRUN WHICH DOES NOTHING.

   START BATCH   1                          RANDOM=  1164413184

         ************************
         *** SOURCE INPUT DATA ***
         ************************

   *** POINT SOURCE ***

     XO,YO,ZO,X1,X2,Y1,Y2,Z1,Z2 =      0.0       0.0     660.00      0.0       0.0       0.0       0.0       0.0       0.0

     BIASED ISOTROPIC EMISSION
        UINP,TIMES=      0.273      2.751

     MONOENERGY = 0.12500E+07EV
YOU ARE USING THE DEFAULT VERSION OF GTMED WHICH ASSUMES GEOMETRY AND XSECT MEDIA ARE IDENTICAL.
    WT=   7.2699E+01   UAVE=   3.6673E-02   VAVE=  -2.3839E-02   WAVE=   6.4576E-01   AGEAVE=   0.0
    IAVE=    1.00   XAVE=   0.0          YAVE=   0.0          ZAVE=   6.6000E+02
                                  ****************************************
                                           GEOMETRY SEARCH ARRAY FULL
                                  ****************************************

NUMBER OF COLLISIONS OF TYPE NCOLL
  SOURCE SPLIT(D)    FISHN   GAMGEN REALCOLL   ALBEDO    BDRYX   ESCAPE    E-CUT TIMEKILL R R KILL R R SURV  GAMLOST
     200       0        0        0     6427        0      567       94        0         0      106       11        0

   START BATCH   2                          RANDOM=   531691776
    WT=   7.2699E+01   UAVE=   4.9081E-02   VAVE=  -2.3755E-02   WAVE=   6.0515E-01   AGEAVE=   0.0
    IAVE=    1.00   XAVE=   0.0          YAVE=   0.0          ZAVE=   6.6000E+02

NUMBER OF COLLISIONS OF TYPE NCOLL
  SOURCE SPLIT(D)    FISHN   GAMGEN REALCOLL   ALBEDO    BDRYX   ESCAPE    E-CUT TIMEKILL R R KILL R R SURV  GAMLOST
     200       0        0        0     6722        0      608       94        0         0      106       13        0

   START BATCH   3                          RANDOM=  1518395648
    WT=   7.2699E+01   UAVE=   1.8876E-03   VAVE=   4.9286E-02   WAVE=   6.4189E-01   AGEAVE=   0.0
    IAVE=    1.00   XAVE=   0.0          YAVE=   0.0          ZAVE=   6.6000E+02

NUMBER OF COLLISIONS OF TYPE NCOLL
  SOURCE SPLIT(D)    FISHN   GAMGEN REALCOLL   ALBEDO    BDRYX   ESCAPE    E-CUT TIMEKILL R R KILL R R SURV  GAMLOST
     200       0        0        0     6768        0      562       73        0         0      127       12        0

   START BATCH   4                          RANDOM=  1222473984
    WT=   7.2699E+01   UAVE=  -3.0813E-02   VAVE=  -3.5127E-02   WAVE=   6.4524E-01   AGEAVE=   0.0
    IAVE=    1.00   XAVE=   0.0          YAVE=   0.0          ZAVE=   6.6000E+02

NUMBER OF COLLISIONS OF TYPE NCOLL
  SOURCE SPLIT(D)    FISHN   GAMGEN REALCOLL   ALBEDO    BDRYX   ESCAPE    E-CUT TIMEKILL R R KILL R R SURV  GAMLOST
     200       0        0        0     6529        0      582       87        0         0      113       14        0

   START BATCH   5                          RANDOM=  1831727360
    WT=   7.2699E+01   UAVE=   6.6525E-03   VAVE=  -7.9512E-03   WAVE=   6.3187E-01   AGEAVE=   0.0
    IAVE=    1.00   XAVE=   0.0          YAVE=   0.0          ZAVE=   6.6000E+02

NUMBER OF COLLISIONS OF TYPE NCOLL
  SOURCE SPLIT(D)    FISHN   GAMGEN REALCOLL   ALBEDO    BDRYX   ESCAPE    E-CUT TIMEKILL R R KILL R R SURV  GAMLOST
     200       0        0        0     6143        0      644       99        0         0      101        5        0

   START BATCH   6                          RANDOM=  1016855296
    WT=   7.2699E+01   UAVE=   1.5130E-02   VAVE=  -2.4823E-02   WAVE=   6.2881E-01   AGEAVE=   0.0
```

```
THIS CASE WAS RUN ON

DOSE  PHOTON DOSE CONVERSION FACTOR
```

DETECTOR	RESPONSES(DETECTOR) UNCOLL RESPONSE	FSD UNCOLL	RESPONSE FUNCTION (MR/HR) TOTAL RESPONSE	FSD TOTAL
1	2.8465E-28	0.00048	1.0059E-14	0.09303
2	3.9786E-29	0.00038	2.1494E-15	0.07685
3	9.6000E-30	0.00065	6.0602E-16	0.12057

FLUENCE(ENERGY,DETECTOR) PHOTON/SEC/CM**2/EV

ENERGIES	DETECTOR NO. 1	2	3
1.330E+06	3.757E-31	5.257E-32	3.667E-24
	0.001	0.001	1.000
1.000E+06	3.420E-23	7.519E-36	1.455E-23
	1.000	0.185	1.000
8.000E+05	1.422E-19	9.004E-20	2.130E-20
	0.956	0.486	0.460
6.000E+05	7.279E-19	1.334E-19	6.593E-20
	0.485	0.371	0.335
4.000E+05	6.276E-18	1.471E-18	5.316E-19
	0.192	0.130	0.139
3.000E+05	1.511E-17	4.194E-18	8.000E-19
	0.171	0.196	0.151
2.000E+05	4.109E-17	9.802E-18	1.822E-18
	0.092	0.164	0.136
1.000E+05	2.791E-16	3.888E-17	1.304E-17
	0.199	0.126	0.277
5.000E+04	5.163E-16	1.399E-16	4.546E-17
	0.076	0.108	0.158
2.000E+04			

```
                                  **************************
                                  *** SURFACE CROSSING ***
                                  **************************

                              ******************************
                              * (1) FLUX                    *
                              *     REAL CROSSING            *
                              ******************************


                               ********************************
                               * SURFACE NO. =  1             *
                               * SURFACE TYPE = PLANE(R-T)    *
                               ********************************
```

* SPATIAL MESH * RADIUS	AZIMUTHAL ANGLE	
7000.000	0.0	6.283
9000.000	0.0	6.283
11000.000	0.0	6.283
14000.000	0.0	6.283
18000.000	0.0	6.283
22000.000	0.0	6.283
25000.000	0.0	6.283
28000.000	0.0	6.283
32000.000	0.0	6.283
38000.000		

```
                                  * REACTION RATE *
                  RESPONCE NO. =   1  MEAN VALUE =  3.0459E-16 ( 0.2040)
```

SPATIAL MESH ; REACTION RATE ; F.S.D	1	2	3	4	5	6	7	8	9
	2.7080E-15	1.2991E-15	1.1122E-15	4.6268E-16	8.3649E-17	9.9873E-17	5.6477E-17	4.1856E-16	1.6063E-17
	0.3845	0.6802	0.5798	0.3847	0.4390	0.8935	0.5996	0.5008	0.5991

```
                                  * FLUX SPECTRUM *
```

ENERGY ; MEAN VALUE ; F.S.D	1	2	3	4	5	6	7	8	9
	0.0	0.0	0.0	0.0	0.0	2.5827E-19	7.1820E-19	9.4559E-18	2.7424E-17
	0.0	0.0	0.0	0.0	0.0	0.7568	0.6219	0.3782	0.2163

ENERGY SPATIAL MESH	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
```
```

```
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0
  4  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0
  5  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0
        0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
        0.0
  6  0.0          0.0          0.0          8.4492E-19   0.0          0.0          0.0          1.0505E-18
        0.0
        0.0          0.0          0.0          1.0000       0.0          0.0          0.0          1.0000
        0.0
  7  6.4464E-18   1.4395E-17   1.3375E-18   0.0          0.0          0.0          0.0          4.9781E-19
        0.0
        1.0000       1.0000       1.0000       0.0          0.0          0.0          0.0          1.0000
        0.0
  8  7.9539E-17   5.6869E-18   4.9736E-17   1.9064E-17   0.0          6.5876E-18   0.0          1.2669E-17
        6.6271E-19
        0.7744       1.0000       0.8197       0.5823       0.0          1.0000       0.0          1.0000
        1.0000
  9  2.9296E-16   1.1487E-16   8.3382E-17   3.2293E-17   1.8589E-17   2.4311E-18   1.2550E-17   3.3012E-17
        1.5814E-18
        0.4290       0.8272       0.4378       0.6039       0.4390       0.8524       0.5996       0.5562
        0.5395
```

```
*******************************
* (1) FLUX                    *
*     EXPECTED CROSSING       *
*******************************
```

```
*******************************
* SURFACE NO. =  1            *
* SURFACE TYPE = PLANE(R-T)   *
*******************************
```

```
  * SPATIAL MESH *
  RADIUS      AZIMUTHAL ANGLE
 7000.000      0.0          6.283
 9000.000      0.0          6.283
11000.000      0.0          6.283
14000.000      0.0          6.283
18000.000      0.0          6.283
22000.000      0.0          6.283
25000.000      0.0          6.283
28000.000      0.0          6.283
32000.000      0.0          6.283
38000.000
```

```
                                  * REACTION RATE *
                RESPONCE NO. =   1  MEAN VALUE =  2.9180E-15 ( 0.0616)

SPATIAL MESH / REACTION RATE / F.S.D
          1            2            3            4            5            6            7            8
          9
      1.9529E-14   1.3164E-14   8.3772E-15   5.9494E-15   2.8354E-15   1.7203E-15   1.7406E-15   1.1788E-15
      6.5100E-16
         0.1354       0.1392       0.1534       0.1123       0.1464       0.1659       0.1607       0.1718
         0.2165
```

```
                                  * FLUX SPECTRUM *

ENERGY / MEAN VALUE / F.S.D
          1            2            3            4            5            6            7            8
          9
      3.1757E-35   4.3835E-36   1.8593E-19   3.4080E-19   3.1617E-18   3.7069E-18   1.0503E-17   6.2572E-17
      1.8155E-16
         0.7325       0.3715       0.7013       0.5683       0.3021       0.1407       0.1116       0.0858
         0.0608

 ENERGY      SPATIAL MESH
          1            2            3            4            5            6            7            8
          9
   1  9.2652E-34   3.4334E-34   1.0227E-35   0.0          0.0          0.0          9.5381E-37   0.0
      4.3060E-42
         1.0000       1.0000       0.9832       0.0          0.0          0.0          1.0000       0.0
         1.0000
   2  4.8240E-36   8.4688E-37   2.6489E-35   2.9515E-35   2.2453E-38   1.1180E-36   0.0          3.6049E-39
      0.0
         0.7773       0.7079       0.6707       0.4998       0.8100       0.9658       0.0          1.0000
         0.0
   3  3.5666E-38   4.8162E-37   3.1316E-39   1.0397E-18   7.8932E-19   0.0          0.0          7.1517E-42
      0.0
         0.4899       0.6783       0.9163       1.0000       1.0000       0.0          0.0          1.0000
         0.0
   4  2.3564E-18   8.1877E-40   3.6236E-18   7.8299E-40   2.5100E-19   2.8366E-19   0.0          1.0854E-19
      5.2478E-20
         1.0000       0.9792       0.8065       0.9941       1.0000       1.0000       0.0          1.0000
         1.0000
   5  2.9963E-17   1.9563E-17   5.1856E-18   4.9711E-18   1.0487E-18   3.8683E-19   2.3839E-18   1.1823E-18
      1.8067E-18
         0.5977       0.5436       0.6116       0.7019       0.5120       1.0000       0.5177       0.7621
         0.6650
   6  1.3642E-17   2.1898E-17   8.5921E-18   8.4855E-18   3.4291E-18   2.0935E-18   1.9867E-18   2.8878E-18
      6.5540E-19
         0.4972       0.4221       0.5412       0.3298       0.5467       0.6256       0.4949       0.4038
         0.2957
   7  9.0468E-17   5.4012E-17   2.8218E-17   2.5747E-17   6.3586E-18   4.9481E-18   6.4602E-18   3.6443E-18
      1.3494E-18
         0.2204       0.2158       0.2543       0.2433       0.2030       0.2798       0.3886       0.2862
         0.2827
   8  4.1635E-16   2.7872E-16   2.2007E-16   1.3366E-16   6.0057E-17   3.3370E-17   3.1209E-17   2.3880E-17
      9.9857E-18
         0.1591       0.2194       0.2463       0.1959       0.2069       0.1890       0.2609       0.3738
         0.5043
   9  1.0780E-15   7.2072E-16   4.1787E-16   3.1323E-16   2.2451E-16   1.6903E-16   1.3851E-16   7.2050E-17
      4.6262E-17
         0.1132       0.1253       0.1052       0.0986       0.1988       0.2508       0.2122       0.1496
         0.1055

ELAPSED TIME /   4.25 MIN.
```

D.9 Sample Problem for BREM

```
MEMBER NAME > B:BSTEP2.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.2 I.3 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  // EXEC LMGO,LM='J1446.FCSTEP2X'
    8 :  //FT08F001 DD DSN=J3631.DLC15.DATA,DISP=SHR,LABEL=(,,,IN)
    9 :  //FT11F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(50,20)),
   10 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   11 :  //FT13F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(50,20)),
   12 :  //   DCB=(LRECL=16804,BLKSIZE=16804,RECFM=F)
   13 :  //FT14F001 DD DSN=&&F4,UNIT=WK10,SPACE=(TRK,(50,20)),
   14 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   15 :  //FT16F001 DD DSN=&&F6,UNIT=WK10,SPACE=(TRK,(50,20)),
   16 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   17 :  //FT17F001 DD DSN=&&F7,UNIT=WK10,SPACE=(TRK,(50,20)),
   18 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   19 :  //FT18F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(50,20)),
   20 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   21 :  //FT21F001 DD DSN=&&FA,UNIT=WK10,SPACE=(TRK,(50,20)),
   22 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   23 :  //FT22F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(50,20)),
   24 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   25 :  //FT23F001 DD DSN=&&FC,UNIT=WK10,SPACE=(TRK,(50,20)),
   26 :  //   DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   27 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   28 :  //SYSIN DD *
   29 :   FAIR-CROSS STEP-2 FOR BREMSSTRAHLUNG SAMPLE PROBLEM
   30 :   &UNIT FXSN=91 &END
   31 :   1** 2  1    0  19  16  4HEG19  1  1  T
   32 :   3**  7.235E+6  7.065E+6  6.215E+6  6.045E+6  5.535E+6  5.025E+6
   33 :        4.515E+6  4.005E+6  3.495E+6  2.985E+6  2.475E+6  2.135E+6
   34 :        1.795E+6  1.455E+6  1.115E+6  0.775E+6  0.605E+6  0.435E+6
   35 :        0.265E+6  0.095E+6   T
   36 :  LEAD CROSS SECTION BY DLC-15
   37 :   4**  4HPB00  0  0  3  1  0
   38 :   5**      82
   39 :   8**     82.0
   40 :   9**   3.295E-2
   41 :  10**    300.0
   42 :    T
   43 :  17**    10  0  0  0  2  2  T
   44 :  29**     0   1   0   0   T
   45 :  ++
   46 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
MEMBER NAME > B:BDIAC1.TXT    ------------------------------------------------ PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.3 I.4 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  //DIAC EXEC LMGO,LM='J1446.DIACX',OBSIZE=137,ORECFM=FA
    8 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(300,100)),
    9 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   10 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(300,100)),
   11 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   12 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(300,100)),
   13 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   14 :  //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(300,100)),
   15 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   16 :  //FT12F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(300,100)),
   17 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   18 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   19 :  //SYSIN DD *
   20 :  DIAC SAMPLE PROBLEM NO.1 FOR BREMSSTRAHLUNG OF 5CM LEAD
   21 :   &UNIT  FXSN=91,FLX1=91,FLX2=0 &END
   22 :  14**   0 19  0  0  0  0  0  1   0  0  0
   23 :  15** 500  0  16  16  1  0  0  1  12  0   19  3  4   22  0  0  1  1  1
   24 :        0  0   1   1  50  0  0  0  0  1  2  0  0  0  1  0  0
   25 :  16**  1.0  0.1  1.0-4  1.420892  3R0.0  0.0  0.0  0.5  1.0-4  3R0.0 T
   26 :   6**  0.0 0.0244936 0.0413296 0.0392569 0.0400796 0.0643754
   27 :            0.0442079 0.109085  0.1371702  1N8
   28 :   7**  -0.9902984 -0.9805009 -0.9092855 -0.8319966 -0.7467506
   29 :        -0.6504264 -0.5370966 -0.3922893 -0.1389568 1M8  T
   30 :  13**  4HEG19  4HFX16  4HPB00 T
   31 :  18**  17R0.07  17R0.0  17R0.93  F0.0  T
   32 :   3**  F0.0  T
   33 :   1**  F0.0
   34 :   4**  1110.0  6.0
   35 :   5** F1.0
   36 :   8**  F1
   37 :   9**  1
   38 :  21**  0.0  10R1.0  0.0
   39 :    T
   40 :  ++
   41 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
MEMBER NAME > B:BDIAC2.TXT     ---------------------------------------------- PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.3 !.4 P.0 W.2 C.4 SRP
    6 :   OPTP PASSWORD=########
    7 :  //BREM EXEC LMGO,LM='J1446.BREM',
    8 :  //  ORECFM=FA,OBSIZE=137,SYSOUT=*
    9 :  //FT01F001 DD DSN=J1446.BSOURCE.DATA,UNIT=TSSWK,SPACE=(TRK,(10,5)),
   10 :  // DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS),DISP=(NEW,CATLG,DELETE)
   11 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   12 :  //SYSIN DD *
   13 :  BREMSSTRAHLUNG SOURCE CALCULATION FOR LEAD
   14 :   &UNIT FLX1=91,BREM=91 &END
   15 :   1¥¥  10  1  12  1  1  0  0  0  T
   16 :   2¥¥  4HEG19  4H 500
   17 :  13¥¥  4HEG19  4HFX16  4HPB00
   18 :  21**  0.0  10R1.0  0.0  T
   19 :  /*
   20 :  //DIAC EXEC LMGO,LM='J1446.DIACX',OBSIZE=137,ORECFM=FA
   21 :  //FT01F001 DD DSN=&&F1,UNIT=WK10,SPACE=(TRK,(300,100)),
   22 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   23 :  //FT02F001 DD DSN=&&F2,UNIT=WK10,SPACE=(TRK,(300,100)),
   24 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   25 :  //FT03F001 DD DSN=&&F3,UNIT=WK10,SPACE=(TRK,(300,100)),
   26 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   27 :  //FT08F001 DD DSN=&&F8,UNIT=WK10,SPACE=(TRK,(300,100)),
   28 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   29 :  //FT12F001 DD DSN=&&FB,UNIT=WK10,SPACE=(TRK,(300,100)),
   30 :  //  DCB=(LRECL=19064,BLKSIZE=19068,RECFM=VBS)
   31 :  //FT20F001 DD DSN=J1446.BSOURCE.DATA,DISP=SHR
   32 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR
   33 :  //SYSIN DD *
   34 :  SAMPLE PROBLEM NO.2 FOR BREMSSTRAHLUNG 5CM LEAD
   35 :   &UNIT  FXSN=91,FLX1=91,FLX2=0 &END
   36 :  14¥¥   0 19  0  0  0  0  0  1   0  0  0
   37 :  15¥¥ 600  0  16  16  1  0  0  1  12  0   19  3  4   22  0  0  1  1  1
   38 :        0  2   0   0  50  0  0  0  0  1  2  0  0  0  1  0  0
   39 :  16**  1.0  0.1  1.0-4  1.420892  3R0.0  0.0  0.0  0.5  1.0-4  3R0.0  T
   40 :   6**  0.0 0.0244936 0.0413296 0.0392569 0.0400796 0.0643754
   41 :            0.0442079 0.109085  0.1371702  1N8
   42 :   7**  -0.9902984 -0.9805009 -0.9092855 -0.8319966 -0.7467506
   43 :        -0.6504264 -0.5370966 -0.3922893 -0.1389568 1M8  T
   44 :  13¥¥  4HEG19  4HFX16  4HPB00 T
   45 :   3**  F0.0  T
   46 :   1**  F0.0
   47 :   4**  1110.0  6.0
   48 :   5** F1.0
   49 :   8¥¥  F1
   50 :   9¥¥  1
   51 :  21**  0.0  10R1.0  0.0
   52 :    T
   53 :  ++
   54 :  //
---------------------------------- END OF FILE ----------------------------------
```

```
MEMBER NAME > B:BREM.TXT      ------------------------------------------------  PAGE :  1
LINE NO: ....+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
    1 :  //JCLG JOB
    2 :  // EXEC JCLG
    3 :  //SYSIN DD DATA,DLM='++'
    4 :  // JUSER ########,##.######,####.##
    5 :   T.1 1.2 P.0 W.0 C.1 SRP
    6 :   OPTP PASSWORD=########
    7 :  //BREM EXEC LMGO,LM='J1446.BREM',
    8 :  //    ORECFM=FA,OBSIZE=137,SYSOUT=*
    9 :  //FT91F001 DD DSN=J1446.POOL87.DATA,DISP=SHR,LABEL=(,,,OUT)
   10 :  //SYSIN DD *
   11 :  BREMSSTRAHLUNG EDIT CALCULATION FOR LEAD
   12 :   &UNIT FLX1=91,FLX2=91,FLX3=91 &END
   13 :   1¥¥ 700  2  12  1  1  1  0  0  T
   14 :   3¥¥  4HEG19  4H 500  4H 600
   15 :  13¥¥  4HEG19  4HFX16  4HP800
   16 :  21**  0.0  10R1.0  0.0  T
   17 :  ++
   18 :  //
------------------------------------ END OF FILE ------------------------------------
```

```
 1* ARRAY      8 ENTRIES READ
  T
 3* ARRAY     20 ENTRIES READ
  T
```

**** MAIN TITLE ****

FAIR-CROSS STEP-2 FOR BREMSSTRAHLUNG SAMPLE PROBLEM

**** MAIN CONTROL PARAMETERS ****

SELECTION OF THE CALCULATIONAL STEP	---	2
NO. OF NUCLIDE OR MIXTURE TO BE PROCESSED	---	1
NO. OF NEUTRON ENERGY GROUPS	---	0
NO. OF GAMMA-RAY ENERGY GROUPS	---	19
NO. OF ANGULAR MESH IN CROSS SECTION TABLE	---	16
NODE NAME OF ENERGY GROUP STRUCTURE	---	EG19
TYPE OF INPUT NEUTRON GROUP STRUCTURE	---	1
TYPE OF INPUT GAMMA-RAY GROUP STRUCTURE	---	1

SECONDARY PHOTON PRODUCTION BY BREMSSTRAHLUNG

SNK.	SOC. 1	SOC. 2	SOC. 3	SOC. 4	SOC. 5	SOC. 6	SOC. 7	SOC. 8
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.33167E-05	3.45675E-06	0.0	0.0	0.0	0.0	0.0	0.0
3	8.71879E-06	2.26323E-06	0.0	0.0	0.0	0.0	0.0	0.0
4	4.55496E-05	1.72123E-05	5.91645E-06	2.98400E-06	1.06305E-06	0.0	0.0	0.0
5	1.20861E-04	6.99774E-05	4.23867E-05	2.13780E-05	7.61589E-06	0.0	0.0	0.0
6	2.32063E-04	1.55620E-04	1.04726E-04	5.28190E-05	1.88167E-05	0.0	0.0	0.0
7	5.00877E-04	3.99624E-04	3.33671E-04	2.09386E-04	1.50271E-04	6.56217E-05	2.29240E-05	0.0
8	9.60449E-04	8.45653E-04	7.76169E-04	5.24160E-04	4.30940E-04	2.11894E-04	7.43486E-05	3.00579E-07
9	1.77118E-03	1.63666E-03	1.57618E-03	1.15605E-03	1.03565E-03	5.80015E-04	2.96803E-04	8.67250E-05
10	3.11980E-03	2.97448E-03	2.94419E-03	2.28834E-03	2.14623E-03	1.30261E-03	8.00780E-04	3.27826E-04
11	3.40482E-03	3.31009E-03	3.33482E-03	2.68430E-03	2.58278E-03	1.65145E-03	1.10432E-03	5.28905E-04
12	4.93162E-03	4.81898E-03	4.87392E-03	4.02064E-03	3.91392E-03	2.61136E-03	1.87620E-03	1.01363E-03
13	7.75524E-03	7.66559E-03	7.84383E-03	6.58871E-03	6.49783E-03	4.44570E-03	3.26439E-03	1.87463E-03
14	1.23912E-02	1.22955E-02	1.25766E-02	1.07450E-02	1.06342E-02	7.51681E-03	5.77958E-03	3.57587E-03
15	2.21753E-02	2.21408E-02	2.27335E-02	1.97387E-02	1.96346E-02	1.42815E-02	1.12612E-02	7.38736E-03
16	1.73763E-02	1.71553E-02	1.75791E-02	1.56245E-02	1.56644E-02	1.17874E-02	9.62028E-03	6.65307E-03
17	2.57559E-02	2.53777E-02	2.54288E-02	2.23374E-02	2.18524E-02	1.67836E-02	1.42405E-02	1.03567E-02
18	3.20478E-02	3.14475E-02	3.13989E-02	2.84603E-02	2.79940E-02	2.27848E-02	2.02513E-02	1.59383E-02
19	3.38681E-02	3.47623E-02	3.5927BE-02	3.38547E-02	3.39873E-02	2.85536E-02	2.49443E-02	2.05314E-02

SNK.	SOC. 9	SOC. 10	SOC. 11	SOC. 12	SOC. 13	SOC. 14	SOC. 15	SOC. 16
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SNK. 2 THRU SNK. 7 SAME AS ABOVE							
8	1.05161E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.03417E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	1.25425E-04	1.00242E-05	0.0	0.0	0.0	0.0	0.0	0.0
11	2.34572E-04	4.75099E-05	3.24389E-06	2.75348E-07	0.0	0.0	0.0	0.0
12	5.04764E-04	1.57927E-04	4.57883E-05	4.70101E-06	8.68840E-08	0.0	0.0	0.0
13	1.02687E-03	4.16935E-04	1.70084E-04	5.19722E-05	8.09557E-06	3.91148E-07	0.0	0.0
14	2.13500E-03	1.09147E-03	5.45343E-04	3.51153E-04	2.34702E-04	3.08827E-05	0.0	0.0
15	4.79768E-03	2.90877E-03	1.71282E-03	1.36726E-03	1.20157E-03	4.17303E-04	3.90405E-05	0.0
16	4.55687E-03	3.02166E-03	1.95119E-03	1.64906E-03	1.54236E-03	7.07180E-04	1.09284E-04	0.0
17	7.39712E-03	5.21534E-03	3.56142E-03	3.11283E-03	2.98321E-03	1.55224E-03	2.78174E-04	0.0
18	1.22618E-02	9.36890E-03	6.77509E-03	5.87077E-03	5.60511E-03	3.32496E-03	6.69483E-04	0.0
19	1.75078E-02	1.54336E-02	1.22617E-02	1.19216E-02	1.20412E-02	7.09198E-03	1.42613E-03	0.0

SNK.	SOC. 17	SOC. 18	SOC. 19
1	0.0	0.0	0.0
	SNK. 2 THRU SNK. 19 SAME AS ABOVE		

CROSS SECTION TABLE

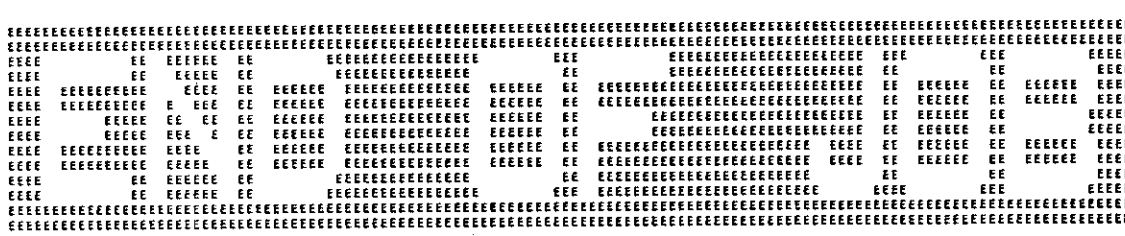
POS	GRP 1	GRP 2	GRP 3	GRP 4	GRP 5	GRP 6	GRP 7	GRP 8
1	3.30424E-01	3.14267E-01	2.97959E-01	2.85776E-01	2.66433E-01	2.45010E-01	2.21493E-01	1.96127E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	5.06350E-01	4.99768E-01	4.94065E-01	4.89833E-01	4.83750E-01	4.77762E-01	4.72500E-01	4.68702E-01
4	1.85241E-03	7.45626E-03	2.46124E-03	6.26494E-03	7.41361E-03	8.95797E-03	1.11273E-02	1.41723E-02
5	0.0	1.28224E-02	2.76776E-03	9.41180E-03	1.08847E-02	1.29460E-02	1.57608E-02	1.97851E-02
6	0.0	0.0	0.0	8.07660E-03	8.61230E-03	1.05756E-02	1.28661E-02	1.53069E-02
7	0.0	0.0	0.0	6.83289E-03	8.24152E-03	9.74085E-03	1.08895E-02	1.33126E-02
8	0.0	0.0	0.0	0.0	5.72558E-03	7.78809E-03	6.86299E-03	1.07776E-02
9	0.0	0.0	0.0	0.0	0.0	4.85399E-03	8.24245E-03	9.06998E-03
10	0.0	0.0	0.0	0.0	0.0	0.0	7.95659E-03	9.01274E-03
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.01501E-03
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

POS 13 THRU POS 22 SAME AS ABOVE

POS	GRP 9	GRP 10	GRP 11	GRP 12	GRP 13	GRP 14	GRP 15	GRP 16
1	1.70196E-01	1.41401E-01	1.20298E-01	1.10208E-01	1.05727E-01	1.28507E-01	2.38788E-01	4.58445E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	4.68965E-01	4.73650E-01	4.88662E-01	5.16027E-01	5.57871E-01	6.44034E-01	8.51465E-01	1.18467E+00
4	1.86609E-02	2.57850E-02	2.58381E-02	3.51797E-02	5.05774E-02	7.91217E-02	1.41399E-01	1.60798E-01
5	2.51513E-02	3.36512E-02	3.12566E-02	4.33655E-02	5.94491E-02	8.53688E-02	1.32468E-01	1.18908E-01
6	1.94917E-02	2.52253E-02	2.21493E-02	3.13381E-02	4.30869E-02	5.87684E-02	8.52336E-02	6.54724E-02
7	1.59111E-02	2.02704E-02	1.76147E-02	2.29107E-02	3.17654E-02	4.43587E-02	6.33923E-02	4.67504E-02
8	1.30619E-02	1.66659E-02	1.36694E-02	1.80182E-02	2.45214E-02	3.49895E-02	5.19040E-02	3.79463E-02
9	1.12713E-02	1.48556E-02	1.15798E-02	1.46061E-02	1.98921E-02	2.76862E-02	4.19264E-02	3.12382E-02
10	9.74382E-03	1.12982E-02	9.80790E-03	1.35418E-02	1.71610E-02	2.30575E-02	3.47066E-02	2.64110E-02
11	8.90009E-03	1.25301E-02	8.44669E-03	1.02476E-02	1.38960E-02	1.94626E-02	2.96721E-02	2.24981E-02
12	8.13382E-03	9.87717E-03	7.62529E-03	1.05566E-02	1.32988E-02	1.85818E-02	2.73060E-02	1.99744E-02
13	0.0	8.45138E-03	7.68218E-03	8.02052E-03	1.12545E-02	1.51327E-02	2.31790E-02	1.74540E-02
14	0.0	0.0	6.78654E-03	8.22805E-03	1.07861E-02	1.49053E-02	2.23557E-02	1.58679E-02
15	0.0	0.0	0.0	9.05641E-03	1.01769E-02	1.51649E-02	1.99937E-02	1.45871E-02
16	0.0	0.0	0.0	0.0	9.37514E-03	1.26216E-02	1.94581E-02	1.34254E-02
17	0.0	0.0	0.0	0.0	0.0	1.19070E-02	1.74997E-02	1.33033E-02
18	0.0	0.0	0.0	0.0	0.0	0.0	1.75631E-02	1.19771E-02
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.19941E-02
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

POS 21 THRU POS 22 SAME AS ABOVE

POS	GRP 17	GRP 18	GRP 19
1	8.87506E-01	2.47114E+00	1.89967E+01
2	0.0	0.0	0.0
3	1.73981E+00	3.56310E+00	2.09697E+01
4	2.72512E-01	5.55194E-01	1.97301E+00
5	2.07601E-01	3.29446E-01	5.36763E-01
6	1.13871E-01	2.00475E-01	2.50347E-01
7	7.35036E-02	1.43264E-01	1.57349E-01
8	5.73236E-02	1.08683E-01	9.52349E-02
9	4.74657E-02	8.92073E-02	5.62779E-02
10	4.12427E-02	7.62648E-02	3.76831E-02
11	3.57088E-02	6.64157E-02	2.73516E-02
12	3.05788E-02	5.72382E-02	2.09140E-02
13	2.70798E-02	4.94003E-02	1.58300E-02
14	2.39114E-02	4.31953E-02	1.20054E-02
15	2.22619E-02	3.89485E-02	9.52226E-03
16	1.97628E-02	3.48191E-02	7.81378E-03
17	1.84890E-02	3.20651E-02	6.62275E-03
18	1.84321E-02	2.99945E-02	5.60381E-03
19	1.67164E-02	2.99718E-02	5.02987E-03
20	1.73196E-02	2.62130E-02	4.91050E-03
21	0.0	2.63237E-02	4.02271E-03



TOTAL CPU TIME --- 0.07 MIN

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    D I A C  CONTROL  OPTION
 ING      NO. OF NEUTRON   ENERGY GROUP                          0
 IGG      NO. OF GAMMA-RAY ENERGY GROUP                        19
 NREACT   0/1/2/3= REACTION RATE NO/CARD/TAPE/DATA POOL         0
 NNELM    NO. OF NEUTRON RESPONSE                              0
 NGELM    NO. OF GAMMA-RAY RESPONSE                            0
 IIANLL   0/1=PRINT ANGULAR FLUX ALL/INPUT                     0
 IIBOUD   0/1=PRINT TOTAL FLUX AT MID./BOUND.                  0
 IISPTM   0/1/2=PRINT SPECTRUM NO/DELTA E/DELTA U              1
 NACTPR   0/1=PRINT ACTIVITY NORMAL/DETAIL                     0
 NRESAT   0/1=USE RESTART OPTION NO/YES                        0
 NPLOT    0/1=OUTPUT PLOT DATA NO/YES                          0

 ID     PROBLEM ID NO.                    500      ITH   0/1 = REG./ADJ.                      0
 ISCT   NO. OF ANGULAR MESH                16      ISN   QUADRATURE ORDER                    16
 IGE    1/2/3 = PLA/CYL/SPH                 1      IBL   0/1/2/3 = NO REFL/REFL/PER/WHITE    0
 IBR    RT. B.C. SAME AS LEFT B.C.,IBL      0      IZM   NO. OF ZONES                        1
 IM     NO. OF INTERVALS                   12      IEVT  0/1/2/3/4/5/6=G/K/ALPHA/C/Z/R/H     0
 IGM    NO. OF GROUPS                      19      IHT   POS. OF SIGMA T                     3
 IHS    POS. OF SIGMA GG                    4      IHM   TABLE LENGTH                       22
 MS     NOT USED                            0      MCR   NOT USED                            0
 MTP    NO. MATLS. FROM LIB TAPE            1      MT    NO. OF MATLS.                       1
 IDFM   0/1=NONE/DENSITY FACTORS(21*)       1      IPVT  0/1/2=NONE/K/ALPHA                  0
 IQM    0/1=NONE/DIST. SOURCE               0      IPM   0/1/IM=NONE/S(MM,IPP)/S(MM,IM)      1
 IPP    INTERVAL OF SHELL SOURCE            1      IIM   INNER ITER. MAX.                   50
 ID1    0/1/2/3=NO/PRNT NO/PNCH N/BOTH      0      ID2   NOT USED                            0
 ID3    0/N=NO/N ACT. BY ZONE               0      ID4   0/1=NO/N ACT. BY INT.               0
 ICM    OUTER ITER. MAX.                    1      IDAT1 0/1/2=NO/MIN/MAX TAPE               2
 IDAT2  0/1=NO/DIFFUSION(24W)               0      IFG   0/1=ND/FEW GRP.                     0
 IFLU   0/1/2=BOTH/LINEAR/STEP              0      IFN   0/1/2=INPUT 2*/3*/PREV. CASE        1
 IPRT   0/1 = PRINT X-SEC/DO NOT            0      IXTR  0/1=CALC/READ P-L CONSTANTS         0

 EV     EIGENVALUE GUESS          1.00000E+00     EVM   EIGENVALUE MODIFIER       1.00000E-01
 EPS    PRECISION DESIRED         9.99998E-05     BF    BUCKLING FACTOR          1.42089E+00
 DY     CYL OR PLA HEIGHT         0.0             DZ    PLANE DEPTH              0.0
 DFM1   HT. FOR VOID CORR.        0.0             XNF   NORM. FACTOR             0.0
 PV     IPVT=1/2 - K/ALPHA        0.0             RYF   LAMBDA2 RELAXATION       5.00000E-01
 XLAL   PT CNVRG EPS. IF .NE.0    9.99998E-05     XLAM  1-LAMBDA MAX.-SEARCH     0.0
 EQL    EV CHANGE EPS.-SEARCH     0.0             XNPM  NEW PARAM. MOD.-SEARCH   0.0
```

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 OUTER INNER      NEUT BAL     UPSCATTER RATIO     EIGENVALUE          LAMBDA1          LAMBDA2
     0     0   0.0                  0.0              9.9999964E-01   0.0              0.0
 GRP.   1 REQUIRED   3 ITERATIONS. MFD OF  3.21571E-05 OCCURRED IN INT.   12
 GRP.   2 REQUIRED   3 ITERATIONS. MFD OF  9.39382E-05 OCCURRED IN INT.   12
 GRP.   3 REQUIRED   3 ITERATIONS. MFD OF  5.86437E-05 OCCURRED IN INT.   12
 GRP.   4 REQUIRED   3 ITERATIONS. MFD OF  5.78972E-05 OCCURRED IN INT.   12
 GRP.   5 REQUIRED   3 ITERATIONS. MFD OF  8.00612E-05 OCCURRED IN INT.   12
 GRP.   6 REQUIRED   4 ITERATIONS. MFD OF  1.33154E-06 OCCURRED IN INT.   12
 GRP.   7 REQUIRED   4 ITERATIONS. MFD OF  7.35003E-07 OCCURRED IN INT.    1
 GRP.   8 REQUIRED   4 ITERATIONS. MFD OF  3.93464E-06 OCCURRED IN INT.    1
 GRP.   9 REQUIRED   4 ITERATIONS. MFD OF  4.84213E-06 OCCURRED IN INT.    1
 GRP.  10 REQUIRED   4 ITERATIONS. MFD OF  6.29422E-06 OCCURRED IN INT.    1
 GRP.  11 REQUIRED   4 ITERATIONS. MFD OF  6.04786E-06 OCCURRED IN INT.   11
 GRP.  12 REQUIRED   4 ITERATIONS. MFD OF  1.32865E-05 OCCURRED IN INT.   11
 GRP.  13 REQUIRED   4 ITERATIONS. MFD OF  3.96506E-05 OCCURRED IN INT.   11
 GRP.  14 REQUIRED   5 ITERATIONS. MFD OF  1.94306E-05 OCCURRED IN INT.   12
 GRP.  15 REQUIRED   5 ITERATIONS. MFD OF  7.66105E-05 OCCURRED IN INT.   12
 GRP.  16 REQUIRED   4 ITERATIONS. MFD OF  9.26385E-05 OCCURRED IN INT.   10
 GRP.  17 REQUIRED   4 ITERATIONS. MFD OF  4.66349E-05 OCCURRED IN INT.    3
 GRP.  18 REQUIRED   4 ITERATIONS. MFD OF  9.48954E-05 OCCURRED IN INT.   12
 GRP.  19 REQUIRED   5 ITERATIONS. MFD OF  1.90301E-05 OCCURRED IN INT.   12                  ANG. FLX ON  2
     1    74   1.0000048E+00   0.0              9.9999964E-01   1.0000000E+00   0.0
     1    74   1.0000048E+00   0.0              9.9999964E-01   1.0000000E+00   0.0          FINAL MONITOR

 ****** OUTER ITERATION LIMIT REACHED

 ELAPSED TIME     0.03 MIN.

 *** SCALAR FLUX WAS OUTPUT TO A DATA POOL
     NODE NAME = EG19- 500-SFX0

*** INFORMATION OF DATA POOL USAGE ***
    LOGICAL UNIT NO.          =      91
    DATA SET NAME             = J1446.POOL87.DATA
    NO. OF WRITTEN RECORDS    =       2
    REMAINS RECORDS           =    9586
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DIAC SAMPLE PROBLEM NO.1 FOR BREMSSTRAHLUNG OF 5

TOTAL FLUX

INT.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	3.50100E-02	1.66524E-05	4.65186E-01	1.77080E-04	1.70268E-04	2.41936E-04	3.16775E-04	4.14222E-04
2	2.43210E-02	1.42456E-04	3.25152E-01	1.48671E-03	1.37412E-03	1.57718E-03	1.25926E-03	1.61470E-03
3	1.48384E-02	2.67563E-04	2.00490E-01	2.80387E-03	2.59841E-03	2.94851E-03	2.24609E-03	2.87850E-03
4	9.50192E-03	2.51669E-04	1.29597E-01	2.65925E-03	2.48295E-03	2.83510E-03	2.18373E-03	2.81000E-03
5	6.30572E-03	2.18540E-04	8.67401E-02	2.32367E-03	2.18046E-03	2.49965E-03	1.93973E-03	2.50507E-03
6	4.29476E-03	1.83302E-04	5.95479E-02	1.96113E-03	1.84984E-03	2.12950E-03	1.66487E-03	2.15725E-03
7	2.98131E-03	1.50618E-04	4.16489E-02	1.62140E-03	1.53755E-03	1.77780E-03	1.40092E-03	1.82118E-03
8	2.09912E-03	1.22159E-04	2.95388E-02	1.32297E-03	1.26121E-03	1.46476E-03	1.16352E-03	1.51752E-03
9	1.49408E-03	9.82256E-05	2.11745E-02	1.07005E-03	1.02539E-03	1.19610E-03	9.57646E-04	1.25307E-03
10	1.07246E-03	7.85102E-05	1.53058E-02	8.60211E-04	8.28502E-04	9.70568E-04	7.83064E-04	1.02792E-03
11	7.74982E-04	6.24745E-05	1.11368E-02	6.88388E-04	6.66309E-04	7.83794E-04	6.37013E-04	8.38753E-04
12	6.51637E-04	5.53027E-05	9.40157E-03	6.11260E-04	5.93264E-04	6.99431E-04	5.70669E-04	7.52599E-04

INT.	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	4.80843E-04	1.03575E-03	6.91030E-04	8.62513E-04	1.35705E-03	2.09304E-03	2.98434E-03	2.03073E-03
2	1.81098E-03	2.57058E-03	1.66484E-03	1.88274E-03	2.61028E-03	3.73494E-03	4.91926E-03	3.15837E-03
3	3.22607E-03	4.18849E-03	2.70838E-03	2.96988E-03	3.89960E-03	5.32733E-03	6.59985E-03	3.96380E-03
4	3.17237E-03	4.08731E-03	2.67294E-03	2.92480E-03	3.77464E-03	5.03272E-03	6.01798E-03	3.43278E-03
5	2.84550E-03	3.65970E-03	2.41940E-03	2.65342E-03	3.39769E-03	4.47515E-03	5.26443E-03	2.92451E-03
6	2.46474E-03	3.16936E-03	2.11616E-03	2.32647E-03	2.95910E-03	3.84996E-03	4.43869E-03	2.38702E-03
7	2.09275E-03	2.69266E-03	1.81465E-03	1.99945E-03	2.52735E-03	3.25026E-03	3.68350E-03	1.93902E-03
8	1.75370E-03	2.25883E-03	1.53572E-03	1.69572E-03	2.13108E-03	2.71097E-03	3.02423E-03	1.56104E-03
9	1.45615E-03	1.87806E-03	1.28756E-03	1.42459E-03	1.78067E-03	2.24185E-03	2.46260E-03	1.24793E-03
10	1.20098E-03	1.55110E-03	1.07181E-03	1.18803E-03	1.47725E-03	1.84181E-03	1.99736E-03	1.00030E-03
11	9.84962E-04	1.27300E-03	8.85454E-04	9.81337E-04	1.20965E-03	1.48234E-03	1.55446E-03	7.42902E-04
12	8.86141E-04	1.14522E-03	7.98951E-04	8.84358E-04	1.08227E-03	1.30611E-03	1.31899E-03	5.88024E-04

INT.	GRP. 17	GRP. 18	GRP. 19
1	2.56823E-03	3.00129E-03	1.73494E-04
2	3.78828E-03	3.94816E-03	3.19337E-04
3	4.39351E-03	3.87708E-03	3.33246E-04
4	3.55803E-03	2.93794E-03	2.64194E-04
5	2.93549E-03	2.28002E-03	2.11264E-04
6	2.30615E-03	1.78821E-03	1.70631E-04
7	1.84356E-03	1.38825E-03	1.33576E-04
8	1.45615E-03	1.10558E-03	1.09654E-04
9	1.14879E-03	8.53868E-04	8.35051E-05
10	9.14692E-04	6.98653E-04	7.14446E-05
11	6.38989E-04	4.32991E-04	4.62617E-05
12	4.42325E-04	2.01651E-04	1.60583E-05

TOTAL FLUX SUMED OVER GAMMA GROUP

1	5.18811E-01
2	3.87335E-01
3	2.70558E-01
4	1.90197E-01
5	1.37779E-01
6	1.01765E-01
7	7.63045E-02
8	5.78327E-02
9	4.41346E-02
10	3.39404E-02
11	2.58208E-02
12	2.20058E-02

SUMMARY FOR SYSTEM

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	3.52316E-02	0.0	0.0	6.26889E-05	5.89095E-03	1.11821E-02	1.81584E-02	1.00000E+00
2	0.0	0.0	4.33934E-04	5.87372E-06	1.40255E-04	2.47566E-04	4.61115E-05	1.00000E+00
3	4.68077E-01	0.0	2.18032E-06	1.13258E-03	8.91085E-02	1.37110E-01	2.41859E-01	1.00000E+00
4	0.0	0.0	4.56858E-03	5.26180E-05	1.66122E-03	2.40017E-03	5.07180E-04	1.00000E+00
5	0.0	0.0	4.25473E-03	5.85849E-05	1.65873E-03	2.10545E-03	4.90564E-04	9.99998E-01
6	0.0	0.0	4.84388E-03	8.14410E-05	2.03462E-03	2.22750E-03	5.81792E-04	9.99997E-01
7	0.0	0.0	3.77029E-03	7.92034E-05	1.70744E-03	1.57657E-03	4.86264E-04	1.00000E+00
8	0.0	0.0	4.82613E-03	1.30554E-04	2.38040E-03	1.80671E-03	6.39090E-04	9.99993E-01
9	0.0	0.0	5.47891E-03	1.96015E-04	2.94227E-03	1.78776E-03	7.48964E-04	9.99993E-01
10	0.0	0.0	7.15168E-03	3.52340E-04	4.18767E-03	1.93217E-03	1.03194E-03	9.99992E-01
11	0.0	0.0	4.91765E-03	2.34829E-04	3.11302E-03	1.09332E-03	7.11371E-04	9.99994E-01
12	0.0	0.0	5.62929E-03	3.52613E-04	3.71498E-03	1.10464E-03	8.09797E-04	9.99989E-01
13	0.0	0.0	7.59894E-03	6.51619E-04	5.17363E-03	1.36214E-03	1.06333E-03	9.99990E-01
14	0.0	0.0	1.10167E-02	1.34298E-03	7.40737E-03	2.18124E-03	1.42822E-03	9.99992E-01
15	0.0	0.0	1.59761E-02	2.82531E-03	9.41667E-03	4.77125E-03	1.78827E-03	9.99996E-01
16	0.0	0.0	1.25683E-02	1.79754E-03	6.32076E-03	5.12487E-03	1.12290E-03	9.99992E-01
17	0.0	0.0	1.82563E-02	3.13166E-03	6.66287E-03	1.01990E-02	1.39458E-03	9.99995E-01
18	0.0	0.0	3.07529E-02	5.36059E-03	5.18266E-03	2.38598E-02	1.71069E-03	9.99997E-01
19	0.0	0.0	1.66554E-02	1.71958E-03	1.04774E-08	1.65567E-02	9.88131E-05	9.99998E-01
20	5.03309E-01	0.0	1.58702E-01	1.95686E-02	1.58704E-01	2.28629E-01	2.74677E-01	1.00000E+00

GRP.	RT BDY FLUX	RT BDY J+	RT BDY J	RT LEAKAGE	LFT LEAKAGE	FISS RATE	TOTAL FLUX	DENSITY
1	6.51636E-04	5.38758E-04	5.38758E-04	5.38758E-04	-1.76197E-02	0.0	5.16726E-02	5.16726E-02
2	5.53027E-05	4.37210E-05	4.37210E-05	4.37210E-05	-2.39052E-06	0.0	8.23735E-04	8.23735E-04
3	9.40157E-03	7.74866E-03	7.74866E-03	7.74866E-03	-2.34111E-01	0.0	6.97460E-01	6.97460E-01
4	6.11259E-04	4.81505E-04	4.81505E-04	4.81505E-04	-2.56754E-05	0.0	8.79296E-03	8.79296E-03
5	5.93263E-04	4.65621E-04	4.65621E-04	4.65621E-04	-2.49425E-05	0.0	8.28411E-03	8.28411E-03
6	6.99431E-04	5.45216E-04	5.45216E-04	5.45216E-04	-3.65756E-05	0.0	9.56215E-03	9.56215E-03
7	5.70669E-04	4.36056E-04	4.36056E-04	4.36056E-04	-5.02083E-05	0.0	7.56162E-03	7.56162E-03
8	7.52599E-04	5.72657E-04	5.72657E-04	5.72657E-04	-6.64335E-05	0.0	9.79538E-03	9.79538E-03
9	8.86140E-04	6.70107E-04	6.70107E-04	6.70107E-04	-7.88572E-05	0.0	1.11876E-02	1.11876E-02
10	1.14522E-03	8.38824E-04	8.38824E-04	8.38824E-04	-1.93115E-04	0.0	1.47550E-02	1.47550E-02
11	7.98950E-04	5.77963E-04	5.77963E-04	5.77963E-04	-1.33408E-04	0.0	9.83343E-03	9.83343E-03
12	8.84357E-04	6.27357E-04	6.27357E-04	6.27357E-04	-1.82440E-04	0.0	1.08966E-02	1.08966E-02
13	1.08227E-03	7.44973E-04	7.44973E-04	7.44973E-04	-3.18360E-04	0.0	1.41033E-02	1.41033E-02
14	1.30611E-03	8.68121E-04	8.68121E-04	8.68121E-04	-5.60097E-04	0.0	1.86732E-02	1.86732E-02
15	1.31899E-03	8.21074E-04	8.21074E-04	8.21074E-04	-9.67196E-04	0.0	2.21328E-02	2.21328E-02
16	5.88024E-04	3.37119E-04	3.37119E-04	3.37119E-04	-7.85782E-04	0.0	1.24882E-02	1.24882E-02
17	4.42325E-04	2.30132E-04	2.30132E-04	2.30132E-04	-1.16445E-03	0.0	1.29971E-02	1.29971E-02
18	2.01651E-04	9.00762E-05	9.00762E-05	9.00762E-05	-1.62062E-03	0.0	1.12568E-02	1.12568E-02
19	1.60582E-05	6.40111E-06	6.40111E-06	6.40111E-06	-9.24120E-05	0.0	9.66331E-04	9.66331E-04
20	2.20058E-02	1.66443E-02	1.66443E-02	1.66443E-02	-2.58033E-01	0.0	9.33242E-01	9.33242E-01

ELAPSED TIME 0.05 MIN.

```
                                                                                                    PAGE-0001

                    ********************
                    *                  *
                    *  INPUT DATA LIST *
                    *                  *
                    ********************

      ....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
    1 BREMSSTRAHLUNG SOURCE CALCULATION FOR LEAD                                          1
    2  &UNIT FLX1=91,BREM=91 &END                                                        2
    3   1*¥  10  1  12  1  1  0  0  0  T                                                 3
    4   2*¥  4HEG19  4H 500                                                           4
    5  13**  4HEG19  4HFX16  4HPB00                                                  5
    6  21**  0.0  10R1.0  0.0  T                                                     6
      ....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

      *** INPUT DATA END ***

 1¥ ARRAY      8 ENTRIES READ

  T

 2¥ ARRAY      2 ENTRIES READ

13¥ ARRAY      3 ENTRIES READ

21* ARRAY     12 ENTRIES READ

  T
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  *** STARTS MODE=1 ( SOURCE CALCULATION ) ***

  BREMSSTRAHLUNG SOURCE CALCULATION FOR LEAD

                                    *** PARAMETERS IN DIAC CAL. ***

                                    TITLE : DIAC SAMPLE PROBLEM NO.1 FOR BREMSSTRAHLUNG OF S
                                    ING  NO. OF NEUTRON GROUP    =   0
                                    IGG  NO. OF GAMMA-RAY GROUP  =  19
                                    IM   NO. OF INTERVALS        =  12
                                    IZM  NO. OF ZONE             =   1
                                    ISN  QUADRATURE              =  16
                                    ISCT NO. OF ANGULAR MESH     =  16
                                    IGE  1/2/3 = PLA/CYL/SPH     =   1
                                    MT   NO. OF MATERIALS        =   1
                                    IDFM USE OF DENSITY FACTORS  =   1

  SCALAR  FLUX DATA POOL       EG19= 500-SFX0

  BREM CROSS SECTION DATA POOL EG19
```

SOURCE BY BREMSSTRAHLUNG

INT.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	3.24367E-07	2.12372E-07	3.03844E-06	1.67738E-05	3.98223E-05	1.21383E-04	2.77651E-04
3	0.0	1.98523E-07	1.29979E-07	1.87504E-06	1.03899E-05	2.46785E-05	7.56594E-05	1.73474E-04
4	0.0	1.27404E-07	8.34147E-08	1.21183E-06	6.73496E-06	1.60035E-05	4.92687E-05	1.13156E-04
5	0.0	8.47265E-08	5.54728E-08	8.11111E-07	4.52031E-06	1.07450E-05	3.32111E-05	7.63983E-05
6	0.0	5.78255E-08	3.78599E-08	5.56943E-07	3.11194E-06	7.39976E-06	2.29603E-05	5.28998E-05
7	0.0	4.02218E-08	2.63343E-08	3.89641E-07	2.18259E-06	5.19157E-06	1.61698E-05	3.73112E-05
8	0.0	2.83756E-08	1.85783E-08	2.76429E-07	1.55219E-06	3.69322E-06	1.15458E-05	2.66807E-05
9	0.0	2.02357E-08	1.32488E-08	1.98216E-07	1.11565E-06	2.65533E-06	8.33150E-06	1.92807E-05
10	0.0	1.45529E-08	9.52819E-09	1.43324E-07	8.08572E-07	1.92503E-06	6.06190E-06	1.40484E-05
11	0.0	1.05361E-08	6.89829E-09	1.04320E-07	5.89879E-07	1.40477E-06	4.43947E-06	1.03029E-05
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

INT.	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	5.60432E-04	1.04381E-03	1.18054E-03	1.72627E-03	2.77635E-03	4.45684E-03	8.06575E-03	6.25670E-03
3	3.51384E-04	6.56392E-04	7.44078E-04	1.09034E-03	1.75663E-03	2.82688E-03	5.13135E-03	3.99492E-03
4	2.29788E-04	4.30166E-04	4.88445E-04	7.16859E-04	1.15641E-03	1.86443E-03	3.39211E-03	2.64808E-03
5	1.55518E-04	2.91722E-04	3.31768E-04	4.87634E-04	7.87594E-04	1.27208E-03	2.31953E-03	1.81549E-03
6	1.07939E-04	2.02878E-04	2.31085E-04	3.40142E-04	5.5003BE-04	8.89969E-04	1.62634E-03	1.27620E-03
7	7.63082E-05	1.43706E-04	1.63935E-04	2.41650E-04	3.91229E-04	6.34129E-04	1.16134E-03	9.13616E-04
8	5.46916E-05	1.03194E-04	1.17897E-04	1.74032E-04	2.82087E-04	4.58022E-04	8.40624E-04	6.62962E-04
9	3.96116E-05	7.48816E-05	8.56764E-05	1.26647E-04	2.05520E-04	3.3427BE-04	6.14826E-04	4.86076E-04
10	2.89261E-05	5.47836E-05	6.27723E-05	9.29191E-05	1.50960E-04	2.45961E-04	4.53349E-04	3.59283E-04
11	2.12606E-05	4.03401E-05	4.62892E-05	6.86139E-05	1.11599E-04	1.82138E-04	3.36399E-04	2.67217E-04
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

INT.	GRP. 17	GRP. 18	GRP. 19
1	0.0	0.0	0.0
2	9.07614E-03	1.12602E-02	1.28964E-02
3	5.80419E-03	7.24875E-03	8.38142E-03
4	3.85221E-03	4.83480E-03	5.63018E-03
5	2.64428E-03	3.33443E-03	3.90926E-03
6	1.86110E-03	2.35763E-03	2.78215E-03
7	1.33397E-03	1.69746E-03	2.01583E-03
8	9.69189E-04	1.23869E-03	1.48007E-03
9	7.11476E-04	9.13221E-04	1.09771E-03
10	5.26537E-04	6.78689E-04	8.20553E-04
11	3.92065E-04	5.07368E-04	6.16722E-04
12	0.0	0.0	0.0

```
    D I A C  CONTROL  OPTION
ING     NO. OF NEUTRON   ENERGY GROUP                      0
IGG     NO. OF GAMMA-RAY ENERGY GROUP                     19
NREACT  0/1/2/3= REACTION RATE NO/CARD/TAPE/DATA POOL      0
NNELM   NO. OF NEUTRON RESPONSE                            0
NGELM   NO. OF GAMMA-RAY RESPONSE                          0
IIANLL  0/1=PRINT ANGULAR FLUX ALL/INPUT                   0
IIBOUD  0/1=PRINT TOTAL FLUX AT MID./BOUND.                0
IISPTM  0/1/2=PRINT SPECTRUM NO/DELTA E/DELTA U            1
NACTPR  0/1=PRINT ACTIVITY NORMAL/DETAIL                   0
NRESAT  0/1=USE RESTART OPTION NO/YES                      0
NPLOT   0/1=OUTPUT PLOT DATA NO/YES                        0

ID    PROBLEM ID NO.                  600     ITH   0/1 = REG./ADJ.                    0
ISCT  NO. OF ANGULAR MESH              16     ISN   QUADRATURE ORDER                  16
IGE   1/2/3 = PLA/CYL/SPH               1     IBL   0/1/2/3 = NO REFL/REFL/PER/WHITE   0
IBR   RT. B.C. SAME AS LEFT B.C.,IBL    0     IZM   NO. OF ZONES                       1
IM    NO. OF INTERVALS                 12     IEVT  0/1/2/3/4/5/6=Q/K/ALPHA/C/Z/R/H    0
IGM   NO. OF GROUPS                    19     IHT   POS. OF SIGMA T                   3
IHS   POS. OF SIGMA GG                  4     IHM   TABLE LENGTH                     23
MS    NOT USED                          0     MCR   NOT USED                          0
MTP   NO. MATLS. FROM LIB TAPE          1     MT    NO. OF MATLS.                     1
IDFM  0/1=NONE/DENSITY FACTORS(21*)     1     IPVT  0/1/2=NONE/K/ALPHA                 0
IQM   0/1=NONE/DIST. SOURCE             2     IPM   0/1/IM=NONE/S(MM,IPP)/S(MM,IM)    0
IPP   INTERVAL OF SHELL SOURCE          0     IIM   INNER ITER. MAX.                  50
ID1   0/1/2/3=NO/PRNT NO/PNCH M/BDTH    0     ID2   NOT USED                          0
ID3   0/N=NO/N ACT. BY ZONE             0     ID4   0/1=NO/N ACT. BY INT.             0
ICM   OUTER ITER. MAX.                  1     IDAT1 0/1/2=NO/MIN/MAX TAPE             2
IDAT2 0/1=NO/DIFFUSION(24Y)             0     IFG   0/1=NO/FEW GRP.                   0
IFLU  0/1/2=BOTH/LINEAR/STEP            0     IFN   0/1/2=INPUT 2*/3*/PREV. CASE      1
IPRT  0/1 = PRINT X-SEC/DO NOT          0     IXTR  0/1=CALC/READ P-L CONSTANTS       0

EV    EIGENVALUE GUESS        1.00000E+00     EVM   EIGENVALUE MODIFIER      1.00000E-01
EPS   PRECISION DESIRED       9.99998E-05     BF    BUCKLING FACTOR          1.42089E+00
DY    CYL OR PLA HEIGHT       0.0             DZ    PLANE DEPTH              0.0
DFM1  HT. FOR VOID CORR.      0.0             XNF   NORM. FACTOR             0.0
PV    IPVT=1/2 - K/ALPHA      0.0             RYF   LAMBDA2 RELAXATION       5.00000E-01
XLAL  PT CHNRG EPS. IF .NE.0  9.99998E-05     XLAM  1-LAMBDA MAX.-SEARCH    0.0
EQL   EV CHANGE EPS.-SEARCH   0.0             XNPM  NEW PARAM. MOD.-SEARCH  0.0
```

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OUTER INNER      NEUT BAL    UPSCATTER RATIO    EIGENVALUE          LAMBDA1          LAMBDA2
    0     0   0.0              0.0              9.9999964E-01   0.0              0.0
GRP.   1 REQUIRED   1 ITERATIONS. MFD OF  0.0          OCCURRED IN INT.   12
GRP.   2 REQUIRED   4 ITERATIONS. MFD OF  1.04237E-06 OCCURRED IN INT.   12
GRP.   3 REQUIRED   3 ITERATIONS. MFD OF  1.47579E-05 OCCURRED IN INT.   12
GRP.   4 REQUIRED   4 ITERATIONS. MFD OF  8.43754E-07 OCCURRED IN INT.    4
GRP.   5 REQUIRED   4 ITERATIONS. MFD OF  7.40840E-07 OCCURRED IN INT.   10
GRP.   6 REQUIRED   4 ITERATIONS. MFD OF  1.48904E-06 OCCURRED IN INT.   11
GRP.   7 REQUIRED   4 ITERATIONS. MFD OF  2.85454E-06 OCCURRED IN INT.    9
GRP.   8 REQUIRED   4 ITERATIONS. MFD OF  1.78032E-06 OCCURRED IN INT.   11
GRP.   9 REQUIRED   4 ITERATIONS. MFD OF  3.78834E-06 OCCURRED IN INT.   11
GRP.  10 REQUIRED   4 ITERATIONS. MFD OF  7.36990E-06 OCCURRED IN INT.   10
GRP.  11 REQUIRED   4 ITERATIONS. MFD OF  7.80619E-06 OCCURRED IN INT.   11
GRP.  12 REQUIRED   4 ITERATIONS. MFD OF  1.51107E-05 OCCURRED IN INT.   11
GRP.  13 REQUIRED   4 ITERATIONS. MFD OF  3.55799E-05 OCCURRED IN INT.   11
GRP.  14 REQUIRED   4 ITERATIONS. MFD OF  8.77851E-05 OCCURRED IN INT.   10
GRP.  15 REQUIRED   5 ITERATIONS. MFD OF  4.04775E-05 OCCURRED IN INT.   10
GRP.  16 REQUIRED   5 ITERATIONS. MFD OF  1.24930E-05 OCCURRED IN INT.    8
GRP.  17 REQUIRED   5 ITERATIONS. MFD OF  2.28096E-05 OCCURRED IN INT.   12
GRP.  18 REQUIRED   4 ITERATIONS. MFD OF  4.47637E-05 OCCURRED IN INT.    1
GRP.  19 REQUIRED   4 ITERATIONS. MFD OF  6.60668E-05 OCCURRED IN INT.   12                  ANG. FLX ON  2
    1    75   1.0000067E+00   0.0              9.9999964E-01   1.0000000E+00   0.0
    1    75   1.0000067E+00   0.0              9.9999964E-01   1.0000000E+00   0.0          FINAL MONITOR

****** OUTER ITERATION LIMIT REACHED

ELAPSED TIME    0.03 MIN.

*** SCALAR FLUX WAS OUTPUT TO A DATA POOL
    NODE NAME = EG19- 600-SFXQ

*** INFORMATION OF DATA POOL USAGE ***
   LOGICAL UNIT NO.          =     91
   DATA SET NAME             = J1446.POOL87.DATA
   NO. OF WRITTEN RECORDS    =      2
   REMAINS RECORDS           =   9580
```

SAMPLE PROBLEM NO.2 FOR BREMSSTRAHLUNG 5CM LEAD

TOTAL FLUX

INT.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	0.0	2.26614E-07	1.49282E-07	2.15753E-06	1.20492E-05	2.90333E-05	8.96641E-05	2.08295E-04
2	0.0	2.67940E-07	1.76353E-07	2.54929E-06	1.42260E-05	3.42235E-05	1.05638E-04	2.45133E-04
3	0.0	2.80506E-07	1.84689E-07	2.67867E-06	1.49758E-05	3.60642E-05	1.11600E-04	2.59393E-04
4	0.0	2.24006E-07	1.47723E-07	2.15583E-06	1.21062E-05	2.92641E-05	9.10459E-05	2.12567E-04
5	0.0	1.73686E-07	1.14639E-07	1.68156E-06	9.47378E-06	2.29580E-05	7.17248E-05	1.68019E-04
6	0.0	1.33302E-07	8.80683E-08	1.29806E-06	7.33646E-06	1.78234E-05	5.59069E-05	1.31390E-04
7	0.0	1.01653E-07	6.72280E-08	9.95521E-07	5.64454E-06	1.37493E-05	4.32997E-05	1.02096E-04
8	0.0	7.70899E-08	5.10377E-08	7.59173E-07	4.31806E-06	1.05466E-05	3.33442E-05	7.88811E-05
9	0.0	5.80523E-08	3.84754E-08	5.74762E-07	3.27927E-06	8.03135E-06	2.54890E-05	6.04968E-05
10	0.0	4.31229E-08	2.86121E-08	4.29080E-07	2.45531E-06	6.03015E-06	1.92069E-05	4.57356E-05
11	0.0	3.01867E-08	2.00657E-08	3.01852E-07	1.73325E-06	4.27556E-06	1.36698E-05	3.26950E-05
12	0.0	2.38582E-08	1.58884E-08	2.39392E-07	1.37842E-06	3.41450E-06	1.09465E-05	2.62810E-05

INT.	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	4.26724E-04	8.07555E-04	9.14112E-04	1.33028E-03	2.10050E-03	3.22441E-03	5.10842E-03	3.29381E-03
2	5.01999E-04	9.50120E-04	1.07793E-03	1.57500E-03	2.50341E-03	3.89330E-03	6.34416E-03	4.24499E-03
3	5.32303E-04	1.00968E-03	1.14717E-03	1.67883E-03	2.67195E-03	4.16170E-03	6.77106E-03	4.51010E-03
4	4.38200E-04	8.34771E-04	9.48930E-04	1.38731E-03	2.19896E-03	3.39312E-03	5.37784E-03	3.46420E-03
5	3.47689E-04	6.64994E-04	7.57192E-04	1.10836E-03	1.75645E-03	2.70591E-03	4.25112E-03	2.70701E-03
6	2.72882E-04	5.23896E-04	5.97402E-04	8.75216E-04	1.38558E-03	2.12565E-03	3.28075E-03	2.03485E-03
7	2.12804E-04	4.10052E-04	4.68131E-04	6.86104E-04	1.08442E-03	1.65551E-03	2.51610E-03	1.53922E-03
8	1.66998E-04	3.19069E-04	3.64618E-04	5.34458E-04	8.43108E-04	1.28054E-03	1.91771E-03	1.15548E-03
9	1.26963E-04	2.46415E-04	2.81026E-04	4.13071E-04	6.50202E-04	9.82158E-04	1.44913E-03	8.62178E-04
10	9.63269E-05	1.87578E-04	2.14702E-04	3.14657E-04	4.94215E-04	7.42638E-04	1.08139E-03	6.37573E-04
11	6.91423E-05	1.35203E-04	1.54724E-04	2.26309E-04	3.53370E-04	5.24034E-04	7.38248E-04	4.20348E-04
12	5.57538E-05	1.09367E-04	1.25038E-04	1.82353E-04	2.82726E-04	4.12542E-04	5.56008E-04	2.97332E-04

INT.	GRP. 17	GRP. 18	GRP. 19
1	3.68702E-03	2.66828E-03	4.87090E-04
2	4.98382E-03	4.01290E-03	8.97283E-04
3	5.23174E-03	4.05608E-03	7.37170E-04
4	3.83238E-03	2.83003E-03	5.10616E-04
5	2.74357E-03	2.05593E-03	3.54048E-04
6	2.13735E-03	1.51477E-03	2.68207E-04
7	1.60520E-03	1.10492E-03	1.87996E-04
8	1.18295E-03	8.32501E-04	1.46723E-04
9	8.78807E-04	6.07119E-04	1.03756E-04
10	6.46659E-04	4.64388E-04	8.20761E-05
11	4.13031E-04	2.82616E-04	5.33267E-05
12	2.65396E-04	1.59636E-04	1.78411E-05

TOTAL FLUX SUMED OVER GAMMA GROUP

1	2.43898E-02
2	3.13871E-02
3	3.29330E-02
4	2.55639E-02
5	1.99264E-02
6	1.52305E-02
7	1.16364E-02
8	8.87012E-03
9	6.69961E-03
10	5.03613E-03
11	3.42308E-03
12	2.50629E-03

SAMPLE PROBLEM NO.2 FOR BREMSSTRAHLUNG 5CM LEAD

DISTRIBUTED SOURCE - G=GROUP NO. N= 0

INT.	G=N= 1	G=N= 2	G=N= 3	G=N= 4	G=N= 5	G=N= 6	G=N= 7	G=N= 8
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	1.24367E-07	2.12372E-07	3.03844E-06	1.67738E-05	3.98223E-05	1.21383E-04	2.77651E-04
3	0.0	1.98523E-07	1.29979E-07	1.87504E-06	1.03899E-05	2.46785E-05	7.56594E-05	1.73474E-04
4	0.0	1.27404E-07	8.34147E-08	1.21183E-06	6.73496E-06	1.60035E-05	4.92687E-05	1.13156E-04
5	0.0	8.47265E-08	5.54728E-08	8.11111E-07	4.52031E-06	1.07450E-05	3.32111E-05	7.63983E-05
6	0.0	5.78255E-08	3.78599E-08	5.56943E-07	3.11194E-06	7.39976E-06	2.29603E-05	5.28998E-05
7	0.0	4.02218E-08	2.63343E-08	3.89641E-07	2.18259E-06	5.19157E-06	1.61690E-05	3.73112E-05
8	0.0	2.83756E-08	1.85783E-08	2.76429E-07	1.55219E-06	3.69322E-06	1.15458E-05	2.66807E-05
9	0.0	2.02357E-08	1.32488E-08	1.98216E-07	1.11565E-06	2.65533E-06	8.33150E-06	1.92807E-05
10	0.0	1.45529E-08	9.52819E-09	1.43324E-07	8.08572E-07	1.92503E-06	6.06190E-06	1.40484E-05
11	0.0	1.05361E-08	6.89829E-09	1.04320E-07	5.89879E-07	1.40477E-06	4.43947E-06	1.03029E-05
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DISTRIBUTED SOURCE - G=GROUP NO. N= 8

INT.	G=N= 1	G=N= 2	G=N= 3	G=N= 4	G=N= 5	G=N= 6	G=N= 7	G=N= 8
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	5.60432E-04	1.04381E-03	1.18054E-03	1.72627E-03	2.77635E-03	4.45684E-03	8.06575E-03	6.25670E-03
3	3.51384E-04	6.56392E-04	7.44078E-04	1.09034E-03	1.75663E-03	2.82680E-03	5.13135E-03	3.99492E-03
4	2.29788E-04	4.30166E-04	4.88445E-04	7.16859E-04	1.15641E-03	1.86443E-03	3.39211E-03	2.64808E-03
5	1.55518E-04	2.91722E-04	3.31768E-04	4.87634E-04	7.87594E-04	1.27208E-03	2.31953E-03	1.81549E-03
6	1.07939E-04	2.02878E-04	2.31085E-04	3.40142E-04	5.50038E-04	8.89969E-04	1.62634E-03	1.27620E-03
7	7.63082E-05	1.43706E-04	1.63935E-04	2.41650E-04	3.91229E-04	6.34129E-04	1.16134E-03	9.13616E-04
8	5.46916E-05	1.03194E-04	1.17897E-04	1.74032E-04	2.82087E-04	4.58022E-04	8.40624E-04	6.62962E-04
9	3.96116E-05	7.48816E-05	8.56764E-05	1.26647E-04	2.05520E-04	3.34270E-04	6.14826E-04	4.86076E-04
10	2.89261E-05	5.47836E-05	6.27723E-05	9.29191E-05	1.50960E-04	2.45961E-04	4.53349E-04	3.59283E-04
11	2.12606E-05	4.03401E-05	4.62892E-05	6.86139E-05	1.11599E-04	1.82138E-04	3.36399E-04	2.67217E-04
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DISTRIBUTED SOURCE - G=GROUP NO. N= 16

INT.	G=N= 1	G=N= 2	G=N= 3
1	0.0	0.0	0.0
2	9.07614E-03	1.12602E-02	1.28964E-02
3	5.80419E-03	7.24875E-03	8.38142E-03
4	3.85221E-03	4.83480E-03	5.63018E-03
5	2.64428E-03	3.33443E-03	3.90926E-03
6	1.86110E-03	2.35763E-03	2.78215E-03
7	1.33397E-03	1.69746E-03	2.01583E-03
8	9.69189E-04	1.23869E-03	1.48007E-03
9	7.11476E-04	9.13221E-04	1.09771E-03
10	5.26537E-04	6.73689E-04	8.20553E-04
11	3.92065E-04	5.07368E-04	6.16722E-04
12	0.0	0.0	0.0

SUMMARY FOR SYSTEM

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00000E+00
2	4.53384E-07	0.0	0.0	5.18038E-09	1.23700E-07	2.18343E-07	1.11336E-07	1.00000E+00
3	2.96842E-07	0.0	1.92296E-09	1.12834E-09	8.87753E-08	1.36598E-07	7.33893E-08	1.00000E+00
4	4.30264E-06	0.0	9.92615E-09	4.20496E-08	1.32756E-06	1.91809E-06	1.06687E-06	1.00000E+00
5	2.38898E-05	0.0	8.27312E-08	2.80044E-07	7.92893E-06	1.00643E-05	5.97907E-06	1.00000E+00
6	5.67594E-05	0.0	5.69883E-07	8.19501E-07	2.04734E-05	2.24142E-05	1.44411E-05	1.00000E+00
7	1.74515E-04	0.0	2.00980E-06	3.17644E-06	6.84767E-05	6.32279E-05	4.48186E-05	1.00000E+00
8	4.00600E-04	0.0	7.63384E-06	9.46994E-06	1.72665E-04	1.31052E-04	1.04513E-04	1.00000E+00
9	8.12928E-04	0.0	2.44055E-05	2.57830E-05	3.87014E-04	2.35154E-04	2.15157E-04	1.00000E+00
10	1.52095E-03	0.0	7.12925E-05	6.80952E-05	8.09335E-04	3.73423E-04	4.09450E-04	1.00000E+00
11	1.72624E-03	0.0	1.30315E-04	7.76773E-05	1.02974E-03	3.61652E-04	4.65147E-04	1.00000E+00
12	2.53255E-03	0.0	2.62700E-04	1.54778E-04	1.63068E-03	4.84877E-04	6.79666E-04	1.00000E+00
13	4.08420E-03	0.0	5.28907E-04	3.52565E-04	2.79925E-03	7.37001E-04	1.07682E-03	1.00000E+00
14	6.58235E-03	0.0	1.14101E-03	8.49154E-04	4.68360E-03	1.37917E-03	1.66051E-03	1.00000E+00
15	1.19708E-02	0.0	2.64019E-03	2.38451E-03	7.94750E-03	4.02685E-03	2.63646E-03	1.00000E+00
16	9.34025E-03	0.0	3.41591E-03	1.73469E-03	6.09976E-03	4.94567E-03	1.71061E-03	1.00000E+00
17	1.35856E-02	0.0	5.84554E-03	3.25046E-03	6.91561E-03	1.05859E-02	1.92937E-03	1.00000E+00
18	1.70356E-02	0.0	1.10957E-02	4.93046E-03	4.76680E-03	2.19453E-02	1.41906E-03	1.00000E+00
19	1.98151E-02	0.0	1.21740E-02	3.29610E-03	1.35042E-08	3.17359E-02	2.53072E-04	1.00000E+00
20	8.96673E-02	0.0	3.73403E-02	1.71381E-02	3.73404E-02	7.70398E-02	1.26263E-02	1.00000E+00

GRP.	RT BDY FLUX	RT BDY J+	RT BDY J-	RT LEAKAGE	LFT LEAKAGE	FISS RATE	TOTAL FLUX	DENSITY
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.38582E-08	1.49537E-08	1.49537E-08	1.49537E-08	-9.63824E-08	0.0	8.20007E-07	8.20007E-07
3	1.58864E-08	9.96013E-09	9.96013E-09	9.96013E-09	-6.34292E-08	0.0	5.41030E-07	5.41030E-07
4	2.39392E-07	1.49472E-07	1.49472E-07	1.49472E-07	-9.17397E-07	0.0	7.91035E-06	7.91036E-06
5	1.37842E-06	8.59290E-07	8.59290E-07	8.59290E-07	-5.11978E-06	0.0	4.44881E-05	4.44881E-05
6	3.41450E-06	2.12855E-06	2.12855E-06	2.12855E-06	-1.23125E-05	0.0	1.07707E-04	1.07707E-04
7	1.09465E-05	6.80607E-06	6.80607E-06	6.80607E-06	-3.80126E-05	0.0	3.35767E-04	3.35767E-04
8	2.62809E-05	1.63228E-05	1.63228E-05	1.63228E-05	-8.81906E-05	0.0	7.85489E-04	7.85490E-04
9	5.57538E-05	3.45684E-05	3.45684E-05	3.45684E-05	-1.80588E-04	0.0	1.62290E-03	1.62290E-03
10	1.09367E-04	6.77032E-05	6.77032E-05	6.77032E-05	-3.41747E-04	0.0	3.09935E-03	3.09935E-03
11	1.25038E-04	7.73066E-05	7.73066E-05	7.73066E-05	-3.87841E-04	0.0	3.52588E-03	3.52588E-03
12	1.82353E-04	1.12605E-04	1.12605E-04	1.12605E-04	-5.67060E-04	0.0	5.15596E-03	5.15596E-03
13	2.82726E-04	1.74319E-04	1.74319E-04	1.74319E-04	-9.02500E-04	0.0	8.16242E-03	8.16242E-03
14	4.12542E-04	2.53382E-04	2.53382E-04	2.53382E-04	-1.40713E-03	0.0	1.25507E-02	1.25507E-02
15	5.56008E-04	3.36383E-04	3.36383E-04	3.36383E-04	-2.30007E-03	0.0	1.96959E-02	1.96959E-02
16	2.97332E-04	1.74677E-04	1.74677E-04	1.74677E-04	-1.53594E-03	0.0	1.25835E-02	1.25835E-02
17	2.65396E-04	1.49773E-04	1.49773E-04	1.49773E-04	-1.77960E-03	0.0	1.39039E-02	1.39039E-02
18	1.59636E-04	7.98202E-05	7.98202E-05	7.98202E-05	-1.33924E-03	0.0	1.02946E-02	1.02946E-02
19	1.78411E-05	1.07574E-05	1.07574E-05	1.07574E-05	-2.42315E-04	0.0	1.92306E-03	1.92307E-03
20	2.50629E-03	1.49758E-03	1.49758E-03	1.49758E-03	-1.11287E-02	0.0	9.38009E-02	9.38009E-02

ELAPSED TIME 0.05 MIN.

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                    **********
                    *        *
                    *  INPUT DATA LIST  *
                    *        *
                    **********

        ....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
     1  BREMSSTRAHLUNG EDIT CALCULATION FOR LEAD                                        1
     2   $UNIT FLX1=91,FLX2=91,FLX3=91 $END                                             2
     3    1¥¥ 200  2  12  1  1  1  0  0  T                                             3
     4    3¥¥  4HEG19  4H 500  4H 600                                                  4
     5   13¥¥  4HEG19  4HFX16  4HPB00                                                  5
     6   21**  0.0  10R1.0  0.0  T                                                     6
        ....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

        *** INPUT DATA END ***

 1¥ ARRAY       8 ENTRIES READ

  T

 3¥ ARRAY       3 ENTRIES READ

13¥ ARRAY       3 ENTRIES READ

21* ARRAY      12 ENTRIES READ

  T


  *** STARTS MODE=2 ( PHOTON FLUX PRINTING ) ***

 BREMSSTRAHLUNG EDIT CALCULATION FOR LEAD

                                *** PARAMETERS IN DIAC CAL. ***

                                ID1 = 500 : DIAC SAMPLE PROBLEM NO.1 FOR BREMSSTRAHLUNG OF 5
                                ID2 = 600 : SAMPLE PROBLEM NO.2 FOR BREMSSTRAHLUNG SCM LEAD
                                ING  NO. OF NEUTRON GROUP    =   0
                                IGG  NO. OF GAMMA-RAY GROUP  =  19
                                IM   NO. OF INTERVALS        =  12
                                IZM  NO. OF ZONE             =   1
                                ISN  QUADRATURE              =  16
                                IGE  1/2/3 = PLA/CYL/SPH     =   1

                                INT. ZONE NUMBER     RADIUS        VOLUME
                                   1         1      0.0        5.00000E-01
                                   2         1      5.00000E-01  5.00000E-01
                                   3         1      1.00000E+00  5.00000E-01
                                   4         1      1.50000E+00  5.00000E-01
                                   5         1      2.00000E+00  4.99999E-01
                                   6         1      2.50000E+00  5.00000E-01
                                   7         1      3.00000E+00  5.00000E-01
                                   8         1      3.50000E+00  5.00000E-01
                                   9         1      4.00000E+00  4.99999E-01
                                  10         1      4.50000E+00  5.00000E-01
                                  11         1      5.00000E+00  5.00000E-01
                                  12         1      5.50000E+00  5.00000E-01
                                  13                6.00000E+00
```

*** PHOTON FLUXES FOR GROUP 1 ***

INT.	PHOTON	BREM.	TOTAL
1	3.50100E-02	0.0	3.50100E-02
2	2.43210E-02	0.0	2.43210E-02
3	1.48384E-02	0.0	1.48384E-02
4	9.50192E-03	0.0	9.50192E-03
5	6.30572E-03	0.0	6.30572E-03
6	4.29476E-03	0.0	4.29476E-03
7	2.98131E-03	0.0	2.98131E-03
8	2.09912E-03	0.0	2.09912E-03
9	1.49408E-03	0.0	1.49408E-03
10	1.07246E-03	0.0	1.07246E-03
11	7.74982E-04	0.0	7.74982E-04
12	6.51637E-04	0.0	6.51637E-04

*** PHOTON FLUXES FOR GROUP 2 ***

INT.	PHOTON	BREM.	TOTAL
1	1.66524E-05	2.26614E-07	1.68790E-05
2	1.42456E-04	2.67940E-07	1.42724E-04
3	2.67563E-04	2.80506E-07	2.67843E-04
4	2.51669E-04	2.24006E-07	2.51893E-04
5	2.18540E-04	1.73686E-07	2.18714E-04
6	1.83302E-04	1.33302E-07	1.83435E-04
7	1.50618E-04	1.01653E-07	1.50720E-04
8	1.22159E-04	7.70899E-08	1.22236E-04
9	9.82256E-05	5.80523E-08	9.82836E-05
10	7.85102E-05	4.31229E-08	7.85533E-05
11	6.24745E-05	3.01867E-08	6.25047E-05
12	5.53027E-05	2.38582E-08	5.53265E-05

*** PHOTON FLUXES FOR GROUP 3 ***

INT.	PHOTON	BREM.	TOTAL
1	4.65186E-01	1.49282E-07	4.65186E-01
2	3.25152E-01	1.76353E-07	3.25152E-01
3	2.00490E-01	1.84689E-07	2.00490E-01
4	1.29597E-01	1.47723E-07	1.29597E-01
5	8.67401E-02	1.14639E-07	8.67402E-02
6	5.95479E-02	8.80683E-08	5.95480E-02
7	4.16489E-02	6.72280E-08	4.16490E-02
8	2.95388E-02	5.10377E-08	2.95389E-02
9	2.11745E-02	3.84754E-08	2.11745E-02
10	1.53058E-02	2.86121E-08	1.53058E-02
11	1.11368E-02	2.00657E-08	1.11368E-02
12	9.40157E-03	1.58884E-08	9.40159E-03

*** PHOTON FLUXES FOR GROUP 4 ***

INT.	PHOTON	BREM.	TOTAL
1	1.77080E-04	2.15753E-06	1.79238E-04
2	1.48671E-03	2.54929E-06	1.48926E-03
3	2.80387E-03	2.67867E-06	2.80655E-03
4	2.65925E-03	2.15583E-06	2.66141E-03
5	2.32567E-03	1.68156E-06	2.32535E-03
6	1.96115E-03	1.29806E-06	1.96243E-03
7	1.62140E-03	9.95521E-07	1.62239E-03
8	1.32297E-03	7.59173E-07	1.32373E-03
9	1.07005E-03	5.74762E-07	1.07062E-03

*** GROUP TOTAL ***

INT.	PHOTON	BREM.	TOTAL
1	5.18811E-01	2.43898E-02	5.43201E-01
2	3.87335E-01	3.13871E-02	4.18722E-01
3	2.70558E-01	3.29330E-02	3.03491E-01
4	1.90197E-01	2.55639E-02	2.15761E-01
5	1.37779E-01	1.99264E-02	1.57705E-01
6	1.01765E-01	1.52305E-02	1.16995E-01
7	7.63045E-02	1.16364E-02	8.79410E-02
8	5.78327E-02	8.87012E-03	6.67028E-02
9	4.41346E-02	6.69961E-03	5.08342E-02
10	3.39404E-02	5.03613E-03	3.89766E-02
11	2.58208E-02	3.42308E-03	2.92439E-02
12	2.20058E-02	2.50629E-03	2.45121E-02
13	9.33241E-01	9.38009E-02	1.02704E+00

NOTE : VALUES FOR THE LAST INTERVAL ARE TOTAL

*** ZONE TOTAL ***

ZONE 1

GRP.	PHOTON	BREM.	TOTAL
1	5.16726E-02	0.0	5.16726E-02
2	8.23735E-04	8.20007E-07	8.24554E-04
3	6.97459E-01	5.41030E-07	6.97460E-01
4	8.79296E-03	7.91035E-06	8.80088E-03
5	8.28411E-03	4.44881E-05	8.32861E-03
6	9.56215E-03	1.07707E-04	9.66985E-03
7	7.56162E-03	3.35767E-04	7.89739E-03
8	9.79538E-03	7.85489E-04	1.05809E-02
9	1.11876E-02	1.62290E-03	1.28105E-02
10	1.47550E-02	3.09935E-03	1.78543E-02
11	9.83343E-03	3.52588E-03	1.33593E-02
12	1.08966E-02	5.15596E-03	1.60526E-02
13	1.41033E-02	8.16242E-03	2.22657E-02
14	1.86732E-02	1.25507E-02	3.12240E-02
15	2.21328E-02	1.96959E-02	4.18288E-02
16	1.24882E-02	1.25835E-02	2.50717E-02
17	1.29971E-02	1.39039E-02	2.69010E-02
18	1.12568E-02	1.02946E-02	2.15514E-02
19	9.66331E-04	1.92306E-03	2.88940E-03

*** INFORMATION OF DATA POOL USAGE ***
LOGICAL UNIT NO. = 91
DATA SET NAME = J1446.POOL87.DATA
NO. OF WRITTEN RECORDS = 2
REMAINS RECORDS = 9508