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A Computer Program for the Reactivity and Kinetic Parameters for Two-Dimensional Triangular Geometry by Transport Perturbation Theory

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T P T R I A

A Computer Program for the Reactivity and Kinetic Parameters for Two-Dimensional Triangular Geometry by Transport Perturbation Theory

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Abstract

TPTRIA is a Fortran 77 program for the calculation of the reactivity, effective delayed neutron fractions and mean generation time for two-dimensional triangular geometry on the basis of neutron transport perturbation theory. Group cross-sections, microscopic data of delayed neutron fractions and spectra, isotope dependent prompt neutron fission spectrum, and direct and adjoint angular fluxes provided by the corresponding transport code DIAMANT2 are read from disk files. This code was developed in the same way as the two-dimensional transport perturbation code TP2 for rectangular geometry, therefore the code structure is nearly the same as in TP2. The code was designed to run under control of the modular code system KAPROS together with DIAMANT2 and other modules of this KArlsruhe PROgram System.

As in the TP2 code, there are two main options. One is for the exact perturbation calculation of the reactivity, where the direct and adjoint angular fluxes are used for unperturbed and perturbed systems, respectively. The other option is for first order perturbation calculations of the probe reactivity where usually unperturbed direct and adjoint angular fluxes are used. The effect of the finite size of the probe in z-direction can be taken into account based on the assumption of a cosine shape of the total flux for that direction. In both cases, reactivities for each reaction process are printed optionally including the energy and space dependence according to the input specification.

The criticality factor calculated by the S_n transport code using an isotope independent fission spectrum can be corrected by the TPTRIA code by taking into account an isotope dependence of the prompt fission spectrum and the difference of the delayed neutron spectrum from the prompt fission spectrum.

Some results as well as input and output listings of sample calculations are included and explained in the report.

TPTRIA - ein Rechenprogramm zur Bestimmung von Reaktivitätswerten und kinetischen Parametern für zweidimensionale Dreiecks-Geometrie durch Transport-Störungsrechnungen

Zusammenfassung

TPTRIA ist ein FORTRAN-77 Rechenprogramm zur Bestimmung von Reaktivitätswerten, den effektiven Anteilen von verzögerten Neutronen und der mittleren Neutronenlebensdauer für zweidimensionale Dreiecksgeometrie auf der Grundlage der Neutronen-Transporttheorie. Gruppen-Wirkungsquerschnitte, mikroskopische Daten der Anteile der verzögerten Neutronen und der zugehörigen Spektren, isotopenabhängige Spektren der prompten Neutronen sowie die aus der direkten und adjungierten Neutronen-Transportrechnung mit dem zugehörigen Transportcode DIAMANT2 berechneten Neutronen-Flußverteilungen werden von Zwischenspeichern gelesen. Der Code TPTRIA wurde für reguläre Dreiecksgeometrie in derselben Weise entwickelt wie der zweidimensionale Transport-Störungscode TP2 für Rechtecksgeometrie und weist deshalb nahezu dieselbe Programmstruktur wie TP2 auf. Der Code wurde für das modulare Programmsystem KAPROS entwickelt, unter dessen Kontrolle es zusammen mit DIAMANT2 und anderen Moduln zur Erstellung der makroskopischen Gruppenkonstanten ausgeführt wird.

TPTRIA enthält wie TP2 zwei grundlegende Möglichkeiten zur Durchführung von Störungsrechnungen. Unter Verwendung der aus der direkten Neutronen-Transportrechnung für das ungestörte System und der aus der adjungierten Neutronen-Transportrechnung für das gestörte System berechneten winkelabhängigen Neutronenflußverteilungen wird eine sogenannte exakte Störungsrechnung durchgeführt. Im anderen Fall werden die beiden winkelabhängigen Neutronen-Flußverteilungen aus der direkten und adjungierten Neutronen-Transportrechnung für das ungestörte System bestimmt und damit durch sogenannte Störungsrechnungen 1. Ordnung die Reaktivitätswerte für die in das System eingebrachten Störungen berechnet. Der Einfluß der in z-Richtung endlichen Ausdehnung einer in das System eingebrachten Störung, die sich nicht über die gesamte Höhe des Systems erstreckt, wird durch eine angenommene Kosinusverteilung des totalen Flusses in dieser Richtung berücksichtigt. In beiden Fällen können die Reaktivitätswerte für jede zu ermittelnde Störung wahlweise energie- und ortsabhängig gemäß den in der Eingabe spezifizierten Größen ausgedruckt werden.

Der mit einem S_N Transportcode unter Verwendung eines isotopenunabhängigen Spaltspektrums berechnete Kritikalitätsfaktor kann mit TPTRIA korrigiert werden, wobei die Isotopenabhängigkeit der prompten Spaltspektren und die Differenz zwischen den Spaltspektren der prompten und der verzögerten Neutronen berücksichtigt wird.

Der vorliegende Bericht enthält Listen der Ein- und Ausgabe von Rechenbeispielen sowie einige Resultate, die erläutert werden.

Contents

COMPUTER PROGRAM ABSTRACT

1. Name or Designation of Program: TPTRIA
   A Multigroup Neutron Transport Perturbation Code for Reactivity and Kinetic Parameters in Two-Dimensional Regular Triangular Geometry

2. Computer for which Program is Designed:
   IBM 3090, SIEMENS 7890 and compatibles

3. Nature of Physical Problem Solved:
   Reactivity, mean generation time and effective delayed neutron fraction can be calculated by exact or first order perturbation theory. Criticality factor corrected for the isotope dependence of the prompt fission spectrum and the difference between the delayed neutron spectrum and the prompt fission spectra can also be calculated.

4. Method of Solution:
   Direct and adjoint angular fluxes for unperturbed and perturbed cases are taken from the discrete ordinate code, and the reactivity etc. are calculated by the perturbation theory.

5. Restrictions on the Complexity of the Problem:
   Only two-dimensional regular triangular geometry is considered. There is no restriction for the number of energy groups. The size of a problem is restricted by the available maximum region of the computer memory. At present only down-scattering and an S_N approximation up to N=8 is allowed.

6. Typical Running Time:
   Sample 1: First order perturbation with S2, 4 energy groups
   3 probe samples for a mesh grid consisting of 30 x 15 triangles: 0.11 sec on a SIEMENS 7890 computer
   Sample 2: Exact perturbation calculation with S2, 4 energy groups for a mesh grid consisting of 30 x 15 triangles: 0.5 sec on a SIEMENS 7890 computer

7. Unusual Features of the Program:
   Anisotropic scattering is allowed, however, this option is not yet tested.

8. Related and Auxiliary Programs:

The present code reads the direct and adjoint angular flux and related data from the interface files created by the discrete ordinates transport code DIAMANT2. Group cross sections, fission spectra and delayed neutron data are read from an extended SIGMN-file.

9. Status:

Tested.

10. References:

K. Kobayashi, G. Buckel and K. Küfner: "TPTRIA, A Computer Program for the Reactivity and Kinetic Parameters for Two-Dimensional Triangular Geometry by Transport Perturbation Theory", KfK-4116 (1986), this report.

11. Machine Requirements:

TPTRIA requires 130 K bytes plus dynamically allocated space for working arrays roughly in the range of 3 times the product consisting of the number of triangles times the number of S_N directions times the number of energy groups, and uses 3 disk files.

12. Program Language Used:

FORTRAN 77

13. Operating System/Monitor under which Program is Executed:

IBM OS-MVS and compatible systems

14. Any Other Programming or Operating Information:

This code was designed to run under control of the modular code system KAPROS with DIAMANT2 and GRUCAL codes. However, a stand alone code could be easily prepared, if the read and write statements are rewritten and all necessary data are provided.

15. Name and Establishment of Authors:

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16. Material Available:

Source Deck, Sample Problems, Documentation Manual will be available from Institut für Neutronenphysik und Reaktortechnik, Kernforschungszentrum Karlsruhe.

I. INTRODUCTION

The transport perturbation code TPTRIA calculates the reactivity, effective delayed neutron fraction, mean neutron generation time and the corrected criticality factor taking into account the isotope dependence of the fission spectra and the delayed neutron spectrum in two-dimensional regular triangular geometry.

The details of the transport perturbation theory are described in Ref. 1. Here only the results, the explicit expression of those quantities which are used in TPTRIA code in the perturbation calculations, are given in Chap. II, where the reactor is assumed to be homogeneous in z-direction and leakage in z-direction is treated simply by using a buckling.

In the case of first order perturbation calculation, the finite size of the perturbed probe in z-direction should be taken into account, and equations are given also in Chap. II.

The code TPTRIA reads the direct and adjoint angular fluxes which are calculated by the two-dimensional S_n transport code DIAMANT2 for triangular geometry /3,4/. Isotope dependent fission spectra, and delayed neutron spectra and fractions are read from the cross-section file SIGMN. They are used to correct the criticality factor for the isotope dependence of fission spectrum and for the influence of the delayed neutron spectrum and to calculate the effective delayed neutron fraction. This correction arises from the fact that the usual transport code uses only a common unique fission spectrum, which is the same for all compositions.

The mesh size, the outer boundary and the corresponding boundary conditions must remain unchanged between the reference and perturbed problems. The perturbation due to the expansion of the system can be taken into account only through the change of the number density of the material.

In Chap. III, a detailed description of the program and an input description are given. If all input data, described in Chap. III, which are read by several subroutines, are available, the TPTRIA code can be used together with any other S_n transport code for regular triangular geometry and the appropriate nuclear data file.

In Chap. IV, sample calculations are given to show the accuracy of the reactivity and criticality factor with respect to the number of mesh points and the order of the S_n method.

Typical fields of application for the 2-dimensional transport perturbation code TPTRIA (for regular triangular meshes and the possibility to take into account the leakage in the separated direction at least in an approximate manner by using the so-called buckling concept) are:

All types of cores which have subassemblies of hexagonal shape (e.g. Liquid Metal cooled Fast Breeder Reactors (LMFBRs) or Advanced Pressurized Water Reactors, APWRs) and for which the application of the diffusion approximation appears to be questionable for determining reactivity effects in certain circumstances. The application of transport theory could become especially important for cases where steep local gradients of the real and/or adjoint fluxes and, thus, strong local leakage effects exist, as e.g. in the neighbourhood of irregularities like absorbers, followers or diluents in regular arrays or of partially slumped or voided or otherwise damaged fuel elements in distorted core configurations. For such types of problems the application of a triangular mesh in the perturbation code becomes essential because a modeling of the core geometry in (x,y)- or (r,θ)-geometry would introduce additional uncertainties and the results would be doubtful since one is usually not able to conserve the surface-to-volume-ratio between reality and calculational model even if one restricted this requirement to the most important part or fuel elements of the whole core region. Other kinds of reactor cores where the application of TPTRIA could be favourable and, therefore, is recommended are e.g. the usually loosely coupled cores of so-called heterogeneous LMFBRs where fertile zones of dimensions of about 20 - 40 cm are inserted into an environment of fissile material (heterogeneous or modular LMFBRs) or APWRs based on the so-called seed-blanket concept.

The intrinsic principal difficulty of the missing third dimension in the perturbation code TPTRIA and the related transport code DIAMANT2 can at least be partially compensated for by comparing the results of equivalent 2-dimensional diffusion and transport calculations both using the buckling concept to simulate the separated z-direction. The correction factors derived in such a manner could subsequently be used in combination with

diffusion results obtained directly from a fully 3-dimensional code which is considered to be a standard calculational tool in most laboratories. In this way TPTRIA could be used to determine approximate reactivity values for 3-dimensional problems based mainly on transport theory (possible refinements could even be imagined by including additional correction factors for the difference in z-dependence between diffusion and transport theory by comparing corresponding results along the axis of calculations in r-z-geometry).

II. EQUATIONS

1. Explicit Expression of Reactivity for the Exact Perturbation

The derivation of the reactivity by the perturbation theory is given in Ref. /1/ and used in TP2 code /2/. Here, only the final results are given in the following.

In the DIAMANT2 code /3/, the following discrete ordinate transport equation is solved:

$$\vec{\Omega}_m \nabla f_g(\vec{r},\vec{\Omega}_m) + \Sigma_{tg} f_g(\vec{r},\vec{\Omega}_m) = \sum_{g'=1}^{g} \sum_{m'} \Sigma_s(\vec{\Omega}_m, g \leftarrow \vec{\Omega}_{m'}, g') \times f_{g'}(\vec{r},\vec{\Omega}_{m'})\Delta\Omega_{m'} + \frac{1}{4\pi k} \chi_g \sum_{g'} \nu\Sigma_{fg'} \sum_{m'} f_{g'}(\vec{r},\vec{\Omega}_{m'})\Delta\Omega_{m'} + S_g(\vec{r},\vec{\Omega}_m) \quad . \tag{1}$$

where

$\vec{\Omega}_m$	unit vector of the flight direction of m-th direction,
$\vec{r}$	position vector
g	group index
$f_g(\vec{r},\vec{\Omega}_m)$	angular flux
Σ_{tg}	total cross section
$\Sigma_s(\vec{\Omega}_m, g \leftarrow \vec{\Omega}_{m'}, g')$	differential scattering cross-section from the direction $\vec{\Omega}_{m'}$, and energy group g' to the direction $\vec{\Omega}_m$ and energy group g
χ_g	fission spectrum

$\nu\Sigma_{fg}$ mean number of fission neutrons multiplied by the fission cross-section

$S_g(\vec{r},\vec{\Omega})$ external source

In the present calculation, it is assumed that there is no external source, and only the criticality problem is considered.

The angular flux is expanded using the spherical harmonics functions in a form:

$$f_g(\vec{r},\vec{\Omega}) = \frac{1}{4\pi} \sum_{l=0}^{\infty} (2l+1) \sum_{m=-l}^{l} f_g^{lm}(\vec{r})\, Y_{lm}(\vec{\Omega}) \tag{2}$$

where $Y_{\ell m}(\vec{\Omega})$ is a spherical harmonics function defined by

$$Y_{lm}(\vec{\Omega}) = \left[\frac{(l-m)!}{(l+m)!}\right]^{1/2} P_{lm}(\cos\theta)e^{im\phi} \tag{3}$$

and $P_{\ell m}(\mu)$ is an associated Legendre function of μ. In order to avoid confusion, the index l of the spherical harmonics expansion is sometimes also written as ℓ.

The following relations hold for the spherical harmonics functions:

$$\int Y_{lm}(\vec{\Omega})\, Y^*_{l',m'}(\vec{\Omega})\, d\Omega = \frac{4\pi}{2l+1}\, \delta_{ll'}\delta_{mm'} \tag{4}$$

$$Y^*_{lm}(\vec{\Omega}) = (-1)^m Y_{l,-m}(\vec{\Omega}) \tag{5}$$

where the notation * indicates to take the complex conjugate. Using the real functions $f^{c\ell m}(\vec{r})$ and $f^{s\ell m}(\vec{r})$, the angular moment can be written in the form,

$$f^{lm}(\vec{r}) = f^{clm}(\vec{r}) - if^{slm}(\vec{r}) \tag{6}$$

(sometimes the superscripts c and s are also used as subscripts)

Since the angular flux $f(\vec{r},\vec{\Omega})$ is real, the following relation holds:

$$f^{lm*}(\vec{r}) = (-1)^m f^{l,-m}(\vec{r}) \tag{7}$$

In the DIAMANT2 code, the following spherical harmonics functions $\hat{Y}^c_{\ell n}(\vec{\Omega}_m)$ and $\hat{Y}^s_{\ell n}(\vec{\Omega}_m)$ are used:

$$\hat{Y}^c_{ln}(\vec{\Omega}_m) = \left[\frac{\varepsilon_n (1-n)!}{(1+n)!}\right]^{1/2} P_{ln}(\cos\theta_m)\cos n\Phi_m \tag{8}$$

$$\hat{Y}^s_{ln}(\vec{\Omega}_m) = \left[\frac{\varepsilon_n (1-n)!}{(1+n)!}\right]^{1/2} P_{ln}(\cos\theta_m)\sin n\Phi_m \tag{9}$$

where $\varepsilon_o = 1$, $\varepsilon_1 = \varepsilon_2 = \ldots = 2$.

With these spherical harmonics functions, the angular flux is expanded in the form:

$$f(\vec{r},\vec{\Omega}) = \frac{1}{4\pi} \sum_{l=0}^{\infty} (2l+1) \sum_{n=0}^{l} (\hat{f}^{ln}_c(\vec{r})\hat{Y}^c_{ln}(\vec{\Omega}) + \hat{f}^{ln}_s(\vec{r})\hat{Y}^s_{ln}(\vec{\Omega})) \tag{10}$$

Using Eqs. (2), (6) and (10), we obtain the relations,

$$\hat{f}^{ln}_c(\vec{r}) = \sqrt{\varepsilon_n}\, f^{ln}_c(\vec{r}) \ , \quad \hat{f}^{ln}_s(\vec{r}) = \sqrt{\varepsilon_n}\, f^{ln}_s(\vec{r}) \tag{11}$$

The group and space dependent static reactivity for each reaction process is calculated by the following equations:

$$\rho_{cg}(\vec{r}) = -\delta\hat{\Sigma}_{cg} \sum_m \Delta\Omega_m f^+_{kg}(\vec{r},\vec{\Omega}_m) f_{kog}(\vec{r},\vec{\Omega}_m)/[F] \qquad \text{(capture)} \tag{12}$$

$$\rho_{fg}(\vec{r}) = -\delta\Sigma_f \sum_m \Delta\Omega_m f^+_{kg}(\vec{r},\vec{\Omega}_m) f_{kog}(\vec{r},\vec{\Omega})/[F] \qquad \text{(fission)} \tag{13}$$

where the $^+$ indicates the solution of the adjoint problem and k_o and k characterize that the unperturbed real (or direct) and the perturbed adjoint problem, respectively, are concerned; g specifies the energy group index.

$$\rho_{rg}(\vec{r}) = -\delta\hat{\Sigma}_{tg} \sum_{m} \Delta\Omega_m f^{+}_{kg}(\vec{r},\vec{\Omega}_m) f_{kog}(\vec{r},\vec{\Omega}_m)/[F] \qquad \text{(removal)} \qquad (14)$$

$$\rho_{sog}(\vec{r}) = -\delta\Sigma_{sg} \sum_{m} \Delta\Omega_m f^{+}_{kg}(\vec{r},\vec{\Omega}_m) f_{kog}(\vec{r},\vec{\Omega}_m)/[F] \qquad \text{(scattering out)} \qquad (15)$$

$$\rho_{sig}(\vec{r}) = \sum_{g'=1}^{g} \sum_{l=0}^{L_s} \frac{2l+1}{4\pi} \delta\Sigma_{sl}(g\leftarrow g') \sum_{m=0}^{l} (\hat{f}^{+clm}_{kg}(\vec{r}) \hat{f}^{clm}_{kog'}(\vec{r})$$

$$+ \hat{f}^{+slm}_{kg}(\vec{r}) \cdot \hat{f}^{slm}_{kog'}(\vec{r}))/[F] \qquad \text{(scattering in)} \qquad (16)$$

$$\rho_{sig\leftarrow g-1}(\vec{r}) = \sum_{l=0}^{L_s} \frac{2l+1}{4\pi} \delta\Sigma_{sl}(g\leftarrow g-1) \sum_{m=0}^{l} (f^{+clm}_{kg}(\vec{r}) \cdot f^{clm}_{kog-1}(\vec{r})$$

$$+ f^{+slm}_{kg}(\vec{r}) \cdot f^{slm}_{kog-1}(\vec{r}))/[F] \qquad \text{(scattering in from g-1-th group)} \qquad (17)$$

$$\rho_{fsg}(\vec{r}) = f^{+oo}_{kg}(\vec{r}) \Big(\sum_{j} \chi^{j}_{g} \sum_{g'=1}^{G} \delta(\nu_p \Sigma_f)^{j}_{g'} + \sum_{i} \chi_{ig} \sum_{g'=1}^{G} \delta(\nu^{i}_{d} \Sigma_f)_{g'} \Big) f^{oo}_{kog'}(\vec{r})/4\pi k_o [F]$$

$$\text{(fission source)} \qquad (18)$$

$$\rho_{afg}(\vec{r}) = \sum_{g'=1}^{G} f^{+oo}_{kg'}(\vec{r}) \Big(\sum_{j} \chi^{j}_{g'} \delta(\nu_p \Sigma_f)^{j}_{g} + \sum_{i} \chi_{ig'} \delta(\nu^{i}_{d} \Sigma_f)_{g} \Big) f^{oo}_{kog}(\vec{r})/4\pi k_o [F]$$

$$\text{(adjoint fission source)} \qquad (19)$$

$$\rho_{g}(\vec{r}) = \rho_{rg}(\vec{r}) + \rho_{sig}(\vec{r}) + \rho_{fsg}(\vec{r}) \qquad \text{(total)} \qquad (20)$$

$$[F] = \frac{1}{4\pi} \sum_{p} \Delta V_p \sum_{g=1}^{G} f^{+oo}_{kg}(\vec{r}_p) \Big(\sum_{j} \chi^{j}_{g} \sum_{g'=1}^{G} (\nu_p \Sigma_f)^{j}_{g'} + \sum_{i} \chi_{ig} \sum_{g'=1}^{G} (\nu^{i}_{d} \Sigma_f)_{g'} \Big) f^{oo}_{kog'}(\vec{r}_p)$$

$$(21)$$

$$\hat{\Sigma}_{tg} = \hat{\Sigma}_{ag} + \Sigma_{sg} \tag{22}$$

$$\hat{\Sigma}_{ag} = \Sigma_{absg} + D_g B_g^2 \tag{23}$$

$$\delta\Sigma = \Sigma(\text{perturbed}) - \Sigma(\text{unperturbed}) , \tag{24}$$

where ko and k are suffixes for unperturbed direct and perturbed adjoint equation, respectively, and the indices j and i denote the isotope and delayed neutron group, respectively. Index L_s means the maximum order of anisotropic scattering, and ΔV_p the volume element. In the equations, the space dependence of the group cross sections and the prompt and delayed fission spectra are not indicated explicitly.

Summing up the energy and space dependent reactivities over all energy groups, we obtain the space dependent reactivities,

$$\rho_\alpha(\vec{r}) = \sum_g \rho_{\alpha g}(\vec{r}) \tag{25}$$

where α denotes each reaction process. Integrating them over space, we obtain the energy dependent reactivities,

$$\rho_{\alpha g} = \sum_p \Delta V_p \, \rho_{\alpha g}(\vec{r}_p) \tag{26}$$

Summing them up over all energy groups and integrating over space, we obtain the reactivity for the whole perturbation within the reactor,

$$\rho_\alpha = \sum_g \sum_p \Delta V_p \, \rho_{\alpha g}(\vec{r}_p) \tag{27}$$

The mean generation time $\bar{\Lambda}$ is calculated as,

$$\bar{\Lambda} = \sum_p \Delta V_p \sum_{g=1}^{G} \frac{1}{v_g} \left(\sum_m \Delta\Omega_m f^+_{kg}(\vec{r}_p, \vec{\Omega}_m) f_{kog}(\vec{r}_p, \vec{\Omega}_m) \right) / [F] \tag{28}$$

The effective delayed neutron fractions $\bar{\beta}_i^j$ are given by

$$\bar{\beta}_i^j = \sum_p \Delta V_p \sum_{g=1}^{G} \left(f_{kog}^{+oo}(\vec{r}_p) \chi_{ig} \sum_{g'=1}^{G} (\nu_d^i \Sigma_f)_{g'}^j f_{kog'}^{oo}(\vec{r}_p) \right) / [F] \qquad (29)$$

and

$$\bar{\beta}_i = \sum_j \bar{\beta}_i^j \qquad (30)$$

$$\bar{\beta}^j = \sum_i \bar{\beta}_i^j \qquad (31)$$

2. Correction for Buckling or Leakage in z-Direction

When the reactor has a finite height in z-direction so that the flux is not flat in this direction and the corresponding buckling and leakage in z-direction is not negligible (as would be the case for an infinite extension in z-direction), it is appropriate to take into account this buckling or leakage effect for the first order probe perturbation calculations, especially if the extension of the probe does not cover the full height of the reactor in z-direction.

We write the unperturbed direct and perturbed adjoint equation in three-dimensional space as

$$(G^{o} + \frac{1}{k_o} F^{o}) f_{kog}(\vec{r},\vec{\Omega}) = 0 \tag{32}$$

$$(G^{+} + \frac{1}{k} F^{+}) f^{+}_{kg}(\vec{r},\vec{\Omega}) = 0 \tag{33}$$

respectively, where

$$G^{o} = -\vec{\Omega}\nabla - \Sigma^{o}_{tg} + \sum_{g'} \int d\Omega' \Sigma^{o}_{s}(\vec{\Omega}, g \leftarrow \vec{\Omega}', g') \tag{34}$$

$$F^{o} = \frac{1}{4\pi} \chi_g \sum_{g'} \nu\Sigma_{fg'} \int d\Omega' \tag{35}$$

$$G = G^{o} + \delta G , \quad F = F^{o} + \delta F \tag{36}$$

Multiplying $f^{+}_{kg}(\vec{r},\vec{\Omega})$ to Eq. (32) and $f_{kog}(\vec{r},\vec{\Omega})$ to Eq. (33), subtracting the resulting equation and integrating over space and solid angle, we obtain

$$\left(\frac{1}{k_o} - \frac{1}{k}\right) \langle f^{+}_{kg} F^{o} f_{kog} \rangle = \frac{1}{k} \langle f^{+}_{kg} \delta F f_{kog} \rangle + \langle f_{kog} G^{+} f^{+}_{kg} \rangle - \langle f^{+}_{kg} G^{o} f_{kog} \rangle \tag{37}$$

The second and third term of the right hand side of Eq. (37) are

$$<f_{kog}G^{+}f_{kg}^{+}>-<f_{kg}^{+}G^{o}f_{kog}> = <f_{kog}(-\vec{\Omega}\cdot\nabla)f_{kg}^{+}-f_{kg}^{+}\vec{\Omega}\cdot\nabla f_{kog}>+<f_{kg}^{+}\delta Gf_{kog}>$$

$$= \int_S ds\int d\Omega\vec{n}\cdot\vec{\Omega}f_{kg}^{+}(\vec{r},\vec{\Omega})f_{kog}(\vec{r},\vec{\Omega})+<f_{kg}^{+}\delta Gf_{kog}> \quad (38)$$

where vector $\vec{n}$ is an outward unit vector normal to the outer surface of the reactor and $\int_S ds$ means the integration over it. This integral at the surface vanishes on account of the boundary condition for the direct and adjoint angular fluxes.

We assume that the total flux has the following form separable in z-direction, (where it is assumed that the unperturbed real and the perturbed adjoint flux have the same shape in z-direction, so that the same group-independent value of B_z can be adopted to describe the z-dependence of both fluxes)

$$\Phi_{kog}(\vec{r}) = \Phi_{kog}(x,y)\cos B_z Z \quad (39)$$

$$\Phi_{kg}^{+}(\vec{r}) = \Phi_{kg}^{+}(x,y)\cos B_z Z \quad (40)$$

where $\phi_{kog}(x,y)^{*)}$ and $\phi_{kg}^{+}(x,y)^{*)}$ are the two-dimensional total flux at $z = 0$, which can be calculated e.g. by the S_n code DIAMANT2 for two-dimensional triangular geometry. B_z^2 is the buckling in z-direction. For first order perturbation calculations, there are some restrictions for the allowed buckling options, in order to avoid the application of TPTRIA for unreasonable cases:

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*) Please note that x,y have only a symbolic meaning here to illustrate a spatial dependence in two dimensions; in reality a regular triangular coordinate mesh is used.

(I) The bucklings for the real and adjoint case have to agree with each other for corresponding groups and/or compositions.

(II) If the probe height does not cover the full (extrapolated) core height, only a global buckling is allowed, i.e. MBK = 1 is required.

(III) Only if the probe height covers the full (extrapolated) core height, MBK = 2 or 3 is possible. In this case HPED = 0. has to be specified in the input (and ZL and ZU are meaningless). With respect to the formulae used in TPTRIA and in the following equations, especially Eq. (58), this is equivalent to the assumption that the following relations hold: HPED = $\pi/\sqrt{B^2}$, Z_L = -0.5*HPED, Z_U = +0.5*HPED, g_c = 1.0, g_s = 1.0.

The current in z-direction is assumed to be given by the diffusion approximation, namely,

$$J_{zkog}(\vec{r}) = -D_g^o \frac{\partial \Phi_{kog}(\vec{r})}{\partial z} = D_g^o B_z \sin B_z Z \Phi_{kog}(x,y) \tag{41}$$

$$J^+_{zkg}(\vec{r}) = +D_g \frac{\partial \Phi^+_{kg}(\vec{r})}{\partial z} = -D_g B_z \sin B_z Z \Phi^+_{kg}(x,y) \tag{42}$$

In the P_1 approximation, the currents in x and y directions are written as

$$J_x(\vec{r}) = \frac{1}{\sqrt{2}} \left(f^{1,-1}(\vec{r}) - f^{1,1}(\vec{r}) \right) = -D \frac{\partial \Phi(\vec{r})}{\partial x} \tag{43}$$

$$J_y(\vec{r}) = \frac{1}{\sqrt{2}\, i} \left(f^{1,-1}(\vec{r}) + f^{1,1}(\vec{r}) \right) = -D \frac{\partial \Phi(\vec{r})}{\partial y} \tag{44}$$

Substitution of Eq. (39) into Eq. (43) and (44) gives

$$J_x(\vec{r}) = -D \frac{\partial \Phi(x,y)}{\partial x} \cos B_z Z \ , \quad J_y(\vec{r}) = -D \frac{\partial \Phi(x,y)}{\partial y} \cos B_z Z \tag{45}$$

which means

$$f^{1,-1}(\vec{r}) = f^{1,-1}(x,y)\cos B_z Z, \quad f^{1,1}(\vec{r}) = f^{1,1}(x,y)\cos B_z Z \tag{46}$$

Since $J_z(\vec{r}) = f^{10}(\vec{r})$, Eq. (41) becomes

$$f^{10}_{ko}(\vec{r}) = f^{oo}_{ko}(x,y)D^o B_z \sin B_z Z \tag{47}$$

Substituting Eqs. (46) and (47) into Eq. (2), Eq. (2) can be written as

$$\begin{aligned} f_{kog}(\vec{r},\vec{\Omega}) &= \frac{1}{4\pi}\Big[\big(\Phi_o(x,y)+3f^{1,1}(x,y)Y_{1,1}(\vec{\Omega})+3f^{1,-1}(x,y)Y_{1,-1}(\vec{\Omega})\big)\cos B_z Z \\ &\quad + 3f^{oo}(x,y)D^o B_z \sin B_z Z Y_{10}(\vec{\Omega}) + \ldots\Big] \\ &\doteq f_{kog}(x,y,\vec{\Omega})\cos B_z Z + \frac{3}{4\pi} f^{oo}_{kog}(x,y)Y_{10}(\vec{\Omega})D^o_g B_z \sin B_z Z \end{aligned} \tag{48}$$

Similarly, Eq. (2) for adjoint flux can be written as

$$f^{+}_{kg}(\vec{r},\vec{\Omega}) \doteq f^{+}_{kg}(x,y,\vec{\Omega})\cos B_z Z - \frac{3}{4\pi} f^{+oo}_{kg}(x,y)Y_{10}(\vec{\Omega})D_g B_z \sin B_z Z \tag{49}$$

Using Eqs. (48) and (49), we obtain the surface integral which appears in Eq. (38) in the form:

$$\begin{aligned} \int d\Omega\, f^{+}_{kg}(\vec{r},\vec{\Omega})f_{kog}(\vec{r},\vec{\Omega}) &= \int d\Omega\, f^{+}_{kg}(x,y,\vec{\Omega})f_{kog}(x,y,\vec{\Omega})\cos^2 B_z Z \\ &\quad - \frac{3}{4\pi} f^{+oo}_{kg}(x,y)f^{oo}_{kog}(x,y)D^o_g D_g B_z^2 \sin^2 B_z Z \end{aligned} \tag{50}$$

Then the second and third terms of the right hand side of Eq. (37) become

$$<f^{+}_{kg}\delta G f_{kog}> = <f^{+}_{kg}\left(-\delta\Sigma_{tg}\cdot\delta_{gg'} + \sum_{g'}\int d\Omega'\delta\Sigma_{s}(\vec{\Omega},g\leftarrow\vec{\Omega}',g')\right)f_{kog'}>$$

$$= -<f^{+}_{kg}\delta\Sigma_{tg}f_{kog}> + <f^{+}_{kg}\sum_{g'}\int d\Omega'\delta\Sigma_{s}(\vec{\Omega},g\leftarrow\vec{\Omega}',g')f_{kog'}>$$

$$= -\int dxdy\delta\Sigma_{tg}\int d\Omega\ f^{+}_{kg}(x,y,\vec{\Omega})f_{kog}(x,y,\vec{\Omega})\int_{\Delta z} dz\cos^2 B_z Z$$

$$+ \frac{3}{4\pi}\int dxdy\ \delta\Sigma_{tg}f^{+oo}_{kg}(x,y)f^{oo}_{kog}(x,y)D^{o}_{g}D_{g}B^{2}_{z}\int_{\Delta z}\sin^2 B_z Z dz$$

$$+ <f^{+}_{kg}\sum_{g'}\int d\Omega'\delta\Sigma_{s}(\vec{\Omega},g\leftarrow\vec{\Omega}',g')f_{kog'}> \qquad (51)$$

For a moment, the summation over g will be omitted.

The third term on the right hand side of Eq. (51) becomes

$$<f^{+}_{kg}\sum_{g'}\int d\Omega'\delta\Sigma_{s}(\vec{\Omega},g\leftarrow\vec{\Omega}',g')f_{kog'}> = <\quad>_{si}\ \text{scattering-in contribution}$$

$$= \int d\vec{r}\sum_{g'=1}^{g}\sum_{l=0}^{L_s}\frac{2l+1}{4\pi}\delta\Sigma_{sl}(g\leftarrow g')\sum_{m=0}^{l}\Sigma_{m}\left(f^{+lm}_{kgc}(\vec{r})f^{lm}_{kog'c}(\vec{r})+f^{+lm}_{kgs}(\vec{r})f^{lm}_{kog's}(\vec{r})\right) \qquad (52)$$

where the same notations as those given in Ref. /1/ are used.

The moments calculated from the two-dimensional angular flux should be multiplied by cos $B_z Z$ as seen in Eq. (48). Then, we get an approximate expression for Eq. (52) using Eq. (47) for $f^{10}(\vec{r})$:

$$<\quad>_{si} = \sum_{g'=1}^{g}\sum_{l=0}^{L_s}\frac{2l+1}{4\pi}\delta\Sigma_{sl}(g\leftarrow g')\sum_{m=0}^{l}\varepsilon_{m}\int_{\Delta x\Delta y}\left(f^{+lm}_{kgc}(x,y)f^{lm}_{kog'c}(x,y)+\right.$$

$$\left.+ f^{+lm}_{kgs}(x,y)f^{lm}_{kog's}(x,y)\right)dxdy\times\int_{\Delta z}dz\cos^2 B_z Z$$

$$-\sum_{g'=1}^{g}\frac{3}{4\pi}\delta\Sigma_{sl}(g\leftarrow g')\int_{\Delta x\Delta y}dxdy\ f^{+oo}_{kgc}(x,y)f^{oo}_{kog'c}(x,y)D_{g}D^{o}_{g'}B^{2}_{z}\int_{\Delta z}\sin^2 B_z Z dz \qquad (53)$$

which is valid within P_1 approximation.

Combining the second term of the right hand side of Eq. (51) and the term with g'=g of the second term of Eq. (53) gives

$$\frac{3}{4\pi} <\delta\Sigma_{tg} D_g^o D_g \Phi_{kg}^+(x,y)\Phi_{kog}(x,y)>_{xy} B_z^2 \int_{\Delta z} \sin^2 B_z Z dz$$

$$- \frac{3}{4\pi} <\delta\Sigma_{sl}(g\leftarrow g) D_g^o D_g \Phi_{kg}^+(x,y)\Phi_{kog}(x,y)> B_z^2 \int_{\Delta z} \sin^2 B_z Z dz$$

$$= - \frac{1}{4\pi} <\delta D_g \Phi_{kg}^+(x,y)\Phi_{kog}(x,y)> B_z^2 \int_{\Delta z} \sin^2 B_z Z dz \qquad (54)$$

where we used the following relation,

$$D_g = \frac{1}{3\Sigma_{trg}}, \quad \Sigma_{trg} = \Sigma_{tg} - \Sigma_{slg}, \quad \Sigma_{s\ell g} = \Sigma_{s\ell}(g\leftarrow g), \quad \Sigma_{slg} = \mu_g \Sigma_{sog} \qquad (55)$$

The terms for $g' \neq g$ of the second term of Eq. (53) will be included in ρ_{sig} as shown in Eq. (64).

The first term of Eq. (51) gives the reactivity due to the increase of the absorption, scattering out and leakage in x-y plane by the increase of total cross section, and the second term and the third term for g'=g gives the contribution due to the increase of the leakage in z-direction by the increase of the diffusion coefficient; from this, we can confirm that Eq. (51) gives the appropriate value in the case of P_1 approximation.

Using the total fluxes of Eqs. (39) and (40), the integral of the left hand side of Eq. (37) becomes

$$<f_{kg}^+ F^o f_{kog}> = [F]_{xy} \int_{-H/2}^{H/2} dz \cos^2 B_z Z \qquad (56)$$

where

$$[F]_{xy} = \frac{1}{4\pi} \int_V dxdy \sum_{g=1}^{G} \Phi^{+}_{kg}(x,y)\chi_g \sum_{g'=1}^{G} \nu\Sigma_{fg'}\Phi_{kog'}(x,y) \qquad (57)$$

we use the following notations,

$$g_c = \frac{\int_{Z_L}^{Z_U} \cos^2 B_z Z dz}{\int_{-H/2}^{H/2} \cos^2 B_z Z dz}, \qquad g_s = \frac{\int_{Z_L}^{Z_U} \sin^2 B_z Z dz}{\int_{-H/2}^{H/2} \cos^2 B_z Z dz} \qquad (58)$$

where Z_U and Z_L are the upper and lower coordinates, respectively, of the probe perturbation in Z-direction. H is the height of the reactor including an extrapolation distance and $B_Z = \pi/H$. For exact perturbation theory it is not necessary to take into account the axial extension of a probe so that the following relations hold $Z_L = -H/2$, $Z_U = H/2$ and $g_c = g_s = 1$.

The reactivity for each process can be written in the following form:

$$\rho_{cg}(x,y) = -\delta\Sigma_{cg} \sum_m \Delta\Omega_m f^{+}_{kg}(x,y,\vec{\Omega}_m) f_{kog}(x,y,\vec{\Omega}_m) g_c / [F]_{xy}, \quad \text{(capture)} \qquad (59)$$

$$\rho_{fg}(x,y) = -\delta\Sigma_{fg} \sum_m \Delta\Omega_m f^{+}_{kg}(x,y,\vec{\Omega}) f_{kog}(x,y,\vec{\Omega}) g_c / [F]_{xy}, \quad \text{(fission)} \qquad (60)$$

$$\rho_{Bg}(x,y) = -\delta D \cdot B_z^2 f^{+oo}_{kg}(x,y) f^{oo}_{kog}(x,y) g_s / [F]_{xy}, \quad \text{(Buckling)} \qquad (61)$$

In order to allow more flexibility in those cases of first order perturbation calculations where the probe height covers the full core height and where in addition the scattering is assumed to be isotropic, TPTRIA allows to use group- or group- and composition-dependent bucklings (to be specified in DIAMANT2); it is, however, necessary that the bucklings attributed to mixtures (or probes) in corresponding spatial domains remain unchanged when going from the unperturbed to the perturbed system or when replacing the unperturbed mixture by a probe mixture. This corresponds to the assumption of $g_c = g_s = 1.$ and replacing B_z^2 in Eq. (61) by the buckling values provided by DIAMANT2.

$$\rho_{sog}(x,y) = -\delta\Sigma_{sg} \sum_{m} \Delta\Omega_m f^{+}_{kg}(x,y,\vec{\Omega}_m) f_{kog}(x,y,\vec{\Omega}_m) g_c / [F]_{xy},$$

(scattering out) (62)

$$\rho_{rg}(x,y) = \rho_{cg}(x,y)+\rho_{fg}(x,y)+\rho_{sog}(x,y)+\rho_{Bg}(x,y) \qquad \text{(removal)} \quad (63)$$

$$\rho_{sig}(x,y) = \Bigg[\sum_{g'=1}^{g} \sum_{l=0}^{L_s} \frac{2l+1}{4\pi} \delta\Sigma_{sl}(g\leftarrow g') \sum_{m=0}^{l} \varepsilon_m \Big(f^{+lm}_{kgc}(x,y) f^{lm}_{kog'c}(x,y) +$$

$$+ f^{+lm}_{kgs}(x,y) f^{lm}_{kog's}(x,y) \Big) g_c$$

$$- \sum_{g'=1}^{g-1} \frac{3}{4\pi} \delta\Sigma_{sl}(g\leftarrow g') f^{+oo}_{kgc}(x,y) f^{oo}_{kog'c}(x,y) D_g D^{o}_{g'} B_z^2 \cdot g_s \Bigg] / [F]_{xy}$$

(scattering in) (64)

For the sake of clarity it might be worthwhile to mention that both the scattering-in- and the scattering-out-term contain the contribution of within-group scattering; this feature is different from that in diffusion perturbation calculations.

$$\rho_{g\leftarrow g-1}(x,y) = \Bigg[\sum_{l=0}^{L_s} \frac{2l+1}{4\pi} \delta\Sigma_{sl}(g\leftarrow g-1) \sum_{m=0}^{l} \varepsilon_m \Big(f^{+lm}_{kgc}(x,y) f^{lm}_{kog-1c}(x,y) +$$

$$+ f^{+lm}_{kgs}(x,y) f^{+lm}_{kog-1s}(x,y) \Big) g_c$$

$$- \frac{3}{4\pi} \delta\Sigma_{sl}(g\leftarrow g-1) f^{+oo}_{kgc}(x,y) f^{oo}_{kog-1c}(x,y) D_g D^{o}_{g-1} B_z^2 g_s \Bigg] / [F]_{xy}$$

(scattering in from g-1 to g) (65)

$$\rho_{fsg}(x,y) = f^{+oo}_{kg}(x,y) \Bigg[\sum_{j} \chi^{j}_{g} \sum_{g'=1}^{G} \delta(\nu_p \Sigma_f)^{j}_{g'} + \sum_{i} \chi_{ig} \sum_{g'=1}^{G} \delta(\nu^{i}_{d} \Sigma_f)_{g'} \Bigg] f^{oo}_{kog'}(x,y) g_c /$$

$$4\pi k_o [F]_{xy} \qquad \text{(fission source)} \quad (66)$$

$$\rho_{afg}(x,y) = \sum_{g'=1}^{G} f_{kg'}^{+oo}(x,y)\left(\sum_{j} \chi_{g'}^{j}\delta(\nu_p\Sigma_f)_g^j + \sum_{i} \chi_{ig'}\delta(\nu_d^i\Sigma_f)_g\right) f_{kog}^{oo}(x,y)g_c /$$

$$4\pi k_o [F]_{xy} \qquad \text{(adjoint fission source)} \quad (67)$$

$$\rho_g(x,y) = \rho_{rg}(x,y) + \rho_{sig}(x,y) + \rho_{fsg}(x,y) \qquad \text{(total)} \quad (68)$$

$$[F]_{xy} = \frac{1}{4\pi}\sum_{p} \Delta V_p \sum_{g=1}^{G} f_{kg}^{+oo}(x,y)\left(\sum_{i} \chi_g^j \sum_{g'=1}^{G} (\nu_p\Sigma_f)_{g'}^j + \sum_{i} \chi_{ig} \sum_{g'=1}^{G} (\nu_d^i\Sigma_f)_{g'}\right) f_{kog'}^{oo}(x,y)$$

(69)

3. Correction to the Criticality Factor for Isotope Dependence of the Fission Neutron Spectrum

In the DIAMANT2 code, an isotope independent fission spectrum is used for direct and adjoint calculations. Using a first order perturbation equation, corrections to the criticality factor can be done for the isotope dependency of fission neutron spectrum of prompt neutrons and also for the dependency of delayed neutron spectra on the delayed neutron groups as done in TP1 and TP2 codes.

DIAMANT2 solves the following equation,

$$(G^{o} + \frac{1}{k_o'} F^{o'}) f'_{kog}(\vec{r},\vec{\Omega}) = 0 \qquad (70)$$

as an unperturbed system, where an isotope independent fission spectrum χ_g is used, namely,

$$F'_o = \frac{1}{4\pi} \chi_g \sum_{g'} \nu\Sigma_{fg'} \sum_m \Delta\Omega_m \qquad (71)$$

In order to calculate a correction to the criticality factor to take into account the isotope dependency of the prompt neutron spectrum and the delayed neutron spectrum, we consider the "perturbed" adjoint equation of Eq. (70),

$$(G^{o+} + \frac{1}{k_o} F^{o+}) f^{+}_{kog}(\vec{r},\vec{\Omega}) = 0 \qquad (72)$$

where G^{o+} is the adjoint operator of G^{o} in Eq. (70) and

$$F^{o} = \frac{1}{4\pi} \left[\sum_j \chi_g^j \sum_{g'} (\nu_p \Sigma_f)^j_{g'} + \sum_i \chi_{ig} \sum_{g'} (\nu_d^i \Sigma_f)_{g'} \right] \sum_m \Delta\Omega_m \qquad (73)$$

Multiplying Eq. (70) by f^{+}_{kog} and Eq. (72) by f'_{kog}, subtracting the resulting equations and integrating over space and solid angle, the following correction factor ρ' can be obtained

$$\rho' = \frac{1}{k'_o} - \frac{1}{k_o} = \frac{1}{k'_o} \frac{\langle f^{+}_{ko} \delta F^{o} f'_{ko} \rangle}{\langle f^{+}_{ko} F^{o} f'_{ko} \rangle} \tag{74}$$

where

$$\delta F^{o} = F^{o} - F^{o'} = \delta F_p + \delta F_d \tag{75}$$

$$\delta F_p = \frac{1}{4\pi} \left[\sum_j \chi^j_g \sum_{g'} (\nu_p \Sigma_f)^j_{g'} - \chi_g \sum_{g'} (\nu_p \Sigma_f)_{g'} \right] \sum_m \Delta\Omega_m \tag{76}$$

$$\delta F_d = \frac{1}{4\pi} \left[\sum_i \chi_{ig} \sum_{g'} (\nu^i_d \Sigma_f)_{g'} - \chi_g \sum_{g'} (\nu_d \Sigma_f)_{g'} \right] \sum_m \Delta\Omega_m \tag{77}$$

If we calculate ρ' by Eq. (74), we can obtain the corrected criticality factor k_o of Eq. (72) as

$$k_o = \frac{k'_o}{1 - \rho' k'_o} \tag{78}$$

The difference of the fission operators F^{o} and $F^{o'}$ should be only in the fission spectrum χ_g, χ^j_g and χ_{ig}.

In the option of exact perturbation calculation, this correction factor ρ' is calculated. However, in order to obtain an accurate value of ρ', the perturbed adjoint flux f^{+}_{k} should be close to f^{+}_{ko} and also the fission cross section taken from the perturbed ones included in Eq. (73) should be close to the unperturbed ones.

As indicated before, most transport codes are not able to solve Eq. (72). Therefore, in evaluating Eq. (74), we have to use an approximate solution $f_{ko}^{+'}$ which is obtained from the DIAMANT2 code by solving the equation

$$(G^{o+} + \frac{1}{k_o'} F^{o'+}) f_{kog}^{'+}(\vec{r},\vec{\Omega}) = 0 \tag{79}$$

instead of $f_{ko}^{+}(\vec{r},\vec{\Omega})$, which means the application of the first order perturbation method. This procedure is usually justified, because the "perturbation" due to the difference of fission spectra is reasonably small and the corresponding reactivity effect is generally well below 1 %.

In the TPTRIA code, the correction factors ρ_p and ρ_d due to the influence of the difference of the prompt and delayed neutron spectra from the isotope independent fission spectrum assumed usually in transport codes are also printed:

$$\rho' = \rho_p + \rho_d \tag{80}$$

where

$$\rho_p = \frac{1}{k_o^+} \frac{\langle f_{ko}^{+} \delta F_p f_{ko}' \rangle}{\langle f_{ko}^{+} F^o f_{ko}' \rangle} \tag{81}$$

$$\rho_d = \frac{1}{k_o^+} \frac{\langle f_{ko}^{+} \delta F_d f_{ko}' \rangle}{\langle f_{ko}^{+} F^o f_{ko}' \rangle} \tag{82}$$

III. COMPUTER PROGRAM

1. Problem Solved by TPTRIA Code

The transport perturbation code TPTRIA is able to calculate two cases according to the input specification: the exact perturbation and the first order perturbation due to a probe substitution, for two-dimensional regular triangular meshes. In the cases of exact perturbation, the direct equation should be solved, for example, using the unperturbed cross section and the adjoint equation using the perturbed cross section. The perturbation is simply the difference of two cross section sets used for the direct and the adjoint equations. The outer boundary and the corresponding boundary conditions should remain unchanged between the unperturbed and perturbed problems.

In the case of first order perturbation, the same cross section set should be used for direct and adjoint equations. The cross section and the size for the substituted probe should be specified, and the perturbation is the difference between the cross sections used to solve the equations for the nominal case and the cross sections for the substituted probe. If the length of the probe in z-direction is finite, this is taken into account by specifying the height of the reactor and the position of the probe in z-direction.

Although the TPTRIA code is written at the moment to be used together with the two-dimensional discrete ordinates transport code DIAMANT2, the present code can also be used together with any other discrete ordinates transport code for regular triangular geometry, if all input data, which are read by several subroutines, are supplied. For this purpose, it is only necessary to replace or to rewrite some subroutines for reading input data which are described in detail in this report.

2. Program Chain for Perturbation Calculation

The perturbation calculation is performed by using the DIAMANT2 /3/ and TPTRIA code as shown in Fig. 1.

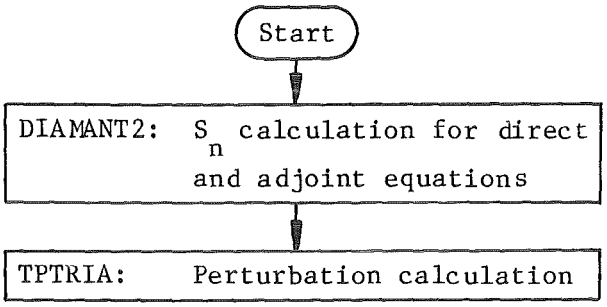


Fig. 1: Program Chain

(1) DIAMANT2 reads macroscopic cross sections from the SIGMN file on the disk IGRUC and computes first the direct angular flux and the criticality factor and then the adjoint angular flux and the criticality factor, and writes them on disk in two files, IDIAM1 and IDIAM2.

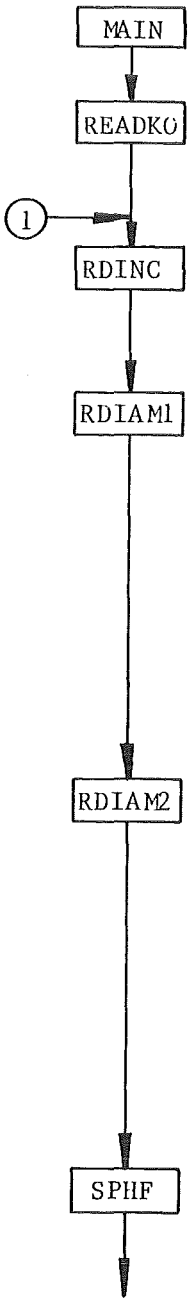
(2) In addition to the problem identification and some integer and real variables indicating the actual problem, TPTRIA reads the table of materials, the weights used for the different angular directions, the cross section table, the reciprocal neutron velocities VE = 1./V, the buckling values and the tables of material distributions used by DIAMANT2 as well as the angular flux values and the criticality factors from IDIAM1 for the direct and from IDIAM2 for the adjoint problem, respectively. The contents of the interface files IDIAM1 and IDIAM2 are checked for consistency. The isotope dependent fission cross sections, the fission spectra and the delayed neutron data are taken over out of the SIGMN-block.

3. Description of the Program TPTRIA

1) Flow diagram and subroutines

The flow diagram of the TPTRIA program is shown in Fig. 2.

Fig. 2: Flow Diagram of TPTRIA



Comments

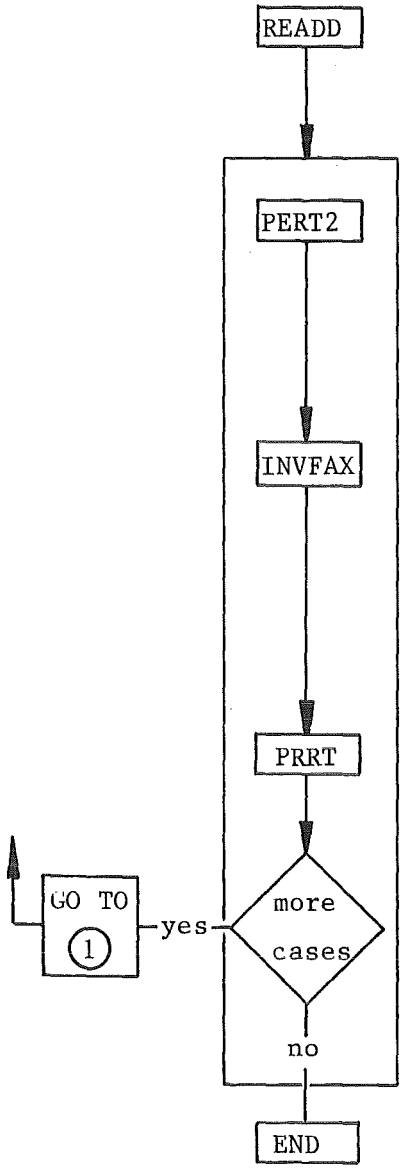
Connection of interface files to the actual run.

Input data for TPTRIA are read according to the input description given in chapter 6.

General information data (as for example the numbers of energy groups, mesh points, materials) from DIAMANT2 according to the description given in chapter 4 are read from unit IDIAM1 for the direct and from unit IDIAM2 for the adjoint calculation, respectively. A check for consistency is performed.

Array data (as for example tables of material distributions, weights for different directions, cross sections, bucklings) from DIAMANT2 according to the description given in chapter 4 are read from unit IDIAM1 for the direct and from unit IDIAM2 for the adjoint calculation, respectively.

Calculation of factors for the spherical harmonics functions.



Fission spectrum and delayed neutron data are taken over from SIGMN file for the unperturbed and perturbed system.

Reading of angular fluxes of DIAMANT2 from disk file IDIAM1 for the direct and from disk file IDIAM2 for the adjoint problem.

Contains indices to make the order of the adjoint angular flux inverse with respect to the angular index. Denominator [F] and effective delayed neutron fractions etc. are computed.

Reactivities for each reaction are computed and printed.

Use is made of 3 interface files IDIAM1, IDIAM2 and IDSK2. As described in the next section, interface files IDIAM1 and IDIAM2 are used to read the input specifications and output angular fluxes of the S_n calculation by the DIAMANT2 code. The delayed neutron data (which are usually prepared by the codes GRUCAL and SIGMUT) are taken over from the SIGMN file in subroutine READD. The file IDSK2 is used to write and read the intermediate data of the total fluxes for direct and adjoint cases.

The unit numbers for IDIAM1, IDIAM2 and IDSK2 have to be given in the input data for TPTRIA (see chapter 6).

4. Description of Subroutines and the Contents of the DIAMANT2 /4/ Interface Files

The following subroutines are used in TPTRIA:

a) RDINC: All card input data for TPTRIA are read, which are described in the input description.

b) RDIAM1: The following data are read from the disk unit IDIAM1 and partially compared with those read from IDIAM2 (unit numbers IDIAM1 and IDIAM2 have to be given as input data - see section III.6).

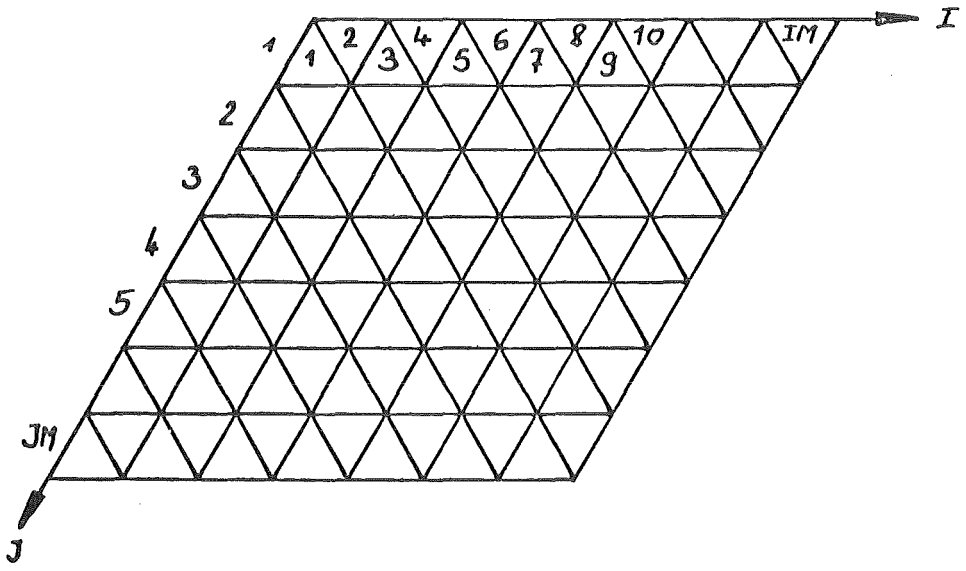


Fig. 3: Indices for triangular meshes

(i) 1st record: problem identification consisting of 15 character words of length 4

2nd record: consisting of 10 integer parameters transmitted from DIAMANT2, from which the following 6 are taken:

ISN : Order of S_n, 2, 4, 6, 8

IGM : Number of energy groups

IM : Number of triangles in horizontal direction as shown in Fig. 3

JM : Number of mesh intervals in vertical direction as shown in Fig. 3

MT : Total number of mixtures (including anisotropic moments) to be stored

MAT : Total number of mixtures to be used. MAT = Abs(MATE) (see page 39)

(ii) 3rd record: consisting of 8 integer parameters which are transmitted from DIAMANT2, from which the following 6 are taken:

ISCT : order of anisotropic scattering

MBK*): Buckling option
= 0 : No buckling
= 1 : Global buckling value
= 2 : Group-dependent buckling
= 3 : Group- and composition-dependent buckling

IHS : Location of $\Sigma_{so}(g' \leftarrow g)$

IHT : Location of the total cross section in the group cross section table

IHM : Length of cross section table (see 9th record)

IPSFIS: pointer to the fission cross section within the cross section table

MM : Number of discrete directions (=ISN(ISN+2)·3/4+ISN)

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*) Please note: For TPTRIA applications it is not allowed that MBK has different values for the real and adjoint case, respectively, in the DIAMANT2 input.

4th record: consisting of 7 real parameters which are transmitted from DIAMANT2, from which the following 2 are taken:

BF : $= B^2$: Buckling is calculated by $B^2 = (\pi/H_o^2)$ using the height H_o, which is meaningful only for MBK=1. This value is not used in TPTRIA.

S : Volume of uniform triangle of unit height

c) RDIAM2: The following records of the interface files on disk units IDIAM1 and IDIAM2 are read or skipped respectively.

(iii) 5th record: read from IDIAM1, skipped on IDIAM2

IMAT(MAT): Mixture indices used in DIAMANT2

6th and 7th record: skipped on IDIAM1 as well as IDIAM2

(iv) 8th record: read from IDIAM1, compared with weights on IDIAM2

W(MM): Integration weight

(v) 9th record: read from IDIAM1, compared with cross section table on IDIAM2

C(IHM,IGM,MT): Cross section table

$$C(IHT-6,G,N) = \Sigma^m_{fg}, \quad C(IHT-5,G,N) = \Sigma^m_{cg}$$

$$C(IHT-4,G,N) = \Sigma^m_{n,2ng}, \quad C(IHT-3,G,N) = \Sigma^m_{trg}$$

$$C(IHT-2,G,N) = \Sigma^m_{ag}, \quad C(IHT-1,G,N) = \nu\Sigma^m_{fg}$$

$$C(IHT,G,N) = \Sigma^m_{tg}, \quad C(IHS+G-G',G,N) = \Sigma^m_{so}(g\leftarrow g')$$

$$C(IHS+G-G',G,N+L) = \Sigma^m_{sL}(g\leftarrow g') \text{ for } 1\leq L\leq ISCT\leq 6,$$

where m is the mixture index, G=g, G'=g', m=IMAT(M), M=MTS(I,J) and N=MTC(I,J). The values related to locations and length of the cross section table are given by: IHS=8, IHT=7 and IHM=IGM+7. The arrays MTS(IM,JM) and MTC(IM,JM) specify the material distribution for each triangular mesh as shown in Fig. 8.

(vi) 10th record: read from IDIAM1, compared with the same record on IDIAM2

VE(IGM): = 1.0/V where V means the group velocity

(vii) 11th record: bucklings transmission record read from IDIAM1 and IDIAM2

B(1) = B^2, global buckling value, if MBK=1.
B(IGM)=B_g^2, group-dependent buckling, if MBK=2.
B2(MAT,IGM)=B_g^2, buckling, which depend on the group and the composition index, when MBK=3, for the direct calculation

for adjoint calculation
BP(1) = B^{*2}
BP(IGM)=B^{*2}_g
BP2(MAT,IGM)=B^{*2}_g.

(viii) 12th record: Location of the 0th moment of scattering cross section in the cross section array C for each triangle for direct and adjoint calculation, respectively. Read from IDIAM1 and IDIAM2.

MTC(IM,JM): Location of the 0th moment of scattering cross section in the cross section array C for each triangle for the direct calculation.

MTCP(IM,JM): for the adjoint calculation.

(ix) 13th record: skipped on IDIAM1 as well as on IDIAM2

(x) 14th record: if ISCT.GT.0 read from IDIAM1, skipped on IDIAM2

TW(IS,IS,MM): Spherical harmonics function multiplied by weight w_m, where IS=ISCT+1

d) FCT(N): = N! for the normalization of the spherical harmonics functions.

e) SPHF: The spherical harmonics functions are stored in the following form as done in the DIAMANT2 code /3 - page 49/.

$$\left.\begin{aligned} T(L,N,M) &= P_{L-1,N-1}(\xi_m)\cos(N-1)\phi_m \\ &= 0 \end{aligned}\right] \quad \begin{aligned} &\text{for } L=1\sim IS,\ N=1\sim L,\ L+N=\text{even}, \\ &\qquad\qquad\qquad\qquad L+N=\text{odd}. \end{aligned}$$

$$\left.\begin{aligned} T(L,N,M) &= P_{N-1,L}(\xi_m)\sin L\phi_m \\ &= 0 \end{aligned}\right] \quad \begin{aligned} &\text{for } L=1\sim(IS-1),\ N=(L+1)\sim IS, \\ &\qquad\qquad\qquad\qquad L+N+1=\text{even}, \\ &\qquad\quad " \qquad\qquad\quad L+N+1=\text{odd}. \end{aligned}$$

$$TW(N,J,M) = W_m * T(N,J,M),\quad N=1\sim IS,\ J=1\sim IS,\ M=1\sim MM.$$

In this subroutine, the array TW is multiplied by an appropriate constant such that

$$TW(L,N,M) = W_m\left[\frac{2(L-N)!}{(L-1+N-1)!}\right]^{1/2} P_{L-1,N-1}(\xi_m)\cos(N-1)\phi_m, \quad \text{for } 2\le N\le L \le IS,$$

$$TW(L,N,M) = W_m\left[\frac{2(N-L-1)!}{(N-L+1)!}\right]^{1/2} P_{N-1,L}(\xi_m)\sin L\phi_m, \quad \text{for } L+1\le N\le IS \le IS-1.$$

f) READD: This subroutine is the same as the one used in the TP2 code. The following data are taken over from the datablock SIGMN named 'SIGMN TPTRIA' prepared usually by GRUCAL, SIGMNC and SIGMUT codes.

SNFTJ(IGM,IFM,MTP) = $(\nu\Sigma_f)_g^j$; Number of total fission neutrons times fission cross section of j-isotope,

SNFDJ(IGM,IDM,IFM,MTP) = $(\nu_d{}^i\Sigma_f)_g^j$; Number of ith-group delayed neutrons times fission cross section of j-isotope,

XKIJ(IGM,IFM,MTP) = χ_g^j; Prompt fission spectrum of j-isotope,

DKI(IGM,IDM) = χ_{ig}; Delayed neutron spectrum of i-th delayed neutron (precursor) group,

KAI(IGM) = χ_g; isotope independent fission spectrum,

where MTP, IFM and IDM are number of mixtures, number of fissile isotopes and number of delayed neutron groups, respectively. After reading these data, the following cross sections are computed.

SNFP(IGM,MTP) $= (\nu_p\Sigma_f)_g = \sum_j (\nu_p\Sigma_f)_g^j$

SNFPJ(IGM,IFM,MTP) $= (\nu_p\Sigma_f)_g^j = (\nu\Sigma_f)_g^j - \sum_i (\nu_d^i\Sigma_f)_g^j$

SNFD(IGM,IDM,MTP) $= (\nu_d^i\Sigma_f)_g = \sum_j (\nu_d^i\Sigma_f)_g^j$

g) WQRG: This subroutine /7/ is used in READD to read cross sections from the SIGMN file.

h) CLEAR: This subroutine is used to set the values in an array equal to zero.

i) PRINT1: Print one-dimensional array,

j) PRINT2: Print two-dimensional array,

k) PRINT3: Print three-dimensional array,

l) PERT2: Denominator [F], mean generation time and effective delayed neutron fractions are computed.

From the disk unit IDIAM1, direct angular fluxes and the criticality factor are read as follows. The angular flux values FKO and FKD, respectively, are preceded by the numbers for the energy group IGG and the angular direction MMM for which they are calculated. (The angular directions are arranged in the ordering which was determined in DIAMANT2 to be suitable for an efficient solution algorithm.)

```
DIMENSION FKO(IM,JM,MM,IGM),FKD(IM,JM,MM,IGM)

   DO 1 IG=1,IGM
   DO 1 M=1,MMMM
   READ(IDIAM1)IGG
   READ(IDIAM1)MMM
1  READ(IDIAM1)((FKO(I,J,MMM,IG),I=1,IM),J=1,JM)
   READ(IDIAM1)
   READ(IDIAM1)
   READ(IDIAM1)RKO
```

In nearly the same way the adjoint angular fluxes are read from the disk unit IDIAM2. In TPTRIA the adjoint fluxes are stored in the same group ordering as the real fluxes. This is accomplished by reversing the ordering when reading them from the IDIAM2 interface file, where they were written by DIAMANT2 in inverse order (as usual for adjoint problems).

```
      DO 3 IG=IGM,1,-1
      DO 3 M=1,MMMM
      READ(IDIAM2)IGG
      READ(IDIAM2)MMM
    3 READ(IDIAM2)((FKD(I,J,MMM,IG),I=1,IM),J=1,JM)
      READ(IDIAM2)
      READ(IDIAM2)
      READ(IDIAM2)RKD
```

where MMMM=MM-ISN
with MM equal to the number of discrete angular directions .

m) INVAFX: The order of the angular flux with respect to the angular index must be changed, because in the DIAMANT2 code, the adjoint equation is solved by replacing $\vec{\Omega}_m$ by $-\vec{\Omega}_m$. Therefore, the order of angular fluxes is rearranged such that $-\vec{\Omega}_m = \vec{\Omega}_{m'}$. For example, $f_g^+(\vec{r},-\vec{\Omega}_8)$ in S_2 case must be transferred to the second place as $f_g^+(\vec{r},\vec{\Omega}_2)$. The indices M'=m' needed for this purpose are stored in the array IAN(MM), and used always when FKD(IM,JM,MM) is referred.

Please note, that presently the ordering of the indices is specific for the connection between DIAMANT2 and TPTRIA. At the moment it is restricted to the S_N order of N = 8. Therefore, it has to be extended if S_N orders of N > 8 are desired.

Figs. 4 and 5 show the basic grid points in a 60° sector. The complete net of grid points used in DIAMANT2 is obtained by rotating this sector in multiples of 60°. The corresponding discretization mesh is shown in Figs. 6 and 7 where also the indices for the angular direction are shown. From these figures, we can infer the index for the inverse direction. Table I gives the indices for the angular directions used in DIAMANT2 to solve the direct and adjoint equations, respectively.

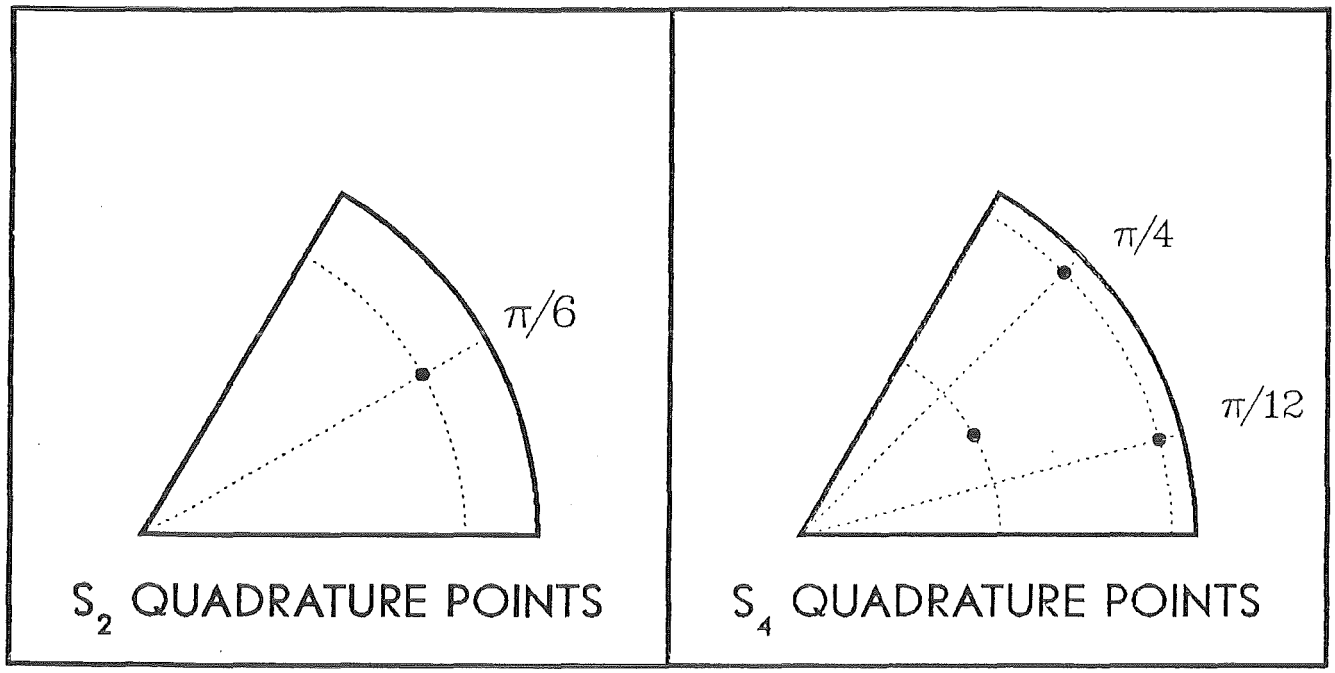


Fig.4 : Basic quadrature grid points in DIAMANT2 for S_2 and S_4

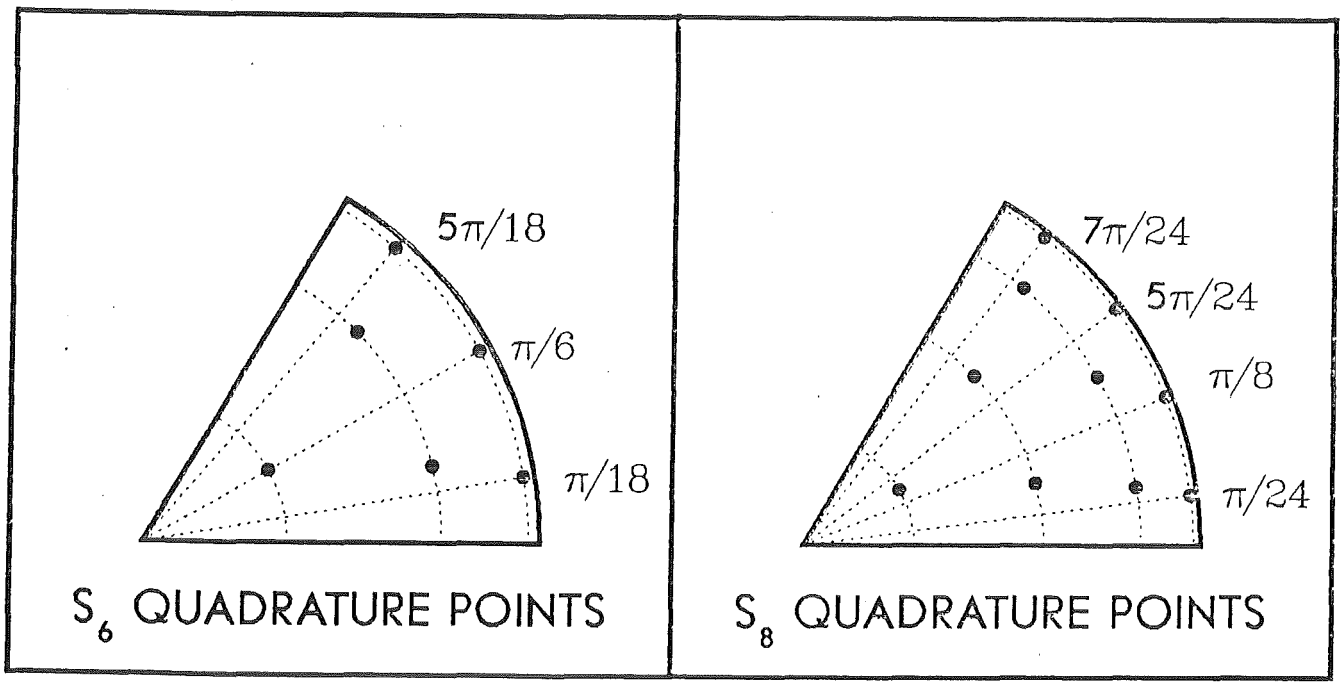
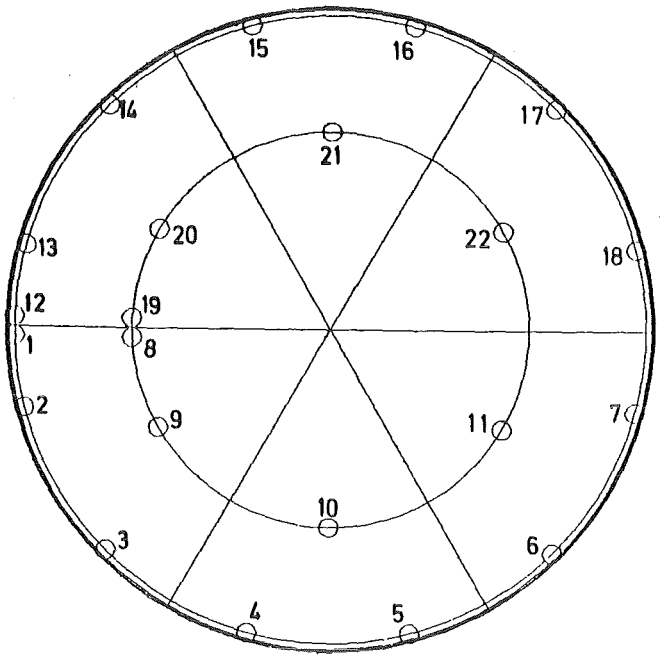
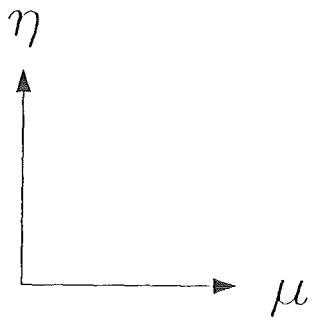


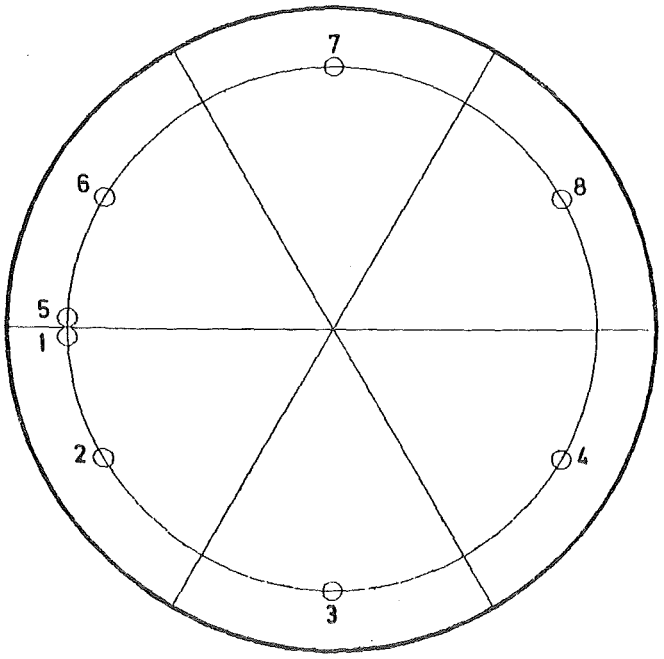
Fig.5 : Basic quadrature grid points in DIAMANT2 for S_6 and S_8

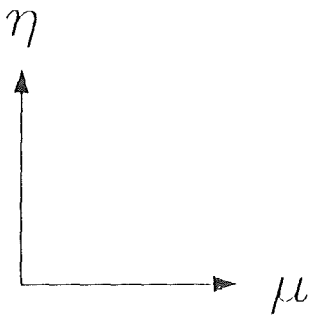




The 4 directions with $\eta = 0$ have weight zero and are not used by the code

Numbering of discrete S_4 quadrature points

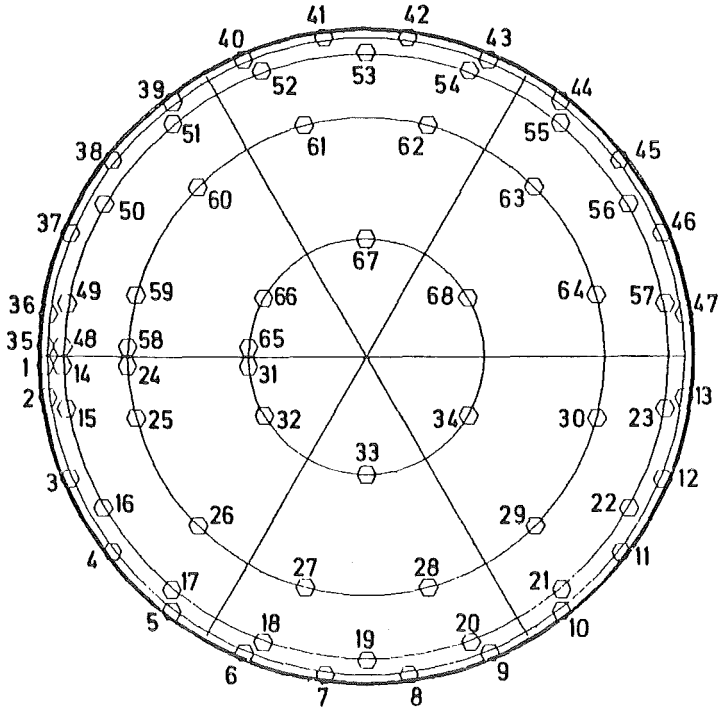




The 2 directions with $\eta = 0$ have weight zero and are not used by the code

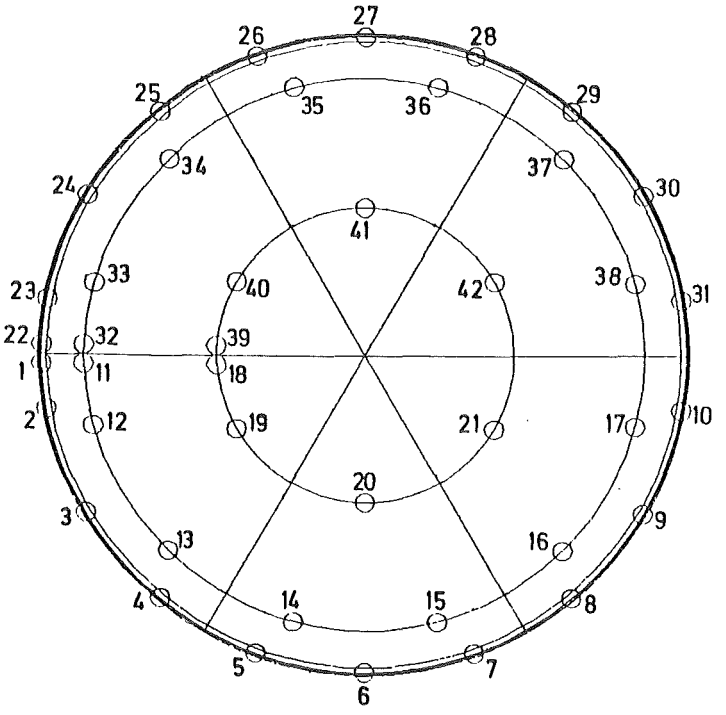
Numbering of discrete S_2 quadrature points

Fig.6 : Discrete directions in DIAMANT2 for S_2 and S_4 projected into x-y plane



The 8 directions with $\eta = 0$ have weight zero and are not used by the code

Numbering of discrete S_8 quadrature points



The 6 directions with $\eta = 0$ have weight zero and are not used by the code

Numbering of discrete S_6 quadrature points

Fig.7: Discrete directions in DIAMANT2 for S_6 and S_8 projected into x-y plane

Table I: Angular Indices for Direct and Adjoint Equations

S2

M	1,	2,	3,	4,	5,	6,	7,	8
M'	5,	8,	7,	6,	1,	4,	3,	2

S4

M	1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16,	17,	18,
M'	12,	18,	17,	16,	15,	14,	13,	19,	22,	21,	20,	1,	7,	6,	5,	4,	3,	2,

M	19,	20,	21,	22
M'	8,	11,	10,	9

S6

M	1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16,	17,	18,
M'	22,	31,	30,	29,	28,	27,	26,	25,	24,	23,	32,	38,	37,	36,	35,	34,	33,	39,

M	19,	20,	21,	22,	23,	24,	25,	26,	27,	28,	29,	30,	31,	32,	33,	34,	35,	36,
M'	42,	41,	40,	1,	10,	9,	8,	7,	6,	5,	4,	3,	2,	11,	17,	16,	15,	14,

M	37,	38,	39,	40,	41,	42
M'	13,	12,	18,	21,	20,	19

S8

M	1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16,	17,	18,
M'	35,	47,	46,	45,	44,	43,	42,	41,	40,	39,	38,	37,	36,	48,	57,	56,	55,	54,

M	19,	20,	21,	22,	23,	24,	25,	26,	27,	28,	29,	30,	31,	32,	33,	34,	35,	36,
M'	53,	52,	51,	50,	49,	58,	64,	63,	62,	61,	60,	59,	65,	68,	67,	66,	1,	13,

M	37,	38,	39,	40,	41,	42,	43,	44,	45,	46,	47,	48,	49,	50,	51,	52,	53,	54,
M'	12,	11,	10,	9,	8,	7,	6,	5,	4,	3,	2,	14,	23,	22,	21,	20,	19,	18,

M	55,	56,	57,	58,	59,	60,	61,	62,	63,	64,	65,	66,	67,	68
M'	17,	16,	15,	24,	30,	29,	28,	27,	26,	25,	31,	34,	33,	32

5. Integers, Real Variables and Arrays

1) Integer and real variables used in TPTRIA

Integer		Location in IAA
IGRUC		not used
IDIAM1	Disk unit number to read the interface file from DIAMANT2 code containing the results of the direct calculation	2
IDIAM2	Disk unit number to read the interface file from DIAMANT2 code containing the results of the adjoint calculation	3
IDIAM3		not used
IDSK1		not used
IDSK2	Disk unit number to store FTKO(IM,JM,IGM) and FTKD(IM,JM,IGM)	6
KRD	Standard unit number for input	8
KWT	Standard unit number for output	9
ISCT	Order of anisotropic scattering	10
ISN	Order of S_n equation	11
IGE	= 4, Index to specify the geometry of triangular mesh (not used)	12
IGM	Number of energy groups	13

IM IMP	Number of triangles in horizontal direction = IM+1	16
JM JMP	Number of mesh intervals in vertical direction = JM+1	17
MBK	Buckling option	18
MT	Total number of mixtures including anisotropic moments of scattering cross-sections stored in the array C.	19
MTR	MTR = MT+3. This integer is the third argument of dimension statement for array C, where C(IH,IG,N) = 0, for IH=1,IHM and N=MT+1,MTR.	
MATE	Number of mixtures existing in 'SIGMN TPTRIA' block, which is equal to the number of mixtures to be read in DIAMANT2 code. If ISCT = 0 (isotropic scattering), MATE = MT; if ISCT > 0 (anisotropic scattering), MATE $\leq$ MT.	
MAT	MAT=|MATE|	20
MM	=3*ISN(INS+2)/4+ISN, Number of discrete directions	21
IHS	Location of $\Sigma_{so}(g \leftarrow g)$ in the array C	22
IHT	Location of total cross-section in the array C	23
IHM	Dimension of the first variable of the array C	24
IS	=ISCT+1, used in the array TW(IS,IS,MM)	25
IBM	Dimension for the array B used to store buckling values. IBM=1, if MBKA=1, IBM=IGM, if MBKA=2, IBM=MAT*IGM, if MBKA=3.	26

IFM	Number of fissile isotopes	30
IDM	Number of delayed neutron groups	31
IFEX	1/0 = Yes/No, Integer for the option of exact perturbation	32
IFFP	1/0 = Yes/No, Integer for the option of first order perturbation	33
IFPG	1/0 = Yes/No, Integer characterizing how the data for specifying the perturbed region are provided in the input, i.e. global or pointwise (not relevant if IFFP=0)	34
IFGS	1/0 = Yes/No, Integer for the option to print group and space dependent reactivities	35
IFS	1/0 = Yes/No, Integer for the option to print space dependent reactivities	36
IFG	1/0 = Yes/No, Integer for the option to print group dependent reactivities	37
IFK	1/0 = Yes/No, Integer for the option to print the corrected criticality factor	38
IPAF	1/0 = Yes/No, Integer for the option to print direct and adjoint angular fluxes	39
IPFX	1/0 = Yes/No, Integer for the option to print direct and adjoint total fluxes	40
IPCS	1/0 = Yes/No, Integer for the option to print cross sections	41
IUIS	= 0, if there is no anisotropic scattering. = 1, if there is anisotropic scattering	42

IRSI	= 0, if scattering is isotropic = 1, if the reactivity due to the change of the anisotropic scattering RSI(IM,JM,IGM) is computed.	43
LIAN	Location of array IAN(MM)	44
LIPX	Initial mesh point in horizontal direction of perturbed probe	45
LJPY	Initial mesh point in vertical direction of perturbed probe	46
LVE	Location of VE(IGM) = 1.0/V where V means the group velocity	47
LKAI	Location of RKAI(IGM) = LXKI for universal fission spectrum	48
LAST	Maximum area of array A used in TPTRIA code	49
IRIS	Extension of the working area, IRIS=LAST-LIMAT	69
LIMAT	Starting pointer for the dynamically extended working array	70
IDMP	IDM+1	71
IFMP	IFM+1	72
MAT1	MAT+1	73
LHILF	First word address of an auxiliary working area	74
IEXP	1/0 = Yes/No, integer indicating whether or not an exact perturbation calculation can be performed	
IFFOP	counts internally the number of already performed first order perturbation calculations	
NFOP	number of first order perturbation calculations	

NPR	Mixture index of the perturbed probe which replaces the mixture of the unperturbed system; used for the array C(IHM,IGM,MT)	-
MPR	Mixture index of the perturbed probe; used for the array SNFD(IGM,IDM,MTP), etc.	
IL	Left mesh point of the perturbed probe (horiz. dir.)	
IR	Right mesh point of the perturbed probe (horiz. dir.)	
JL	First mesh point of the perturbed probe (vert. dir.)	
JU	Last mesh point of the perturbed probe (vert. dir.)	
IPT	Total number of mesh boxes where the original mixture is replaced by the probe mixture NPR in the case of IFFP=1 and IFPG=1	
Real		
BF	= B^2, This value is not used; instead the equivalent values B(1) and BP(1) are taken from the 11th records of the disk unit IDIAM1 and IDIAM2, respectively, written by DIAMANT2 from the DIAMANT2 input quantity BF for MBK=1.	50
H	= h, Height of a reactor in z-direction for unperturbed reactor; calculated according to $h = \pi/\sqrt{B(1)}$ in case of MBK = 1	52
HP	= h', Height of a reactor in z-direction for perturbed reactor; calculated according to $h = \pi/\sqrt{BP(1)}$ in case of MBK = 1	53
PAI	= 3.14159265 = π	54
FPAI	= 4	55

RKO	Criticality factor for direct equation	57
RKD	Criticality factor for adjoint equation	
BNB	= 1./SMF, SMF = [F]	58
FCF	= $1./(k_o * SMF)$	59
HPED	Height of a core including the extrapolation distance for the calculation of the reactivity of a probe by the first order perturbation calculation. HPED=0. indicates that in the first order perturbation calculation the probe height is assumed to cover the full (extrapolated) core height.	60
BZ	$B_z = \pi/HPED$	61
ZL	Lower coordinate of perturbed probe in z-direction	62
ZU	Upper coordinate of perturbed probe in z-direction (for HPED=0. the values of ZL and ZU are not relevant)	63
GC	= g_c, correction factor of cosine form due to the finite size in z-direction	64
GS	= g_s, correction factor of sine form due to the finite size in z-direction	65
S	Area of a triangular mesh	67
RIPT	= IPT, Number of triangles of the probe region	68

2) Arrays used in TPTRIA

A(1)	Working array . A(1) = IA(1) This working array is dynamically extended by calling the KAPROS routine KSPUTP to an extension of LAENGE which is calculated problem dependent.	Address of arrays in IAA
NAIST(2*IFMP)	Name of fissile isotopes. IFMP=IFM+1	
IMAT(M) (MTP)	= m, Mixture index, for example, Σ^m_{tg}, m can be a big number, although M is a small number from 1 to MTP. (see pp. 28, 29 and also section 3.8)	
MTS(I,J) (IM,JM)	= M, Mixture number for each triangle (I,J). Mixture index m is obtained by m = IMAT(M). If m is negative, anisotropic scattering is included.	
MTC(I,J) (IM,JM)	= N, Cross section array C is used with this integer. For example, $C(1,G,\|N\|) = \Sigma^m_{fg}$, where m = IMAT(M) and M = MTS(I,J). If N is negative, anisotropic scattering is included.	
MTSP(IM,JM)	MTS(IM,JM) for adjoint calculation	
MTCP(IM,JM)	MTC(IM,JM) for adjoint calculation	
IPLATZ(M) (MTP)	= N, With this integer, cross section array C is used. For example, $C(1,G,\|N\|) = \Sigma^m_{fg}$, where m =IMAT(M). If N is negative, anisotropic scattering is included.	
W(M) (MM)	= W_m, Quadrature weight for angular integration.	

TW(L,N,M) (IS,IS,MM)	Spherical harmonics functions multiplied by the weight W_m : $= \begin{cases} W_m N_{L-1,n-1} P_{L-1,n-1}(\xi_m)\cos(n-1)\phi_m, & \text{for } L=1\sim IS,\ n=1\sim L,\ L+n=\text{even} \\ 0 & L+n=\text{odd} \end{cases}$ $= \begin{cases} W_m N_{n-1,L} P_{n-1,L}(\xi_m)\sin L\phi_m & \text{for } L=1\sim(IS-1),\ n=(L+1)\sim IS \text{ and } L+n+1=\text{even} \\ 0 & \text{for } L+n+1=\text{odd}, \end{cases}$ where n = N and $N_{L,n} = \left[\frac{2(L-n)!}{(L+n)!}\right]^{1/2}$	
B(IBM)	IBM = 0, if MBK = 0 $= B^2$ and IBM = 1, if MBK = 1 $= B_g^2$ and IBM = IGM, if MBK = 2 $= B_g^{2m}$ and IBM = MAT*IGM, if MBK = 3	
BP(IBM)	B(IBM) for adjoint calculation	
VE(IG) IGM)	$= \frac{1}{v_g}$, v_g is the neutron velocity for group g, where g=IG	47
KAI(IGM)	$= \chi_g$, Isotope independent fission spectrum used in DIAMANT2 code	48

C(IHM,IGM,MT)	Cross section table $C(IHT-6,IG,N) = \Sigma^m_{fg}$, $C(IHT-5,IG,N) = \Sigma^m_{cg}$ $C(IHT-4,IG,N) = \Sigma^m_{n,2ng'}$, $C(IHT-3,IG,N) = \Sigma^m_{trg}$, $C(IHT-2,IG,N) = \Sigma^m_{ag}$, $C(IHT-1,IG,N) = \nu\Sigma^m_{fg}$, $C(IHT,IG,N) = \Sigma^m_{tg}$, $C(IHS+IG-IGP,IG,N) = \Sigma^m_{so}(g\leftarrow g')$, $C(IHS+IG-IGP,IG,N+L) = \Sigma^m_{sL}(g\leftarrow g')$, where m is the mixture index, namely, m=IMAT(M), M=MTS(I,J), N=MTC(I,J), IG=g and IGP=g'. The values related to locations and length of the cross section table are given by: IHS=8, IHT=7 and IHM=IHT+IGM. Presently, upscattering is not allowed in TPTRIA, i.e. $g' \leq g$; where group numbering begins with g = 1 in the group with highest energy.
SNFDJ(IG,ID,IF,M) (IGM,IDM,IFM,MTP)	$= (\nu^i_d\Sigma_f)^j_g$, where IG=g, ID=i, IF=j and M=MTS(I,J) for the (I,J)-th triangle
SNFD(IG,ID,M) (IGM,IDM,MTP)	$= (\nu^i_d\Sigma_f)_g = \sum_j (\nu^i_d\Sigma_f)^j_g$, where IG=g, ID=i and M=MTS(I,J)
SNFIJ(IG,IF,M) (IGM,IFM,MTP)	$= (\nu\Sigma_f)^j_g = \sum_j (\nu^i_d\Sigma_f)^j_g + (\nu_p\Sigma_f)^j$, where IG=g, IF=j and M=MTS(I,J)
SNFPJ(IG,IF,M) (IGM,IFM,MTP)	$= (\nu_p\Sigma_f)^j_g$, where IG=g, IF=j and M=MTS(I,J)
SNFP(IG,M) (IGM,MTP)	$= (\nu_p\Sigma_f)_g = \sum_j (\nu_p\Sigma_f)^j_g$

XKIJ(IG,IF,M) (IGM,IFM,MTP)	$= \chi_g^j$, Isotope dependent fission spectrum, where IF = j.
DKI(IG,ID) (IGM,IDM)	$= \chi_{ig}$, Delayed neutron spectrum, where ID = i.
FKO(I,J,MD,IG) (IM,JM,MM,IGM)	$= f_{kogij}(\vec{\Omega}_m)$, Angular flux for the (i,j)-th triangle, where I=i, J=j and MD=m.
FKD(I,J,MD,IG) (IM,JM,MM,IGM)	$= f^+_{kgi,j}(\vec{\Omega}_m)$, Adjoint angular flux for the (i,j)-th triangle, where I=i, J=j and MD=m. (for reordering see comment to subroutine INVAFX - section III.4)
FTKO(I,J,IG) (IM,JM,IGM)	$= f^{oo}_{kogij}$, Total flux for the direct equation of the (i,j)-th triangle, where I=i, J=j and IG=g.
FTKD(IM,JM,IGM)	$= f^{+oo}_{kgij}$, Total flux for adjoint equation
AFKOD (IM,JM,IGM)	$= \sum_m W_m f^+_{kgij}(\vec{\Omega}_m) f_{kogij}(\vec{\Omega}_m)$
SMFD(ID) (IDM)	$= \sum_g (\nu_d \Sigma_f)_g \, f^{oo}_{kog}$, ID=i
SMDFD(ID) (IDM)	$= \sum_g \delta(\nu^i \Sigma_f)_g \, f^{oo}_{kog}$, ID=i
SMXD(ID) (IDM)	$= \sum_g f^{+oo}_{kg} \, \chi_{ig}$, ID=i
SMFDJ(IGF,ID,MP) (IFM,IDM,MAT)	$= \sum_g (\nu^i_d \Sigma_f)^j_g \, f^{oo}_{kog}$, IF=j, ID=i and MP=MTSP(I,J).
SMFP(IF) (IFM)	$= \sum_g (\nu_p \Sigma_f)^j_g \, f^{oo}_{kog}$, IF=j

SMDFP(IF) (IFM)	$= \sum_g \delta(\nu_p \Sigma_f)_g^j f_{kog}^{oo}$, IF=j	
SMXP(IF) (IFM)	$= \sum_g f_{kg}^{+oo} \chi_g^j$, IF=j	
BETAJ(IF,ID,MP) (IFMP,IDMP,MAT1)	$= \bar{\beta}_i^j$, IF=j, ID=i and MP=MTSP(I,J)	
RG(K,IG) (11,IGM)	$= \rho_g$, Group dependent reactivity for K-th reaction	
RSI(I,J,IG) (IM,JM,IGM)	$= \rho_{si}(\vec{r}_{ij})$, Reactivity due to scattering in from the component of $L \geq 1$.	43
U(IEXT)	Used for cross-section preparation. The extension IEXT is calculated automatically by WQRG.	
IU(IEXT)	= Integer name of U(IEXT)	
IAN(M) (MM)	= MP, Angular indices for adjoint angular flux.	44
IPX(I) (IPT)	Mesh indices of I triangles (for horizontal direction, see Fig. 3), where a probe is inserted.	45
JPY(I) (IPT)	Mesh indices of J intervals (for vertical direction, see Fig. 3), where a probe is inserted.	46

6. Input Description of the TPTRIA Code

In order to run the TPTRIA code, 3 input data blocks are required:

1) INPUT TPTRIA — containing input data to direct the sequence flow

2) INIT READ TPTRIA — to join data blocks and external files to the TPTRIA code

3) SIGMN TPTRIA — containing the group constants

Additionally 2 interface data files - up to now prepared by DIAMANT2 to provide the results of the direct and adjoint two-dimensional transport calculations, respectively - are necessary. TPTRIA uses a third interface file in order to store the angle integrated flux values for the direct and adjoint calculations in a suitable order for later use.

Description of the input data contained in data block INPUT TPTRIA (in free format structure) denoted by the following KAPROS input card:

*KSIOX DBN=INPUT_TPTRIA,IND=1,TYP=CARD,PMN=PRDUM ('_' means 'blank')

Card	Variable		Meaning
K1(17A4)	TITLE(17):		Information Text
K2(24I3)	IFM:		Number of fissile isotopes
	IDM:		Number of delayed neutron groups
	IFEX:	1	Exact perturbation is calculated.
		0	This is not done.
	IFFP:	1	The first order perturbation for a material probe is calculated.
		0	This is not done.

IFPG:	1	Global input of perturbed region (K5)
	0	Pointwise input of perturbed region (K6)
		If IFFP=0, this integer has no meaning.
IFGS:	1	Group and space dependent reactivity is printed.
	0	This is not done.
IFS:	1	Space dependent reactivity is printed.
	0	This is not done.
IFG:	1	Group dependent reactivity is printed.
	0	This is not done.
IFK:	1	Corrected criticality factor for isotope dependent fission spectrum is printed.
	0	This is not done.
IPAF:	1	Direct and adjoint angular fluxes are printed.
	0	This is not done.
IPFX:	1	Direct and adjoint total fluxes are printed.
	0	This is not done.
IPCS:	1	Group cross sections are printed according to the arrays defined in Chap. III, 3.
	0	This is not done.
IDIAM1:		Unit number for first interface file containing results of the direct calculation
IDIAM2:		Unit number for second interface file containing results of the adjoint calculation

	IDSK2:	Unit number for file containing intermediate data
K3	NAIST(IFM) (9A8)	Names of fissile isotopes
S1	End of TPTRIA input for IFFP=0.	
	If IFFP=1 K4 is read.	
K4(I3,3E12.4)	NFOP	Number of first order perturbation calculations
	HPED:	Height of a core including the extrapolation distance for the calculation of the reactivity of a probe by the first order perturbation calculation. HPED = 0. indicates that in the first order perturbation calculation the probe height is assumed to cover the full (extrapolated) core height.
	ZL:	Lower coordinate of the perturbed probe in units of cm, where z=0 is the symmetry plane of the reactor.
	ZU:	Upper coordinate of the perturbed probe in units of cm. (for HPED = 0. the values of ZL and ZU are not relevant)
S2	If IFPG=1, K5, if IFPG=0, K6 are read NFOP times	
K5(5I3)	MPR:	Mixture index of the probe which replaces the mixture of the unperturbed system.
	IL:	Left mesh index of the probe in I-direction (for indexing see Fig. 3)

	IR:	Right mesh index in I-direction
	JL:	First mesh index of the probe in J-direction
	JU:	Last mesh index in J-direction
S3	End of TPTRIA input for IFFP=1 and IFPG=1	
K6(24I3)	MPR:	Mixture index of the probe which replaces the mixture of the unperturbed system of IPT triangular meshes.
	IPT:	Total number of triangular meshes.
	IPX(IPT):	Indices of triangular meshes in I-direction (for indexing see Fig. 3)
	JPY(IPT):	Indices of triangular meshes in J-direction
S4	End of TPTRIA input for IFFP=1 and IFPG=0	

Description of the input data contained in data block INIT READ TPTRIA denoted by the following KAPROS input card

```
*KSIOX DBN=INIT_READ_TPTRIA,IND=1,TYP=CARD,PMN=RRDUM   ('_' means 'blank')

36 'INTERFACE 1'  1  6  0  0
37 'INTERFACE 2'  1  6  0  0
15 'INTERFACE IDSK2' 1  6  0  0
10 'INPUT TPTRIA'  1  1  0  0
*$*$
```

according to the description of READKO /8/.

In the above example IDIAM1 = 36, IDIAM2 = 37 and IDSK2 = 15 are chosen. These numbers may be chosen arbitrarily but they must correspond to the unit numbers of files containing the DIAMANT2 results (see sample problem in Appendix).

7. Output Description of TPTRIA Code

The effective neutron generation time Λ and the delayed neutron fraction β_i^j for each fissile isotope, β^j for each mixture, and the sum over mixtures are always printed. The criticality factor corrected for the isotope dependency of prompt fission spectrum and the influence of the difference of the delayed neutron spectrum from the prompt neutron spectrum is printed separately according to the input specification.

The space and energy dependent reactivities are printed according to the input specification in the following order: mesh indices i and j, group index, reactivities due to capture $\rho_{cg}(\vec{r}_{ij})$, absorption by fission cross section $\rho_{fg}(\vec{r}_{ij})$, removal $\rho_{rg}(\vec{r}_{ij})$, buckling in z-direction, scattering out $\rho_{sog}(\vec{r}_{ij})$, scattering in $\rho_{sig}(\vec{r}_{ij})$,*) scattering out + in $\rho_{sog}(\vec{r}_{ij})+\rho_{sig}(\vec{r}_{ij})$, scattering in from g-1, $\rho_{sig\leftarrow g-1}(\vec{r}_{ij})$, fission source $\rho_{fsg}(\vec{r}_{ij})$, adjoint fission source $\rho_{afg}(\vec{r}_{ij})$ and total $\rho_g(\vec{r}_{ij})$. PSUM, NSUM and SUM mean the summation over energy group for positive, negative and total components, respectively. INTEGRAL or INTEG means integration over space.

The reactivity by a probe perturbation is printed as an integral over the specified triangular meshes.

An output example is shown in the Appendix.

*) The user should be aware that contrary to usual diffusion perturbation calculations, in the transport perturbation calculations the scattering-out- and the scattering-in-term do contain the contribution of within-group scattering.

8. Example of Input Data to DIAMANT2 Code

Example of input data to DIAMANT2 code for the perturbation calculation is shown below in order to show the meaning of the integers and arrays used in TPTRIA code (for explanation of the variables see section III.5, page 38).

ISCT=1

IM=6

JM=3

MT=7: Total number of mixtures including anisotropic scattering component in the array C.

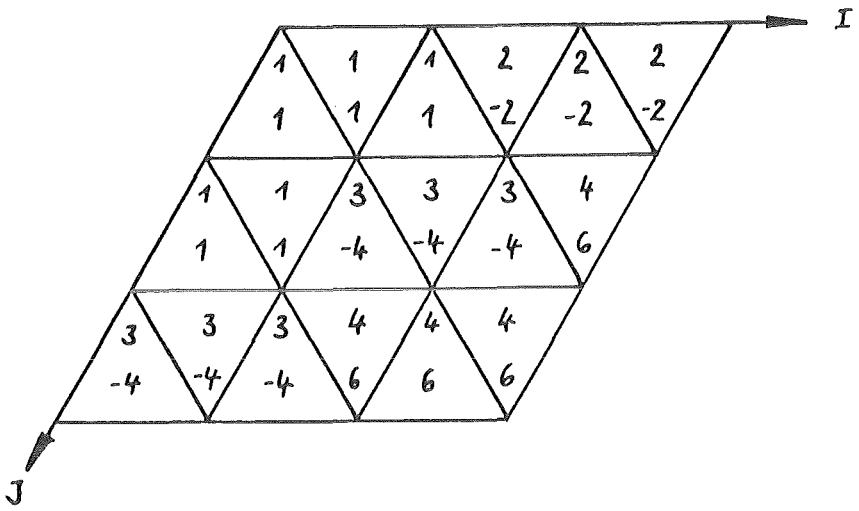
MTP=5: Number of mixtures

IMAT(MTP): = 1, -2, -3, 4, 5

IPLATZ(MTP): = 1, 2, 4, 6, 7

Examples of the arrays MTS, MTC, MTSP and MTCP are shown in Figs. 8 and 9. The minus sign of the mixture index indicates that such mixtures have anisotropic scattering components.

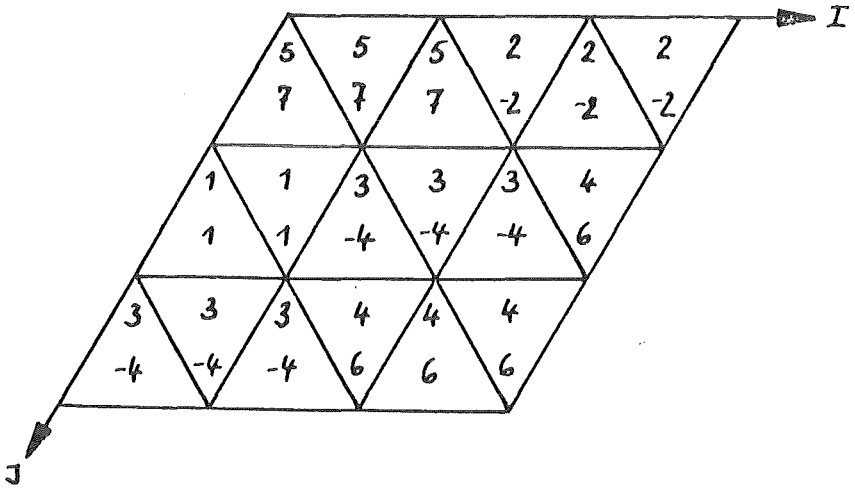
MTC(IM,JM) and IMAT(MTP) in TPTRIA correspond to MIXDIS(MCMM,MCM) and MATTAB(MAT) in DIAMANT2 code, respectively, with IM=MCMM, JM=MLM and MTP=MAT.



Upper index MTS(IM,JM)

Lower index MTC(IM,JM)

Fig. 8 Mixture index for direct equation



Upper index MTSP(IM,JM)

Lower index MTCP(IM,JM)

Fig. 9 Mixture index for adjoint equation

IV. NUMERICAL EXAMPLES

1. Exact Perturbation Calculation for Godiva

In order to check the program, sample calculations are done for the small fast reactor Godiva /5/. Godiva is a homogeneous bare reactor of spherical shape with a radius 8.741 cm, which is approximated by triangular cells of side length 1.5963 cm in x-y plane with IM=30 and JM=15, and the leakage in z-direction is approximated by space dependent bucklings.

The same input data of four group constants as used before by K. Küfner /6/ for another purpose was used in the DIAMANT2 calculation, which is shown in the Appendix. Perturbed cross sections for the adjoint calculation are made by increasing the number density for Pu^{239}, which is added to the core composition by an amount of 5 % of the number density of U^{235} originally present in that composition. This perturbation is sufficiently large to get the accurate reactivity from the difference of the criticality factors for unperturbed direct and perturbed adjoint calculations.

These reactivities from the criticality factors and those by the exact perturbation calculations are shown in Table II for the cases of S2, S4, S6 and S8 approximations together with CPU time and the necessary regions of the fast memories. The convergence error criteria of 10^{-4} was used both for the criticality factor and flux. From this Table, it is seen that the agreement between the reactivities from the criticality factors and the perturbation calculations is very good, from which we can confirm that the perturbation calculation is adequate.

In the present sample problem, the reactivity by the S4 approximation has a sufficient accuracy, whose error is 0.2 % compared with the S8 approximation. The output list for S8 approximation is given in the Appendix.

In addition to the reactivities ρ derived from the criticality factors and those obtained by perturbation calculations, Table II also shows the correction ρ' to the criticality factor which results from taking into account the isotope dependence of the prompt fission spectrum and the difference of the delayed neutron fission spectra from the prompt fission spectrum, as given in equations (80) through (82) of Section II.3. Obviously its magnitude is fairly small but this depends on the choice of the global fission spectrum applied in the DIAMANT2 calculations.

Table II. Reactivity for GODIVA by the Exact Perturbation Calculation

DIAMANT2					TPTRIA			
Order of S_n	CPU Time* (sec)	Regions of Memory (K words)	k k^+	ρ	ρ	ρ'	CPU Time* (sec)	Regions of Memory (K words)
2	0.8 0.9	12	0.99106 1.06022	6.582×10^{-2}	6.588×10^{-2}	-4.3×10^{-5}	0.5	19.6
4	1.8 2.4	22	1.00754 1.07680	6.384×10^{-2}	6.377×10^{-2}	-5.5×10^{-5}	0.5	32.3
6	3.5 4.2	36	1.00827 1.07749	6.372×10^{-2}	6.374×10^{-2}	-5.6×10^{-5}	0.6	50.4
8	5.7 6.7	55	1.00828 1.07750	6.371×10^{-2}	6.374×10^{-2}	-5.6×10^{-5}	0.6	73.8

* on a SIEMENS 7890 computer

2. First Order Perturbation Calculation for Godiva

In order to check the first order perturbation option, sample calculations are done also for the small fast reactor Godiva. In this case, a space-independent buckling in z-direction is determined such that the criticality factor becomes close to 1. As seen in Table III, the criticality factor is close to 1 within 1 % difference when the effective height is chosen to be 18.94 cm.

The material worths for B^{10}, Pu^{239} and Pu^{240} are calculated for a probe extending between the axial positions ZL = 0. and ZU = 0.1 cm placed in the central cell of (I,J)=(15,8). The material worths, the reactivities per mole are shown in Table IV calculated for the case 3 of Table III, which seems to be reasonable compared with the experimental values /5/, although there is a systematic discrepancy. The fact that the C/E values in Table IV are around 0.80 and are, therefore, deviating appreciably from the usually desirable value of unity is most probably due to the application of a universal, group- and space-independent buckling. This concept is obviously not adequate to approximate the spherical shape of the real GODIVA assembly. It is, however, necessary for first order perturbation calculations, because otherwise the finite extension of the probe cannot be taken into account in an easy and appropriate manner. The application of this inadequate buckling concept in that example evidently influences the normalization integral, the real and adjoint flux distribution near the center of the assembly, and, thus, also the importance and reactivity effects of probes inserted close to that position. For this reason the deviation between calculated and experimental values is not at all surprising. The test case was chosen because the input data and experimental values were easily available. The fact that the C/E value is practically the same for all three isotopes in Table IV is considered to be a confirmation that the perturbation code TPTRIA can also be reliably applied for the case of first order perturbation theory. This confirmation is supported by the fact that internally in the code exact and first order perturbation cases are treated nearly in the same manner and the correctness of the absolute reactivity calibration was shown in Section IV.1.

Table III. Criticality Factor versus Buckling

Case	Height (cm)	B^2 (cm^{-2})	Criticality factor
1	13.72	0.05242	0.8502
2	17.47	0.03232	0.9747
3	18.94	0.02750	1.0099

Table IV. Material Worth at the Center of Godiva

Isotope	Reactivity, 10^{-5}/mole		
	Calculation	Experiment	C/E
B^{10}	-287	-365±7	0.79
Pu^{239}	1552	1881±12	0.83
Pu^{240}	890	1122±130	0.79

3. Conclusion

A transport perturbation code for regular triangular meshes is developed and sample calculations for the cases of the exact and first order perturbation problems for the critical assembly GODIVA are performed. Using relatively large perturbed cross sections, it is confirmed that the reactivity from the difference of criticality factors agrees well with that from the exact perturbation calculation.

Acknowledgement

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APPENDIX

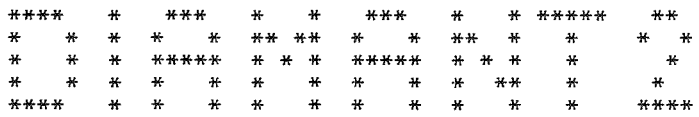
Sample Problem Output and Input List for Exact Perturbation

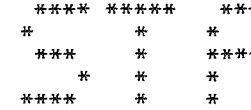
Sample problem output and input list for GODIVA is shown as obtained from a KAPROS-Job for the case of the exact perturbation with S2 approximation in the following (some less important parts were omitted).

```
11:20:52 IAT2000 JOB 4709 INR654AA SELECTED M7890    GRP=JGOP
          *
          *
          *

//INR654AA JOB (0654,107,P6M2D),KOBAYASHI,REGION=2400K,TIME=(,30),     *
//             MSGCLASS=H,NOTIFY=INR654,USER=INR654,PASSWORD=
//*MAIN LINES=10                                                        00031026
//*********************************************************************  00040000
//*  SAMPLE JOB FOR CONNECTED CALCULATION OF DIAMANT2 (SOLUTION OF      00050036
//*              THE NEUTRON TRANSPORT EQUATION FOR DIRECT AND ADJOINT  00051036
//*              PROBLEMS IN 2-DIMENSIONAL REGULAR TRIANGULAR GEOMETRY) 00052037
//*              AND TPTRIA (TRANSPORT PERTURBATION CALCULATION) IN THE 00052137
//*              FRAMEWORK OF THE KARLSRUHE PROGRAMME SYSTEM KAPROS.    00053037
//*  SUBMIT DATEI: TS0654.TPTRIA.CNTL(SAMPLEPR)                         00060032
//*********************************************************************  00120000
//TESTDIAM  EXEC  KSG7                                                  00130037
//K.FT17F001 DD DISP=SHR,DSN=INR986.KSA1.A,LABEL=(,,,IN)                00200012
//K.FT13F001 DD UNIT=SYSDA,SPACE=(TRK,(5,1))                           00201000
//K.FT15F001 DD UNIT=SYSDA,SPACE=(TRK,(15,5)),DCB=DCB.VBS              00203000
//K.FT16F001 DD UNIT=SYSDA,SPACE=(TRK,(15,5))                          00220000
//K.FT37F001 DD UNIT=SYSDA,SPACE=(TRK,(15,5)),DCB=DCB.VBS              00240000
//K.FT38F001 DD UNIT=SYSDA,SPACE=(TRK,(15,5)),DCB=DCB.VBS              00250000
//K.SYSIN DD *                                                         00270000
/*                                                                     00370000

          *
          *
          *
*******************************************************************************
IEF375I  JOB /INR654AA/ START 86182.1120
IEF376I  JOB /INR654AA/ STOP  86182.1121 CPU    0MIN 03.01SEC SRB    0MIN 00.29SEC
*******************************************************************************
```





THIS IS A MAJOR REVISION OF THE DIAMANT2 CODE (VERSION 1.4) - NEW RELEASE: 2.0
THIS VERSION IS PROGRAMMED ACCORDING TO THE FORTRAN77 STANDARDS
A GREAT DEAL OF EFFORT HAS GONE INTO CODE RESTRUCTURING, CLARIFICATION AND DOCUMENTATION
THIS VERSION SHOULD RUN EFFICIENTLY ON VECTOR COMPUTERS, TOO

```
*********************************************************************
*                                                                   *
* EINHEIT 14 REALISIERT ALS NORMALER DB: DIAMANT2 EINGABE     1 *
* EINHEIT 15 REALISIERT ALS EXTERNE EINHEIT                     *
* EINHEIT 16 REALISIERT ALS EXTERNE EINHEIT                     *
* EINHEIT 17 REALISIERT ALS NORMALER DB: SIGMN                1 *
* EINHEIT 37 REALISIERT ALS EXTERNE EINHEIT                     *
* EINHEIT 38 REALISIERT ALS EXTERNE EINHEIT                     *
*                                                                   *
*********************************************************************

FREE MAIN STORAGE PLACE IN THE BEGINNING :    312668 WORDS

TITLE OF THIS RUN:

*************************************************************************
*                                                                       *
*    SAMPLE PROBLEM ; HOMOGENEOUS FINITE REACTOR (GODIVA) , S2          *
*                                                                       *
*************************************************************************

   NO  FLUX  GUESS
```

```
     DIAMANT2   INPUT   CONTROL
     ========================

K1:      SAMPLE PROBLEM ; HOMOGENEOUS FINITE REACTOR (GODIVA) , S2
K2:
ID        2      IDENTIFICATION NUMBER OF THE RUN
ITH       0      THEORY OPTION (0=REGULAR , 1=ADJOINT)
ISN       2      ORDER OF THE ANGLE DISCRETIZATION (MAXIMUM ALLOWED : 12 )
IGM       4      NUMBER OF ENERGY GROUPS (MAXIMUM ALLOWED : 26 )
IEVT      1      PROBLEM TYPE ( 0: EXTERNAL SOURCE PROBLEM ; 1: EIGENVALUE PROBLEM)
MLM      15      NUMBER OF INTERVALS ON THE OBLIQUE SIDE OF THE REFERENCE PARALLELOGRAM
MCM      15      NUMBER OF INTERVALS ON THE HORIZONTAL SIDE OF THE REFERENCE PARALLELOGRAM
MT       15      NUMBER OF MIXTURES TO BE USED
MAT      15      NUMBER OF XS-TABLES ( MAT = MT FOR ISOTROPIC CASE , MAT >= MT FOR ANISOTROPIC CASE)
ICM      50      MAXIMUM NUMBER OF OUTER ITERATIONS
IIM      10      MAXIMUM NUMBER OF INNER ITERATIONS
IIL       5      INITIAL-MAXIMUM NUMBER OF INNER ITERATIONS DURING FIRST FEW OUTER ITERATIONS
KTR       0      CONTROL OF PRINTOUT OF NEUTRON FLUXES (-1/0/1 : ALL/NONE/SELECTED FLUXES TO BE PRINTED)
KDUM      0      CROSS-SECTION INPUT BY SIGMN-BLOCK ( 1=NO, 0=YES)
NFPERT   37      FORTRAN UNIT FOR INTERFACE FILE TO PERTURBATION MODULE
NFDMPN    0      FINAL FLUX WRITTEN ON UNIT (0=NOT USED, >0 : FORTRAN UNIT NUMBER OF DATA SET)
NFDMPO    0      INITIAL FLUX READ FROM UNIT (0=NOT USED, >0 : FORTRAN UNIT NUMBER OF DATA SET)
INBO      0      CONTROL OF VARIOUS BOUNDARY FLUX OPTIONS ( 0: NO BOUNDARY FLUX; 1: BOUNDARY FLUX BY INTERVAL AND GROUP;
                                                            2: BY ENERGY SPECTRUM AND SOURCE)

K4:
IQUELL    0      DISTRIBUTED SOURCE OPTION INDICATOR ( 0: NONE; 1: GIVEN BY TRIANGLE AND GROUP; -1: GIVEN BY MIXTURE AND GROUP;
                                                       2: GIVEN BY SPECTRUM AND SOURCE FOR EACH TRIANGLE;
                                                      -2: GIVEN BY SPECTRUM AND SOURCE FOR EACH MIXTURE)
MBK       3      BUCKLING CORRECTION OPTION ( 0: NONE; 1: CONSTANT VALUE; 2: GROUP DEPENDENT VALUES; 3: GROUP AND MIXTURE DEPENDENT)
IQUER     1      PRINT CROSS-SECTION TABLES (0=NO,1=YES)
ID1       0      ACTIVATION RATES OR DENSITIES FOR FISSION CROSS-SECTION ( 0/1/2 : NONE/DENSITY/RATE )
ID2       0      ACTIVATION RATES OR DENSITIES FOR CAPTURE ACTIVATION CROSS SECTION  ( 0/1/2 : NONE/DENSITY/RATE )
ID3       0      ACTIVATION RATES OR DENSITIES FOR ABSORBTION CROSS-SECTION ( 0/1/2 : NONE/DENSITY/RATE )
ID4       0      ACTIVATION RATES OR DENSITIES FOR 'NUSF' CROSS-SECTION ( 0/1/2 : NONE/DENSITY/RATE )
ID5       0      ACTIVATION RATES OR DENSITIES FOR TOTAL CROSS-SECTION ( 0/1/2 : NONE/DENSITY/RATE )
ISCT      0      ANISOTROPY OPTION INDICATOR ( 0: ISOTROPIC; MAXIMUM ALLOWED: 6 )
KAUSW     0      NEUTRON BALANCES SELECTOR ( 0/1/10/11 : GLOBAL/GLOBAL AND ZONES/GLOBAL AND MIXTURES/ALL )
NFANI1    0      FORTRAN UNIT FOR ANISOTROPY WORKING DATASET
NFSCR1    0      FORTRAN UNIT FOR AUXILIARY WORKING DATASET FOR STORAGE OPTIMIZATION 2
INORM     1      FLUX NORMALIZATION INDICATOR ( 1: ONE FISSION; 2: POWER = 1 WATT )

K5:
EPS     1.0000E-04     CONVERGENCE CRITERION FOR OUTER ITERATIONS ( < 0: INTEGRAL; > 0: POINTWISE; = 0: USE TEPS )
EV      1.0000E+00     START VALUE FOR EIGENVALUE
BF      0.0            BUCKLING HEIGHT ( USED IF MBK = 1 )
H       1.5963E+00     SIDE OF TRIANGLE (IN CM)
EPSA    1.0000E-04     CONVERGENCE TEST SELECTOR FOR INNER ITERATIONS ( < 0: INTEGRAL; > 0; POINTWISE; = 0: USE EPS )
TEPS    0.0            CONVERGENCE CRITERION FOR OUTER ITERATIONS IF EIGENVALUE BOUNDS ARE REQUESTED (EPS=0.0)

K7:
USED MIXTURE NUMBERS

      1    2    3    4    5    6    7    8    9   10
     11   12   13   14   15
```

```
          *
          *
          *

BUCKLING

MIXTURE:  1
      GROUP    1            2            3            4
         0.11245E+00  0.17446E+00  0.40163E+00  0.54160E+00
MIXTURE:  2
      GROUP    1            2            3            4
         0.40720E-01  0.52420E-01  0.79280E-01  0.90050E-01
MIXTURE:  3
      GROUP    1            2            3            4
         0.26310E-01  0.32150E-01  0.44120E-01  0.48480E-01
MIXTURE:  4
      GROUP    1            2            3            4
         0.21220E-01  0.25380E-01  0.33530E-01  0.36390E-01
MIXTURE:  5
      GROUP    1            2            3            4
         0.19040E-01  0.22550E-01  0.29290E-01  0.31610E-01
MIXTURE:  6
      GROUP    1            2            3            4
         0.18070E-01  0.21310E-01  0.27460E-01  0.29570E-01
MIXTURE:  7
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE:  8
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE:  9
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE: 10
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE: 11
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE: 12
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE: 13
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE: 14
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE: 15
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
```

```
* * * * * INTERFACE FILES ARE BEING CREATED FOR PERTURBATION THEORY MODULE ON UNIT 37

**************************************************************************
* EINHEIT 37 (INTERFACE 2     ) VERWENDET MIT SEQUENZNUMMER:   1      *
**************************************************************************

          *
          *
          *

ANGULAR QUADRATURE PERFORMED WITH    P N  SET

CHECK OF SN CONSTANTS:

   SUM (WEIGHT)          :    1.0000E+00
   SUM (WEIGHT*MUE)      :   -1.1921E-07
   SUM (WEIGHT*ETA)      :    0.0
   SUM (WEIGHT*MUE**2)   :    3.3333E-01
   SUM (WEIGHT*ETA**2)   :    3.3333E-01
   SUM (WEIGHT*MUE*ETA)  :    0.0

      DIRECTIONS                 WEIGHTS

     MUE           ETA
 -0.81650E+00   0.0             0.0               1  NOT USED
 -0.70711E+00  -0.40825E+00    0.16667E+00        2
 -0.25636E-06  -0.81650E+00    0.16667E+00        3
  0.70711E+00  -0.40825E+00    0.16667E+00        4
 -0.81650E+00   0.0             0.0               5  NOT USED
 -0.70711E+00   0.40825E+00    0.16667E+00        6
 -0.25636E-06   0.81650E+00    0.16667E+00        7
  0.70711E+00   0.40825E+00    0.16667E+00        8

  DIRECTIONS NUMBER          REFLECTIVE DIRECTIONS
IN ORDER OF EXPLORATION      LEFT     TOP    RIGHT
       2                       3        8        6        1
       4                       8        6        3        2
       7                       6        3        8        3
       8                       7        2        4        4
       6                       2        4        7        5
       3                       4        7        2        6


 FISSION FRACTIONS
 0.76051E+00 0.23949E+00 0.0         0.0
 GROUP SUM= 1.00000E+00
```

CROSS SECTIONS

XS-TABLE 1

TYPE \ GROUP	1	2	3	4
SFISS	0.57625E-01	0.58610E-01	0.15707E+00	0.41992E+00
SCAPT	0.30383E-02	0.10959E-01	0.54796E-01	0.21641E+00
SN2N	0.44961E-03	0.0	0.0	0.0
STR	0.23204E+00	0.34271E+00	0.87561E+00	0.10605E+01
SABS	0.60214E-01	0.69569E-01	0.21187E+00	0.63633E+00
NUSF	0.15490E+00	0.14503E+00	0.38073E+00	0.10174E+01
STRTR	0.23282E+00	0.36235E+00	0.90346E+00	0.12787E+01
S G->G	0.11998E+00	0.29275E+00	0.69149E+00	0.64242E+00
G- 1->G	0.0	0.52597E-01	0.24769E-04	0.10579E-03
G- 2->G	0.0	0.0	0.21643E-04	0.17130E-06
G- 3->G	0.0	0.0	0.0	0.73340E-06

XS-TABLE 2

TYPE \ GROUP	1	2	3	4
SFISS	0.57625E-01	0.58610E-01	0.15707E+00	0.41992E+00
SCAPT	0.30383E-02	0.10959E-01	0.54796E-01	0.21641E+00
SN2N	0.44961E-03	0.0	0.0	0.0
STR	0.23204E+00	0.34271E+00	0.87561E+00	0.10605E+01
SABS	0.60214E-01	0.69569E-01	0.21187E+00	0.63633E+00
NUSF	0.15490E+00	0.14503E+00	0.38073E+00	0.10174E+01
STRTR	0.23282E+00	0.36235E+00	0.90346E+00	0.12787E+01
S G->G	0.11998E+00	0.29275E+00	0.69149E+00	0.64242E+00
G- 1->G	0.0	0.52597E-01	0.24769E-04	0.10579E-03
G- 2->G	0.0	0.0	0.21643E-04	0.17130E-06
G- 3->G	0.0	0.0	0.0	0.73340E-06

XS-TABLE 3

TYPE \ GROUP	1	2	3	4
SFISS	0.57625E-01	0.58610E-01	0.15707E+00	0.41992E+00
SCAPT	0.30383E-02	0.10959E-01	0.54796E-01	0.21641E+00
SN2N	0.44961E-03	0.0	0.0	0.0
STR	0.23204E+00	0.34271E+00	0.87561E+00	0.10605E+01
SABS	0.60214E-01	0.69569E-01	0.21187E+00	0.63633E+00
NUSF	0.15490E+00	0.14503E+00	0.38073E+00	0.10174E+01
STRTR	0.23282E+00	0.36235E+00	0.90346E+00	0.12787E+01
S G->G	0.11998E+00	0.29275E+00	0.69149E+00	0.64242E+00
G- 1->G	0.0	0.52597E-01	0.24769E-04	0.10579E-03
G- 2->G	0.0	0.0	0.21643E-04	0.17130E-06
G- 3->G	0.0	0.0	0.0	0.73340E-06

XS-TABLE 4

TYPE \ GROUP	1	2	3	4
SFISS	0.57625E-01	0.58610E-01	0.15707E+00	0.41992E+00
SCAPT	0.30383E-02	0.10959E-01	0.54796E-01	0.21641E+00
SN2N	0.44961E-03	0.0	0.0	0.0
STR	0.23204E+00	0.34271E+00	0.87561E+00	0.10605E+01
SABS	0.60214E-01	0.69569E-01	0.21187E+00	0.63633E+00
NUSF	0.15490E+00	0.14503E+00	0.38073E+00	0.10174E+01
STRTR	0.23282E+00	0.36235E+00	0.90346E+00	0.12787E+01
S G->G	0.11998E+00	0.29275E+00	0.69149E+00	0.64242E+00
G- 1->G	0.0	0.52597E-01	0.24769E-04	0.10579E-03
G- 2->G	0.0	0.0	0.21643E-04	0.17130E-06
G- 3->G	0.0	0.0	0.0	0.73340E-06

XS-TABLE 5

TYPE \ GROUP	1	2	3	4
SFISS	0.57625E-01	0.58610E-01	0.15707E+00	0.41992E+00
SCAPT	0.30383E-02	0.10959E-01	0.54796E-01	0.21641E+00
SN2N	0.44961E-03	0.0	0.0	0.0
STR	0.23204E+00	0.34271E+00	0.87561E+00	0.10605E+01
SABS	0.60214E-01	0.69569E-01	0.21187E+00	0.63633E+00
NUSF	0.15490E+00	0.14503E+00	0.38073E+00	0.10174E+01
STRTR	0.23282E+00	0.36235E+00	0.90346E+00	0.12787E+01
S G->G	0.11998E+00	0.29275E+00	0.69149E+00	0.64242E+00
G- 1->G	0.0	0.52597E-01	0.24769E-04	0.10579E-03
G- 2->G	0.0	0.0	0.21643E-04	0.17130E-06
G- 3->G	0.0	0.0	0.0	0.73340E-06

XS-TABLE 6

TYPE \ GROUP	1	2	3	4
SFISS	0.57625E-01	0.58610E-01	0.15707E+00	0.41992E+00
SCAPT	0.30383E-02	0.10959E-01	0.54796E-01	0.21641E+00
SN2N	0.44961E-03	0.0	0.0	0.0
STR	0.23204E+00	0.34271E+00	0.87561E+00	0.10605E+01
SABS	0.60214E-01	0.69569E-01	0.21187E+00	0.63633E+00
NUSF	0.15490E+00	0.14503E+00	0.38073E+00	0.10174E+01
STRTR	0.23282E+00	0.36235E+00	0.90346E+00	0.12787E+01
S G->G	0.11998E+00	0.29275E+00	0.69149E+00	0.64242E+00
G- 1->G	0.0	0.52597E-01	0.24769E-04	0.10579E-03
G- 2->G	0.0	0.0	0.21643E-04	0.17130E-06
G- 3->G	0.0	0.0	0.0	0.73340E-06

XS-TABLE 7

GROUP TYPE	1	2	3	4
SFISS	0.61749E-01	0.62130E-01	0.16272E+00	0.45092E+00
SCAPT	0.30897E-02	0.11289E-01	0.58763E-01	0.23974E+00
SN2N	0.47435E-03	0.0	0.0	0.0
STR	0.24277E+00	0.35895E+00	0.91368E+00	0.11534E+01
SABS	0.64364E-01	0.73419E-01	0.22148E+00	0.69066E+00
NUSF	0.16816E+00	0.15536E+00	0.39676E+00	0.11033E+01
STRTR	0.24355E+00	0.37942E+00	0.94032E+00	0.13654E+01
S G->G	0.12458E+00	0.30598E+00	0.71872E+00	0.67474E+00
G- 1->G	0.0	0.54587E-01	0.27854E-04	0.12137E-03
G- 2->G	0.0	0.0	0.23279E-04	0.19056E-06
G- 3->G	0.0	0.0	0.0	0.75039E-06

XS-TABLE 8

GROUP TYPE	1	2	3	4
SFISS	0.61749E-01	0.62130E-01	0.16272E+00	0.45092E+00
SCAPT	0.30897E-02	0.11289E-01	0.58763E-01	0.23974E+00
SN2N	0.47435E-03	0.0	0.0	0.0
STR	0.24277E+00	0.35895E+00	0.91368E+00	0.11534E+01
SABS	0.64364E-01	0.73419E-01	0.22148E+00	0.69066E+00
NUSF	0.16816E+00	0.15536E+00	0.39676E+00	0.11033E+01
STRTR	0.24355E+00	0.37942E+00	0.94032E+00	0.13654E+01
S G->G	0.12458E+00	0.30598E+00	0.71872E+00	0.67474E+00
G- 1->G	0.0	0.54587E-01	0.27854E-04	0.12137E-03
G- 2->G	0.0	0.0	0.23279E-04	0.19056E-06
G- 3->G	0.0	0.0	0.0	0.75039E-06

XS-TABLE 9

GROUP TYPE	1	2	3	4
SFISS	0.61749E-01	0.62130E-01	0.16272E+00	0.45092E+00
SCAPT	0.30897E-02	0.11289E-01	0.58763E-01	0.23974E+00
SN2N	0.47435E-03	0.0	0.0	0.0
STR	0.24277E+00	0.35895E+00	0.91368E+00	0.11534E+01
SABS	0.64364E-01	0.73419E-01	0.22148E+00	0.69066E+00
NUSF	0.16816E+00	0.15536E+00	0.39676E+00	0.11033E+01
STRTR	0.24355E+00	0.37942E+00	0.94032E+00	0.13654E+01
S G->G	0.12458E+00	0.30598E+00	0.71872E+00	0.67474E+00
G- 1->G	0.0	0.54587E-01	0.27854E-04	0.12137E-03
G- 2->G	0.0	0.0	0.23279E-04	0.19056E-06
G- 3->G	0.0	0.0	0.0	0.75039E-06

XS-TABLE 10

TYPE \ GROUP	1	2	3	4
SFISS	0.61749E-01	0.62130E-01	0.16272E+00	0.45092E+00
SCAPT	0.30897E-02	0.11289E-01	0.58763E-01	0.23974E+00
SN2N	0.47435E-03	0.0	0.0	0.0
STR	0.24277E+00	0.35895E+00	0.91368E+00	0.11534E+01
SABS	0.64364E-01	0.73419E-01	0.22148E+00	0.69066E+00
NUSF	0.16816E+00	0.15536E+00	0.39676E+00	0.11033E+01
STRTR	0.24355E+00	0.37942E+00	0.94032E+00	0.13654E+01
S G->G	0.12458E+00	0.30598E+00	0.71872E+00	0.67474E+00
G- 1->G	0.0	0.54587E-01	0.27854E-04	0.12137E-03
G- 2->G	0.0	0.0	0.23279E-04	0.19056E-06
G- 3->G	0.0	0.0	0.0	0.75039E-06

XS-TABLE 11

TYPE \ GROUP	1	2	3	4
SFISS	0.61749E-01	0.62130E-01	0.16272E+00	0.45092E+00
SCAPT	0.30897E-02	0.11289E-01	0.58763E-01	0.23974E+00
SN2N	0.47435E-03	0.0	0.0	0.0
STR	0.24277E+00	0.35895E+00	0.91368E+00	0.11534E+01
SABS	0.64364E-01	0.73419E-01	0.22148E+00	0.69066E+00
NUSF	0.16816E+00	0.15536E+00	0.39676E+00	0.11033E+01
STRTR	0.24355E+00	0.37942E+00	0.94032E+00	0.13654E+01
S G->G	0.12458E+00	0.30598E+00	0.71872E+00	0.67474E+00
G- 1->G	0.0	0.54587E-01	0.27854E-04	0.12137E-03
G- 2->G	0.0	0.0	0.23279E-04	0.19056E-06
G- 3->G	0.0	0.0	0.0	0.75039E-06

XS-TABLE 12

TYPE \ GROUP	1	2	3	4
SFISS	0.61749E-01	0.62130E-01	0.16272E+00	0.45092E+00
SCAPT	0.30897E-02	0.11289E-01	0.58763E-01	0.23974E+00
SN2N	0.47435E-03	0.0	0.0	0.0
STR	0.24277E+00	0.35895E+00	0.91368E+00	0.11534E+01
SABS	0.64364E-01	0.73419E-01	0.22148E+00	0.69066E+00
NUSF	0.16816E+00	0.15536E+00	0.39676E+00	0.11033E+01
STRTR	0.24355E+00	0.37942E+00	0.94032E+00	0.13654E+01
S G->G	0.12458E+00	0.30598E+00	0.71872E+00	0.67474E+00
G- 1->G	0.0	0.54587E-01	0.27854E-04	0.12137E-03
G- 2->G	0.0	0.0	0.23279E-04	0.19056E-06
G- 3->G	0.0	0.0	0.0	0.75039E-06

XS-TABLE 13

GROUP TYPE	1	2	3	4
SFISS	0.57625E-01	0.58610E-01	0.15709E+00	0.42025E+00
SCAPT	0.30707E-02	0.11060E-01	0.55575E-01	0.21961E+00
SN2N	0.44961E-03	0.0	0.0	0.0
STR	0.23223E+00	0.34312E+00	0.87665E+00	0.10645E+01
SABS	0.60246E-01	0.69670E-01	0.21266E+00	0.63987E+00
NUSF	0.15490E+00	0.14503E+00	0.38078E+00	0.10183E+01
STRTR	0.23300E+00	0.36276E+00	0.90446E+00	0.12825E+01
S G->G	0.12010E+00	0.29306E+00	0.69169E+00	0.64265E+00
G- 1->G	0.0	0.52633E-01	0.24921E-04	0.10688E-03
G- 2->G	0.0	0.0	0.21643E-04	0.17130E-06
G- 3->G	0.0	0.0	0.0	0.73340E-06

XS-TABLE 14

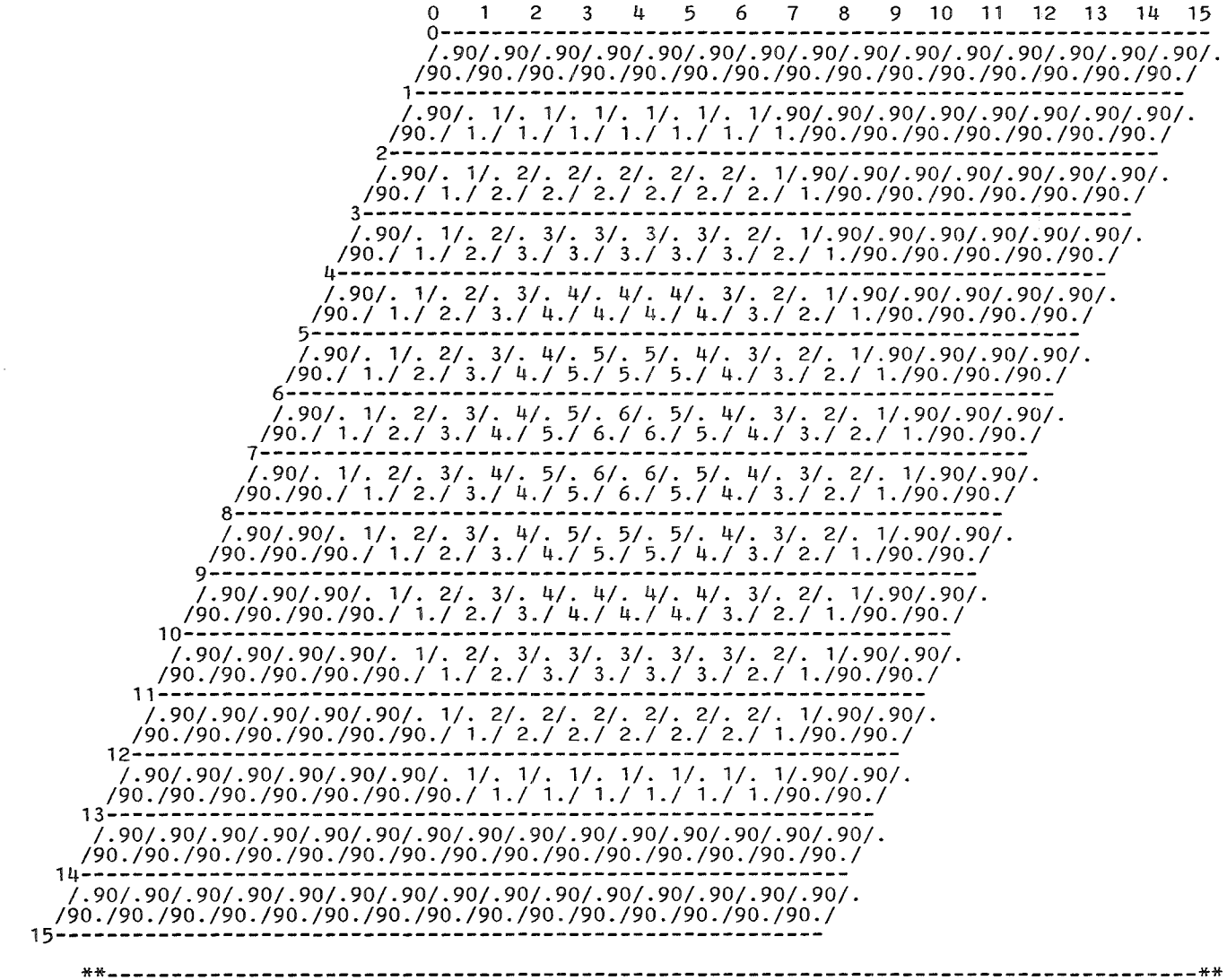
GROUP TYPE	1	2	3	4
SFISS	0.57808E-01	0.58767E-01	0.15733E+00	0.42141E+00
SCAPT	0.30406E-02	0.10973E-01	0.54975E-01	0.21757E+00
SN2N	0.45071E-03	0.0	0.0	0.0
STR	0.23252E+00	0.34343E+00	0.87733E+00	0.10650E+01
SABS	0.60398E-01	0.69740E-01	0.21230E+00	0.63899E+00
NUSF	0.15549E+00	0.14549E+00	0.38146E+00	0.10216E+01
STRTR	0.23329E+00	0.36311E+00	0.90511E+00	0.12829E+01
S G->G	0.12019E+00	0.29334E+00	0.69271E+00	0.64392E+00
G- 1->G	0.0	0.52685E-01	0.24906E-04	0.10649E-03
G- 2->G	0.0	0.0	0.21716E-04	0.17216E-06
G- 3->G	0.0	0.0	0.0	0.73416E-06

XS-TABLE 15

GROUP TYPE	1	2	3	4
SFISS	0.57775E-01	0.58647E-01	0.15710E+00	0.42029E+00
SCAPT	0.30471E-02	0.10983E-01	0.54950E-01	0.21748E+00
SN2N	0.44996E-03	0.0	0.0	0.0
STR	0.23249E+00	0.34341E+00	0.87723E+00	0.10640E+01
SABS	0.60372E-01	0.69630E-01	0.21205E+00	0.63776E+00
NUSF	0.15538E+00	0.14514E+00	0.38082E+00	0.10183E+01
STRTR	0.23326E+00	0.36308E+00	0.90502E+00	0.12822E+01
S G->G	0.12019E+00	0.29343E+00	0.69286E+00	0.64448E+00
G- 1->G	0.0	0.52674E-01	0.24852E-04	0.10655E-03
G- 2->G	0.0	0.0	0.21691E-04	0.17227E-06
G- 3->G	0.0	0.0	0.0	0.73456E-06

MATERIAL DISTRIBUTION ON THE INTERVALS

BOUNDARY CONDITIONS : 90=VACUUM, 91=REFLECTIVE, 92=FIXED BOUNDARY SOURCE



TITLE OF THIS RUN:

```
**************************************************************************
*                                                                        *
*    SAMPLE PROBLEM ; HOMOGENEOUS FINITE REACTOR (GODIVA) , S2           *
*                                                                        *
**************************************************************************
```

INFORMATION ON VECTORLENGTHS FOR THIS CASE :
MINIMUM VECTORLENGTH : 6
MAXIMUM VECTORLENGTH : 12
AVERAGE VECTORLENGTH : 9

OUTER CONVERGENCE BASED ON POINTWISE TEST

INNER CONVERGENCE BASED ON POINTWISE TEST

***** ITERATION MONITOR *****

OUTER ITERATIONS	INNER ITERATIONS	EV(LOW)	EIGENVALUE	EV(HIGH)	ERR(OUT)	GROUP	INNER ITERATIONS	ERR(INN)	POINTS OF MAX. ERRORS OUT/INN	REBAL. FACTOR	TIME USED SECONDS
0	0	0.0	1.000000	0.0	1.000E+00				(0, 1)		0.0
						1	0	0.0	(0, 1)	0.0	
						2	0	0.0	(0, 1)	0.0	
						3	0	0.0	(0, 1)	0.0	
						4	0	0.0	(0, 1)	0.0	
1	9	0.0	0.848886	1.204635	1.539E+00				(7, 2)		0.06000
						1	2	7.677E-02	(7, 7)	1.009E+00	
						2	3	5.544E-02	(8, 8)	1.012E+00	
						3	2	9.976E-02	(2, 2)	1.014E+00	
						4	2	7.309E-02	(2, 2)	1.003E+00	
2	17	0.701983	0.932343	1.089983	2.212E-01				(7, 7)		0.03000
	*										
	*										
	*										
12	119	0.990983	0.991056	0.991122	8.506E-05				(7, 8)		0.02000
						1	1	9.239E-05	(8, 7)	1.000E+00	
						2	1	7.457E-05	(7, 7)	1.000E+00	
						3	1	8.303E-05	(7, 7)	1.000E+00	
						4	1	8.029E-05	(8, 8)	1.000E+00	
13	123	0.991024	0.991070	0.991108	5.293E-05				(8, 7)		0.03000

NEGATIVE FLUX FIXUP ACTIVATED

0 TIMES	1	1	5.233E-05	(7, 7)	1.000E+00
0 TIMES	2	1	5.299E-05	(8, 7)	1.000E+00
0 TIMES	3	1	6.592E-05	(7, 8)	1.000E+00
0 TIMES	4	1	6.109E-05	(7, 8)	1.000E+00

***** INFORMATION *****
FINISHED BY CONVERGENCE OF OUTER ITERATIONS

A FINAL ITERATION IS PERFORMED

FLUX NORMALIZATION PARAMETER INORM= 1
(1: FLUXES NORMALIZED TO UNIT FISSION SOURCE IN THE CALCULATED REGION OF THE REACTOR
2: FLUXES NORMALIZED TO A POWER OF 1 WATT IN THE CALCULATED REGION OF THE REACTOR)

NORMALIZATION FACTOR IS : 4.1958E-03

NEUTRON BALANCE OF THE WHOLE SYSTEM

GR.	EXTERN.SOURCE	FISSION SOURCE	INSCATTER	TOTAL PRODUCT.	TOTAL FLUX	FISSION PROD.	SELFSCATTER
1	0.0	0.7605037E+00	0.0	0.7605037E+00	0.3677326E+01	0.5696094E+00	0.4412219E+00
2	0.0	0.2394934E+00	0.1934164E+00	0.4329098E+00	0.2904348E+01	0.4212319E+00	0.8502797E+00
3	0.0	0.0	0.1515286E-03	0.1515286E-03	0.5785085E-03	0.2202625E-03	0.4000354E-03
4	0.0	0.0	0.3255499E-05	0.3255499E-05	0.4737477E-05	0.4820098E-05	0.3043419E-05
5	0.0	0.9999971E+00	0.1935712E+00	0.1193568E+01	0.6582256E+01	0.9910663E+00	0.1291903E+01

GR.	ABSORPTION	BUCKL.LEAKAGE	OUTSCATTER	TOTAL LEAKAGE	TOTAL LOSSES	CAPTURE DENSITY	FISSION DENSITY
1	0.2214257E+00	0.2018750E+00	0.1934986E+00	0.1436936E+00	0.7604928E+00	0.1117283E-01	0.2119060E+00
2	0.2020540E+00	0.1411862E+00	0.7243648E-04	0.8959204E-01	0.4329046E+00	0.3182854E-01	0.1702258E+00
3	0.1225686E-03	0.1817655E-04	0.6120177E-07	0.1072290E-04	0.1515293E-03	0.3170018E-04	0.9086769E-04
4	0.3014563E-05	0.1564315E-06	0.0	0.8466424E-07	0.3255658E-05	0.1025240E-05	0.1989350E-05
5	0.4236051E+00	0.3430794E+00	0.1935710E+00	0.2332963E+00	0.1193551E+01	0.4303410E-01	0.3822246E+00

GR.	NEUTRON BAL.	NO-WEST	NO-EAST	SOUTH	SO-EAST	SO-WEST	NORTH
1	0.1000014E+01	0.2394895E-01	0.2394896E-01	0.2394895E-01	0.2394895E-01	0.2394896E-01	0.2394895E-01
2	0.1000011E+01	0.1493202E-01	0.1493202E-01	0.1493202E-01	0.1493201E-01	0.1493203E-01	0.1493203E-01
3	0.9999958E+00	0.1787149E-05	0.1787149E-05	0.1787151E-05	0.1787148E-05	0.1787151E-05	0.1787150E-05
4	0.9999511E+00	0.1411072E-07	0.1411072E-07	0.1411071E-07	0.1411071E-07	0.1411072E-07	0.1411072E-07
5	0.1000014E+01	0.3888276E-01	0.3888277E-01	0.3888276E-01	0.3888275E-01	0.3888278E-01	0.3888277E-01

VOLUME-INTEGRATED FISSION SOURCE

GROUP	FISSIONS
1	0.76051E+00
2	0.23949E+00
3	0.0
4	0.0
5	0.10000E+01

TITLE OF THIS RUN:

```
**************************************************************************
*                                                                        *
*    SAMPLE PROBLEM ; HOMOGENEOUS FINITE REACTOR (GODIVA) , S2           *
*                                                                        *
**************************************************************************
```

********** FINAL ITERATION RESULT **********

OUTER CONVERGENCE BASED ON POINTWISE TEST

INNER CONVERGENCE BASED ON POINTWISE TEST

OUTER ITERATIONS	INNER ITERATIONS	EV(LOW)	EIGENVALUE	EV(HIGH)	ERR(OUT)	GROUP	INNER ITERATIONS	ERR(INN)	POINTS OF MAX. ERRORS OUT/INN	REBAL. FACTOR	TIME USED SECONDS
14	127	0.991049	0.991077	0.991099	3.016E-05				(8, 7)		0.03000
NEGATIVE FLUX FIXUP ACTIVATED											
0 TIMES						1	1	2.819E-05	(7, 7)	1.000E+00	
0 TIMES						2	1	3.368E-05	(8, 7)	1.000E+00	
0 TIMES						3	1	4.685E-05	(7, 8)	1.000E+00	
0 TIMES						4	1	3.982E-05	(7, 8)	1.000E+00	

NEGATIVE FLUX FIX UP SUMMARY FOR LAST OUTER ITERATION
IN EACH GROUP THERE ARE 1296 ANGULAR FLUXES CALCULATED

NEGATIVE ANGULAR FLUXES IN GROUP 1 : 0 TIMES ENCOUNTERED (= 0.0 PERCENT)
NEGATIVE ANGULAR FLUXES IN GROUP 2 : 0 TIMES ENCOUNTERED (= 0.0 PERCENT)
NEGATIVE ANGULAR FLUXES IN GROUP 3 : 0 TIMES ENCOUNTERED (= 0.0 PERCENT)
NEGATIVE ANGULAR FLUXES IN GROUP 4 : 0 TIMES ENCOUNTERED (= 0.0 PERCENT)

***** INFORMATION *****
FINISHED BY CONVERGENCE OF OUTER ITERATIONS

********** TIMING STATISTICS **********

TIME USED BY THE CASE WITH ID= 2 0.0140 MINUTES
AVERAGE TIME PER OUTER ITERATION 0.0010 MINUTES
INNER ITERATION USED 0.0108 MINUTES = 77.4 PER CENT

TIME USED BY THE WHOLE JOB UP TO NOW 0.0140 MINUTES

KEYWORD CONT ENCOUNTERED IN INPUT NOT EQUAL ENDE - CONTINUATION RUN EXPECTED

```
TITLE OF THIS RUN:

*************************************************************************
*                                                                       *
*    SAMPLE PROBLEM ; HOMOGENEOUS REACTOR (GODIVA) , S2, ADJOINT        *
*                                                                       *
*************************************************************************

   NO  FLUX  GUESS

      DIAMANT2   INPUT   CONTROL
      ==========================

 K1:     SAMPLE PROBLEM ; HOMOGENEOUS REACTOR (GODIVA) , S2, ADJOINT


 K2:
 ID       2      IDENTIFICATION NUMBER OF THE RUN
 ITH      1      THEORY OPTION (0=REGULAR , 1=ADJOINT)

          *
          *
          *

 K4:
 IQUELL   0      DISTRIBUTED SOURCE OPTION INDICATOR ( 0: NONE; 1: GIVEN BY TRIANGLE AND GROUP; -1: GIVEN BY MIXTURE AND GROUP;
                                                      2: GIVEN BY SPECTRUM AND SOURCE FOR EACH TRIANGLE;
                                                     -2: GIVEN BY SPECTRUM AND SOURCE FOR EACH MIXTURE)
 MBK      3      BUCKLING CORRECTION OPTION ( 0: NONE; 1: CONSTANT VALUE; 2: GROUP DEPENDENT VALUES; 3: GROUP AND MIXTURE DEPENDENT)
 IQUER    1      PRINT CROSS-SECTION TABLES (0=NO,1=YES)

          *
          *
          *

 K5:
 EPS     1.0000E-04     CONVERGENCE CRITERION FOR OUTER ITERATIONS ( < 0: INTEGRAL; > 0: POINTWISE; = 0: USE TEPS )
 EV      1.0000E+00     START VALUE FOR EIGENVALUE
 BF      0.0            BUCKLING HEIGHT ( USED IF MBK = 1 )
 H       1.5963E+00     SIDE OF TRIANGLE (IN CM)
 EPSA    1.0000E-04     CONVERGENCE TEST SELECTOR FOR INNER ITERATIONS ( < 0: INTEGRAL; > 0; POINTWISE; = 0: USE EPS )
 TEPS    0.0            CONVERGENCE CRITERION FOR OUTER ITERATIONS IF EIGENVALUE BOUNDS ARE REQUESTED (EPS=0.0)

 K7:
 USED MIXTURE NUMBERS

        1    2    3    4    5    6    7    8    9   10
       11   12   13   14   15
```

```
          *
          *
          *

BUCKLING

MIXTURE:  1
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE:  2

          *
          *
          *
MIXTURE:  6
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE:  7
      GROUP    1            2            3            4
         0.54160E+00  0.40163E+00  0.17446E+00  0.11245E+00
MIXTURE:  8
      GROUP    1            2            3            4
         0.90050E-01  0.79280E-01  0.52420E-01  0.40720E-01
MIXTURE:  9
      GROUP    1            2            3            4
         0.48480E-01  0.44120E-01  0.32150E-01  0.26310E-01
MIXTURE: 10
      GROUP    1            2            3            4
         0.36390E-01  0.33530E-01  0.25380E-01  0.21220E-01
MIXTURE: 11
      GROUP    1            2            3            4
         0.31610E-01  0.29290E-01  0.22550E-01  0.19040E-01
MIXTURE: 12
      GROUP    1            2            3            4
         0.29570E-01  0.27460E-01  0.21310E-01  0.18070E-01
MIXTURE: 13
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE: 14
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0
MIXTURE: 15
      GROUP    1            2            3            4
         0.0          0.0          0.0          0.0

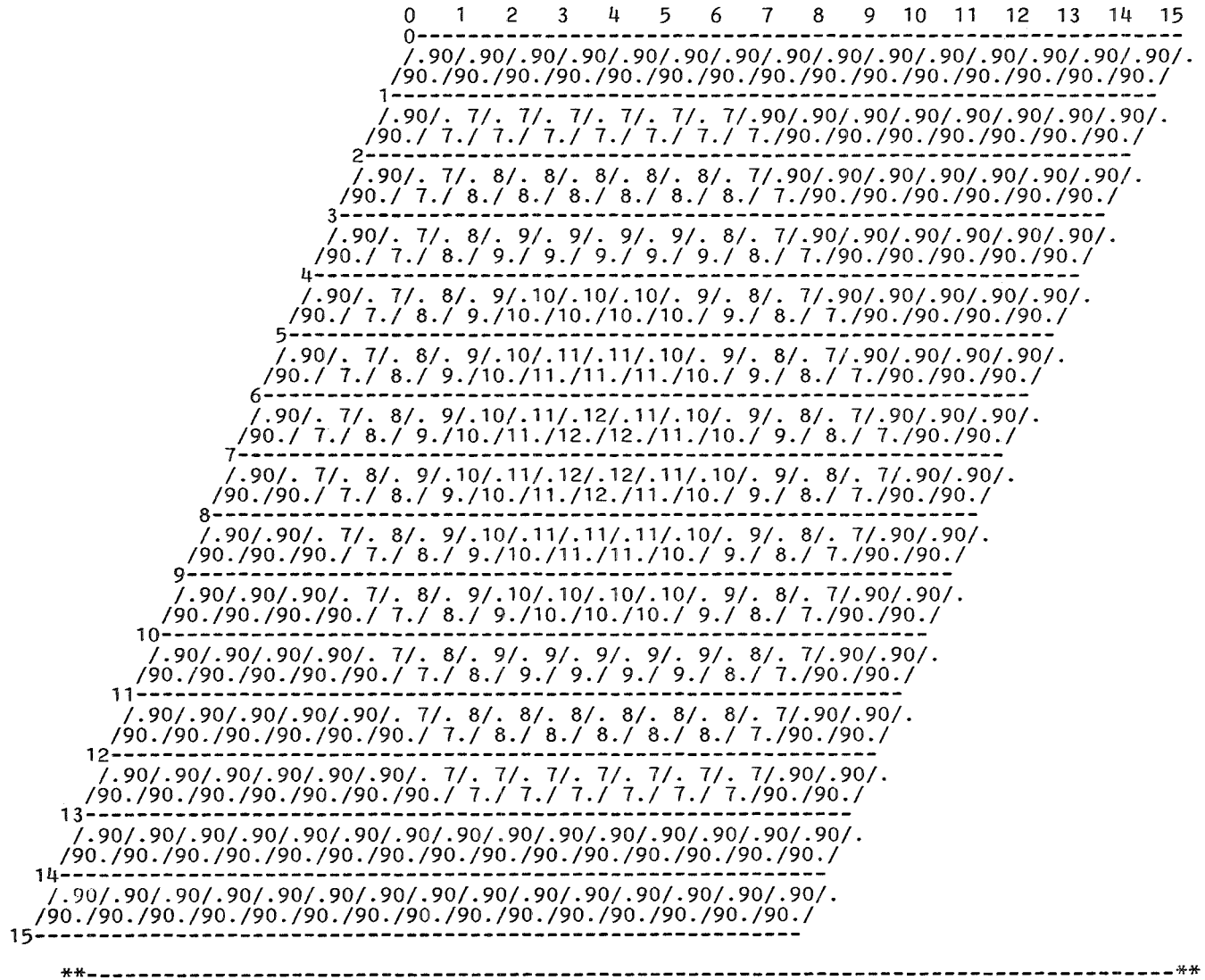

* * * * * INTERFACE FILES ARE BEING CREATED FOR PERTURBATION THEORY MODULE ON UNIT 38


**************************************************************************
* EINHEIT 38 ( INTERFACE 3     ) VERWENDET MIT SEQUENZNUMMER:   1       *
**************************************************************************

          *
          *
          *
```

MATERIAL DISTRIBUTION ON THE INTERVALS

BOUNDARY CONDITIONS : 90=VACUUM, 91=REFLECTIVE, 92=FIXED BOUNDARY SOURCE



TITLE OF THIS RUN:

```
**************************************************************************
*                                                                        *
*    SAMPLE PROBLEM ; HOMOGENEOUS REACTOR (GODIVA) , S2, ADJOINT         *
*                                                                        *
**************************************************************************
```

INFORMATION ON VECTORLENGTHS FOR THIS CASE :
MINIMUM VECTORLENGTH : 6
MAXIMUM VECTORLENGTH : 12
AVERAGE VECTORLENGTH : 9

OUTER CONVERGENCE BASED ON POINTWISE TEST

INNER CONVERGENCE BASED ON POINTWISE TEST

***** ITERATION MONITOR *****

OUTER ITERATIONS	INNER ITERATIONS	EV(LOW)	EIGENVALUE	EV(HIGH)	ERR(OUT)	GROUP	INNER ITERATIONS	ERR(INN)	POINTS OF MAX. ERRORS OUT/INN	REBAL. FACTOR	TIME USED SECONDS
0	0	0.0	1.000000	0.0	1.000E+00				(0, 1)		0.0
						1	0	0.0	(0, 1)	0.0	
						2	0	0.0	(0, 1)	0.0	
						3	0	0.0	(0, 1)	0.0	
						4	0	0.0	(0, 1)	0.0	
1	10	0.0	0.906907	1.405813	1.114E+00				(13, 7)		0.05000
						1	2	8.986E-02	(2, 2)	1.006E+00	
						2	3	7.120E-02	(8, 2)	1.014E+00	
						3	3	6.915E-02	(7, 7)	1.016E+00	
						4	2	6.678E-02	(8, 7)	1.008E+00	
2	20	0.830449	0.993960	1.279926	3.198E-01				(2, 2)		0.06000
	*										
	*										
	*										
13	147	1.060169	1.060246	1.060259	4.673E-05				(2, 2)		0.03000
						1	1	8.643E-05	(7, 8)	1.000E+00	
						2	1	9.418E-05	(7, 8)	1.000E+00	
						3	1	7.260E-05	(8, 8)	1.000E+00	
						4	1	5.394E-05	(8, 7)	1.000E+00	
14	151	1.060199	1.060250	1.060254	2.658E-05				(7, 7)		0.03000

NEGATIVE FLUX FIXUP ACTIVATED

0 TIMES	1	1	5.871E-05	(7, 7)	1.000E+00
0 TIMES	2	1	6.294E-05	(2, 2)	1.000E+00
0 TIMES	3	1	3.242E-05	(8, 2)	1.000E+00
0 TIMES	4	1	3.117E-05	(7, 7)	1.000E+00

***** INFORMATION *****
FINISHED BY CONVERGENCE OF OUTER ITERATIONS

A FINAL ITERATION IS PERFORMED

FLUX NORMALIZATION PARAMETER INORM= 1
(1: FLUXES NORMALIZED TO UNIT FISSION SOURCE IN THE CALCULATED REGION OF THE REACTOR
2: FLUXES NORMALIZED TO A POWER OF 1 WATT IN THE CALCULATED REGION OF THE REACTOR)

NORMALIZATION FACTOR IS : 6.8991E-04

NEUTRON BALANCE OF THE WHOLE SYSTEM

GR.	EXTERN.SOURCE	FISSION SOURCE	INSCATTER	TOTAL PRODUCT.	TOTAL FLUX	FISSION PROD.	SELFSCATTER
1	0.0	0.1814070E+00	0.0	0.1814070E+00	0.2455055E+00	0.0	0.1656540E+00
2	0.0	0.6523931E-01	0.2979762E-04	0.6526905E-01	0.2412003E+00	0.0	0.1733594E+00
3	0.0	0.2554502E-01	0.6765088E-05	0.2555178E-01	0.1699872E+00	0.3839680E-01	0.5201174E-01
4	0.0	0.2765045E-01	0.9284813E-02	0.3693526E-01	0.1757097E+00	0.1260343E+00	0.2188859E-01
5	0.0	0.2998418E+00	0.9321373E-02	0.3091631E+00	0.8324026E+00	0.1644310E+00	0.4129137E+00

GR.	ABSORPTION	BUCKL.LEAKAGE	OUTSCATTER	TOTAL LEAKAGE	TOTAL LOSSES	CAPTURE DENSITY	FISSION DENSITY
1	0.1695636E+00	0.7479016E-02	0.3002862E-04	0.4365563E-02	0.1814381E+00	0.5885734E-01	0.1107053E+00
2	0.5342175E-01	0.7311214E-02	0.1233346E-04	0.4505854E-02	0.6525111E-01	0.1417366E-01	0.3924783E-01
3	0.1248000E-01	0.7878449E-02	0.9279016E-02	0.5188480E-02	0.3482595E-01	0.1918918E-02	0.1056126E-01
4	0.1130941E-01	0.9210430E-02	0.0	0.6819922E-02	0.2733976E-01	0.5428977E-03	0.1084995E-01
5	0.2467747E+00	0.3187911E-01	0.9321377E-02	0.2087982E-01	0.3088549E+00	0.7549274E-01	0.1713642E+00

GR.	NEUTRON BAL.	NO-WEST	NO-EAST	SOUTH	SO-EAST	SO-WEST	NORTH
1	0.9998285E+00	0.7275953E-03	0.7275946E-03	0.7275939E-03	0.7275939E-03	0.7275939E-03	0.7275946E-03
2	0.1000275E+01	0.7509755E-03	0.7509755E-03	0.7509755E-03	0.7509759E-03	0.7509759E-03	0.7509759E-03
3	0.7336995E+00	0.8647470E-03	0.8647474E-03	0.8647463E-03	0.8647470E-03	0.8647463E-03	0.8647470E-03
4	0.1350972E+01	0.1136654E-02	0.1136653E-02	0.1136653E-02	0.1136653E-02	0.1136655E-02	0.1136654E-02
5	0.1000998E+01	0.3479972E-02	0.3479971E-02	0.3479969E-02	0.3479970E-02	0.3479971E-02	0.3479972E-02

VOLUME-INTEGRATED FISSION SOURCE

GROUP	FISSIONS
1	0.18141E+00
2	0.24664E+00
3	0.27216E+00
4	0.29979E+00
5	0.10000E+01

```
TITLE OF THIS RUN:

*************************************************************************
*                                                                       *
*    SAMPLE PROBLEM ; HOMOGENEOUS REACTOR (GODIVA) , S2, ADJOINT        *
*                                                                       *
*************************************************************************


********** FINAL ITERATION RESULT **********

OUTER CONVERGENCE BASED ON POINTWISE TEST

INNER CONVERGENCE BASED ON POINTWISE TEST


 OUTER  INNER     EV(LOW)     EIGENVALUE    EV(HIGH)  ERR(OUT)   GROUP   INNER     ERR(INN)     POINTS OF MAX.   REBAL.      TIME USED
 ITERATIONS                                                          ITERATIONS                  ERRORS OUT/INN   FACTOR       SECONDS

  15    155      1.060231     1.060251     1.060266  1.973E-05                                    (  7,  7)                     0.03000

    NEGATIVE FLUX FIXUP ACTIVATED
                          0 TIMES                                    1        1       4.053E-05    (  7,  7)    1.000E+00
                          0 TIMES                                    2        1       4.578E-05    (  2,  2)    1.000E+00
                          0 TIMES                                    3        1       2.408E-05    (  8,  2)    1.000E+00
                          0 TIMES                                    4        1       2.003E-05    (  7,  7)    1.000E+00

NEGATIVE FLUX FIX UP SUMMARY FOR LAST OUTER ITERATION
IN EACH GROUP THERE ARE   1296 ANGULAR FLUXES CALCULATED

NEGATIVE ANGULAR FLUXES IN GROUP  1 :     0 TIMES ENCOUNTERED ( =  0.0  PERCENT)
NEGATIVE ANGULAR FLUXES IN GROUP  2 :     0 TIMES ENCOUNTERED ( =  0.0  PERCENT)
NEGATIVE ANGULAR FLUXES IN GROUP  3 :     0 TIMES ENCOUNTERED ( =  0.0  PERCENT)
NEGATIVE ANGULAR FLUXES IN GROUP  4 :     0 TIMES ENCOUNTERED ( =  0.0  PERCENT)

***** INFORMATION *****
FINISHED BY CONVERGENCE OF OUTER ITERATIONS
```

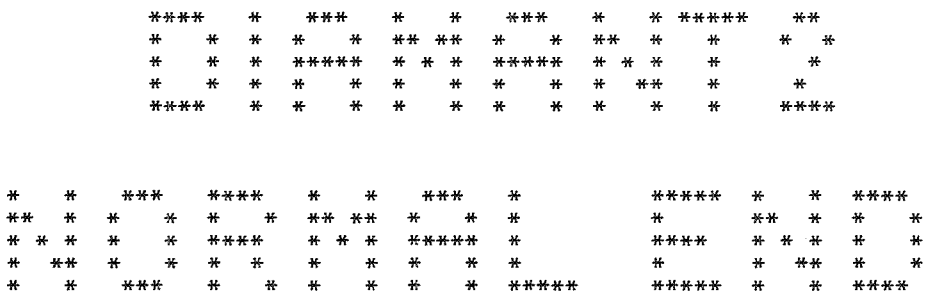
********** TIMING STATISTICS **********

TIME USED BY THE CASE WITH ID= 2	0.0165 MINUTES	
AVERAGE TIME PER OUTER ITERATION	0.0011 MINUTES	
INNER ITERATION USED	0.0127 MINUTES =	76.8 PER CENT

TIME USED BY THE WHOLE JOB UP TO NOW 0.0305 MINUTES

KEYWORD ENDE ENCOUNTERED IN INPUT STOPS EXECUTION

FREE MAIN STORAGE PLACE AT THE END : 290070 WORDS



```
MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA

START START START START START START START START START START START START START START START START START START START

OUTPUT OF READKO:

*****************************************************************
*                                                               *
* EINHEIT 10 REALISIERT ALS NORMALER DB: INPUT TPTRIA         1 *
* EINHEIT 15 REALISIERT ALS EXTERNE EINHEIT                     *
* EINHEIT 37 REALISIERT ALS EXTERNE EINHEIT                     *
* EINHEIT 38 REALISIERT ALS EXTERNE EINHEIT                     *
*                                                               *
*****************************************************************

 REACTIVITY, MEAN GENERATION TIME AND EFFECTIVE DELAYED NEUTRON FRACTION BY TRANSPORT PERTURBATION CODE TPTRIA


  TEST DATA OF GODIVA FOR TPTRIA                (20.3.1985)
NUMBER OF FISSILE ISOTOPE            IFM=  5
NUMBER OF DELAYED NEUTRONS GROUPS    IDM=  6

NAME OF ISOTOPE      PU239    PU240    U 234    U 235    U 238

*************************************************************************
* EINHEIT 37 (INTERFACE 2     ) VERWENDET MIT SEQUENZNUMMER:   1        *
*************************************************************************

*************************************************************************
* EINHEIT 38 (INTERFACE 3     ) VERWENDET MIT SEQUENZNUMMER:   1        *
*************************************************************************

*************************************************************************
* EINHEIT 37 (INTERFACE 2     ) VERWENDET MIT SEQUENZNUMMER:   2        *
*************************************************************************
RESULTS FROM DIAMANT2 FOR DIRECT SOLUTION ARE TAKEN FROM FILE IDIAM1 =  37
FILE IDENTIFICATION IS AS FOLLOWS:

     SAMPLE PROBLEM ; HOMOGENEOUS FINITE REACTOR (GODIVA) , S2

*************************************************************************
* EINHEIT 38 (INTERFACE 3     ) VERWENDET MIT SEQUENZNUMMER:   2        *
*************************************************************************
RESULTS FROM DIAMANT2 FOR ADJOINT SOLUTION ARE TAKEN FROM FILE IDIAM2 =  38
FILE IDENTIFICATION IS AS FOLLOWS:

     SAMPLE PROBLEM ; HOMOGENEOUS REACTOR (GODIVA) , S2, ADJOINT

INPUT DATA FROM DIAMANT2 TAKEN FROM THE DIRECT CASE
ISCT=  0   ISN=  2   IGE=  4  IGM=  4  IM= 30    JM= 15   MBK=  3   BF=  0.0
  MT= 15  MATE= 15    MM=  8  IHS=  8 IHT=  7   IHM= 11     S= 1.10339E+00

LENGTH=   42295          LAST=   44919          IRIS=   41845
```

FOR DIRECT EQUATION

MTC(IM,JM)=

```
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16  1  1  1  1  1  1  1  1  1  1  1  1  1 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16  1  1  2  2  2  2  2  2  2  2  2  2  2  1  1 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16  1  1  2  2  3  3  3  3  3  3  3  3  3  2  2  1  1 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16  1  1  2  2  3  3  4  4  4  4  4  4  4  3  3  2  2  1  1 16 16 16 16 16 16 16 16 16 16 16
16 16  1  1  2  2  3  3  4  4  5  5  5  5  5  4  4  3  3  2  2  1  1 16 16 16 16 16 16 16 16 16
16 16  1  1  2  2  3  3  4  4  5  5  6  6  6  5  5  4  4  3  3  2  2  1  1 16 16 16 16 16 16 16
16 16 16  1  1  2  2  3  3  4  4  5  5  6  6  6  5  5  4  4  3  3  2  2  1  1 16 16 16 16 16 16
16 16 16 16 16  1  1  2  2  3  3  4  4  5  5  5  5  5  4  4  3  3  2  2  1  1 16 16 16 16 16 16
16 16 16 16 16 16 16  1  1  2  2  3  3  4  4  4  4  4  4  4  3  3  2  2  1  1 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16  1  1  2  2  3  3  3  3  3  3  3  3  3  2  2  1  1 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16 16 16  1  1  2  2  2  2  2  2  2  2  2  2  2  1  1 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16 16 16 16 16  1  1  1  1  1  1  1  1  1  1  1  1  1 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
```

MTS(IM,JM)=

```
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  1  1  2  2  2  2  2  2  2  2  2  2  1  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  1  1  2  2  3  3  3  3  3  3  3  3  2  2  1  1  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  1  1  2  2  3  3  4  4  4  4  4  4  3  3  2  2  1  1  0  0  0  0  0  0  0  0  0  0  0
 0  0  1  1  2  2  3  3  4  4  5  5  5  5  5  4  4  3  3  2  2  1  1  0  0  0  0  0  0  0  0
 0  0  1  1  2  2  3  3  4  4  5  5  6  6  6  5  5  4  4  3  3  2  2  1  1  0  0  0  0  0  0
 0  0  0  1  1  2  2  3  3  4  4  5  5  6  6  6  5  5  4  4  3  3  2  2  1  1  0  0  0  0  0
 0  0  0  0  0  1  1  2  2  3  3  4  4  5  5  5  5  5  4  4  3  3  2  2  1  1  0  0  0  0  0
 0  0  0  0  0  0  0  1  1  2  2  3  3  4  4  4  4  4  4  4  3  3  2  2  1  1  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  1  1  2  2  3  3  3  3  3  3  3  3  3  2  2  1  1  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  1  1  2  2  2  2  2  2  2  2  2  2  2  1  1  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

FOR ADJOINT EQUATION

MTC(IM,JM)=

```
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16  7  7  7  7  7  7  7  7  7  7  7  7  7 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16  7  7  8  8  8  8  8  8  8  8  8  8  8  7  7 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16  7  7  8  8  9  9  9  9  9  9  9  9  9  8  8  7  7 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16  7  7  8  8  9  9 10 10 10 10 10 10 10  9  9  8  8  7  7 16 16 16 16 16 16 16 16 16 16 16
16 16  7  7  8  8  9  9 10 10 11 11 11 11 11 10 10  9  9  8  8  7  7 16 16 16 16 16 16 16 16 16
16 16  7  7  8  8  9  9 10 10 11 11 12 12 12 11 11 10 10  9  9  8  8  7  7 16 16 16 16 16 16 16
16 16 16  7  7  8  8  9  9 10 10 11 11 12 12 12 11 11 10 10  9  9  8  8  7  7 16 16 16 16 16 16
16 16 16 16 16  7  7  8  8  9  9 10 10 11 11 11 11 11 10 10  9  9  8  8  7  7 16 16 16 16 16 16
16 16 16 16 16 16 16  7  7  8  8  9  9 10 10 10 10 10 10 10  9  9  8  8  7  7 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16  7  7  8  8  9  9  9  9  9  9  9  9  9  8  8  7  7 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16 16 16  7  7  8  8  8  8  8  8  8  8  8  8  8  7  7 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16 16 16 16 16  7  7  7  7  7  7  7  7  7  7  7  7  7 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
```

```
MTS( IM,JM)=

  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  7  7  7  7  7  7  7  7  7  7  7  7  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  7  7  8  8  8  8  8  8  8  8  8  8  8  7  7  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  7  7  8  8  9  9  9  9  9  9  9  9  9  8  8  7  7  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  7  7  8  8  9  9 10 10 10 10 10 10 10  9  9  8  8  7  7  0  0  0  0  0  0  0  0  0  0
  0  0  7  7  8  8  9  9 10 10 11 11 11 11 11 10 10  9  9  8  8  7  7  0  0  0  0  0  0  0  0
  0  0  7  7  8  8  9  9 10 10 11 11 12 12 12 11 11 10 10  9  9  8  8  7  7  0  0  0  0  0  0
  0  0  0  7  7  8  8  9  9 10 10 11 11 12 12 12 11 11 10 10  9  9  8  8  7  7  0  0  0  0  0
  0  0  0  0  0  7  7  8  8  9  9 10 10 11 11 11 11 11 11 10 10  9  9  8  8  7  7  0  0  0  0
  0  0  0  0  0  0  0  7  7  8  8  9  9 10 10 10 10 10 10 10 10  9  9  8  8  7  7  0  0  0  0
  0  0  0  0  0  0  0  0  0  7  7  8  8  9  9  9  9  9  9  9  9  9  9  8  8  7  7  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  7  7  8  8  8  8  8  8  8  8  8  8  8  8  7  7  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  7  7  7  7  7  7  7  7  7  7  7  7  7  7  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

*****************************************************************************************************************

FLUXES AND ADJOINTS FOR ALL FOLLOWING PERTURBATION CALCULATIONS ARE OBTAINED BY USING THE FOLLOWING COMPOSITIONS

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15

*****************************************************************************************************************

CROSS SECTIONS CORRECTLY PREPARED
TOTAL FLUX OF DIRECT FLUX     INTEGRATED OVER THE REACTOR IN THE ORDER  OF ENERGY GROUP

  1  7.94303E+02  2  6.27338E+02  3  1.24957E-01  4  1.02330E-03

*************************************************************************
* EINHEIT 15 ( INTERFACE IDSK2 ) VERWENDET MIT SEQUENZNUMMER:   1       *
*************************************************************************
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CRITICALITY FACTOR FOR DIRECT EQUATION 9.910766E-01
CRITICALITY FACTOR FOR ADJOINT EQUATION 1.060251E+00
REACTIVITY FROM THE CRITICALITY FACTOR 6.583101E-02
TOTAL FLUX OF ADJOINT FLUX INTEGRATED OVER THE REACTOR IN THE ORDER OF ENERGY GROUP

1 2.30821E+02 2 2.23303E+02 3 3.16854E+02 4 3.22505E+02

DENOMINATOR= 3.065249E+02

CORRECTION TO THE CRITICALITY FACTOR OF DIAMANT2 WHERE AN ISOTOPE INDEPENDENT FISSION SPECTRUM IS USED FOR PROMPT AND DELAYED NEUTRONS
CORRECTED CRITICALITY FACTOR FOR DIRECT EQUATION 9.910340E-01 (R O=-4.334E-05 ROP= 2.398E-05 ROD=-6.695E-05)

NEUTRON MEAN GENERATION TIME LAMBDA= 5.00375E-09 SEC

EFFECTIVE DELAYED NEUTRON FRACTION FOR EACH ISOTOPE AND MIXTURE

MIXTURE INDEX= 1

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
SUM	0.0	0.0	0.0	0.0	0.0	0.0

MIXTURE INDEX= 2

* UM
* UM
* UM

MIXTURE INDEX= 6

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
SUM	0.0	0.0	0.0	0.0	0.0	0.0

MIXTURE INDEX= 7

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	2.54500E-07	7.13417E-10	3.21261E-08	9.54929E-06	7.50574E-08	9.91169E-06
2	1.89078E-06	7.01295E-09	3.15803E-07	5.39612E-05	7.97564E-07	5.69724E-05
3	1.44905E-06	4.89966E-09	2.20638E-07	4.73148E-05	9.36872E-07	4.99262E-05
4	2.24116E-06	9.09778E-09	4.09683E-07	1.04332E-04	2.28561E-06	1.09277E-04
5	6.99185E-07	3.30551E-09	1.48850E-07	3.25973E-05	1.31677E-06	3.47653E-05
6	2.37594E-07	7.48901E-10	3.37239E-08	6.62125E-06	4.38926E-07	7.33224E-06
SUM	6.77226E-06	2.57782E-08	1.16082E-06	2.54376E-04	5.85080E-06	2.68185E-04

MIXTURE INDEX= 8

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	8.27439E-07	2.27852E-09	1.02815E-07	3.11608E-05	2.36967E-07	3.23303E-05
2	6.09715E-06	2.22147E-08	1.00241E-06	1.74647E-04	2.49736E-06	1.84267E-04
3	4.69191E-06	1.55843E-08	7.03221E-07	1.53765E-04	2.94566E-06	1.62121E-04
4	7.17457E-06	2.86090E-08	1.29094E-06	3.35223E-04	7.10474E-06	3.50821E-04
5	2.24731E-06	1.04366E-08	4.70937E-07	1.05160E-04	4.10973E-06	1.11999E-04
6	7.63675E-07	2.36454E-09	1.06696E-07	2.13602E-05	1.36990E-06	2.36029E-05
SUM	2.18020E-05	8.14876E-08	3.67701E-06	8.21316E-04	1.82644E-05	8.65140E-04

MIXTURE INDEX= 9

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	1.42184E-06	3.88851E-09	1.75604E-07	5.36204E-05	4.02577E-07	5.56243E-05
2	1.04485E-05	3.78079E-08	1.70739E-06	2.99702E-04	4.23107E-06	3.16127E-04
3	8.05212E-06	2.65622E-08	1.19953E-06	2.64253E-04	4.99791E-06	2.78529E-04
4	1.22627E-05	4.85632E-08	2.19310E-06	5.73757E-04	1.20055E-05	6.00267E-04
5	3.84665E-06	1.77416E-08	8.01207E-07	1.80251E-04	6.95464E-06	1.91871E-04
6	1.30715E-06	4.01958E-09	1.81523E-07	3.66125E-05	2.31821E-06	4.04234E-05
SUM	3.73389E-05	1.38583E-07	6.25835E-06	1.40819E-03	3.09099E-05	1.48284E-03

MIXTURE INDEX= 10

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	1.66134E-06	4.52745E-09	2.04543E-07	6.26973E-05	4.67619E-07	6.50354E-05
2	1.21928E-05	4.39638E-08	1.98621E-06	3.49988E-04	4.90837E-06	3.69119E-04
3	9.40329E-06	3.09097E-08	1.39644E-06	3.08816E-04	5.80219E-06	3.25448E-04
4	1.42911E-05	5.63963E-08	2.54789E-06	6.69145E-04	1.39090E-05	6.99949E-04
5	4.48623E-06	2.06183E-08	9.31502E-07	2.10370E-04	8.06321E-06	2.23872E-04
6	1.52449E-06	4.67133E-09	2.11043E-07	4.27306E-05	2.68773E-06	4.71586E-05
SUM	4.35593E-05	1.61087E-07	7.27762E-06	1.64375E-03	3.58381E-05	1.73058E-03

MIXTURE INDEX= 11

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	1.33767E-06	3.63795E-09	1.64396E-07	5.05030E-05	3.75231E-07	5.23840E-05
2	9.81057E-06	3.53017E-08	1.59525E-06	2.81722E-04	3.93589E-06	2.97099E-04
3	7.56916E-06	2.48299E-08	1.12204E-06	2.48683E-04	4.65454E-06	2.62053E-04
4	1.14904E-05	4.52512E-08	2.04486E-06	5.38227E-04	1.11450E-05	5.62952E-04
5	3.60852E-06	1.65505E-08	7.47906E-07	1.69281E-04	6.46354E-06	1.80118E-04
6	1.22623E-06	3.74973E-09	1.69447E-07	3.43846E-05	2.15451E-06	3.79385E-05
SUM	3.50425E-05	1.29321E-07	5.84390E-06	1.32280E-03	2.87287E-05	1.39254E-03

MIXTURE INDEX= 12

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	5.12168E-07	1.39157E-09	6.28910E-08	1.93402E-05	1.43440E-07	2.00601E-05
2	3.75509E-06	1.34993E-08	6.10090E-07	1.07852E-04	1.50411E-06	1.13735E-04
3	2.89771E-06	9.49664E-09	4.29194E-07	9.52217E-05	1.77908E-06	1.00337E-04
4	4.39657E-06	1.72981E-08	7.81773E-07	2.05982E-04	4.25766E-06	2.15435E-04
5	1.38099E-06	6.32791E-09	2.85986E-07	6.47966E-05	2.46969E-06	6.89396E-05
6	4.69282E-07	1.43367E-09	6.47935E-08	1.31616E-05	8.23230E-07	1.45203E-05
SUM	1.34118E-05	4.94471E-08	2.23472E-06	5.06354E-04	1.09772E-05	5.33027E-04

MIXTURE INDEX= 13

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
SUM	0.0	0.0	0.0	0.0	0.0	0.0

MIXTURE INDEX= 14

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
SUM	0.0	0.0	0.0	0.0	0.0	0.0

MIXTURE INDEX= 15

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
SUM	0.0	0.0	0.0	0.0	0.0	0.0

SUM OVER MIXTURE

GROUP	PU239	PU240	U 234	U 235	U 238	ROW SUM
1	6.01496E-06	1.64374E-08	7.42374E-07	2.26871E-04	1.70089E-06	2.35346E-04
2	4.41949E-05	1.59800E-07	7.21714E-06	1.26787E-03	1.78744E-05	1.33732E-03
3	3.40632E-05	1.12282E-07	5.07107E-06	1.11805E-03	2.11162E-05	1.17841E-03
4	5.18565E-05	2.05216E-07	9.26824E-06	2.42666E-03	5.07074E-05	2.53870E-03
5	1.62689E-05	7.49804E-08	3.38639E-06	7.62456E-04	2.93776E-05	8.11564E-04
6	5.52842E-06	1.69877E-08	7.67226E-07	1.54871E-04	9.79250E-06	1.70976E-04
SUM	1.57927E-04	5.85704E-07	2.64524E-05	5.95678E-03	1.30569E-04	6.27231E-03

EXACT PERTURBATION

I	J	GROUP	CAPTURE	FISSION	REMOVAL	BUCKL.	SCATT.OUT	SCATT.IN	OUT+IN	G-1 TO G	FIS.SOURCE	AD.FIS.SO.	TOTAL
3	2	1	-1.851E-08	-1.484E-06	-3.862E-06	2.567E-06	-2.360E-06	5.327E-06	2.967E-06	0.0	1.837E-05	1.492E-05	2.240E-05
3	2	2	-8.875E-08	-9.464E-07	-4.592E-06	2.064E-06	-3.557E-06	1.046E-05	6.908E-06	1.906E-06	4.399E-06	7.845E-06	1.234E-05
3	2	3	-3.056E-10	-4.352E-10	-2.840E-09	4.908E-10	-2.099E-09	7.066E-09	4.967E-09	2.246E-09	1.785E-11	1.876E-09	4.735E-09
3	2	4	-2.099E-11	-2.789E-11	-7.796E-11	1.234E-11	-2.908E-11	7.369E-11	4.462E-11	1.933E-12	0.0	9.023E-11	8.078E-12
3	2	PSUM	0.0	0.0	0.0	4.632E-06	0.0	1.580E-05	9.880E-06	1.909E-06	2.277E-05	2.277E-05	3.474E-05
3	2	NSUM	-1.076E-07	-2.431E-06	-8.457E-06	0.0	-5.919E-06	0.0	0.0	0.0	0.0	0.0	0.0
3	2	SUM	-1.076E-07	-2.431E-06	-8.457E-06	4.632E-06	-5.919E-06	1.580E-05	9.880E-06	1.909E-06	2.277E-05	2.277E-05	3.474E-05
3	3	1	-3.490E-08	-2.798E-06	-7.283E-06	4.840E-06	-4.450E-06	8.800E-06	4.351E-06	0.0	3.072E-05	2.483E-05	3.708E-05
3	3	2	-1.730E-07	-1.844E-06	-8.949E-06	4.023E-06	-6.932E-06	1.845E-05	1.152E-05	3.265E-06	7.627E-06	1.352E-05	2.115E-05
3	3	3	-6.168E-10	-8.783E-10	-5.732E-09	9.906E-10	-4.237E-09	1.332E-08	9.085E-09	4.172E-09	3.243E-11	3.410E-09	8.613E-09
3	3	4	-3.824E-11	-5.082E-11	-1.420E-10	2.249E-11	-5.298E-11	1.315E-10	7.853E-11	3.644E-12	0.0	1.574E-10	1.195E-11
3	3	PSUM	0.0	0.0	0.0	8.865E-06	0.0	2.726E-05	1.588E-05	3.269E-06	3.835E-05	3.835E-05	5.824E-05
3	3	NSUM	-2.085E-07	-4.644E-06	-1.624E-05	0.0	-1.139E-05	0.0	0.0	0.0	0.0	0.0	0.0
3	3	SUM	-2.085E-07	-4.644E-06	-1.624E-05	8.865E-06	-1.139E-05	2.726E-05	1.588E-05	3.269E-06	3.835E-05	3.835E-05	5.824E-05
		*											
		*											
		*											
26	13	1	-1.851E-08	-1.484E-06	-3.862E-06	2.567E-06	-2.360E-06	5.327E-06	2.967E-06	0.0	1.837E-05	1.492E-05	2.240E-05
26	13	2	-8.875E-08	-9.464E-07	-4.592E-06	2.064E-06	-3.557E-06	1.046E-05	6.908E-06	1.906E-06	4.399E-06	7.845E-06	1.234E-05
26	13	3	-3.056E-10	-4.352E-10	-2.840E-09	4.908E-10	-2.099E-09	7.066E-09	4.967E-09	2.246E-09	1.785E-11	1.876E-09	4.735E-09
26	13	4	-2.099E-11	-2.789E-11	-7.796E-11	1.234E-11	-2.908E-11	7.369E-11	4.462E-11	1.933E-12	0.0	9.023E-11	8.078E-12
26	13	PSUM	0.0	0.0	0.0	4.632E-06	0.0	1.580E-05	9.880E-06	1.909E-06	2.277E-05	2.277E-05	3.474E-05
26	13	NSUM	-1.076E-07	-2.431E-06	-8.457E-06	0.0	-5.919E-06	0.0	0.0	0.0	0.0	0.0	0.0
26	13	SUM	-1.076E-07	-2.431E-06	-8.457E-06	4.632E-06	-5.919E-06	1.580E-05	9.880E-06	1.909E-06	2.277E-05	2.277E-05	3.474E-05
INTEGRAL		1	-1.559E-04	-1.250E-02	-3.253E-02	5.028E-03	-1.988E-02	1.575E-02	-4.121E-03	0.0	5.782E-02	4.574E-02	4.607E-02
INTEGRAL		2	-8.250E-04	-8.797E-03	-4.268E-02	3.588E-03	-3.306E-02	4.242E-02	9.359E-03	6.701E-03	1.646E-02	2.853E-02	1.979E-02
INTEGRAL		3	-3.076E-06	-4.380E-06	-2.859E-05	5.996E-07	-2.113E-05	4.151E-05	2.038E-05	1.201E-05	8.589E-08	8.985E-06	1.361E-05
INTEGRAL		4	-1.491E-07	-1.982E-07	-5.539E-07	9.679E-09	-2.066E-07	3.800E-07	1.734E-07	1.243E-08	0.0	3.898E-07	-1.642E-07
INTEG.		PSUM	0.0	0.0	0.0	8.617E-03	0.0	5.822E-02	9.379E-03	6.713E-03	7.428E-02	7.428E-02	6.587E-02
INTEG.		NSUM	-9.841E-04	-2.130E-02	-7.524E-02	0.0	-5.296E-02	0.0	-4.121E-03	0.0	0.0	0.0	-1.642E-07
INTEG.		SUM	-9.841E-04	-2.130E-02	-7.524E-02	8.617E-03	-5.296E-02	5.822E-02	5.259E-03	6.713E-03	7.428E-02	7.428E-02	6.587E-02

NOTE: SUM MEANS SUMMATION OVER ENERGY GROUPS AND INTEGRAL MEANS VOLUME INTEGRATION OVER SPACE;
SEE KFK REPORT 2787 P. 4 AND P. 24

MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA MODUL TPTRIA
END END END END END END END END END END END END END END END END END END END END END END END END END

```
*KSIOX DBN=SIGMN,IND=1,TYP=ARCI,SPEC=FT17G004

*KSIOX DBN=DIAMANT2 EINGABE,IND=1,TYP=CARD,PMN=PRDUM

*$ K1: *************  SAMPLE PROBLEM  ***********************************
'SAMPLE PROBLEM ; HOMOGENEOUS FINITE REACTOR (GODIVA) , S2   '
*$ K2:
*$       ID    ITH    ISN    IGM   IEVT    MLM    MCM     MT   MATE    ICM    IIM
          2     -2      2      4      1     15     15     15     15     50     10
*$      IIL    KTR   KDUM   IINP   ITP3   ITP4   INBO
          5      0      0     37      0      0      0
*$ K4:
*$  IQUELL    MBK IQUER    ID1    ID2    ID3    ID4    ID5   ISCT KAUSW
          0      3      1      0      0      0      0      0      0      0
*$ KTPUN1 KTPUN2 INORM
          0      0      1
*$ K5:
*$        EPS            EV            BF             H          EPSA          TEPS
       1.0E-4           1.0           0.0        1.5963        1.0E-4           0.0
*$ K7: USED MIXTURE NUMBERS
  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15
*$  LAYOUT  BEGINNING
*$ K8:
*$ ITYP IZEI ISPA MISH INTZ INTS      ITYP IZEI ISPA MISH INTZ INTS
        4    0    0   90   15   15        5    1    1    1    6    6
        5    2    2    2    5    5        5    3    3    3    4    4
        5    4    4    4    3    3        5    5    5    5    2    2
        5    6    6    6    1    1
*$ K8A:   LAYOUT END
       6*6
*$ K14B: BUCKLING VALUES  B(J,I),J=1,MT)  FOR  I=1,IGM
0.11245  0.04072  0.02631  0.02122  0.01904  0.01807 9*0.0
0.17446  0.05242  0.03215  0.02538  0.02255  0.02131 9*0.0
0.40163  0.07928  0.04412  0.03353  0.02929  0.02746 9*0.0
0.54160  0.09005  0.04848  0.03639  0.03161  0.02957 9*0.0
'CONT'
```

```
*$ K1: **************  SAMPLE PROBLEM  ***********************************
'SAMPLE PROBLEM ; HOMOGENEOUS REACTOR (GODIVA) , S2, ADJOINT '
*$ K2:
*$       ID    ITH    ISN    IGM   IEVT    MLM    MCM     MT   MATE    ICM    IIM
          2     -1      2      4      1     15     15     15     15     50     10
*$      IIL    KTR   KDUM   IINP   ITP3   ITP4   INBO
          5      0      0     38      0      0      0
*$ K4:
*$  IQUELL    MBK  IQUER    ID1    ID2    ID3    ID4    ID5   ISCT KAUSW
          0      3      1      0      0      0      0      0      0      0
*$ KTPUN1 KTPUN2 INORM
          0      0      1
*$ K5:
*$        EPS           EV           BF            H         EPSA         TEPS
       1.0E-4          1.0          0.0       1.5963       1.0E-4          0.0
*$ K7: USED MIXTURE NUMBERS
  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15
*$  LAYOUT  BEGINNING
*$ K8:
*$ ITYP IZEI ISPA MISH INTZ INTS      ITYP IZEI ISPA MISH INTZ INTS
       4    0    0   90   15   15         5    1    1    7    6    6
       5    2    2    8    5    5         5    3    3    9    4    4
       5    4    4   10    3    3         5    5    5   11    2    2
       5    6    6   12    1    1
*$ K8A:    LAYOUT END
       6*6
*$ K14B: BUCKLING VALUES  B(J,I),J=1,MT)  FOR  I=1,IGM
6*0.0 0.54160  0.09005  0.04848  0.03639  0.03161  0.02957 3*0.0
6*0.0 0.40163  0.07928  0.04412  0.03353  0.02929  0.02746 3*0.0
6*0.0 0.17446  0.05242  0.03215  0.02538  0.02255  0.02131 3*0.0
6*0.0 0.11245  0.04072  0.02631  0.02122  0.01904  0.01807 3*0.0
'ENDE'
*$*$
```

```
*KSIOX DBN=INIT READ DIAMAN,TYP=CARD,PMN=PRDUM

14 'DIAMANT2 FINGABE' 1 1 0 0
15 'DIAMAN ANISO 1   ' 1 6 0 0
16 'DIAMAN ANISO 2   ' 1 6 0 0
17 'SIGMN            ' 1 1 0 0
37 'INTERFACE 2      ' 1 6 0 0
38 'INTERFACE 3      ' 1 6 0 0
*$*$

*KSIOX DBN=INIT READ TPTRIA,TYP=CARD,PMN=PRDUM

37 'INTERFACE 2      ' 1 6 0 0
38 'INTERFACE 3      ' 1 6 0 0
15 'INTERFACE IDSK2  ' 1 6 0 0
10 'INPUT TPTRIA     ' 1 1 0 0
*$*$

*KSIOX DBN=INPUT TPTRIA,TYP=CARD,PMN=PRDUM

*$ 345678901234567890123456789012345678901234567890123456789012345678,
'  TEST DATA OF GODIVA FOR TPTRIA                (20.3.1985)          '
*$  IFM IDM IFEX IFFP IFPG IFGS IFS IFG IFK IPAF IPFX IPCS
      5   6    1    0    0    1   1   1   1    0    0    0
*$  IDIAM1 IDIAM2 IDSK
       37     38   15
   'PU239   ' 'PU240   ' 'U 234   ' 'U 235   ' 'U 238   '
*$*$


 *GO SM=DIANEU


 *GO SM=RENDB,MPARM='SIGMN',1


 *GO SM=RENDB,MPARM='SIGMN TPTRIA',1


 *GO SM=TPTRIA

/*
//
```