JAERI-M
87-123

ANISN—DD
ONE—DIMENSIONAL Sn TRANSPORT CODE USING MULTI—GROUP DOUBLE—DIFFERENTIAL FORM CROSS SECTIONS

August 1987

Takamasa MORI, Makoto SASAKI* and Masayuki NAKAGAWA

日本原子力研究所
Japan Atomic Energy Research Institute

JAERI-M レポートは，日本原子力研究所が不定期に公刊している研究報告書です。
入手の問合わせは，日本原子力研究所技術情報部情報資料課（〒319—11 茨城県那珂郡東海村）あて，お申しこしください。なお，このほかに財団法人原子力弘済会資料センター（〒319-11 茨城県那珂郡東海村日本原子力研究所内）で複写による実費頒布をおこなっております。

JAERI-M reports are issued irregularly.
Inquiries about availability of the reports should be addressed to Information Division, Department of Technical Information, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 319-11, Japan.

編集兼発行　日本原子力研究所
印　　刷　山田軽印刷所

JAERI-M 87-123

ANISN-DD
One-Dimensional Sn Transport Code Using Multi-Group Double-Differential Form Cross Sections

Takamasa MORI, Makoto SASAKI* and Masayuki NAKAGAWA

Department of Reactor Engineering
Tokai Research Establishment
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken

(Received July 23, 1987)

A modified version of a one-dimensional Sn transport code ANISN has been developed on the basis of ANISN-JR. The present version is useful to solve neutron transport problems in materials with highly anisotropic scattering cross sections as encountered in neutronic calculations in fusion reactors. In order to treat accurately an anisotropy of scattering, the present code uses the multi-group double-differential form cross sections (DDX) instead of the conventional Legendre expansion method. As a result, the energy-angle correlation of scattering process can be accurately taken into account in a frame of the multi-group approximation. The present code has the following functions in addition to those of ANISN-JR:

(1) forward transport calculation with external volume and/or shell sources by using a DDX library,
(2) collapsing a macroscopic or microscopic DDX library into the one of fewer energy groups and fewer angle bins,
(3) adjoint transport calculation by using a DDX library,
(4) solving several types of eigenvalue problems by using a DDX library.

Keywords: One-dimensional Sn Transport Code, ANISN, Multi-group Double-differential Form Cross Section, Fusion Neutronics, User Manual

---

* Visiting researcher from Japan Information Service Co., Ltd.

ANISN−DD

多群二重微分型断面積を用いる一次元Snコード

日本原子力研究所東海研究所原子炉工学部

森　貴正・佐々木誠*・中川正幸

（1987年7月23日受理）

一次元SnコードANISNの改良版をANISN−JRコードを基に作成した。本コードは特に，核融合炉のニュートロニクス計算で見られるような強い非等方散乱断面積を持つ物質中での中性子輸送計算において有用である。本コードでは強い非等方散乱を精度良く取り扱うために，従来のルジャンドル展開に代って，多群二重微分型断面積（DDX）を用いている。その結果，散乱後のエネルギーと散乱角の相関が多群近似の範囲で正確に考慮されている。本コードはANISN−JRコードの機能の他に次の機能を持っている。

(1) DDXライブラリーを用いた固定源（体積線源あるいは面線源）問題の計算，

(2) 巨視的あるいは微視的DDXライブラリーの少数群かつ少数角度ビンのライブラリーへの縮約，

(3) DDXライブラリーを用いたadjoint計算，

(4) DDXライブラリーを用いた各種固有値計算。

東海研究所：〒319−02　茨城県那珂郡東海村白方白根2−4

*　日本情報サービス㈱

Contents

目　　次

1. Introduction

An anisotropy of neutron scattering angular distribution plays an important role in the neutron energy and spatial distributions at the high energy region as encountered in fusion reactor shielding and blanket neutronics calculations. The conventional multi-group method using the P_l expansion for anisotropic scattering sometimes significantly mispredicts the neutron transport phenomena in the materials with highly anisotropic scattering cross sections. The use of the lower order P_l expansion of the angular distribution leads to negative energy transfer matrices, hence sometimes to negative flux. Moreover, the conventional multi-group method cannot accurately take account of the energy-angle correlated kinematics for neutron scattering. In order to overcome such problems, the multi-group double-differential form cross section library (DDX library) has been developed to treat accurately the scattering anisotropy[1]. Adequacy of this library was examined with use of a Monte Carlo code MORSE-DD in the previous works[2)3)].

Since a one-dimensional Sn transport code is widely used for survey calculations and for benchmark calculations to check cross section data, it is meaningful to improve its accuracy still now. Hence, the one-dimensional Sn code ANISN-JR[4] has been modified to use the DDX library. The newly developed code named as ANISN-DD has the following functions in addition to those of the original ANISN-JR:

(1) forward transport calculation in one-dimensional slab, sphere and cylinder geometries with external volume and/or shell sources by using the DDX library,

(2) collapsing a macroscopic or microscopic DDX library into the one with fewer energy groups and fewer angle bins,

(3) adjoint transport calculation by using the DDX library,

(4) solving several types of eigenvalue problems by using the DDX library.

The output file of ANISN-DD can be processed by auxiliary codes REACT[2] and PLTJOINT[5] to calculate a reaction rate and to draw a figure of calculated energy spectrum, respectively.

2. New Features of ANISN-DD

2.1 Cross Section

2.1.1 Multi-group Double-differential Form Cross Section

The collision source term in the transport equation is written as

$$q(r,\Omega,E)=\int dE'\int d\Omega'\psi(r,\Omega',E')\sum_j N_j\{\sigma^j_{el}(\Omega'\to\Omega,E'\to E)$$

$$+\sum_i\sigma^j_{in,i}(\Omega'\to\Omega,E'\to E)+\sum_m m\sigma^j_{n,mn}(\Omega'\to\Omega,E'\to E)$$

$$+\sum_X\sigma^j_{n,n'X}(\Omega'\to\Omega,E'\to E)\},\qquad(1)$$

where σ^j denotes a microscopic differential cross section of nuclide j, and the subscript el stands for elastic scattering, (in,i) discrete and continuum level inelastic scatterings, (n,mn) neutron multiplying reaction emitting m neutrons, $(n,n'X)$ neutron and charged particle emission. If we define the production cross section by

$$\sigma_{pr}(E)=\sigma_{el}(E)+\sum_i\sigma_{in,i}(E)+\sum_m m\sigma_{n,mn}(E)+\sum_X\sigma_{n,n'X}(E),\qquad(2)$$

Equation (1) can be written as

$$q(r,\Omega,E)=\int dE'\int d\Omega'\psi(r,\Omega',E')$$

$$\times\sum_j N_j\{\sigma^j_{pr}(E')\sum_x R^j_x(E')P^j_x(\mu,;E'\to E)\},\qquad(3)$$

where

$\mu=\Omega\cdot\Omega'$ and $R_x(E')=m_x\ \sigma_x(E')/\sigma_{pr}(E')$.

$P_x(\mu;E'\to E)$ is the energy-angle distribution of neutrons emitted from the reaction x. This is represented by using the Legendre polynomial series in the conventional ANISN code. At the present code, we adopt a direct presentation of the distribution in energy and angle. In the multi-group formulation, P_x is written as $P_x(k;g'\to g)$, which means a transfer probability from g'-th group to the g-th energy group in the k-th angular interval. The summation over all reaction types is reduced to the double-differential form cross section (DDX)

$$\sigma(k;g'\to g)=\sigma_{pr,g'}I(k;g'\to g),\qquad(4)$$

where

$$I(k;g'\to g)=\sum_x R_{x,g'}P_x(k;g'\to g).\qquad(5)$$

By using the multi-group DDX, the collision term of Eq.(3) is rewritten in the multi-group formula as

$$q_g(r,\Omega)=\sum_{g'}\int d\Omega'\,\psi_{g'}(r,\Omega')\sum_j N_j\frac{\sigma^j(k;g'\to g)}{2\pi\Delta\mu_k},$$

$$=\sum_{g'}\int d\Omega'\,\psi_{g'}(r,\Omega')\sum_j N_j\sigma^j_{pr,g'}\frac{I^j(k;g'\to g)}{2\pi\Delta\mu_k}, \qquad (6)$$

where k indicates an angle bin such as $\mu_{k+1}<\Omega\cdot\Omega'<\mu_k$, and $\Delta\mu_k=\mu_k-\mu_{k+1}$.

2.1.2 Cross Section Library

The multi-group DDX library has been produced from ENDF/B-IV[6] and JENDL-3PR1[7] by using the PROF-DD code system[1]. The number of energy group is 125, and 20 equi-cosine bins are employed. Note that the last group is assumed to be a thermal group and the cross sections of this group can be replaced with those given by a user. The energy group structure and the identification number for each nuclide are shown in Appendix 2. This library contains production, fission, capture, ν*fission and total cross sections and the energy-angle distribution of secondary neutron I for each nuclide. The format of the library is described in Section 4.2.

2.1.3 Preparation of Macroscopic Cross Section - Cross Section Mixing

In ANISN-DD, the user can start the calculation with use of the processed macroscopic cross section library and bypass the cross section mixing process by setting the input value IANISN=3. If the cross section mixing is necessary (IANISN=2 or 4), the user must specify the input parameter MTP and MT of 15$ data, where MTP and MT are the sum of numbers of constituent nuclides for each material and the number of materials for which the macroscopic cross sections are prepared, respectively. Besides these data, the following ones are required for the cross section mixing: the numbers of constituent nuclides for MT materials MB(j) (10$ data in Data Block 4) and, three arrays of MTP length, MC(i), XMD(i) and MTT(i) (11$, 12* data in Data Block 4 and 13$ data in Data Block 2), which are the identification number, atomic number density and logical unit number from which the microscopic cross sections are read, respectively. Accordingly, MTP should satisfy the relation

$$\mathrm{MTP}=\sum_{j=1}^{\mathrm{MT}}\mathrm{MB}(j). \qquad (7)$$

By using these data, the macroscopic cross sections for the J-th material are produced as follows:

$$IS=\sum_{j=1}^{J-1}\mathrm{MB(j)}+1, \tag{8}$$

$$IE=\sum_{j=1}^{J}\mathrm{MB(j)}, \tag{9}$$

$$\Sigma_{a,g}^{J}=\sum_{i=IS}^{IE}\mathrm{XMD(i)}\times\{\sigma_{c,g}^{\mathrm{MC(i)}}+\sigma_{f,g}^{\mathrm{MC(i)}}\}, \tag{10}$$

$$\nu\Sigma_{f,g}^{J}=\sum_{i=IS}^{IE}\mathrm{XMD(i)}\times\nu\sigma_{f,g}^{\mathrm{MC(i)}}, \tag{11}$$

$$\Sigma_{t,g}^{J}=\sum_{i=IS}^{IE}\mathrm{XMD(i)}\times\sigma_{t,g}^{\mathrm{MC(i)}}, \tag{12}$$

$$\Sigma_{s}^{J}(k;g\rightarrow g')=\sum_{i=IS}^{IE}\mathrm{XMD(i)}\times\sigma_{pr,g}^{\mathrm{MC(i)}}\times\bar{I}^{\mathrm{MC(i)}}(k;g\rightarrow g'), \tag{13}$$

where $\mathrm{X}^{\mathrm{MC(i)}}$ is a quantity for the nuclide with the identification number MC(i), which is read from logical unit MTT(i). These mixing process is carried out by using the direct access file, and after the process for all materials has completed, the elements of scattering matrices are rearranged into the group-independent form library, which is suitable for an ANISN-DD calculation. The rearrangement of cross sections for the adjoint calculation is also performed through this process, if necessary.

The format of the group-independent form library is described in Section 4.2. In the case of IANISN=3, this group independent form library should be provided by the user.

2.1.4 Collapsing of DDX

In ANISN-DD, the macroscopic or microscopic cross sections are collapsed into those with fewer energy groups and fewer angle bins by using a zonal neutron flux as a weighting function when it is required (IFG in 15$ data, 19$, 27$ 28$ and 29$ data in Data Block 4). The user can obtain collapsed cross sections: either microscopic cross sections for each component of each material in each zone or macroscopic cross sections for each material in each zone or for each cell composed of several zones. The collapsing is performed by using the following formulae:

Microscopic cross section for a component i in a zone r

$$\tilde{\sigma}^{i,r}_{x,G}=\sum_{g\in G}\psi^r_g\sigma^i_{x,g}/\sum_{g\in G}\psi^r_g, \tag{14}$$

$$\tilde{I}^{i,r}(K;G'\to G)=\sum_{g'\in G'}\sum_{g\in G}\sum_{h\in K}\psi^r_g\cdot\sigma^i_{pr,g'}\cdot I^i(h;g'\to g)\ /\sum_{g'\in G'}\psi^r_g\cdot\sigma^i_{pr,g'}. \tag{15}$$

Macroscopic cross section for a material m in a zone r

$$\tilde{\Sigma}^m_{x,G}=\sum_{g\in G}\psi^r_g\Sigma^m_{x,g}/\sum_{g\in G}\psi^r_g, \tag{16}$$

$$\tilde{\Sigma}^m_s(K;G'\to G)=\sum_{g'\in G'}\sum_{g\in G}\sum_{h\in K}\psi^r_g\cdot\Sigma^m_s(h;g'\to g)\ /\sum_{g'\in G'}\psi^r_g, \tag{17}$$

$$\tilde{\Sigma}^m_{pr,G'}=\sum_G\sum_K\tilde{\Sigma}^m_s(K;G'\to G), \tag{18}$$

$$\tilde{I}^m(K;G'\to G)=\tilde{\Sigma}^m_s(K;G'\to G)\ /\tilde{\Sigma}^m_{pr,G'}. \tag{19}$$

Macroscopic cross section for a cell R (cell averaging)

$$\tilde{\Sigma}^R_{x,G}=\sum_{r\in R}\psi^r_G V^r\Sigma^r_{x,G}/\sum_{r\in R}\psi^r_G V^r, \tag{20}$$

$$\tilde{\Sigma}^R_s(K;G'\to G)=\sum_{r\in R}\psi^r_G\cdot V^r\Sigma^r_s(K;G'\to G)\ /\sum_{r\in R}\psi^r_G\cdot V^r, \tag{21}$$

$$\tilde{\Sigma}^R_{pr,G'}=\sum_G\sum_K\tilde{\Sigma}^R_s(K;G'\to G), \tag{22}$$

$$\tilde{I}^R(K;G'\to G)=\tilde{\Sigma}^R_s(K;G'\to G)\ /\tilde{\Sigma}^R_{pr,G'}. \tag{23}$$

The output format of collapsed cross sections, as described in Section 4.2, is similar to that of the original DDX library in the case of microscopic cross sections and that of either the original one or the group-independent form library in the case of macroscopic cross sections.

2.2 Solution Algorithm

The solution algorithm is similar to that used in ANISN-JR or ANISN[8] except for the calculation of scattering source.

2.2.1 Calculation of Scattering Source

In the Sn method using the DDX library, the scattering source expressed as Eq.(6) is not calculated with P_l moments of flux but with angular fluxes as follows:

$$q_{g,m}=\sum_{g'}\sum_{m'}\psi_{g',m'}\cdot w_{m'}\cdot\sum_{k}\frac{\Sigma_s^J(k;g'\to g)}{2\pi\Delta\mu_k}$$

$$\times\frac{4\pi}{\Delta\Omega_{m'}\cdot\Delta\Omega_m}\int_{\Delta\Omega_{m'}}d\bar{\Omega}'\int_{\Delta\Omega_m}d\bar{\Omega}\,\delta_{\mu^*,k}, \tag{24}$$

where

$$\delta_{\mu^*,k}=\begin{cases}1 & \text{for } \mu_{k+1}\leqq\mu^*=\bar{\Omega}\cdot\bar{\Omega}'\leqq\mu_k,\\ 0 & \text{otherwise,}\end{cases}$$

and m and w_m denote the quadrature direction and its weight, respectively. $\Delta\Omega_m$ is a solid angle corresponding to the direction m and given by $\Delta\Omega_m=4\pi w_m$. Note that $q_{g,m}$ and $\psi_{g',m'}$ in Eq.(24) are the scattering source and angular flux per unit weight, respectively. Equation (24) is rewritten as

$$q_{g,m}=\sum_{g'}\sum_{m'}\psi_{g',m'}\cdot w_{m'}\cdot\sum_{k}\Sigma_s^J(k;g'\to g)\times P(k,m',m)$$

$$=\sum_{g'}\sum_{m'}\psi_{g',m'}\cdot w_{m'}\cdot\Sigma^J(g'\to g,m'\to m), \tag{25}$$

where P is the angular transfer probability defined by

$$P(k,m',m)=\frac{1}{2\pi\Delta\mu_k}\frac{4\pi}{\Delta\Omega_{m'}\cdot\Delta\Omega_m}\int_{\Delta\Omega_{m'}}d\bar{\Omega}'\int_{\Delta\Omega_m}d\bar{\Omega}\,\delta_{\mu^*,k}, \tag{26}$$

and

$$\Sigma^J(g'\to g,m'\to m)=\sum_{k}\Sigma_s^J(k;g'\to g)\times P(k,m',m). \tag{27}$$

The angular transfer probability P is symmetric for the indeces m and m', and it satisfies the following relations.

$$\sum_{k}\frac{\Delta\mu_k}{2}P(k,m',m)=1 \qquad \text{for all } m' \text{ and } m,$$

$$\sum_{m}w_m\,P(k,m',m)=1 \qquad \text{for all } m' \text{ and } k, \tag{28}$$

$$\sum_{m'}\sum_{m}w_{m'}\cdot w_m\,P(k,m',m)=1 \qquad \text{for all } k.$$

2.2.2 Angular Transfer Probability

(1) One-dimensional slab and sphere geometry

In the case of slab or sphere geometry, Eq.(26) can be expressed by

$$P(k,m',m)=\frac{1}{2\pi\Delta\mu_k}\frac{1}{4\pi w_{m'}\cdot w_m}\int_{\mu_{m-1/2}}^{\mu_{m+1/2}}2\pi d\mu\int_{\mu_{m'-1/2}}^{\mu_{m'+1/2}}d\mu'\int_0^{2\pi}d\varphi'\,\delta_{\mu^*,k}, \tag{29}$$

where

$$\mu^{*}=\mu\mu'+\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}\cos\varphi', \tag{30}$$

and $\mu_{m\pm1/2}$ are the boundaries of m-th quadrature direction which are defined recurrently by

$$\mu_{1/2}=-1, \quad \mu_{m+1/2}=\mu_{m-1/2}+2\omega_{m}. \tag{31}$$

We introduce the function $p(k,\mu',\mu)$:

$$p(k,\mu',\mu)=\int_{0}^{2\pi}d\varphi'\,\delta_{\mu^{*},k}$$

$$=2\int_{\beta_1}^{\beta_2}d\lambda\left|\frac{d\varphi'}{d\lambda}\right|\delta_{\mu^{*},k}, \tag{32}$$

where

$$\lambda=\mu\mu'+\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}\cos\varphi', \tag{33}$$

$$\beta_1=\mu\mu'-\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}, \tag{34}$$

$$\beta_2=\mu\mu'+\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}. \tag{35}$$

Carrying out the integration in Eq.(32), we obtain the following formulae:

When $|\mu|\neq1$ and $|\mu'|\neq1$,

$$p(k,\mu',\mu)=2\left[\sin^{-1}\frac{\beta_2-\mu\mu'}{\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}}-\sin^{-1}\frac{\mu_{k+1}-\mu\mu'}{\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}}\right],$$

$$(\text{if } \beta_1<\mu_{k+1}<\beta_2<\mu_{k}), \tag{36}$$

$$p(k,\mu',\mu)=2\left[\sin^{-1}\frac{\mu_{k}-\mu\mu'}{\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}}-\sin^{-1}\frac{\mu_{k+1}-\mu\mu'}{\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}}\right],$$

$$(\text{if } \beta_1\leqq\mu_{k+1} \text{ and } \mu_{k}\leqq\beta_2), \tag{37}$$

$$p(k,\mu',\mu)=2\left[\sin^{-1}\frac{\mu_{k}-\mu\mu'}{\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}}-\sin^{-1}\frac{\beta_1-\mu\mu'}{\sqrt{1-\mu^{2}}\sqrt{1-\mu'^{2}}}\right],$$

$$(\text{if } \mu_{k+1}<\beta_1<\mu_{k}<\beta_2), \tag{38}$$

and

$$p(k,\mu',\mu)=0,$$

$$(\text{otherwise}), \tag{39}$$

When $|\mu|=1$ or $|\mu'|=1$,

$$p(k,\mu',\mu)=2\pi,$$

$$(\text{if } \mu_{k+1}<\mu\mu'<\mu_{k}), \tag{40}$$

and

$$p(k,\mu',\mu)=0,$$

$$(\text{otherwise}). \tag{41}$$

By using $p(k,\mu',\mu)$ obtained thus, Eq.(29) is rewritten as

$$P(k,m',m)=\frac{1}{2\pi\Delta\mu_k}\frac{1}{4\pi w_{m'}w_m}\int_{\mu_{m-1/2}}^{\mu_{m+1/2}}2\pi d\mu\int_{\mu_{m'-1/2}}^{\mu_{m'+1/2}}d\mu' p(k,\mu',\mu). \tag{42}$$

In ANISN-DD, the integration in Eq.(29) is performed numerically, and its procedure is described in Appendix 3.

(2) Infinite cylinder geometry

In this case, angular flux depends on angle φ. Therefore, the angular transfer probability cannot be calculated in the same way as mentioned above for the slab and sphere geometries. ANISN-DD calculates it on the basis of the assumption that each Sn weight w_m is sufficiently small compared with the angle bin width $\Delta\mu_k$.

Let $\overline{\Omega}_{m'_1}=(\mu',\eta',\xi')$ and $\overline{\Omega}_m=(\mu,\eta,\xi)$ be incident and outgoing directions of scattering, respectively. In the infinite cylindrical system, angular fluxes are the same in the following four directions:

$$\overline{\Omega}_{m'_1}=(\mu',\eta',\xi'),\ \overline{\Omega}_{m'_2}=(\mu',-\eta',\xi'),\ \overline{\Omega}_{m'_3}=(\mu',\eta',-\xi'),$$

and $\overline{\Omega}_{m'_4}=(\mu',-\eta',-\xi')$.

For each direction, cosine of scattering angle is defined by

$$\lambda_1=(\overline{\Omega}_{m'_1},\overline{\Omega}_m)=\mu'\mu+\eta'\eta+\xi'\xi, \tag{43}$$

$$\lambda_2=(\overline{\Omega}_{m'_2},\overline{\Omega}_m)=\mu'\mu-\eta'\eta+\xi'\xi, \tag{44}$$

$$\lambda_3=(\overline{\Omega}_{m'_3},\overline{\Omega}_m)=\mu'\mu+\eta'\eta-\xi'\xi, \tag{45}$$

$$\lambda_4=(\overline{\Omega}_{m'_4},\overline{\Omega}_m)=\mu'\mu-\eta'\eta-\xi'\xi. \tag{46}$$

Then ANISN-DD sets as

$$P(k,m',m)=\frac{2}{\Delta\mu_k}\times(\text{Number of } \lambda_i \text{ such that } \mu_{k+1}<\lambda_i<\mu_k). \tag{47}$$

When the present assumption is not satisfied, $P(k,m',m)$ should be calculated by a more sophisticated method. The MONTA code, which performs the integration in Eq.(26) by the Monte Carlo method, has been prepared for this purpose. A detailed description of the MONTA code is given elsewhere[9].

3. Input Instruction

The input data for ANISN-DD consist of two parts: input data required in the original ANISN with use of the FIDO format and additional input data for new options in ANISN-DD with use of the free format (FORTRAN77), which are the same as those used in ANISN-JR. At first, the data for the additional options (Section A to G) are read with the free format. Then, the ANISN input data[8] are read with the FIDO format. At last, the optional data for reaction rate calculations (Section H) are read with a specified format. At the end of the input data, a "STOP" card is required, which contains four letters "STOP" at column 1-4 on a card. In order to print out the input data, it is required to input "LIST" at column 1-4 on the first card. The FIDO format is described in Appendix 4. Note that "$" in the FIDO format can be replaced by "¥".

3.1 Input Data for Additional Options of ANISN-DD

ANISN-DD reads the following data with the free format except for those in Section H.

(1) Section A

1) IANISN cross section type and excecution mode

P_l mode;

=0, original format

=1, format of the cross section generated by RADHEAT-V3

DDX mode;

=2, mixing of DDX type cross section only

=3, flux calculation by using DDX type cross section already mixed

=4, mixing and flux calculation using a DDX library

2) ITMAX maximum execution time in minutes

If ITMAX=0, this option is ignored. ANISN-DD checks ITMAX at the end of each outer iteration, and if it has been exceeded, the problem is terminated with full output.

3) IENRGY input option for 17* (distributed volume source)

or 18* (shell source)

=0, normal

=1, input 17* or 18* for each group with "T"

4) IINPT option for source input

=0, from cards

=1, from I/O unit 25

(2) Section B

1) IIBOUD output option for total flux

=0, print total fluxes at the midpoint of each mesh interval

=1, print total fluxes at the boundary of each mesh interval

2) IISPTM output option for neutron spectrum (total flux)

=0, no effect

=1, calculate and print neutron spectrum $\psi_g/\Delta E_g$ at each mesh

=2, calculate and print neutron spectrum $\psi_g/\Delta U_g$ at each mesh

If IISPTM=1,2, energy group boundaries should be specified by Section D.

3) IIANLL output option for angular flux

=0, print angular fluxes at all spatial meshes

=1, print angular fluxes at only required meshes

The required meshes are given by Section E and Section F. If angular fluxes are required, ID1=1 must be entered in 15$ array.

=2, write boundary angular fluxes of mesh NOANLL(1) on I/O unit 16 for use as a shell source in the next run

=3, print angular fluxes at midpoint of each mesh interval (effective only in *DDX* mode)

4) IGMNEW number of total energy groups

In *DDX* mode, a negative value means that the cross sections of group | IGMNEW | are given in Section X, and the mixed DDX has | IGMNEW | energy groups.

5) IGMNEU number of neutron groups

If only neutron is considered, IGMNEU = | IGMNEW |.

6) NACTPR

=0, no effect

=1, print activities for each group and zone

7) NREACT

=0, no effect

=1, calculate and print reaction rates for neutron and gamma ray

=2, calculate reaction rates and also collapse response functions of detectors

=3, collapse and punch response functions of detectors

The response functions for neutron and gamma ray are given in Section H. To collapse the response functions, IFG=1 in 15$ array, and 27$ and 28$ arrays must be entered.

8) NASYMM

=0, no effect

=1, use asymmetric quadrature set (only in P_l mode)

The reflective condition for left boundary can not be used.

9) NRESAT

=0, no effect

=1, write/read final fluxes on a tape for use as an initial flux guess in the next run

Final fluxes are written on the I/O unit 15 and read from 14. For the first run, NRESAT=1, IFN=1 or 2 (in 15$ array) must be specified, and for the following run, NRESAT=1 and IFN=3.

10) NXSOUT

P_l mode;

=0, no effect

=1, obtain a few group cross sections for DOT, TWOTRAN or MORSE, and write them on I/O unit 40

(IFG=1 in 15$, and 27$ 28$ 29$ arrays)

In this case, input data on Section G are necessary.

DDX mode;

=0, output collapsed cross sections on I/O unit 11 in the form ANISN-DD or DOT-DD can use directly without mixing (ICON≠0,1 in 27$)

=1, output collapsed macroscopic or microscopic cross sections on I/O unit 11 in the form of original DDX library

11) NPLOT output option for I/O unit 30

=0, no effect

=1, obtain the file for plotting on I/O unit 30

12) NAOUT option for card output of angular flux

=0, no effect

=N, punch out angular flux at the left boundary of interval N

13) LENGPL P_ℓ; maximun number of the order of Legendre expansion
DDX; number of angle bins in DDX library

(3) Section C (IISPTM=1)

1) NOYGRE number of energies to be specified in Section D
NOYGRE = IGM+1 for neutron or gamma-ray problem
NOYGRE = IGM+2 for coupled neutron and gamma-ray problem

(4) Section D (IISPTM=1)

(YGRENE(I), I=1, NOYGRE) energy group boundaries given in descending order of energy in eV

(5) Section E (IIANLL≧1)

1) NOANNO number of mesh boundaries or midpoints to print angular fluxes (≦10)

(6) Section F (IIANLL≧1)

(NOANLL(I), I=1, NOANNO) mesh numbers to print angular fluxes

(7) Section G (NXSOUT=1 and IANISN≦1)

1) NACT number of detectors for which response functions are added at the top of cross section table
2) IDOT output format for collapsed cross section
=0, TWOTRAN format
=1, DOT format
3) NPU output of collapsed cross section
=0, print only
=1, punch
=2, write on disk (I/O unit 40)
=3, add cross sections to the file produced in the previous case
4) IGNT number of groups of (n,2n) down scattering

Normally, total number of neutron groups is entered. When IDOT=1, IGNT is put to be zero.

5) IGMN number of energy groups to be obtained (from highest energy)

6) ITL2 length of outpt cross section table
Specify ITL2=NACT+IGMN+3 for DOT and ITL2=NACT+IGMN+5 for TWOTRAN.

(8) Section M (IANISN≧2)

(XMU(M), M=1,LENGPL+1) anglular mesh boundaries of DDX from 1.0 to -1.0

The input values are replaced with those read in from I/O unit 24 (group independent library) if IANISN=3.

(9) Section X (IANISN≧2 and IGMNEW < 0)

Input the following thermal group cross sections for required nuclide:

nuclide ID, $\sigma_{production}$, $\sigma_{fission}$, $\sigma_{capture}$, $\nu\sigma_{fission}$, σ_{total}.

Data input for Section X is terminated by an arbitrary negative integer and /. As for nuclides for which no data is given in this section, thermal cross sections are set to be 0.0.

(10) Section H (NREACT≠0)

Section H must be placed after the data for the first case of ANISN-DD run. Section H gives the names of detectors and their response functions. When the neutron and gamma-ray responses are calculated, Section H for neutron and gamma-ray must be given, that is, at first the neutron's data and the gamma-ray's data.

Card H-1 format (I5)

1) NELM number of detectors for which the response functions for neutrons or gamma-rays are stored

Card H-2 format (I5,4A4) (NELM>0)

1) NAME identification number for the detector

2) DXCM title of the detector

Cards H-3 format (6E12.5) (NELM>0)

1) (OSIG(I), I=1, NG) response function of the detector in descending order of energy

NG is the number of neutron groups or gamma-ray groups.

Card H-2 and card H-3 are repeated by NELM times.

3.2 ANISN-DD Input Data with FIDO Format

< Data Block 0 >

Problem title (A48)

* Control Data

< Data Block 1 >

/15$/ Integer data

1) ID problem ID number
2) ITH problem type
   =0, forward calculation
   =1, adjoint calculation
3) ISCT P_l; maximum order of Legendre expansion of scattering
   DDX; number of DDX angle bins (= LENGPL)
4) ISN order of angular quadrature
5) IGE geometry type
   =1, slab; =2, cylinder; =3, sphere
6) IBL left boundary condition
   = 0, vacuum (no incoming flux)
   = 1, reflective
   = 2, periodic
   = 3, white/albedo
7) IBR right boundary condition with the same options as IBL
8) IZM number of zones
9) IM number of mesh intervals
10) IEVT eigenvalue type
   = 0, fixed source
   = 1, k calculation
   = 2, 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_t in cross section table

(=3 in *DDX* mode, automatically set)

13) IHS P_l; position of $\sigma_{g'g}$ in cross section table

DDX; position of the beginning of $\sigma_{g'g}$

(=4, automatically set)

14) IHM cross section table length

(automatically set in *DDX* mode)

15) MS P_l; mixing table length

DDX; no effect

16) MCR number of cross section sets to be read from cards

(automatically set as 0 in *DDX* mode)

17) MTP P_l; number of cross section sets from file

DDX; sum of the numbers of nuclides used in each material

18) MT P_l; total number of cross section sets

DDX; number of mixtures to be prepared by mixing process (IANISN=2,4), or number of mixtures in group independent library (IANISN=3)

19) IDFM density factors (21*)

=0, not used

=1, used

20) IPVT type of parametric eigenvalue search

=0, no effect

=1, search for specified k

=2, search for specified α

k or α values are input as PV of 16*

21) IQM distributd volume source (17*)

=0, no effect

=1, enter distributed source

22) IPM shell source (18*)

=0, no effect

=1, enter shell source by group and angle

=IM, enter shell source by interval, group and angle

23) IPP interval number which contains shell source if IPM = 1;

enter zero otherwise

24) IIM maximum number of inner iterations

25) ID1

=0, no effect

=1, print angular flux

=2, punch scalar flux

=3, both 1 and 2.

26) ID2 cross section type and fixed source (P_l mode only)

=0, no effect

=1, use specially prepared group independent cross section file (contains MTP materials)

=2, use cross sections and fixed source from previous problem

27) ID3 number of activities calculated by zone

If ID3=0, no activity calculation.

28) ID4

=0, no effect

=1, calculate ID3 (not ID4) activities by interval

29) ICM maximum number of outer iterations

30) IDAT1 storage mode

=0, all data stored in core if possible

=1, cross sections and fixed source stored on disk

=2, fluxes and currents (angular flux) on disk also

=3, furthermore, products of angular transfer probability an DDX are stored by incident group on I/O unit 60 (effective only in *DDX* mode).

31) IDAT2 calculation selector

=0, no effect

=1, execute diffusion solution for specified groups (24$)

32) IFG cross section collapsing

=0, no collapsing

=0, flux weighted cross section (27$ and 28$)

33) IFLU flux calculation model

=0, step model used when a linear extrapolation yields negative flux (mixed mode)

=1, use linear model only

=2, use step model only

34) IFN initial guess

=0, enter fission guess (2*)

=1, enter flux guess (3*)

=2, use fluxes from previous case

35) IPRT cross section print option

=0, print cross sections

=1, do not print cross sections

36) IXTR

P_l mode;

=0, calculate Legendre coefficients

=1, read Legendre coefficients from cards

DDX mode;

=0, calculate angular transfer probabilities

=1, read angular transfer probabilities from I/O unit 62

=-1, read angular transfer probabilities and quadrature constants from I/O unit 62

/16*/ Floating point data

1) EV first eigenvalue guess for search

2) EVM eigenvalue modifier for search

The second eigenvalue guess = EV ± EVM where the plus sign is taken if the system is supercritical for the first guess.

3) EPS genaral convergence criterion

This criterion is applied to tests on the integral inner iteration convergence, lamda, and fission density.

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 source normalization factor (ignored if XNF=0.0)

9) PV 0.0, k_0 or p_0 according to IPVT = 0, 1 or 2

10) RYF λ_2 relaxation factor, normally set as 0.5

11) XLAL criterion for pointwise flux convergence

Not used if XLAL=0.0.

12) XLAH upper limit for $|\lambda - 1.0|$ used in linear search

13) EQL eigenvalue change epsilon for search calculations; zero otherwise

14) XNPM new parameter modifier for search calculations; zero otherwise

T Terminator

* Array Data

< Data Block 2 > Cross Sections

/13$/ P_l; Nuclide identification numbers from data set on I/O unit 8 (MTP≠0) (MTP entries)

DDX; I/O unit of DDX library from which cross sections for each nuclide are read (MTP≠0) (MTP entries)

/14*/ cross sections (MCR≠0 and IANISN≦1)
(MCR*IGM*IHM entries)

Note that no data of Data Block 2 are necessary in *DDX* mode if MTP=0.

T Terminator

< Data Block 3 > Fixed Source

/17*/ Volume-distributed source (IQM>0)
IENRGY = 0;
((Q(i,g),i=1,IM),g=1,IGM) (IGM*IM entries)
IENRGY = 1;
Input 17* for each group, and each array is followed by "T". (IM entries for each group)

/18*/ Shell source (IPM>0)
MM = ISN+1 (IGE=1,3) or ISN*(ISN+4)/4 (IGE=2)
IENRGY = 0;
((Q(m,i,g),m=1,MM),i=1,IPM),g=1,IGM)
(MM*IPM*IGM entries)
IENRGY = 1;
Like as for 17* (MM*IPM entries for each group)

T Terminator

< Data Block 4 > Flux or Fission Guess (IFN<2)

/2*/ Fission density (IFN=0) (IM entries)

/3*/ Flux guess (IFN=1) (IGM*IM entries)
((F(i,g),i=1,IM),g=1,IGM)

T Terminator

< Data Block 5 > Remainder of Data

/1*/ Fission spectrum. (IGM entries)
/4*/ Radii by interval boundary (IM+1 entries)
/5*/ Velocities (IGM entries)
/6*/ Angular quadrature weights (MM entries)
/7*/ Angular quadrature cosines (MM entries)
/8$/ Zone numbers by interval (IM entries)
/9$/ Material numbers by zone (IZM entries)
/10$/ P_l; mixture numbers in mixing table (MS entries)
DDX; number of nuclides by mixture (MT entries)
A user can omit this input if IANISN=3.
/11$/ P_l; component numbers in mixing table (MS entries)
DDX; nuclide ID numbers for all mixtures (MTP entries)
/12*/ P_l; number densities in mixing table (MS entries)
DDX; number densities (MTP entries)
/19$/ P_l; order of scattering by zone (ISCT>0) (IZM entries)
DDX; few angle number for each angle (IPUN=1)
(ISCT entries)
In *DDX* mode, 19$ data is used in cross section collapsing.
See the description for 27$ data.
/20$/ Radius modifiers by zone (IEVT=4) (IZM entries)
/21*/ Density factors by interval (IDFM=1) (IM entries)
/22$/ Material numbers for activities (ID3>0) (ID3 entries)
/23$/ Table position for activation cross section (ID3>0)
(ID3 entries)
/24$/ Diffusion calculation markers (IDAT2=1) (IGM entries)
=0, Sn transport theory
=1, S_2 calculation
=2, homogeneous flux
/25*/ Right boundary albedo by group (IBR=3) (IGM entries)
/26*/ Left boundary albedo by group (IBL=3) (IGM entries)
/27$/ Few group parameters (IFG=1)

1. ICON

=0, no effect

=1, microscopic cross section desired

=2, macroscopic cross section desired
(minus implies cell weighting over all zones)

=3, macroscopic cross section desired
(cell-weighting for arbitrary zones)

2. IHTF position of total cross section in weighted cross section table
(automatically set in *DDX* mode)

3. IHSF position of self scattering cross section in weighted cross section table
(automatically set in *DDX* mode)

4. IHMF table length of weighted cross section
(automatically set in *DDX* mode)

5. IPUN

=0, no effect

=1,
P_l; punch weighted cross sections
DDX; angle collapsing (19$)

=2, obtain weighted cross section file on I/O unit 11

In *DDX* mode, weighted cross sections are always written on I/O unit 11.

/28$/ Few group number for each multigroup (IFG=1)
(IGM entries)

/29$/ Cell numbers for each zone, which become the numbers for cell weighted cross sections (IFG=1, ICON=3). (IZM entries)

/34*/ P_l constants (IXTR=1) (JT*MM entries)

T Terminator

4. Job Control Instruction

4.1 Job Control Statements

A sample of job control statements for a FACOM M-series computer is shown in Fig.4.1. The overlay structure of ANISN-DD is also shown in this figure as input data for the linkage editor. An executive load module of ANISN-DD has been prepared in J3803.ANISNDD.LOAD(ANISNDD). The size of common for ANISN-DD in this module is 30k words, and a user should replace Main routine by user's one having an appropriate size of common as described in Section 4.3.

4.2 I/O File Requirements

I/O files required by ANISN-DD are summarized in Table 4.1. Format of DDX library and a detail of contents and their formats for each output file in DDX mode are as follows:

i) Double differential form cross section library

m = 1, Element
- 1) MAXI, IDUMMY, IDUMMY, MATNO, (TITLE(i), i=1,12)
- 2) (MAXSD(i), i=1,MAXI)
- 3) ($\sigma_{pr}^{g'}$, $\sigma_f^{g'}$, $\sigma_c^{g'}$, $\nu\sigma_f^{g'}$, $\sigma_t^{g'}$, g'=1,MAXI)

g' = 1, MAXI
- 4) (($I(k;g'\rightarrow g)$, k=1,MAXMU), g=1,MAXSD(g')

ii) Processed cross section (I/O unit 24)

1) MAXMU, (DUMMY, i=1,5)
2) (XMU(i), i=1,MAXMU+1)
3) MT, MBSUM, IHM, (DUMMY, i=1,5)
4) (MTT(i), i=1, MBSUM) : data in 13$
5) (MB(i), i=1,MT) : data in 10$
6) (MC(i), i=1,MBSUM) : data in 11$
7) (XMD(i), i=1,MBSUM) : data in 12*

g = 1, IGMNEU
- 8) ($\Sigma_a^m(g)$, $\nu\Sigma_f^m(g)$, $\Sigma_t^m(g)$, (($\Sigma_s^m(k, g-g'+1\rightarrow g)$, k=1,MAXMU), g'=1,IHMM), m=1,MT)

Note that IHMM=(IHM-3)/MAXMU and MBSUM=MTP(data in 15$). The cross section library of this type is called as "group independent form library".

iii) Collapsed DDX library (I/O unit 11 if IFG=1)

Microscopic cross section (ICON=1)

For each nuclide in each zone,

1) IGMF, IZ, IDUM, IDUM, MATN, (T(i), i=1,12)

IGMF : number of collapsed groups,

IZ : zone number,

IDUM : dummy data,

MATN : nuclide ID number,

T : title

2) (MAXSD(i), i=1,IGMF) : number of slowing down group

3) 1-D cross section data σ_x

4) energy-angle probability distribution I

Macroscopic cross section (ICON=2,3)

(1) group independent form (if NXSOUT=0)

1) MAXMU, (DUMMY, i=1,5)

2) (XMU(i), i=1,MAXMU+1)

3) IZM, IZM, IHMF, (DUMMY, i=1,5)

4) DUMMY, i=1,IZM

5) DUMMY, i=1,IZM

6) DUMMY, i=1,IZM

7) DUMMY, i=1,IZM

8) group independent data

Note that this file has the same structure as I/O unit 24.

(2) DDX type (if NXSOUT=1)

For each zone, the following data are written.

1) IGMF, ICON, DUMMY, IZ, (T(i), i=1,12)

2) (IGMF, i=1,IGMF) : the same as MAXSD(i)

3) ($\tilde{\Sigma}_{pr,G}$, 0.0, $\tilde{\Sigma}_{a,G}$, $\nu\tilde{\Sigma}_{f,G}$, $\tilde{\Sigma}_{t,G}$, G=1,IGMF)

4) energy-angle probability distribution $\tilde{I}$

Note that this file has the same structure as the double-differential form cross section library.

iv) Output file for plotting (I/O unit 30 if NPLOT=1)

1) (Title(i), i=1,12)

2) IGM, IGMNEU, IGMGAM, IM, IZM, IIBOUD, IISPTM, IIANIL

3) $(E_n(i), i=1, IGMNEU+1)$ (if IGMNEU>0)

4) $(E_\gamma(i), i=1, IGMGAM+1)$ (if IGMGAM>0)

5) $(R(i), i=1, IM+1)$: spatial boundary

6) $(M(i), i=1, IM)$: zone number

7) $((XN(i,j), i=1, IM+1), j=1, IGMNEU)$ (if IGMNEU>0)
: neutron total flux processed according to IIBOUD and IISPTM

8) $((XN(i,j), i=1, IM+1), j=1, IGMGAM)$ (if IGMGAM>0)
: γ-ray total flux processed according to IIBOUD and IISPTM

9) $NELM_n$: number of reaction rates calculated for neutron

┌ 1, $NELM_n$
10) $(CM(i), i=1, 18)$: title for reaction
11) $(RR(i), i=1, IM)$: reaction rate
└ 12) $NELM_\gamma$: number of reaction rates calculated for γ-ray

┌ 1, $NELM_\gamma$
13) $(CM(i), i=1, 18)$: title for reaction
└ 14) $(RR(i), i=1, IM)$: reaction rate

┌ 1, IGM (if ID1=1 or 3)
└ 15) $((XND(i,m), i=1, IM+1), m=1, MM)$:
angular flux per unit solid angle and group. If IIBOUD=3, these values are those at midpoint in the interval.

v) Angular transfer probability (I/O unit 62, if IIXTRI=1)
See the description for the MONTA code[9].

4.3 Core Requirement

The core storage requirement by ANISN-DD depends on the problem solved and some parameters such as IDAT1. Note that IDAT1 is automatically changed by the code according to the common size allowed for the problem (common BULKBU) and that ANISN-DD terminates by printing the message about the common size required for the present problem if the size is insufficient. ANISN-DD also stops by printing a similar message, when the size of common PMMBUF is insufficient for the calculation of angular transfer probability. The size of the common PMMBUF must be greater than *MAX*, where *MAX*=MAXMU+ISN+4 for IGE=1 or 3 and *MAX*=MAXMU+3 for IGE=2. ANISN-DD adopts a

flexible dimensioning technique. A user must specify the size of both commons as follows:

```
C----- MAIN ROUTINE OF ANISN-DD
      COMMON /BULKBU/ D(1),LIM1,DUMY(xxxxxx)
      COMMON /PMMBUF/ P(1),LIMP,DUMMY2(yyyy)
      LIM1 = xxxxxx
      LIMP = yyyy
      CALL ERRSET(257,300,-1,1,1,257)
      CALL ANISN
      STOP
      END
```

Table 4.1 ANISN-DD file requirements

Logical unit	Remarks	I/O DDXmode		I/O P1 mode	
1	Scratch file for cross section	A*	I/O**	A	I/O
2	Scratch file for cross section	A	I/O	A	I/O
3	Scratch file for flux etc.	A	I/O	A	I/O
4	P1 cross section library	X		A	I
8	Scratch file for flux etc.	A	I/O	A	I/O
9	Necessary for NXOUT=1in P1 mode	X		B	I/O
11	Collapsed cross section	B	O	B	O
14	Restart file (NRESAT=1)	B	I	B	I
15	Restart file (NRESAT=1)	B	O	B	O
16	Output for shell source (IIANLL=2)	B	O	B	O
20	Scratch for boundary total flux (IIBOUD=1)	B	I/O	B	I/O
24	Group independent macro-DDX	A	I/O	X	
25	Source input file (IINPT=1)	B	I	B	I
30	Output file for plotting etc. (NPLOT=1)	B	O	B	O
40	Collapsed cross section for DOT or TWOTRAN (NXSOUT=1,NPU=2,3)	X		B	O
50	Scratch file for DDXmixing DCB=(RECFM=F,DSORG=DA)	A	I/O	X	
51	Scratch file for DDXmixing	A	I/O	X	
52	Scratch file for DDXmixing	A	I/O	X	
55	Scratch file for data input	A	I/O	A	I/O
60	Scratch file for DDX* ATP	A	I/O	X	
61	Scratch file for source	A	I/O	X	
62	Angular transfer probability (IXTR=1,-1)	B	I	X	
90	Check write	B	O	B	O
5	Card-image input for ANISN-DD	A	I	A	I
6	Output of final result	A	O	A	O

* A : always necessary file.
B : necessary file (To specify a DUMMY file is allowed).
X : unnecessary file.

** I and O mean read-only and write-only files, respectively.

```
//JCLG JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER XXXXXXXX,MOR1,0431.110
  T.6  C.3  W.4  I.5
  OPTP PASSWORD=XXXXXX,MSGCLASS=R
//*******************************************
//*  J3803.DDX.CNTL(GOANISN2)
//*  ANISN-DD ( BY DDX )
//*******************************************
//    EXEC FORT77,A='SOURCE'
       COMMON /BULKBU/ D(1),LIM1,DUMY(600000)
       COMMON /PMMBUF/ P(1),LIMP,DUMMY2(2000)
             LIM1   =  600000
             LIMP   =  2000
       CALL ERRSET(257,300,-1,1,1,257)
       CALL ANISN
       STOP
       END
//FORT77.SYSPRINT DD DUMMY
//    EXEC LKED77,A='OVLY'
//OLDLM  DD DSN=J3803.ANISNDD.LOAD,DISP=SHR,UNIT=D0430
//SYSIN  DD *
    ENTRY MAIN
    INCLUDE OLDLM(ANISNDD)
    OVERLAY ANSO1
    INSERT PLSNT,FIDO,TP,ADJNT,S804,S805,S814,WOT8,S966,FFREAD
    OVERLAY ANSO1
    INSERT GUTS,S807,S810,S821,S824,S833,DT,CELL,S851
    OVERLAY ANSO1
    INSERT FINPR,FINPR1,PUNSH,DTFPUN,FLTFX,NWSUB1,NWSUB2,ACTPRT
    INSERT WOTYT
    OVERLAY ANSO4
    INSERT BT,SUMARY,FACTOR,NWSUB3,NWSUB4
    OVERLAY ANSO4
    INSERT FEWG,WATE,CONVT,CRATE
    OVERLAY ANSO4
    INSERT DDFEWG,FMICRO,FMACRO
    NAME TEMPNAME(R)
// EXEC ANY
// EXEC GO,OBSIZE=137
//*------------ FT1,FT2 : CROSS SECTION STORAGE ----------------------
//FT01F001 DD UNIT=WK10,SPACE=(TRK,(200,10)),DCB=(BLKSIZE=19069)
//FT02F001 DD UNIT=WK10,SPACE=(TRK,(200,10)),DCB=(BLKSIZE=19069)
//*------------ FT3,FT8 : FLUX & ANGULAR FLUX STORAGE ----------------
//FT03F001 DD UNIT=WK10,SPACE=(TRK,(200,10)),DCB=(BLKSIZE=19069)
//FT08F001 DD UNIT=WK10,SPACE=(TRK,(200,10)),DCB=(BLKSIZE=19069)
//*------------ FT9 : GROUP INDEPENDENT X-SEC. FOR DOT,TWOTRAN -------
//FT09F001 DD UNIT=WK10,SPACE=(TRK,(50,10)),DCB=(BLKSIZE=19069)
//*------------ FT11 : COLLAPSED X-SEC. FOR DOT,TWOTRAN --------------
//FT11F001 DD DSN=J3803.FEWGXS.DATA,UNIT=D0430,SPACE=(TRK,(5,1)),
//         DISP=(NEW,CATLG,DELETE),DCB=(RECFM=VBS,LRECL=X,BLKSIZE=19069)
//*------------ FT20 : BOUNDARY TOTAL FLUX STRAGE (IIBOUD=1) ---------
//FT20F001 DD UNIT=WK10,SPACE=(TRK,(50,10)),DCB=(BLKSIZE=19069)
//*------------ FT24 : GROUP INDEPENDENT X-SEC. (DDX TYPE) -----------
//FT24F001 DD UNIT=WK10,SPACE=(TRK,(20,20)),DISP=(NEW,PASS),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=19069)
//*------------ FT25 : INPUT SOURCE ----------------------------------
//FT25F001 DD DUMMY
//*------------ FT50 : WORK FILE FOR MIXING (DDX MODE) ---------------
//*                    ( NEEDED WHEN IANISN = 2 )
//*------------ FT51 : MIXED OR WEIGHTED BUT NOT GROUP INDEPENDENT X-SEC
//*                    ( NEEDED WHEN IANISN = 2 OR IFG = 1 )
//*------------ FT52 : TEMPORARY STORAGE OF DDX LIBRARY --------------
//*                    ( NEEDED WHEN IANISN = 2 )
//FT50F001 DD UNIT=WK10,SPACE=(TRK,(300,10)),DCB=(RECFM=F,DSORG=DA)
//FT51F001 DD UNIT=WK10,SPACE=(TRK,(100,10)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=19069)
//FT52F001 DD UNIT=WK10,SPACE=(TRK,(100,10)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=19069)
//*------------ FT55 : TEMPORARY STORAGE OF INPUT DATA ---------------
//FT55F001 DD UNIT=WK10,SPACE=(TRK,(2,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=19069)
//*------------ FT60 : STORAGE FOR ANGULAR TRANSFER FUNCTION ---------
//*------------ FT61 : ANGULAR DEPENDENT SOURCE (FOR SUMMARY) --------
//*------------ FT62 : ANGULAR TRANSPORT FUNCTION (PMM) --------------
//FT60F001 DD UNIT=WK10,SPACE=(TRK,(500,100)),
//            DCB=(LRECL=X,BLKSIZE=19069)
//FT61F001 DD UNIT=WK10,SPACE=(TRK,(100,50)),DCB=(BLKSIZE=19069)
//FT62F001 DD UNIT=WK10,SPACE=(TRK,(100,50)),DCB=(BLKSIZE=19069)
//*------------ ARBITRARY FILE NO. : INPUT DDX-LIBRARY ---------------
//FT71F001 DD DSN=J3803.DDXLIB3.DATA,DISP=SHR,LABEL=(,,,IN)  (DDXLIB3)
//*------------ FT04 : PL CROSS SECTION INPUT ------------------------
//*T04F001 DD DSN=J9067.ENDGIX.DATA,DISP=SHR,LABEL=(,,,IN)   (B-4)
//*T04F001 DD DSN=J9067.JENGIX.DATA,DISP=SHR,LABEL=(,,,IN)   (J-3)
//*------------ FT90 : CHECK WRITE -----------------------------------
//FT90F001 DD DUMMY
//*T90F001 DD SYSOUT=*,          ( CHECK WRITE )
//*  DCB=(RECFM=FB,LRECL=137,BLKSIZE=1370)
//*------------ FT30 : OUTPUT OF PLOT DATA ---------------------------
//FT30F001 DD DSN=J3803.PLTANISN.DATA(SAMPLE),DISP=OLD
//SYSIN DD DSN=J3803.FNS.DATA(L120C),DISP=SHR,LABEL=(,,,IN)
++
//
```

Fig. 4.1 Job control statements

5. Sample Input and Output

The sample ANISN-DD input data and output are shown in Figs. 5.1 and 5.2, respectively. This problem calculates neutron flux distribution in a Li_2O-C sphere surrounded by a stainless steel zone, for which the schematic diagram is shown in Fig.5.3. This configuration is similar to the Li_2O-C sphere integral experiment conducted at the FNS facility[10]. The cross sections of the thermal group (125th group) are input by cards. In addition to the flux calculation, the collapsing of macroscopic cross sections for each zone is performed. The specification of this problem is as follows:

(1) Geometry : sphere

(2) Dimensions : outer radius of each zone is as follows:

Source : r=0.5 cm

Void : r=3.33 cm

Li_2O: r=22.4 cm

Graphite : r=46.77 cm

SUS316 lattice : r=71.77 cm

(3) Material composition : shown in Table 5.1

(4) Source :

Isotropic volume source is located at the center of the vacuum cavity. Source intensity is normalized to a unity.

(5) Spatial mesh specification :

Source : 1 interval

Void : 3 intervals

Li_2O : 19 intervals

Graphite : 24 intervals

SUS lattice : 5 intervals

The intervals are equally spaced in each zone.

(6) Boundary condition :

Reflective boundary condition at the center, and vacuum boundary condition at the outer boundary of the SUS316 lattice zone.

(7) Angular quadrature : S_{16}

(8) Collapsing of DDX :

Macroscopic cross sections of 9 groups and 4 angle bins for 5 zones :

Energy group			Angle bin	
Collapsed	Original	:	Collapsed	Original
1	1 - 10	:	1	1 - 5
2	11 - 20	:	2	6 - 10
3	21 - 32	:	3	11 - 15
4	33 - 64	:	4	16 - 20
5	65 - 82	:		
6	83 - 98	:		
7	99 - 107	:		
8	108 - 124	:		
9	125	:		

Figure 5.4 shows input data for the calculation by using the collapsed cross sections with ANISN-DD. In this case, cross section mixing is not necessary. Therefore, the paramerter IANISN is set to 3. MTP can be 0. In this sample input, however, MTP is set to be 20, and dummy data for 13$, 10$, 11$ and 12* arrays are input in the appropriate location.

Table 5.1 Matrial composition for sample problem[a]

Isotope	Void	Li_2O	Graphite	SUS lattice
Li-6	0.	3.355-3	0.	0.
Li-7	0.	4.186-2	0.	0.
O-16	0.	2.261-2	0.	0.
C	0.	0.	6.930-2	0.
Cr	1.751-3[b]	1.935-3	1.751-3	1.161-3
Mn	8.185-5	9.632-5	8.185-5	5.632-5
Fe	6.349-3	7.030-3	6.349-3	4.159-3
Ni	7.303-4	8.106-4	7.303-4	4.821-4

(a) Units in 10^{24} atoms/cm^3

(b) Read as 1.751×10^{-3}

```
LIST
    4    0    0    0                                                  / A
    0    2    1 -125  125    0    0    0    0    0    1    0   20    / B
  126
 1.6487E+7
 1.62310E+07 1.59800E+07 1.57320E+07 1.54880E+07 1.52480E+07 1.50120E+07
 1.47790E+07 1.45500E+07 1.43240E+07 1.41020E+07 1.38830E+07 1.36680E+07
 1.34560E+07 1.32480E+07 1.30420E+07 1.28400E+07 1.26410E+07 1.24450E+07
 1.22520E+07 1.20620E+07 1.18750E+07 1.16910E+07 1.15100E+07 1.13310E+07
 1.11560E+07 1.09830E+07 1.08120E+07 1.06450E+07 1.04800E+07 1.03170E+07
 1.01570E+07 9.99990E+06 9.39400E+06 8.82490E+06 8.29020E+06 7.78790E+06
 7.31610E+06 6.87280E+06 6.45640E+06 6.06520E+06 5.69780E+06 5.35250E+06
 5.02820E+06 4.72360E+06 4.43740E+06 4.16860E+06 3.91600E+06 3.67870E+06
 3.45590E+06 3.24650E+06 3.04980E+06 2.86500E+06 2.69140E+06 2.52840E+06
 2.37520E+06 2.23130E+06 2.09610E+06 1.96910E+06 1.84980E+06 1.73770E+06
 1.53350E+06 1.35330E+06 1.19430E+06 1.05400E+06 9.30130E+05 8.20840E+05
 7.24380E+05 6.39270E+05 5.64150E+05 4.97860E+05 4.39360E+05 3.87740E+05
 3.42170E+05 3.01970E+05 2.66490E+05 2.35170E+05 2.07540E+05 1.83150E+05
 1.61630E+05 1.42640E+05 1.25880E+05 1.11090E+05 9.80350E+04 8.65150E+04
 7.63490E+04 6.73780E+04 5.94610E+04 5.24740E+04 4.63080E+04 4.08670E+04
 3.60650E+04 3.18270E+04 2.80870E+04 2.47870E+04 2.18740E+04 1.93040E+04
 1.50340E+04 1.17090E+04 9.11860E+03 7.10160E+03 5.53070E+03 4.30730E+03
 3.35460E+03 2.61250E+03 2.03460E+03 1.58460E+03 1.23410E+03 9.61100E+02
 5.82930E+02 3.53570E+02 2.14450E+02 1.30070E+02 7.88910E+01 4.78500E+01
 2.90230E+01 1.76030E+01 1.06770E+01 6.47580E+00 3.92780E+00 2.38230E+00
 1.44490E+00 8.76400E-01 5.31560E-01 3.22410E-01 1.0001E-05 // C,D
    3
    2   12   22                                                      / E,F
  1.0  0.9  0.8  0.7  0.6  0.5  0.4  0.3  0.2  0.1  0.0
 -0.1 -0.2 -0.3 -0.4 -0.5 -0.6 -0.7 -0.8 -0.9 -1.0     / MU
  306  0.73493  0.0  940.368   0.0  941.103
  307  0.97000  0.0    0.0454  0.0    1.0154
  612  4.746    0.0    0.00353 0.0    4.74954
  816  3.7496   0.0    0.00019 0.0    3.74979
 2800  7.77     0.0    2.91    0.0   10.68
 2400  3.14     0.0    1.54    0.0    4.68
 2600  11.35    0.0    2.56    0.0   13.91
 1197  2.54     0.0    0.36    0.0    2.90
-1000  /
 L12O-C SPHERE BY ANISN-DD WITH DDXLIB3
15¥¥
        1    0   20   16    3         1    0    5   52    0
      125    3    4    0    1         0   20    4    0    0
        1    0    0   40    1         0    0    0   10    0
        0    1    0    1    1         0
16**
      0.0          0.0        1.0E-4     1.420892          0.0          0.0
      0.0          1.0          0.0          0.5          1.0E-3       0.0
      0.0          0.0   T
13¥¥
      F  71 T
17**
    0.002418   51R 0.0   0.002418   51R 0.0   0.002418   51R 0.0
    0.002418   51R 0.0   0.1529     51R 0.0   0.1529     51R 0.0
    0.1529     51R 0.0   0.1529     51R 0.0   0.03132    51R 0.0
    0.03132    51R 0.0   0.03132    51R 0.0   0.03132    51R 0.0
    0.002757   51R 0.0   0.002757   51R 0.0   0.002757   51R 0.0
    0.002757   51R 0.0   0.001036   51R 0.0   0.001036   51R 0.0
    0.001036   51R 0.0   0.001036   51R 0.0   0.0005003  51R 0.0
```

Fig. 5.1 Sample input for ANISN-DD

```
    0.0005003  51R 0.0   0.0005003  51R 0.0   0.0005003  51R 0.0
    0.0005232  51R 0.0   0.0005232  51R 0.0   0.0005232  51R 0.0
    0.0005232  51R 0.0   0.0005821  51R 0.0   0.0005821  51R 0.0
    0.0005821  51R 0.0   0.0005821  51R 0.0
    0.002342   51R 0.0   0.0022147  51R 0.0   0.0020554  51R 0.0
    0.0022167  51R 0.0   0.0024684  51R 0.0   0.0023964  51R 0.0
    0.0022866  51R 0.0   0.0024911  51R 0.0   0.0027163  51R 0.0
    0.0026936  51R 0.0   0.0027146  51R 0.0   0.0031332  51R 0.0
    0.0035989  51R 0.0   0.0039861  51R 0.0   0.0043055  51R 0.0
    0.0041489  51R 0.0   0.0038996  51R 0.0   0.0036911  51R 0.0
    0.0038804  51R 0.0   0.0041880  51R 0.0   0.0044818  51R 0.0
    0.0047559  51R 0.0   0.0050145  51R 0.0   0.0052236  51R 0.0
    0.0052974  51R 0.0   0.0053324  51R 0.0   0.0053453  51R 0.0
    0.0053388  51R 0.0   0.0105750  51R 0.0   0.010327   51R 0.0
    0.010109   51R 0.0   0.010002   51R 0.0   0.0097711  51R 0.0
    0.0094292  51R 0.0   0.0090041  51R 0.0   0.0084924  51R 0.0
    0.0074342  51R 0.0   0.0063462  51R 0.0   0.0054361  51R 0.0
    0.0046736  51R 0.0   0.0040301  51R 0.0   0.0034850  51R 0.0
    0.0030203  51R 0.0   0.0026234  51R 0.0   0.0022112  51R 0.0
    0.0018020  51R 0.0   0.0014839  51R 0.0   0.0012306  51R 0.0
    0.0010286  51R 0.0   0.00086510 51R 0.0   0.00073188 51R 0.0
    0.00062217 51R 0.0   0.00053121 51R 0.0   0.00045531 51R 0.0
    0.00039235 51R 0.0   0.00035985 51R 0.0   0.00033794 51R 0.0
    0.00031509 51R 0.0   0.00029183 51R 0.0   0.00026880 51R 0.0
    0.00024626 51R 0.0   0.00022477 51R 0.0   0.00020420 51R 0.0
    0.00018502 51R 0.0   0.00031740 51R 0.0   0.00025619 51R 0.0
    0.00020524 51R 0.0   0.00016333 51R 0.0   0.00012938 51R 0.0
    0.000016526
       F   0.0  T
3**
       F   1.0  T
1**
       F   1.0
4**
    0.0  21 0.5  18I 3.33  23I 22.4  4I 46.77 71.77
5**   F   1.0
6**
    0.0          0.0244936  0.0413296  0.0392569  0.0400796  0.0643754
    0.0442097  0.1090850  0.1371702  0.1371702  0.1090850  0.0442097
    0.0643754  0.0400796  0.0392569  0.0413296  0.0244936
7**
    -1.0         -0.9805009 -0.9092855 -0.8319966 -0.7467506 -0.6504264
    -0.5370966 -0.3922893 -0.1389568 0.1389568  0.3922893  0.5370966
    0.6504264  0.7467506  0.8319966  0.9092855  0.9805009
8¥¥       1   3R    2  19R    3   24R    4   5R    5
9¥¥       4    4    1    2    3
10¥¥
          7    5    4    4
11¥¥
           306   307   816  2600  2800  2400  1197
          2600  2800  2400  1197   612
          2600  2800  2400  1197
          2600  2800  2400  1197
12**
    3.3550-3  4.1860-2  2.2610-2  7.0300-3  8.1060-4  1.9350-3 9.6320-5
    6.3490-3  7.3030-4  1.7510-3  8.1850-5  6.9300-2
    4.1590-3  4.8210-4  1.1610-3  5.6320-5
    6.3490-3  7.3030-4  1.7510-3  8.1850-5
19¥¥  5R 1  5R 2  5R 3  5R 4
27¥¥  2  0  0  0  1
28¥¥  10R 1  10R 2  12R 3  32R 4  18R 5  16R 6  9R 7  17R 8  9
   T
STOP
```

Fig. 5.1 (Continued)

```
   *** ANISN-DD ADDITIONAL OPTION ***

   IANISN =      4 ( DDX. MIX & FLUX  )

   ITMAX    MAXIMUM EXECUTION TIME (MIN)              0
   IENRGY   0/1=READ 17* 18*  NORMAL/BY E GRP.        0
   IINPT    0/1=READ SOURCE FROM CARD/FILE(25)        0

   IIBOUD   0/1=PRINT TOTAL FLUX AT MID./BOUND.       0
   IISPTM   0/1=PRINT SPECTRUM NO/YES                 2
              2=PER UNIT LETHARGY
   IIANLL   0/1=PRINT ANGULAR FLUX ALL/INPUT          1
            2/3=ANG. FLUX TO DISK/DDX. MID POINT
   IGMNEW   NO. OF TOTAL   ENERGY GROUP            -125
   IGMNEU   NO. OF NEUTRON ENERGY GROUP              125
   NACTPR   0/1=PRINT ACTIVITY NORMAL/DETAIL          0
   NREACT   0/1=CALCULATE REACTION RATE NO/YES        0
   NASYMM   0/1=USE ASYMMETRIC SN SET NO/YES          0
   NRESAT   0/1=USE RESTART OPTION NO/YES             0
   NXSOUT   0/1=CALCULATE 2-D X-SEC. NO/YES           0
              1= OUTPUT DDX-TYPE X-SEC.
   NPLOT    0/1=OUTPUT PLOT DATA NO/YES               1
   NAOUT    O/N=OUTPUT ANGULAR FLUX NO/INT. N         0
   LENGPL   PL ORDER IN PL-TYPE LIBRARY OR           20
            NUMBER OF ANGULAR INTERVALS IN DDX

    PRINT ANGULAR FLUX AT FOLLOWING INTERVALS

        2   12   22

    COSINES OF DDX-LIBRARY

      0.1000E+01  0.9000E+00  0.8000E+00  0.7000E+00  0.6000E+00  0.5000E+00  0.4000E+00  0.3000E+00  0.2000E+00  0.1000E+00

      0.0        -0.1000E+00 -0.2000E+00 -0.3000E+00 -0.4000E+00 -0.5000E+00 -0.6000E+00 -0.7000E+00 -0.8000E+00 -0.9000E+00

     -0.1000E+01

<< X-SEC & SCATTREING MATRIX FOR LAST GROUP WILL BE CREATED >>

 --- ADDED DATA FOR LAST GROUP ---

 CODE #    PRODUCTION  FISSION     CAPTURE      NU*FIS      TOTAL

   306     7.3493E-01  0.0         9.4037E+02   0.0         9.4110E+02
   307     9.7000E-01  0.0         4.5400E-02   0.0         1.0154E+00
   612     4.7460E+00  0.0         3.5300E-03   0.0         4.7495E+00
   816     3.7496E+00  0.0         1.9000E-04   0.0         3.7498E+00
  2800     7.7700E+00  0.0         2.9100E+00   0.0         1.0680E+01
  2400     3.1400E+00  0.0         1.5400E+00   0.0         4.6800E+00
  2600     1.1350E+01  0.0         2.5600E+00   0.0         1.3910E+01
  1197     2.5400E+00  0.0         3.6000E-01   0.0         2.9000E+00
```

Fig. 5.2 Sample output of ANISN-DD

```
   LI2O-C SPHERE BY ANISN-DD WITH DDXLIB3

    15¥ ARRAY      36 ENTRIES READ

    16* ARRAY      14 ENTRIES READ

      T

 <<< READ 13¥,10¥,11¥ AND 12* ONLY FOR DDX MIXING >>>

    13¥ ARRAY      20 ENTRIES READ

      T

      T

      T

    10¥ ARRAY       4 ENTRIES READ

    11¥ ARRAY      20 ENTRIES READ

    12* ARRAY      20 ENTRIES READ

      T

    15¥ ARRAY      36 ENTRIES READ

    16* ARRAY      14 ENTRIES READ

      T
```

```
   LI2O-C SPHERE BY ANISN-DD WITH DDXLIB3            ( MIXING & REORDERING FOR FORWARD SOLUTION )

<< MATERIAL NO.  1 >>

      ** COMPONENT  7 **      B41197TA
MAXI   125 : IDUM1   125 : IDUM2      0 : NUCLIDE CODE  1197

         << SLOW DOWN NUMBER FOR EACH GROUP  >>

      125  124  123  122  121  120  119  118  117  116  115  114  113  112  111  110  109  108  107  106
      105  104  103  102  101  100   99   98   97   96   95   94   93   92   91   90   89   88   87   86
       85   84   83   82   81   80   79   78   77   76   75   74   73   72   71   70   69   34   59   21
       63   32   55   27   50    3    4    4    4    5    5    5    6    7    7    9   10   12   15   19
       41    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2
        2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2
        2    2    2    2    1
```

Fig. 5.2 (Continued)

```
      ** COMPONENT  5 **      B42800TA
MAXI   125 : IDUM1   125 : IDUM2     0 : NUCLIDE CODE  2800

         << SLOW DOWN NUMBER FOR EACH GROUP  >>

      125  124  123  122  121  120  119  118  117  116  115  114  113  112  111  110  109  108  107  106
      105  104  103  102  101  100   99   98   97   96   95   94   93   92   91   90   89   88   87   86
       85   84   83   82   81   80   79   72   73   62   65   74   58   59   57   57   54   56   16   18
       30   51   45   51   47   47   23   47    8    9   11   13   17   25   40    5    5    6    7    7
        8   10   12   14   17   33    2    2    2    2    2    2    2    2    2    2    2    2    2    2
        2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2    2
        2    2    2    2    1

     **** INFORMATIONS FOR MIXING ****

         NUMBER OF NUCLIDES (NMAT)          :     7
         NUMBER OF GROUP    (MAXI)          :   125
         NUMBER OF ANGULAR INTERVAL (MAXMU) :    20

      << MAXIMUM OF SLOWDOWN NUMBER FOR EACH GROUP >>

           125        124        123        122        121        120        119        118        117        116
           115        114        113        112        111        110        109        108        107        106
           105        104        103        102        101        100         99         98         97         96
            95         94         93         92         91         90         89         88         87         86
            85         84         83         82         81         80         79         78         77         76
            75         74         73         72         71         70         69         68         67         66
            65         55         57         51         50         50         52         47         49         48
            18         27         45         25         40          9         11         14         18         25
            41         10         12         14         17         33          7          7          7          7
             7          6          6          6          7          8         15         20          4          4
             4          4          4          4          4          4          3          3          3          3
             3          3          3          3          3          3          3          3          3          3
             3          3          3          2          1

      << SELECTED NUCLIDES >>

           306        307        816       2600       2800       2400       1197

+++ CPU TIME FOR SEARCH    0.44300E+00 SEC +++
 *** RECORD LENGTH OF DIRECT ACCESS FILE (50) IS SET TO 2500  WORDS


     **** NUMBER DESITY OF NUCLIDES ****

     DDX FILE # | NUCLIDE CODE #  | NUMBER DENSITY
     -----------|-----------------+---------------
         71     |         306     |   3.35499E-03
         71     |         307     |   4.18599E-02
         71     |         816     |   2.26099E-02
         71     |        2600     |   7.02997E-03
         71     |        2800     |   8.10597E-04
         71     |        2400     |   1.93499E-03
         71     |        1197     |   9.63195E-05
```

Fig. 5.2 (Continued)

```
          **** MIXED CROSS SECTIONS ****

 GROUP #          1           2           3           4           5           6           7           8           9          10
-------------------------------------------------------------------------------------------------------------------------------
ABSORPTION   4.35144E-03 4.70123E-03 5.24749E-03 5.59245E-03 5.56651E-03 5.49150E-03 5.70403E-03 5.96025E-03 6.20612E-03 6.39040E-03
NU*FISSION   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
TOTAL        1.20644E-01 1.20699E-01 1.22359E-01 1.23384E-01 1.23611E-01 1.26555E-01 1.27870E-01 1.27500E-01 1.27063E-01 1.27052E-01

 GROUP #         11          12          13          14          15          16          17          18          19          20
-------------------------------------------------------------------------------------------------------------------------------
ABSORPTION   6.55594E-03 6.65025E-03 6.69560E-03 6.61588E-03 6.45407E-03 6.27697E-03 6.13039E-03 6.03892E-03 6.05954E-03 6.34228E-03
NU*FISSION   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
TOTAL        1.27745E-01 1.29164E-01 1.29014E-01 1.29237E-01 1.29862E-01 1.31827E-01 1.31335E-01 1.31478E-01 1.31663E-01 1.32184E-01

 GROUP #         21          22          23          24          25          26          27          28          29          30
-------------------------------------------------------------------------------------------------------------------------------
ABSORPTION   6.98210E-03 7.49445E-03 7.06306E-03 6.53792E-03 6.26752E-03 5.96611E-03 6.02198E-03 6.46859E-03 7.10635E-03 7.73213E-03
NU*FISSION   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
TOTAL        1.35913E-01 1.37900E-01 1.38997E-01 1.37973E-01 1.39035E-01 1.38530E-01 1.33789E-01 1.31374E-01 1.32767E-01 1.35184E-01

 GROUP #         31          32          33          34          35          36          37          38          39          40
-------------------------------------------------------------------------------------------------------------------------------
ABSORPTION   8.21634E-03 8.11929E-03 6.35992E-03 6.07945E-03 4.75730E-03 3.36760E-03 3.13190E-03 3.81558E-03 3.61986E-03 2.60526E-03
NU*FISSION   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
TOTAL        1.37753E-01 1.37612E-01 1.36795E-01 1.38001E-01 1.42656E-01 1.43666E-01 1.47754E-01 1.48942E-01 1.49873E-01 1.53552E-01

 GROUP #         41          42          43          44          45          46          47          48          49          50
-------------------------------------------------------------------------------------------------------------------------------



 GROUP #        101         102         103         104         105         106         107         108         109         110
-------------------------------------------------------------------------------------------------------------------------------
ABSORPTION   2.74088E-04 1.83387E-04 1.65871E-04 1.06762E-04 1.74252E-04 8.43402E-04 1.19792E-04 4.54595E-03 1.37862E-04 3.34143E-04
NU*FISSION   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
TOTAL        1.22642E-01 9.79345E-02 1.03899E-01 7.95013E-02 1.00847E-01 7.25490E-02 6.97788E-02 8.71996E-02 7.85356E-02 9.34449E-02

 GROUP #        111         112         113         114         115         116         117         118         119         120
-------------------------------------------------------------------------------------------------------------------------------
ABSORPTION   1.31772E-03 3.72471E-04 4.67882E-04 5.75727E-04 7.12327E-04 9.07225E-04 1.12151E-03 1.46285E-03 1.84957E-03 2.33539E-03
NU*FISSION   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
TOTAL        1.34089E-01 9.26031E-02 9.46286E-02 9.59765E-02 9.70410E-02 9.78011E-02 9.83567E-02 9.89047E-02 9.94541E-02 1.00060E-01

 GROUP #        121         122         123         124         125         126         127         128         129         130
-------------------------------------------------------------------------------------------------------------------------------
ABSORPTION   3.04115E-03 3.99793E-03 4.90548E-03 6.22116E-03 2.11045E-02
NU*FISSION   0.0         0.0         0.0         0.0         0.0
TOTAL        1.00803E-01 1.01801E-01 1.02865E-01 1.04276E-01 1.04546E-01

      **** MATRIX DATA FOR GROUP   1 TO GROUP 125 WERE MIXED AND STORED ON UNIT 50, USED CORE SIZE =   140529 ****

 +++ CPU TIME FOR MIXING    0.14210E+01 SEC +++

 *** CONVERT DATA FROM GROUP    1 TO   58 TO GROUP INDEPENDENT FORM ****

 *** CONVERT DATA FROM GROUP   59 TO  116 TO GROUP INDEPENDENT FORM ****

 *** CONVERT DATA FROM GROUP  117 TO  125 TO GROUP INDEPENDENT FORM ****
```

Fig. 5.2 (Continued)

```
*** CROSS SECTIONS SUCCESSFULLY CONVERTED TO GROUP INDEPENDENT FORM ***

 TYPE                                        :  FORWARD

 UNIT NUMBER OF CREATED CROSS SECTION FILE   :       24

 GROUP NUMBER OF CREATED CROSS SECTION FILE  :      125

 RECORD LENGTH FOR ONE GROUP ( IHM )         :     2503 WORDS

 MIXTURE NUMBER INVOLVED                     :        4
```

ID	PROBLEM ID NO.	1	ITH	0/1 = REG./ADJ.	0
ISCT	ORDER OF SCATTERING	20	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	IZM	NO. OF ZONES	5
IM	NO. OF INTERVALS	52	IEVT	0/1/2/3/4/5/6=Q/K/ALPHA/C/Z/R/H	0
IGM	NO. OF GROUPS	125	IHT	POS. OF SIGMA T	3
IHS	POS. OF SIGMA GG	4	IHM	TABLE LENGTH	2503
MS	MIXING TABLE LENGTH	1	MCR	NO. MATLS. FROM CARDS	0
MTP	NO. MATLS. FROM LIB TAPE	20	MT	NO. OF MATLS.	4
IDFM	0/1=NONE/DENSITY FACTORS(21*)	0	IPVT	0/1/2=NONE/K/ALPHA	0
IQM	0/1=NONE/DIST. SOURCE	1	IPM	0/1/IM=NONE/S(MM,IPP)/S(MM,IM)	0
IPP	INTERVAL OF SHELL SOURCE	0	IIM	INNER ITER. MAX.	40
ID1	0/1/2/3=NO/PRNT ND/PNCH N/BOTH	0	ID2	0/1/2=NO/X-SEC TAPE/PREV	0
ID3	0/N=NO/N ACT. BY ZONE	0	ID4	0/1=NO/N ACT. BY INT.	0
ICM	OUTER ITER. MAX.	10	IDAT1	0/1/2=NO/MIN/MAX TAPE	0
IDAT2	0/1=NO/DIFFUSION(24X)	0	IFG	0/1=NO/FEW GRP.	1
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	0.0	EVM	EIGENVALUE MODIFIER	0.0
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	1.00000E+00
PV	IPVT=1/2 - K/ALPHA	0.0	RYF	LAMBDA2 RELAXATION	5.00000E-01
XLAL	PT CNVRG EPS. IF .NE.0	9.99998E-04	XLAH	1-LAMBDA MAX.-SEARCH	0.0
EQL	EV CHANGE EPS.-SEARCH	0.0	XNPM	NEW PARAM. MOD.-SEARCH	0.0

```
 1544391 LOCATIONS REQUIRED WHEN IDAT1 IS 0

  296455 LOCATIONS WILL BE USED FOR THIS PROBLEM ( IDAT1 = 1, LIM1 =   600000 )

   10272 LOCATIONS WILL BE USED TO READ CROSS SECTIONS

4 X-SEC. SETS READ FROM GRP. INDEPENDENT TAPE

 13* ARRAY     20 ENTRIES READ                Dummy read
   T

 17* ARRAY   6500 ENTRIES READ
   T

  3* ARRAY   6500 ENTRIES READ
   T
```

Fig. 5.2 (Continued)

```
   1* ARRAY    125 ENTRIES READ
   4* ARRAY     53 ENTRIES READ
   5* ARRAY    125 ENTRIES READ
   6* ARRAY     17 ENTRIES READ
   7* ARRAY     17 ENTRIES READ
   8¥ ARRAY     52 ENTRIES READ
   9¥ ARRAY      5 ENTRIES READ
  10¥ ARRAY      4 ENTRIES READ
  11¥ ARRAY     20 ENTRIES READ
  12* ARRAY     20 ENTRIES READ
  19¥ ARRAY     20 ENTRIES READ
  27¥ ARRAY      5 ENTRIES READ
  28¥ ARRAY    125 ENTRIES READ
    T
<<      25977 LOCATIONS WILL BE USED FOR X-SEC WEIGHTING >>
 *** IN CALCULATION OF ANGULAR TRANSPORT FUNCTION, ANGLE MESH IS DIVIDED INTO  12 FINE ANGLES ***
 +++++ CPU TIME FOR PPP1  9.9100E-01 SEC. +++++
 +++++ CPU TIME FOR PMMM  6.7962E+01 SEC. +++++
```

Dummy read

Fig. 5.2 (Continued)

LI2O-C SPHERE BY ANISN-DD WITH DDXLIB3

INT.	ZONE NUMBER	RADIUS	AREA	VOLUME	FISS DENS	DENS FACTOR
1	1	0	0	5.23598E-01	0	
2	2	5.00000E-01	3.14159E+00	1.20711E+01	0	
3	2	1.44333E+00	2.61783E+01	4.43512E+01	0	
4	2	2.38666E+00	7.15801E+01	9.77292E+01	0	
5	3	3.33000E+00	1.39347E+02	1.86250E+02	0	
6	3	4.33368E+00	2.36006E+02	2.95971E+02	0	
7	3	5.33736E+00	3.57984E+02	4.31103E+02	0	
8	3	6.34104E+00	5.05279E+02	5.91646E+02	0	
9	3	7.34473E+00	6.77893E+02	7.77603E+02	0	
10	3	8.34841E+00	8.75825E+02	9.88969E+02	0	
11	3	9.35209E+00	1.09907E+03	1.22574E+03	0	
12	3	1.03558E+01	1.34764E+03	1.48793E+03	0	
13	3	1.13595E+01	1.62153E+03	1.77554E+03	0	
14	3	1.23631E+01	1.92073E+03	2.08855E+03	0	
15	3	1.33668E+01	2.24526E+03	2.42697E+03	0	
16	3	1.43705E+01	2.59510E+03	2.79081E+03	0	
17	3	1.53742E+01	2.97026E+03	3.18001E+03	0	
18	3	1.63779E+01	3.37073E+03	3.59473E+03	0	
19	3	1.73815E+01	3.79653E+03	4.03473E+03	0	
20	3	1.83852E+01	4.24764E+03	4.50025E+03	0	
21	3	1.93889E+01	4.72407E+03	4.99110E+03	0	
22	3	2.03926E+01	5.22581E+03	5.50743E+03	0	
23	3	2.13963E+01	5.75288E+03	6.04941E+03	0	
24	4	2.24000E+01	6.30529E+03	6.69708E+03	0	
25	4	2.34154E+01	6.88989E+03	7.30385E+03	0	
26	4	2.44308E+01	7.50041E+03	7.93693E+03	0	
27	4	2.54462E+01	8.13685E+03	8.59641E+03	0	
28	4	2.64616E+01	8.79920E+03	9.28208E+03	0	
29	4	2.74771E+01	9.48746E+03	9.99406E+03	0	
30	4	2.84925E+01	1.02016E+04	1.07324E+04	0	
31	4	2.95079E+01	1.09417E+04	1.14972E+04	0	
32	4	3.05233E+01	1.17077E+04	1.22880E+04	0	
33	4	3.15387E+01	1.24996E+04	1.31053E+04	0	
34	4	3.25541E+01	1.33175E+04	1.39489E+04	0	
35	4	3.35695E+01	1.41612E+04	1.48191E+04	0	
36	4	3.45850E+01	1.50309E+04	1.57150E+04	0	

LI2O-C SPHERE BY ANISN-DD WITH DDXLIB3

	FISS SPEC	VELOCITY	RT ALBEDO	LFT ALBEDO	DIFF MARKER	MAT'L/ZONE	L OF P(L)	RADIUS MOD
1	1.00000E+00	1.00000E+00				4		0
2	1.00000E+00	1.00000E+00				4		0
3	1.00000E+00	1.00000E+00				1		0
4	1.00000E+00	1.00000E+00				2		0
5	1.00000E+00	1.00000E+00				3		0
6	1.00000E+00	1.00000E+00						
7	1.00000E+00	1.00000E+00						
8	1.00000E+00	1.00000E+00						
9	1.00000E+00	1.00000E+00						
10	1.00000E+00	1.00000E+00						
11	1.00000E+00	1.00000E+00						
12	1.00000E+00	1.00000E+00						
13	1.00000E+00	1.00000E+00						

Fig. 5.2 (Continued)

LI2O-C SPHERE BY ANISN-DD WITH DDXLIB3

ANGULAR TRANSPORT FUNCTION FOR S(16) SCATTERING

OUT 1

MU	IN 1	IN 2	IN 3	IN 4	IN 5	IN 6	IN 7	IN 8	IN 9	IN 10
1	2.05751E+01	1.99984E+01	1.16665E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	8.33729E+00	1.66702E+01	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	3.33169E+00	2.00176E+01	1.66661E+00	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	1.50131E+01	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	3.33237E+00	1.83529E+01	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	1.66665E+00	8.33795E+00	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00061E+01	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.66601E+00	5.00214E+00	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.33458E+00	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.66605E+00	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.66605E+00
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.33458E+00
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.00214E+00
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MU 15 THRU MU 20 SAME AS ABOVE

MU	IN 11	IN 12	IN 13	IN 14	IN 15	IN 16	IN 17
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MU 2 THRU MU 12 SAME AS ABOVE

13	1.66601E-00	0.0	0.0	0.0	0.0	0.0	0.0
14	1.00061E+01	0.0	0.0	0.0	0.0	0.0	0.0
15	8.33795E+00	1.66665E+00	0.0	0.0	0.0	0.0	0.0
16	0.0	1.83529E+01	3.33237E+00	0.0	0.0	0.0	0.0
17	0.0	0.0	1.50131E+01	0.0	0.0	0.0	0.0
18	0.0	0.0	1.66661E+00	2.00176E+01	3.33168E+00	0.0	0.0
19	0.0	0.0	0.0	0.0	1.66702E+01	8.33728E+00	0.0
20	0.0	0.0	0.0	0.0	0.0	1.16665E+01	1.99984E+01

OUT 2

MU	IN 1	IN 2	IN 3	IN 4	IN 5	IN 6	IN 7	IN 8	IN 9	IN 10
1	2.05751E+01	1.75302E+01	9.66973E+00	3.74632E+00	5.98816E-01	0.0	0.0	0.0	0.0	0.0
2	0.0	2.46922E+00	7.72845E+00	7.39124E+00	5.55165E+00	1.66429E+00	0.0	0.0	0.0	0.0
3	0.0	0.0	2.55428E+00	6.01513E+00	6.08948E-00	4.91715E+00	2.05448E+00	6.35140E-02	0.0	0.0
4	0.0	0.0	4.99894E-02	2.73588E+00	5.08252E+00	5.26183E+00	4.48596E+00	1.38354E+00	0.0	0.0
5	0.0	0.0	0.0	1.12521E-01	2.54630E+00	4.62756E+00	4.78513E-00	3.38811E+00	1.07137E-01	0.0
6	0.0	0.0	0.0	0.0	1.32590E-01	2.89366E+00	4.43388E+00	4.22252E+00	1.08418E+00	0.0
7	0.0	0.0	0.0	0.0	0.0	6.37145E-01	3.30740E+00	4.22761E+00	2.57873E-00	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	9.34258E-01	3.66584E+00	3.67636E+00	3.98075E-01
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.24827E+00	3.95995E+00	1.53397E+00
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.72710E-01	3.75554E+00	2.90666E+00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.02746E-02	2.90666E-00	3.75554E+00
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.53397E-00	3.95995E+00
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.98075E-01	3.67636E+00
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.57873E+00
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.08418E+00
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.07137E-01
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Fig. 5.2 (Continued)

LI2O-C SPHERE BY ANISN-DD WITH DDXLIB3

CROSS SECTION MIXING TABLE

	MIXTURE	COMPONENT	NO. DENSITY
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			

ANGULAR QUADRATURE CONSTANTS

	COSINE (MU)	WEIGHT	REFL DIRECT	WT. X COS.
	-1.00000E+00	0	17	0
	-9.80497E-01	2.44935E-02	17	-2.40158E-02
	-9.09282E-01	4.13294E-02	16	-3.75801E-02
	-8.31993E-01	3.92568E-02	15	-3.26614E-02
	-7.46748E-01	4.00794E-02	14	-2.99292E-02
	-6.50424E-01	6.43751E-02	13	-4.18711E-02
	-5.37095E-01	4.42095E-02	12	-2.37447E-02
	-3.92288E-01	1.09085E-01	11	-4.27925E-02
	-1.38956E-01	1.37170E-01	10	-1.90606E-02
	1.38956E-01	1.37170E-01	9	1.90606E-02
	3.92288E-01	1.09085E-01	8	4.27925E-02
	5.37095E-01	4.42095E-02	7	2.37447E-02
	6.50424E-01	6.43751E-02	6	4.18711E-02
	7.46748E-01	4.00794E-02	5	2.99292E-02
	8.31993E-01	3.92568E-02	4	3.26614E-02
	9.09282E-01	4.13294E-02	3	3.75801E-02
	9.80497E-01	2.44935E-02	2	2.40158E-02

ELAPSED TIME 1.75 MIN.

OUTER	INNER	NEUT BAL	UPSCATTER RATIO	EIGENVALUE	LAMBDA1	LAMBDA2
0	0	0.0	0.0	0.0	0.0	0.0
1	1172	9.9997222E-01	0.0	0.0	1.0000000E+00	0.0
2	1299	9.9997336E-01	0.0	0.0	1.0000000E+00	9.9999642E-01

GRP.	1	REQUIRED	1	ITERATIONS.	MFD OF	8.07626E-06	OCCURRED IN INT.	52
GRP.	2	REQUIRED	1	ITERATIONS.	MFD OF	3.45375E-06	OCCURRED IN INT.	52
GRP.	3	REQUIRED	1	ITERATIONS.	MFD OF	5.57761E-06	OCCURRED IN INT.	49
GRP.	4	REQUIRED	1	ITERATIONS.	MFD OF	2.74855E-06	OCCURRED IN INT.	52
GRP.	5	REQUIRED	1	ITERATIONS.	MFD OF	3.72316E-06	OCCURRED IN INT.	44
GRP.	6	REQUIRED	1	ITERATIONS.	MFD OF	1.34934E-06	OCCURRED IN INT.	48
GRP.	7	REQUIRED	1	ITERATIONS.	MFD OF	8.75337E-07	OCCURRED IN INT.	33
GRP.	8	REQUIRED	1	ITERATIONS.	MFD OF	2.13423E-06	OCCURRED IN INT.	46
GRP.	9	REQUIRED	1	ITERATIONS.	MFD OF	1.90712E-06	OCCURRED IN INT.	52
GRP.	10	REQUIRED	1	ITERATIONS.	MFD OF	1.60911E-06	OCCURRED IN INT.	38
GRP.	11	REQUIRED	3	ITERATIONS.	MFD OF	7.70256E-05	OCCURRED IN INT.	9

Fig. 5.2 (Continued)

LI2O-C SPHERE BY ANISN-DD WITH DDXLIB3

INT.	ZONE NUMBER	RADIUS	INT. MIDPOINT	AREA	VOLUME	FISSION DENS
1	1	0.0	2.50000E-01	0.0	5.23598E-01	0.0
2	2	5.00000E-01	9.71665E-01	3.14159E+00	1.20711E+01	0.0
3	2	1.44333E+00	1.91500E+00	2.61783E+01	4.43512E+01	0.0
4	2	2.38666E+00	2.85833E+00	7.15801E+01	9.77292E+01	0.0
5	3	3.33000E+00	3.83184E+00	1.39347E+02	1.86250E+02	0.0
6	3	4.33368E+00	4.83552E+00	2.36006E+02	2.95971E+02	0.0

LI2O-C SPHERE BY ANISN-DD WITH DDXLIB3

TOTAL FLUX

INT.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8	GRP. 9	GRP. 10
1	1.67627E-03	1.67681E-03	1.67708E-03	1.67726E-03	1.06006E-01	1.06047E-01	1.06066E-01	1.06077E-01	2.18012E-02	2.17766E-02
2	1.40940E-04	1.41093E-04	1.41175E-04	1.41235E-04	8.91495E-03	8.92630E-03	8.93213E-03	8.93589E-03	1.85319E-03	1.84756E-03
3	4.30863E-05	4.31795E-05	4.32278E-05	4.32633E-05	2.72610E-03	2.73302E-03	2.73643E-03	2.73863E-03	5.74378E-04	5.70537E-04
4	2.35335E-05	2.36058E-05	2.36432E-05	2.36704E-05	1.48935E-03	1.49472E-03	1.49737E-03	1.49905E-03	3.17077E-04	3.13884E-04
5	1.24573E-05	1.26185E-05	1.27110E-05	1.27854E-05	7.88214E-04	7.98572E-04	8.05894E-04	8.11060E-04	1.98464E-04	1.93157E-04
6	7.00029E-06	7.21943E-06	7.33315E-06	7.42295E-06	4.42348E-04	4.55564E-04	4.64952E-04	4.71457E-04	1.27920E-04	1.19879E-04
7	4.29900E-06	4.60569E-06	4.71692E-06	4.80457E-06	2.71321E-04	2.89869E-04	2.99111E-04	3.05521E-04	9.00318E-05	8.20018E-05

SPECTRUM (NEUTRONS / LETHARGY)

INT.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8	GRP. 9	GRP. 10
1	1.07118E-01	1.07592E-01	1.07228E-01	1.07304E-01	6.78795E+00	6.79872E+00	6.78074E+00	6.79286E+00	1.39265E+00	1.39417E+00
2	9.00644E-03	9.05314E-03	9.02632E-03	9.03559E-03	5.70854E-01	5.72269E-01	5.71027E-01	5.72229E-01	1.18382E-01	1.18284E-01
3	2.75333E-03	2.77059E-03	2.76387E-03	2.76780E-03	1.74561E-01	1.75215E-01	1.74939E-01	1.75374E-01	3.66911E-02	3.65268E-02
4	1.50386E-03	1.51465E-03	1.51168E-03	1.51433E-03	9.53682E-02	9.58274E-02	9.57262E-02	9.59952E-02	2.02548E-02	2.00954E-02
5	7.96054E-04	8.09660E-04	8.12704E-04	8.17956E-04	5.04720E-02	5.11968E-02	5.15204E-02	5.19380E-02	1.26778E-02	1.23662E-02
6	4.47338E-04	4.63231E-04	4.68862E-04	4.74888E-04	2.83250E-02	2.92064E-02	2.97242E-02	3.01908E-02	8.17152E-03	7.67485E-03
7	2.74718E-04	2.95522E-04	3.01587E-04	3.07375E-04	1.73736E-02	1.85836E-02	1.91220E-02	1.95647E-02	5.75121E-03	5.24990E-03
8	1.81925E-04	1.94128E-04	2.00779E-04	2.06725E-04	1.14926E-02	1.21738E-02	1.27742E-02	1.31772E-02	4.25515E-03	3.80775E-03
9	1.23066E-04	1.34431E-04	1.39483E-04	1.43833E-04	7.76484E-03	8.40878E-03	8.83124E-03	9.17653E-03	3.24999E-03	2.86542E-03
10	8.65114E-05	9.57182E-05	1.00099E-04	1.03961E-04	5.45751E-03	5.97097E-03	6.34100E-03	6.63823E-03	2.53972E-03	2.21703E-03
11	6.23723E-05	7.01052E-05	7.39247E-05	7.72544E-05	3.92540E-03	4.36125E-03	4.68296E-03	4.93649E-03	2.02061E-03	1.75084E-03
12	4.59559E-05	5.25131E-05	5.58101E-05	5.86860E-05	2.88877E-03	3.25800E-03	3.53452E-03	3.75234E-03	1.63049E-03	1.40602E-03

Fig. 5.2 (Continued)

```
  24  7.80985E-04
  25  7.38801E-04
  26  6.94241E-04
  27  6.51162E-04
  28  6.09091E-04
  29  5.68565E-04
  30  5.29500E-04
  31  4.91980E-04
  32  4.55982E-04
  33  4.21499E-04
  34  3.88498E-04
  35  3.56945E-04
  36  3.26797E-04
  37  2.98003E-04
  38  2.70510E-04
  39  2.44262E-04
  40  2.19199E-04
  41  1.95260E-04
  42  1.72379E-04
  43  1.50481E-04
  44  1.29504E-04
  45  1.09274E-04
  46  8.98447E-05
  47  6.98898E-05
  48  5.06357E-05
  49  3.76168E-05
  50  2.84631E-05
  51  2.10566E-05
  52  1.45220E-05

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  4.61807E-03  4.61807E-03  4.61807E-03  4.61807E-03  2.92020E-01  2.92020E-01  2.92020E-01  2.92020E-01
   2  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      INT.    3 THRU INT.   52 SAME AS ABOVE

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  5.98173E-02  5.98173E-02  5.98173E-02  5.98173E-02  5.26552E-03  5.26552E-03  5.26552E-03  5.26552E-03
   2  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      INT.    3 THRU INT.   52 SAME AS ABOVE

DISTRIBUTED SOURCE - G=GROUP NO.    N= 16

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  1.97863E-03  1.97863E-03  1.97863E-03  1.97863E-03  9.55509E-04  9.55509E-04  9.55509E-04  9.55509E-04
   2  0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      INT.    3 THRU INT.   52 SAME AS ABOVE

DISTRIBUTED SOURCE - G=GROUP NO.    N= 24
```

Fig. 5.2 (Continued)

** ANGULAR FLUX AT INTERVAL BOUNDARY (NEUTRONS/SOLID ANGLE) **

FLUX BY ANGLE AND POINT FOR GROUP 1

PNT.	ANGL 1	ANGL 2	ANGL 3	ANGL 4	ANGL 5	ANGL 6	ANGL 7	ANGL 8
2	3.40846E-16	7.18732E-16	2.96919E-15	2.53985E-14	4.62132E-13	3.93123E-12	1.37955E-11	1.01620E-10
12	1.06489E-16	1.10247E-16	1.19383E-16	1.33823E-16	1.73126E-16	3.64915E-16	9.78443E-16	7.96744E-15
22	3.78721E-17	4.07976E-17	4.84534E-17	5.91478E-17	7.54818E-17	1.19986E-16	2.21576E-16	1.01280E-15

PNT.	ANGL 9	ANGL 10	ANGL 11	ANGL 12	ANGL 13	ANGL 14	ANGL 15	ANGL 16
2	8.05983E-10	6.64104E-05	1.77718E-04	2.37051E-04	2.66974E-04	2.87714E-04	2.92913E-04	2.85232E-04
12	1.24656E-13	5.22228E-12	9.37008E-11	2.91512E-10	1.07785E-09	6.01459E-09	2.03138E-08	1.48684E-07
22	1.25695E-14	2.10475E-13	3.39183E-12	1.41541E-11	7.78202E-11	3.45130E-10	1.68361E-09	1.00432E-08

PNT.	ANGL 17
2	2.63050E-04
12	2.38050E-06
22	2.15565E-07

FLUX BY ANGLE AND POINT FOR GROUP 2

PNT.	ANGL 1	ANGL 2	ANGL 3	ANGL 4	ANGL 5	ANGL 6	ANGL 7	ANGL 8
2	2.49863E-14	7.70119E-13	4.14929E-12	1.26637E-11	2.94585E-11	7.44406E-11	1.53919E-10	4.69586E-10
12	1.72172E-16	2.04503E-16	3.93293E-16	1.04271E-15	2.78513E-15	1.05541E-14	3.14899E-14	2.26145E-13
22	6.14077E-17	7.11351E-17	1.16324E-16	2.42256E-16	5.74731E-16	2.01761E-15	5.79591E-15	3.57732E-14

SUMMARY FOR ZONE 1 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 126

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	2.41801E-03	0.0	0.0	4.14709E-06	1.24550E-05	1.61304E-06	2.40393E-03	1.00000E+00
2	2.41801E-03	0.0	9.82469E-07	4.30027E-06	1.24052E-05	1.61785E-06	2.40496E-03	1.00000E+00
3	2.41801E-03	0.0	1.33013E-06	4.47607E-06	1.23381E-05	1.62434E-06	2.40537E-03	1.00000E+00
4	2.41801E-03	0.0	1.54480E-06	4.66756E-06	1.22654E-05	1.63215E-06	2.40565E-03	1.00000E+00
5	1.52901E-01	0.0	1.84362E-06	3.07829E-04	7.70802E-04	1.03590E-04	1.52028E-01	1.00000E+00
6	1.52901E-01	0.0	7.48591E-05	3.21639E-04	7.66924E-04	1.04025E-04	1.52104E-01	1.00000E+00
7	1.52901E-01	0.0	1.00314E-04	3.34342E-04	7.63002E-04	1.05104E-04	1.52132E-01	1.00000E+00
8	1.52901E-01	0.0	1.14030E-04	3.45392E-04	7.59274E-04	1.06932E-04	1.52148E-01	1.00000E+00
9	3.13202E-02	0.0	1.34249E-04	7.36175E-05	1.54989E-04	2.23495E-05	3.12770E-02	1.00000E+00
10	3.13202E-02	0.0	7.59385E-05	7.62391E-05	1.53837E-04	2.26890E-05	3.12195E-02	1.00000E+00
11	3.13202E-02	0.0	6.24418E-05	7.90434E-05	1.52992E-04	2.29782E-05	3.12065E-02	1.00000E+00
12	3.13202E-02	0.0	5.89688E-05	8.12298E-05	1.53257E-04	2.29567E-05	3.12028E-02	1.00000E+00
13	2.75701E-03	0.0	5.12208E-05	7.45934E-06	1.37856E-05	2.05388E-06	2.79238E-03	1.00000E+00
14	2.75701E-03	0.0	2.78698E-05	7.54075E-06	1.37393E-05	2.03160E-06	2.76910E-03	1.00000E+00
15	2.75701E-03	0.0	2.20757E-05	7.72609E-06	1.37308E-05	2.02230E-06	2.76332E-03	1.00000E+00

Fig. 5.2 (Continued)

```
<  LI2O-C SPHERE BY ANISN-OD WITH ODXLIB3          >

 ** CROSS SECTION WEIGHTING INFORMATIONS **

  ICON     2 : 0/1/2/3=NO WEIGHTING/MICRO/MACRO BY ZONE(-2 BY TOTAL REGION)/MACRO BY ARBITRARY CELL SPLITTING
  IHTF     0 : POSITION OF TOTAL CROSS SECTION
  IHSF     0 : HEAD POSITION OF SLOWING DOWM MATRIX
  IHMF    36 : TABLE LENGTH
  IPUN     1 : ANGLE COLLAPTION  0/1=NO/YES
  IGMF     9 : NO. OF FEW GROUP
  NXSOUT     0 : 0/1 = GROUP INDEPENDENT /ODXLIB TYPE

  FEW GROUP NUMBER FOR EACH FINE GROUP

    1    1    1    1    1    1    1    1    1    1    2    2    2    2    2    2    2    2    2    2
    3    3    3    3    3    3    3    3    3    3    3    3    4    4    4    4    4    4    4    4
    4    4    4    4    4    4    4    4    4    4    4    4    4    4    4    4    4    4    4    4
    4    4    4    4    5    5    5    5    5    5    5    5    5    5    5    5    5    5    5    5
    5    5    6    6    6    6    6    6    6    6    6    6    6    6    6    6    6    6    7    7
    7    7    7    7    7    7    7    8    8    8    8    8    8    8    8    8    8    8    8    8
    8    8    8    8    9

  COLLAPSED ANGLE NO. FOR EACH ANGLE

    1    1    1    1    1    2    2    2    2    2    3    3    3    3    3    4    4    4    4    4

  CELL NUMBER FOR EACH ZONE

     1     2     3     4     5

  *** INTEGRATED FLUX ( NEUTRONS ) ***

 GRP.    CELL  1       CELL  2       CELL  3       CELL  4       CELL  5
    1  2.48437E-01   1.68128E+00   6.90715E+00   1.64422E+00   4.73235E-01
    2  2.83785E-02   1.99021E-01   2.33189E+00   1.36543E+00   5.12229E-01
    3  2.41966E-03   2.77726E-02   7.44611E-01   6.94312E-01   2.28326E-01
    4  5.41062E-02   6.31533E-01   1.39137E+01   1.21161E+01   3.87587E+00
    5  3.15220E-02   4.73129E-01   1.88790E+01   2.03735E+01   4.75939E+00
    6  2.38236E-03   8.83603E-02   1.24023E+01   1.98399E+01   3.65608E+00
    7  2.66500E-04   2.32378E-02   5.63646E+00   1.75512E+01   4.33541E+00
    8  2.28690E-05   6.66511E-03   2.90240E+00   3.41678E+01   1.20431E+01
    9  1.02628E-14   2.19105E-12   3.06752E-03   3.40382E+00   9.46264E-01

  *** VOLUME ( CC ) ***

        CELL  1       CELL  2       CELL  3       CELL  4       CELL  5
    1  6.54490E+01   1.92682E+04   5.86448E+06   4.76673E+07   1.39996E+08

  *** AVERAGED FLUX ( NEUTRONS/VOLUME ) ***

 GRP.    CELL  1       CELL  2       CELL  3       CELL  4       CELL  5
    1  3.79589E-03   8.72564E-05   1.17779E-06   3.44936E-08   3.38034E-09
    2  4.33597E-04   1.03290E-05   3.97629E-07   2.86451E-08   3.65888E-09
    3  3.69701E-05   1.44137E-06   1.26970E-07   1.45658E-08   1.63094E-09
    4  8.26693E-04   3.27758E-05   2.37254E-06   2.54179E-07   2.76856E-08
    5  4.81627E-04   2.45548E-05   3.21922E-06   4.27410E-07   3.39965E-08
    6  3.64002E-05   4.58580E-06   2.11482E-06   4.16215E-07   2.61156E-08
    7  4.07187E-06   1.20602E-06   9.61118E-07   3.68203E-07   3.09681E-08
    8  3.49418E-07   3.45912E-07   4.94912E-07   7.16797E-07   8.60248E-08
    9  1.56805E-16   1.13713E-16   5.23067E-10   7.14079E-08   6.75922E-09

  *** BOUNDARY COSINES FOR COLLAPSED ANGLES ***
```

Fig. 5.2 (Continued)

```
  1.000000    0.500000    0.0         -0.500000   -1.000000
*** CONVERT DATA FROM GROUP     1 TO     9 TO GROUP INDEPENDENT FORM ****
***** CROSS SECTIONS COLLAPSED TO ANISN-TYPE *****
ELAPSED TIME     7.98 MIN.
```

Fig. 5.2 (Continued)

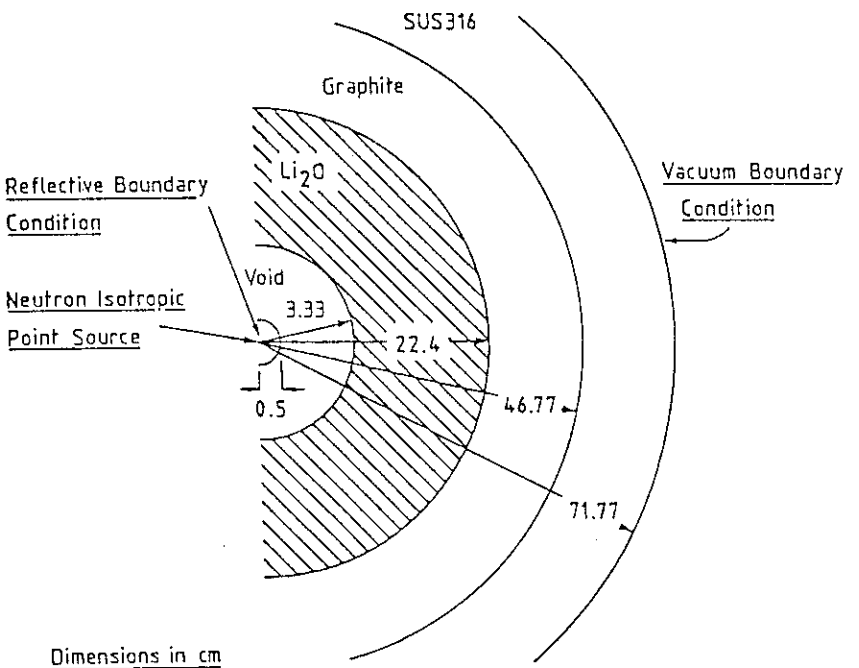

Fig. 5.3 Schematic diagram of the spherical model for ANISN-DD sample problem

```
LIST
    3    0    0    0                                                    / A
    0    2    1    9    9    0    0    0    0    0    1    0    4    / B
   10
 1.64870E+07 1.41020E+07 1.20620E+07 1.00000E+07 1.05400E+06 1.11090E+05
 1.17090E+04 1.23410E+03 3.22410E-01 1.0001E-05 // C,D
    3
    2   12   22                                              / E,F
  1.0  0.5  0.0  -0.5  -1.0  / MU
 LI2O-C SPHERE BY ANISN-DD WITH COLLAPSED DDX
15$$
         1    0    4   16    3         1    0    5   52    0
         9    3    4    0    1         0   20    5    0    0
         1    0    0   40    1         0    0    0   10    0
         0    0    0    1    1         0
16**
      0.0          0.0       1.0E-4    1.420892          0.0          0.0
      0.0          1.0         0.0         0.5         1.0E-3         0.0
      0.0          0.0    T
13$$                        } Dummy input
      F  71 T               }
17**
    0.68393    51R 0.0   0.077811   51R 0.0   0.0064221  51R 0.0
    0.14323    51R 0.0   0.082367   51R 0.0   0.0057403  51R 0.0
    0.0005145  51R 0.0
       F   0.0  T
 3**
       F   1.0  T
 1**
       F   1.0

 4**
    0.0  2I 0.5  18I 3.33  23I 22.4  4I 46.77 71.77
 5**   F   1.0
 6**
    0.0         0.0244936  0.0413296  0.0392569  0.0400796  0.0643754
    0.0442097   0.1090850  0.1371702  0.1371702  0.1090850  0.0442097
    0.0643754   0.0400796  0.0392569  0.0413296  0.0244936
 7**
    -1.0        -0.9805009 -0.9092855 -0.8319966 -0.7467506 -0.6504264
    -0.5370966 -0.3922893 -0.1389568 0.1389568  0.3922893  0.5370966
    0.6504264  0.7467506  0.8319966  0.9092855  0.9805009
 8$$        1   3R    2  19R    3   24R    4   5R    5
 9$$        1    2    3    4    5
10$$                                                          }
           7    5    4    4    0                             }
11$$                                                          } These cards can
            306   307   816  2600  2800  2400  1197          }
           2600  2800  2400  1197   612                      }   be omitted.
           2600  2800  2400  1197                            }
           2600  2800  2400  1197                            }
12**
    3.3550-3  4.1860-2  2.2610-2  7.0300-3  8.1060-4  1.9350-3 9.6320-5
    6.3490-3  7.3030-4  1.7510-3  8.1850-5  6.9300-2
    4.1590-3  4.8210-4  1.1610-3  5.6320-5
    6.3490-3  7.3030-4  1.7510-3  8.1850-5
   T
STOP
```

Fig. 5.4 Sample input for ANISN-DD
(calculation with collapsed cross sections)

6. Concluding Remarks

A one-dimensional Sn transport code ANISN-DD has been developed to be applicable to a fusion neutronic calculation by modifying the well-known code ANISN-JR. The present code can treat accurately the anisotropy of scattering by the usage of the multi-group double-differential form cross sections which can accurately take into account the energy-angle correlation of scattering process in a frame of the multi-group approximation. ANISN-DD has been used for parametric servey calculations and benchmark calculations to check a validity of cross section library, and the usefulness of the present code has been verified by these calculations[1].

Auxiliary codes REACT and PLTJOINT have been prepared in order to make a reaction rate calculation and plotting of calculated spectrum by using the output file of ANISN-DD, respectively. How to use these auxiliary codes is described elsewhere[2),5)].

References

1) Mori T., Nakagawa M., Ishiguro Y.:"PROF-DD: A Code System for Generation of Multi-group Double-differential Form Cross Section Library," JAERI-M 86-124 (1986).
2) Nakagawa M., Mori T.:"MORSE-DD: A Monte Carlo Code Using Multi-group Double-differential Form Cross Sections," JAERI-M 84-126 (1984).
3) Nakagawa M., Mori T., Ishiguro Y.:"Benchmark Test of MORSE-DD Code Using Multi-group Double-differential Form Cross Sections," JAERI-M 85-009 (1985).
4) Koyama K., et al.:"ANISN-JR: A One-Dimensional Discrete Ordinates Code for Neutron and Gamma-ray Transport Calculations," JAERI-M 6954 (1977).
5) Sasaki M., et al.: private communication(1986).
6) Drake M.K.(ed.):"Data Formats and Procedures for ENDF Neutron Cross Section Library", BNL 50274(T-601), ENDF 102, Vol.1, (1970).
7) Shibata K.: ^{6}Li in JAERI-M 84-198, ^{7}Li in JAER-M 84-204, ^{12}C in JAERI-M 84-221 (1984). Kikuchi Y.: unpublished for Fe, Cr and Ni.
8) Engle W.W. Jr.:"A User Manual for ANISN, A One Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering," K-1693 (1967).
9) Mori T., et al:"DOT-DD",to be published in JAERI-M report.
10) Maekawa H., et al.: J. Nucl. Sci. Technol., 16, 5 (1979).
11) Nakagawa M., Mori T., et al.:"U.S./JAERI Fusion Neutronics Calculational Benchmarks for Nuclear Data and Codes Intercomparison," JAERI-M 85-201 (1985).

Appendix 1. Group structure of 125 group double differential form cross section library

GROUP	ENERGY RANGE	LETHARGY RANGE	GROUP	ENERGY RANGE	LETHARGY RANGE
1	1.6231E+07 - 1.6487E+07	-0.500 - -0.484	64	1.0540E+06 - 1.1943E+06	2.125 - 2.250
2	1.5980E+07 - 1.6231E+07	-0.484 - -0.469	65	9.3013E+05 - 1.0540E+06	2.250 - 2.375
3	1.5732E+07 - 1.5980E+07	-0.469 - -0.453	66	8.2083E+05 - 9.3013E+05	2.375 - 2.500
4	1.5488E+07 - 1.5732E+07	-0.453 - -0.437	67	7.2438E+05 - 8.2083E+05	2.500 - 2.625
5	1.5248E+07 - 1.5488E+07	-0.437 - -0.422	68	6.3927E+05 - 7.2438E+05	2.625 - 2.750
6	1.5012E+07 - 1.5248E+07	-0.422 - -0.406	69	5.6415E+05 - 6.3927E+05	2.750 - 2.875
7	1.4779E+07 - 1.5012E+07	-0.406 - -0.391	70	4.9786E+05 - 5.6415E+05	2.875 - 3.000
8	1.4550E+07 - 1.4779E+07	-0.391 - -0.375	71	4.3936E+05 - 4.9786E+05	3.000 - 3.125
9	1.4324E+07 - 1.4550E+07	-0.375 - -0.359	72	3.8773E+05 - 4.3936E+05	3.125 - 3.250
10	1.4102E+07 - 1.4324E+07	-0.359 - -0.344	73	3.4217E+05 - 3.8773E+05	3.250 - 3.375
11	1.3883E+07 - 1.4102E+07	-0.344 - -0.328	74	3.0197E+05 - 3.4217E+05	3.375 - 3.500
12	1.3668E+07 - 1.3883E+07	-0.328 - -0.312	75	2.6649E+05 - 3.0197E+05	3.500 - 3.625
13	1.3456E+07 - 1.3668E+07	-0.312 - -0.297	76	2.3517E+05 - 2.6649E+05	3.625 - 3.750
14	1.3248E+07 - 1.3456E+07	-0.297 - -0.281	77	2.0754E+05 - 2.3517E+05	3.750 - 3.875
15	1.3042E+07 - 1.3248E+07	-0.281 - -0.266	78	1.8315E+05 - 2.0754E+05	3.875 - 4.000
16	1.2840E+07 - 1.3042E+07	-0.266 - -0.250	79	1.6163E+05 - 1.8315E+05	4.000 - 4.125
17	1.2641E+07 - 1.2840E+07	-0.250 - -0.234	80	1.4264E+05 - 1.6163E+05	4.125 - 4.250
18	1.2445E+07 - 1.2641E+07	-0.234 - -0.219	81	1.2588E+05 - 1.4264E+05	4.250 - 4.375
19	1.2252E+07 - 1.2445E+07	-0.219 - -0.203	82	1.1109E+05 - 1.2588E+05	4.375 - 4.500
20	1.2062E+07 - 1.2252E+07	-0.203 - -0.187	83	9.8035E+04 - 1.1109E+05	4.500 - 4.625
21	1.1875E+07 - 1.2062E+07	-0.187 - -0.172	84	8.6515E+04 - 9.8035E+04	4.625 - 4.750
22	1.1691E+07 - 1.1875E+07	-0.172 - -0.156	85	7.6349E+04 - 8.6515E+04	4.750 - 4.875
23	1.1510E+07 - 1.1691E+07	-0.156 - -0.141	86	6.7378E+04 - 7.6349E+04	4.875 - 5.000
24	1.1331E+07 - 1.1510E+07	-0.141 - -0.125	87	5.9461E+04 - 6.7378E+04	5.000 - 5.125
25	1.1156E+07 - 1.1331E+07	-0.125 - -0.109	88	5.2474E+04 - 5.9461E+04	5.125 - 5.250
26	1.0983E+07 - 1.1156E+07	-0.109 - -0.094	89	4.6308E+04 - 5.2474E+04	5.250 - 5.375
27	1.0812E+07 - 1.0983E+07	-0.094 - -0.078	90	4.0867E+04 - 4.6308E+04	5.375 - 5.500
28	1.0645E+07 - 1.0812E+07	-0.078 - -0.063	91	3.6065E+04 - 4.0867E+04	5.500 - 5.625
29	1.0480E+07 - 1.0645E+07	-0.063 - -0.047	92	3.1827E+04 - 3.6065E+04	5.625 - 5.750
30	1.0317E+07 - 1.0480E+07	-0.047 - -0.031	93	2.8087E+04 - 3.1827E+04	5.750 - 5.875
31	1.0157E+07 - 1.0317E+07	-0.031 - -0.016	94	2.4787E+04 - 2.8087E+04	5.875 - 6.000
32	9.9999E+06 - 1.0157E+07	-0.016 - 0.000	95	2.1874E+04 - 2.4787E+04	6.000 - 6.125
33	9.3940E+06 - 9.9999E+06	0.000 - 0.063	96	1.9304E+04 - 2.1874E+04	6.125 - 6.250
34	8.8249E+06 - 9.3940E+06	0.063 - 0.125	97	1.5034E+04 - 1.9304E+04	6.250 - 6.500
35	8.2902E+06 - 8.8249E+06	0.125 - 0.188	98	1.1709E+04 - 1.5034E+04	6.500 - 6.750
36	7.7879E+06 - 8.2902E+06	0.188 - 0.250	99	9.1186E+03 - 1.1709E+04	6.750 - 7.000
37	7.3161E+06 - 7.7879E+06	0.250 - 0.313	100	7.1016E+03 - 9.1186E+03	7.000 - 7.250
38	6.8728E+06 - 7.3161E+06	0.313 - 0.375	101	5.5307E+03 - 7.1016E+03	7.250 - 7.500
39	6.4564E+06 - 6.8728E+06	0.375 - 0.438	102	4.3073E+03 - 5.5307E+03	7.500 - 7.750
40	6.0652E+06 - 6.4564E+06	0.438 - 0.500	103	3.3546E+03 - 4.3073E+03	7.750 - 8.000
41	5.6977E+06 - 6.0652E+06	0.500 - 0.563	104	2.6125E+03 - 3.3546E+03	8.000 - 8.250
42	5.3525E+06 - 5.6977E+06	0.563 - 0.625	105	2.0346E+03 - 2.6125E+03	8.250 - 8.500
43	5.0282E+06 - 5.3525E+06	0.625 - 0.688	106	1.5846E+03 - 2.0346E+03	8.500 - 8.750
44	4.7236E+06 - 5.0282E+06	0.688 - 0.750	107	1.2341E+03 - 1.5846E+03	8.750 - 9.000
45	4.4374E+06 - 4.7236E+06	0.750 - 0.813	108	9.6109E+02 - 1.2341E+03	9.000 - 9.250
46	4.1686E+06 - 4.4374E+06	0.813 - 0.875	109	5.8293E+02 - 9.6109E+02	9.250 - 9.750
47	3.9160E+06 - 4.1686E+06	0.875 - 0.938	110	3.5357E+02 - 5.8293E+02	9.750 - 10.250
48	3.6787E+06 - 3.9160E+06	0.938 - 1.000	111	2.1445E+02 - 3.5357E+02	10.250 - 10.750
49	3.4559E+06 - 3.6787E+06	1.000 - 1.063	112	1.3007E+02 - 2.1445E+02	10.750 - 11.250
50	3.2465E+06 - 3.4559E+06	1.063 - 1.125	113	7.8891E+01 - 1.3007E+02	11.250 - 11.750
51	3.0498E+06 - 3.2465E+06	1.125 - 1.188	114	4.7850E+01 - 7.8891E+01	11.750 - 12.250
52	2.8650E+06 - 3.0498E+06	1.188 - 1.250	115	2.9023E+01 - 4.7850E+01	12.250 - 12.750
53	2.6914E+06 - 2.8650E+06	1.250 - 1.313	116	1.7603E+01 - 2.9023E+01	12.750 - 13.250
54	2.5284E+06 - 2.6914E+06	1.313 - 1.375	117	1.0677E+01 - 1.7603E+01	13.250 - 13.750
55	2.3752E+06 - 2.5284E+06	1.375 - 1.438	118	6.4758E+00 - 1.0677E+01	13.750 - 14.250
56	2.2313E+06 - 2.3752E+06	1.438 - 1.500	119	3.9278E+00 - 6.4758E+00	14.250 - 14.750
57	2.0961E+06 - 2.2313E+06	1.500 - 1.563	120	2.3823E+00 - 3.9278E+00	14.750 - 15.250
58	1.9691E+06 - 2.0961E+06	1.563 - 1.625	121	1.4449E+00 - 2.3823E+00	15.250 - 15.750
59	1.8498E+06 - 1.9691E+06	1.625 - 1.688	122	8.7640E-01 - 1.4449E+00	15.750 - 16.250
60	1.7377E+06 - 1.8498E+06	1.688 - 1.750	123	5.3157E-01 - 8.7640E-01	16.250 - 16.750
61	1.5335E+06 - 1.7377E+06	1.750 - 1.875	124	3.2241E-01 - 5.3157E-01	16.750 - 17.250
62	1.3533E+06 - 1.5335E+06	1.875 - 2.000	125	1.0010E-05 - 3.2241E-01	17.250 - 27.630
63	1.1943E+06 - 1.3533E+06	2.000 - 2.125			

Appendix 2. Identification number of nuclides prepared in 125-group DDL/B4 and /J3P1 library*

Element	ID number ENDF/B4	ID number JENDL-3PR1	Element	ID number ENDF/B4	ID number JENDL-3PR1
H	1269		Si	1194	
^{6}Li	1271	306	K	1150	
^{7}Li	1272	307	Ca	1195	
^{12}C	1274	612	Cr	1191	2400
^{9}Be	1289	409	Fe	1192	2600
^{14}N	1275		Ni	1190	2800
^{16}O	1276	816	^{55}Mn	1197	
^{23}Na	1156		Cu	1295	
Mg	1280		Mo	1287	
^{27}Al	1193		Pb	1288	

* This library is called as DDXLIB3 in Ref. 1).
weighting spectrum : Maxwellian < 0.32 eV
1/E > 0.32 eV.

Appendix 3. Angular Transfer Probability

Numerical integration of Eq.(42) over μ and μ' is carried out as follows:

$$\mu_{min}^{DDX}=\min_{k}\ \Delta\mu_k,$$

$$\mu_{max}^{Sn}=\max_{m}\ |\mu_m-\mu_{m-1}|.$$

Each interval $2\omega_m$ corresponding to a quadrature direction m is divided into n sub-intervals with a width Δ_m:

$$\Delta_m=\frac{2\omega_m}{n},$$

where

$$n=4\times\frac{\mu_{max}^{Sn}}{\mu_{min}^{DDX}}.$$

Then, the angular transfer probability is calculated by

$$P(k,m',m)=\frac{1}{\pi\Delta\mu_k\cdot n^2}\sum_{l=1}^{n}\sum_{l'=1}^{n}p\left(k,\mu_{m'-1/2}+\frac{2l'-1}{2}\Delta_{m'},\mu_{m-1/2}+\frac{2l-1}{2}\Delta_m\right),$$

for $|\mu_m|\neq 1$, $|\mu_{m'}|\neq 1$.

and

$$P(k,m',m)=\frac{1}{\pi\Delta\mu_k\cdot n}\sum_{l=1}^{n}p\left(k,\mu_{m'},\mu_{m-1/2}+\frac{2l-1}{2}\Delta_m\right),$$

for $|\mu_{m'}|=1$.

Similarly, $P(k,m',m)$ is calculated for $|\mu_m|=1$. In the above equation, $p(k,\mu',\mu)$ is defined by Eq.(31).

ANISN-DD normalizes P as follows:

$$\sum_m \omega_m P(k,m',m)=1 \qquad \text{for all } k \text{ and } m'. \tag{A1}$$

If $\sum_m \omega_m P(k,m',m)=0$ for some k, then, larger n is selected again, and ω_m is divided into finer sub-intervals. The procedure mentioned above is repeated until Eq.(A1) is satisfied.

As a result of the renormalization, the following relation is always conserved:

$$\sum_m \omega_m\cdot\Sigma(g'\to g,m'\to m)=\sum_k \Sigma_s(k;g'\to g).$$

Appendix 4. FIDO Format(*)

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 (fixed-form) FIDO formats were designed to reduce these difficulties. Lots of convienient options for array operation were prepared for a user to input large amounts of data. A description of each option is given below. The usefulness of one of such options, 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 Sn cosines are negated and reflected about μ=0., a fact of which suggests the use of the M option. Despite the usefulness of the options, there are justifiable complaints with the input formats; for example, where convenient 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 fixed form FIDO 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 FIDO input scheme which has data items separated by blank (as others do), but still allows all of the important convenient 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 FIDO option. Data can be easily written and key-punched, since there is no 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 real arrays, respectively.

---

* All of the descriptions are cited from Ref. 4).

In the following, the fixed-form FIDO format is explained first with a description of the options. Then, restictions and exampls of the free-form FIDO input are given.

Type 1 Format (Fixed Form)

Each card is divided into six 12-digit data fields which are divided into 3 subfields. The first subfield is a 2-digit integer; and second subfield contains either a blank or one of the following characters: $, *, R, I, T, S, F, A, C, E, Q, L, N, M, O, U, V, Z, + and -, which define the type of array operation. The third subfield contains either an integer or a real number. The contents of the first two subfields will define the operation to be performed on the third field.

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 free-form FIDO format.

Input Restrictions

The following restrictions must be observed when using the FIDO 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 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.

(5) Integer data in the third subfield must be right adjusted. Real data may be written with or without an exponent. If the decimal is omitted, it is assumed to be immediately to the left of the exponent field. If there is no exponent, the decimal point is assume to be to the extreme right of the nine-column subfield.

Array Operation

$ indicates the beginning of an integer array. The first subfield identifies the array.

* indicates the beginning of an real array. The first subfield identifies the array.

R indicates that the entry in the third subfield is to be repeated by the number of times specified in the first subfield.

I indicates linear interporation between the entry in the third subfield and the third subfield of the next data field. The number of points to be placed with an equal space is specified by the entry in the first subfield.

T indicates termination of a particular data block. A data 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 subfield can contain the first entry following the skips (i.e., 15S 1 enters a 1 in the 16th location of the present array). A blank third subfield would be ignored.

F is used to fill the remainder of an array with the data 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 ia blank. The next non-blank data entry is entered in this location of the present array.

C is used to obtain a count of a number of data read into an array up to the point where C is placed. An integer ZZ in front of the C will be used as an 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 data in a particular array. The data in question are replaced, and the use of an E prevents having to count and skip to the end of the array.

L is similar to **I** except that a logarithmic interpolation is performed between the entry data. This option is particularly useful for defining energy structures equally spaced in lethargy unit.

Q is used to repeat a sequence 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.

N is used to repeat a sequence of numbers in reversed order. 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.

M is used to negate and repeat an inverted sequence. 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.

O is used to turn on (or off) the card image edit of 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 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 after 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 zeros; e.g. 49Z would place forty-nine zeros into an array.

+ or − indicates exponentiation. The data in the third subfield is multiplies by $10^{\pm N}$, where N is an integer in the first subfield. This option allows one to specify a number up to nine significant digits.

Blank fields are ignored. One can use any or all fields on a card. For example, a set of blank cards sandwiched anywhere in a data array would be completely ignored.

Type 2 Format (Free Form)

The free-form FIDO 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 real arrays, respectively.

In the free-form FIDO input, data items are separated by blank, and all of the important convenient features of the earlier formats are still allowed. By using this input format, the user can easily write and key-punch data, since it is unnecessary to worry about which type character falls in which column or how many blanks are left between entries.

Input Restrictions

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 FIDO option. They are summarized as follows:

(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 column 1-72 are used.

(3) Numbers with exponents must not have imbedded blank; e.g. use 1.0E+4, but not 1.0 E+4 or 1.0E +4.

(4) The old + or - options (second subfield) are not optional.

(5) No more than 9 digits in a number can be entered. The exponent is 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 allowed either. An entry like 3Q4 accomplishes the same as Q4 Q4 Q4. This is now true for either format.

Example of Free-Form FIDO Input

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.